3 CHARACTERIZATION OF CURRENT CONDITIONS

As prescribed by the 1997 LTCP, PWD has committed to a detailed watershed-based monitoring program in the Cobbs and Tookany/Tacony-Frankford (TTF) Creek Watersheds. This monitoring program includes chemical, biological and physical assessments to characterize the current state of the watershed and identify existing problems and their sources. The need for this detailed watershed monitoring program was rooted in the fact that insufficient physical, chemical and biological information existed on the nature and causes of water quality impairments, sources of pollution, and appropriate remedial measures prior to PWD's watershed based assessment.

Through this assessment process, PWD has sought to gain a good understanding of the physical, chemical and biological conditions of the water bodies, understand the character of the watershed land uses that will drive wet weather water quality conditions, and build a common understanding of these factors among all stakeholders. A compendium document is produced following the analysis of all collected data; this Comprehensive Characterization Report (CCR) assessment serves to document the watershed baseline health prior to implementation of any plan recommendations, allowing for the measure of progress as implementation takes place upon completion of the plan. The CCR is shared with watershed partners for comments and feedback.

CCRs have been completed for the Cobbs Creek Watershed in 2004, the TTF Creek Watershed in 2005 and the Pennypack Creek Watershed in 2009 (Section 1, Table 1.4). These CCR documents are available on the partnership website at www.phillyriverinfo.org. Data related to the Cobbs and TTF Watersheds within this section have been pulled from these CCRs. Data related to the Schuylkill and Delaware River Watersheds have been assembled from a number of sources including PWD sampling locations, the United States Geological Survey (USGS) gage stations and the Delaware River Basin Commission (DRBC) monitoring locations.

In order to further understand the complex nature and causes of water quality impairments, PWD has continued to monitor and model the collection system within Philadelphia. This section additionally presents information characterizing Philadelphia's network of sewer systems, regulating structures, drainage districts, contributing watersheds and outlying community municipalities, precipitation data collection and analysis and the collection of water quantity and quality information.

3.1 MONITORING AND DATA COLLECTION

Data collection and monitoring is an essential component to appropriately develop and analyze alternatives for the LTCPU. The collected data is organized, assessed for errors and analyzed using a variety of models, tools and methods. The sections below present data necessary to the LTCPU development process and how it was collected. More information specific to the models, methods and tools used to analyze the data is available in Section 5.

3.1.1 Overview of Input Data Collection

The development of the LTCPU required extensive data collection and analysis. The data collection and analysis included characterization of the City's local climate through precipitation data sources; analysis, collection and correct representation of existing infrastructure data; analysis of the contribution of contaminants and flow data with established flow metering programs; analysis of the topography through extensive use of Geographic Information Systems analyses; analysis and collection of socioeconomic status and the cost for improving the infrastructure. The following sections discuss how this data was collected and the sources used to characterize the City for the LTCPU.

3.1.2 Meteorological Monitoring Data

Precipitation data are a fundamental component of a Combined Sewer System monitoring program required to calibrate and validate CSO models and develop design conditions needed for characterizing the CSS and estimating CSO statistics. Both long-term temporal rainfall data and event based rainfall data synchronized with CSS flow monitoring are needed to appropriately calibrate and characterize the CSS. There are three primary sources of precipitation data used in the CSO Program.

- National Weather Service (NWS) operated Philadelphia International Airport (PIA) surface observation station
- PWD's city-wide rain gage network
- Calibrated radar rainfall estimates

3.1.2.1 PIA Precipitation Data Sources

NWS gage at the Philadelphia International Airport (PIA), located in southwestern Philadelphia, has over 100 years of hourly precipitation data; the period of record runs from January 3, 1902 through the present. An annual online subscription is maintained by PWD for the Philadelphia International Airport station (PIA) that allows the download of monthly Edited Local Climatological Data published by the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center. The reports are downloaded on a monthly basis when made available - typically four to six weeks behind the end of the current month. Along with hourly rainfall data, the report includes snowfall, temperature, wind speed, atmospheric pressure and other relevant and useful climatological data.

3.1.2.2 PIA Precipitation Data Processing and QA/QC

The NWS applies quality assurance procedures to the PIA data internally prior to its release, therefore, no quality assurance protocols are proposed for the PIA data.

3.1.2.3 PWD Precipitation Data Sources

PWD maintains a rain gage network consisting of 24 tipping bucket rain gages located throughout the City that record rainfall depths (minimum recorded depth of 0.01 inches) in 2.5-minute increments. The PWD data is considered reliable from 1990-present, with all 24 gages replaced with heated units beginning in the year 2004 in order to allow for accurate measurement of frozen precipitation events. The raw 2.5-minute tipping bucket rain gage data is extracted from a link to the PWD Collector System's real-time control unit (RTU) database which collects data directly via automatic telephone polling of the gages.

The approximate locations of the 24 PWD rain gages are presented in Figure 3-1. The total number of rain gages within each watershed is shown in Table 3-1.

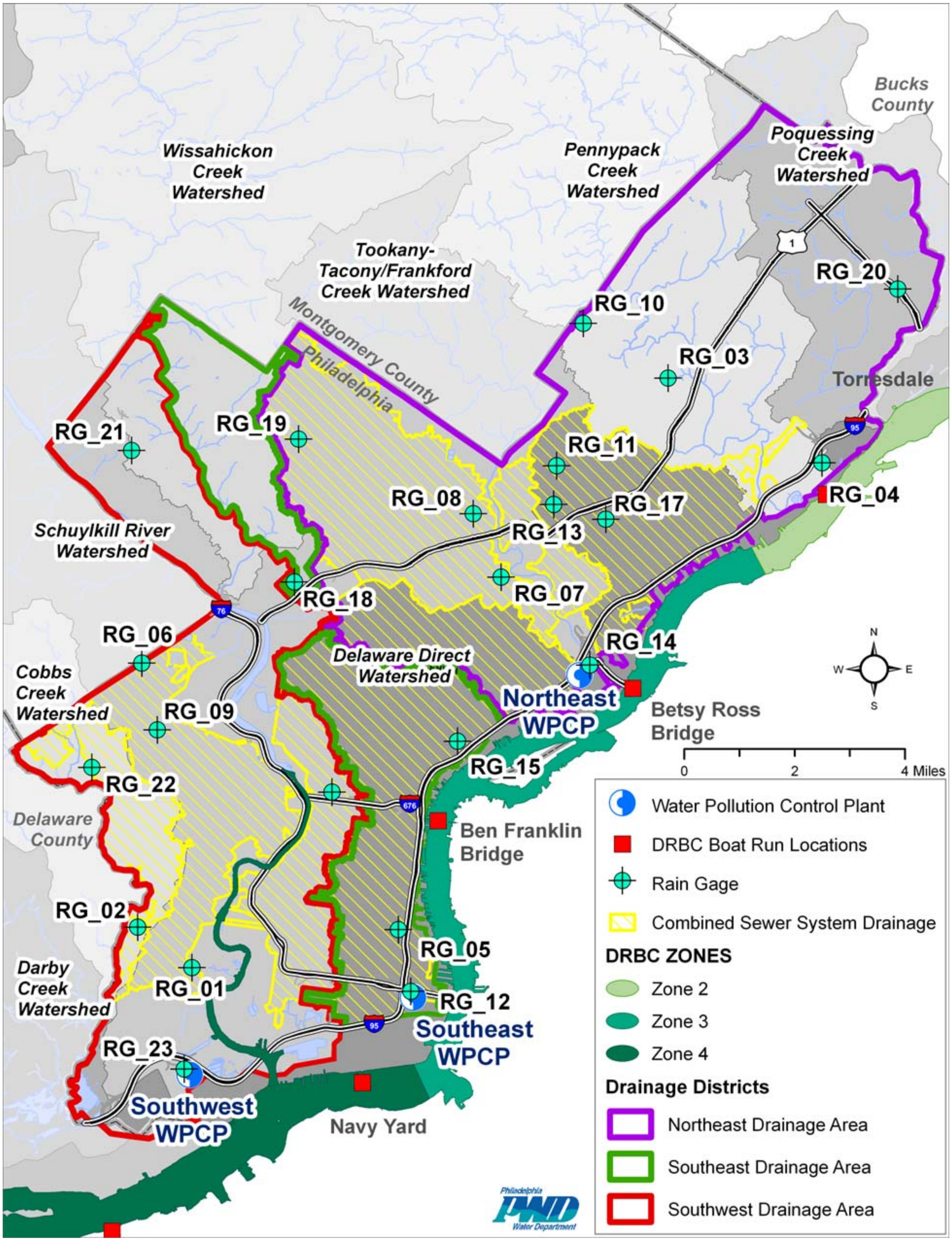


Figure 3-1 PWD Rain Gage Locations and Combined Sewer Drainage Areas

Table 3-1 Number of PWD Rain Gages within each Watershed

Watershed	Total Number of Rain Gages
Delaware River	10
Schuylkill River	7
Darby-Cobbs Creek	2
Tookany/Tacony Frankford Creek	5

3.1.2.4 PWD Precipitation Data Processing and QA/QC

The PWD raw 2.5-minute data are summed to fixed 15-minute intervals. QA/QC of this data is performed on a monthly basis by visual inspection using comparison of data across the network in order to identify and flag missing or questionable data. Flagged data are then filled with coincident data from the six nearest gages using inverse distance squared weighting.

On an annual basis, daily rainfall totals for each gage are compared to the network mean using double mass and cumulative residual time series plots in order to identify changes in non-climatic biases at the gages. In this way, gage malfunctions not readily apparent from initial visual inspection of the raw gage data can be identified. Furthermore, bias adjustment periods are identified for each gage and along with comparisons to radar rainfall estimates obtained for a 15-month period of the gage record, a bias adjusted rainfall record is produced for each gage location. Detailed descriptions of the tools and methods of the precipitation bias adjustment are available in Section 5.

3.1.2.5 Calibrated Radar Rainfall Data Sources

Due to the fact that storm events are inherently variable and do not evenly distribute rainfall spatially or temporally, PWD obtained discrete measurements of rainfall intensity during storm events targeted for wet weather sampling. For each 15-minute interval, RADAR tower-mounted equipment measured high frequency radio wave reflection in the atmosphere as a series of relative reflectivity measurements for individual 1 km^2 blocks. This information was used along with PWD rain gage network data to generate gage calibrated RADAR rainfall estimates and provided to PWD and is further discussed in Section 5.2.1.

The National Weather Service's Next Generation Weather Radar (NEXRAD) program generates products used for estimating spatially variable rainfall data. Several vendors offer gage adjusted radar-rainfall data. PWD rain gage data are used to calibrate NEXRAD data in order to create a detailed and accurate rainfall record that preserves the total rainfall volume reported at the gages while incorporating the spatial variability provided by the NEXRAD data. Detailed rainfall records for areas outside of the City are required for calibration of rainfall dependent inflow and infiltration (RDII) from sanitary sewers contributing flows to the CSS, as well as for watershed modeling performed as part of Phase III of the CSO LTCP. In addition, increased spatial resolution of rainfall data within the City can improve model accuracy as the models are refined with further shed sub-delineation.

The PWD has purchased calibrated radar rainfall data as follows:

1. NEXRAIN Corporation provided 18 months of 15-minute 2 x 2 km grid gage calibrated radar rainfall data covering 399 square miles including the PWD service area plus all surrounding

contributory watershed areas. This data was acquired for use in calibration of PWD CSO, Cobbs Creek restoration, and Main and Shurs models. The time periods covered include:

- 12- month period from September 1st, 1999 through August 31st, 2001
- 4-month period from March 1st, 2002 through June 30th, 2002
- 2 months containing historic rainfall events: July 1994 and October 1996

2. Vieux & Associates provided event based 15-minute 1 x 1 km gage calibrated radar rainfall data covering the PWD service area plus the Tacony-Frankford and the Darby-Cobbs Watersheds. This data was acquired for the wet weather water quality monitoring program and the calibration of open channel flow models and as part of the Tacony-Frankford and Darby-Cobbs Watershed management plans. The time periods covered include:
   - Spring 2003 (4 events): May 2nd, 5th, 7th and 16th
   - Summer 2003 (5 events): July 10th, 23rd and 24th ; September 13th and 23rd
   - Fall 2003 (1 event): October 14th
   - Summer 2004 (2 events): July 7th and August 30th

3. Vieux & Associates provided 21 months of continuous 1-hour 4 x 4 km calibrated radar rainfall data covering the Lower Delaware River Basin for the period July 1st 2001 through March 31st 2003. This data was acquired for calibration of the Delaware River Basin PCB loading model.

3.1.2.6 Radar Rainfall Data Processing and QA/QC

The vendor evaluates the NEXRAD radar reflectivity data and makes corrections for anomalies such as beam blockages and ground clutter. PWD approved, 15-minute unfilled data – which is randomly missing or errant data due to data collection errors that have not been filled in or adjusted using averaging techniques – are provided to the vendor for calibration of the radar rainfall estimates using mean field bias adjustments. The vendor also evaluates the rain gage data and removes questionable gage data from the calibration process.

3.1.3 Municipal Collector Sewer System Data

PWD maintains the following primary sources of flow and level monitoring data for its municipal sewer collection system:

- Water Pollution Control Plant (WPCP) Influent
- Permanent Collection System Level Monitoring
- Portable Flow and Level Monitoring
- Outlying Community Contributing Flow Meter
- National Oceanographic and Atmospheric Agency (NOAA) Tide

To efficiently analyze these data a variety of tools and models were used, including SHAPE and RTK spreadsheet tools created specifically for the LTCPU. Details of these tools are available in Section 5.

3.1.3.1 Water Pollution Control Plant (WPCP) Influent Data

All three WPCPs record influent flow and level/depth data in daily and hourly time increments. PWD WPCP daily qualitative data - unusual color or odors of influent flow - and quantitative data -

flow level, pH, total suspended solids, fecal coliform, biological oxygen demand, and chlorine residual - are reported to regulatory agencies in monthly Discharge Monitoring Reports (DMR). The data in the DMRs exist in digital format and are accessible through MS EXCEL.

The Central Schuylkill Pumping Station (CSPS) records influent flow and level data in 20-minute intervals in digital format (EXCEL). Pumping rates are recorded for each of the six pumps and level data is recorded for the North and South shafts of the Central Schuylkill Siphon.

3.1.3.2 Permanent Collection System Level Monitoring

PWD maintains real-time sewer monitors in the combined sewer system at regulator locations and system hydraulic control points. The regulator chamber level monitors are typically located in the trunk sewer just above the regulator and in the outfall pipe itself. Hydraulic control point level monitors are generally located in interceptor sewers upstream of confluence points, and in trunk sewers at diversion structures. These level monitors are used for system operation and control, as well as, identification of combined sewer overflows, and for determining head losses and hydraulic grade lines used for calibration and validation of system hydraulic models.

3.1.3.3 Portable Flow and Level Monitoring

Monitoring of combined sewer flow is critical to establish a baseline for the urban water budget, against which future progress can be measured. Hydrologic and hydraulic computer models are calibrated to these measured flows so that they accurately represent baseline conditions. Rain that falls in the urban environment can take one of three main pathways – interception by vegetation or depression storage on impervious surfaces, leading to eventual evaporation; infiltration into soil, leading to eventual uptake and transpiration by plants, or continuation to groundwater recharge; or direct runoff to the combined sewer system. Of these three pathways, stormwater flows in the combined sewer system are the easiest to monitor. Measured flows are separated into their components – base wastewater flow, groundwater inflow, and stormwater – using tools described in Section 5.

The PWD portable flow and level monitoring program, initiated in July 1999, deployed flow meters throughout targeted Philadelphia sewershed areas to quantify wastewater flow through sanitary sewers and characterize the tributary sewersheds. This work continued through 2004 with a primary focus on flow monitoring of sanitary sewersheds in order to characterize rainfall dependent inflow and infiltration rates, as well as base wastewater and ground water infiltration rates from service areas both within and outside the City of Philadelphia. Approximately 56 locations were monitored over this period (1999-2004) with deployment durations ranging from two months to over three years.

Beginning in 2005, portable flow and level-only monitoring was performed at three (3) sanitary sewer locations selected to support the monitoring of an extreme wet weather sanitary sewer overflow upstream of the Upper Delaware Low Level Interceptor. In addition, sixteen (16) flow and nine (9) level only monitoring locations were selected in targeted combined sewer storm flood relief areas that are experiencing basement flooding caused by sewer backups.

During the spring of 2006, CSL services were contracted to deploy portable flow monitors in targeted combined sewer storm flood relief areas with a focus on locations surrounding flow splits between CSO regulator drainage basins. Approximately twenty (20) locations were deployed as part of this work.

Additional flow monitoring was performed for calibration and verification of detailed CSS models used for characterizing the response of the system to wet weather under current conditions and for the evaluation of the performance benefit of proposed LTCP projects.

Monitors are generally left in place until a sufficient duration of dry weather days and a sufficient number and range of smaller and larger rain events are captured. The monitors are then removed and reinstalled at other selected sewer sites to maximize the coverage of the PWD service area. Because variability is generally greater from storm to storm rather than between locations, it is desirable to monitor a set of representative locations continuously over the duration of the monitoring program.

Metering location, monitoring period and type are shown in Table 3-2 with locations and contributory areas shown on the map in Figure 3-2. Similarly, Table 3-3 gives location and meter details for the fall 2005 and spring 2006 storm flood relief deployments with locations and contributory areas shown on the map in Figure 3-3.

Table 3-2 Metering Location IDs, Type and Deployment Dates for PWD Portable Flow Monitoring Program

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
005	Level and Flow	Sanitary	NE	9,382	8/10/99 - 6/13/00
012	Level and Flow	Sanitary	NE	630	8/12/99 - 4/28/00
014	Level and Flow	Sanitary	NE	181	8/12/99 - 4/28/00
015	Level and Flow	Sanitary	NE	191	8/10/99 - 4/10/00
018	Level and Flow	Sanitary	NE	355	8/30/99 - 6/12/00
019	Level and Flow	Sanitary	NE	381	8/9/99 - 11/3/99
023	Level and Flow	Sanitary	NE	402	8/9/99 - 4/27/00
027	Level and Flow	Sanitary	NE	353	8/12/99 - 4/27/00
029	Level and Flow	Sanitary	NE	266	8/9/99 - 11/3/99
030	Level and Flow	Sanitary	NE	276	8/12/99 - 4/27/00
031	Level and Flow	Sanitary	NE	383	8/10/99 - 6/19/00
032	Level and Flow	Sanitary	NE	263	9/20/99 - 6/28/00
040	Level and Flow	Sanitary	SW	4,895	8/11/99 - 9/10/01
041	Level and Flow	Sanitary	SW	6,079	11/2/99 - 9/24/01
043	Level and Flow	Sanitary	NE	2,416	11/3/99 - 2/14/00
044	Level and Flow	Sanitary	NE	1,986	11/3/99 - 6/12/00
045	Level and Flow	Sanitary	SW	42	3/10/00 - 8/31/00
046	Level and Flow	Sanitary	SW	117	5/4/00 - 4/24/01
047	Level and Flow	Sanitary	SW	148	5/4/00 - 9/27/01
048	Level and Flow	Sanitary	SE	897	5/3/00 - 10/10/00

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
049	Level and Flow	Sanitary	SE	1,784	4/28/00 - 9/24/01
051	Level and Flow	Sanitary	SW	5,358	5/3/00 - 2/14/01
052	Level and Flow	Sanitary	SE	278	5/3/00 - 9/14/00
055	Level and Flow	Sanitary	SW	235	6/12/00 - 10/10/00
056	Level and Flow	Sanitary	SW	187	6/13/00 - 4/24/01
057	Level and Flow	Sanitary	SW	164	6/13/00 - 9/10/01
058	Level and Flow	Sanitary	SW	105	6/23/00 - 9/27/01
060	Level and Flow	Sanitary	SE	1,818	6/28/00 - 9/27/01
070	Level and Flow	Sanitary	NE	276	10/5/00 - 9/26/01
071	Level and Flow	Sanitary	SE	711	10/13/00 - 4/23/01
072	Level and Flow	Sanitary	NE	301	11/13/00 - 9/27/01
073	Level and Flow	Sanitary	SW	68	2/13/00 - 9/10/01
074	Level and Flow	Sanitary	SW	90	2/16/01 - 4/24/01
075	Level and Flow	Sanitary	NE	179	5/16/01 - 9/26/01
076	Level and Flow	Sanitary	NE	196	5/18/01 - 9/26/01
077	Level and Flow	Sanitary	NE	162	7/11/01 - 9/10/02
078	Level and Flow	Combined	SW	116	9/21/01 - 9/11/02
079	Level and Flow	Combined	SW	117	10/11/01 - 9/10/02
080	Level and Flow	Sanitary	SW	252	10/16/01 - 9/23/02
081	Level	Sanitary	SW	715	1/23/02 - 5/6/02
082	Level and Flow	Combined	SW	203	2/16/02 - 9/10/02
083	Level and Flow	Combined	SW	20	10/17/02 - 5/2/05
084	Level and Flow	Combined	SW	25	10/18/02 - 5/2/06
085	Level and Flow	Combined	SW	99	10/24/02 - 07/29/04
088	Level and Flow	Sanitary	NE	338	4/25/03 - 6/24/03
090	Level and Flow	Sanitary	NE	359	8/31/04 - 7/25/07
091	Level and Flow	Combined	SW	29	7/07/04 - 3/9/06
092	Level and Flow	Sanitary	NE	257	9/15/04 - 5/4/05
095	Level and Flow	Sanitary	NE	3,543	6/08/04 - 9/19/07
096	Level and Flow	Sanitary	NE	12,985	6/03/04 - 9/18/2007
097	Level and Flow	Sanitary	NE	273	10/01/04 - 5/4/2005
098	Level and Flow	Sanitary	NE	12,960	4/06/05 - 9/18/07
099	Level and Flow	Combined	SW	24	9/9/05 - 9/4/07
100	Level	Combined	SW	42	9/23/05 - 7/24/06
101	Level	Combined	SW	80	9/12/05 - 2/26/07
102	Level	Combined	SW	214	9/28/05 - 7/18/06
103	Level	Combined	SW	148	9/23/05 - 7/24/06
104	Level and Flow	Combined	SW	82	9/23/05 - 3/8/07

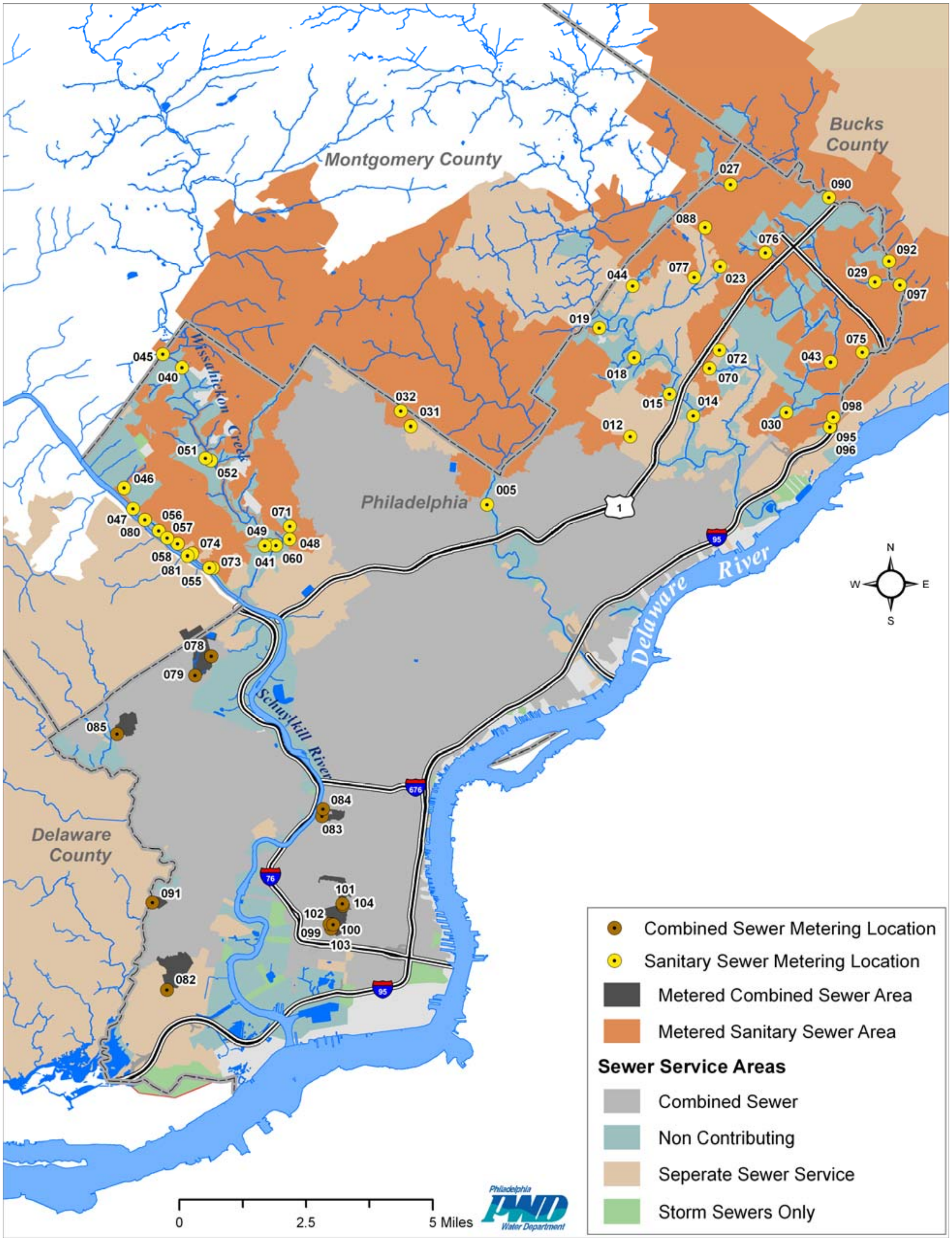


Figure 3-2 PWD Portable Flow Monitoring Program Metering Locations

Table 3-3 Fall 2005 and Spring 2006 Deployment Dates, Locations and Meter IDs for Targeted Storm Flood Relief Areas

Meter ID	Measurement Type	Location	Date Installed	Deployment Phase
S42-130	Level and Flow	Passyunk Avenue	11/1/2005	Fall 2005
D68-1505	Level and Flow	Passyunk Avenue	11/7/2005	Fall 2005
D68-430	Level Only	Passyunk Avenue	9/20/2005	Fall 2005
D68-135	Level and Flow	Passyunk Avenue	11/1/2005	Fall 2005
D68-85	Level and Flow	Passyunk Avenue	9/21/2005	Fall 2005
D66-1625	Level and Flow	Tasker Street	10/10/2005	Fall 2005
D66-125	Level and Flow	Tasker Street	10/18/2005	Fall 2005
D54-3890	Level and Flow	Washington West	9/19/2005	Fall 2005
D54-3320	Level and Flow	Washington West	9/19/2005	Fall 2005
D54-95	Level and Flow	Washington West	10/10/2005	Fall 2005
D54-80	Level Only	Washington West	9/21/2005	Fall 2005
D54-70	Level Only	Washington West	9/19/2005	Fall 2005
D45-3620	Level Only	Northern Liberties	9/20/2005	Fall 2005
D45-1660	Level and Flow	Northern Liberties	9/19/2005	Fall 2005
D45-1415Y	Level Only	Northern Liberties	11/1/2005	Fall 2005
D45-445	Level Only	Northern Liberties	9/21/2005	Fall 2005
D45-165	Level Only	Northern Liberties	11/1/2005	Fall 2005
D45-80	Level Only	Northern Liberties	9/20/2005	Fall 2005
D44-75	Level Only	Northern Liberties	9/20/2005	Fall 2005
S42-130	Level and Flow	Passyunk Avenue	4/25/2006	Spring 2006
D68-85	Level and Flow	McKean & Snyder	4/25/2006	Spring 2006
D68-135	Level and Flow	McKean & Snyder	5/8/2006	Spring 2006
D66-1585	Level and Flow	Tasker Street	4/25/2006	Spring 2006
D66-140	Level and Flow	Tasker Street	4/25/2006	Spring 2006
D54-70	Level and Flow	Washington West	4/21/2006	Spring 2006
D54-3890	Level and Flow	Washington West	4/24/2006	Spring 2006
D54-3653	Level and Flow	Washington West	4/24/2006	Spring 2006
D54-15	Level and Flow	Washington West	5/18/2006	Spring 2006
D45-70	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D45-610	Level and Flow	Northern Liberties	4/21/2006	Spring 2006
D45-510	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D45-490	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D45-450	Level and Flow	Northern Liberties	5/19/2006	Spring 2006
D45-45	Level and Flow	Northern Liberties	5/5/2006	Spring 2006
D45-3705	Level and Flow	Northern Liberties	4/21/2006	Spring 2006
D45-1425	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D44-75	Level and Flow	Northern Liberties	4/20/2006	Spring 2006
D39-110	Level and Flow	Northern Liberties	4/21/2006	Spring 2006

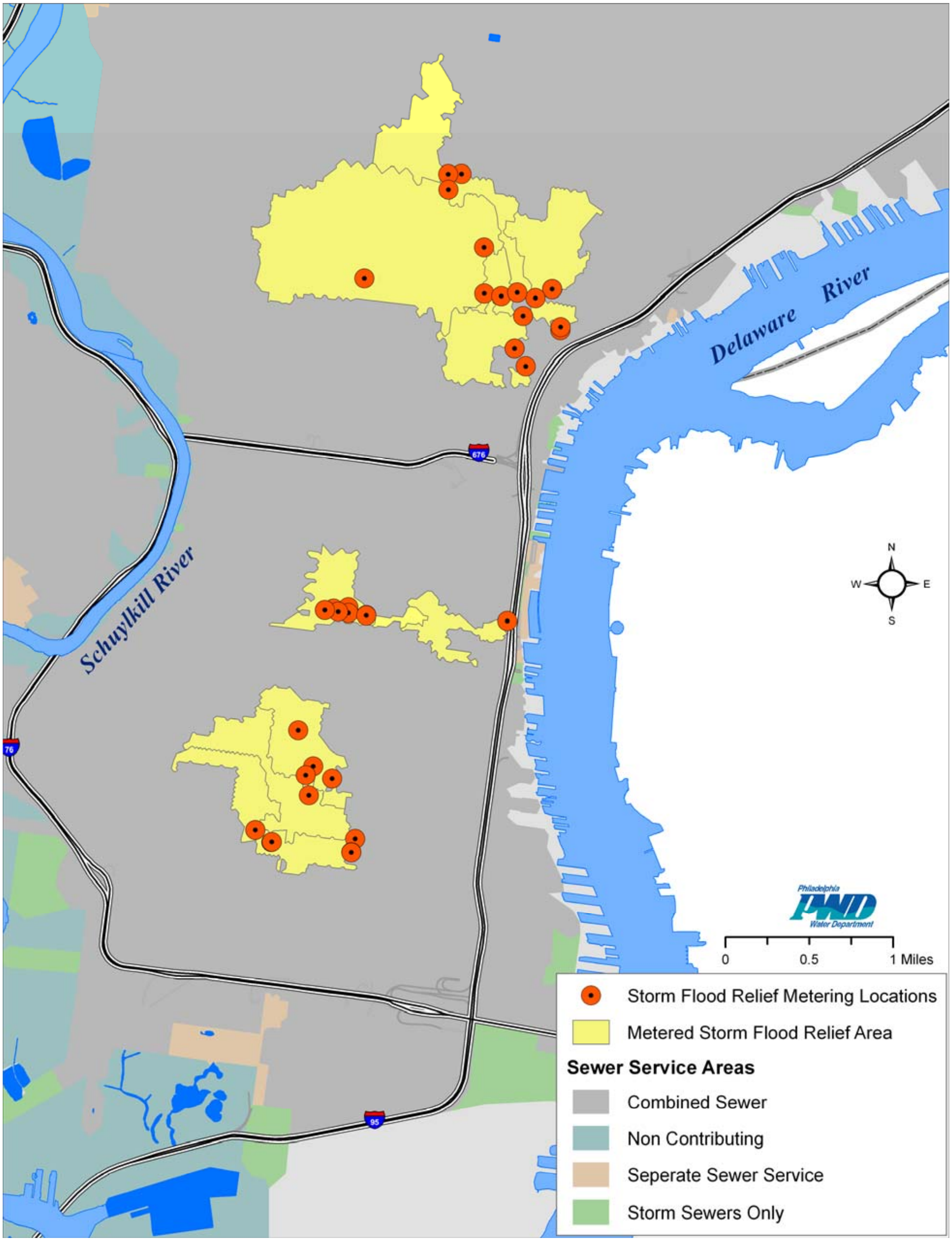


Figure 3-3 PWD Targeted Storm Flood Relief Monitoring Program Meter Locations

Portable Flow Monitoring Data Processing and QA/QC
Flow monitoring field personnel install and maintain depth and velocity recording monitors and upload hydraulic data, via a laptop computer, on a bi-weekly basis throughout the monitoring period. All deployed monitors have data uploaded in a period of 2 – 3 days. Obtaining and recording field-measured depth, velocity, and flow points are vital in verifying the monitoring equipment is properly calibrated and providing reliable results. During the site visits, field calibration measurements are taken at various times of the day and under various ranges of depths and flows to check and verify the equipment is functioning correctly. Wastewater depths are measured from the crown of the pipe using a ruler. Average velocities through the pipe are measured using a hand-held portable velocity meter. Several of the field calibration events for each meter location take place in high flow periods during wet weather, at locations where it a measurement may be safely obtained by the crew during the wet weather event. The calibration data and observed discrepancies are documented by field crews in a field log and submitted along with interrogated data from every deployed site. After several site visits, the field-measured flow points are used to establish a depth versus flow relationship and rating curves used in quality assurance procedures.

The monitored data are transferred from the field to the Office of Watersheds Server on a bi-weekly basis where they undergo a comprehensive QA/QC review process. Several procedures have been formulated and implemented for reviewing the portable flow monitoring data, assessing its accuracy, and making any required adjustments. Time-series plots and scatter-plots of the raw monitored data are produced to facilitate initial investigations of the flow and level trends at each of the monitoring locations.

The QA/QC methods and procedures implemented in the PWD Flow Monitoring Program assist the data analyst in reviewing the monitored flow data and identifying errors. Subsequently, procedures were developed and implemented to correct erroneous data. Two categories or types of data errors were detected, random errors and systematic errors.

Random errors are typically caused by temporary hydraulic conditions or sensor problems that usually lasted less then an hour. Since randomly errant data points usually were surrounded by reliable data points, both depth and velocity errors could be corrected by matching the adjacent data. The corrections are made by observing the reliable depths, velocities, and flows from the adjacent monitored data, observing the trends, and applying linear interpolations between the adjacent data points to determine the appropriate value for the incorrect data point(s).

Systematic errors are typically caused by long-term hydraulic conditions, sensor fouling, improper calibrations, and/or equipment failures that can last several hours, several days, or even several weeks in extreme cases. Systematic errors in depth measurement usually can not be corrected. When depth sensors are fouled or fail for long durations, there are usually no reliable means by which to recover or correct the lost or errant data. Detected errant data are flagged for unacceptable quality, regarded as data gaps, and not used in the subsequent data analyses. However, systematic errors in velocity measurement usually can be corrected as long as the corresponding depth measurements are reliable. Systematic errors may be corrected by using the envelope curve(s) from the scatter-plots to mathematically define the typical depth-flow relationships (rating curves) at the monitoring site. The rating curve can then be applied to the level data to obtain an estimate of the flow.

To quantify RDII, a four-step process is used to perform dry weather and wet weather flow analyses of the monitored sewer system flow data. The analyses are performed using the CDM SHAPE software, which is further discussed in Section 5. The four-step procedure used to perform the RDII analyses on the monitored data is listed below and described in the following paragraphs.

- Flow data preparation
- Precipitation data preparation
- Dry weather flow evaluations and determination of base flow quantities
- Hydrograph decomposition to determine rainfall derived inflow and infiltration (RDII) quantities in sanitary sewers and stormwater runoff loading in combined sewers

Flow Data Preparation:
After initial QA of monitored flow data, the data are entered into the CDM SHAPE software and reviewed to confirm that it was complete, properly formatted, and compatible with the requirements of the subsequent RDII analysis processes, which is discussed in greater detail in Section 5. The review also includes error checking, identifying data gaps, and filling in periods of missing data.

Precipitation Data Preparation:
The monitored rain gage data is reviewed to confirm that it was complete and met the requirements of the RDII analysis process. To quantify RDII, there must be a corresponding rainfall data point for each wastewater flow data point. The review includes error checking and filling in periods of missing data with corresponding data from adjacent gages.

Dry Weather Flow Evaluations:
After the data entry, format conversions, and reviews of the flow and precipitation data are completed, dry weather analyses are performed to quantify base wastewater flow (BWWF), ground water infiltration (GWI), and rainfall dependant inflow and infiltration (RDII). The specifics of this analysis and the models employed are available in Section 5. The analyses consist of identifying days within the monitoring period of record that are not affected by a rainfall event. The method also eliminates other atypical days in which the dry weather flows may have been affected by holidays or other special events. Mean maximum, minimum, and average daily flows for the selected dry weather days are computed and used to identify GWI and BWWF. Average weekday and weekend dry weather flow hydrographs are computed and used in subsequent analysis processes to determine the RDII flows during rainfall events.

Hydrograph Decomposition:
The average daily dry weather flow (ADDWF) hydrographs calculated by the program are then used to quantify RDII volumes for each of the storms that occurred during the flow monitoring period. The first step in the analysis is to manually adjust GWI rates to account for seasonal variations. The seasonal adjustments are based on the assumption that the difference between monitored flows and the computed ADDWF hydrograph should be approximately zero before and after a storm. RDII volumes and peak flows for individual storm events are calculated by subtracting the seasonally adjusted dry weather flow hydrograph (wastewater plus GWI) from the total monitored flow (wastewater plus GWI plus RDII). The subtraction process is called hydrograph decomposition. For each monitored storm, the total rainfall volume over the monitored sewershed area, the storm-induced RDII volume, and the total R-value are computed. The total R-value is defined as the ratio

of the calculated RDII volume to the rainfall volume over the sewered area, expressed as a percent. An R-value of 0.07 indicated that 7 percent of the total monitored rainfall volume that fell over the sewershed area made its way into the sewer system.

Additionally, the service area tributary to each monitor site is delineated to obtain accurate estimates of service populations and areas.

Dry Weather Flow Characterization:
Average dry weather flow patterns are identified using the CDM SHAPE software. Initially, days are automatically excluded from the average daily dry weather flow calculations based on selected rainfall amounts for the given day as well as each of the two preceding days to account for residual influences from previous storm events and snow melt. In addition, days are automatically excluded based on a selected number of standard deviations from the mean. Further manual selection of dry weather days are performed based on a consistent diurnal cycle typical for the tributary sewershed area. Time series plots of flow and precipitation are generated for each individual day within the period of record. Dry weather flow calculations are performed separately for weekdays and weekends due to the fact that base wastewater flow patterns will differ for the two. The monitoring locations are analyzed on a monthly basis to characterize seasonal variations.

The average daily dry weather flows consist of total domestic wastewater, commercial and industrial flow, ground water infiltration, and direct stream inflow flowing through the sewer. Dry weather flows are quantified with respect to population and tributary sewershed acreage to provide a basis of comparison amongst all monitored sites. Additionally, the SHAPE software is used to calculate average daily maximum and minimum flows during dry weather to illustrate the magnitude of fluctuation for diurnal flow. The average daily minimum flow rate is used to estimate the quantity of ground water infiltration that is conveyed through the system (assuming a negligible quantity of early morning commercial/industrial activity).

Extreme Event Analysis:
Once the monitor has been removed and all available data has undergone QA/QC protocols, the five largest (peak, not volume) RDII responses for the period of record at each monitoring site are identified and the maximum hourly-sustained peak flows, total rainfall depth, unit per capita and per acre flows are calculated. Extreme events can provide valuable insight into sewer hydraulics during surcharged conditions. The flow and rainfall data for these events is used to identify the potential for sanitary sewer overflows in a given monitor location.

Portable Flow Monitoring Data Storage
The quality checked and corrected monitored data, along with the monthly raw and corrected plots for each site are kept in a Microsoft Excel workbook for each quarter year. A Microsoft Access database is also maintained that contains all corrected flow monitoring data with flagging to identify corrected or removed data. This database is maintained as a source of flow data for use in subsequent analyses. The CDM SHAPE software generates Microsoft Access databases that are maintained for each flow monitoring site. In addition, a Microsoft Access database is maintained containing the results of all wet and dry weather flow analyses performed using the CDM SHAPE software.

Arcview point and polygon coverages are maintained indicating the monitor location and contributing area, respectively.

3.1.3.4 Outlying Community Contributing Flow Meter

Permanent flow meters are installed at major points of connection for municipalities contributing sanitary sewage to the PWD system. PWD has also performed portable flow monitoring of all non-metered outlying community points of connection with the City of Philadelphia, when seventeen sanitary sewer locations were monitored for two months during the fall of 2004. In addition, portable flow monitoring was provided by Bensalem Township beginning in August 2004 for each of its fifteen points of connection to the City. The outlying community meter locations are listed in Table 3-4 and shown along with contributing areas on the map in Figure 3-4.

Table 3-4 Outlying Community Permanent and Portable Metering Chamber IDs and Locations

Sewer District	Meter IDs	Townships	Interceptor Systems	Number of Meters
NE	MA1, MA2, MA3, MA4, MB1, MBE1, MBE2, MBE3, MBE4, MBE5, MBE6, MBE7, MBE8, MBE9, MBE10, MBE11, MBE12, MBE13, MBE14, MBE15, MBE16, MC1, MC2, MC3, MC4, MC5, MC6, MC7, MLM1, MLM2, MLM4, MLM5, MSH1	Abington, Bucks County, Bensalem, Cheltenham, Lower Moreland, Lower Southampton	PP, UDLL, POQ, FHL, Upper PP	33
SE	MS1, MS6	Springfield	WHL	2
SW	MD1, ML1, ML2, ML3, ML4, ML5, ML6, ML7, MS2, MS3, MS4, MS5, MS7, MS8, MUD1-N, MUD1-O, MUD1-S	Delaware Co., Lower Merion, Springfield, Upper Darby	CCHL, WHL, WLL, SWMG, DELCORA	17

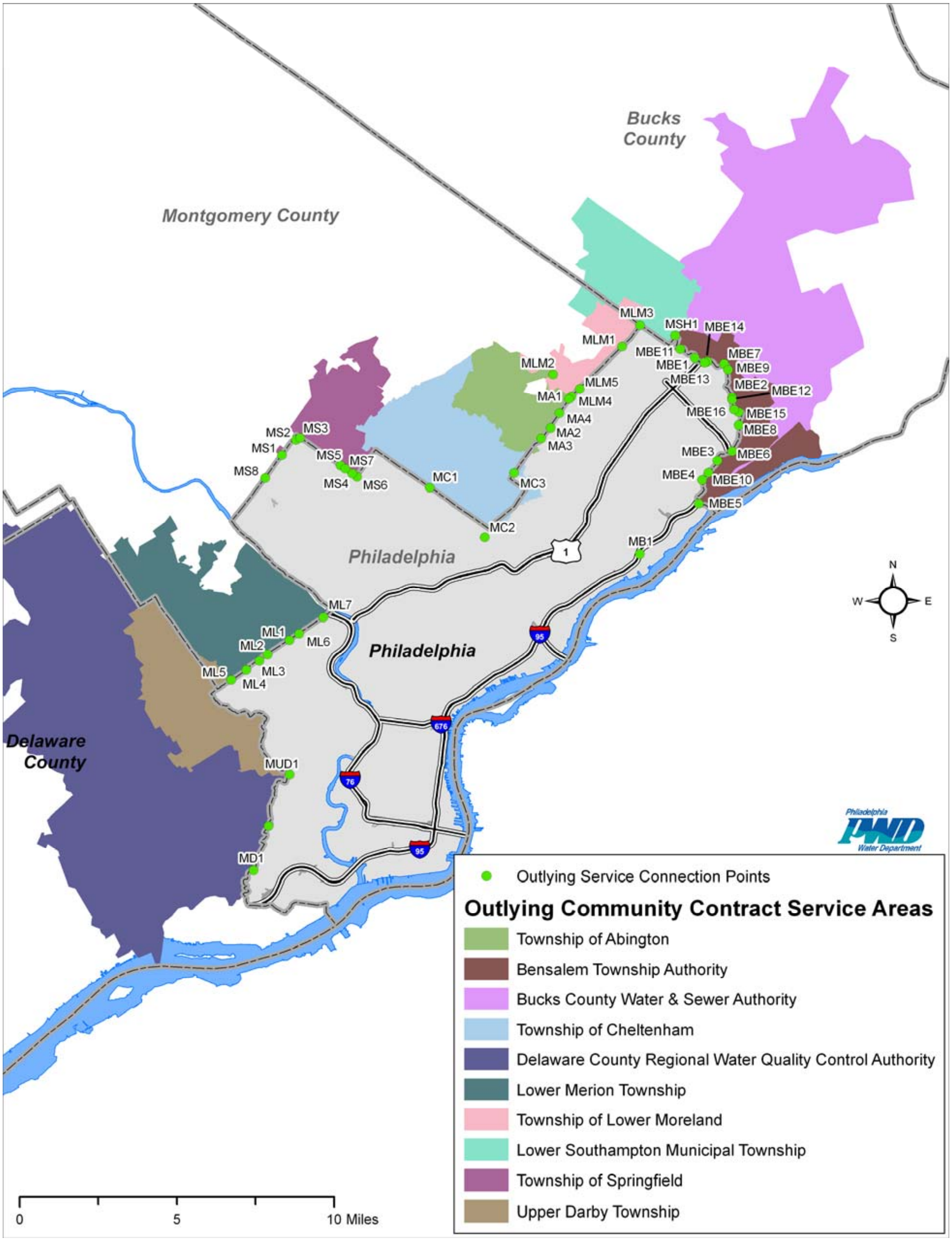


Figure 3-4 PWD Outlying Community Contract Service Areas and Connection Locations

3.1.3.5 National Oceanographic and Atmospheric Agency (NOAA) Tide

NOAA maintains hourly tidal data for the Delaware River station # 8545240 (USCG station at Washington Ave). Data is available in a preliminary form (most recent) and a verified form after NOAA performs quality assurance measures to ensure data integrity. NOAA verified hourly water level data is downloaded, converted to City datum, and interpolated to 15-minute intervals. Three sets of data are created from this to estimate three different tidal zones accounting for shifting tidal boundaries using a water-level offset and the time it takes the tide to affect the various zones based on distance upstream from the gage station.

Tidal boundary conditions are needed because many of the CSO regulator outfalls are located in tidal waters and are equipped with flap gates to prevent tidal inflows to the collection system. The tidal boundary condition in turn determines the effective overflow elevation for these regulators.

3.1.3.6 Ongoing Combined Sewer System Monitoring

Monitoring of combined sewer system wet and dry weather water quality and quantity will continue over the implementation period in order to track the performance of LTCPU control measures over time, including implementation of the NMCs, as well as, to refine hydrologic and hydraulic models of the system.

The continued monitoring of fixed long-term monitoring locations within the combined sewer system is important for tracking system performance over time in terms of dry and wet weather flow and pollutant loadings. The primary sources for continued monitoring at fixed long-term locations are:

- Water Pollution Control Plant (WPCP) influent flow data including hourly flow quantities and daily water quality monitoring of suspended solids, biological oxygen demand, fecal coliform
- Outlying community metering chamber flow data
- Permanent metering of water levels at CSO regulators, along interceptors, and in key locations that control the hydraulic grade line in the system
- Pumping station records

In addition to these sources of fixed long-term monitoring locations, a portable flow monitoring program will continue to be implemented.

Each interceptor system will be individually targeted for flow monitoring investigations aimed at identifying representative locations highly suitable for flow monitoring. Some of the larger CSO basins may call for monitoring of multiple smaller sub-sewershed basins or warrant investigating alternative portable high-rate metering technology or permanent meter installation.

Primary flow monitoring locations should also target key hydraulic control points coordinated with permanent metering programs as part of automated and real time CSS operation decision support systems.

Secondary flow monitoring should continue in selected sanitary and combined sewer areas identified in support of LTCP projects, extreme wet weather sanitary overflows, combined sewer storm flood relief projects, planning unit development, wet weather flow capacity evaluations, inflow and infiltration reduction programs, and watershed monitoring programs.

Flow Monitor Deployment Frequency and Duration
Maintaining long-term continuous primary flow monitoring stations in ideal representative priority locations is desirable to track the CSS performance improvement over time, and because the CSS response to wet weather conditions is generally greater over the range of events experienced than it is between locations across the CSS. Long-term continuous monitoring of select locations is also valuable for estimating inter-annual base groundwater inflow and infiltration rates, and relating short-term monitoring results with long-term average hydrologic conditions.

Secondary monitoring locations are deployed on a rotating basis in continued support of CSS remediation projects and investigations. Installed monitors are generally left in place until a sufficient number of dry weather days and rainfall events are captured, including storms of varying intensity, total volume, and antecedent dry periods. The monitors are then removed and reinstalled at other selected sewer sites to maximize the coverage of the PWD service area.

3.1.4 Receiving Water Monitoring

3.1.4.1 Overview

Comprehensive assessments of waterways are integral to planning for the long-term health and sustainability of water systems. PWDconsiders such assessments essential to measure the spatial and temporal differences within each watershed and to compare differences between watersheds. The watershed approach is used for monitoring in order to investigate the multiple sources of degradation which include stormwater and CSOs. While developing a comprehensive baseline condition in each watershed, the PWD can also measure the water quality and water quantity effects of the programs. Finally, the watershed approach to monitoring raises the awareness in Southeastern Pennsylvania of the impact that land development activities are having on waterbody health. By measuring all factors that contribute to supporting fishable, swimmable, and drinkable water uses, appropriate management strategies can be developed for each watershed land area that Philadelphia shares. The results of these monitoring efforts are reported in Section 3.4.2.

From 1999 to 2008, PWD has implemented a comprehensive watershed assessment strategy, integrating biological, chemical and physical assessments to provide both quantitative and qualitative information regarding the aquatic integrity of the Philadelphia regional watersheds. This information is being used to plan improvements to the watersheds in the Southeast Region of Pennsylvania.

In addition to discrete chemical sampling, PWD incorporated *in situ* continuous water quality monitoring at strategic locations within each watershed as part of the 1999-2008 comprehensive monitoring strategy. Using submerged instruments, dissolved oxygen, temperature, pH, conductivity, depth (stage) and turbidity were logged at 15-minute intervals. The instruments were deployed for approximately two weeks, retrieved and replaced with fresh calibrated instruments in order to produce nearly seamless temporal and spatial data.

Biological, physical and chemical sampling and monitoring follow the quality management procedures and Standard Operating Protocols (SOPs) as prepared by the Philadelphia Water Department's Bureau of Laboratory Services (BLS). These documents cover the elements of quality assurance, including field and laboratory procedures, chain of custody, holding times, collection of blanks and duplicates, and health and safety.

In addition to discrete and continuous sampling, the third water quality component of PWD's comprehensive monitoring strategy 1999-2008 was collecting water samples during wet weather flows. Automated samplers were strategically placed in locations throughout the watershed and used to collect samples during runoff producing rain events. This automated system obviated the need for staff to manually collect samples, thereby greatly increasing sampling efficiency. Automated samplers were programmed to commence sampling with a small (0.1 ft.) increase in stage. Once sampling was initiated, a computer-controlled peristaltic pump and distribution system collected grab samples at 30 min. to 1 hr. intervals, the actual interval being adjusted on a site by site basis according to "flashiness". Adjustment of the rising-limb hydrograph sampling interval allows optimum characterization of water quality responses to stormwater runoff and wet weather sewer overflows (Figure 3-5). Due to sample volume restrictions, fewer chemical analyses are performed on samples collected in wet weather.

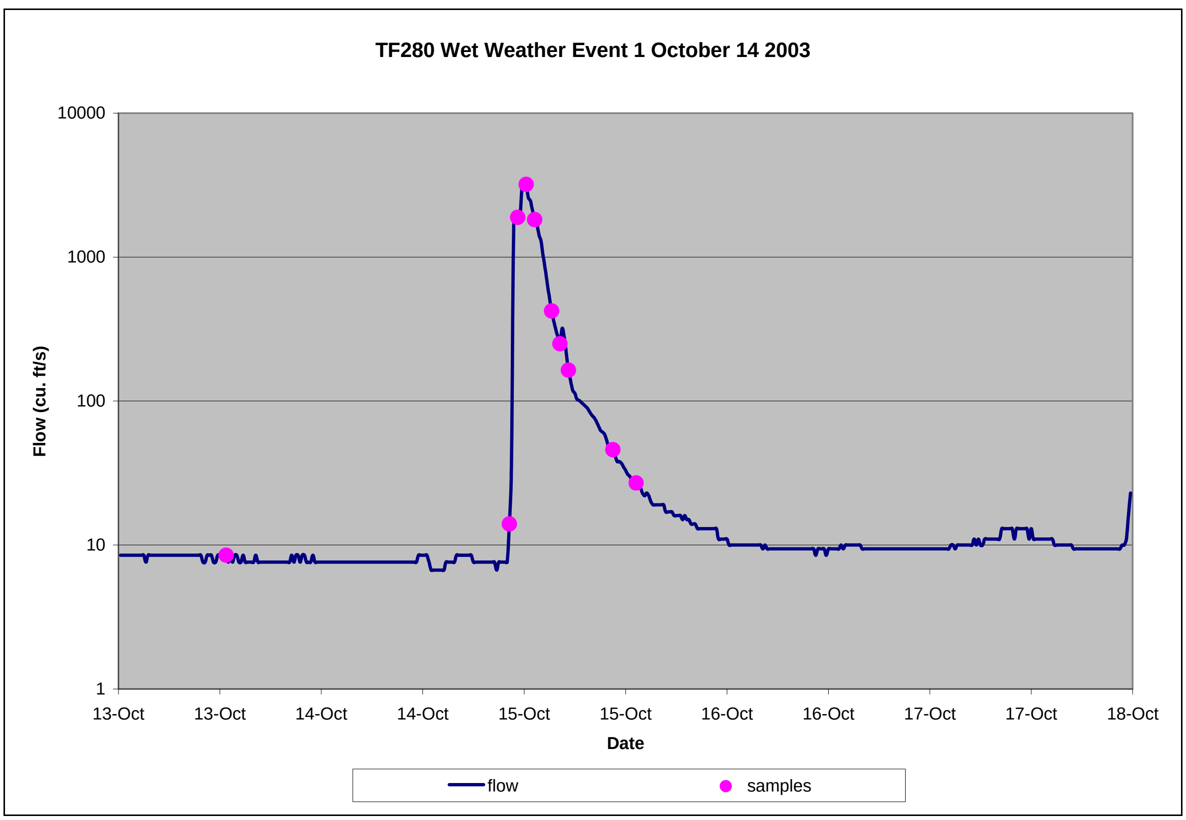


Figure 3-5 Hydrograph Showing Complete Capture of the October 14, 2008 Wet Weather Event from an Automatic Sampler in the Tookany/Tacony-Frankford Creek

PWD integrated biological assessments into the monitoring strategy for the IWMPs as a means of characterizing health of biological communities, identifying potential physical impairments or chemical stressors, and as a "baseline" for measuring the effects of future restoration projects. The biological monitoring protocols employed by PWD are based on methods developed by the United States Environmental Protection Agency (Barbour et al. 1999) and the Pennsylvania Department of Environmental Protection. These procedures are as follows:

- EPA Rapid Bioassessment Protocol III and PADEP ICE (Benthic Macroinvertebrates)
- EPA Rapid Bioassessment Protocol V (Fish)
- EPA Rapid Periphyton Assessment (Algae)
- EPA Physical Habitat Assessment

From 1999 through 2008, PWD has sampled fish communities throughout each of Philadelphia's watersheds using USEPA Rapid Bioassessment V Methods (RBP V).

From 2002 through 2008, PWD collected algal periphyton samples from a small number of sites in selected watersheds using components of USEPA Rapid Bioassessment Protocol 6.1 (laboratory-based approach). Algal periphyton are collected from natural substrates and biomass is estimated based on a quantitative chlorophyll-a and total chlorophyll analysis. Periphyton sampling is performed primarily to address the question of whether anthropogenic nutrient sources are causing eutrophication, which may result in violations of water quality criteria for dissolved oxygen, pH, and have adverse effects on aquatic food webs. Large concentrations of chlorophyll indicate excessively dense algal growth, which may partially explain observed aquatic life impairments.

Habitat assessments are conducted at each monitoring site based on the Environmental Protection Agency's Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (Barbour *et al.*, 1999). Reference conditions are used to normalize the assessment to the "best attainable" situation. Habitat parameters are separated into three principal categories: (1) primary, (2) secondary, and (3) tertiary parameters:

- Primary parameters are those that characterize the stream "microscale" habitat and have greatest direct influence on the structure of indigenous communities.
- Secondary parameters measure "macroscale" habitat such as channel morphology characteristics.
- Tertiary parameters evaluate riparian and bank structure and comprise three categories: (1) bank vegetative protection, (2) grazing or other disruptive pressure, and (3) riparian vegetative zone width.

A description of the models and tools developed to facilitate analysis of receiving water quality is presented in Section 5.

3.1.4.1.1 Cobbs Creek and Tacony-Frankford Creek

PWD had planned and carried out an extensive sampling and monitoring program to characterize conditions in the Darby-Cobbs Creek Watershed and in the Tacony-Frankford Creek Watershed. The program includes hydrologic studies, water quality monitoring, biological assessments, habitat investigations, and fluvial geomorphologic modeling. These investigations, combined with considerable urban planning and community stewardship efforts, have culminated in the Cobbs

Creek Integrated Watershed Management Plan (CCIWMP) and the Tookany/Tacony-Frankford Integrated Watershed Management Plan (TTFIWMP). Comprehensive watershed assessments conducted in 1999 and 2003 informed the decision-making and prioritization processes of the plan. Future assessments will complement state water quality criteria by providing a scientific means to measuring improvements once restoration activities are implemented.

3.1.4.1.2 Tidal Schuylkill and Delaware Rivers

Water quality and hydrological data used to characterize wet and dry weather conditions of the tidal Schuylkill and Delaware Rivers were obtained from the U.S. Geologic Survey (USGS), the Delaware River Basin Commission (DRBC), the Philadelphia Water Department The monitoring programs target different features of the tidal Delaware River Estuary, and when analyzed together, they present a complete picture of the wet and dry weather hydrologic conditions within and bordering Philadelphia.

USGS water quality monitoring in the Delaware Estuary is a part of the National Water Information System that records the physical and chemical characteristics of waters across the U.S. The data from five USGS monitoring stations are used in this characterization of the tidal Schuylkill and Delaware Rivers.

The DRBC is a regional governing body created in 1961 to regulate the water resources of the Delaware River Basin. DRBC activities include water quality protection, water supply allocation, regulatory review, water conservation, watershed planning, and drought management. DRBC monitors the water quality of the Delaware River through its Boat Run Monitoring Program. Six Boat Run sampling locations in the tidal Delaware River are examined in addition to the USGS locations.

PWD operates extensive water monitoring programs that support the drinking water treatment, stormwater management, and wastewater treatment functions of the utility. A number of PWD monitoring programs are used in this application to characterize the dry and wet weather water quality of the tidal Schuylkill and Delaware Rivers. Tidal Schuylkill River data include the results from an Office of Watersheds dry and wet weather sampling program between 2005 and 2006 and a continuous deployment of Sondes in the tidal Schuylkill from 2007-2009. The Bureau of Laboratory Services records tidal Delaware River data at the Baxter Water Treatment Plant intake located in the Torresdale section of Philadelphia. The Baxter intake data tracks water quality conditions in the tidal Delaware River which is the source water supply to Philadelphia and surrounding municipalities.

3.1.4.2 Historical Data

3.1.4.2.1 Tacony-Frankford Creek

From 1971 to 1980, PWD and the USGS established six stream gauging stations in Tacony-Frankford Watershed and conducted monthly water quality sampling at five of these locations. Monthly water quality samples were collected at each site and analyzed for conductivity, BOD_5, total phosphate, ammonia, nitrite, nitrate, and fecal coliform. The program collected about ten years of monthly samples. Figure 3-6 shows the locations of the monitoring stations from the PWD/USGS Cooperative Program.

PWD and the USGS augmented the existing stream gage network in the watershed as part of the Cooperative sampling program, establishing three new stream gages from 1971 to 1973. A gage was established at Castor Avenue in 1982, which is the only gage still in operation. However, PWD and USGS have re-established the former gage at the City line. Table 3-5 contains summary information for each of the six gauging stations for their respective periods of record.

Table 3-5 Periods of Record for Flow and Water Quality Data

Station ID	Location	Quality Data (Period)	Streamflow Data (Period)
01467089	Frankford Creek at Torresdale Ave.	10/9/67 - 3/7374	10/1/64 - 6/29/82, 5/14/82 – 6/29/82
01467087	Frankford Creek at Castor Ave.*	9/24/25 - 8/24/76	7/1/82 - 9/30/03
01467086	Tacony Creek at County Line*	11/9/67 - 10/1/73	10/1/65 - 11/17/88
01467085	Jenkintown Creek At Elkins Park		10/01/73 - 9/30/78
01467084	Rock Creek above Curtis Arboretum near Philadelphia	10/4/71 - 10/1/73	5/1/71 – 9/30/78
01467083	Tookany Creek near Jenkintown		10/1/73 - 9/30/78
	*Active Gage		

In general, the majority of the historical data are available from STORET, USEPA's water quality database. For the Tookany/Tacony-Frankford Watershed, data were from the PWD/USGS Cooperative Program, "Urbanization of the Philadelphia Area Streams."

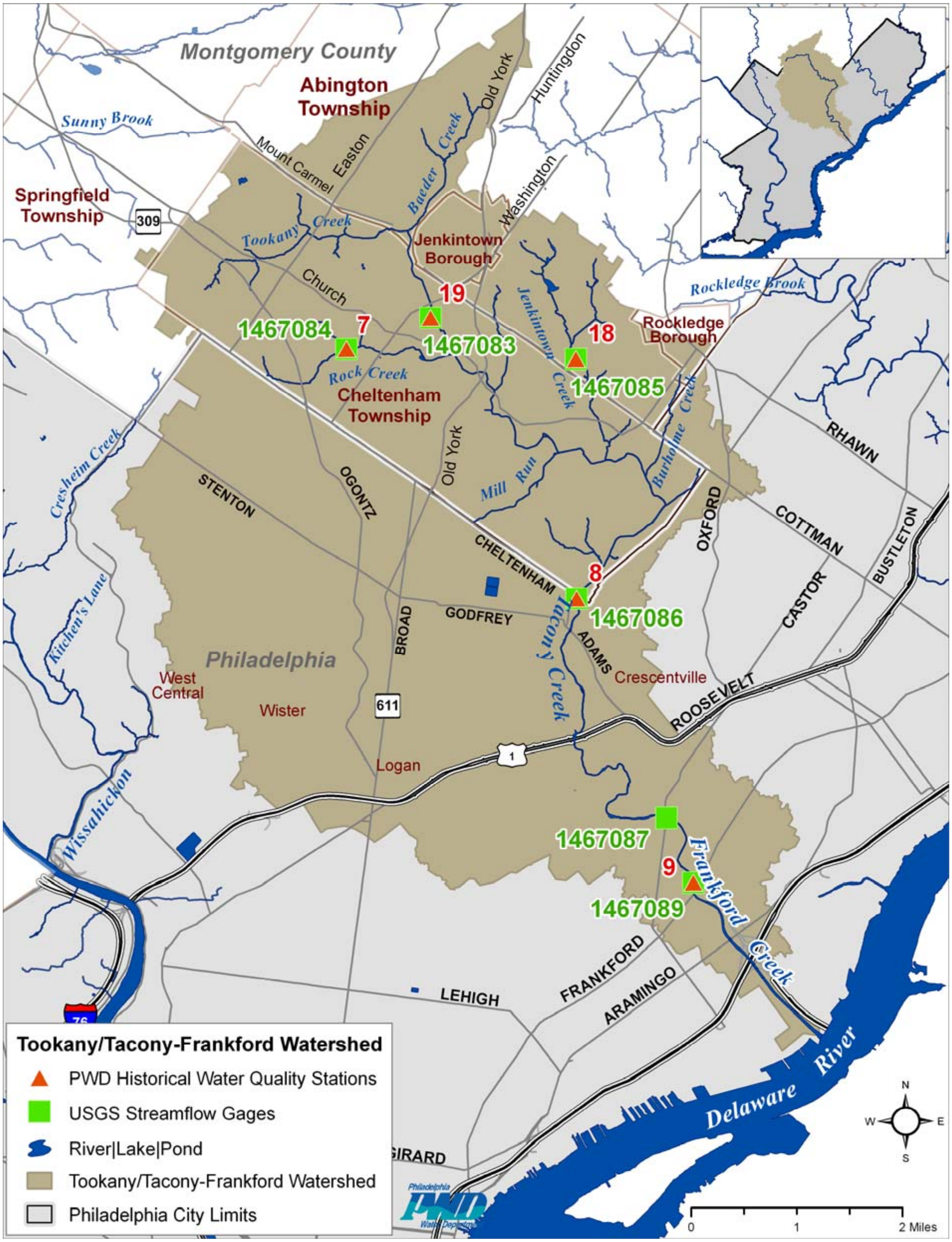


Figure 3-6 PWD/USGS Cooperative Program Water Quality Stations in the Tookany/Tacony-Frankford Watershed

3.1.4.2.2 Cobbs Creek

In the early 1970s, the Philadelphia Water Department began a study in cooperation with the USGS titled, "Urbanization of the Philadelphia Area Streams." The purpose of this study was to quantify the pollutant loads in some of Philadelphia's streams and possibly relate the degradation in water quality to urbanization. The study included four locations in Darby-Cobbs Watershed (Figure 3-7). Water quality monitoring at the four stations in Cobbs Creek began in 1967, but was eventually terminated by 1983. Similarly, measurements of streamflow commenced in 1964 and were discontinued at all locations by 1990.

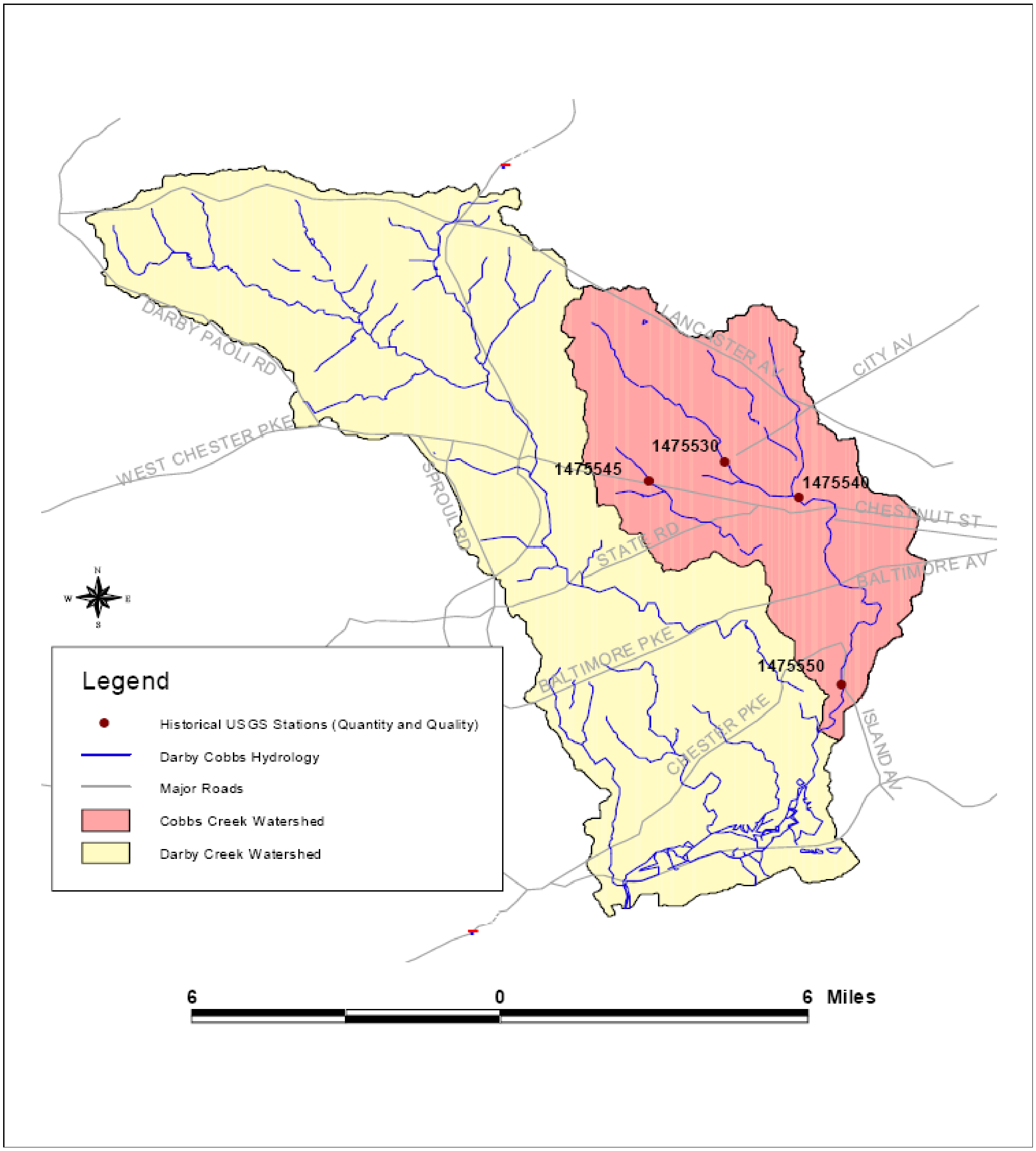


Figure 3-7 Historical USGS Monitoring Locations in Darby-Cobbs Watershed

3.1.4.2.3 Tidal Schuylkill and Delaware Rivers

The USGS and DRBC play central roles in monitoring the water quality of the Delaware Estuary. The DRBC boat run program began in the late 1960s and collects water quality data from the center channel of the main stem Delaware River and Delaware Bay. These stations extended from RM 127.5, a short distance south of Trenton, New Jersey, to South Brown Shoal in Delaware Bay at RM 6.5, near the bay mouth, and throughout the Philadelphia segment of the Delaware River. The stations are plotted on an estuary map in Figure 3-8 and listed by RM and geographic coordinates in Table 3-6. Data categories include routine pollutants: bacteria and radioactivity; heavy metals; algae and organic carbon; and oxygen demand. Additional surveys for other pollutants are performed on an as needed basis.

In the vicinity of Philadelphia, all but three historic USGS stations collect water quality and/or streamflow data. Presented below in Table 3-6 are the descriptions of these stations.

Table 3-6 Tidal Schuylkill and Delaware River Historic Monitoring Locations

Station ID	Location	Quality Data (Period)	Streamflow / Gage Data (Period)
01464600	Delaware River at Bristol, PA	10/1/54 - 11/26/80	NA
01475200	Delaware River at Paulsboro, NJ	5/22/80 – 11/26/80	12/20/86 – 1/11/88
01474500	Schuylkill River at Philadelphia, PA	10/31/25 – 2/9/04	**

NA – Not applicable because data was never recorded
** Ongoing data collection

Figure 3-8 DRBC Boat Run Monitoring Locations

3.1.4.3 Recent Data

3.1.4.3.1 Tacony-Frankford

Tables 3-7 and 3-8 summarize the types, amounts, and dates of sampling and monitoring performed by PWD, PA DEP, and USGS. A river mile-based naming convention is followed for sampling and monitoring sites located along waterways in the watershed. The naming convention includes three or four letters and three or more numbers which denote the watershed, stream, and distance from the mouth of the stream. For example, site TFJ110 is named as follows:

- "TF" indicates the Tookany/Tacony-Frankford Watershed
- "J" indicates Jenkintown Creek, a tributary to Tookany Creek
- "110" places the site 1.10 miles upstream of the confluence of Jenkintown Creek and Tookany Creek

Table 3-7 Summary of Physical and Biological Sampling and Monitoring Tookany/Tacony-Frankford Watershed

		Physical			Biology			
	USGS		USGS	USGS Annual	PWD			PA DEP
Site Name	Gage	Stream Name	Daily Flow	Peak Flow	RBP III*	RBP V**	Habitat	
	1467089	Frankford Creek	1965-1982	1966-1980				
TF280	1467087	Tacony Creek	1982-Present	1982-Present				
TF324		Tacony Creek			November 2000 March 2004	November 2000 June 2004	November 2000 March 2004	
TF396		Tacony Creek			Mar-04	Jun-04	Mar-04	
TF500		Tacony Creek			November 2000 March 2004	Jun-04	November 2000 March 2004	
TF620	1467086	Tacony Creek	1965-1986; 2005-2009	1966-1985	November 2000 March 2004	November 2000 June 2004	November 2000 March 2004	1999
TF760		Tookany Creek			Nov-00		Nov-00	
TF827		Tookany Creek			Mar-04	Jun-04	Mar-04	
TF975		Tookany Creek			November 2000 March 2004	November 2000 June 2004	November 2000 March 2004	

		Physical			Biology			
	USGS		USGS	USGS Annual	PWD			PA DEP
Site Name	Gage	Stream Name	Daily Flow	Peak Flow	RBP III*	RBP V**	Habitat	
TF1120	1467083	Tookany Creek	1973-1978	1974-1978	November 2000 March 2004	November 2000 June 2004	November 2000 March 2004	
TF1270		Tookany Creek			Mar-04		Mar-04	1999
TFU010		Unnamed Tributary			Mar-04		Mar-04	1999
TFJ013		Jenkintown Creek			Mar-04		Mar-04	1999
	1467085	Jenkintown Creek	1973-1978	1974-1978				
TFJ110		Jenkintown Creek			Nov-00		Nov-00	
TFM006		Mill Run			Mar-04		Mar-04	
TFR064		Rock Creek			Mar-04		Mar-04	1999

* EPA Rapid Bioassessment Protocol III Benthic Macroinvertebrates
** EPA Rapid Bioassessment Protocol V Ichthyofaunal (Fish)

A range of water quality samples were collected between 1999 and 2004 at 9 sites in the watershed. The sites are listed in Table 3-8 and are shown on Figure 3-9. Three different types of sampling were performed as discussed below. Parameters were chosen based on state water quality criteria or because they are known or suspected to be important in urban watersheds. The parameters sampled during each type of sampling are listed in Table 3-9.

The sampling and analysis program meets AMSA (2002) recommendations for the minimum criteria that should form the basis for impairment listings:

- Data collected during the previous five years may be considered to represent current conditions
- At least ten temporally independent samples should be collected and analyzed for a given parameter
- "A two-year minimum data set is recommended to account for inter-year variation, and the sample set should be distributed over a minimum of two seasons to account for inter-seasonal variation."
- "No more than two-thirds of the samples should be collected in any one year."
- "Samples collected fewer than four days apart at the same riverine location should be considered one sample event."
- "Samples collected within 200 meters [about 0.1 miles] of each other will be considered the same station or location." This convention was followed except where two sampling sites were chosen to represent conditions upstream and downstream of a modification such as a dam

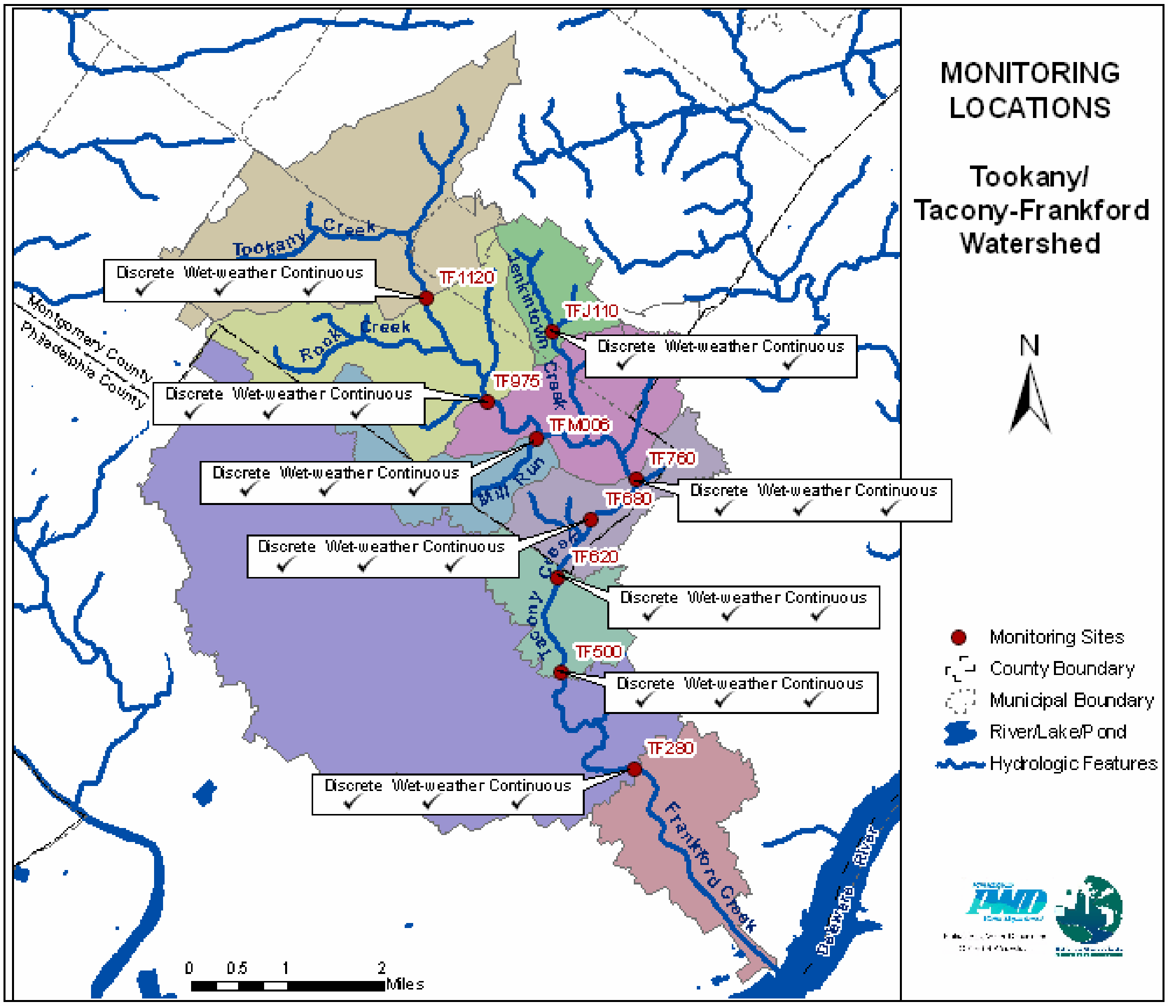


Figure 3-9 Water Quality Sampling Sites in Tookany/Tacony-Frankford Watershed

Table 3-8 Summary of Water Quality Sampling and Monitoring in the Tookany/Tacony-Frankford Watershed

Site	USGS Gage	Discrete	Continuous (hrs)	Wet Weather
TF280	1467087	32 samples 6/29/2000 - 9/2/2004	11109	12 periods 3/19/2001 - 9/1/2004
TF500		25 samples 6/29/2000 - 8/26/2004	3335.5	2 periods 5/21/2001 - 11/1/2002
TF620*	1467086	27 samples 6/29/2000 8/26/2004	9972.5	13 periods 10/15/2002 - 3/7/2003
TF680*		4 samples 7/27/2004 - 9/2/2004		9 periods 5/1/2003 - 9/1/2004
TF760		22 samples 6/29/2000 - 8/26/2004	1701.25	2 periods 5/21/2001 - 11/1/2002
TF975		27 samples 6/29/2000 - 9/2/2004	6298	12 periods 10/29/2002 - 9/1/2004
TF1120	1467083	24 samples 6/29/2000 - 9/2/2004	6462.75	10 periods 10/15/2002 - 9/1/2004
TFJ110	1467085	21 samples 6/29/2000 - 8/26/2004	2593.25	
TFM006		16 samples 11/29/2001 - 9/2/2004	2543.25	2 periods 7/7/2004 - 9/1/2004

* Sites TF620 and TF680 were combined for analysis in many instances.

Table 3-9 Water Quality Parameters Sampled in the Tookany/Tacony-Frankford Watershed

Parameter	Units	Discrete	Wet Weather	Continuous
Physical Parameters				
Temperature	deg C	X	X	X
pH	pH units	X	X	X
Specific Conductance	µMHO/cm @ 25C	X	X	X
Alkalinity	mg/L	X	X	
Turbidity	NTU	X	X	X
TSS	mg/L	X	X	
TDS	mg/L	X	X	
Oxygen and Oxygen Demand				
DO	mg/L	X	X	X
BOD_5	mg/L	X	X	
BOD_{30}	mg/L	X	X	
$CBOD_5$	mg/L	X	X	
Nutrients				
Ammonia	mg/L as N	X	X	
TKN	mg/L	X	X	
Nitrite	mg/L	X	X	
Nitrate	mg/L	X	X	
Total Phosphorus	mg/L	X	X	
Phosphate	mg/L	X	X	
Metals				
Aluminum (Total)	mg/L	X	X	
Aluminum (Dissolved)	mg/L	X	X	
Calcium (Total)	mg/L	X	X	
Cadmium (Total)	mg/L	X	X	
Cadmium (Dissolved)	mg/L	X	X	
Chromium (Total)	mg/L	X	X	
Chromium (Dissolved)	mg/L	X	X	
Copper (Total)	mg/L	X	X	
Copper (Dissolved)	mg/L	X	X	
Fluoride (Total)	mg/L	X	X	
Fluoride (Dissolved	mg/L	X	X	
Iron (Total)	mg/L	X	X	
Iron (Dissolved)	mg/L	X	X	
Magnesium (Total)	mg/L	X	X	
Manganese (Total)	mg/L	X	X	
Manganese (Dissolved)	mg/L	X	X	
Lead (Total)	mg/L	X	X	
Lead (Dissolved)	mg/L	X	X	
Zinc (Total)	mg/L	X	X	
Zinc (Dissolved)	mg/L	X	X	
Biological				
Total Chlorophyll	µg/L	X	X	
Chlorophyll-α	µg/L	X	X	

Parameter	Units	Discrete	Wet Weather	Continuous
Fecal Coliform	CFU/100mls	X	X	
E. coli	CFU/100mls	X	X	
Osmotic Pressure	mOsm	X		
Miscellaneous				
Phenolics	mg/L	X	X	

3.1.4.3.2 Cobbs Creek

3.1.4.3.2.1 Water Quality Sampling and Monitoring (1999-2000)

Tables 3-10 and 3-11 summarize the types, amounts, and dates of sampling and monitoring performed through 2000 by PWD, PADEP, and USGS in a cooperative effort. As in the Tookany/Tacony-Frankford Watershed, a river mile-based naming convention is followed for sampling and monitoring sites located along waterways in the watershed. For example, site DCC-110 is located as follows:

- "DC" stands for the Darby-Cobbs Watershed
- "C" stands for Cobbs Creek
- "110" places the site 1.10 miles upstream of the mouth of Cobbs Creek, where it flows into Darby Creek

For dissolved oxygen, discrete sampling is not sufficient to characterize the condition of the stream. The magnitude of the diurnal pattern exhibited by DO is an indicator of the amount of algal activity in the stream, and the minimum DO occurs in darkness when sampling is impractical. For this reason, PWD monitored dissolved oxygen on a continuous basis at several sites in the Cobbs Creek system as part of the 1999 comprehensive assessment (Table 3-11).

A range of water quality samples were collected between 1999 and 2001 at eleven sites in the watershed. The sites are listed in Table 3-12 and are shown on Figure 3-10. Three different types of sampling were performed as discussed below. Parameters were chosen because state water quality criteria apply to them or because they are known or suspected to be important in urban watersheds. The parameters sampled during each type of sampling are listed in Table 3-13.

The sampling and analysis program meets AMSA (2002) recommendations for the minimum criteria that should form the basis for impairment listings.

Table 3-10 Summary of Physical and Biological Sampling and Monitoring in Darby-Cobbs Watershed through 2000

Site ID	USGS Gage	PWD Geomorph.	USGS Daily Flow	USGS Annual Peak Flow	PWD			PADEP
					RBP III	RBP V	Habitat	
DCC-110	01475550	Assessments were performed at cross-sections located throughout the system	1964-1990	1964-1990	December 1999		December 1999	
DCC-175						April 2000		
	01475548		2005-2009	2006-2008				
DCC-455					December 1999		December 1999	
DCC-505						April 2000		
	01475540		1964-1973	1965-1971				
DCC-770	01475530		1964-1981; 2004-2009	1965-2008			December 1999	
DCC-820						April 2000		
DCC-865					December 1999		December 1999	
DCD-765	01475510		1964-1990	1964-1990				
	01475545		1972-1978	1972-1978				
DCD-1170								
DCD-1570								
DCD-1660								
	01475300		1972-1997*	1972-1996				
STA01 – STA12								1995-1996
DCI-010								
DCI-135					December 1999		December 1999	
DCIW-010					December 1999		December 1999	
DCIW-100						April 2000		
DCIW-185					December 1999		December 1999	
DCM-300								
DCN-010								
DCN-185					December 1999		December 1999	
DCN-215						April 2000		
DCS-170								

* Provisional data are available up to the present.

Table 3-11 Summary of Water Quality Sampling and Monitoring in Darby-Cobbs Watershed through 2000

		Chemical		
	USGS	PWD		
Site ID	Gage	Discrete	Continuous	Wet Weather
DCC-110	01475550	14 samples 5/11/99-6/29/00	3379 hrs	3 periods 5/23/00-7/28/00
DCC-115			951 hrs	
DCC-175				
DCC-455		10 samples 5/11/99-7/20/99	3176 hrs	
DCC-505				
	01475540			
DCC-770	01475530	10 samples 5/11/99-7/20/99	2486 hrs	
DCC-820				
DCC-865				
DCD-765	01475510	12 samples 5/11/99-6/12/00	1854 hrs	3 periods 5/23/00-7/28/00
	01475545			
DCD-1170		10 samples 5/11/99-7/20/99		
DCD-1570		10 samples 5/11/99-7/20/99		
DCD-1660		4 samples 6/1/00-7/13/00	2645 hrs	1 period 7/27/00-7/28/00
	01475300			
STA01 - STA12				
DCI-010		10 samples 5/11/99-7/20/99		
DCI-135				
DCIW-010				
DCIW-100				
DCIW-185				
DCM-300		10 samples 5/11/99-7/20/99		
DCN-010		10 samples 5/11/99-7/20/99	167 hrs	
DCN-185				
DCN-215				
DCS-170		10 samples 5/11/99-7/20/99		

Table 3-12 Water Quality Sampling Sites in Darby-Cobbs Watershed 1999-2000

Cobbs Creek	Darby Creek	Tinicum
Mainstem	**Mainstem**	**MuckinpattisCreek**
DCC110	DCD765	DCM300
DCC455	DCD1570	
DCC770	DCD1660	
Naylors Run		**Stony Creek**
DCN010		DCS170
Indian Creek		
DCI010		

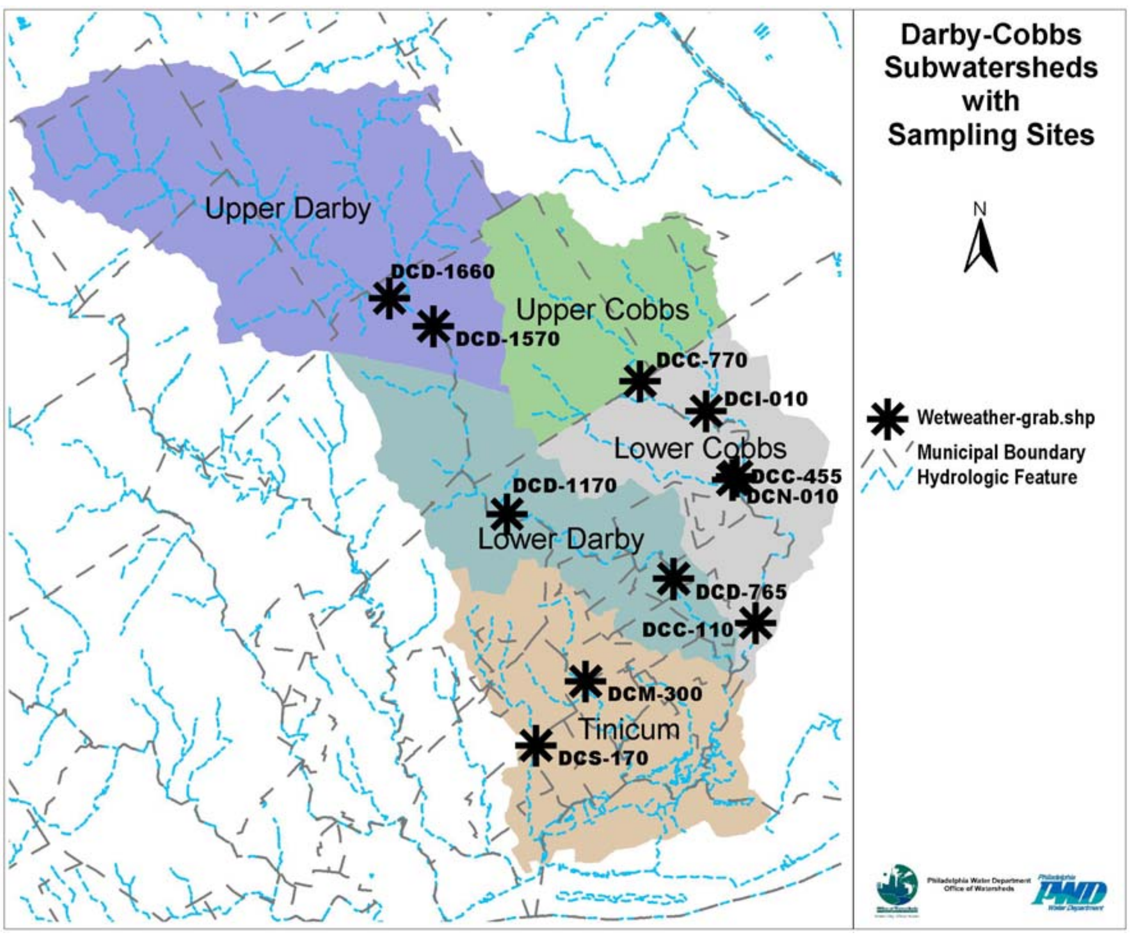


Figure 3-10 Darby-Cobbs Watershed 1999-2000 Water Quality Sampling Sites

Table 3-13 Darby-Cobbs Watershed Water Quality Parameters Sampled 1999-2000

Parameter	Units	Discrete	Wet Weather	Continuous
PHYSICAL PARAMETERS				
Temperature	deg. C	X	X	X
pH	none	X	X	X
Specific Conductance	uS/cm	X	X	X
Alkalinity	mg/L as CaCO3	X	X	
Turbidity	NTU	X	X	X
TSS	mg/L	X	X	
TDS	mg/L	X	X	
OXYGEN AND OXYGEN DEMAND				
DO	mg/L	X	X	X
BOD5	mg/L	X	X	
BOD30	mg/L	X	X	
CBOD5	mg/L	X		
NUTRIENTS				
Total Ammonia	mg/L as N	X	X	X*
Nitrate	mg/L as N	X	X	X*
Nitrite	mg/L as N	X	X	X*
TKN	mg/L as N	X	X	
Phosphate	mg/L as P	X	X	
Total Phosphorus	mg/L	X	X	
METALS				
Aluminum	mg/L	X	X	
Calcium	mg/L	X	X	
Cadmium	mg/L	X	X	
Chromium	mg/L	X	X	
Copper	mg/L	X	X	
Fluoride	mg/L	X	X	
Iron	mg/L	X	X	
Dissolved Iron	mg/L	X		
Magnesium	mg/L	X	X	
Manganese	mg/L	X	X	
Lead	mg/L	X	X	
Zinc	mg/L	X	X	
BIOLOGICAL				
Chlorophyll A	ug/L	X	X	
Total Chlorophyll	ug/L	X	X	
Fecal Coliform	/100 mL	X	X	
E. coli	/100 mL	X	X	
Osmotic Pressure	mosm	X	X	
MISCELLANEOUS				
Phenolics	mg/L	X	X	

* Results did not pass quality assurance but may have some value as a relative measure.

3.1.4.3.2.2 Water Quality Sampling and Monitoring (2003)

Since the 1999 comprehensive assessment, the understanding of the watershed has been advanced by numerous studies and modeling exercises, funded largely by the Commonwealth of Pennsylvania (e.g., Acts 167, 104b3 and 537). The PWD Watershed Sciences Group 2003 comprehensive assessment was designed to further investigate and characterize the Darby-Cobbs Watershed. Locations of the 27 water quality sampling sites for 2003 are depicted in Figure 3-11. Sites DCC770, DCC455, DCC208, DCD1570, DCD1170, DCD765, DCI010 and DCN010 were included in PWD's baseline chemical assessment of Darby-Cobbs Watershed in 1999. Sites in the Tinicum sub-basin (DCM300 and DCS170) were sampled in 1999 but not in 2003. A single new site (DCD1660), located on Darby Creek upstream of its confluence with Ithan Creek was added for 2003. Figure 3-11 displays locations of these monitoring sites, as well as the type of assessments performed (i.e., discrete chemical, RBP III, habitat, RBP V, or tidal assessments).

Tables 3-14 and 3-15 summarize the types, amounts, and dates of sampling and monitoring performed by PWD, PADEP, and USGS during 2003.

A range of water quality samples were collected during 2003 at eleven sites in the watershed. The sites are listed in Table 3-14 and are shown on Figure 3-11. Three different types of sampling were performed as discussed below. Parameters were chosen because state water quality criteria apply to them or because they are known or suspected to be important in urban watersheds. The parameters sampled during each type of sampling are listed in Table 3-16.

The sampling and analysis program meets AMSA (2002) recommendations for the minimum criteria that should form the basis for impairment listings:

Table 3-14 Summary of Physical and Biological Sampling and Monitoring in Darby-Cobbs Watershed 2003

Site ID	Waterbody	Chemical	PWD		Tidal
			RBP III / Habitat	RBP V	
DCC037	Cobbs				X
DCC1003	Cobbs		X		
DCC208 (DC-06N)	Cobbs	X	X	X	
DCC455 (DC-07)	Cobbs	X	X	X	
DCC770 (DC-10)	Cobbs	X			
DCC793	Cobbs		X	X	
DCD0765 (DC-03)	Darby	X	X	X	
DCD053	Darby				X
DCD100	Darby				X
DCD1105	Darby		X	X	
DCD1170 (DC-04)	Darby	X			

Site ID	Waterbody	Chemical	PWD		Tidal
			RBP III / Habitat	RBP V	
DCD1570 (DC-05)	Darby	X	X	X	
DCD1660 (DC-12)	Darby	X	X		
DCD1880	Darby		X	X	
DCD2138	Darby		X	X	
DCD310	Darby				X
DCD390	Darby				X
DCD480	Darby				X
DCD550	Darby				X
DCD630	Darby				X
DCI010 (DC-09)	Indian	X	X	X	
DCIC007	Indian		X		
DCIE186	East Branch of Indian		X		
DCIW177	West Branch of Indian		X		
DCLD034	Little Darby		X		
DCN010 (DC-08)	Naylors	X	X		
DCN208	Naylors		X		

Table 3-15 Summary of PWD Water Quality Sampling and Monitoring in Darby-Cobbs Watershed 2003

Site Name	Discrete	Continuous	Wet Weather
DCC208 (DC-06)	13 Samples 2/13/03-9/4/03	792.75 hrs	4 Periods 7/21/03 - 9/14/03
DCC455 (DC-07)	13 Samples 2/13/03-9/4/03	793 hrs	4 Periods 7/21/03 - 9/14/03
DCC770 (DC-10)	13 Samples 2/13/03-9/4/03	793 hrs	4 Periods 7/21/03 - 9/14/03
DCD765 (DC-03)	13 Samples 2/13/03-9/4/03	793.25 hrs	4 Periods 7/21/03 - 9/14/03
DCD1170 (DC-04)	12 Samples 2/13/03-9/4/03		
DCD1570 (DC-05)	12 Samples 2/13/03-9/4/03		
DCD1660 (DC-12)	13 Samples 2/13/03-9/4/03	792 hrs	4 Periods 7/21/03 - 9/14/03
DCI010 (DC-09)	12 Samples 2/13/03-9/4/03		
DCN010 (DC-08)	12 Samples 2/13/03-9/4/03		

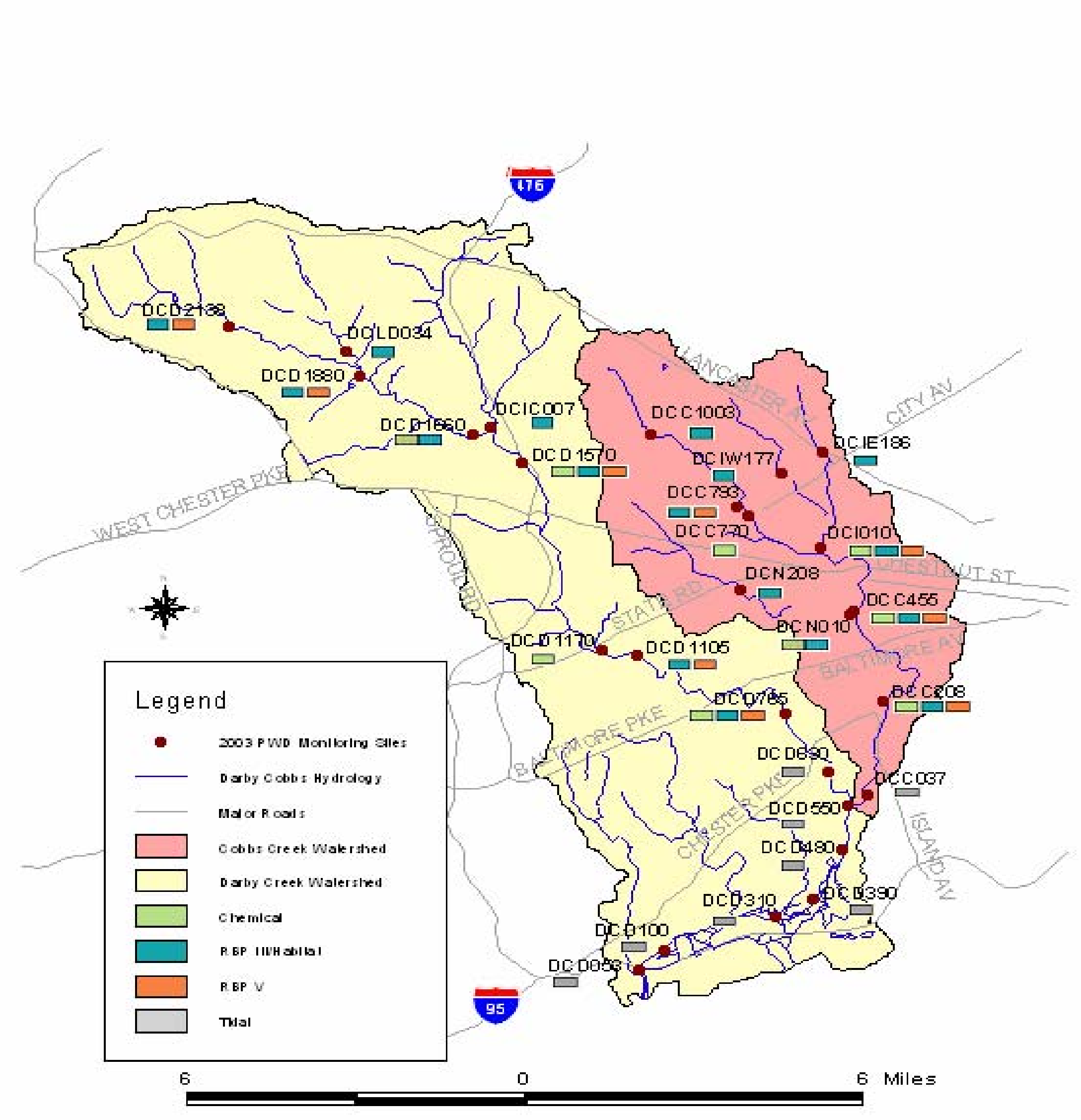


Figure 3-11 PWD Monitoring Locations in Darby-Cobbs Watershed (2003)

Table 3-16 Water Quality Parameter Sampled in Darby-Cobbs Watershed 2003

Parameter	Units	Discrete	Wet Weather	Continuous
PHYSICAL PARAMETERS				
Temperature	deg C	X	X	X
pH	pHU	X	X	X
Specific Conductance	uS/cm	X		X
Alkalinity	mg/L	X	X	
Turbidity	NTU	X	X	X
TSS	mg/L	X	X	
TDS	mg/L	X	X	
OXYGEN AND OXYGEN DEMAND				
DO	mg/L	X	X	X
BOD5	mg/L	X	X	
BOD30	mg/L	X	X	
CBOD5	mg/L	X		
NUTRIENTS				
Nitrate	mg/L	X	X	
Nitrite	mg/L	X	X	
TKN	mg/L	X	X	
Total Phosphorus	mg/L		X	
METALS				
Aluminum	mg/L	X	X	
Calcium	mg/L	X	X	
Cadmium	mg/L	X	X	
Chromium	mg/L	X	X	
Copper	mg/L	X	X	
Fluoride	mg/L	X	X	
Iron	mg/L	X	X	
Dissolved Iron	mg/L	X		
Magnesium	mg/L	X	X	
Manganese	mg/L	X	X	
Lead	mg/L	X	X	
Zinc	mg/L	X	X	
BIOLOGICAL				
Chlorophyll A	ug/L	X		
Fecal Coliform	#/100 mls	X	X	
E. coli	#/100 mls	X	X	
Osmotic Pressure	milliosmoles	X		
MISCELLANEOUS				
Phenolics	mg/L	X		

3.1.4.3.3 Tidal Delaware River

Tidal Delaware River water quality monitoring is conducted by three complementary monitoring efforts on behalf of DRBC, USGS, and PWD. The locations of sampling sites are shown in Figure 3-12.

The DRBC Boat Run monitoring program locations used to characterize the receiving waters are limited to the monitoring stations nearest Philadelphia. Only six of twenty-two DRBC Boat Run stations are included in the following assessment of receiving waters due to their locations far upstream and downstream of Philadelphia. DRBC Boat Run stations and the River Mile locations are presented in Table 3-17 below.

Table 3-17 DRBC Boat Run Stations

Station ID	River Mile	Station Name
332052	87.9	Paulsboro, New Jersey
892065	93.2	Philadelphia Navy Yard
892071	100.2	Ben Franklin Bridge
892070	104.75	Betsy Ross Bridge
892077	110.7	Torresdale (Baxter Water Treatment Plant)
892080	117.8	Burlington Bristol Bridge

The parameters collected at each of the Boat Run stations include:

- Acidity as $CaCO_3$
- Alkalinity, Hydroxide as $CaCO_3$
- Chloride
- Chromium, hexavalent
- Copper
- Dissolved oxygen (DO)
- Dissolved oxygen saturation
- Enterococcus Group Bacteria
- Escherichia coli
- Fecal Coliform
- Hardness, carbonate
- Nitrogen, ammonia (NH3) as NH3
- Nitrogen, Kjeldahl
- Nitrogen, Nitrate (NO3) as NO3
- Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N
- Nitrogen, Nitrite (NO2) as NO2
- pH
- Phosphorus as P
- Phosphorus, orthophosphate as P
- Sodium
- Solids, volatile
- Solids, suspended
- Specific conductance
- Temperature, air
- Temperature, water
- Turbidity
- Zinc

DRBC also conducts specialized monitoring programs at some locations for a range of contaminants including pesticides and toxic compounds such as benzene, TCE, methyl bromide, and MTBE.

The locations of USGS gages supporting the analysis of receiving waters extend through the Delaware Estuary from north of Philadelphia to the mouth of the Delaware Bay. The USGS gage descriptions and parameters collected are presented below in Table 3-18.

Table 3-18 USGS Gage Descriptions

Station ID	Location	Water Quality Parameters
01467200	Delaware River at Ben Franklin Bridge at Philadelphia	Specific Conductance pH Water Temperature Dissolved Oxygen
01477050	Delaware River at Chester, PA	Specific Conductance pH Water Temperature Dissolved Oxygen
01464600	Delaware River at Bristol, PA	Specific Conductance pH Water Temperature Dissolved Oxygen
01412350	Delaware Bay at Ship John Shoal Lighthouse, NJ	Specific Conductance Water Temperature
01482800	Delaware River at Reedy Island Jetty, DE	Specific Conductance pH Water Temperature Dissolved Oxygen

PWD monitoring of the tidal Delaware River is conducted by the Bureau of Laboratory Services at the intake to the Baxter Water Treatment Plant. The Baxter intake monitoring program assesses the raw water quality of the Delaware River in support of treatment decisions made in order to produce high quality drinking water. Monitoring of the intake is conducted daily, weekly, bi-weekly, or monthly depending upon the relationship of the parameter to treatment processes and ongoing research needs.

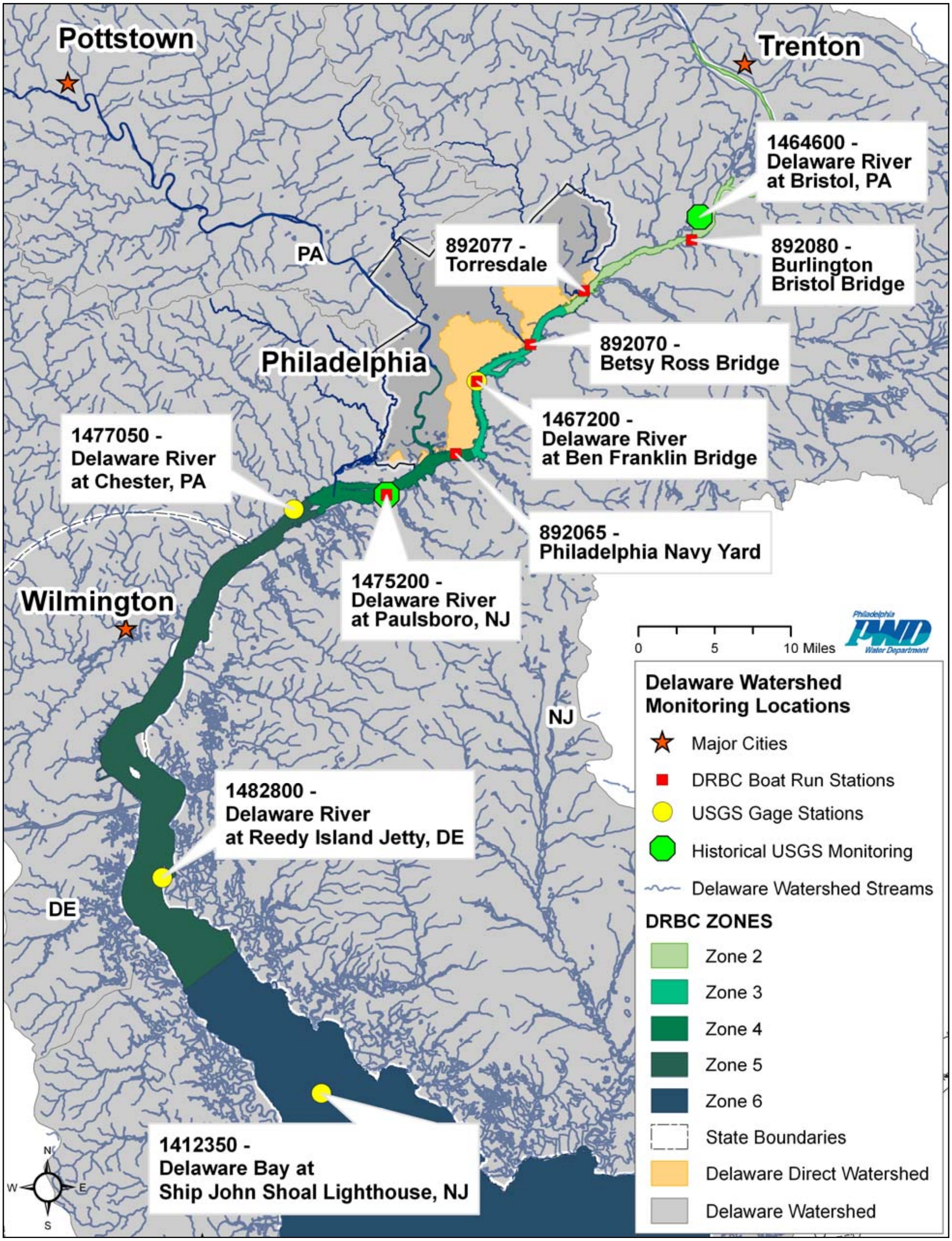


Figure 3-12 Monitoring Locations Used to Characterize Water Quality in the Delaware River

3.1.4.3.4 Tidal Schuylkill River

Table 3-19 summarizes the types, amounts, and dates of sampling and monitoring performed by PWD and USGS through the monitoring period. The locations of monitoring sites are depicted on Figure 3-13. A river mile-based naming convention is followed for sampling and monitoring sites located along waterways in the watershed. For example, site SCH-789 is located as follows:

- "SCH" stands for the Schuylkill River Watershed
- "789" places the site 7.89 miles upstream of the mouth of the Schuylkill River, where it flows into the Delaware

A range of water quality samples were collected during the monitoring period at six sites in the watershed. The sites are listed in Table 3-19 and are shown on Figure 3-13. Three different types of sampling were performed as discussed below. Parameters were chosen because state water quality criteria apply to them or because they are known or suspected to be important in urban watersheds. The parameters sampled during each type of sampling are listed in Table 3-20.

