The water resources of the Delaware River Basin are vital to the long term health of our citizens and the stability of our economy. These resources supply our drinking water, support our industries, transport our products, provide habitat to a wide array of living resources and contribute to overall quality of life. Management of these resources is a complex task involving all levels of government, public-private partnerships, and a multitude of laws, regulations, and competing interests.

Policy makers and citizens alike often ask me if the health of the system is “getting better.” My answer is both “yes” and “no.” While we have made great strides in water quality improvement, we still have a long way to go in many respects. To truly assess issues of ecosystem health and sustainable use, we need to answer a series of questions spanning multiple dimensions of resource management. Examples include:

- How clean are the water resources of the Delaware River, its tributaries and Bay?
- Do we have enough water for drinking and commerce? Is it safe to drink?
- Are our waters “useable”?
- Are fish abundant and safe to eat? How are other living resources faring?
- Is critical habitat being protected?
- Are years of management and stewardship yielding good results?
- Are we prepared to meet the issues we might face in the future?

Responding to these questions requires environmental managers to set goals for the protection and improvement of resources, to efficiently assess issues and trends, and to monitor the success of implemented management strategies—all of which require high-quality data, scientific information, and an effective feedback system. You can’t manage what you don’t measure.

This State of the Basin Report 2008 is designed to serve as a benchmark of current conditions and a point of reference for gauging progress toward management goals. It also provides a platform for measuring and reporting future progress in water resource management, and a guide for adjusting monitoring and assessment programs. Finally, it is intended to communicate our understanding of the health of the Basin, to increase public involvement in Delaware River Basin and Estuary Program activities, and to build consensus on a broad array of actions that can be taken to continue to improve water quality, water availability, and enhance the living resources of the Delaware River Basin.

Carol R. Collier
December 2008


Members of the Delaware River Basin Commission

Delaware: Governor Ruth Ann Minner
New Jersey: Governor Jon S. Corzine
New York: Governor David A. Paterson
Pennsylvania: Governor Edward G. Rendell
United States: Brigadier General Todd T. Semonite

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The Delaware River Basin Commission staff are grateful to the following organizations that helped assemble and assess information for this report:

- Delaware Water Resources Agency, Institute for Public Administration, University of Delaware
- Pennsylvania Centers for Water Resources Research, Watershed Stewardship, Pennsylvania State University
- New Jersey Water Resource Research Institute, Rutgers, the State University of New Jersey
- New York State Water Resources Research Center, Cornell University
- Partnership for the Delaware Estuary
- New Jersey Water Science Center, US Geological Survey
- US Environmental Protection Agency, Regions II and III

In addition to DRBC publications and in-house data, major sources of information for this report include USEPA, USEPA NDRRC, and an array of environmental quality information from NPDES PADEP, USEPA, US Fish and Wildlife Service, US Forest Service, and the Nature Conservancy. In 1998, as part of the National Water Quality Assessment Program (NWQAP), the US Geological Survey undertook a four-year study (1998–2002) of water quality issues in the Delaware River Basin. This Report draws on some of the results of that study. The introduction to Category II: Water Quality relies significantly on Richard C. Albert’s seminal article on the history of water resource management in the basin.1 Much of the information and trends reported in Category III: Living Resources was published in the State of the Delaware Estuary. For references to DRBC, 1981 Level B Study have been used where appropriate to bridge the past and present. A Technical Summary of data underpinning this Report has been published separately by the Water Resources Agency at the University of Delaware.2 DRBC staff are also grateful to the many members of state agencies and the

Science and Technical Advisory Committee of the Partnership for the Delaware Estuary for their review and contributions to this report.

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INTRODUCTION
1. The Basin – Overview
2. Welcome to the Delaware River Basin

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CATEGORY I: HYDROLOGY

- Indicators:
  - Flow at Trenton
  - Sediment Location
  - Water Use Efficiency
  - Water Use
  - Water Supply

- Features:
  - Flood Damage

---

CATEGORY II: WATER QUALITY

- Indicators:
  - Nitrogen
  - Dissolved Oxygen
  - Water Quality

- Features:
  - Contaminants of Emerging Concern
  - Support of Designated Use: Delaware River & Bay
  - Support of Designated Use: Delaware River & Bay

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CATEGORY III: LIVING RESOURCES

- Indicators:
  - Macroinvertebrates
  - Freshwater Mussels
  - Oysters
  - Invasive Species

- Features:
  - Invasive Species

---

CATEGORY IV: LANDSCAPE

- Indicators:
  - Population Growth and Distribution
  - Population Density
  - Land Use

- Features:
  - Urban Growth

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ILLUSTRATIONS

- Water Resources
  - Population Distribution
  - Usery, J. Kent Barr

- Partners:
  - Vocks Natural Landscapes

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ACKNOWLEDGMENTS


In addition to identifying desired environmental and social states, the ‘Water Resources Plan for the Delaware River Basin’ includes goals for the development of partnerships; the exchange of data, information and technology; and the improvement of coordination and cooperation among basin institutions, agencies and organizations. The State of the Basin Report 2008, produces of a comprehensive collaborative effort, fulfills these goals.
The Basin – Then and Now

Introduction

The Delaware River Basin is one of the most intensively studied basins in the world. The study began in 1976, a comprehensive study was conducted to identify and resolve water resource problems in the Basin. The resulting “Level B Study” issued in 1981 by the Delaware River Basin Commission (DRBC) reported the findings of that study, including resource conditions and recommendations for management. Since then, many excellent specialized studies have been published on a variety of water resource issues, but the Level B Study remains the last comprehensive assessment of the Basin – including water supply, water quality and flow management issues – published in one volume.

In 1980 when the Level B Study was under development, the population of the basin was slightly greater than 7 million; the Clean Water Act was not yet a decade old; and industrial and municipal wastewater did not receive the level of treatment that it does today. There are

How clean are the water resources of the Delaware River, its tributaries and Bay?
Do we have enough water for drinking and for commerce? Is it safe to drink?
Are our waters ‘swimmable’?
Are fish abundant and safe to eat?

The Final Report and Environmental Impact Statement is commonly referred to as the Level B Study, since it conformed to guidelines established by the now defunct US Water Resource Council for a study of its magnitude, or Level B.

In 1999, a process was begun to develop a new and unifying vision for water resource management. The Water Resources Plan for the Delaware River Basin (Basin Plan), unveiled in 2004, presents a direction for integrated water resource management, acknowledging the connection between land and water and valuing aquatic habitat protection in the course of ensuring adequate flows and supplies for human needs. In accepting the new Basin Plan, the Governors directed the preparation of a periodic environmental condition report. This Delaware River Basin Report 2008 fulfills that mandate.

STATE OF THE DELAWARE RIVER BASIN REPORT 2008

Hawk’s Nest, NY

The Delaware River and valley are formed.
1376 The Declaration of Independence is adopted.
1410 Delaware Bay is named in honor of Lord De La Warre (Thomas West), governor of Jamestown.
1610 Philadelphia’s water department is formed.
1854 The Delaware Journal is founded.
1861 The Delaware River is formally declared a navigable river by the US Congress.
1876 At Philadelphia is described as a “mess” by a visiting Englishman.
1900 Philadelphia’s water department is the first in America to supply an entire city with drinking water; Fairmount Water Works on the Schuylkill River serve as a model for other American water delivery systems.
1911 The Delaware River Basin Commission (DRBC) reported the findings of that study, including resource conditions and recommendations for management. Since then, many excellent specialized studies have been published on a variety of water resource issues, but the Level B Study remains the last comprehensive assessment of the Basin – including water supply, water quality and flow management issues – published in one volume.

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In 1980 when the Level B Study was under development, the population of the basin was slightly greater than 7 million; the Clean Water Act was not yet a decade old; and industrial and municipal wastewater did not receive the level of treatment that it does today. There are now more than half a million additional people living in the River Basin and 25 years of advanced water treatment and remediation technology have been applied to water resource problems.

Have conditions improved? Has the imbalance noted in the 1981 Study been restored in the intervening 25 years? As we will see, the answer is both yes, and no. There have been improvements in resource condition, especially water quality, because of important changes in management policies. For example, required improvements in wastewater treatment have raised the levels of dissolved oxygen and restored shad runs to the River. However, the presence of toxic compounds and our ever-increasing ability to detect them in more minute quantities still leads to consumption advisories for many fish species in spite of site clean ups and cleaner water. Nutrients are holding steady, but concerns about pharmaceuticals and other compounds are growing. A trio of floods ravaged portions of the Basin in 2004, 2005 and 2006, re-focusing interest in flood mitigation.

And international panels are preparing reports on

The Delaware River Basin Commission (DRBC) reported the findings of that study, including resource conditions and recommendations for management. Since then, many excellent specialized studies have been published on a variety of water resource issues, but the Level B Study remains the last comprehensive assessment of the Basin – including water supply, water quality and flow management issues – published in one volume.
a changing climate, predicting more rapid changes that challenge our planning and management. Based on 25 additional years of investigation and assessment, we know more about many issues, from toxic compounds to the effects of landscape changes, than we did in 1981. Yet our knowledge remains incomplete. We are still learning about the relationships among the natural elements of the system—such as soil, geology, slope, temperature and chemistry—and of the effects of human influence on parts of this complex system. Changes occur even as we examine and calculate.

This State of the Basin Report 2008 offers a view of conditions of the Basin’s landscapes and waters based on available information on a set of discrete indicators.

Indicators
An indicator is a measure of condition; an environmental indicator is a measurement, value or statistic that provides an approximate gauge of the state of the environment and may help evaluate the effectiveness of an environmental management program. Ideally, an indicator is relevant, sensitive to change, easy to measure with low measurement error, and cost effective. For this report, indicators were chosen in part because information on them was readily available.

For each indicator, we include a Description and a statement of Desired Condition linked to a goal from the 2004 Water Resources Plan for the Delaware River Basin (WMP), an action item from the 1997 Comprehensive Conservation Management Plan for the Delaware Estuary (CCMP), and, when appropriate, to regulatory standards. There is also a report of condition Status and, if relevant, of historic or recent Trends. A status bar resembling a horizontal thermometer with a red-to-green color gradient accompanies each indicator, where green represents a good condition, red an unfavorable condition. The placement of an icon indicates the condition status along the continuum, and its style reflects a stable, improving or worsening trend.

Concluding each indicator page is a statement of Actions and Needs, advising on improvements or changes that should be considered to enhance reporting capabilities and environmental conditions.

Reporting
Indicators are assembled into four categories:
- Category I: Hydrology
- Category II: Water Quality
- Category III: Living Resources
- Category IV: Landscape

The State of the Basin Report 2008 offers a view of conditions of the Basin’s landscapes and waters based on available information. It serves as a benchmark of current conditions, as a companion to the 1981 Level B Study, and as a point of reference for gauging progress towards the goals of the 2004 Water Resources Plan for the Delaware River Basin.

Each category section begins with an introduction and event timeline, and ends with a special feature on emerging issues to suggest ideas for future reporting. The final section of the Report summarizes conditions and recommendations.

The State of the Basin Report 2008 is designed to serve as a benchmark of current conditions, as a point of reference for gauging progress towards management goals. It also provides a platform for measuring and reporting future progress in water resource management, and a guide for adjusting monitoring and assessment programs.

Welcome to the Delaware River Basin
Welcome to the Delaware River Basin

Lying in the densely populated corridor of the northeastern US, the 13,600 square mile Delaware River basin stretches approximately 310 miles from headwaters in New York State to its confluence with the Atlantic Ocean. The basin includes approximately 12,800 square miles of land area, nearly 800 square miles of bay and over 2,000 miles of streams, including many that are river in their own right. The Delaware River’s condition is very much a product of the cumulative flows from its many tributaries, which in turn take their character from the underlying geology, topography, microclimates and land uses of their watersheds.

The northermmost tributaries to the Delaware River originate in the forested western slopes of the Catskill Mountains that reach elevations of up to 4,000 feet. The East and West Branches meet at Hancock NY where the Delaware River officially begins. The River descends about 800 feet on its journey to the sea.

Political Setting

The drainage area encompasses extensive landscapes in New York, New Jersey, Pennsylvania and Delaware and 8 square miles in Maryland, which are not included in this report. All or portions of 42 counties and 858 municipalities within four states contribute to and benefit from the resources of the Delaware River Basin. Water resources are also exported to cities in NJ and NY outside of the Basin’s boundary. While the states retain autonomy, the Delaware River Basin is unique in governance. It is the only river basin with both an interstate and a federal Commission and a national estuary program in place. The 1961 Compact establishing the Delaware Watershed Commission (DRCB) was the first such interstate-agreement for the basin and watershed resources management. The DRCB pre-dates the first Earth Day, the establishment of the Environmental Protection Agency and the passage of the Clean Water Act. The national significance of the Delaware Estuary was acknowledged in 1988 when it became part of the National Estuary Program.

How old is the Delaware River?

It is thought that the formation of the Delaware River valley began during cycles of erosion and uplift approximately 30 to 30 million years ago. From Port Jervis to the Water Gap, the Delaware follows a strike (or valley) eroded in soft and limurites. The U-shaped curve at Wallpack Bend is a meander of a tributary stream eroded in this time period. From the Water Gap to Trenton the Delaware flows in a southeast course and this is thought to be the original flow direction of the River. Below Trenton the River closely follows its contact with the bedrock formations of the Paulinskill. Why and how the Delaware River was diverted in a right-angle turn at Trenton by softer sediments—when it had eroded through the harder conditions existed—thought to be the original fl ow direction of the River.

Below Trenton the River eventually became the product of stream capture by smaller streams flowing parallel to the southeast strike and created the existing course of the Delaware River and Bay.

Introduction

Basin Overview

What’s in a name?

Introduction

The Delaware River Basin straddles two very different hydrologic provinces corresponding to major physiographic divisions: the Appalachian Highlands and the Atlantic Coastal Plain (Figure 1.1 on the next page) and, as such, the natural division between these provinces, running southwest to northeast along the western edges of the River and crossing it near Trenton NJ. Above the fall line freshwater conditions exist. Below the fall line the River is subject to tidal influences and, with increased proximity to the Bay, estuarine conditions exist.

This report honors the Basin as a whole system of functioning parts, and the majority of reporting is on the basin scale. There is also reporting on the regional scale, referencing four regions of the basin. In the context of this Report:

• The Upper Region covers the Delaware River headwaters and contributing watersheds to just below Port Jervis NY.
• The Central Region is the remaining freshwater river and contributing watersheds between the Upper Region and Trenton NJ.
• The Lower Region is the area of tidal fall from Trenton to the head of the Bay and all contributing watersheds.
• The Bay Region includes the Bay and the surrounding watersheds.

Combined, the Lower and Bay Regions may also be referred to as the Estuary Region. It is the same area that is included in the National Estuary Program.

Within each region watershed are grouped together based on the segment of river or bay to which they drain, irrespective of political divisions. For example, in the Upper Region, the Neversink and Mongaup watershed in New York are grouped together with smaller tributaries in Pennsylvania because they all flow into the same stretch of Delaware. The Delaware River Basin is defined by its natural physical characteristics and by the legacies of hundreds of years of human settlement and use. The basin has been shaped by the interactions of both humans and nature.

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Tides – The physical behavior of the Delaware River water system can be compared to a simple pool bordered at its perimeter. If water is evaporated (at any location), the dynamics of the system change; water stored during periods of high runoff affects the degree to which sea level is regulated toward the basin; the swath of ground water basins and the effects of climatic changes are evident in the system. In addition to the natural hydrologic conditions illustrated in Table 1.1, the physical behavior of the Delaware River water system can still be compared to that of a single pool. Changes in one region can affect circumstances in another. The replenishment of both surface and ground water basins is linked to weather and precipitation, soil and geology, human use and transport.

