ENVIRONMENTAL MONITORING PLAN

FOR

DELAWARE'S INLAND BAYS

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INLAND BAYS
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The Delaware Center for the Inland Bays is a nonprofit organization and a National Estuary Program. It was created to promote the wise use and enhancement of the Inland Bays watershed by conducting public outreach and education, developing and implementing restoration projects, encouraging scientific inquiry and sponsoring needed research, and establishing a long-term process for the protection and preservation of the Inland Bays watershed.

EXECUTIVE SUMMARY

The purpose of the Inland Bays Environmental Monitoring Plan (IBEMP) is to track the status and trends of key environmental indicators used to assess the chemical, physical, and biological integrity of the estuary and surrounding study area, and to evaluate whether the goals of the Inland Bays Comprehensive Conservation and Management Plan (CCMP) are being met. It is a comprehensive inventory of existing, new, and proposed monitoring activities to meet these objectives and is intended to guide future research and monitoring efforts. The plan is also intended to lead to increased integration of work and consolidation of resources.

The original Monitoring Plan for the Delaware Inland Bays was written in 1995 and last updated in 1996. Since then, collection of additional relevant parameters has been initiated, responsibilities for collection have changed, and both monitoring technology and the scientific understanding of the Bays have evolved significantly. The Center for the Inland Bays (CIB) manages or supports some of these programs, but most are led and supported financially by academic, county, state, and federal partners. It is the CIB's role to facilitate these partnerships and regularly synthesize, analyze, and report indicator data for the Inland Bays. This updated document provides an opportunity to re-engage stakeholders around its cooperative implementation.

This IBEMP presents an inventory of existing projects and programs that conduct ongoing, long-term environmental monitoring in Delaware's Inland Bays. Many of these programs contribute data that are used by the CIB to develop *State of the Delaware Inland Bays* reports every five years. Other entities produce data that may illuminate progress toward achieving goals of the CCMP, provide data for new environmental models, or may be useful for development of new indicators in the future. For each program we identify CCMP objectives addressed, responsible entities, data collected, data gaps, frequency of data collection and reporting, and how the data are shared, reported and used. The programs are organized into seven sections that cover monitoring of: (1) surface water; (2) groundwater; (3) wastewater; (4) atmospheric deposition; (5) wetlands; and (6) climate.

Of primary importance in this IBEMP are recommendations made for new monitoring programs, or enhancement of existing programs. These recommendations are made based upon critical data gaps (including emerging issues), the availability of new methods or technologies, and/or changes needed to make programs sustainable over the long term.

Highest priority recommendations are:

- Development of a new hydrodynamic/watershed model for the Inland Bays;
- Upgrade of the University of Delaware's Citizen Monitoring Program database to a format that is sustainable long-term and can serve data to the public through STORET and/or the state's Water Quality Portal;
- Long-term, continuous monitoring of dissolved oxygen and chlorophyll at key stations;
- Monitoring of submerged aquatic vegetation in tidal regions of the Inland Bays; and
- Monitoring of local indicators of sea level rise.

Other recommendations, judged to be important but of slightly lower priority, include:

- Continued monitoring of the tidal prism at the Indian River Inlet;
- Long-term monitoring of oyster recruitment and growth in the Bays, particularly as aquaculture begins, and shellfish restoration and enhancement projects are undertaken;
- Shoreline condition and modification monitoring to evaluate the effectiveness of living shoreline initiatives;
- Continued analyses of tidal marsh acreage and condition using GIS methodology established in a 2014 study conducted by the University of Delaware;
- Monitoring of estuary acidification; and
- Monitoring of recreational Blue Crab and Hard Clam harvests from the Inland Bays.

- Build and maintain a list of research and monitoring activities focused on emerging contaminants in the Inland Bays.

For each recommended program, partner organizations or agencies are identified to be responsible for, or participate in, its implementation. Where possible, estimated costs and potential funding sources are provided. Coordination among those organizations involved in data collection, processing and analysis, storage and provision, and presentation is key to the success of monitoring in the Inland Bays. The Center for the Inland Bays Scientific and Technical Advisory Committee (STAC) will be responsible for ensuring the implementation of this plan. This includes engagement of all partners collecting data and ensuring that data are submitted to the CIB for State of the Bays reporting.

The IBEMP is a living document intended to evolve to meet future needs for tracking the status and trends of conditions within the Inland Bays and progress toward meeting the goals of each of the CCMP focus areas. As the CCMP is revised, or new monitoring opportunities or technologies appear, revisions to the plan may need to be made. In order to ensure that monitoring programs are implemented and coordinated, and that the IBEMP is kept up to date, a CCMP/Monitoring subcommittee of the STAC is responsible for assisting the CIB with a biannual review/update.

This version of the document represents the first update, completed in January 2021. The inventory of existing long-term monitoring programs in the Inland Bays study area (Appendix C) was updated to reflect current program status and recent changes. Summaries of progress to date on each of the report's recommendations for new or enhanced monitoring programs were added. Significant progress has been made on many of the recommendations in the two years since the IBEMP was developed.

INTRODUCTION

THE INLAND BAYS AND THEIR WATERSHED

Delaware's Inland Bays (the Bays) refers to all tidal waters and tidal wetlands encompassing the Indian River Bay, Indian River, Rehoboth Bay, and Little Assawoman Bay (Figure 1). The 292-square mile Inland Bays watershed is located in southeastern Sussex County, and drains to 35 square miles of bays and tidal tributaries. Rehoboth Bay and Indian River Bay are tidally connected to the Atlantic Ocean by the Indian River Inlet. Little Assawoman Bay is connected by the Ocean City Inlet, 10 miles to the south in Maryland. As of 2012, agriculture represented the largest land use in the watershed (31%), followed by developed/developing lands (24%), forested lands (17%), wetlands (16%), and open water (12%) (Figure 2).