Table 3-19 Summary of Water Quality Sampling and Monitoring in Tidal Schuylkill River

Site Name	USGS Gage	Chemical		
		PWD		USGS
		Wet Weather	Continuous	Discrete
SC136		7 Periods 4/20/2005-5/15/2007		
SCH587		7 Periods 4/20/2005-5/15/2007		
SCH791		7 Periods 4/20/2005-5/15/2007		
	1474500			945 Samples 10/31/1925 to 9/2/2004
SCHU823			3,597.25 hrs	
SCH048			1,297.5 hrs	

Table 3-20 Water Quality Parameters Sampled in Tidal Schuylkill River

Parameter	Units	Discrete	Wet Weather	Continuous
PHYSICAL PARAMETERS				
Temperature	deg C	X	X	X
pH	pHU	X	X	X
Specific Conductance	uMHO/cm @25C	X	X	X
Alkalinity	ug/L	X	X	
Turbidity	NTU	X	X	X
OXYGEN AND OXYGEN DEMAND				
DO	ug/L	X	X	
BOD5	mg/L	X		
CBOD5	mg/L	X		
NUTRIENTS				
Total Ammonia	mg/L as N	X		
Nitrate	mg/L as N & ug/L	X	X	
Nitrite	mg/L as N & ug/L	X	X	
TKN	ug/L		X	
Phosphate	mg/L	X		
Total Phosphorus	ug/L		X	
METALS				
Aluminum	ug/L	X	X	
Calcium	mg/L & ug/L	X	X	
Cadmium	ug/L	X	X	
Chromium	ug/L	X	X	
Copper	ug/L	X	X	
Fluoride	mg/L & ug/L	X	X	
Iron	ug/L	X	X	
Dissolved Iron	ug/L		X	
Magnesium	mg/L & ug/L	X	X	
Manganese	mg/L & ug/L	X	X	
Lead	ug/L	X	X	
Zinc	ug/L	X	X	
BIOLOGICAL				
Chlorophyll A	mg/m^2	X		
Fecal Coliform	#/100 mls	X	X	
E. coli	#/100 mls		X	

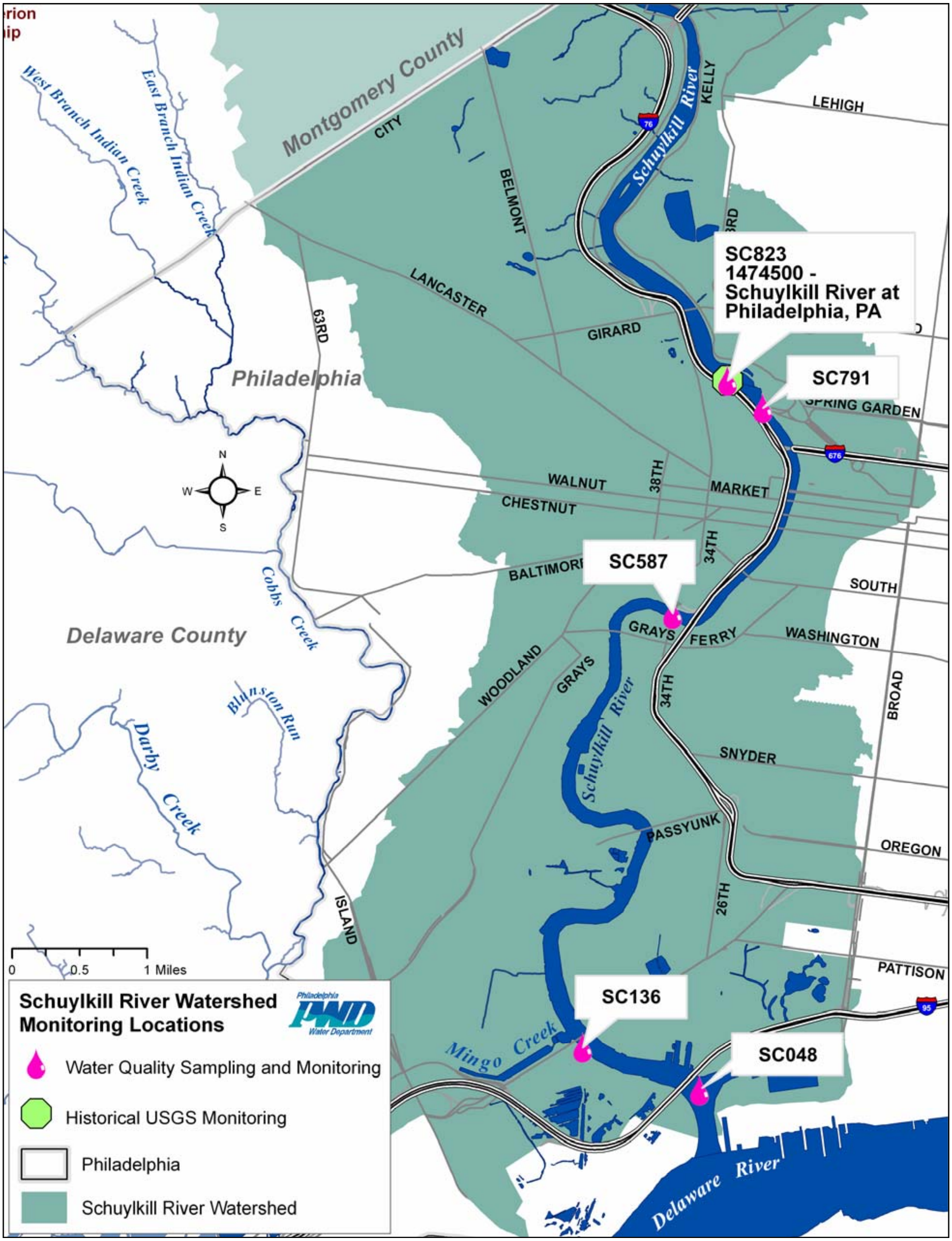


Figure 3-13 USGS and PWD Monitoring Locations in the Schuylkill River

Hydrologic monitoring of the Schuylkill and Delaware Rivers at Philadelphia is conducted mainly at two non-tidal USGS gages; 01474500 Schuylkill River at Philadelphia, and 01463500 Delaware River at Trenton. Sites 01474500 and 01463500 are the most downstream streamflow monitoring locations on the two largest freshwater inputs to the Delaware River Estuary.

3.1.4.4 Continued Monitoring of Receiving Water

PWD will continue to monitor the receiving waters with the watershed approach throughout the implementation phase of the LTCPU. The focus of this monitoring will be to further characterize certain watersheds conditions and to continue collecting water chemistry at USGS stations. The methods and scheduling of all future sampling will be based on the evolving watershed management planning process. All monitoring used for adaptive management of LTCPU implementation is discussed in Section 11.

On-going Monitoring of Tookany/Tacony-Frankford and Cobbs Creek Watersheds

Throughout the LTCPU implementation period (2009-2029), PWD will continue water chemistry assessment activities for the purpose of maintaining a consistent record of data. Assessment will be guided by recognition of the fact that water quality changes dramatically during wet weather. Water quality assessment will advance the understanding of wet weather effects on stream water quality as well as the stormwater and sewer infrastructure. Aligned with LTCPU targets A, B, and C, PWD's water quality assessment strategy has been designed to facilitate separate analyses of dry weather (*i.e.*, baseflow) and wet weather water quality conditions. This program has evolved over time, as personnel and technological advancements have improved PWD abilities to collect more data from an increasing number of sampling locations in a more efficient manner. Automated sampling, in particular, has greatly increased the temporal resolution of stormwater sampling at multiple sampling locations for a single storm event.

Of the 39 water quality parameters regularly sampled during PWD baseline and comprehensive assessments (1999-2009), some have been identified as potentially contributing to water quality problems. However, many parameters are not typically present in concentrations that would cause concern. Furthermore, changes to analytical methods and regulatory requirements and the desire to remain up-to-date with best practices encourage frequent re-evaluation of the suite of chemical parameters to be sampled during various monitoring activities. By tailoring the group of chemical parameters monitored to project goals, PWD hopes to increase sampling efficiency. When fewer parameters are sampled, a smaller volume is required for each sample, increasing the number of samples that can be collected. This philosophy is especially beneficial in automated wet weather sampling programs. The parameters selected for the initial phase of monitoring are presented in Table 3-21.

Dry Weather Water Chemistry Assessment

Surface water grab samples will be collected quarterly at ten Philadelphia area USGS gage stations in dry weather, baseflow conditions in order to build upon a long term record of water quality trends over time. Sample results from the previous monitoring period will be summarized in PWD NPDES Annual Report. Two of the USGS gages sampled are located in Cobbs Creek Watershed and two are located in Tookany-Tacony/Frankford Watershed. In both watersheds, the upstream USGS gage is located at or near the Philadelphia County line, while the downstream gage is located within the downstream-most non-tidal segment of the creek

Surface water grab samples will also be collected for the purpose of updating water quality indicator status from the Tookany/Tacony-Frankford Creek and the Cobbs Creek Integrated Watershed Management Plans. PWD will sample watersheds on a rotational basis, following the same order as monitoring for the original baseline characterizations. For example, Cobbs Creek samples will be collected at sites DCC208, DCC455, and DCC770 (Figure 3-11) in dry weather baseflow conditions during spring and summer seasons of a designated year within the initial implementation phase. Water quality analysis results will be published in a watershed indicator status update report for the Cobbs Creek. The Tookany/Tacony-Frankford Creek will be the next watershed sampled at sites TF280, TF620, TF975, and TF1120 (Figure 3-9) during spring and summer seasons in order to characterize water quality for a watershed indicator status update report for the Tookany/Tacony-Frankford Watershed.

Wet Weather Targeted Water Chemistry Assessment
Wet weather water quality assessment is an important component of PWD Comprehensive Watershed Assessments, which provide the technical basis for Integrated Watershed Management Plans and IWMP update reports for water quality indicators (Target C). Wet weather targeted water chemistry assessment will be conducted with automated water sampling equipment during four runoff-producing wet weather events during a given year following the same watershed assessment rotation as proscribed in the Integrated Watershed Management process. The Cobbs Creek watershed will be monitored first followed by The Tookany/Tacony-Frankford Watershed. Monitoring locations will be similar to the sites listed above in the Dry Weather Water Chemistry Assessment.

Continuous Water Chemistry Assessment
PWD provides ongoing support to the USGS to collect continuous water quality data at ten locations within Philadelphia's watersheds, addressing both dry and wet water quality. PWD staff are currently responsible for installing and maintaining water quality monitoring instruments (YSI 6600, 6600 EDS and 600 XLM sondes) which measure dissolved oxygen, temperature, pH, conductivity, depth (stage) and, optionally, turbidity at 30-minute intervals. Sondes are connected to USGS transmitters uploading data to the USGS National Water Information System (NWIS) at least every four hours. Continuous data, including intervals during which water quality exceeded PADEP criteria, are summarized for each gage in PWD Combined Stormwater NPDES Annual Report.. Sondes deployed in urban environments require frequent cleaning and maintenance. Field meter readings and Winkler titration dissolved oxygen tests are performed on a regular weekly basis and following a significant wet weather event.

In addition to the permanent continuous water quality monitoring at USGS gages 01467087 and 01467086, PWD will monitor continuous water quality in the Tookany/Tacony-Frankford Watershed using *in situ* continuous water quality monitoring equipment at sites TF975 and TF1120 (Figure 3-9) from March to December 2013.

Table 3-21 Parameters Analyzed for PWD Water Chemistry Assessment Programs

Parameter	Units	Dry Weather Assessment	Wet Weather Assessment	Continuous Assessment
Alkalinity	mg/L			
Ammonia	mg/L as N			
BOD5	mg/L			
Calcium	mg/L			
Specific Conductance	µS/cm	X		X
Enterococcus	CFU/100mL	X	X	
E. coli	CFU/100mL	X	X	
Fecal Coliform	CFU/100mL	X	X	
Hardness	mg/L CaCO3			
Magnesium	mg/L			
Nitrate	mg/L	X	X	
Nitrite	mg/L			
Orthophosphate	mg/L	X	X	
Dissolved Oxygen	mg/L	X		X
pH	pH units	X		X
Total Phosphorus	mg/L		X	
Suspended Solids	mg/L	X	X	
Total Solids	mg/L		X	
Temperature	°C	X		X
TKN	mg/L		X	
Turbidity	NTU		X	X

On-going Monitoring of the Tidal Rivers

PWD is currently developing an assessment program for the tidal river segments within Philadelphia. This program will include the collection of discrete dry weather samples, wet weather samples, and continuous monitoring at USGS gages and sondes deployed in the Tidal Schuylkill. PWD will continue to monitor water quality in the Tidal Schuylkill for the purposes of further characterizing baseline conditions. Other studies will be conducted as needed and likely focus on the tidally-influenced tributaries since previous studies focused on non-tidal portions of these watersheds. PWD will continue to use DRBC Boat Run data to assess the water quality in the Delaware River.

All sampling and monitoring will continue to follow the Standard Operating Protocols (SOPs) as prepared by the Philadelphia Water Department's Bureau of Laboratory Services (BLS). These documents cover the elements of quality assurance, including field and laboratory procedures, chain of custody, holding times, collection of blanks and duplicates, and health and safety. These procedures may evolve as our understanding of the watersheds and science change and technology for sampling and analysis advance.

3.1.5 PWD Interceptor System and Regulator Structure Data

Data collection of the Philadelphia interceptor systems and regulator structures as used for development of the LTCPU were compiled using the return plans, design and as-built drawings provided by the Engineering Records Viewer (ERV) maintained by PWD, model pipe and node layers provided by a GIS database maintained by OOW, drainage plats and regulator structure inspection reports.

3.1.6 Geographic Information System (GIS) Data

In 2005 PWD completed a data conversion project resulting in the creation of GIS coverages for all of the City's water, sewer, and high pressure fire infrastructure. The conversion project consisted of extracting data from over 250,000 engineering documents stored in digital format and indexed by location. Project execution occurred in three phases: Initiation, Pilot and Production. The Initiation Phase included a series of workshops designed to ensure the conversion process properly utilized the 85 different types of source documents maintained by the department. It also included customization of data conversion tools to meet the project's data specifications, the development of a detailed conversion work plan, and conversion of the data for a 2-block area within the City. The Pilot Phase included further definition of the project's data dictionary and conversion tools and applied both to data from 2 of the City's 121 map tiles. The final phase, Production, included conversion of the remaining tiles and the establishment of links between the GIS data and legacy databases related to valves, hydrants and storm sewer inlets.

The project was supported through the use of customized conversion tools for data collection, data scrubbing, data entry, graphical placement, and quality control. Conflicts and anomalies in the data were tracked using a web-based tool and database. PWD expects to utilize the GIS coverages as the foundation for many of their operations including maintenance management, capital improvements, and hydraulic modeling. A list of GIS data used to support the LTCPU process includes:

- Land use data from the DVRPC
- Geology data
- Detailed information on size and types of impervious cover
- Rain gage, flow monitoring, and receiving water monitoring sites
- Sewer system information (manholes, pipes, regulator structures, outfalls)
- Drainage areas to individual regulator structures
- Hydrography
- Soil type
- Public property (Philadelphia Streets Department, Philadelphia Water Department, School District of Philadelphia, Fairmount Park Commission, Philadelphia Department of Recreation, etc.)
- Land surface slope
- Vacant and abandoned lands
- Aerial photos
- PWD's Engineer Records Viewer, georeferenced contract and construction drawings.
- U.S. Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing)
- General base layers prepared by the City of Philadelphia Department of Technology

One of the most important GIS data layers produced from the updated data conversion, which was used throughout the development process of the LTCPU, was the impervious surfaces analysis. The impervious area analysis was necessary to more accurately determine the benefit of implementing green infrastructure into the City by determining the extent to which green infrastructure could be feasible for the City of Philadelphia specifically. A brief account of how the impervious data used to characterize the impervious area throughout the City of Philadelphia was produced and the governing criteria for that process using the above mentioned GIS utilities and tools is provided in the following sub-section. Soil type analysis was also conducted using GIS capabilities and is discussed briefly below.

Determining soil types was also fundamental to correctly characterizing the City's current hydrologic condition. GIS was used to analyze soil characteristics and define soil types. Based on the GIS data layers, it was found that most of Philadelphia lies within the Coastal Plain Physiographic Province with the northwest portion of the City and a small section of the northeast extending into the Piedmont Uplands section of the Piedmont Physiographic Province. Elevations in the Coastal Plain range from 10 feet mean sea level (msl) along the Delaware River, to slightly more than 40 feet (msl) at the northwest edge of the Province. The Piedmont Uplands Section ranges from 40 feet (msl) at the Coastal Plains Section to approximately 150 feet (msl). The soil coverage in the Philadelphia service area is categorized into two types:

- C2a: Chester-Glenelg Association – Soils formed in materials igneous and metamorphic rocks
- E3a: Howell-Fallsington Association – Soils formed in unconsolidated water alluvial materials

The soils associated with the Piedmont Uplands Section primarily have a B-type hydrologic rating and, therefore, moderate rates of infiltration can be expected. This section has slopes averaging from 15-20 percent, and soil depths of 50-70 inches. Soils associated with the Coastal Plain Province are influenced by their substrate of marine clay and sand, and slow infiltration rates can be expected. Note that most of the combined sewer area in the PWD service area is densely developed and highly impervious. Therefore, the soils in this area are primarily disturbed urban land, and the drainage to the combined sewer system is dominated by the imperviousness of the drainage area.

GIS Impervious Area Analysis

Impervious surface information was obtained from the 2004 Sanborn planimetric layer maintained by the Office of Watersheds. This layer is known to contain some inaccuracies but is the best information on impervious surfaces currently available. Impervious surface classifications in the layer were grouped into three broad categories (buildings, parking, streets/sidewalks). Pervious surfaces and surfaces with no or limited green stormwater infrastructure potential (e.g., bridges, water bodies) were excluded from the analysis with the exception of bridges on interstate highways, which were included in the analysis.

For subsequent hydrologic model simulation analyses and alternatives analysis, it was necessary to determine the impervious area within each shed modeled for the City. Boundaries were determined for lands owned and maintained by the following City departments and other City entities: PWD, Recreation, the School District and the Fairmount Park Commission. A number of the above listed

GIS layers were intersected with the 2004 planimetric layer to allocate area to each of the above public entities, a private land category and vacant lands and homes. Once these categories were identified, the amount of impervious cover for each shed was summed based on the three broad categories previously mentioned (buildings, parking and streets/sidewalks).

This impervious data were used as the foundation from which many LID analyses were conducted for the LTCPU.

3.1.7 Improvement Cost Data

Source Controls

Costs for stormwater controls are site-specific. PWD's approach is to compile a number of real post-construction stormwater management plans submitted to PWD by developers required to comply with the City's stormwater regulations. These projects include a range of drainage areas, densities, and control requirements. Using quantities from the plans and realistic local unit costs, PWD estimated the marginal cost to the developer of complying with the stormwater ordinance. The marginal cost is the cost in addition to traditional development. For example, demolition typically should not be included, but excavation and hauling of material needed to build a subsurface basin should be included. Costs on each site are expressed as a range to represent uncertainty.

Costs are expressed in terms of cost per unit area of impervious cover on the site before redevelopment. This range of costs per unit area was scaled to give an estimate over a given drainage area undergoing redevelopment.

Infrastructure Options

PWD developed an Alternative Costing Tool (ACT) for cost estimating of infrastructure options. Costs are based on quantities of labor and materials required for construction. Additional costs for design, geotechnical investigations when needed, and operations and maintenance are added and expressed as a present value. Unit costs are based on a combination of local experience, site specific factors, and best professional judgment. These estimates are suitable for the long-term planning level. More precise cost estimates will be required in the facilities planning and design phases. The ACT is discussed in greater detail in Section 5.

3.1.8 Socio/Economic Data

The following Socio/Economic Analysis (Tables 3-22 and 3-23) used geographic and demographic data from the U.S. Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing) database. These files contain local and state political boundaries, rivers and waterways, roads and railroads, and census block and block group boundaries for demographic analysis. Additional demographic data are discussed in the watershed Comprehensive Characterization Reports.

3.1.8.1 Tacony-Frankford Watershed

Figure 3-14 and Figure 3-15 show there is a distinct contrast in the socio-economic status between areas in the Tookany/Tacony-Frankford Watershed that lie within the City of Philadelphia and those in surrounding municipalities in Montgomery County. Average Housing Unit Value within the TTF Watershed within Philadelphia is $58,605 and in Montgomery County is $164,340. Median

Household Income in the TTF Watershed within Philadelphia is $32,654 and in Montgomery County is $66,708.

3.1.8.2 Cobbs Creek Watershed

Figure 3-16 and Figure 3-17 show there is a distinct contrast in the socio-economic status between areas in the Cobbs Creek Watershed that lie within the City of Philadelphia and those in surrounding municipalities in Delaware and Montgomery Counties. Average Housing Unit Value within the Cobbs Creek Watershed within Philadelphia is $47,397 and in Delaware and Montgomery Counties, the average is $212,410. Median Household Income in the Cobbs Creek Watershed within Philadelphia is $30,240 and in Delaware and Montgomery Counties, the average is $75,668.

3.1.8.3 Tidal Delaware River Watershed

Figure 3-18 and Figure 3-19 illustrate the socio-economic status in the Delaware Direct Watershed. Average Housing Unit Value within the Delaware Direct Watershed is $55,908 and Median Household Income is $38,934, the highest in Philadelphia.

3.1.8.4 Schuylkill River Watershed

Figure 3-20 and Figure 3-21 illustrate the socio-economic status in the Combined Area in the Schuylkill Watershed. Average Housing Unit Value within the Combined Area in the Schuylkill Watershed is $60,869, the highest in Philadelphia and Median Household Income is $25,756.

Table 3-22 Mean Home Value (MHV) in Philadelphia Watersheds

Watershed	MHV	MHV within Philadelphia	MHV in other Municipalities
Tookany-Tacony Frankford	$111,472	$58,605	$164,334
Cobbs Creek	$157,406	$47,397	$212,410
Delaware Direct	$55,908	$55,908	N.A.
Schuylkill	$60,869	$60,869	N.A.

Table 3-23 Mean Household Income (MHI) in Philadelphia Watersheds

Watershed	MHI	MHI in Philadelphia	MHI in Outside Municipalities
Tookany-Tacony Frankford	$49,681	$32,654	$66,708
Cobbs Creek	$60,526	$30,240	$75,668
Delaware Direct	$38,934	$38,934	N.A.
Schuylkill	$25,756	$25,756	N.A.

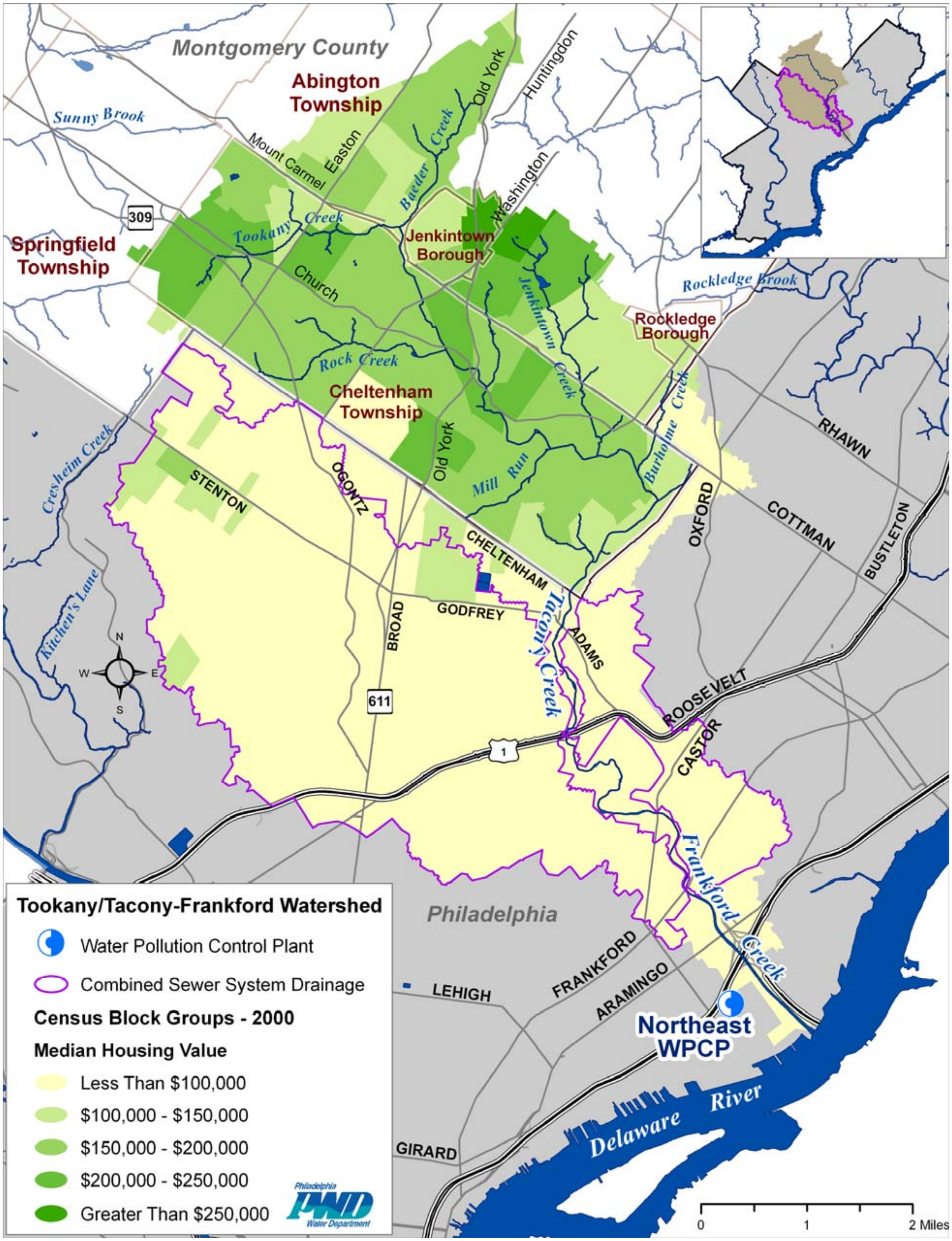


Figure 3-14 Mean Home Value in Tookany/Tacony-Frankford Watershed

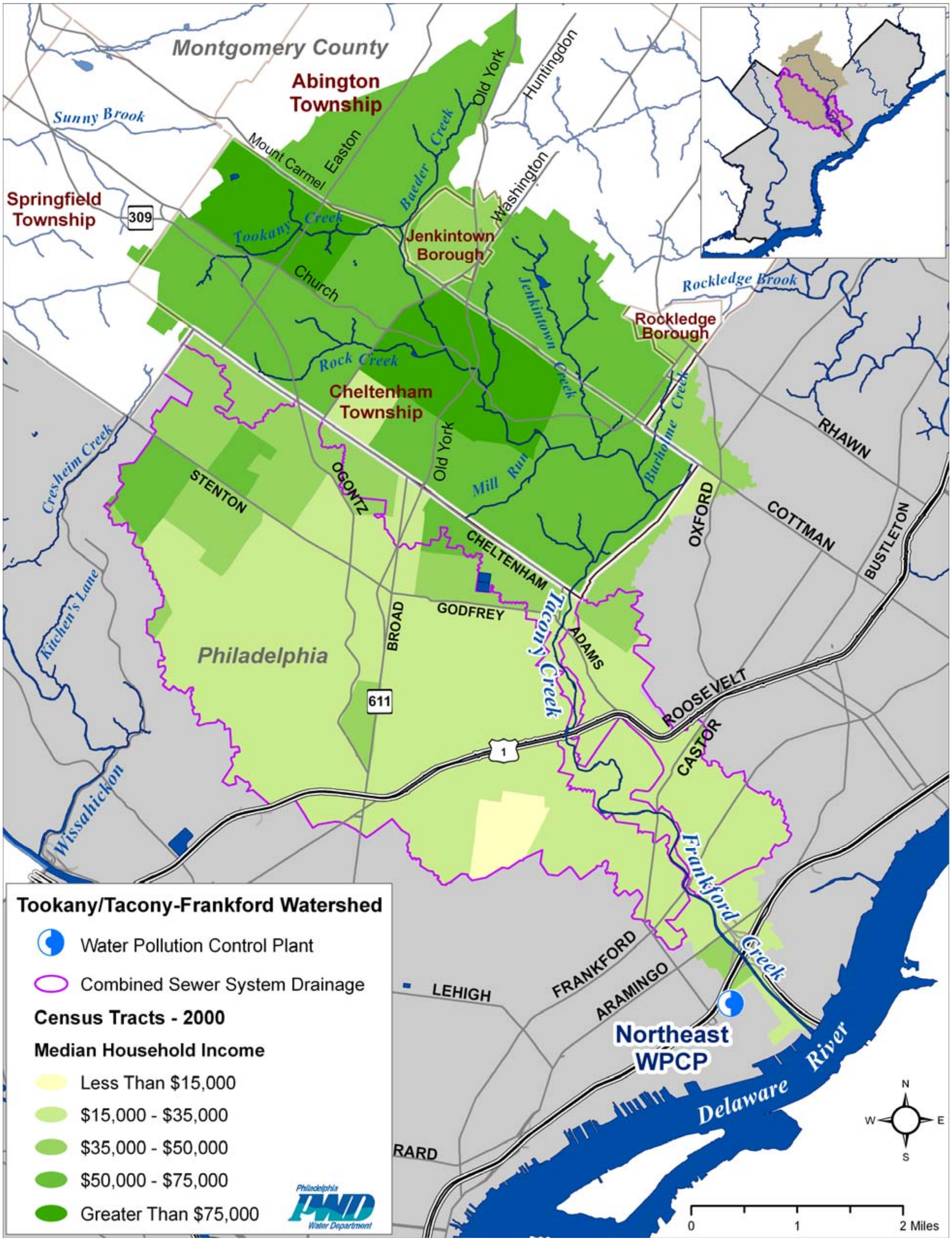


Figure 3-15 Median Household Income in Tookany/Tacony-Frankford Watershed

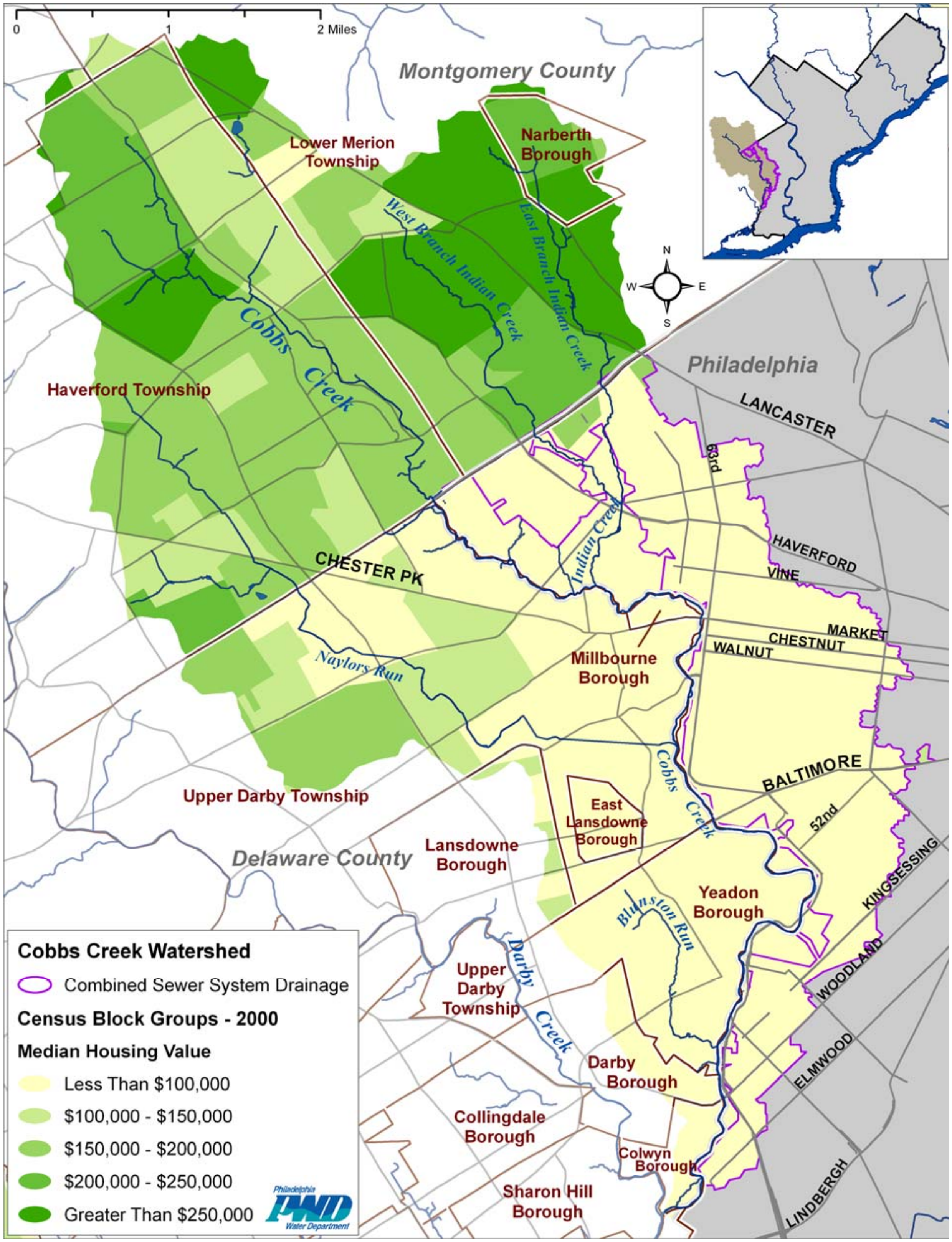


Figure 3-16 Mean Home Value in Cobbs Creek Watershed

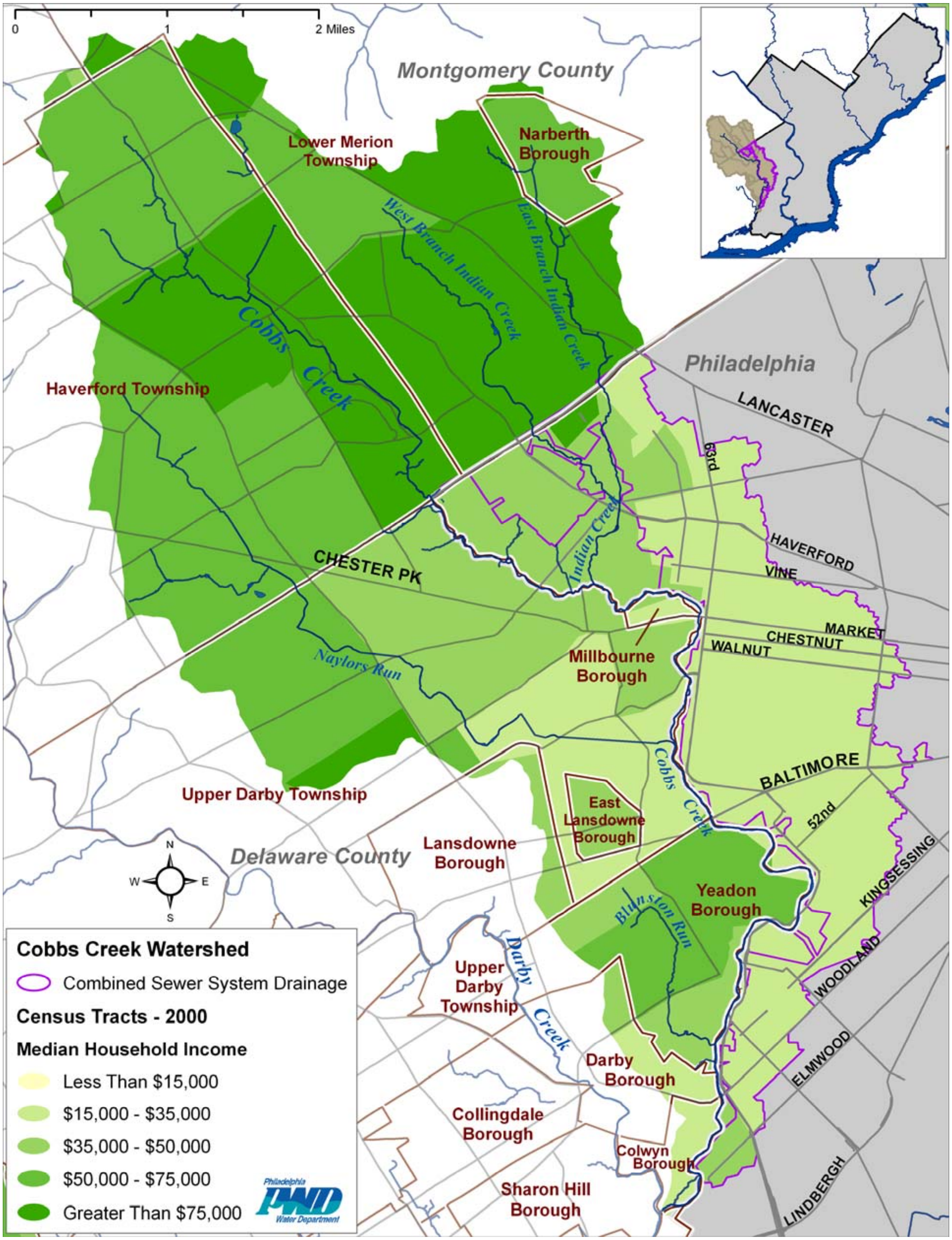


Figure 3-17 Median Household Income in Cobbs Creek Watershed

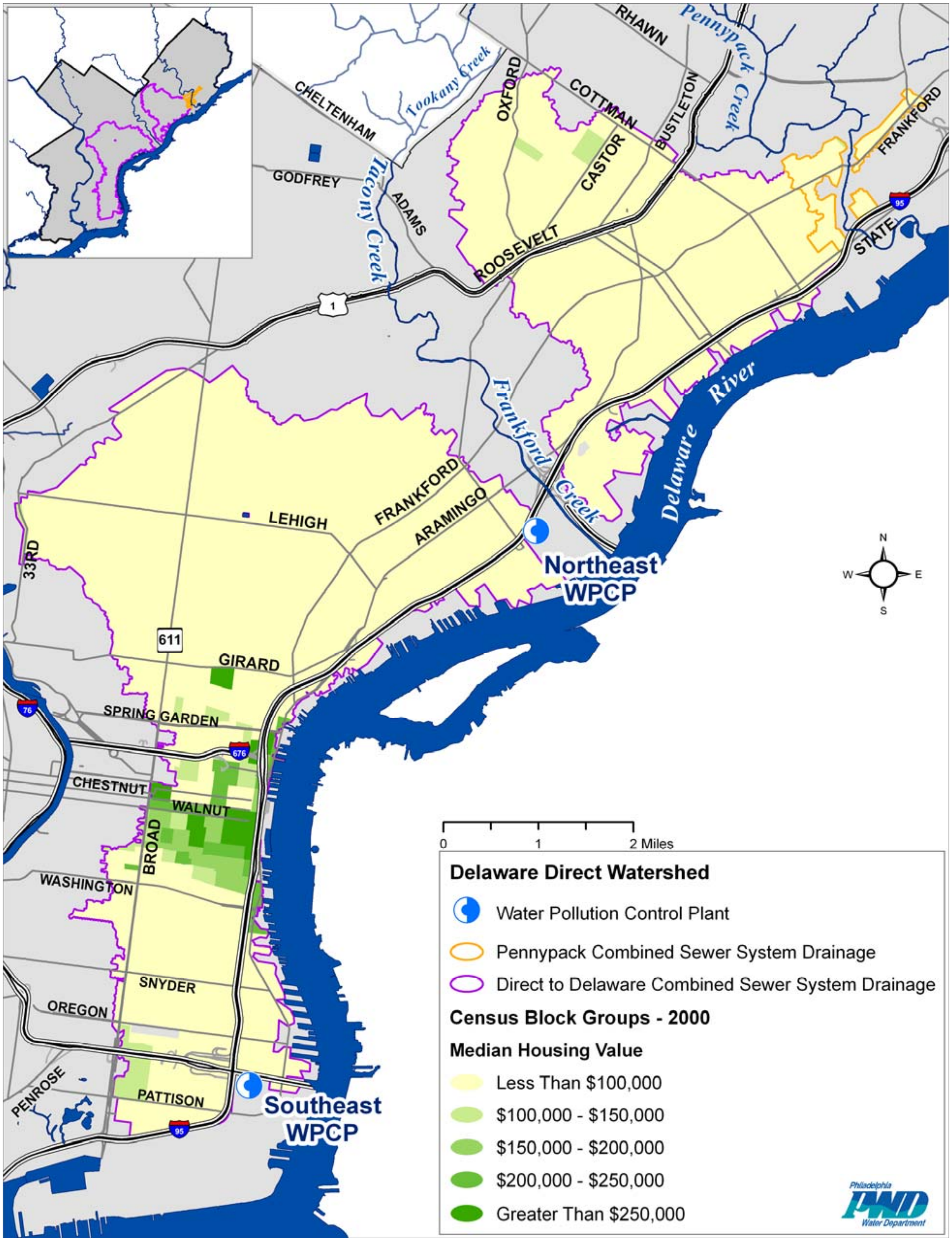


Figure 3-18 Mean Home Value in the Delaware Direct Watershed

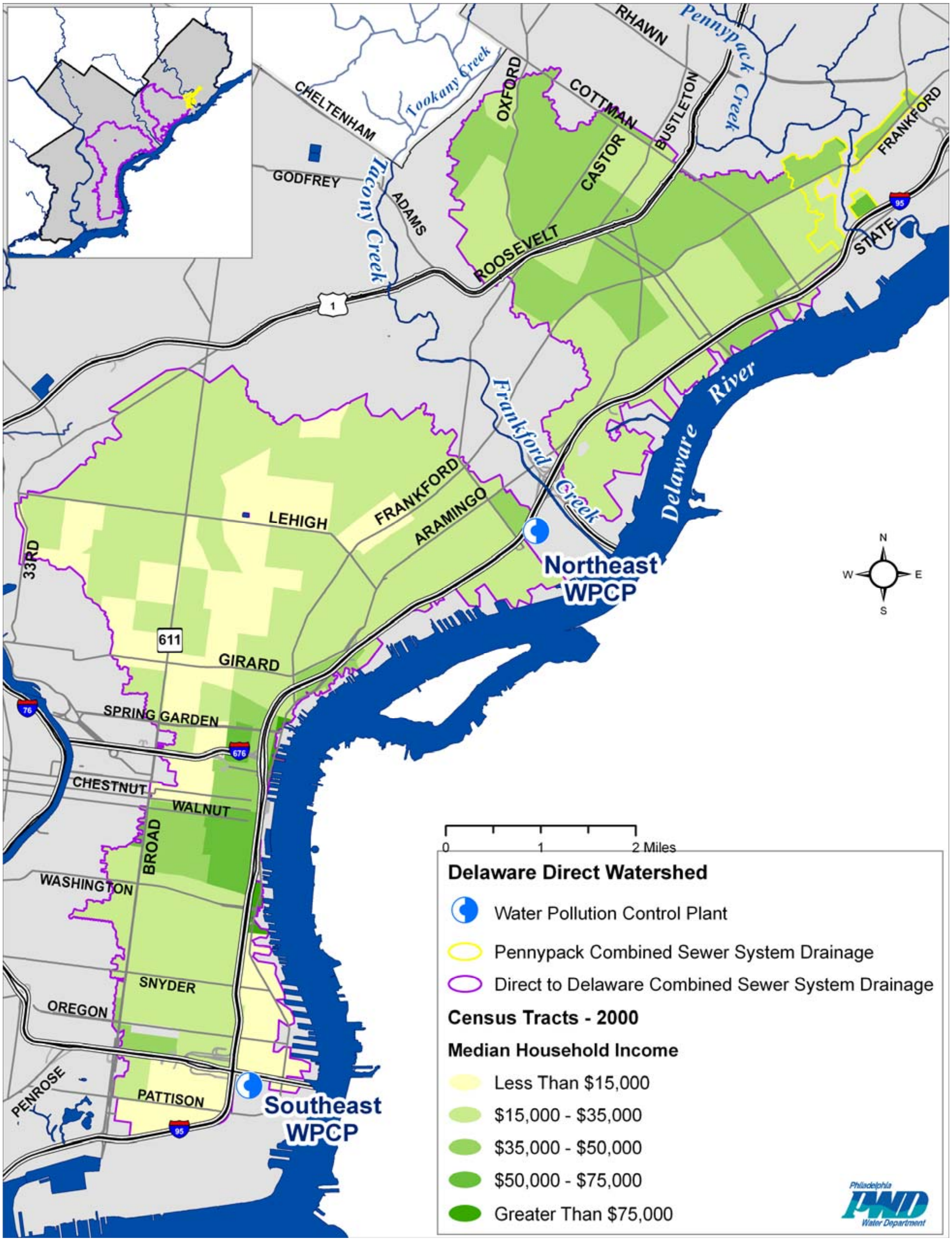


Figure 3-19 Median Household Income in the Delaware Direct Watershed

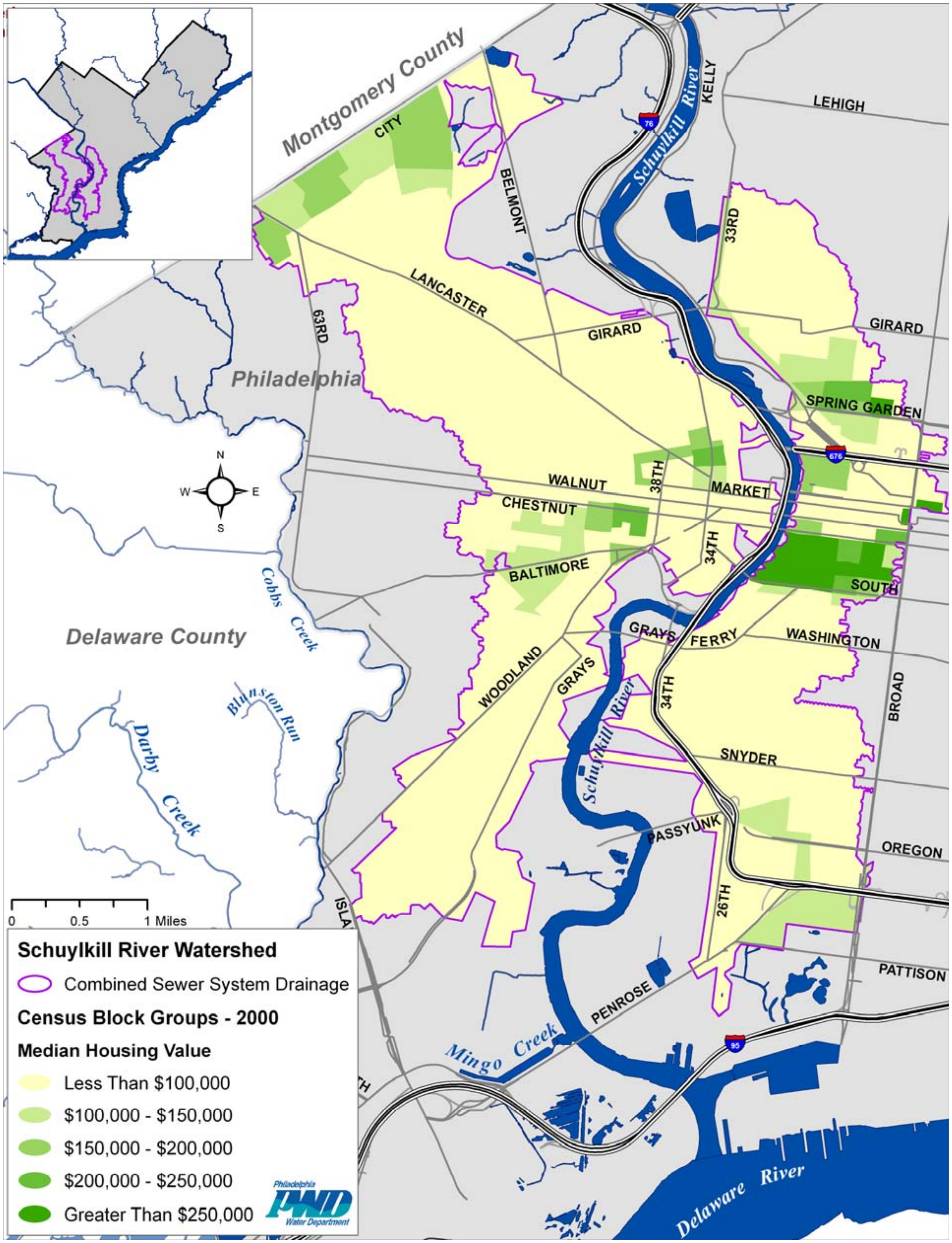


Figure 3-20 Mean Home Value in the Schuylkill River Watershed

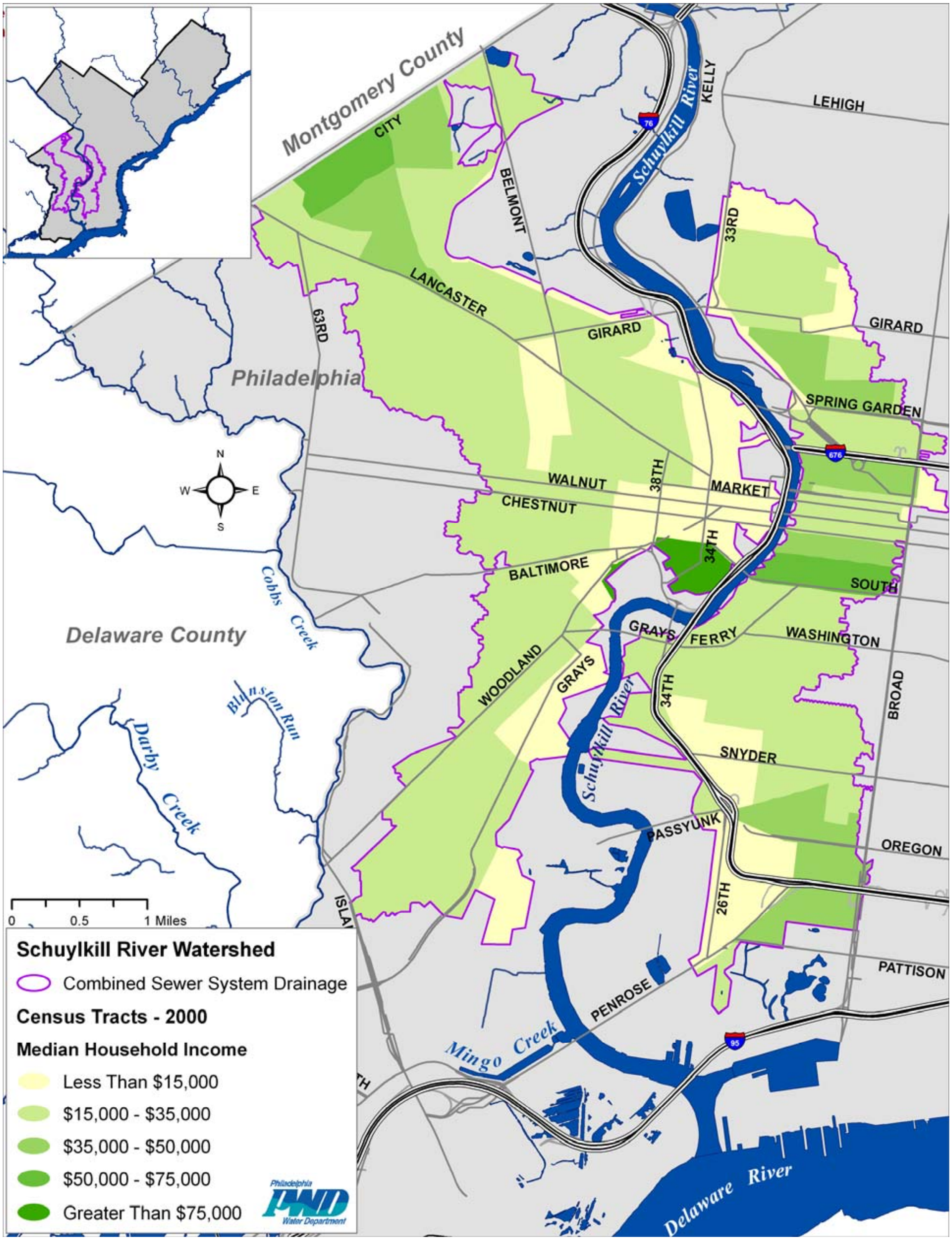


Figure 3-21 Median Household Income in the Schuylkill River Watershed

3.2 PWD WASTEWATER COLLECTION AND TREATMENT SYSTEM

3.2.1 Contributing Area Description

Service Area Description

The greater Philadelphia area is the fifth largest urban population center in the United States, and the City of Philadelphia has a population of nearly 1.5 million and a total land area of 136 square miles. Of this area, approximately 64 square miles are served by combined sewers carrying a mix of domestic and industrial wastewaters, which are combined with stormwater runoff during wet weather, and approximately 42 square miles are served by separate sanitary sewers which carry wastewater only. PWD operates three water pollution control plants (WPCPs): Northeast, Southeast, and Southwest. In addition, the department operates the system of branch sewers, trunk sewers, regulator chambers, and interceptor sewers that convey the combined wastewater to the WPCPs.

The PWD wastewater service area consists of the entire City of Philadelphia, as well as outlying communities and authorities that discharge wastewater to the WPCPs. The ten municipalities and authorities that have discharge agreements with the City are:

- Township of Abington
- Bensalem Township
- Bucks County Water and Sewer Authority, including all or parts of the townships of Bensalem, Bristol, Falls, Lower Wakefield, Lower Southampton, Middletown, Newtown, and Northampton; and the boroughs of Hulmeville, Langhorne, Langhorne manor, Newtown, and Pendel.
- Township of Cheltenham
- The Delaware County Regional Water Quality Control Authority (DELCORA) including all or part of Haverford, Radnor, Newtown, Upper Providence, Tinicum; the boroughs of Norwood, Glenolden, Morton, Rutledge, Prospect Park, Ridley Park, and Swarthmore; and the townships of Darby, Upper Darby, Ridley, Springfield, Marple, and Nether Providence.
- The Township of Lower Merion
- Township of Lower Moreland and the Lower Moreland Township Authority
- Lower Southampton Municipal Authority
- Township of Springfield, Montgomery County
- Upper Darby Township and Haverford Township

The City of Philadelphia is bounded by the Delaware River on the east and south, and by the suburban communities of Bucks, Montgomery and Delaware counties on the west, north, and east. Combined Sewer Overflows discharge to the Delaware and Schuylkill Rivers and to the Cobbs, Frankford, Old Frankford, Pennypack, Tacony, West Branch Indian and East Branch Indian Creeks. Figure 3-22 shows the City of Philadelphia and the combined sewer drainage areas in the PWD system.

Drainage Area Delineation

The drainage basin sub areas are the smallest units used to determine how flow enters into the collection system. The drainage areas were digitized from the PWD drainage plats, currently maintained by Collection Systems Support: Drainage Information Unit. Prior to digitizing, each plat was reviewed to determine if it should be subdivided for modeling purposes and to identify the point where flow enters the collection system. Subdivisions are marked on the existing drainage plat so that PWD will be able to maintain the model in future years. Information is stored in a geographic information system (GIS).

3.2.2 Collection System Configuration

This section describes the configuration, current capacity, CSO response to rainfall and the existing conditions of the water pollution control plants for each district. A variety of models and tools were used to represent and analyze the CSS for the LTCPU, including SWMM4, NetStorm, a number of proprietary spreadsheet analysis tools specific to the City of Philadelphia and this LTCPU and SAS software. These models and tools are discussed in greater detail in Sections 5.

Description of Collection System

The PWD service area is divided into three drainage districts: Northeast, Southeast, and Southwest (Figure 3-22). Each of these drainage districts conveys flow to the respective WPCP of the same name. These three drainage basins are hydraulically independent except during conditions of high flow, when cross connections in the trunk sewer system allow conveyance of some flow between drainage districts.

Each drainage district contains a variety of sewers types – trunks, storm relief, combined, separate sanitary and interceptors – throughout the City as shown in Figure 3-22. This network of sewers collects stormwater and wastewater and conveys the flow to regulator chambers located throughout the CSS. Flow passing through the regulator chambers is conveyed to the WPCPs. During many rainfall events the regulating chambers divert excess flow that cannot be treated at the WPCPs to overflow outfalls or storm relief diversion chambers to prevent combined sewer backups.

PWD design criteria for the combined sewers are based on an empirical expression relating design rainfall intensity to the estimated basin time of concentration. This intensity is used in the Rational Method with an estimate of the runoff coefficient (C) and the size of the drainage area to obtain a design flow rate. Standard sewer design methods using the continuity and Manning's equation for flow were then applied in determining the size, grade, design depth, and other sewer system characteristics for the combined sewer system.

A brief description of the collection systems for each drainage district follows.

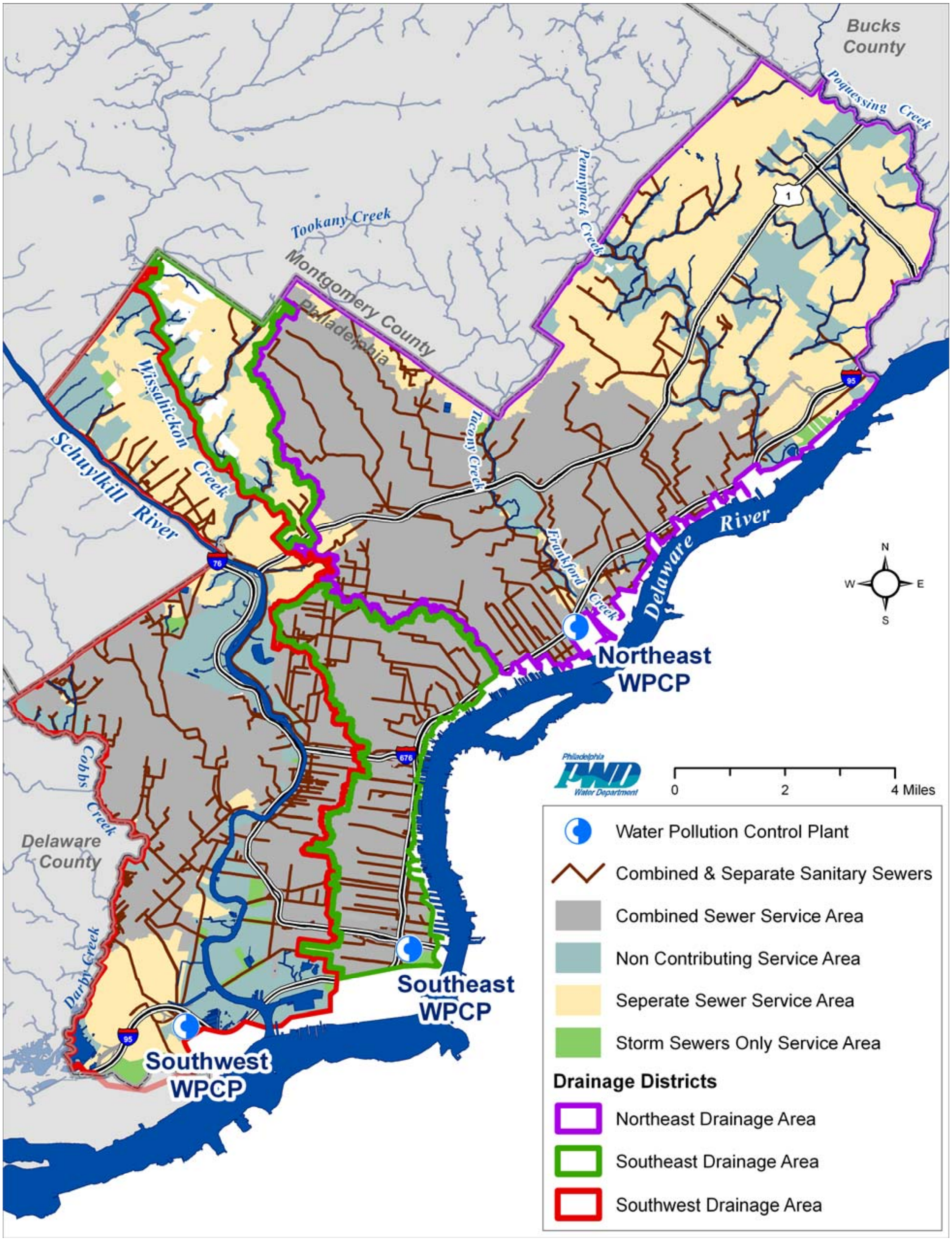


Figure 3-22 Philadelphia Sewer Area with Drainage Districts Boundaries

3.2.2.1 Northeast Drainage District

Figure 3-23 shows the collection system for the Northeast drainage district. This figure depicts the combined and separate sanitary sewer interceptors, as well as the location of the CSO regulators and major hydraulic control points – strategic flow control points in the sewer system where flow is redirected using weirs or in cases of extreme wet weather. Suburban communities served by the Northeast WPCP include:

- Township of Abington
- Bensalem Township
- Bucks County Water and Sewer Authority, including all or parts of the townships of Bristol, Falls, Lower Wakefield, Middletown, Newtown, and Northampton; and the boroughs of Hulmeville, Langhorne, Langhorne manor, Newtown, and Pendel.
- Township of Cheltenham
- Township of Lower Moreland
- Lower Southampton Township

The Northeast drainage district serves an in-City population of approximately 752,000 and conveys flows to two hydraulically independent interceptor systems. The low level system includes the Upper Delaware Low Level (UDLL), Upper Frankford Low Level (UFLL), Lower Frankford Low Level (LFLL), Pennypack (PP), and Somerset Low Level (SOM). These interceptors convey wastewater and stormwater to the WPCP where it is pumped into the preliminary treatment building. The Pennypack and Lower Frankford Low Level interceptors are tributary to the Upper Delaware Low Level, which conveys flow to the Northeast WPCP through Junction Chamber A (JCA) to the preliminary treatment building (PTB) for screening and pumping. The Somerset and Upper Frankford Low Level interceptors combine outside of the WPCP at Diversion Chamber A (DivA), at which point flows are metered and conveyed through the JCA to the preliminary treatment building for screening and pumping. The high level interceptor system consists of the Tacony (TAC) interceptor and the Frankford High Level (FHL) interceptor. The Tacony interceptor conveys flows to the Frankford High Level interceptor. The Frankford High Level conveys flows into the WPCP by gravity.

Upper Delaware Low Level

The UDLL interceptor originates in the northeast region of Philadelphia near the confluence of the Poquessing Creek and the Delaware River. Two sanitary sewer interceptors contribute flow here, the Byberry Interceptor and the Poquessing Interceptor, in addition to a metered flow from Bensalem Township. Bensalem, Southampton and Lower Moreland Townships also contribute flows to the PWD system through the Poquessing Interceptor. Wastewater flow from Bucks County enters the UDLL interceptor just upstream of Pennypack Creek through a 42 inch force main. The interceptor flows southwest, parallel to the Delaware River until it reaches the NE WPCP. Table 3-24 lists the combined sewer regulators on the UDLL.

The Pennypack (PP) interceptor conveys flows from Holmes Avenue in northeast Philadelphia to the UDLL interceptor on the south side. The Pennypack interceptor receives sanitary flows from several small interceptor systems and metered flow from Abington. Table 3-24 lists the combined sewer regulators on the Pennypack interceptor.

The Lower Frankford Low Level (LFLL) lies between the Delaware Expressway and the UDLL interceptor. It conveys flows from Church Street on the southwest and Bridget Street on the northeast to the junction with the UDLL near Margaret and Garden Streets. Table 3-24 lists the combined sewer regulators on the LFLL.

Somerset/Upper Frankford Low Level

The Somerset Low Level (SOM) interceptor originates near Somerset Street and conveys flow along the Delaware River northeast into the NE WPCP. The UFLL interceptor begins near Wyoming and Castor Streets, and conveys flows southeasterly toward the WPCP, parallel to New Frankford Creek. The UFLL interceptor combines with the Somerset interceptor near Luzerne and Richmond Streets at Diversion Chamber A. Table 3-24 lists the combined sewer regulators on the Somerset and upper Frankford Low Level interceptors.

Tacony/Frankford High Level

The Tacony (TAC) and FHL interceptors combine to convey flows from near Cheltenham Township southeasterly along the Tacony and New Frankford Creeks to the NE WPCP. The Tacony interceptor runs along the Tacony Creek to where the FHL interceptor begins at the Frankford Grit Overflow Chamber (R_18) located near Hunting Park Avenue and Castor Street. From here, the FHL interceptor conveys flow to the "O" Street and Erie Avenue Diversion Chamber (H_22), where flows split into parallel sewers. The parallel sewers convey wastewater and stormwater along Frankford Creek by gravity into the NE WPCP. Table 3-24 lists the combined sewer regulators on the Tacony and Frankford High Level interceptors. Table 3-25 lists ranges of interceptor sewer diameters in the Northeast drainage district by interceptor system

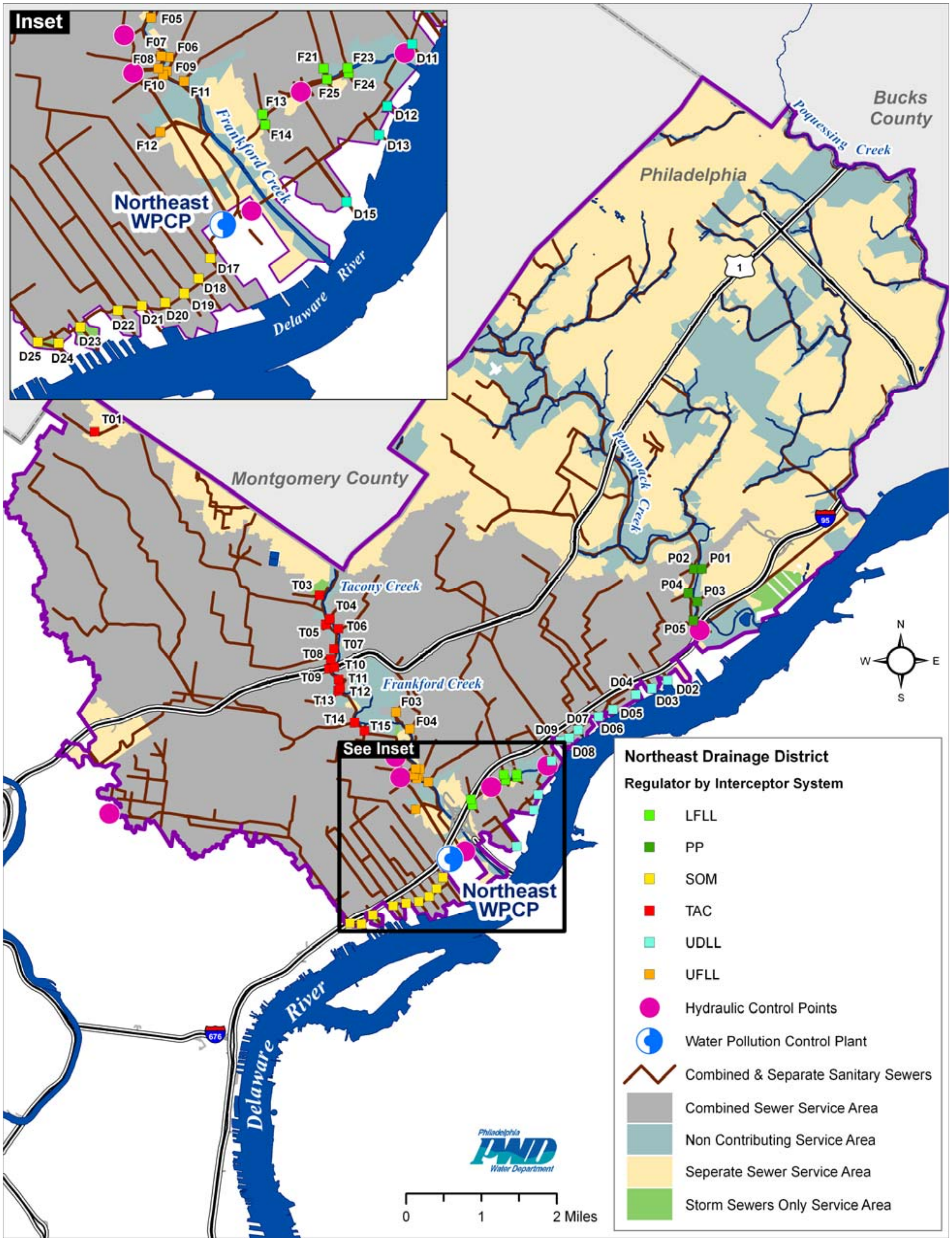


Figure 3-23 Northeast Drainage District Collection System

.Table 3-24 Northeast Drainage District CSO Regulators (NPDES Permit # PA 0026689)

Site ID	Outfall ID	Point Source #	Interceptor System	Regulator Location	Regulator Type
D_17	D_17	2	SOM	Castor Ave. and Balfour St	Brown & Brown
D_18	D_18	3	SOM	Venango St. NW of Casper St.	Brown & Brown
D_19	D_19	4	SOM	Tioga St. NW of Casper St.	Brown & Brown
D_20	D_20	5	SOM	Ontario St. NW of Casper St.	Brown & Brown
D_21	D_21	6	SOM	Westmoreland St. NW of Balfour	Brown & Brown
D_22	D_22	7	SOM	Allegheny Ave. SE of Bath St	Water Hydraulic-Sluice Gate
D_23	D_23	8	SOM	Indiana Ave. SE of Sedgwick	Slot
D_24	D_25	10	SOM	Cambria St. E of Melvale St.	Slot
D_25			SOM	Somerset St. E of Richmond St.	Brown & Brown
D_02	D_02	11	UDLL	Cottman St. SE of Milnor St.	CC-Sluice Gate
D_03	D_03	12	UDLL	Princeton Ave SE of Milnor St.	CC-Sluice Gate
D_04	D_04	13	UDLL	Disston St. SE of Wissinoming	Brown & Brown
D_05	D_05	14	UDLL	Magee St. SE of Milnor St.	CC-Brown & Brown
D_06	D_06	15	UDLL	Levick St. SE of Milnor St.	Water Hydraulic-Sluice Gate
D_07	D_07	16	UDLL	Lardner St. SE of Milnor St.	CC-Sluice Gate
D_08	D_08	17	UDLL	Comly St. SE of Milnor St.	Water Hydraulic-Sluice Gate
D_09	D_09	18	UDLL	Dark Run La and Milnor St	CC-Sluice Gate
D_11	D_11	19	UDLL	Sanger St. SE of Milnor St.	CC-Sluice Gate
D_12	D_12	20	UDLL	Bridge St. SE of Garden St.	Brown & Brown
D_13	D_13	21	UDLL	Kirkbride St. and Delaware Ave.	Water Hydraulic-Sluice Gate
D_15	D_15	22	UDLL	Orthodox St. and Delaware Ave.	CC-Sluice Gate
P_01	P_01	23	PP	Frankford Ave. and Asburner St	Slot
P_02	P_02	24	PP	Frankford Ave. and Holmesburg	Slot

Site ID	Outfall ID	Point Source #	Interceptor System	Regulator Location	Regulator Type
P_03	P_03	25	PP	Torresdale Ave. NW of	Slot
P_04	P_04	26	PP	Cottage Ave. and Holmesburg	Slot
P_05	P_05	27	PP	Holmesburg Ave. SE of	Slot
T_01	T_01	28	TAC	Williams Ave. SE of Sedgwick	Manual-Sluice Gate
T_03	T_03	29	TAC	Champlost Ave. W of Tacony Cr.	Slot
T_04	T_04	30	TAC	Rising Sun Ave. E of Tacony Cr.	Slot
T_05	T_05	31	TAC	Rising Sun Ave. W of Tacony Cr.	Slot
T_06	T_06	32	TAC	Bingham St. E of Tacony Cr.	Manual-Sluice Gate
T_07	T_07	33	TAC	Tabor Rd. W of Tacony Cr.	Slot
T_08	T_08	34	TAC	Ashdale Sr. W of Tacony Cr.	Manual-Sluice Gate
T_09	T_09	35	TAC	Roosevelt Blvd. W of Tacony Cr.	Slot
T_10	T_10	36	TAC	Roosevelt Blvd. E of Tacony Cr.	Slot
T_11	T_11	37	TAC	Ruscomb St. E of Tacony Cr.	Slot
T_12	T_12	38	TAC	Whitaker Ave. E of Tacony Cr.	Slot
T_13	T_13	39	TAC	Whitaker Ave. W of Tacony Cr.	Slot
T_14	T_14	40	TAC	I St. and Ramona St.	2-Manual-Sluice Gate
T_15	T_15	41	TAC	J St. and Juniata Park	Slot
F_03	F_03	42	UFLL	Castor Ave and Unity Street	Slot
F_04	F_04	43	UFLL	Wingohocking St. SW of Adams	Water Hydraulic-Sluice Gate
F_05	F_05	44	UFLL	Bristol St. W of Adams Ave.	Water Hydraulic-Sluice Gate
F_06	F_06	45	UFLL	Worrel St. E of Frankford Cr.	Dam
F_07	F_07	46	UFLL	Worrel St. W of Frankford Cr.	Water Hydraulic-Sluice Gate
F_08	F_08	47	UFLL	Torresdale Ave. and Hunting Park	Water Hydraulic-Sluice Gate
F_09	F_09	48	UFLL	Frankford Ave. NE of Frankford	Water Hydraulic-Sluice Gate
F_10	F_10	49	UFLL	Frankford Ave. SW of Frankford	Water Hydraulic-Sluice Gate
F_11	F_11	50	UFLL	Orchard St. S of Vandyke St.	Water Hydraulic-Sluice Gate
F_12	F_12	51	UFLL	Sepviva St. NE of Butler St.	Slot

Site ID	Outfall ID	Point Source #	Interceptor System	Regulator Location	Regulator Type
F_13	F_13	52	LFLL	Duncan St. Under I-95	Brown & Brown
F_14	F_13	52	LFLL	Bristol St. NW of Belgrade	Brown & Brown
F_21	F_21	54	LFLL	Wakeling St. NW of F-25	Brown & Brown
F_23	F_23	55	LFLL	Bridge St. NW of Creek Basin	Water Hydraulic-Sluice Gate
F_24	F_24	56	LFLL	Bridge St. SE of Creek Basin	Water Hydraulic-Sluice Gate
F_25	F_25	57	LFLL	Ash St. W of Creek Basin	CC-Brown & Brown
R_13	D_FRW	58	UDLL	Wakeling Relief Sewer	Dam
R_14			UDLL	Wakeling Relief Sewer	Dam
R_15	T_RRR	59	TAC	Rock Run Storm Flood Relief Sewer	Dam
R_18	F_FRFG	60	FHL	Frankford High Level Relief Sewer	Dam

Table 3-25 Interceptor Sewer Systems in the Northeast Drainage District

Interceptor System	Length (miles)	Size Range (ft)
Upper Delaware Low Level	7.0	4 - 12.25
Pennypack Low Level	3.0	1.67 - 6
Lower Frankford Low Level	1.0	1 - 5
Somerset Low Level	2.1	4 by 4 - 5 by 5.5
Upper Frankford Low Level	2.5	1.67 - 4.5
Tacony High Level	3.5	3 - 8.5
Frankford High Level	3.0	5.5 - 11 by 8.5

3.2.1.2 Southeast Drainage District

Figure 3-24 shows the collection system for the Southeast drainage district. This figure depicts the combined sewer and separate sewer interceptors, as well as the location of the CSO regulators and major hydraulic control points. The only suburban community served by the Southeast WPCP is Springfield Township.

The Southeast drainage district serves an in-City population of approximately 279,000 and conveys flows to the two combined sewer interceptors, the Lower Delaware Low Level (LDLL) and Oregon Avenue (O) interceptors. The Oregon Avenue Interceptor combines with the LDLL upstream from the Southeast WPCP pumping station, which lifts the wastewater from both interceptors into the preliminary treatment building.

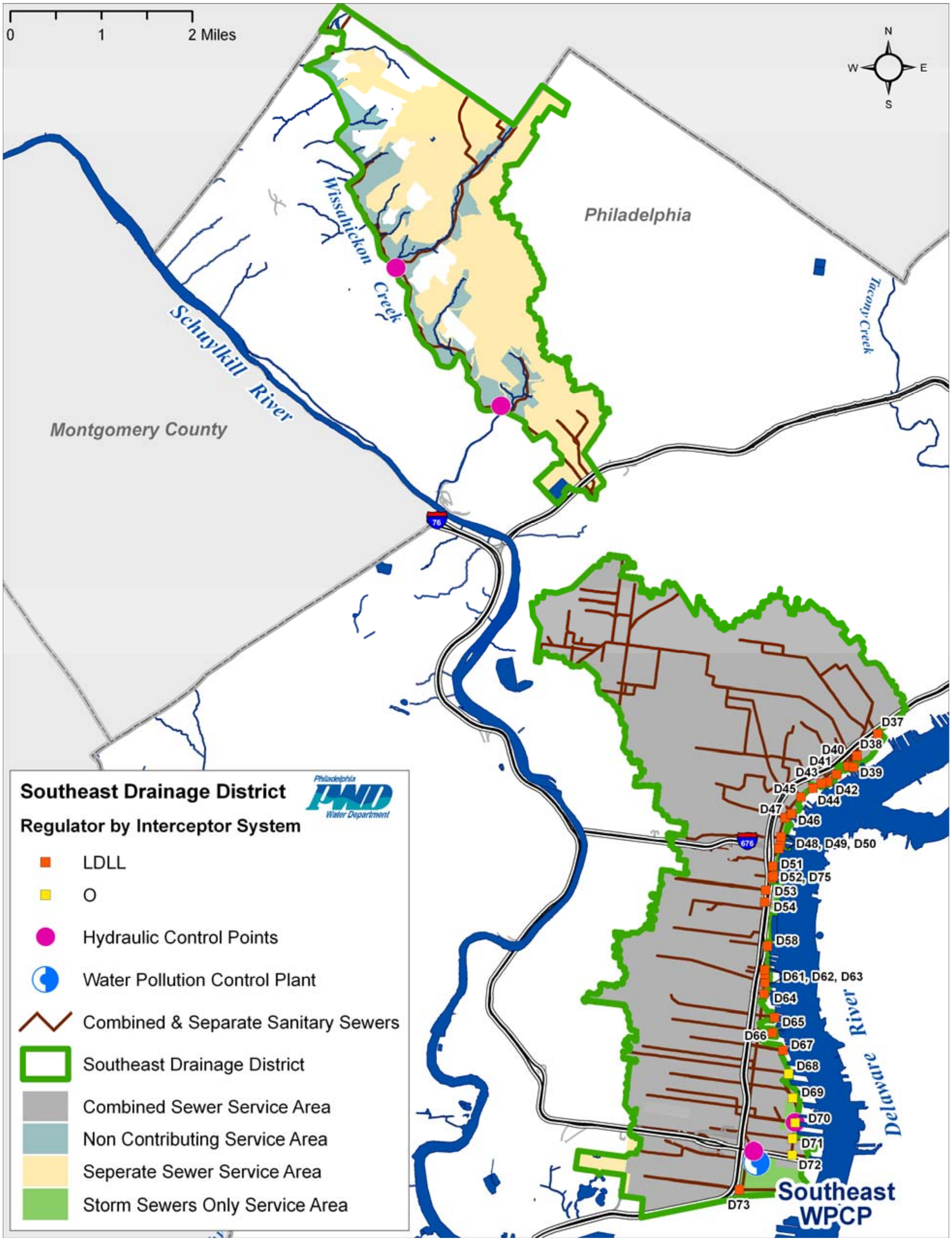


Figure 3-24 Southeast Drainage District Collection System

Lower Delaware Low Level

The LDLL interceptor begins in central Philadelphia at the intersection of Dyott Street and Delaware Avenue. The LDLL heads south along the Delaware River and combines with the Oregon Avenue interceptor at Oregon Avenue and Swanson Street. Separate sanitary wastewater flows from the Wissahickon High Level, Monoshone and Cresheim Valley interceptors, including flow from areas outside the City, are collected by the LDLL. Table 3-26 lists the combined sewer regulators on the LDLL.

Oregon Avenue

The Oregon Avenue interceptor runs on Delaware Avenue from Snyder Avenue to Packer Avenue, with a portion between Jackson Street and Snyder Avenue on River Street. Wastewater flows to the intersection of Oregon and Delaware Avenues where it heads west along Oregon Avenue to Swanson Street and feeds into the LDLL. Table 3-26 lists the combined sewer regulators on the Oregon Ave. Interceptor.

Table 3-27 lists ranges of interceptor sewer diameters in the Southeast Drainage district by interceptor system.

Table 3-26 Southeast Drainage District CSO Regulators (NPDES Permit # PA 0026662)

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
D_37	D_37	36	LDLL	Cumberland St.and Richmond St.	Brown & Brown
D_38	D_38	2	LDLL	Dyott St and Delaware Ave	Brown & Brown
D_39	D_39	3	LDLL	Susquehanna Ave SE of Beach	Brown & Brown
D_40	D_40	4	LDLL	Berks St. SE of Beach St	Slot
D_41	D_41	5	LDLL	Palmer St. SE of Beach St	Brown & Brown
D_42	D_42	6	LDLL	Columbia Ave. SE of Beach St	Slot
D_43	D_43	7	LDLL	Marlborough St. and Delaware	Slot
D_44	D_44	8	LDLL	Shackamaxon St. E of Delaware	Brown & Brown
D_45	D_45	9	LDLL	Laurel St. SE of Delaware Ave	Brown & Brown
D_46	D_46	10	LDLL	Penn St. and Delaware Ave	Slot
D_47	D_47	11	LDLL	Fairmount Ave. W of Delaware	Brown & Brown
D_48	D_48	12	LDLL	Willow St. W of Delaware Ave	Brown & Brown
D_49	D_49	13	LDLL	Callowhill St. and Delaware Ave.	Brown & Brown
D_50	D_50	14	LDLL	Delaware Ave N of Vine St	Brown & Brown
D_51	D_51	15	LDLL	Race St. W of Delaware Ave	Brown & Brown
D_52	D_52	16	LDLL	Delaware Ave. and Arch St	Brown & Brown
D_53	D_53	17	LDLL	Market St and Front St	Brown & Brown
D_54	D_54	20	LDLL	Front St S of Chestnut St	Brown & Brown
D_58	D_58	21	LDLL	South St and Delaware Ave	Brown & Brown
D_61	D_61	22	LDLL	Catherine St. E of Swanson St	Brown & Brown
D_62	D_62	23	LDLL	Queen St E of Swanson St	Brown & Brown

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
D_63	D_63	24	LDLL	Christian St W of Delaware Ave	Brown & Brown
D_64	D_64	25	LDLL	Washington Ave E of Delaware	Brown & Brown
D_65	D_65	26	LDLL	Reed St E of Delaware Ave	Brown & Brown
D_66	D_66	27	LDLL	Tasker St E of Delaware Ave	Brown & Brown
D_67	D_67	28	LDLL	Moore St E of Delaware Ave	Brown & Brown
D_73	D_73	33	LDLL	Pattison Ave and Swanson St	Brown & Brown
D_68	D_68	29	O	Snyder Ave and Delaware Ave	Brown & Brown
D_69	D_69	30	O	Delaware Ave N of Porter St	Brown & Brown
D_70	D_70	31	O	Oregon Ave and Delaware Ave	Brown & Brown
D_71	D_71	32	O	Bigler St and Delaware Ave	Brown & Brown
D_72	D_72	34	O	Packer Ave E of Delaware Ave	Brown & Brown

Table 3-27 Interceptor Sewer Systems in the Southeast Drainage District

Interceptor System	Length (miles)	Size Range (ft)
Lower Delaware Low Level	5.0	3 - 11
Oregon Avenue	1.5	2.5 - 4

3.2.1.3 Southwest Drainage District

Figure 3-25 shows the collection system for the Southwest drainage district. This figure depicts the combined sewer and separate sewer interceptors, as well as the location of the CSO regulators and major hydraulic control.

The Southwest drainage district serves an in-City population of approximately 451,000 and conveys flows to the combined sewer interceptors of the Central Schuylkill East Side (CSES), Central Schuylkill West Side (CSWS), Lower Schuylkill East Side (LSES), Southwest Main Gravity (SWMG), Cobbs Creek High Level (CCHL), and Cobbs Creek Low Level (CCLL). The CSES, CSWS, and LSWS interceptors are all tributary to the Central Schuylkill Pumping Station (CSPS), which pumps to the upstream end of the SWMG. The CCHL is also tributary to the SWMG which conveys flow by gravity to the Southwest WPCP preliminary treatment building. Wet weather flow in excess of treatment capacity of regulators along the SWMG overflows to the LSWS regulators which delivers flow to the Southwest WPCP pumping station. The Southwest WPCP pump station receives additional flow from the CCLL and lifts the wastewater from these interceptors into the preliminary treatment building to be combined with the flow from SWMG and the DELCORA force main for screening. The Southwest drainage district collects separate sanitary wastewater flows from the Wissahickon Low Level and Upper Schuylkill interceptors, including large areas outside the City. The suburban communities served by the Southwest WPCP are:

- Delaware County Regional Water Quality Control Authority (DELCORA) including all or part of Haverford, Radnor, Newtown, Upper Providence, Tinicum; the boroughs of Norwood, Glenolden, Morton, Rutledge, Prospect Park, Ridley Park, and Swarthmore; and the townships of Darby, Upper Darby, Ridley, Springfield, Marple, and Nether Providence
- Lower Merion Township

- Springfield Township
- Upper Darby Township and Haverford Township

Cobbs Creek High Level

The CCHL interceptor begins in the westernmost sections of Philadelphia along Cobbs and Indian Creeks. Several small interceptors consolidate to form the main interceptor that runs parallel to Cobbs Creek. This interceptor, which once continued south along Cobbs Creek, heads east in the Cobbs Creek High Level Cutoff sewer along 60th Street until it combines with the SWMG interceptor. Table 3-28 lists the combined sewer regulators on the CCHL.

Southwest Main Gravity

The SWMG interceptor begins at the force main from the Central Schuylkill Pumping Station and continues south to the Southwest WPCP. A tributary interceptor, which conveys flow from the Mill Creek drainage basin, enters the main SWMG interceptor at 47th Street and Grays Ferry Avenue. Wastewater from DWOs of regulators S_50 and S_51 is pumped to the SWMG interceptor by the 42nd Street pumping station. The CCHL interceptor combines with the SWMG at 60th Street and Grays Avenue. The SWMG interceptor enters a dispersion chamber near the intersection of 70th Street and Dicks Avenue and becomes a triple barrel parallel sewer, which conveys the wastewater directly into the Southwest WPCP without additional inflows. There are gates on each of the three pipes at this dispersion chamber with automatic controls enabling selected barrels to be closed during dry weather or for service as needed.. Table 3-28 lists the combined sewer regulators on the SWMG. Five CSO regulating chambers, S_34, S_39, S_40, S_43, and S_47, are hydraulic control points that regulate flow to the SWMG and overflow to regulators along the LSWS interceptor. Additionally, two more regulators, S_27 and S_28, are hydraulic control points that regulate flow to the SWMG and overflow to S_50.

Central Schuylkill East Side

The CSES interceptor begins at the downstream end of the Upper Schuylkill separate sanitary sewer interceptor. The CSES travels along the east bank of the Schuylkill River, collecting combined sewer flows from regulators including the Main Relief real time control sewer storage structure. The CSES combines with the LSES prior to flowing under the Schuylkill River at the Central Schuylkill Siphon. Table 3-28 lists the combined sewer regulators on the CSES.

Central Schuylkill West Side

The CSWS conveys flow north of the Spring Garden Street Bridge to the Central Schuylkill Pumping Station (CSPS). It travels along the west bank of the Schuylkill River and combines with outflow from the Central Schuylkill Siphon at the CSPS. Table 3-28 lists the combined sewer regulators on the CSWS.

Lower Schuylkill East Side

The LSES intercepts flow at 26th and Penrose Avenue and conveys flow north to the CSPS. The LSES combines with the CSES at the upstream end of the Central Schuylkill Siphon prior to flowing under the Schuylkill River. Table 3-28 lists the combined sewer regulators on the LSES.

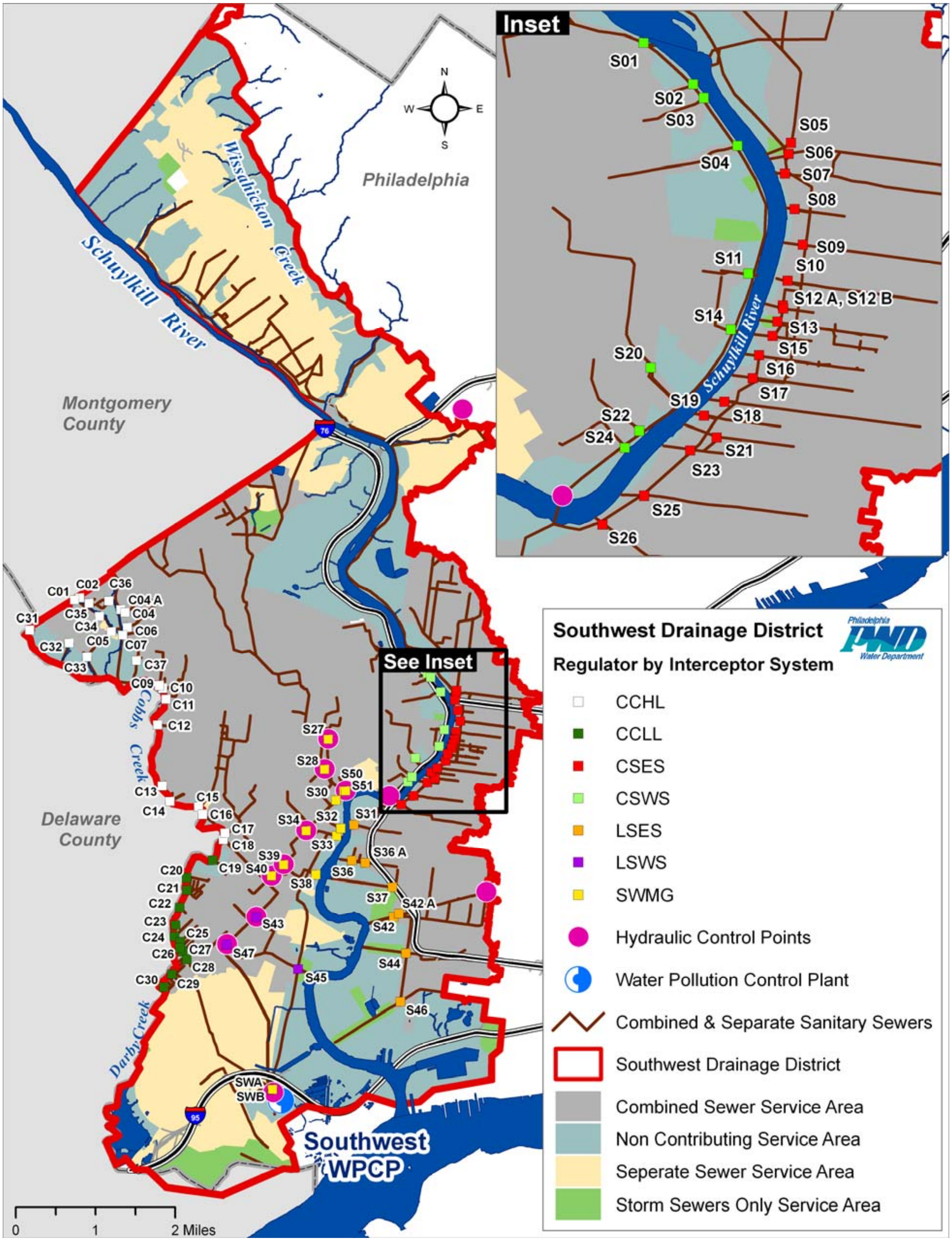


Figure 3-25 Southwest Drainage District Collection System

Cobbs Creek Low Level
The CCLL interceptor system consists of two distinct segments – the continuation of the Cobbs Creek Interceptor south of the high-level cutoff, and the 80th Street and Island Road Interceptor. The interceptor originally discharged directly to Cobbs Creek, but the 80th Street and Island Road Interceptor was later built to convey this flow to the Southwest WPCP pumping station. There are no regulators or overflow structures along this interceptor, with the exception of the Eagle Creek emergency relief sewer serving the pumping station. Table 3-28 lists the combined sewer regulators on the CCLL.

Lower Schuylkill West Side
This interceptor lies east of the SWMG line and west of the Schuylkill River. It services four regulator structures (S-32, S-33, S-38, and S-45). Three of the regulators (all except S-32) receive overflows from the SWMG system, in addition to controlling their own tributary areas. Flow from the LSWS combines with flow from the CCLL at the Southwest WPCP pump station where three Archimedes positive displacement pumps lift and deliver it to the pretreatment building where it is combined with SWMG and DELCORA Force Main flow for screening at the PTB. Table 3-28 lists the combined sewer regulators on the LSWS.

Table 3-29 lists ranges of interceptor sewer diameters in the Southwest drainage district by interceptor system.

Table 3-28 Southwest Drainage District CSO Regulators (NPDES Permit # PA 0026671)

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
S_05	S_05	9	CSES	24th St. 155' S. of Park Towne	Brown & Brown
S_06	S_06	10	CSES	24th St. 350' S. of Park Towne	Brown & Brown
S_07	S_07	11	CSES	24th St. and Vine St	Brown & Brown
S_08	S_08	12	CSES	Frace St W of Bonsall St	Brown & Brown
S_09	S_09	13	CSES	Arch St W of 23rd St	Brown & Brown
S_10	S_10	14	CSES	Market St 275' W of 23rd	Water Hydraulic-Sluice Gate
S_12	S_12A	15	CSES	24th St N of Chestnut St Bridge	Slot
S_12A	S_12A	15	CSES	24th St under Chestnut St Bridge	Slot
S_13	S_13	16	CSES	Sansom St W of 24th St	Slot
S_15	S_15	17	CSES	Walnut St W of 24th St	Brown & Brown
S_16	S_16	18	CSES	Locust St and 25th St	Brown & Brown
S_17	S_17	19	CSES	Spruce St and 25th St	Slot
S_18	S_18	20	CSES	Pine St W of Taney St	Brown & Brown
S_19	S_19	21	CSES	Lombard St W of 27th St	Brown & Brown
S_21	S_21	22	CSES	South St E of 27th St	Dam
S_23	S_23	23	CSES	Schuylkill Ave and Bainbridge	Brown & Brown
S_25	S_25	24	CSES	Schuylkill Ave and Christian St	Brown & Brown
S_26	S_26	25	CSES	Ellsworth St. W of Schylkill Ave	Brown & Brown
S_01	S_01	26	CSWS	West River Dr 1600' NW Spring	Brown & Brown

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
S_02	S_02	27	CSWS	West River Dr 375' NW Spring	Brown & Brown
S_03	S_03	28	CSWS	Spring Garden St. W of	Slot
S_04	S_04	29	CSWS	Schuylkill Expressway 600' NW	Brown & Brown
S_11	S_11	30	CSWS	Market St W of Schuylkill	Dam
S_14	S_14	31	CSWS	Schuylkill Expy Under Walnut St	Brown & Brown
S_20	S_20	32	CSWS	440' NNW of South St	Brown & Brown
S_22	S_22	33	CSWS	660' S of South St. E of Penn	Brown & Brown
S_24	S_24	34	CSWS	1060' S of South St. E of Penn	Brown & Brown
C_01	C_01	51	CCHL	City Line Ave 100' S of Creek	Slot
C_02	C_02	52	CCHL	City Line Ave and 73rd St	Slot
C_04	C_04A	82	CCHL	Malvern Ave and 68th St	Slot
C_04A	C_04A	82	CCHL	68th St. NW of Mavern Ave	Slot
C_05	C_05	54	CCHL	Lebanon Ave SW of 73rd St	Slot
C_06	C_06	55	CCHL	Lebanon Ave and 68th St	Slot
C_07	C_07	56	CCHL	Landsdowne Ave and 69th St	Slot
C_09	C_09	57	CCHL	64th St and Cobbs Cr.	Slot
C_10	C_10	58	CCHL	Gross St and Cobbs Cr.	Slot
C_11	C_11	59	CCHL	63rd St S of Market St	Slot
C_12	C_12	60	CCHL	Spruce St at Cobbs Cr	Slot
C_13	C_13	61	CCHL	62nd St at Cobbs Cr.	Slot
C_14	C_14	62	CCHL	Baltimore Ave and Cobbs Cr.	Slot
C_15	C_15	63	CCHL	59th St and Cobbs Creek	Slot
C_16	C_16	64	CCHL	Thomas Ave and Cobbs Cr.	Slot
C_17	C_17	65	CCHL	Beaumont St and Cobbs Creek	Slot
C_18	C_18	41	CCHL	60th St. at Cobbs Cr Parkway	Slot
C_31	C_31	66	CCHL	Cobbs Cr. Park S of City Line	Slot
C_32	C_32	72	CCHL	Cobbs Creek Parkway & 77th St	Slot
C_33	C_33	67	CCHL	Brockton Rd and Farrington Rd.	Slot
C_34	C_34	68	CCHL	Woodcrest Ave and Morris Park	Slot
C_35	C_35	69	CCHL	Morris Park W of 72nd St. and	Slot
C_36	C_36	70	CCHL	Woodbine Ave S of Brentwood	Slot
C_37	C_37	71	CCHL	Cobbs Creek Parkway S of 67th	Slot
C_19	C_19	42	CCLL	Cobbs Cr. And 62nd Thru	Slot
C_20	C_20	43	CCLL	65th St and cobbs Cr. Parkway	Slot
C_21	C_21	44	CCLL	68th St and Cobbs Cr. Parkway	Slot
C_22	C_22	45	CCLL	70th St and Cobbs Cr. Parkway	Slot
C_23	C_23	46	CCLL	Upland St Cobbs Cr. Parkway	Slot
C_24	C_25	47	CCLL	Greenway Ave and Cobbs Cr.	Slot
C_25	C_25	47	CCLL	Woodland Ave and Cobbs Cr.	Slot
C_26	C_28A	78	CCLL	Saybrook Ave and Island Ave	Slot

Site ID	Outfall ID	Point Source #	Interceptor System	Location	Regulator Type
C_27	C_28A	78	CCLL	Paschall Ave and Island Ave	Slot
C_28A	C_28A	78	CCLL	Island Ave SE of Glenmore Ave	Dam
C_29	C_29	49	CCLL	Claymount St and Grays Ave	Slot
C_30	C_30	50	CCLL	77th St W of Elmwood Ave	Slot
S_31	S_31	2	LSES	Reed St and Schuylkill Ave	Brown & Brown
S_35	S_36A	3	LSES	35th St and Mifflin St	Slot
S_36	S_36A	3	LSES	36th St and Mifflin St	Slot
S_36A	S_36A	3	LSES	34th St and Mifflin St	Brown & Brown
S_37	S_37	4	LSES	Vare Ave and Jackson St	Brown & Brown
S_42	S_42	5	LSES	Passyunk Ave and 29th St	Brown & Brown
S_42A	S_42A	6	LSES	Passyunk Ave and 28th St	Brown & Brown
S_44	S_44	7	LSES	26th St 700' N off Hartranft St	Brown & Brown
S_46	S_46	8	LSES	Penrose Ave and 26th St	Brown & Brown
S_32	S_32	37	LSWS	49th St S of Botanic St	Slot
S_33	S_33	38	LSWS	51st St and Botanic St	Brown & Brown
S_38	S_38	39	LSWS	56th St E of P&R RR	Brown & Brown
S_45	S_45	40	LSWS	67th St E of P&R RR	Brown & Brown
S_30	S_30	35	SWMG	46th St and Paschall Ave	Slot
S_50	S_50	36	SWMG	43rd St Se of Woodland Ave	Brown & Brown
S_51	S_51	36	SWMG	42nd St SE of Woodland Ave	Slot
R_7	S_FRM	75	CSES	16th Street and Clearfield Street	Dam
R_8	S_FRM	75	CSES	22nd Street and Dauphin Street	Dam
R_9	S_FRM	75	CSES	22nd Street and Berks Street	Dam
R_10	S_FRM	75	CSES	22nd Street and Montgomery Ave	Dam
R_11	S_FRM	75	CSES	24th Street and North College Ave	Dam
R_11A	S_FRM	75	CSES	23rd Street and North College Ave	Dam
R_12	S_FRM	75	CSES	23rd Street and North College Ave	Dam
R_1	C_FRTR	83	CCHL	56th Street and Locust Street	Dam
R_1A	C_FRTR	83	CCHL	56th Street and Locust Street	Dam
R_2	C_FRTR	83	CCHL	56th Street and Spruce Street	Dam
R_3	C_FRTR	83	CCHL	56th Street and Spruce Street	Dam
R_4	C_FRTR	83	CCHL	56th Street and Pine Street	Dam
R_5	C_FRTR	83	CCHL	56th Street and Cedar Avenue	Dam
R_6	C_FRTR	83	CCHL	56th Street and Webster Street	Dam
R_24	C_FRA	84	CCHL	Arch Street and Cobbs Creek	Dam

Table 3-29 Interceptor Sewer Systems in the Southwest Drainage District

Interceptor System	Length (miles)	Size Range (ft)
Cobbs Creek High Level	7.1	1 - 8
Southwest Main Gravity	10.1	5.5 - 14
Central Schuylkill East Side	2.5	5.5 - 8.5
Central Schuylkill West Side	2.0	2.5 - 4.5
Lower Schuylkill East Side	2.8	3 - 5.5
Cobbs Creek Low Level	2.0	2.5 - 4
Lower Schuylkill West Side	3.5	1.75 - 5

3.2.3 Current Collection System Capacities

This section presents the results of the LTCPU collection system models to study the maximum theoretical flows that can be delivered to each of the water pollution control plants. Scenarios were analyzed for each drainage district model (NE, SE and SW) and peak flows observed. The study was conducted as a part of the LTCPU to identify the maximum flow that can be delivered to each of the treatment plants regardless of their treatment capacity so as to study the conveyance limits of each sewer system.

3.2.3.1 Northeast Drainage District

The Northeast drainage district consists of the Northeast High Level system and the Northeast Low Level system. The Northeast Low Level system pumps flow into the NE WPCP from the Somerset (SOM), Upper Frankford Low Level (UFLL), and the Upper Delaware Low Level (UDLL) interceptors. The Northeast High Level system delivers flow to the Northeast WPCP by gravity from the Frankford High Level Interceptor (FHL) through a double barrel sewer. Presently only one of the barrels is in service and the other barrel is closed.

Table 3-30 presents the estimated maximum potential flow conveyed to the NE WPCP through each interceptor system based on model simulation results from running the combined Northeast High and Low Level simplified model using the September 28, 2004 rainfall. This event produced the largest peak flows based on continuous simulation of existing conditions for the years 2002 through 2004 and can be considered representative of expected peak hydrologic response.

Table 3-30 Northeast Drainage District Estimated Maximum Potential Flow Delivery to the WPCP through Existing Interceptor Systems

Interceptor system	Peak Flow (cfs)	Peak Flow (MGD)	Notes
FHL	124	80	- Includes head losses between R18 and PTB - Only One Barrel in Service
UFLL	63	41	Free Outfall Upstream of Diversion Chamber A (DivA)
UDLL	504	326	Free Outfall at Junction Chamber A (JCA) with Grit
SOM	94	61	Free Outfall Upstream of Diversion Chamber A (DivA)
Total	**786**	**508**	

3.2.3.2 Southeast Drainage District

The Southeast WPCP receives flows from two interceptor systems, the Lower Delaware Low Level (LDLL) and the Oregon Avenue (O) interceptor systems. The Oregon Avenue interceptor is a tributary to the Lower Delaware Low Level system. All the flows that come to the SE WPCP are pumped. The simplified SE drainage district model with median runoff and baseflow estimates was used for simulating the ramp rainfall. The ramp rainfall had a total rainfall of 79 inches falling over 48 hours with a peak intensity of 2.5 inches per hour sustained over 24 hours. The ramp rainfall was used to simulate maximum potential flows throughout the system. To determine the unrestricted maximum flow that may be delivered to the plant by the LDLL and O interceptors, the boundary conditions due to the pump at the SE WPCP were removed. The results are presented in Table 3-31.

Table: 3-31 Estimated Maximum Potential Flow Delivery to the SE WPCP

Scenario no.	Description	SE Total (cfs)	SE Total (mgd)
1	SE model using ramp rainfall with SE pump replaced by a free outfall	638	412
* SE flow is the sum of Lower Delaware Low Level and Oregon Ave interceptor systems.			

3.2.3.3 Southwest Drainage District

The Southwest WPCP receives low-level flows from the screw pumps which pump flows from the Cobbs Creek Low Level and Lower Schuylkill West Side Interceptors. SW High-level (SWHL) flows are delivered to the SW WPCP from the DELCORA Force Main and the SW Main Gravity Triple Barrel. The Triple Barrel conveys flows by gravity from the Cobbs Creek High Level and the SW Main Gravity Interceptors. The SW Main Gravity Interceptor also receives flows that are pumped through the Central Schuylkill Pump Station (CSPS) from the Upper Schuylkill East Side, Central Schuylkill East Side, Central Schuylkill West Side, and Lower Schuylkill East Side Interceptors.

The following maximum flow scenario is analyzed for the Southwest drainage district:
LTCPU SW drainage district model with the rainfall ramp described above in the Southeast section was used for the simulation. DELCORA is removed from the system in order to eliminate competition with the SW Main Gravity Triple Barrel for capacity at the plant. The SWHL immediately downstream of the Triple Barrel is modeled as unrestricted to allow the maximum amount of flow through the pipes and the Low Level Screw pumps are disconnected to remove the boundary conditions at the plant – which limit the flow conveyed to the plant – allowing for maximization of flow delivery. The results are presented in Table 3-32.

Table: 3-32 Estimated Maximum Potential Flow Delivery to the SW WPCP Through Existing Interceptor Systems

Scenario No.	Description	SW Low Level (mgd)	SW High Level (mgd)	Total (mgd)
1	Southwest model with median runoff and baseflow estimates using ramp rainfall with DELCORA removed, a free outfall for SWHL immediately downstream of the Triple Barrel, and the Low Level screw pumps replaced by a free outfall.	278	478 *	756
* Not achievable through gravity flow - free outfall at WPCP				

3.2.4 Wastewater Treatment Plant Descriptions

Stress testing and hydraulic model evaluations were conducted for each of PWD's three WPCPs in order to determine current maximum reliable capacities of plant unit processes and to identify cost effective improvements capable of increasing peak wet weather capacities of the existing facilities.

- CH2MHILL, 2001 Stress Testing of the Northeast WPCP, Prepared for the Philadelphia Water Department. December
- CH2MHILL, 2001 Stress Testing of the Southeast WPCP, Prepared for the Philadelphia Water Department. December
- CH2MHILL, 2001 Stress Testing of the Southwest WPCP, Prepared for the Philadelphia Water Department. December

3.2.4.1 Northeast Water Pollution Control Plant

The Northeast WPCP influent flow is conveyed by the Frankford High Level (FHL), Upper Frankford Low Level (UFLL), Somerset (SOM) , and the Upper Delaware Low Level (UDLL) interceptors while the plant's treated effluent is released into the Delaware River. A summary of the plant's treatment processes as well as descriptions of the processes are listed within Table 3-33. The sludge produced during the treatment process is treated on site and the final product is moved to the BRC center for composting.