Natural Flows

Compared to many other river systems, the Delaware Basin is blessed with a relative abundance of water, realizing over 45 inches of rainfall on average in a year. In a natural system flows are variable, but unregulated, and depend on precipitation and ground base water flows. Flow regimes, tracked as a hydrograph of flow volumes over time, reflect the effect of precipitation on streams.

The Delaware River is a complex system of streams实体经济；effects水文；characteristics. A large number of streams实体经济；effects水文；characteristics. A large number of streams实体经济；effects water quality. In the Appalachian Highlands includes four provinces each of which has distinctive geology, landforms, and hydrologic characteristics. Two major tributaries, the Lehigh (Central Region) and Schuylkill (Estuary Region) Rivers, flow through all or most of the provinces of the Appalachian Highland, which includes four primary provinces:

- Appalachian plateaus. The 1,000–2,000-foot-high uplands of this province from the Catskill & Pocono Mountains where river. The highest base flow yields are found in the Appalachian plateau where, even in times of drought, base flows may exceed those found in some upstream streams under normal conditions. Table 1.1. Water is abundant here, especially in glacial valleys, which are also vulnerable to pollution. The landforms, especially in the northern reaches, are amenable to damming to create reservoirs for power generation and water supply. In general, the large reservoirs in this region serve distant populations, such as those of New York City, and many communities rely on ground water from these sources. While encompassing one third of the basin, only about 3% of the population lives in the Appalachian Plateau. The natural beauty, availability of water, and access to distant employment centers is increasing development here.

- Ridge and Valley. The northern section of this province is a series of long, narrow forested mountain ridges oriented southwest to northeast characterized by extreme topographic relief; distances from ridge top to valley bottom can reach 1,000 feet or more. These features and the associated valleys have been extensively developed to provide land for farming and agriculture dominate the valleys. The 1,000–2,000-foot-high uplands of this province from the Catskill & Pocono Mountains where river. The highest base flow yields are found in the Appalachian plateau where, even in times of drought, base flows may exceed those found in some upstream streams under normal conditions. Table 1.1. Water is abundant here, especially in glacial valleys, which are also vulnerable to pollution. The landforms, especially in the northern reaches, are amenable to damming to create reservoirs for power generation and water supply. In general, the large reservoirs in this region serve distant populations, such as those of New York City, and many communities rely on ground water from these sources. While encompassing one third of the basin, only about 3% of the population lives in the Appalachian Plateau. The natural beauty, availability of water, and access to distant employment centers is increasing development here.

- Fall Line. The physical behavior of the Delaware River water system can be compared to that of a single pool. Changes in one region can affect circumstances in another. The replenishment of both surface and ground water basins is linked to weather and precipitation, soil and geology, human use and transport.

- Schuylkill–Lehigh Province. The Delaware River Basin lies in two different hydrologic regions which correspond to the two major physiographic divisions in the northeastern US: 1) the Appalachian Highlands and 2) the Coastal Plain. While physiographic provinces do not follow watershed boundaries, they help define the character of water and influence flows and flow regimes.

- Ridge and Valley Province. The Ridge and Valley province provides yields comparable to the Appalachian plateau. Water is abundant here, especially in glacial valleys, which are also vulnerable to pollution. The landforms, especially in the northern reaches, are amenable to damming to create reservoirs for power generation and water supply. In general, the large reservoirs in this region serve distant populations, such as those of New York City, and many communities rely on ground water from these sources. While encompassing one third of the basin, only about 3% of the population lives in the Appalachian Plateau. The natural beauty, availability of water, and access to distant employment centers is increasing development here.

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- Catskill Region. The Catskill Region includes four provinces each of which has distinctive geology, landforms, and hydrologic characteristics. The highest base flow yields are found in the Appalachian plateau where, even in times of drought, base flows may exceed those found in some upstream streams under normal conditions. Table 1.1. Water is abundant here, especially in glacial valleys, which are also vulnerable to pollution. The landforms, especially in the northern reaches, are amenable to damming to create reservoirs for power generation and water supply. In general, the large reservoirs in this region serve distant populations, such as those of New York City, and many communities rely on ground water from these sources. While encompassing one third of the basin, only about 3% of the population lives in the Appalachian Plateau. The natural beauty, availability of water, and access to distant employment centers is increasing development here.
A major test of any water management plan is to determine whether it is compatible with the hydrologic cycle and related natural systems of the Basin—patterns of precipitation, streamflow, dependence on surface and ground water, ground water recharge and storage.

Linda B. Tracy, May 1981

### New England

Underlain by hard rock, this province is one of extensively forested hills and ridges drained by a network of steep, rocky streams. Less than 5% of the basin has this type of landscape and less than 5% of the population lives here. Known as the Reading Prong in PA and the Highlands in NJ, this province has been declared a landscape of national significance for its forested habitats and biological diversity. In 2006 New Jersey enacted legislation to protect the Highlands as an area of statewide significance, especially for water resources. The USDA Forest Service has characterized the attributes of the Pennsylvanian formation, which cuts through the Lehigh (Central) and Schuylkill (Estuary) watersheds in Pennsylvania and the Central watersheds in New Jersey. Ground water recharge and storage is important because we use our waterways to assimilate waste water, and without minimum flows water quality will suffer.

### More About Flow

Flows in all provinces vary seasonally, and are also affected by diversions and withdrawals of water for human uses, movement of water and wastewater within and among watersheds, and development that alters runoff and recharge patterns. Both high flows and low flows are important. High flows are associated with seasonal conditions in spring, as well as precipitation events and flooding. Low flows are associated with seasonal conditions of early autumn and can be exacerbated by diversions and withdrawals for human use. Low flows are also important because we use our waterways to transport materials and without minimum flows water quality problems may occur.

### Flow Management

Although the Delaware River does not have a dam on its main stem, the flows of the River can be moderated to some extent through coordinated management of flows on reservoirs on the tributaries. A 1954 Supreme Court decree and subsequent modifications sanctioned the use of the reservoirs and the exports of up to 800 mgd of water to NYC and 100 mgd to New Jersey through the Delaware & Raritan Canal. Conditions of the decree also require the maintenance of minimum flows at Montague NJ (1,750 cfs) and at Trenton NJ (3,000 cfs). In periods of low flow, this is accomplished through the cooperative management of New York City’s water supply reservoirs in NY, several multipurpose reservoirs in PA, and a privately-owned reservoir in NJ.

Permanent storage capacity in tributary reservoirs totals over 410 billion gallons of which 68% is held in the three New York City water supply reservoirs in the Upper Basin. Of the 24 reservoirs in the basin, nine are dedicated for water supply, two generate hydroelectric power, three are solely for flood loss reduction, one is strictly for flow augmentation. Nine are dual or multi-purpose, providing water for a combination of water supply, flow augmentation, and flood loss reduction. Enhancement of fish and wildlife habitat, recreation, and conservation are additional benefits of many of these reservoirs.

Since the Delaware River is subject to tidal influence as far north as Trenton NJ, one purpose of the 3,000 cfs flow target at Trenton has historically been to maintain the salt line—where sub-tidal or near-surface waters, which have an average density of 14 parts per million (ppm)—at River Mile 1985, 98, safely downstream of intake for public supply.

### Reporting

Hydrologic indicators included in this report are:

- Flows at Trenton NJ
- Salt line location
- Water usage
- Water supply sources
- Areas of ground water stress
- Floods and flood damage

Each indicator supplies a look at one piece of the complex hydrologic puzzle. A feature on predicted changes to climatic conditions and the challenges they pose to water resource management concludes this section.
Reservoirs provide a means of maintaining minimum flows at target gages. During the period from 1980 to the construction of the last large reservoir in the Basin in 2007, the 3,000 cfs normal flow target at Trenton NJ has been maintained 95% of the time compared to 87.5% of the time for the period prior to reservoir construction (1913–1949). Occasions when the flow target is not met may be due to reductions in watershed baseflow, other land-based strategies are also necessary to maintain normal flow.
upstream reservoirs to augment flows and meet a daily flow target of 3,000 cfs at Trenton NJ. The program has worked well. Since 1970 low flows that once occurred 10% of the time now occur only 1% of the time. The salt line has been successfully repositioned below drinking water intakes, protecting drinking water supplies in the area.

**Actions and Needs**
- Investigation of additional sources of chlorides, such as from road salts and runoff, is warranted.
- Documented sea level rise and reporting of residential water use separately from other uses—such as commercial and industrial—within a public water system would provide for more accurate and comparable estimates of water use efficiency.

**Desired Condition**
- Very good: Drinking water intakes in the tidal River are effectively protected.
- Status:

**Water Use Efficiency**

- Per Capita Use: 133 gallons per capita per day (gpcd) and ranges from 90 to 190 gpcd.
- Regional differences among the sub-basins in Figure 1.8. The Schuylkill Valley subbasin shows the highest per capita use with a close to 200 gpcd.
- The basin average for consumptive use in public water distribution systems is approximately 10%.
- Pennsylvania DEP currently collects data in this manner. Achieving this across the basin would permit more realistic comparisons of water use efficiency.
Consumptive Use

736 million gallons of water exported for populations in New York City and northeastern New Jersey, which account for approximately 8% of the total amount of water withdrawals. A system of reservoirs in the Upper basin for water export to New York City and make compensating releases to maintain water temperatures and flows for wildlife and downstream uses. New Jersey exports water from the basin via the Delaware and Raritan canal.

Uses related to power generation dominate both basin and regional water use patterns. However, which sectors use the water may not be as important as the sheer volume of water used ensures a substantial water loss to the hydrologic system through evaporation. These plants are generally placed where drinking water supplies.

The key challenge is to manage actions and needs to a growing population while maintaining adequate instream flows to meet aquatic ecosytems needs of aquatic ecosytems are necessary for achieving the desired water supply goals.

The data suggest that in the past decade, basin-wide water use has remained fairly constant. An increase in population has been offset by a decline in industrial water use and benefits attributable to conservation. Reliable data on agricultural use are generally not available; a situation that hampers efforts to plan for reliable supplies for all sectors.

The dominant use sectors, in the basin and regionally, are shown in Figures 1.10 and 1.11.

Fig. 1.10. Daily Water Withdrawals, Exports and Consumptive Use in the Delaware River Basin

Fig. 1.11. Regional Water Withdrawals, Exports, and Consumptive Use

<table>
<thead>
<tr>
<th>Indicator Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>How water is used for potable supply and commerce is one indicator of the necessity and value of water to society. Accurate and comprehensive water use information enables the proper assessment, planning and management of water resources.</td>
<td>Good: Human needs are being met; conscious needs are being investigated for consideration in management options.</td>
</tr>
</tbody>
</table>

Total Lower and Bay Region

<table>
<thead>
<tr>
<th>Population using Delaware basin</th>
<th>Basin per capita water use</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 million people</td>
<td>133 gallons per day per person</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water exported out of basin</th>
<th>Water withdrawn for use in the basin</th>
<th>Water use in the basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>736 million gallons</td>
<td>45% of basin withdrawals</td>
<td>13% of regional withdrawals</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water in the basin</th>
<th>Water use in the basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>65% Domestic wells</td>
<td>10% Industrial</td>
</tr>
</tbody>
</table>

Population growth hotspots, especially in the Pocono and select bayshore watersheds, compel attention. Additional demand may compete with the need to maintain seasonal flows for aquatic life needs.

In groundwater-dependent areas where surface water is not an immediate option, additional planning for alternative sources, such as aquifer storage and recovery or beneficial reuse may be in order.
The source of potable water varies across the basin. As illustrated in Figure 1.12, 64% of potable water in the Basin is supplied from surface water sources and 36% from ground water, a portion of which is domestic supply. Domestic supply refers to private household wells, reliance on domestic wells varies greatly across the Basin.

The Upper region is particularly dependent on ground water (nearly 80%) and domestic wells specifically (43%). Supply sources vary within a region as well. Note that while 70% of the Eocene region relies on surface water to meet demand, the Bayshore region is totally dependent on ground water, 23% of which is from domestic wells.

Trend
Interconnections among public supply systems and the ability to use both ground and surface water to meet demand (conjunctive use) are measures of the capacity of the system to adapt to changing conditions; these can be depicted using a mix of sources.

Critical areas should be identified; multiple potable supply sources available in many, but not all, regions of the basin; some source protections in place.

The ability to draw from a mix of sources increases reliability, especially during times of drought.

The role of the New Jersey Coastal Plains Aquifer was made in part because more than 7 million coastal plain residents depend on this ground water to serve 75% or more of their drinking water needs.

Additional information on the adoption of wellhead protection programs should be collected and reported.

Further efforts for protection of locally-significant ground water supplies, especially areas served by community wells and domestic well clusters, should be encouraged and supported.

Additional supply sustainability indicators should be identified; measures of system interconnection and source water protection should be considered.

Water for drinking, industrial uses, irrigation and power supply can come from surface sources, such as rivers, streams, reservoirs, or from sources in the ground (aquifers). The ability to draw from a mix of sources increases reliability, especially during times of drought. Knowledge about water supply sources is important in planning for growth, for water supply and drainage, for water pollution, and for maintaining hydrologic integrity in watersheds.

An adequate and reliable supply of suitable quality water to sustain human and economic activities, and to maintain hydrologic integrity (RI P Goals 1, 1.2, 1.3, and 3.1).

Good: Multiple potable supply sources available in many, but not all, regions of the basin; some source protections in place.

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Trend
Interconnections among public supply systems and the ability to use both ground and surface water to meet demand (conjunctive use) are measures of supply sustainability. Supply needs to be protected from depletions withdrawals and from quality impairments that could impact the long term viability of the source. Source water protection can be accomplished in several ways and is especially important in areas dependent on ground water as a sole source of supply.

The Upper region is particularly dependent on ground water (nearly 80%) and domestic wells specifically (43%). Supply sources vary within a region as well. Note that while 70% of the Eocene region relies on surface water to meet demand, the Bayshore region is totally dependent on ground water, 23% of which is from domestic wells.

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and appear to be stabilizing in most parts of Critical Area #2. An example is shown in the hydrograph from USGS Elm Tree 3 observation well (Fig. 1.16), over 700 feet deep in the Middle PRM aquifer in Camden County NJ.

Additional Problem Areas in the Lower Estuary and Bay Region. PRM aquifer system extends under the Delaware River, through Delaware and into portions of Maryland. A 2007 draft report ... water model developed for northern New Castle County DE concluded that ground water withdrawals in Delaware are dimin-

Figure 1.16 illustrates how water levels at a USGS observation well in NJ Critical Area 2 have rebounded.

Category I - Hydrology

Trends

Since the creation of the protected areas, conjunctive use projects and regional alternatives have provided a measure of sustainability. However, depletive use in areas beyond these critical areas is emerging as a problem.

Airline and Needs

Comprehensive information on stream flow and ground water conditions in the PA-GWPA would enhance the ongoing analysis of this region.

A detailed study of projected demand, outstanding allocations and water availability are a necessary part of ongoing regional, state and basin-wide water supply planning efforts.
The Delaware River Basin Interstate Flood Mitigation Task Force (Task Force) developed a set of 45 consensus recommendations that address a wide variety of actions to improve conditions in the basin, including flood map modernization, improved regulations, and integrated watershed and floodplain management. These recommendations are available at www.drbc.net.

In addition to residential and commercial properties whose owners choose not to purchase flood insurance, much of our constructed infrastructure – including roads, bridges, canals and utility lines – suffer damages that are not captured in insurance claims. Much of our infrastructure was built before the advent of flood insurance and, in many cases, has no floodplain setbacks. Flood insurance claims data have been collected and used as an indicator of flood damage since the start of the Federal Emergency Management Agency (FEMA). National Flood Insurance Program (NFIP) flood damage records date back more than 60 years. NFIP provides federally backed flood insurance in communities that adopt and enforce floodplain management ordinances to help reduce future flood losses. Repetitive loss is a useful indicator of flooding as a recurring economic and environmental problem. Repetitive loss is applicable to a property that endures two or more losses of at least $1,000 each. The two losses must be within ten years of each other and at least 10 days apart. While insurance claims can provide a general picture of flood damage, within the basin they reflect only a fraction of the total cost of property damage caused by flooding. In addition to residential and commercial properties whose owners choose not to purchase flood insurance, much of our constructed infrastructure – including roads, bridges, canals and utility lines – suffer damages that are not captured in insurance claims or by insurance program records. Five types of criteria are used to identify repetitive losses, and to determine whether or not a property is a repetitive loss property. These criteria include:

- Prior to 2004, FEMA reported a total of 317 repetitive loss properties in the basin. Since then, over 1,070 repetitive loss properties have been reported. The density of claims reflects population, number of snow events, and the length of the snow melt period.