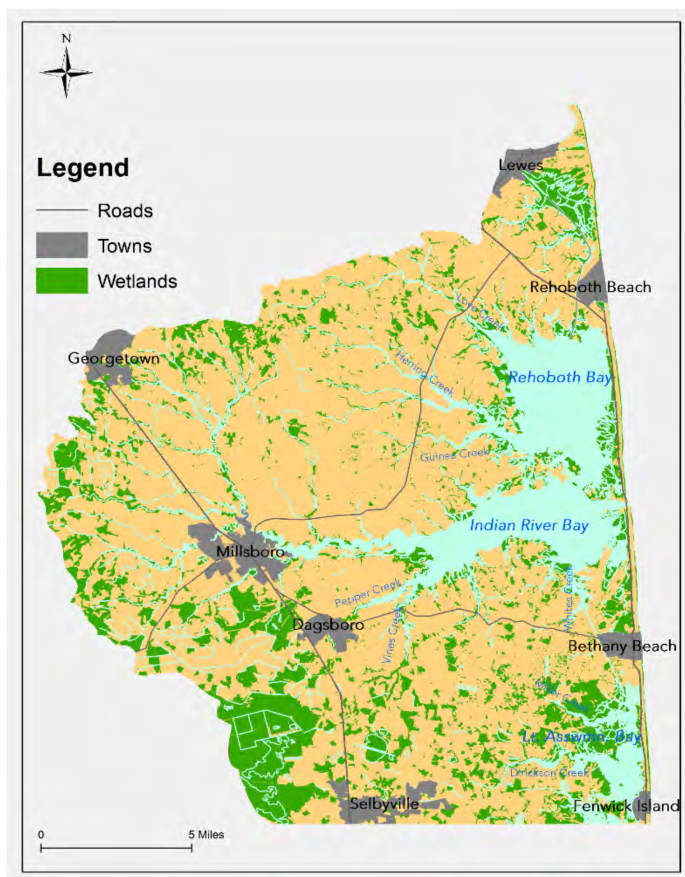

FIGURE 1 – Map of the Delaware Inland Bays Watershed

Historically, the Bays have been extremely dynamic. Prior to the 1930's the Indian River system consisted entirely of freshwater with the only connection to the Atlantic occurring during storm surges when the barrier island was breached, at various locations. The Indian River Inlet, as it exists today, was stabilized in the late 1930's and has deepened over time, passing greater volumes of water and increasing the tidal range of the Bays. This has led to a long-term increase in the salinity of the Bays. The greatest impacts of the salinity shift are evident in the upper reaches of the tributaries where tidal freshwater segments have been virtually eliminated. The dynamic flux of the Inland Bays poses an exceptional challenge to those responsible for monitoring the health of the system and establishing scientifically defensible status and trends data and analyses.

The degradation of the Bays has been a gradual process occurring over many decades, and it is anticipated that the recovery process will proceed over a similar period of time. Nutrient contaminated groundwater in the Inland Bays watershed, for example, moves very slowly, and the contamination reaches depths of just over 100 feet. If all contamination of the aquifer were to stop immediately, it is predicted that it would take 75 to over 100 years for replacement water to purge the system and reach the Bays.

While there are other issues raised in the CCMP, two areas of priority problems have been identified in the Inland Bays: eutrophication caused by excessive nutrient loading, and habitat loss and modification.

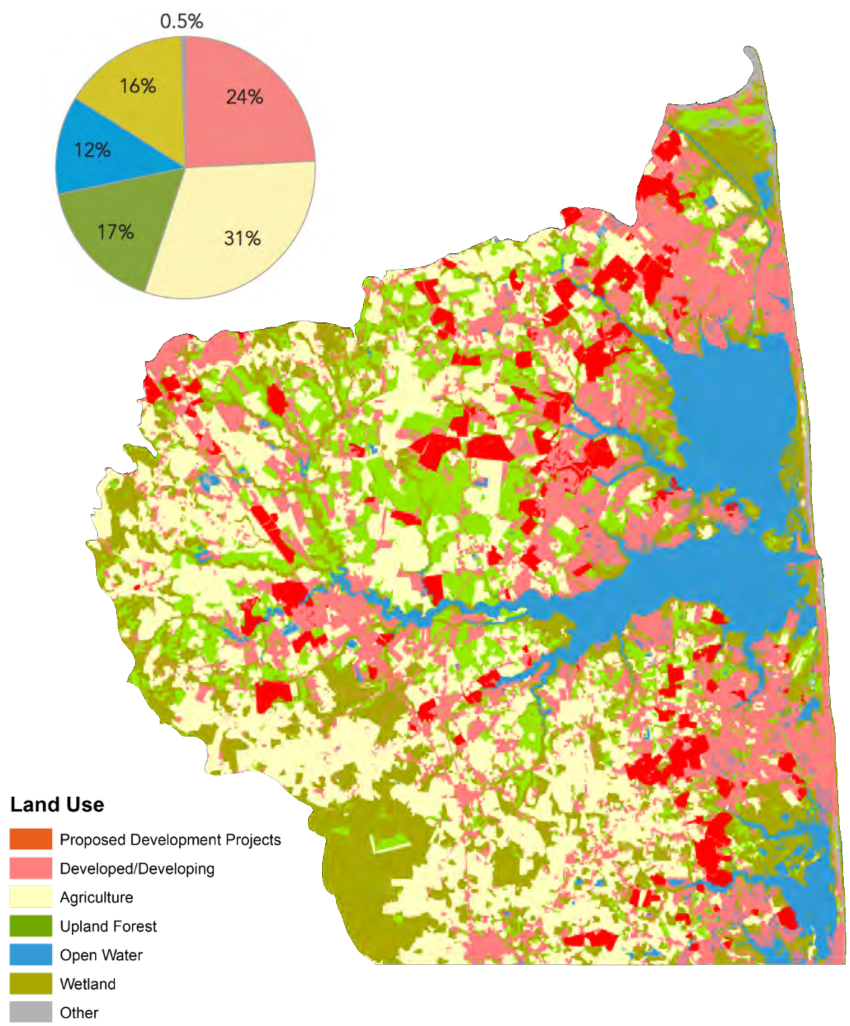

FIGURE 2 – Map: Watershed Land Use, 2012

THE INLAND BAYS ENVIRONMENTAL MONITORING PLAN

Background

A key requirement of National Estuary Programs is to monitor the effectiveness of actions taken to implement their Comprehensive Conservation and Management Plans (CCMPs). This type of research must include the understanding of the natural variability of the ecosystems and populations that make up the estuary and its watershed.

The original Inland Bays CCMP was developed in 1995 to guide the work of the partners and cooperators charged with its implementation. Subsequent to this, Total Maximum Daily Load (TMDL) regulations for nitrogen and phosphorus were established for Indian River, Indian River Bay, and Rehoboth Bay in 1998, and for Little Assawoman Bay and the major tributaries of the Inland Bays in 2005. In 2008 the Inland Bays Pollution Control Strategy (PCS) was promulgated with the intention to implement the TMDLs. Furthermore, since 1995 population growth and development have brought significant changes to the watershed.

A comprehensive update to the Inland Bays CCMP was published in 2012 as an Addendum to the original plan (Delaware Center for the Inland Bays, 2012). The Addendum includes 10 goals and 81 objectives, organized under eight focus areas:

- Nutrient Management
- Wastewater Management
- Stormwater Management
- Water Quality Management
- Managing Living Resources and Their Habitat
- Planning for Climate Change
- Coordinating Land and Water Use Decisions
- Outreach and Education

Actions that would be required to accomplish the goals and objectives were written, as were Performance Measures that could be used to track progress (Appendix A). The CCMP is currently being revised and is due to be completed in 2021.

During the Center for the Inland Bays (CIB's) original CCMP development process that culminated in 1995, a *Plan for Inland Bays Environmental Monitoring* was produced and included as Appendix G of that report. The plan assembled the metadata of relevant environmental parameters collected at the time and put forth hypotheses for their change based on CCMP implementation. An updated *Monitoring and Assessment Plan for Delaware's Inland Bays (1996-2000)* was published in December 1996.