Table 3-33 Summary of NE WPCP Unit Processes

Unit Process	Number	Description
Bar Screen	7	Width = 8ft, single-rake front cleaned, 1-in. opening
	1	Width = 8ft, multiple-rake front cleaned, 5/8-in. opening
Low-Level Pumps	6	Centrifugal Pumps
		Q = 85 mgd, at 55-ft head
Grit Removal	4	Rectangular detritors
		Length = 55ft, width = 55ft, SWD = 7.5ft, volume = 22,690 ft^3 (each)
Influent Flow Meter	2	Venturi - 48 inch - Set 1 primary clarifiers
	1	Venturi - 66 inch - Set 2 primary clarifiers

Unit Process	Number	Description
Primary Clarifiers	8 (Set 1)	Length = 240ft, width = 65ft, SWD = 10ft
		Surface area = 15,600ft^2, weir length = 450ft (each)
		C and F sludge mechanism, influent end hopper
	4 (Set 2)	Length = 250ft, width = 125ft, SWD = 10ft
		Surface area = 31,250ft^2, weir length = 900ft (each)
		C and F sludge mechanism, influent end hopper
Aeration Basin	7	Four-pass - through flow only
		Length = 371ft, width = 87ft, SWD = 15ft, volume = 3.286mg (each)
		Operate with selector
Blowers	4	Centifugal Q = 35,000 acfm
	2	Centifugal Q = 27,000 acfm
Diffusers	Fine bubble	Ceramic; 12,000 per tank
Secondary Settling Tanks	8 (Set 1)	Length = 214ft, width = 75ft, SWD = 11ft
		Surface area = 16,100 ft^2, weir length = 869ft (each)
		Gould-type central hopper, C&F sludge mechanism
	8 (Set 2)	Length = 231ft, width = 70ft, SWD = 13ft
		Surface area = 16,200ft^2, weir length = 860ft (each)
		Gould-type central hopper, C&F sludge mechanism
Chlorine Contact Chamber	2	Three-pass serpentine flow
		Length = 300ft, width = 84ft, SWD = 11ft, volume = 2.06mg
		Chlorine gas solution feed
Sludge Thickening	12	Dissolved air flotation
Anerobic Digesters	8 (Set 1)	Digesters - Diameter = 110ft, SWD = 30ft, volume = 300,000ft^3 (each)
		Sludge transfer tanks
		Volume = 1.5 mg (each)
		Diameter = 96ft, SWD = 26ft

A summary of NEWPCP National Pollutant Discharge Elimination System (NPDES) effluent requirements are listed within Table 3-34. Since July 2000, PWD has received and implemented revised NPDES permits that are used during increased flow caused by wet weather. During this time period the increase in flow will reduce the frequency and volume of untreated sewage discharged from CSOs. However, this additional flow to the WPCP will exceed the plant's rated hydraulic capacity. The revised standards are as follows:

- If a calendar month includes one or more days where flow exceeds 315mgd, a value of 85 percent may be used for those days for the purpose of calculating average monthly TSS percent removal. The actual TSS percent removal associated with those days shall be reported on the appropriate space provided on the daily monitoring report (DMR).
- If a calendar month includes one or more days where flow exceeds 315mgd, a value of 86 percent may be used for those days for the purpose of calculating average monthly

BOD_5 percent removal. The actual BOD_5 percent removal associated with those days shall be reported on the appropriate space provided on the DMR.

- When daily flows exceed 315mgd, the average monthly and average weekly TSS and BOD_5 mass loadings for those days may be calculated by using the lesser of the actual load or the permit's allowable average monthly and average weekly limit, respectively. The actual TSS and BOD5 loadings associated with those days shall be reported on the appropriate space provided on the DMR.

Table 3-34 NPDES Permit Requirements

Parameter		Units	Monthly Average	Weekly Average	Maximum Day	Peak Instantaneous
BOD_5	Concentration	mg/L	30	45	-	60
	Mass Loading	lbs/day	42000	63600	-	
	Percent Removal	%	86			
TSS	Concentration	mg/L	30	45	-	60
	Mass Loading	lbs/day	52540	78810	-	
	Percent Removal	%	85			
Flow		mgd	210		315	420

A maximum instantaneous treatment capacity was estimated during the 2001 stress test that was performed on the NEWPCP. During the stress test, each unit process within the treatment process was estimated using a combination of manufacturer's information, standard engineering design loading and performance criteria, operations staff observation of previous performance, and field testing of specific unit processes. A summary of the capacity estimates is shown in Table 3-35 below.

Table 3-35 NE WPCP Treatment Capacity Assessment

Unit Process	Estimated Capacity (mgd)	Criteria
Pumping and Screening	500 mgd - screening and raw sewage pumping capacity	
	Low-Level interceptor[1] - 375 mgd	Observed capacity of pumps
	High-Level interceptor - 125 mgd	Observed maximum flow
Grit Removal	525 mgd - grit removal[2]	SOR - 58,000 gpd/ft^2
Primary Treatment	460 mgd - existing	Based on allowable SOR
	505 mgd - modified inlet baffle	SOR - 2,500 gpd/ft^2
	567 mgd - improved sludge pumping	SOR - 2,800 gpd/ft^2
	710 mgd - potential	SOR - 3,500 gpd/ft^2
	Set 1[3] - 273 mgd (existing)	2,500 gpd/ft2 - test results
	Set 2[3] - 187 mgd (existing)	2,000 gpd/ft2 - test results
	Set 2 - 235 mgd (modified inlet baffle)	2,500 gpd/ft2 - test results

Unit Process	Estimated Capacity (mgd)	Criteria
Aeration Basins	N/A - no change to organic loading patterns	
Secondary Clarifiers	270 - 380 mgd - existing condition	Long-term monitoring results
	440 mgd - improved flow/solids distribution between clarifiers	Based on allowable SOR - 1,800 gpd/ft^2
	322 mgd - mixed liquor concentration 2,000 mg/L	Based on allowable SLR - 30 lbs/day/ft^2
Chlorine Contact Chamber	430 mgd - meeting disinfection requirements at current flows	
	800 mgd - volume of chlorine basin and plant outfall	HRT- 15 minutes

[1]Based on one pump and one screen out of service: Rated capacity of raw sewage pumps – 85mgd at 55 feet TDH, Observed maximum capacity 75 mgd, Channel velocity of screens – 0.41 ft/s at 5 ft channel depth.
[2]Based on removal of 60 mesh (0.25mm) particles
[3]Based on one clarifier out of service

A sustainable flow analysis was performed on the NEWPCP in order to determine the current sustainable treatment capacity at which the plant could operate while still meeting its current NPDES permit effluent requirements. It was determined that the performance of the secondary clarifiers would determine the final effluent quality of the NEWPCP. A summary of the findings from the sustainable flow analysis is show in Table 3-36 below.

Table 3-36 NE WPCP NPDES Permit Requirements and Results of the Sustainable Flow Analysis

Parameter	Units	NPDES Limit	Maximum Sustainable Flow based on SOR		Maximum Sustainable Flow Based on SLR
			TSS Limit	BOD_5 Limit	
Maximum Day Limits	Mgd	420			375
Maximum Week Limits	Mgd		320	305	
BOD_5 Concentration	mg/L	45			
BOD_5 Mass Loading	lbs/day	63600			
TSS Concentration	mg/L	45			
TSS Mass Loading	lbs/day	78810			
Maximum Monthly Limits	Mdg	210	260	235	
BOD_5 Concentration	mg/L	30			
BOD_5 Mass Loading	lbs/day	42000			
BOD_5 Percent Removal	%	86			
TSS Concentration	mg/L	30			
TSS Mass Loading	lbs/day	52540			
TSS Percent Removal	%	85			

3.2.4.2 Southeast Water Pollution Control Plant

The Southeast WPCP influent flow is generated by the Lower Delaware Low Level interceptor while the plant's treated effluent is released into the Delaware River. A summary of the plant's treatment processes as well as descriptions of the processes are listed within Table 3-37. The sludge from the primary clarifiers is piped for further treatment to SWWPCP sludge handling facility.

Table 3-37 Summary of Unit Processes SE WPCP

Unit Process	Number	Description
Coarse Screens	2	Width = 6.5 ft, single-rake front cleaned
Low-Level Pumps	6	Centrifugal pumps; 3 VSD, 3 constant speed
		Design Q = 70 mgd, at 45-ft head
Bar Screens	6	Width = 6.5 ft, 75 percent inclined, 1-inch opening
Grit Removal	6	Grit channels
		Length = 140 ft, width = 10 ft, SWD = 10 ft, volume = 14,000 ft3 (each)
Flocculation Pre-aeration	2	Aerated channel
		Length = 225 ft, width = 28 ft, SWD = 13 ft, volume = 81,900 ft3 (each)
Primary Clarifier	4	Length = 250 ft, width = 125 ft, SWD = 12 ft
		Surface area = 31,250 ft2, weir length = 635 ft (each)
		C&F sludge mechanism, influent end hopper
Flow Spit Chamber	24	Gates at 60-inch weir length
		6 gates for 2 aeration basins
Aeration Basin	8	Four-pass - through flow only
		Length = 210 ft, width = 52.5 ft, SWD = 14.3 ft, volume 1.18 mg (each)
		Operate with first pass as selector
Aeration System	4	1 @ 40 Hp, 3 @ 30 Hp (per basin)
Secondary Settling Tanks	12	Length = 214 ft, width = 68 ft, SWD = 11 ft
		Surface area = 14,552 ft2
		Weir length = 784 ft (each)
		Gould-type central hopper, C&F mechanism
Effluent Pumps	5	Q = 70 mgd at 11 head, VSD 3 units

A summary of SEWPCP National Pollutant Discharge Elimination System (NPDES) effluent requirements are listed within Table 3-38. Since August 2000, PWD has received and implemented revised NPDES permits that are used during increased flow caused by wet weather. During this time period the increase in flow will reduce the frequency and volume of untreated sewage discharged from CSOs. However, this additional flow to the WPCP will exceed the plant's rated hydraulic capacity. The revised standards are as follows:

- If a calendar month includes one or more days where flow exceeds 168mgd, a value of 85 percent may be used for those days for the purpose of calculating average monthly TSS percent removal. The actual TSS percent removal associated with those days shall be reported on the appropriate space provided on the DMR.
- If a calendar month includes one or more days where flow exceeds 168mgd, a value of 86 percent may be used for those days for the purpose of calculating average monthly

BOD5 percent removal. The actual BOD5 percent removal associated with those days shall be reported on the appropriate space provided on the DMR.

- When daily flow exceeds 168mgd, the TSS and BOD5 mass loadings for those days may be omitted from the average monthly and average weekly mass loading calculations, in accordance with the requirements of the Delaware River Basin Commission for Zone 3 of the Delaware Estuary. The actual TSS and BOD5 loadings associated with those days shall be reported on the appropriate space provided on the DMR.

Table 3-38 NPDES Permit Requirements SE WPCP

Parameter		Units	Monthly Average	Weekly Average	Maximum Day	Peak Instantaneous
BOD_5	Concentration	mg/L	30	45	-	60
	Mass Loading	lbs/day	19,650	29,475		
	Percent Removal	%	86			
TSS	Concentration	mg/L	30	45	-	60
	Mass Loading	lbs/day	28,025	42,035		
	Percent Removal	%	85			
Flow		mgd	112		168	224

A maximum instantaneous treatment capacity was estimated during the 2001 stress test performed on the SEWPCP. During the stress test, each unit process within the treatment process was estimated using a combination of manufacturer's information, standard engineering design loading and performance criteria, operations staff observation of previous performance, and field testing of specific unit processes. A summary of the capacity estimates is shown in Table 3-39 below.

Table 3-39 Treatment Capacity Assessment SE WPCP

Unit Process	Estimated Capacity (mgd)	Criteria
Pumping and Screening	286	Observed maximum flow
	240 [1] - 1 coarse screen partially blocked	Observed maximum flow
	200 [2] - 1 wet well out of service	Observed maximum flow
Grit Removal	350 [3] - 1 channel out of service	
Primary Treatment	225 mgd[4] - existing condition (hydraulic limitations)	2,400 gpd/ft^2 - test results
	260 mgd[4] - new launders	2,800 gpd/ft^2 - SW test results
	330 mgd[4] - improved sludge pumping	3,500 gpd/ft^2 - potential
Aeration Basins	N/A	
	No change in organic loading pattern	

Unit Process	Estimated Capacity (mgd)	Criteria
Secondary Clarifiers	200 mgd[4] - existing (sludge bulking incidence)	Long-term monitoring results
	330 mgd[4] - current mixed liquor concentration	Based on allowable SOR of 1,800 gpd/ft^2
	236 mgd[4] - mixed liquor concentration 2,000 mg/L	Based on allowable SLR or 30 lbs/day
Effluent Pump Station	280 mgd[5] (1 pump out of service)	70 mgd per pump
Disinfection	395 mgd - volume of plant outfall	HRT - 15 minutes

[1]Based on one screen partially blocked
[2]Based on one screen (1/2 of wet well) out of service
[3]Based on removal of 60 mesh (0.25 mm) particles
[4]Based on one clarifier out of service
[5]Based on 1 pump out of service rated capacity of pumps 70 mgd

A sustainable flow analysis was performed on the SEWPCP in order to determine the current sustainable treatment capacity at which the plant could operate while still meeting its current NPDES permit effluent requirements. It was determined the performance of the secondary clarifiers would determine the final effluent quality of the SEWPCP. A summary of the findings from the sustainable flow analysis is show in Table 3-40 below.

Table 3-40 NPDES Permit Requirements and Sustainable Flow Analysis for SE WPCP

Parameter	Units	NPDES Limit	Maximum Sustainable Flow based on SOR		Maximum Sustainable Flow based on SLR
			TSS Limit	BOD_5 Limit	
Maximum Day Limits	mgd	168			190
Maximum Week Limits	mgd		195	165	
BOD_5 Concentration	mg/L	45			
BOD_5 Mass Loading	lbs/day	29,475			
TSS Concentration	mg/L	45			
TSS Mass Loading	lbs/day	42,035			
Maximum Monthly Limits	mgd	112	150	125	
BOD_5 Concentration	mg/L	30			
BOD_5 Mass Loading	lbs/day	19,650			
BOD_5 Percent Removal	%	86			
TSS Concentration	mg/L	30			
TSS Mass Loading	lbs/day	28,025			
TSS Percent Removal	%	85			

3.2.4.3 Southwest Water Pollution Control Plant

The Southwest SWWPCP influent flow is generated by three sources; Southwest Main Gravity Triple-barrel sewer, Low-level pump station and DELCORA Force Main. The plant's treated effluent is released into the Delaware River. A summary of the plant's treatment processes as well as descriptions of the processes are listed within Table 3-41. The SWWPCP system contains a solids handling facility that treats the solids from the plant and also the solids from the SEWPCP. This system contains a dissolved air flotation sludge thickener and an anaerobic digester which create compost out of the waste activated sludge (WAS) from the two WPCPs.

Table 3-41 Summary of Unit Processes SW WPCP

Unit Process	Number	Description
Influent Flow Meter	1	Parshall flume - low-level gravity sewer
	3	Venturi - high-level gravity sewer
	1	Venturi - DELCORA forcemain
Low-Level Pumps	6	Archimedes screw (operating 2 in series)
		Q = 32 mgd, diameter = 8.5 ft, head = 22 ft (each), 42 ft total
Bar Screens	5	Width = 6 ft, 84^o incline, front cleaned, 1-in. opening
	1	Width = 6 ft, 84^o incline, front cleaned, 5/8-in opening
Grit Removal	4	Rectangular Detritor
		Length = 60 ft, width = 60 ft, SWD = 8 ft
Flocculation (Pre-aeration)	1 (west)	Length = 127.25 ft, width = 28.75 ft, SWD = 12 ft,
		Volume = 43,900 ft^3
	1 (east)	Length = 127.24 ft, width = 28.75 ft, SWD = 12 ft,
		Volume = 43,900 ft^3
Primary Clarifiers	5	Length = 250 ft, width = 125 ft, SWD = 12 ft
		Area = 31,250 ft2, weir length = 1,008 ft (each)
		C and F sludge mechanism, influent end hopper
Flow Split Chamber	36	Gates of 86-in. weir length
		6 gates for 2 aeration basins
Aeration Basin	10	Four-pass - through flow only
		Length = 160 ft, width = 40 ft, SWD = 17 ft
		Operate with first pass as selector - seasonally
Aeration System	2	Cryogenic, 90lb O2 per day
	40	125 hp, 100 hp, 75 hp, 60 hp (per basin)
Secondary Settling Tanks	20	Length = 260 ft, width = 76 ft, SWD = 11 ft
		Weir length = 816 ft (each)
RAS Pumps		Chain and flight sludge mechanism
	30	Q = 6.2 mgd, 3 pumps for 2 clarifiers
Effluent Pumps	5	Q = 115 mgd, hp = 500, VSD 3 units
DAF	8	Length = 70 ft, width = 18 ft, SWD = 12 ft
Anaerobic Digesters	12	Diameter = 110 ft, SWD = 30 ft, volume = 2.1 mg (each)
	1	Sludge storage tanks

A summary of SWWPCP National Pollutant Discharge Elimination System (NPDES) effluent requirements are listed within Table 3-42. Since July 2000, PWD has received and implemented revised NPDES permits used during increased flow caused by wet weather. During this time period the increase in flow will reduce the frequency and volume of untreated sewage discharged from CSOs. However, this additional flow to the WPCP will exceed the plant's rated hydraulic capacity. The revised standards are as fallows:

- If a calendar month includes one or more days where flows exceed 300mgd, a value of 85 percent may be used for those days for the purpose of calculating average monthly TSS percent removal. The actual TSS percent removal associated with those days shall be reported on the appropriate space provided on the DMR.
- If a calendar month includes one or more days where flows exceed 300mgd, a value of 89.95 percent may be used for those days for the purpose of calculating average monthly BOD5 percent removal. The actual BOD5 percent removal associated with those days shall be reported on the appropriate space provided on the DMR.
- When daily flows exceed 300mgd, the TSS and BOD5 mass loadings for those days may be omitted from the average monthly and average weekly mass loading calculations. The actual TSS and BOD5 loading associated with those days shall be reported on the appropriate space provided on the DMR.

Table 3-42 NPDES Permit Requirements SW WPCP

Parameter		Units	Monthly Average	Weekly Average	Maximum Day	Peak Instantaneous
BOD_5	Concentration	mg/L	30	45		60
	Mass Loading	lbs/day	21,650	32,475	-	
	Percent Removal	%	89.25			
TSS	Concentration	mg/L	30	45		60
	Mass Loading	lbs./day	50,040	75,060	-	
	Percent Removal	%	85			
Flow		mgd	200		300	400

A maximum instantaneous treatment capacity was estimated during the 2001 stress test performed on the SWWPCP. During the stress test, each unit process within the treatment process was estimated using a combination of manufacturer's information, standard engineering design loading and performance criteria, operations staff observation of previous performance, and field testing of specific unit processes. A summary of the capacity estimates is shown in Table 3-43 below

Table 3-43 Treatment Capacity Assessment

Unit Process	Estimated Capacity (mgd)	Criteria
Preliminary Treatment	540 mgd - screening and raw sewage pumping capacity Low level interceptor [1] - 64 mgd High level interceptor - 475 mgd	 Rated capacity of pumps Observed maximum flow
Grit Removal	625 mgd - grit removal [2]	SOR - 58,000 gpd/ft^2

Unit Process	Estimated Capacity (mgd)	Criteria
Primary Treatment	250 mgd [3] - with BRC solids 350 mgd [3] - with BRC solids 440 mgd [3] - without BRC solids	Based on allowable SOR - 2,000 gpd/ft^2 Based on allowable SOR - 2,800 gpd/ft^2 Based on allowable SOR - 3,500 gpd/ft^2
Aeration Basins	N/A no change to organic loading patterns	
Secondary Clarifier	675 mgd 3 - existing 550 mgd 3 - mixed liquor concentration 2,000 mg/L 350 mgd 3 - mixed liquor concentration 3,000 mg/L	Based on allowable SOR - 1,800 gpd/ft2 Based on allowable SLR - 30 lbs/day/ft2 Based on allowable SLR - 30 lbs/day/ft2
ES station	460 mgd 4 (1 pump out of service)	115 mgd rated capacity
Chlorination	830 mgd - volume of plant outfall	HRT - 15 minutes

[1] Based on design capacity of 32mgd for each pump, with one pump out of service
[2] Based on unit out of service
[3] Based on one clarifier out of service
[4] Based on one pump out of service

A sustainable flow analysis was performed on the SWWPCP in order to determine the current sustainable treatment capacity at which the plant could operate while still meeting its current NPDES permit effluent requirements. It was determined the performance of the secondary clarifiers would determine the final effluent quality of the SWWPCP. A summary of the findings from the sustainable flow analysis is show in Table 3-44 below.

Table 3-44: NPDES Permit Requirements and Results of the Sustainable Flow Analysis SW WPCP

Parameter	Units	NPDES Limit	Maximum Sustainable Flow based on SOR		Maximum Sustainable Flow based on SLR
			TSS Limit	BOD_5 Limit	
Maximum Day Limits	Mgd	400			320
Maximum Week Limits	Mgd		380	225	
BOD_5 Concentration	mg/L	45			
BOD_5 Mass Loading	lbs/day	32,475			
TSS Concentration	mg/L	45			
TSS Mass Loading	lbs/day	75,060			
Maximum Monthly Limits	Mgd	200	288	175	
BOD_5 Concentration	mg/L	30			
BOD_5 Mass Loading	lbs/day	21,650			

			Maximum Sustainable Flow based on SOR		
BOD_5 Percent Removal	%	89			
TSS Concentration	mg/L	30			
TSS Mass Loading	lbs/day	50,040			
TSS Percent Removal	%	85			

1 - BOD_5 limits based on old permit, plant now monitors $cBOD_5$ for compliance

3.2.5 Current Collection System CSO Response to Rainfall

The response of the current combined sewer collection system to wet weather events is characterized in terms of the average annual volume of wet weather flow captured and treated, and the volume overflowed to receiving waters. Percent capture, defined as the fraction of wet weather combined sewer flow that is captured and treated, is also commonly used to characterize the performance of the combined sewer collection system. Table 3-45 presents wet weather performance measures estimated for each watershed based on system hydrologic and hydraulic model simulations for a typical year precipitation record using a low and a high range of estimated hydrologic parameters.

Table 3-45 Combined Sewer System Wet Weather Characterization of Current Conditions

Watershed	Captured Volume (MG)	Overflow Volume (MG)	Capture %
Cobbs	1,713 - 1,971	651 - 1,015	66% - 72%
Delaware	9,629 - 11,068	4,133 - 6,737	62% - 70%
Schuylkill	5,757 - 5,740	2,204 - 3,463	62% - 72%
TTF	3,221 - 3,945	3,319 - 4,659	46% - 49%
System-Wide	20,320 - 22,724	10,307 - 15,873	59% - 66%

The frequency of combined sewer overflows is also a measure of system wet weather performance and is presented in Figure 3-26 as box and whisker plots for each watershed under existing conditions. The plot shows the range of overflow frequencies that occur among different combined sewer outfalls within each watershed. The average annual overflow frequency for each outfall is based on model simulations for the typical year precipitation record and is determined as the average of the low and high hydrologic parameter estimates. The annual number of overflows is seen to vary significantly between regulators within each watershed.

Wet weather performance is detailed further with regulator specific information in Supplemental Documentation Volume 4: Hydrologic and Hydraulic Modeling.

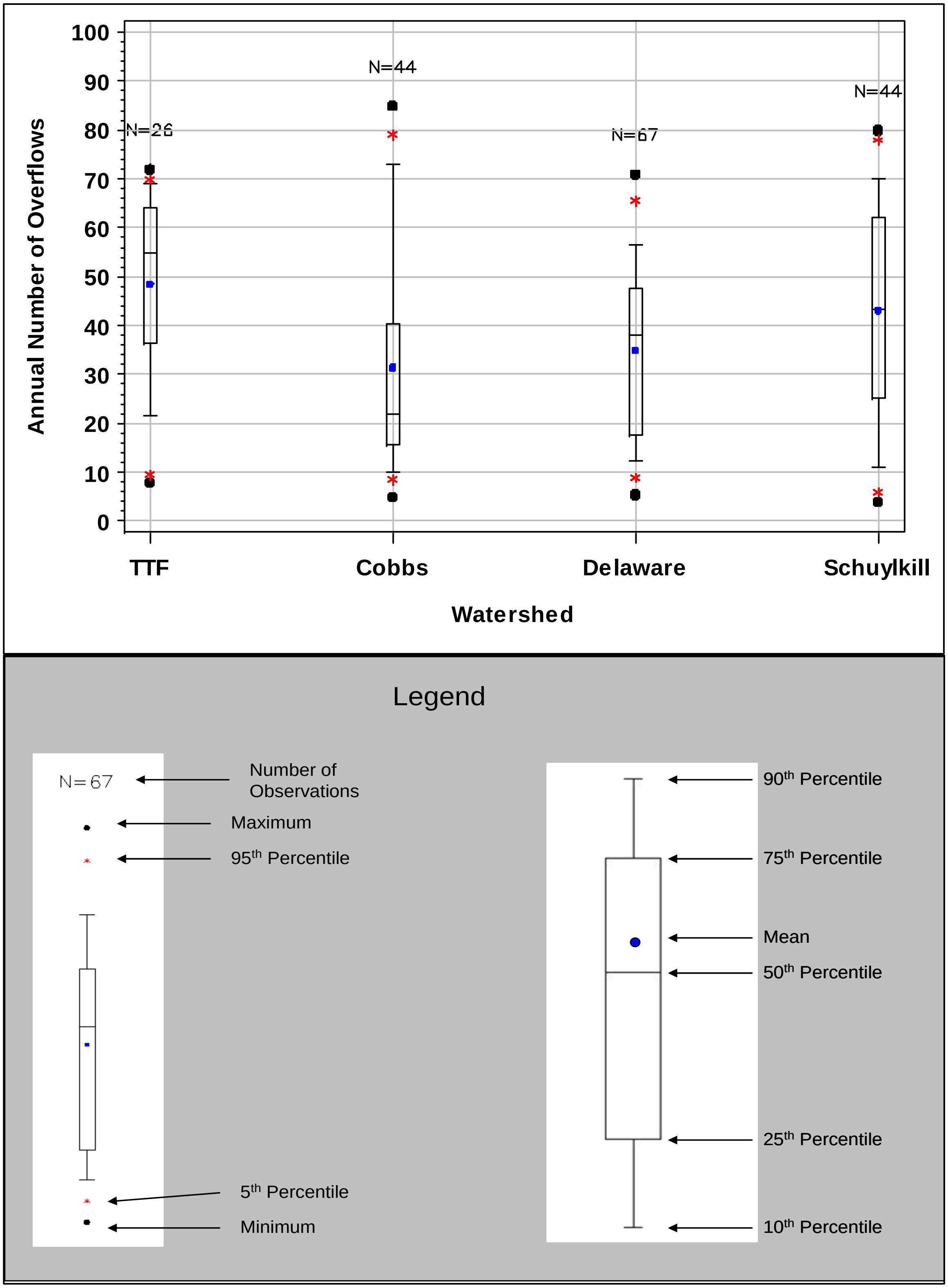


Figure 3-26 Average Annual Regulator Overflow Frequency by Watershed for Existing Conditions (Average of Low and High Uncertainty Range Using Typical Year Rainfall)

3.3 CONTRIBUTING MUNICIPALITIES

3.3.1 Contributing Area Description

This section provides additional details on metered flows for those communities contributing sanitary sewage, inflow, and infiltration to the PWD collection system. These communities, as listed in the previous section, are:

- Township of Abington
- Bensalem Township
- Bucks County Water and Sewer Authority, including all or parts of the townships of Bensalem, Bristol, Falls, Lower Wakefield, Lower Southampton, Middletown, Newtown, and Northampton; and the boroughs of Hulmeville, Langhorne, Langhorne manor, Newtown, and Pendel.
- Township of Cheltenham and Abington Township and Jenkintown Borough
- The Delaware County Regional Water Quality Control Authority (DELCORA) including all or part of Haverford, Radnor, Newtown, Upper Providence, Tinicum; the boroughs of Norwood, Glenolden, Morton, Rutledge, Prospect Park, Ridley Park, and Swarthmore; and the townships of Darby, Upper Darby, Ridley, Springfield, Marple, and Nether Providence.
- Township of Lower Merion
- Township of Lower Moreland and the Lower Moreland Township Authority
- Lower Southampton Municipal Authority and Upper Southampton Township
- Township of Springfield, Montgomery County and Whitemarsh and Upper Dublin Township
- Upper Darby Township and Haverford Township

PWD has entered into agreements with the municipalities, townships and authorities outside the City of Philadelphia (wholesale purchasers) to provide for the receipt, conveyance, treatment and disposal of wastewater and its by-products. In addition to water quality loading limits, the agreements provide maximum average annual or daily flow limits and instantaneous peak flow limits. The average long-term flow limits are based on the portion of secondary treatment capacity being reserved for the wholesale purchaser, while the instantaneous peak flow limit is established to limit the amount of wet weather inflow and infiltration entering the City in order to assure adequate wet weather conveyance and treatment capacity will be available. Chronically exceeding peak flow limits requires an accepted plan of action to eliminate the flow exceedances within a specified time period or financial penalties will be imposed upon the wholesale purchaser to encourage proper maintenance and rehabilitation of their community sanitary sewer collection system in order to mitigate the sources of excessive wet weather inflow and infiltration.

Table 3-48 provides details for each community being serviced by the NE WPCP including service area and population, maximum contractual flow limits, and connection points. The relative location of each community to the City boundary is shown in Figure 3-4.

Table 3-46 Summary of Outlying Communities Contributing to the Northeast Drainage District

Northeast Drainage District						
Community	Cheltenham Township	Abington Township	Bensalem Township	Bucks County	Southampton Township	Lower Moreland Township
Population	58,871	14,605	22,317	94,261	24,662	6,287
Area (acres)	8,855	4,489	5,143	24,990	6,411	1,917
Watershed	Tacony-Frankford Creek	Pennypack Creek	Poquessing Creek	Neshaminy Creek and Delaware River	Poquessing Creek	Pennypack Creek and Poquessing Creek
Downstream Combined Sewer Interceptor	Frankford High Level	Upper Delaware Low Level	Upper Delaware Low Level	Upper Delaware Low Level	Upper Delaware Low Level	Upper Delaware Low Level
Connection Points	MC_1, MC_2, MC_3	MA_1, MA_2, MA_3, MA_4	MBE_1, MBE_2, MBE_3, MBE_4, MBE_5, MBE_6, MBE_7, MBE_8, MBE_9, MBE_10, MBE_11, MBE_12, MBE_13, MBE_14, MBE_15, MBE_16	MB_1	MSH_1, MSH_2	MLM_1, MLM_2, MLM_3, MLM_4, MLM_5, MLM_6, MLM_7
Contractual Flows						
Peak (MGD)	13.41	5.974	7.584	54.962	10.205	5.795
Daily (MGD)	-	4.453	-	37	-	2.9
Annual (MGD)	-	-	6.133	24	7.14	1.45

Table 3-49 provides details for each community being serviced by the SW WPCP and the SE WPCP including service area and population, maximum contractual flow limits, and connection points.

Table 3-47 Summary of Outlying Communities Contibuting to the Southwest and Southeast Drainage Districts

Southwest and Southeast Drainage Districts				
Community	Lower Merion Township	Upper Darby Township	DELCORA	Springfield Township
Population	53,861	96,784	468,801	21,640
Area (acres)	10,079	7,659	45,771	4,804
Watershed	Schuylkill River	Darby Creek and Cobbs Creek	Cobbs Creek	Wissahickon Creek
Downstream Combined Sewer Interceptor	Southwest Main Gravity and Cobbs Creek	Cobbs Creek High Level	DELCORA Force Main	Central Schuylkill East Side and Lower Delaware Low Level
Connection Points	ML_1, ML_2, ML_3, ML_4, ML_5, ML_6, ML_7	MUD_1N, MUD_1S, MUD1_O	MD-1	MS_1, MS_2, MS_3, MS_4, MS_5, MS_6, MS_7, MS_8
Contractual Flows				
Peak (MGD)	20.39	22.61	100	4.22
Daily (MGD)	14.5	-	75	-
Annual (MGD)	-	17	50	4.2

A summary of the preliminary peak wet weather flows contributed by the above listed municipalities are available in Table 3-50 and 3-51 below. These flows have undergone a preliminary QA process, but the numbers have not been finalized.

Table 3-48 Outlying Community Permanent Meter Flow Summary

Permanent Meter Flows (1/1/2000 - 3/31/2005)				
Meter ID	Drainage District	Average Daily Dry Weather Flow (mgd)	Peak 15-Minute Flow (mgd)	Wet / Dry Ratio
MA2	NE	1.50	4.94	3.3
MB1	NE	17.14	84.58	4.9
MBE5	NE	0.63	4.68	7.4
MBE6	NE	0.78	3.49	4.5
MBE7	NE	0.22	1.61	7.4
MC1	NE	0.50	2.93	5.8
MC2	NE	15.89	33.27	2.1
MC3	NE	0.04	0.23	6.3
MD1	SW	33.27	81.69	2.5
ML1	SW	1.09	2.99	2.7
ML3	SW	0.44	1.88	4.3
ML4	SW	3.89	14.40	3.7
ML5	SW	0.60	1.99	3.3
ML6	SW	0.10	0.59	5.8
ML7	SW	0.19	1.39	7.4
MLM1	NE	0.13	1.86	14.0
MLM2	NE	1.18	4.39	3.7
MS2	SW	1.22	7.50	6.2
MS3	SW	0.84	6.00	7.1
MS6	SW	0.43	1.98	4.7
MSH1	NE	5.63	25.00	4.4
MUD1-N	SW	6.57	20.10	3.1
MUD1-S	SW	5.03	38.50	7.7

Table 3-49 Outlying Community Temporary Meter Flow Summary

Meter ID	Drainage District	Average Daily Dry Weather Flow (mgd)	Peak 15-minute Flow (mgd)	Wet / Dry Ratio	Temporary Monitor Data Period
MA1	NE	0.009	0.043	4.8	11/15/04 - 1/16/05
MA3	NE	0.495	0.877	1.8	11/16/04 - 2/18/05
MA4	NE	0.063	0.204	3.2	11/15/04 - 1/16/05
MBE1	NE	0.121	1.313	10.9	8/1/2004 - 12/31/2004
MBE2	NE	0.332	1.464	4.4	8/1/2004 - 12/31/2004
MBE3	NE	0.035	0.480	13.7	8/1/2004 - 12/31/2004
MBE4	NE	0.163	1.888	11.6	8/1/2004 - 12/31/2004
MBE8	NE	0.379	1.771	4.7	8/1/2004 - 12/31/2004
MBE9	NE	0.381	1.689	4.4	8/1/2004 - 12/31/2004
MBE10	NE	0.067	0.444	6.7	8/1/2004 - 12/31/2004
MBE11	NE	0.014	0.174	12.7	8/1/2004 - 12/31/2004
MBE12	NE	0.150	0.620	4.1	8/1/2006 - 11/12/2006
MBE13	NE	0.013	0.152	11.5	8/1/2006 - 11/12/2006
MBE14	NE	0.017	0.392	22.8	8/1/2006 - 11/12/2006
MBE15	NE	0.010	0.104	10.8	8/1/2006 - 11/12/2006
MBE16	NE	0.130	1.320	10.2	9/3/2006 - 12/1/2006
ML2	SW	0.043	0.524	12.2	11/12/04 - 1/18/05
MLM3	NE	0.037	0.126	3.4	11/24/04 - 3/06/05
MLM4	NE	0.035	0.080	2.3	11/30/04 - 2/07/05
MS1	SE	0.134	0.822	6.1	11/12/04 - 1/18/05
MS4	SW	0.108	0.319	2.9	11/16/04 - 1/18/05
MS5	SW	0.106	0.380	3.6	11/12/04 - 1/26/05
MS7	SW	0.013	0.066	4.9	11/12/04 - 1/18/05
MSH2	NE	0.041	0.431	10.5	10/25/2006 - 1/25/2007

3.4 Regional Watershed and Receiving Water Characterization

3.4.1 Receiving Water Quality Standards and Use Designations

Information on segments considered impaired, causes of impairment, and TMDL status were obtained from the 2008 Pennsylvania Integrated Water Quality Monitoring and Assessment Report. Additional information on PADEP's plans for TMDL development was obtained from their "Six-Year Plan for TMDL Development".

The water quality in the Delaware River and its tidal tributaries are regulated by standards set specifically for the Delaware Estuary. The DRBC uses water quality zones which dictate the designated use and water quality standards for each segment of the river (DRBC, 2008a).
The Delaware River is assessed every two years by the DRBC for Support of Designated Uses.

Information on fish consumption advisories was obtained from PADEP (last revised July 17, 2006), New Jersey DEP (issued 2006), and USEPA's national listing of fish advisories (current as of December 2004).

3.4.1.1 Tacony-Frankford Creek

Designated Uses

Title 25, Chapter 93 of the Pennsylvania Code assigns water quality standards to each reach of a water body. Water quality standards consist of designated uses, water quality criteria, and an antidegradation requirement. Except when otherwise specified, the statewide water uses set forth below apply to all surface waters.

- Aquatic Life
- WWF Warm Water Fishes—Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
- Water Supply
- PWS Potable Water Supply
- IWS Industrial Water Supply—Use by industry for inclusion into nonfood products, processing and cooling.
- LWS Livestock Water Supply—Use by livestock and poultry for drinking and cleansing.
- AWS Wildlife Water Supply—Use for waterfowl habitat and for drinking and cleansing by wildlife.
- IRS Irrigation—Used to supplement precipitation for growing crops.
- Recreation
- B Boating—Use of the water for power boating, sail boating, canoeing and rowing for recreational purposes when surface water flow or impoundment conditions allow.
- F Fishing—Use of the water for the legal taking of fish. For recreation or consumption.
- WC Water Contact Sports—Use of the water for swimming and related activities.
- E Esthetics—Use of the water as an esthetic setting to recreational pursuits.

Use Attainment Status and Total Maximum Daily Load Development

Use attainment status listed by PADEP for the non-tidal Tacony-Frankford Creek is shown in Table 3-50. Reaches of this creek are listed as impaired by causes related to the quantity and velocity of discharge: municipal point sources, urban runoff, storm sewers, flow variability, flow variations, and associated habitat alterations. These physical alterations lead to impairment but are not considered pollutants as defined by the Clean Water Act, and do not by themselves require a TMDL. It is important to note that the Frankford Creek is a tidal tributary to the Delaware River of the Tidal Delaware River as described in Section 3.4.1.3.

The PADEP categorized the aquatic life impairments of the TTF Creek on the list 4c, Streams Impaired by Pollution not Requiring a TMDL. The Fish Consumption impairment is listed as category 5. A TMDL is planned for PCBs in the TTF Watershed, but it is not clear on the timeframe of this TMDL development.

Table 3-50 Philadelphia Impaired Streams in the Tacony-Frankford Creek Watershed

Waterbody Name	Designated Use	Attainment Status	Cause of Impairment	Source	Stream Miles	Date Listed
Tacony Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/ Storm Sewers	1.34	2002
			Flow Alterations	Urban Runoff/ Storm Sewers		
			Other Habitat Alterations	Urban Runoff/ Storm Sewers		
			Water/Flow Variability	Urban Runoff/ Storm Sewers		
			Flow Alterations	Urban Runoff/ Storm Sewers		
Frankford Creek (Rising Sun Ave. to Aramingo Ave.)	Aquatic Life	Impaired	Other Habitat Alterations	Urban Runoff/ Storm Sewers	3.93	2002
Frankford Creek (Aramingo Ave. to confluence)	Fish Consumption	Impaired	PCBs	Source Unknown	1.59	2006
Tributaries						
Burholme Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/ Storm Sewers	0.94	2002
			Flow Alterations	Urban Runoff/ Storm Sewers		
			Other Habitat Alterations	Urban Runoff/ Storm Sewers		
Tookany Creek, unnamed tributary	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/ Storm Sewers	0.40	2002
			Flow Alterations	Urban Runoff/ Storm Sewers		
			Other Habitat Alterations	Urban Runoff/ Storm Sewers		

3.4.1.2 Cobbs Creek

Designated Uses

Title 25, Chapter 93 of the Pennsylvania Code assigns water quality standards to each reach of a water body. Except when otherwise specified, the statewide water uses set forth below apply to all surface waters.

Use Attainment Status and Total Maximum Daily Load Development

Use attainment status listed as category 5 by PADEP for Cobbs Creek is shown in Table 3-51. Reaches are listed as impaired by causes related to the quantity and velocity of discharge: municipal point sources, urban runoff, storm sewers, flow variability, flow variations, and associated habitat alterations. These physical alterations lead to impairment but are not considered pollutants as defined by the Clean Water Act, and do not by themselves require a TMDL. Cobbs Creek is listed for "siltation" related to these same physical factors. Because Siltation/sediment is considered a pollutant requiring a TMDL, it is unclear at this time when the TMDL will be developed. PADEP is currently updating its process for producing TMDLs and tentatively scheduled the Cobbs Creek TMDL for the year 2015.

Fish Consumption Advisories

No fish consumption advisories have been issued by PADEP for the non-tidal portions of Cobbs Creek..

3.4.1.3 Tidal Delaware and Tidal Schuylkill Rivers, Including Tributaries

Designated Uses

Water quality standards for the tidal Delaware River and tidal portions of tributaries, including the entire length of the Schuylkill River within the combined sewer service area, are assigned by the Delaware River Basin Commission. The Delaware Direct includes Zones 2, 3 and 4. The Schuylkill River drains to the Delaware River in Zone 4. Zone 5 is included in the reporting of designated use since it is downstream of the City of Philadelphia and the CSO receiving waters.

<u>Zone 2</u>

Zone 2 is that part of the Delaware River extending from the head of tidewater at Trenton, New Jersey, R.M. (River Mile) 133.4 (Trenton-Morrisville Toll Bridge) to R.M. 108.4 below the mouth of Pennypack Creek, including the tidal portions of the tributaries thereof. It is important to note that the tidal portion of the Pennypack Creek is included in Zone 2 of the Delaware River.

The quality of Zone 2 waters shall be maintained in a safe and satisfactory condition for the following uses:

1. a. public water supplies after reasonable treatment,
   b. industrial water supplies after reasonable treatment,
   c. agricultural water supplies;
2. a. maintenance and propagation of resident fish and other aquatic life,
   b. passage of anadromous fish,
   c. wildlife;
3. a. recreation;
4. a. navigation.

Table 3-51 Philadelphia Impaired Streams in the Cobbs Creek Watershed

Waterbody Name	Designated Use	Attainment Status	Cause of Impairment	Source	Stream Miles	Date Listed
Cobbs Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	9.61	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		
			Cause Unknown	Municipal Point Source; Urban Runoff/Storm Sewers		
Tributaries						
East Branch Indian Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	2.04	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		
			Cause Unknown	Municipal Point Source, Urban Runoff/Storm Sewers		
Indian Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	2.04	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		
			Cause Unknown	Municipal Point Source, Urban Runoff/Storm Sewers		
Naylors Run	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	9.61	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		
			Cause Unknown	Municipal Point Source ; Urban Runoff/Storm Sewers		
West Branch Indian Creek	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	9.61	2002
			Siltation	Urban Runoff/Storm Sewers		
			Other Habitat Alterations	Habitat Modification		

Zone 3

Zone 3 is that part of the Delaware River extending from R.M. 108.4 to R.M. 95.0 below the mouth of Big Timber Creek, including the tidal portions of the tributaries thereof. It is important to note that the tidal portion of the Frankford Creek is included in Zone 3 of the Delaware River.

The quality of Zone 3 waters shall be maintained in a safe and satisfactory condition for the following uses:

1. a. public water supplies after reasonable treatment,
   b. industrial water supplies after reasonable treatment,
   c. agricultural water supplies;
2. a. maintenance of resident fish and other aquatic life,
   b. passage of anadromous fish,
   c. wildlife;
3. a. recreation - secondary contact;
4. a. navigation.

Zone 4

Zone 4 is that part of the Delaware River extending from R.M. 95.0 to R.M. 78.8, the Pennsylvania-Delaware boundary line, including the tidal portions of the tributaries thereof. It is important to note that the tidal potion of the Schuylkill River is included in Zone 4.

The quality of Zone 4 waters shall be maintained in a safe and satisfactory condition for the following uses:

1. a. industrial water supplies after reasonable treatment;
2. a. maintenance of resident fish and other aquatic life,
   b. passage of anadromous fish,
   c. wildlife;
3. a. recreation - secondary contact above R.M. 81.8,
   b. recreation below R.M. 81.8;
4. a. navigation.

Zone 5

Zone 5 is that part of the Delaware River extending from R.M. 78.8 to R.M. 48.2, Liston Point, including the tidal portions of the tributaries thereof.

The quality of waters in Zone 5 shall be maintained in a safe and satisfactory condition for the following uses:

1. a. industrial water supplies after reasonable treatment;
2. a. maintenance of resident fish and other aquatic life,
   b. propagation of resident fish from R.M. 70.0 to R.M. 48.2,
   c. passage of anadromous fish,
   d. wildlife;
3. a. recreation;
4. a. navigation.

Use Attainment Status and Total Maximum Daily Load Development

Table 3-52 shows the results of the 2008 Assessment for the Water Quality Zones within the Delaware Direct Watershed. The colors are used to summarize the zones and designated use. If two or more uses/zones are not supporting the heading is colored red. If one zone/use is not supporting, the heading is colored orange. If all zones support the designated use, the heading is colored green.

Table 3-52 DRBC Integrated Assessment Summary

Zone	Designated Use				Final 2008 Assessment Category
	Aquatic Life	Recreation	Drinking Water	Fish Consumption	
2	Not Supporting	Supporting	Supporting	Not Supporting	5
3	Supporting	Supporting	Supporting	Not Supporting	4A
4	Not Supporting	Supporting	Not Applicable	Not Supporting	5
5	Not Supporting	Supporting	Not Applicable	Not Supporting	4A

4A: A TMDL to address a specific segment/pollutant combination has been approved or established
5: Available Data and/or information indicate that at least one designated use is not being supported or is threatened, and a TMDL is needed.
Source: DRBC, 2008b

Use attainment status listed by PADEP for segments of the Delaware and Schuylkill Rivers intersecting Philadelphia County is shown in Table 3-53. Listed sources of impairment include industrial and municipal point sources, metals, urban runoff, storm sewers, and flow variability. The science behind impairment by PCBs is well documented. However, the scientific basis for impairments caused by metals and priority organics is unclear.

In December 2003, USEPA Regions II and III issued Total Maximum Daily Loads for polychlorinated biphenyls (PCBs) for Zones 2 - 5 of the Tidal Delaware River. The TMDL established waste load allocations (WLAs) for point sources in each zone, including continuous point sources, municipal separate storm sewer systems (MS4s), and combined sewer systems. The TMDL also assigned load allocations to nonpoint sources and to runoff from contaminated sites.

PWD has agreed to a good faith commitment to reduce discharges of PCBs from the Northeast Water Pollution Control Plant, Southeast Water Pollution Control Plant and Southwest Water Pollution Control Plant to the Delaware Estuary through the Pollutant Minimization Plan (PMP) process in accordance with the Delaware River Basin Commission PMP Rule 4.30.9. The PCB pollution minimization plan was submitted in September of 2005 and is implemented through the Operations Division.

A TMDL for the Pennypack Creek is planned, but it is unclear at this time if the tidal portion of the creek will be included and when the TMDL will be produced.

A TMDL was produced in 2007 for PCBs in the tidal Schuylkill River. The Pollution Minimization Plan described above also manages PCBs in the tidal Schuylkill River within the City of Philadelphia. No other TMDLs are planned for the Schuylkill River Watershed within Philadelphia at this time.

Table 3-53 Delaware and Schuylkill Rivers Impaired Reach Status Under PADEP Integrated List

Waterbody Name	Designated Use	Attainment Status	Cause of Impairment	Source	Stream Miles	Date Listed
Delaware River	Fish Consumption	Impaired	Source Unknown - PCB	Unknown	21.87	1996
Schuylkill River	Fish Consumption	Impaired	PCB	Unknown	17.32	1998
Schuylkill River (City line to Penrose Ave.)	Aquatic Life	Supporting	-	-	15.14	NA
Schuylkill River (Falls Bridge to Roosevelt Blvd.)	Potable Water Supply	Supporting	-	-	0.31	NA
Tributaries						
Tidal Pennypack Creek	Aquatic Life	Impaired	Priority Organics	Industrial Point Source	3.07	1998
			Organic Enrichment/Low D.O.	Municipal Point Source		1998
Tidal Pennypack Creek	Potable Water Supply	Impaired	Pathogens	Municipal Point Source	3.07	1998
Old Frankford Creek	Fish Consumption	Impaired	Source Unknown - PCB	Unknown	0.83	1996
Dobsons Run	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	0.99	2002
Gulley Run	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers	0.03	2002
Manayunk Canal	Aquatic Life	Supporting	-	-	1.35	NA
Schuylkill River, unnamed trib	Aquatic Life	Impaired	Water/Flow Variability	Removal of Vegetation, Road Runoff	0.72	2002
			Siltation	Removal of Vegetation, Road Runoff		2002
Schuylkill River, 6 unnamed tribs	Aquatic Life	Impaired		Urban Runoff/ Storm Sewers - Water/Flow Variability	2.93	2002
Schuylkill River, unnamed trib	Aquatic Life	Supporting	-	-	1.55	NA
Shaw Run	Aquatic Life	Impaired	Water/Flow Variability	Urban Runoff/Storm Sewers, Road Runoff	0.74	2002
			Siltation	Urban Runoff/Storm Sewers, Road Runoff		2002

Fish Consumption Advisories
In the late 1980s, the states of Delaware, New Jersey and Pennsylvania began issuing fish consumption advisories for portions of the Delaware Estuary due to elevated concentrations of PCBs measured in fish tissue. Today, the states' advisories cover the entire estuary and bay. The advisories range from a no-consumption recommendation for all species taken between the C&D Canal and the Delaware-Pennsylvania border to consumption of no more than one meal per month of striped bass or white perch in Zones 2 through 4 (EPA, 2003). PADEP and NJDEP have issued fish consumption advisories for the Delaware and Schuylkill Rivers as shown in Table 3-54. These advisories identify PCBs as a pollutant of concern in fish tissue. An NJDEP advisory issued in 2004 identifies dioxin as a pollutant of concern. While NJDEP advisories recommend high-risk individuals limit consumption of certain species due to mercury exposure, these recommendations are similar to those imposed nationwide for all freshwater fish. It is important to note that the differences in fish consumption advisories in the Delaware River from Pennsylvania and New Jersey are based on the methodology used to assess risk, not by the levels of contamination found in fish tissue.

3.4.2 Receiving Water Quality and Watershed Characterization

This section describes the baseline conditions of the receiving waters and watersheds. The watershed descriptions characterize both CSO and non-CSO sources of pollution and the status of watershed characterization. A detailed summary of water quality analysis includes chemical and biological data. Finally, a brief description of aquatic habitat conditions is also included to summarize overall water quality health in terms of its ability to support of aquatic life.

As discussed in Section 1, the Philadelphia Water Department is committed to managing CSOs through a watershed approach. Complete characterization of the receiving watersheds has been conducted in a series of Comprehensive Characterization Reports (CCRs). CCRs are completed for the TTF and Darby-Cobbs Creek Watersheds. Although the findings of the CCRs are summarized in this section of the LTCPU, these documents extensively describe in greater detail the land use, geology, soils, topography, demographics, meteorology, hydrology, water quality, ecology, pollutant loadings, and fluvial geomorphology in the watersheds. Additionally, the Philadelphia Water Department has developed Integrated Watershed Management Plans (IWMPs) to utilize the baseline data published in the CCRs in order to guide informed decision making for the CSO program and other watershed restoration efforts. The status and dates of publishing of these reports are explained and referenced in the following section for each receiving watershed.

The Tidal Delaware and Schuylkill Rivers are also receiving waters. This section of the LTCPU documents results from water quality monitoring in Philadelphia sections of these rivers relevant to CSOs. As explained earlier in Section 3, much of these data come from the USGS, the Delaware River Basin Commission, and supplemental PWD monitoring. Based on this continuing effort to characterize these two large rivers, PWD is currently developing IWMPs for the Philadelphia portion of the Delaware River Basin and the Schuylkill Watershed.

Table 3-54 Fish Consumption Advisories for the Tidal Delaware and Schuylkill Rivers

Issued By	Water Body	Area Under Advisory	Species	Meal Frequency		Contaminant
				General Population	High-Risk Individual	
PADEP 2006	Delaware Estuary, including the tidal portion of all PA tributaries and the Schuylkill River to the Fairmount Dam (Bucks, Philadelphia, and Delaware Counties)	Trenton, NJ-Morrisville, PA Bridge to PA/DE border	white perch	1 meal/month	not specified	PCB
			channel catfish			
			flathead catfish			
			striped bass			
			American eel	no consumption		
			carp			
PADEP	Schuylkill River (Chester, Montgomery, and Philadelphia Counties)	Black Rock Dam to Fairmount Dam in Philadelphia	carp	no consumption	not specified	PCB
			channel catfish	1 meal/month		
			flathead catfish			
PADEP	Schuylkill River (Berks, Chester, Montgomery, and Philadelphia Counties)	Felix Dam above Reading to Fairmount Dam	American eel	no consumption	not specified	PCB
			white sucker	1 meal/month		
NJDEP * 2004	Delaware River (Burlington County)	Trenton to Camden	largemouth bass	not specified	1 meal/week	Mercury
			white catfish	not specified		
NJDEP * 2004	Delaware River (Camden and Gloucester Counties)	Camden to Delaware/NJ state line	wtriped hybrid bass	not specified	1 meal/week	Mercury
NJDEP * 2004	Delaware River, including all tributaries up to the head of tide	from Easton(PA)/Phillipsburg(NJ) to PA/DE border	striped bass**	varies by subpopulation	no consumption	Dioxin
			channel catfish	6 meals/yr		
			American eel	varies by subpopulation		
			striped bass	varies by subpopulation		PCBs (Total)
			channel catfish	6 meals/yr		
			American eel	varies by subpopulation		

* NJDEP advisories are listed in EPA's National Listing of Fish Advisories (2004), but not found in NJDEP's listing (2006).
** A commercial fishing ban has been imposed on this species.

3.4.2.1 TTF Watershed Characterization

The Tacony and Frankford Creeks receive combined sewer overflows. Both creeks are part of the TTF Watershed (Figure 3-27). A Comprehensive Characterization Report (CCR) was completed for the TTF Watershed in August 2005. The CCR fully documents the baseline conditions and lays the groundwork for future CSO planning and watershed management. The Integrated Watershed Management Plan guides the Philadelphia Water Department's efforts to restore and protect the designated uses. The IWMP and CCR can both be located at http://www.phillyriverinfo.org. Table 3-55 includes the titles and links to other reports that can be referenced for more detailed characterization of the TTF Watershed.

The breakdown by sewer type is as follows:

- Combined sewer areas make up 9,800 acres, or 47% of the drainage area.
- Separate sewers, including areas outside of the City of Philadelphia, account for 9,200 acres or 44% of the drainage area.
- Non-contributing sewers make up 1,900 acres or 9% of the drainage area.

Table 3-55 Existing Documents Relevant to Characterization of the TTF Watershed

File Name	Year Published
Tacony-Frankford Act 167 Final Report	2008
Tacony FGM Report	2007
Southeast Regional Wetland Inventory and Water Quality Improvement Initiative	2006
TTF Integrated Watershed Management Plan	2005
TTF Comprehensive Characterization Report	2005
Tacony-Frankford River Conservation Plan	2004
Tacony-Frankford Watershed Historical Overview of the Philadelphia Section	2003
Baseline Biological Assessment of Mill Run Report	Draft, 2002
Biological Assessment of the Tacony-Frankford Watershed Report	2000

Municipalities and Demographics

The TTF Watershed is located in Montgomery County and Philadelphia County and covers a total of approximately 29 square miles, or about 20,000 acres. Figure 3-27 includes the watershed boundaries, hydrologic features, and municipal boundaries that are important to visualize in order to understand the character of the TTF Watershed.

Land Use

The TTF drainage area is a highly urbanized watershed. The lower reaches are primarily dominated by row homes in Philadelphia County, and the less densely populated upper reaches contain mostly single-family homes in Montgomery County. The combined sewer area within the TTF Watershed is 58% residential, 45% of the area consists of homes. This leads to an average population density in the combined area of 17,342 people per square mile (Figure 3-28). Figure 3-29 illustrates the land use of the Combined Sewer Area within the TTF Watershed is primarily residential and commercial. According to the CCR and TTFIWMP, the TTF Watershed is covered by more than 41% of impervious surfaces. The combined sewer area within the watershed is 62%. The population of the entire drainage area, based on 2000 census data, is approximately 331,400 people.

Pollution Sources
In addition to CSO discharges to Frankford Creek from the City of Philadelphia, the drainage area receives a significant amount of point and non-point source discharges that impact water quality. The waters in the drainage area receive point source discharges including CSOs and other urban and suburban stormwater, sanitary sewer overflows, and industrial storm, process, and cooling waters. Non-point sources in the watershed include atmospheric deposition, overland runoff from urban and suburban areas, and potentially some remaining individual on-lot domestic sewage systems discharging through shallow groundwater.

More detailed information including watershed geology, hydrology, topography, wetlands, infrastructure features, history, cultural features, zoning, and ordinances can be found in the TTF CCR.

Receiving Waterbody Characterization
The receiving creek is referred to as the Tookany Creek until it enters Philadelphia at Cheltenham Avenue. It is then called the Tacony Creek from that Montgomery County border until the confluence with the historical Wingohocking Creek in Juniata Park. The section of stream from Juniata Park to the Delaware River is referred to as the Frankford Creek, portion of which is underlain by a concrete channel. The lower portion of the Frankford Creek is tidally influenced from the Delaware Estuary.

The streams in the western portion of the watershed are contained in pipes and combined sewer infrastructure. Historic streams, including the Wingohocking Creek, Rock Run, and Little Tacony Creek, were encapsulated in combined sewers to facilitate the development of this watershed in the early twentieth century. Combined sewers convey sanitary waste, as well as stormwater to the City's wastewater treatment facilities. The total number of stream miles in this watershed is 14.4 miles in the mainstem creek and approximately 31.9 miles of encapsulated tributaries.

3.4.2.1.1 TTF Creek Hydrologic Characterization

Components of the Urban Hydrologic Cycle
One way to develop an understanding of the hydrologic cycle is to develop a water balance. The balance is an attempt to characterize the flow of water into and out of the system by assigning estimated rates of flow for all of the components of the cycle. It is also important to understand that the natural water cycle components including precipitation, evapotranspiration (ET), infiltration, stream baseflow, and stormwater runoff must be supplemented by the many artificial interventions related to urban water, wastewater, and stormwater systems. A water balance conducted for the TTF Watershed is summarized in this section of the LTCPU and fully described in detail in the TTF CCR.

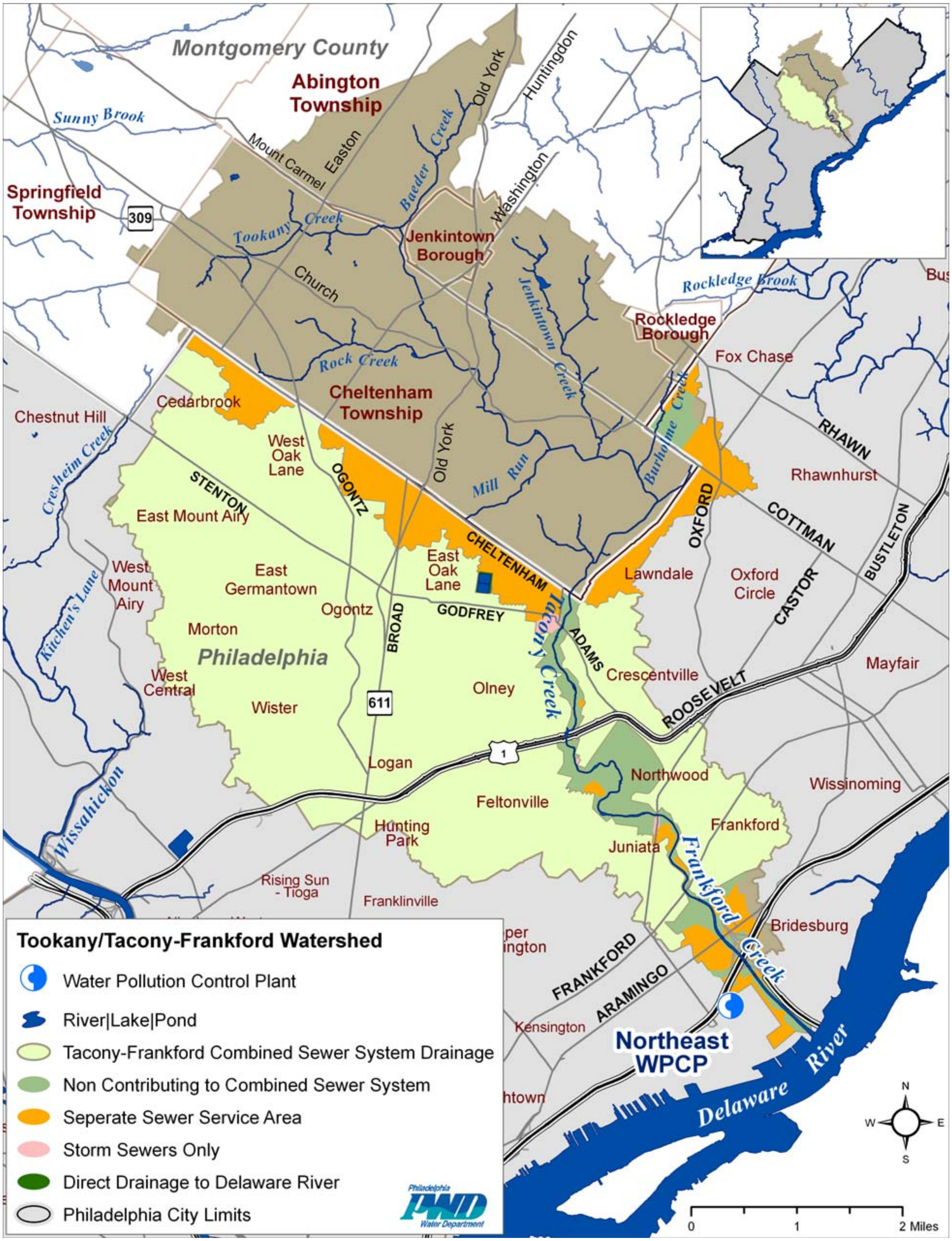


Figure 3-27 The TTF Watershed

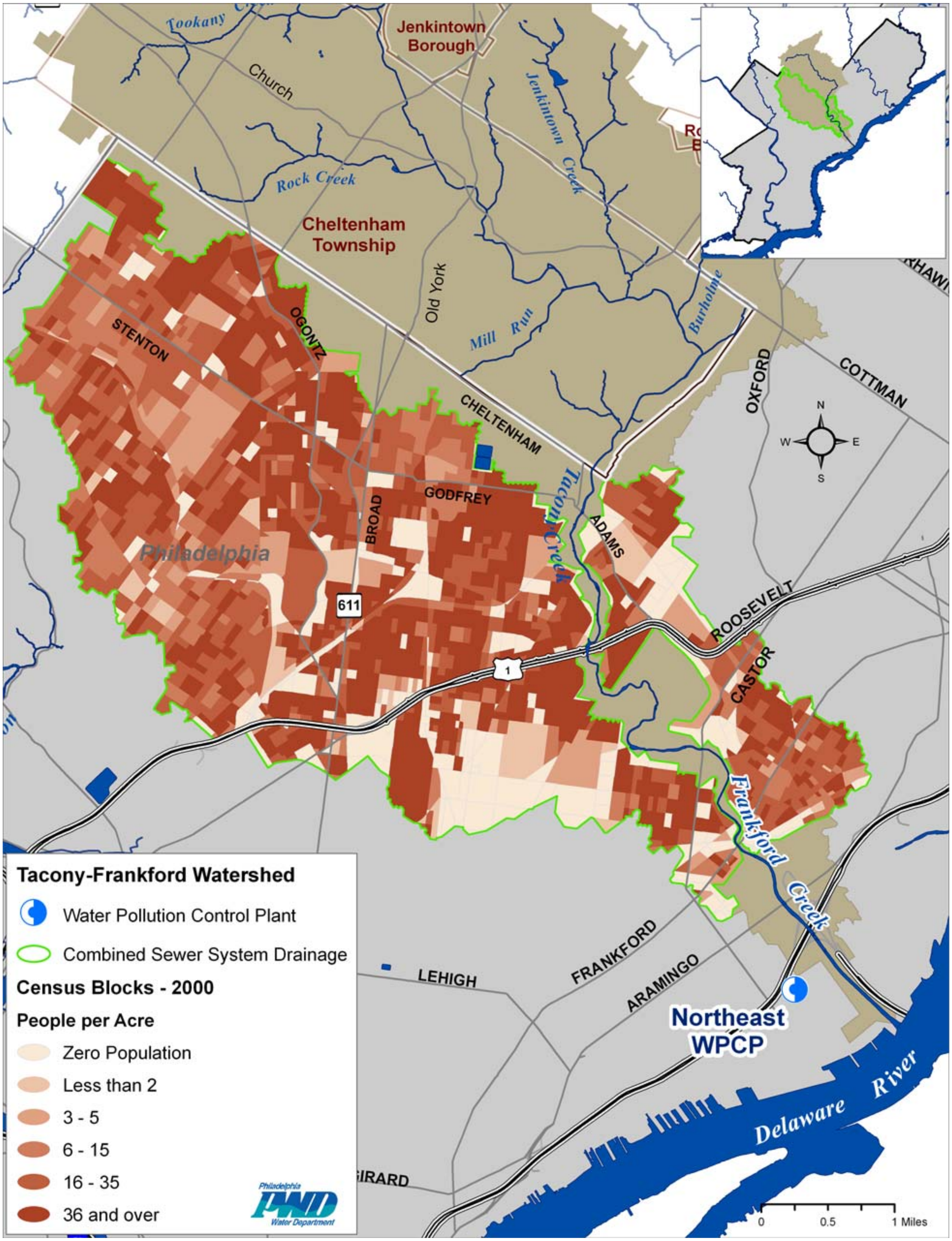


Figure 3-28 Population Density in the TTF Watershed

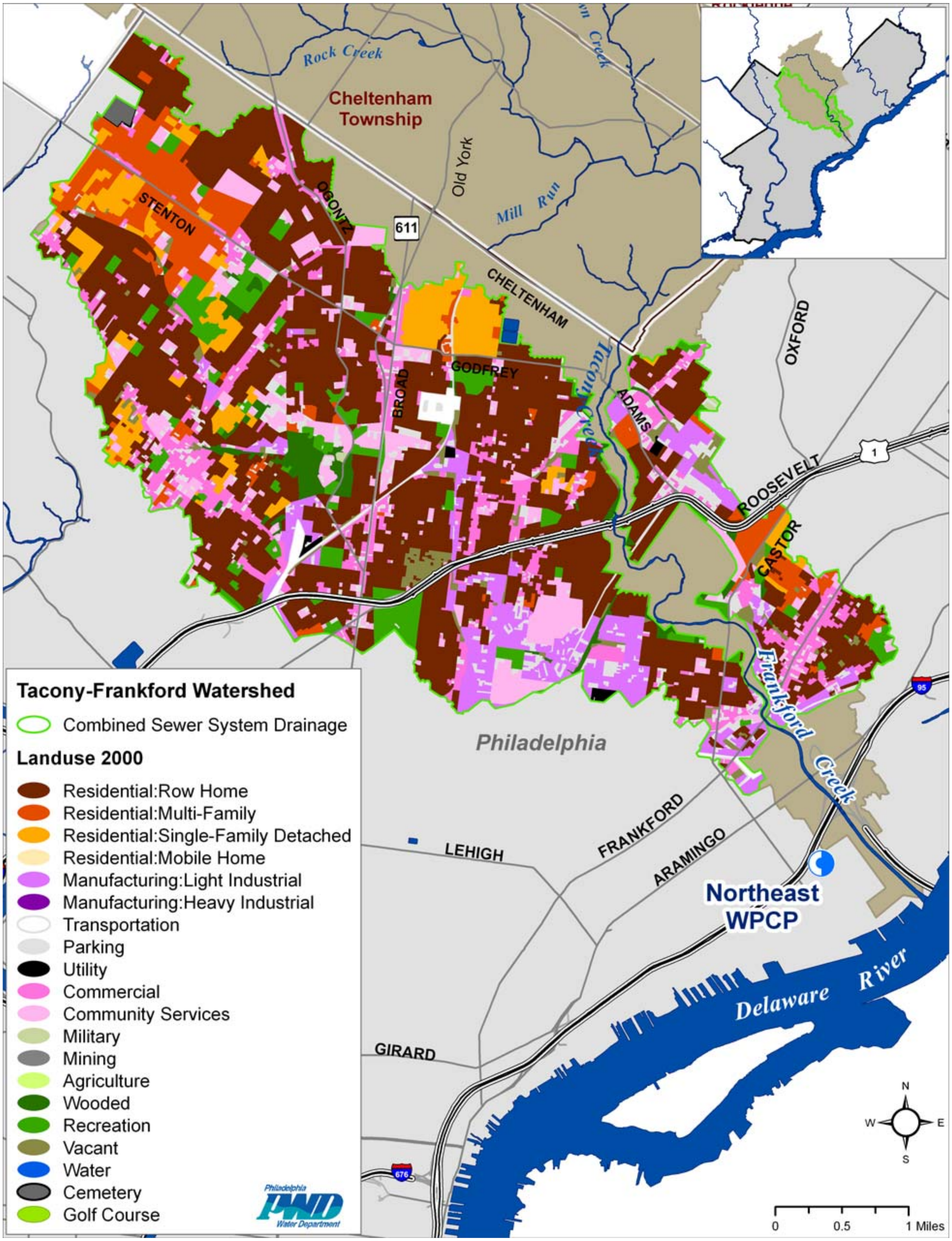


Figure 3-29 Land Use in the Combined Sewer Areas of the TTF Watershed

TTF Creek Water Cycle Component Tables

The relevant components of the urban water cycle have been estimated for the TTF Watershed. Outside Potable Water (OPW) is assumed to balance Outside Wastewater Discharges (OWD), with stormwater and CSO's considered as part of the Runoff component of the water cycle. Table 3-56 shows the results of the analysis, first in inches per year, then in million gallons per day. The inches per year figure simply takes all the flows over an average year, and divides by the area of the watershed. The million gallons per day table takes all the flows over an average year, and divides by 365 days to get an average day value.

Table 3-56 Water Budget Components in the TTF Creek (TTF CCR, Section 4.2, Table 4.3, Page 4-11)

	Period of Record	Inflow		Outflow		
		P	EDR	RO	BF	ET+Error
Component (in/yr)	1982 – 2002	42.1	0.085	11.4	7.06	23.7
Component (MGD)	1982 – 2002	66.1	0.134	17.9	11.1	37.3

*Period of Record applies to Runoff and Baseflow.

** Precipitation uses 100 year rainfall record.

- ***ET*** is the evaporation and transpiration of water and is used to close the equation. It thus contains the sum of errors of the other terms as well as the estimated ET value.
- ***EDR*** is the estimated domestic recharge from private septic systems,
- ***RO*** is the surface water runoff component of precipitation,
- ***BF*** is the median baseflow of streams,
- ***P*** is the average precipitation at the Philadelphia gage,

Hydrograph Decomposition Analysis

<u>Areas and Gages Studied</u>

The TTF Creek Watershed is highly urbanized and contains a large proportion of impervious cover. The hydrologic impact of urbanization can be observed through analysis of streamflow data taken from USGS gages. Table 3-57 lists six gages with available data, including their locations, periods of record, and drainage areas.

<u>Baseflow Separation</u>

Baseflow due to groundwater inflow is the main component of most streams in dry weather. Baseflow slowly increases and decreases with the elevation of the shallow aquifer water table. In wet weather, a stormwater runoff component is added to the baseflow. Estimation and comparison of these two components can provide insights into the relationship between land use and hydrology in urbanized and more natural systems.

Baseflow separation was carried out following procedures similar to those found in the USGS "HYSEP" program. A summary of the HYSEP procedure can be found in the TTF CCR.

Table 3-57 Data Used for Baseflow Separation of TTF Creek (TTF CCR, Section 4.3.2, Table 4-5, Page 4-15)

Gage	Name	Period of Record (yrs)	Drainage Area (mi^2)	N (days)	2N* (days)
01467083	Tacony Creek near Jenkintown	6	5.25	1.39	3
01467084	Rock Creek above Curtis Arboretum near Philadelphia	8	1.15	1.03	3
01467085	Jenkintown Creek At Elkins Park	6	1.17	1.03	3
01467086	Tacony Creek at County Line	24	16.6	1.75	3
01467087	Frankford Creek at Castor Ave.	21	30.4	1.98	3
01467089	Frankford Creek at Torresdale Ave.	18	33.8	2.02	5

The interval 2N* used for hydrograph separations is the odd integer between 3 and 11 nearest to 2N. N is calculated based on watershed area.

Summary Statistics

The results of the hydrograph decomposition exercise support the relationships between land use and hydrology discussed above. For convenience, the flows in Table 3-58 are expressed as a mean depth (flow per unit area) over a one-year time period. Table 3-58 shows streamflow statistics for French Creek as representative of a minimally impaired stream, compared to the six gages of the TTF Watershed. The degree of urban impact to baseflow and runoff can be seen in this table. The upstream portions of the watershed still show reasonable levels of baseflow, similar to those of French Creek (in the 12-13 inch per year range). In the downstream segments of Frankford Creek, baseflow is significantly reduced due to the high degree of impervious cover. Looking at baseflow as a percentage of total flow, the same pattern is evident, however, the effects of urbanization in the upstream areas is more evident using this way of measuring, because it accounts for the higher unit area total flow of the TTF Watershed compared with French Creek. The table also indicates the elevated runoff due to urbanization (as a percentage of total rainfall). Again, runoff is generally higher in the downstream areas, and lower in the upstream areas.

As expected, the quantity of stormwater runoff on a unit-area basis follows patterns of impervious cover in the drainage area. The French Creek Watershed, the least developed, has the smallest amount of stormwater runoff both as an annual mean quantity (7.4 in) and as an annual mean percent of rainfall (17%). As expected, the more highly-developed downstream Frankford Creek has the most runoff both as an annual mean quantity (14.9 in) and as an annual mean percent of rainfall (34%). Mean runoff from Frankford Creek is twice the mean runoff in the French Creek basin. The more upstream gages in the Tacony and Tookany have intermediate quantities of stormwater runoff.

Table 3-58 Annual Summary Statistics for Baseflow and Stormwater Runoff (TTF CCR, Section 4.3.2, Table 4-6, Page 4-17)

	Baseflow (in/yr)				Runoff (in/yr)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	12.9	20.8	5.8	3.8	7.4	15.4	2.9	3.1
Frankford Creek 01467089	7.9	11.5	3.5	2.1	14.9	21.3	8.0	4.3
Frankford Creek 01467087	7.1	13.0	4.5	2.2	11.4	20.3	6.2	3.5
Tacony Creek 01467086	12.6	18.1	7.5	3.2	9.2	13.2	5.2	2.3
Jenkintown Creek 01467085	14.0	18.6	9.5	4.0	9.0	12.0	5.1	2.7
Rock Creek 01467084	12.6	17.0	9.4	3.0	14.9	20.5	10.2	3.6
Tacony Creek 01467083	13.5	18.0	10.8	2.9	10.3	13.6	6.7	2.6

	Baseflow (% of Annual Rainfall)				Runoff (% of Annual Rainfall)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	31%	44%	15%	7%	17%	30%	7%	5%
Frankford Creek 01467089	18%	24%	9%	4%	34%	46%	21%	7%
Frankford Creek 01467087	18%	25%	11%	4%	29%	39%	17%	6%
Tacony Creek 01467086	29%	40%	19%	6%	21%	27%	13%	3%
Jenkintown Creek 01467085	32%	38%	19%	8%	20%	23%	15%	3%
Rock Creek 01467084	28%	36%	19%	6%	33%	41%	21%	7%
Tacony Creek 01467083	31%	36%	22%	6%	24%	31%	20%	5%

	Baseflow (% of Annual Total Flow)				Runoff (% of Annual Total Flow)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	64%	75%	53%	5%	36%	47%	25%	5%
Frankford Creek 01467089	35%	48%	27%	5%	65%	73%	52%	5%
Frankford Creek 01467087	38%	49%	26%	6%	62%	74%	51%	6%
Tacony Creek 01467086	58%	67%	48%	5%	42%	52%	33%	5%
Jenkintown Creek 01467085	61%	68%	50%	7%	39%	50%	32%	7%
Rock Creek 01467084	46%	61%	36%	7%	54%	64%	39%	7%
Tacony Creek 01467083	57%	63%	51%	5%	43%	49%	37%	5%

3.4.2.1.2 TTF Water Quality Analysis

PWD collected water quality data from 2000 through 2004 for sampling locations in the non-tidal portion of the TTF Watershed. From 2007 through 2008 water quality data was monitored at two USGS stations in the Watershed. Tables 3-59 thru 3-64 provide a basic, statistical profile of the data from this recent water quality monitoring program. Tables 3-59 to 3-60 provide data from the discrete monitoring program and Tables 3-61 to 3-64 provide data from the continuous monitoring program.

Sample results were compared to relevant PADEP general water quality criteria to provide an indication of which parameters might need further investigation. Applicable relevant standards include water uses to support a potable water supply, recreation and fish consumption, human health, and aquatic life to support warm water fishes. The Target values are explained in the discussion of individual parameter. Parameters highlighted in yellow are considered potential problem parameters because 2-10% of the samples exceeded the target value. Parameters highlighted in red are considered problem parameters with more than 10% of the samples exceeded the target value. For a detailed analysis comparing historical water quality data with more recent data, including modified Tukey box plots, refer to Appendix A of the TTF CCR.

Wet weather is characterized using the 9 PWD operated rain gages in the TTF drainage district. Samples were considered wet when there was greater than 0.1 inches of rainfall recorded in at least one gage in the previous 48 hours. The monitoring methods including rain gage locations and PWD water quality monitoring locations are previously described in detail in Section 3.1.

Discussion of Possible Parameters of Concern
The following analysis of water quality data is focused on parameters that were listed in USEPA's 1995 Guidance for Long Term Control Plan and those considered as a "parameter of concern" (>10% samples exceeding target value) or "parameter of potential concern" (2-10% samples exceeding target value) in the TTF Watershed on Tables 3-59 through 3-64. The water quality criteria or target value is discussed in each parameter analysis.

pH
Water quality criteria established by PADEP regulate pH to a range of 6 to 9 in Pennsylvania's freshwater streams (Commonwealth of Pennsylvania, 2001). Direct effects of low pH on aquatic ecosystems have been demonstrated in streams affected by acid mine drainage (Butler et al. 1973) and by acid rain (Sutcliff and Carrick 1973). Aquatic biota may also be indirectly affected by pH due to its influences on other water quality parameters, such as ammonia (NH_3). As pH increases, a greater fraction of ammonia N is present as un-ionized NH_3 (gas). For example, NH_3 is approximately ten times as toxic at pH 8 as at pH 7. Extreme pH values may also affect solubility and bioavailability of metals (e.g., Cu, Al), which have individually regulated criteria established by PADEP.

Based on sampling by the Philadelphia Water Department (PWD) during 2000 – 2004, pH is not considered a parameter of concern in the TTF Watershed (<2% of samples exceeded standards). However, it is discussed in this section because it is listed in the USEPA's 1995 Guidance for Long Term Control Plan.

Continuous pH data show that pH fluctuations most often occur at highly productive sites with abundant periphytic algae (Figure 3-30). Pronounced diurnal fluctuations in pH were observed at site TF620, and occasionally at site TF280. These sites occasionally exceeded water quality criteria by exceeding pH 9.0; minimum pH standards were rarely exceeded. pH at shadier sites (i.e., TF500 and sites upstream of site TF680) was probably less strongly influenced by metabolic activity and fluctuations in pH appeared noticeably damped as a result. Algal densities and stream metabolism effects on stream pH are discussed further in section 5.4, Stream Metabolism of the TTF Creek Watershed Comprehensive Characterization Report.

Table 3-59 Dry Weather Water Quality Summary (2000-2004) - Parameters with Standards (TTF CCR Section 5.2, Table 5-4, Page 5-7)

Parameter	Standard	Target Value	Units	No. Obs	Percentiles						No. Exceed-ing	% Exceed-ing
					0	25	50	75	90	100		
Al	Acute Maximum	0.75	mg/L	149	0.00100	0.0200	0.0370	0.0610	0.0980	0.574	0	-
Al	Chronic Maximum	0.087	mg/L	149	0.00100	0.0200	0.0370	0.0610	0.0980	0.574	15	10.1
Alkalinity	Minimum	20	mg/L	130	21.0	65.0	72.0	77.0	81.0	89.0	0	-
BOD_{30}	No Standard	--	mg/L	98	2.00	3.41	4.15	5.24	8.10	100	--	--
BOD_5	No Standard	--	mg/L	130	0.300	2.00	2.00	2.00	2.19	20.4	--	--
Conductivity **	No Standard	--	µS/cm	142	227	411	508	605	697	1225	--	--
Diss Cd	Acute Maximum	* 0.0043	mg/L	83	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cd	Chronic Maximum	* 0.0022	mg/L	83	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cr	Acute Maximum	0.0016	mg/L	46	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cr	Chronic Maximum	0.01	mg/L	46	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cu	Acute Maximum	* 0.013	mg/L	74	0.00200	0.00400	0.00500	0.00500	0.00600	0.0220	0	-
Diss Cu	Chronic Maximum	* 0.009	mg/L	74	0.00200	0.00400	0.00500	0.00500	0.00600	0.0220	1	1.4
Diss Fe	Maximum	0.3	mg/L	110	0.0195	0.0500	0.0505	0.0770	0.133	0.587	3	2.7
Diss Pb	Acute Maximum	* 0.065	mg/L	65	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Pb	Chronic Maximum	* 0.0025	mg/L	65	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Zn	Acute Maximum	* 0.120	mg/L	73	0.00100	0.00700	0.0100	0.0170	0.0220	0.0260	2	2.7
Diss Zn	Chronic Maximum	* 0.120	mg/L	73	0.00100	0.00700	0.0100	0.0170	0.0220	0.0260	3	4.1
DO **	Instantaneous Minimum	4	mg/L	133	2.45	8.78	10.1	13.0	14.5	16.2	2	1.5

Parameter	Standard	Target Value	Units	No. Obs	Percentiles						No. Exceed-ing	% Exceed-ing
					0	25	50	75	90	100		
DO **	Minimum Average	5	mg/L	133	2.45	8.78	10.1	13.0	14.5	16.2	3	2.3
E. coli	No Standard	--	/100mL	144	10.0	145	290	500	1800	36000	--	--
F	Maximum	2	mg/L	130	0.0783	0.100	0.110	0.125	0.168	0.374	1	0.8
Fe	Maximum	1.5	mg/L	161	0.0294	0.0820	0.133	0.264	0.513	1.58	1	0.6
Fecal coliform	Swimming Season Dry weather Maximum	200	CFU/ 100mL	77	90.0	420	700	2600	5200	47000	71	92.0
Fecal coliform	Non-swimming Season Dry weather Maximum	2000	CFU/ 100mL	77	10.0	80.0	200	390	742	3200	3	3.9
Hardness	No Standard	--	mg/L	86	32.4	164	178	192	200	214	--	--
Mn	Maximum	1	mg/L	161	0.00490	0.0200	0.0380	0.0560	0.0840	0.167	0	-
NH_3	Maximum	(pH dependent)	mg/L	103	0.100	0.100	0.100	0.100	0.200	1.13	0	-
NO_2	No Standard	--	mg/L	133	0.0100	0.0500	0.0500	0.0500	0.0500	0.287	--	--
Nitrate+Nitrite	Maximum	10	mg/L	133	0.399	2.15	2.53	2.89	3.33	3.64	0	-
NO3	No Standard	--	mg/L	133	0.277	2.11	2.49	2.85	3.28	3.59	--	--
pH **	Maximum	9	--	132	6.85	7.35	7.52	7.64	7.76	8.03	0	-
pH **	Minimum	6	--	132	6.85	7.35	7.52	7.64	7.76	8.03	0	-
PO_4	No Standard	--	mg/L	133	0.0400	0.100	0.100	0.100	0.100	0.208	--	--
TDS	Maximum	750	mg/L	92	160	273	318	381	441	643	0	-
Temp **	Maximum	(varies)	°C	129	0.100	5.50	16.1	20.2	21.8	27.6	9	7.0
TKN	No Standard	--	mg/L	124	0.00	0.300	0.350	0.500	0.616	1.83	--	--
TN	No Standard	--	mg/L	124	0.869	2.21	2.50	2.91	3.08	3.98	--	--

Parameter	Standard	Target Value	Units	No. Obs	Percentiles						No. Exced-ing	% Exceed-ing
					0	25	50	75	90	100		
TOC	No Standard	--	mg/L	8	1.23	1.30	1.58	1.84	1.99	1.99	--	--
Total Chlorophyll	No Standard	--	mg/L	33	0.750	1.35	1.79	3.96	5.99	12.8	--	--
TP	No Standard	--	mg/L	138	0.00100	0.0500	0.0505	0.0860	0.163	0.691	--	--
TSS	No Standard	--	mg/L	104	1.00	1.00	1.00	2.00	3.00	24.0	--	--
Turbidity	Maximum	100	NTU	154	0.207	0.533	0.657	0.96	2.09	7.76	0	-

*Water quality standard requires hardness correction; value listed is water quality standard calculated at 100 mg/L
** These values are hand probe readings taken at the time of grab sampling.

Table 3-60 Wet Weather Water Quality Summary (2000-2004) - Parameters with Standards (TTF CCR sec 5.2 table 5.5, page 5-9)

Parameter	Standard	Target Value	Units	No. Obs	Percentiles						No. Exceed-ing	% Exceed-ing
					0	25	50	75	90	100		
Al	Maximum	0.75	mg/L	552	0.00167	0.0710	0.171	0.586	2.16	19.3	120	21.7
Alkalinity	Minimum	20	mg/L	562	14.0	43.0	56.5	70.0	77.0	91.0	7	1.2
BOD30	No Standard	--	mg/L	150	1.96	4.57	6.29	10.9	21.3	125	--	--
BOD5	No Standard	--	mg/L	567	1.95	2.00	3.45	6.62	14.4	147	--	--
Conductivity **	No Standard	--	µS/cm	243	76	249	381	516	658	1897	--	--
Diss Cd	Acute Maximum	* 0.0043	mg/L	194	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cr	Acute Maximum	0.0016	mg/L	76	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0	-
Diss Cu	Acute Maximum	* 0.013	mg/L	81	0.00200	0.00500	0.00700	0.00800	0.0110	0.0150	6	7.4
Diss Fe	Maximum	0.3	mg/L	199	0.0240	0.0640	0.0970	0.156	0.229	0.701	11	5.5
Diss Pb	Acute Maximum	* 0.065	mg/L	76	0.00100	0.00100	0.00100	0.00100	0.00100	0.00300	0	-
Diss Zn	Acute Maximum	* 0.120	mg/L	56	0.00300	0.00650	0.0110	0.0170	0.0260	0.263	1	1.8
DO**	Minimum Average	4	mg/L	232	1.99	8.06	9.21	11.3	13.1	17.3	6	2.6
DO**	Instantaneous Minimum	5	mg/L	232	1.99	8.06	9.21	11.3	13.1	17.3	4	1.7
E. coli	No Standard	--	/100mL	628	0.00	1500	4700	20000	69000	1820000	--	--
F	Maximum	2	mg/L	564	0.0675	0.0980	0.104	0.121	0.151	0.888	0	-
Fe	Maximum	1.5	mg/L	610	0.0403	0.224	0.419	1.27	4.20	50.0	139	22.8
Fecal coliform	Swimming Season Wet weather Maximum	200	CFU/100mL	532	10	1900	6250	30000	107900	1820000	516	97.0
Fecal coliform	Non-swimming Season	2000	CFU/100mL	141	20	390	4100	19000	32000	91000	94	67.0

Parameter	Standard	Target Value	Units	No. Obs	Percentiles						No. Exceed-ing	% Exceed-ing
					0	25	50	75	90	100		
	Wet weather Maximum											
Hardness	No Standard	--	mg/L	468	0.710	94.1	127	162	182	282	--	--
Mn	Maximum	1	mg/L	611	0.00760	0.0370	0.0710	0.139	0.283	3.05	13	2.1
NH3	Maximum	(pH dependent)	mg/L	196	0.100	0.100	0.113	0.205	0.398	2.98	0	-
NO2	No Standard	--	mg/L	604	0.0100	0.0500	0.0500	0.0500	0.0760	0.366	--	--
Nitrate+Nitrite	Maximum	10	mg/L	604	0.3000	1.10	1.72	2.22	2.51	3.32	0	-
NO3	No Standard	--	mg/L	604	0.249	1.02	2.19	1.65	2.47	3.27	--	--
pH**	Maximum	9	--	238	6.61	7.23	7.39	7.53	7.64	8.01	0	-
pH**	Minimum	6	--	238	6.61	7.23	7.39	7.53	7.64	8.01	0	-
PO4	No Standard	--	mg/L	603	0.0400	0.100	0.100	0.100	0.100	0.423	--	--
TDS	Maximum	750	mg/L	184	56	159	231	308	398	1054	2	1.1
Temp **	Maximum	(varies)	°C	238	0.500	8.00	13.9	19.8	21.7	24.7	6	2.5
TKN	No Standard	--	mg/L	524	0.154	0.500	0.752	1.21	2.97	15.9	--	--
TN	No Standard	--	mg/L	524	0.0560	2.09	2.57	3.06	4.27	17.1	--	--
TOC	No Standard	--	mg/L	5	1.35	1.51	1.54	1.82	1.83	1.83	--	--
Total Chlorophyll	No Standard	--	mg/L	76	0.660	1.44	2.37	4.93	17.1	83.3	--	--
TP	No Standard	--	mg/L	601	0.00100	0.0670	0.114	0.255	0.557	3.45	--	--
TSS	No Standard	--	mg/L	188	1.00	1.00	2.60	10.0	54.5	408	--	--
Turbidity	Maximum	100.0	NTU	579.0	0.2	1.8	4.8	12.0	35.1	379.0	13.0	2.2

*Water quality standard requires hardness correction; value listed is water quality standard calculated at 100 mg/L CaCO3 hardness
** These values are hand probe readings taken at the time of grab sampling.

Table 3-61 Continuous Water Quality Data (2001-2004) - Parameter with Standards (TTF CCR Section 5.2, Table 5.6, Page 5-11)

Parameter	Standard	Period	No. Obs.	No. Exceed	% Exceeding	% Meeting
Sonde DO avg	Daily Average Minimum	03/20/01 - 10/05/04	1540	29	1.9	98
Sonde DO min	Daily Minimum	03/20/01 - 10/05/04	1540	104	6.8	93
Sonde Temp	Maximum	03/20/01 - 10/05/04	177208	23350	13	87
Sonde pH mean	Maximum	03/20/01 - 10/05/04	2003	1	0.05	99.95
Sonde pH mean	Minimum	03/20/01 - 10/05/04	2003	1	0.05	99.95

Table 3-62 Continuous Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gage	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01467087	Instantaneous Minimum	4	mg/L	11664	2.00	3.10	4.50	6.60	8.90	11.2	15.8	2171	18.6
DO	01467086	Instantaneous Minimum	4	mg/L	24201	0.0500	5.90	7.10	8.90	10.9	12.7	18.23	460	1.9
DO	01467087	Daily Minimum	5	mg/L	287	2.31	3.33	4.37	6.19	8.47	10.7	14.5	95	33.3
DO	01467086	Daily Minimum	5	mg/L	517	0.597	6.46	7.48	8.85	10.9	12.0	15.0	10	1.9

Table 3-63 Continuous Wet Weather Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gage	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01467087	Instantaneous Minimum	4	mg/L	5314	2.00	2.90	3.90	5.70	8.40	11.0	15.8	1353	25.5
DO	01467086	Instantaneous Minimum	4	mg/L	12442	0.05	5.44	6.64	8.36	10.4	12.4	17.9	441	3.5
DO	01467087	Daily Minimum	5	mg/L	161	2.40	3.13	4.18	5.54	8.38	10.5	14.1	65	40.4
DO	01467086	Daily Minimum	5	mg/L	307	0.597	6.05	6.92	8.25	10.9	12.1	15.0	10	3.3

Table 3-64 Continuous Dry Weather Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gage	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01467087	Instantaneous Minimum	4	mg/L	6350	2.00	3.60	5.30	7.10	9.10	11.3	15.2	818	12.9
DO	01467086	Instantaneous Minimum	4	mg/L	11759	0.730	6.40	7.65	9.46	11.2	12.9	18.2	19	0.2
DO	01467087	Daily Minimum	5	mg/L	126	2.31	3.52	5.04	7.00	8.47	11.0	14.5	30	23.8
DO	01467086	Daily Minimum	5	mg/L	210	6.31	7.42	8.19	9.34	10.9	11.9	13.4	0	0

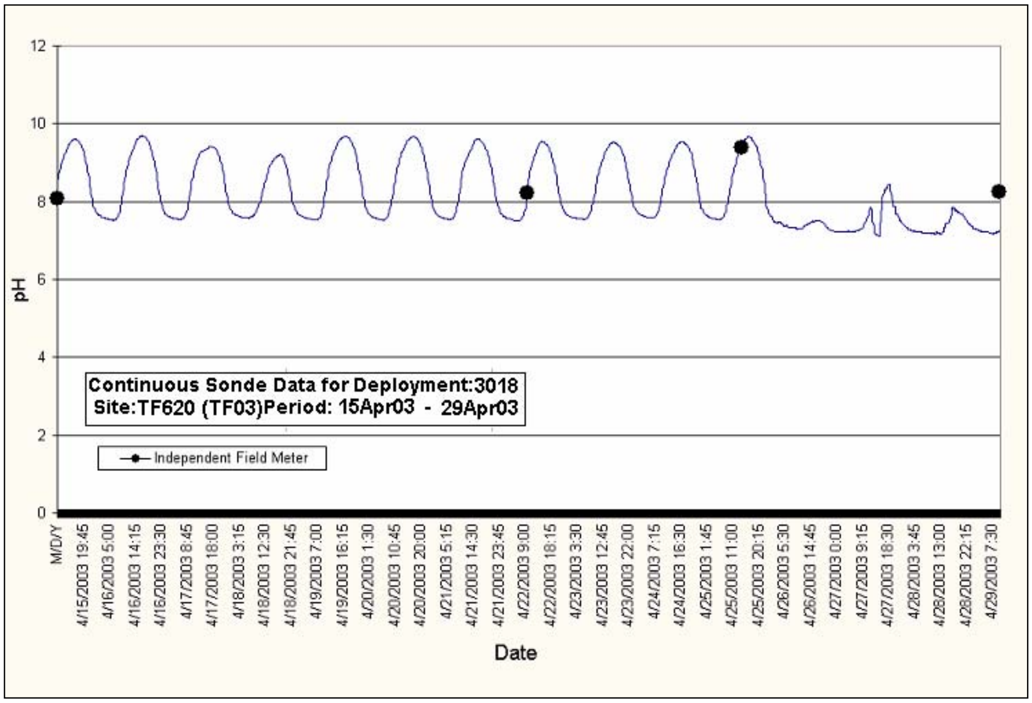


Figure 3-30 pH- From CCR (TTF CCR Section 5.3.3, Figure 5-3, Page 5-15)

Biochemical Oxygen Demand (BOD)

As warm stream water has a limited capacity for DO, excess BOD may preclude warm water streams from meeting WQ criteria despite re-aeration due to diffusion and algal production of DO.

Evaluation of BOD_5 results in a watershed where most sources exhibit spatial and temporal variability is difficult. The BOD_5 test provides little information when samples are dilute (Method Reporting Limit= 2mg/L), which is often the case in dry weather samples from streams lacking point source discharges or other sources of organic enrichment (87% of dry weather samples and 28% of wet weather samples had BOD_5 concentration below reporting limits). Analysts must also determine an appropriate series of dilution ratios without *a priori* knowledge of the sample's potential to deplete oxygen. For this reason, 4% of samples were reported as minimum values (*i.e.*, actual values were known to be greater than the value reported but the dilution sequence did not allow computation of an actual value); all samples in which BOD_5 concentration were reported as minimum values were collected in wet weather.

As BOD_5 concentration data were affected by a large number of imprecise values, nonparametric statistics were used in comparing between sites and evaluating wet weather effects. In the latter analysis, data from all sites were combined, non-detects were included as half the method reporting limit (MRL), and minimum values were included as if they were actual values. BOD_5 concentration was found to be significantly greater in wet weather than in dry weather (Mann-Whitney U test, $Z_{2,689} = -7.27$, $p<0.001$), and there was a significant effect of site in wet weather (Kruskal-Wallis ANOVA, $H_{8,565}= 73.32$, $p<0.001$, which is likely due to frequent CSO discharge at site TF280 (mean wet weather BOD_5 11.79±18.22). Though the sampling effort was not equal across sites, mean wet weather BOD_5 data suggest CSO discharge at site TF620/680 (5.98±6.55mg/L) and occasional SSO discharge or other sources of organic enrichment at sites TFM006 (7.21±7.84mg/L), TF975 (4.95±5.74mg/L) and TF1120 (4.13±3.89mg/L) (Figure 3-31).

Table 3-65 Sonde Parameters of Concern in the TTF Watershed by site (2001-2004) (TTF CCR Section 5.3.1, Table 5.7, Page 5-12)

Site	Parameter	Standard	Ref	Dry Weather			Wet Weather			Comments
				No. Obs.	No. Exceed	% Exceed	No. Obs.	No. Exceed	% Exceed	
TF280	Sonde DO	5mg/L daily avg. 4mg/L min		17492	1243	7.1	16617	1798	11	Potential Concern
	Sonde Turbidity		8.05 NTU	5192	1045	20	7074	3563	50	Concern
TF500	Sonde DO	5mg/L daily avg. 4mg/L min		5125	0	0	3378	261	7.7	Potential Concern
	Sonde Turbidity		8.05 NTU	2579	10	0.39	1647	396	24	Concern
TF620	Sonde Turbidity		8.05 NTU	5298	244	4.6	7083	1727	24	Concern
	Sonde pH	6-9 inclusive		19380	598	3.1	20510	155	0.76	Potential Concern
TF760	Sonde Turbidity		8.05 NTU	3623	732	20	2710	1411	52	Concern
TF975	Sonde Turbidity		8.05 NTU	9328	360	3.9	9333	2972	32	Concern
TF1120	Sonde Turbidity		8.05 NTU	8972	561	6.3	8862	2722	31	Concern
TFJ110	Sonde Turbidity		8.05 NTU	550	0	0	894	251	28	Concern
TFM006	Sonde Turbidity		8.05 NTU	2412	40	1.7	3191	863	27	Concern
7th and Cheltenham	Sonde Turbidity		8.05 NTU	963	1	0.10	182	37	20	Concern

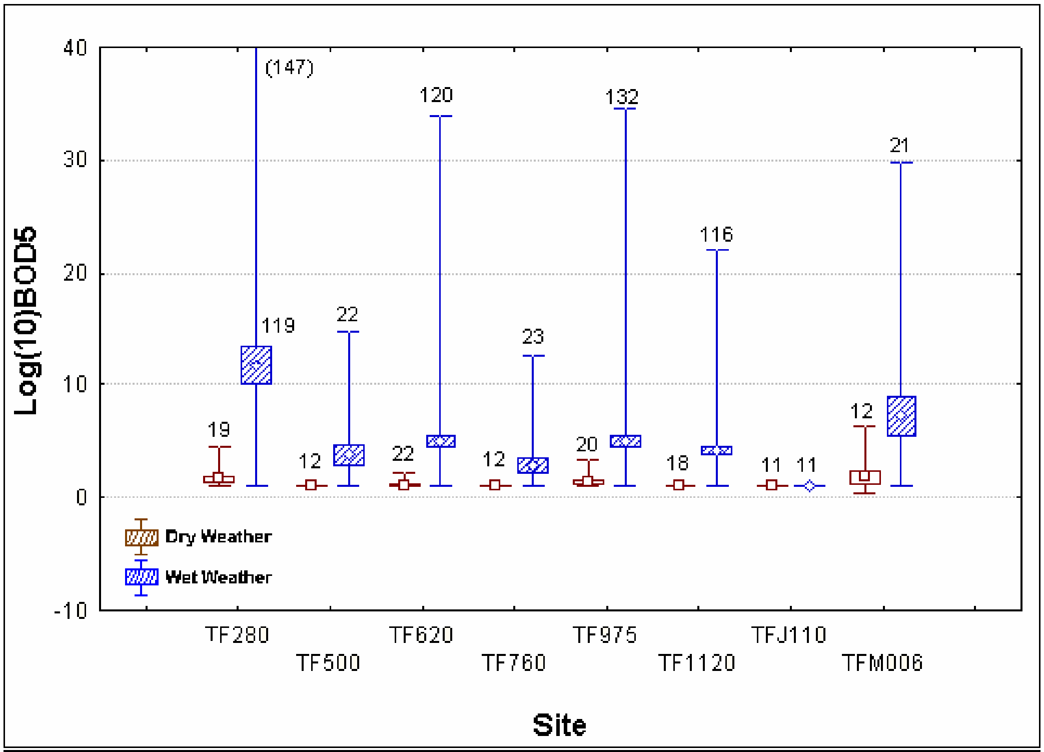


Figure 3-31 Five Day BOD of Samples Collected From Eight Sites in TTF Watershed in Dry and Wet Weather (TTF CCR Section 5.3.2, Figure 5.2, Page 5-14)

Dissolved Oxygen

The PADEP has established criteria for both instantaneous minimum and minimum daily average DO concentration. Criteria are intended to be protective of the types of aquatic biota inhabiting a particular lake, stream, river, or segment thereof. TTF Watershed is considered a Warm Water Fishery (WWF) that cannot support salmonid fish year-round. Furthermore, the stream is not considered appropriate for a put-and-take fishery (i.e., stocking trout to provide recreational opportunities). PADEP water quality criteria, therefore, require that minimum DO concentration in a WWF not fall below 4 mg/L and that daily averages remain at or above 5 mg/L.

Based on sampling by the Philadelphia Water Department during 2000-2004, DO is considered to be a parameter of potential concern because water quality criteria were exceeded (Tables 3-61 through 3-63). Based on these results, dissolved oxygen is a parameter of concern at USGS station 01467087 (Castor Avenue) and a potential concern at USGS station 01467086 (Adams Avenue).

When interpreting continuous DO data, one must keep in mind that in situ DO probes can only measure dissolved oxygen concentration of water in direct contact with the probe membrane. Furthermore, to obtain accurate measurements, DO probes should be exposed to flowing water or probes themselves must be in motion. Conditions found in urban areas (e.g., severe flows, infrastructure effects, debris accumulation, vandalism, etc.) complicated installation, and it was not always possible to situate instruments in ideal locations. Local microclimate conditions surrounding probes and biological growth on probes themselves probably contributed to errors in measurement. Often Sondes situated in subtly different areas of the same stream site to exhibit marked differences in DO concentration due to flow, shading, and local microclimate differences.

DO concentrations in the TTF Watershed were found to be highly variable, both seasonally and spatially, but in general, DO was controlled by temperature, natural community metabolism and inputs of combined sewage and untreated stormwater. As cold water has a much higher capacity for DO than warm water, DO violations were generally restricted to the warmer months. This appears to occur at site TF280, but DO suppression also was observed at site TF500 (Table 3-65). Pronounced diurnal fluctuations in DO concentration were observed at sites TF280, TF1120, and TF620/680; most other sites showed only moderate fluctuation due to biological activity. Effects of stream metabolism on DO concentration are addressed in more detail in the TTF Comprehensive Characterization Report.

Continuous water quality data indicated that certain sites in the TTF experience diurnal fluctuations in DO and pH that can be reduced in magnitude following storm events (Figure 3-32), generally within 3 miles of the confluence with the Delaware River. As TTF Watershed was not found to have large dry weather concentrations of chlorophyll in the water column that would be indicative of suspended phytoplankton, it was hypothesized that these pronounced fluctuations were due largely to periphytic algae.

Supporting this conclusion are observed reductions in the magnitude of fluctuations during and immediately after storms and increases in water column chlorophyll-a during storm events observed at some sites. The latter effect is difficult to characterize, as the degree to which chlorophyll-a increased in wet weather is believed to have been affected by algal density, predominant growth form, and stream velocity.

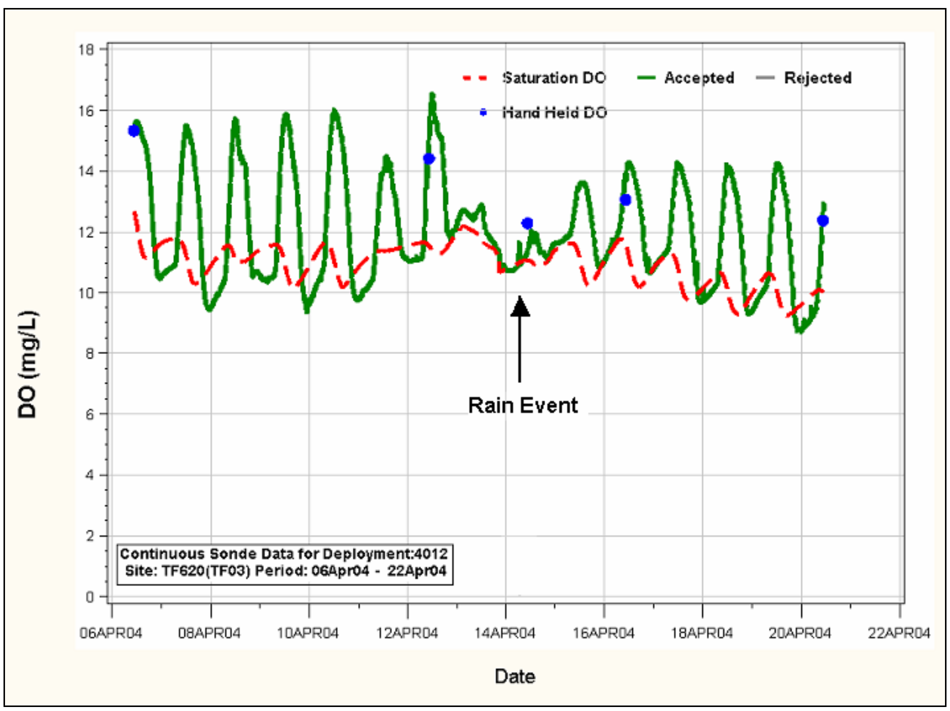


Figure 3-32 Continuous Plot of Water Column Dissolved Oxygen Concentration at Site TF620, April 2004 (TTF CCR Section 5.4, Figure 5.16, Page 5-41)

Relation of Algal Activity to Dissolved Oxygen Concentration

DO concentrations often strongly reflect autotrophic community metabolism and in turn, affect the heterotrophic community structure as a limiting factor for numerous organisms. Stream sites that support abundant algal growth often exhibit dramatic diurnal fluctuations in dissolved oxygen concentration. Algal photosynthesis infuses oxygen during the day (often to the point of supersaturation), while algae and heterotrophic organisms remove oxygen throughout the night. Diurnal fluctuations are more pronounced in the summer months than the autumn and winter months as colder water has a greater capacity for DO and biological metabolic activity is generally regulated by temperature.

Mainstem sites on Tacony and Frankford Creeks experience pronounced diurnal fluctuations in dissolved oxygen (DO) concentrations. When biological activity is high, DO concentrations may fall below the state-regulated limit of 4 mg/L., generally in the stretch of river within 6 miles of the confluence with the Delaware River and common within the lower three miles of the confluence (i.e., downstream of site TF500). Dry weather dissolved oxygen suppression tends to occur at night and is likely caused by respiration of algae and microbial decomposition of algae and other organic constituents in the absence of additional photosynthetic oxygen production.

Following storm events, amplitude of daily DO fluctuations was reduced. DO concentrations may decrease sharply upon increase in stage, but it was difficult to determine how much of these instantaneous decreases were due to DO probe membrane fouling (Figure 3-33). It was hypothesized that anoxic effluent from storm sewers contributes to a sudden reduction in water column DO, but modeling of CSO discharge DO concentrations indicated that the discharge alone could not account for the observed DO reductions. BOD and SOD may have increased due to organic matter present in sewage. Mean BOD_5 was substantially higher at TF280 than at TF620 (Figure 3-33), although numerous samples were below reporting limits. Additionally, the scouring effect of high flows reduces algal biomass, and the oxygen produced through photosynthesis and consumed through respiration is reduced. As algal biomass accrues following scouring events, peak DO concentrations and range of diurnal fluctuations return to pre-flow conditions (Figure 3-34).

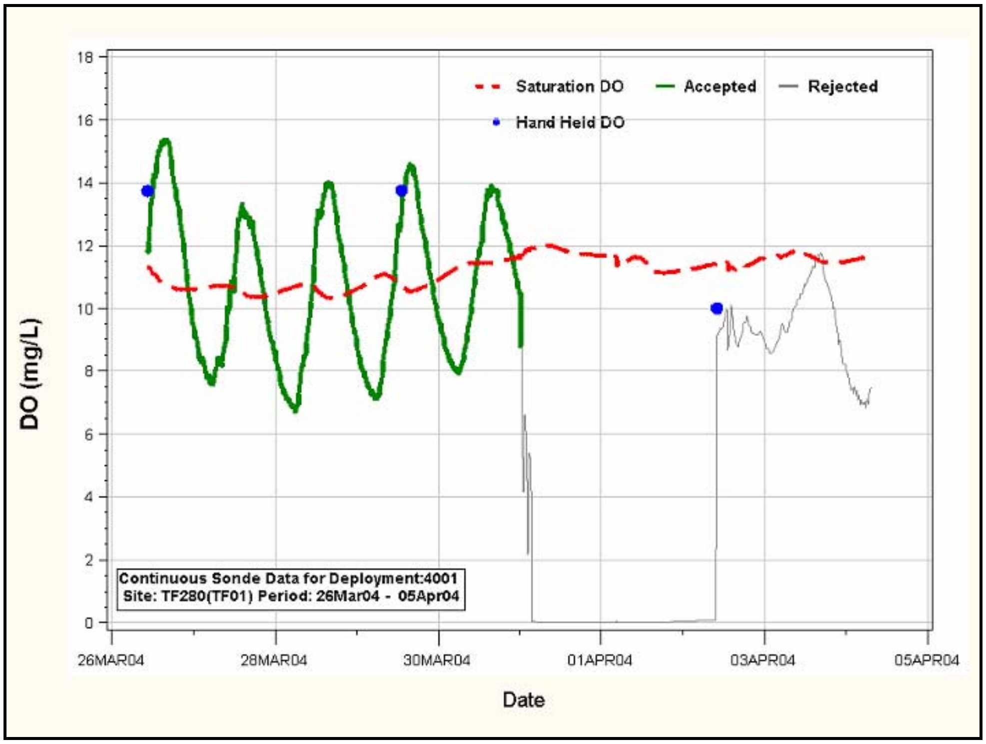


Figure 3-33 Continuous plot of Dissolved Oxygen Concentration at Site TF280 Showing DO Probe Failure (TTF CCR Section 5.4.1, Figure 5.19, Page 5-44)

Algal biomass at site TF280 was lower than at site TF620 further upstream. However, TF620 exhibits a higher mean DO and less pronounced diurnal fluctuations suggesting that the relationship between biomass and primary production is not straightforward. It is hypothesized that in dry weather the algae in combination with the residual effects of anoxic effluent, BOD and SOD accounts for the greater fluctuations in DO at site TF280. Further confounding the interpretation of this data is the fact that the sonde at site TF280 is located within a stagnant pool, the only location offering enough depth to allow the instrument to remain submerged at baseflow. Conversely, sonde locations at site TF620/680 are exposed to more streamflow, which replenishes the water surrounding the DO probe more frequently and helps keep the DO membrane itself from accumulating algae and debris. Microclimate conditions surrounding the DO probe membrane probably partially explain the difference in DO fluctuations observed between these two sites.

Future Investigation of Dissolved Oxygen Conditions in the Tacony and Frankford Creeks

The nature, causes, severity and opportunities for control of the dissolved oxygen conditions in the lower Tacony Creek and the Frankford Creek are not well understood at this juncture. Efforts to better understand the dissolved oxygen situation in Philadelphia's streams continue including, in addition to ongoing continuous long-term monitoring, process studies conducted for PWD by the USGS. The USGS is conducting a study to calculate the rate at which the atmosphere replenishes the creek with oxygen. The collection of that data, combined with local measurements of sediment oxygen demand and biochemical oxygen demand, are intended to better quantify the factors that contribute to dissolved oxygen conditions in the stream.

Estimates will be refined and analyses performed on the loading of water quality constituents related to the dissolved oxygen dynamics, both from the City as well as from dischargers to the Tookany

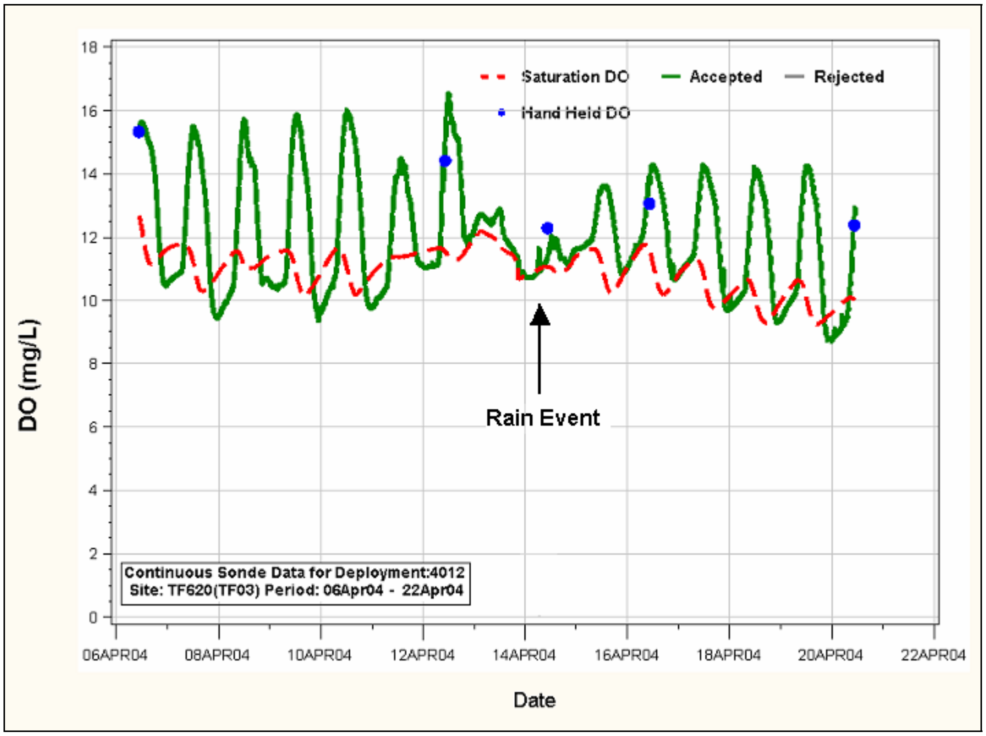


Figure 3-34 Continuous plot of Dissolved Oxygen Concentration at site TF280 returning to pre-flow conditions

Creek and other upstream tributaries. If a relationship between loadings and the dissolved oxygen conditions is suspected, informational total maximum daily loads will be investigated for the watershed. Progress and results of the monitoring and process studies, the revised loading work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Conductivity and Total Dissolved Solids

PADEP's established maximum criterion for an instantaneous maximum concentration of Total Dissolved Solids (TDS) is 750 mg/L. The criterion is intended for waterways that are used as potable water supplies (PWS).

Conductivity and TDS are measures of the concentration of ions and solids dissolved in water. TDS is an empirical laboratory procedure in which a water sample is filtered and dried to yield the mass of dissolved solids, while conductivity is a measure of the ability of water to conduct electricity over a given distance, expressed as microsiemens (µS)/cm (corrected to 25ºC) (Greenberg et al. 1993). With sufficient data, a good relationship between conductivity and TDS can be established. Waters containing large relative proportions of organic ions (e.g., bog or wetland samples containing organic acids) generally have less conductivity for equivalent TDS concentration than waters containing primarily inorganic ions.

Dissolved ion content is perhaps most useful in determining the start of wet weather events at ungaged water quality monitoring stations. Conductivity probes are generally simple in design, robust, and very accurate. They are extremely sensitive to changes in flow, as stormwater (diluent) usually contains smaller concentrations of dissolved ions than stream baseflow. A notable exception to this rule concerns the application of ice melt chemicals to roads (primarily Sodium, Magnesium, and Potassium salts). When present in runoff or snowmelt, these substances can cause large increases in ionic strength of stream water. Though some formulations may increase levels of Chloride, PADEP WQ criteria for Chloride (maximum 250mg/L) are intended to protect water supplies, and aquatic life effects have not been reliably demonstrated at moderate levels typically experienced in streams.

Conductivity ranged from 227 to 1225 µS/cm during dry weather sampling and 76 to 1897 µS/cm. TDS samples ranged from 160 to 643 mg/L in dry weather and 56 to 1054 mg/L during wet weather. Two wet weather samples exceeded the TDS target value of 750 mg/L, but neither Conductivity or TDS are considered parameters of concern or potential concern. It is discussed in this section because it is listed in the USEPA's 1995 Guidance for Long Term Control Plan.

Total Suspended Solids

There is no established state standard for Total Suspended Solids (TSS) but it is discussed in this section because it is listed in the USEPA's 1995 Guidance for Long Term Control Plan. Sediment transport in small streams is dynamic and difficult to quantify. Numerous factors can affect a stream's ability to transport sediment, but generally sediment transport is related to streamflow and sediment particle size. Stable streams are generally capable of maintaining equilibrium between sediment supply and transport, while unstable streams may be scoured of smaller substrate particles or accumulate fine sediments. The latter effect is particularly damaging to aquatic habitats. PADEP has identified the cause of impairment in TTF Watershed to be a combination of "Water/Flow Variability", "Flow Alterations", and "Other Habitat Alterations". "Siltation" was not listed as a cause of impairment, but the effects of sediment deposition, where and when they occur, are probably addressed by "Other Habitat Alterations".

Water sampling techniques that are adequate to characterize most water quality parameters (e.g., grab samples, automated sampling) are not generally appropriate for evaluating sediment transport in fluvial systems (Edwards and Glysson 1988); errors related to sampling technique should preclude computation of sediment transport during severe storm events that mobilize large streambed particles. TSS concentration (Log transformed) was significantly greater in wet weather than in dry weather ($F_{2,286} = 8.72$, $p<0.001$).

Maximum daily TSS concentration (log transformed) was found to be significantly positively correlated to average daily streamflow at site TF280 ($r(33)= 0.85$, $p<0.001$, (Figure 3-35) and instantaneous TSS concentration (log transformed) was positively significantly correlated with instantaneous discharge at all gaged sites in the PWD historical water quality database (unpublished data). These comparisons of TSS concentration to stream discharge supported the use of TSS concentration as a surrogate measure of the intensity of streamflow and the presence of eroded soil and streambed particles for the purpose of comparing concentrations of certain water quality parameters (i.e., Phosphorus, Nitrate, toxic metals) with intensity of streamflow and soil erosion at stations where USGS gages have been eliminated.

Turbidity

Turbidity is a measure of the light scattering properties of particles suspended in water. In streams, turbidity can come from many sources, but the chief cause of increased turbidity is suspended sediment. While a correlation between turbidity and TSS certainly exists, the relationship between turbidity and TSS may differ between water bodies and even among different flow stages/seasons in the same waterbody due to sediment characteristics. Consistently turbid waters often show impairment in aquatic communities. Light penetration is reduced, which may result in decreased

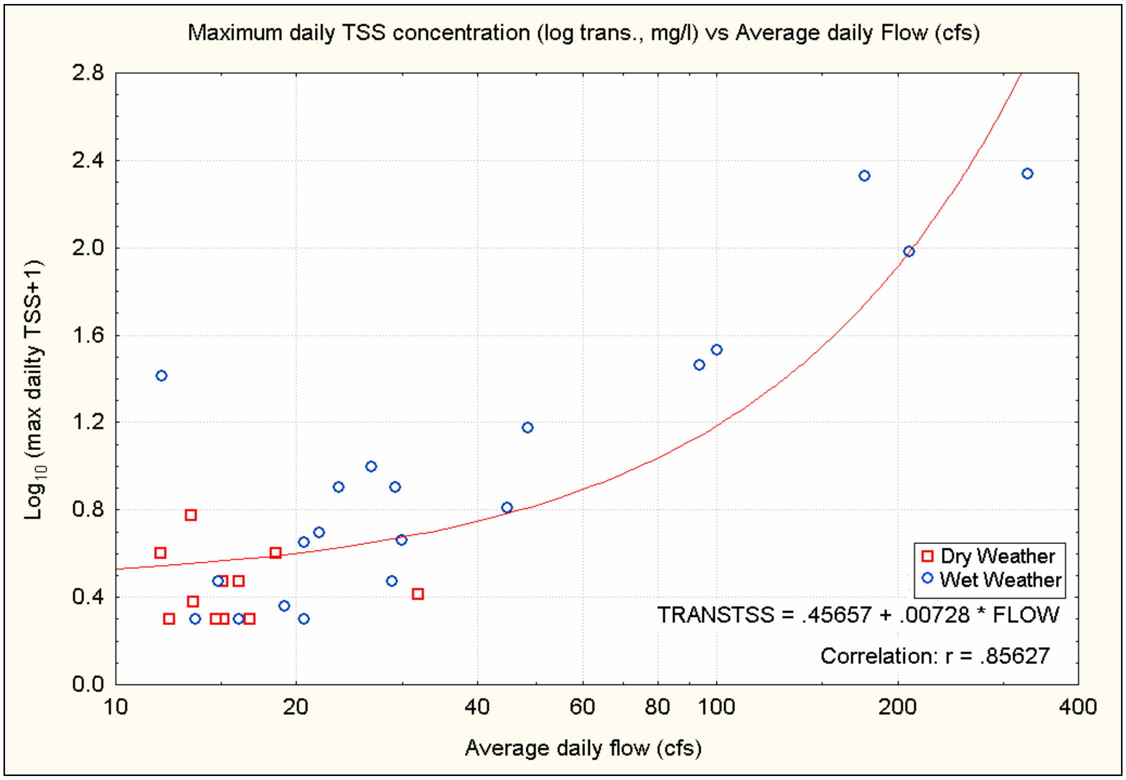


Figure 3-35 Maximum Daily Total Suspended Solids Concentration and Corresponding Average Daily Flow at site TF280 (TTF CCR section 5.3.6.1 figure 5.6 page 5-22)

algal production; suspended particles can clog gills and feeding apparatus of fish, benthic invertebrates, and microorganisms. Feeding efficiency of visual predators may also be reduced.

PADEP WQ criterion for turbidity is a maximum of 100 NTU. Discharge of substances that produce turbidity are also specifically prohibited and, General Water Quality Criteria (Title 25, Section 93.6) specifically prohibit substances attributable to any point or non-point source in concentrations inimical or harmful to aquatic life. Turbidity is considered a parameter of potential concern since it exceeded the 100 NTU standard in 2.2% of wet weather samples.

Nutrients

Phosphorus

Phosphorus (P) concentrations are often correlated with algal density and are used as a primary indicator of cultural eutrophication of water bodies. N:P ratio analysis strongly suggests that P is the limiting macronutrient in the TTF Watershed. Readily available dissolved orthophosphate (PO_4) was only detected in 5 of 129 total samples collected in dry weather, and in 55 of 584 wet weather samples, so nutrient analyses considered only total P concentrations (TP). TP includes some smaller fraction of P that is considered to be bioavailable, or readily usable by stream producers. Bioavailable P (BAP) includes soluble reactive P (SRP) and, depending on other factors, some portion of particulate inorganic P. Furthermore, some producer taxa can produce endogenous alkaline phosphatases and obtain P that is not normally available.

The TTF Watershed has not been listed by PADEP as impaired due to nutrients, and no WQ criteria exist for TP or PO_4. For the TTFIWMP, TP concentrations were evaluated using a frequency distribution approach. Data were compiled for reference reaches in USEPA Ecoregion

IX, subregion 64 (75th percentile of observed data=140 µg/L). This reference value is considerably greater than the mesotrophic/eutrophic boundary for TP suggested by Dodds et al. (1998) (i.e., 75 µg/L). Dry weather TP concentrations were usually below both reference values.

Total P concentration was below reporting limits in 58 of 135 samples collected in dry weather, but in only 87 of 555 wet weather samples. Elevated dry weather TP concentration was observed at sites TF280 and TFM006, possibly due to dry weather sewage inputs. Log-transformed Mean TP concentration was significantly greater in wet weather than in dry weather ($F_{2,183}=1.55$, $p=0.008$), so stream producers in the TTF Watershed are generally exposed to somewhat constant TP concentrations punctuated with episodic inputs of greater TP concentration due to runoff and erosion. Point sources of P include CSO and SSO discharges, contributing large amounts of phosphorus where and when they occur.

P readily adsorbs to soil and sediment particles and is generally less mobile in soils than nitrogen compounds. Potential non-point sources of P are decomposing organic matter in or near the stream, runoff from industrial parks, golf courses, agriculture and residential areas, and inorganic P adsorbed to soil particles that are washed into the stream by erosive forces. In fact, soil erosion may be the greatest source of P in separate-sewered portions of TTF. TP concentration was significantly positively correlated with TSS concentration, (Log transformed, $r(183)=0.60$, $p<0.001$) (Figure 3-36). Wet weather phosphorus inputs, however, are coupled with physical disturbances (e.g., hydraulic shear stress, other abrasive forces, reduced light availability). These stressors respond to changes in flow in a non-linear fashion. Some taxa have the ability to store intercellular reserves of inorganic nutrients ("luxury consumption") when concentrations exceed immediate demands. It is thus very difficult to estimate P concentrations available to stream producers and draw conclusions about stream trophic status.

Ammonia

Ammonia, present in surface waters as un-ionized ammonia gas (NH_3), or as ammonium ion (NH_4^+), is produced by deamination of organic nitrogen-containing compounds, such as proteins, and also by hydrolysis of urea. In the presence of oxygen, NH_3 is converted to nitrate (NO3) by a pair of bacteria-mediated reactions, together known as the process of nitrification. Nitrification occurs quickly in oxygenated waters with sufficient densities of nitrifying bacteria, effectively reducing NH_3, although at the expense of increased NO3 concentration. PADEP WQ criteria for NH_3 reflect the relationship between stream pH, temperature, and ammonia speciation/ dissociation. Ammonia toxicity is inversely related to hydrogen ion [H^+] concentration; an increase in pH from 7 to 8 increases NH_3 toxicity by approximately an order of magnitude. At pH 9.5 and above, even background concentrations of NH_3 may be toxic.

Historic data comparisons show that, in the watershed overall, NH_3 concentrations have decreased significantly compared to samples collected from 1970 to 1980 (F2,1001=6.18, $p<0.001$). Dry weather NH_3 concentrations, in particular, have improved dramatically. For example, in samples collected from 1970 to 1980, there was no significant difference in NH_3 concentrations between dry and wet weather samples at site TF280 (F2,99=1.19, $p=0.77$), suggesting that sewage inputs were common at this site regardless of weather.

Though no dry weather samples collected from the TTF Watershed from 2000-2004 contained NH_3 concentration in excess of 0.8 mg/L and there were no violations of WQ criteria, 20 of 87 samples were above reporting limits, suggesting occasional inputs of untreated sewage, anoxic conditions, or the presence of other decomposing organic material. Site TF280 was responsible for most of these

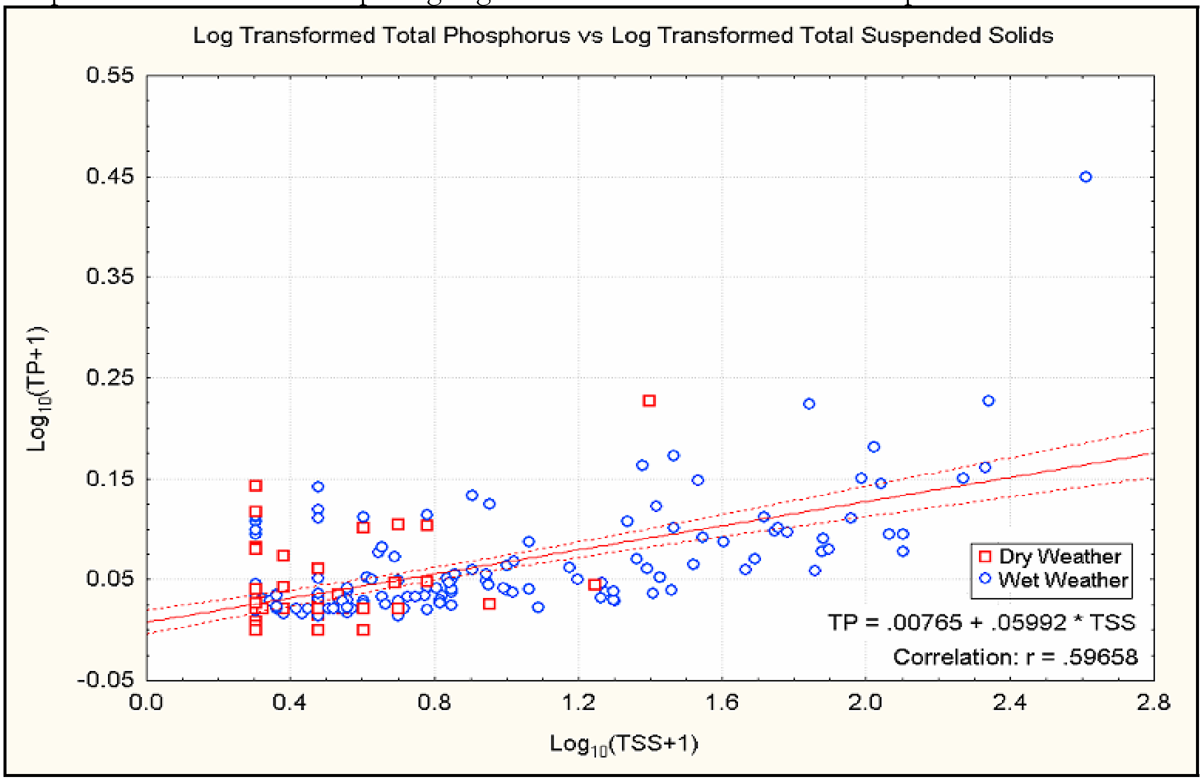


Figure 3-36 Scatterplot of Paired Total Phosphorus and Total Suspended Solids Concentrations of Samples Collected from 8 Sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.3.8.1, Figure 5.13, Page 5-36)

observations, and is believed to be the site most seriously affected by dry weather sewage inputs and anoxic conditions. Target A of the TTFIWMP is directed at further reducing dry weather sewage inputs through source track-down and infrastructure repair/improvements.

NH_3 concentration of sites within TTF Watershed (log-transformed, all sites combined) was significantly higher in wet weather than in dry weather ($F2,710=2.30$, $p=.0047$). NH_3 concentration was above detection limits in 211 of 436 total wet weather samples, though all samples with concentrations greater than 0.8mg/L were collected at site TF280.

There were no violations of WQ criteria due to the fact that pH remained near neutrality at the time samples were taken. Algal activity was observed to cause pH fluctuations, particularly at site TF620 in spring 2003. When severe, these fluctuations in pH caused NH3 WQ criteria to decrease to within the range of values observed at other times. The NH3 sampling regime was not ideal for identifying possible violations of WQ standards as discrete interval grab samples were collected in the morning, while daily pH maxima were typically reached in afternoon/early evening hours. NH3 was not considered a problem parameter since the standard was never exceeded.

<u>Nitrite</u>

As an intermediate product in the oxidation of organic matter and ammonia to nitrate, nitrite (NO_2) is seldom found in unimpaired natural waters in great concentrations provided that oxygen and nitrifying bacteria are present. For this reason, NO_2 may indicate sewage leaks from illicit connections, defective laterals, or storm sewer overflows and/or anoxic conditions in natural waters.

NO_2 was detected in only 14 dry weather samples collected from the TTF Watershed; most of these observations were at site TF280 and most were collected prior to 2004. Comparison to data collected from 1970-1980 showed that the incidence of Nitrite detections in dry weather has been drastically reduced, suggesting fewer dry weather sources of sewage and/or reduced severity of anoxic conditions.

NO_2 concentrations were greater than reporting limits more frequently in wet weather (129 of 585 total samples) than in dry weather, but contribution of NO2 to total inorganic nitrogen was usually small and concentrations of many samples were estimated to be half the detection limit for the purpose of evaluating nutrient ratios. Large numbers of samples below detection limits prevented the use of parametric statistical methods to evaluate weather effects. Mann-Whitney U test analysis showed significantly greater NO_2 concentration (log transformed, samples below MRL included as half the MRL) in wet weather than in dry weather (Z2,717 = -2.75, p<0.005).

<u>Nitrate</u>
Concentrations of nitrate (NO3) are often greatest in watersheds impacted by (secondary) treated sewage and agricultural runoff, but elevated NO3 concentrations in surface waters may also be attributed to runoff from residential and industrial land uses, atmospheric deposition and precipitation (e.g., HNO3 in acid rain) and decomposing organic material of natural or anthropogenic origin. Nitrate is a less toxic inorganic form of N than ammonia and serves as an essential nutrient for photosynthetic autotrophs. Availability of inorganic N can be a growth-limiting factor for producers, though usually only in oligotrophic (nutrient-poor) lakes and streams or acidic bogs.

PADEP has established a limit of 10 mg/L for oxidized inorganic N species (NO3 + NO_2) (Commonwealth of Pennsylvania, 2001). This limit is based on public water supply use and intended to prevent methemoglobinemia, or "blue baby syndrome", and eutrophication of natural water bodies. Waters of the Commonwealth that have been determined to be impaired due to excess nutrients have Waste Load Allocations (WLA) determined through the Total Maximum Daily Load (TMDL) process; TTF Watershed has not been listed as impaired due to nutrient enrichment. For the TTFIWMP, Inorganic N concentrations were evaluated using a frequency distribution approach. Data were compiled for reference reaches in USEPA Ecoregion IX, subregion 64 (75th percentile of observed data=2.9mg/L). This reference value is considerably greater than the mesotrophic/eutrophic boundary for Total N suggested by Dodds et al. (1998) (i.e., 1.5 mg/L TN). However, based on PADEP standards, Inorganic N is not considered to be a problem parameter since the standard was never exceeded.

Dry weather NO_3 concentrations in the TTF Watershed are almost always found between the two aforementioned reference points (i.e., between 1.5 mg/L and 2.9 mg/L). NO_3 concentrations typically decreased in wet weather. Mean NO_3 concentration (log transformed, all sites combined) was significantly lower in wet weather than in dry weather (F^2,180=1.70, p<0.001), and NO_3 was significantly negatively correlated with TSS concentration (Log transformed r(182)= -0.55, p<0.001, Figure 3-37). This relationship demonstrates dilution by stormwater and is the reverse of the phenomenon observed with P concentration. However, other forms of N (i.e., TKN, NH_3, NO_2) tended to increase in concentration in wet weather. Nutrient dynamics and relationships to autotrophic community production are addressed in greater detail in section 5.4, Stream Metabolism of the TTF Watershed Comprehensive Characterization Report.

Unusual dry weather samples were collected from site TF280 on July 7, 2004 and TFM006 on August 30, 2004 in which NO3 concentration seemed diluted compared to most other dry weather baseflow samples. In the first case, accompanying data showed increases in TKN and NO_2, as would be expected under anoxic conditions, but DO suppression could not be verified due to probe failure. In the second case, TKN was slightly elevated for a dry weather sample, but NO_2 was below reporting limits and no DO data were available.

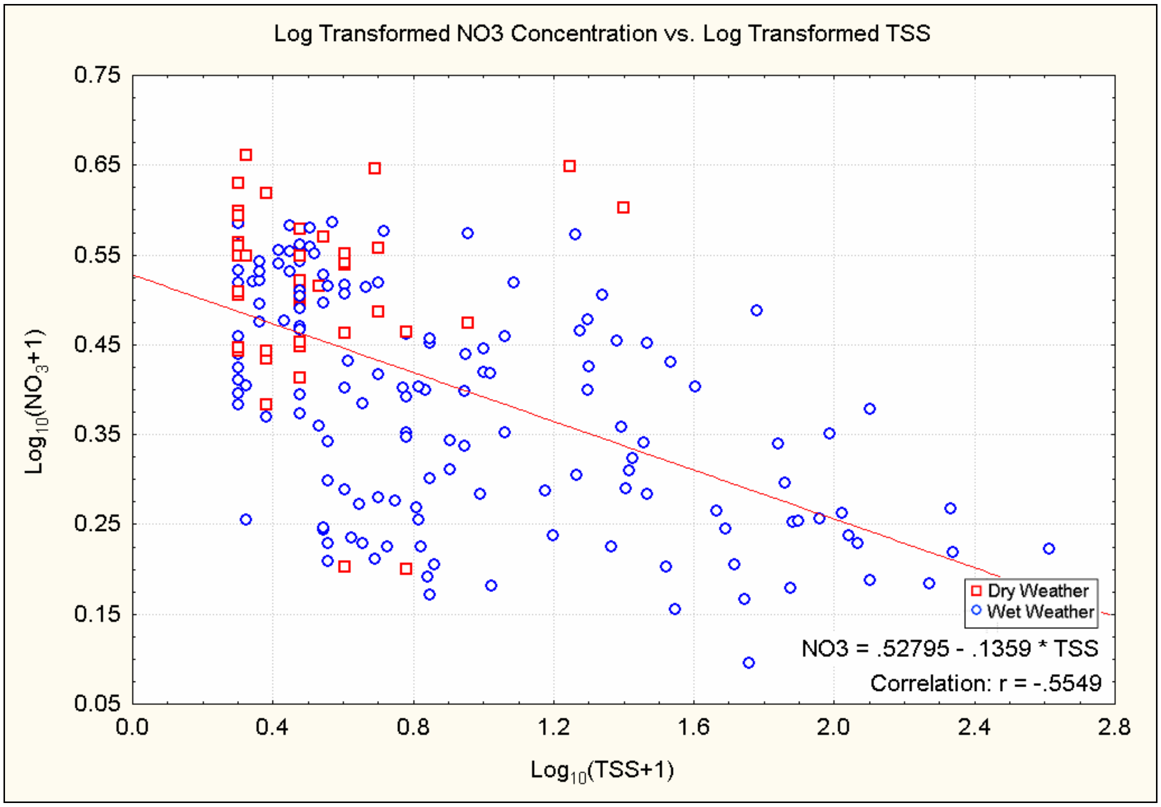


Figure 3-37 Scatterplot of Paired Nitrate and Total Suspended Solids Concentrations of Samples Collected from Eight Sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.3.8.4, Figure 5.14, Page 5-39)

Total Kjeldahl Nitrogen

The Total Kjeldahl Nitrogen (TKN) test provides an estimate of the concentration of organically-bound N, but actually measures all N present in the tri-negative oxidation state. Ammonia must be subtracted from TKN values to give the organically bound fraction. TKN analysis also does not account for several other N compounds (e.g., azides, nitriles, hydrazone); these compounds are rarely present in significant concentrations in surface waters. Sampling results suggest the most important source of organic N is sewage inputs from CSO and SSO discharge. Log-transformed Organic N concentration was significantly greater in wet weather than in dry weather ($F_{2,654}=14.04$, $p<0.001$). Organic N was also significantly positively correlated with fecal coliform bacteria concentration, $r(647)=0.70$, $p<0.001$ (Figure 3-38). As most organic N loadings to the watershed occur in wet weather, this N is probably transported out of the system and into the Delaware estuary before exerting nitrification DO demand or becoming available for uptake by algae.

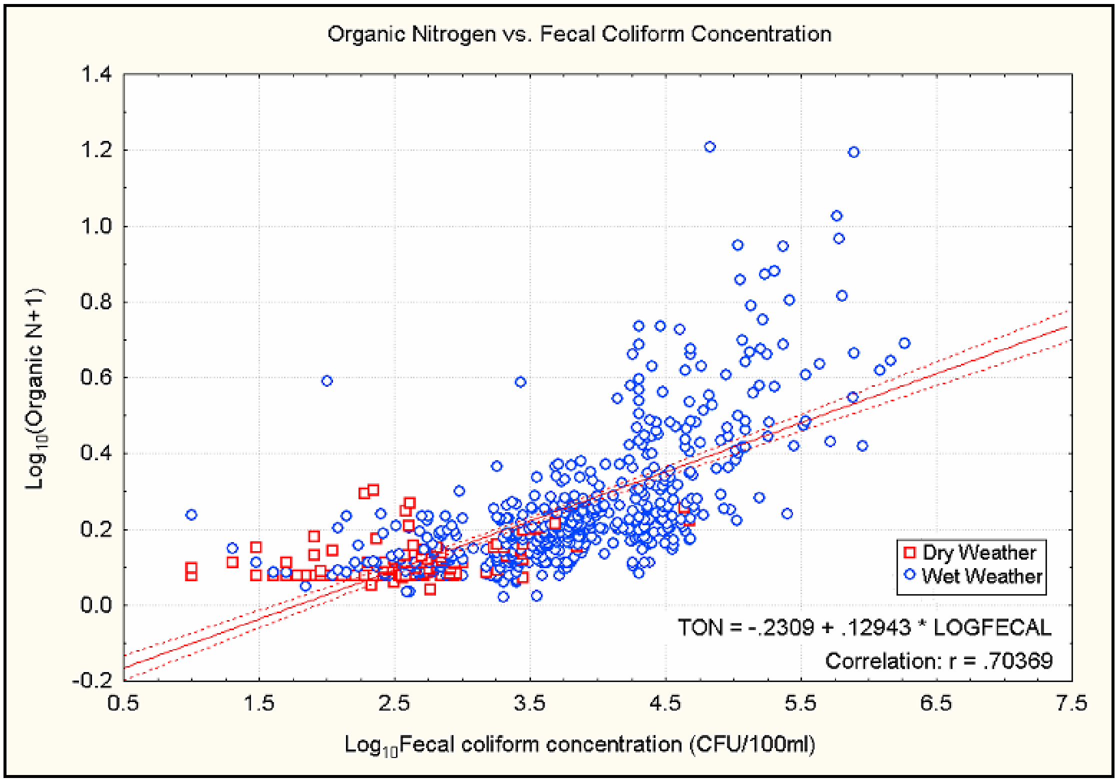


Figure 3-38 Scatterplot of Organic Nitrogen and Fecal Coliform Bacteria Concentrations of Samples Collected from 8 sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.3.8.5, Figure 5.15, Page 5-40)

TKN exceeded the 0.675 mg/L US EPA standard during both dry and wet weather, but is not considered a parameter of concern since there is no state standard.

Nutrient Limitation Effects on Primary Production

Nutrients are arguably the most important factor dictating algal standing crop, primary production, and community composition with examination of the nutrient-algae relationship requiring both an autecological and community-level approach (Borchardt 1996).

Nutrients can be a limiting factor to algal growth. In any given scenario, only one nutrient can limit algal growth for a given species at a time, although, at the community level, this rule does not apply where different species might be limited by different nutrients. Growth rates are not affected by nutrient concentrations alone. Light and temperature can affect nutrient uptake rates (e.g.,Falkner et al. 1980, Wynne and Rhee 1988), and more nutrients are often needed when light and temperature conditions are less than ideal (Goldman 1979, Rhee and Gotham 1981a,b, Wynne and Rhee 1986, van Donk and Kilham 1990). Additionally, nutrient uptake rates can vary depending on nutrient conditions. In steady-state growth conditions, the rate of nutrient uptake is equivalent to the rate at which nutrients are used in growth. However, cells may take up fewer or greater amounts of nutrients (for example, during nutrient pulses) and alter the nutrient ratios within the cell (Borchardt 1996).

The relationship between nutrients and algal biomass is complicated by numerous factors and findings are not consistent across ecoregions and waterbody types. Typically, nutrient enrichment stimulates periphyton growth in lotic systems and many studies have shown strong relationships between nutrient concentrations and algal biomass (e.g., Jones et al. 1984, Welch et al. 1988, Kjeldsen 1994, Chetelat et al. 1999, Francouer 2001). However, other studies have shown no relationship between biomass and nutrient concentration (Biggs and Close 1989, Lohman et al. 1992). Periphyton standing crop can be highly variable (Morin and Cattaneo 1992) and other factors (described in subsequent sections) may override nutrient effects.

Of the necessary components for algal growth, nitrogen and phosphorus are likely to be growth-limiting in aquatic systems (Wetzel 2001) although carbon (Fairchild et al. 1989, Fairchild and Sherman 1993), trace metals (Winterbourn 1990), organic phosphorus (Pringle 1987) and silicates (Duncan and Blinn 1989) have also been implicated in limiting algal growth. Based on periphyton-nutrient studies, phosphorus is typically the limiting nutrient in the northern US (see Borchardt 1996 for review) while nitrogen has been shown to be limiting in the southwest (Grimm and Fisher 1986, Hill and Knight 1988a, Peterson and Grimm 1992) and Ozark (Lohman et al. 1991) regions.

In an effort to develop a practical system of stream classification based on nutrient concentrations similar to those used for lakes, Dodds et al. (1998) examined the relationship between chl-a (mean and maximum benthic chl-a and sestonic chl-a) and total nitrogen (TN) and total phosphorus (TP) in a large, global dataset. They defined the oligotrophic-mesotrophic boundary by the lower third of the distribution of values with mean and maximum benthic chl-a concentrations of 20 mg/m2 and 60 mg/m2, respectively; and TN and TP concentrations of 700 µg/L and 25 µg/L, respectively. The mesotrophic-eutrophic boundary was represented by the upper third of the distribution of values with mean and maximum benthic chl-a concentrations of 70 mg/m2 and 200 mg/m2, respectively; and TN and TP concentrations of 1500 µg/L and 75 µg/L, respectively. Other recent studies examining specific chl-a-nutrient relationships include Dodds et al. (1997), Biggs (2000), Francouer (2001), Dodds et al. (2002a, b), Kemp and Dodds (2002).

N:P Ratio

Although nitrogen and phosphorus are the nutrients commonly limiting algal growth, the concentrations required to limit growth are less clear. Concentrations of phosphorus ranging from 0.3-0.6 µg PO4-P/L have been shown to maximize growth of benthic diatoms (Bothwell 1988) but higher concentrations have been needed in filamentous green algal communities (Rosemarin 1982), and even higher concentrations (25-50 µg PO4-P/L) as algal mats develop (Horner et al. 1983, Bothwell 1989). Nitrogen has been shown to limit benthic algal growth at 55 µg NO3-N/L (Grimm and Fisher 1986) and 100 µg NO3-N/L (Lohman et al. 1991). In the past, the Redfield ratio (Redfield 1958) of cellular carbon, nitrogen, and phosphorus at 106:16:1 has been used to determine nutrient limitation. In benthic algae studies, ambient N:P ratios greater than 20:1 are considered phosphorus limited whereas those less than 10:1 are considered nitrogen limited. Nutrient limitation analysis was focused on steady state (i.e., dry weather) conditions because these are the conditions under which limitation is most likely to affect periphyton communities.

Combining the above frameworks, most samples collected from sites in the TTF Watershed in dry weather would be considered P-limited, mesotrophic with respect to TP, and eutrophic with respect to TN. A small number of samples would be considered not strongly limited by N or P and eutrophic with respect to both macronutrients. Sites TF500, TFJ110, and TF1120 were P-limited and never had TP concentrations exceeding the mesotrophic/eutrophic boundary of .075mg/L. TF620 was P-limited and not eutrophic for all but one sample which was considered co-limited and eutrophic. TF760 was always P-limited and did not have eutrophic concentrations of P in all but one sample. Two sites, TF280 and TFM006, were P-limited and had TP concentrations above the eutrophic boundary more often than not. The latter two sites also had other indicators of sewage (e.g., fecal coliform bacteria) elevated in concentration in dry weather.

Sites TF280 and TF620 had similar mean TN values (2.59 ±0.49mg/L and 2.77± 0.45mg/L respectively), but mean dry weather TP concentration at site TF280 was significantly greater than at site TF620 ($F(47)= 9.35$ $p=0.0002$). Given the greater TP concentration, one might expect greater algal biomass at site TF280. However, observed biomass was consistently smaller at site TF280 than at site TF620, which indicates that other parameters such as light, disturbance, grazing and scouring are controlling algal biomass.

<u>Flow Effects on Stream Nutrient Concentrations</u>

Stream nutrient concentrations in TTF are dynamic. Macronutrients of greatest concern exhibited different responses to wet weather. NO_3 concentrations were relatively stable and adequate for abundant algal growth during dry weather and diluted in wet weather (mean NO3 concentration 2.37mg/L ±0.65, and 1.49mg/L ±0.70, respectively). Conversely, other forms of N (i.e., NH3, NO_2, TKN) generally increased in concentration during wet weather, which is likely due to CSO and SSO discharge as well as presence of other organic constituents in stormwater runoff. Nitrate (NO_3) and ammonium ions (NH^{4+}) forms are generally bioavailable, but other forms are not available for algal growth. Total organic nitrogen concentration (TON; calculated as TKN minus NH_3) showed a significant positive correlation with fecal coliform concentration, suggesting that sewage is a primary source of organic loading to the watershed ($r(648)=0.70$, $p<0.001$).

Phosphorous concentration followed a pattern similar to NH_3 and TON, increasing in wet weather (Figure 3-36). This increase was likely due to CSO and SSO discharge, runoff, and soil erosion. Particle size mobilization and transport, traditionally related to flow by entrainment velocity curves (i.e. Shields curve), may determine the effective P loading for a given sediment load. Smaller particles, due to their greater relative surface area, can absorb relatively more P than larger particles. Smaller particles are also generally more readily eroded and entrained in stormwater flow than larger particles.

Smaller storm events in TTF thus probably contribute more to eutrophication than larger events. For example, if smaller sediment particles adsorb more P than larger particles as has been suggested, P loading becomes less efficient as larger particles are entrained in runoff. As shear stresses increase, streambank materials comprise a greater proportion of the sediment load. These particles are likely more similar to the soil parent material (i.e., lower in P concentration) than more superficial soils layers that tend to incorporate more organic material. Furthermore, NH_3 showed a significant positive correlation with TSS ($r(380)=0.46$, $p<0.001$), but the greatest concentrations of NH_3 were observed accompanying moderate TSS concentrations, suggesting that NH_3 concentration increases immediately due to sewage inputs but is diluted by stormwater in larger, more severe storm events (Figure 3-39).

In addition to the decrease in relative bioavailability that accompanies high flows; physical stressors probably impose limits on the degree to which stream producers can take advantage of these increased concentrations. As flows increase, a greater proportion of the total nutrient load is transported out of the system, a greater proportion of the total load is inaccessible to producers, and much of the photosynthetic biomass (filamentous green algae and their associated epiphytes in particular) may be sloughed away and transported out of the system.

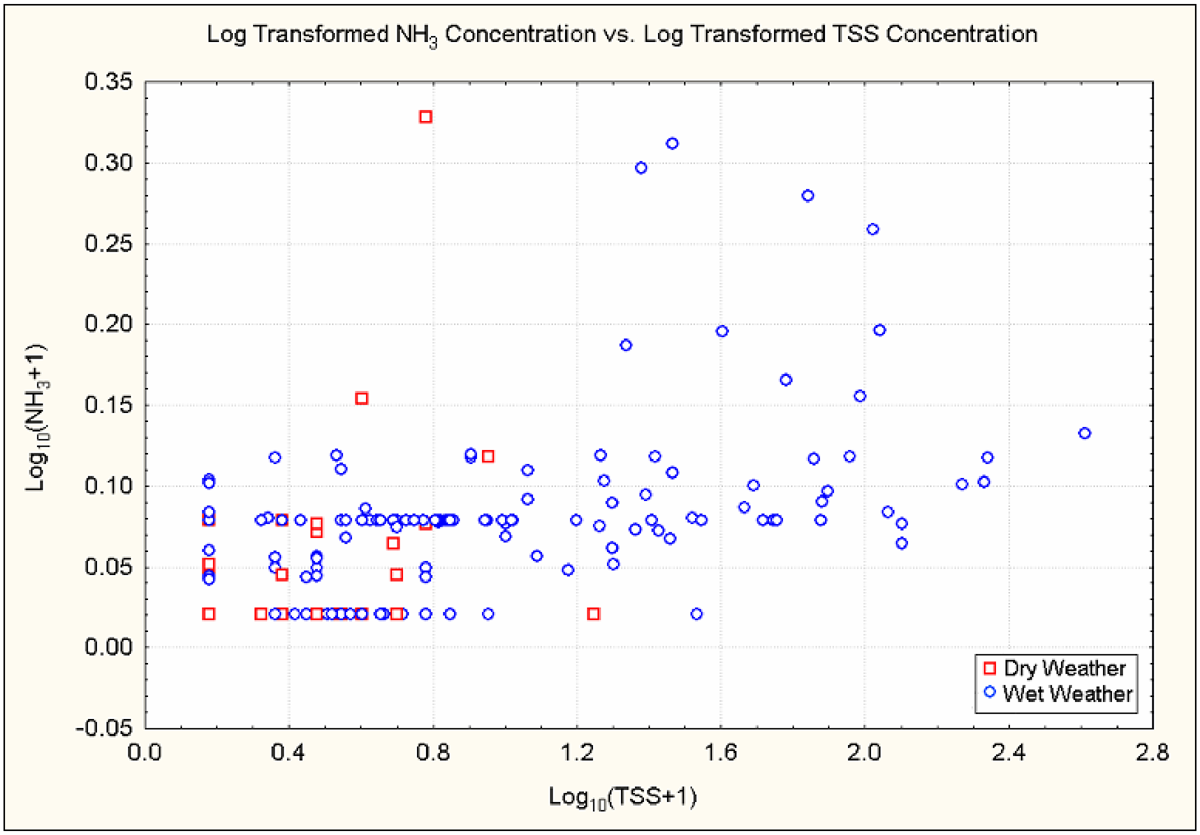


Figure 3-39 Scatterplot of Log-Transformed Ammonia and Total Suspended Solids Concentration of Samples Collected from Eight sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.4.2.2, Figure 5.20, Page 5-49)

In areas served by combined sewers, the relative impact of small, intense storms is magnified. CSO discharge is minimally diluted by stormwater in the initial overflow phase, or "first flush". If nutrients present in these overflows can become deposited along with sediment or rapidly taken up by stream producers, discharges of short duration, particularly in which shear stresses do not result in major sloughing of algal communities, may have far-reaching consequences for stream nutrient dynamics and aquatic biota. A greater benefit may result from reducing frequency, number, and volume of small CSO discharges rather than attempting to capture releases from larger events.

Metals

Iron and Manganese

Iron (Fe) and Manganese (Mn) are generally not toxic in streams, but are regulated in waters of the Commonwealth of Pennsylvania for public water supply (PWS) protection (Commonwealth of Pennsylvania, 2001) because excess concentrations of these metals can cause color, taste, odor, and staining problems in drinking water and industrial applications. The Pennsylvania Department of Environmental Protection (PADEP) has established criteria for a 30 day average as total recoverable maximum concentration for Fe. PADEP water quality criteria requires that the concentration of the 30 day average of Fe not exceed 1.5 mg/L. PADEP water quality criteria requires that the concentration of Mn as total recoverable not exceed 1 mg/L. Both elements are essential nutrients for all life and relatively abundant in the soils and surface geology of the TTF Watershed. Fe is particularly abundant (at approximately 5% of the Earth's crust it is second only to Aluminum in abundance among metals) and was detected in 746 of 761 samples collected from the TTF Watershed. Mn was less abundant but nevertheless detected in 745 of 762 samples. Presence of these metals in surface water samples may be natural- related to weathering of rock and soils- or due to stormwater runoff and ferrous materials in contact with the stream (e.g., pipes and metal debris).

Fe was not considered a parameter of concern in dry weather because the maximum standard of 1.5 mg/L as total recoverable was only exceeded in 0.60% of samples; however, Fe was considered a parameter of concern in wet weather because the standard was exceeded in 23% of the samples. Mn was not considered a parameter of concern in dry weather because the maximum standard of 1 mg/L as total recoverable was never exceeded; however, Mn was considered a parameter of potential concern in wet weather because the standard was exceeded in 2.1% of the samples. Neither Fe nor Mn are toxic to aquatic life at concentrations observed, and these constituents cannot be responsible for observed impairments in aquatic communities.

Toxic Metals

Toxic metals have been recognized as having the potential to create serious environmental problems even in relatively small concentrations (Warnick and Bell 1969, LaPoint et al. 1984, Clements et al. 1988). As such, their presence in waters of the Commonwealth, treatment plant effluents, and other permitted discharges is specially regulated by Pennsylvania Code Title 25, Chapter 16-Toxic Substances Criteria. Considerable research over the past two decades has been directed at understanding the ecotoxicology of heavy metals (e.g., biological pathways, physical and chemical mechanisms for aquatic toxicity, thresholds for safe exposure both acute and chronic, roles of other water quality constituents in bioavailability of toxic metals, etc.).

It is now widely accepted that dissolved metals best reflect the potential for toxicity to organisms in the water column, and many states, including PA, have adopted dissolved metals criteria (40 CFR 22227-22236). As many metals occur naturally in various rocks, minerals, and soils, storm events can expose and entrain soil and sediment particles that naturally contain metals. These inert particles are removed when samples are filtered for dissolved metals analysis (Greenberg et al. 1992). Total recoverable metals samples are digested and acidified to liberate organically-bound and complexed metals, but this process may also solubilize metals in inorganic and particulate states that are stable and inert under normal stream conditions, overestimating the potential for toxicity.

However, since it is not possible to filter samples collected with automatic sampling equipment immediately after collection, PWD has collected a greater number of total metals samples than dissolved metals samples. In order to ensure an adequate number of dissolved samples, particularly in wet weather, samples were collected from site TF280 during wet weather on two dates in summer 2004. Samples were collected manually by pumping through the automatic sampling tubing and apparatus and filtered immediately after collection. Site TF280 was sampled to conservatively direct sampling effort to the drainage that would be expected to contain the most potential sources of urban wet weather runoff pollution.

Analysis of paired dissolved/total metals concentration data suggests that most metals are generally found in considerably greater concentrations when total metals are measured, particularly in wet weather. Since dissolved metals concentrations are usually small or undetectable in both dry and wet weather, the potential for heavy metal toxicity in TTF, at least for water column organisms, is believed to be low. Sediment and pore water conditions may result in greater concentrations or otherwise contribute to increased potential for toxicity to benthic organisms within stream sediment microhabitats, but these effects remain poorly defined and are difficult to measure. Total recoverable metals results and comparisons to discontinued total metals water quality criteria are included herein as a reference measure of the potential for sediment metal loading and metals loading to the Delaware estuary from Philadelphia's urban stormwater; though it is believed that, for at least some metals, samples more closely reflect natural soil and geologic features than water pollution.

With the exception of Al and hexavalent Cr, PA WQ criteria are based on hardness (as $CaCO_3$), to reflect inverse relationships between hardness and toxicity that exist for most metals (Figure 3-40). While these criteria are much improved over simple numeric criteria, they fail to describe the complex interactions between dissolved metals and other water constituents and physicochemical properties (e.g., Dissolved Organic Carbon, pH, temperature, and ions other than Ca and Mg,). Hardness-based criteria may represent an intermediate step between simple numeric criteria and criteria based on more complex water quality models (i.e., Biotic Ligand Model), drafts of which have been recently been presented by USEPA.

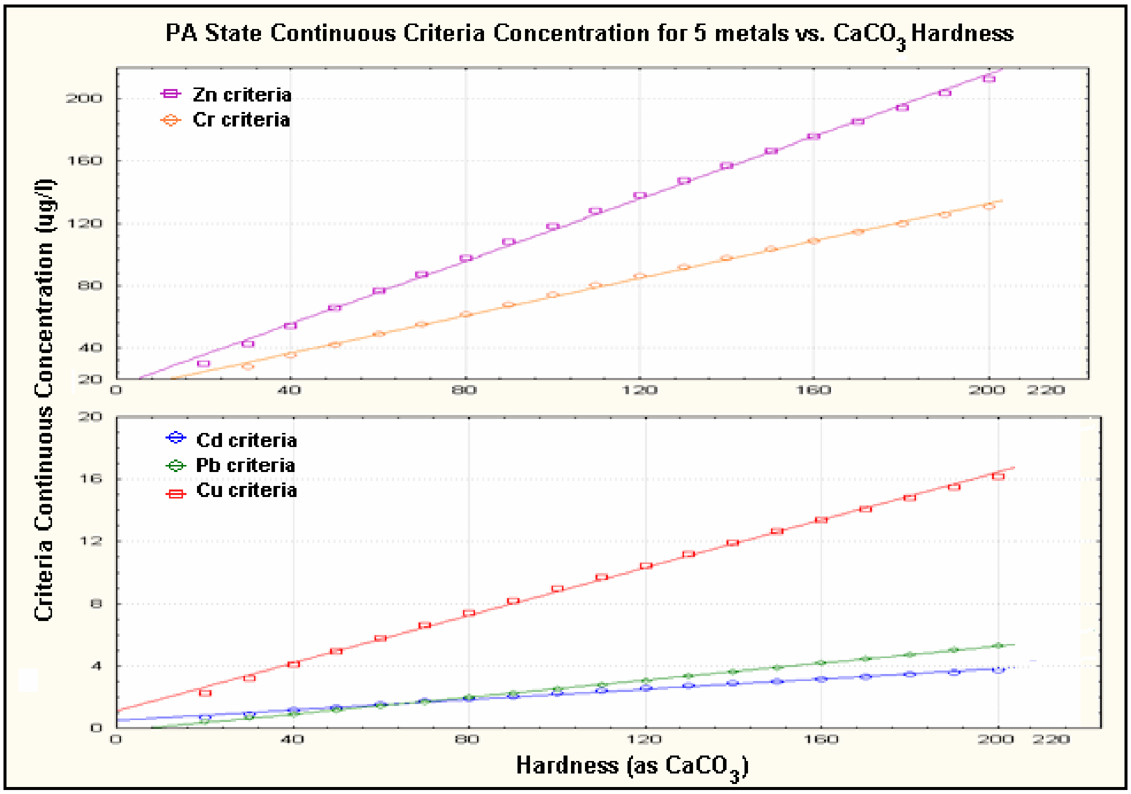


Figure 3-40 PADEP Hardness-based Criteria Continuous Concentrations for Five Toxic Metals (TTF CCR Section 5.3.7, Figure 5.7, Page 5-26)

Aluminum

The PADEP has established criteria for maximum concentrations for aquatic life acute exposure that states that the concentration of Al should not exceed 0.75 mg/L (National Recommended Water Quality Criteria, 2006). The USEPA requires that the concentration of Al should not exceed 0.087 mg/L for aquatic life chronic exposure. Water column Al concentrations were significantly higher in wet weather than in dry weather (Mann-Whitney test $Z_{2,699} = -13.28$, $p < .05$), which may be due to both natural and anthropogenic sources. Examination of paired dissolved and total recoverable Al concentrations from 45 samples collected from TTF shows that while total recoverable Al concentrations may often exceed 100 μg/L in wet weather, dissolved Al is rarely present in similar concentrations (Figure 3-41). This finding suggests that most Al is present in particulate form.

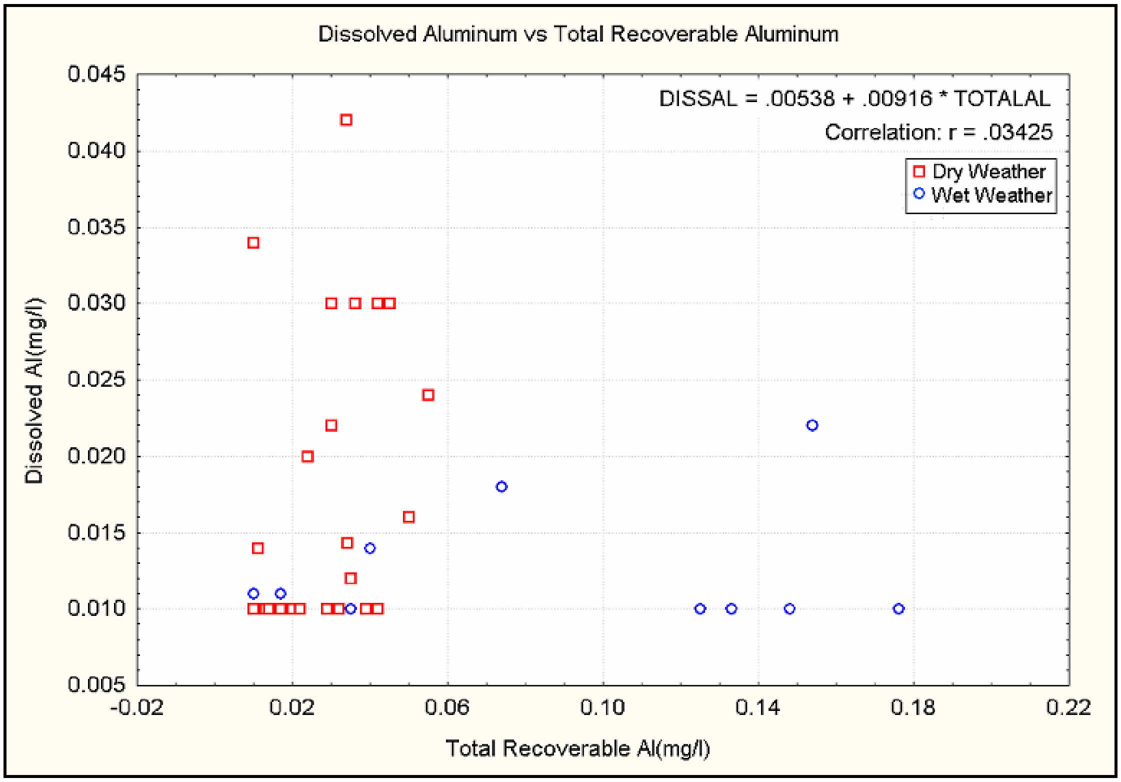


Figure 3-41 Scatterplot of Paired Dissolved Aluminum and Total Recoverable Aluminum Concentrations of Samples Collected from Eight Sites in TTF Watershed, 2000-2004 (TTF CCR Section 5.3.7.1, Figure 5.8, Page 5-27)

Al was detected in 643 of 701 samples from TTF (Table 3-66). Though 120 of 135 samples collected in wet weather were found to be in violation of water quality criteria, violations occurred with similar relative frequency in dry and wet weather because wet weather samples were much more numerous overall and dry weather criteria are far more stringent than wet weather criteria (87 µg/L and 750 µg/L, respectively).

The strong correlation between Al and TSS (Figure 3-42) suggests that most of the Al present in wet weather water samples may be due to suspended particulate Al. However, wet weather suspended solids loads consist of a mixture of urban stormwater, eroded upland soils, and streambank particles. It is impossible to determine individual Al contributions of these sources. State water quality criteria for Al are based upon total recoverable fractions rather than dissolved, partially because under experimental conditions, Brook Trout (Salvelinus fontinalis) experienced greater mortality with increased total Al concentration despite constant levels of dissolved Al (the form of particulate Al present in this experiment was Aluminum hydroxide, and experimental pH was low). Furthermore, USEPA has documented HQ waters that exceed WQ standards for Al (63FR 68353-68364). Al found in natural streams may be predominantly mica and clays, which are inert under normal stream conditions. As the TTF Watershed is rich in both mica and clay soils, and rarely experiences pH < 6.0, other factors should probably be ruled out before attributing biological impairment to Al toxicity.

Table 3-66 Summary of Toxic Metals Samples Collected in Dry and Wet Weather and Corresponding Number of Samples Found to have Concentrations Below Reporting Limits (TTF CCR Section 5.3.7.1, Table 5-12, Page 5-27)

Parameter	Number of Dry Samples	Number of Dry Non-Detects	Number of Wet Samples	Number of Wet Non-Detects
Total Al	149	22	552	36
Dissolved Al	55	26	12	7
Total Cd	129	129	605	560
Dissolved Cd	83	83	194	194
Total Cr	102	82	548	267
Dissolved Cr	46	45	76	76
Total Cu	154	0	609	0
Dissolved Copper	74	0	81	0
Total Pb	146	113	605	123
Dissolved Pb	65	65	76	59
Total Zn	143	8	528	6
Dissolved Zn	66	12	56	6

Al was not considered a parameter of concern in dry weather for aquatic life acute exposure because the water quality standard of 0.75 mg/L was never exceeded, however, Al was considered a parameter of concern in wet weather for aquatic life acute exposure because the standard was exceeded in 21.7% of the samples. Al was considered a concern in dry weather for aquatic life chronic exposure because the standard of 0.087 mg/L was exceeded in 10.1% of the dry weather samples.

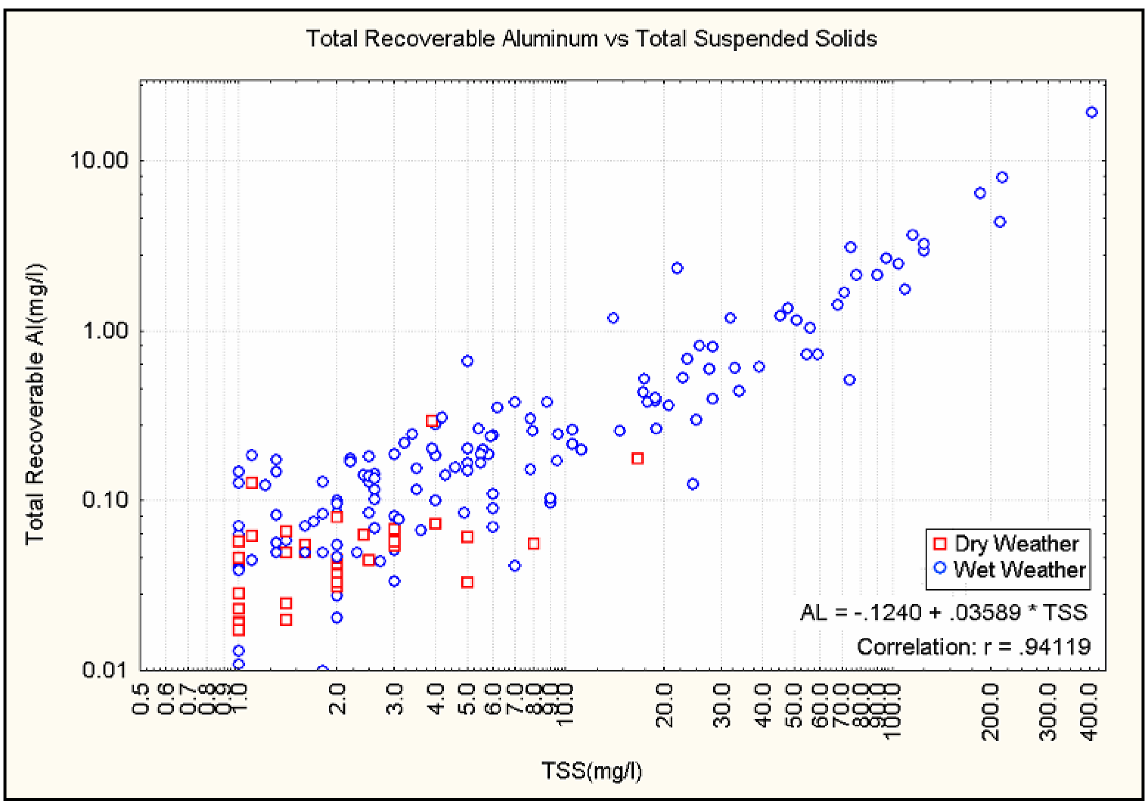


Figure 3-42 Scatterplot of Paired Total Recoverable Aluminum and Total Suspended Solids concentrations of samples collected from 8 sites in TTF Watershed, 2000-2004 (TTF CCR section 5.3.7.1 figure 5.9 page 5-28)

<u>Copper</u>

The PADEP has established Copper (Cu) concentration criteria for aquatic life acute exposure and aquatic life chronic exposure. Both criteria require a hardness correction. The standards that are stated below were calculated with 100 mg/L of CaCO3 hardness. PADEP water quality criteria require that the concentration of dissolved Cu should not exceed 0.013 mg/L for the aquatic life acute exposure standard and 0.009 mg/L for the aquatic life chronic exposure standard. The USEPA also has an established criterion for maximum dissolved Cu concentration for human health standards of 1 mg/L, but there is equivalent state standard. Based on PADEP standards, Dissolved Cu is not considered a parameter of concern in dry weather for aquatic life acute exposure and aquatic life chronic exposure because the standards were all exceeded less than two percent of the time. Dissolved Cu is considered a parameter of potential concern in wet weather for aquatic life acute exposure because the standard was exceeded in 7.4% of the samples.

Cu was always detectable in TTF; all of the 763 samples collected in 2000-2004 had Cu concentration above reporting limits. Basic statistics for Total Cu and Dissolved Cu appear in Table 3-66 and outliers excluded from subsequent analyses are tabulated in Appendix D of the TTF CCR. Contamination was suspected in two samples where the ratio of dissolved to total Cu exceeded 2:1, and also in a dry weather sample at site TF500 where Total Cu concentration was 102 μg/L. Some samples lacked hardness data, so conservative hardness values were substituted for the purpose of comparing observed dissolved Cu to WQ criteria. These substitute hardness values were mean hardness minus one standard deviation, calculated separately for dry and wet weather (hardness data aggregated for all sites and dates).

In 2004, PWD reinstated separate determinations of total and dissolved fractions on metals samples collected as part of the discrete interval sampling program. PWD also conducted two rounds of intensive metals sampling during wet weather at site TF280, which is believed to be the most chemically impaired non-tidal site in the watershed. As of May 2005, 152 paired dissolved and total copper results were available. The ratio of dissolved Cu to total recoverable Cu was significantly higher in dry weather samples than in wet weather samples (t-test, $F(2,148)=2.809$, $p=.000039$). Furthermore, there was no strong relationship between dissolved and total recoverable Cu in wet weather samples (Figure 3-43). Despite total recoverable concentrations that ranged up to 200 μg/L, maximum observed concentration of dissolved Cu was 22 μg/L.

As Cu strongly associates with sediment, pore water/sediment toxicity should not be ignored as a potential stressor to benthic invertebrates. The only sensitive taxa that were consistently collected throughout the watershed (though densities were low) were tipulid larvae; these relatively large larvae are shredders, and enshroud themselves in leaf packets. A diet and microhabitat rich in organic acids may confer resistance to heavy metal pollution. Mayflies, on the other hand, have been characterized as very sensitive to metals pollution (Clements et al. 1988, Clements et al. 1990) and the obvious disparity between TTF sites and reference sites with respect to number and abundance of mayfly taxa may be attributable to heavy metal pollution. Sediment metals concentrations and reference site chemistry data are needed before any conclusions can be drawn.

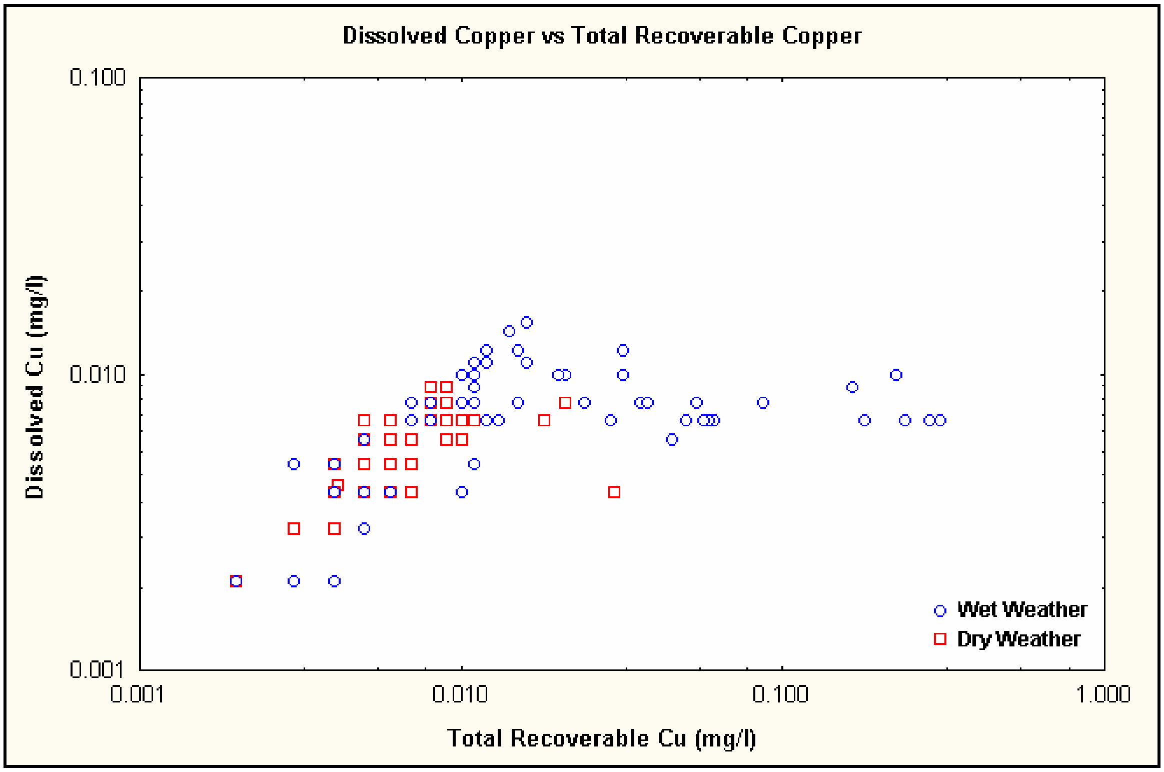


Figure 3-43 Paired Dissolved and Total Recoverable Copper Concentration of Samples Collected from 8 Sites in TTF Watershed, 2000-2004 (TTF CCR section 5.3.7.4 figure 5.10 page 5-31)

Cu toxicity was also investigated using the Biotic Ligand Model (BLM) (DiToro et al. 2001). Data were lacking for some model input parameters, so conservative values were substituted. Many water chemistry parameters can affect Cu toxicity, particularly other ions and organic molecules that tend to compete with gill ligand bonding sites for available Cu. Figure 3-44 illustrates the effects of pH and temperature on Cu bioavailability and toxicity. BLM data were used only to determine whether Cu toxicity could affect the biology of TTF Watershed, not to develop alternative water quality criteria. USEPA is in the process of developing new WQ criteria for Cu incorporating the BLM with appropriate margins of safety for protecting aquatic life.

The BLM was used to determine the LD50 of dissolved copper to Fathead Minnow (Pimephales promelas), and two cladoceran microcrustaceans (Ceriodaphnia dubia, and Daphnia pulex). For most parameters data entered into the model came from samples collected from TTF Watershed. Data from each sample were entered into the model as a separate case and the LD50 of Cu was determined for each case. When data from TTF Watershed were not available estimates from nearby streams were used. Parameters for which estimates were used included: (Dissolved Organic Carbon) DOC, Percent of DOC contributed by Humic Acids, Potassium, and Chloride. DOC competes for Cu with gill ligand sites and is positively correlated to the LD50 of Cu, therefore a conservative estimate of 2.9 mg/L from French Creek was used in place of 5.4 mg/L , an estimate given for PA streams (USEPA document #822-B-98-005). Due to the lack of DOC characterization data, ten percent was used for the relative proportion of DOC made up by Humic acids as recommended by the model documentation (DiToro et al. 2001). Model input values for Potassium (K) were estimated by averaging potassium values from Pickering Creek, Trout Creek, and Wissahickon Creek, though K currently has no direct effect on metal toxicity in the BLM.

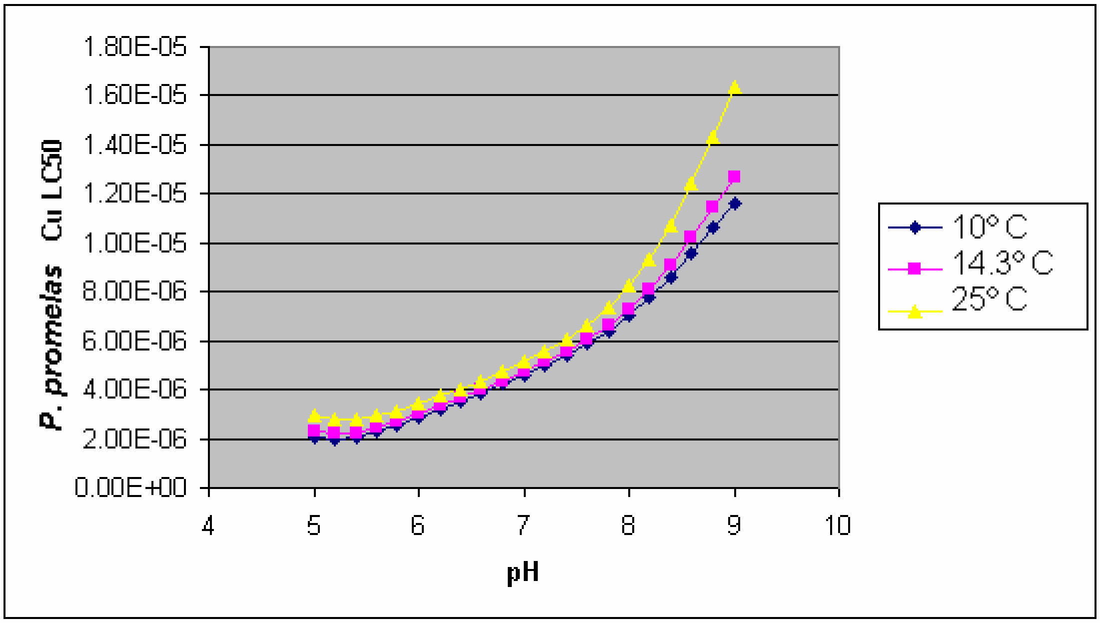


Figure 3-44 Effects of pH and Temperature on Copper Toxicity to Fathead Minnows (TTF CCR section 5.3.7.4 figure 5.11 page 5-32)

Chloride model input values were calculated by averaging values from Pickering Creek and Trout Creek. When comparing dissolved Cu concentrations from Tookany/Tacony-Frankford Watershed to predicted LD50, the predicted LD50 concentration was reduced by an order of magnitude (margin of safety). Even with this margin of safety, no sample had dissolved Cu concentration above the LD50 for any of the target organisms.

Zinc

The PADEP has established criteria for both aquatic life acute exposure and aquatic life chronic exposure. Both aquatic life acute exposure and aquatic life chronic exposure require a hardness correction. The standards that are stated below were calculated with 100 mg/L of CaCO3 hardness. The criteria requires that the concentration of dissolved Zn not exceed 0.12 mg/L for the aquatic life acute exposure and 0.12 mg/L for the aquatic life chronic exposure. The USEPA has an established maximum criterion for dissolved Zn concentration for human health standards of 5 mg/L, but there is no equivalent state standard. Based on the state standards, Dissolved Zn is considered a parameter of potential concern in dry weather for both aquatic life acute exposure and aquatic life chronic exposure because the standards were exceeded in 2.7% and 4.1% of the dry weather samples, respectively. Dissolved Zn is not considered a parameter of concern in wet weather for aquatic life acute exposure because the standard was exceeded in less than 2% of the samples.

Zn is usually present in surface waters of TTF; only 14 of 671 individual total recoverable Zn samples and 18 of 122 dissolved Zn samples from TTF had Zn below reporting limits (Table 3-66), though concentrations were relatively small.

In the TTF Comprehensive Characterization Report, contamination was suspected in four sets of samples collected in 2004, where dissolved concentrations were consistently greater than total recoverable concentrations in 30 of 32 samples (Figure 3-45). Dates and sample information for these sample dates are summarized in Appendix D of the TTF CCR. Of 15 dissolved Zn samples exceeding WQ criteria, 14 are likely to have been affected by contamination. If these samples are

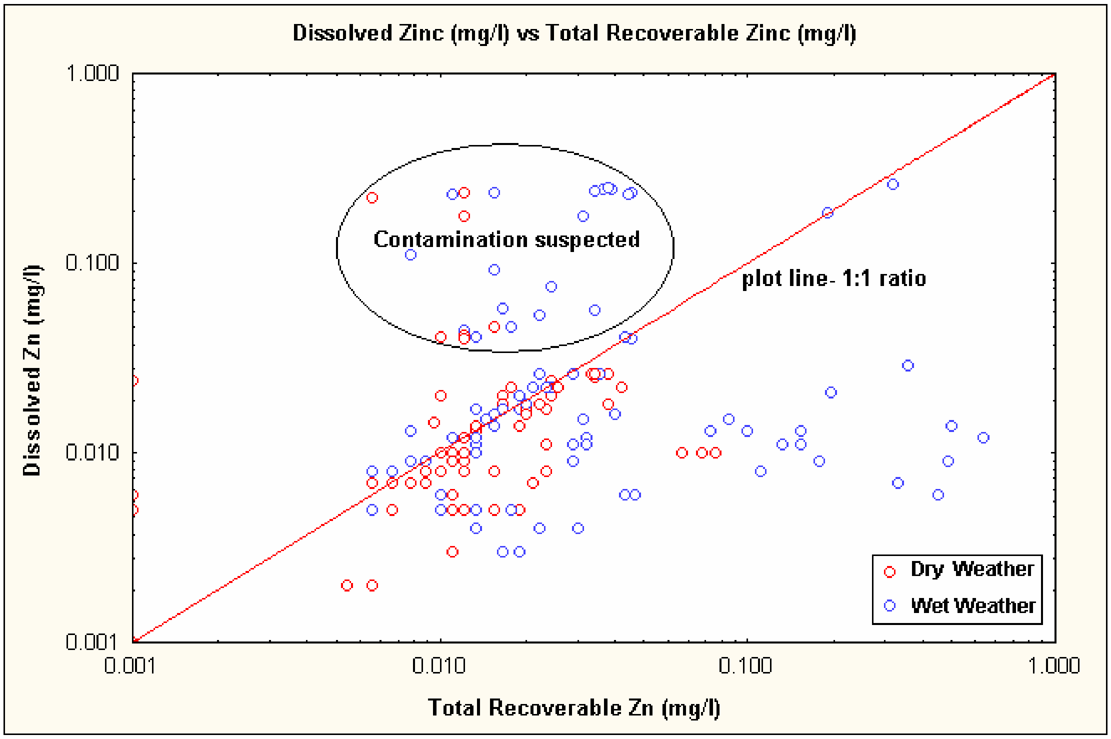


Figure 3-45 Paired Total Recoverable and Dissolved Zinc Concentrations of Samples collected from 8 sites in TTF Watershed, 2000-2004 (TTF CCR section 5.3.7.6 figure 5.12 page 5-34)

ignored, dissolved Zn/total recoverable Zn ratios more closely mirror those of other metals (i.e., higher in dry weather than in wet weather).

Discrepancies occurred with both dry and wet weather samples. Bench sheets did not indicate any problems with samples or the instrumentation, and all QC checks were passed. As samples were preserved and stored, the PWD Bureau of Laboratory Services (BLS) was able to re-analyze these samples, obtaining similar results. The analyst visually confirmed the presence of settled solids in sample containers used for total recoverable metal, while sample containers used for dissolved metals were visually clear. A series of subsequent filter blank trials showed filters used to prepare dissolved metals samples may have leached Zn, but the magnitude of the difference in total and dissolved concentrations was much too great to be explained by filter contamination. The source of contamination remains unknown.

The BLM was used to estimate the toxicity of dissolved Zn to Fathead Minnows (Pimephales promelas), rainbow trout (Oncorhynchus mykiss), and cladoceran (Daphnia magna). Input data were compiled or estimated in the same manner as dissolved copper model input data. An order of magnitude safety factor was applied to the LD50 concentrations generated by the model and the resulting concentration was compared with dissolved zinc data collected from the TTF Watershed. Even with this safety margin, no observed dissolved Zn concentrations exceeded the calculated LD50 for the studied organisms.

Fecal Coliform and E. coli Bacteria

The PADEP has established maximum concentration criteria for fecal coliform during both swimming season and non-swimming season of 200 CFU/100mL and 2000 CFU/100mL, respectively. Based on data from numerous sources (e.g., USEPA, USGS, USDA-NRCS, volunteer monitoring organizations, etc.), it appears likely that many, if not most, southeastern PA streams would be found in violation of water quality criteria for fecal coliform bacteria concentration during the swimming season given sufficient sampling effort. PWD has expended considerable resources toward documenting concentrations of fecal coliform bacteria and *E. coli* in Philadelphia's watersheds. The sheer amount of data collected allows for more comprehensive analysis and a more complete picture of the impairment than does the minimum sampling effort needed to verify compliance with water quality criteria. In keeping with the organizational structure of the watershed management plan, fecal coliform bacteria analysis has been separated into dry (Target A) and wet weather (Target C) components, defined by a period with at least 48 hours without rain as measured at the nearest gage in PWD's rain gage network.

Dry Weather Fecal Coliform Bacteria (Target A)
Fecal coliform was considered a parameter of concern during the dry weather non-swimming season because the standard of 2000 CFU/100mL was exceeded in 3.9% of the samples. In the swimming season, Fecal coliform was considered a parameter of concern because the standard of 200 CFU/100mL was exceeded in 92% of the samples.

The geometric mean of 63 fecal coliform bacteria concentration samples collected from TTF Watershed in dry weather during the non-swimming season from 2000-2004 did not exceed 2000 CFU/100 mL (Table 3-67). Only one sample, collected from site TF280, exceeded 2000 CFU/100 mL (estimated fecal coliform concentration 2100 CFU/100mL). In contrast, dry weather geometric mean fecal coliform concentration exceeded water quality criteria of 200 CFU/100 mL during the swimming season at all sites except TFJ110 (Table 3-68). An improvement in mean fecal coliform concentration can be seen in both swimming and non-swimming season when data from 2000-2004 is compared to historical data from 1970-1980 (t-test $F_{2,140} = 5.6$, $p < 0.05$; $F_{2,163} = 3.76$, $p < 0.05$ respectively).

Table 3-67 Fecal Coliform Concentration (CFU/100mL) Dry Weather Non-swimming Season (1 Oct. - 30 Apr.) (TTF CCR section 5.3.4.1 table 5.8 page 5-17)

Site	Valid N	Mean	Geometric Mean	Median	Minimum	Maximum	Std. Dev.
TF280	9	600	286	290	30	2100	777
TF500	8	468	226	330	10	1500	500
TF620	10	259	187	225	30	550	187
TF760	8	139	83	105	10	390	129
TF975	9	408	312	450	90	900	276
TF1120	9	229	186	200	40	410	131
TFJ110	6	55	42	65	10	90	34
TFM006	4	293	231	210	100	650	244

Collectively, mean fecal coliform bacteria concentration of sites in the City of Philadelphia were significantly higher during the swimming season than during the non-swimming season ($F_{2,68} = 1.48$, $p = .000016$). Sites in Montgomery County follow the same temporal pattern and have a significantly higher mean during the swimming season ($F_{2,64} = 1.83$, $p < 0.05$).

Table 3-68 Fecal Coliform Concentration (CFU/100mL) Dry Weather Swimming Season (1 May - 30 Sept.) (TTF CCR section 5.3.4.1 table 5.9 page 5-17)

Site	Valid N	Mean	Geometric Mean	Median	Minimum	Maximum	Std. Dev.
TF280	12	1474	773	425	190	4800	1591
TF500	6	2655	2003	2300	800	6900	2261
TF620	15	833	700	700	340	2700	644
TF760	5	562	514	440	300	1000	275
TF975	13	1620	1130	860	450	6000	1652
TF1120	11	632	541	450	260	1500	409
TFJ110	4	175	173	185	130	200	31

Wet Weather Fecal Coliform Bacteria Concentration (Target C)
Fecal coliform is considered a parameter of concern in wet weather during both the swimming and non-swimming season because the standard was exceeded in 97% and 67% of the samples, respectively.

Wet weather fecal coliform concentration of 480 samples collected during the swimming season (i.e., 5/1 - 9/30) and 140 samples collected during the non-swimming season were estimated. Geometric mean fecal coliform concentration of all samples collected in wet weather during the swimming season exceeded the 200 CFU/100mL water quality criterion (Figure 3-46, Table 3-69). All sites except TFJ110 had geometric mean fecal coliform concentration greater than $3x10^3$ CFU/100mL. Sites TF280 and TFM006 showed evidence of severe wet weather sewage impacts (estimated geometric mean fecal coliform concentration 23,773 and 13,787 CFU/100mL respectively).

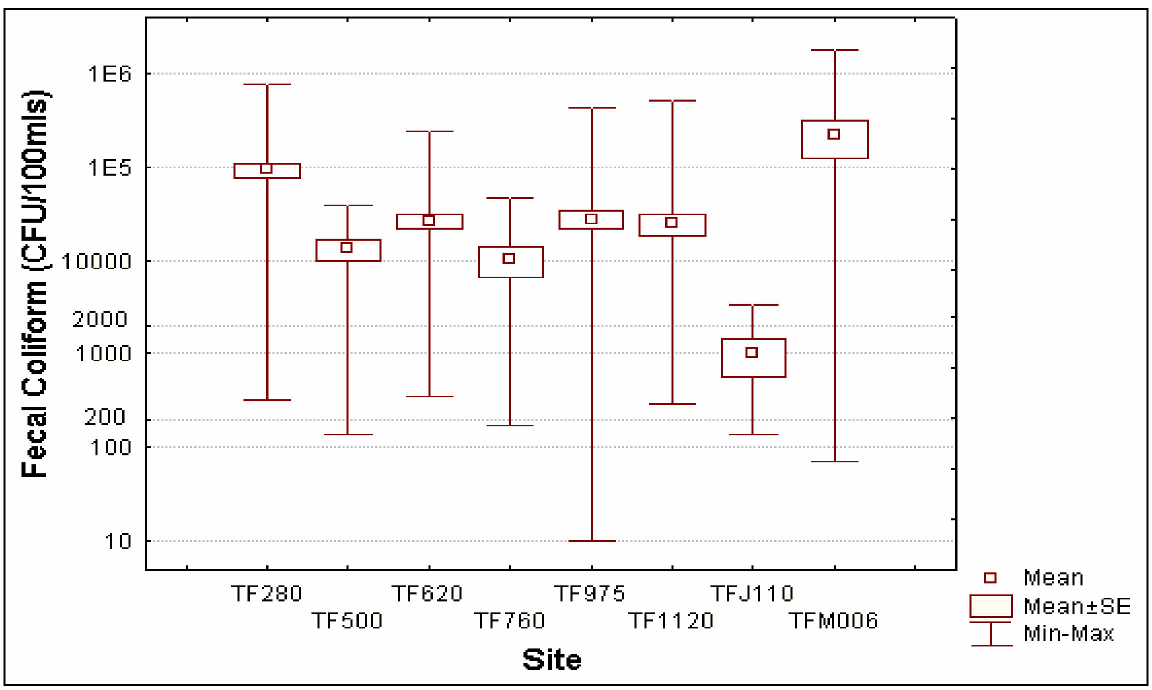


Figure 3-46 Fecal Coliform Bacteria Concentrations of Samples Collected from 8 sites in TTF Watershed in Wet Weather during the Swimming Season, 2000-2004 (TTF CCR section 5.3.4.2 figure 5.4 page 5-18)

Table 3-69 Fecal Coliform Concentration (CFU/100mL) Wet Weather, Swimming Season (1 May - 30 Sept.) (TTF CCR section 5.3.4.2 table 5.10 page 5-19)

	Valid N	Mean	Geometric Mean	Median	Minimum	Maximum	Std. Dev.
TF280	104	95132	23774	32000	320	780000	163153
TF500	14	13766	6199	8500	140	40000	13323
TF620	98	27064	8808	8250	350	250000	44437
TF760	14	10446	3357	2950	170	48000	14147
TF975	107	28750	7275	6500	10	430000	61335
TF1120	110	25256	5503	4850	290	520000	66313
TFJ110	8	1004	580	455	140	3500	1219
TFM006	27	223534	15049	11200	70	1820000	497239

Surface water samples collected at site TFM006 in dry weather (n=6) do not indicate severe problems, however, results from a targeted wet weather sampling event 8/30/04-9/1/04 suggest that sewage impacts in wet weather are still a serious problem at this stormwater outfall (Figure 3-47). Source(s) of these sewage inputs remain unknown. PWD's Waterways Restoration Team completed a streambank restoration project at this outfall in 2005, and removal of a large plunge pool was one component of the restoration design. It is hoped that reduction of stagnant water will reduce the influence of small wet weather sewage impacts on dry weather fecal coliform concentrations.

Mean wet weather fecal coliform concentration during the swimming season was significantly greater than that of the non-swimming season both within the City of Philadelphia ($F_{2,316}$= 1.11, $p < 0.05$) and in Montgomery County ($F_{2,302}$= 1.35, p= 0.002). However geometric mean fecal coliform concentrations during the non-swimming season exceeded 2,000 CFU/100mL at sites TF280, TF500, TF620, TF975 and TF1120 (Table 3-70). Although few samples were collected in wet weather during the non-swimming season, Sites TFM006 (geometric mean 137, n=2) and TFJ110 (geometric mean 51, n=3) did not exceed water quality standards. Improvements in mean fecal coliform concentration were observed in both the swimming (historical n=22, modern n=482) and non-swimming season when data from 2000-2004 was compared with historical data from 1970-1980 (t-test $F_{2,502}$=1.08, p=.004 and $F_{2,164}$=1.24, p=.002 respectively).

Table 3-70 Fecal Coliform Concentration (CFU/100mL) Wet Weather, Non-swimming Season (1 Oct. - 30 Apr.) (TTF CCR section 5.3.4.2 table 5.11 page 5-21)

Site	Valid N	Mean	Geometric Mean	Median	Minimum	Maximum	Std.Dev.
TF280	30	19959	4439	13150	20	70000	22417
TF500	9	14734	2439	3800	140	91000	29570
TF620	34	9038	3397	4000	110	35000	11028
TF760	9	4721	1311	3100	100	22000	6992
TF975	34	10361	3785	4750	100	49000	13111
TF1120	19	11272	3189	6200	50	47000	13559
TFJ110	3	60	51	40	30	110	44
TFM006	2	170	137	170	70	270	141

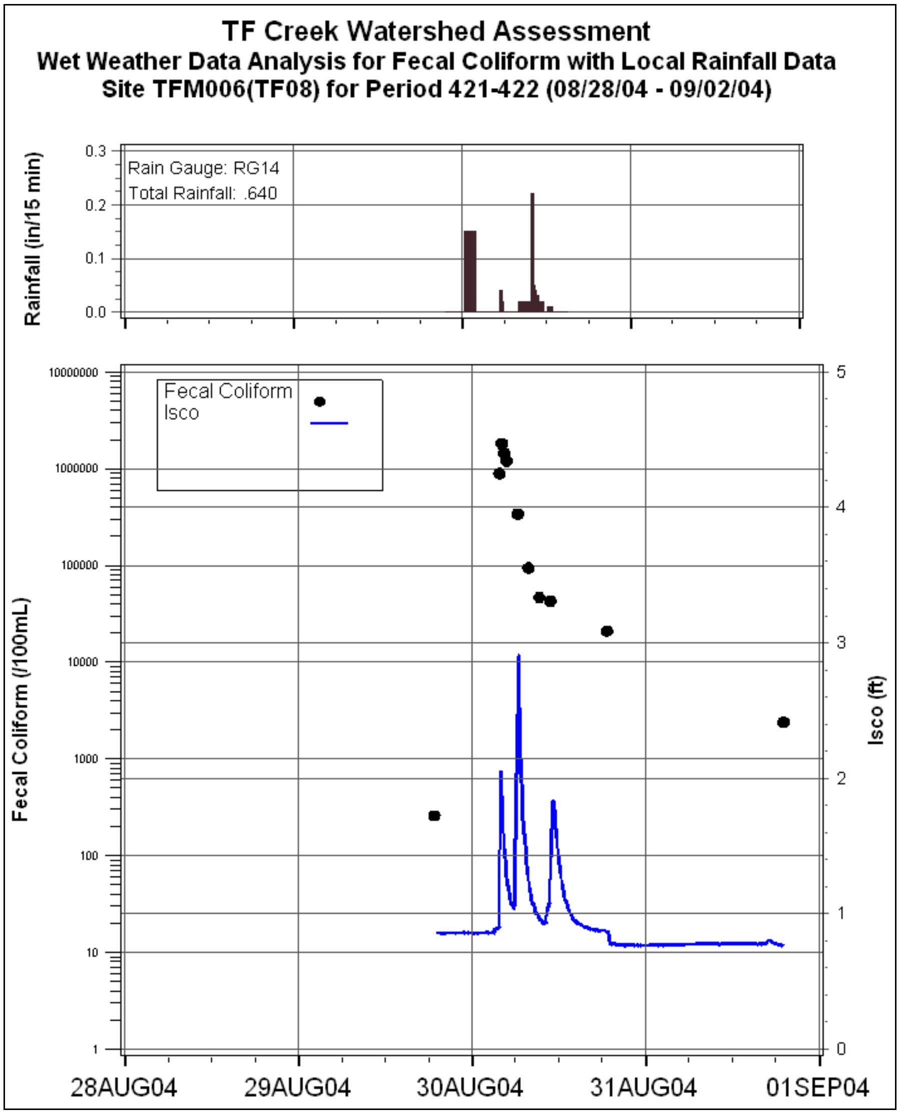


Figure 3-47 Fecal coliform analysis for wet weather event on August 30, 2004 at TFM006 (TTF CCR section 5.3.4.2 figure 5.5 page 5-20)

<u>Future Investigation of Bacteria Conditions in the Tacony and Frankford Creeks</u>

Investigations continue into the nature, causes, severity and opportunities for control of the bacteria conditions in the lower Tacony Creek and the Frankford Creek. In the future, work efforts will be expanded to include the development of informational total maximum daily load assessments for bacteria in the watershed, both for loadings from the City as well as from dischargers to the Tookany Creek and other upstream tributaries. Progress and results of this work and any proposed remedial control actions will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Temperature

Continuous water quality monitoring results suggest that temperatures in TTF sometimes exceed maximum WQ criteria and therefore is a parameter of potential concern. But increases of 2°F over a one hour period are common due to natural temperature fluctuations. Flow modifications have probably reduced the influence of groundwater on baseflow water temperature. Dam construction and riparian buffer removal have also probably resulted in enhanced solar heating of stream water.

3.4.2.1.3 Biological Assessment of the TTF Watershed

Though TTF Watershed fish and benthic macroinvertebrate data suggest that many taxa have been extirpated or nearly extirpated in the past century, historical information to support these findings is generally lacking. There are simply no data to indicate what the biological communities of TTF Watershed looked like prior to changes wrought by man. While some measures of community structure (e.g., diversity indices) may provide meaningful information alone, conclusions of most analyses and metrics are enhanced by, or require, comparison to an unimpaired reference site. These unimpaired reference sites are often difficult to identify in southeast Pennsylvania due to extensive development and agricultural land uses. The most robust application of the reference site approach is a pair of sites located upstream and downstream of a suspected source of impairment. The downstream site in this scenario can be assumed to have a rather constant source of colonists, or "drift" from the upstream site, and all life stages of fish and macroinvertebrates are prone to displacement from the upstream site to the downstream site.

As applied to TTF Watershed, reference site-based biological indexing methods assume that all similar habitats within a given ecoregion will have similar communities (absent major stressors) and that recovery of biological communities, particularly benthic macroinvertebrate communities, will occur quickly once stressors are removed. However, in regions where impairments occur watershed-wide and most first order streams have been eliminated, one cannot assume that study sites have a constant upstream source of colonists. Therefore, the most likely means of colonization of TTF Watershed by rare or extirpated macroinvertebrate taxa is by winged adults, and the most likely means of re-colonization by rare or extirpated fish taxa is by passive dispersal (i.e., purposeful or incidental inter-basin transfer by man).

TTF Watershed is at the center of a region of widespread impairment due to urbanization. Some areas of the watershed may have water quality suitable for re-establishment of pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT), but these taxa are generally much more abundant west of the Schuylkill River than in the Philadelphia region. Sites in TTF Watershed were compared to reference sites on French Creek and Rock Run in Chester County, PA (Figure 3-48 and Appendix F of the TTF CCR).

Reference sites were chosen to represent a range of stream drainage areas, yet extensive impervious cover in portions of TTF Watershed complicates these comparisons. Due to baseflow suppression, piping of tributaries, exaggerated storm flows and widespread erosion, sites in the urbanized TTF Watershed are difficult to categorize according to traditional frameworks (e.g., stream order, link magnitude, drainage area, geomorphological attributes). These details are addressed in greater detail in Section 7.1 Habitat Assessment of the TTF CCR. TTF Watershed is only linked to the tidal Delaware River and is considered a warm water stream, while the reference sites have better connectivity and are classified as trout stocking fisheries or high quality trout stocking fisheries.

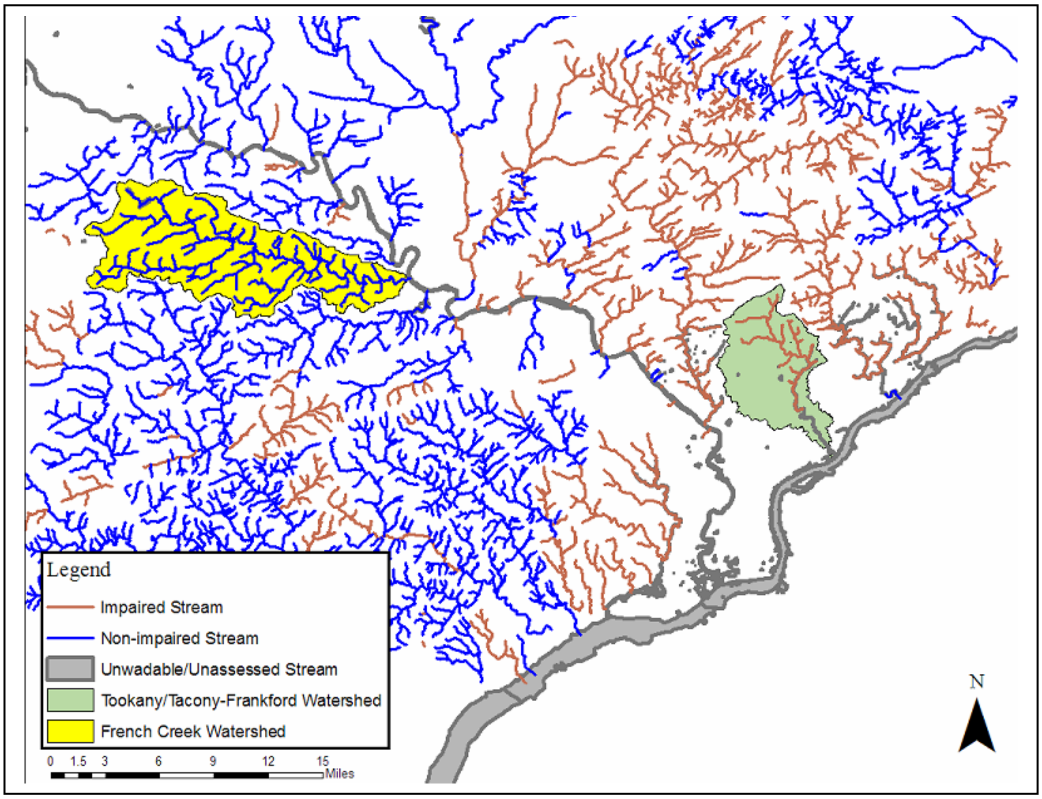


Figure 3-48 Southeastern PA stream segments in TTF Watershed, French Creek Watershed, and the surrounding region showing attainment status from PADEP 2004 List of Waters (formerly 303d list). (TTF CCR section 6.2 figure 6.1 page 6-3)

Benthic Macroinvertebrates Assessment

A total of 2,137 individuals from 19 taxa were identified during the 2004 benthic macroinvertebrate survey of TTF Watershed. The average taxa richness of the watershed was 7. Overall, moderately tolerant (91%) and generalist feeding taxa (96%) dominated the watershed. The average Hilsenhoff Biotic Index (HBI) of all assessment sites was 6.16. EPT taxa were absent throughout the watershed (Table 3-71). One site had one modified EPT taxon present. Modified EPT taxa are EPT taxa with Hilsenhoff Biotic Index score less than or equal to four. Seven of 12 sites included in the present study were sampled by PWD in November 2000 using the same protocols, allowing some rough comparisons to be made. Most sites had reduced taxa richness and metric scores compared to year 2000 samples.

Chironomidae (midges) dominated the benthic macroinvertebrate communities within the watershed (percent contribution ranged from 63% to 97%). Net-spinning caddisflies (Hydropsychidae), isopods, amphipods, tipulids, gastropods, and oligochaetes were also present throughout the watershed but in very low abundance. Benthic macroinvertebrate communities of TTF Watershed are thoroughly dominated by midges, suggesting stressors are affecting survival of more sensitive taxa.

Tolerance/intolerance measures are intended to be representative of relative sensitivity to perturbation and may include numbers of pollution tolerant and intolerant taxa or percent composition (Barbour *et al.* 1999). Moderately tolerant individuals (91%) dominated

Table 3-71 Summary of Benthic Macroinvertebrate Metric Scores from 12 sites in TTF Watershed and Reference Sites in French Creek Watershed, Spring 2004 (TTF CCR section 6.4 table 6.4 page 6-15)

Site	Taxa Richness	Modified EPT Taxa	Hilsenhoff Biotic Index (modified)	Percent Dominant Taxon	Percent Modified Mayflies	Biological Quality (%)	Biological Assessment	Habitat Quality (%)	Habitat Assessment
TF324	6	0	8.92	72.15 (*Tubificidae*)	0.00	0.00	Severely Impaired	31.84	Non-Supporting
TF396	13	0	5.79	63.31 (*Chironomidae*)	0.00	0.00	Severely Impaired	74.53	Supporting
TF500	4	0	5.98	96.99 (*Chironomidae*)	0.00	0.00	Severely Impaired	62.03	Partially Supporting
TF620	5	0	5.96	96.11 (*Chironomidae*)	0.00	0.00	Severely Impaired	72.41	Partially Supporting
TF827	6	0	5.94	95.22 (*Chironomidae*)	0.00	0.00	Severely Impaired	58.25	Non-Supporting
TF975	8	0	5.94	89.09 (*Chironomidae*)	0.00	0.00	Severely Impaired	54.95	Non-Supporting
TF1120	5	0	6.04	95.58 (*Chironomidae*)	0.00	0.00	Severely Impaired	58.02	Non-Supporting
TF1270	7	0	5.91	91.79 (*Chironomidae*)	0.00	0.00	Severely Impaired	48.03	Non-Supporting
TFU010	8	0	5.99	93.12 (*Chironomidae*)	0.00	0.00	Severely Impaired	48.46	Non-Supporting
TFM006	5	0	5.94	95.59 (*Chironomidae*)	0.00	0.00	Severely Impaired	38.60	Non-Supporting
TFR064	9	0	5.93	89.25 (*Chironomidae*)	0.00	0.00	Severely Impaired	64.69	Partially Supporting
TFJ013	11	1	5.57	63.24 (*Chironomidae*)	0.00	20.00	Moderately Impaired	60.53	Partially Supporting
FCR025	25	10	4.47	42.24 (*Chironomidae*)	27.44	Reference Sites			
FC1310	21	9	3.69	21.60 (*Hydropsyche*)	13.59				

macroinvertebrates communities of TTF Watershed. Sensitive taxa were poorly represented (2%), suggesting watershed-wide perturbation.

The Hilsenhoff Biotic Index (HBI) is a metric used to determine the overall pollution tolerance of a site's benthic macroinvertebrate community. The HBI is oriented toward the detection of organic pollution. The HBI can range from zero (very sensitive) to ten (very tolerant). Differences in HBI score between reference and assessment sites greater than 0.71 indicate impairment. Mean HBI score of sites within TTF Watershed was 6.16. Dominance by moderately tolerant individuals and general lack of pollution-sensitive taxa contributed to the elevated HBI. In comparison, the mean reference site HBI score was 4.08. When compared to reference conditions, TTF Watershed mean HBI exceeded reference site mean HBI by 2.08, indicating severe impairment overall.
While HBI is very effective in determining whether a site is impaired relative to a reference site, HBI scores are not very useful in comparing impaired urban sites to one another, as these systems typically have one to three dominant taxa with similar HBI scores. For example, 90% of benthic macroinvertebrate samples collected by PWD in urban streams had HBI scores between 5 and 6.

This lack of resolution is exacerbated when chironomids are not identified beyond the family level, as has been PWD practice.

Fish Assessment

During the 2004 Tacony-Frankford Watershed fish assessment, PWD collected a total of 9774 individuals representing 17 species in 7 families. Blacknose dace (*Rhinichthys atratulus)* and mummichog (*Fundulus heteroclitus),* two taxa extremely tolerant of poor stream conditions, were most abundant and comprised over half (56%) of all fish collected. Other common species included white sucker (*Catostomus commersoni*), satinfin shiner (*Cyprinella analostana*), banded killifish (*Fundulus diaphanus*), and swallowtail shiner (*Notropis procne*). Of 17 species collected in the watershed, four species comprised over 80% of the entire fish assemblage. Similarly, five species made up greater than 80% of the total fish biomass, with redbreast sunfish (*Lepomis auritus*) and American eel (*Anguilla rostrata*) contributing 42% of the biomass. American eel, blacknose dace, and satinfin shiner were found at all sites while bluegill sunfish (*Lepomis macrochirus*) and green sunfish (*L. cyanellus*) were each only found at one site and represented by a single individual. Two individual tessellated darters (*Etheostoma olmstedi*) were collected at two different sites (TF500, TF620) in the watershed; however, scientists from the Academy of Natural Sciences of Philadelphia likely stocked these fish as part of a reintroduction effort. The presence of only one tessellated darter at each site suggests that they have not become established and therefore were not included in the scoring criteria for the Index of Biotic Integrity. Overall, the non-tidal TTF Watershed displayed the lowest fish diversity (*i.e.*, species richness) of all the watersheds in Philadelphia.

Trophic composition evaluates quality of the energy base and foraging dynamics of a fish assemblage. This is a means to evaluate the shift towards more generalized foraging that typically occurs with increased degradation of the physicochemical habitat (Barbour, *et al.*, 1999). For example, the Tacony-Frankford fish assemblage was dominated by generalist feeders (69%) with insectivores composing 30% and top carnivores at less than 1% (Table 3-72). Generalists become dominant and top carnivores become rare when certain components of the food base become less reliable (Halliwell *et al.*, 1999). Relative abundance of insectivores decreases with degradation in response to availability of the insect supply, which reflects alterations of water quality and instream habitat (Daniels, *et al.* 2002). The near absence of insectivores in the two upstream-most sites illustrates this point. Trophic composition was poor compared to reference sites. Though community composition varied between sites, the fish assemblage in TTF Watershed was highly skewed towards a pollution tolerant, generalist feeding community.

Tolerance designations describe the susceptibility of a species to chemical and physical perturbations. Intolerant species are typically first to disappear following a disturbance (Barbour, *et al.*, 1999). For example, at least 70% of the fish collected at each monitoring station in TTF Watershed were classified as "tolerant", and no "intolerant" species were collected (Figure 3-49). Moderately tolerant individuals were absent from the lowermost (TF280) and uppermost (TF1120) stations, and represented less than one percent (TF396) to 29% (TF500) of the assemblage at the remaining five sites. Furthermore, with approximately 91% of the fish assemblage composed of tolerant individuals, this watershed had the greatest percentage of fishes tolerant of poor stream conditions in all of Philadelphia's watersheds.

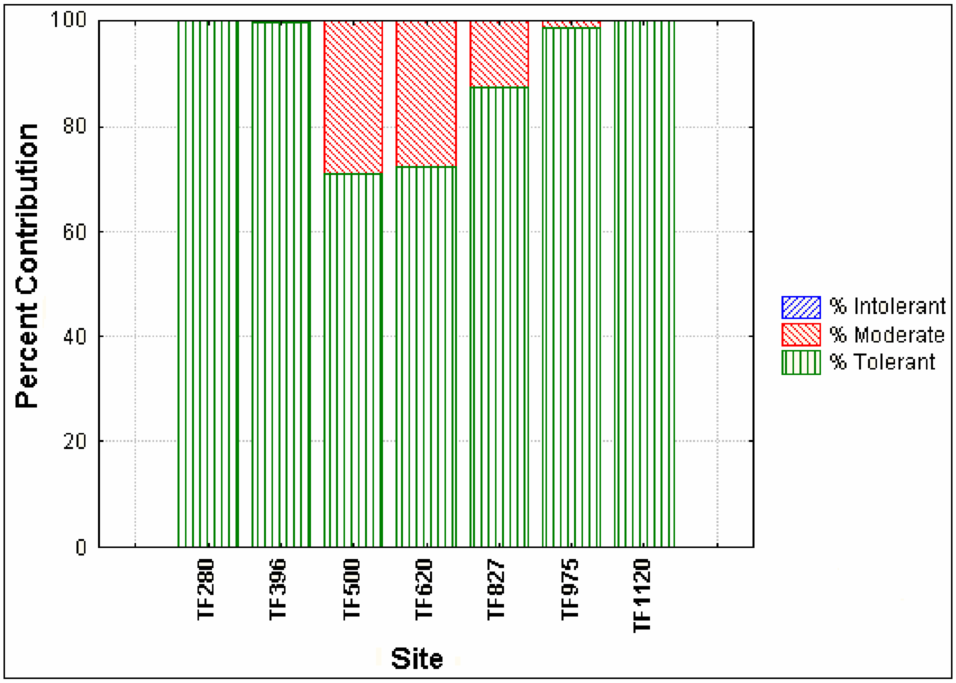


Figure 3-49 Fish Tolerance Composition of the TTF Watershed (TTF CCR section 6.3 figure 6.3 page 6-7)

The Index of Biotic Integrity (IBI) is useful in determining long-term effects and coarse-scale habitat conditions because fish are relatively long-lived and mobile. A site with high integrity (*i.e.* high score) is associated with communities of native species that interact under natural ecosystem processes and functions (Karr, 1986). Since biological integrity is closely related to environmental quality, assessments of integrity can serve as a surrogate measurement of health (Daniels, *et al.* 2002). The mean IBI score for TTF Watershed was 21 (out of 50), placing it in the "poor" category for biotic integrity. Low diversity, absence of benthic insectivorous species, absence of intolerant species, skewed trophic structure dominated by generalist feeders, high percentage of individuals with disease and anomalies, and high percentage of dominant species are characteristics of a fish community with "poor" biotic integrity. Spatial trends showed that only two sites received a "fair" IBI score, both centrally located within the watershed. Similar spatial trends were seen in Modified Index of Well-Being and Shannon Diversity Index values, which are measures of diversity and abundance. These indices were lowest in the lower and upper monitoring stations and highest in the middle of the watershed. This was to be expected because diversity is typically lower in upstream/smaller reaches of southeast Pennsylvania (Whiteside and McNatt, 1972; Platts, 1979). Overall, monitoring stations in the central portion of the watershed had higher biological integrity than downstream and upstream stations.

Table 3-72 Fish Community Attributes, Sampling Information, and Metric Scores for 7 Sites in TTF Watershed and 3 Reference Sites in French Creek Watershed (TTF CCR section 6.3 table 6.2 page 6-8)

Metric	FC472	FC1310	FCR025	TF324	TF396	TF500	TF620	TF827	TF975	TF1120	Avg(TF)
Total Number of Fish Species*	22	18	18	6	9	13	12	9	10	5	9
Number of Benthic Insectivorous Species**	5	4	3	0	0	0	0	0	0	0	0
Number of Water Column Species	3	5	2	2	4	6	5	3	3	1	3
Number of Intolerant/Sensitive Species	3	4	3	0	0	0	0	0	0	0	0
Percent White Sucker	7.50	11.39	2.90	0.12	0.00	0.74	4.00	12.35	16.23	0.80	5
Percent Generalists	34.58	53.42	57.56	98.65	92.59	26.08	36.00	66.20	97.90	99.08	74
Percent Insectivores	37.56	35.02	38.77	1.11	7.33	72.11	63.41	31.47	1.81	0.10	25
Percent Top Carnivores	27.86	11.56	3.67	0.25	0.08	1.81	0.59	2.33	0.29	0.82	1
Percent Individuals with Disease and Anomalies	6.97	2.83	14.54	2.34	4.36	3.57	4.49	5.71	8.78	8.98	5
Percentage of Dominant Species	14.40	14.98	29.70	98.40	90.62	37.81	37.22	41.00	79.33	86.50	67
IBI Score	Reference Streams			16	20	34	30	22	14	14	21
Integrity Class				POOR	POOR	FAIR	FAIR	POOR	POOR	POOR	POOR
Area (m^2)	1420.14	1192.50	400.00	1972.71	1123.52	1046.19	1208.14	1327.33	1163.05	630.81	1210
Density (# Individuals/m^2)	0.28	0.98	1.70	0.41	1.08	1.69	1.70	0.65	1.80	1.55	1
Number Of Individuals	402.00	1168.00	681	813.00	1215.00	1763.00	2050.00	858.00	2095.00	980.00	1396
Total Biomass (g)	17612.56	9413.91	5040	4917.13	1219.66	13267.95	16001.37	9939.68	11270.18	7183.74	9114
Biomass per m^2	12.40	7.89	12.60	2.49	1.09	12.68	13.24	7.49	9.69	11.39	8
Modified Index Of Well-Being (MIwb)	12.21	12.21	11.37	0.00	2.71	10.22	10.58	9.37	6.75	0.00	6
Shannon-Weiner Diversity Index (H')	2.84	2.51	2.10	0.10	0.44	1.29	1.41	1.45	0.70	0.46	1
Number of Cyprinid Species	9	10	8	2	4	7	7	5	5	3	5
Percent Resident Species	92.54	100.00	99.12	100.00	100.00	100.00	99.95	99.88	99.95	100.00	100
Percent Introduced/Exotic Species	7.46	0.00	0.88	0.00	0.00	0.00	0.05	0.12	0.05	0.00	0
Percent Tolerant Fish	35.32	29.45	45.23	100.00	99.67	71.09	72.34	87.53	98.57	100.00	90
Percent Moderately Tolerant Fish	48.76	61.30	24.82	0.00	0.33	28.91	27.66	12.47	1.43	0.00	10

Metric	FC472	FC1310	FCR025	TF324	TF396	TF500	TF620	TF827	TF975	TF1120	Avg(TF)
Percent Intolerant Fish	15.92	9.25	29.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total Electrofishing Time (min)	62.28		77.23	77.43	61.68	61.44	67.87	50.62	61.76	42.32	60
Catch per Unit Effort (# Individuals/min)	6.45		8.82	10.50	19.70	28.71	30.21	16.95	33.92	23.16	23
Stream Order	4	3	2	3	3	3	3	3	3	3	

*"Total # of fish species" metric excluded non-resident fish and tessellated darter (recently introduced)

**"Number of benthic insectivorous species" metric excluded tessellated darter (recently introduced)
excluded from MIwb were brown bullhead, American eel, white sucker, satinfin shiner, spotfin shiner, green sunfish, bluegill sunfish, blacknose dace, banded killifish, mummichog, and common shiner.

3.4.2.1.4 Habitat Assessment of the TTF Creek Watershed

Habitat features at twelve TTF Watershed sites were compared to those of the reference sites located in nearby Chester County. Mainstem and third order tributary sites were compared to French Creek reference sites, located in Coventry Township, Chester County, PA. Tributary sites, second order or less, were compared to Rock Run, a tributary to French Creek located in Coventry Township, Chester County, PA (Figure 3-48, also see Appendix F of the TTF CCR). In general, habitat was determined to be very poor, with seven of twelve sites designated "non-supporting" of the watershed's designated uses. Five sites, including three in Tacony Creek Park in the City of Philadelphia, had slightly better scores and were designated "partially supporting". Habitat degradation was considered to be the most important impairment in TTF Watershed, corroborating the results of biotic indexing. Figure 3-50 and Table 3-73 summarize the results of habitat assessment using USEPA habitat assessment protocols.

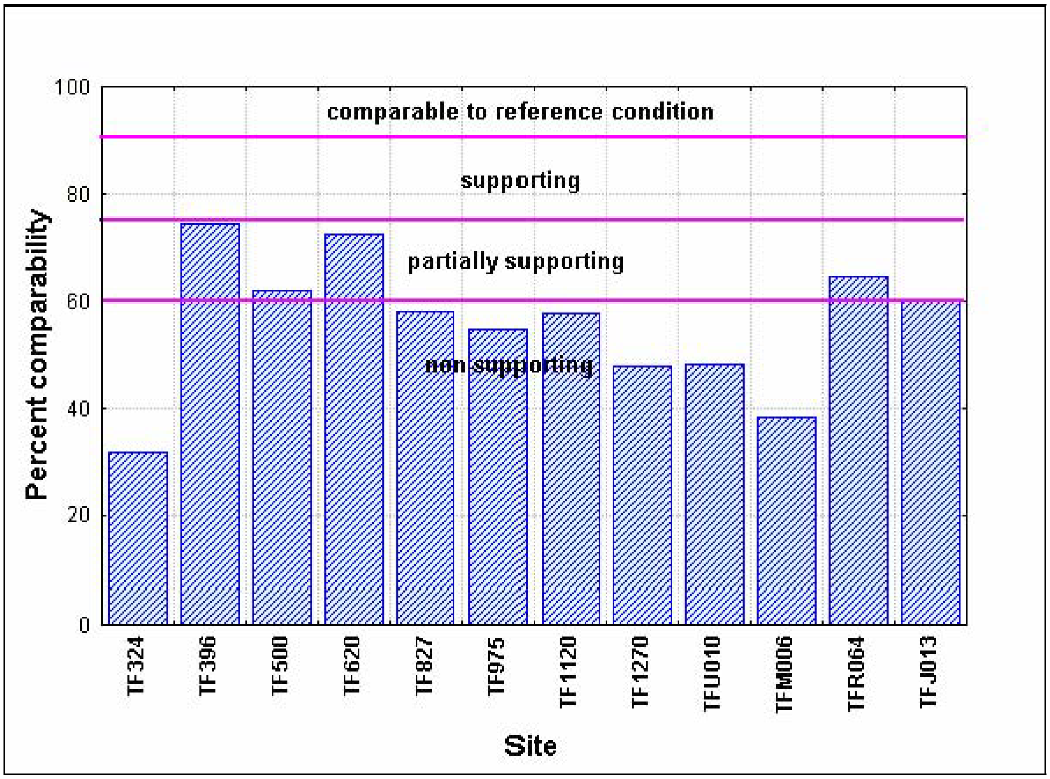


Figure 3-50 USEPA Habitat Assessment Percent Comparability to Reference Sites (TTF CCR section 7.2 figure 7.3 page 7.3)

Table 3-73 USEPA Physical Habitat Assessment Results for 12 Sites in TTF Watershed, Spring 2004 (TTF CCR section 7.2 table 7.1 page 7-4)

	Scores by Site											
Attribute	**TF324**	**TF396**	**TF500**	**TF620**	**TF827**	**TF975**	**TF1120**	**TF1270**	**TFJ013**	**TFM006**	**TFR064**	**TFU010**
Epifaunal Substrate/Available Cover	3	12.5	9.5	11	8.5	8	10	6.5	10.5	5	7.5	6
Pool Substrate	3	11	9.5	10.5	9	8.5	7	6.5	9	6	6	6
Pool Variability	4.5	11.5	9	9.5	8.5	6.5	10	5	12	2.5	4.5	2
Sediment Deposition	12	9	7	8	10	10	7.5	6.5	11	5.5	13.5	9
Channel Flow Status	8.5	11	7.5	12	9	9.5	7	8.5	11	7.5	8	7.5
Channel Alterations	1.5	16.5	12.5	16	10	9.5	8	11.5	6.5	6.5	14.5	12.5
Sinuosity	1	13	9	10.5	9.5	10.5	12	8.5	13.5	7.5	10	6.5
Bank Stability (Left Bank)	4	6	6.5	6	6	6.5	6	7.5	5	6	7.5	6.5
Bank Stability (Left Bank)	1.5	5	6	5.5	1	3.5	6	6	4	6.5	5	3.5
Vegetative Protection (Left Bank)	3.5	4.5	4.5	6	5	6	5	5	5.5	2	7.5	6.5
Vegetative Protection (Right Bank)	3	7	4	5.5	2	4	5	5	4	2	7.5	3.5
Riparian Zone Width (Left Bank)	1.5	5	5	7.5	3	3	4.5	4	4	2	8	5
Riparian Zone Width (Right Bank)	3.5	9	5	7.5	6	3.5	2	4.5	4	2	4.5	3.5
Embeddedness	3.5	11.5	9	14	9	10	8.5	8	12	8	15	9.5
Velocity/Depth Regime	8.5	13	16	14	14	8	13	8.5	13.5	8	12	8
Frequency of Riffles/Bends	5	12.5	11.5	10	13	9.5	11.5	8	12.5	11	16.5	15
Total	**67.5**	**158**	**131.5**	**153.5**	**123.5**	**116.5**	**123**	**109.5**	**138**	**88**	**147.5**	**110.5**

3.4.2.2 Darby-Cobbs Creek Watershed Characterization

Cobbs Creek is a receiving water body of combined sewer overflows. Cobbs Creek is located in Darby-Cobbs Creek Watershed (Figure 3-51). After a series of technical memos characterized Darby-Cobbs Creek Watershed (2000-2001), a Comprehensive Characterization Report (CCR) was completed for Darby-Cobbs Creek Watershed in 2002 and updated in 2004. These reports fully document the baseline conditions and lay the groundwork for future CSO planning and watershed management. Although the findings of the CCR are summarized in this section of the LTCPU, these reports extensively describe the land use, geology, soils, topography, demographics, meteorology, hydrology, water quality, ecology, fluvial geomorphology, and pollutant loads found in the watershed. The CCR provides the scientific basis for Cobbs Creek Integrated Watershed Management Plan (2004) (IWMP). The management plan guides the Philadelphia Water Department's efforts to restore and protect the designated uses described in Section 3.4.1. The IWMP and Comprehensive Characterization Report (CCR) can both be located at www.phillyriverinfo.org. Table 3-74 includes the titles and links to other reports that can be referenced for more detailed characterizations of the Darby-Cobbs Creek Watershed.

Table 3-74 Existing Documents Relevant to Characterization of Cobbs Creek Watershed

File Name	Year Published
Darby-Cobbs Creek Watershed Update (1st Annual Report)	2007
Southeast Regional Wetland Inventory and Water Quality Improvement Initiative: Cobbs Creek Watershed	2006
Darby-Cobbs Creek Comprehensive Characterization Report Update	2004
COBBS CREEK RESTORATION PROJECT: Baseline for Evaluating the Benefits of FGM-Based Stream Restoration in Cobbs Creek	2003
Geomorphologic Survey – Level II Guiding Principles for Fluvial Geomorphologic Restoration	2003
Darby-Cobbs Creek Watershed Comprehensive Characterization Report	2002
Inventory and Assessment of Existing Wetlands Within the Lower Cobbs Creek	2000

Darby-Cobbs Creek Watershed is defined as the land area that drains to the mouth of Darby Creek at the Delaware Estuary, encompassing approximately 80 square miles of southeast Pennsylvania (Figure 3-51). This area includes the drainage area of Cobbs Creek, Darby Creek, and Tinicum subwatersheds.

Cobbs Creek drains approximately 14,500 acres or 27% of the total Darby-Cobbs-Tinicum Watershed area. The upper portions and headwaters of Cobbs Creek, including East and West Branch Indian Creek, include portions of Philadelphia, Montgomery, and Delaware Counties. The lower portion of Cobbs Creek watershed, including the lower main stem and Naylors Run, drains parts of Philadelphia and Delaware Counties. Cobbs Creek discharges to Darby Creek. Within Cobbs Creek Watershed, combined sewers service over 20% of the drainage area. The City of Philadelphia has 38 CSOs and 3 major stormwater outfalls within Cobbs Creek Watershed.

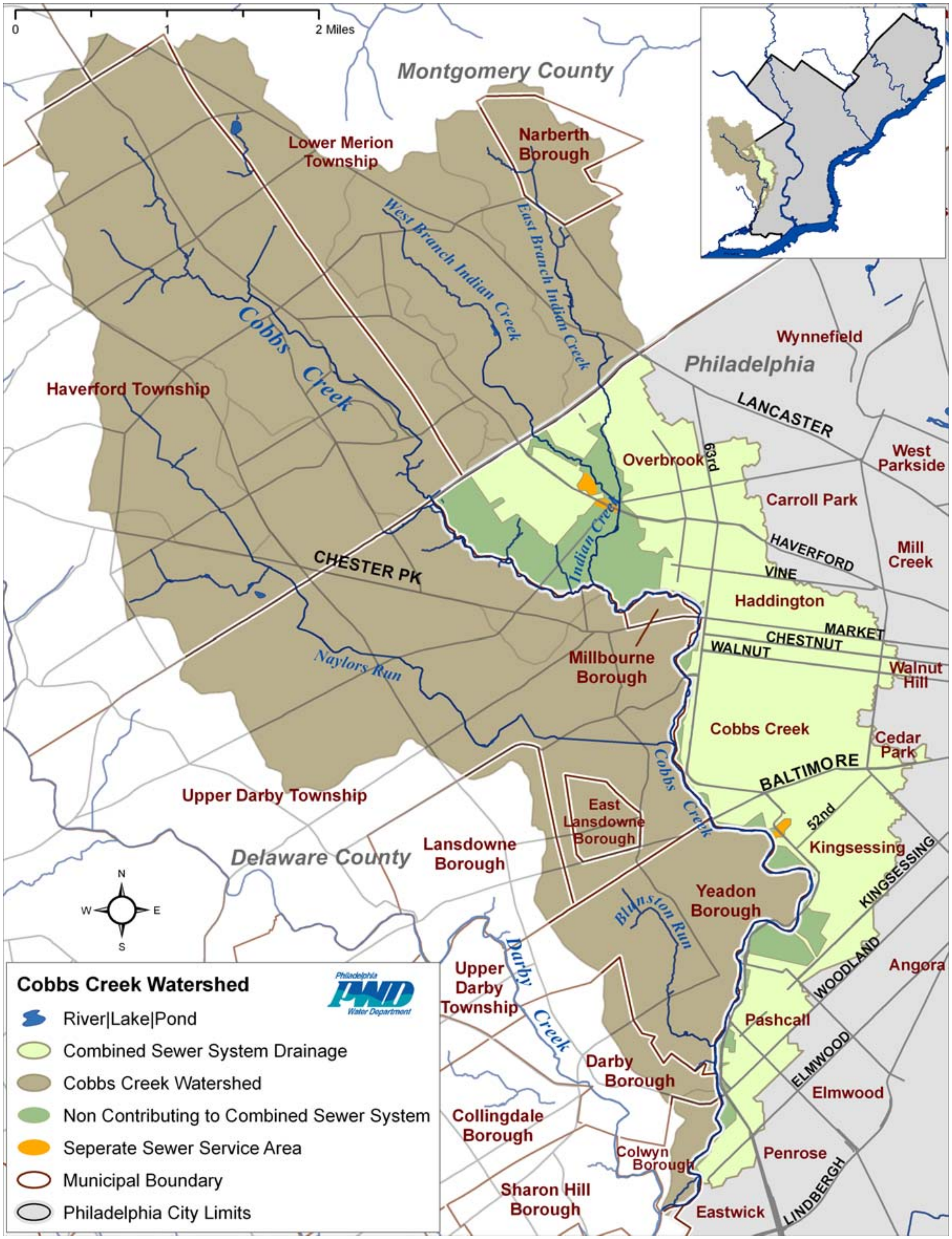


Figure 3-51: Cobbs Watershed

Darby Creek watershed drains approximately 29,000 acres or 55% of the total study area. The watershed is located primarily in Delaware County. The northwest corner of the watershed, including the headwaters of the main stem, is located in Chester County. Darby Creek has a number of small tributaries, including Little Darby Creek, Ithan Creek, and Foxes Run.

Darby-Cobbs Creek watershed discharges to Delaware River through the wetlands of Tinicum Refuge. Tinicum watershed includes portions of Philadelphia and Delaware Counties and totals 9800 acres or 18% of the total. Much of the area consists of low-lying wetlands, including the John Heinz National Wildlife Refuge. Named streams in the subwatershed include Hermesprota, Muckinipattis, and Stony Creeks.

Municipalities and Demographics
Darby-Cobbs Creek Watershed includes portions of Chester, Delaware, Montgomery, and Philadelphia Counties. The smaller Cobbs Creek Watershed does not include Chester County, but does include the other three counties. Figure 3-51 includes the watershed boundaries, hydrologic features, and municipal boundaries of Cobbs Creek Watershed.
Population density and other demographic information in the watershed are available from the results of the 2000 census. Approximately 104,000 people live within the drainage area of Cobbs Creek combined sewer area. Spatial trends in population correspond closely to land use, with multi-family row homes displaying the greatest population density of 20 people per acre or more, single-family homes displaying a lower density, and other land use types displaying the lowest density (Figure 3-52). The average population density is 23,436 people per square mile in the area that contributes to Cobbs Creek combined sewer service area.

Land Use
Figure 3-53 shows land use patterns in Cobbs Creek Watershed Combined Sewer Area. The area consists primarily of residential areas (73% of combined sewer area), almost all rowhouses (67% of combined sewer area). Parklands represent approximately 4%, and 5% of the combined sewer area is wooded. The area contributing to the combined sewer system is calculated to be 67% impervious.

Pollution Sources
In addition to CSO discharges to Cobbs Creek from the City of Philadelphia, the drainage area receives a significant amount of point and non-point source discharges that impact water quality. These sources include Municipal and Industrial Process Water Discharges, Sanitary Sewer Overflows (SSOs), Stormwater and Urban Drainage, septic tank, and atmospheric deposition. More detail on these sources is included in the 2002 Comprehensive Characterization Report and the 2004 Update.

Additionally, more detailed information including watershed geology, hydrology, topography, wetlands, infrastructure features, history, cultural features, zoning, and ordinances can be found in Darby-Cobbs Creek Watershed CCR.

Receiving Waterbody Characterization
The Combined Sewer Area contains 11.7 miles of tributaries to Cobbs Creek and almost 6 miles of historic streams that are now encapsulated in pipes below the city's surface.

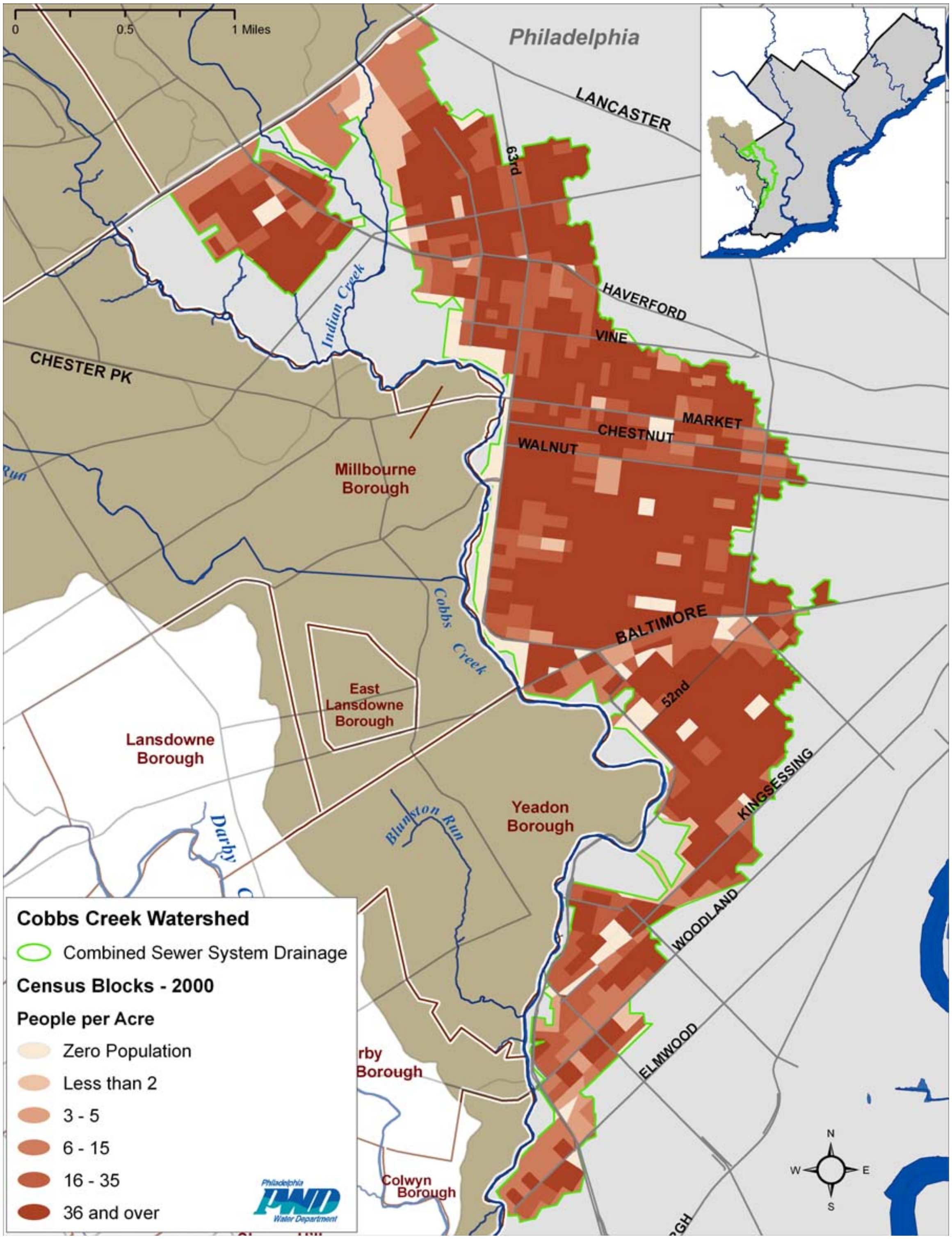


Figure 3-52: Population Density in Cobbs Combined Sewer Area

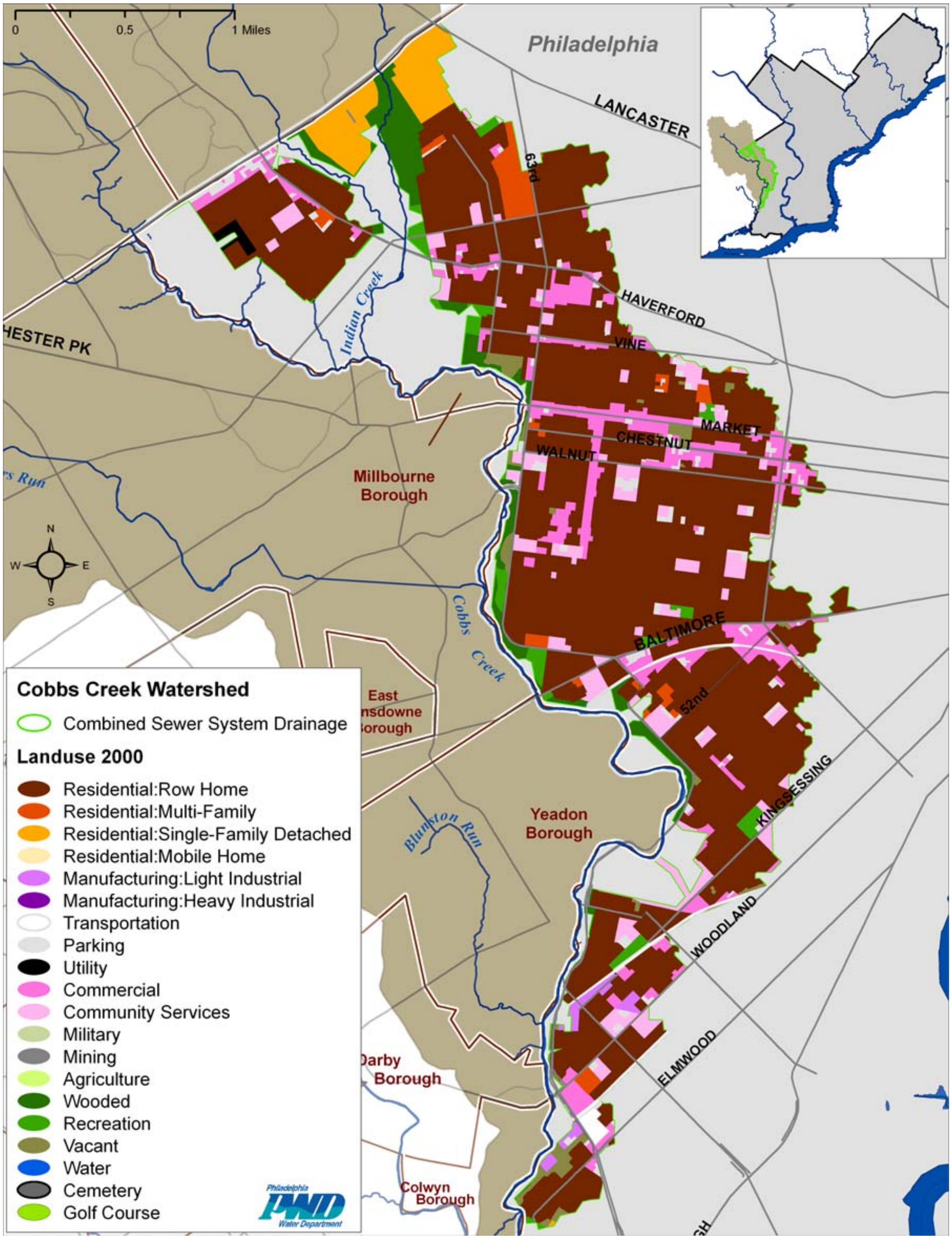


Figure 3-53: Land Use of the Combined Sewer Area in Cobbs Creek Watershed

3.4.2.2.1 Darby-Cobbs Creek Hydrologic Characterization

Components of the Urban Hydrologic Cycle

A water balance conducted for Darby-Cobbs Creek watershed is summarized in this section of the LTCPU and fully described in detail in Darby-Cobbs Creek Watershed CCR (2002).

Cobbs Creek Water Cycle Component Tables

The relevant components of the urban water cycle have been estimated for Darby-Cobbs watershed. Outside Potable Water is assumed to balance Outside Wastewater Discharges, with stormwater and CSO's considered as part of the Runoff component of the water cycle. Tables 3-75 and 3-76 show the results of the analysis, first in inches per year, then in million gallons per day. The inches per year figure simply takes all the flows over an average year, and divides by the area of the watershed. The million gallons per day table takes all the flows over an average year, and divides by 365 days to get an "average" day value.

Table 3-75: Water Budget Components (in/yr) (D-C CCR 2002 section 4.2 table 4-5 page 4-12)

		Inflow		Outflow		
	Period of Record	P	EDR	RO	BF	ET+Error
Cobbs Creek	1964 - 1990	42.1	0.05	10.6	8.1	23.4
Darby Creek	1964 - 1990	42.1	0.11	8.9	14.4	18.9

Table 3-76: Water Budget Components (MGD) (D-C CCR 2002 section 4.2 table 4-6 page 4-12)

	Period of Record	Inflow		Outflow		
		P	EDR	RO	BF	ET + Error
Cobbs Creek	1964-1990	44.4	0.06	11.2	8.6	24.7
Darby Creek	1964-1990	79.6	0.2	16.8	27.3	35.7

- ***ET*** is the evaporation and transpiration of water and is used to close the equation. It thus contains the sum of errors of the other terms as well as the estimated ET value.
- ***EDR*** is the estimated domestic recharge from private septic systems,
- ***RO*** is the surface water runoff component of precipitation,
- ***BF*** is the median baseflow of streams,
- ***P*** is the average precipitation at the Philadelphia gage

Hydrograph Decomposition Analysis

Areas and Gauges Studied

As discussed above, Cobbs Creek watershed and the lower portions of Darby Creek watershed are highly urbanized and contain a large proportion of impervious cover. The hydrologic impact of urbanization can be observed through analysis of streamflow data taken from USGS gauges on

Darby and Cobbs Creeks. In addition, data from French Creek in Chester County provide a picture of a nearby, less-developed watershed. Table 3-77 lists four gauges with available data, including their locations, periods of record, and drainage areas.

Table 3-77: Data Used for Baseflow Separation (D-C CCR 2002 section 4.3.2 table 4.8 page 4-19)

Gauge	Name	Period of Record (yrs)	Drainage Area	N	2N*
			(Sq. mi.)	(days)	(days)
01472157	French Creek near Phoenixville Pa.	33.0	59.1	2.26	5
01475550	Cobbs Creek at Darby Pa.	26.7	22.0	1.86	3
01475510	Darby Creek near Darby Pa.	26.7	37.4	2.06	5
01475300	Darby Creek at Waterloo Mills Pa.	25.4	5.15	1.39	3

The interval 2N* used for hydrograph separations is the odd integer between 3 and 11 nearest to 2N. N is calculated based on watershed area.

Summary Statistics

The results of the hydrograph decomposition exercise support the relationships between land use and hydrology discussed above. For convenience, the flows in Tables 3-78 and 3-79 are expressed as a mean depth (flow per unit area) over a one-year time period. Based on the French Creek gauge and the two Darby Creek gauges, the hydrologic behavior of these two systems is similar. Effective impervious cover allows sufficient groundwater recharge to give streamflow relatively natural characteristics; a mean of approximately 20% of annual rainfall contributes to the stormwater component of streamflow, and baseflow represents approximately 65% of total annual streamflow. This is fairly typical of streams in the Piedmont Province. Cobbs Creek exhibits behavior typical of a highly urbanized stream, with over 25% of rainfall contributing to stormwater runoff in a mean year and with mean baseflow comprising only 43% of mean annual streamflow.

Table 3-78: Summary of Hydrograph Separation Over the Period of Record (D-C CCR 2002 section 4.3.2 table 4-9 page 4-21)

Gauge	Mean Total Flow (in/yr)	Mean Baseflow (in/yr)	Mean Runoff (in/yr)	Baseflow (% of Total Flow)	Runoff (% of Rainfall)
French Creek 01475127	20.3	12.9	7.4	64	18
Cobbs Creek 01475550	18.8	8.1	10.7	43	26
Darby Creek D/S 01475510	23.3	14.5	8.9	62	21
Darby Creek U/S 01475300	23.7	15.6	8.1	66	20

Table 3-79: Annual Summary Statistics for Baseflow and Stormwater Runoff (D-C CCR 2002 section 4.3.2 table 4-10 page 4-21)

	Baseflow (in/yr)				Runoff (in/yr)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	12.9	20.8	5.8	3.8	7.4	15.4	2.9	3.1
Cobbs Creek 01475550	8.1	16.1	1.8	3.6	10.7	15.6	5.2	2.7
Darby Creek D/S 01475510	14.5	21.4	7.6	4.0	8.9	15.6	3.6	2.9
Darby Creek U/S 01475300	15.6	26	8.0	4.3	8.1	16.7	3.8	2.9

	Baseflow (in/yr)				Runoff (in/yr)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	31%	44%	15%	7%	17%	30%	7%	5%
Cobbs Creek 01475550	19%	31%	5%	7%	25%	33%	18%	3%
Darby Creek D/S 01475510	34%	44%	20%	8%	21%	31%	12%	4%
Darby Creek U/S 01475300	37%	51%	18%	9%	19%	32%	10%	5%

	Baseflow (% of Annual Total Flow				Runoff (% of Annual Total Flow)			
	Mean	Max	Min	St.Dev.	Mean	Max	Min	St.Dev.
French Creek 01475127	64%	75%	53%	5%	36%	47%	25%	5%
Cobbs Creek 01475550	42%	54%	16%	10%	58%	84%	46%	10%
Darby Creek D/S 01475510	62%	75%	54%	6%	38%	46%	25%	6%
Darby Creek U/S 01475300	66%	78%	50%	6%	34%	50%	22%	6%

As expected, the quantity of stormwater runoff on a unit-area basis follows patterns of impervious cover in the drainage area. The French Creek watershed, the least developed, has the smallest amount of stormwater runoff both as an annual mean quantity (7.4 in) and as an annual mean percent of rainfall (17%). As expected, the highly-developed Cobbs Creek watershed has the most runoff both as an annual mean quantity (10.7 in) and as an annual mean percent of rainfall (25%). Further highlighting the effects of development, mean runoff from Cobbs basin is almost 50% greater than mean runoff in the French Creek basin. The two Darby Creek gauges have an intermediate quantity of stormwater runoff; the downstream gauge, representing most of Darby basin, has slightly more runoff (8.9 in) on a unit-area basis than the gauge representing the less-developed headwaters (8.1 in).
The summary statistics for stormwater runoff in Table 3-79 present some interesting results. The standard deviation of annual stormwater flows for Cobbs Creek, both in inches (2.7 in) and as a percentage of rainfall (3%), is the lowest of the four gauges studied, indicating that these flows are less variable from year to year. A possible explanation for this pattern is that the capture of some stormwater as part of combined sewage reduces the variability of runoff reaching streams.

The magnitude of groundwater-derived stream baseflow also depends on impervious cover because pervious areas are necessary for groundwater to recharge. As expected, the unit-area Cobbs Creek baseflows (8.1 inches) shown in Table 3-79 are smaller than those in either Darby Creek (15.6 inches upstream, 14.5 inches downstream) or French Creek (12.9 inches). Baseflow is between 62% and 66% of mean annual streamflow in Darby and French Creeks and only 43% of mean baseflow in Cobbs Creek. Although Darby Creek watershed contains more impervious cover than the French Creek watershed, it has higher mean baseflows on a unit-area basis. The most likely explanation for this behavior is a difference in the groundwater yield of the geologic formations underlying each basin.

3.4.2.2.2 Darby-Cobbs Creek Water Quality Analysis

The Philadelphia Water Department carried out a comprehensive sampling and monitoring program in Darby-Cobbs Creek watershed between 1999-2000 and again in 2003 (see Section 3 of the Comprehensive Characterization Report). From 2007 through 2008 water quality data was monitored at two USGS stations in the Watershed. Tables 3-80 through 3-84 list parameters monitored, applicable state water quality standards, number of samples, and number of samples that exceed the standards.

Discrete (fixed interval) chemical sampling was conducted weekly under a variety of conditions (e.g., wet weather, ice) that may have influenced results of many chemical and water quality analyses. For example, instream measurements of dissolved oxygen and grab samples taken for fecal coliform analyses may exhibit great variability in response to environmental conditions. The former is dependent on time of day and sunlight intensity, while the latter may vary with rainfall. For this reason, results of discrete chemical sampling are most useful for characterizing dry weather water quality under Target A of the Watershed Management Plan. Target C and indicator 9 of the Watershed Management Plan were specifically targeted by PWD's Wet Weather Monitoring Program and Continuous Water Monitoring Program, respectively.

Wet weather is characterized using the five PWD operated rain gages in Darby-Cobbs Creek Watershed. Samples were considered wet when there was greater than 0.1 inches of rainfall recorded in at least one gage in the previous 48 hours. The rain gages and PWD water quality monitoring locations are depicted on Figure 3-49.

Much of Cobbs Creek Watershed in Philadelphia is served by a combined sewer system. Wet weather overflows at CSO structures periodically cause releases of combined sewage to streams. Effects of these releases may extend beyond the times when rain is falling or overflows are occurring. CSO discharges, even when infrequent, may be a significant factor in shaping a stream's water quality. Currently Philadelphia's streams do not meet water quality criteria during wet weather (Target C) because stormwater concentrations of bacteria are above the criteria and addressing only CSOs will not correct the problem.

PWD periodically monitors and continues to assess water quality of Cobbs Creek Watershed. The following results are largely based on the 2002 Darby-Cobbs Creek Watershed Comprehensive Characterization Report and the 2004 Update. Data collected since 2003 will continue to be published in future reports.

Discussion of Possible Problem Parameters
The following analysis of water quality data is focused on parameters that were listed in EPA's 1995 Guidance for Long Term Control Plan and those considered as a "parameter of concern" (>10% samples exceeding target value, highlighted in red) or a "parameter of potential concern" (2-10% samples exceeding target value, highlighted in yellow) in Darby-Cobbs Creek Watershed on Tables 3-80 to 3-84. The water quality criteria or target value is discussed in each parameter analysis.

pH
Water quality criteria established by PADEP regulate pH to a range of 6 to 9 in Pennsylvania's freshwater streams. pH is not considered a parameter of concern since the maximum standard of 9 was not exceeded during either the wet weather samples and dry weather samples (Tables 3-80 and 3-81). Acidity in Darby-Cobbs Creek watershed is chiefly determined by biochemical metabolic activity; the watershed is not heavily influenced by bedrock composition, groundwater sources or anthropogenic inputs, such as acid mine drainage.

Continuous monitoring through the use of sondes on the Darby-Cobbs Creeks recorded pH values at each of five sites. Continuous pH data was discretized to 15 min intervals and plotted against time and stream depth. Figures 3-54 through 3-85 depict pH trends at each of five continuously-monitored sites on the Darby-Cobbs Creek watershed, including the large diel pH fluctuations that accompany highly productive sites with abundant periphytic algae. Community metabolism regulates the extent of pH fluctuations. Environmental conditions, including ample sunlight, led to a dense autotrophic community at sites DCC208 and DCD765, which exhibited greater diel pH fluctuations than the other monitored sites; these sites also generally came closest to and occasionally violated water quality criteria by exceeding pH 9.0 (Figures 3-54 and 3-58, respectively). pH at shadier sites (i.e., DCC770, DCC455 and DCD1660) is probably less influenced by metabolic activity, and oscillations in pH appear noticeably damped as a result..

Two separate rain events occurred during the period of Sonde deployments in Darby-Cobbs Creek Watershed. Increased velocities and larger flows during wet weather swept away attached algae, macrophytes and suspended periphyton. Figures 3-54 through 3-58 demonstrate that without autotrophs to produce carbon dioxide through photosynthesis, pH levels remain steady. The autotrophic community recovers from this disturbance over subsequent weeks and pH gradually

Table 3-80: Dry Weather Water Quality Summary (1999-2000) – Parameters with Standards (D-C CCR 2002 section 5.2 table 5.5 page 35)

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles					No. Exceeding	% Exceeding
					0	25	50	75	100		
Alkalinity	Minimum	20	mg/L	59	58.0	66.0	74.0	79.0	98.0	0	0
Cd	Aquatic Life Acute Maximum	* 0.0043	mg/L	59	ND	ND	ND	ND	ND	0	0
Cd	Aquatic Life Chronic Maximum	* 0.0022	mg/L	59	ND	ND	ND	ND	ND	0	0
Cr	Aquatic Life Acute Maximum	0.0015	mg/L	59	ND	ND	ND	ND	0.00247	0	0
Cr	Aquatic Life Chronic Maximum	0.001	mg/L	59	ND	ND	ND	ND	0.00247	0	0
Cu	Aquatic Life Acute Maximum	* 0.013	mg/L	59	0.00107	0.00236	0.00330	0.00409	0.0101	0	0
Cu	Aquatic Life Chronic Maximum	* 0.0090	mg/L	59	0.00107	0.00236	0.00330	0.00409	0.0101	0	0
Diss Fe	Maximum	0.3	mg/L	59	0.0545	0.136	0.173	0.209	0.436	4	6.8
DO	Average Daily Minimum	5	mg/L	58	4.88	6.98	7.96	8.80	10.7	1	1.7
DO	Instantaneous Minimum	4	mg/L	58	4.88	6.98	7.96	8.80	10.7	0	0
F	Maximum	2	mg/L	59	ND	ND	ND	0.108	0.142	0	0
Fe	Maximum	1.5	mg/L	59	0.152	0.231	0.286	0.399	0.918	0	0
Fecal coliform	Maximum	Swimming Season Maximum 200 & Non-Swimming Season Maximum 2000	/100mL	60	90	290	410	620	23000	51	85.0
Nitrate + Nitrite	Maximum	10	mg/L	60	2.90	2.90	2.90	2.90	2.90	0	0

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles					No. Exceeding	% Exceeding
					0	25	50	75	100		
Mn	Maximum	1	mg/L	59	0.0137	0.0251	0.0330	0.0460	0.0972	0	0
NH_3	Maximum	(pH dependent)	mg/L	58	ND	ND	ND	ND	0.186	0	0
Osmotic Pressure	Maximum	50	mOsm/kg	20	3.00	4.00	5.00	6.00	6.00	0	0
Pb	Aquatic Life Acute Maximum	* 0.065	mg/L	59	ND	ND	ND	0.0010	0.00433	0	0
Pb	Aquatic Life Chronic Maximum	* 0.025	mg/L	59	ND	ND	ND	0.0010	0.00433	0	0
pH	Maximum	9	--	58	7.09	7.39	7.57	7.73	8.18	0	0
TDS	Maximum	750	mg/L	59	148.0	210	234	289	420	0	0
Temp	Instantaneous Maximum	(varies)	^{o}C	58	13.7	15.7	18.9	20.3	24.1	7	12.1
Turbidity	Maximum	100	NTU	134	0.3	0.9	1.6	2.5	12.1	0	0
Zn	Aquatic Life Acute Maximum	* 0.120	mg/L	59	ND	0.00640	0.00947	0.0138	0.0582	0	0
Zn	Aquatic Life Chronic Maximum	* 0.120	mg/L	59	ND	0.00640	0.00947	0.0138	0.0582	0	0

*Water quality standard requires hardness correction; value listed is water quality standard calculated at 100 mg/L CaCO3 hardness.

Table 3-81: Wet Weather Water Quality Summary (1999-2000)– Parameters with Standards (D-C CCR 2002 section 5.2 table 5.5 page 35)

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles					No. Exceeding	% Exceeding
					0	25	50	75	100		
Alkalinity	Minimum	20	mg/L	96	24.0	42.0	58.5	68.0	85.0	0	0
Cd	Aquatic Life Acute Maximum	* 0.0043	mg/L	93	ND	ND	ND	ND	ND	0	0
Cd	Aquatic Life Chronic Maximum	* 0.0022	mg/L	93	ND	ND	ND	ND	ND	0	0
Cr	Aquatic Life Acute Maximum	0.0015	mg/L	93	ND	ND	0.00151	0.00360	0.0140	0	0
Cr	Aquatic Life Chronic Maximum	0.001	mg/L	93	ND	ND	0.00151	0.00360	0.0140	6	6.5
Cu	Aquatic Life Acute Maximum	* 0.013	mg/L	93	0.00183	0.00428	0.00625	0.00960	0.0340	11	11.8
Cu	Aquatic Life Chronic Maximum	* 0.0090	mg/L	93	0.00183	0.00428	0.00625	0.00960	0.0340	23	24.7
Diss Fe	Maximum	0.3	mg/L	93	0.0739	0.129	0.155	0.214	0.392	5	5.4
DO	Average Daily Minimum	5	mg/L	94	1.73	5.27	6.52	8.07	10.3	22	23.4
DO	Instantaneous Minimum	4	mg/L	94	1.73	5.27	6.52	8.07	10.3	9	9.6
F	Maximum	2	mg/L	96	ND	ND	0.101	0.115	0.194	0	0
Fe	Maximum	1.5	mg/L	93	0.181	0.317	0.550	0.747	6.46	13	14.0
Fecal Coliform	Maximum	Swimming Season Maximum 200 & Non-Swimming Season Maximum 2000	/100mL	95	100	2100	7900	31000	200000	94	98.9

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles					No. Exceeding	% Exceeding
					0	25	50	75	100		
Nitrate + Nitrite	Maximum	10	mg/L	102	2.90	2.90	2.90	2.90	2.90	0	0
Mn	Maximum	1	mg/L	93	0.0170	0.0385	0.0553	0.0744	0.212	0	0
NH_3	Maximum	(pH dependent)	mg/L	93	ND	ND	0.100	0.198	1.62	0	0
Osmotic Pressure	Maximum	50	mOsm/kg	10	2.00	2.00	3.00	3.00	4.00	0	0
Pb	Aquatic Life Acute Maximum	* 0.065	mg/L	93	ND	0.00144	0.00246	0.00577	0.0571	1	1.1
Pb	Aquatic Life Chronic Maximum	* 0.025	mg/L	93	ND	0.00144	0.00246	0.00577	0.0571	40	43.0
pH	Maximum	9	--	94	6.82	7.21	7.33	7.54	7.83	0	0
TDS	Maximum	750	mg/L	96	20.0	128	185	235	391	0	0
Temp	Instantaneous Maximum	(varies)	^{o}C	94	14.2	16.5	19.8	21.5	25.3	9	9.6
Turbidity	Maximum	100	NTU	278	0.5	3.0	5.9	13.0	155	2	1.1
Zn	Aquatic Life Acute Maximum	* 0.120	mg/L	93	ND	0.0110	0.0180	0.0295	0.111	3	3.2
Zn	Aquatic Life Chronic Maximum	* 0.120	mg/L	93	ND	0.0110	0.0180	0.0295	0.111	6	6.5

*Water quality standard requires hardness correction; value listed is water quality standard calculated at 100 mg/L CaCO3 hardness.

Table 3-82: Continuous Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gauge	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01475530	Instantaneous Minimum	4	mg/L	25307	0.0100	5.70	7.10	8.20	9.67	11.8	16.8	1678	6.6
DO	01475548	Instantaneous Minimum	4	mg/L	24158	0.0400	4.83	6.50	8.38	10.4	12.0	19.6	1547	6.4
DO	01475530	Daily Minimum	5	mg/L	533	0.0573	5.39	7.29	8.05	9.80	11.4	16.5	46	8.6
DO	01475548	Daily Minimum	5	mg/L	517	0.0513	5.28	6.83	8.41	10.4	11.7	14.5	46	8.9

Table 3-83: Continuous Wet Weather Water Quality Summary (2007-2008) – Parameter with Standards

Parameter	USGS Gauge	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01475530	Instantaneous Minimum	4	mg/L	12477	0.0200	5.02	6.90	7.96	9.61	11.7	16.8	954	7.6
DO	01475548	Instantaneous Minimum	4	mg/L	11362	0.0400	4.29	5.82	7.63	9.87	11.4	19.4	911	8
DO	01475530	Daily Minimum	5	mg/L	335	0.0742	4.94	7.10	7.87	10.0	11.7	16.5	35	10.4
DO	01475548	Daily Minimum	5	mg/L	320	0.0533	4.81	6.17	7.78	10.0	11.8	14.5	37	11.6

Table 3-84: Continuous Dry Weather Water Quality Summary (2007-2008) – Parameter and Standards

Parameter	USGS Gauge	Standard	Target	Units	No. Obs	Percentile							No. Exceeding	% Exceeding
						0	10	25	50	75	90	100		
DO	01475530	Instantaneous Minimum	4	mg/L	12830	0.0100	6.43	7.27	8.40	9.70	11.8	16.3	724	5.6
DO	01475548	Instantaneous Minimum	4	mg/L	12796	0.0400	5.64	7.13	8.96	10.7	12.4	19.6	636	5
DO	01475530	Daily Minimum	5	mg/L	198	0.0573	6.31	7.60	8.30	9.79	11.0	13.7	11	5.6
DO	01475548	Daily Minimum	5	mg/L	197	0.0513	6.78	8.04	8.94	10.5	11.5	14.2	9	4.6

Table 3-85: Sites with at least one Observed Exceedance of Water Quality Criteria (1999-2000) (D-C CCR 2002 section 5.2 table 5.7 page 39)

	Dry											
Parameter	**DCC110**	**DCC115**	**DCC455**	**DCC770**	**DCN010**	**DCI010**	**DCD765**	**DCD1170**	**DCD1570**	**DCD1660**	**DCM300**	**DCS170**
Cr												
Cu												
Diss Fe	X				X						X	X
DO		X										
Fe												
Fecal Coliform	X		X	X	X	X	X	X	X		X	X
Pb												
Temp							X		X	X		
Zinc												
	Wet											
Parameter	**DCC110**	**DCC115**	**DCC455**	**DCC770**	**DCN010**	**DCI010**	**DCD765**	**DCD1170**	**DCD1570**	**DCD1660**	**DCM300**	**DCS170**
Cr	X					X	X		X			
Cu	X		X			X	X					X
Diss Fe	X						X					X
DO	X	X					X			X		
Fe	X											
Fecal Coliform	X		X	X	X	X	X	X	X	X	X	X
Pb	X		X	X		X	X			X		X
Temp							X	X	X	X		
Zn	X						X					

Note: DCC115 was sampled for DO only on a continuous basis.

returns to normal fluctuations at each site. Decreased pH levels during and following wet weather events did not violate minimum pH standards.

Dissolved Oxygen
Based on the discrete sampling during 1999-2003, Dissolved Oxygen (DO) is not considered a parameter of concern during dry weather because state standards for daily average minimum of 5 mg/L and instantaneous minimum of 4 mg/L were never exceeded (Table 3-80). However, DO is considered a parameter of potential concern during wet weather for the instantaneous minimum because the standard was exceeded in 9.6% of samples (Table 3-81).

Samples analyzed from the continuous USGS monitoring from 2007-2008 show that DO concentrations are of potential concern in dry weather when compared to the instantaneous and daily minimum standards (Table 3-84). During wet weather, DO is considered a potential concern compared to the instantaneous standard, and a parameter of concern when compared to the daily average minimum standard at both USGS stations.

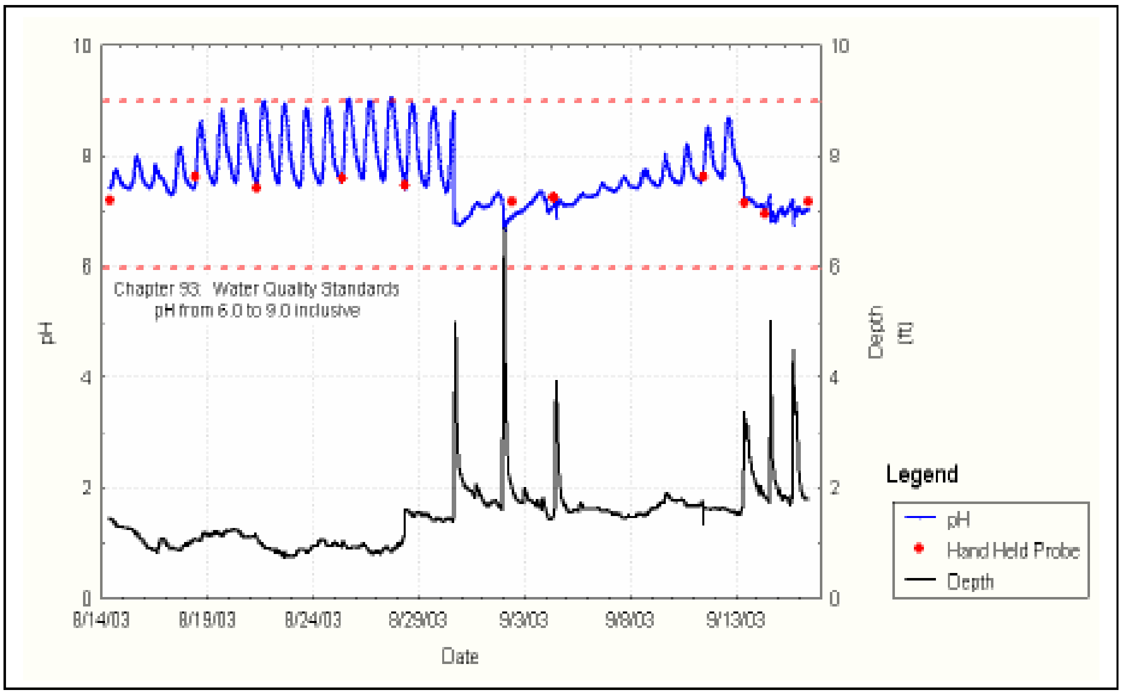


Figure 3-54: Continuous measurements of pH at DCC 208. (D-C CCR 2004 section 5.4.5 figure 6 page 98)

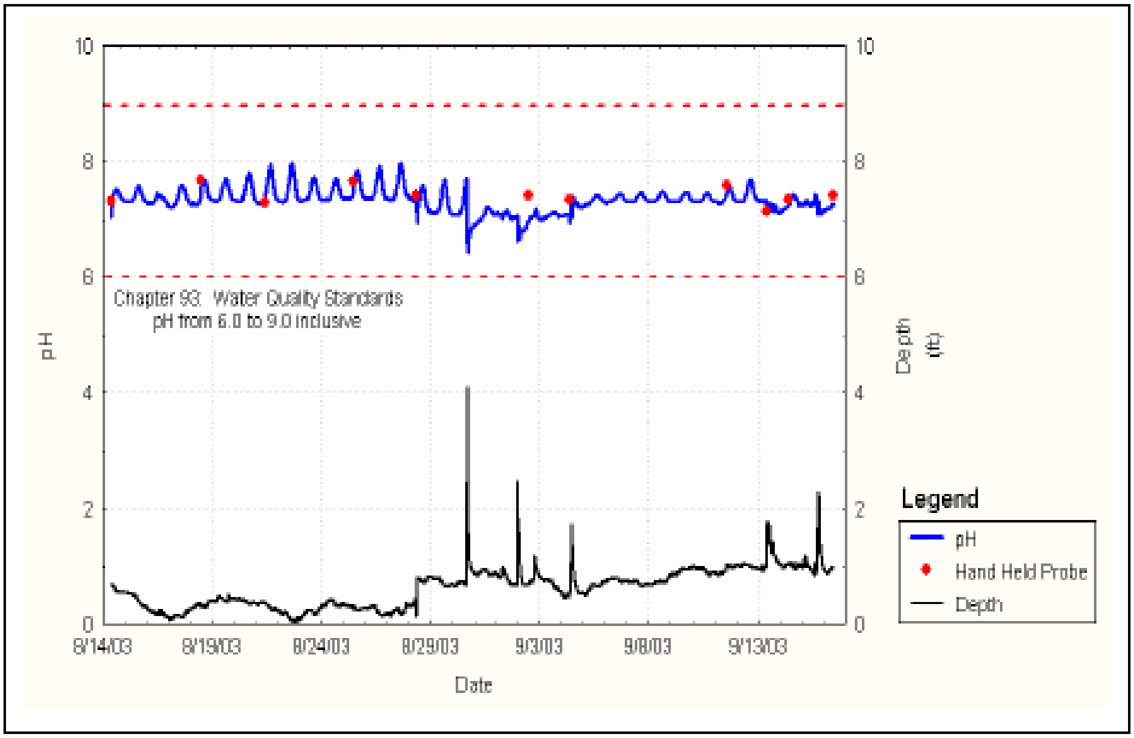


Figure 3-55: Continuous measurements of pH at DCC 455 (D-C CCR 2004 section 5.4.5 figure 7 page 99).

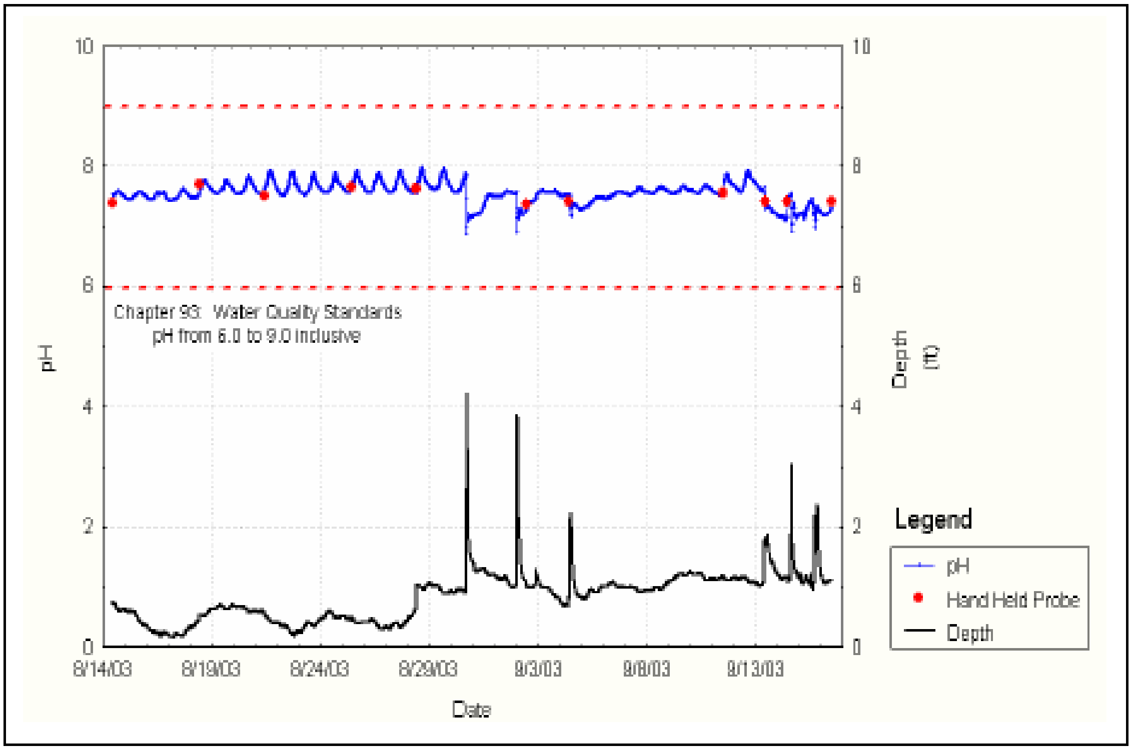


Figure 3-56: Continuous measurements of pH at DCC 770 (D-C CCR 2004 section 5.4.5 figure 8 page 99).

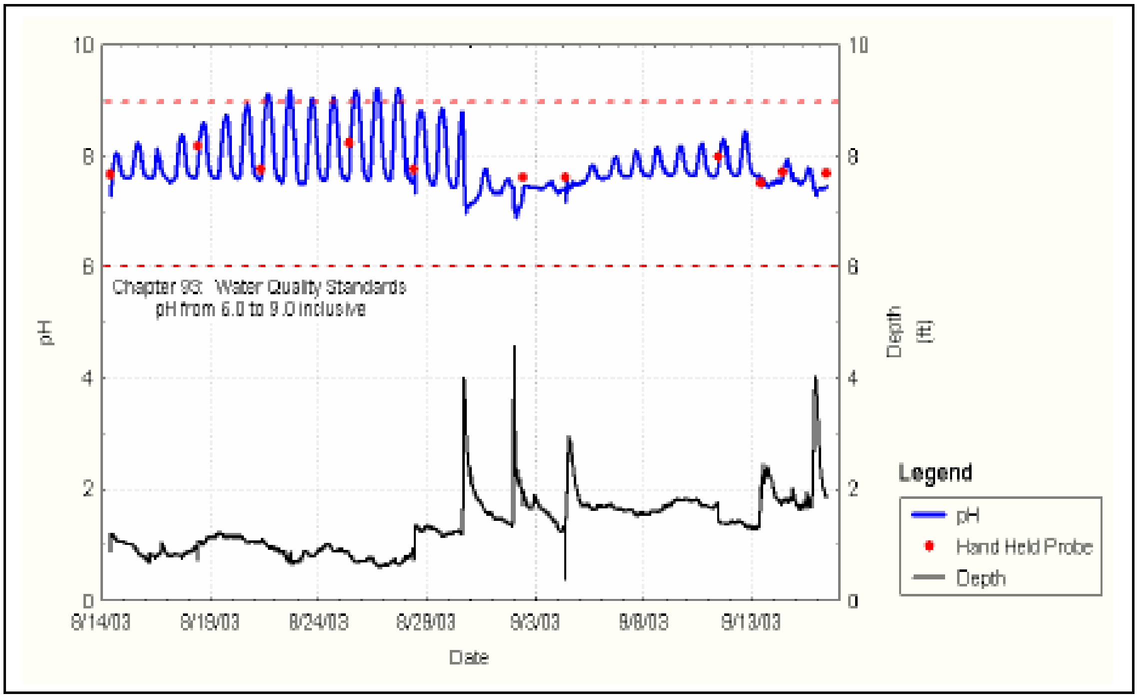


Figure 3-57: Continuous measurements of pH at DCD 765 (D-C CCR 2004 section 5.45 figure 9 page 100).

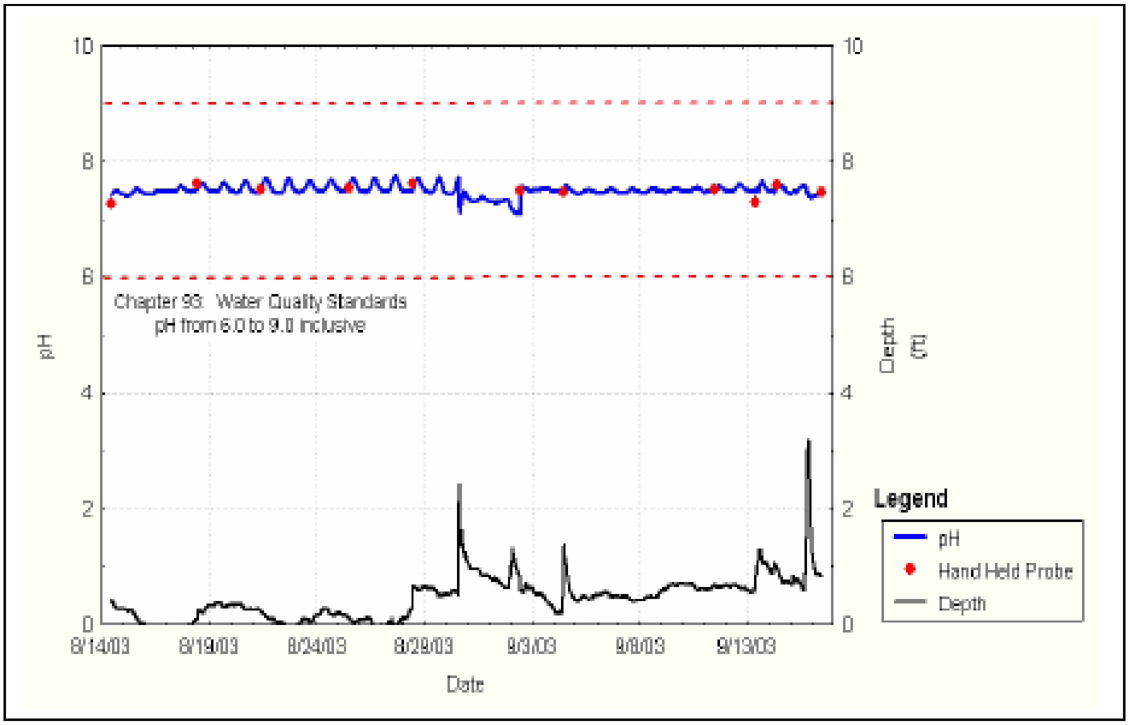
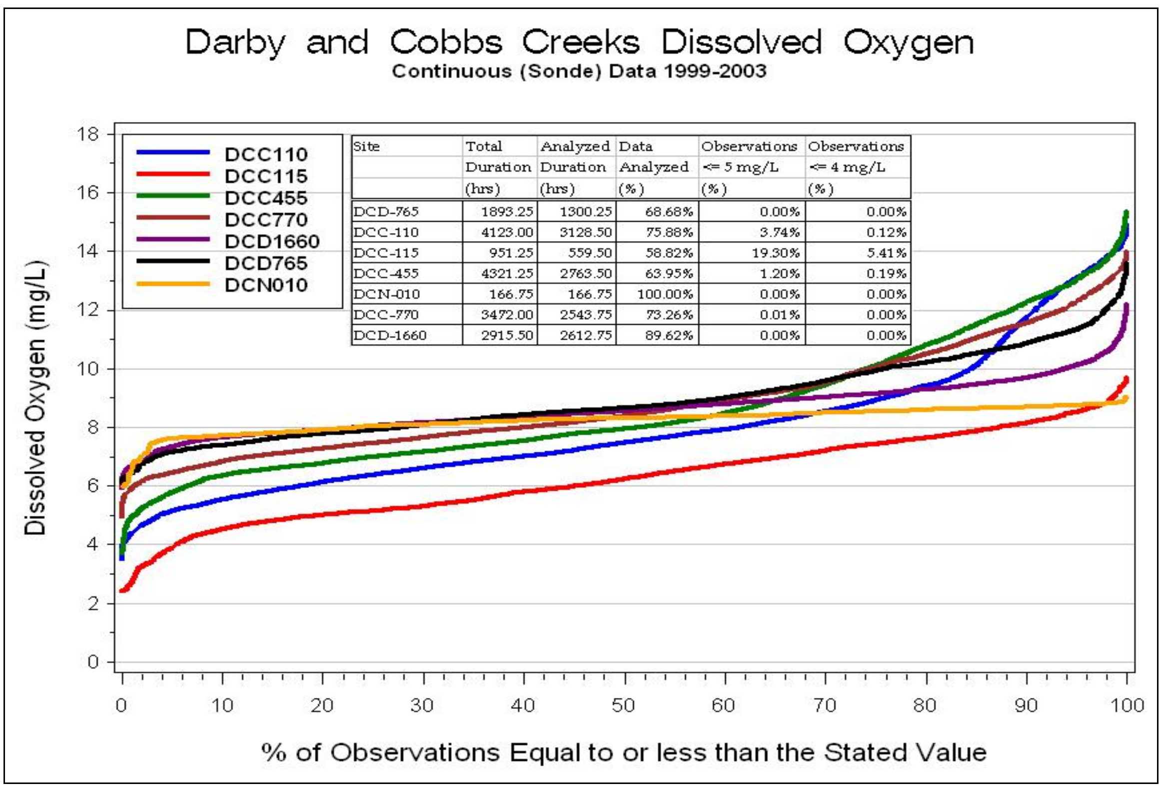


Figure 3-58: Continuous measurements of pH at DCD 1660 (D-C CCR 2004 section 5.4.5 figure 10 page 100).

PADEP also conducted continuous water quality monitoring from 1999-2003. All water chemistry monitoring sites within Darby-Cobbs Creek Watershed, with the exception of DCD1660, are designated as Warm Water Fisheries (WWF). Site DCD1660, and all segments of Darby Creek north of PA Rte. 3 (West Chester Pike) are designated a Trout Stocking Fishery (TSF). A TSF such as DCD1660 has more stringent DO standards to support more sensitive stocked salmonid fish species from February 15 to July 31 each year. During this period, a minimum daily DO average of 6.0 mg /L is required, and the allowable DO instantaneous minimum is 5.0 mg /L. For the remainder of the year, TSF criteria align with WWF standards. These regulations, along with corresponding temperature criteria, form the foundation of stream protection in general and allow for propagation and maintenance of healthy fish communities. Figure 3-59 shows that for data taken between 1999 and 2003, at sites DCC110 and DCC455, concentrations were occasionally (less than 5% of observations) below the average daily limit of 5 mg/L. The only site where concentrations were often below the average standard (20% of observations) and the instantaneous standard (5% of observations) is site DCC115. This site is just above the low dam at Woodland Ave.

Combinations of natural and anthropogenic environmental factors may affect DO concentration. Autotrophic and heterotrophic organisms are influenced by nutrient concentrations, solar radiation, temperature, and other environmental factors. Daily fluctuations of oxygen in surface waters are due primarily to the metabolic activity of these organisms. If temperature alone influenced DO concentration, saturation would increase at night, when water temperature drops, and decrease during the day as the water warms. Because the watershed is generally dominated by biological



Site	Total Duration (hrs)	Analyzed Duration (hrs)	Data Analyzed (%)	Observations <= 5 mg/L (%)	Observations <= 4 mg/L (%)
DCD-765	1893.25	1300.25	68.68%	0.00%	0.00%
DCC-110	4123.00	3128.50	75.88%	3.74%	0.12%
DCC-115	951.25	559.50	58.82%	19.30%	5.41%
DCC-455	4321.25	2763.50	63.95%	1.20%	0.19%
DCN-010	166.75	166.75	100.00%	0.00%	0.00%
DCC-770	3472.00	2543.75	73.26%	0.01%	0.00%
DCD-1660	2915.50	2612.75	89.62%	0.00%	0.00%

Figure 3-59: Continuous DO Monitoring Results (1999-2003) (D-C CCR 2002 section 5.3.5 figure 5.10 page 1-62)

activity, the reverse occurs: DO concentrations in Darby-Cobbs Creek Watershed rise during the day when autotrophic organisms are photosynthesizing and decrease at night when community respiration is the dominant influence. Another factor in the amount of oxygen dissolved in the water is re-aeration; the saturation deficit influences the amount of oxygen transferred to the stream from the atmosphere. Effects of re-aeration tend to augment or diminish (rather than shift or change) effects of stream metabolism.

DO fluctuations were more pronounced at some sites than at others, due in part to specific placement of the continuous monitoring instrument (Sonde) at each site. When interpreting this continuous DO data, one must keep in mind that the instrument can only measure dissolved oxygen concentration of water in direct contact with the DO probe membrane. Furthermore, to obtain the most accurate readings of DO, probes should be exposed to flowing water or probes themselves must be in motion. Local microclimate conditions surrounding the probe and biological growth on the probe itself may also contribute to errors in measurement. It is possible for Sondes situated in subtly different areas of the same stream site to exhibit marked differences in DO concentration due to flow, shading, and local microclimate differences. Sonde measurements of DO concentrations during the summer period (8/14/03-9/14/03) are depicted in Figures 3-60 thru 3-64.
The Sonde located at DCC208, for example, is located in a pool upstream of a dam. Additionally, the Sonde at DCC208 is not shaded. Deep pools, slower stream velocity, and ample sunlight provide excellent conditions for algal growth which are reflected in diel DO fluctuations (Figure 3-60). DCD765 is another site in which the Sonde is only partially shaded.
While not as large as DCC208, the amplitude of DO fluctuations exceeded 3 mg/L at this site. In contrast, the Sonde at DCD1660 is located under a bridge in shallow water. While not measured quantitatively, it is likely that algal periphyton density was smaller at this site; resulting diel fluctuations are damped in comparison to sites exposed to more sunlight (Figure 3-64). Sondes at sites DCC455 and DCC770 are in areas that are mostly shaded (Figures 3-61 and 3-62, respectively).

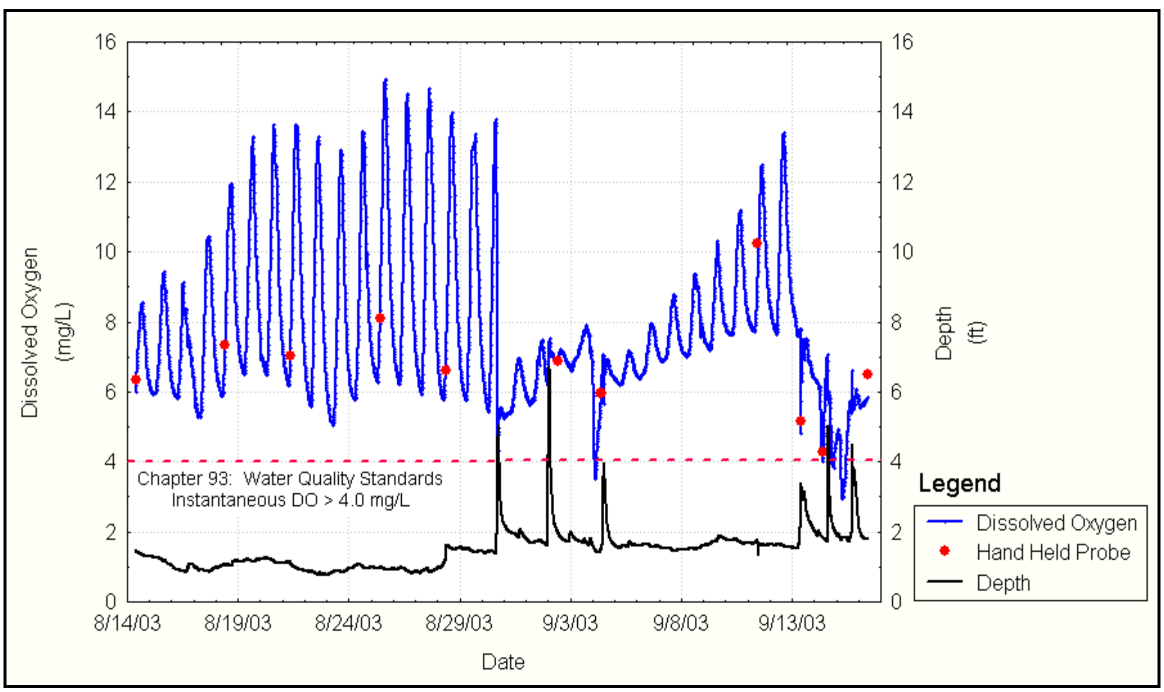


Figure 3-60: Continuous measurements of dissolved oxygen at DCC 208 (D-C CCR 2004 section 5.4.4 figure 1 page 94).

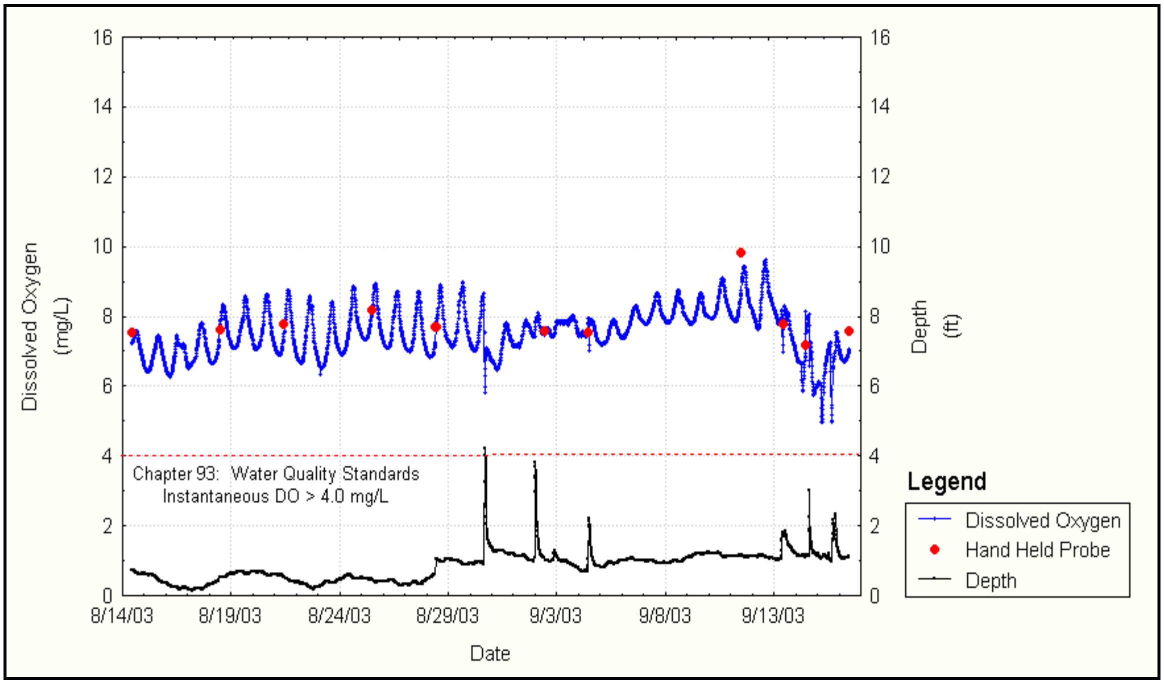


Figure 3-61: Continuous measurements of dissolved oxygen at DCC 455 (D-C CCR 2004 section 5.4.4 figure 2 page 95).

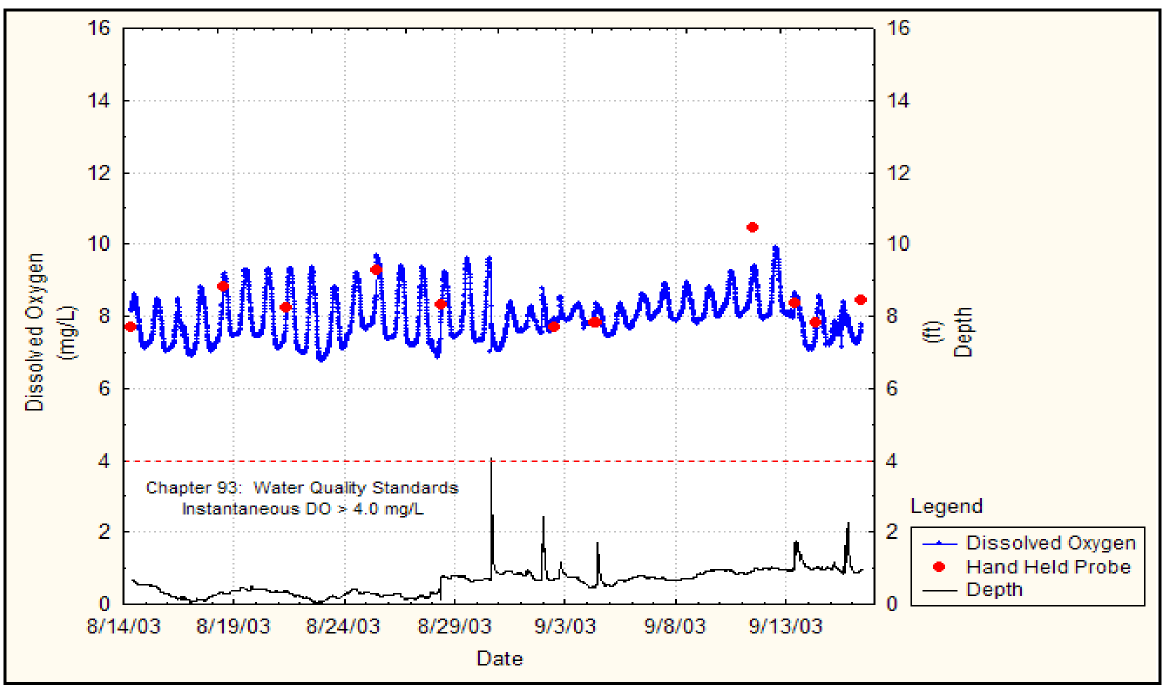


Figure 3-62: Continuous measurements of dissolved oxygen at DCC 770 (D-C CCR 2004 section 5.4.4 figure 3 page 95).

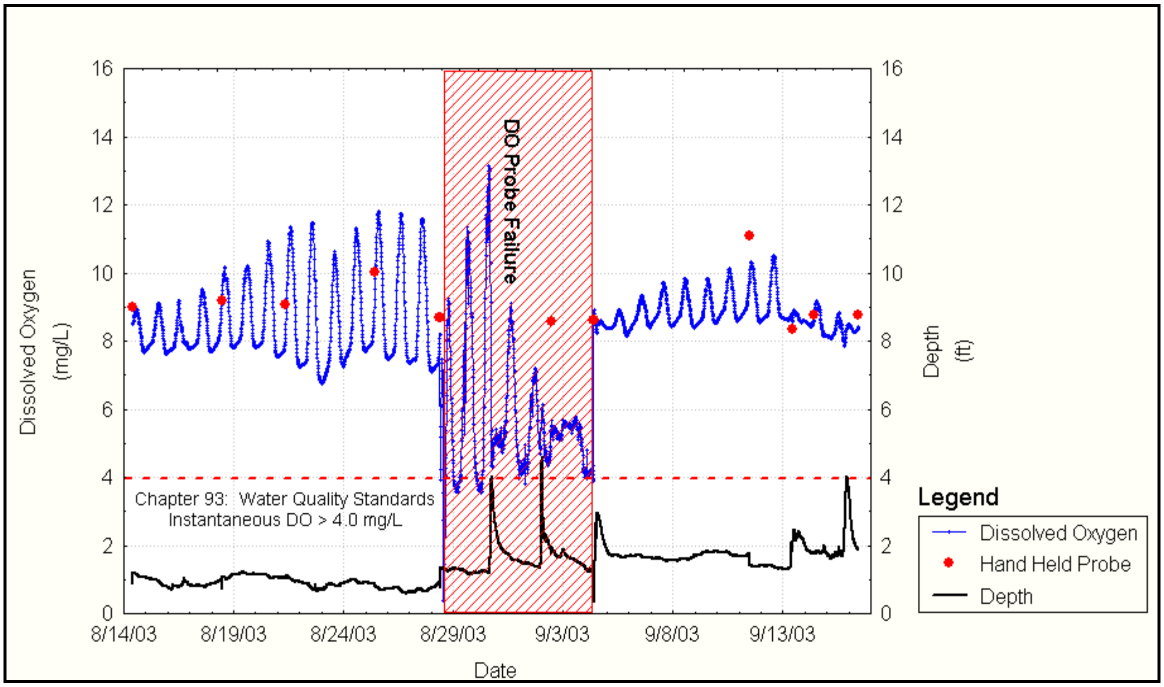


Figure 3-63: Continuous measurements of dissolved oxygen at DCD 765 (D-C CCR 2004 section 5.4.4 figure 4 page 96).

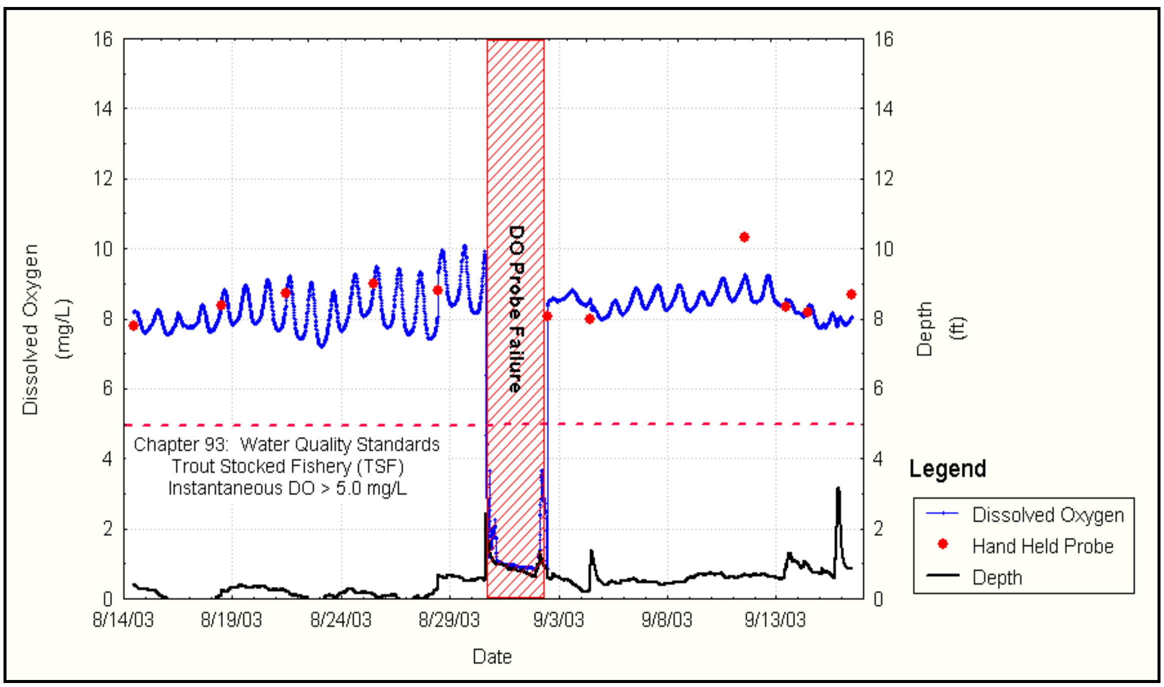


Figure 3-64: Continuous measurements of dissolved oxygen at DCD 1660 (D-C CCR 2004 section 5.4.4 figure 5 page 96).

Relation of Algal Activity to Dissolved Oxygen Concentration

Water quality monitoring sites on Cobbs Creek experience pronounced diurnal fluctuations in dissolved oxygen (DO) concentrations. When biological activity is high, DO concentrations may fall below the state-regulated limit of 4.0 mg/L. Dry weather dissolved oxygen suppression tends to occur at night and is likely caused by respiration of algae and microbial decomposition of algae and other organic constituents in the absence of additional photosynthetic oxygen production.

Following storm events, amplitude of daily DO fluctuations was reduced. DO concentrations may decrease sharply upon increase in stage, but it was difficult to determine how much of these instantaneous decreases were due to DO probe membrane fouling (Figures 3-63 and 3-64). It was hypothesized that anoxic effluent from storm sewers contributes to a sudden reduction in water column DO, but modeling of CSO discharge DO concentrations indicated that the discharge alone could not account for the observed DO reductions. BOD and SOD may have increased due to organic matter present in sewage. The scouring effect of high flows reduces algal biomass, and the oxygen produced through photosynthesis and consumed through respiration is reduced. As algal biomass accrues following scouring events, peak DO concentrations and range of diurnal fluctuations return to pre-flow conditions (Figures 3-61 and 3-62).

It is hypothesized that in dry weather the algae in combination with the residual effects of anoxic effluent, BOD and SOD accounts for the greater fluctuations in DO in stream segments heavily influenced by CSO discharge. Further confounding the interpretation of the data is the fact that microclimate conditions surrounding the DO probe membrane probably partially explain DO fluctuations observed.

Future Investigation of Dissolved Oxygen Conditions in Cobbs Creek

The nature, causes, severity and opportunities for control of the dissolved oxygen conditions in Cobbs Creek are not well understood at this juncture. Efforts to better understand the dissolved oxygen situation in Philadelphia's streams continue including, in addition to ongoing continuous long-term monitoring, process studies conducted for PWD by the USGS. Estimates will be refined and analyses performed on the loading of water quality constituents related to the dissolved oxygen dynamics, both from the City as well as from other dischargers to Cobbs Creek and its tributaries. If a relationship between loadings and the dissolved oxygen conditions is suspected, informational total maximum daily loads will be investigated for the watershed. Progress and results of this work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Total Dissolved Solids

Although it is has been monitored for the CSO program, Total Dissolved Solids (TDS) is not considered a parameter of concern in Darby-Cobbs Creek Watershed. The PADEP standard and target value of 750 mg/L was never exceeded during monitoring from 1999-2003. Often, average wet and dry weather TDS concentrations were well below the standard. Generally, average wet weather TDS concentrations were lower than average dry weather concentrations by about 10% when compared on a site by site basis. TDS appears to decrease slightly from the upstream to the downstream sampling stations. (PWD, 2000b)

Total Suspended Solids

There is no established state standard for Total Suspended Solids (TSS) but it is discussed in this section because it is listed in the EPA's 1995 Guidance for Long Term Control Plan. Data on TSS was not collected in Darby-Cobbs Creek Watershed.

Nutrients
With the exception of ammonia, PADEP does not currently have aquatic life-based nutrient criteria, only a limit on oxidized inorganic nitrogen (i.e., nitrate and nitrite) that is intended to protect public water supplies.

Nitrogen species
Though deep stagnant water is present in a few locations, particularly in pools behind dams and in "plunge pools", most of Darby-Cobbs Creek Watershed consists of shallow, well mixed and (at a minimum, partially) oxygenated stream segments. Inputs of organic matter and inorganic N, particularly concentrated inputs from SSOs and CSOs, may tax dissolved oxygen levels and result in violations of water quality standards. These effects are most severe in summer, when the rate of N-oxidizing reactions is fastest, dissolved oxygen capacity of stream water is reduced, instream biomass is high, and baseflow may be at or near yearly minimum.

Nitrite
As an intermediate product in the oxidation of organic matter and ammonia to nitrate, nitrite is seldom found in unimpaired natural waters in great concentrations provided that oxygen and denitrifying bacteria are present. Nitrite was never detected in any 2003 samples from Darby Creek or Naylors Run regardless of weather conditions, but was detected in 21 of 100 wet weather samples and 3 of 69 dry weather samples from Cobbs Creek. Observed wet-weather nitrite concentrations are likely due to CSO/SSO discharge and runoff. On 6/12/03, nitrite was detected during dry weather at sites DCI010, DCC455 and DCC208. The inability to detect nitrite at site DCC770 and observed pattern of longitudinally diminishing concentrations (from upstream to downstream) suggested a point source, later determined to be a leaking sewer. PADEP has established a maximum limit of 10 mg/L for total nitrate and nitrite N (Inorganic N) (note this limit is based on protection of drinking water and cannot reasonably be expected to prevent eutrophication of natural water bodies). Nitrite concentrations in Darby-Cobbs Creek watershed never exceeded nitrate concentrations, and were never responsible for water samples exceeding this criterion.

Nitrate
According to US EPA's nutrient criteria database, samples collected from unimpaired surface waters in the eastern coastal plain region of Pennsylvania had mean nitrate concentration of 1.9mg/l (n = 786). The 75th percentile seasonal median nitrate + nitrite concentration in EPA ecoregion IV, sub region 64 watersheds was 2.9mg/l. Close examination of nitrate data collected from southeastern PA streams by PWD and PADEP showed at least some nutrient impaired streams could be assigned to one of two broadly defined categories- streams in which nitrate concentrations increase due to runoff, and streams in which nitrate concentrations are elevated during baseflow conditions and diluted by stormwater. The former stream type is characteristic of agricultural regions, while the latter is characteristic of streams affected by wastewater effluent.

No sites in Darby-Cobbs Creek Watershed violated water quality criteria of 10 mg/L (see note above). The watershed is not affected by treated wastewater effluent, does not contain extensive areas of agricultural land use, and has not been listed as nutrient impaired by PADEP under section 303d of the Clean Water Act. However, all sites in Darby-Cobbs Creek have mean nitrate concentration >1.5 mg/L and would be considered "eutrophic" under the stream trophic classification system of Dobbs (1998).

During wet weather, nitrate concentrations were generally diluted; nitrate concentration was significantly higher (t-test, $p<0.05$) in dry weather at five of nine sites in Darby Cobbs Watershed (Figure 3-65). While nitrate concentrations were similar among Darby Creek sites, Cobbs Creek sites showed nitrate concentration decreasing in a downstream direction, suggesting uptake by producers, dilution as link magnitude increases, or denitrification by bacteria under anoxic conditions, where they exist. The Indian Creek Watershed had the highest mean nitrate concentration of all sites. Land use in the Indian Creeks' basins includes golf courses as well as areas where resident Canada geese congregate; topography is steep upstream of the sampling site.

Ammonia

Overall, Darby-Cobbs Creek Watershed sites had relatively low ammonia (NH_3) concentration and NH_3 is not considered a parameter of concern. 95 of 208 discrete grab samples (45%) taken in 2003 had NH_3 concentration below detection limits. Mean NH_3 concentration was highest at site DCI010, but this value was artificially high due to a sewage leak during dry weather on 6/12/03 (0.907mg/L). Wet weather impacts on NH_3concentration were most noticeable at Cobbs Creek sites DCC208 and DCC455 (Figure 3-66), which are likely affected by CSO discharge. NH_3 impacts from wet weather event 1 appeared more severe than from event 2.

PADEP has established maximum total NH_3 nitrogen standards for the waters of the Commonwealth, but each sample must be compared individually to a standard that integrates sample temperature and pH to account for dissociation of NH_3 in water. Higher temperatures and more alkaline pH allow more NH_3 to be present in the toxic, unionized form. Total NH_3 nitrogen concentration was above 1.0 mg/L in only 1 of 208 samples, a wet weather sample from site

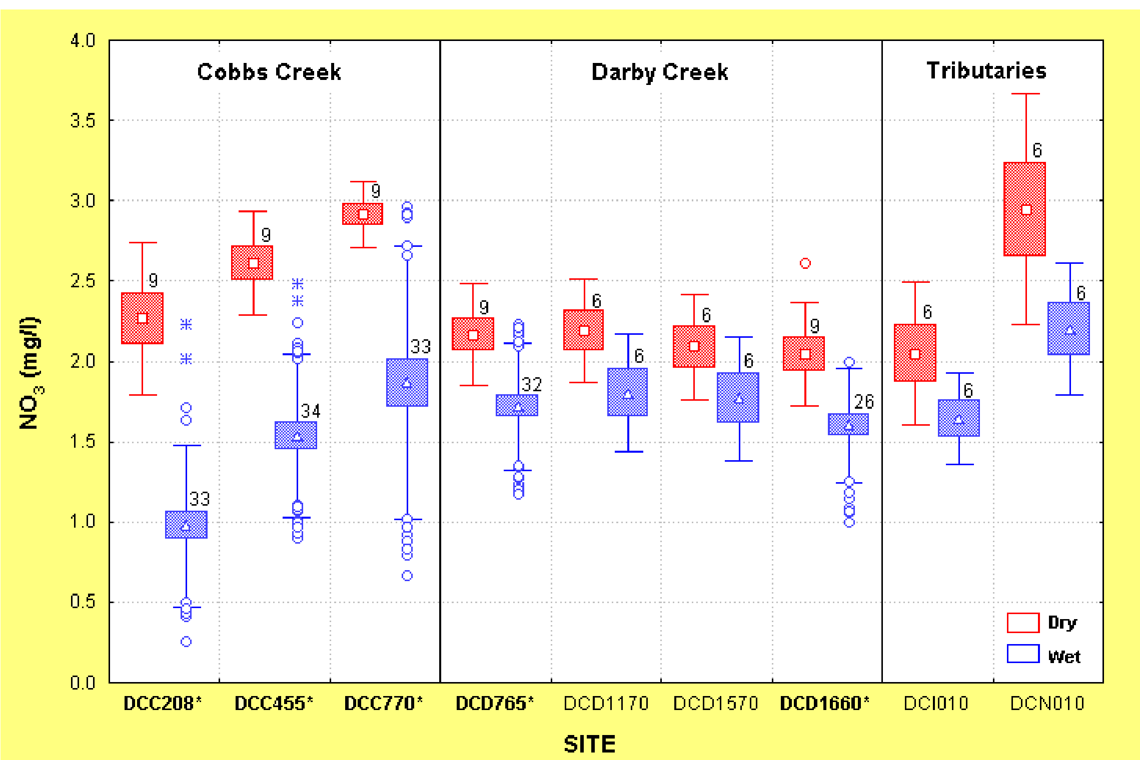


Figure 3-65: Dry and wet weather nitrate concentrations at the 9 monitoring sites (D-C CCR 2004 section 5.4.8.5 figure 21 page 109).

DCC208. Despite pH values that occasionally exceeded 8.0, no violations of NH_3 water quality standards were observed. However, continuous water quality monitoring instruments recorded pronounced fluctuations in pH at sites DCD765 and DCC110 due to algal blooms. It is likely that if ammonia nitrogen were present during periods of upper-range pH violations (i.e., measurements greater than 9.0), its toxicity would be high.

Total Kjeldahl Nitrogen (TKN)
Although PADEP does not have an establish criteria for maximum Total Kjeldahl Nitrogen (TKN) concentration, the Environmental Protection Agency (EPA) requires that the TKN concentration not exceed 0.675 mg/L.

TKN provides an estimate of the concentration of organically-bound N, but the test actually measures all N present in the trinegative oxidation state. NH_3 must be subtracted from TKN values to give the organically bound fraction. TKN analysis also does not account for several other N compounds (e.g., azides, nitriles, hydrazone); these compounds are rarely present in significant concentrations in surface waters. Two outliers were excluded from the data analysis and graphics- these samples were collected from sites DCI010 and DCC455 during a sewer leak 6/12/03. TKN concentrations from these two sites were much greater than other dry weather samples and correspond with abnormally large concentrations of other parameters that serve as indicators of sewage contamination, (i.e., fecal coliform and *E. coli* bacteria, nitrate, ammonia, etc.) observed at these sites on this date.

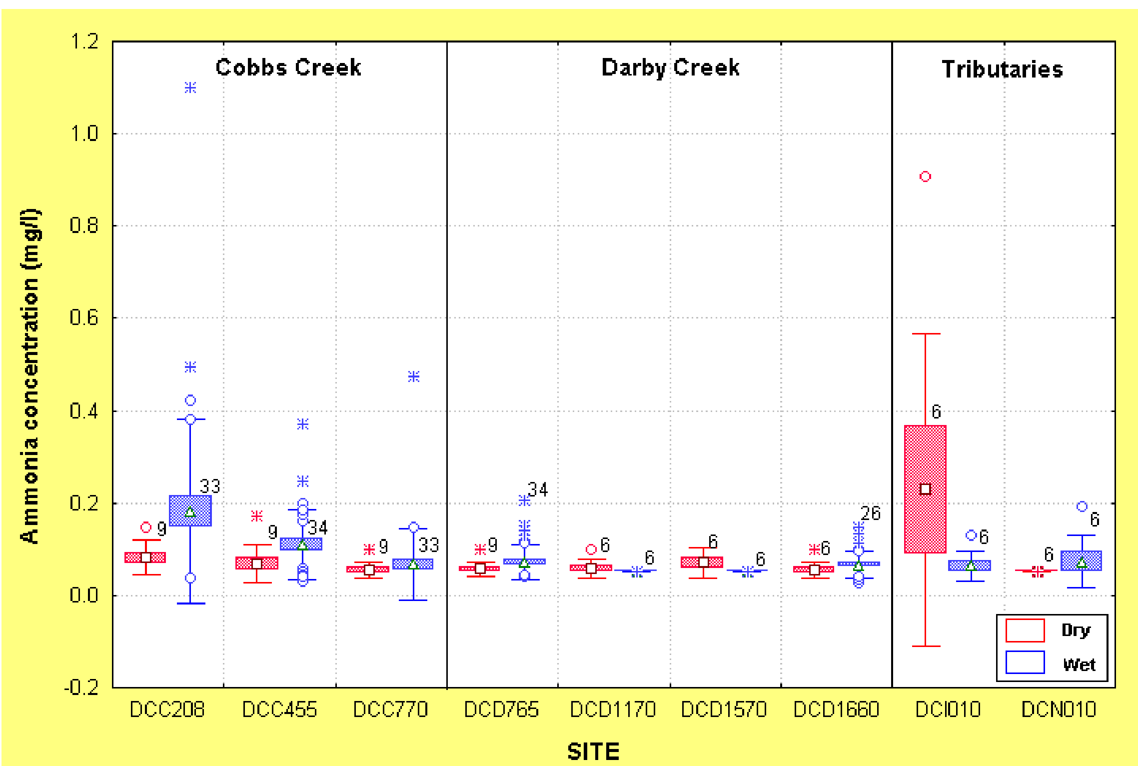


Figure 3-66: Dry and wet weather ammonia concentrations at the 9 monitoring sites (D-C CCR 2004 section 5.4.8.4 figure 22 page 110).

Every site but DCC208 had TKN concentration less than the reporting limit of 0.3 mg/L on at least one occasion. All sites experienced increases in TKN concentration during wet weather, but this phenomenon was more pronounced at Darby Creek sites. Increases during wet weather can probably be attributed to organic compounds in stormwater runoff, breakdown products of accumulated streamside (allochthonous) plant material, re-suspended organic sediment particles, and displaced (sloughed) algae. Much of the TKN present during larger flows in Darby-Cobbs Creek Watershed may reach the Delaware estuary still in an organically-bound state.

Phosphorus

Phosphorus (P), like N, is a macronutrient (element required by plants in relatively large amounts); P concentrations are often correlated with algal density and are used as a primary indicator of cultural eutrophication of water bodies. P readily adsorbs to soil particles and is generally less mobile in soils than nitrogen compounds. Potential non-point sources of P are decomposing organic matter in or near the stream, runoff from industrial parks, agriculture and residential areas, and inorganic P adsorbed to soil particles that are washed into the stream by erosive forces. In fact, soil erosion may be the greatest source of P in some portions of Darby-Cobbs Creek watershed. Point sources of P include CSO and SSO discharges; though infrequent, they contribute large amounts of phosphorus where and when they occur.

Stream producers in Darby-Cobbs Creek Watershed are exposed to flow and a somewhat constant rate of nutrient delivery, albeit one that is punctuated with episodic inputs of greater P concentration due to runoff and erosion. These inputs, however, are coupled with physical disturbances (e.g., hydraulic shear stress, other abrasive forces, reduced light availability). These stressors respond to changes in flow in a non-linear fashion. Many taxa have the ability to store intercellular reserves of inorganic nutrients ("luxury consumption") when concentrations exceed immediate demands. It is thus very difficult to estimate the concentration of P available to stream producers and draw conclusions about stream trophic status from the (usually limited) data available.

Nevertheless, stream nutrient criteria have been proposed. For example, New Jersey's Department of Environmental Protection (NJDEP) has established a criterion of 0.10 mg/L total P for streams and rivers and 0.05 mg/L total P for lakes and their tributaries. USEPA has suggested the use of ecoregion-specific criteria based on the 75th percentile of total P concentration in unimpacted reference streams, or, in the case of insufficient reference stream data, the 25th percentile of TP for all streams in the ecoregion. For the ecoregion that includes Darby-Cobbs Creek Watershed, this criterion is (0.14) mg/l. Dobbs (1998) suggested that the mesotrophic/eutrophic boundary for TP is 0.07mg/l.

Total P concentration was used in analysis of Darby-Cobbs Creek Watershed because orthophosphate (PO4) concentrations were nearly always below reporting limits. Two data points from 6/12/03 at sites DCI010 and DCC455 were excluded from the analysis, because TP concentrations at these sites (0.22 and 0.130 mg/l, respectively) were likely influenced by a sewer leak in the immediate area. This sample from DCI010 was also the only dry weather sample in which PO4 was detected (0.149mg/l).

Phosphorus Concentration: Dry Weather

Darby Creek sites generally had less TP in dry weather than Cobbs Creek sites (Figure 3-67). Overall, 77% of Darby Creek dry weather samples had total P concentration below the reporting limit of 0.05 mg/l, while only 21% of Cobbs Creek sites had dry weather TP concentration below reporting limits. Though only two samples were above reporting limits, greatest mean total P concentration in dry weather (0.106 mg/l) was observed at site DCI010, which is located downstream of golf courses and areas where resident Canada geese congregate. Excluding samples below reporting limits, the watershed overall had mean dry weather TP concentration of 0.073mg/l, which is below NJDEP's criterion, approximately half the proposed EPA criterion, and slightly greater than the mesotrophic-eutrophic boundary concentration proposed by Dobbs (1998).

Phosphorus Concentration: Wet Weather
Total P concentrations were significantly higher in wet weather than in dry weather at sites DCC208, DCC455, DCC770, and DCD767 (student's t-tests, $p<0.05$) (Figure 3-67). Total P concentrations were also higher at all other sites, but statistical power was limited with too few samples exceeding reporting limits. Despite greater total P concentrations in wet weather, PO4 concentrations never exceeded reporting limits in wet weather, indicating that the majority of P within the watershed is adsorbed to sediment particles or organically-bound and is not immediately usable by stream producers. The degree to which wet weather P becomes bioavailable to stream producers depends on a variety of factors. Organically-bound macronutrients probably become transported out of the system (loading to the Delaware Estuary) during larger flows; P appears to be no exception.

Dry Weather N:P Ratios
Estimates of dry weather total N:P nutrient ratios were hindered by the number of samples with nitrite, total phosphorus, ammonia and/or TKN values below reporting limits. Only 3 of 69 samples could have nutrient ratios estimated directly. To generate a greater number of N:P ratio estimates, a value equal to half the reporting limit was substituted for all parameters with sample

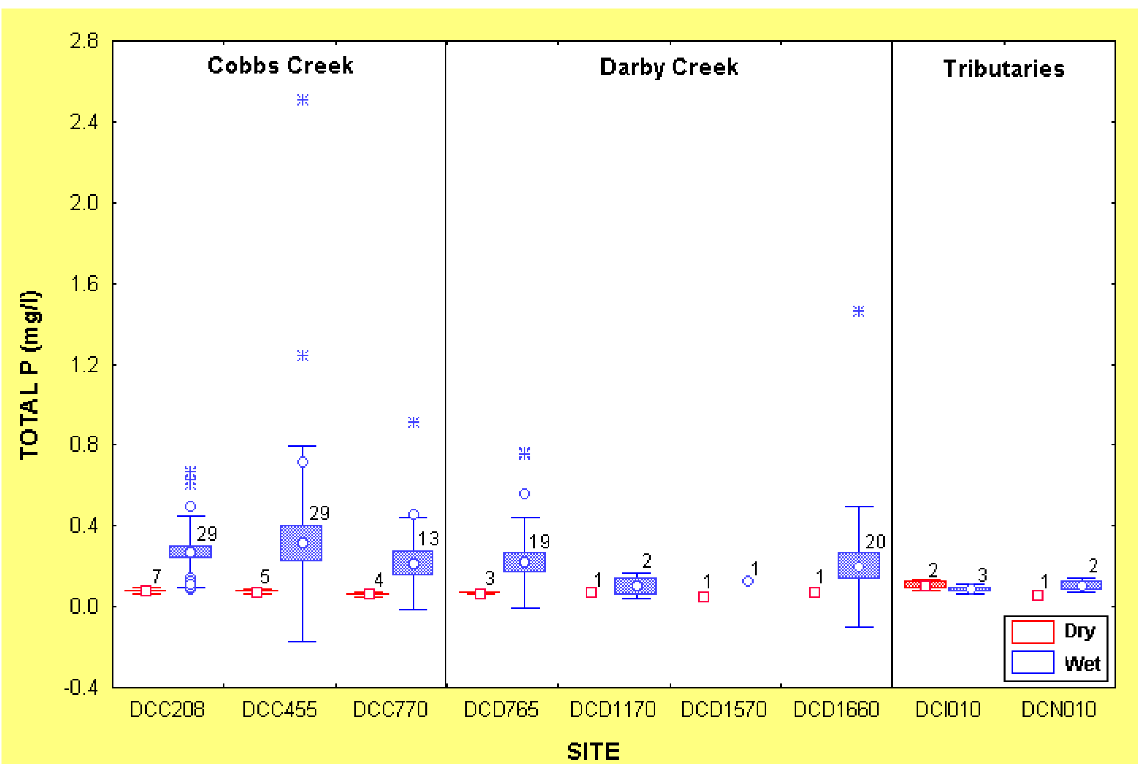


Figure 3-67: Dry and wet weather total phosphorus concentrations at the 9 monitoring sites (D-C CCR 2004 section 5.4.8.8 figure 23 page 113).

concentration less than the reporting limit (Figure 3-68). However, because of the lower reporting limit for total P, these values probably greatly overestimated N:P ratio. A more unorthodox comparison of NO3 vs. actual TP observations was also used in an attempt to better estimate the relative proportions of these two nutrients (Figure 3-68). In any case, all sites within the watershed appear strongly P-limited.

Stream Nutrient Concentrations: Flow Implications

Stream nutrient concentrations in Darby-Cobbs Creek Watershed are dynamic, often increasing in wet weather due to CSO discharge, runoff, and erosion. But concomitant increases in physical stressors probably impose limits on the degree to which stream producers can take advantage of these increased concentrations. Particle size selection, traditionally related to flow by entrainment velocity curves, may determine the effective P loading for a given sediment load. Smaller particles, due to their greater relative surface area, can adsorb relatively more P than larger particles. Smaller particles are also generally more readily eroded and entrained in stormwater flow than larger particles.

Smaller storm events in Darby-Cobbs Creek Watershed probably contribute more to eutrophication than larger events. For example, if smaller sediment particles adsorb more P than larger particles as has been suggested, P loading becomes less efficient as larger particles are entrained in runoff. As shear stresses increase, streambank materials comprise a greater proportion of the sediment load. These particles are likely more similar to the soil parent material (i.e., lower in P concentration than more superficial soils layers that tend to incorporate more organic material). As flows increase, a greater proportion of the total load is transported out of the system, a greater proportion of the total

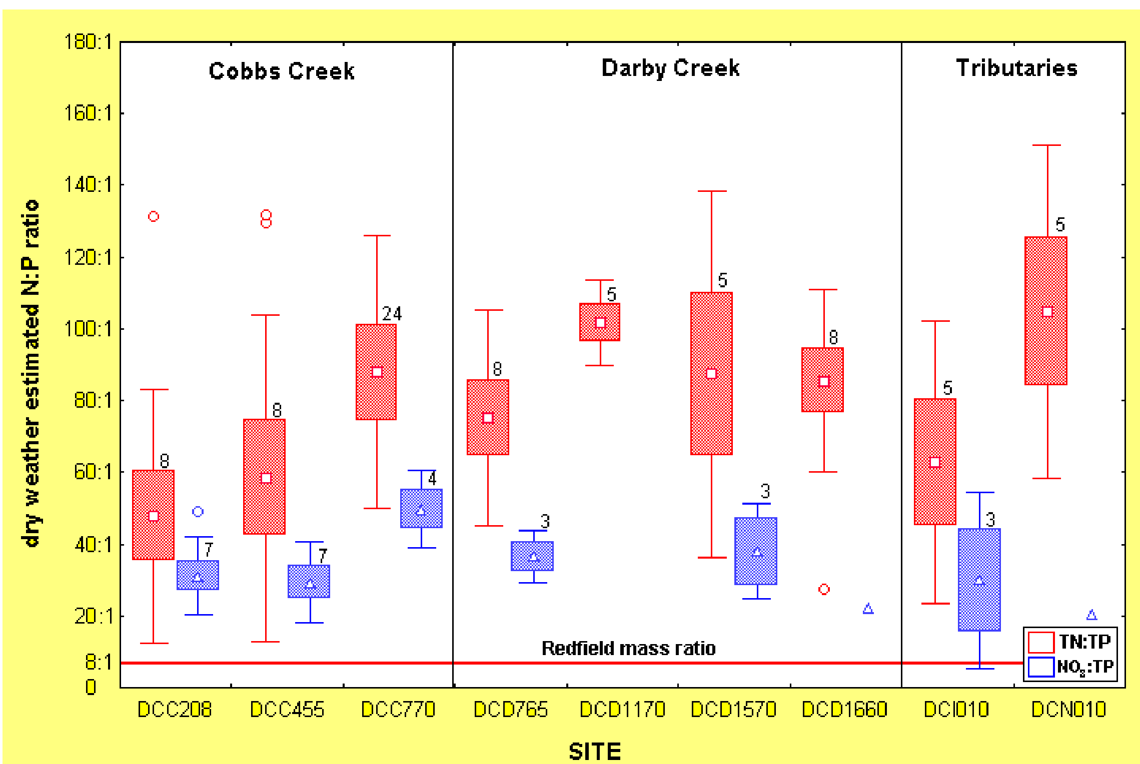


Figure 3-68: Estimated dry weather N:P ratios at the 9 monitoring sites (D-C CCR 2004 section 5.4.8.9 figure 24 page 114).

nutrient load is inaccessible to producers, and much of the photosynthetic biomass (filamentous green algae and their associated epiphytes in particular) may be sloughed away and transported out of the system.

In areas served by combined sewers, the relative impact of small, intense storms is magnified. CSO discharge is minimally diluted by stormwater in the initial overflow phase, or "first flush". If nutrients present in these overflows can become deposited along with sediment or rapidly taken up by stream producers, discharges of short duration, particularly in which shear stresses do not result in major sloughing of algal communities, may have far-reaching consequences for stream nutrient dynamics and aquatic biota. A greater benefit may result from reducing frequency, number, and volume of small CSO discharges rather than attempting to capture releases from larger events.

Metals

Metals occur in all natural waters in varying concentrations due to runoff, erosion, atmospheric deposition, and interactions with streambed geological features. However, because certain metals may be toxic even in very small concentrations, toxic metals concentrations are included in the CCIWMP (indicator 8). Darby Creek Watershed (32.3 river miles including Darby Creek, Hermesprota Creek, Muckinipattis Creek, Stony Creek, Langford Run, and Whetstone Run) was listed by PADEP in 1996 as impaired due to metals in urban runoff/storm sewers, though individual segments were not identified. Cobbs Creek watershed (24.8 river miles, including Indian creek) was listed by PADEP in 2002 as impaired due to urban runoff/storm sewers and municipal point sources, but cause(s) of the impairment were not identified.

Metals of concern (e.g., lead, chromium, cadmium, copper, and zinc) were most often undetectable or present in minimal concentrations in water samples taken in 2003 from Darby-Cobbs Creek watershed. However, increases in concentration during rainfall were observed for copper, iron, and lead. Though water column toxic metal concentrations may be generally small, many metals readily adsorb to sediment particles, interact with organic molecules, or otherwise precipitate or become deposited or incorporated into stream sediments. Since most aquatic organisms either inhabit sediments or feed upon benthic invertebrates, possible toxic effects may not be reflected by water column concentrations alone.

Calcium and magnesium concentrations of Darby-Cobbs Creek watershed were not unusual, keeping with the predominant rock types in the watershed (schists and gneiss). As the major divalent cations in surface water, Calcium and Magnesium are used to compute hardness (expressed as mg/l $CaCO_3$). This is an important parameter, because toxicity of other metals generally has an inverse relationship with hardness. Most EPA and PADEP toxic metal water quality criteria are currently defined as linear regression equations that account for observed decreases in toxicity as hardness increases. Each sample metal concentration is evaluated against the criterion as calculated with sample hardness. Furthermore, two water quality criteria exist for each toxic metal, criteria continuous concentration (CCC) and criteria maximum concentration (CMC); these criteria address chronic and acute toxicity, respectively. Dry weather water samples were compared to CCC and wet weather samples were compared to CMC.

PADEP dissolved metal criteria are based on EPA toxic metals standards originally developed for total recoverable metals. Though these criteria have been modified to include a conversion factor for use with dissolved metals data, actual dissolved metal concentrations cannot be predictably determined as a proportion of total recoverable metals concentrations. Solubility of metals in natural waters varies with other environmental variables. Because of the degree to which metals may adsorb to sediment and form complexes with organic particles, it is likely that actual water column dissolved metal concentrations in the Darby-Cobbs Creek Watershed are smaller than those predicted using these conversion factors. To assess the effects of using these conversion factors, total recoverable metal concentrations were compared to both dissolved and total recoverable criteria.

Dry Weather Metals Concentrations

With the exception of copper, metals concentrations were relatively small in dry weather (Table 3-86). Cadmium and Chromium were not detected in any of 69 dry weather samples from Darby-Cobbs Creek Watershed. Lead was detected in only 3 samples, 2 from site DCC208 and one from site DCC455; only one of these three detections was a possible violation of the dry weather (continuous) criterion (CCC) for lead. Aluminum and zinc were detected in approximately two thirds of dry weather samples. Aluminum concentrations were consistently small, the maximum value was less than 50% of the CMC and the mean concentration was less than 10% of the CMC (no CCC has been established for aluminum). Zinc concentrations were typically 10% or less of the CCC. Copper was detected in all dry weather samples; three samples may have exceeded the CCC. While standards for each sample vary with hardness, many samples had copper concentration at 50% or more of the CCC. Based on ICP-MS performance on individual check standards, reporting limits for some metals were higher than 1μg/l on some occasions.

Table 3-86: Metal concentrations collected during dry weather in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.4.3.1 table 1 page 92).

Metal	non-detects	Max	Min	Arithmetic Mean	Std. Dev.	Geometric Mean	WQ Violations
Aluminum	16	0.363	0.015	0.067	0.053	0.055	N/A
Cadmium	69	N/A	N/A	N/A	N/A	N/A	0
Calcium	0	52.0	24.0	34.89	6.573	34.311	N/A
Chromium	69	N/A	N/A	N/A	N/A	N/A	0
Copper	0	0.020	0.002	0.006	0.004	0.006	3
Iron	4	0.785	0.052	0.196	0.113	0.171	0
Lead	66	0.007	0.002	0.004	0.003	0.003	1
Magnesium	0	19.320	11.700	14.945	1.510	14.781	N/A
Manganese	3	0.142	0.010	0.033	0.024	0.027	0
Zinc	19	0.084	0.002	0.017	0.017	0.012	0

Wet Weather Metals Concentrations

Wet weather metals concentrations were generally greater than concentrations in dry weather; the incidence of possible water quality violations was much higher overall in wet weather than in dry weather. For example, metals that may have violated water quality criteria only in wet weather included aluminum, cadmium, manganese, and zinc. Possible violations of copper and lead criteria were more frequent in wet weather as well. Hydrograph-matched scatterplots of toxic metal concentrations appear in (Appendix G of the Darby-Cobbs Creek Watershed Comprehensive Characterization Report 2004 Update).

While surface runoff undoubtedly contributes to increases in wet weather metals concentrations, it is likely that re-suspension of metals associated with sediments contributes to excursions from water quality criteria. Metal parameters considered to be a potential problem during wet weather were dissolved iron and Zn. Zn concentrations were found above both the aquatic life acute maximum and the aquatic life chronic maximum 3.2% and 6.5% of samples respectively. Metals considered parameters of concern in the CCR are Cu (aquatic life acute and chronic maximums exceeded), Fe (chronic maximum only), and Pb (chronic maximum only).

As seen in the list of parameters of concern and potential concern, most metal concentration were higher during wet weather samples. Concentrations of Fe and dissolved Fe do not always follow the trend of increasing in wet weather. This is especially true in the upper reaches of the watershed, where concentrations are higher. Mean dissolved iron is lower in wet weather at both sites in the Upper Cobbs (PWD 2002). In the Lower Cobbs, mean total iron increases in wet weather in the main stem of Cobbs Creek but decreases slightly at the Naylors Run site.

Public Health Effects (Metals and Fish Consumption)

Relatively small amounts of certain toxic compounds can kill aquatic life through acute poisoning, while chronic levels may be harmful to developmental stages of fish and macroinvertebrates. For example, bioaccumulation of toxins in fish may have a profound effect on fecundity and may also pose a threat to humans who regularly consume fish.

The established indicator measures the percent of cadmium, chromium, copper and zinc samples meeting state standards at various sites in Darby-Cobbs Creek Watershed. In 2003, PWD scientists collected 48 samples at each site for Cd, Cr, Cu and Zn during dry and wet weather. An additional 48 to 56 samples were collected at each site during two wet-weather targeted events. Results suggest standards intended to protect aquatic life were met at all locations during dry-weather in 2003 with the exception of copper in the upper reach of Darby Creek (Figure 3-69).

Conversely, wet-weather exceedances were omnipresent on both Darby Creek and Cobbs Creek (Figure 3-70). Of the metals, aluminum and copper generally exceeded standards more than 10 % of the time, while chromium and lead samples were greater than Pennsylvania's water quality criteria between 2% - 10% of the time.

Bacteria

Fecal coliform bacteria concentration is positively correlated with point and non-point contamination of water resources by human and animal waste and is used as an indicator of poor water quality (Indicator 7 of the Watershed Management Plan). PADEP has established a maximum limit of 200 colony forming units, or "CFUs," per 100 mL sample during the period 05/01-9/30, the "swimming season" and a less stringent limit of 2000 CFUs/100 ml for all other times. It should be noted that the state criterion is based on the geometric mean of five consecutive samples collected over a 30-day period. As bacterial concentrations can be significantly affected by rain events and otherwise may exhibit high variability, individual samples are not as reliable as replicate or multiple samples taken over a short period.

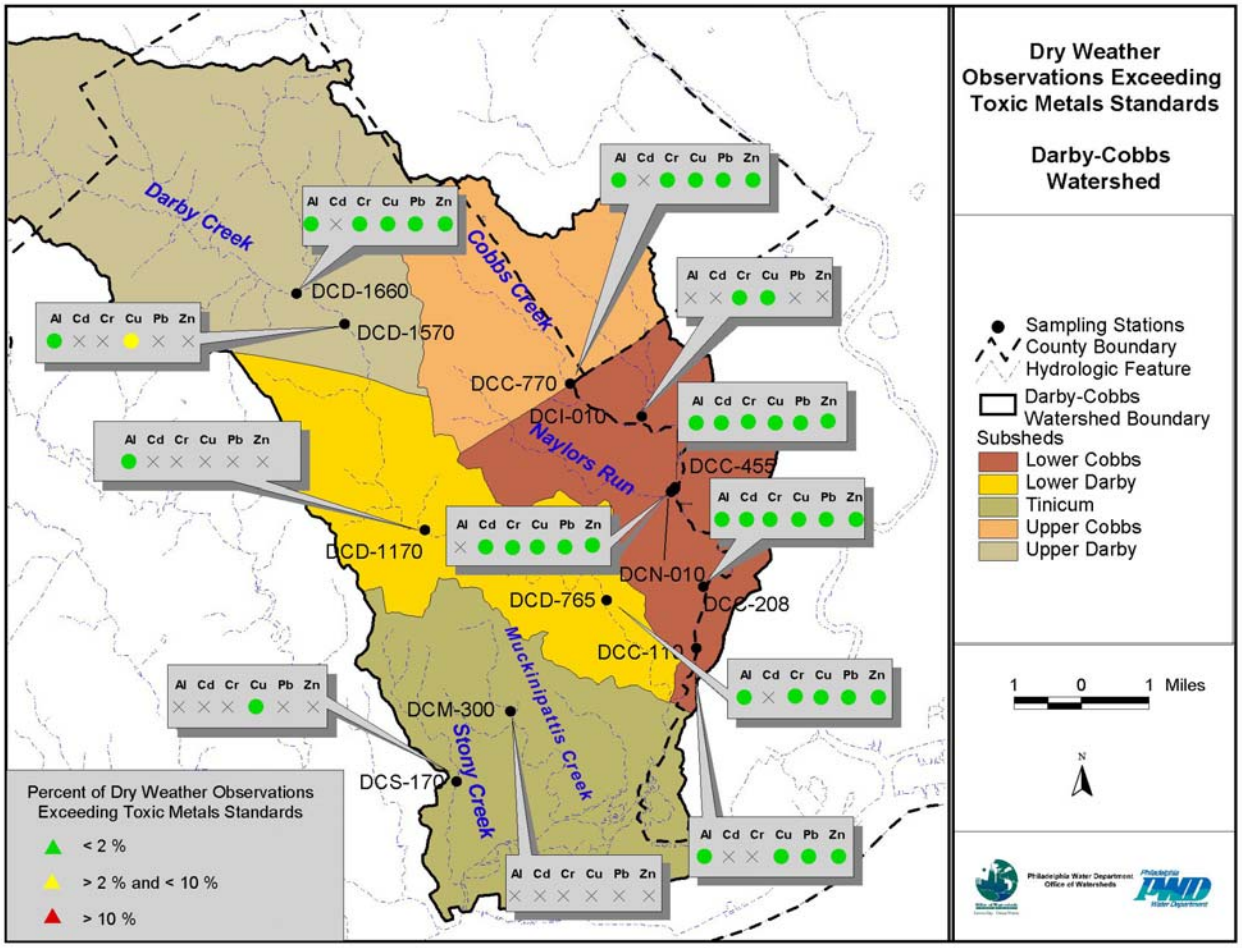


Figure 3-69: Dry weather metals indicator status update (D-C CCR 2004 section 6.7 figure 32 page 128).

Based on data from numerous sources (PADEP, EPA, USDA-NRCS, volunteer and non-profit organizations, etc.), it appears likely that many, if not most, southeastern PA streams would be found in violation of water quality criteria given sufficient sampling effort. PWD has expended considerable resources toward documenting concentrations of fecal coliform bacteria and *E. coli* in Philadelphia's watersheds. The sheer amount of data collected allows for more comprehensive analysis and a more complete picture of the impairment than does the minimum sampling effort needed to verify compliance with water quality criteria. In keeping with the organizational structure of the watershed management plan, fecal coliform bacteria analysis has been broken into dry (Target A) and wet weather (Target C) components, defined by a period with at least 48 hours without rain as measured at the nearest gauge in PWD's rain gauge network.

Dry Weather Fecal Coliform Bacteria (Target A)

Based on discrete sampling conducted during 1999-2003 (Table 3-80), fecal coliform is considered a dry weather parameter of concern because the standards for both swimming season and non-swimming season were exceeded in 85% of the samples.

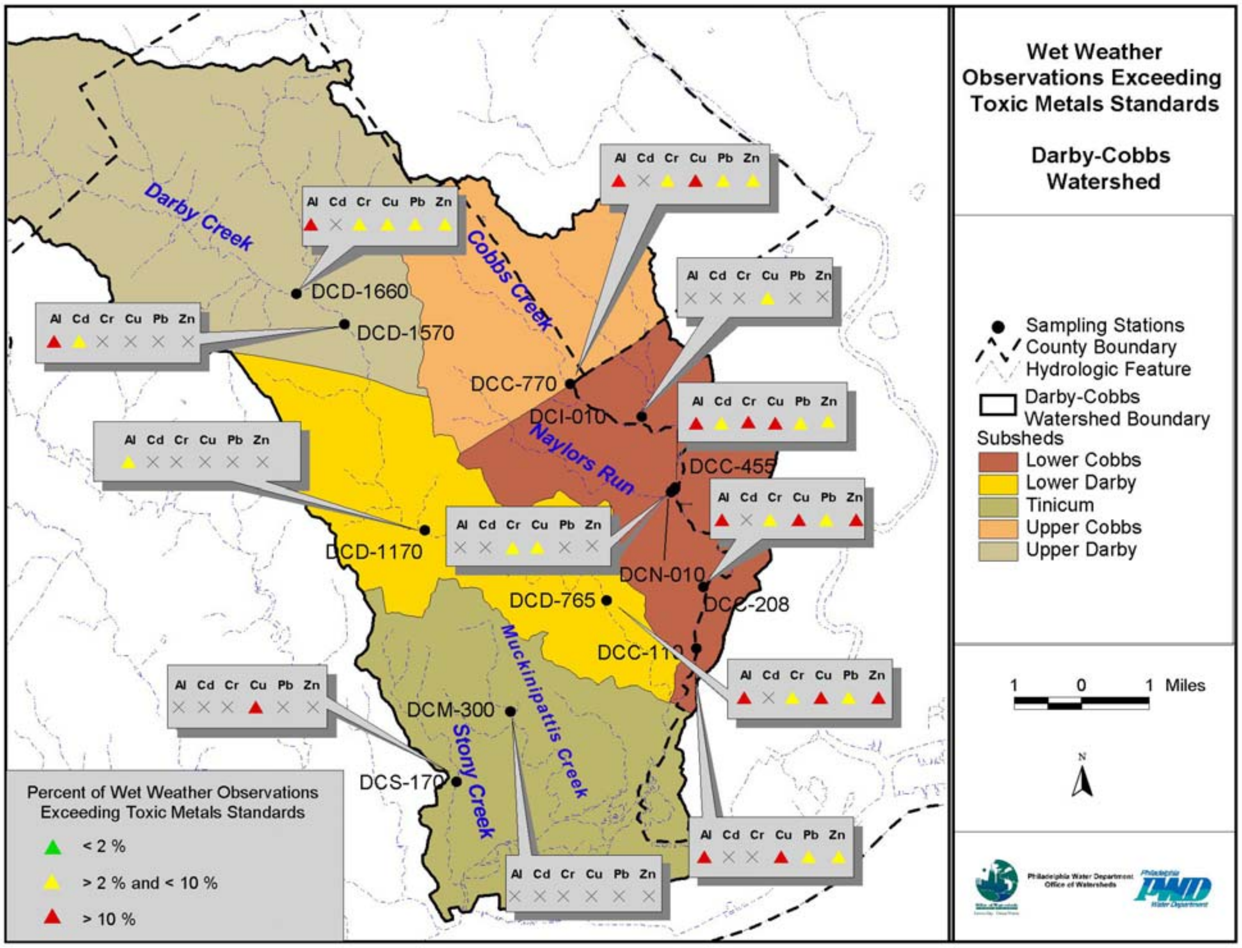


Figure 3-70: Wet weather metals indicator status update (D-C CCR 2004 section 6.7 figure 33 page 1289)

Data collected as part of PWD's 2003 fixed interval (weekly) discrete chemical sampling program also showed that the geometric mean of fecal coliform concentration at all sites exceeded water quality criteria during the swimming season (Table 3-87 and Figure 3-71). However, all individual dry weather samples collected from Darby-Cobbs Creek Watershed during the non-swimming season (n=18) showed fecal coliform bacteria concentration well below the water quality criterion of 2000 CFU/100mL. Samples from sites DCI010, DCC208, and DCC455 on 6/12/03 were likely affected by a leaking sewer. The sewer leak was subsequently detected by PWD biologists conducting a fish assessment downstream. Geometric means of fecal coliform from these sites would be 366, 324 and 696, respectively, with these samples omitted.

Overall, 33.3 % of all sites along Darby Creek mainstem met water quality standards during dry weather in 2003 (Figure 3-72). Geometric means calculated for Darby Creek sites revealed that values were generally between 2 to 4 times the season standards (i.e., 200 CFU/100 ml or 2000 CFU/100 ml) (Figure 3-73). In Cobbs Creek, sites DCI 010 and DCC 208 met water quality standards in 50.0 % and 33.3 % of the samples, respectively. Upstream and midstream sites (DCC 770 and DCC 455) had less desirable results, with standards being met only 22% of the time. No samples taken on Naylor's Run (DCN 010) met water quality standards during the swimming and non-swimming seasons.

With the exception of intense sampling upstream and downstream of a point source, surface water grab samples do not usually allow one to determine the source(s) of fecal contamination. Recent research has shown that fecal coliform bacteria may adsorb to sediment particles and persist for extended periods in sediments (VanDonsel, et al. 1967, Gerba 1976). Presence of bacterial indicators in dry weather may thus more strongly reflect past wet weather loadings than dry weather inputs (Dutka and Kwan, 1980). Clearly, there exist several possible sources of fecal coliform bacteria within the watershed, all or combinations of which may be acting within different spatial and temporal dimensions. PWD is piloting a Bacterial Source Tracking (BST) program that may eventually be useful in identifying the sources of fecal coliform bacteria collected in dry weather. Of particular interest is the relative proportion of the total bacterial load from human sources vs. domestic and wildlife animal sources.

Wet Weather Fecal Coliform Bacteria (Target C)

Based on discrete wet weather sampling conducted during 1999-2003 (Table 3-81), fecal coliform is considered a wet weather parameter of concern because the standards for both swimming season and non-swimming season were exceeded in 94% of the samples.

Table 3-87: Fecal coliform concentrations at the nine water quality monitoring sites (D-C CCR 2004 section 5.4.2.1 table 11 page 88).

Site	n	Max	Min	Median	Mean	Std. Dev.	Geometric Mean
DCC208	7	2600	140	410	674.29	859.03	437.06
DCC455	7	2900	390	540	1097.14	991.66	815.75
DCC770	7	1060	220	300	407.14	293.58	351.92
DCD765	7	530	160	310	311.43	118.80	292.60
DCD1170	4	700	120	400	412.50	32.02	411.61
DCD1570	4	320	210	240	252.50	49.92	249.00
DCD1660	7	380	160	240	257.14	68.97	249.36
DCI010	4	20000	150	600	5337.50	9778.40	995.67
DCN010	4	3000	770	1020	1227.50	598.02	1136.70

Surface water grab samples (n=54) were collected at nine sites throughout Darby- Cobbs Watershed during or within 48 hours of wet weather as part of PWD's 2003 fixed interval (weekly) discrete chemical sampling program. Results of weekly discrete fecal coliform bacteria concentration analysis appear in Table 3-88. An additional 130 automatic sampler composite samples were collected from 5 sites during two individual wet weather events as part of PWD's intensive wet weather monitoring program. Hydrograph-matched scatterplots of fecal coliform bacteria concentration at each site for each event appear in (Appendix F of the Darby-Cobbs Creek Watershed Comprehensive Characterization Report 2004 Update). The data from these events is summarized in Tables 3-89 and 3-90.

Not surprisingly, wet weather fecal coliform bacteria concentration is elevated significantly at each site compared to dry weather concentrations. Both Cobbs and Darby Creeks exhibited a typical pattern of fecal coliform bacteria concentration increasing at downstream locations. Wet weather sampling results showed concentrations of fecal coliform exceeding water quality standards at all sites in Darby-Cobbs Creek Watershed (Figure 3-70). Thirty-three percent of samples at Darby Creek sites met standards while only 16.7% of samples in Cobbs Creek were below water quality

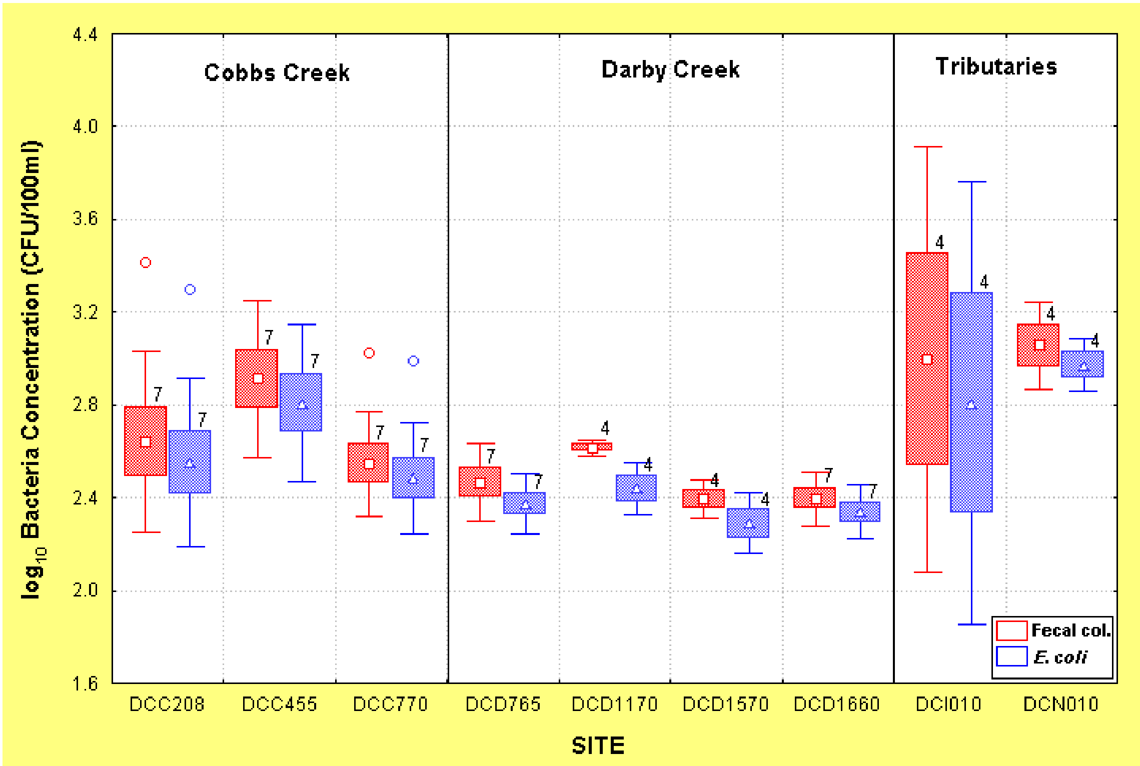


Figure 3-71: Dry weather fecal coliform and E. coli concentrations at the 9 monitoring sites, 2003 (D-C CCR 2004 section 5.4.2.1 figure 8 page 88).

standards. Moreover, fecal coliform concentrations were between 2 to 10 times greater than standard values in Darby Creek (i.e., 400-2000 CFU/100 ml during the swimming season). Similarly, mean concentrations of fecal coliform were greater than the water quality standard but varied spatially along the river continuum (Figure 3-71). For example, concentrations at the upstream location (DCC 770) were between 2 to 10 times the standard limit and increased steadily until values reached between 50 to 200 times (i.e., 10,000-40,000 CFU/100 ml) the water quality standards at Site DCC 208. Similarly, concentrations of fecal coliform at tributary locations (i.e., DCN 010 and DCI 010 ranged between 2,000 to 10,000 CFU/100 ml during wet conditions.

Table 3-88: Fixed interval fecal coliform samples collected in wet weather, 2003 (D-C CCR 2004 section 5.4.2.2 table 12 page 89).

Site	n	Max	Min	Median	Arithmetic Mean	Std. Dev.	Geometric Mean
DCC208	6	43,000	350	6,700	15,192	17,184	6,648
DCC455	6	36,000	310	2,550	8,162	13,838	2,629
DCC770	6	2,900	140	495	1,115	1,174	657
DCD765	6	4,000	440	710	1,452	1,402	1,040
DCD1170	6	3,000	320	675	1,288	1,274	802
DCD1570	6	4,000	160	325	1,133	1,537	532
DCD1660	6	5,300	30	275	1,772	2,474	449
DCI010	6	110,000	450	3,000	21,017	43,706	3,614
DCN010	6	4900	590	3,300	2,902	1,888	2,187

Table 3-89: Fecal coliform concentrations recorded at the 5 wet weather monitoring locations during storm event 1, 2003 (D-C CCR 2004 section 5.4.2.2 table 13 page 90).

Site	n	Max	Min	Median	Arithmetic Mean	Std. Dev.	Geometric Mean
DCC208	18	182,000	350	78,500	71,275	54,242	28,423
DCC455	19	200,000	1,400	43,000	63,168	63,202	28,615
DCC770	18	20,000	420	2,300	6,004	7,424	2,378
DCD765	11	41,000	1,000	9,400	12,100	11,731	7,199
DCD1660	19	161,000	1,800	6,600	26,763	39,534	11,101

Table 3-90: Fecal coliform concentrations recorded at the 5 wet weather monitoring locations during storm event 2, 2003 (D-C CCR 2004 section 5.4.2.2 table 14 page 90).

Site	n	Max	Min	Median	Arithmetic Mean	Std. Dev.	Geometric Mean
DCC208	9	82,000	25,000	29,000	41,000	21,529	36,891
DCC455	9	103,000	8,800	30,000	32,744	28,561	24,975
DCC770	9	46,000	2,200	6,600	14,167	16,827	8,387
DCD765	9	20,000	3,600	8,500	8,300	4,220	7,466
DCD1660	9	18,000	3,100	5,500	6,733	5,140	5,721

Future Investigation of Bacteria Conditions in Cobbs Creek

Investigations continue into the nature, causes, severity and opportunities for control of the bacteria conditions in the lower Tacony Creek and the Frankford Creek. Future work efforts will include the development of informational total maximum daily load assessments for bacteria from all potential sources in the watershed. Progress and results of this work and any proposed remedial control actions will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Temperature

Based on discrete sampling, temperature is considered a parameter of concern because the state standard was exceeded in 12% of the samples collected during dry weather (Table 3-80). During wet weather, temperature is considered to be a parameter of potential concern because the standard was exceeded in 9.6% of the wet weather samples (Table 3-81). Although, discrete sampling indicated temperature was a concern, thermal maxima for sites in Darby Cobbs Watershed, as measured in 2003 with continuous water quality monitoring equipment, never exceeded state water quality standards. Changes in temperature of 2ºC or more were observed at most sites on a number of occasions; however, changes of this magnitude occurred in dry and in wet weather.

The role of temperature in shaping aquatic communities cannot be understated. With the exception of birds and mammals, all freshwater aquatic organisms are poikilotherms ("cold-blooded"). Unable to regulate body temperature through metabolism, these organisms must select suitable temperature conditions within their habitats. PADEP has established temperature criteria for the waters of the commonwealth, largely to delineate areas requiring more stringent thermal protection for naturally-reproducing populations of sensitive ("cold water") fish species, recreationally-sought salmonids, in particular. Temperature criteria also serve to protect aquatic life from increases in temperature from

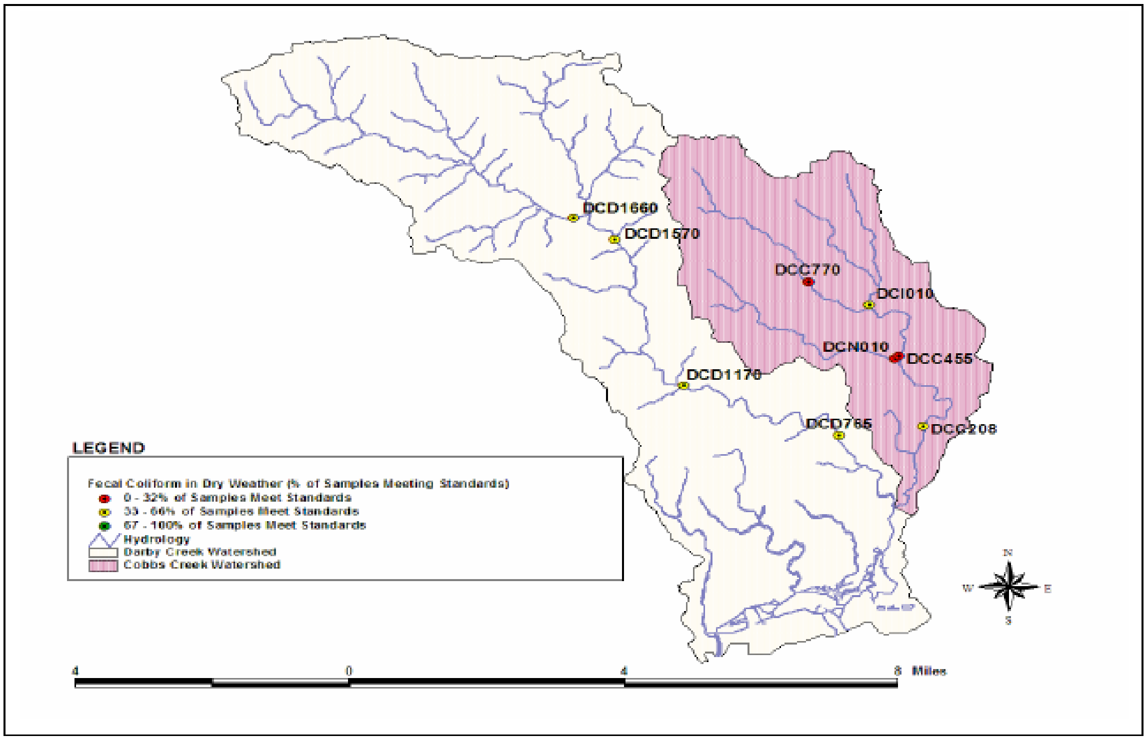


Figure 3-72: Dry weather fecal coliform indicator status update (D-C CCR 2004 section 6.5 figure 28 page 123).

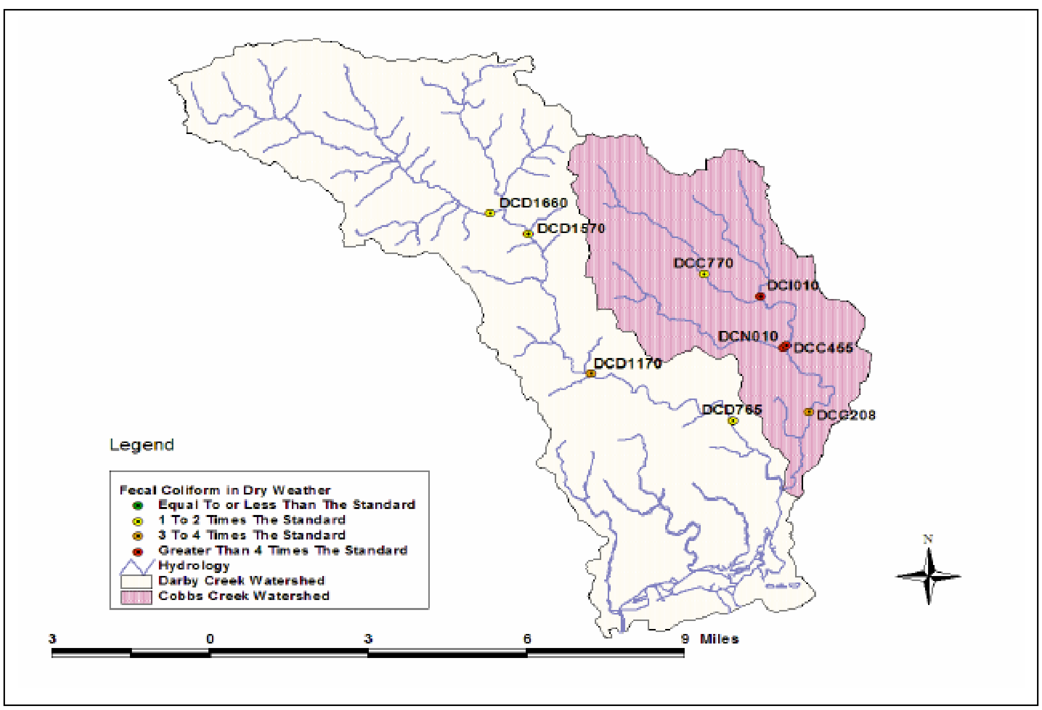


Figure 3-73: Geometric means of fecal coliform concentrations in dry weather (D-C CCR 2004 section 6.5 figure 29 page 124).

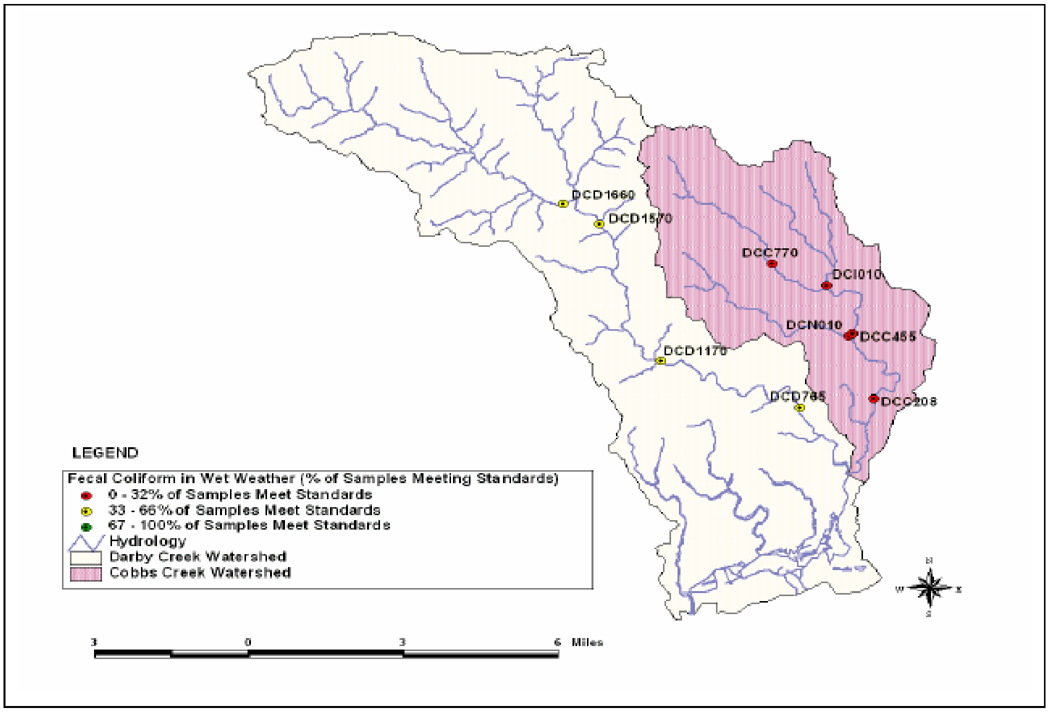


Figure 3-74: Wet weather fecal coliform indicator status update (D-C CCR 2004 section 6.5 figure 30 page 125).

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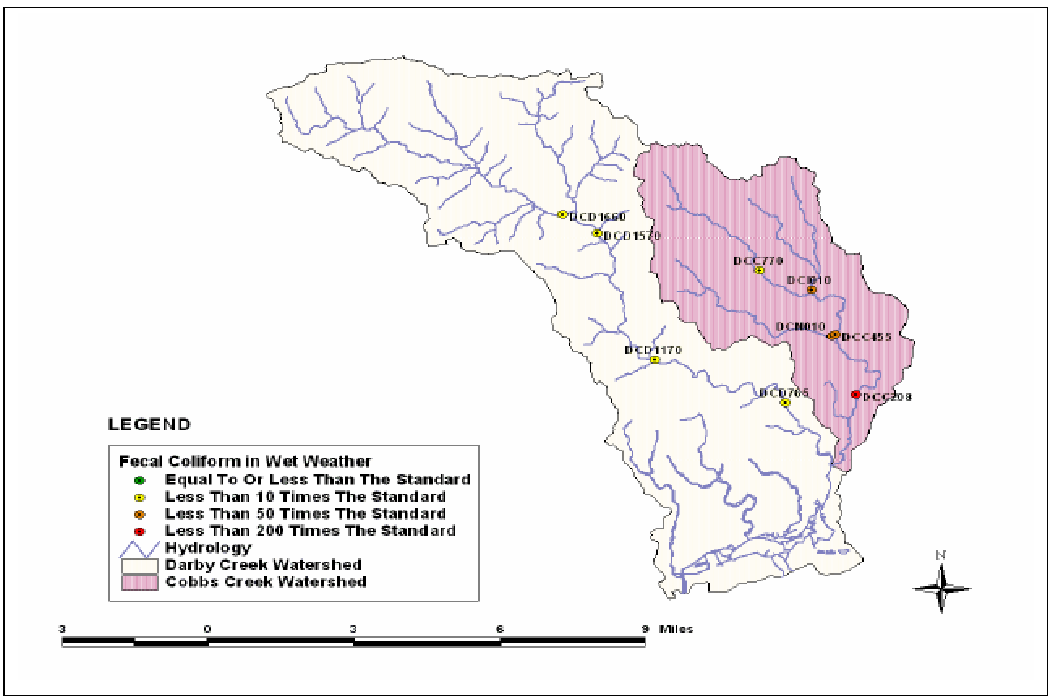


Figure 3-75: Geometric means of fecal coliform concentrations in wet weather (D-C CCR 2004 section 6.5 figure 31 page 126).

industrial activity (e.g., cooling water). Darby-Cobbs Creek Watershed does not support natural populations of coldwater fish, and is not known to be significantly affected by discharges of cooling waters.any water bodies that cannot support natural populations of cold water fish do have adequate thermal protection to maintain hatchery-raised adult trout. Segments of Darby Creek watershed north of PA Rte 3 (West Chester Pike) are so protected and are designated a trout stocking fishery (TSF); the remainder of Darby-Cobbs Creek Watershed is designated a warm water fishery (WWF).

In addition to limiting effects of lethal and sublethal temperatures on fish survival, temperature regime has myriad implications for aquatic communities. These effects are discussed in greater detail in Section 5.3.5, Habitat Suitability Indices of the 2004 Update to Darby-Cobbs Creek Watershed CCR.

3.4.2.2.3 Biological Assessment of Darby-Cobbs Creek Watershed

Biological monitoring is a useful means of detecting anthropogenic impacts to the aquatic community. Resident biota (e.g. benthic macroinvertebrates, fish, periphyton) in a water body are natural monitors of environmental quality and can reveal the effects of episodic and cumulative pollution and habitat alteration (Plafkin et. al.1989, Barbour et al. 1995). Biological surveys and assessments are the primary approaches to biomonitoring. During this period, macroinvertebrate, ichthyfauna and habitat assessments were conducted at specified locations within Cobbs Creek watershed. Geographical Information Systems (GIS) databases and watershed maps were also constructed to provide accurate locations of the sampling sites. The Office of Watersheds and the Bureau of Laboratory Services then analyzed compiled data to provide both a quantitative and qualitative assessment of the biological integrity of Cobbs Creek and to provide insight on the current problems associated with this urban stream system. Darby-Cobbs Creek Watershed Comprehensive Characterization Report and the 2004 Update address future assessments and potential solutions for the restoration of Darby-Cobbs Creek Watershed.
(PWD, 2004)

Sites in Darby-Cobbs Creek Watershed were compared to reference sites on French Creek and Rock Run, in Chester County, PA. Reference sites were chosen to reflect the range of stream drainage areas in Darby-Cobbs Creek Watershed, yet extensive impervious cover in portions of Darby-Cobbs Creek Watershed complicates this comparison. Due to exaggerated storm flows and concomitant erosion, many sites in the Darby-Cobbs Creek Watershed may be categorized as first or second order streams, yet exhibit geomorphological attributes (e.g., bankfull discharge area) similar to sites with much larger drainage areas. These details are addressed in greater detail in Section 5.3: Habitat Assessment of the Comprehensive Characterization Report 2004 Update.

Benthic Macroinvertebrate Assessment

Benthic macroinvertebrate monitoring occurred at 17 sites in Darby-Cobbs Creek Watershed during 2003. Similar to the 1999 sampling effort, Rapid Bioassessment Protocol III (RBP III) was chosen as the approved method for assessing the condition of the macroinvertebrate community in Darby-Cobbs Creek Watershed.

The assessment conducted in 2003 reconfirmed findings of the Pennsylvania Department of Environmental Protection (PADEP) and Philadelphia Water Department (PWD). Benthic impairment in Cobbs Creek was omnipresent; stream designations ranged from "moderately impaired" to "severely impaired" (Figure 3-76). Darby Creek monitoring sites received the same designations, with the exception of one upstream site which scored as "slightly impaired".

A total of 2,114 individuals of 40 taxa were collected and identified during the 2003 benthic macroinvertebrate survey of Darby-Cobbs Creek Watershed. Mean taxa richness of all sites within the watershed was 14.3 (Table 3-91). Overall, moderately tolerant (89.74%) and generalist feeding taxa (75.72%) dominated the watershed. Mean Hilsenhoff Biotic Index (HBI) of all assessment sites was 5.63 (Figure 3-77). Overall, the watershed lacked pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa. While present at four upstream Darby Creek sites, abundance of EPT taxa was very low (Figure 3-78). Midges (family Chironomidae) and net-spinning hydropsychid caddisflies (Hydropsyche and Cheumatopsyche) dominated the benthic assemblage of most sites within the watershed (percent contribution ranged from 23.14% to 74.07%). Annelids, riffle beetles, isopods, amphipods, tipulids, gastropods, and oligochaetes were also present throughout the watershed. Results of benthic macroinvertebrate studies are discussed in greater detail in the 2004 Comprehensive Characterization Report Update.

The severity of impairment throughout Darby-Cobbs Creek Watershed suggests that attaining healthy benthic communities in mainstem localities and associated tributaries is not a feasible option at this time without active habitat restoration. Habitat restoration, flow attenuation and active re-introduction (i.e., "invertebrate seeding") may be the only solutions to ensure a viable benthic community within this watershed.

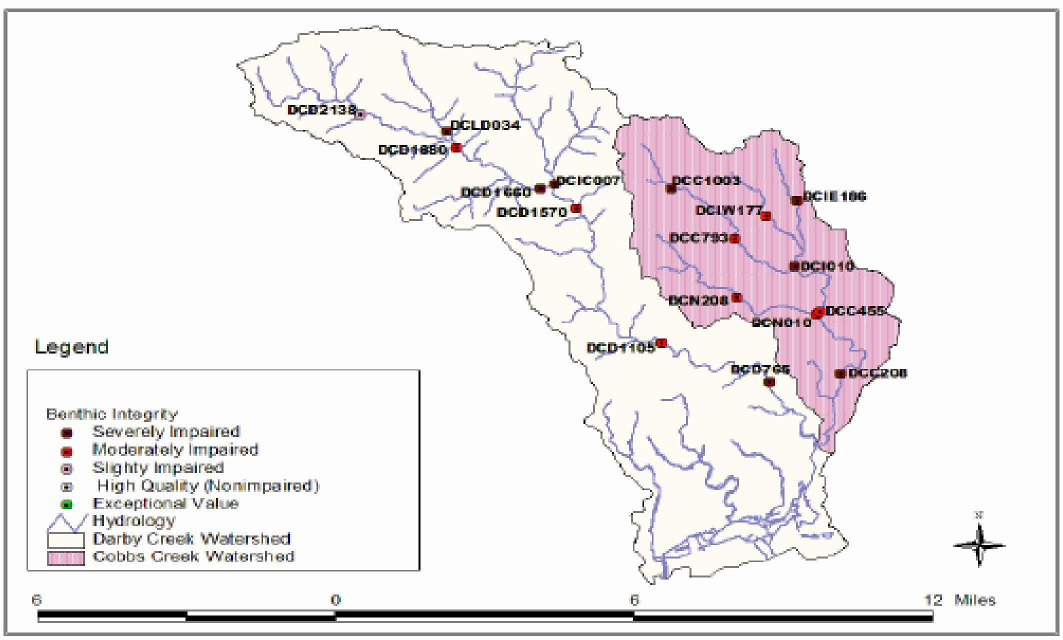


Figure 3-76: Benthic impairment in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 6.4 figure 27 page 121).

Table 3-91: Biological condition results for RBP III (D-C CCR 2004 section 5.1.1 table 1 page 46).

Watershed	Monitoring Site	Taxa Richness	Modified EPT Taxa	Hilsenhoff Biotic Index (modified)	Percent Dominant Taxon	% Modified Mayflies	Biological Quality (%)	Indicator Status
Cobbs	DCC208	12	0	7.06	42.42%	0.00	0.00	Severely Impaired
	DCC455	12	0	5.24	44.86%	0.00	26.67	Moderately Impaired
	DCC793	15	1	5.44	39.44%	0.00	40.00	Moderately Impaired
	DCC1003	13	0	5.88	57.80%	0.00	13.33	Severely Impaired
Darby	DCD765	11	1	5.69	68.70%	0.00	0.00	Severely Impaired
	DCD1105	17	1	5.38	32.08%	0.00	20.00	Moderately Impaired
	DCD1570	16	4	5.04	33.09%	100.00	46.67	Moderately Impaired
	DCD1660	14	1	5.45	61.42%	0.00	13.33	Severely Impaired
	DCD1880	17	3	4.81	23.14%	0.00	46.67	Moderately Impaired
	DCD2138	23	3	5.03	34.42%	100.00	73.33	Slightly Impaired
Tributaries	DCN010	16	1	6.13	15.04%	0.00	40.00	Moderately Impaired
	DCN208	13	0	6.02	23.97%	0.00	33.33	Moderately Impaired
	DCI010	12	0	5.97	60.29%	0.00	13.33	Severely Impaired
	DCIW177	12	1	5.83	37.82%	0.00	33.33	Moderately Impaired
	DCIE186	11	0	5.78	74.07%	0.00	6.67	Severely Impaired
	DCLD034	13	1	5.28	51.68%	0.00	13.33	Severely Impaired
	DCIC007	16	2	5.65	51.32%	0.00	6.67	Severely Impaired

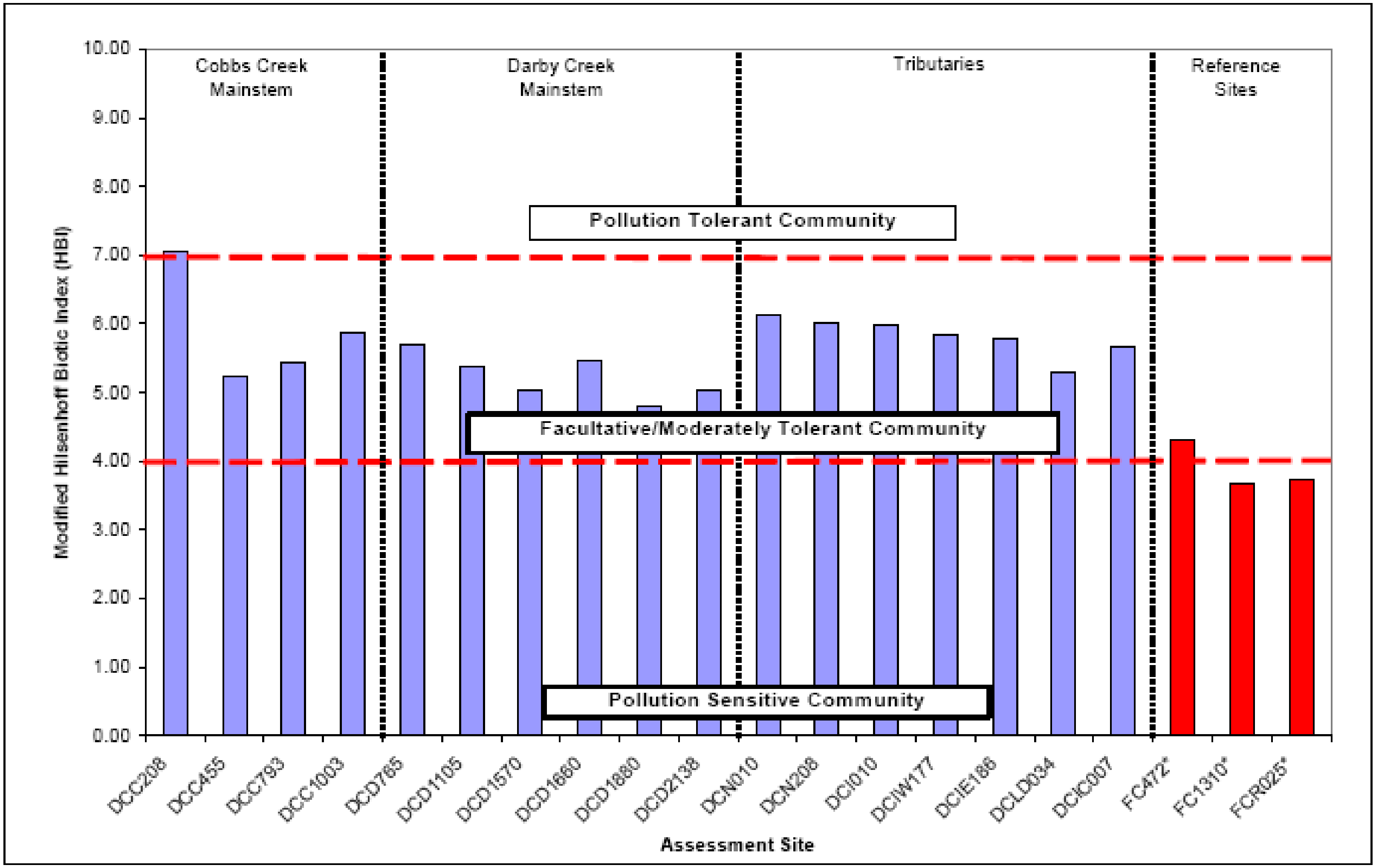


Figure 3-77: Modified Hilsenhoff Biotic Index (HBI) scores of assessment sites in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.1.1 figure 1 page 47).

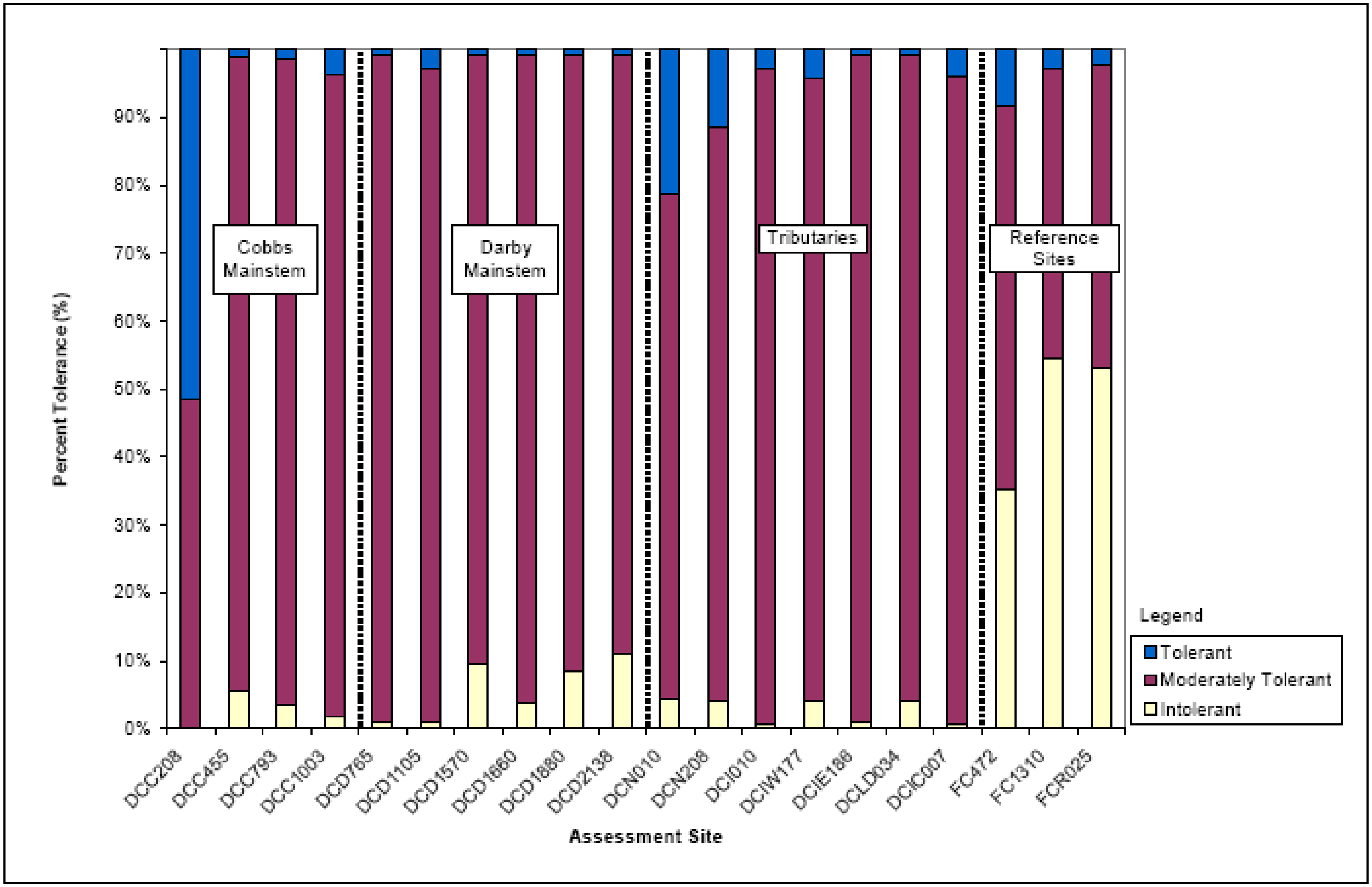


Figure 3-78: Pollution tolerance values (%) of macroinvertebrate assemblages at each assessment site in Darby-Cobbs Watershed (D-C CCR 2004 section 5.1.1 figure 2 page 49).

Fish Assessment

A total of 12,882 individuals of 44 species representing 13 families were collected throughout Darby-Cobbs Creek Watershed in the 2003 bioassessment (Table 3-92). Blacknose dace (Rhinichthys atratulus) and Banded killifish (Fundulus diaphanus), two taxa highly tolerant of poor stream conditions, were most abundant and comprised approximately 33% of all fish collected. Other common species were White sucker (Catostomus commersoni), Mummichog (Fundulus heteroclitus), Common shiner (Luxilus cornutus), and Swallowtail shiner (Notropis procne). Of 44 species collected, seven species comprised 78% of the entire fish assemblage. Similarly, four species made up nearly 70% of total biomass, with white sucker and American eel (Anguilla rostrata) contributing greater than 55%. In general, Darby Creek had greater species richness, but Cobbs Creek had higher abundance, density (individuals per unit area), and catch rates (catch per unit effort).

Trophic composition evaluates quality of the energy base and foraging dynamics of a fish assemblage. This is a means to evaluate the shift towards more generalized foraging that typically occurs with increased degradation of the physicochemical habitat (Barbour et al., 1999). Generalist feeders (54.7%) and insectivores (38.2%) dominated Darby-Cobbs Creek Watershed, with 6.1% top carnivores and approximately 1% herbivores and filter feeders. Trophic composition was fair compared to reference sites. In Cobbs Creek, top carnivore and insectivore taxa abundance decreased while abundance of generalist feeders increased in an upstream direction (Figure 3-79). Also, percentage of White suckers (C. commersoni) increased in an upstream direction, as White suckers typically increase in abundance in degraded streams. In Darby Creek, abundance of generalist feeders increased, whereas the percentage of insectivore taxa decreased in an upstream direction. Results of benthic macroinvertebrate studies are discussed in greater detail in the 2004 Comprehensive Characterization Report Update.

Tolerance designations describe the susceptibility of a species to chemical and physical perturbations. Intolerant species are typically first to disappear following a disturbance (Barbour et al., 1999). Tolerant and moderately tolerant species composed 95% of the fish fauna in Darby-Cobbs Creek Watershed (Figure 3-80). Cutlips minnow (Exoglossum maxillingua) and stocked trout (Oncorhynchus mykiss, Salmo trutta, Salvelinus fontinalis) were the only intolerant taxa found in the non-tidal sites. Eastern silvery minnow (Hybognathus regius) and Striped bass (Morone saxatilis) were additional intolerant species found in the tidal portions of the watershed. No more than one sensitive species was found at any given non-tidal site. Furthermore, all but two assessment sites were dominated by taxa tolerant of poor water quality. The non-tidal portion of Cobbs Creek was devoid of pollution-sensitive taxa. The relative low abundance of intolerant species implies a high level of disturbance that appears to increase upstream.

The Index of Biotic Integrity (IBI) is useful in determining long-term effects and coarse-scale habitat conditions because fish are relatively long-lived and mobile. A site with high integrity (i.e. high score) is associated with native communities that interact under natural community processes and functions (Karr 1981). Since biological integrity is closely related to environmental quality, assessments of integrity can serve as a surrogate measurement of health (Daniels et al., 2002). Mean IBI score for Darby-Cobbs Creek Watershed was 31 (out of 50), placing it in the "fair" category (Figure 3-81). Skewed trophic structure and rare intolerant species are characteristics of a fish community in the "fair" category. The Modified Index of Well-Being and Shannon Diversity Index values, which are measures of diversity and abundance, decreased in an upstream direction. Overall, the more downstream sites had higher biological integrity than upstream sites (Figure 3-82).

After a thorough review of historical and recent data compiled on Cobbs Creek (i.e., 1999 and 2003), it is evident that active restoration strategies must be implemented and monitored over time to measure the efficacy of planned habitat restoration projects, as defined in Darby-Cobbs Integrated Watershed Management Plan.

Table 3-92: Species list and relative abundance of fish taxa collected in the Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.2.1 table 2 page 55).

Scientific Name	Common Name	Number Of Individuals Identified
Alosa aestivalis	Blueback Herring	42
Alosa sapidissima	American Shad	1
Ameiurus catus	White Catfish	1
Ameiurus natalis	Yellow Bullhead Catfish	1
Ameiurus nebulosus	Brown Bullhead Catfish	60
Ambloplites rupestris	Rock Bass	76
Anguilla rostrata	American Eel	555
Carassius auratus	Goldfish	11
Catostomus commersoni	White Sucker	831
Cyprinella analostana	Satinfin Shiner	219
Cyprinus carpio	Common Carp	32
Cyprinella spiloptera	Spotfin Shiner	9
Dorosoma cepedianum	Gizzard Shad	3
Esox lucius x Esox masquinongy	Tiger Muskellunge	1
Etheostoma olmstedi	Tessellated Darter	237
Exoglossum maxillingua	Cutlips Minnow	442
Fundulus diaphanus	Banded Killifish	1917
Fundulus heteroclitus	Mummichog	1088
Gambusia affinis	Mosquitofish	3
Hybognathus regius	Eastern Silvery Minnow	117
Ictalurus punctatus	Channel Catfish	2
Lepomis auritus	Redbreast Sunfish	651
Lepomis cyanellus	Green Sunfish	8
Lepomis gibbosus	Pumpkinseed Sunfish	129
Lepomis auritus x Lepomis gibbosus	Sunfish Hybrid	1
Lepomis macrochirus	Bluegill Sunfish	52
Luxilus cornutus	Common Shiner	1018
Micropterus dolomieui	Smallmouth Bass	23
Micropterus salmoides	Largemouth Bass	6
Morone americana	White Perch	1
Morone saxatilis	Striped Bass	1
Notemigonus crysoleucas	Golden Shiner	11
Notropis hudsonius	Spottail Shiner	200
Notropis procne	Swallowtail Shiner	1465
Oncorhynchus mykiss	Rainbow Trout	26
Pimephales notatus	Bluntnose Minnow	65
Pimephales promelas	Fathead Minnow	148
Pomoxis nigromaculatus	Black Crappie	1
Rhinichthys atratulus	Blacknose Dace	2157
Salvelinus fontinalis	Brook Trout	1
Salmo trutta	Brown Trout	31
Semotilus atromaculatus	Creek Chub	143
Semotilus corporalis	Fallfish	24
Umbra pygmaea	Eastern Mudminnow	1

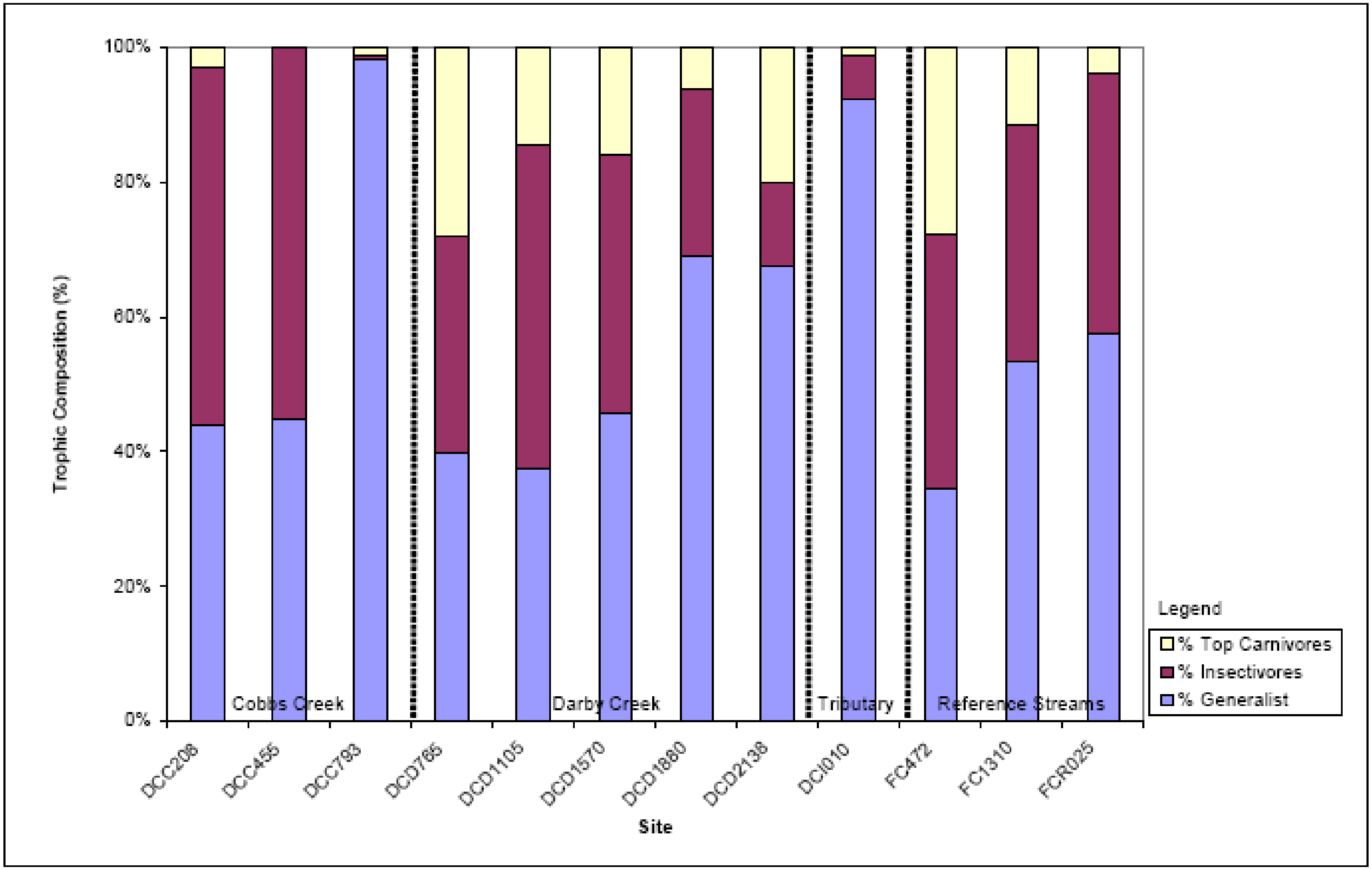


Figure 3-79: Trophic structure of fish assemblages in the Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.2.1 figure 3 page 56).

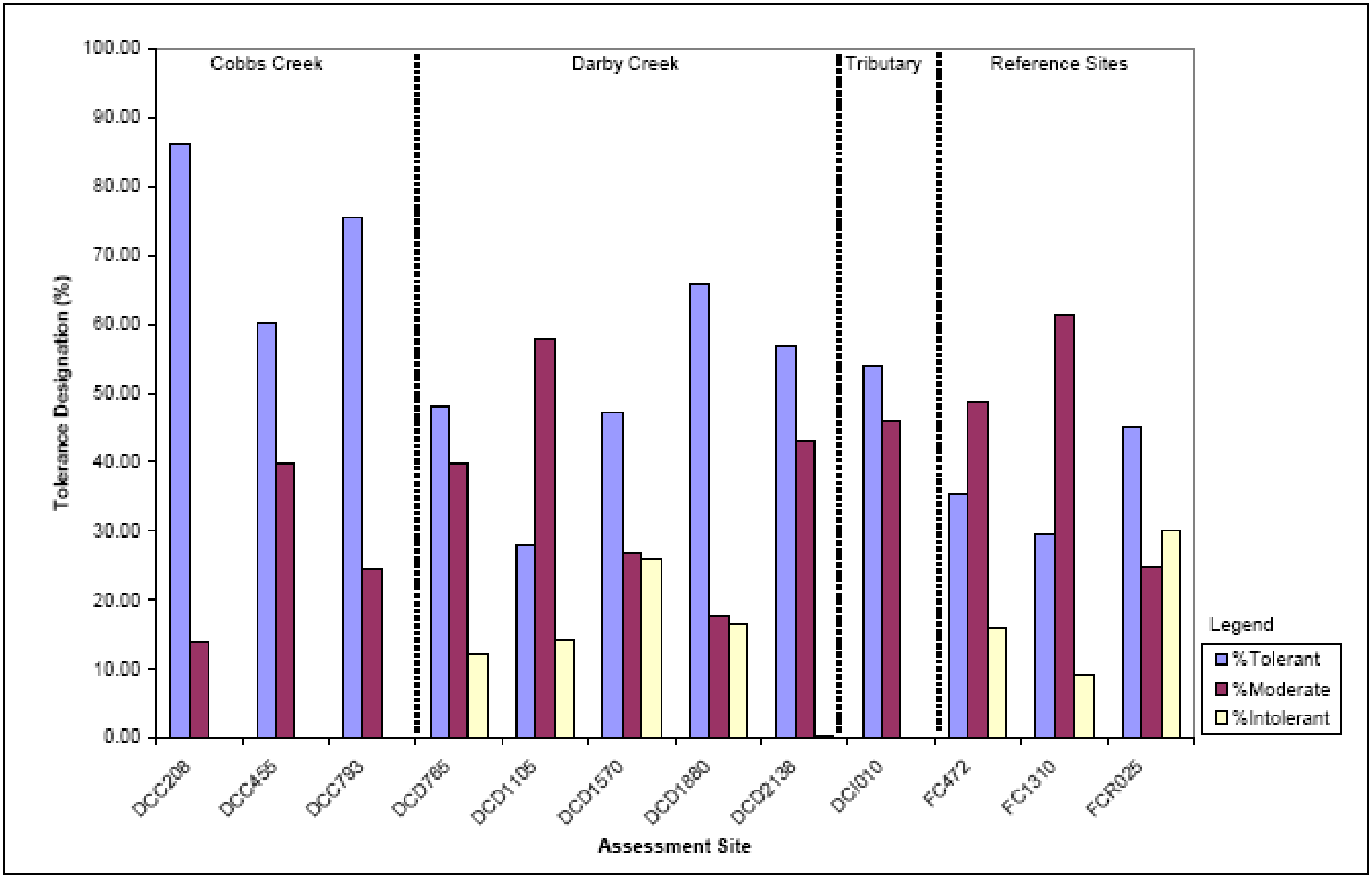


Figure 3-80: Pollution tolerance values at the monitoring sites in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.2.2.1 figure 4 page 58).

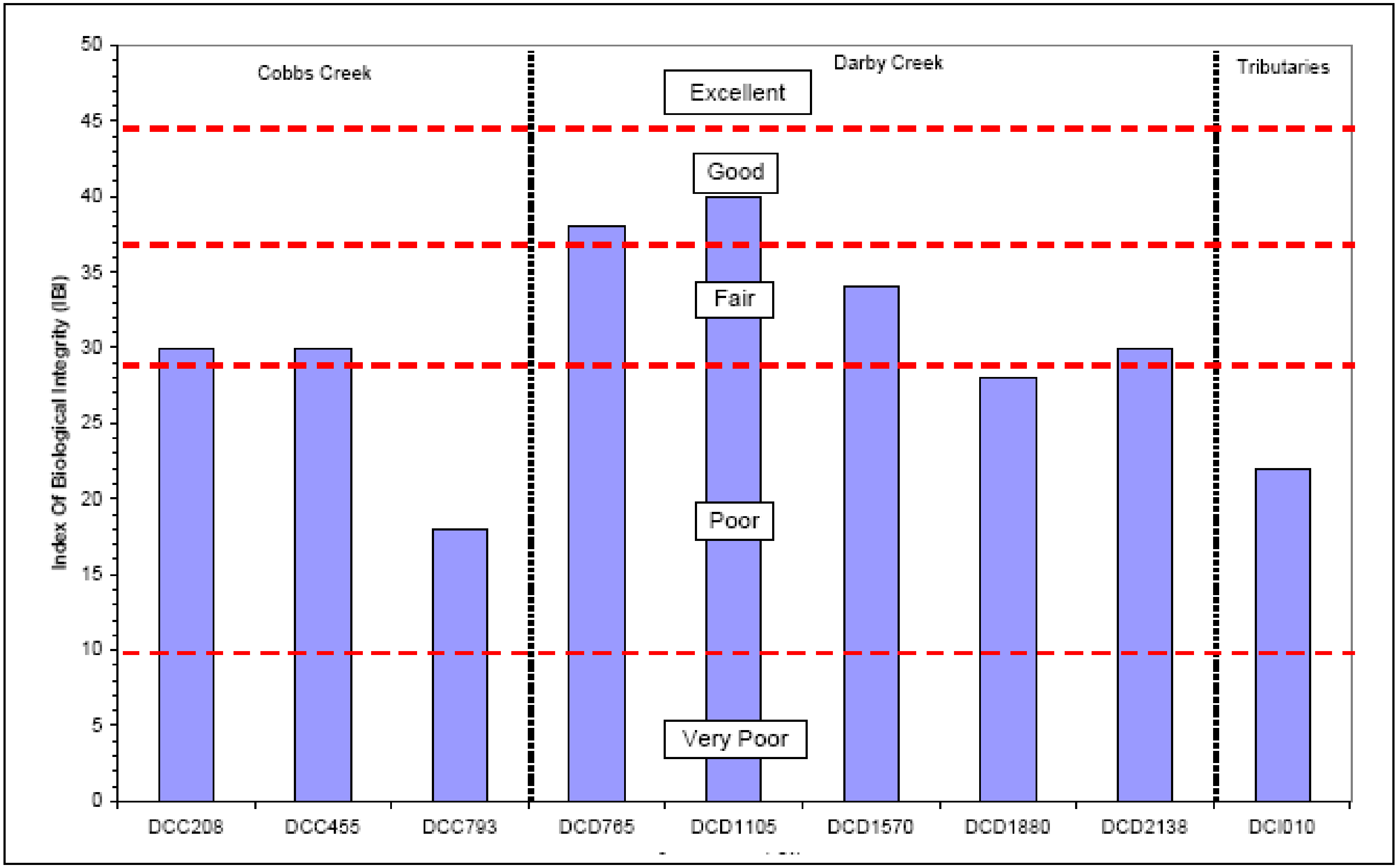


Figure 3-81: Index of Biological Integrity (IBI) scores at the nine assessment sites in Darby-Cobbs Creek Watershed (D-C CCR 2004 section 5.2.2.1 figure 5 page 59).

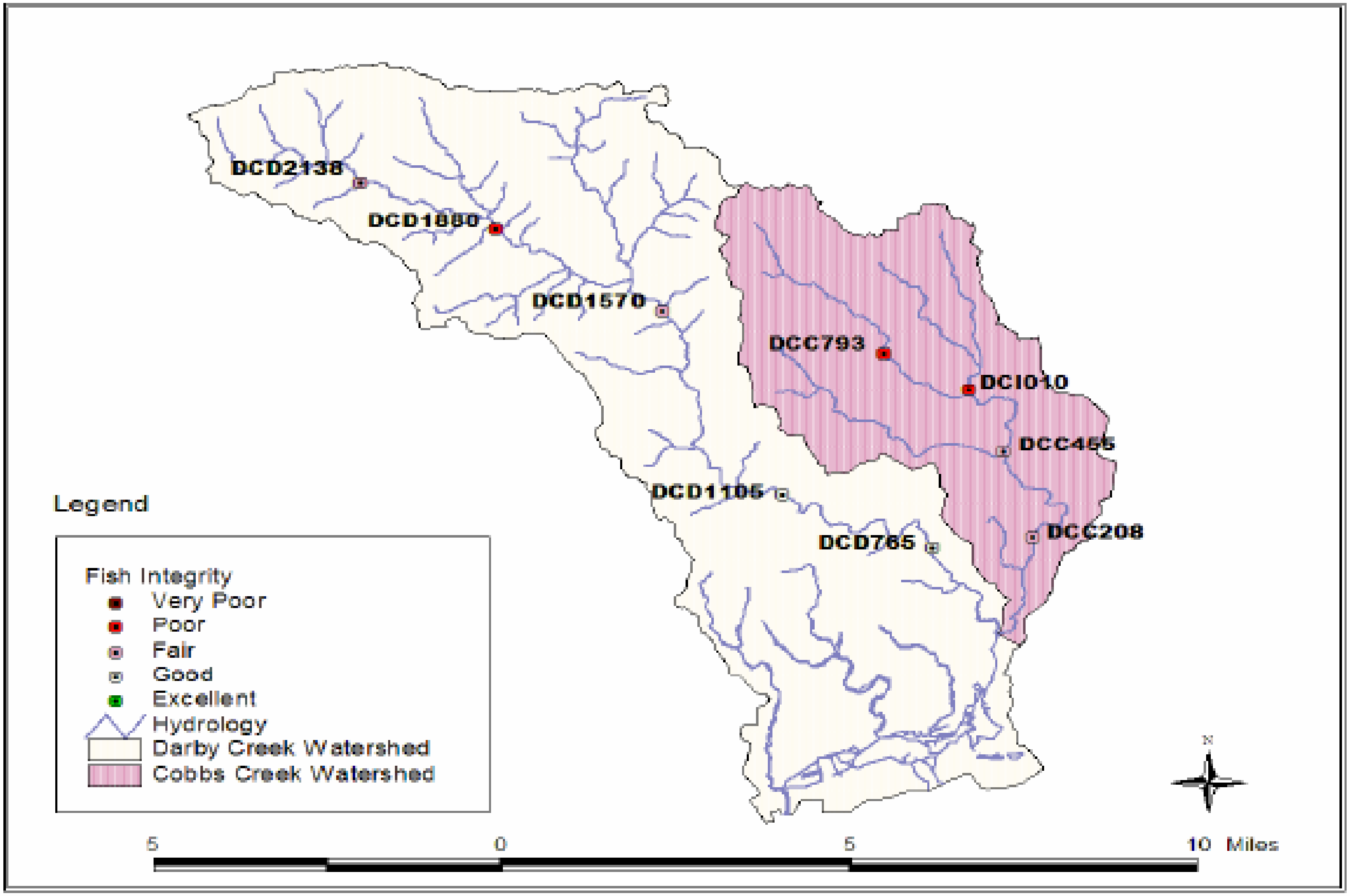


Figure 3-82: Fish assessment of the Darby-Cobbs Creek Watershed, 2003 (D-C CCR 2004 section 6.4 figure 26 page 120)

3.4.2.2.4 Habitat Assessment of Darby-Cobbs Creek Watershed

Habitat impairments in the Darby-Cobbs Creek Watershed are numerous, mirroring those of other urban stream systems assessed by PWD. First and foremost, stream habitats within the Darby-Cobbs Creek Watershed are impaired due to effects of stormwater. Preponderance of impervious surfaces, particularly within Cobbs Creek Watershed, has diminished baseflow and caused small streams to exhibit increasingly “flashy” hydrographs in response to rain events. According to a baseflow separation analysis based on 27 years of flow data at USGS gauge 01475550, baseflow currently accounts for only 42% of mean total yearly flow from Cobbs basin. In contrast, Darby Creek Watershed is less affected by impervious surfaces and has a yearly flow regime similar to the reference stream.

Exaggerated storm flows typical of urbanized watersheds result in erosion of banks and deposition of sediment in pools and on point bars. Many stream reaches in the watershed have been excessively over-widened and downcut; channels have been enlarged so severely that baseflow does not completely fill the channel or adequately cover riffle substrates. In many reaches, floodplain disconnection exists during almost all flow conditions. Due to ongoing erosion, nearly all stormwater forces are applied to a bare soil interface. Streambank erosion has also exposed sewer infrastructure (e.g., Manholes, interceptor sewers) increasing susceptibility of infrastructure to damage and leaks.

Fish and benthic macroinvertebrate sampling reinforced the view that stormwater flow is probably the most important factor shaping biological communities in most of the watershed. Stream organisms ill-adapted to extreme flows may be washed downstream and displaced from their optimum habitat. Erosion and sedimentation may decrease reproductive success of invertebrates and fish by washing away eggs, or alternately, covering eggs with sediment. Fish and benthic macroinvertebrate community responses to habitat modification were not consistent throughout the watershed. Serious effects were observed in Cobbs Creek and its tributaries, while upstream reaches of Darby Creek were similar in some aspects to reference conditions. Lower reaches of Darby Creek showed contrasting responses overall.

Common invertebrates of the most degraded portions of Cobbs and Lower Darby Creek have morphological or behavioral adaptations to increased stream velocities. Chironomid midges construct tubes made of silk that are firmly attached to stream substrates. The insect's body may be completely retracted within this protective tube. Similarly, hydropsychid caddisflies construct silk nets, which serve as refugia during exaggerated flow conditions. Free-living shredder taxa (e.g., case building caddisflies and tipulids) were not present at most degraded sites, and very few species with external gills were present.

Dominant fish in degraded reaches also exhibit morphological and behavioral adaptations to increased stream velocities. Blacknose dace and white suckers are generally more rounded in body cross-section (i.e., dorsoventrally flattened) than many other stream fish. This body shape may allow these fish to better hug the stream bottom or slope, thereby avoiding the highest velocities. American eels were dominant (in terms of biomass) at many sites. These fish have the ability to completely bury themselves in sediments, enter small crevices, and easily extract themselves from tight spaces by reversing their undulations and swimming backwards. American eels also have the advantage of reproducing at sea, only entering the watershed once they are able to swim freely. All other fish in the watershed are vulnerable to severe flows or smothering by silt during their embryo or larval stage.

Continuous DO and pH data suggest that periphyton biomass and community structure change fundamentally following severe storm events. Dense periphyton carpets are found in slower water throughout the watershed. While these algae have not been investigated taxonomically, filamentous greens (e.g., Cladophora sp.) appear to dominate the biomass of the periphyton climax community. Soil erosion and runoff, particularly during smaller storm events, may be a significant source of the phosphorus that drives these algal blooms.

Instream habitat was evaluated with EPA protocols at seventeen (n=17) sites targeted for benthic macroinvertebrate sampling. A much more detailed reach ranking survey, based in fluvial geomorphological principles, was conducted for Cobbs Creek, and West and East Indian Creeks in 2000. This document, entitled "Cobbs Creek Geomorphologic Survey-Level II: Guiding Principles for Fluvial Geomorphologic Restoration of Cobbs Creek" is available from PWD's Office of Watersheds.

Comparisons to Reference Site
Habitat features at Darby-Cobbs Creek Watershed sites were compared to those of the reference sites located in nearby Chester County. Mainstem and third order tributary sites were compared to French Creek reference sites, located in Coventry Township, Chester County, PA. Tributary sites, second order or less, were compared to Rock Run, a tributary to French Creek located in Coventry Township, Chester County, PA.

In 2003, habitat at 17 sites throughout Darby-Cobbs Creek Watershed was surveyed by PWD staff biologists. Monitoring locations along Darby Creek mainstem received consistent scores, ranging from the highest value, “Comparable to Reference Conditions”, to the next incremental level, “Supporting” (Figure 3-83). Five Darby Creek sites had greater habitat scores than the reference site, indicating good habitat conditions along mainstem reaches of Darby Creek. Similarly, two tributary sites, Little Darby Creek and Ithan Creek, received ratings of “Comparable to Reference Conditions” (Figure 3-84).

In contrast to Darby Creek, habitat values along Cobbs Creek and its tributaries were less desirable. Of the four main stem locations, two sites received “Supporting” while the remaining two locations were designated as “Partially Supporting” (i.e., marginal). Naylor’s Run, a 2nd order tributary to lower Cobbs Creek, received rankings of “Supporting” in the upper portion and “Non-Supporting” near the confluence with Cobbs Creek. Similarly, sites on the east and west branches of Indian Creek were determined to be only “Partially Supporting” of aquatic communities.

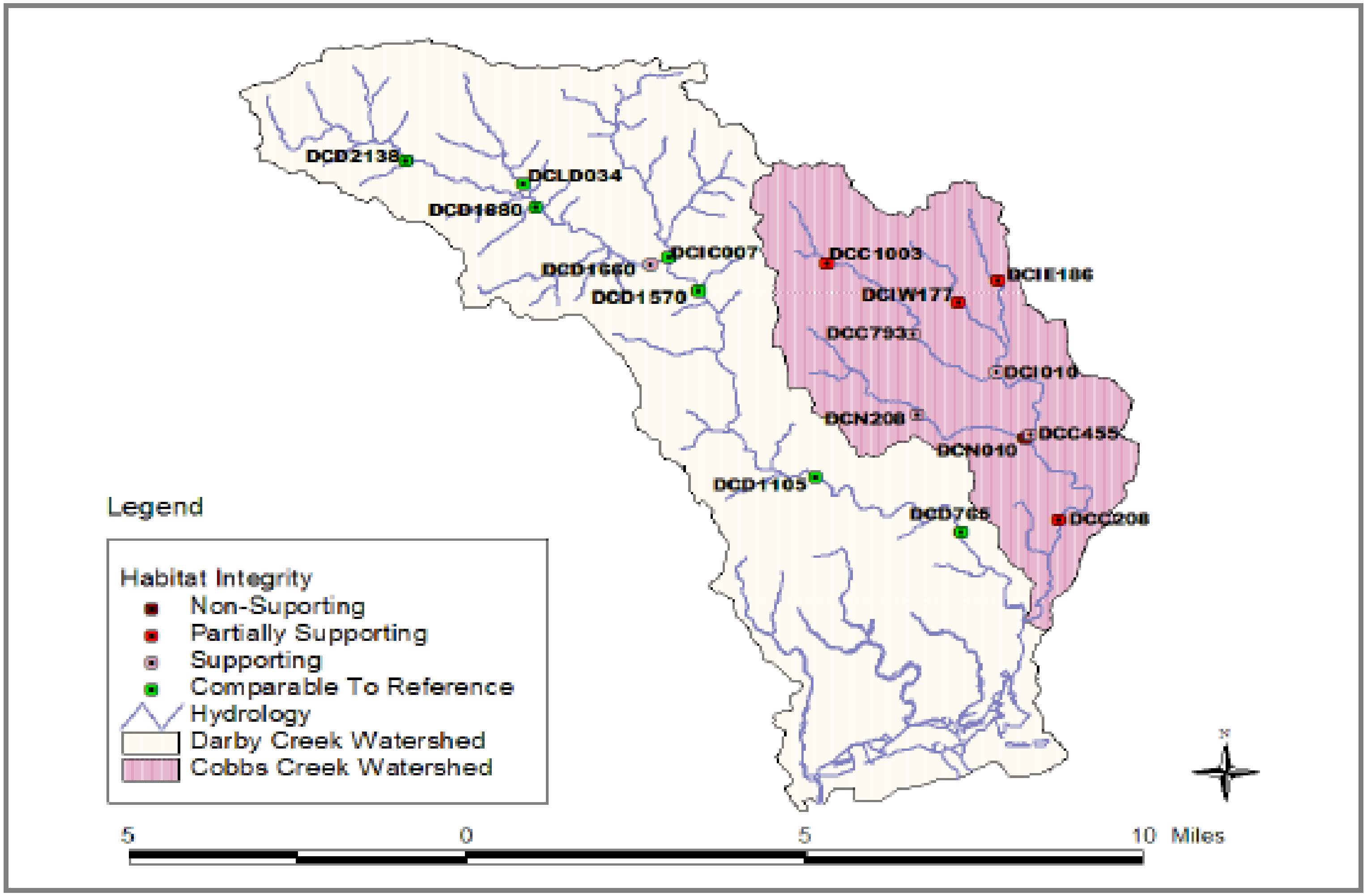


Figure 3-83: Stream channels and aquatic habitat assessment in the Darby-Cobbs Creek Watershed, 2003 (D-C CCR 2004 section 6.2 figure 25 page 118)

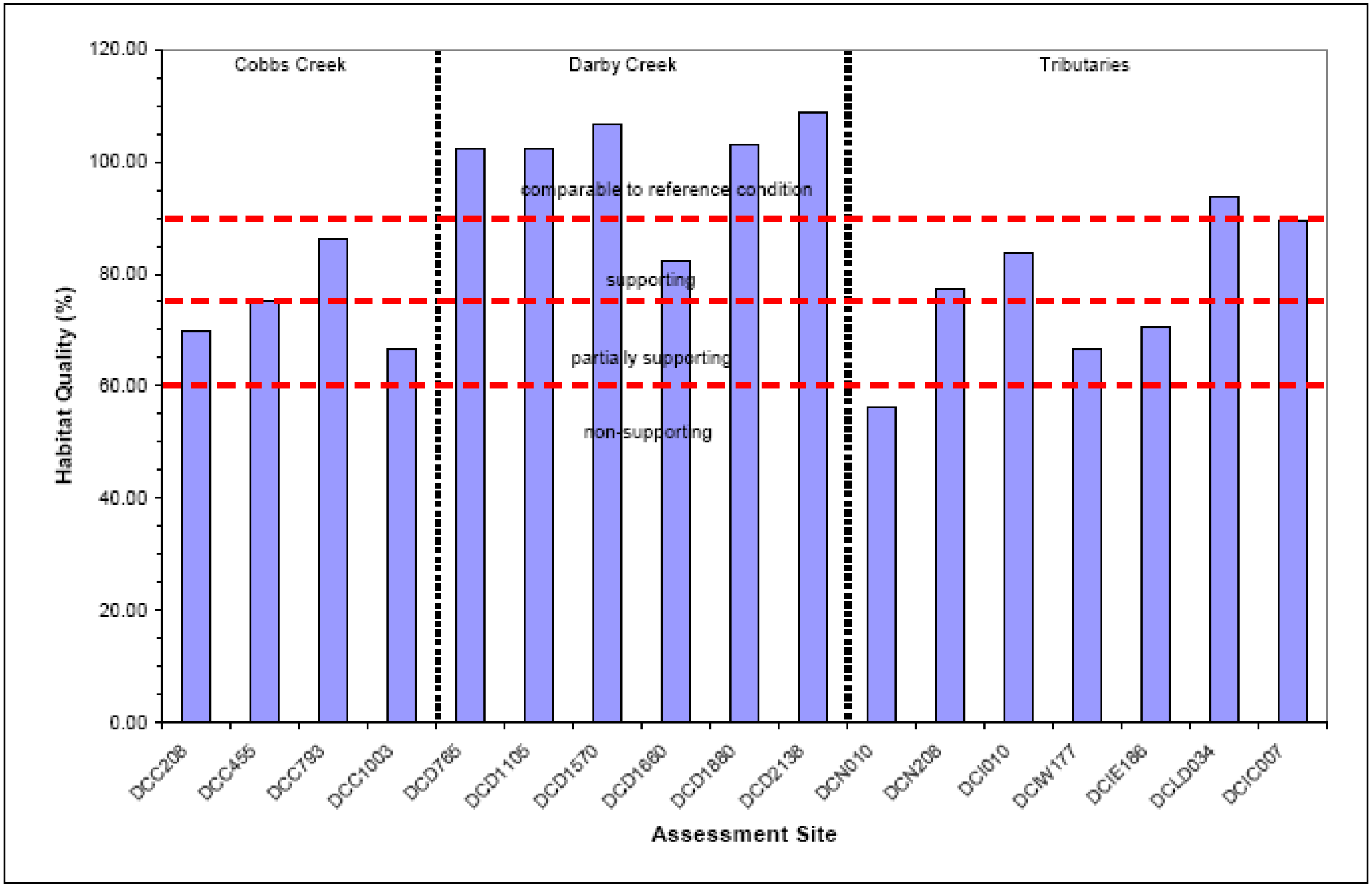


Figure 3-84: Habitat quality of 17 assessment sites in Darby-Cobbs Creek Watershed. Values are represented as percent comparability to reference conditions (D-C CCR 2004 section 5.3.4.1.3 figure 7 page 69).

Factor Analysis

Principal components analysis (PCA) in Statistica (Statsoft, 1998) was used to reduce the number of variables needed to explain the variation between scores for 13 different habitat attributes among Darby-Cobbs Creek sites. The first factor extracted accounted for 53% of the variance in the data matrix. Habitat attributes with high loading values for factor one included epifaunal substrate, velocity/depth regime, channel flow status, bank vegetative protection, and all pool attributes. The second factor extracted accounted for 19% of the variance, for a cumulative total of 72% variance explained. No habitat attributes showed high loading scores for factor two. An ordination plot of Darby-Cobbs Creek sites and three reference sites showed the sites distributed widely across PCA axis one, with five highest-rated upstream Darby Creek sites grouped closely between French Creek and Rock Run reference sites.

Overall, the placement of sites along axis 1 correlated closely with total habitat scores and relative comparability to the reference sites (Figure 3-85). PCA axis 2 was not particularly useful, except for weak negative associations with channel alteration and riparian zone width and positive associations with frequency of riffles, sedimentation, and embeddedness.

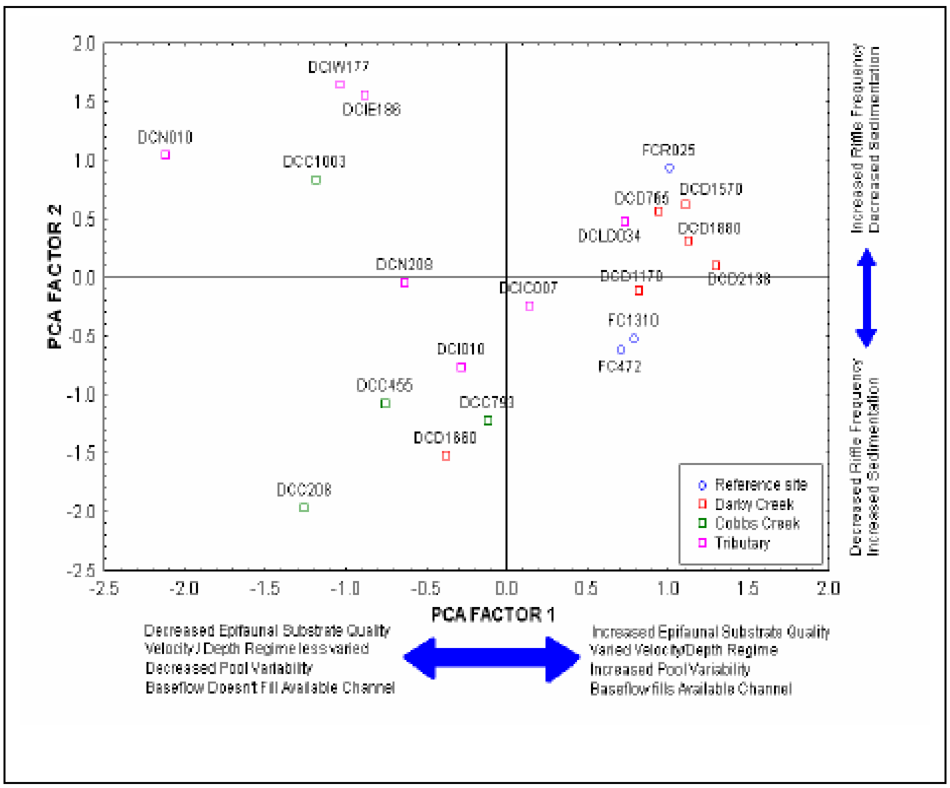


Figure 3-85 Principal Components Analysis ordination plot of 17 monitoring sites and 3 reference locations (D-C CCR 2004 section 5.3.3 figure 6 page 67).

Habitat Suitability Indices

Habitat Suitability Indices (HSI) developed by The U.S. Fish and Wildlife Service (USFWS) were applied to sites in Darby-Cobbs Creek Watershed targeted for fish sampling. These models integrate the expected effects of a variety of environmental, physicochemical, and hydrological variables on representative native species, as well as species of special environmental or economic concern. As stream restoration activities recommended under Target B of the Integrated Watershed Management Plan are implemented, these indices will allow for habitat improvements to be measured quantitatively. This work is discussed in more detail for each fish specie in the Section 5.3.5 of the Comprehensive Characterization Report Update (PWD, 2004).

3.4.2.3 Delaware River Basin and Delaware Direct Watershed Characterization

The Delaware Direct Watershed area was delineated as part of the approach being undertaken by the Philadelphia Water Department for watershed planning and CSO management (Figure 3-86). The Delaware Direct is the portion of the City of Philadelphia that drains directly to the Delaware River and is within the CSS. The 20.5 mile segment of the Delaware River that runs through Philadelphia is tidally influenced and water quality is regulated by standards set specifically for the Delaware Estuary. Additionally, the tidal portion of the Pennypack Creek is included in this plan under the Delaware Direct Watershed and is subject to the Delaware River Basin Commission's water quality standards for tidal Zone 2 as explained in Section 3.4.1. Only the tidal portion of the Pennypack Creek Watershed is within the CSS.

The Delaware Direct, at 28.5 square miles, includes the core of the City – the bulk of the Philadelphia Center City shopping district including Market Street East, the City Hall complex, the Pennsylvania Convention Center complex, Kimmel Center and Avenue of the Arts, Independence Mall and Independence National Historic Park and the related historic Society Hill surrounding neighborhood. Delaware Direct includes the rapidly redeveloping Delaware River Waterfront and the Temple University campus in North Philadelphia. Major transportation routes are included in the Delaware Direct Watershed, such as virtually the entire north/south Broad Street Corridor, the I-95 corridor from extreme North Philadelphia to South Philadelphia.

As of mid-2009, the PWD is developing a Rivers Conservation Plan (RCP) and an Integrated Watershed Management Plan (IWMP) for the Delaware Direct study area. The Rivers Conservation Plan will include a detailed description of the watershed and its history. The IWMP is being developed to guide the management of watershed protection and restoration. Both plans involved the development of goals and recommendations based on public participation in outreach activities. Both plans will be available at http://www.PhillyRiverInfo.org.

Due to local events and a growing national interest in urban riverfronts, the Delaware Waterfront is an area of high public attention for re-development. Both the North Delaware and the Central Delaware are the focus of large-scale planning initiatives. Other planning efforts have focused on specific neighborhoods or development sites. The Integrated Watershed Management Plan includes a comprehensive review of the plans related to watershed management and integrates the goals and recommendations of these and other PWD initiatives.

The Delaware Direct watershed is a small part (less than 1%) of the entire Delaware River Basin (Figure 3-87), which covers 13,539 square miles in New York, Pennsylvania, New Jersey, and Delaware (PWD, 2007). The Delaware River Basin is one of the most densely populated corridors in the northeastern United States, averaging 603 people/square mile (DRBC, 2008b). The Delaware River Basin Commission (DRBC) was created in 1961 as a regional body with legal enforcement capability to oversee the Delaware River Watershed. The DRBC is composed of five commissioners representing the federal government and the four states listed above. The DRBC provides watershed management, water resources stewardship, seeks public involvement in Delaware River issues, and coordinates interagency and state projects. Figure 3-88 depicts the entire Delaware River Basin.

Figure 3-86 The Delaware Direct Watershed in Philadelphia, PA

In 2004 the DRBC produced the Water Resources Plan for the Delaware River Basin, often called *The Basin Plan,* which incorporates watershed management policies, goals, and implementation strategies. The Basin Plan outlined key points of interest that will guide the actions of the DRBC for the next thirty years, including: sustainable use and supply, waterway corridor management, linking land and water resources management, institutional coordination and cooperation, and education and involvement for stewardship. The hydrology, water quality, living resources and landscape of the Delaware River Basin are characterized in the DRBC's 2008 Report, *The State of the Basin*. Both reports are available at http://www.drbc.net.

Land Use and Demographics of Delaware Direct Watershed
The Delaware Direct may be the most urbanized watershed in Pennsylvania (PWD 2009). It is almost entirely covered with impervious surface (72%). The population totals 499,750 at an average density of 17,530 people/square mile. Figure 3-88 illustrates the distribution of population density throughout the Combined Sewer Area. Almost half of the neighborhoods in Philadelphia are located at least partially in the Delaware Direct including some of the most affluent and some of the most impoverished. Although 48% of the combined sewer area is residential, the defining use is commercial (16%) and industrial (9%), since this land use is a higher percentage than any combined sewer area in Philadelphia due to a large number of abandoned industrial areas. The Delaware Riverfront is most likely to experience more redevelopment than other parts of Philadelphia. The current land use is shown in Figure 3-89. The Integrated Watershed Management Plan will take the current and future re-development into account and will include a detailed land use analysis based on the most up-to-date land use available.

The Delaware Direct Watershed includes approximately 20.5 miles of the Delaware River that flows through the City of Philadelphia, the tidal portion of the Pennypack Creek, and the "Old Frankford Creek," a small tidal tributary that was once connected to and the outlet of the Frankford Creek. Additionally, 63 miles of historic tributaries now encapsulated in pipes are part of the sewer system that flows into the Delaware River.

Pollution Sources
In addition to CSOs, other sources of pollution affect the water quality of the Delaware River. Numerous point and non-point sources exist in the drainage area upstream from the City of Philadelphia. Within the Delaware Direct Watershed, stormwater runoff from the highly impervious residential and industrial areas contributes to degraded water quality. Accidental sources of contamination are a greater concern in the Delaware Direct and include spills or leaks from cars, trains, shipping vessels, underground pipeline bursts, and industrial accidents (PWD, 2007).

3.4.2.3.1 Delaware River Basin Hydrologic Characterization

Annual average precipitation within the Delaware River Basin is about 45 inches of precipitation per year. The driest month is normally February, with precipitation totals ranging from 2.7 to 3 inches. In contrast, July and August are the months with the most precipitation, measuring from 4.5 to 4.7 inches of precipitation. The precipitation in the cold months results from the passage of fronts in the low-pressure systems of the westerly wind belt. During the warm months, much of the precipitation occurs as convectional storms, which are supplemented by the occasional passage of a front (Climate and Man, 1941 in Majumdar, Millar, and Sage, 1988).

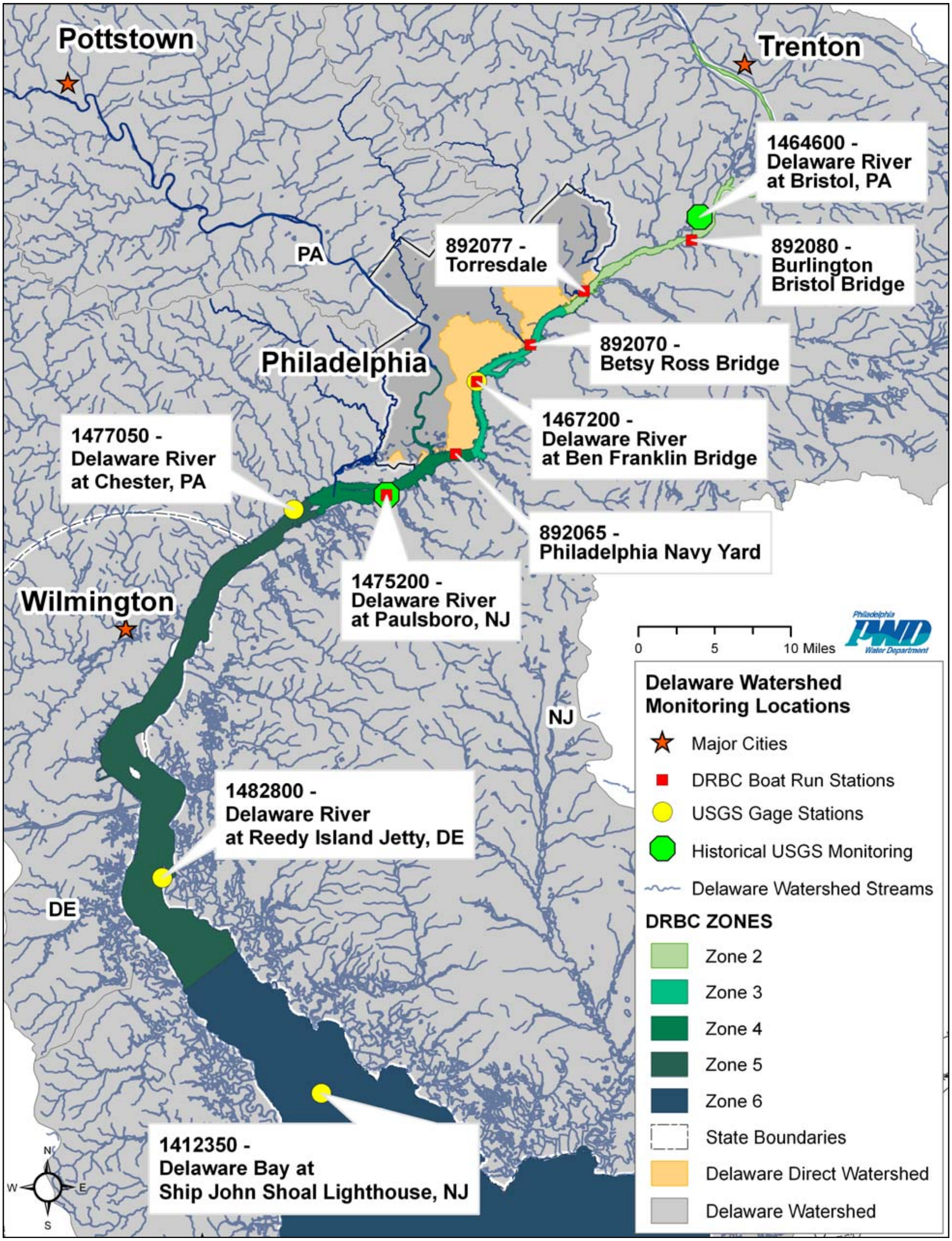


Figure 3-87 The Delaware River Basin (Source: DRBC)

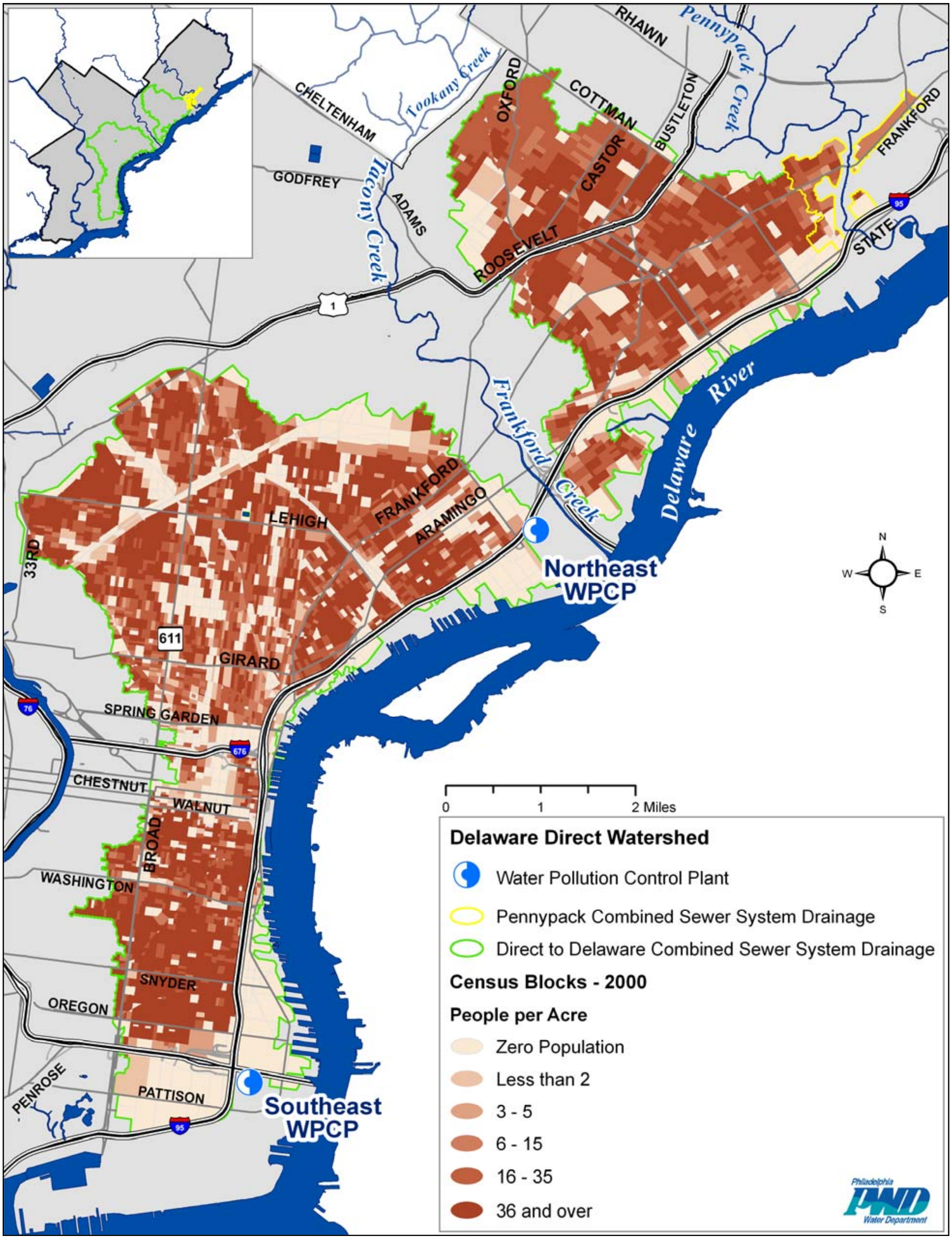


Figure 3-88 Population Density in the Delaware Direct Watershed in Philadelphia, PA Receiving Waters Characterization

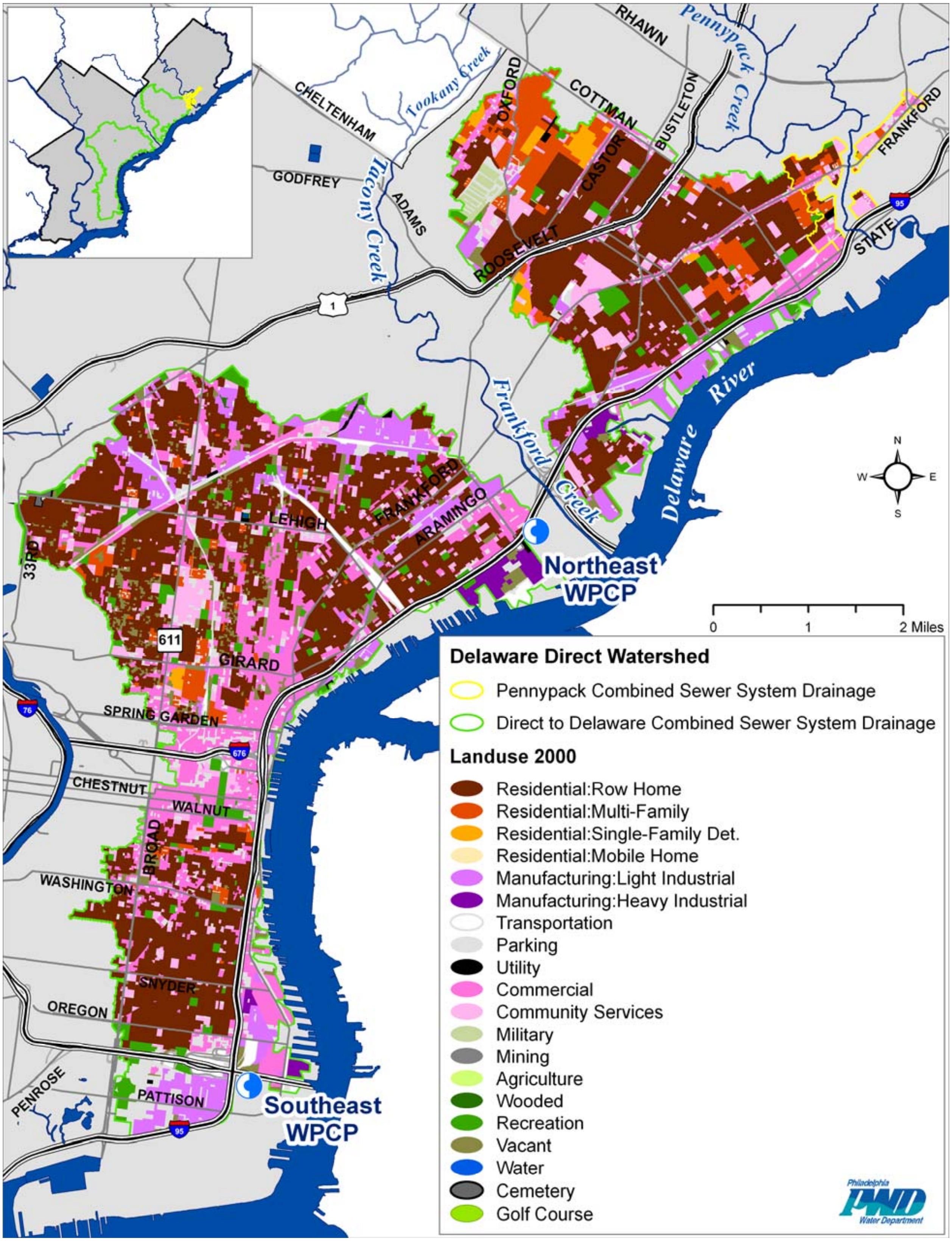


Figure 3-89 Land Use in the Delaware Direct Watershed

Table 3-93 gives a summary of the major tributaries in the Delaware River below Trenton New Jersey, their drainage areas, river mile location, and length. These tributaries are located within the tidal zone, and are therefore affected by water quantity and quality tidal cycles. The Neshaminy River and the Rancocas Creek are the two largest tributaries in this area. Both of these tributaries drain into the Delaware River above the Delaware Direct area in Philadelphia.

Table 3-93 Characteristics of Tributaries in the Lower Delaware River Watershed

Major tributary	Drainage Area (mi^2)	River Mile Location	Length (mi)
Assiscunk Creek	45.9	119	16.31
Big Timber Creek	55.2	96	16.00
Bustleton Creek	2.6	121	2.91
Byberry Creek	18.7	112	10.595
Cooper Creek	40.2	102	15.81
Crafts Creek	13.8	125	11.38
Crosswicks Creek	138.5	129	26.46
Martins Creek (Lower)	11.5	123	5.05
Mill Creek	19.8	119	39.96
Mill Run	37	105	14.81
Neshaminy Creek	232.4	116	51.37
Newton Creek	10.6	97	10.58
Pennsauken Creek	36.1	106	13.06
Pompeston Creek	7.7	109	5.37
Rancocas Creek	347.7	111	33.65
Rockledge Branch	55.1	110	15.57

The daily average streamflow of the Delaware River from 1910 to 2009 is presented in Figure 3-90. The measurements were recorded at USGS Gage 01463500 at Trenton, New Jersey, the nearest upstream USGS gauge to Philadelphia monitoring continuous flow. The historical daily average Delaware River streamflow at Trenton, NJ is 12,100 cubic feet per second (CFS).

3.4.2.3.2 Delaware River Water Quality Analysis

From 2003 through 2008, the Delaware River Basin Commission (DRBC) has collected water quality data from sampling locations within the Delaware River Watershed. Tables 3-94 thru 3-98 provide a basic, statistical profile of the data from the recent water quality monitoring program. Tables 3-94 thru 3-97 provide data from the discrete monitoring program and Table 3-98 provides data from the continuous monitoring program.

The Delaware River Basin was segmented into zones as defined by the above mentioned DRBC manual. This analysis will use water quality standards from zone 2 through zone 6. Zone 2 is defined as any location along the Delaware River between Rivermile (R.M.) 133.4 through R.M. 108.4 and any tidal portions of any tributaries. Zone 3 is defined as any location along the Delaware River between R.M. 108.4 through R.M. 95.0 and any tidal portions of any tributaries. Zone 4 is defined as any location along the Delaware River between R.M. 95.0 through R.M. 78.8 and any tidal portions of any tributaries. Zone 5 is defined as any location along the Delaware River between R.M. 78.8 through R.M. 48.2 and any tidal portions of any tributaries. Zone 6 is defined as any location along the Delaware River between R.M. 48.2 through R.M. 0.0 and any tidal portions of any tributary. The

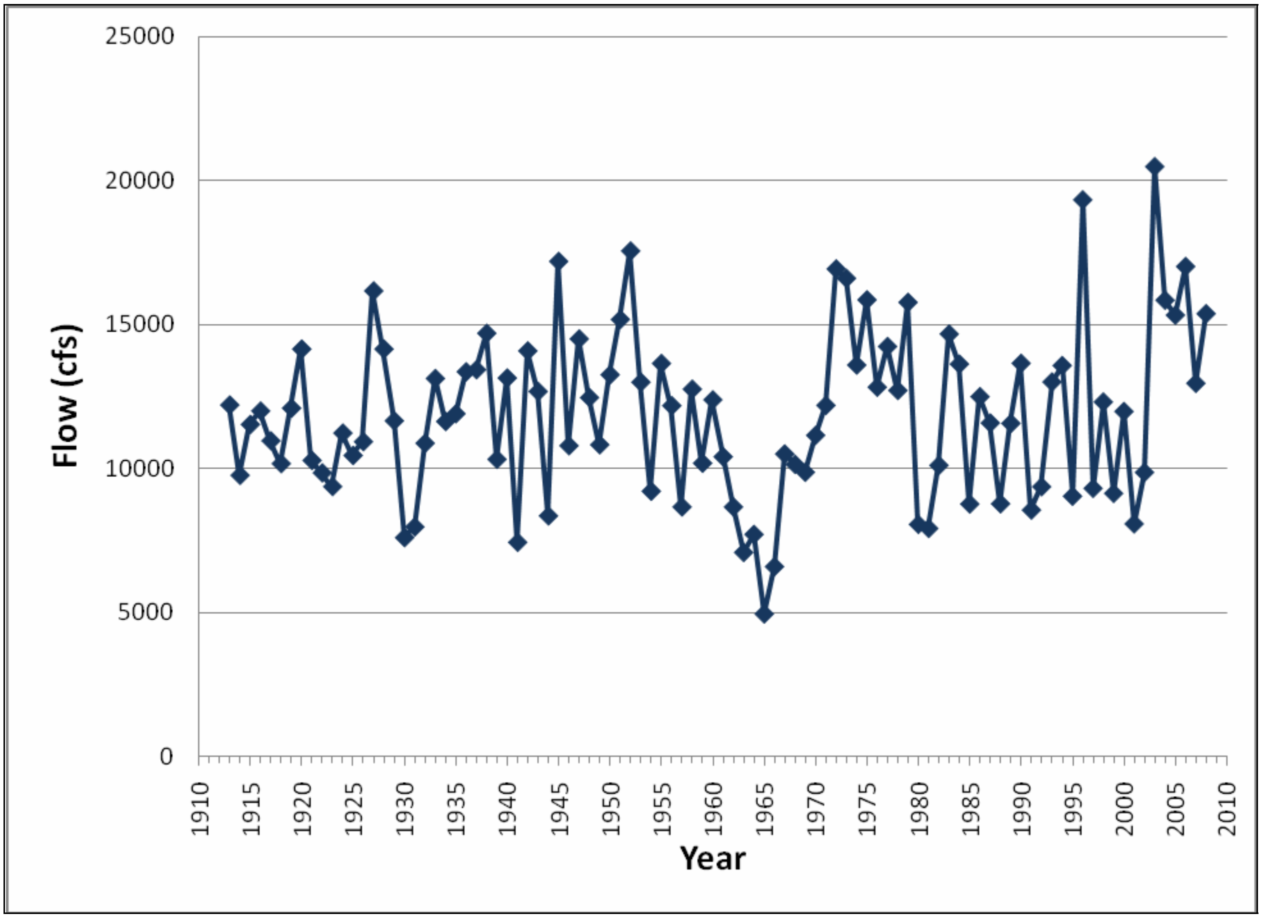


Figure 3-90 Daily Average Delaware River Flow at Trenton, NJ USGS gauge 01463500

Delaware Direct watershed includes part of Zone 2, Zone 3, and part of Zone 4 of the Delaware River between RM approximately 90 and 112.

Wet weather is characterized using the 11 PWD operated rain gages in the Delaware direct drainage district. Samples were considered wet when there was greater than 0.1 inches of rainfall recorded in at least one gage in the previous 48 hours. Rain Gage locations, and PWD, DRBC, and USGS monitoring sites are depicted and discussed in Section 3.1.4.3.3.

The U.S. Geological Survey (USGS) recorded a baseline of existing water quality that can now be compared with the data collected by DRBC. Table 3-98 consists of USGS continuous monitoring data that was collected from 2003 through 2008. Tables 3-94 through 3-97 consist of DRBC discrete monitoring data that was collected from 2003 through 2008. This comparison allows for a more comprehensive analysis of water quality and the impacts of urbanization on the Delaware River Basin over the past 10 years. In some cases, historical data is provided for further analysis.

Table 3-94 Delaware River Dry Weather Water Quality Summary Statistics and Exceedances 2003 – 2008

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Alkalinity	2	Maximum	100	mg/L	DRBC	33	27.5	39.2	42.8	50.3	55.4	57.5	0	0
Alkalinity	3	Maximum	120	mg/L	DRBC	32	27.0	38.5	43.7	50.9	53.4	56.5	0	0
Alkalinity	4	Maximum	120	mg/L	DRBC	35	34.3	38.6	45.6	52.9	54.9	57.4	0	0
Alkalinity	2	Minimum	20	mg/L	DRBC	33	27.5	39.2	42.8	50.3	55.4	57.5	0	0
Alkalinity	3	Minimum	20	mg/L	DRBC	32	27.0	38.5	43.7	50.9	53.4	56.5	0	0
Alkalinity	4	Minimum	20	mg/L	DRBC	35	34.3	38.6	45.6	52.9	54.9	57.4	0	0
Diss Cu	2	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	22	1.40	1.40	1.50	2.40	3.80	6.60	0	0
Diss Cu	3	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	24	1.40	1.40	1.60	2.25	4.30	5.60	0	0
Diss Cu	4	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	31	1.10	1.50	2.10	2.60	5.30	8.50	0	0
Diss Cu	2	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	22	1.40	1.40	1.50	2.40	3.80	6.60	0	0
Diss Cu	3	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	24	1.40	1.40	1.60	2.25	4.30	5.60	0	0

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Diss Cu	4	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	31	1.10	1.50	2.10	2.60	5.30	8.50	0	0
Diss Zn	2	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	40	1.30	3.35	4.60	6.40	11.0	17.6	0	0
Diss Zn	3	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	38	0.400	4.30	5.05	7.80	10.0	32.4	0	0
Diss Zn	4	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	45	1.10	4.30	5.40	7.00	9.30	28.4	0	0
Diss Zn	2	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	40	1.30	3.35	4.60	6.40	11.0	17.6	0	0
Diss Zn	3	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	38	0.40	4.30	5.05	7.80	10.0	32.4	0	0
Diss Zn	4	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	45	1.10	4.30	5.40	7.00	9.30	28.4	0	0
Diss Zn	2	Toxicants FIO Maximum	68700	µg/L	DRBC	40	1.30	3.35	4.60	6.40	11.0	17.6	0	0
Diss Zn	3	Toxicants FIO Maximum	68700	µg/L	DRBC	38	0.400	4.30	5.05	7.80	10.0	32.4	0	0

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Diss Zn	4	Toxicants FIO Maximum	68700	µg/L	DRBC	45	1.10	4.30	5.40	7.00	9.30	28.4	0	0
Diss Zn	2	Toxicants FWI Maximum	9110	µg/L	DRBC	40	1.30	3.35	4.60	6.40	11.0	17.6	0	0
Diss Zn	3	Toxicants FWI Maximum	9110	µg/L	DRBC	38	0.400	4.30	5.05	7.80	10.0	32.4	0	0
Diss Zn	4	Toxicants FWI Maximum	9110	µg/L	DRBC	45	1.10	4.30	5.40	7.00	9.30	28.4	0	0
DO	2			mg/L		67	5.39	7.02	8.23	9.94	11.0	12.2	--	--
DO	3			mg/L		62	4.88	5.89	7.29	9.35	10.1	11.8	--	--
DO	4			mg/L		75	4.65	5.81	6.59	8.75	10.0	12.0	--	--
Enterococcus	2	Maximum	33	#/100mL	DRBC	77	1.00	6.00	13.0	24.0	34.0	160	8	10.4
Enterococcus	3	Maximum	88	#/100mL	DRBC	68	1.00	6.00	9.00	18.5	73.0	240	6	8.8
Enterococcus	4	Maximum	(2)	#/100mL	DRBC	80	1.00	5.00	10.0	15.0	28.5	117	2	2.5
Fecal Coliform	2	Maximum	200	#/100mL	DRBC	70	9.00	22.0	42.5	90.0	130	270	4	5.7
Fecal Coliform	3	Maximum	770	#/100mL	DRBC	65	13.0	38.0	68.0	150	240	520	0	0
Fecal Coliform	4	Maximum	(3)	#/100mL	DRBC	77	6.00	23.0	46.0	77.0	140	430	0	0
Inorganic N	2	No Standard	--	mg/L		24	0.601	0.841	0.969	1.09	1.29	1.53	--	--
Inorganic N	3	No Standard	--	mg/L		24	0.756	0.929	1.03	1.32	1.67	1.91	--	--
Inorganic N	4	No Standard	--	mg/L		31	0.890	1.29	1.53	1.90	2.46	2.77	--	--
NH_3	2	No Standard	--	mg/L		24	0.0200	0.0685	0.0825	0.123	0.143	0.164	--	--
NH_3	3	No Standard	--	mg/L		24	0.0210	0.0620	0.101	0.174	0.290	0.357	--	--

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
NH_3	4	No Standard	--	mg/L		31	0.0210	0.0290	0.126	0.265	0.316	0.389	--	--
pH	2	Maximum	8.5		DRBC	67	6.01	6.98	7.21	7.40	7.66	8.86	1	1.5
pH	3	Maximum	8.5		DRBC	62	5.87	6.88	7.10	7.24	7.38	7.76	0	0
pH	4	Maximum	8.5		DRBC	75	6.08	6.91	7.12	7.24	7.46	7.94	0	0
pH	2	Minimum	6.5		DRBC	67	6.01	6.98	7.21	7.40	7.66	8.86	7	10.5
pH	3	Minimum	6.5		DRBC	62	5.87	6.88	7.10	7.24	7.38	7.76	6	9.7
pH	4	Minimum	6.5		DRBC	75	6.08	6.91	7.12	7.24	7.46	7.94	6	8.0
Temp	2	Maximum	(1)	°C	DRBC	67	7.07	15.5	19.5	25.3	27.1	30.2	19	28.4
Temp	3	Maximum	(1)	°C	DRBC	62	8.00	15.2	20.0	25.0	25.9	29.0	12	19.4
Temp	4	Maximum	(1)	°C	DRBC	75	8.70	15.4	20.0	24.5	26.0	29.1	11	14.7
TKN	2	No Standard	--	mg/L		6	0.374	0.392	0.427	0.481	0.500	0.500	--	--
TKN	3	No Standard	--	mg/L		6	0.390	0.451	0.530	0.617	0.681	0.681	--	--
TKN	4	No Standard	--	mg/L		9	0.469	0.505	0.605	0.650	0.696	0.696	--	--
TN	2	No Standard	--	mg/L		6	1.19	1.21	1.43	1.51	2.01	2.01	--	--
TN	3	No Standard	--	mg/L		6	1.41	1.42	1.56	1.71	1.92	1.92	--	--
TN	4	No Standard	--	mg/L		9	1.75	1.94	2.02	2.05	2.28	2.28	--	--
TP	2	No Standard	--	mg/L		20	0.0240	0.0375	0.0615	0.0785	0.0840	0.0890	--	--
TP	3	No Standard	--	mg/L		16	0.0390	0.0670	0.0790	0.0980	0.113	0.113	--	--
TP	4	No Standard	--	mg/L		19	0.0440	0.0700	0.0990	0.121	0.148	0.165	--	--
TSS	2	No Standard	--	mg/L		66	3.00	5.00	7.00	10.0	15.0	25.0	--	--
TSS	3	No Standard	--	mg/L		61	2.00	7.00	12.0	17.0	22.0	38.0	--	--
TSS	4	No Standard	--	mg/L		74	4.00	10.0	14.0	21.0	29.0	73.0	--	--

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Turbidity	2	Maximum	150	NTU	DRBC	76	1.00	4.00	5.00	9.00	150	150	0	0
Turbidity	3	Maximum	150	NTU	DRBC	62	2.00	4.00	6.00	10.0	15.0	19.0	0	0
Turbidity	4	Maximum	150	NTU	DRBC	75	2.00	6.00	10.0	13.0	18.0	55.0	0	0

(1) Water Temperature Standards Change by Zone and Month
(2) Enterococcus (Above R.M. 81.8 Maximum 88, Below R.M. 81.8 Maximum 33)
(3) Fecal Coliform (Above R.M. 81.8 Maximum 770, Below R.M. 81.8 Maximum 200)
(4) Water Quality Standard Requires Hardness Correction; Value listed is water quality standard calculated at 100 ug/L $CaCO_3$ hardness

Table 3-95 Delaware River Dry Weather Water Quality Problem Parameters 2003 – 2008

Parameter	Zone	RM	Standard	Target Value	Units	Source	No. Obs.	Percentiles						No. Exceeding	% Exceeding
								0	25	50	75	90	100		
Enterococcus	2	117.8	Maximum	33	#/100mL	DRBC	36	1.00	7.00	16.0	25.5	37.0	113	6	16.7
Enterococcus	2	110.7	Maximum	33	#/100mL	DRBC	37	1.00	5.00	10.0	18.0	28.0	160	2	5.4
Enterococcus	3	104.75	Maximum	88	#/100mL	DRBC	34	2.00	6.00	8.50	21.0	57.0	240	3	8.8
Enterococcus	3	100.2	Maximum	88	#/100mL	DRBC	34	1.00	4.50	9.00	16.0	73.0	220	3	8.8
Enterococcus	4	93.2	Maximum	88	#/100mL	DRBC	41	2.00	6.00	11.0	16.0	25.0	117	1	2.4
Enterococcus	4	87.9	Maximum	88	#/100mL	DRBC	34	1.00	4.00	8.00	13.0	32.0	100	1	2.9
Fecal Coliform	2	117.8	Maximum	200	#/100mL	DRBC	32	9.00	21.0	37.0	88.0	130	230	1	3.1
Fecal Coliform	2	110.7	Maximum	200	#/100mL	DRBC	34	14.0	22.0	55.5	77.0	180	270	3	8.8
pH	2	131.04	Minimum	6.5		DRBC	2	6.28					8.86	1	50.0
pH	2	122.4	Minimum	6.5		DRBC	2	6.12					8.21	1	50.0
pH	2	117.8	Minimum	6.5		DRBC	31	6.03	7.04	7.21	7.43	7.66	7.80	2	6.5
pH	2	110.7	Minimum	6.5		DRBC	32	6.01	6.99	7.23	7.38	7.47	7.79	3	9.4
pH	3	104.75	Minimum	6.5		DRBC	31	5.87	6.88	7.13	7.25	7.40	7.75	2	6.5
pH	3	100.2	Minimum	6.5		DRBC	31	5.88	6.87	7.10	7.20	7.34	7.76	4	12.9
pH	4	93.2	Minimum	6.5		DRBC	37	6.08	6.96	7.08	7.20	7.40	7.71	2	5.4
pH	4	87.9	Minimum	6.5		DRBC	32	6.11	6.90	7.15	7.27	7.46	7.94	3	9.4

Parameter	Zone	RM	Standard	Target Value	Units	Source	No. Obs.	Percentiles						No. Exceeding	% Exceeding
								0	25	50	75	90	100		
pH	4	84	Minimum	6.5		DRBC	6	6.10	7.04	7.32	7.46	7.84	7.84	1	16.7
Temp	2	131.04	Maximum	*	°C	DRBC	2	11.4					16.2	1	50.0
Temp	2	122.4	Maximum	*	°C	DRBC	2	11.3					15.8	1	50.0
Temp	2	117.8	Maximum	*	°C	DRBC	31	7.07	15.8	20.2	25.3	27.3	30.2	10	32.3
Temp	2	110.7	Maximum	*	°C	DRBC	32	7.84	15.3	20.1	25.4	26.7	29.5	7	21.9
Temp	3	104.75	Maximum	*	°C	DRBC	31	8.00	15.2	20.0	25.1	25.9	29.0	7	22.6
Temp	3	100.2	Maximum	*	°C	DRBC	31	8.61	15.1	20.0	24.6	25.9	28.8	5	16.1
Temp	4	93.2	Maximum	*	°C	DRBC	37	8.70	15.8	20.3	24.6	25.8	28.9	4	10.8
Temp	4	87.9	Maximum	*	°C	DRBC	32	8.97	15.7	21.1	24.5	26.0	29.1	6	18.8
Temp	4	84	Maximum	*	°C	DRBC	6	8.87	9.07	16.6	19.4	24.9	24.9	1	16.7

* Water Temperature Standard Change by Month and Zone

Table 3-96 Delaware River Wet Weather Water Quality Summary Statistics and Exceedances 2003 - 2008

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Alkalinity	2	Maximum	100	mg/L	DRBC	14	10.7	30.1	46.0	53.4	57.9	64.5	0	0
Alkalinity	3	Maximum	120	mg/L	DRBC	14	12.0	23.7	45.1	51.1	55.8	57.6	0	0
Alkalinity	4	Maximum	120	mg/L	DRBC	14	13.4	31.8	46.3	57.3	58.9	60.0	0	0
Alkalinity	2	Minimum	20	mg/L	DRBC	14	10.7	30.1	46.0	53.4	57.9	64.5	2	14.3
Alkalinity	3	Minimum	20	mg/L	DRBC	14	12.0	23.7	45.1	51.1	55.8	57.6	2	14.3
Alkalinity	4	Minimum	20	mg/L	DRBC	14	13.4	31.8	46.3	57.3	58.9	60.0	2	14.3
Diss Cu	2	Aquatic Life Acute Maximum	18[(4)]	µg/L	DRBC	24	1.40	1.40	1.45	2.35	3.85	7.90	0	0
Diss Cu	3	Aquatic Life Acute Maximum	18[(4)]	µg/L	DRBC	24	1.00	1.40	1.80	4.00	6.10	12.2	0	0

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Diss Cu	4	Aquatic Life Acute Maximum	18(4)	µg/L	DRBC	31	1.20	1.40	2.40	4.30	6.20	11.8	0	0
Diss Cu	2	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	24	1.40	1.40	1.45	2.35	3.85	7.90	0	0
Diss Cu	3	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	24	1.00	1.40	1.80	4.00	6.10	12.2	0	0
Diss Cu	4	Aquatic Life Chronic Maximum	12(4)	µg/L	DRBC	31	1.20	1.40	2.40	4.30	6.20	11.8	0	0
Diss Zn	2	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	30	0.800	2.30	4.70	8.00	14.0	33.9	0	0
Diss Zn	3	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	31	0.400	2.90	5.30	8.10	11.3	18.9	0	0
Diss Zn	4	Aquatic Life Acute Maximum	117(4)	µg/L	DRBC	36	1.30	2.95	5.50	9.88	18.6	36.0	0	0
Diss Zn	2	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	30	0.800	2.30	4.70	8.00	14.0	33.9	0	0

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
Diss Zn	3	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	31	0.400	2.90	5.30	8.10	11.3	18.9	0	0
Diss Zn	4	Aquatic Life Chronic Maximum	106(4)	µg/L	DRBC	36	1.30	2.95	5.50	9.88	18.6	36.0	0	0
Diss Zn	2	Toxicants FIO Maximum	68700	µg/L	DRBC	30	0.800	2.30	4.70	8.00	14.0	33.9	0	0
Diss Zn	3	Toxicants FIO Maximum	68700	µg/L	DRBC	31	0.400	2.90	5.30	8.10	11.3	18.9	0	0
Diss Zn	4	Toxicants FIO Maximum	68700	µg/L	DRBC	36	1.30	2.95	5.50	9.88	18.6	36.0	0	0
Diss Zn	2	Toxicants FWI Maximum	9110	µg/L	DRBC	30	0.800	2.30	4.70	8.00	14.0	33.9	0	0
Diss Zn	3	Toxicants FWI Maximum	9110	µg/L	DRBC	31	0.400	2.90	5.30	8.10	11.3	18.9	0	0
Diss Zn	4	Toxicants FWI Maximum	9110	µg/L	DRBC	36	1.30	2.95	5.50	9.88	18.6	36.0	0	0
DO	2			mg/L		66	4.69	7.15	8.23	10.4	12.0	13.9	--	--
DO	3			mg/L		59	4.96	6.19	8.05	9.80	11.7	13.3	--	--
DO	4			mg/L		76	4.94	6.14	7.45	9.39	11.8	12.9	--	--
Enterococcus	2	Maximum	33	#/100mL	DRBC	68	1.00	9.00	16.0	78.5	160	600	22	32.4
Enterococcus	3	Maximum	88	#/100mL	DRBC	60	3.00	10.0	23.0	78.5	225	370	11	18.3

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile 0	Percentile 25	Percentile 50	Percentile 75	Percentile 90	Percentile 100	No. Exceeding	% Exceeding
Enterococcus	4	Maximum	(2)	#/100mL	DRBC	75	1.00	7.00	12.0	25.0	42.0	330	5	6.7
Fecal Coliform	2	Maximum	200	#/100mL	DRBC	68	8.00	30.3	55.0	133	320	770	9	13.2
Fecal Coliform	3	Maximum	770	#/100mL	DRBC	59	17.0	73.0	130	430	600	600	0	0
Fecal Coliform	4	Maximum	(3)	#/100mL	DRBC	78	1.00	27.0	56.5	210	310	600	0	0
Inorganic N	2	No Standard	--	mg/L		24	0.621	0.788	0.886	1.12	1.29	1.43	--	--
Inorganic N	3	No Standard	--	mg/L		25	0.587	0.837	0.960	1.25	1.58	1.77	--	--
Inorganic N	4	No Standard	--	mg/L		36	0.804	1.14	1.46	1.99	2.42	4.25	--	--
NH_3	2	No Standard	--	mg/L		24	0.0220	0.0575	0.0730	0.0965	0.110	0.202	--	--
NH_3	3	No Standard	--	mg/L		25	0.0150	0.0530	0.0840	0.156	0.259	0.399	--	--
NH_3	4	No Standard	--	mg/L		36	0.00800	0.0590	0.107	0.216	0.292	0.459	--	--
pH	2	Maximum	8.5		DRBC	66	6.31	7.13	7.30	7.52	7.90	8.34	0	0
pH	3	Maximum	8.5		DRBC	59	6.31	7.03	7.20	7.40	7.65	7.80	0	0
pH	4	Maximum	8.5		DRBC	76	6.34	7.00	7.18	7.40	7.70	7.85	0	0
pH	2	Minimum	6.5		DRBC	66	6.31	7.13	7.30	7.52	7.90	8.34	2	3.0
pH	3	Minimum	6.5		DRBC	59	6.31	7.03	7.20	7.40	7.65	7.80	1	1.7
pH	4	Minimum	6.5		DRBC	76	6.34	7.00	7.18	7.40	7.70	7.85	1	1.3
Temp	2	Maximum	(1)	°C	DRBC	66	2.81	10.9	17.3	24.1	26.0	27.3	22	33.3
Temp	3	Maximum	(1)	°C	DRBC	59	2.80	13.3	17.4	23.7	26.1	26.9	13	22.0
Temp	4	Maximum	(1)	°C	DRBC	76	3.64	13.3	17.8	23.6	26.1	27.5	15	19.7
TKN	2	No Standard	--	mg/L		12	0.126	0.335	0.426	0.464	0.479	0.540	--	--
TKN	3	No Standard	--	mg/L		13	0.346	0.384	0.417	0.550	0.727	0.743	--	--

Parameter	Zone	Standard	Target Value	Units	Source	No. Obs.	Percentile						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
TKN	4	No Standard	--	mg/L		21	0.391	0.453	0.487	0.547	0.759	0.851	--	--
TN	2	No Standard	--	mg/L		12	0.908	1.12	1.27	1.47	1.55	1.57	--	--
TN	3	No Standard	--	mg/L		13	1.14	1.34	1.48	1.62	1.691	1.70	--	--
TN	4	No Standard	--	mg/L		21	1.29	1.62	1.85	2.04	2.171	2.45	--	--
TP	2	No Standard	--	mg/L		28	0.0260	0.0500	0.0765	0.0935	0.105	0.110	--	--
TP	3	No Standard	--	mg/L		20	0.0350	0.0780	0.0900	0.109	0.158	0.161	--	--
TP	4	No Standard	--	mg/L		23	0.0510	0.0970	0.120	0.132	0.152	0.164	--	--
TSS	2	No Standard	--	mg/L		64	2.00	5.00	7.50	11.5	18.0	144	--	--
TSS	3	No Standard	--	mg/L		59	4.00	8.00	11.0	16.0	23.0	206	--	--
TSS	4	No Standard	--	mg/L		76	5.00	10.0	14.0	20.0	29.0	178	--	--
Turbidity	2	Maximum	150	Units	DRBC	74	1.00	3.00	6.00	12.0	150	150	0	0
Turbidity	3	Maximum	150	Units	DRBC	59	1.00	4.00	6.00	11.0	16.0	200	2	3.4
Turbidity	4	Maximum	150	Units	DRBC	76	3.00	6.00	9.00	13.0	18.0	170	2	2.6

(1) Water Temperature Standards Change by Zone and Month
(2) Enterococcus (Above R.M. 81.8 Maximum 88, Below R.M. 81.8 Maximum 33)
(3) Fecal Coliform (Above R.M. 81.8 Maximum 770, Below R.M. 81.8 Maximum 200)
(4) Water Quality Standard Requires Hardness Correction; Value listed is water quality standard calculated at 100 ug/L CaCO3 hardness

Table 3-97 Delaware River Wet Weather Water Quality Problem Parameters 2003 – 2008

Parameter	Zone	RM	Standard	Target Value	Units	Source	No. Obs.	Percentiles						No. Exceeding	% Exceeding
								0	25	50	75	90	100		
Alkalinity	2	117.8	Minimum	20	mg/L	DRBC	7	15.0	30.1	48.8	57.9	64.5	64.5	1	14.3
Alkalinity	2	110.7	Minimum	20	mg/L	DRBC	7	10.7	28.0	43.4	49.7	54.7	54.7	1	14.3
Alkalinity	3	104.75	Minimum	20	mg/L	DRBC	7	14.2	23.7	46.1	51.1	57.6	57.6	1	14.3
Alkalinity	3	100.2	Minimum	20	mg/L	DRBC	7	12.0	22.7	44.1	54.0	55.8	55.8	1	14.3
Alkalinity	4	93.2	Minimum	20	mg/L	DRBC	7	13.4	26.1	45.8	58.1	58.9	58.9	1	14.3
Alkalinity	4	87.9	Minimum	20	mg/L	DRBC	7	13.7	31.8	46.9	57.3	60.0	60.0	1	14.3
Enterococcus	2	117.8	Maximum	33	#/100mL	DRBC	30	4.00	9.0	21.0	113	173	335	12	40.0
Enterococcus	2	110.7	Maximum	33	#/100mL	DRBC	30	2.00	10.0	16.0	57.0	157	600	10	33.3
Enterococcus	3	104.75	Maximum	88	#/100mL	DRBC	30	3.00	10.0	23.0	55.0	147	370	3	10.0
Enterococcus	3	100.2	Maximum	88	#/100mL	DRBC	30	4.00	11.0	22.5	107	280	340	8	26.7
Enterococcus	4	87.9	Maximum	88	#/100mL	DRBC	29	1.00	6.00	10.0	22.0	42.0	220	3	10.3
Enterococcus	4	84	Maximum	88	#/100mL	DRBC	10	1.00	5.00	7.00	10.0	17.0	19.0	2	20.0
Fecal Coliform	2	117.8	Maximum	200	#/100mL	DRBC	30	10.0	29.5	58.0	160	350	590	5	16.7
Fecal Coliform	2	110.7	Maximum	200	#/100mL	DRBC	30	8.00	35.0	71.5	140	310	770	4	13.3
pH	2	117.8	Minimum	6.5	--	DRBC	29	6.31	7.10	7.30	7.50	8.12	8.30	1	3.4
pH	2	110.7	Minimum	6.5	--	DRBC	29	6.32	7.14	7.27	7.40	7.71	7.90	1	3.4
Turbidity	3	104.75	Maximum	150	NTU	DRBC	29	2.00	4.00	6.00	10.0	14.0	170	1	3.4
Turbidity	3	100.2	Maximum	150	NTU	DRBC	30	1.00	4.00	6.00	11.0	16.0	200	1	3.3
Turbidity	4	93.2	Maximum	150	NTU	DRBC	37	3.00	6.00	8.00	12.0	17.0	170	1	2.7
Turbidity	4	87.9	Maximum	150	NTU	DRBC	29	3.00	6.00	9.00	13.0	28.0	170	1	3.4
Temp	2	131.04	Maximum	*	°C	DRBC	4	5.08	7.98	17.8	25.1	25.4	25.4	3	75.0
Temp	2	122.4	Maximum	*	°C	DRBC	4	3.88	5.97	16.0	24.2	24.5	24.5	1	20.0
Temp	2	117.8	Maximum	*	°C	DRBC	29	2.86	13.8	17.1	23.9	26.9	27.3	9	31.0
Temp	2	110.7	Maximum	*	°C	DRBC	29	2.81	13.6	17.5	23.4	26.2	27.0	9	31.0
Temp	3	104.75	Maximum	*	°C	DRBC	29	2.80	13.6	17.4	23.5	26.1	26.9	7	24.1
Temp	3	100.2	Maximum	*	°C	DRBC	30	3.14	13.3	17.3	23.7	26.0	26.7	6	20.0
Temp	4	93.2	Maximum	*	°C	DRBC	37	3.64	13.5	17.8	23.8	26.1	27.1	7	18.9
Temp	4	87.9	Maximum	*	°C	DRBC	29	3.87	13.3	17.8	23.5	26.3	27.4	6	20.7
Temp	4	84	Maximum	*	°C	DRBC	10	3.95	9.34	18.8	23.2	27.2	27.5	2	20.0

* Water Temperature Standards Change by Zone and Month

Table 3-98 Delaware River Continuous Water Quality Summary Statistics and Exceedances 2003 – 2008

Parameter	USGS Gauge	RM	Standard	Target Value	Units	No. Obs.	Percentiles						No. Exceeding	% Exceeding
							0	25	50	75	90	100		
DO	1482800	37	Daily Minimum	5	mg/L	1838	4.10	6.70	8.40	11.1	12.3	14.0	182	9.9
DO	1477050	82	Daily Minimum	3.5	mg/L	1377	3.70	5.30	6.60	8.30	10.0	13.2	0	0
DO	1467200	100.2	Daily Minimum	3.5	mg/L	1396	3.20	4.90	6.80	9.00	10.5	13.7	6	0.4
pH	1482800	37	Maximum	8.5		2201	6.90	7.40	7.50	7.70	7.80	8.40	0	0
pH	1477050	82	Maximum	8.5		1415	6.80	7.10	7.20	7.30	7.50	8.10	0	0
pH	1467200	100.2	Maximum	8.5		1460	6.40	7.00	7.20	7.30	7.40	7.80	0	0
pH	1482800	37	Minimum	6.5		2201	6.70	7.20	7.40	7.50	7.60	8.00	0	0
pH	1477050	82	Minimum	6.5		1415	6.70	7.00	7.10	7.20	7.30	7.60	0	0
pH	1467200	100.2	Minimum	6.5		1460	6.20	6.90	7.10	7.20	7.30	7.60	40	2.7
Temp	1482800	37	Maximum	*	°C	2174	-0.300	5.40	14.5	24.3	27.2	30.7	38	1.7
Temp	1477050	82	Maximum	*	°C	1415	4.30	14.9	21.3	26.1	27.7	30.8	342	24.2
Temp	1467200	100.2	Maximum	*	°C	1459	3.40	13.5	19.6	25.2	26.8	29.4	277	19.0

*Water Temperature Standard Changes by Zone and Month

Discussion of Possible Problem Parameters
The following analysis of water quality data is focused on parameters that were listed in US EPA's 1995 Guidance for Long Term Control Plan. All sample results were compared to relevant DRBC water quality criteria as defined in Administrative Manual Part III Water Quality Regulations 18 CFR Part 410. Tables 3-94 through 3-98 were compared to stream quality objectives set forth in section 3.30 of the above mentioned DRBC manual. Water quality parameters were classified as a "parameter of concern" (>10% samples exceeding target value, highlighted in red) or a "parameter of potential concern" (2-10% samples exceeding target value, highlighted in yellow). The water quality criteria or target value is discussed in each parameter analysis.

pH
Both the continuous and discrete monitoring tracked pH at several sites within the monitored watershed. DRBC WQ criteria set minimum and maximum pH limits of 6.5 and 8.5, respectively, for Zones 2, 3, and 4. The continuous data (Table 3-98) shows the minimum DRBC pH standards were rarely exceeded, except for within Zone 3 (exceeded 2.7% of the time). Overall, pH is considered to be of little concern. During the DRBC discrete monitoring the minimum pH standard was exceeded both during dry and wet weather. The minimum standard was exceeded during dry weather (Table 3-94) within Zones 2, 3, and 4 and accounted for 10.5%, 9.7%, and 8.0% of the samples respectfully. During dry weather pH was considered a problem parameter in Zone 2 and a potential problem parameter in Zones 3 and 4. The minimum standard was also exceeded during wet weather (Table 3-96) within Zone 2. The minimum standard was exceeded in Zone 2 within 3.0% of the samples. During wet weather pH was considered to be a potential problem parameter.*Dissolved Oxygen*
The DRBC has set minimum DO daily averages as well as minimum seasonal averages for the mainstem of the Delaware River. The minimum DO daily average values change by zone throughout the monitored area while the minimum seasonal averages are constant within Zones 1 through 5. Seasonal averages are effective between April 1st thru June 15th and September 16th thru December 31st and require a minimum average seasonal DO level of 6.5 mg/L. DRBC water quality criteria require a minimum daily average DO concentration within Zone 2 of 5 mg/L. Both zones 3 and 4 require a minimum daily average DO concentration of 3.5 mg/L. The continuous data (Table 3-98) shows that the most serious exceedances occurred at USGS gage 01482800. DO is therefore considered a potential concern in Zone 2.

Historical data show an improving trend over time. Figure 3-91 illustrates that historically, DO has dropped below standards downstream of the Delaware Direct Watershed, however, the DO in the Delaware River has generally improved since 1980. Figure 3-92 indicates that DO has improved over time since 1984 at the Navy Yard, the most downstream point in the Delaware River in the Delaware Direct Watershed. DRBC sampling has found the DO standard was met continuously since 1980.

According to the "Development of a Hydrodynamic and Water Quality Model for the Delaware River" (DRBC, 1998) "the elimination of the CSO loading," … "shows almost no impact on dissolved oxygen concentrations."

Future Investigation of Dissolved Oxygen Conditions in the Tidal Delaware River
The nature, causes, severity and opportunities for control of the dissolved oxygen conditions in the tidal Delaware River are not well understood at this juncture. Efforts to better understand the dissolved oxygen conditions will continue through evaluation of ongoing continuous long-term

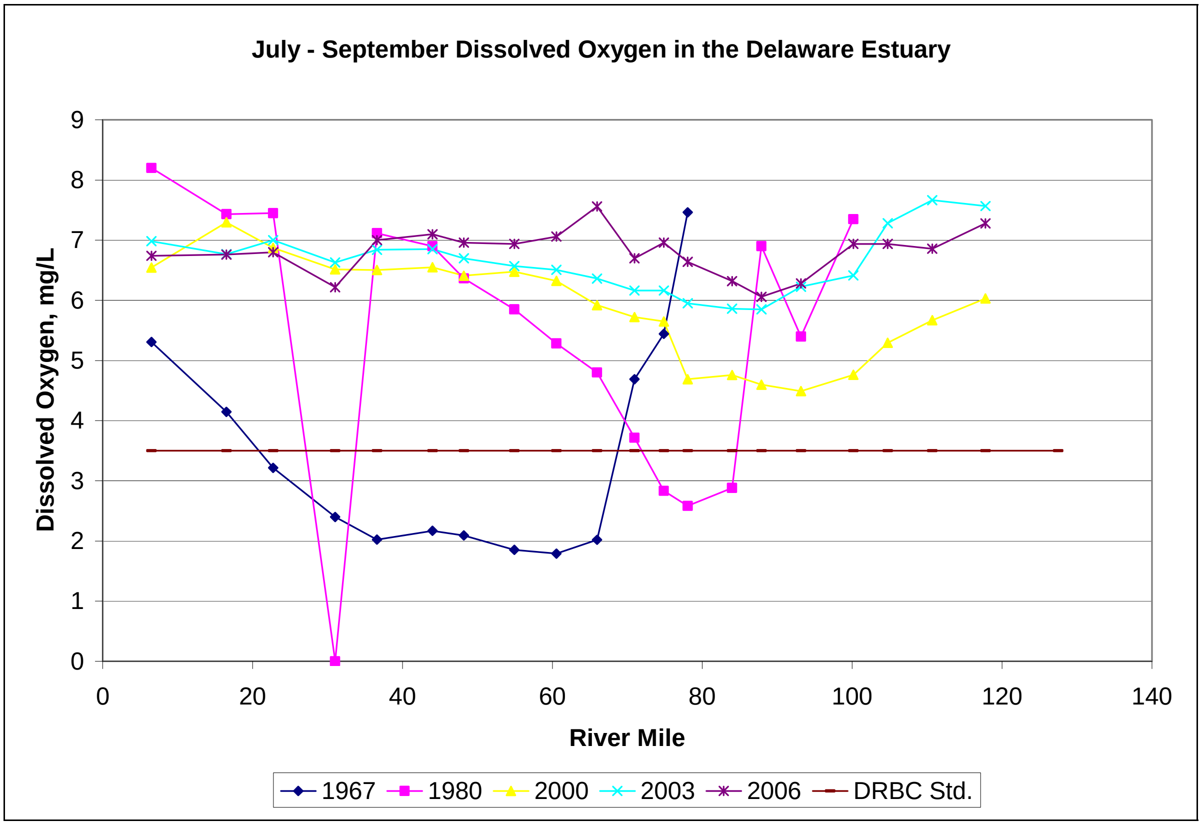


Figure 3-91 Historical Dissolved Oxygen in the Delaware River Estuary by river mile, 1967 – 2006

monitoring. PWD continues to work with the Delaware River Basin Commission and its partners on issues related to the dissolved oxygen conditions in the estuary. Estimates will be refined and analyses performed on the loading of water quality constituents related to the dissolved oxygen dynamics, both from the City as well as from other dischargers to the tributaries that run through the City. If a relationship between loadings and the dissolved oxygen conditions in the River adjacent to the City is suspected, informational total maximum daily loads will be investigated for all potential sources of the identified water quality constituents to the City's watersheds. Progress and results of this work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Total Dissolved Solids

Total Dissolved Solids (TDS) were not included in the wet weather and dry weather sampling in the Schuylkill River because the DRBC has no standard for TDS in Zone 2 through 4. TDS are not considered a parameter of concern in the Philadelphia portion of the Delaware River.

Total Suspended Solids

Total Suspended Solids (TSS) is a measure of the concentration of solids suspended in the water column. TSS ranged from 2.0 mg/L in Zone 2 to 206 mg/L in Zone 3 during wet weather sampling (Table 3-96). Dry weather samples (Table 3-94) ranged from 2 mg/L to 73 mg/L in Zone 4. The DRBC does not have water quality standards for TSS and TSS is not considered to be a concern in the Philadelphia portion of the Delaware River.

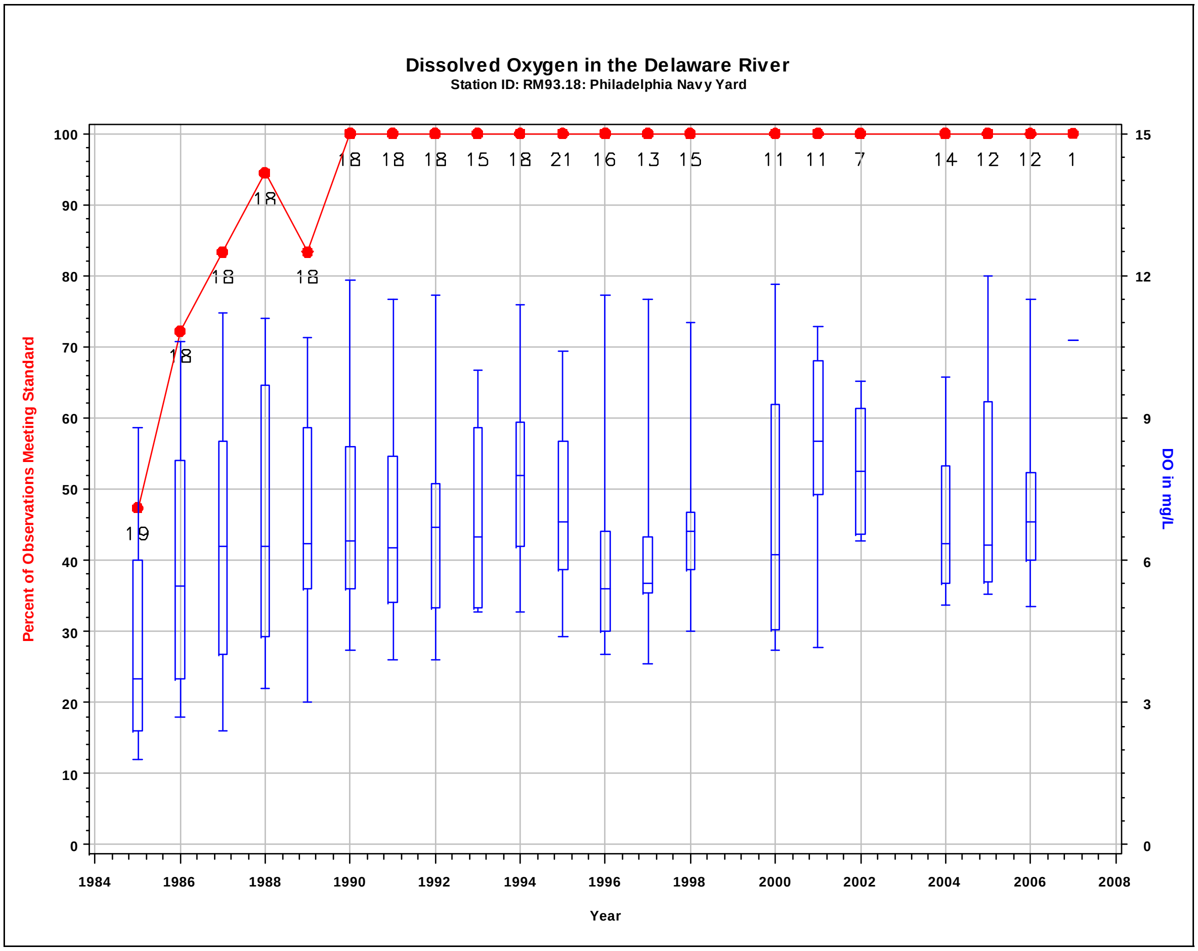


Figure 3-92 Delaware River Dissolved Oxygen at the Philadelphia Navy Yard 1984 - 2007

Turbidity

Turbidity is a measure of the light scattering properties of particles suspended in water. In streams, turbidity can come from many sources, but the chief cause of increased turbidity is suspended sediment. While a correlation between turbidity and TSS certainly exists, the relationship between turbidity and TSS may differ between water bodies and even among different flow stages/seasons in the same water body due to sediment characteristics. Consistently turbid waters often show impairment in aquatic communities. Light penetration is reduced, which may result in decreased algal production; suspended particles can clog gills and feeding apparatus of fish, benthic invertebrates, and microorganisms. Feeding efficiency of visual predators may also be reduced. Turbidity is measured in Turbidity Units, and the DRBC has set a water quality standard of 150 units maximum.

In the Delaware River Zones 2 through 4, turbidity ranged from 1 NTU in Zone 2 to 150 NTU in Zone 3 during dry weather (Table 3-94). Wet weathers samples (Table 3-96) ranged from 1 NTU in Zone 2 to 200 NTU in Zone 3. The DRBC standard was exceeded twice in both Zones 2 (3.4% of observations) and 4 (2.6 % of observations. Turbidity is not considered to be a concern during dry weather, as no samples exceeded the standard, and is considered a potential concern during wet weather.

Nutrients
Nutrient samples were collected by the DRBC from 2005-2008. The DRBC has not set water quality standards for nutrients in Zones 2-4, which includes the tidal portions of the Delaware River. Therefore, collected data could not be compared to a target value.

Total Phosphorous
The DRBC reported sampling of Total Phosphorous (TP) in the Delaware River from 2003 to 2008. TP dry weather samples (Table 3-94) ranged from 0.0450 mg/L in Zone 2 to 0.165 mg/L at the Zone 4 sampling site. During wet weather events (Table 3-96), samples ranged from 0.0240 mg/L in Zone 2 to 0.165 mg/L in Zone 4. DRBC has no standards for nutrients in the tidal waters of the Delaware River Basin. Total Phosphorous is not considered a problem parameter in the Philadelphia portion of the Delaware River.

Ammonia
Ammonia, present in surface waters as un-ionized ammonia gas (NH3), or as ammonium ion (NH4+), is produced by deamination of organic nitrogen-containing compounds, such as proteins, and also by hydrolysis of urea. In the presence of oxygen, NH3 is converted to nitrate (NO3) by a pair of bacteria-mediated reactions, together known as the process of nitrification. Nitrification occurs quickly in oxygenated waters with sufficient densities of nitrifying bacteria, effectively reducing NH3, although at the expense of increased NO3 concentration.

During dry weather (Table 3-94), ammonia concentrations ranged from 0.02 mg/L (Zone 2) to 0.389 mg/L (Zone 4). During wet weather events (Table 3-96), samples ranged from 0.008 mg/L (Zones 4) to 0.459 mg/L (Zone 4). DRBC has no standards for nutrients in the tidal waters of the Delaware River Basin, and ammonia is not considered to a parameter of concern in the Philadelphia portion of the Delaware River.

Total Nitrogen
TN dry weather samples (Table 3-94) ranged from 1.41 mg/L in Zone 3 to 2.28 mg/L in Zone 4. During wet weather events (Table 3-96), samples ranged from 0.908 mg/L in Zone 2 to 2.45 mg/L in Zone 4. DRBC has no standards for nutrients in the tidal waters of the Delaware River Basin. TN is not considered to be a concern in the Philadelphia portion of the Delaware River.

Total Kjeldahl Nitrogen
The Total Kjeldahl Nitrogen (TKN) test provides an estimate of the concentration of organically-bound N, but actually measures all N present in the trinegative oxidation state. Ammonia must be subtracted from TKN values to give the organically bound fraction. TKN analysis also does not account for several other N compounds (e.g., azides, nitriles, hydrazone); these compounds are rarely present in significant concentrations in surface waters.

TKN dry weather samples (Table 3-94) ranged from 0.374 mg/L in Zone 2 to 0.696 mg/L in Zone 4. During wet weather events (Table 3-96), samples in the Philadelphia Zones of the Delaware ranged from 0.126 mg/L (Zone 2) to 0.851 mg/L (Zone 4). DRBC has no standards for nutrients in the tidal waters of the Delaware River Basin. TKN is not considered to be a concern in the Philadelphia portion of the Delaware River.

Toxic Metals
With the exception of Aluminum (Al) and hexavalent Chromium (Cr), PA WQ criteria are based on hardness (as CaCO3), to reflect inverse relationships between hardness and toxicity that exist for

most metals (Figure 3-36). While these criteria are much improved over simple numeric criteria, they fail to describe the complex interactions between dissolved metals and other water constituents and physicochemical properties (e.g., Dissolved Organic Carbon, pH, temperature, and ions other than Ca and Mg,). Hardness-based criteria may represent an intermediate step between simple numeric criteria and criteria based on more complex water quality models (i.e., Biotic Ligand Model), drafts of which have been recently been presented by US EPA.

Dissolved Zinc
Zinc (Zn) is a common element present in many rocks and in small concentrations in soil. Zn is a micronutrient needed by plants and animals, but when present in greater concentrations in surface water, it is moderately toxic to fish and other aquatic life. Toxicity is most severe during certain sensitive (usually early) life stages. Zn is a component of common alloys such as brass and bronze and is used industrially for solders, galvanized coatings, and in roofing materials.

Since the water quality criteria for dissolved Zn requires a hardness correction, the standard was calculated at 100 μg/L $CaCO_3$ hardness. With the correction, the Aquatic Life Acute Maximum for Dissolved Zn is 117 μg/L and the Aquatic Life Chronic Maximum is 106 μg/L . The toxicity limit for Fish Ingestion Only (FIO) Maximum is 68700 μg/L and the toxicity limit for Fish and Water Ingestion (FWI) Maximum is 9110 μg/L.

Dissolved Zn samples in the Philadelphia segment of the Delaware River ranged from 0.400 μg/L in Zone 3 to 32.4 μg/L in Zone 3 during dry weather (Table 3-94). Wet weather samples (Table 3-96) ranged from 0.400 μg/L in Zone 3 to 36.0 μg/L in Zone 4. The water quality standards were never exceeded during sampling, therefore, Dissolved Zn is not considered to be a parameter of concern in the Philadelphia portion of the Delaware River.

Dissolved Copper
Copper (Cu) occurs naturally in numerous forms and is present to some degree in most soils and natural waters. Cu is also used industrially for electric wires and coils, as well as in building materials such as roofing and pressure-treated lumber. Cupric Ion (Cu2+) is the bioavailable form of Cu in aquatic systems and its mode of toxicity involves ligand bonding with the gill surface of fish or similar structures of invertebrates. As such, WQ criteria are based on dissolved Cu concentration, which is a better predictor of Cu toxicity than total recoverable metal concentration. Dissolved concentrations are usually much smaller than total recoverable concentrations in natural waters, as Cu forms complexes and ligand bonds with other water column constituents (Morel & Hering, 1993).

Since the water quality criteria for dissolved copper requires a hardness correction, PWD calculated the standard at 100 μg/L $CaCO_3$ hardness. With the correction, the Aquatic Life Acute Maximum for Dissolved Cu is 18 μg/L and the Aquatic Life Chronic Maximum is 12 μg/L. In the Delaware River Zones 2-4, Dissolved Cu ranged from 1.10 μg/L in Zone 4 to 8.50 μg/L in Zone 4 during dry weather (Table 3-94). Wet weather samples (Table 3-96) ranged from 1.00 μg/L in Zone 3 to 12.2 μg/L in Zone 3. The standards were never exceeded during sampling, and therefore Dissolved Cu is not considered a concern in the Philadelphia portion of the Delaware River.

Indicator Bacteria
Fecal Coliform
The fecal coliform criteria change by Zone within the monitoring area. DRBC water quality criteria limit fecal coliform levels within Zone 2, Zone5, and Zone 6 to 200 per 100 mL. The DRBC water

quality standard within Zone 3 for fecal coliform is set at 770 per 100 mL. Within Zone 4 the fecal coliform limit is broken down by R.M. such that, below R.M. 81.8 the limit is set at 200 per 100 mL and above R.M. 81.8 the limit is set at 770 per 100 mL. No areas of the Delaware Direct Watershed are located below R.M. 81.8.

Dry Weather Fecal Coliform Bacteria Concentration
The discrete sampling program conducted by DRBC from 2003-2008 broke down sampling into both dry weather (Tables 3-94 and 3-95) and wet weather (Tables 3-96 and 3-97). During dry weather only Zone 2 showed exceedance of fecal coliform criteria (5.7 % of observations) and is considered to be a potential concern. Sampling within Zone 2 consisted of two locations along the Delaware River. The first location was at R.M. 110.7, which had fecal coliform levels above the standard 8.8% of the time. The second location was at R.M. 117.8, which had fecal coliform levels above the standard 3.1% of the time.

Wet Weather Fecal Coliform Bacteria Concentration
During wet weather (Tables 3-96 and 3-97) the only zone to exceed the criteria for fecal coliform was Zone 2. Roughly 13.2% of all wet weather samples within Zone 2 exceeded the standard for fecal coliform concentration. At R.M 110.7, the standard was exceeded 13.3% of the time. At R.M. 117.8, and it was exceeded 16.7% of the time.

A review of historical data collected by DRBC (1984-2007) shows Zone 2, Zone 3 and Zone 4 in Philadelphia had the lowest percent of observations meeting standards (Figure 3-93). However, since 1997, fecal coliform has remained below the standard at the Navy Yard, the most downstream monitoring station in Philadelphia which includes all drainage from the Delaware Direct Watershed (Figure 3-94).

Enterococcus
Enterococcus is a bacteria genus used to indicate human pathogens. DRBC has set maximum enterococcus concentrations for this watershed. The maximum enterococcus concentration changes by zone throughout the monitoring area. The water quality limit for enterococcus concentration levels in Zone 2 is 33 per 100mL. Within Zone 3, the limit is increased to 88 per 100mL. Within Zone 4 the enterococcus limit is broken down by R.M. such that, below R.M. 81.8 the limit is 33 per 100mL and above R.M. 81.8 the limit is 88 per 100mL.

Within each zone a significant increase in exceedances can be seen between the dry and wet weather. During periods of dry weather (Tables 3-94 and 3-95) Zone 2 had the largest percentage of data that exceeded the standard set forth by DRBC with 10.4% of all data samples. During periods of wet weather (Table 3-95 and 3-96), the standard was exceeded in 32.4% of observations. The two monitoring sites within Zone 2 were located at R.M. 110.7 and 117.8. At R.M 110.7, the standard was exceeded in 5.4% of observations in dry weather and in 33.3% of observations in wet weather. Similarly, at R.M. 117.8, the number of samples exceeding the standard increased from 16.7% in dry weather to 40% in wet weather.

Zone 3 contained the second largest percentage of data that exceeded the standard in dry weather (8.8% exceedance) and wet weather (18.3% exceedance). Monitoring sites within Zone 3 were located at R.M. 100.2 and 104.75. 8.8% of all samples at both stations exceeded the standard in dry weather. In wet weather, 26.7% and 10% of their total samples exceeded the standards, respectively.

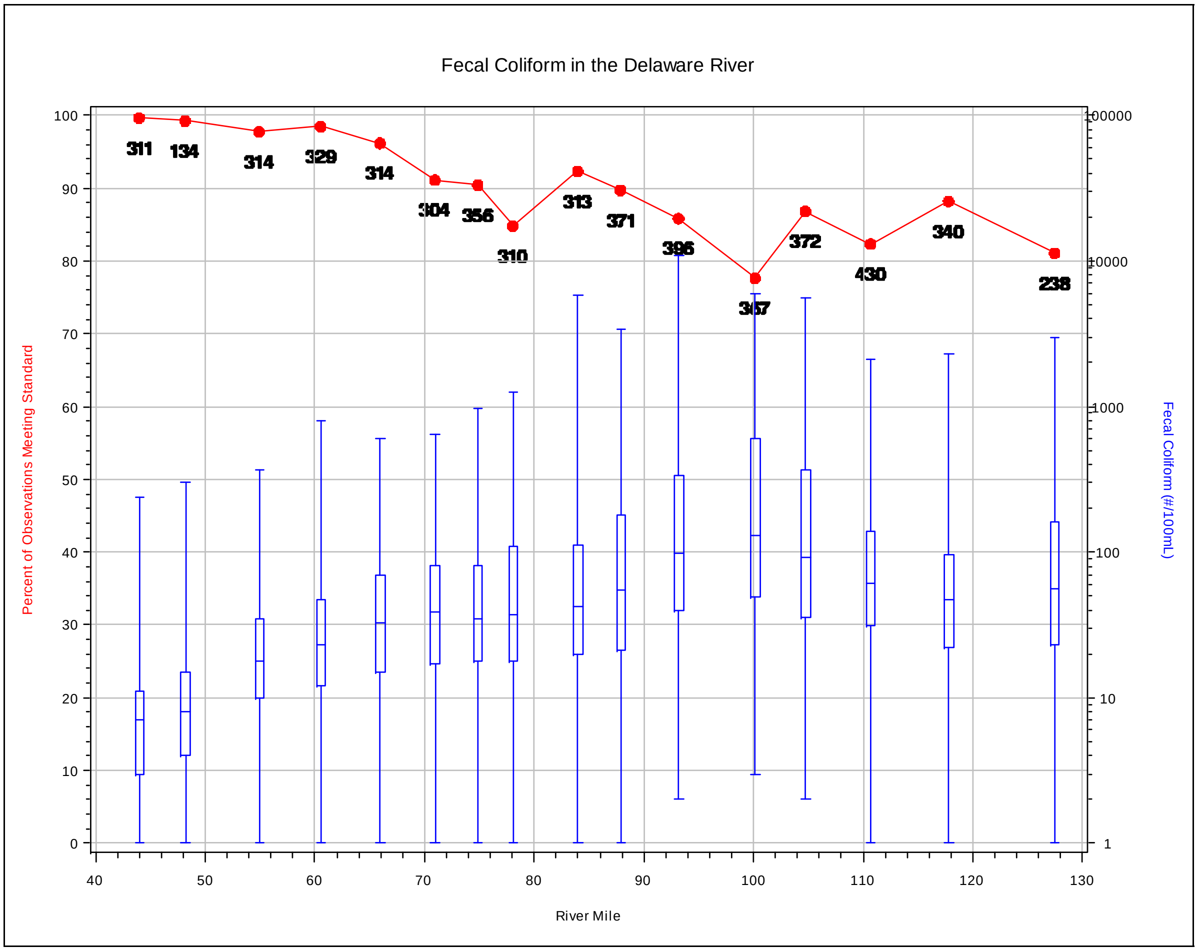


Figure 3-93 DRBC Boat Run Fecal Coliform in the Delaware River Estuary by river mile 1984 - 2007

Lastly, Zone 4 had the smallest increase in exceedances between dry and wet weather observations. At the station at R.M. 87.9, 2.4% of all samples exceeding the set limit during dry weather and 10.3% of samples exceeded the limit during wet weather.

Overall, enterococcus is parameter of concern in Zones 2 through 4 during both dry and wet weather, and especially in Zone 2 where the maximum limits are more stringent.

Future Investigation of Bacteria Conditions in the Tidal Delaware River

The nature, causes, severity and opportunities for control of the bacteria conditions in the tidal Delaware River are not well understood at this juncture. Efforts to better understand the bacteria conditions will continue through evaluation of ongoing monitoring efforts, and the establishment of additional monitoring efforts if necessary to better define potential problems. PWD will work with the Delaware River Basin Commission and its partners on issues related to the bacteria conditions in the estuary if such efforts are initiated by DRBC. Estimates will be refined and analyses performed on the loading of bacteria, both from the City as well as from other dischargers to the tributaries that run through the City. If a relationship between loadings and the bacteria conditions in the River adjacent to the City is suspected, informational total maximum daily loads will be investigated for the City's watersheds. Progress and results of this work, and any proposed remedial control actions,

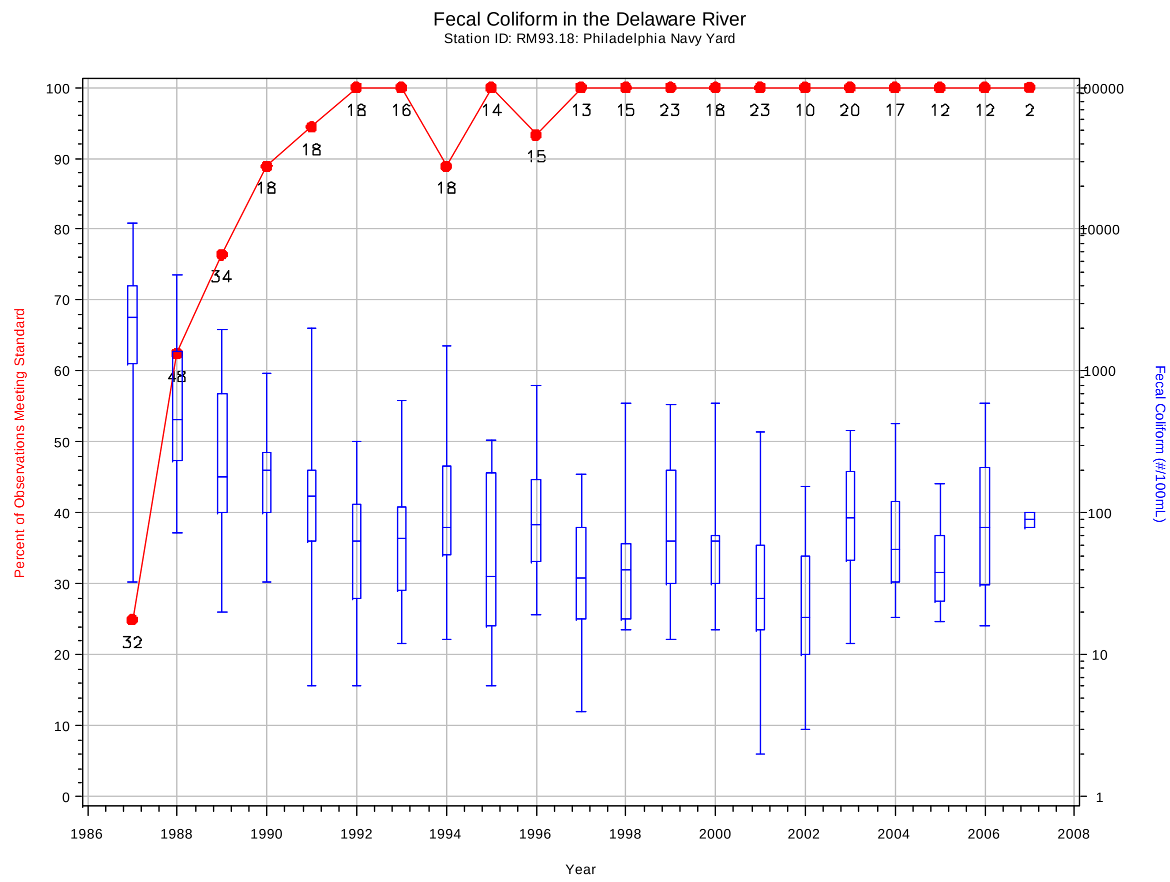


Figure 3-94 Delaware River Fecal Coliform at the Philadelphia Navy Yard 1984 - 2007

will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Temperature

The DRBC has set water quality criteria for temperature based on month and zone. Exceedances of temperature standards within the Delaware River were recorded by both discrete and continuous sampling in Zones 2 through 4. Temperature is therefore considered a parameter of concern in all three zones. The continuous data (Table 3-98) shows that the largest percentage of exceedance occurred at USGS gauge 01477050 in Zone 4. However, the discrete monitoring data (Table 3-94 and 3-96) shows that the largest exceedance occurred within Zone 2. During dry weather the standard was exceeded 28.4% of the time and during wet weather the standard was exceeded 33.3% of the time.

Total Alkalinity

The maximum and minimum total alkalinity standards set by DRBC change by zone throughout the monitoring area. DRBC water quality criteria limit the maximum value to 100 mg/L and a minimum value to 20 mg/L for any location within Zone 2. Zones 3 through 6 have a maximum value of 120 mg/L and a minimum value of 20 mg/L throughout their areas.

The standard for minimum alkalinity was often exceeded during discrete wet weather monitoring (Table 3-96). These exceedances occurred in Zone 2, 3, and 4, and occurred 14.3%, 14.3%, and 14.3% of the time.

3.4.2.3.3 Biological Assessment of the Delaware Direct Watershed

Benthic Assessment

The Partnership for the Delaware Estuary (PDE) is currently leading the Delaware Estuary Benthic Inventory Program (DEBI) due to an expressed need in "*White Paper on the Status and Needs of Science in the Delaware Estuary*" (Kreeger, et al 2006). The Benthos community is expected to differ in the Delaware River than in other non-tidal stream. Previously, no reference site was available to study benthos in the tidal streams in Philadelphia. The Delaware Direct IWMP will summarize the findings of DEBI in the Delaware Direct Watershed to help guide watershed management and restoration.

The Philadelphia Water Department has performed Biological Monitoring in the Delaware Direct Watershed, focusing on the tidal portion of the Pennypack Creek. Site PP180 was studied in the 2002-2003 Baseline Assessment of the Pennypack Creek and is located in the Delaware Direct Watershed (Figure 3-95). Reference sites used for Pennypack Creek Watershed were located on French Creek and Pine Creek in Chester County, PA (Figure 3-45). French Creek had high taxa richness (n = 27) and low HBI score (4.470). Seven EPT taxa were found, and all trophic levels were represented. Biological assessment scores of this site may be biased due to poor reference site scores. This comparison resulted in better scores and "moderately impaired" designations, which do not accurately portray the benthic population at these sites. The Pennypack Creek Watershed Comprehensive Characterization Report provides additional detail on the tidal Pennypack Creek and will be released in the Summer 2009.

Site PP180 received a total metric score of zero out of a possible 30 (Figure 3-96). When compared to the French Creek reference location, it was designated as "severely impaired." Impairment is based on low taxa richness (n = 7) and an elevated Hilsenhoff Biotic Index (HBI). This site had the highest HBI score of all Pennypack Creek sites (6.087), and midge larvae (Chironomidae) dominated benthic assemblage (74.02% of all individuals). Because of the abundance of chironomids, feeding structure was skewed toward generalist gatherer/collectors. This portion of Pennypack Creek is tidal; its "impairment" is largely due to water level fluctuations (i.e., the riffle ceases to be a functional riffle at high tide).

Fish Assessment in the Pennypack Creek

Site PP180 at High Tide

Site PP180 is located near the head of tide (Figure 3-95) and was sampled at both high and low tide to determine if the fish community and biological integrity changed. A total of 705 individuals representing 20 species were collected at PP180 at high tide. Three species comprised 83% of all fish collected, with banded killifish (F. diaphanus) most abundant. As in all sites, tolerant and moderately tolerant species dominated the fish community (99%). However, this site had the largest percentage of intolerant fish (0.85%) in the watershed, with striped bass (Morone saxatilis) as the only intolerant species. Intolerant species are usually the first to disappear following a disturbance.

Despite the high diversity (n=20), this site had low number of individuals, density (fish per unit effort), and biomass. PP180, at high tide, received an Index of Biotic Integrity (IBI) score of 32 (out of 50), placing this site in the "fair" category.

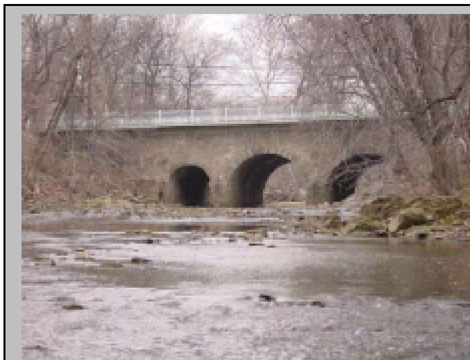
One reason for the “fair” IBI score is that PP180 displayed a well-balanced trophic structure, with the highest percentage of insectivores and lowest percentage of generalist feeders. This trophic structure is similar to that of the reference site. The main factor that kept the IBI score down was that the percentage of individuals with disease, lesions, tumors, and anomalies were highest in the Pennypack Watershed (26.8%).

Site PP180 at Low Tide
At low tide, PP180 had greater abundance but less diversity than at high tide. The five-fold increase in top carnivores shifted the trophic structure, but insectivores still dominated. At low tide, this site had no intolerant species. Conversely, the percentage of individuals with disease, lesions, tumors, and anomalies was greatly reduced from the high-tide assemblage. This site received an IBI score of 34 (out of 50), placing it in the “fair” category similar to the high-tide conditions. Overall, the biological integrity of this site did not change significantly with tidal fluctuation.

3.4.2.3.4 Habitat Assessment of the Delaware Direct Watershed
The Philadelphia Water Department has performed habitat assessment in the Delaware Direct Watershed, focusing on the tidal portion of the Pennypack Creek.

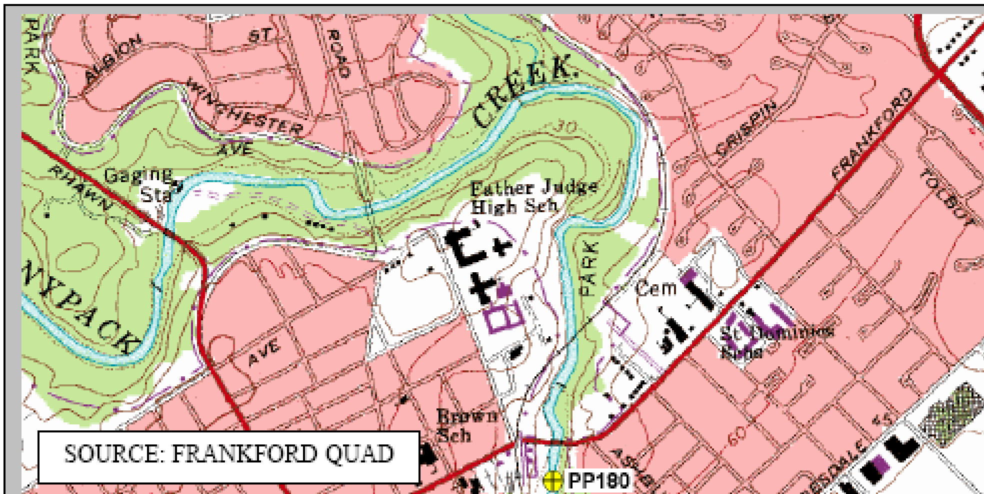
Habitat Assessment of the Tidal Pennypack Creek
Site PP180 (Figure 3-95) received a habitat assessment score of 175.34, or 85% comparability to the reference site ("supporting" designation). This tidally-influenced site had a desirable combination of bedrock and smaller gravel/sand substrates, as well as a variety of depth/velocity regimes. As with many sites located within parklands, this site had high scores for measures of bank stability and vegetative protection. Streambanks were quite steep in places and evidence of moderate sedimentation and embeddedness were observed. Pennypack Creek lacks sinuosity in a majority of the tidal area. Sediment deposition in tidal areas appears to be increasing, possibly due to headcutting of the stream channel upstream of breached dam(s).

PP180: Pennypack Creek Study Area *Philadelphia County*



Upstream view of PP180

Downstream view of PP180



SOURCE: FRANKFORD QUAD

Location and Description:

Location:

Access gained at unmarked paved trail at Frankford Avenue Bridge (Latitude: 40.04278, Longitude: -75.02103).

Description:

Site PP180 is the most downstream monitoring location in the Pennypack Watershed, located approximately 100m downstream from Frankford Avenue Bridge. Land use is varied and includes multi-family residential properties, forested parkland (Pennypack Park), and community services.

Assessment Type(s):

Chemical, Benthic (RBP III), Fish (RBP V), Habitat

Figure 3-95: Site PP180 in the 2002-2003 Baseline Assessment of the Pennypack Creek

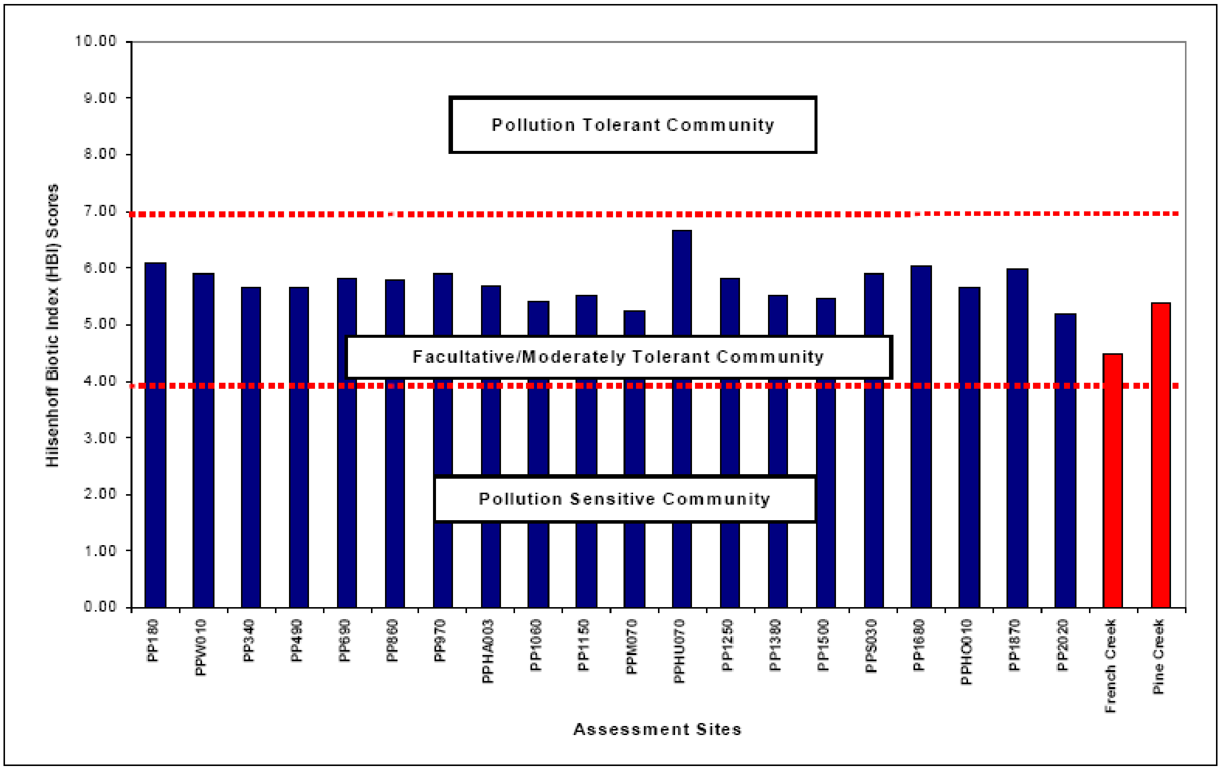


Figure 3-96: Site PP180 in the 2002-2003 Baseline Assessment of the Pennypack Creek

3.4.2.4 Combined Sewer Area of Schuylkill River Watershed Characterization

Approximately 15 square miles contribute to the combined sewers directed to the tidal Schuylkill River. This area is called the Combined Sewer Area of the Schuylkill River and is 40% of the Schuylkill River Watershed in Philadelphia (Figure 3-97).

The Tidal Schuylkill River Master Plan conducted by the Schuylkill River Development Corporation in 2003 provides additional characterization of the tidal Schuylkill River. The Master Plan can be found online at www.schuylkillbanks.org/admin/controls/doc/2_20051213123301.pdf. As of mid-2009, PWD is developing an Integrated Watershed Management Plan (IWMP) to guide restoration and management of the Schuylkill River Watershed within the city boundaries of Philadelphia.

The entire Schuylkill River Watershed is over 130 miles long, includes over 180 tributaries, and drains an area of 2,000 square miles. The watershed is located in southeastern Pennsylvania and is comprised of eleven counties and over three million residents (Figure 3-98). The headwaters of the Schuylkill River drain approximately 270 square miles of Schuylkill County and flow in a southeasterly direction into the tidal waters at the river's confluence with the Delaware Estuary. The basin includes large parts of Schuylkill, Berks, Montgomery, Chester, and Philadelphia counties and smaller parts of Carbon, Lehigh, Lebanon, Lancaster, Bucks, and Delaware counties. The major towns and cities along the river are Pottsville, Reading, Pottstown, Phoenixville, Norristown, Conshohocken, and Philadelphia.

Land Use and Demographics

As shown in Figure 3-99, the Combined Sewer Area in Schuylkill River Watershed is dominated by residential (50%) and commercial (13%) land uses. Consequently, the area is covered by 66% impervious surface. The population of the Combined Sewer Area of the Schuylkill River is 290,251, averaging 19,013 people per square mile. Figure 3-100 shows the distribution of population density throughout the Combined Sewer Area in the Schuylkill River Watershed.

Receiving Waters Characterization

The Combined Sewer Area in Schuylkill River Watershed includes the Schuylkill River and almost 7 miles of tributaries plus 33 miles of historic streams that are now encapsulated in pipes.

Pollution Sources

In addition to CSO discharges to the Schuylkill River from the City of Philadelphia, the drainage area receives a significant amount of point and non-point source discharges that impact water quality. The main sources of pollution in the Schuylkill River are acid mine drainage in the headwaters, agricultural and suburban runoff in the middle reaches, and suburban and urban stormwater runoff in the lower reaches. Minor sources of pollution are likely to include atmospheric deposition, overland runoff from urban and suburban areas, and individual on-lot domestic sewage systems discharging through shallow groundwater. A complete list of industrial and municipal dischargers can be found in the Schuylkill River Source Water Protection Plan located online at http://www.phillyriverinfo.org. The urban and industrial nature of the combined sewer area is likely to contribute pollutants to the stormwater and combined sewer flows.

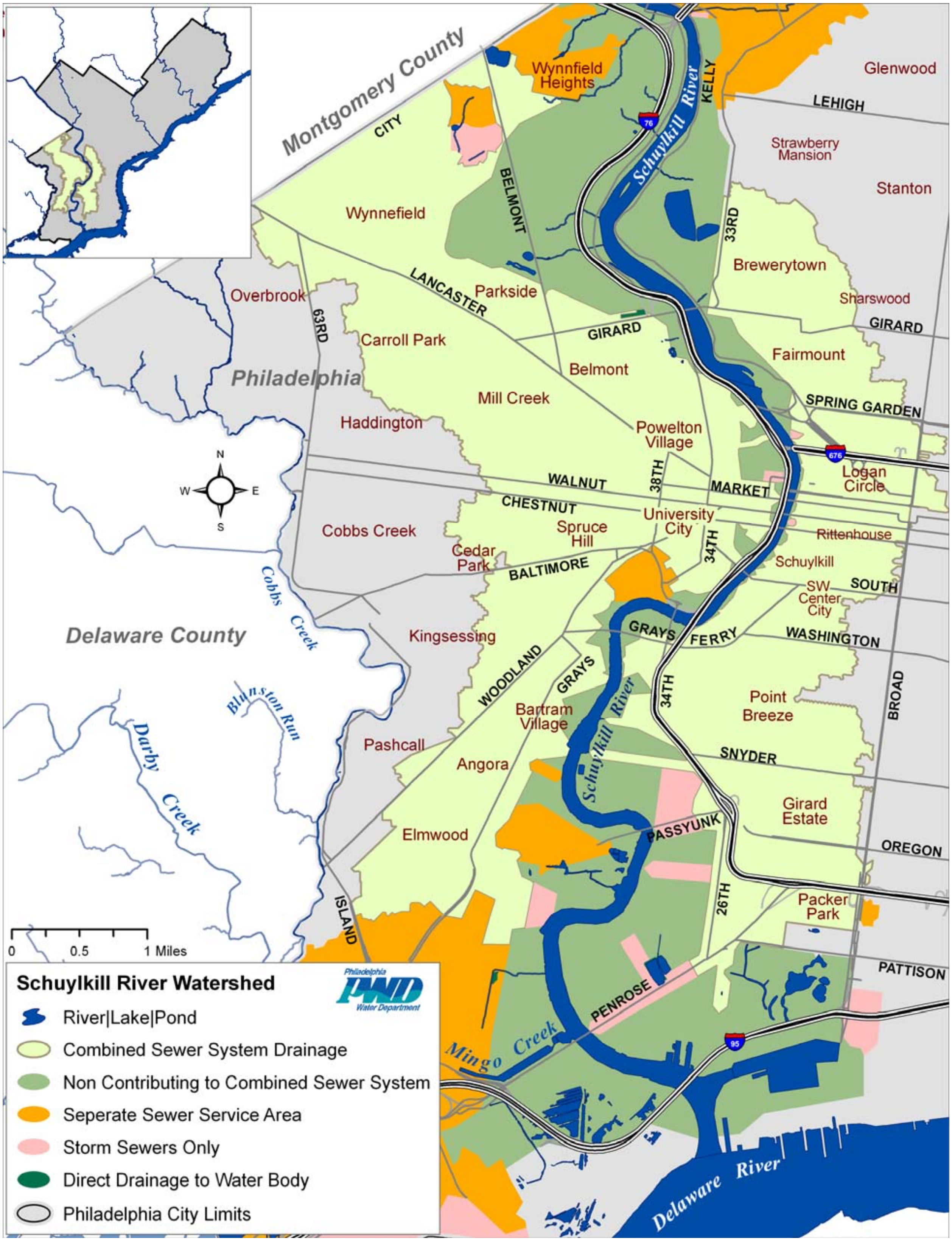


Figure 3-97: The Combined Sewer Area in the Schuylkill River Watershed.

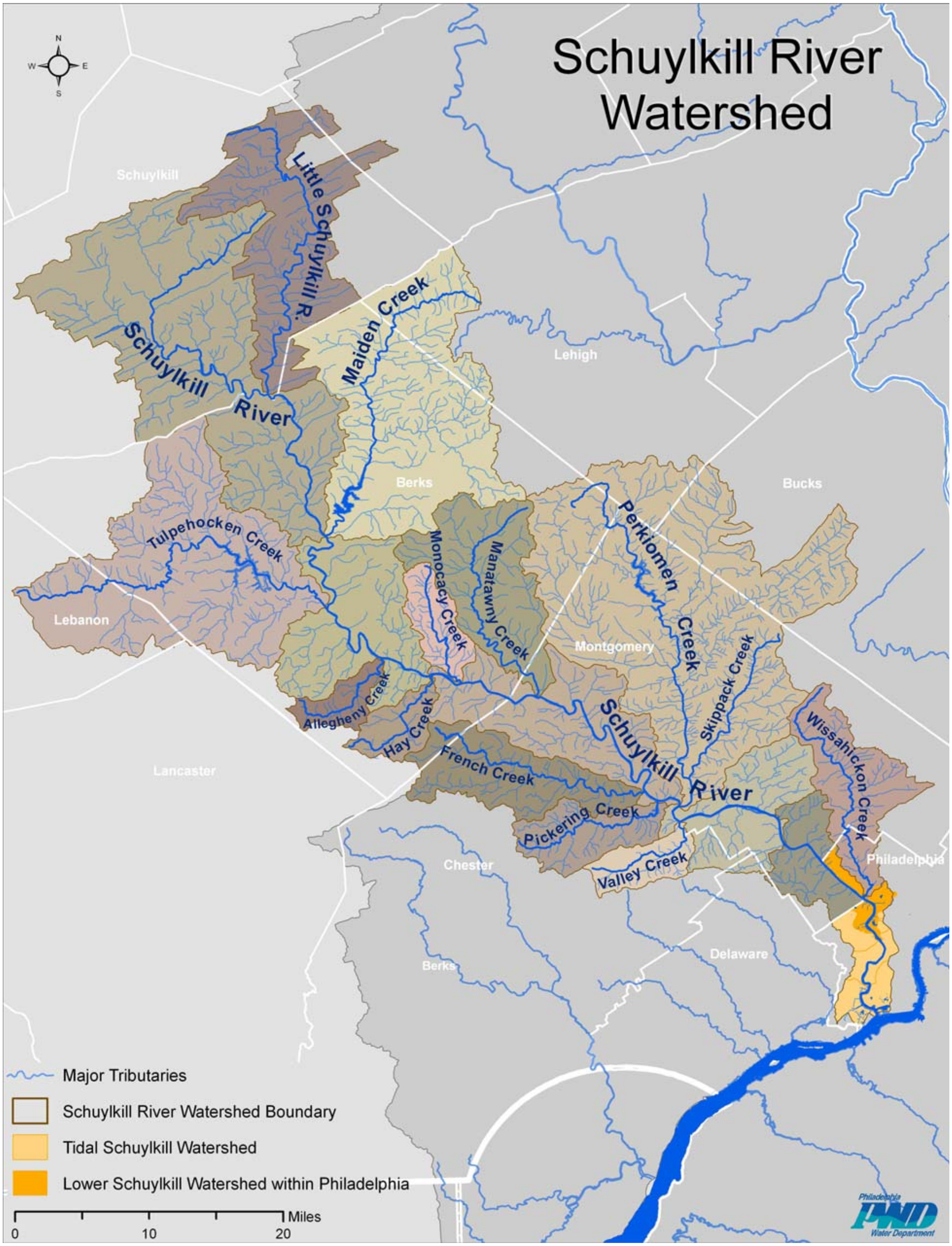


Figure 3-98 Schuylkill River Watershed

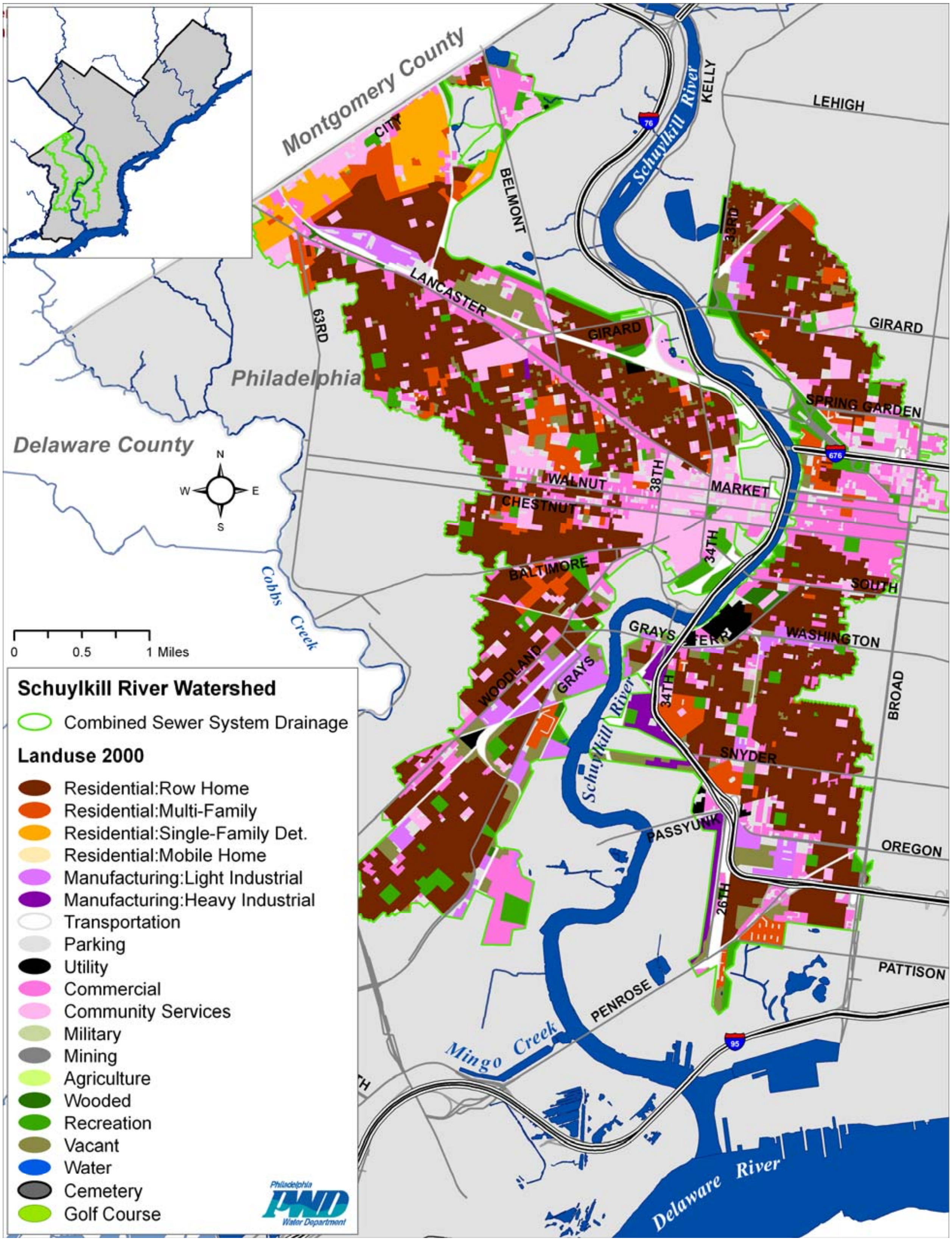


Figure 3-99 Land Use in the Combined Sewer Areas in the Schuylkill River Watershed

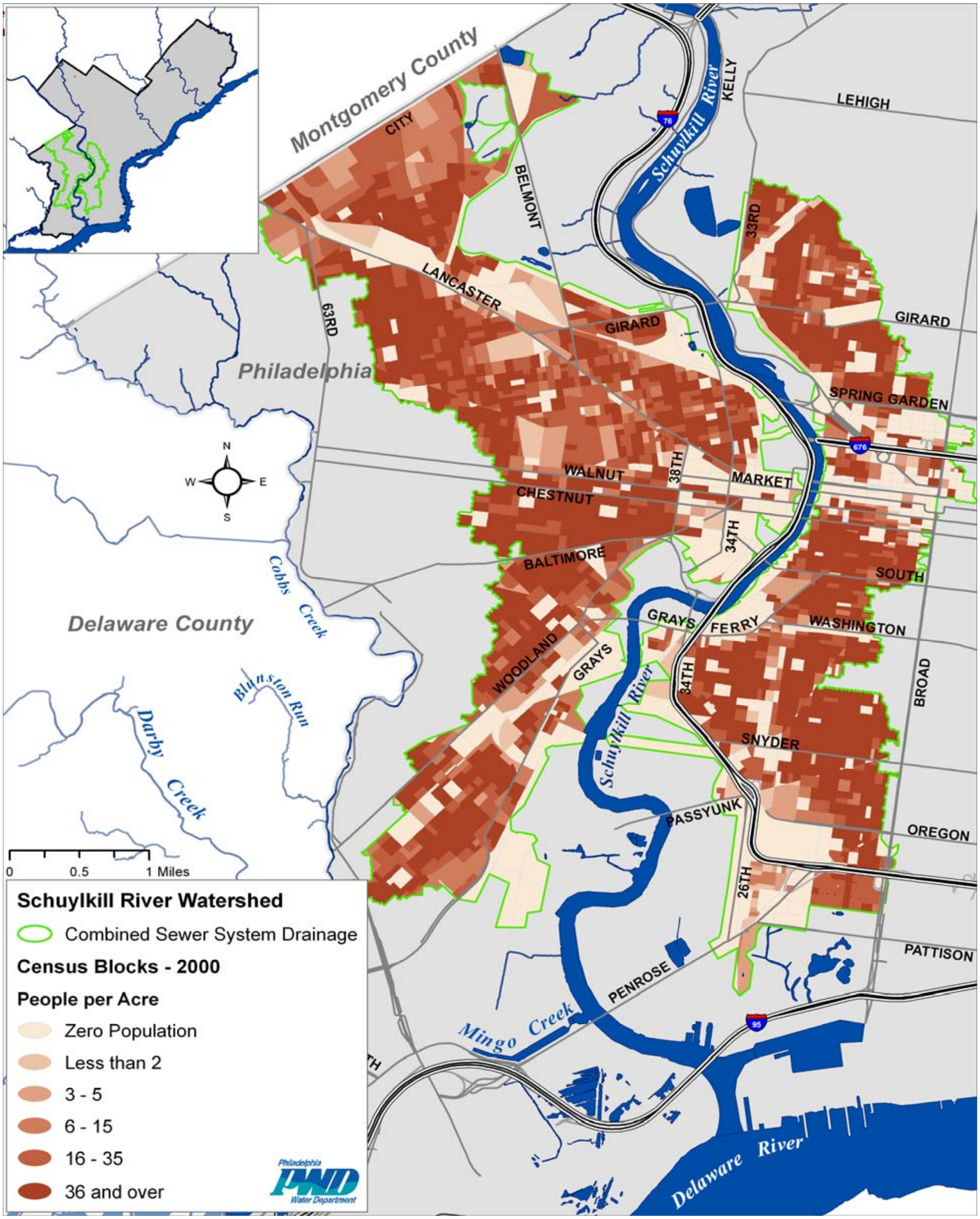


Figure 3-100 Population Density of the Combined Sewer Area in the Schuylkill River Watershed

3.4.2.4.1 Schuylkill River Watershed Hydrologic Characterization

Average annual Schuylkill River flow at Philadelphia is 2,721 cfs. Daily average Schuylkill River flow at Fairmount Dam through the 1990s is summarized in Figure 3-101 and indicates extremely high flow conditions in January 1996, with less pronounced high flow conditions occurring in 1994 and 1995. Lowest flows through the decade were not always associated with extended low levels of summer precipitation, suggesting that evaporation, groundwater storage, and surface water removal are important components in the water budget of the region. Based on monthly averages, no long-term temporal trends in flow were evident through this period (n = 120, Rho = -0.013, P = 0.884 for non-parametric rank order regression).

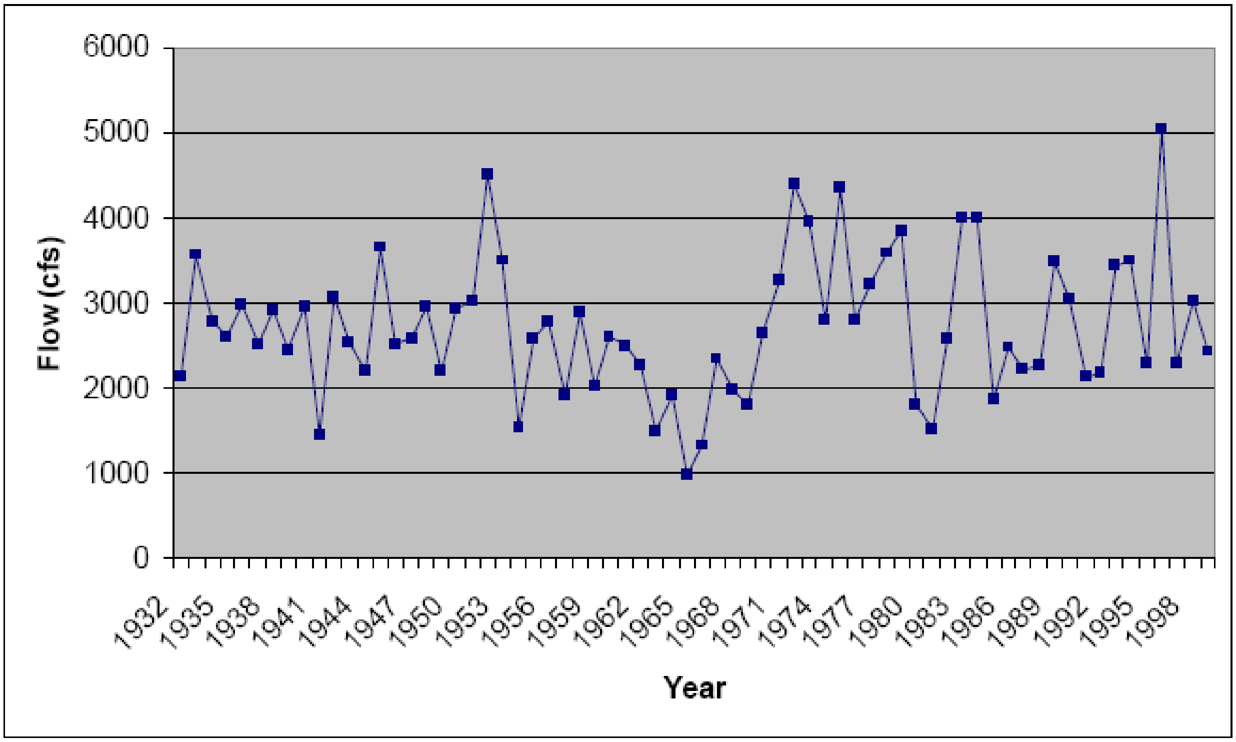


Figure 3-101 Daily Average Schuylkill River Flow at Fairmount Dam through the 1990's

Seasonal variation is driven primarily by precipitation, which is highest in spring, and evaporation, which is highest in summer months. Lowest flows occurred in 1993 and 1999. Minimum flows were higher through the 1990s than earlier in the century.

Surface Water

Runoff generated as overland flow just after a storm in the Schuylkill River Basin has a distinct seasonal variation. The most runoff occurs during winter or early spring, and the lowest amount of runoff occurs during the late summer or early fall. Runoff is chiefly dependent on the amount of rainfall that a specific area receives; after the winter months, the accumulated snow melts in the early spring create additional runoff. During the late summer months, there is very little runoff. The northern area of the basin, specifically in the area surrounding Tamaqua, receives the most precipitation and runoff, and runoff decreases with the amount of precipitation from north to south. As a result of loss of precipitation by evaporation, transpiration, and consumptive use, only about half of the precipitation falling within the watershed ever reaches surface waters. Table 3-99 summarizes the locations, drainage areas, annual mean flows, and annual runoff at 21 gauging stations along the Schuylkill River. The first gauging station listed is the northernmost one located along the Little Schuylkill River. The last gauging station on the chart is located along the lower portion of the Schuylkill River. As shown, Perkiomen, Tulpehocken and Maiden Creeks are by far the largest tributaries discharging to the Schuylkill River and can have significant impacts on Schuylkill water quality. First order streams comprise approximately 57% of the total stream miles within the Schuylkill River Watershed.

Table 3-99 Stream Gauging Data in the Schuylkill River Basin

Station ID	Location	Drainage Area (mi^2)	Period of Record	Annual Mean Flow (cfs)	Annual Runoff (Inches)	10% Exceeds (cfs)	50% Exceeds (cfs)	90% Exceeds (cfs)
01468500	Schuylkill at Landingville	133	1947-1953 1963-1965 1973-1999	278	28.43	560	195	75
01469500	Little Schuylkill at Tamaqua	43	1933-1999	84.2	N/A	177	51	13
01470500	Schuylkill at Berne	355	1947-1999	716	27.41	1480	450	158
01470779	Tulpehocken Creek Near Bernville	67	1975-1999	108	22.13	183	85	43
01470853	[1]Furnace Creek at Robesonia	4	1983-1999	6.87	22.33	14	4.7	1.4
01470960	Tulpehocken Creek at Blue Marsh Dam	175	1979-1999	273	N/A	539	174	65
01471000	Tulpehocken Creek Near Reading	211	1980-1999	320	N/A	625	213	83
01471510	Schuylkill River at Reading	880	1977-1999	1630	N/A	3330	1070	400
01471875	Manatawny Creek Near Spangsville	57	1993-1999	91	21.73	171	58	22
01471980	Manatawny Creek Near Pottstown	86	1974-1999	131	20.86	243	85	34
01472000	Schuylkill River at Pottstown	1147	1928-1999	1909	N/A	3860	1300	473
01472157	French Creek Near Phoenixville	59	1969-1999	89	20.47	170	56	20
01472198	Perkiomen Creek at East Greenville	38	1982-1999	60.4	21.59	115	37	15
01472199	West Branch Perkiomen at Hillegrass	23	1982-1999	38.1	22.43	74	23	7.9
01472620	East Branch Perkiomen Near Dublin	4	1990-1999	41.2	N/A	62	42	13
01472810	East Branch Perkiomen Near	59	1991-1999	126	N/A	191	72	48

Station ID	Location	Drainage Area (mi^2)	Period of Record	Annual Mean Flow (cfs)	Annual Runoff (Inches)	10% Exceeds (cfs)	50% Exceeds (cfs)	90% Exceeds (cfs)
	Schwenksville							
01473000	Perkiomen Creek at Graterford	279	1957-1999	411	N/A	831	180	60
01473169	Valley Creek Near Valley Forge	21	1983-1999	32.3	21.09	52	23	15
01473900	Wissahickon Creek at Fort Washington	21	N/A	N/A	N/A	N/A	N/A	N/A
01474000	Wissahickon Creek Mouth at Philadelphia	64	1966-1999	104	22.02	177	60	28
01474500	Schuylkill River at Philadelphia	1893	1932-1999	2721	N/A	5850	1670	430

3.4.2.4.2 Schuylkill River Water Quality Analysis

From 2005 through 2007, PWD collected water quality data from sampling locations along the Schuylkill River. PWD conducted continuous monitoring and discrete monitoring along the river. The continuous monitoring (Tables 3-100 through 3-103) was located at the Fairmount Fish Ladder (SC823), Tidal Schuylkill Buoy (SC048) and Bartram Garden (SC482). The discrete monitoring (Tables 3-101 and 3-102) was located at the BRC Pier (SC136), Gray's Ferry Ave. (SC587), and West River Drive (SC791). Tables 3-100 through 3-102 provide a basic, statistical profile of the data from the recent water quality monitoring program.

The Delaware River Basin tidal areas are segmented into zones as defined above in Section 3.4.2.3.2 The Schuylkill River falls within Zone 4 because it flows into the Delaware River between river mile (R.M.) 95.0 and R.M. 78.8.

Wet weather is characterized using the 7 PWD operated rain gages in the Schuylkill River direct drainage area. Samples were considered wet when there was greater than 0.1 inches of rainfall recorded in at least one gage in the previous 48 hours. The rain gages are depicted on Figure 3-1.

USGS collected water quality data at the Fairmount Dam (USGS 01474500) historically through 2004. Data collected in 2003 and 2004 were used in this analysis and are summarized in Table 3-103. These data combined with the PWD data from 2005 through 2007 provide the status of the water quality in the Schuylkill River.

All monitoring locations are depicted on Figure 3-13 in Section 3.1.4.3.4.

Table 3-100 Schuylkill River Continuous Water Quality Summary Statistics and Exceedances 2007 - 2008

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
DO	Daily Average Minimum	SC823	3.5	mg/L	153	6.81	8.60	9.63	11.2	12.0	14.0	0	0.0
DO	Daily Average Minimum	SC048	3.5	mg/L	297	3.54	4.73	5.19	7.99	8.85	13.0	0	0.0
DO	Daily Average Minimum	SC482	3.5	mg/L	184	3.19	6.48	7.86	10.0	11.0	14.8	4	2.2
pH	Maximum	SC823	8.5		14390	7.21	7.65	7.74	7.90	8.07	8.65	66	0.5
pH	Maximum	SC048	8.5		29720	4.28	7.07	7.16	7.32	7.44	8.99	12	0.0
pH	Maximum	SC482	8.5		17599	3.98	7.37	7.57	7.69	7.80	9.45	556	3.2
pH	Minimum	SC823	6.5		14390	7.21	7.65	7.74	7.90	8.07	8.65	0	0.0
pH	Minimum	SC048	6.5		29720	4.28	7.07	7.16	7.32	7.44	8.99	19	0.1
pH	Minimum	SC482	6.5		17599	3.98	7.37	7.57	7.69	7.80	9.45	28	0.2
Turbidity	Maximum	SC823	150	NTU	14388	0.00	3.10	5.90	15.9	47.6	1508	577	4.0
Turbidity	Maximum	SC048	150	NTU	29718	0.70	4.50	6.00	7.90	10.0	1185	7	0.0
Turbidity	Maximum	SC482	150	NTU	17596	0.30	4.70	5.80	7.50	10.2	1452	49	0.3
Temp	Maximum	SC823	*	°C	14390	5.89	16.5	23.5	26.2	27.8	30.5	6592	45.8
Temp	Maximum	SC048	*	°C	29720	4.28	18.2	23.7	26.0	27.6	29.9	2704	9.1
Temp	Maximum	SC482	*	°C	17599	5.44	18.3	24.5	26.9	27.8	30.5	3183	18.1

* Water Temperature Standards Change by Month

Table 3-101 Schuylkill River Dry Weather Summary Statistics and Exceedances 2005 – 2007

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
Diss Cu	Aquatic Life Acute Maximum	SC587	18**	µg/L	6	3.00	3.00	3.00	4.00	7.00	7.00	0	0
Diss Cu	Aquatic Life Acute Maximum	SC791	18**	µg/L	8	3.00	3.00	4.00	4.50	7.00	7.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC791	12**	µg/L	8	3.00	3.00	4.00	4.50	7.00	7.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC136	12**	µg/L	6	2.00	3.00	3.50	5.00	7.00	7.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC587	12**	µg/L	6	3.00	3.00	3.00	4.00	7.00	7.00	0	0
Diss Cu	Aquatic Life Acute Maximum	SC136	18**	µg/L	6	2.00	3.00	3.50	5.00	7.00	7.00	0	0
Diss Zn	Aquatic Life Acute Maximum	SC136	117**	µg/L	6	5.00	6.00	7.50	9.00	11.0	11.0	0	0
Diss Zn	Aquatic Life Acute Maximum	SC587	117**	µg/L	6	6.00	6.00	8.00	9.00	13.0	13.0	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
Diss Zn	Aquatic Life Acute Maximum	SC791	117**	µg/L	8	6.00	8.00	8.50	10.5	14.0	14.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC136	106**	µg/L	6	5.00	6.00	7.50	9.00	11.0	11.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC587	106**	µg/L	6	6.00	6.00	8.00	9.00	13.0	13.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC791	106**	µg/L	8	6.00	8.00	8.50	10.5	14.0	14.0	0	0
Diss Zn	Toxicants FIO Maximum	SC136	68700	µg/L	6	5.00	6.00	7.50	9.00	11.0	11.0	0	0
Diss Zn	Toxicants FIO Maximum	SC587	68700	µg/L	6	6.00	6.00	8.00	9.00	13.0	13.0	0	0
Diss Zn	Toxicants FIO Maximum	SC791	68700	µg/L	8	6.00	8.00	8.50	10.5	14.0	14.0	0	0
Diss Zn	Toxicants FWI Maximum	SC136	9110	µg/L	6	5.00	6.00	7.50	9.00	11.0	11.0	0	0
Diss Zn	Toxicants FWI Maximum	SC587	9110	µg/L	6	6.00	6.00	8.00	9.00	13.0	13.0	0	0
Diss Zn	Toxicants FWI Maximum	SC791	9110	µg/L	8	6.00	8.00	8.50	10.5	14.0	14.0	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
DO	Daily Average Min	SC136	3.5	mg/L	5	3.57	10.2	12.0	12.4	12.6	12.6	0	0
DO	Daily Average Min	SC587	3.5	mg/L	5	6.34	10.0	11.9	12.5	12.9	12.9	0	0
DO	Daily Average Min	SC791	3.5	mg/L	7	7.34	8.57	10.7	12.7	12.8	12.8	0	0
Fecal Coliform	Maximum	SC136	770	#/100mL	6	18.0	30.0	65.0	90.0	260	260	0	0
Fecal Coliform	Maximum	SC587	770	#/100mL	6	10.0	10.0	71.0	109	160	160	0	0
Fecal Coliform	Maximum	SC791	770	#/100mL	8	9.00	10.0	15.0	45.0	100	100	0	0
Inorganic N	No Standard	SC136	--	mg/L	6	2.46	2.47	2.77	2.91	3.27	3.27	--	--
Inorganic N	No Standard	SC587	--	mg/L	6	2.46	2.47	2.77	2.91	3.27	3.27	--	--
Inorganic N	No Standard	SC791	--	mg/L	8	2.46	2.60	2.82	3.22	3.41	3.41	--	--
NH_3	No Standard	SC136	--	mg/L	4	0.134	0.136	0.175	0.281	0.350	0.350	--	--
NH_3	No Standard	SC587	--	mg/L	4	0.134	0.136	0.175	0.281	0.350	0.350	--	--
NH_3	No Standard	SC791	--	mg/L	5	0.101	0.104	0.106	0.133	0.173	0.173	--	--
pH	Maximum	SC136	8.5	--	5	7.23	7.69	7.70	7.94	8.01	8.01	0	0
pH	Maximum	SC587	8.5	--	5	7.59	7.64	7.74	7.80	8.11	8.11	0	0
pH	Maximum	SC791	8.5	--	7	7.42	7.45	7.79	7.84	7.98	7.98	0	0
pH	Minimum	SC136	6.5	--	5	7.23	7.69	7.70	7.94	8.01	8.01	0	0
pH	Minimum	SC587	6.5	--	5	7.59	7.64	7.74	7.80	8.11	8.11	0	0
pH	Minimum	SC791	6.5	--	7	7.42	7.45	7.79	7.84	7.98	7.98	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile 0	25	50	75	90	100	No. Exceeding	% Exceeding
Temp	Maximum	SC136	*	^oC	5	5.90	6.40	9.80	18.7	28.1	28.1	2	40.0
Temp	Maximum	SC587	*	^oC	5	6.00	6.70	9.80	18.1	27.6	27.6	2	40.0
Temp	Maximum	SC791	*	^oC	7	6.00	6.30	17.5	20.9	26.0	26.0	4	57.1
TKN	No Standard	SC136	--	mg/L	6	0.486	0.507	0.599	0.820	1.01	1.01	--	--
TKN	No Standard	SC587	--	mg/L	6	0.486	0.507	0.599	0.820	1.01	1.01	--	--
TKN	No Standard	SC791	--	mg/L	6	0.441	0.510	0.627	0.870	1.14	1.14	--	--
TN	No Standard	SC136	--	mg/L	6	3.07	3.27	3.39	3.76	3.77	3.77	--	--
TN	No Standard	SC587	--	mg/L	6	3.07	3.27	3.39	3.76	3.77	3.77	--	--
TN	No Standard	SC791	--	mg/L	6	3.20	3.33	3.60	4.06	4.37	4.37	--	--

* Water Temperature Standards Change by Month
** Water quality standard requires hardness correction; values listed is water quality standard calculated at 100 µg/L $CaCO_3$ hardness

Table 3-102 Schuylkill River Discrete Wet Weather Summary Statistics and Exceedances 2005 – 2007

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
Diss Cu	Aquatic Life Acute Maximum	SC136	18*	µg/L	4	3.00	3.50	4.50	5.00	5.00	5.00	0	0
Diss Cu	Aquatic Life Acute Maximum	SC587	18*	µg/L	4	4.00	4.00	4.50	5.00	5.00	5.00	0	0
Diss Cu	Aquatic Life Acute Maximum	SC791	18*	µg/L	9	3.00	4.00	5.00	6.00	10.0	10.0	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC136	12*	µg/L	4	3.00	3.50	4.50	5.00	5.00	5.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC587	12*	µg/L	4	4.00	4.00	4.50	5.00	5.00	5.00	0	0
Diss Cu	Aquatic Life Chronic Maximum	SC791	12*	µg/L	9	3.00	4.00	5.00	6.00	10.0	10.0	0	0
Diss Zn	Aquatic Life Acute Maximum	SC136	117*	µg/L	4	8.00	8.50	9.50	18.5	27.0	27.0	0	0
Diss Zn	Aquatic Life Acute Maximum	SC587	117*	µg/L	4	7.00	7.50	8.50	10.5	12.0	12.0	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
Diss Zn	Aquatic Life Acute Maximum	SC791	117*	µg/L	9	8.00	8.00	9.00	13.0	13.0	13.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC136	106*	µg/L	4	8.00	8.50	9.50	18.5	27.0	27.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC587	106*	µg/L	4	7.00	7.50	8.50	10.5	12.0	12.0	0	0
Diss Zn	Aquatic Life Chronic Maximum	SC791	106*	µg/L	9	8.00	8.00	9.00	13.0	13.0	13.0	0	0
Diss Zn	Toxicants FIO Maximum	SC136	68700	µg/L	4	8.00	8.50	9.50	18.5	27.0	27.0	0	0
Diss Zn	Toxicants FIO Maximum	SC587	68700	µg/L	4	7.00	7.50	8.50	10.5	12.0	12.0	0	0
Diss Zn	Toxicants FIO Maximum	SC791	68700	µg/L	9	8.00	8.00	9.00	13.0	13.0	13.0	0	0
Diss Zn	Toxicants FWI Maximum	SC136	9110	µg/L	4	8.00	8.50	9.50	18.5	27.0	27.0	0	0
Diss Zn	Toxicants FWI Maximum	SC587	9110	µg/L	4	7.00	7.50	8.50	10.5	12.0	12.0	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
Diss Zn	Toxicants FWI Maximum	SC791	9110	µg/L	9	8.00	8.00	9.00	13.0	13.0	13.0	0	0
DO	Daily Average Minimum	SC136	3.5	mg/L	4	8.07	8.73	10.7	13.0	14.0	14.0	0	0
DO	Daily Average Minimum	SC587	3.5	mg/L	4	9.25	9.66	11.1	12.8	13.4	13.4	0	0
DO	Daily Average Minimum	SC791	3.5	mg/L	9	7.81	9.14	10.2	11.1	13.8	13.8	0	0
Fecal Coliform	Maximum	SC136	770	#/100mL	4	144	202	425	640	690	690	0	0
Fecal Coliform	Maximum	SC587	770	#/100mL	4	10.0	30.0	140	285	340	340	0	0
Fecal Coliform	Maximum	SC791	770	#/100mL	9	10.0	30.0	300	370	510	510	0	0
Inorganic N	No Standard	SC136	--	mg/L	3	1.575	1.58	2.47	3.35	3.35	3.35	--	--
Inorganic N	No Standard	SC587	--	mg/L	3	1.865	1.87	2.67	3.03	3.03	3.03	--	--
Inorganic N	No Standard	SC791	--	mg/L	8	1.90	2.62	2.68	3.01	3.57	3.57	--	--
NH_3	No Standard	SC136	--	mg/L	3	0.158	0.158	0.184	0.246	0.246	0.246	--	--
NH_3	No Standard	SC587	--	mg/L	2	0.125					0.139	--	--
NH_3	No Standard	SC791	--	mg/L	7	0.105	0.122	0.132	0.168	0.170	0.170	--	--
pH	Maximum	SC136	8.5	--	4	7.66	7.67	7.67	7.77	7.87	7.87	0	0
pH	Maximum	SC587	8.5	--	4	7.60	7.66	7.78	7.87	7.89	7.89	0	0
pH	Maximum	SC791	8.5	--	9	7.35	7.44	7.50	7.71	7.90	7.90	0	0

Parameter	Standard	Site	Target Value	Units	No. Obs.	Percentile						No. Exceeding	% Exceeding
						0	25	50	75	90	100		
pH	Minimum	SC136	6.5	--	4	7.66	7.67	7.67	7.77	7.87	7.87	0	0
pH	Minimum	SC587	6.5	--	4	7.60	7.66	7.78	7.87	7.89	7.89	0	0
pH	Minimum	SC791	6.5	--	9	7.35	7.44	7.50	7.71	7.90	7.90	0	0
Temp	Maximum	SC136	*	℃	4	5.30	5.85	8.70	16.4	21.8	21.8	1	25.0
Temp	Maximum	SC587	*	℃	4	5.40	5.95	8.55	16.2	21.7	21.7	1	25.0
Temp	Maximum	SC791	*	℃	9	4.90	9.30	14.7	21.3	24.5	24.5	1	11.1
TKN	No Standard	SC136	--	mg/L	3	0.562	0.562	0.971	1.01	1.01	1.01	--	--
TKN	No Standard	SC587	--	mg/L	3	0.526	0.526	0.758	0.963	0.963	0.963	--	--
TKN	No Standard	SC791	--	mg/L	8	0.558	0.569	0.591	0.677	0.799	0.799	--	--
TN	No Standard	SC136	--	mg/L	2	2.546					3.91	--	--
TN	No Standard	SC587	--	mg/L	2	2.828					3.55	--	--
TN	No Standard	SC791	--	mg/L	7	2.70	3.18	3.28	3.70	4.19	4.19	--	--

* Water Temperature Standards Change by Month
** Water quality standard requires hardness correction; values listed is water quality standard calculated at 100 µg/L $CaCO_3$ hardness

Table 3-103 Schuylkill River at USGS 014745000 Fairmount Dam Summary Statistics and Exceedances 2003 - 2004

Parameter	Standard	Target Value	Units	No. Obs.	Percentiles						No. Exceeding	% Exceeding
					0	25	50	75	90	100		
Alkalinity	Maximum	120	mg/L	16	42.0	59.5	65.0	74.5	78.0	80.0	0	0
Alkalinity	Minimum	20	mg/L	16	42.0	59.5	65.0	74.5	78.0	80.0	0	0
DO	Daily Average Minimum	3.5	mg/L	16	7.90	9.00	10.2	13.5	14.6	15.6	0	0
pH	Maximum	8.5	--	19	7.20	7.50	7.70	7.80	8.10	8.60	1	5.3
pH	Minimum	6.5	--	19	7.20	7.50	7.70	7.80	8.10	8.60	0	0
Temp	Maximum	*	°C	16	1.40	4.95	13.7	21.5	24.4	27.0	0	0

* Water Temperature Standards Change by Month

Discussion of Possible Problem Parameters

The following analysis of water quality data is focused on parameters that were listed in EPA's 1995 Guidance for Long Term Control Plan and those considered as a "parameter of concern" (>10% samples exceeding target value, highlighted in red) or a "parameter of potential concern" (2-10% samples exceeding target value, highlighted in yellow) in the Schuylkill River on Tables 3-102 through 3-105. The water quality criteria or target value is discussed in each parameter analysis. The data were compared to stream quality objectives (DRBC 2008A). This analysis was completed in order to provide an initial impression of which parameters might need further investigation.

pH

The pH standards within the Schuylkill River Watershed set by DRBC are constant throughout the monitoring area and are set at a maximum of 8.5 and a minimum of 6.5.

Exceedances of the maximum pH limit were observed during USGS (Table 3-103) and continuous PWD monitoring (Table 3-100). During continuous monitoring at the SC482, the maximum standard was exceeded less than 3.2% of the time. At all other sites, pH rarely exceeds the maximum limit. During the USGS monitoring the maximum standard for pH was exceeded 5.3% of the time. pH is considered a parameter of potential concern in the Schuylkill River.

Dissolved Oxygen

The DRBC has set minimum DO daily averages as well as minimum seasonal averages for this watershed. DRBC water quality criteria require a daily average minimum DO concentration of 3.5 mg/L. The DRBC seasonal standard requires a minimum seasonal average of 6.5 mg/L between April 1 thru June 15 and September 16 thru December 31.

The daily minimum DO standard was exceeded during continuous monitoring (Table 3-100) at SC482 (2.2% of observations). At other sites, no violations were observed. Therefore, DO is not a concern in the Schuylkill River.

Future Investigation of Dissolved Oxygen Conditions in the Tidal Schuylkill River

Investigations continue into the nature, causes, severity and opportunities for control of the dissolved oxygen conditions in the tidal Schuylkill River. The nature, causes and severity are not well understood at this juncture. Efforts to better understand the dissolved oxygen conditions will continue through evaluation of ongoing continuous long-term monitoring. PWD continues to work with the Delaware River Basin Commission and its partners on issues related to the dissolved oxygen conditions in the Delaware estuary and its tidal tributaries. Estimates will be refined and analyses performed on the loading of water quality constituents related to the dissolved oxygen dynamics, both from the City, from other dischargers to the tributaries that run through the City, and at the fall-line of the River. If a relationship between loadings and the dissolved oxygen conditions in the tidal River adjacent to the City is suspected, informational total maximum daily loads will be investigated for all potential sources of the identified water quality constituents to the City's watersheds. Progress and results of this work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to thePADEP.

Total Dissolved Solids
Total Dissolved Solids (TDS) were not included in the wet weather and dry weather sampling in the Schuylkill River. DRBC standards state that TDS should not exceed 133% of background levels or 500 mg/L (whichever is less) in Zone 2 and 3; and 133% of background levels in Zone 4.

Total Suspended Solids
Like TDS, Total Suspended Solids (TSS) were not included in the wet weather and dry weather sampling in the Schuylkill River. DRBC requires that wastewater treatment projects maintain minimum levels of treatment using "Best Demonstrable Technology" that includes 30-day average TSS levels at or below 10 mg/L.

Nutrients
Discrete samples of nutrients were collected and analyzed by PWD from 2005-2007. Tables 3-101 and 3-102 document concentrations found in both wet and dry weather conditions. DRBC has not set water quality standards for Zone 4, which includes the tidal portions of the Schuylkill River. Therefore, collected data could not be compared to a target value.

Ammonia
Ammonia, present in surface waters as un-ionized ammonia gas (NH3), or as ammonium ion (NH4+), is produced by deamination of organic nitrogen-containing compounds, such as proteins, and also by hydrolysis of urea. In the presence of oxygen, NH3 is converted to nitrate (NO3) by a pair of bacteria-mediated reactions, together known as the process of nitrification. Nitrification occurs quickly in oxygenated waters with sufficient densities of nitrifying bacteria, effectively reducing NH3, although at the expense of increased NO3 concentration

NH3 concentrations observed during dry weather (Table 3-101) ranged from 0.101 mg/L at SC791 to 0.350 mg/L at stations SC136 and SC587. During wet weather events (Table 3-102), samples ranged from 0.105 mg/L at SC791 to 0.246 mg/L at SC136.

Total Nitrogen
PWD sampled for Total Nitrogen (TN) in the Schuylkill River from 2005 to 2007. TN dry weather samples (Table 3-101) ranged from 3.07 mg/L at SC136 to 4.37 mg/L at SC791. During wet weather events (Table 3-102), samples ranged from 2.55 mg/L at SC136 to 4.19 mg/L at SC791.

Total Kjeldahl Nitrogen
TKN dry weather samples (Table 3-101) ranged from 0.441 mg/L at SC791 to 1.14 mg/L at SC791. During wet weather events (Table 3-102), samples ranged from 0.562 mg/L at SC136 to 1.01 mg/L at SC136.

Toxic Metals
It is now widely accepted that dissolved metals best reflect the potential for toxicity to organisms in the water column, and many states, including PA, have adopted dissolved metals criteria (40 CFR 22227-22236). As many metals occur naturally in various rocks, minerals, and soils, storm events can expose and entrain soil and sediment particles that naturally contain metals. These inert particles are removed when samples are filtered for dissolved metals analysis (Greenberg *et al.* 1992).

Dissolved Zinc
Since the water quality criteria for dissolved zinc requires a hardness correction the standard was calculated at 100 µg/L $CaCO_3$ hardness. With hardness correction, the Aquatic Life Acute Maximum for Dissolved Zn is 117 µg/L and the Aquatic Life Chronic Maximum is 106 µg/L. Toxicity limits for Fish Ingestion Only (FIO) are a maximum of 68700 µg/L; and for Fish and Water Ingestion (FWI) a maximum of 9110. µg/L.

Dissolved Zn ranged from 5.00 µg/L at SC136 to 14.0 µg/L at SC791 during dry weather (Table 3-101). Wet weather samples (Table 3-102) were slightly elevated, ranging from 7.00 µg/L at SC587 to 27.0 µg/L at SC136, although PA water quality standards were never exceeded during sampling. Dissolved Zn is not considered a parameter of concern in the Schuylkill River. Wet weather sampling and flow are shown in Figures 3-101 through 3-111.

Dissolved Copper
Since the water quality criteria for dissolved Cu requires a hardness correction, the standard was calculated at 100 µg/L $CaCO_3$ hardness. With hardness correction, the Aquatic Life Acute Maximum for dissolved Cu is 18 µg/L and the Aquatic Life Chronic Maximum is 12 µg/L. Dissolved Cu ranged from 2.00 at SC136 to 7.00 at all sites during dry weather (Table 3-101). Wet weather samples (Table 3-102) ranged from 3.00 µg/L at sites SC136 and SC791 to 10.0 µg/L at SC791 (Figures 3-101 through 3-111). The standards were never exceeded during sampling and therefore dissolved Cu is not considered a parameter of concern in the Schuylkill River.

Fecal Coliform
DRBC has set maximum fecal coliform concentrations for this watershed. Within Zone 4, the fecal coliform limit is broken down by R.M., such that, below R.M. 81.8 the limit is 200 per 100mL and above R.M. 81.8 the limit is 770 per 100 mL. All monitoring sites in the tidal Schuylkill are subjected to a maximum fecal coliform limit of 770 per 100 mL. Water quality sampling from the USGS station upstream of the Fairmount Dam was also analyzed due to the lack of samples in the tidal portion. Water quality sampling performed by PWD in the tidal areas from 2005 through 2007 captured 10 quality samples. This monitoring in the tidal portion of the Schuylkill River does not show any exceedance of the DRBC criteria. Additional monitoring data at the USGS monitoring station at the Fairmount Dam is subjected to the PADEP water quality criteria but was compared against the DRBC criteria for this study in order to characterize the quality of the water entering the tidal area. River conditions and access on the tidal portion of the river make it difficult to obtain water quality samples during wet weather and can account for the lack of fecal coliform samples not exceeding the standard.

Figure 3-100 is a summary of fecal coliform in the Schuylkill River following rainfall events from a study performed in the 1990's. The figure suggests that after approximately 2 days, fecal coliform measurements fall below the DRBC standard of 770 per 100 mL. Figures 3-101 through 3-111 show fecal coliform concentrations in response to rainfall during wet weather events at all sampling locations, and show that concentrations are below the DRBC standard 2 to 3 days following rainfall.

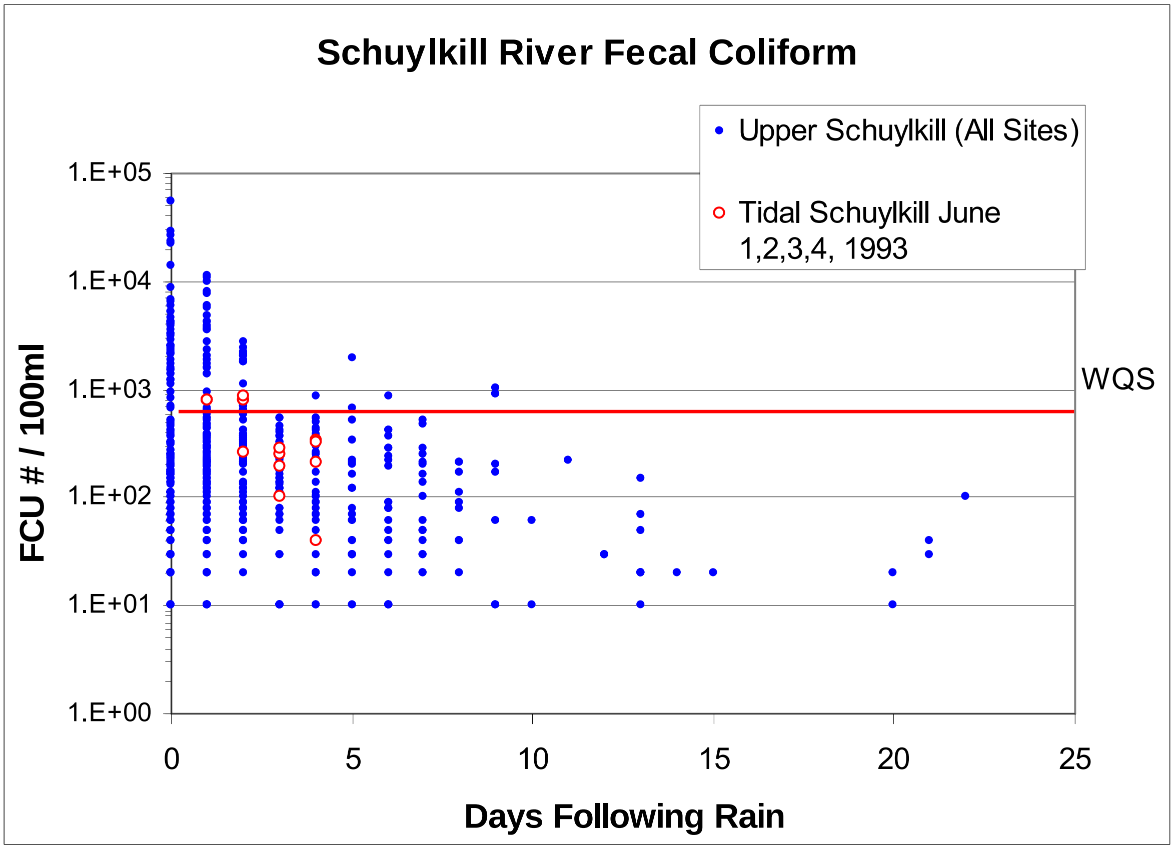


Figure 3-102 Fecal Coliform in Schuylkill River following rainfall events.

Future Investigation of Bacteria Conditions in the Tidal Schuylkill River

Investigations continue into the nature, causes, severity and opportunities for control of the bacteria conditions in the tidal Schuylkill River. Efforts to better understand the bacteria conditions will continue through evaluation of ongoing monitoring efforts, and the establishment of additional monitoring efforts if necessary to better define potential problems. PWD will work with the Delaware River Basin Commission and its partners on issues related to the bacteria conditions in the estuary if such efforts are initiated by DRBC. Estimates will be refined and analyses performed on the loading of bacteria, both from the City as well as from other dischargers to the tributaries to the Schuylkill River that run through the City. If a relationship between loadings and the bacteria conditions in the tidal River adjacent to the City is suspected, informational total maximum daily loads will be investigated for all identified sources that discharge to the City's watersheds. Progress and results of this work, and any proposed remedial control actions, will be documented in the Department's CSO Annual Report to the Pennsylvania Department of Environmental Protection.

Temperature

The DRBC has a maximum value which changes by month within the monitoring area. The temperature standard was exceeded at all continuously monitored sites (Table 3-100). At site SC823, maximum limits were exceeded in 46% of all observations and at site SC482, limits were exceeds in 18% of observation. At all discrete sampling sites, greater than 10% of observations violated temperature limits during both dry and wet weather. Temperature is therefore considered to be a parameter of concern for the Schuylkill River.

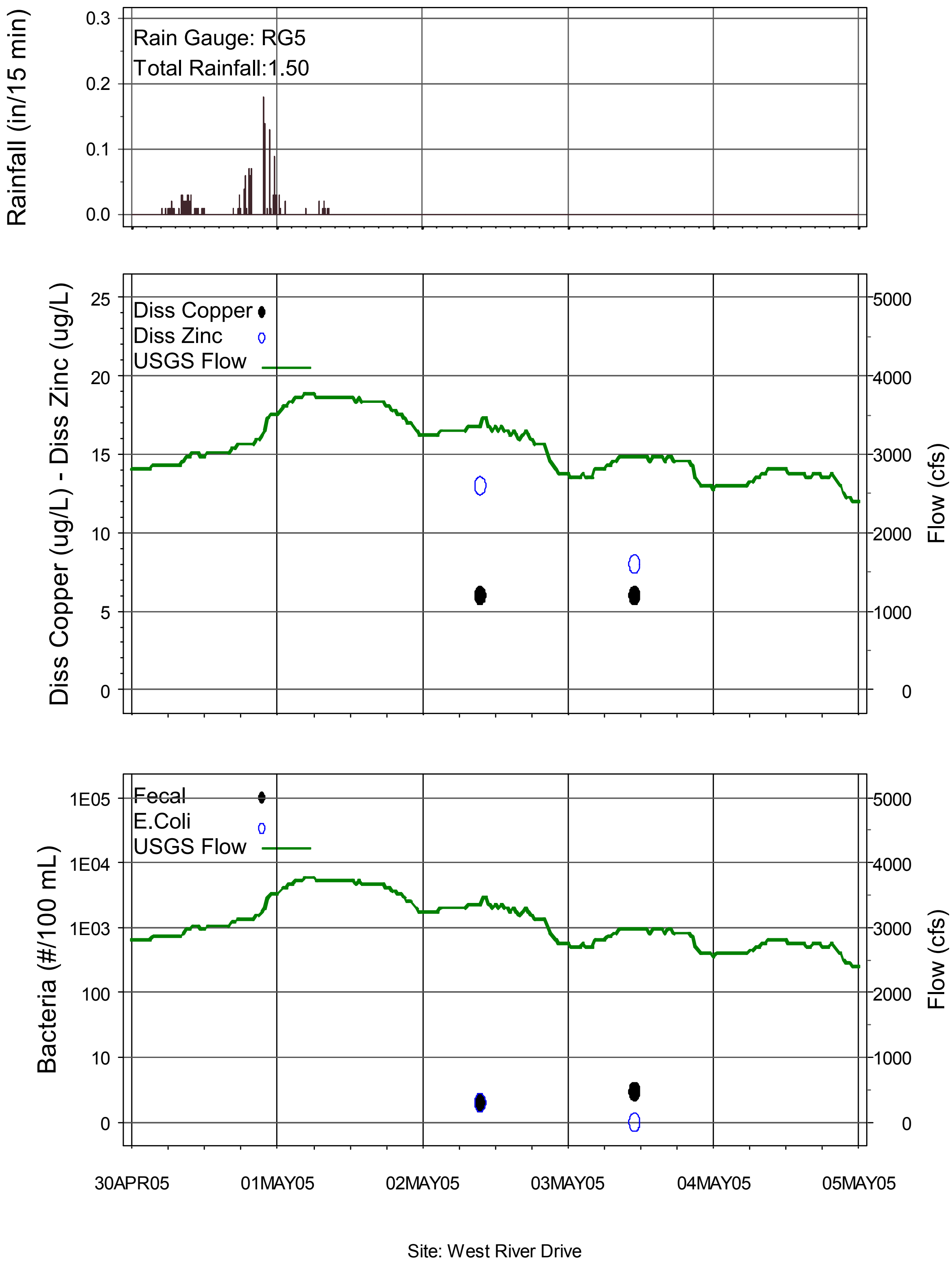


Figure 3-103 Bacteria and Dissolved Metals wet weather event on April 30, 2005 at SC791

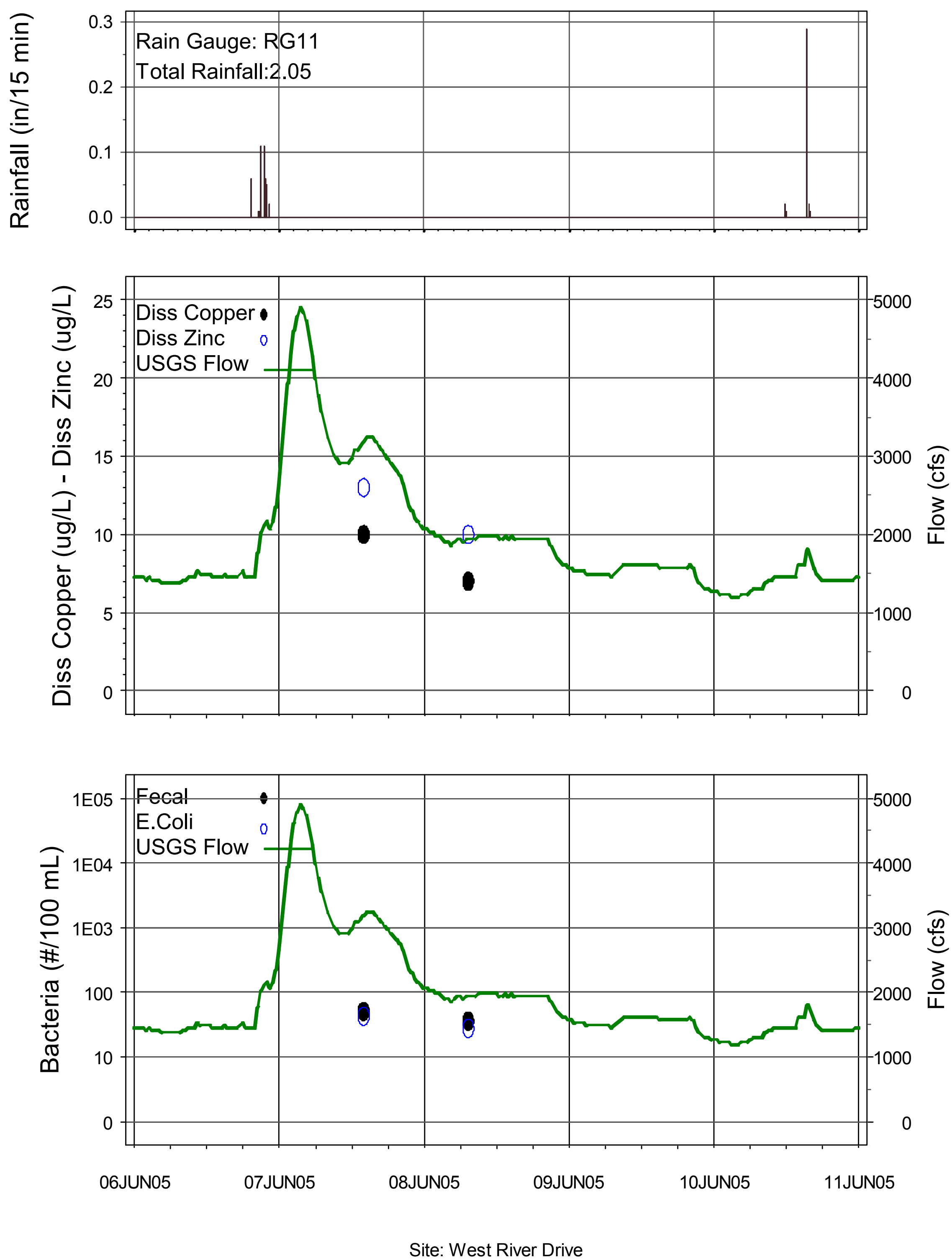


Figure 3-104 Bacteria and Dissolved Metals wet weather event on June 6, 2005 at SC791

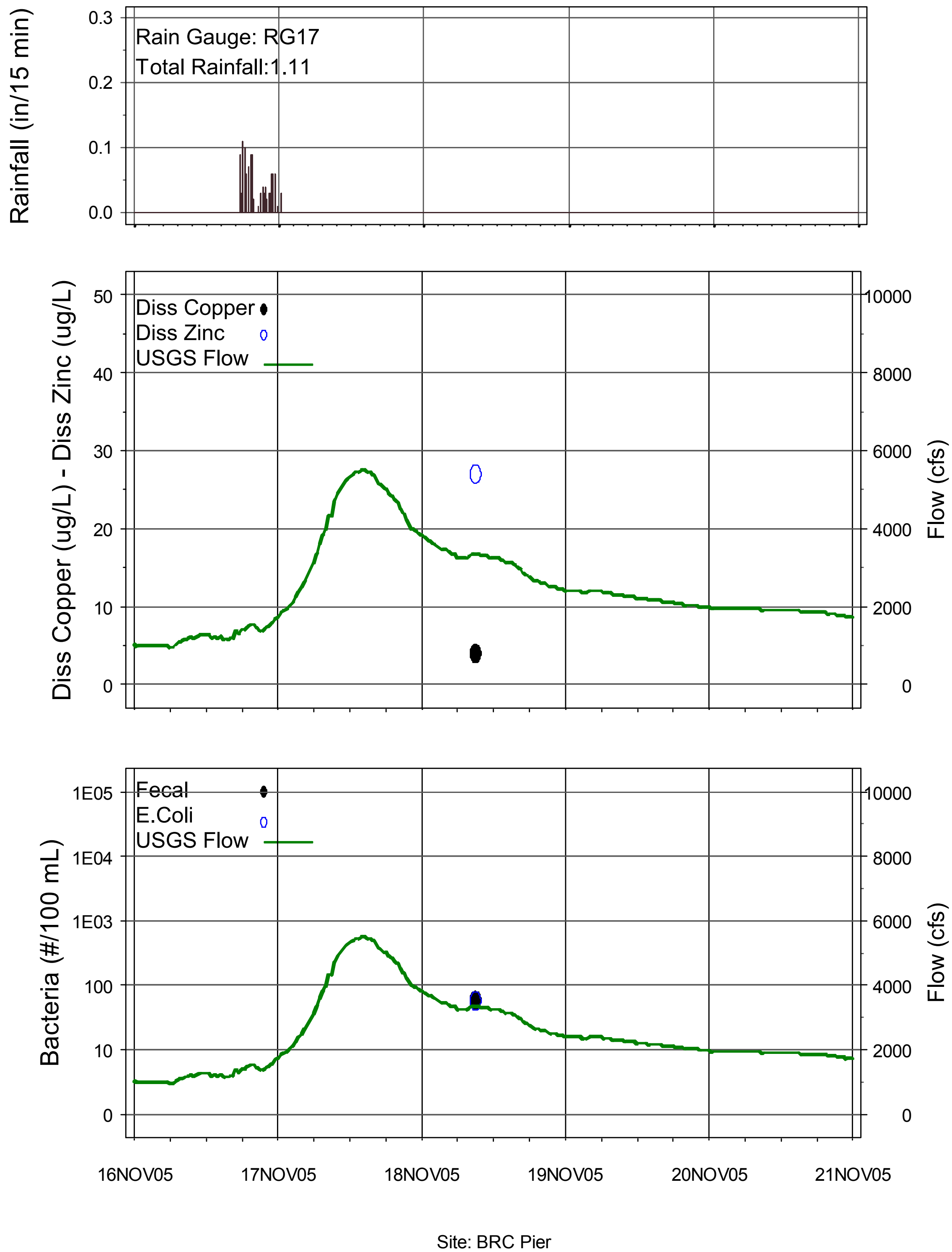


Figure 3-105 Bacteria and Dissolved Metals wet weather event on November 16, 2005 at SC136

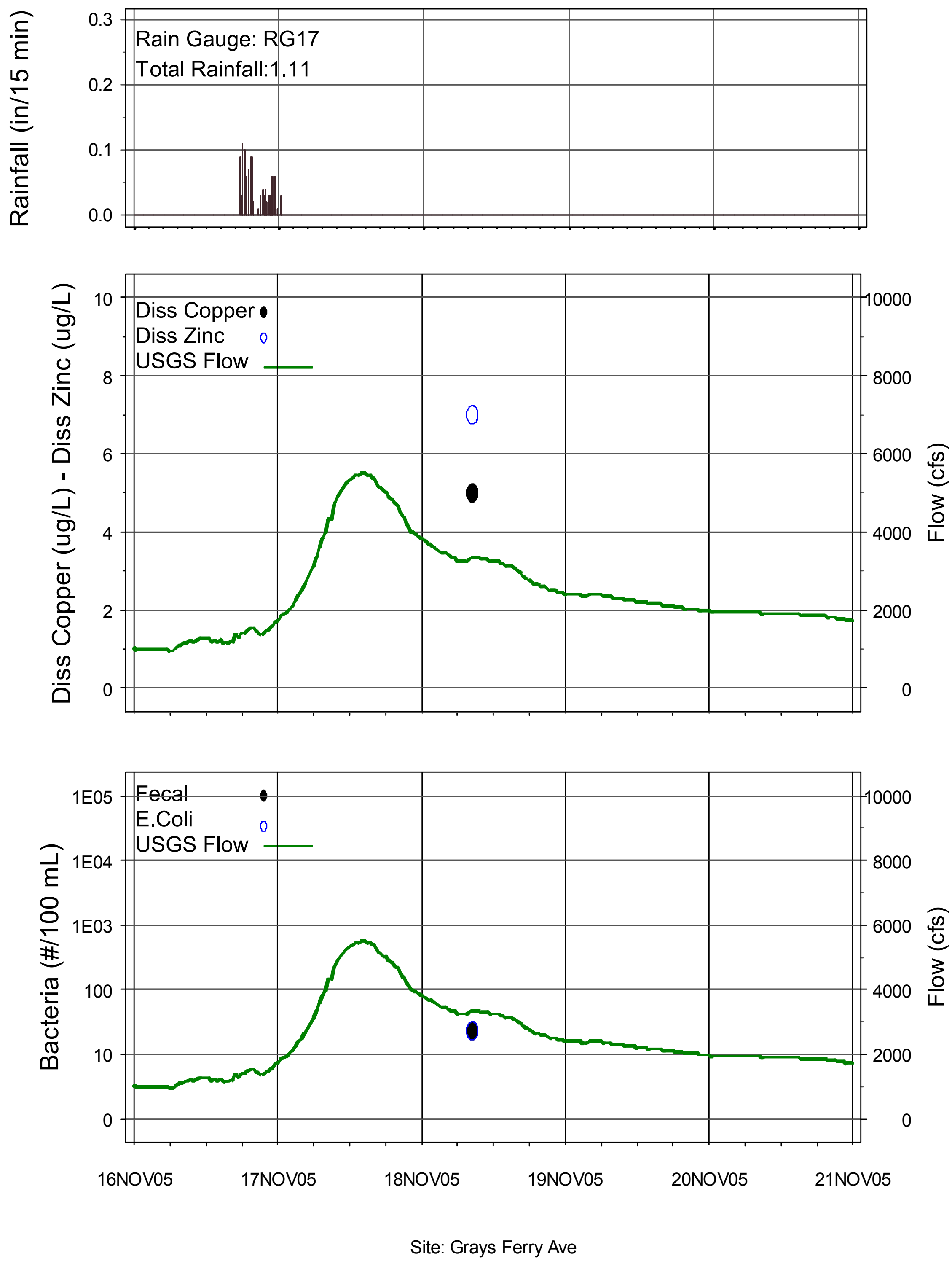


Figure 3-106 Bacteria and Dissolved Metals wet weather event on November 16, 2005 at SC587

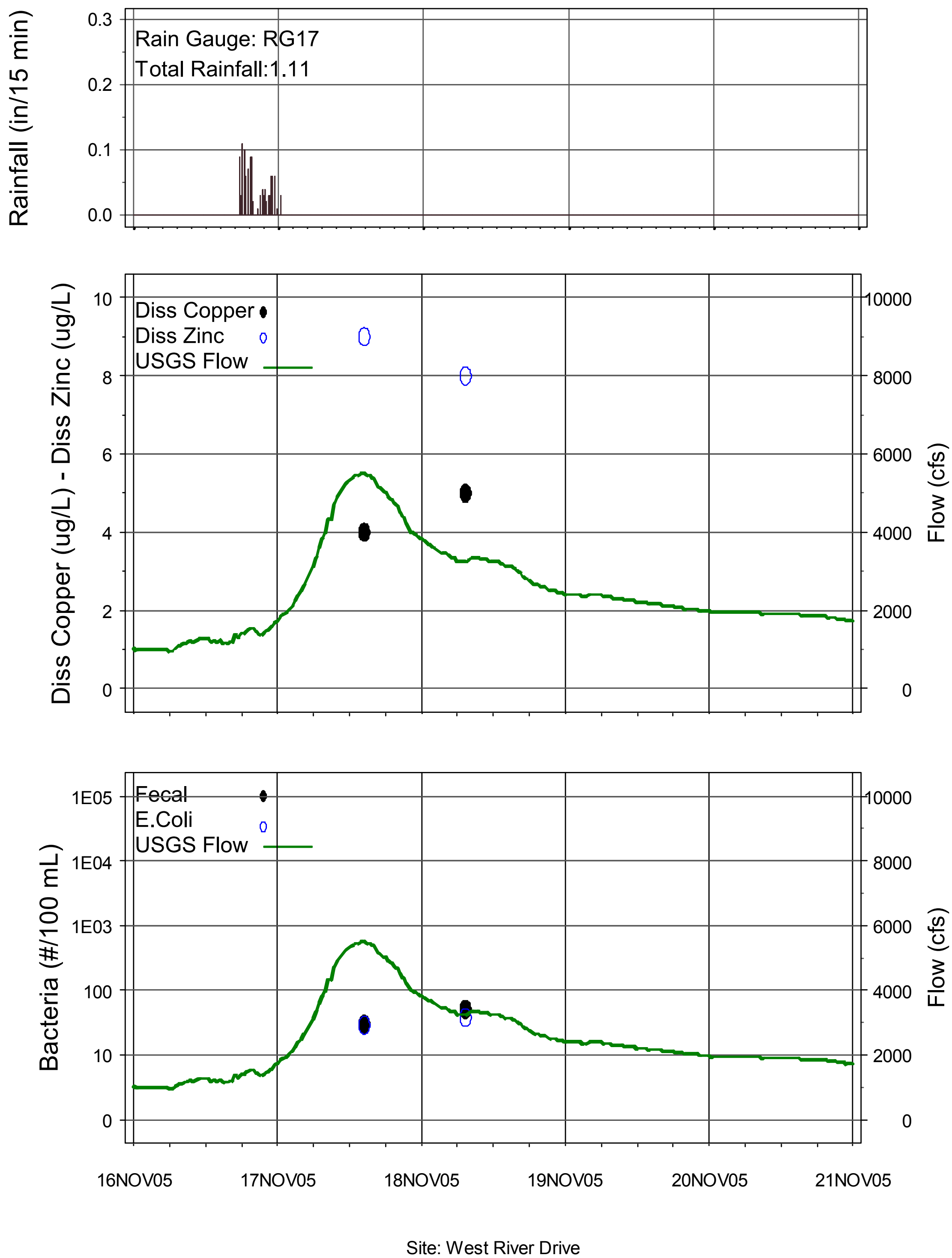


Figure 3-107 Bacteria and Dissolved Metals wet weather event on November 16, 2005 at SC791

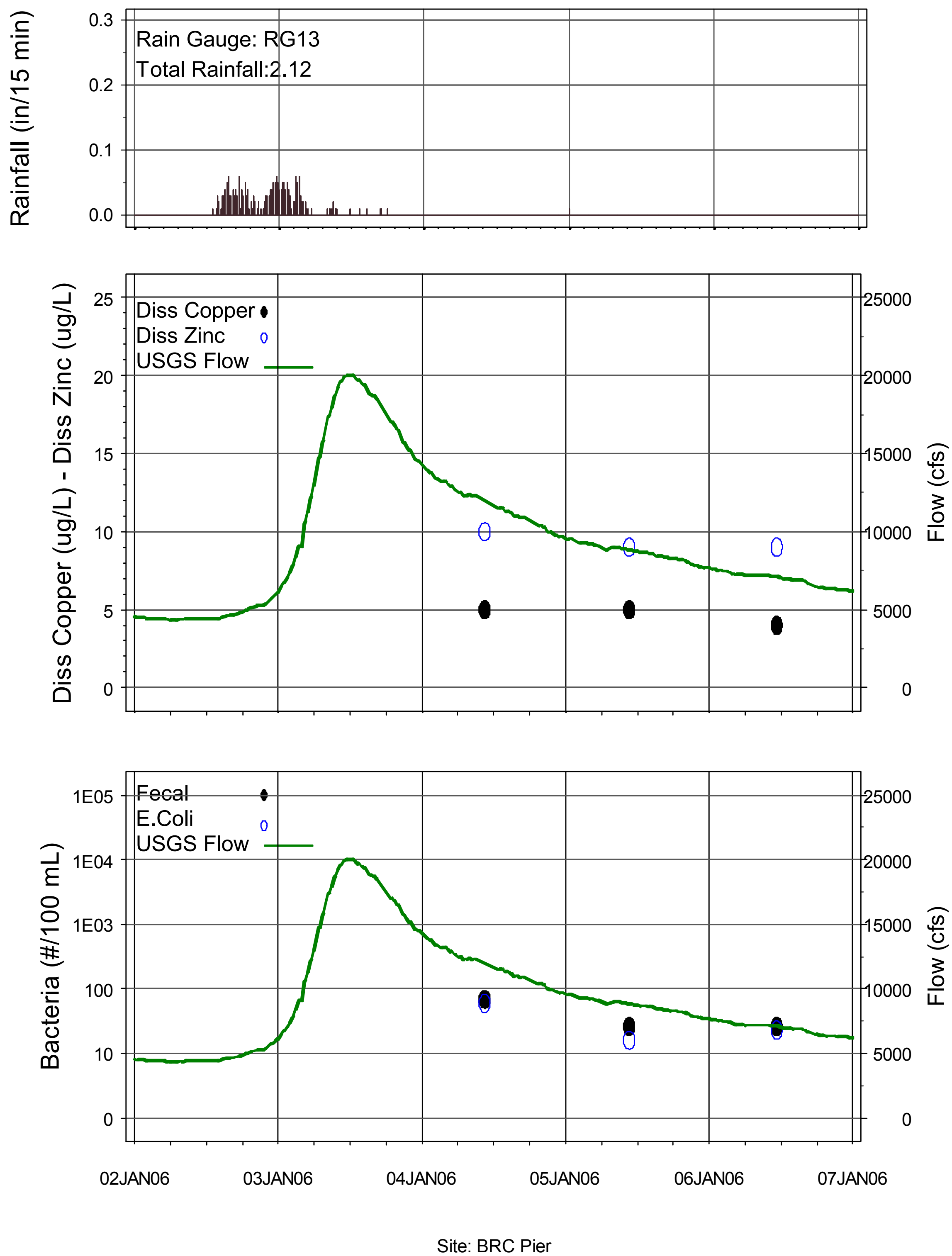


Figure 3-108 Bacteria and Dissolved Metals wet weather event on January 2, 2006 at SC136

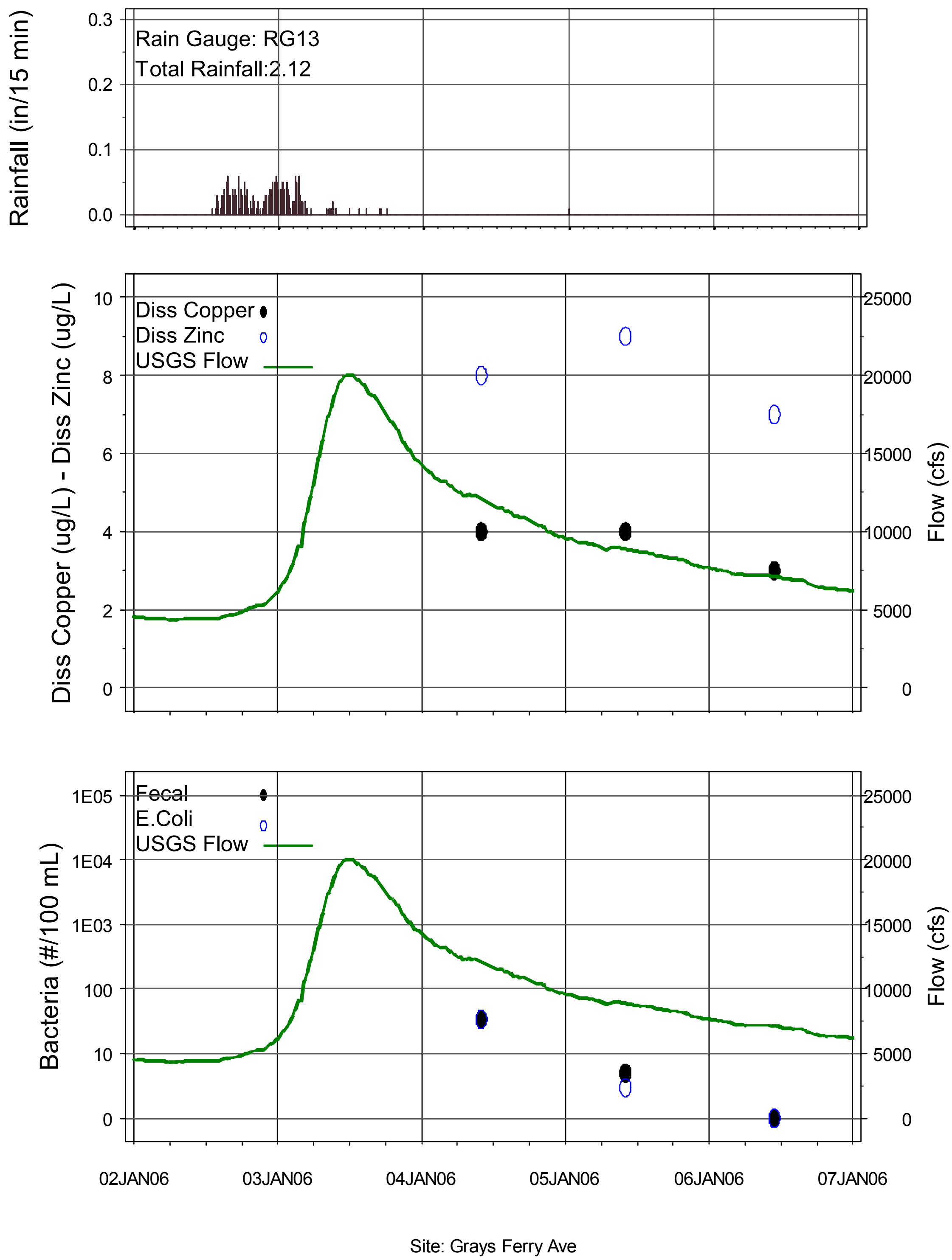


Figure 3-109 Bacteria and Dissolved Metals wet weather event on January 2, 2006 at SC587

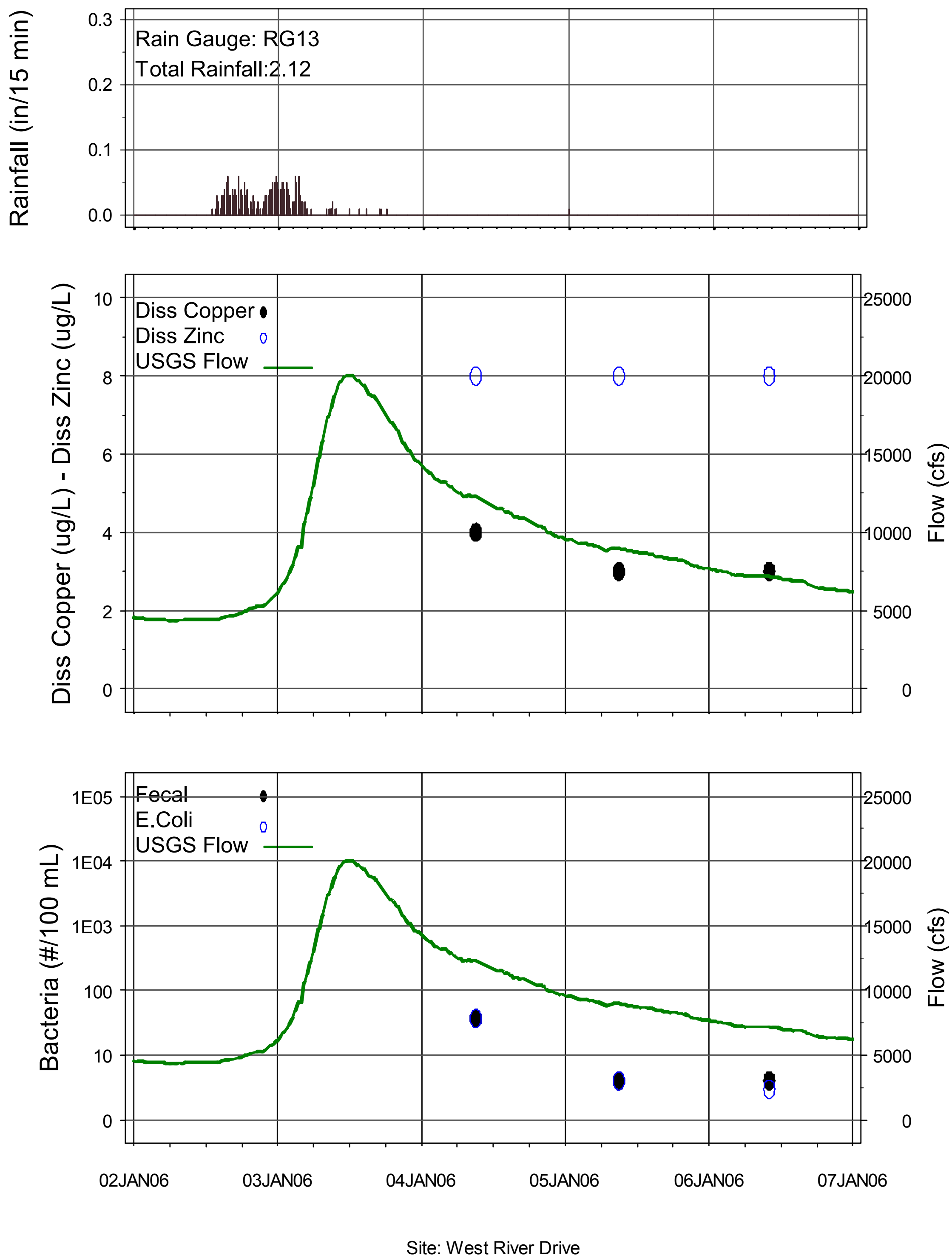


Figure 3-110 Bacteria and Dissolved Metals wet weather event on January 2, 2006 at SC791

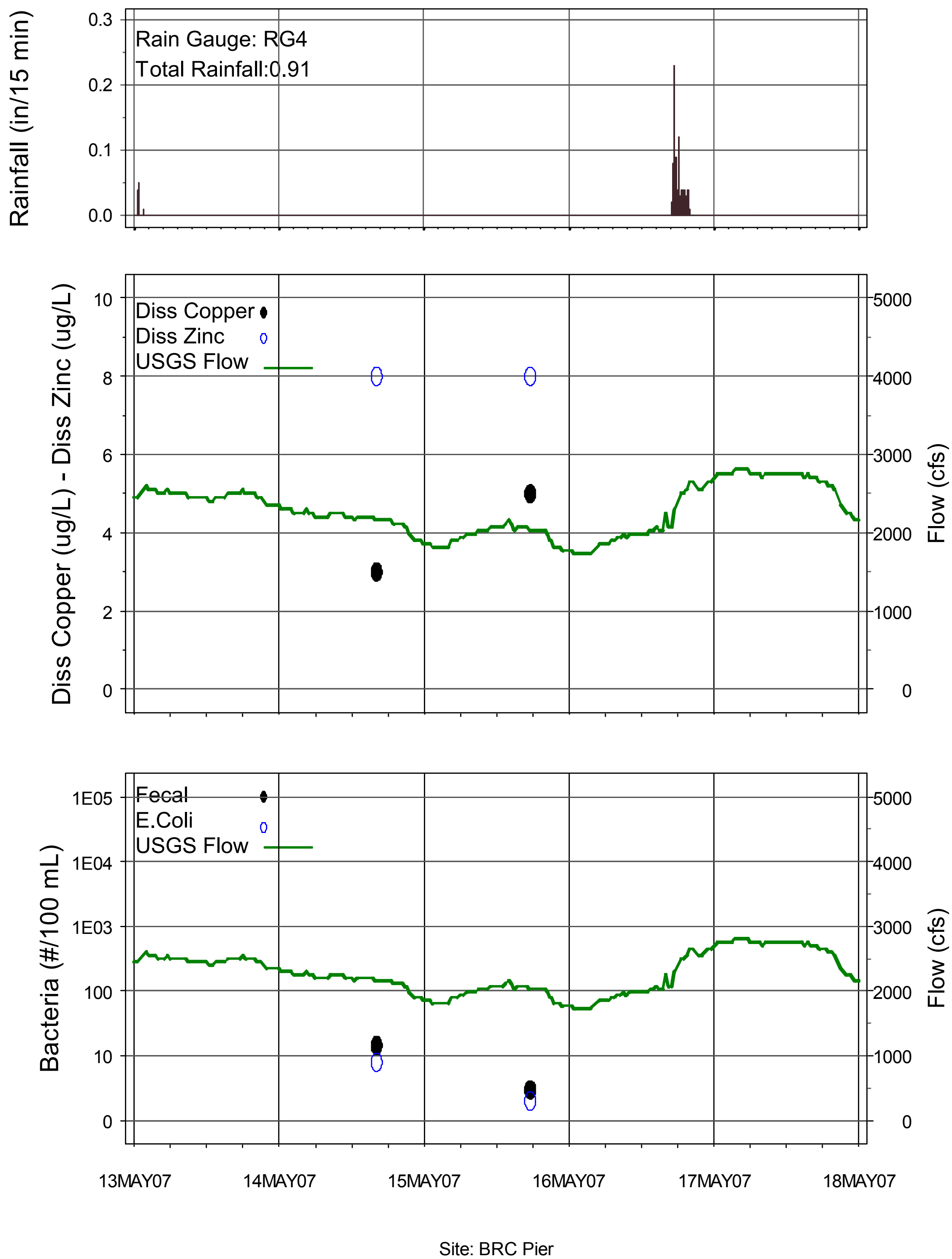


Figure 3-111 Bacteria and Dissolved Metals wet weather event on May 13, 2007 at SC136

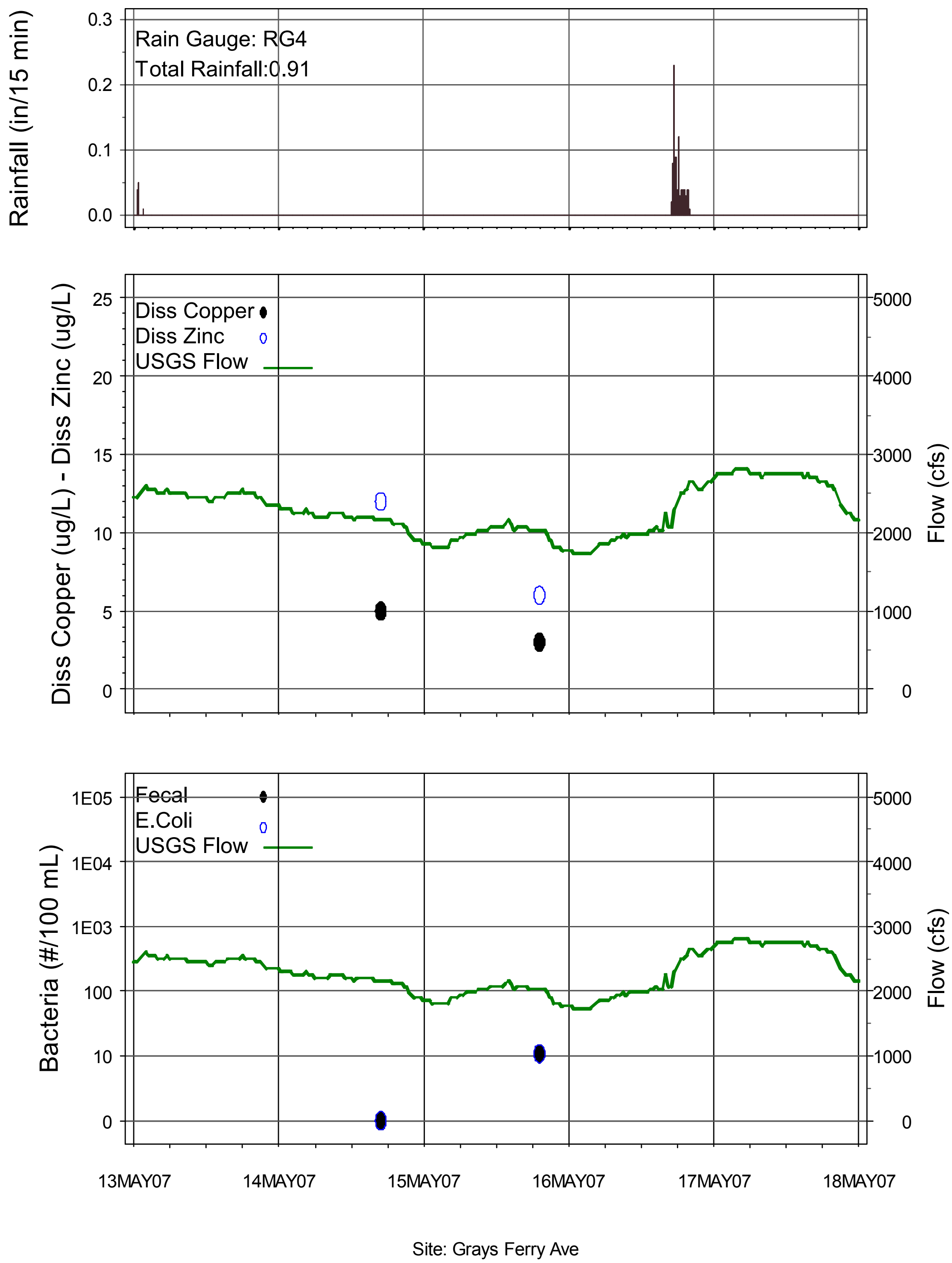


Figure 3-112 Bacteria and Dissolved Metals wet weather event on May 13, 2007 at SC587

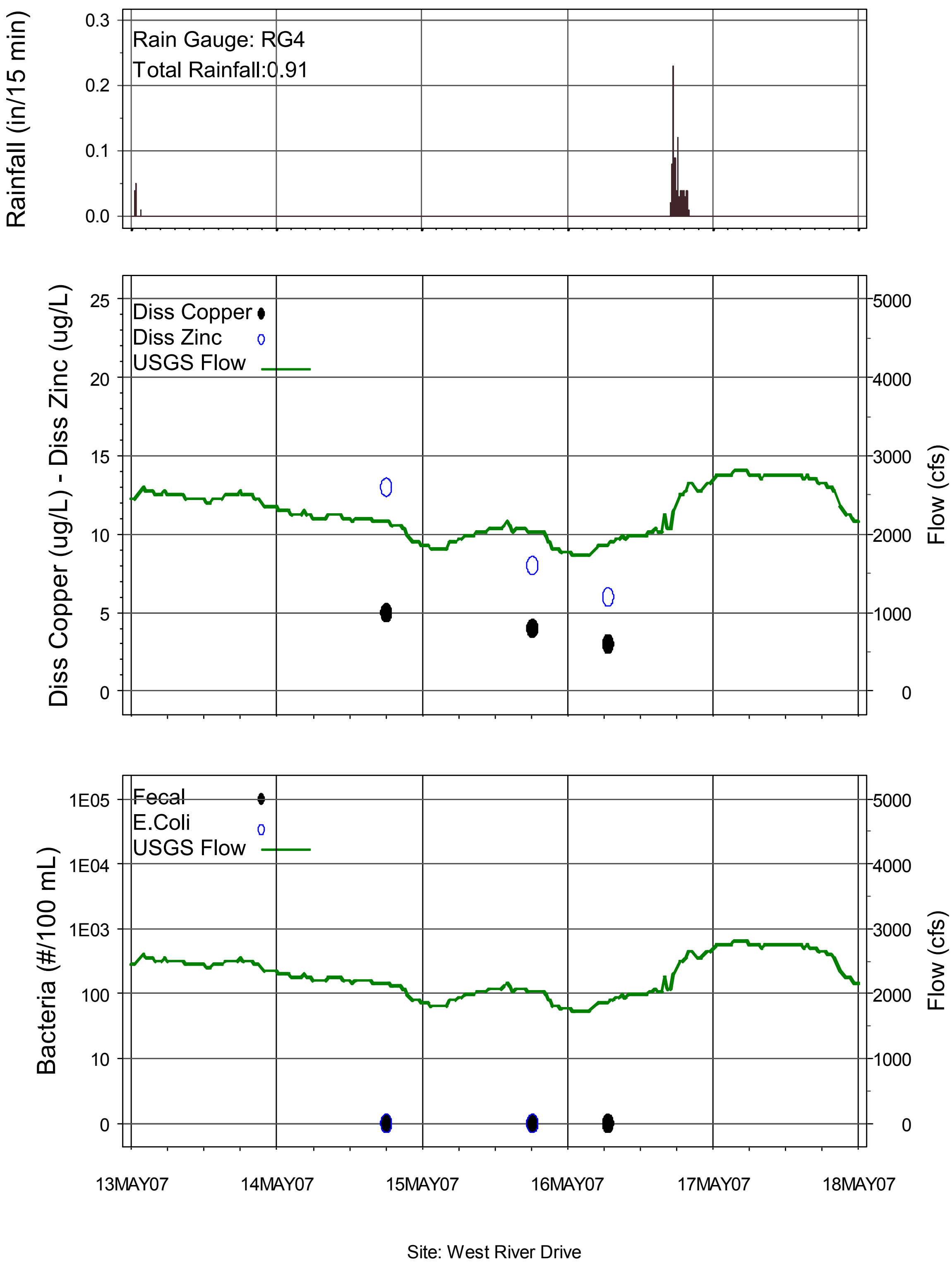


Figure 3-113 Bacteria and Dissolved Metals wet weather event on May 13, 2007 at SC791

3.4.2.4.3 Biological Assessment of the Schuylkill River

Benthic Assessment

The Partnership for the Delaware Estuary (PDE) is currently leading the Delaware Estuary Benthic Inventory Program (DEBI) due to an expressed need in "*White Paper on the Status and Needs of Science in the Delaware Estuary*" (Kreeger, et al 2006). The Benthos community is expected to differ in the Delaware and Schuylkill Rivers from other non-tidal streams. Previously, no reference site was available to study benthos in the tidal streams in Philadelphia. The Delaware Direct IWMP will summarize the findings of DEBI in the Delaware Direct Watershed to help guide watershed management and restoration for both the Schuylkill and Delaware Rivers.

Fish Assessment

Between 2002 and 2006, PWD directed its monitoring efforts above and below the Fairmount Dam fishway (Perillo and Butler, 2009). Electrofishing surveys were conducted three to four times per month from April 1st to July 1st, between 2002 and 2006. A video monitoring program was established in 2003 to assess fish passage at the Fairmount Dam fishway and determine temporal variability of fish assemblages inhabiting the lower Schuylkill River. All fish captured on video were identified to species, time stamped (*i.e.*, h:m:s) and dispersal direction (*i.e.*, upstream vs. downstream) was recorded.

Table 3-104 summarizes fish collection results during electrofishing surveys from 2002 to 2006. In 2002, a total of 1728 fish representing 23 species were collected during spring sampling events (Table 3-105). Species diversity was greatest in 2002 (*H'=2.38*) and a more evenly distributed fish assemblage (E=0.68) was represented when compared to all of the sampling years (*i.e.*, 2003-2006). Table 3-106 summarizes the fish passage observed through video monitoring from 2004 to 2006. During this three-year study, a total of twenty-six species of fish, as well as several hybrid species, were documented using the fishway during spring migrations. Anadromous fishes such as American shad, hickory shad, striped bass, and river herring frequently utilized the fishway for passage above the dam, and the presence of juvenile alewife upstream of the fishway in 2005-2006 suggests that quality spawning and nursery habitats still exist above Fairmount Dam. Moreover, fish passage counts for adult American shad show a discernable increase during the three-year period and although the numbers are significantly lower than historical records, fish surveys below Fairmount Dam indicate increasing trends in fish density during spring migrations.

Repairs and improvements to the Fairmount Dam fishway were completed in 2009. The slots between the chambers of the fishway have been widened, the flow through the chambers has been modified, and the entrance and exit channels have been redesigned. The improvements were made to increase the variety of species and the numbers of fish using the fishway. PWD will continue to monitor fish in the tidal Schuylkill River and passage through the Fairmount Dam fishway. The results will be incorporated into long-term CSO program planning and the Schuylkill River IWMP.

Table 3-104 Fish collection counts by species below the Fairmount Dam, Schuylkill River, during spring monitoring, 2002-2006

Species		2002		2003		2004		2005		2006	
Scientifc Name	Common Name	Number (n)	Percent Contribution (%)	Number (n)	Percent Contribution (%)	Number (n)	Percent Contribution (%)	Number (n)	Percent Contribution (%)	Number (n)	Percent Contribution (%)
Alosa mediocris	Hickory shad	0	0.0	0	0.0	4	0.2	120	4.2	51	1.0
Alosa sapidissima	American shad	63	3.6	535	32.0	470	26.6	1047	36.2	1950	38.0
*Alosa. sp**	Herring*	97	5.6	173	10.3	261	14.8	12	0.4	1215	23.7
Ambloplites rupestris	Rock bass	0	0.0	1	0.1	0	0.0	1	0.0	0	0.0
Anchoa mitchilli	bay anchovy	3	0.2	0	0.0	0	0.0	0	0.0	1	0.0
Anguilla rostrata	American eel	35	2.0	26	1.6	39	2.2	65	2.2	40	0.8
Catostomus commersoni	White sucker	107	6.2	44	2.6	56	3.2	193	6.7	67	1.3
Carassius auratus	goldfish	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0
Carpiodes cyprinus	Quillback	204	11.8	226	13.5	145	8.2	310	10.7	337	6.6
Cyprinella spiloptera	Spotfin shiner	0	0.0	0	0.0	0	0.0	0	0.0	5	0.1
Cyprinus carpio	Common carp	189	10.9	26	1.6	221	12.5	237	8.2	306	6.0
Dorosoma cepedianum	Gizzard shad	425	24.6	485	29.0	387	21.9	275	9.5	592	11.5
Esox lucius x Esox masquinongy	Tiger muskellunge	0	0.0	0	0.0	1	0.1	0	0.0	1	0.0
Hybognathus regius	Eastern silvery minn	13	0.8	0	0.0	0	0.0	0	0.0	0	0.0
Ictalurus punctatus	Channel catfish	146	8.4	48	2.9	37	2.1	134	4.6	178	3.5
Lepomis auritus	Redbreast sunfish	3	0.2	3	0.2	6	0.3	1	0.0	3	0.1
Lepomis gibbosus	Pumpkinseed sunfis	4	0.2	5	0.3	7	0.4	4	0.1	1	0.0
Lepomis macrochirus	Bluegill sunfish	6	0.3	3	0.2	3	0.2	4	0.1	11	0.2
*Lepomis sp***	Lepomis sp**	144	8.3	0	0.0	1	0.1	5	0.2	13	0.3
Menidia beryllina	inland silverside	1	0.1	0	0.0	0	0.0	0	0.0	0	0.0
Micropterus dolomieui	Smallmouth bass	74	4.3	19	1.1	7	0.4	15	0.5	67	1.3
Micropterus salmoides	Largemouth bass	21	1.2	28	1.7	5	0.3	16	0.6	37	0.7
Morone americana	White perch	8	0.5	2	0.1	0	0.0	197	6.8	42	0.8
Morone saxatilis	Striped bass	166	9.6	40	2.4	102	5.8	153	5.3	127	2.5
Morone saxatilis x Morone chryso	Hybrid striped bass	0	0.0	0	0.0	1	0.1	14	0.5	4	0.1
Notropis amoenus	Comely shiner	0	0.0	0	0.0	0	0.0	0	0.0	1	0.0
Notropis hudsonius	Spottail shiner	0	0.0	0	0.0	0	0.0	2	0.1	1	0.0
Oncorhynchus mykiss	Rainbow trout	0	0.0	0	0.0	0	0.0	1	0.0	0	0.0
Perca flavesins	Yellow perch	7	0.4	3	0.2	3	0.2	14	0.5	22	0.4
Pomoxis nigromaculatus	Black crappie	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Pylodictis olivaris	Flathead catfish	0	0.0	0	0.0	0	0.0	0	0.0	3	0.1
Salmo trutta	Brown trout	3	0.2	1	0.1	1	0.1	1	0.0	0	0.0
Sander vitreus	Walleye	8	0.5	6	0.4	7	0.4	69	2.4	58	1.1

**Alosa sp.* include both *A. aestivalis* and *A. pseudoharengus*.
***Lepomis sp.* include all sunfish that were not identified to species.

Table 3-105 Fish community metrics for electrofishing surveys below Fairmount Dam, Schuylkill River, during spring migration (2002-2006)

Metrics	Year				
	2002	2003	2004	2005	2006
Total (N)	1728	1674	1764	2890	5133
Species Richness	23	19	21	24	26
Shannon Index (H')	2.39	1.85	2.03	2.18	1.92
Evenness (E)	0.68	0.53	0.58	0.62	0.55

Table 3-106 Fish passage counts by species at the Fairmount Dam Fishway, Schuylkill River, Pennsylvania, during spring monitoring. Species status codes are as follows: NA = native anadromous; NC = native catadromous; NR = native resident; IR = introduced resident; and I = introduced.

Scientific Name	Common Name	Status	2004[a] Number Passed	2005[b] Number Passed	2006[c] Number Passed
Alosa mediocris	hickory shad	NA	0	0	9
Alosa sapidissima	American shad	NA	91	41	345
Ameiurus catus	white catfish	NR	6	1	6
Ameiurus spp.	bullhead catfish	NR	0	0	2
Ambloplites rupestris	rock bass	IR	0	1	0
Anguilla rostrata	American eel	NC	32	70	34
Catostomus commersoni	white sucker	NR	731	1767	2887
Carpiodes cyprinus	quillback	NR	1807	2042	2631
Ctenopharyngodon idella	grass carp	I	2	0	1
Cyprinella analostana	satinfin shiner	NR	0	2	0
Cyprinus carpio	common carp	IR	401	1197	2215
Dorosoma cepedianum	gizzard shad	NR	691	553	2899
Ictalurus punctatus	channel catfish	IR	1816	1663	3421
Lepomis auritus	redbreast sunfish	NR	13	3	4
Lepomis gibbosus	pumpkinseed sunfish	NR	0	7	1
Lepomis macrochirus	bluegill sunfish	IR	22	147	276
Lepomis species	unknown sunfish		72	10	2
Micropterus dolomieui	smallmouth bass	IR	143	124	1225
Micropterus salmoides	largemouth bass	IR	11	10	42
Morone americana	white perch	NR	55	105	112
Morone saxatilis	striped bass	NA	161	127	61
Morone saxatilis x Morone chrysops	hybrid striped bass	IR	20	16	48
Oncorhynchus mykiss	rainbow trout	I	7	13	16
Pylodictis olivaris	flathead catfish	IR	68	43	466
Alosa aestivalis or pseudoharengus	River Herring	NA	2	5	7
hybrid trout	hybrid trout	I	0	8	40
Salmo trutta	brown trout	I	4	7	5
Sander vitreus	walleye	IR	57	33	84
	unknown		172	14	11
	unknown catfish		12	0	0
	unknown minnow		3	7	0
	unknown shad		32	0	0
	unknown trout		7	1	0
TOTAL			6438	8017	16850

3.4.3 Sensitive Areas

In accordance with the National CSO Control Policy, PWD is required to give highest priority to controlling overflows to receiving waters considered sensitive areas. As part of developing the LTCPU, PWD performed an analysis to identify any sensitive water bodies and the CSO outfalls that discharge to them. This analysis has not identified any portions of CSO receiving waters that meet the definition of sensitive areas. According to the National CSO Control Policy, sensitive areas include:

- Outstanding National Resource Waters
- National Marine Sanctuaries
- Waters with threatened or endangered species or their designated critical habitat
- Primary contact recreation waters, such as bathing beaches
- Public drinking water intakes or their designated protection areas
- Shellfish beds.

Outstanding National Resource Waters

No Outstanding National Resource Waters have been identified in areas impacted by Philadelphia's CSO outfalls.

National Marine Sanctuaries

No National Marine Sanctuaries have been identified in areas impacted by Philadelphia's CSO outfalls.

Waters with threatened or endangered species or their designated critical habitat

In Pennsylvania, four different agencies have the primary responsibility for administering the program for protection and management of threatened and endangered species and other species of special concern. The federal U.S. Fish and Wildlife Service is responsible for federally listed, proposed and candidate species under the Federal Endangered Species Act. The Pennsylvania Fish and Boat Commission are responsible for fish, reptiles, amphibians, and aquatic organisms. The Pennsylvania Game Commission is responsible for wild birds and mammals. The Department of Conservation and Natural Resources is responsible for preserving the Commonwealth's native wild plants, terrestrial invertebrates, significant natural communities and geologic features.

Two endangered species and two threatened species known to occur in the Delaware River basin (Pennsylvania or New Jersey) are listed under the Federal Endangered Species Act.

Shortnose Sturgeon, Acipenser brevirostrum (endangered)

The shortnose sturgeon is found on the Atlantic Coast of North America where its range extends from the Saint John River, New Brunswick, to the St. Johns River, Florida. The federal recovery plan (NMFS 1998) for the species identifies 19 distinct population segments, each defined as a river/estuarine system in which shortnose sturgeons have been captured in the generation time of the species (30 years). Although originally listed as endangered rangewide, the NMFS recognizes 19 distinct population segments occurring in New Brunswick, Canada (1), Maine (2), Massachusetts (1), Connecticut (1), New York (1), New Jersey/Delaware (1), Maryland/Virginia (1), North Carolina (1), South Carolina (4), Georgia (4) and Florida (2). The population in the Delaware River in the early 1980s was estimated to be somewhere between 6,000 and 14,000 (NMFS, 1998).

Dwarf Wedgemussel, Alasmidonta heterodon (endangered)
This freshwater mussel has declined precipitously over the last hundred years. Once known from at least 70 locations in 15 major Atlantic slope drainages from New Brunswick to North Carolina, it is now known from only 20 localities in eight drainages. These localities are in New Hampshire, Vermont, Connecticut, New York, Maryland, Virginia, and North Carolina. The dwarf wedge mussel was listed as an endangered species in March of 1990 (U.S. Fish and Wildlife Service, 1993). Pennsylvania has proposed to change the status of the dwarf wedgemussel to extirpated.

Bald Eagle, Haliaeetus leucocephalus (threatened)
Federal status is categorized by state/region, rather than by subspecies. The bald eagle is listed as threatened in the coterminous U.S. It is not federally classified as endangered anywhere as of mid-1995 (USFWS, Federal Register, 12 July 1995). It was proposed for delisting July 6, 1999 (USFWS 1999). (Source: NatureServe, 2006) This species has been observed in the Philadelphia Naval Yard and in the John Heinz National Wildlife Refuge at Tinicum. The recovery of the species in recent decades, along with associated improvements in water quality in the Delaware River, suggests that this species will continue to recover as CSO controls are implemented.

Bog Turtle, Clemmys muhlenbergii (threatened)
The northern population of the bog turtle was listed as a threatened species on November 4, 1997. This population is currently known to occur in Connecticut (5 sites), Delaware (4), Maryland (71), Massachusetts (3), New Jersey (165), New York (37), and Pennsylvania (75). The bog turtle has experienced at least a 50 percent reduction in range and numbers over the past 20 years. The greatest threats to its survival include the loss, degradation, and fragmentation of its habitat, compounded by the take of long-lived adult animals from wild populations for illegal wildlife trade. Bog turtles usually occur in small, discrete populations, generally occupying open-canopy, herbaceous sedge meadows and fens bordered by wooded areas. The bog turtle is listed as extirpated in Philadelphia in the USFWS recovery plan (USFWS, 2001).

Additional information on threatened and endangered species that may be present in CSO receiving waters was collected from the Pennsylvania Natural Heritage Program (PNHP). PNHP is a partnership between the Department of Conservation and Natural Resources, the Nature Conservancy, Western Pennsylvania Conservancy, Pennsylvania Game Commission, Pennsylvania Fish and Boat Commission and the U.S. Fish and Wildlife Service. PNHP conducts inventories and collects data regarding the Commonwealth's native biological diversity. PNHP lists a number of species present in Philadelphia County that are considered endangered or threatened under the Pennsylvania Code, but not listed under the federal Endangered Species Act.

- American Bittern, Botaurus lentiginosus (endangered)
- Great Egret, Casmerodius albus (endangered)
- Banded Sunfish, Enneacanthus obesus (endangered)
- Threespine Stickleback, Gasterosteus aculeatus (endangered)*
- Peregrine Falcon, Falco peregrinus (endangered)**
- Least Bittern, Ixobrychus exilis (endangered)
- Tadpole Madtom, Noturus gyrinus (endangered)
- Black-crowned Night-heron, Nycticorax nycticorax (endangered)
- Coastal Plain Leopard Frog, Rana sphenocephala (endangered)
- Brook Floater, Alasmidonta varicosa (endangered)

- King Rail, Rallus elegans (endangered)
- Osprey, Pandion haliaetus (threatened)

* A subspecies of the threespine stickleback is listed as endangered under the federal Endangered Species Act in California.

** Eurasian subspecies PEREGRINUS is listed by USFWS as Endangered. Subspecies TUNDRIUS was delisted by USFWS in 1994. USFWS proposed removing all Endangered Species Act protections from all subspecies (including removing designation of endangered due to similarity of appearance for falcons with the 48 conterminous U.S.) (Federal Register 63:45446-45463, 26 August 1998). Subspecies ANATUM was formally removed from the U. S. federal list of endangered and threatened wildlife, along with the 'similarity of appearance' provision for free flying Peregrine Falcons in the conterminous U. S. (Federal Register, 25 August 1999)(NatureSource, 2006).

The literature reviews performed as part of this analysis have yielded no basis to infer that these species or their habitat are directly impacted or excluded by the discharge of stormwater runoff in the Philadelphia area. Absent any such direct evidence specific to Philadelphia's CSO receiving waters, it was not possible to identify any geographic subset of the receiving waters that can be specifically identified as meeting this definition of sensitive areas. Without a basis to prioritize one area over another, it is not possible to prioritize control scenarios geographically based on this definition of sensitive areas. However, the selection of CSO control alternatives that will evolve from the implementation of this Plan will reduce overflows of combined sewage to all receiving waters.

Primary contact recreation waters, such as bathing beaches
An annual triathlon, including a swimming component, is held in the nontidal portion of the Schuylkill River above Fairmount Dam. This area is upstream of PWD's CSO outfalls on the Schuylkill River. Occasional primary contact recreation occurs in Cobbs Creek and Tacony-Frankford Creek. These activities are physically unsafe in addition to exposing recreators to potentially unsafe levels of pathogens in wet weather. The City of Philadelphia is addressing these concerns through education, signage, and enforcement.

Public drinking water intakes or their designated protection areas
The Philadelphia Water Department operates two drinking water intakes on the Schuylkill River and one on the Delaware River. On both rivers, all CSOs are downstream of intakes. On the Schuylkill River, the Fairmount Dam prevents any movement of water and pollutants upstream to the water intakes. The closest CSO that discharges to the Delaware River is CSO D02, which is located approximately 2 miles downstream of the Baxter Intake. There are also 5 CSOs on the Pennypack Creek. The Pennypack Creek flows into the Delaware River approximately 0.7 miles downstream of the Baxter intake.

Shellfish beds
No shellfish beds have been identified in areas impacted by Philadelphia's CSO outfalls.

3.4.4 Pollutant Loads

3.4.4.1 Background and Methods

Estimating pollutant loads is a key step of a watershed approach to urban water resources planning and management. The analysis identifies sources of pollutants and their relative importance for a number of constituents that affect water quality. Pollutant loads contributed by CSOs are compared to upstream loads and to loads from separate storm sewer systems, for example. Loads of key constituents will be compared to observed water quality conditions to draw conclusions about the extent to which CSOs cause or contribute to observed impairments. Finally, this section defines baseline pollutant loads that future reductions can be measured against.

For the TTF and Cobbs Creek Watersheds, watershed-wide estimates of pollutant loads and their sources are presented in detail in the Comprehensive Characterization Report for each watershed. These results are summarized below. Estimated loads contributed by combined sewer overflows have been updated to reflect the representative year precipitation record and results of hydrologic/hydraulic computer modeling used in LTCPU planning. Pollutant concentrations in combined sewer overflow have been estimated based on a flow-weighted average of their sanitary sewage and stormwater components.

In the tributaries, baseflow loads were estimated based on observed dry weather flows and concentrations in the streams. Dry weather flows were derived from long-term USGS daily flow monitoring data, while concentrations were derived from PWD dry weather instream monitoring data. Stormwater flows were estimated from hydrologic modeling and from streamflow records where available. Stormwater event mean concentrations used for this study for urban land uses are from Smullen, Shallcross, and Cave (1999). These values represent a compilation of stormwater monitoring data from NURP, the USGS, and NPDES Phase I Municipal Stormwater Monitoring Requirements.

In the tidal estuary, estimates of pollutant loads for the entire contributing area were impractical due to the size of the Delaware and Schuylkill Watersheds. An alternative approach was taken focusing on just the system of interest, the portions of the Schuylkill and Delaware Rivers impacted by Philadelphia's combined sewer outfalls. Estimated loads contributed by combined sewer overflows have been updated to reflect the representative year precipitation record and results of hydrologic/hydraulic computer modeling used in LTCPU planning. Pollutant concentrations in CSOs have been estimated based on a flow-weighted average of the sanitary sewage and stormwater components.

Loads entering the boundary of the CSO-impacted area were estimated using USGS flow monitoring and water quality data. Flow monitoring and water quality data collected at the USGS station at Trenton was used for the Delaware River and from the USGS station at the Fairmount Dam for the Schuylkill River. Streamflow volumes were estimated from the average daily flow measurements. Water quality parameter concentrations were estimated from data collected at the monitoring locations. The water quality data collected at Trenton was summarized into an average concentration for the period of 1999-2008. The water quality sampled at the Fairmount Dam was less comprehensive and average concentrations were used for the period of record that was available for each parameter.

3.4.4.2 Tookany/Tacony-Frankford Pollutant Loads

Table 3-107 presents the approximate load each source contributes to the TTF Creek. Runoff from areas with separate sanitary and storm sewer systems is a significant (over 10%) source of most pollutant types except fecal coliform. Discharges of untreated sanitary sewage may be a significant source of pollutants, but information concerning these sources was insufficient to include in the current analysis. Baseflow contributes a significant amount of total nitrogen. Results indicate that over 90% of the fecal coliform introduced to the system is the result of CSOs, excluding any sources of sanitary sewage such as SSOs and illicit connections, which have not been explicitly accounted for.

Table 3-107 TTF Estimated Annual Pollutant Loads (lb except as noted)

Parameter	Stormwater Runoff	Baseflow	CSO	Summed Load	CSO
	lb/yr	lb/yr	lb/yr	lb/yr	% of Summed Load
BOD	2.54E+05	5.26E+04	9.91E+05	1.30E+06	76%
TSS	1.44E+06	1.43E+05	2.09E+06	3.68E+06	57%
Fecal Coliform (#/yr)	2.49E+15	2.06E+14	3.65E+16	3.92E+16	93%
Total Nitrogen	4.42E+04	1.24E+05	1.66E+05	3.34E+05	50%
Total Phosphorus	5.67E+03	7.16E+03	2.39E+04	3.67E+04	65%
Copper	2.27E+02	3.16E+02	7.16E+02	1.26E+03	57%
Lead	1.36E+03	4.21E+01	1.49E+03	2.89E+03	51%
Zinc	3.06E+03	8.63E+02	4.88E+03	8.80E+03	55%

3.4.4.3 Cobbs Creek Pollutant Loads

Lower Cobbs includes the combined-sewered portions of the watershed inside Philadelphia. Table 3-108 presents the approximate load each source contributes to the Cobbs Creek watershed. Runoff from areas with separate sanitary and storm sewer systems is a significant source of most pollutant types, except fecal coliform. Discharges of untreated sanitary sewage may be a significant source of pollutants, but information concerning these sources was insufficient to include in the current analysis. Baseflow contributes a significant amount of total nitrogen. The results indicate that CSOs represent more than 10% of the total load for every parameter except total nitrogen and lead. The model indicates that over 50% of the fecal coliform introduced to the system is the result of CSOs, excluding any sources of sanitary sewage such as SSOs and illicit connections, which have not been explicitly accounted for.

Table 3-108 Cobbs Estimated Annual Pollutant Loads (lb except as noted)

Parameter	Stormwater Runoff	Baseflow	CSO	Summed Load	CSO
	lb/yr	lb/yr	lb/yr	lb/yr	% of Summed Load
BOD	5.34E+05	1.70E+05	1.88E+05	8.92E+05	21%
TSS	2.99E+06	4.05E+05	4.28E+05	3.82E+06	11%
Fecal Coliform (#/yr)	5.06E+15	3.20E+14	6.53E+15	1.19E+16	55%
Total Nitrogen	9.06E+04	3.07E+05	3.16E+04	4.29E+05	7%
Total Phosphorus	1.19E+04	5.72E+03	4.52E+03	2.21E+04	20%
Copper	5.41E+02	3.81E+02	1.39E+02	1.06E+03	13%
Lead	2.97E+03	1.06E+02	3.16E+02	3.39E+03	9%
Zinc	6.28E+03	1.25E+03	1.00E+03	8.53E+03	12%

3.4.4.4 Tidal Delaware Pollutant Loads

Table 3-109 presents the average loads contributed by runoff from boundary and combined sewer areas.

Table 3-109 Tidal Delaware Estimated Annual Pollutant Loads

Parameter	Boundary load	CSO load	Summed Load	CSO
	lb/yr	lb/yr	lb/yr	% of Summed Load
BOD	5.84E+07	1.15E+06	5.95E+07	1.9%
TSS	7.64E+08	2.75E+06	7.66E+08	0.4%
Fecal Coliform (#/yr)*		3.80E+16		
Total Nitrogen	3.60E+07	1.93E+05	3.62E+07	0.5%
Total Phosphorus	2.23E+06	2.75E+04	2.26E+06	1.2%
Copper	6.22E+07	8.59E+02	6.22E+07	0.001%
Lead	4.22E+07	2.08E+03	4.22E+07	0.005%
Zinc	4.88E+08	6.42E+03	4.88E+08	0.001%

* Insufficient data to estimate boundary load.

2.4.4.5 Tidal Schuylkill Pollutant Loads

Table 3-110 presents the average loads contributed by runoff from boundary and combined sewer areas.

Table 3-110 Tidal Schuylkill Estimated Annual Pollutant Loads

Parameter	Boundary load	CSO load	Summed Load	CSO
	lb/yr	lb/yr	lb/yr	% of Summed Load
BOD*		5.12E+05		
TSS	2.48E+08	1.52E+06	2.49E+08	0.6%
Fecal Coliform (#/yr)*		1.31E+16		
Total Nitrogen	2.48E+07	8.68E+04	2.48E+07	0.3%
Total Phosphorus	1.86E+06	1.21E+04	1.88E+06	0.6%
Copper	6.89E+04	4.10E+02	6.93E+04	0.6%
Lead*		1.25E+03		
Zinc	7.10E+05	3.56E+03	7.13E+05	0.5%

* Insufficient data to estimate boundary load.

3.5 METEOROLOGIC CHARACTERIZATION

3.5.1 Background

The EPA CSO Control Policy (1994) requires the characterization of the combined sewer system (CSS) area and evaluation of control measure performance in terms of system-wide average annual hydrologic conditions. The identification of an average annual precipitation record, therefore, is critical for the evaluation of CSS performance.

3.5.2 Long-Term Meteorologic Conditions

The hydrologic conditions over the Philadelphia CSS area are characterized using the long-term historic hourly precipitation record, 59-year period (1948-2006), for the National Weather Service Cooperative Station located at the Philadelphia International Airport (WBAN#13739). Statistical analyses of the long-term record are performed to determine the average frequency, volume, and peak intensity of rainfall events. A selection of these analyses generally characterizing average precipitation volume and frequency are presented below. Results of further analyses are found in the Supplemental Documentation Volume 5.

Average Precipitation Volumes

Average annual and monthly precipitation volumes are determined from the long-term record at the PIA. Comparisons are made between the individual annual precipitation volumes and the long-term average to identify relatively ‘wet’ and ‘dry’ years.

Figure 3-112 shows the total annual precipitation volume at the PIA for the years 1948-2006 along with one standard deviation from the mean. By this measure, 1983 and 1965 are shown to be the wettest and driest years on record, respectively.

Average monthly total precipitation volumes are used to characterize relatively ‘wet’ and ‘dry’ months. Figure 3-113 shows the average monthly precipitation volumes relative to a range of plus and minus one standard deviation from the mean based upon the PIA historical record. Table 3-111 presents accompanying historical monthly precipitation volume statistics. Long term seasonal variation in monthly precipitation volumes can readily be seen between summer and winter, with summer months having marginally more rainfall than winter months.

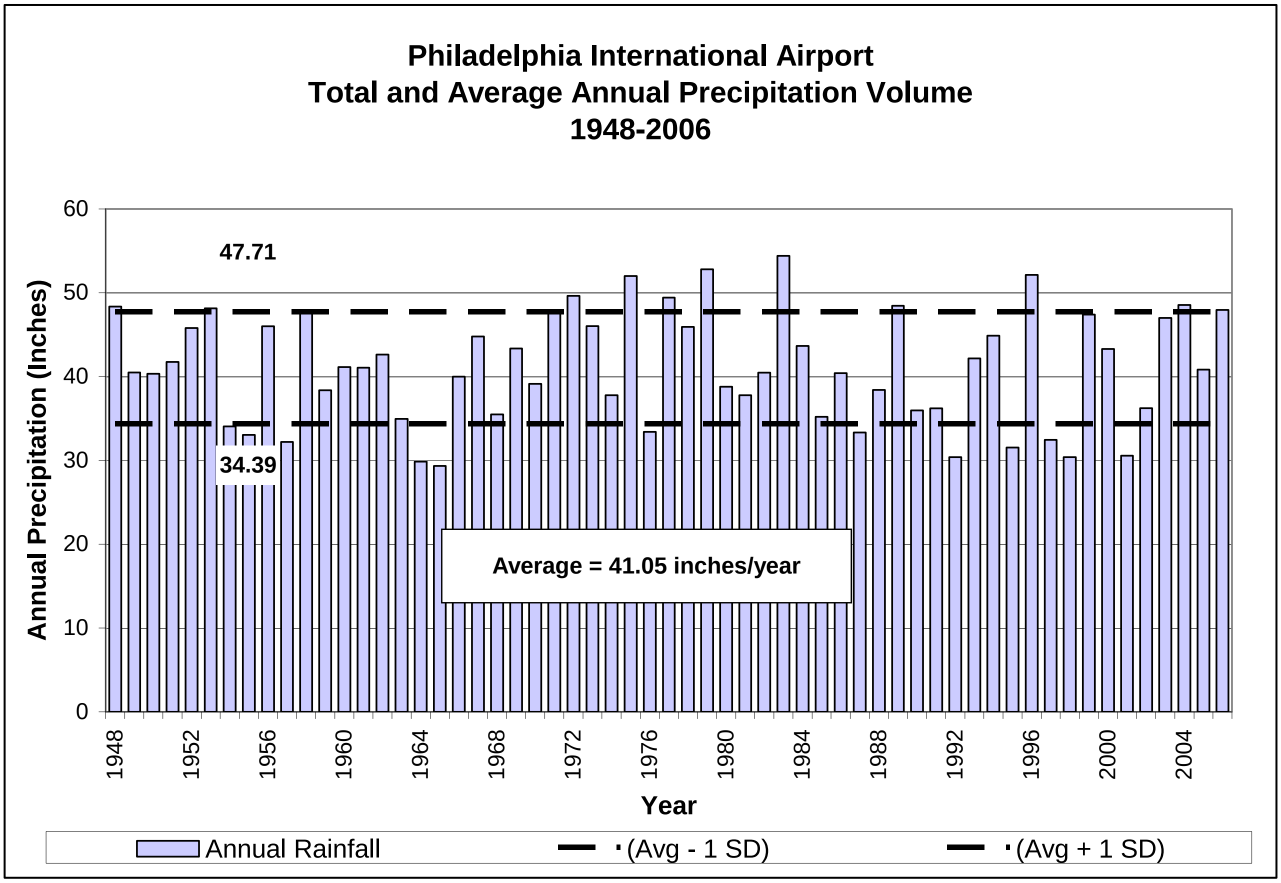


Figure 3-114 PIA total annual precipitation volume (1948-2006)

Figure 3-115 PIA average monthly precipitation volume (1948-2006)

Table 3-111 Monthly Precipitation Inches Statistics for PIA Historical Record (1948-2006)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average	3.18	2.69	3.79	3.41	3.51	3.59	4.07	3.82	3.60	2.86	3.21	3.33	41.05
Avg + 1SD	4.83	3.89	5.32	4.95	5.13	5.67	6.40	5.83	5.92	4.46	5.11	5.14	47.71
Avg - 1SD	1.54	1.49	2.26	1.87	1.89	1.51	1.73	1.80	1.28	1.27	1.31	1.53	34.39
Std. Dev.	1.65	1.20	1.53	1.54	1.62	2.08	2.34	2.01	2.32	1.59	1.90	1.80	6.66
Maximum	8.86	6.44	6.89	8.12	7.03	8.08	10.42	9.70	13.07	8.68	9.05	8.09	54.41
Minimum	0.45	0.46	0.69	0.61	0.48	0.11	0.37	0.49	0.21	0.09	0.32	0.25	29.34

Event Based Precipitation Analyses

Event based analysis of the long-term precipitation record is used to best represent average annual CSO frequency and volume statistics needed for measurement of collection system performance. These event statistics are specific for a given minimum inter-event time (MIT) used for event definition.

A minimum inter-event time (MIT) is chosen for event definition so that the coefficient of variation (the ratio of the standard deviation to the mean) of inter-event times most closely approximates unity. A six-hour minimum inter-event time is selected on this basis for the PIA using hourly precipitation data for the period 1948-2006 as seen in Table 3-112.

Table 3-112 Inter-event Time (IET) statistics determined for a range of minimum inter-event times (MIT) using PIA hourly precipitation (1948-2006)

MIT (Hours)	Mean IET (Hours)	Std. Dev.IET (Hours)	CV IET
2	48.2	70.7	146.5
4	66.2	76.2	115.1
6	75.5	77.5	102.7
8	81.4	78.0	95.8
10	85.6	78.2	91.3
12	89.5	78.2	87.4
14	92.7	78.2	84.4
16	95.2	78.2	82.1
18	97.5	78.1	80.1
20	99.5	78.1	78.4
22	101.8	78.0	76.6
24	104.0	77.9	74.9

A minimum total event volume of 0.05 inches is selected as the minimum storm depth needed for precipitation events to significantly increase wastewater flows potentially contributing to CSO discharges. Table 3-113 presents event-based summary statistics for the PIA long-term precipitation record.

Table 3-113 Philadelphia International Airport Average Annual Wet Weather Event Statistics (1948-2006)

Month	Event Size Class	Average Number of Events	Average Total Rainfall (Inches)	Average Event Peak Hourly Intensity (In / hour)	Average Event Duration (hours)	Average Inter-Event Time (hours)
1	>= 0.05 in	6.4	3.04	0.11	11.2	83.2
2	>= 0.05 in	5.9	2.66	0.11	11.1	82.0
3	>= 0.05 in	7.1	3.81	0.14	10.9	83.6
4	>= 0.05 in	7.1	3.27	0.15	9.4	66.5
5	>= 0.05 in	7.6	3.46	0.18	7.9	73.5
6	>= 0.05 in	7.3	3.51	0.25	5.8	79.5
7	>= 0.05 in	7.2	4.02	0.29	5.6	83.7
8	>= 0.05 in	6.7	3.77	0.32	6.0	90.3
9	>= 0.05 in	5.7	3.58	0.26	8.1	95.7
10	>= 0.05 in	4.9	2.82	0.19	9.3	115.1
11	>= 0.05 in	5.7	3.16	0.16	9.9	100.1
12	>= 0.05 in	6.0	3.31	0.13	11.9	89.4
All	>= 0.05 in	77.6	40.39	0.19	8.7	77.1
All	< 0.05 in	30.3	0.62	0.02	1.7	74.6
All	All	107.9	41.05	0.14	6.7	76.4
* Events defined based on 6 hour Minimum Interevent Time (MIT)						

3.5.3 Local Meteorologic Conditions

The average spatial distribution of precipitation over the CSS areas is characterized using the 17-year rainfall record for the PWD 24-raingage network collected over the period 1990-2006, along with fifteen months of gage calibrated radar rainfall data. Extensive analyses of non-climatic gage biases based on inter-gage comparison and radar rainfall data are performed leading to the creation of a bias adjusted rainfall dataset for the PWD 24-raingage network over the period of record (1990-2006). The detailed analyses are presented in Supplemental Documentation Volume 5.

Increasing the level of detail of the rainfall input spatially increases the accuracy and precision of the model results. The method selected to estimate rainfall values in areas between rain gages is an inverse distance-squared weighting procedure to populate a 1-km square grid followed by area weighting for each modeled sewershed. The details of this procedure are presented in Supplemental Documentation Volume 5.

3.5.4 Average Annual Precipitation Record

The characterization of long-term system-wide average hydrologic conditions across the CSS is necessary in order to identify a continuous short–term period contained within the PWD 24-gage fifteen-minute rainfall record (1990-present) that simulates long-term average annual CSO statistics needed for the evaluation of CSO control measure performance. After initial identification of the continuous 12-month period in the short-term PWD 24-gage record that most closely represents long-term conditions, adjustment of selected events is performed to further match long-term statistics.

CSO occurrence is considered to be a complex function of storm-event characteristics such as total volume, duration, peak intensity, and length of antecedent dry period or inter-event time (IET). In order to identify short-term continuous periods likely to generate CSO statistics representative of the long-term record, continuous 12-month periods selected from the recent PWD 24-raingage record (1990-2006) are evaluated against the long-term record based on the following storm-event characteristics:

- Annual number of storm events
- Total annual rainfall volume
- Best fit CDF plot of event peak hourly rainfall intensity

The calendar year 2005 is selected to represent long-term average hydrologic conditions for CSO LTCP project evaluations, based on the annual number of storm events, the total annual rainfall volume, and the best fit CDF plot of event peak hourly rainfall intensity, with preference given to more recent calendar years to better represent current conditions. Details of the selection process are presented in Supplemental Documentation Volume 5.

The calendar year 2005, however, contains the extreme event of October 8, 2005 which recorded an average rainfall volume across the PWD 24-gage network of 5.40 inches between October 7 12:15 PM and October 9 8:45 AM. This rainfall event has the third largest annual peak rainfall volume recorded at the Philadelphia International Airport (PIA) station over the long-term period of 1948-2006. Furthermore, this rainfall event accounts for nearly thirty percent of the total annual estimated combined sewer overflow volume for the year 2005 based on SEDD baseline model simulations. Because the extreme rainfall event of October 8, 2005 accounts for a disproportionately large fraction of the total annual overflow volume, the results of CSO LTCPU project evaluations may be unintentionally skewed to minimize the long-term effectiveness of certain alternatives in favor of others.

In response to these concerns, a decision was made to adjust the rainfall record for the calendar year 2005 to better represent long-term average hydrologic conditions by scaling down the October 8th rainfall event so that the average rainfall volume across the PWD 24-gage network for this event is equal to the median peak annual rainfall volume estimated for the network over the long-term period of 1948-2006. The details of the time-series modification procedures are presented in Supplemental Documentation Volume 5.

3.5.5 Temperature Data

Temperature statistics are shown below in Table 3-114 and were obtained from the National Oceanic and Atmospheric Administration. The air temperature statistics that are shown below come from a period of record from 1947 to 2008. The dry-bulb temperature which is commonly referred to as the ambient air temperature is the temperature of the air that is measured by a thermometer that is freely exposed to the air but is shielded from radiation and moisture. Table 3-114 shows that the highest mean dry-bulb air temperature occurs during the month of July and is 77.3OF while the lowest mean dry-bulb air temperature occurs during the month of January and is 32.3OF.

Table 3-114 Temperature Statistics

Element	Period of Record (years)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Mean Daily Maximum Air Temperature (°F)	61	39.7	42.5	51.5	63.4	73.3	82.0	86.6	84.8	77.7	66.7	55.3	44.0
Mean Dry Bulb Air Temperature (°F)	61	32.3	34.5	42.5	53.3	63.2	72.4	77.3	75.8	68.5	57.1	46.7	36.6
Mean Daily Minimum Air Temperature (°F)	61	24.9	26.4	33.6	43.1	53.1	62.3	68.0	66.8	59.3	47.6	38.1	29.1

3.5.6 Snowfall Data

Snowfall statics are shown below in Table 3-115 and were obtained from the National Oceanic and Atmospheric Administration. The snowfall statistics shown below come from a period of record from 1978 to 2008. The table shows that the average yearly snowfall for the period of record was 19.3 inches with the highest monthly average snowfall occurring during the month of February and accounted for 6.6 inches. The table also shows that for the period of record the average total days with a snowfall amount greater than or equal to 1 inch is only 5.1 days. The table shows that Philadelphia does not normally receive large snow events.

Table 3-115 Snowfall Statistics

Element	Average Monthly Snowfall (in)	No. of Days with Snowfall >= 1.0 in
Period of Record (years)	30	30
JAN	6.4	1.9
FEB	6.6	1.5
MAR	3.2	0.8
APR	0.6	0.2
MAY	0	0
JUN	0	0
JUL	0	0
AUG	0	0
SEP	0	0
OCT	0.1	0
NOV	0.4	0.2
DEC	2	0.5
Total Annual	19.3	5.1

3.5.7 Evaporation Data

Limited long-term daily evaporation data exists for the Philadelphia area. Neither the Philadelphia Airport nor the Wilmington Airport records evaporation data. One site in New Castle County, Delaware was located with recorded daily evaporation data from 1956 through 1994. Average evaporation rates (inches per day) determined from this site is given in Table 3-116.

Table 3-116 Evaporation Statistics

Month	Average Evaporation Rate (in/day)
Jan	0.07
Feb	0.07
Mar	0.07
Apr	0.15
May	0.18
Jun	0.21
Jul	0.22
Aug	0.19
Sep	0.14
Oct	0.09
Nov	0.07
Dec	0.07