- Since 2004, FEMA and the Army Corps of Engineers have been collecting data on floodplain properties that endure repetitive losses. The two losses must be within ten years of each other and be at least 10 days apart. The two losses must be within ten years of each other and be at least 10 days apart. For more information on the Interstate Task Force and its activities, visit: www.state.nj.us/drbc/Flood_Website/taskforce.

- Snow pack, since snow melted by precipitation in areas covered by snow pack.

- The April 2005 flood also illustrated some of these challenges. Repetitive loss is applicable to a property that endures two or more losses of at least $1,000 each. The two losses must be within ten years of each other and at least 10 days apart. In addition to residential and commercial properties whose owners choose not to purchase flood insurance, much of our constructed infrastructure – including roads, bridges, canals and utility lines – suffer damages that are not captured in insurance claims or by insurance program records. Five types of criteria are used to identify repetitive losses, and to determine whether or not a property is a repetitive loss property. These criteria include:

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peak flows, which are now occurring about 7 to 14 days earlier than the long-term average, are expected to be occurring even earlier by the end of the century. While summer precipitation is not predicted to change dramatically, higher air and water temperatures could increase evaporation and reduce summer and autumn stream flows.

Increased droughts. Drought can be classified as short-term (1-3 months), medium-term (3-6 months), or long-term (more than 6 months) duration. The northeastern US typically experiences short-term droughts about once every 2-3 years and medium droughts every 10-15 years; but at 81% in all the countries in which climate change effects are generally positive, the Delmar basin, the most recent major drought lasted from 1961–1967, and is considered the record drought for planning purposes. Dry conditions have led to several times since the 1960s, notably in 1980-81, 1985, 1995, and 1999. More recently, portions of the basin experienced drought conditions in 2001–2002. Delaware has adopted 2022 as its planning drought of record. Under the more extreme climate change scenarios, droughts are expected to become more frequent, with short-term droughts potentially affecting areas of the Catskills and Adirondacks as often as once every year.

Precipitation: Impacts on Water Resources

Water supply. Shorter, wetter winters with reduced snowfall and earlier peak flows will affect the water management system of the basin. Snowpack is depended upon for spring flows to reservoirs and for recharge of groundwater. In the future, these flows will be reduced due to increased temperatures and earlier peak flows. In the frequency of drought would further stress the region’s water supplies and challenge current storage capacities.

Instream flows. Both reduction in flow and increases in extreme precipitation events pose threats to aquatic communities and to water quality. Extended periods of low flow may mean a reduction in the frequency of drought would further stress the region’s water supplies and challenge current storage capacities.

More frequent, flashier storms will have an impact on water quality. Runoff carries non-point source pollution and sediment loadings, and additional pollutants would be added as overburdened storm and wastewater systems add untreated flows to rivers and streams.

Instream flows. Both reduction in flow and increases in extreme precipitation events pose threats to aquatic communities and to water quality. Extended periods of low flow may mean a reduction in the assimilative capacity of streams and the likelihood of increased in pollutant concentrations. Procedures for the protection of aquatic life are in the future, these flows will be reduced due to increased temperatures and earlier peak flows. In the frequency of drought would further stress the region’s water supplies and challenge current storage capacities.

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Flooding. In the near term, increased storm severity in late winter/early spring will also cause increased seasonal flooding in the basin. These conditions are likely to compound over time. In the longer term, snow will be replaced by rain, and winter flooding could be more common. In tidal areas, more severe storms could bring higher waves and storm surges, increasing coastal flooding and beach erosion.

More intense precipitation events are likely to cause increased frequency and magnitude of floods. Areas of the basin already at risk for flooding may find that risk increased and new areas may be identified, with commensurate increases in damages to individual properties and to community infrastructure.

Sea Level Rise: Status and Trends

The effects of global climate change are especially important to Lower and Bay Regions of the basin. With its limited topography and generally low elevation, the coastal plain province is particularly vulnerable to increases in sea level. Many coastal areas are undergoing subsidence which exacerbates the effects of a rising sea elevation.

The trend in mean sea level at Lewes, DE from 1919 through 1999 (Fig. 1.20) showed an increase of 0.124 inches/year, the equivalent to one inch every eight years. The rate of increase at Philadelphia from 1919 through 1999 was 0.108 inches/year, or about one inch every nine years. This rate of increase is comparable to the national average from the Northeast US range from eight inches to three feet by the end of the century. Rising sea level is a principal driver leading to the erosion of costal areas and increased erosion rates.

An increase of one inch every eight to nine years will have significant impacts on coastal areas and communities. Many coastal areas are undergoing subsidence which will exacerbate the effects of a rising sea elevation.

Sea Level Rise: Impacts on Water Resources

Increased salinity. It is projected that salinity will increase as a result of increasing temperatures and the intrusion of saltwater into fresh water resources. Increased salinity could threaten water supplies for public, industrial, and agricultural use, and saltwater intrusion in the tidal wetlands. In the Delaware estuary, freshwater flows from the river and streams naturally buffer against salinity incursions into fresh water. Sea level rise coupled with higher water temperatures will alter the balance of freshwater inflow from the river and streams naturally buffer against salinity incursions into fresh water. Sea level rise coupled with higher water temperatures will alter the balance of freshwater inflow.

Exposure, flooding and habitats. Sea level rise is slowly inundating low lying areas along coastlines, causing significant erosion of beaches. In Salem County NJ, some bay beaches are currently fully submerged and at high tide, and further sea level rise could leave them at low tide. Over time, a measurable loss of wetlands is predicted, especially where existing tidal marshes are between a rising tide and the hard, impenetrable edges of development. Wetland loss puts human settlements at risk. Loss of beaches and wetlands means that buildings and infrastructure take more insults from coastal storms. This is illustrated in Fig. 1.21. As human populations near the coast expand, more of these low lying areas are threatened by the rise of sea level and rising water temperatures.

Increased ambient air temperatures will increase water temperature, compromising its ability to hold dissolved oxygen in solution. Temperature also affects the ability of water to assimilate some pollutants and may cause violations of water quality criteria. Areas that are densely populated with significant areas of rooftops, are adjacent to industrial emissions are vulnerable to even greater localized temperature increases and exacerbated impacts on water resources.

Temperature impacts on water resources

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The current mix, distribution, and abundance of forests are likely to be altered by rising temperatures. Evergreen forests, because of their current temperature regimes, will be especially vulnerable to replacement by deciduous species better adapted to warmer weather. Warmer temperatures tend to accelerate parasites and diseases that attack vulnerable species, warmer temperatures may play a role in the proliferation of woody adelgid that attack hemlock forests. Major changes to forest cover can be expected to affect water resources.

There are numerous other impacts expected with increased temperatures, including human health effects from heat stress, worsening air quality, and infectious diseases; economic shortfalls from the loss of winter recreation and tourism; increased energy demand for cooling; and impacts on agricultural production, plant and animal life cycles and species that are affected by changes in migration patterns.

Costs to replace infrastructure can be expected to reach tens of millions of dollars. Wastewater treatment plants are at risk as drinking water infrastructure. Ice caps are threatened and hosts of valuable thermal waters may be lost. Climate warming and vegetative land cover and vegetation have been documented across the region.

The Northeast US has experienced a warming trend over the past century of about 1.8°F since 1899. Since 1970 the region has warmed at a rate of 0.5°F per decade, with winter temperatures warming at the more rapid rate of 1°F per decade. We have experienced more extreme weather events where temperatures surpassed 90F and weekly temperatures below 3°F, and more snow in winter than months with a moderately increase in December. A warmer world will lead to a reduction in snowpack. Earlier spring snowmelt and vegetation blooms have also been documented across the region.

Some predictions indicate that by 2040–2050 annual mean temperatures for the Delaware River basin will range between 2.5°F and 8.7°F warmer than experienced between 1971 and 2000. While the range of estimates depends on the degree to which greenhouse gas emissions are curbed, increased temperatures are expected to rise to 2.5°F to 4°F in winter and 1.9°F to 3.7°F in summer regardless of any emissions reduction, simply because of residual concentrations of greenhouse gases in the atmosphere.

Temperatures in the northeastern US have increased by about 1°F since 1899. Since 1970 the region has warmed at a rate of 0.5°F per decade, with winter temperatures warming at the more rapid rate of 1°F per decade. We have experienced more extreme weather events where temperatures surpassed 90°F and weekly temperatures below 3°F, and more snow in winter than months with a moderately increase in December. A warmer world will lead to a reduction in snowpack. Earlier spring snowmelt and vegetation blooms have also been documented across the region.

Changes can lead to the inundation or loss of wetlands, increased impacts and deteriorating of existing water supply infrastructure is needed; current and future planning initiatives must address the reality of a changing climate.

To predict the impacts of sea level rise on our wetlands, improved mapping and knowledge of land use at wetlands margins is necessary. The true extent of dead, inactive, and other barriers to wetland movement is necessary for the realistic development of policy alternatives.

Groundwater monitoring may be warranted to ensure tracking of saltwater intrusion.

Several state and local initiatives are currently investigating the effects of climate change on the basin. The New York City Department of Environmental Protection is involved in studies that examine the effects of climate change on the quality and sustainability of its water supply, and the Partnership for the Delaware Estuary was recently awarded a grant from the EPA to look at how climate change, specifically sea level rise, will affect the estuary. DBRC has a project with EPA to assess climate change impacts on Delaware’s coastal habitats. New York, water supply intakes and oyster populations in the estuary. EPA is actively supporting efforts to identify and reduce vulnerability to climate variability and change.

Infrastructure considerations.

Rising sea level will cause problems for infrastructure. Sea level rise could become vulnerable to flooding during storm events, and eventually be permanently inundated. Storm sewers in coastal areas will carry wastewater onto town streets, rather than into rivers. Many local water districts have experienced this already. Higher sea level will also reveal lower bridges too low for the safe passage of barge traffic. Costs to replace infrastructure can be expected to reach tens of millions of dollars.

Increased precipitation events are likely to cause increased frequency and magnitude of floods. Areas of the basin already at risk for flooding may find that risk increased and new areas may be identified, with commensurate increases in damages to individual properties and to community infrastructure.

Economic impacts. The trend in mean sea level at Lewes, DE from 1919 through 1999 (Fig. 1.20) shows an increase of 0.124 inches/year, the equivalent to one inch every eight years. The rate of increase at Philadelphia from 1919 through 1999 was 0.108 inches/year, or about one inch every nine years. This rate of increase is comparable to the national average from the Northeast US range.

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The quality of our water resources is critically linked to the demand for water of great value for drinking and for industrial use, especially the contamination of springs, wells and streams that served as local sources of drinking water. The first pollution survey, conducted in 1799, noted a variety of sources in the Philadelphia harbor area, including ships, wharves, polluted wetlands, and various urban activities. Tanneries and slaughterhouses were already recognized sources of water quality problems.

Franklin’s work led to a Sabbath. Whether the Delaware River system in 1609, water quality was preserved-ably pristine. However, by the early 18th century water pollution was recognized, especially the contamination of springs, wells and streams that served as local sources of drinking water. The first pollution survey, conducted in 1799, noted a variety of sources in the Philadelphia harbor area, including ships, wharves, polluted wetlands, and various urban activities. Tanneries and slaughterhouses were already recognized sources of water quality problems.

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the early 21st century. Public health is still a focus. The concentration of toxic substances, notably mercury and PCBs, in some species of fish is responsible for consumption advisories in all of the basin states. Waterborne diseases used to be far less a threat than they once were, but the rinse too small to be captured by typical mainstream processes remain a potential peril.

Dissolved oxygen (DO) remains a paramount concern. In 1973 US EPA suggested that fishable water quality standards were unattainable in portions of the Delaware, but assessments since have shown that improvements in dissolved oxygen concentrations are possible, and actual levels of dissolved oxygen in populations are far from proof. The most recent monitoring in the estuary region, however, indicates that progress may be slowly eroding and new initiatives may be necessary to maintain and improve DO levels.

Several toxic substances, such as metals and PCBs, are being addressed through discharge requirements, state and federal site remediation programs, TMDLs and pollution minimization plans. The elimination of phosphorus from dewatering contributes to improvements in DO, but nutrient reduction criteria—and strategies to achieve them—remain elusive as we continue to grapple with contributions from point and nonpoint sources, and the specter of increasing wet-weather loadings and temperatures under changing climatic conditions.

New substances are emerging as indicators of concern. In addition to neurological impairment and cancer, our concerns extend to the potential for multi-generational and reproductive effects of new compounds on humans and wildlife.

**WATER QUALITY**

**Category II**

**STATE OF THE DELAWARE RIVER BASIN REPORT 2008**

**NH3**

Nutrients (Nitrogen (TN) and Total Phosphorus (TP)) are critical to the growth of aquatic life. An oversupply of nutrients can lead to excessive plant and algal growth, causing serious—sometimes disastrous—aspects of ecological health and specific water quality problems such as Low Dissolved Oxygen (DO). Whether or not a water body exhibits the negative effects of excessive nutrients is controlled by many other factors: water clarity; temperature; the availability of trace nutrients like silica; and the presence or absence of toxic substances. Because of this, water quality criteria for nutrients can be very different from one stream to another. Despite years of monitoring in the Delaware, the states and DRBC are currently working to determine what concentrations of TN and TP will protect the aquatic resources in the Delaware River Basin, and the appropriate water quality criteria to protect these resources.

**Desired Condition**

Although specific criteria have not been set, nutrients are managed to support aquatic life and DO criteria (BP Goal 1.2, CCMP Action W12). The states and DRBC continue to monitor nutrient concentrations in the Delaware River, and efforts to reduce nutrient inputs from point sources are ongoing. Nutrient concentrations have not resulted in the typical symptoms of excessive nutrients, it is difficult to determine whether the current concentrations are at a level that warrants regulatory control. However, measurements of low DO concentrations raise concerns about nutrients or other pollutants in those areas (see the discussion of DO on the next page).

**Trends**

Data from stations in the Delaware River near the Philadelphia Airport show a very large decrease in phosphorus was observed in 1995. New TMDLs and pollution minimization plans are being developed to address this issue. Levels of TN in the Delaware River and estuary tend to be roughly 10 to 20 times higher than levels of TP. Concentrations of TN are lowest in the headwaters of the Delaware River and increase downstream. Nutrient concentrations peak near the midpoint of the estuary and then decrease again toward the mouth of the Bay (Fig. 2.1). Since the current concentrations of nutrients have not resulted in the typical symptoms of excessive nutrients, it is difficult to determine whether the current concentrations are at a level that warrants regulatory control. However, measurements of low DO concentrations raise concerns about nutrients or other pollutants in those areas (see the discussion of DO on the next page).

**Actions and Needs**

Efforts to continue to monitor and continue to define the relationships between nutrients, water clarity, algal growth, DO, and ecological health and determine nutrient levels that will protect water resources and prevent the harmful effects on aquatic communities.
indicator: dissolved oxygen

**Indicator Description**

Dissolved oxygen (DO) in surface water is one of the most basic and important measures of the health of a waterbody, affecting a wide array of aquatic plants and animals. Low DO has both chronic (long term) and acute (immediate) impacts, ranging from shifts in biological communities to fish kills and disappearance of fish migration. Oxygen enters water at the water surface and through photosynthesis of aquatic plants and algae. Plants and animals also require, utilizing some of this oxygen. DO can become too low to support healthy aquatic communities when concentrations of oxygen-demanding pollutants are too high and/or when high concentrations of nutrients like nitrogen and phosphorus cause excessive plant growth. When the excess plants die and decompose, they use DO in the water.

**Desired Condition**

Dissolved oxygen levels should meet standards supportive of aquatic life (BP Goal 1.3, COMP Action W12). State criteria ... mg/L. DRBC criteria apply to shared waters of the river and estuary and vary by Water Quality Zone, from 3.5 to 6.0 mg/L.

**Trends**

With the water quality improvements to waste treatment in the mid-1980s, the Delaware River and tributaries have been able to maintain DO concentrations that support aquatic life and meet state and DRBC criteria. Figure 2.4 illustrates the increase in dissolved oxygen concentration at the Ben Franklin Bridge since the 1960s. The noticeable change during the 1980s was the direct result of discharge regulations and waste treatment improvements. Before this time much of the tidal river had DO criteria that frequently violated minimum DO criteria. Figure 2.5 shows the number of days criteria has been violated at stations with continuous gages since 1970. Improvements in DO concentrations in the mainstem river have supported the return of shad and other important fisheries to the basin.

**Actions and Needs**

- Because DO tends to be higher in the daytime (when aquatic plants are photosynthesizing) and lower at night, it is important to measure DO around the clock with continuous monitoring stations, to be sure that DO levels are not unhealthy.
- Without continuous monitoring on the tributaries, data reflect intermittent sampling, and only median values can be compared to the criteria, which is usually a minimum value to protect aquatic resources.
they provide sediments to help tidal marshes keep pace with sea level rise, and some suspended particles such as phytoplankton are important foods for animals such as manatees and oysters. In disturbed systems, however, suspended solids and phytoplankton often become overly concentrated and out of balance with natural processes. Therefore, these three measurements provide some indication of both the ecological status and overall health of the river system, especially as it relates to eutrophication (over fertilization).

Many estuaries have an area of elevated turbidity and solids, known as an estuary turbidity maximum (ETM). The ETM is a natural consequence of the chemical and hydraulic processes that control the physical and chemical attributes of estuarine waters. Estuaries in the northeastern United States do not have water quality standards for TSS in streams; New Jersey has set a maximum TSS level of 40 mg/l for warm water streams and 20 mg/l for cold water streams. The DRBC has adopted a TSS maximum of 150 mg/l for the tidal Delaware River. Negative effects from suspended solids and nutrients usually result in impacts to dissolved oxygen.

**Total Suspended Solids (TSS)**
- **Indicator Description**: Total Suspended Solid (TSS), turbidity, and chlorophyll-a are three distinct but related indicators that all pertain to the amount of particulates suspended in water that influence water clarity. TSS is a measure of the total amount of particulate solids per unit volume of water. These solids include living, non-living, organic, and inorganic particles. Turbidity is an optical property of water where particles and colloidal matter from living and non-living sources cause light to scatter, rather than pass through the water column. Excessive turbidity can impair bottom plants by filtering out sunlight needed for photosynthesis. Finally, chlorophyll-a is a photosynthetic pigment found in plants such as phyto-plankton. When measured in surface water, chlorophyll-a provides an indication of how much phytoplankton is in the water.

**Monitoring**
- **TSS values range from 1 or 2 mg/L to more than 60 mg/L (Fig. 2.7). Turbidity is typically between 1 and 4 turbidity units, but will hover the maximum 150 unit criteria (Fig. 2.8). Chlorophyll-a concentrations usually range from below detectable levels to 30 ug/L (Fig. 2.9). In some estuaries, efforts to control eutrophication include surface water standards for chlorophyll-a, as a water clarity indicator of effectiveness of strategies to control excess nutrients. Currently, DRBC does not have criteria for either TSS or chlorophyll-a in surface water, but could consider developing criteria as part of a broader nutrient strategy.

**Desired condition**
- Protection of aquatic life (BP Goals 1.2, 1.3, and 1.4; CACPM Action WI-2).

**Trends**
- Because TSS, turbidity, and chlorophyll-a concentrations change with location, tidal and freshwater flows, temperature and season, identifying specific trends in concentrations is very difficult. Overall, these indicators appear to be stable throughout the period from 1990 through 2005.

**Actions and Needs**
- The regional science and management community will need to continue efforts to define relationships among nutrient concentra-

**Water Quality**
- **WATER QUALITY**

![](http://www.water.ncsu.edu/watersheds/info/turbid.html)
Marine waters, chronic: 9.0 μg/L, Freshwater, chronic: 9.0 μg/L, Freshwater, acute: 13 μg/L

The amount of contaminants fish accumulate depends on the species, size, age, sex, and feeding area of the fish. Generally, older and larger individual fish have accumulated the most contaminants, although in some cases contaminants are shed each time the fish spawn. Since fish accumulate many contaminants in their fatty tissues, certain species with higher oil content can pose more risk than others when both inhabit polluted areas.

The term Bioaccumulation refers to the uptake and retention of a chemical from an organism by all surrounding media (e.g., water, food, sediment).

**Marine waters, chronic:** 4.8 μg/L. However, DRBC’s fresh water criteria are based on water hardness in the Delaware River. The two most common pollutants to cause advisories in the Delaware River Basin are mercury and polychlorinated biphenyls (PCBs), which both bioaccumulate in the aquatic ecosystem. Eating fish that contain these harmful substances is the principal way to be exposed to these chemicals. Therefore, fish consumption advisories are an important tool to help protect public health and to identify areas where further management of pollution may be needed.

Fig. 2.11 Copper Monitoring Sites

**Desired Condition**

Concentrations in water and sediment that do not pose a threat to aquatic life (BP Goal 1.3; CCMP Actions T1-T5).

**Trends**

Dissolved copper concentrations have remained steady.

**Actions and Needs**

- Increased monitoring of copper and other metals is necessary for improved assessment capability, especially river miles 48 to 68.

- Coordination of monitoring among agencies should ensure the use of same algorithms and procedures as well as harmonization of assessment methodologies.

- The Biotic Ligand Model (BLM), developed to improve the prediction of metal bioavailability and toxicity, is currently recommended for use in fresh water.

- Freshwater Chronic Aquatic Life Criterion: 9.0 μg/L

- Freshwater, chronic: 9.0 μg/L, Freshwater, acute: 13 μg/L

- A biotic ligand model (BLM) is used by each state to inform the public when locally-caught fish are not safe to eat due to known levels of contamination. The advisories are either limiting or prohibiting the consumption of certain fish from specific water bodies. The two most common pollutants that cause advisories in the Delaware River Basin are mercury and polychlorinated biphenyls (PCBs), which both bioaccumulate in the aquatic ecosystem. Early detection of these harmful substances is the primary way to be exposed to these chemicals. Therefore, fish consumption advisories are an important tool to help protect public health and to identify areas where further management of pollution may be needed.

**Desired Condition**

Fish and shellfish that are safe to eat; a systematic and coordinated approach to assessing and communicating the results of fish and shellfish consumption data (BP Objective 4.1 D. CCMP Action T6).

**Status**

Fair: Dissolved copper concentrations are below or near water quality criteria.

**Indications:**

Dissolved copper concentrations are below or near water quality criteria.

**Figure 2.10** shows concentrations of copper at sites in the tidal Delaware River (Fig. 2.11). Assessment in coastal areas transitioning from fresh to marine waters is complicated by the impact of tides on the toxicity of copper to aquatic life. DRBC has aquatic life objectives for dissolved copper similar to the following EPA criteria: Concentrations in water and sediment that do not pose a threat to aquatic life (BP Goal 1.3; CCMP Actions T1-T5).

**Desired Condition**

Concentrations in water and sediment that do not pose a threat to aquatic life (BP Goal 1.3; CCMP Actions T1-T5).

**Trends**

Dissolved copper concentrations have remained steady.

**Actions and Needs**

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**Status**

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**Indications:**

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**Desired Condition**

Concentrations in water and sediment that do not pose a threat to aquatic life (BP Goal 1.3; CCMP Actions T1-T5).

**Trends**

Dissolved copper concentrations have remained steady.

**Actions and Needs**

- Increased monitoring of copper and other metals is necessary for improved assessment capability, especially river miles 48 to 68.

- Coordination of monitoring among agencies should ensure the use of same algorithms and procedures as well as harmonization of assessment methodologies.

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**Desired Condition**

Concentrations in water and sediment that do not pose a threat to aquatic life (BP Goal 1.3; CCMP Actions T1-T5).

**Trends**

Dissolved copper concentrations have remained steady.

**Actions and Needs**

- Increased monitoring of copper and other metals is necessary for improved assessment capability, especially river miles 48 to 68.

- Coordination of monitoring among agencies should ensure the use of same algorithms and procedures as well as harmonization of assessment methodologies.

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**Desired Condition**

Fish and shellfish that are safe to eat; a systematic and coordinated approach to assessing and communicating the results of fish and shellfish consumption data (BP Objective 4.1 D. CCMP Action T6).

**Status**

Fair: Dissolved copper concentrations are below or near water quality criteria.

**Indications:**

Dissolved copper concentrations are below or near water quality criteria.

**Figure 2.10** shows concentrations of copper at sites in the tidal Delaware River (Fig. 2.11). Assessment in coastal areas transitioning from fresh to marine waters is complicated by the impact of tides on the toxicity of copper to aquatic life. DRBC has aquatic life objectives for dissolved copper similar to the following EPA criteria: Concentrations in water and sediment that do not pose a threat to aquatic life (BP Goal 1.3; CCMP Actions T1-T5).

**Desired Condition**

Concentrations in water and sediment that do not pose a threat to aquatic life (BP Goal 1.3; CCMP Actions T1-T5).

**Trends**

Dissolved copper concentrations have remained steady.

**Actions and Needs**

- Increased monitoring of copper and other metals is necessary for improved assessment capability, especially river miles 48 to 68.

- Coordination of monitoring among agencies should ensure the use of same algorithms and procedures as well as harmonization of assessment methodologies.

- The Biotic Ligand Model (BLM), developed to improve the prediction of metal bioavailability and toxicity, is currently recommended for use in fresh water.

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**Desired Condition**

Fish and shellfish that are safe to eat; a systematic and coordinated approach to assessing and communicating the results of fish and shellfish consumption data (BP Objective 4.1 D. CCMP Action T6).

**Status**

Fair: Dissolved copper concentrations are below or near water quality criteria.

**Indications:**

Dissolved copper concentrations are below or near water quality criteria.
**Indicator • Pesticides**

**Toxicity:** Metolachlor and atrazine are among the pesticides most frequently detected in ground water and surface water by the USGS NAWQA Program and the USEPA National Survey of Pesticides in Drinking Waters. Both are designed to persist in soil for several months during the growing season for continuous weed control. However, both pesticides are water soluble, allowing the toxins to mobilize and pollute streams and ground water. Atrazine is registered with the EPA as a Restricted Use Pesticide; it is classified as toxic to aquatic life, especially aquatic plants. It is a known human carcinogen, ground water contaminant, and a suspected endocrine disruptor. Atrazine is used primarily to control weeds on agricultural fields for crops such as corn and evergreen tree farms—especially for conservation tillage or “no-till” farming—and along highways for non-selective vegetation control. Metolachlor is of low toxicity to humans but slightly to moderately toxic to some aquatic life. It is classified as a possible human carcinogen based on studies in rats and it may also cause developmental impairment. Metolachlor is primarily used for weed control in the production of corn, soybean, and woody ornamentals. It is sometimes used in formulations with other pesticides such as atrazine, cyanazine, and butyracate.

**Desired condition:** Detection in ground and surface water supplies at concentrations below limits suspected of causing health effects on humans and wildlife (BPH Goals 1, 2, 3, COMP Atrazine T-75). The EPA recommended level for Atrazine is 0.1 μg/L and for Metolachlor is 0.05 μg/L. The World Health Organization (WHO) guidance is 2 ppb. EPA does not currently have a recommended concentration for Metolachlor, but WHO guidance is 10 ppb.

**Status:** Fair: Pesticides prevalent, but in low concentrations. The percentage of sampling sites with detected concentrations of atrazine was higher than that of metolachlor for both surface and ground water, indicating that atrazine contributes more to contamination than metolachlor (Fig 2.13, 2.14). In the basin, atrazine was detected in 95% and Metolachlor in 87% of surface waters sampled. In ground water, atrazine was detected in 64% of samples, and metolachlor in 31% of samples. The median concentration of atrazine in surface waters was almost 0.05 μg/L for urban waterbodies and 0.12 μg/L for agricultural waterbodies. Surface water concentrations are higher in runoff from agricultural fields, especially following major runoff events occurring within a few weeks of application. Ground water concentrations are expected to be highest in areas with a long history of agricultural land use, especially corn crops, and where surface and ground water systems are connected sufficiently to allow infiltration. Concentrations of atrazine and metolachlor break down into degradation products that are detected at frequencies lower than parent compounds, which is the reason for more frequent and less frequent analyses. Table 2.1 contains a list of pesticide compounds and their degradates. Metolachlor is regulated with the EPA as a Restricted Use Pesticide; it is classified as toxic to aquatic life, especially aquatic plants. It is a known human carcinogen, ground water contaminant, and a suspected endocrine disruptor. Atrazine is used primarily to control weeds on agricultural fields for crops such as corn and evergreen tree farms—especially for conservation tillage or “no-till” farming—and along highways for non-selective vegetation control. Metolachlor is of low toxicity to humans but slightly to moderately toxic to some aquatic life. It is classified as a possible human carcinogen based on studies in rats and it may also cause developmental impairment. Metolachlor is primarily used for weed control in the production of corn, soybean, and woody ornamentals. It is sometimes used in formulations with other pesticides such as atrazine, cyanazine, and butyracate.

### Table 2.1 Atrazine and Metolachlor Concentrations

<table>
<thead>
<tr>
<th>Subwatershed</th>
<th>Atrazine</th>
<th>Metolachlor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Region (NY and PA)</td>
<td>0.020</td>
<td>0.020</td>
</tr>
<tr>
<td>EW2 East Branch (Pepacton)</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>EW3 West Branch (Cannonsville)</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>LW1 Lackawaxen</td>
<td>0.005</td>
<td>0.002</td>
</tr>
<tr>
<td>LW2 Hawkeye</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Central Region (PA and NJ)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LC1 Lower Central (below Trenton)</td>
<td>0.056</td>
<td>0.023</td>
</tr>
<tr>
<td>LC2 New Jersey tributaries</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>LC3 New Jersey tributaries</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>LC4 Lehigh River above Lehigh</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>LC5 Lehigh River below Lehigh</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>LC6 C and D Canal, DE</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Lower Region (PA, NJ and DE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LE1 Christina River</td>
<td>0.158</td>
<td>0.045</td>
</tr>
<tr>
<td>LE2 C and D Canal, DE</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>LE3 Swimming Valley Fork</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>LE4 Lehigh River above Lehigh</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>LE5 Lehigh River below Lehigh</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

**Additional information:**

- The percentage of sampling sites with detected concentrations of atrazine was higher than that of metolachlor for both surface and ground water, indicating that atrazine contributes more to contamination than metolachlor (Fig 2.13, 2.14). In the basin, atrazine was detected in 95% and Metolachlor in 87% of surface waters sampled. In ground water, atrazine was detected in 64% of samples, and metolachlor in 31% of samples.
- The median concentration of atrazine in surface waters was almost 0.05 μg/L for urban waterbodies and 0.12 μg/L for agricultural waterbodies. Surface water concentrations are higher in runoff from agricultural fields, especially following major runoff events occurring within a few weeks of application.
- Ground water concentrations are expected to be highest in areas with a long history of agricultural land use, especially corn crops, and where surface and ground water systems are connected sufficiently to allow infiltration.
- Concentrations of atrazine and metolachlor break down into degradation products that are detected at frequencies lower than parent compounds, which is the reason for more frequent and less frequent analyses.
- Table 2.1 contains a list of pesticide compounds and their degradates.

**Concentration of pesticides in surface waters:**

The percentage of sampling sites with detected concentrations of atrazine was higher than that of metolachlor for both surface and ground water, indicating that atrazine contributes more to contamination than metolachlor (Fig 2.13, 2.14). In the basin, atrazine was detected in 95% and Metolachlor in 87% of surface waters sampled. In ground water, atrazine was detected in 64% of samples, and metolachlor in 31% of samples. The median concentration of atrazine in surface waters was almost 0.05 μg/L for urban waterbodies and 0.12 μg/L for agricultural waterbodies. Surface water concentrations are higher in runoff from agricultural fields, especially following major runoff events occurring within a few weeks of application. Ground water concentrations are expected to be highest in areas with a long history of agricultural land use, especially corn crops, and where surface and ground water systems are connected sufficiently to allow infiltration.

**Concentrations of atrazine and metolachlor generally were lowest in the Upper Region (NY and PA).**
The Lower Schuylkill is a major contributor of PCBs in the Delaware Estuary. This photo taken in 1999 at Bartram’s Gardens shows the heavy industrial area along the Schuylkill just above its confluence with the Delaware.

PCBs are toxic compounds shown to cause cancer in animals and serious non- cancer health effects to the immune, reproductive, nervous, and endocrine systems. Studies provide supportive evidence for potential carcinogenic and non-carcinogenic effects in humans as well. PCBs persist in the environment for long periods of time because they bond strongly to soil and sediments and bioaccumulate. (See p. 57 for a definition) in fish and wildlife.

Invented in 1927, PCBs are mixtures of synthetic organic chemicals with the same basic chemical structure and similar physical properties ranging from oily liquids to waxy solids. Due to their non-flammability, chemical stability, high boiling point and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including electrical, heat transfer, and hydraulic equipment, as placemats in paints, plastic and rubber products; in pigments, dyes and carbonless copy paper and many other applications. Based on the evidence that PCBs are persistent in the environment and can cause harmful health effects, the Toxic Substances Control Act (TSCA) of 1976 prohibited the manufacture, processing, and distribution of PCBs.

The Delaware River is to reduce PCB loadings and eliminate consumption advisories based on this contaminant. The first stage is a non-numeric approach, all point sources are required to conduct monitoring and 42 dischargers are required to submit a Pollution Minimization Plan (PMP). This plan identifies all known and potential sources of PCBs on their property, and outlines a procedure to find all unknown sources and implement strategies for minimizing and preventing releases from all identified sources. The permits must also document measured progress this effort in an annual report to DRBC.

**Desired Condition**

PCB concentrations in water, sediment, and fish tissue that are designed to protect human health and the environment (BP Grades A, 1, 2, 3, CCMP Actions T1-T5). Those include the following numeric criteria:

- drinking water: 500 ppt (EPA)
- ambient water for aquatic life protection: 0.074 ppm (EPA-Great Lakes Initiative)
- ambient water to protect human health: 0.016 ppm (DRBC-proposed)

**Status**

Four PCBs are present in the Basin’s water, sediment and fish tissue.

**Trend**

Periodic analysis of PCBs has been conducted by DRBC as part of the development of the Total Maximum Daily Load (TMDL) for Zones 2 & 6. As illustrated in Figure 2.15, the current sources of PCBs to the tidal river are non-point sources accounting for 25% of loadings and point sources contributing 18%. The non-tidal river above Trenton, the Schuylkill River and other tributaries to the tidal river contribute about 34%. Contaminated sites contributed 11% of the total.

This information with a focus on sites of unknown status.

**Future DeITRiP reports will update**

**Fig. 2.16**

**Trends**

Despite the ban on PCB manufacture in 1979, PCBs still persist in landfills, streamsides, sedimentary sediments, and some closed electrical systems. They remain a ubiquitous legacy pollutant in much of the basin, but concentrations vary greatly, and there is evidence that concentrations in fish tissue is decreasing (Figure 2.17). The goal of the TMDL for the tidal Delaware River is to reduce PCB loadings and eliminate consumption advisories based on this contaminant. The first stage is a non-numeric approach, all point sources are required to conduct monitoring and 42 dischargers are required to submit a Pollution Minimization Plan (PMP). This plan identifies all known and potential sources of PCBs on their property, and outlines a procedure to find all unknown sources and implement strategies for minimizing and preventing releases from all identified sources. The permits must also document measured progress this effort in an annual report to DRBC. The Lower Schuylkill is a major contributor of PCBs in the Delaware Estuary. This photo taken in 1979 at Bartram’s Gardens shows the heavy industrial zone along the Schuylkill below to confluence with the Delaware.
Although many years of data are available, 1990 was selected as the beginning year for trend analysis to exclude water quality improvements related to the wastewater infrastructure investments of the 1980s.

### Indicator • Support of Designated Use: Tributaries

**Fig. 2.18**

This indicator reports conditions on tributaries relative to their designated uses. Each state independently identifies uses for each waterbody, support their designated uses per the federal Clean Water Act (BP Goals 1.2, 1.3, 1.4; CCMP Action W12).

**Table 2.3 Trends in Water Quality of Selected Tributary Streams**

<table>
<thead>
<tr>
<th>Stream Name</th>
<th>Data Year</th>
<th>Total Miles</th>
<th>W/o Consum.</th>
<th>% of Total</th>
<th>% of Total Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schuylkill River at Berne, PA</td>
<td>2006</td>
<td>10.1</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Neshaminy Cr. at Langhorne, PA</td>
<td>2006</td>
<td>7.1</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Delaware River at Pt. Jervis, NY</td>
<td>2006</td>
<td>7.2</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Brandywine R. above Wilmington, DE</td>
<td>2006</td>
<td>12.0</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Brandywine R. above Haddonfield, NJ</td>
<td>2006</td>
<td>9.5</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Leipsic River at Route 13, DE</td>
<td>2006</td>
<td>8.2</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Lackawaxen R. at Lackawaxen, PA</td>
<td>2006</td>
<td>12.6</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Delaware River at Stockton, NJ</td>
<td>2006</td>
<td>6.1</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Delaware River at Fries Mill, NY</td>
<td>2005</td>
<td>0.6</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Delaware River at Conococheague, NY</td>
<td>2005</td>
<td>0.2</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Delaware River at Shrewsbury, NJ</td>
<td>2005</td>
<td>0.1</td>
<td></td>
<td>83%</td>
<td></td>
</tr>
</tbody>
</table>

**Legend**

- Constant
- Improving
- Deteriorating

**Table 2.2 Unattaining 303(d) Listed Streams**

<table>
<thead>
<tr>
<th>State</th>
<th>Total Data Year</th>
<th>Total Mileage</th>
<th>Data Year</th>
<th>% of Total</th>
<th>% of Total Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE</td>
<td>Total 2002</td>
<td>2,480</td>
<td></td>
<td>569</td>
<td>23%</td>
</tr>
<tr>
<td>NJ</td>
<td>Total 2006</td>
<td>6,975</td>
<td></td>
<td>5,786</td>
<td>83%</td>
</tr>
<tr>
<td>NY</td>
<td>Total 2006</td>
<td>4,197</td>
<td></td>
<td>81</td>
<td>2%</td>
</tr>
<tr>
<td>PA</td>
<td>Total 2006</td>
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<td>WV</td>
<td>Total 2006</td>
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<td>2,424</td>
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**Category II • Water Quality**

- 303(d) Listed Streams
- 303(c) Listed Streams
- Watershed Monitoring
- Water Quality Improvement

**Fig. 2.19**

Laurel and Boyce Water Quality Stations

**Categories**

- Lower and Bay Regions: Fair
- While good to fair, it is decreasing at 31 of 61 stations. N, while constant, is higher than the moderate target (2.0 mg/L) at half the stations, and phosphorus is constant but above 0.1 mg/L at 8 of 11 stations. TSS is high, but improving, on the Smyrna River (L2E) (Table 2.3).

**Actions and Needs**

- Annual monitoring is needed: at least one station in each region had insufficient periods of record for one or more parameters.
- Metals data were generally not sufficient to assess baseflow, but clearwaters, lower Lehigh station (L5) where it is slightly degraded, but improving. Water quality in the lower Lehigh appears to be degrading since 1990 with respect to N and TSS (Table 2.3).
Shellfishing Zone 6 is based on periodic pathogen exceedences. In most instances, the contaminants are PCBs and mercury. New York did not issue any fish advisories and the designated uses assessed listed for the reservoirs feeding the Delaware River. Recently compiled toxics data from fish tissue collected in 2004 and 2005 also support fish advisories in the tidal river.

PCBs remain the primary cancer risk driver, followed by dioxin and dioxin-like chemicals. Mercury levels in striped bass are moderately elevated and contribute to non-cancer health risks. Shellfishing support varies within Zone 6 based on periodic pathogen exceedences.

Actions and Needs
- Examination of DO issues, including assessment of current monitoring and adequacy of existing criteria in the tidal river.
- Implementation of the PCB Total Maximum Daily Load (TMDL) for Zones 3, 4, 5, and 6.
- Review and assessment of the adequacy of current water quality criteria.
- Additional real-time monitoring is an identified need that can only enhance our ability to assess and report water quality conditions.

Fig. 2.20 Support of Designated Uses: Delaware River and Bay

### Lower Region
- SV • Schuylkill Valley
- LE • Lower Estuary watersheds
- NM • New Berlin and Mongaup watersheds

### Central Region
- UC • Upper Central watersheds
- LV • Lehigh Valley
- LC • Lower Central watersheds

### Bay Region
- HM • Haywood mouth
- HM • Haywood mouth

<table>
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<tr>
<th>Indicator Description</th>
<th>Status</th>
<th>Category</th>
<th>Designation</th>
<th>Desired Condition</th>
<th>Assessed</th>
<th>Action and Needs</th>
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<td>II</td>
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### Integrated Assessment Summary
- Aquatic life support is in Zones 3 and 6. In Zones 1A and 1E, pH does not meet criteria, and Zones 2 and 4 do not meet temperature criteria. Additionally, in Zone 5 approximately 17% of the samples assessed for DO did not meet the 24-hour average criteria.
- Drinking water use is supported in all designated zones.
- Primary contact recreation is supported in all applicable zones, except Zone 4 below RM 81.8, where there are insufficient data.
- Fish consumption is not supported in any zone, based upon the assessment methodology used. This means that an advisory has been issued by a State with a recommendation to limit consumption of at least one species of fish.
Contaminants of emerging concern are chemicals that are not regulated through water quality programs, but are of interest to scientists because of their persistence, bioaccumulation, and potential for toxicity to aquatic life and humans. Although their fate and transport are not fully understood, and a consensus has not yet been reached concerning their toxicity, these substances are believed to have the potential to cause adverse impacts on human health or the environment, including causing cancer and reproductive effects.

Trends

The levels of PBDEs in people’s bodies are reported to be doubling every 2 to 5 years, and are 40 times higher in North America than on other continents. A comparison of PBDE concentration in fish from the Delaware Estuary and fish from other locations is illustrated in Fig. 2.23. These data suggest that PBDE concentrations are significantly higher in fish from the Delaware than from other parts of North America, and orders of magnitude greater than those from Europe and Taiwan. The effect levels and human health implications of these compounds have yet to be established.

Fig. 2.23. PBDE in DE Estuary Fish

Actions and Needs

• Systematic monitoring is needed to understand how and where these substances are being released into the environment, what is happening to them once they enter the environment, and the risk they pose to humans and to our ecosystem.

• Assessment of ecotoxicity from emerging contaminants in the tidal Delaware River would be further informed by ecotoxicity screening bioassay measurements and population (sex ratio) surveys.

Fig. 2.24 Perfluorinated Compounds (PFCs) in the Tidal Delaware River 2007

How small is…

A nanogram is 10^-9 or 1/1,000,000,000 or 1/1 billionth of a gram

A picogram is 10^-12 or 1/1,000,000,000,000 or 1/1 trillionth of a gram

A ppt = part per trillion = ng/Liter

A ppb = parts per billion = pg/Liter

Fig. 2.22. PBDE in DE Estuary Fish

Learn more about contaminants of emerging concern at these web links.

Delaware River Basin Commission Emerging Contaminants
http://www.state.nj.us/drbc/emc.htm

United States Environmental Protection Agency (USEPA) Pharmaceuticals and Personal Care Products
http://www.epa.gov/ppcp/

Proper Disposal of Prescription Drugs Consumer Guidance (White House Office of National Drug Control Policy)
http://www.whitehousedrugpolicy.gov/drugfact/factsht/proper_disposal.html

Fig. 2.24 Perfluorinated Compounds (PFCs) in the Tidal Delaware River 2007
The extensive commercial fishery of the 19th century in the Delaware Bay declined in the 1920s, due to deterioration of water quality and over-harvesting. Fishery conditions have improved in recent years. An objective now must be to maintain and continue the improvement, with traces of toxic substances.

The health of living resources is not just important to maintaining the natural ecology of basin and estuary. Healthy resources are linked to terrestrial and avian populations. The story of living resources in the basin is one of food webs, competition, interconnections, and change. Clear water is a requisite for fish and shellfish, which are principal foods for birds and mammals. Shellfish are filter feeders (DO) because it is necessary for nearly every aquatic resource and is essential for overall ecosystem health. Aside from water quality, there are many other aspects affecting living resource condition. These include, but are not limited to, flows, temperature, nutrients, pollution, harvesting by humans, disease, and habitat loss.

As food and as habitat, healthy aquatic resources are linked to terrestrial and avian populations. The story of living resources in the basin is one of food webs, competition, interconnections, and change. Clear water is a requisite for fish and shellfish, which are principal foods for birds and mammals. Shellfish are filter feeders (DO) because it is necessary for nearly every aquatic resource and is essential for overall ecosystem health. Aside from water quality, there are many other aspects affecting living resource condition. These include, but are not limited to, flows, temperature, nutrients, pollution, harvesting by humans, disease, and habitat loss.

Carrying Capacity

Northern shad, the most commercially valuable species, as well as striped bass and Atlantic sturgeon, are principal foods for birds and mammals. Shellfish are filter feeders. Healthy aquatic resources are linked to terrestrial and avian populations. The story of living resources in the basin is one of food webs, competition, interconnections, and change. Clear water is a requisite for fish and shellfish, which are principal foods for birds and mammals. Shellfish are filter feeders. Healthy aquatic resources are linked to terrestrial and avian populations. The story of living resources in the basin is one of food webs, competition, interconnections, and change. Clear water is a requisite for fish and shellfish, which are principal foods for birds and mammals. Shellfish are filter feeders.

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Benthic macroinvertebrates—mainly insects but also snails, worms, crayfish, and other fauna without backbones—are considered one of the nation’s top biologic indicators of environmental conditions in freshwater systems. In a pristine stream, aquatic invertebrates are typically diverse and abundant, consisting of many species from a wide variety of invertebrate groups. Because most invertebrates have limited movement, they typically spend their life in a short segment of stream and thus reflect the local conditions. In addition, many species live in the stream for a year or more, long enough to experience the full range of environmental conditions at a site but short enough so that they reflect the present and recent conditions.

Among the invertebrates most commonly encountered in streams are species of mayflies, caddisflies, stoneflies, and true flies. Many of the midges (true fly family Chironomidae) can tolerate high levels of pollution and low dissolved oxygen, whereas the mayflies (e.g., Drunella, Ephemerellus), caddisflies (e.g., Rhyacophila) and stoneflies (e.g., Ameletus, PerlIID) typically require clean water and suitable habitats. Scientists continue to learn more about these species, and their requirements and sensitivities to environmental pollutants.

**Desired Condition**

Diverse and abundant species of aquatic invertebrates indicative of high quality water (BP 1.2, 2.3, CCMP Action H).

**Status**

Fair. Ranges from poor to very good; all regions show impacts.

Based on macroinvertebrate diversity, water quality and environmental conditions vary widely across the watershed. The most broadly impacted areas are in the urbanized area of the Lower Region, and in watersheds with a legacy of mining activity. Some level of impairment is found in almost all watershed regions. The best condition is represented in the uppermost portion of the basin where population density is low and a greater proportion of land remains in natural landscapes.

**Trends**

Trend data are not uniformly available. The frequency of macroinvertebrate sampling in the basin ranges from one to 15 years and may not include recent sampling. Differences among streams (temperature, flow regimes, chemistry and physical attributes) make application of a single index inappropriate. For example, a species index for the low-gradient and low-pH waters of the New Jersey Pinelands is very different from that of the numerous trout streams and rivers in New Jersey. Watershed with greater areas of forests and wetlands, more cobble substrate, and maintained base flows have heathier macroinvertebrate communities (Table 3.1). Thus, watersheds that are undergoing development are at risk of degraded conditions for macroinvertebrates. Riparian corridor and wetland conservation efforts should improve macroinvertebrate health.

**Actions and Needs**

Macroinvertebrate studies for the entire Delaware River Basin need to be conducted on a regular basis to facilitate trend analysis.

In addition, the four states should consider standardized methods for reporting macroinvertebrate data to enable interstate comparisons and watershed-based reporting like that attempted here.
Because of their long and complex life-cycle, freshwater mussels provide different environmental information than benthic macroinvertebrates, which are good indicators for short-term changes in conditions. The health, reproductive status, population abundance, and species diversity of the mussel assemblage represent an excellent indicator of water quality and habitat conditions over much of its range. See Table 3.2.

Table 3.2 freshwater mussels – state conservation status

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<th>Scientific Name</th>
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<td>Lampsilis subquadra</td>
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<td>Not Listed*</td>
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</tbody>
</table>
by sea level rise and coastal development, both of which infringe on the sandy shore environments essential for egg laying. See the Horseshoe Crab and Coastal Wetland Buffer Since 2000, horseshoe crab harvest restrictions have been imposed, a sanctuary has been established, and watermen have reduced their use of horseshoe crabs as bait. The success of these measures may take years to measure. It takes 9 to 12 years for horseshoe crabs to reach spawning age and for measurable changes to be seen in the abundance of eggs for the red knots in the spring.

The horseshoe crab, Limulus polyphemus, is one of many species of migratory shorebird that relies on the resources of the Delaware estuary for rest and nutrition to complete its spring flight. Listed as a “Species of High Concern” in the State of the Delaware Estuary 2008, the red knot is of special interest, however, is ecological. Their sheer abundance makes them an important consumer along the bottom where they prey on marine worms and other fauna. Their eggs, deposited on beaches, are a critical food source for migrating shorebirds, including the red knot, listed as a threatened species by NJ (see facing page). Horseshoe crabs also appear to be an important part of the diet of sea turtles and many other animals. The Delaware estuary’s signature commercial species is the horseshoe crab, and the health of this population is one of our region’s most important environmental indicators.

Fig. 3.7. The number of red knots (Calidris canutus rufa) migrating to the Delaware Bay declined during the period 1997 to 2006. Source: State of the Delaware Estuary 2008.

Horseshoe crabs also appear to be an important part of the diet of sea turtles and many other animals. Their eggs, deposited on beaches, are a critical food source for migrating shorebirds, including the red knot, listed as a threatened species by NJ (see facing page). Horseshoe crabs also appear to be an important part of the diet of sea turtles and many other animals. The Delaware estuary’s signature commercial species is the horseshoe crab, and the health of this population is one of our region’s most important environmental indicators.

Aerial surveys conducted in Delaware Bay and South America, along with counts in Canada, show that shorebird populations, particularly red knots, have increased in the past 50 years (Fig. 3.7). In the 1980s for example, up to 150,000 red knots were counted on Delaware Bay beaches. In 2006 they numbered less than 5,000. The red knot, a strong flyer, migrates to the Delaware Bay, NJ and biologists fear that the red knot could become extinct by the end of this decade.

Actions and Needs

- Continued monitoring and management are needed to monitor horseshoe crab populations.
- Habitat restoration projects would also benefit horseshoe crab spawning and could potentially increase the number of eggs available for shorebirds.

Fig. 3.6. Almost 30 beaches are included in the Delaware Bay Horseshoe Crab Spawning Survey, which is undertaken annually. Source: State of the Delaware Estuary 2008.

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- Habitat restoration projects would also benefit horseshoe crab spawning and could potentially increase the number of eggs available for shorebirds.

Fig. 3.5. Adult Horseshoe Spawning Index. Delaware Estuary is the largest stop-over for shorebirds in the Atlantic flyway and is the second largest staging site in North America. Close to a million migratory shorebirds converge on the Delaware Bay to feed and build energy reserves prior to completing their spring flight. There are perhaps the best known migratory shorebirds, described by the National Audubon Society as champion, long-distance migrants.

Trends

- Little data are available for measuring trends in horseshoe crab populations. Data probably declined in the early 1980s due to overharvest and then increased through the 1990s. Bio- overharvest led to a decline in the 2000s, followed by stabilization and recovery in the late 1990s and early 2000s. Horseshoe spawning activity has remained stable since 1999, whereas male spawning activity has significantly increased for the last five years (Fig. 3.5). Since males mature earlier, this increase in males may signal an increase in females to come. New Jersey currently has a harvest moratorium, Delaware allows only limited harvests of males.

Status and Trend

Very poor. Populations may be crashing.

The Delaware Estuary is the largest stop-over for shorebirds in the Atlantic flyway and is the second largest staging site in North America. Close to a million migratory shorebirds converge on the Delaware Bay to feed and build energy reserves prior to completing their spring flight. There are perhaps the best known migratory shorebirds, described by the National Audubon Society as champion, long-distance migrants.

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for example, 96 nests were spotted in CATEGORY III LIVING RESOURCES. The Louisiana waterthrush, *Seiurus motacilla*, is the only obligate headwater riparian songbird in the Delaware River Basin and the eastern United States. It is a biological indicator both of riparian-songbird population and fresh water wetland habitat condition, correlating to healthy land and water environments throughout the Basin. It is a widespread species with breeding populations recorded in nearly all of the hydrologic regions in the basin. Data are compiled semi-annually as part of a national Breeding Bird Survey (BBS).

**Desired Condition**
Robust breeding communities of songbirds indicating adequate habitat of suitable quality for forage and propagation (BP 1.2, 2.3, CCMP Action H5).

**Status**
Fair: Very sensitive to polluted waters and loss of forested riparian habitat.

The status of songbirds generally can be examined by assessing the breeding abundance of the Louisiana waterthrush, which correlates positively with riparian tree density and canopy. However, breeding success, in terms of nest density, is very closely tied to the bird’s reliance on aquatic macroinvertebrates. A paired watershed study of pristine watersheds and polluted watersheds impacted by acid atmospheric deposition and abandoned mine drainage in Pennsylvania, more than double the number of nests per kilometer of streams were found in unpolluted streams versus polluted streams with much lower abundance and diversity of macroinvertebrates.

**Trend**
As of 2002, the abundance of Louisiana water thrushes appears to be decreasing in much of the Basin (Fig. 3.8). Changes seem to coincide with development and change. Decreases in the more heavily developed headwater, stream, and wetland habitats are more pronounced compared to the less developed reaches of the southern bayshore and lower central basin, which show modest increases.

**Actions and Needs**
- Maintaining natural vegetative cover and tree canopy on riparian headwaters is critical for the Louisiana waterthrush and many other riparian species, including amphibians and reptiles.
- Measurements of riparian and wetland habitat integrity would enhance assessment and reporting.
- Identification, tracking, and assessment of additional species related to the water-related habitats of the basin, especially amphibians, is recommended.

**Indicator** Louisiana Waterthrush - *Seiurus motacilla*

**Indicator Description**
The Louisiana waterthrush, *Seiurus motacilla*, is the only obligate headwater riparian songbird in the Delaware River Basin and the eastern United States. It is a biological indicator both of riparian-songbird population and fresh water wetland habitat condition, correlating to healthy land and water environments throughout the Basin. It is a widespread species with breeding populations recorded in nearly all of the hydrologic regions in the basin. Data are compiled semi-annually as part of a national Breeding Bird Survey (BBS).

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- Measurements of riparian and wetland habitat integrity would enhance assessment and reporting.
- Identification, tracking, and assessment of additional species related to the water-related habitats of the basin, especially amphibians, is recommended.

**Indicator** Bald Eagle - *Haliaeetus leucocephalus*

**Indicator Description**
The Bald Eagle (*Haliaeetus leucocephalus*) is the only eagle unique to North America. Fish are an important food source for all bald eagles.

**Desired Condition**
Continued protection and expansion of bald eagle nesting and foraging habitat, and continued monitoring programs.

**Status**
Good and generally improving.

Bald eagle populations are currently in good condition in the Delaware Basin watersheds. Sightings along the non-tidal Delaware River have generally increased annually since 1998. In 2007, a pair of bald eagles established a nest near the confluence of the Schuylkill and Delaware Rivers at the Navy Yard in south Philadelphia, which may be the first nesting pair within the city limits since Colonial times. Since the main diet of the eagles are fish, it is thought that the birds are returning in nests near the Delaware River in greater numbers due to a greater abundance of fish and cleaner water. The return of the bald eagle to Delaware basin watersheds is an astonishing success story. Bald eagle nests have increased significantly. In 2004 for example, 76 nests were spotted in the basin, up from 44 in 2001.

**Trend**
The Bald Eagle Protection Act of 1940 prohibited shooting or otherwise harming the birds in the US, but this protection did not prevent damage from pesticides that harm their eggs. By the 1960s only 400 breeding pairs of bald eagles remained in the lower 48 states and they were declared an endangered species in 1967. The banning of DDT in 1972 and other measures launched an amazing comeback for eagles, and by 1995 their status was upgraded from endangered to threatened. Today, with more than 6,000 breeding pairs, the US Fish and Wildlife Service proposes to remove eagles from the nation’s Endangered Species list later in 2007.

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**Actions and Needs**
- Continued vigilance to monitor water quality, especially emerging contaminants with the capacity to disrupt reproduction cycles in living resources.
- Continued monitoring of eagles and other mammals dependent on aquatic resources and associated habitat in order to determine population health and protect it from reversals.
As a premier sport fish and a top predator in the aquatic food web, striped bass is economically and ecologically important in the Delaware basin. Striped bass is a large anadromous species of fish that live mostly in the ocean and may be found in freshwater. Found throughout the tidal reaches of the Bay and migrating nearshore offshore, both species are economically and recreationally important species.

### Desired Condition

**Water quality and habitat conditions to support healthy and diverse finfish populations (BP 1.2, 2.3; CCMP Action H3).**

**Status**

- **Good:** Striped bass restored.
- **Fair:** Weakfish declining.

#### Indicators Description

- **Striped bass** are economically and recreationally important species.
- **Weakfish** is an ancient fish that, when abundant, is important to the ecosystem and local economy.

#### Trends

- Striped bass were nearly eliminated from the Delaware estuary by the 1960s. Low dissolved oxygen levels in the River created a barrier that prevented fish from migrating to their spawning grounds. Weakfish which generally stay further south in the river were not as affected by this, although their population numbers were also depressed. A further dramatic decline in stripers in the late 1970s led to harvest moratoria in 1985–89 followed by harvest restrictions until 1995.

#### Actions and Needs

- A more detailed investigation of the dynamic interactions among finfish population would help in the prediction of future status and trends, and may suggest management options.

### Desired Condition

**Water quality and habitat conditions to support healthy and diverse finfish populations (BP 1.2, 2.3; CCMP Action H3).**

**Status**

- **Poor and getting worse.**

#### Indicators Description

- The shortnose and Atlantic sturgeon are long-lived species that spend at least part of their life cycle in the Delaware Estuary. The shortnose is currently a federal endangered species, but the Atlantic sturgeon may be even more imperiled. The Atlantic sturgeon is an ancient fish that, when abundant, can represent an important bottom consumer in large eastern rivers.

#### Trends

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#### Actions and Needs

- A better understanding of the impacts of harvest on shortnose sturgeon populations and habitat to inform management strategies.

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**Status**

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#### Actions and Needs

- A better understanding of the impacts of harvest on shortnose sturgeon populations and habitat to inform management strategies.
The spawning cycle of shad:

**Summer**

In the spring, mature shad return to freshwater to spawn. About half live to swim back to the ocean.

**Autumn**

In the fall, young shad migrate downstream to the ocean.

**Winter**

Shad abundance is low, even compared with numbers from the 1990s. Pennsylvania leads the nation in the number of shad caught, as its rivers and streams are still productive. Shad are a valuable indicator of environmental conditions in the Delaware Estuary and Basin.

### Desired Condition

Water quality and habitat conditions to support healthy and diverse fish populations (BP 1.2, 2.3, CCMP Action H5).

**Status**

Fair: Significant improvements in dissolved oxygen and tributary fish passage, but recent reductions evident.

### Trends

Once blocked by a lack of oxygen, shad now move more freely through waterways. Recreational and commercial fisheries have a role in reducing the extent and quality of trout habitat. Few areas remain that can support native brook trout, except those cold water streams that remain unaffected by development.

### Actions and Needs

• Conservation, restoration and management of brook trout populations (BP 1.2, 2.3; CCMP Action H5).

**Trends**

While historical brook trout population data and trends were not available for the report, a habitat-based analysis of their status suggests that this native species has been extirpated or severely reduced across most of its former range across the basin. Remaining brook trout populations are in decline because of changes to water quality and temperature due to acid rain, habitat degradation, and other challenges caused by human development that increase sediment loads in spawning areas or impair water quality and trout habitat. Increasing temperatures and reduction in the timing and amount of snowmelt related to climate change may also be a factor.

**Actions and Needs**

• Conservation, restoration and management attention is needed, particularly in headwater areas, to safeguard and possibly reclaim the habitat and water quality necessary to sustain naturally-reproducing populations of brook trout.

**Efforts should be made to improve the monitoring and reporting of brook trout populations as harbingers of human-induced environmental degradation and climate change impacts.**

**Figure 3.15 Number of Juvenile Shad Collected along the Delaware River 1979-2005**

**Figure 3.16 Shad Monitoring along the Lehigh River**

**Figure 3.17 Brook Trout Conditions in Watersheds**

**Figure 3.18 Number of Shad in Easton Dam Fishway, 1979-2005**

**Figure 3.19 Shad Monitoring along the Lehigh River**

**Figure 3.20 Shad Monitoring along the Lehigh River**

**Table 3.1 Brook Trout Population**

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**Table 3.2 Shad Population**

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**Table 3.3 Shad Spawning Success**

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**Table 3.4 Shad Fishery**

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**Table 3.5 Shad Fishery**

<table>
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Invasive species are those introduced from outside of an ecosystem with characteristics that allow them to dominate and limit the diversity of species within an invaded area. Invasive species can be plants or animals, terrestrial or aquatic. They gain advantage over native species by their capacity to reproduce, grow, or expand their range larger than their native counterparts. A lack of natural predators or disease often gives invasive species an advantage over local native species. Similarly, changes in temperature, precipitation, flow, and chemistry can also exacerbate the establishment and success of invasives. While usually non-native, some native species can become invasive, especially in disturbed areas, an example is poison ivy (Toxicodendron radicans) that appears to be spreading and becoming more virulent in response to increased atmospheric carbon dioxide and global warming.

Invasive species causing the greatest impacts on water resources are directly associated with waterways and their adjacent riparian landscapes. In terms of potential loss of native biodiversity and ecological function, riparian zones are probably the landscape most vulnerable to severe impact by invasive species. As the margin or overlap between aquatic and terrestrial ecosystems, riparian zones have evolved a natural balance of richness, resilience, and complexity that keeps any single species from becoming overly dominant. Invasive species can dangerously affect this balance. Furthermore, a watercourse provides the ideal conduit for the spread of invasive species by water, wind, and animals.

To learn more about invasive species:
- Prevention of additional introductions
- Early detection and eradication of new pests
- Control and management of established problem species
- Protection and recovery of native species and ecosystems
- Improved education of the general public regarding their role in invasive species introduction and control.

Actions and Needs
Where waterways and riparian lands are undisturbed, prevention of invasive species establishment is critical. Where invasive species have become established, the greatest practical effort should be made to eradicate those that pose the greatest risk to aquatic and riparian communities. Establishing appropriate metrics to track progress would be advantageous.

General actions for agencies and organizations include:
- Economic and Ecological Costs Associated with Aquatic Invasive Species
  - 1. Prevention of additional introductions
  - 2. Early detection and eradication of new pests
  - 3. Control and management of established problem species
  - 4. Protection and recovery of native species and ecosystems
  - 5. Improved education of the general public regarding their role in invasive species introduction and control.

The maintenance of healthy and biologically diverse riparian and aquatic ecosystems, and the implementation of invasive species detection and management plans (BP 2.3.E, CCMP Action H6).

Today — The Delaware River Basin drainage area encompasses 12,765 square miles, draining 1% of the land area of the United States. These lands are varied in both terrain and use, from rolling farmland and forest, to marshes and fishing villages along the Bay. At the time of discovery by Europeans, [it] comprised one continuous evolving system, accepting and discharging into the Atlantic Ocean the fresh water and silt from mountains and plains. [and] sapatins were fully and generally discharged in surface streams. In this dynamic system, the activities of man were nearly innumerable. Today, the activities of man vastly affect the behavior of water and the ecology of the Basin.

Today — The activities of man continue to affect the behavior of water in the basin ecology, but a desire to minimize those effects has been embedded in environmental management programs for several decades. Water quality success stories, based on regulating discharges, are now legendary, illustrated by the return of dearth populations to the Delaware River. Other successes are included in the timeline in the Water Quality section of this report. Today, the landscape is the next frontier in water resource management.

**Landscape Change** — Assessing changes to the landscape — how we use and manage it, how much remains in a "natural" state—is a requisite for setting baselines for comparison, for identifying watersheds or areas of immediate concern, and for anticipating effects on water resources. Unfortunately, while we possess the technical ability to interpret data from satellite and aerial images, the financial ability and political will to do this at geographic scales and reference periods that would be most appropriate for water resource conditions from shore to shore for 20 miles of the Delaware River. Other successes are included in the timeline in the Water Quality section of this report. Today, the landscape is the next frontier in water resource management.

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**Reporting** — Indicators of landscape condition included in this report are:

- Population change
- Population density
- Land consumption
- Natural landscape foreors, wetlands and wetland buffers

**USGS reports** that the total area of forests and wetlands has a positive effect on aquatic ecosystems, while urban area growth, impervious cover, population density and total point source flow (discharges to wastewater) often has a negative effect.

**Historic Land Use** — The pre-industrial basin landscape was predominantly woods and wetlands, with expanses of farmland and nodes of human settlement. Decades of development and harvesting resulted in filled wetlands and a decrease in forests, so by 1930, forests and wetlands had been reduced to 32% and 8% of the landscape, respectively.

Conservation efforts, shift to rural land use for production and better understanding of the services that wetlands and forests provide have to some extent reversed the old trends. By the mid-1990s forested land had nearly doubled from its 1950 level; land in agricultural use had been reduced to three- to half- and wetlands had slightly increased. The National Wetland Inventory Status and Trends report attributes recent increases to the creation of ponds which do not provide the same function as vegetated wetlands.

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Lackawaxen watershed added

- Pike and Monroe Counties, straddling the divide between the Upper and the Central regions, are the fastest growing counties in Pennsylvania. Not surprisingly, watershed which include the greater Philadelphia metropolitan area.

- Eight of the ten most densely developed watersheds, located in the Philadelphia metropolitan area, lost a combined total of more than 66,000 people between 1990 and 2000.

-footnote: The greatest percentage increases in the Delaware counties of Kent and Sussex, and Cumberland County NJ. With the exception of Cape May County NJ, areas within the Bayshore Region are also developing rapidly as indicated by substantial increases in the Delaware counties of Kent and Sussex, and Cumberland County NJ. In summary, some sparsely developed watersheds are undergoing substantial growth and some established urban areas are being slowly abandoned. This trend has substantial implications for water resource management, including landscape alternation, construction and maintenance of new infrastructure systems, and abandonment or inefficient use of existing infrastructure.

Population growth is an indicator of potential stress on water resources and natural landscapes. People create demand for water and wastewater provision, buildings, roadways, and parking, all of which increase the potential for impairments to water quality and aquatic resources.

For the report US Census tracts were aligned with 236 watershed units for analysis, and the watersheds aggregated into the basin reporting regions. Results are also reported by political units, e.g., counties and municipalities.

- Population is unevenly distributed across the basin. (Fig. 4.2). The vast majority (78%) of residents live in the Lower Region and nearly half (37%) of the population continue to occur, and where preventive management measures could be employed to mitigate impacts.
4.8). Population density in the Upper and Central regions is about 204 p/mi², while the Emmary density approaches 1,050 p/mi². The US census classifies densities greater than 1,000 p/mi² as urban. Generally, density is lowest in the uppermost watersheds of the Basin (ranging from 30 to 100 p/mi²), increasing with proximity to the River and its confluence with major tributaries. After peaking at the greater Philadelphia metropolitan area (~2,000 p/mi²), density decreases again in the more southern watersheds of the Lower and Bay regions. Headwater streams are especially vulnerable to impacts. Historically, these areas have remained sparsely developed due to distance from other population centers, poor accessibility and problematic terrain. In the last decade, high housing costs within and beyond the basin have fueled a sharp increase in new housing.

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For example, the ten most densely populated watersheds are located in the Upper Estuary around Philadelphia. Between 1990 and 2000, eight of these lost population; in those watersheds alone ... of the existing capacity of support infrastructure such as transportation, water supply and waste treatment systems.

Not Rated
• Improving stormwater management—capture rain water and eliminate to come combining storm flow with sanitary sewer—flows and adding vegetation to cityscapes can mitigate many of the negative impacts of existing communities on water resources. New development can be designed and built to meet Low Impact Design (LID) standards.

Fig. 4.8 Population Density

| CATEGORY IV • LANDSCAPE

Fig. 4.9 Average Basin Density

| CATEGORY IV • LANDSCAPE

Fig. 4.10 Regional Population Density

| CATEGORY IV • LANDSCAPE

There is a critical need to understand the relationship between land cover and water quality and quantity, and population growth and development within the Delaware River watershed.

During the same decade, slightly more than 61,000 people were added to the population of the watersheds in the Upper Central region—areas of Pike and Monroe County PA—where developed land increased by more than 80,000 acres at the rate of ~1.3 ac/person. More than 74,000 acres of forested watershed land was converted for development and agriculture.

Actions and Needs
• Amending to where and how we develop could greatly aid in preventing or limiting negative effects on water resources. More densely developed communities offer many cultural, health and economic benefits, and the downside of imperviousness can be offset by smarter development and land management.

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Land use differs remarkably among the watersheds of the basin (Fig. 4.13). In the Upper and Central Region watersheds, forest cover dominates. The watersheds of the Lower Region have a higher percentage of developed land, while agriculture and wetlands are the more dominant features of the Bay Region.

The concentration of human development and uses, such as ports and industry, in the Lower Region watersheds is related to water quality problems in this portion of the River. See the timeline in the Water Quality Perspective.

Based on a land use change analysis from NOAA’s Center for Coastal Services, about 70 square miles of basin land was developed between 1996 and 2001. The change analysis also revealed a 48 square mile loss of forested land and 18 square mile loss of agricultural land. The wetlands and water category lost about 3.5 sq mile. Table 4.3 shows the change in acres and square miles.

The 2003 Final Report of the New Jersey Comparative Risk Project identified land use change as lying at the heart of many environmental problems, producing by a wide margin the largest negative ecological and social impacts.

The conversion of landscapes to development occurred at a rate of 25 to 35 acres per day, or an average of 132 football fields each week. Figure 4.15 illustrates landscape conversion as a daily average.

Fig. 4.15 Land Use Change per Day 1996-2001

Actions and Needs

Refined landscape assessments, preferably orthophoto, should be coordinated for the basin on a time frame coincident with the decadal and mid-decade census.

Fig. 4.16 Regional Land Use Change 1996-2001

STATE OF THE DELAWARE RIVER BASIN REPORT 2008

Fig. 4.12 Basin Land Use 2001

Fig. 4.13 Watershed Land Use 2001

Fig. 4.14 Map of Basin Land Use 2001
Land Consumption

The amount of land we are developing per person is a measure of land use efficiency. An increase in land consumption indicates that more acres of land are being developed or altered for each additional person.

Desired Condition

Before 1990, the amount of land developed per capita and proportion of total land area developed was low. We as a society have developed the land rapidly through efforts to redevelop areas with existing infrastructure (BP Goal 3.4, CCMP Action L16).

Status

Present. Per capita amount of land being developed is increasing.

In 1995, the population of the basin was 7,591,690 and developed land covered approximately 1,790 square miles or 1.44 million acres. On a per capita basis, each person represented 0.353 acres of developed land. In 2001, per capita figure had risen to 0.415 acres. Although apparently small, it indicates that the rate of land conversion in relation to changes in our society is quite high—over a short 5-year time frame. In 1995 the cumulative result of historic land development was 0.151 acres of developed land per person. Between 1995 and 2000, the basin's population increased by 166,980 people. Developed land increased by nearly 71 square miles (45,280 acres) in roughly the same time period (1996–2001). The land consumption ratio for this five year period was 0.21 acres per person, nearly double the historic average (Fig. 4.17).

Trend

Understanding how we use land is essential for increasing our efficient use and change to resource condition and to identify performance standards for land use management are necessary for comprehensive water resource protection.

LANDSCAPE CATEGORY III

Dams

Indicators

Dams are artificial barriers to a water course to impede the flow of water. Historically, dams were built to impound water for irrigation and drinking water supply, for power production, and to create recreational lakes and ponds. These structures pose some hams to ecosystems by causing genetic isolation among sub-populations of resident aquatic life, contributing to anoxic (de-oxygenated) conditions, and inhibiting the migration of spawning fish.

Trend

There is growing interest in dam removal for both ecological and public safety benefits. Decision making and enhancing stream flows and ecological health and diversity are among the main goals for basin waters (BP Goal 1.2; CCMP Action HS.7). Status

Poor: 1550 dams remain on tributaries of the Delaware, blocking fish passage and disrupting the natural hydrology. The Delaware River is the longest undammed river east of the Mississippi, but approximately 1,550 tributary dams impede stream flow and fish passage. Some ecological impacts of these dams were built since 1900. Most are old and many have exceeded their design life, adding concerns about public safety to those of ecosystem health. It is becoming a common practice to install fish passages to aid the movement of migratory fish up and down stream. Since 1991, the construction of fish ladders has opened approximately 165 miles of streams in the Lower and Bay Regions to fish passage (Fig. 4.18).

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Forested landscapes are those with a high percentage of tree canopy and an absence of agriculture and development. Forested land is of prime importance to water resources, playing an important role in temperature moderation, nutrient transfer, oxygen generation, maintenance of soil health, and protection of natural hydrology.

Vegetated riparian corridors, especially forested edges of headwater streams, are important to water resource quality and aquatic ecosystems. For example, forested corridors significantly reduce nitrogen, phosphorus and sediment loadings to streams in proportion to their width; 100 foot stream buffers can reduce loadings by 80%–90%.

The rate of forest loss in the Delaware basin exceeds 12 football fields per day. One football field-sized swath of forest is cleared every 2 hours.

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**Desired Condition**

Maintenance of forested landscapes of value to water resources and wildlife (BP 3.2; CCMP Actions L4,L6).

**Status**

Fair: The basin is losing forested land important to water resources.

While still the predominant land cover in the basin, forested land decreased by nearly 50 square miles between 1996 and 2001. Forest was lost in every region of the basin, but the greatest loss was in the Central Region (Fig. 4.19) where the Lehigh Valley and Delaware drainage watersheds of Pennsylvania are undergoing substantial population growth.

Of the 6,263 square miles remaining, approximately 782 (11%) are protected under state or federal ownership, i.e., part of federal and state forests, forest preserves and gamelands (Fig. 4.21). Forested land accounts for 88% of state and federal landholdings in these categories.

**Trend**

As a result of re-growth following decades of timber harvesting and clearing of land for agriculture, the amount of forested land increased between the 1930s and the mid-1990s. More recent information, however, shows that forested landscapes are being lost at the rate of more than 6,000 acres per year. In more graphic terms, that is in excess of 12 football fields per day or about one 1.32 acre football field every 2 hours.

As additional forest is converted for development or cultivation, the percentage of protected land will increase even though no additional land is being preserved. Other methods of protection, such as easements, land trusts and forest management plans, can be effective means of ensuring the landscape function of forested land. The extent of such private efforts is not accounted for in this assessment.

**Actions and Needs**

• Forest status, including the extent and function of forested land by region, should be assessed and reported on a regular basis, preferably synchronized to census and development information.

• Assessments of riparian buffers should include active river areas—indicative of all lands within which a river interacts in dynamic processes—and be incorporated into future condition status reports.

• Improve the tracking, assessment and mapping of forested wetlands.
Indicator Description

Wetlands are lands that attain a sufficient degree of saturation to affect soil chemistry and maintain a specialized assemblage of wetland-related plant species. The value of wetlands is especially important in riparian and coastal areas for flood and erosion protection, as they quicken the pace of migration necessary to ensure tidal wetland survival. There is also additional stress, as it quickens the pace of migration necessary to ensure tidal wetland survival. Th is is especially important for tidal wetlands where the inability to migrate can mean a loss of this vital landscape feature.

Desired Condition

Protection of tidal wetlands and their ability to migrate in response to changing conditions (BP Goal 3.2; CCMP Actions H4, H7).

Status

Poor: Upper estuary
Fair: Lower estuary and bay.

The Delaware River has one of the lowest historically documented rates of wetland conversion, and the ratio of tidal wetland cover to non-tidal wetland cover is one of the highest in the world. The Delaware River has one of the lowest historically documented rates of wetland conversion, and the ratio of tidal wetland cover to non-tidal wetland cover is one of the highest in the world. The Delaware River has one of the lowest historically documented rates of wetland conversion, and the ratio of tidal wetland cover to non-tidal wetland cover is one of the highest in the world.

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Wetland Indicators

• Coordinated monitoring and assessment programs are needed to track the extent and condition of freshwater tidal marshes and tidal wetland terrains.

• Additional attention should be paid to freshwater wetlands in forested areas, which are poorly mapped since they are often hidden under forest canopy.

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Natural Capital Project

In 2001, the New Jersey Department of Environmental Protection (NJDEP) began a multi-year study of the economic value of the state’s “natural capital.” The project is based on the recognition that the various components of the natural environment provide long-term streams of benefits to individuals and to society as a whole and can therefore be viewed as capital assets, or, in the aggregate, as “natural capital.”

Many of the benefits provided by natural capital come from ecological systems (ecosystems) such as forests, wetlands, and lakes, and include both goods (products) and services provided by both biotic (living) systems, and abiotic (nonsliving) systems. Goods are tangible commodities such as mineral deposits, fish and timber. Services are process-related outcomes, such as climate regulation, nutrient cycling and nitrogen leaching, soil formation, and carbon sequestration. See tables for examples of the types of ecosystem goods and services that the New Jersey team considered during the valuation process.

The goods and services of natural capital provide economic value to us as individuals and as a society. The on-going benefits are usually expressed in terms of dollars per year; as with any capital asset, the value of natural capital equals the present value of the related benefit stream. In deriving estimates for those values, the studies used a variety of approaches, including value transfer, hedonic analysis, spatial modeling, and market value analysis. The full reports is available from NJDEP at www.state.nj.us/dep/dsr/naturalcap/.

The Delaware River Basin is blessed with visually breathtaking and functionally valuable natural resources. While significant gaps exist in the valuation literature, it is clear that natural systems have substantial economic value and maintenance of these systems in a healthy functioning state can help avoid costly expenditures on artificial replacements such as water treatment plants and flood control infrastructure.

Applying the present value of goods and services derived from the NJ study to the landscapes of the basin yields a coarse estimate of the value of its goods and services. For example, in 2001 forests covered over 5,000 square miles of the basin and, at an average price of $7,716 per acre, were worth nearly $25 billion. Between 1995 and 2001, the basin’s 47 square miles of forest with a natural capital value of $1.7 billion in goods and services. This is a very conservative estimate since it does not include an economic valuation of several services that forests provide, including long-term carbon storage, dampening of stormwater runoff and peak stream flows, and the removal of pollutants such as carbon monoxide, sulfur and nitrogen dioxide, ozone, and particulates from the air. Including such services could conservatively add more than $6,000 to the value of an acre or an additional $36.9 billion to the value of the basin’s forests.

The goods and services of natural capital is subject to change as land use patterns, climate, and other factors change in response to societal land use decisions and wider environmental trends such as global warming.

Results

As economic assets, ecosystems provide substantial benefits over time. Values are reported in 2004 dollars.

- New Jersey’s ecosystem assets are worth at least $2.6 billion per year in goods and services.
- Present value of these New Jersey resources is estimated to be at least $850 billion.
- In general, areas containing wetlands, estuaries, tidal bays, and beaches have the highest ecosystem service values on a per acre basis.
- Different spatial patterns of land use affect ecosystem service levels. Landscape modeling shows that the size and location of ecosystems relative to each other significantly affects their level of economic production. For example, forests located close to an estuary zone contribute more to estuary water quality than forests located further away. For the water quality index, the difference can be as large as 40%.
- Even the overall total, natural goods in the aggregate have an economic value of over $1 billion annually and a present value in the trillions of billions of dollars.
- Estimating sustainable harvest or extraction levels for goods is a major challenge and the amount of natural goods provided is subject to change as land use patterns, climate, and other factors change in response to societal land use decisions and wider environmental trends such as global warming.

Actions and Needs

With the release of the natural capital report in April of 2007, the NJ project entered a second phase focusing on disseminating the report’s findings as widely as possible and developing ways to help state and local officials, planners, and citizen groups use the study’s findings when making decisions on master plans, zoning, and permitting. Economics analyses such as those described above can also help us identify the best use of a particular ecosystem service. In that sense, ecosystem services can be viewed as a consideration of how a natural resource is used. The idea is that some uses of a particular resource may be more valuable than others. For example, a forest might be used for recreation or as a source of water, or for timber. All of these uses are possible and may have different values. To what extent are these other uses valued? Where might the state’s forest capital be directed so as to have the greatest benefit to society? How might we help protect and preserve the state’s forest capital?

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More detailed analyses to fully cover the services of ecosystems found in the basin, especially those that are shared by the basin at large, such as the Delaware River and Bay, would give a fuller picture of the economic value of the basin’s natural capital. Valuing our natural resource base is a necessary step to improving decisions that impact ecosystem function, and to preserving those functions for their long-term value to society.

Table 4.4 Present Value 2004 of New Jersey’s Natural Capital (excluding ecotourism)

<table>
<thead>
<tr>
<th>Area (Acres)</th>
<th>$MM/yr</th>
<th>$/ac/yr</th>
<th>PV $Bn</th>
<th>PV $/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forested &amp; unforested freshwater wetlands</td>
<td>9,612</td>
<td>11,802</td>
<td>320.4</td>
<td>393,394</td>
</tr>
<tr>
<td>Estuary/tidal bay and coastal shelf</td>
<td>6,550</td>
<td>8,670</td>
<td>218.3</td>
<td>288,987</td>
</tr>
<tr>
<td>Forest land</td>
<td>2,512</td>
<td>1,714</td>
<td>83.7</td>
<td>57,136</td>
</tr>
<tr>
<td>Marine</td>
<td>1,194</td>
<td>6,269</td>
<td>39.8</td>
<td>208,973</td>
</tr>
<tr>
<td>Open fresh water</td>
<td>145</td>
<td>1,686</td>
<td>4.8</td>
<td>56,208</td>
</tr>
<tr>
<td>Urban impervious and green space</td>
<td>439</td>
<td>296</td>
<td>14.6</td>
<td>9,869</td>
</tr>
</tbody>
</table>

Table 4.5 Present Value 2004 of Ecosystem Goods and Services

<table>
<thead>
<tr>
<th>Ecosystem Goods</th>
<th>IMF</th>
<th>Decision Support</th>
<th>PV $Bn</th>
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<tr>
<td>Freshwater wetland</td>
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</tr>
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Table 4.6 Present Value 2004 of New Jersey’s Natural Capital (excluding recreation)

<table>
<thead>
<tr>
<th>Area (Acres)</th>
<th>$MM/yr</th>
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<th>PV $Bn</th>
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Summary of Conditions and Recommendations

An indicator is a measure of condition, where condition is a measure of quality and/or quantity. While indicators may be used to identify, express, and interpret information, they may be used in a variety of ways, including to derive useful information and to help to make management decisions. The development of an indicator may be intended to contribute to the effectiveness of an environmental management program or policy.

In all, 37 indicators representing hydrology, water quality, living resources, and landscape conditions have been reviewed in this report. Pertinent data, trends, and possible explanations are provided for each indicator. For each category, summary tables indicate the number of gaps in the reporting of condition, monitoring and assessment were identified during the development of this Report. Several items specifically related to monitoring and reporting are summarized below.

**Summary of Water Resource Status: Fair**

Based on overall ratings of 34 of the 37 indicators, the status of the basin’s water-related resources is Fair. Variations exist among and within the indicator categories, and suggests where additional effort should be focused.

Hydrology: Hydrologic indicators are overall in good shape. We are meeting the flow targets that are the foci of management efforts, meeting human demand for water, and are meeting water quality standards with a degree of efficiency, and making headway in water use and protection, and working to improve flood losses. The potential for significant changes in the basin and its related resources may challenge adaptive management efforts in the future.

Water Quality: Metrics indicate that water quality overall is fair. Dissolved oxygen, nutrients and clarity appear to be good and generally meeting criteria in the river and the tributaries maximum however, toxins remain an issue. A reductionist approach, while powerful in describing the system and providing parameters to make evaluation problems; and, deficiencies in monitoring and assessment under robust assessments of other, especially DO and nutrients.


Landscape: Landscapes are overall in good shape. Changes that are evident or consistent with the standards of the basin and the physical conditions in watersheds and water-related landscapes. The overall condition assessment for this category is Fair with a significant number of indicators having a Poor rating. Selection of additional indicators may be advisable for subsequent reports to include additional species that are of ecological or economic importance.

**Summary of Monitoring Needs**


Several items specifically related to monitoring and reporting are summarized below.

- **Enhance continuous monitoring of additional species:** Monitoring of some water quality parameters—particularly DO, pH, and temperature—is necessary for accurate and timely identification of other stressors. Further, almost all of the indicators used to calculate the overall condition index for each of the three indicator categories. Improvements in data quality, availability and timeliness are necessary for the development of a more accurate picture of the functional linkages between landscape change and other indicators is not always well quantified nor well represented through indicators. Additional metrics to help bridge this gap should be considered for the next report.

**Summary of Issues and Recommendations**

Several monitoring needs, indicator selection, monitoring and assessment were identified during the development of this Report. The change product from NOAA’s Coastal Services Center (2008) comparing 1996 and 2001 is used for this report even though it only covers five years of change, and omits a small but important portion of the basin in the fast-developing Appalachian plateau region. Note that both data provide less than up-to-date information. Furthermore, state photogrammetric data sets lack sufficient conformity to join and analyze. There is a significant gap that needs to be filled for adequate landscape change assessment.

To summarize each assessment, a simple categorical measure of condition was used; each indicator was assigned a rating of Good, Fair, Poor, or Unsatisfactory:

<table>
<thead>
<tr>
<th>Category</th>
<th>Class</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Quality</td>
<td></td>
<td>8</td>
<td>14</td>
<td>7</td>
<td>30</td>
</tr>
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<td>Living Resources</td>
<td></td>
<td>10</td>
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<td>5</td>
<td>33</td>
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<td></td>
<td>10</td>
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<td>3</td>
<td>21</td>
</tr>
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<td></td>
<td>28</td>
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**Summary of Water Quality Status:**

An indicator is a measure or synthesis of a number of related resources, adjusting for the natural variability of the environment. Indicators are measures of quality and/or quantity. While indicators may be used to identify, express, and interpret information, they may be used in a variety of ways, including to derive useful information and to help to make management decisions. The development of an indicator may be intended to contribute to the effectiveness of an environmental management program or policy.

**Summary of Water Resource Status: Good**

Based on overall ratings of 34 of the 37 indicators representing the basin’s water-related resources is Good. Variations exist among and within the indicator categories, and suggests where additional effort should be focused.

Hydrology, Hydrologic indicators are overall in good shape. We are meeting the flow targets that are the foci of management efforts, meeting human demand for water, and are meeting water quality standards with a degree of efficiency, and making headway in water use and protection, and working to improve flood losses. The potential for significant changes in the basin and its related resources may challenge adaptive management efforts in the future.

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Landscape: Landscapes are overall in good shape. Changes that are evident or consistent with the standards of the basin and the physical conditions in watersheds and water-related landscapes. The overall condition assessment for this category is Fair with a significant number of indicators having a Poor rating. Selection of additional indicators may be advisable for subsequent reports to include additional species that are of ecological or economic importance.

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# Delaware River Basin Indicator Rating 2008

## Table S.2

<table>
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<th>Legend</th>
<th>Current Condition</th>
<th>Trend</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Habitat in Tidal Waters:</strong></td>
<td>Good; stable</td>
<td>Good as the 1980s, 95% of the time is maintained</td>
<td></td>
<td>Improve observation and the management of water quality; Evaluate minimum flow needs for tidal and estuarine ecosystems.</td>
</tr>
<tr>
<td><strong>Salt Line Location:</strong></td>
<td>Very good, Revisions within acceptable range</td>
<td>Investigate effects of salt, salinity sources and sea level rise on tidal wetlands, Synchronize land use and population change assessments</td>
<td></td>
<td>Continuation of monitoring; Improve basin-wide monitoring of land use change; Increase frequency and rate of developed land has increased.</td>
</tr>
<tr>
<td><strong>Water Use:</strong></td>
<td>Good, stable</td>
<td>More water needs being met, water stress being addressed</td>
<td></td>
<td>Water use efficiency measures and use of alternative water supplies are required.</td>
</tr>
<tr>
<td><strong>Water Use:</strong></td>
<td>Good, stable</td>
<td>More information needed on agricultural demand and nutrient needs</td>
<td></td>
<td>Improve monitoring of suspended solids; add turbidity probes to automatic monitors.</td>
</tr>
<tr>
<td><strong>Water Supply:</strong></td>
<td>Good, stable</td>
<td>Potable water supplies available in many areas</td>
<td></td>
<td>Improve monitoring of suspended solids; add turbidity probes to automatic monitors.</td>
</tr>
<tr>
<td><strong>Areas of Great Concern:</strong></td>
<td>Fair, conflicting with approved use</td>
<td>More accurate estimates of forested landscapes are needed to protect water resources</td>
<td></td>
<td>Increase accuracy of forested landscapes.</td>
</tr>
<tr>
<td><strong>Flood Damage:</strong></td>
<td>Poor, increasing severity in recent years</td>
<td>Improved floodplain mapping and management</td>
<td></td>
<td>Track population and land use change simultaneously.</td>
</tr>
<tr>
<td><strong>Nutrients:</strong></td>
<td>Good; stable</td>
<td>Nutrients concentrations high compared to other systems, but harmful concentrations not identified</td>
<td></td>
<td>Improve monitoring of suspended solids and turbidity probes to monitor pollution, Synchronize land use and population change assessments.</td>
</tr>
<tr>
<td><strong>Discharge Oxygen:</strong></td>
<td>Good</td>
<td>Continuous monitoring of DO measured throughout the basin</td>
<td></td>
<td>Improve monitoring of suspended solids and turbidity probes to monitor pollution, Synchronize land use and population change assessments.</td>
</tr>
<tr>
<td><strong>Water Clarity:</strong></td>
<td>Good</td>
<td>Water clarity naturally turbid, non-turbid flow generally clear except during storms</td>
<td></td>
<td>Additional research needed to determine effects levels and set criteria for piscicides.</td>
</tr>
<tr>
<td><strong>Copper:</strong></td>
<td>Good</td>
<td>Additional monitoring and modeling required to assess impacts, especially River basin</td>
<td></td>
<td>Investigate nutrients, temperature, pH and Distribution at the level of increased monitoring of water quality, especially emerging contaminants.</td>
</tr>
<tr>
<td><strong>Fish Consumption:</strong></td>
<td>Good</td>
<td>Average fish consumption and dynamic interaction with other species, especially for migratory species, has increased</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Trends &amp; Recommendations:</strong></td>
<td>Good</td>
<td>No significant change observed, but effort continues to improve management</td>
<td></td>
<td>Improve monitoring of suspended solids; add turbidity probes to automatic monitors.</td>
</tr>
<tr>
<td><strong>State of the Delaware River Basin:</strong></td>
<td>Poor; increasing trend in recent years</td>
<td>More accurate estimates of forested landscapes are needed to protect water resources</td>
<td></td>
<td>Increase accuracy of forested landscapes.</td>
</tr>
</tbody>
</table>

## Table S.3

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<th>Current Condition</th>
<th>Trend</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benthic Macroinvertebrates:</strong></td>
<td>Poor; conditions range from poor to very good</td>
<td>Poor; conditions range from poor to very good</td>
<td></td>
<td>Additional data collection for running reaches; Develop criteria for designated use criteria for designated uses.</td>
</tr>
<tr>
<td><strong>Freshwater Fish:</strong></td>
<td>Poor</td>
<td>Poor; conditions range from poor to very good</td>
<td></td>
<td>Additional data collection for running reaches; Develop criteria for designated use criteria for designated uses.</td>
</tr>
<tr>
<td><strong>Horseshoe Crabs:</strong></td>
<td>Poor</td>
<td>Population used is not well populated and unsuitable for migratory use</td>
<td></td>
<td>Continue monitoring and increase monitoring of water quality, especially emerging contaminants.</td>
</tr>
<tr>
<td><strong>Red Knot:</strong></td>
<td>Poor, increasing trend</td>
<td>Poor, increasing trend in recent years</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Waders:</strong></td>
<td>Poor</td>
<td>Poor, increasing trend in recent years</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Efficiency:</strong></td>
<td>Good</td>
<td>Efficiency trends, instream flow needs for River and estuary</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Land Use 2001:</strong></td>
<td>NR</td>
<td>NR</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Dams:</strong></td>
<td>Poor</td>
<td>Poor, increasing trend in recent years</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Wetlands:</strong></td>
<td>Poor</td>
<td>Poor, increasing trend in recent years</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Population Density:</strong></td>
<td>NR</td>
<td>NR</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Toxics:</strong></td>
<td>Poor</td>
<td>Poor, increasing trend in recent years</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Forest Cover:</strong></td>
<td>Poor</td>
<td>Poor, increasing trend in recent years</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
<tr>
<td><strong>Flooding Damage:</strong></td>
<td>Poor</td>
<td>Poor, increasing trend in recent years</td>
<td></td>
<td>Increase monitoring, evaluation and reporting capacity.</td>
</tr>
</tbody>
</table>

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**Table S.2** Delaware River Basin Indicator Rating 2008

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