Since then, collection of additional relevant parameters has been initiated, responsibilities for collection have changed, and both monitoring technology and the scientific understanding of the Bays have evolved significantly. This requires that the Plan be revised and provides an opportunity to re-engage stakeholders around its cooperative implementation.

The current version of the IBEMP was developed with input from the CIB's Scientific and Technical Advisory Committee (STAC), and the participants of a facilitated Ambient Water Quality Monitoring Plan Workshop held in August 2015. These participants included representatives from the Delaware Department of Natural Resources and Environmental Control (DNREC), the University of Delaware, and the U.S. Geological Survey.

Objectives

The purpose of the Inland Bays Environmental Monitoring Plan (IBEMP) is to monitor the conditions of the Inland Bays Estuary and Watershed used to evaluate the overall effectiveness of the CCMP. It serves as a comprehensive blueprint for monitoring activities that relate to the mission of the CIB.

The IBEMP is a living document intended to evolve to meet future needs for tracking the status and trends of eutrophication and habitat loss/modification within the Inland Bays. It is a comprehensive inventory of projects that are ongoing, or are needed to fill data gaps, to monitor progress toward meeting the CCMP goals. The plan is intended to guide research, monitoring, and assessment efforts, and may lead to increased integration of work and consolidation of resources. If the CCMP is revised or updated, the IBEMP will be reviewed and revised if necessary to reflect that new document starting in 2019.

The primary objectives of the IBEMP are to:

- Identify monitoring needed to track progress toward meeting the goals for improving water quality and living resources within the Bays;
- Measure the effectiveness of CCMP actions in bringing about environmental change;
- Identify projects/programs/agencies that are conducting monitoring that meets these goals;
- Identify gaps where data and information are needed (including emerging issues), and suggest alternatives for filling those gaps where possible through integration of work being carried out under active projects;
- Make recommendations for data synthesis, and for coordination among those organizations involved in data collection, processing and analysis, storage and provision, and presentation;
- Identify funding needs and strategies to address data gaps and implement the IBEMP.

Summary of Plan Development Process

Stakeholders and partners assisted the CIB in the development of this IBEMP update. The CIB hosted a facilitated workshop to discuss ambient water quality monitoring in the Inland Bays. A meeting of the STAC was also devoted to discussion of the plan. Notes from the workshop and STAC meeting are included in Appendix B.

MONITORING PLAN UPDATES

Periodic reevaluation of the IBEMP must be conducted to ensure that data gaps are addressed. During this reevaluation, monitoring programs will be checked for current relevance, applicability to emerging needs, and improvements in technology. If necessary, the CIB will revise the IBEMP to reflect any updates.

A standing CCMP/Monitoring Subcommittee was appointed by the Chair of the STAC in 2018. This subcommittee is responsible for biannual review of, and updates to, the Inland Bays Environmental Monitoring Plan, as well as development of strategies for implementation. The biannual period for review was selected to correspond with the State's Combined 305(b) and 303(d) reports to EPA. At a minimum this subcommittee shall include representatives from the Center for the Inland Bays, DNREC Watershed Assessment Section, DNREC Environmental Laboratory, University of Delaware Citizen Monitoring Program, Center for Environmental Monitoring and Analysis (CEMA), and the Delaware Geological Survey.

This version of the IBEMP represents the first update, completed in 2020. STAC subcommittee members worked with CIB staff to review and update the inventory of existing long-term monitoring programs in the Inland Bays study area (Appendix C). The October 2020 meeting of the full STAC also included discussion of progress made on plan recommendations. Summaries of progress and new data needs have been added to the 'Recommendations and Supporting Programs' section of this updated document. The next biannual update will need to consider the CCMP revision, due to be completed in 2021.

ASSESSMENT AND REPORTING

ENVIRONMENTAL INDICATORS AND STATE OF THE ESTUARY REPORTS

Conditions in the Inland Bays are dynamic and it is essential to monitor temporal and spatial changes in water quality across the watershed and understand how changes relate to the health of the estuary.

Comprehensive assessments of the condition of the Inland Bays were published in 1995, 2004, 2011, and 2016. The *State of the Delaware Inland Bays* report currently is updated and published every five years. The 2016 report included assessment of 35 individual environmental indicators, which are included in the IBEMP and identified in Table 1. The indicators are used to assess the status and trends of water quality and the health of Inland Bays habitats and living resources. Status and trends are assigned using best professional judgment and reviewed by scientists knowledgeable in these areas. For each indicator, long-term trends are addressed, as well as short-term changes that have occurred since the previous report was published.

The IBEMP is intended, in part, to ensure that long-term collection of data needed to develop these environmental indicators for the Bays is continued. The next *State of the Delaware Inland Bays* report will be published in fall 2021. Any changes to the list of indicators used in that report will be reflected in the next biannual update of the IBEMP, schedule to be completed in 2022.

TMDL REPORTING AND BENCHMARK GOALS

Section 305(b) of the Federal Clean Water Act requires that states prepare and submit a Watershed Assessment Report to EPA on April 1st of every even numbered year. The 305(b) reports and monitoring data are used to compile a list of impaired waters, commonly referred to as the 303(d) list. When waters are identified as impaired on 303(d) lists, a Total Maximum Daily Load (TMDL) must be developed.

All of the 305(b) Reports and 303(d) lists that Delaware has submitted to EPA are available on the DNREC website (https://dnrec.alpha.delaware.gov/watershed-stewardship/assessment/reports/). Draft Core Documents for the 2020 305(b)/303(d) Integrated Report were posted at the time of completion of this monitoring plan update (December 2020). A copy of the 2020 assessment, listing, and reporting methodologies, including benchmark goals and hypotheses, is included here as Appendix D.

INLAND BAYS MONITORING PROGRAMS

QUESTIONS ADDRESSED BY MONITORING

Two types of monitoring are used to track progress toward meeting goals of the CCMP – programmatic and environmental. The IBEMP focuses on environmental outcomes, i.e., changes in environmental conditions, ecological functions, and biological populations.

The objectives of the 2012 Addendum to the CCMP were expressed as monitoring questions, which drive much of the environmental monitoring conducted by the CIB and its partners. Understanding of both responses to stressors and natural variability is critical for determining relationships between actions taken and responses within the estuary system. These questions, listed below, are organized to correspond with the CCMP Addendum focus areas. Question numbers are referenced in the Monitoring and Indicator Matrix (Table 1).

MONITORING QUESTIONS

Focus Area: Nutrient Management

1. Do nutrient loadings from nonpoint and atmospheric sources meet established TMDL targets?

Focus Area: Wastewater Management

2. Do nutrient loadings from point sources meet established TMDL targets?
3. Are the frequency and spatial distribution of emerging contaminants of concern increasing, decreasing, or remaining stable?

Focus Area: Stormwater Management

4. Is the aerial coverage of effective impervious surface in the watershed increasing, decreasing, or remaining stable?

Focus Area: Water Quality Management

5. Is tributary water quality improving, declining, or remaining stable?
6. Are phytoplankton biomass levels (as indicated by chlorophyll-a concentrations) above, below, or consistent with established targets?
7. Are water column nutrient concentrations above, below, or consistent with established targets?
8. Is water clarity above, below, or consistent with established targets?
9. Is the areal extent of low dissolved oxygen concentrations increasing, decreasing, or remaining stable?
10. Are the frequency and spatial distribution of macroalgal blooms increasing, decreasing, or remaining stable?
11. Are the concentrations and spatial distribution of fecal bacteria increasing, decreasing, or remaining stable?
12. Do concentrations of toxics in water and sediment meet water quality standards?

Focus Area: Managing Living Resources and their Habitat

13. Is the acreage of bay grasses increasing, decreasing or remaining stable?
14. Is the acreage and condition of freshwater wetlands, including isolated wetlands, increasing, decreasing or remaining stable?
15. Is the acreage and condition of tidal wetlands increasing, decreasing or remaining stable?
16. Is the average width of vegetated buffers on waterways increasing, decreasing, or remaining stable?
17. Is the percentage of hardened shorelines in the Inland Bays increasing, decreasing, or remaining stable?
18. Are populations of migratory fish increasing, decreasing or remaining stable?
19. Is the acreage of approved shellfishing waters increasing, decreasing or remaining stable?
20. Are the density and distribution of economically important shellfish (oysters, hard clams, blue crabs) increasing, decreasing or remaining stable?
21. Are the density and distribution of invasive plant and animal species increasing, decreasing or remaining stable?

Focus Area: Planning for Climate Change

25. Are water levels in the estuary increasing, decreasing, or remaining stable?
26. Are water temperatures increasing, decreasing, or remaining stable?
27. Are pH conditions in the estuary increasing, decreasing, or remaining stable?
28. Are shifts of dominant aquatic species changing over time in response to long-term temperature, pH, or salinity changes?

Focus Area: Coordinating Land and Water Use Decisions

29. Is the acreage of natural habitat protected or restored increasing, decreasing, or remaining stable?
30. Are populations of Species of Greatest Conservation Need (as defined by the Delaware Wildlife Action Plan) in the watershed increasing, decreasing or remaining stable?

EXISTING MONITORING PROGRAMS

The IBEMP provides a framework that builds upon existing programs that are conducting ongoing, long-term environmental monitoring within the Delaware's Inland Bays study area. Many of these programs contribute data that are used to develop *State of the Delaware Inland Bays* reports every five years. Others produce data that may illuminate progress toward achieving goals of the CCMP and/or Pollution Control Strategy, provide data for new environmental models, or may be useful for development of new indicators in the future.

CCMP objectives and monitoring questions addressed by these programs, responsible entities, data collected, data gaps, frequency of data collection and reporting, and how the data are shared, reported and used are summarized in the Monitoring and Indicators Matrix (Table 1).

The monitoring programs listed in the Matrix are organized into the following sections:

1. Surface Water
2. Groundwater
3. Wastewater
4. Atmospheric Deposition
5. Wetlands
6. Living Resources
7. Climate

Many of the monitoring programs in Table 1 are described in greater detail in Appendix C. Cross-references to sections of the Appendix are provided in column two of the Table. Appendix C has been updated in 2020 to reflect any changes to programs that have occurred since the IBEMP was originally published in 2018.

The expectation and recommendation of this Plan is that these programs will continue to be funded and conducted long-term. Coordination, collaboration, and long-term support for these monitoring programs are critical for the success of the IBEMP.

The CIB funds and leads the following monitoring programs:

- Long-term salt marsh monitoring
- Seaweed abundance
- Inshore fish and blue crab surveys
- Horseshoe crab surveys and tagging
- Diamondback terrapin surveys (added in 2020)

Responsibility for implementation of the remaining programs lies primarily with other entities, as noted in Table 1. The CIB will work with these entities, as needed, to facilitate partnerships and funding that ensure the sustainability of these programs. Through the STAC and state/regional workgroups such as the Delaware Environmental Coordination Council (https://delawaremonitoringcouncil.org/), the CIB will ensure that data gaps are discussed and addressed in each biannual review of the IBEMP. The CIB also will continue to synthesize Inland Bays monitoring data and communicate findings to the public, stakeholders, and decision makers through State of the Bays reports and other media.

TABLE 1 - Monitoring and Indicators Matrix (♦ = used to develop indicator for State of the Bays reports)

Monitoring Program	Appendix E Cross-reference	CCMP Objectives/ Monitoring Questions	Indicators & Measures	Data Collected	Collection Frequency	Record of Collection	Responsible Entity/Entities	Frequency of Reporting	Sharing/Reporting	Gaps & Funding Needs
1. SURFACE WATER MONITORING PROGRAMS										
Ambient Water Quality, State of Delaware General Assessment Monitoring Network (GAMN) ♦	E.1.1	CCMP: Water Quality Management, Objectives 1, 3, and 6 Questions: 1,3,5,6,7,8,9,11,12,26, 27,28	Comparison with TMDL targets for nitrogen, phosphorus, and bacteria. Data used by CIB to develop a Water Quality Index (WQI) to indicate suitability for eelgrass reestablishment.	TP, ortho-P, ammonia N, NO_2+NO_3, TN, TOC, DOC, Chl a, BOD, DO, TSS, alkalinity, hardness, pH, conductivity, salinity, temperature, Secchi depth, light attenuation, turbidity, chloride, total *Enterococcus*, Cu, Pb, Zn, As	Most stations monitored 6 times/year for three years, then 12 times/year for two years.	1998 to present	DNREC Division of Water, Environmental Laboratory Section DNREC Division of Watershed Stewardship, Watershed Assessment Section	Biannually	GAMN data entered into STORET and publically available via the Delware Water Quality Portal. Data published biannually in 305(b) and 303(d) combined reports. Indicator in *State of the Delaware Inland Bays* reports.	Continue long-term program funding. Continuous/high frequency monitoring for DO and other parameters that fluctuate significantly over short time scales. New hydrodynamic/watershed model for the Inland Bays. Monitoring of estuary acidification. Emerging contaminants of concern.
Ambient Water Quality, Citizen Monitoring Program (CMP) ♦	E.1.2	CCMP: Water Quality Management, Objectives 1, 3, and 6; Outreach and Education, Objective 4 Questions: 5,6,7,8,9,11, 26,27,28	Data used by CIB to develop a Water Quality Index (WQI) to indicate suitability for eelgrass reestablishment. Data included in state's Combined 305(b) Report and 303(d) List, but not used in listing determinations.	Ortho-P, ammonia N, NO_2+NO_3, DO, Chl a, TSS, pH, conductivity, salinity, temperature, Secchi depth, rainfall	weekly to biweekly, dependent upon parameter	Varies by station. Longest records begin in 2000.	University of Delaware, Sea Grant Marine Advisory Service	Semi-monthly summary reports	Summary reports posted online. Beginning with 2019 records, CMP data now to be entered into WQX and publically available via the Delaware Water Quality Portal. Data published as appendix in 305(b) and 303(d) combined reports. Indicator in *State of the Delaware Inland Bays* reports.	Resources to continue data collection at priority Inland Bays stations. Upload all legacy data to WQX and state portal.
Fecal contaminants, Citizen Monitoring Program (CMP) ♦	E.1.2	CCMP: Water Quality Management, Objectives 1, 3, and 6; Managing Living Resources, Objective 5; Outreach and Education, Objective 4 Questions: 11	Indicator derived from percentage of summer samples exceeding safe swimming standard. Harmful algal bloom and TE data used to support State's Shellfish Monitoring Program.	Total *Enterococcus*	Biweekly	Varies by station. Longest records begin in 2000.	University of Delaware, Sea Grant Marine Advisory Service	Semi-monthly summary reports by CMP. Every five years in CIB indicator reports.	Summary reports posted online by CMP. Indicator in *State of the Delaware Inland Bays* reports.	Along with ambient WQ, data shpould be made publically available via STORET/WQ Portal.
Fecal contamininants, State of Delaware Coliform Monitoring Program	E.1.3	CCMP: Water Quality Management, Objectives 1, 3, and 6; Managing Living Resources, Objective 5; Outreach and Education, Objective 4. Questions: 11,19	Assess the suitability of the Inland Bays waters for shellfish harvest using federal standards.	Total/fecal coliforms	9-10 times per year	2008 to present. Fecal coliform collection began in 2016, with plans to succeed total coliforms as the method to assess the suitability of waters.	DNREC Division of Watershed Stewardship Shellfish Program	Changes in shellfish advisories reported as made.	Shellfish advisory interactive map on DNREC website.	Refinement of source tracking. Continue current funding.
Stream/Tide Gaging	E.1.4	CCMP: Water Quality Management, Objectives 1 and 6; Planning for Climate Change, Objective 1. Questions: 1,25	Tide elevation. Real-time and long-term, current and historical streamflow.	Discharge/flow, tide elevation.	Continuous	Varies by station. Longest record begins 1985.	MD-DE-DC Water Science Center	Daily summary data online	Stream/tide data shared online by USGS. Delaware data also available through the Delaware Environmental Observing System (DEOS) site.	Continue funding to maintain existing stream and tide gages. Need for additional stream gauges to facilitate watershed loading model development. Need for monitoring of local indicators of sea level rise, including a flood monitoring network.

TABLE 1 - Monitoring and Indicators Matrix (♦ = used to develop indicator for State of the Bays reports)

Monitoring Program	Appendix E Cross-reference	CCMP Objectives/ Monitoring Questions	Indicators & Measures	Data Collected	Collection Frequency	Record of Collection	Responsible Entity/Entities	Frequency of Reporting	Sharing/Reporting	Gaps & Funding Needs
Tidal Flushing at Indian River Inlet ♦	–	CCMP: Water Quality Management, Objective 1. Questions: 5,28	Tidal prism calaculations.	Tidal range, surface area of basin calculated from transects and bathymetry data.	No set frequency. No plans for future monitoring. Future estimates may come from numerical models.	1939-2004 (irregularly)	U.S. Army Corps of Engineers, Coastal Planning Section	No set frequency	Technical report submitted to CIB for each monitoring event. Indicator in *State of the Delaware Inland Bays* reports.	Funding to repeat tidal prism measurements.
Biological assessments of water quality in wadeable streams	E.1.5	CCMP: Water Quality Management, Objectives 2 and 3. Questions: 5	Biological Index derived to categorize stream water quality according to condition (excellent to severely degraded)	Benthic macroinvertebrates, periphyton	Biannually	2000 to present	DNREC Division of Water, Environmental Laboratory Section	Biannual	Used in 303(d) listings.	Continue current funding.
2. GROUNDWATER PROGRAMS										
Delaware Groundwater Monitoring Network	E.2.1	CCMP: Wastewater Management, Objective 3; Water Quality Management, Objectives 1, 3, and 6; Planning for Climate Change, Objective 1. Questions: 25,28	Water levels in major aquifers, saltwater intrusion.	Long time-series of water levels. Number of wells fluctuates annually with funding and staffing resources. Salinity sensors installed in some wells. Groundwater quality data collected when funded.	Continuous	Varies by well. Records for the oldest wells go to 1957.	Delaware Geological Survey	Continuous	Data and reports shared on DGS website.	Funding to support continued groundwater quality data collection.
Agricultural Shallow Groundwater Monitoring Network	E.2.2	CCMP: Nutrient Management, Objective 1; Wastewater Management, Objective 3; Water Quality Management, Objective 3. Questions: 1	Trends in nitrate concentrations.	Nutrients, major ions, pesticides, and groundwater age.	Continuous	2014 to present.	USGS and Delaware Department of Agriculture	Annually	Reports available from Delaware Dept. of Agriculture.	Continue current funding.
Ambient Groundwater Quality, Public Water Supply Wells	E.2.3	CCMP: Wastewater Management, Objectives 2 and 3; Water Quality Management, Objective 3. Questions: 12	Results evaluated with respect to Primary Maximum Contaminant Levels (PMCLs), Secondary Maximum Contaminant Levels (SMCLs), and Health Advisories (HAs) for public water-supply systems.	Chemical data collected from public water-supply wells. Data drawn from DHSS's Safe Drinking Water Information System (SDWIS) database, DNREC's Source Water Assessment and Protection Program (SWAPP) database, and Tidewater Utilities.	Analyses conducted biannually	2008 to present	DNREC Division of Water, Water Supply Section	Biannually	305(b) *Groundwater-Quality Assessment Based on Public-Well Data* reports	Continue current funding.
3. WASTEWATER MONITORING PROGRAMS										
Point Source Wastewater Discharges ♦	E.3.1	CCMP: Wastewater Management, Objective 2; Water Quality Management, Objectives 1, 2, and 3. Questions: 2,3	Flow, nutrient loads, eutrophication indicators. Data used to assess progress toward TMDL goals.	Flow, BOD, TSS, TP, TN, pH, DO. Some facilities also monitoring fractions of P and N.	Varies by permitted facility/outfall	Varies by permitted facility	DNREC Division of Water, Surface Water Discharges Section	Annually	Data must be requested from DNREC. Point source nutrient loads indicator in *State of the Delaware Inland Bays* reports.	Continue current funding.
Land Application of Wastewater	E.3.2	CCMP: Nutrient Management, Objective 1; Wastewater Management, Objectives 1 and 3; Water Quality Management, Objectives 1, 2, and 3. Questions: 1,2,3	Nutrient loads, eutrophication indicators. Maintenance of soil function. Compliance with drinking water standards.	Effluent: TSS, BOD, TN, TP (and fractions of nitrogen), pH, DO. Groundwater: water table depth, soluble constituents (under and adjacent to spray site).	Varies by permitted facility.	Varies by permitted facility	DNREC Division of Water, Groundwater Discharges Section, Large Systems Branch	Annually	Compliance/monitoring reports prepared by permittees.	Continue current funding.

TABLE 1 - Monitoring and Indicators Matrix (◆ = used to develop indicator for State of the Bays reports)

Monitoring Program	Appendix E Cross-reference	CCMP Objectives/ Monitoring Questions	Indicators & Measures	Data Collected	Collection Frequency	Record of Collection	Responsible Entity/Entities	Frequency of Reporting	Sharing/Reporting	Gaps & Funding Needs
Nutrient Management Practices ◆	–	CCMP: Nutrient Management, Objective 1; Wastewater Management, Objectives 1 and 3; Stormwater Management, Objective 1; Water Quality Management, Objective 2. Questions: 1	Progress toward PCS goals	Agricultural nutrient management practices, EDU's converted from septic to sewer, acres of stormwater retrofits	Annually	2005 to present	U.S. Department of Agriculture, DNREC Division of Watershed Stewardship, DNREC Division of Water, Sussex Conservation District, Sussex County	Every five years	Indicator in *State of the Delaware Inland Bays* report.	Incomplete data collection/reporting on agricultural practices in the watershed.
4. ATMOSPHERIC DEPOSITION PROGRAMS										
Atmospheric Deposition of Nutrients ◆	E.4.1	CCMP: Water Quality Management, Objectives 1and 2. Questions: 1	Wet and dry deposition rates of N and P species to open waters and contiguous marshes in the Inland Bays.	Precipitation, free acidity (H^+ as pH), conductance, Ca^{2+}, Mg^{2+}, Na^+, K^+, SO_4^{2-}, NO_{3^-}, Cl^-, $NH4^+$.	Daily within 24 hours of the start of precipitation.	1992 to present	University of Delaware, College of Earth, Ocean, and Environment	5-6 month time lag between sample collection and posting on website.	Data from the Lewes station DE02 accessed through the main NADP/AIRMoN website or the AIRMoN Data Retrieval Site. icator in *State of the Delaware Inland Bays* report.	Continue current funding to maintain local station.
5. WETLANDS MONITORING PROGRAMS										
State of Delaware Wetlands Monitoring and Assessment Program	E.5.1	CCMP: Managing Living Resources and Their Habitat, Objectives 2 and 6; Planning for Climate Change, Objective 1; Coordinating Land and Water Use Decisions, Objective 2. Questions: 14,15	Wetland acreage, condition, and major stressors. DECAP scores for nontidal wetland functions (habitat, hydrology, buffers, soil cycling). MidTRAM scores for condition of estuarine emergent tidal wetlands, validated with biological data based on bird community and biomass levels.	Delaware Comprehensive Assessment Procedure (DECAP) and Delaware Rapid Assessment Procedure (DERAP) for nontidal wetlands. MidAtlantic Tidal Rapid Assessment Method (MidTRAM) protocol for tidal wetlands.	Rotating basin approach planned following intial assessments.	Nontidal wetlands: 2005-2006 Tidal wetlands: 2008	DNREC Division of Watershed Stewardship, Wetlands Monitoring and Assessment Program	Final reports issued following assessment of each basin.	Data shared on the Delaware Open Data Portal.	Funding to continue Inland Bays assessments. Synthesis of this dataset with other wetlands monitoring efforts in the Bays is needed.
Long-term Salt Marsh elevation	E.5.2	CCMP: Managing Living Resources and Their Habitat, Objectives 2 and 6; Planning for Climate Change, Objective 1. Questions: 15,25	Overall marsh height change, changes in the marsh height as a result of surface accretion/erosion, changes in the root zone.	Sediment elevation, surface accretion, water level	Semi-annually	2008 to present	Delaware Center for the Inland Bays	Every five years	Project technical reports published by the CIB.	Continue current support for three Inland Bays stations. Collection of vegetation data and water level data from these sites would be useful.
Salt Marsh Acreage and Condition ◆	–	CCMP: Managing Living Resources and Their Habitat, Objectives 2 and 6; Planning for Climate Change, Objective 1; Coordinating Land and Water Use Decisions, Objective 2. Questions: 15	Historic trends in the extent and condition of the tidal marshes of the Inland Bays	Extent of vegetated marsh, fractured pooling, ditching, and wetland/upland boundary hardening. Data derived from geospatial analyses of aerial imagery and land cover data.	N/A	Study completed in 2014. Documented data from a number of years between 1937 and 2007. Study repeated in 2020 using recent datasets.	University of Delaware Water Resources Agency Delaware Center for the Inland Bays	Every five years for *State of the Delaware Inland Bays* reporting.	Technical report produced by the University of DE. Geospatial data available. Acreage and fractured pooling used as indicators in the *State of the Delaware Inland Bays* report.	Funding to continue future analyses of tidal marsh acreage and condition using updated imagery and land cover data.
Shoreline condition	–	CCMP: Managing Living Resources and Their Habitat, Objective 2; Planning for Climate Change, Objective 1. Questions: 17	Condition of tidal shorelines.	Riparian land use, bank condition, shoreline features (including hard structure)	N/A	Rehoboth Bay: 2006; Indian River Bay: 2012	DNREC Division of Watershed Stewardship, Wetlands Monitoring and Assessment Program Delaware Center for the Inland Bays	N/A	Current data available on VIMS Center for Coastal Resources Management Shoreline Inventory website. Summary report published for each bay inventory.	Shoreline condition data collection for Little Assawoman Bay and update of data for Rehoboth and Indian River Bays. Ongoing updates to shoreline data needed to assess progress of Living Shoreline Initiative.

TABLE 1 - Monitoring and Indicators Matrix (♦ = used to develop indicator for State of the Bays reports)

Monitoring Program	Appendix E Cross-reference	CCMP Objectives/ Monitoring Questions	Indicators & Measures	Data Collected	Collection Frequency	Record of Collection	Responsible Entity/Entities	Frequency of Reporting	Sharing/Reporting	Gaps & Funding Needs
6. LIVING RESOURCES AND HABITATS										
Land Use Land Cover ♦	–	CCMP: Stormwater Management, Objective 1; Managing Living Resources and Their Habitat, Objective 2; Planning for Climate Change, Objective 1; Coordinating Land and Water Use Decisions, Objectives 1 and 2; Outreach and Education, Objective 5. Questions: 4,14,15,16, 29	Land use change, impervious surface coverage, amean width of forested buffers on croplands	Aerial estimates	Every five years	1992 to present. Most recent dataset is 2017. impervious cover layer updated in 2020.	State of Delaware, Office of Management and Budget, Delaware Geographic Data Committee	Five-year updates	Delaware First Map. Indicator in *State of the Delaware Inland Bays* report.	More frequent updates of impervious cover layer.
Human Population ♦	–	CCMP: Wastewater Management, Objectives 1and 3; Coordinating Land and Water Use Decisions, Objective 1. Questions: 4,29	Resident and seasonal population , Sussex County and watershed	U.S. census, wastewater flows	Every ten years	County: 1790 to present Watershed: 1990 to present	U.S. Census Bureau, Sussex County	Every five years.	Indicator in the *State of the Delaware Inland Bays* report.	A better estimate of seasonal population is needed.
National Aquatic Resource Surveys (NARS)	E.6.1	CCMP: Water Quality Management, Objectives 1 and 3; Managing Living Resources and Their Habitat, Objective 2. Questions: 5,6,7,8,9,11, 12,14,15,18,21,26,27,28	Four individual surveys that are implemented on a rotating basis - National Coastal Condition Assessment, National Lakes Assessment, National Rivers & Streams Assessment, and National Wetland Condition Assessment. . Each has Biological, chemical, physical, and human health indicators.	Biological (benthic macroinvertebrates, Chl a, zooplankton, fish diversity), chemical (DO, salinity, pH, nutrients, sediment contaminants/toxicity), physical (clarity, habitat complexity and disturbance), recreational/human health (algal toxins, cyanobacteria, enterococci)	Five-year cycles	2007 to present	U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds DNREC Division of Water, Environmental Laboratory Section	Five-year cycles for reporting status, trends for each survey.	Data, summary reports, and manuals shared on EPA website.	Continue long-term funding of program.
Natural Habitat Protection/ Restoration ♦	–	CCMP: Managing Living Resources and Their Habitat, Objective 2. Questions: 29	Cumulative acres	Data retrieved from U.S. EPA National Estuary Program Online Reporting Tool (NEPORT) Habitat Reporting	Annually	2003 to present	Delaware Center for the Inland Bays	Annually	Indicator in *State of the Delaware Inland Bays* reports.	NEPORT may not capture all projects in the watershed.
Vegetation Community and Land Cover Mapping	E.6.2	CCMP: Managing Living Resources and Their Habitat, Objectives 2 and 6. Questions: 14,30	Rarity and status of vegetation communities.	Aerial imagery analyses of public lands, combined with field data.	Delaware Statewide Vegetation Community Map updated approximately monthly.	Analyses published for 2011-2013.	DNREC Wildlife Species Conservation and Research Program	Monthly updates	Data held by DNREC Wildlife Species Conservation and Research Program, and the University of Delaware Water Resources Agency.	Continue current program funding.
Seaweed Abundance ♦	E.6.3	CCMP: Water QualityManagement, Objectives 3, 5 and 6; Managing Living Resources and Their Habitats, Objective 5. Questions: 5,10	Macroalgae density	Volume of macroalgae collected at fixed stations by grappling hook.	Monthly, May to September	1999, 2009, 2011, and 2012. Annually since 2017.	Delaware Center for the Inland Bays	Annually	Prior to 2017, reports for each survey published by DNREC. Currently annual data reports published on CIB website. Status and trend data included in *State of the Delaware Inland Bays* reports.	Coverage could be increased by using citizen scientists.

TABLE 1 - Monitoring and Indicators Matrix (◆ = used to develop indicator for State of the Bays reports)

Monitoring Program	Appendix E Cross-reference	CCMP Objectives/ Monitoring Questions	Indicators & Measures	Data Collected	Collection Frequency	Record of Collection	Responsible Entity/Entities	Frequency of Reporting	Sharing/Reporting	Gaps & Funding Needs
Coastal Finfish Assessment ◆	E.6.4	CCMP: Managing Living Resources and Their Habitat, Objectives 3, 4, 5, and 6. Questions: 18,21,28	Abundance and distribution of recreationally important finfish species. Annual young-of-the-year indices, catch per tow. Blue Crab abundance.	Otter trawl surveys (Indian River and Rehoboth Bays). Count by species, fork length, surface temperature, salinity, and DO, tidal stage, weather conditions, water depth, engine speed.	Monthly, April to October	1986 to present	DNREC Division of Fish and Wildlife, Fisheries Section	Annually	Annual summary reports published by DNREC DFW. Status and trends for indicator species reported in the State of *the Delaware Inland Bays* reports.	Continue current program funding.
Inshore Fish and Blue Crabs	E.6.5	CCMP: Managing Living Resources and Their Habitat, Objectives 3, 4, 5, and 6; Outreach and Education, Objective 4. Questions: 18,20,21,28	Abundance and distribution of juvenile fish and Blue Crabs.	Seine counts of fish, by species; fish lengths; Blue Crab counts by size class; salinity, DO, temperature, wave height, antecedent preciptiation, wind speed, tide cycle.	Semi-monthly from April to October.	2011 to present.	Delaware Center for the Inland Bays	Annually	Annual data reports published on CIB website. Five-year trend analyses published by CIB.	Conitinue current funding and level of effort.
Receational Fishing ◆	E.6.6	CCMP: Managing Living Resources and Their Habitat, Objective 3; Coordinating Land and Water Use Decisions, Objectives 1 and 3; Outreach and Education, Objective 5. Questions: 18,28	Marine recreational fishing catch and effort.	Catch rates and effort, by species. Landings per year. Harvester intercept surveys conducted at Indian River Inlet.	Annually	2004 to present	NOAA Fisheries Service, Marine Recreational Information Program (MRIP) DNREC Division of Fish and Wildlife	Annually	MRIP reports, DNREC DFW reports. Status and trends for indicator species reported in the *State of the Delaware Inland Bays* reports.	Monitoring of recreational blue crab and hard clam harvests.
Hard Clam Landings ◆	–	CCMP: Managing Living Resources and Their Habitat, Objective 5; Coordinating Land and Water Use Decisions, Objectives 1 and 3; Outreach and Education, Objective 5. Questions: 20	Number of clams	Commercial and recreational catch	Annually	1943 to present	DNREC Division of Fish and Wildlife, Fisheries Section	Annually	Data available annually from the DNREC Div. of Fish and Wildlife. Used as an indicator in State *of the Delaware Inland Bays* reports.	Continue current program funding.
Fish Tissue ◆	E.1.6	CCMP: Wastewater Management, Objective 2; Water Quality Management, Objective 4; Managing Living Resources and Their Habitat, Objective 5. Questions: 3,12	Fish consumption advisories.	Contaminants in fish and shellfish.	Varies	1992-present	DNREC Division of Fish and Wildlife & Division of Watershed Stewardship Delaware Health and Social Services, Division of Public Health	Annual updates to advisories.	Fish consumption advisory reports. Number of advisories used as indicator in *State of the Delaware Inland Bays* report.	No data to date have led DNREC and DHSS to conclude that an advisory is needed in the Inland Bays as *a result of contaminant sources within the Inland Bays*.
Fish Kills ◆	–	CCMP: Water Quality mangement, Objectives 5 and 6. Questions: 5,9	Number of kills reported.	Reports to DNREC	As reported	1981 to present	DNREC Division of Fish and Wildlife, Fisheries Section	Annually	Data shared by DNREC upon request. Indicator in the *State of the Delaware Inland Bays* reports.	Continue collection of fish kill data.
Shellfish Abundance (Hard Clams, Scallops, Oysters) ◆	E.6.7	CCMP: Managing Living Resources and Their Habitats, Objective 5. Questions: 20	Hard Clam/Scallop abundance in Indian River and Rehoboth Bays, health of the Inland Bays clam shellfishery.	Density and distribution of hard clams and scallops in Indian River and Rehoboth Bays.	No set frequency	1967, 1976, 2011	DNREC Division of Watershed Stewardship	At conclusion of each survey.	Technical report published by DNREC at conclusion of survey. Data included in *State of the Delaware Inland Bays* reports.	Hard Clam data collection repeated at least every five years, for inclusion in *State of the Delaware Inland Bays* reports. Long-term monitoring of oyster recruitment and growth. No long-term surveys currently exist.

TABLE 1 - Monitoring and Indicators Matrix (♦ = used to develop indicator for State of the Bays reports)

Monitoring Program	Appendix E Cross-reference	CCMP Objectives/ Monitoring Questions	Indicators & Measures	Data Collected	Collection Frequency	Record of Collection	Responsible Entity/Entities	Frequency of Reporting	Sharing/Reporting	Gaps & Funding Needs
Horseshoe Crabs	E.6.8	CCMP: Managing Living Resources and Their Habitats, Objective 2; Outreach and Education, Objective 4. Questions: 17,28,30	Spawning surveys conducted on selected beaches.	Counts of spawning crabs along beach transects, sex ratios, wave height, wind speed, salinity, water temperature.	Semi-monthly during spawning season, around full and new mpoons.	2012 to present.	Delaware Center for the Inland Bays	Annually	Annual data reports published on CIB website. Five-year trend analyses.	Protocol changed in 2015 to facilitate comparisons with Delaware Bay surveys. Inland Bays data should be incorporated into regional datasets.
Breeding Bird Atlas	E.6.9	CCMP: Managing Living Resources and Their Habitats, Objective 2; Coordinating Land and Water Use Decisions, Objective 2; Outreach and Education, Objective 4. Questions: 20,30	Trends in breeding bird populations, distribution, and diversity that occur with changes in land use, habitats, and climate.	Verified evidence of breeding, all species, within 10-sq. mi. blocks.	No set frequency. Two atlas surveys conducted to date, 25 years apart.	1983-1987; 2008-2012.	DNREC Division of Fish and Wildlife, Wildlife Species Conservation & Research Program	Report after each 5-year survey period. No set frequency for surveys.	Published as a book at the end of atlas survey. Data shared on USGS BBA Explorer website.	As more data are collected, long-term trend analyses to correlate changes with environmental factors such as disappearance of interior forest and climate change.
Mid-Winter Waterfowl ♦	E.6.10	CCMP: Managing Living Resources and Their Habitats, Objective 2; Coordinating Land and Water Use Decisions, Objective 2. Questions: 13,14,15,30	Wintering populations of ducks and geese, by species.	Aerial survey counts for each species, by zone.	Annually	1974 to present	DNREC Wildlife Species Conservation and Research Program	Annually	Data shared through Delaware Open Data Portal. USFWS Atlantic Flyway annual reports. Status and trends for selected indicator species reported in *State of the Delaware Inland Bays* reports.	Continue funding for January surveys each year, at a minimum.
Bald Eagle and Osprey Nesting ♦	E.6.11	CCMP: Managing Living Resources and Their Habitats, Objective 2; Coordinating Land and Water Use Decisions, Objective 2; Outreach and Education, Objective 4. Questions: 30	Bald Eagle and Osprey populations, measured by number of active nests.	Eagles - Aerial surveys of active nests. Ospreys - State surveys suspended in 2014; volunteer reporting only since then.	Currently every two to five years	Bald Eagles: 1987 to 2014 Ospreys: 1991 to present	DNREC Division of Fish and Wildlife, Wildlife Species Conservation & Research Program	As surveys are done	Volunteer osprey data now shared through OspreyWatch program. Indicator in *State of the Delaware Inland Bays* reports.	Funding to continue surveys at least every five years for both species.
Submerged Aquatic Vegetation ♦	–	CCMP: Water Quality Management, Object 6; Managing Living Resources and Their Habitat, Objective 1. Questions: 13	Acres, distribution, species.	Loccation, area coverage, species.	Data collection begun in 2020.	Last reported natural eelgrass bed in 1975. Acres reported since then are anecdotal. Formal survey begun by CIB in 2020.	Delaware Center for the Inland Bays	As surveys are done	Reported as an indicator in State of the Delaware Inland Bays reports.	Survey begun in 2020 is supported by a one-time grant. Funding for periodic surveys is needed.

TABLE 1 - Monitoring and Indicators Matrix (◆ = used to develop indicator for State of the Bays reports)

Monitoring Program	Appendix E Cross-reference	CCMP Objectives/ Monitoring Questions	Indicators & Measures	Data Collected	Collection Frequency	Record of Collection	Responsible Entity/Entities	Frequency of Reporting	Sharing/Reporting	Gaps & Funding Needs
7. CLIMATE										
Sea Level ◆	–	CCMP: Planning for Climate Change, Objective 1 Questions: 25	Change in mean sea level at Lewes, DE tide gage.	water level	Continuous	1919 to present	NOAA National Ocean Service	Real-time	Data shared on NOAA Tides and Currents website. Status and trends for this station included as an indicator in the State of *the Delaware Inland Bays* report.	Lewes gage was offline from 2011 to 2015. Went back online in 2016. Continue long-term funding for this station. Need for monitoring of local indicators of sea level rise, including a flood monitoring network.
Ocean Acidification ◆	–	CCMP: Planning for Climate Change, Objective 1 Questions: 27,28	Change in ocean pH, measured at Oahu, Hawaii.	pH, pCO_2	Monthly for Hawaii data. Continuous collection of pH at two stations in Inland Bays to begin 2021. Continuous collection of pCO_2 at one to two stations to begin 2022.	1988 to present for discrete pH data. Continuous data collection to begin 2021.	Hawaii Ocean Time-Series Program; University of Delaware/DNERR (continuous data)	Monthly for Hawaii pH; Continuous for Inland Bays pH/pCO_2.	Hawaii pH data shared on HOT website. Status and trends for this station included as an indicator in the State of *the Delaware Inland Bays* report.	Data on estuary acidification.
Atmospheric Carbon Dioxide Concentration ◆	–	CCMP: Planning for Climate Change, