Executive Summary

The purpose of the 2017 Technical Report for the Delaware Estuary and Basin (TREB) is to assess the overall environmental condition of the watershed by examining the status and trends of key indicators that reflect the health of its natural systems. Meeting this goal is challenging because the Delaware River Basin is a large and complex watershed, encompassing more than 35,000 square kilometers (>13,500 square miles) and extending from headwater streams and mountains in New York State, to the coastal plain, and out to the ocean near Cape May, NJ, and Cape Henlopen, DE.

The watershed is home to about 9 million people and supplies drinking water to another seven million in New York City and northern New Jersey living outside of the basin. Hundreds of plant and animal species live in balance with people in diverse habitats, including many ecological treasures. The region also has a storied history, starting with rich Native American peoples and extending through the birth of the United States and the Industrial Revolution, up to the present day where it continues to function as a nationally important economic center and strategic port.

Environmental indicators are aspects of the environment which can be quantified and are representative of prevailing local conditions. The approach used in this report was to gather, analyze and interpret the best and most recent data for a suite of more than 50 indicators that represent different facets of the natural ecosystem, such as water quality, living resources, habitats, and land cover. When considered together, this indicator-based report provides a comprehensive picture of the status and trends in environmental health of the Delaware Estuary and Basin.

The eight chapters of TREB are organized topically into the following sections: watersheds and landscapes, water quantity, water quality, sediments, aquatic habitats, living resources, climate change, and restoration. Each section includes a number of different indicators and was written by a different set of authors with science and management expertise relevant to the topic. For example, the climate change chapter considers long-term changes in air temperature, precipitation, extremes in air temperature and precipitation, snow cover, wind speed, stream flow, ice jams, and sea level.

For each indicator, authors present and interpret the most recent available status and trends data and summarize any actions or needs that could strengthen future indicator reporting, which will lead to improved environmental conditions. Examples of key findings in this report are summarized in the table on page 9 which shows both improving and declining environmental conditions. The list is not prioritized, and many more similar examples can be found in various report sections.

The results from this assessment suggest that the current health of the Delaware Estuary and River Basin in 2017 is “fair,” reflecting a mix of positive and negative trends. The status of many indicators is good, and others are not so good. Trends for some indicators appear to be improving, while others appear to be worsening. The overall assessment of “fair” health is unchanged from TREB 2012 and the smaller State of the Estuary Report in 2008.

The information in this report should be interpreted carefully because changes in some indicators do not necessarily reflect declining or improving conditions per se, but instead reflect natural variability. For example, it is possible that some species or conditions are actually improving at the expense of others, due to complex ecological relationships. In some cases, this report effort was hampered because some components of the ecosystem that could serve as strong indicators were not able to be included due to insufficient data. The development of this report therefore allows us to assess not only the state of the environment, but also the state of our knowledge and understanding. Furthermore, the restoration chapter attempts to assess our management progress in preserving, enhancing and restoring environmental conditions, rather than the environmental conditions per se (which is the focus of most of the rest of this report).
Although the “fair” overall health assessment is unchanged since 2008, it reflects substantial improvement compared to earlier decades for many key indicators. For example, advances in wastewater treatment and implementation of the Clean Water Act led to dramatic improvement in dissolved oxygen in the river’s urban corridor over the past 30 years. Unfortunately, the continued loss and degradation of important habitats and impacts from climate change have undermined the recent recovery and efforts to protect and restore the system. The continued expansion of human activities is likely to increasingly tax our natural resources and require management diligence, especially with regard to water withdrawals, forest cutting, wetland loss, and development. These challenges will be exacerbated by a shifting climate, especially increasing temperature, precipitation, sea level, and salinity.

Where possible, the future status and trends of indicators are also discussed in the context of the expected increase in human activities and climate change. As one example, warming water (from climate change) holds less dissolved oxygen, which is vital for aquatic animals such as fish. Oxygen deficits can also be exacerbated by excess nutrients from runoff, which fuel microbial respiration. With increased water temperature and potentially greater nutrient runoff from more people, it is plausible to expect the trajectory of past improvements in dissolved oxygen conditions to reverse course, requiring even more effort to manage dissolved oxygen than in the past due to changing conditions. Similarly, increasing sea level and wind fetch could interact with bigger waves from larger ships to hasten erosion of coastal wetlands that help to sustain water quality. This report includes many other similar examples of past successes, ecological interactions, and emerging threats.

The cumulative impacts to natural resources from both anthropogenic alterations and shifting climate conditions are difficult to predict. Hence, continued careful monitoring of the indicators reported here will be critical so that environmental managers can make informed decisions to sustain crucial life-sustaining ecosystem services, which are worth billions of dollars per year. Specifically, to address future environmental challenges while preserving prosperity in the region, agencies, scientists, and others must work together to:

- Sustain and strengthen the effectiveness of monitoring, protection and restoration efforts by focusing on a set of shared, strategic priorities
- Set science-based goals that plan for change as part of the natural landscape
- Adopt realistic environmental targets that focus on preserving and enhancing key life-sustaining features
- Apply an ecosystem-based approach to management that considers cumulative impacts
- Facilitate collaboration among states and sectors to implement the Comprehensive Conservation Management Plan of the Delaware Estuary Program, through the congressionally designated National Estuary Program for the Delaware River and Bay.

The information, perspectives and future needs stated in this report reflect the best current scientific consensus of the authors that drafted individual sections and do not necessarily represent the official views of the Partnership for the Delaware Estuary, other members of the Delaware Estuary Program, or any other participating entity or specific author. This report is a collective, peer reviewed effort which attempts to coordinate a consistent style and content among sections. However, the written presentations and depth of analysis will reflect (or vary in accordance with) the availability of data, methods of presentation, analytical rigor and writing styles that are appropriate for different fields and various authors.
Table 0.1 Top positive (A) and negative (B) findings from the 2017 Technical Report for the Estuary and Basin, as judged by the Science and Technical Advisory Committee and this report’s authors. Impact scores are qualitative and based on 1) novelty of the finding for the 2017 reporting period, 2) relative overall impact to estuary and basin wide health, and 3) immediacy of action need. Impact scores of 1 for positives are very good, whereas a score of 6 for a negative is near detrimental. Averaging all impact scores yields a total score of 3.66, or an overall “fair” for the reporting period’s estuary and basin health.

### A. Chapter Positives

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Condition</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watersheds Ecosystem Services</td>
<td>Worth &gt;$12 billion annually</td>
<td>1</td>
</tr>
<tr>
<td>Water Quantity Consumptive Use (Public)</td>
<td>Declined per capita 1990-2014</td>
<td>2</td>
</tr>
<tr>
<td>Water Quality Dissolved Oxygen</td>
<td>Increased dramatically 1960s to present</td>
<td>1</td>
</tr>
<tr>
<td>Sediments Total Organic Carbon</td>
<td>Decreased, suggesting lower organic pollution</td>
<td>2</td>
</tr>
<tr>
<td>Aquatic Habitats Fish Passage</td>
<td>&gt;160 km now accessible on the Lehigh River and Schuylkill</td>
<td>1</td>
</tr>
<tr>
<td>Living Resources Striped Bass</td>
<td>Once nearly extirpated, the current population is a major spawning stock</td>
<td>1</td>
</tr>
<tr>
<td>Climate Ice Jams</td>
<td>Decreased over period of record</td>
<td>2</td>
</tr>
<tr>
<td>Restoration Habitat Type</td>
<td>Progress among types matches current priorities</td>
<td>3</td>
</tr>
</tbody>
</table>

### B. Chapter Negatives

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Condition</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watersheds Land Cover</td>
<td>Development continues to increase; forest acreage continues to decline</td>
<td>6</td>
</tr>
<tr>
<td>Water Quantity Consumptive Use (Industrial)</td>
<td>Increased about 20% between 1994-2014</td>
<td>5</td>
</tr>
<tr>
<td>Water Quality Nutrients</td>
<td>Nitrogen remains high relative to other estuaries</td>
<td>5</td>
</tr>
<tr>
<td>Contaminants</td>
<td>Exceeds risk thresholds for consumption of many fish</td>
<td>5</td>
</tr>
<tr>
<td>Sediments Sediment Budget</td>
<td>Sediment removal exceeds inputs, possibly impairing estuary habitats</td>
<td>6</td>
</tr>
<tr>
<td>Aquatic Habitats Tidal Wetlands</td>
<td>Acreage decreased &gt;1.5% 1996-2010, mainly from salt marsh loss</td>
<td>5</td>
</tr>
<tr>
<td>Living Resources Atlantic Sturgeon</td>
<td>Despite young of year fish seen in 2009, the species is now federally endangered</td>
<td>6</td>
</tr>
<tr>
<td>Freshwater Mussels</td>
<td>Abundance and range continues to decline</td>
<td>5</td>
</tr>
<tr>
<td>Climate Precipitation</td>
<td>Increased, especially in the past 30 years, increased flooding</td>
<td>4</td>
</tr>
<tr>
<td>Restoration Funding</td>
<td>Investment is very low compared to other large estuaries</td>
<td>6</td>
</tr>
</tbody>
</table>
Introduction
The construction of the 2017 Technical Report for the Delaware Estuary and Basin (TREB) was led by the Partnership for the Delaware Estuary’s Science and Technical Advisory Committee (STAC; Fig 0.1) in collaboration with many other contributing scientists and managers. Core members of the STAC include professionals from: Delaware River Basin Commission, Delaware Department of Natural Resources and Environmental Control, New Jersey Department of Environmental Protection, Pennsylvania Department of Environmental Protection, Philadelphia Water Department, and Partnership for the Delaware Estuary. Other authors, contributors and reviewers represented dozens of academic, non-profit, and private business organizations.

The 2017 TREB reviews the status and trends in extent or health of 50 environmental indicators as a way to systematically gauge the current health of the Delaware Estuary and Basin. Environmental indicators are specific, measurable markers that are used to assess the condition of the environment and indicate whether conditions are improving or worsening over time. Additionally, indicators help raise awareness about important environmental issues, serve as tools for evaluating the effectiveness of management actions, and can function as early warning signals for detecting adverse changes in environmental quality. Indicators were reviewed based on data availability and the indicator’s ability to relate something important about the status of the natural resources, water quality, and climate conditions of the Delaware Estuary and its watersheds.

The final list of indicators chosen for study evolved over the course of several years, starting in 2006, but becoming more refined for technical reporting by the end of 2008. The 2008 State of the Estuary report paved the way for a more comprehensive technical effort with the 2012 TREB, which included status and trends data for more than fifty indicators, along with data analyses and interpretation. These indicators were selected and grouped based on consensus by the STAC and core members of the Delaware Estuary Program. The 2017 TREB includes updated data and a richer analysis for 46 of the 58 indicators (79%) reported in the 2012 TREB, and these updated indicators are denoted with bold font in the Table of Contents. Most of the indicators from 2012 that were not updated lacked available new data, and in a few cases a better indicator was developed that replaced the earlier indicator. Hence, this 2017 TREB includes the most current, comprehensive list of trackable metrics which professionals throughout the region find important, useful, and indicative of not only the ecological health of the estuary, but also of the way that the human population inhabiting the area interacts with these valuable resources.

The purpose of this report is to synthesize the most recent status and trends data into a technical report, which can serve as the basis for translation products such as State of the Estuary Reports (PDE) and State of the Basin Reports (DRBC) that are periodically written for the public. Although data and analyses were not able to be obtained for some important resource conditions, the balance of indicator data covered in this report reflects the best possible regional perspective on overall environmental status and trends in the Delaware Estuary and Basin.

TREB results are also vital for measuring the progress made toward implementing the Comprehensive Conservation and Management Plan (CCMP) for the Delaware Estuary. By tracking indicators and assessing their status and trends every 5 years, periodic revisions and updates to CCMP goals and actions can be responsive to changing conditions. To assist with CCMP updates and guide environmental managers and
scientists, this report lists future “Actions and Needs” for each indicator. In many cases, these actions and needs call for improved coordination and/or monitoring. Where data are currently incomplete or unavailable, PDE and partners will work to sustain and improve monitoring to address data gaps and facilitate data sharing and management.

Organization of the Technical Report for the Delaware Estuary and Basin

The sample frame for TREB is the entire Delaware River Basin, although the focus for some indicators is particular sub-watershed areas such as the Delaware Estuary which forms the lower half of the Delaware River Watershed (HUC#0204) (see Fig 0.4). Indicators are grouped into eight chapters, beginning with watershed traits and land use in Chapter 1. The watershed regions considered in this report extend from headwater streams in New York to the mouth of Delaware Bay between Cape May, NJ and Cape Henlopen, DE.

Water resource indicators are next discussed in Chapters 2 and 3, followed by sediment indicators in Chapter 4. Habitat-related indicators are examined in Chapter 5, distinguishing among subtidal, intertidal (Fig. 0.2A and B) and nontidal habitats (Fig 0.2C). Living resources are in Chapter 6, summarizing status and trends of key animals that live in the estuary or river (Fig. 0.2D). Chapter 7 is dedicated to tracking changes in climate-related conditions (Fig. 0.2E). Whereas Chapters 1-7 focus on status and trends in specific environmental conditions, Chapter 8 discusses indicators that track the progress of environmental protection and restoration efforts (Fig. 0.2F).

How to Use the Technical Report for the Delaware Estuary and Basin

For information on the status and trends of any specific indicator (e.g., American eels), refer to the appropriate section. To obtain an overall status summary for the Delaware Estuary and Basin, one can refer to the executive summary although we recommend reviewing the entire report. Many indicators interact through complex physical, chemical and biological relationships, and a complete review facilitates a fuller
understanding of the status of functional interrelationships (i.e. how the system is working) rather than
the abundance of single structural elements (i.e. how much of one parameter is present). For example,
the population abundance of some fish species may depend on others through predation or competition
relationships (e.g. striped bass versus weakfish - both are never abundant at the same time). Suspended
sediment in the water can be a pollutant (e.g. in nontidal tributaries) or an essential limiting resource (e.g. for
tidal wetlands), depending on the perspective.

No single indicator or chapter is diagnostic of overall environmental conditions. With respect to water
quality, for example, there has been dramatic improvement in dissolved oxygen conditions since the 1972
Clean Water Act, which resulted in widespread upgrades to wastewater treatment and other remedies. On
the other hand, the system remains saddled with legacy contamination resulting from being the seat of the
American Industrial Revolution, and some types of pollutants such as nitrogen continue to increase.

The Delaware Estuary and Basin also has many unique facets, such as having globally rare tidal freshwater
ecosystems. Naturally high turbidity in part of the estuary is thought to help stem eutrophication problems
by light shading of phytoplankton blooms, despite high nutrient loadings. By cross-comparing results among
chapters and reading authors’ narratives, one can obtain a better understanding of the system’s unique
features and complex interactions. Taken together, analysis of all chapters provide the best possible basis for
determining key status and trends of environmental conditions in the Delaware Estuary and Basin.

Regional Divisions of the Delaware Estuary and Basin

To simplify status and trend analyses, the Delaware Estuary and Basin are divided into four different
“watersheds” or “regions”. Additional geospatial resolution (e.g. sub-watersheds) varies among indicators,
depending on the coarseness of datasets and scientific intent. Geospatial resolution of sub-regions therefore
varies from course (e.g., nontidal versus tidal; Fig 0.4) to moderate (e.g., ten sub-watersheds; Fig 0.5 and Fig.
0.6) to fine (e.g., twenty-one sub-regions similar HUC12s; Fig 0.7).

Figure 0.3  Examples of the various sub-regions (see Fig. 0.5) of the Delaware
Estuary and Basin: the Delaware Water Gap (A and B, Central), the Christina River, DE
(C, Lower), the view of Philadelphia, PA from Pennsauken, NJ (D, Lower), Pennsville,
NJ (E, Lower), and horseshoe crabs in Egg Island, NJ (F, Bayshore). Photo credits:
Partnership for the Delaware Estuary staff.
Figure 0.4 The Nontidal and Estuary divisions of the Delaware Estuary and Basin.
Figure 0.5  The four regions of the Delaware Estuary and Basin.
Figure 0.6  The ten subregions of the Delaware Estuary and Basin.
Figure 0.7  The 21 watersheds of each subregion within the Delaware Estuary and Basin.

Label Legend
DB - Delaware Bay
EW - East-West Branch
LC - Lower Central
LE - Lower Estuary
LV - Lehigh Valley
LW - Lackawaxen
NM - Neversink-Mongaup
SV - Schuylkill Valley
UC - Upper Central
UE - Upper Estuary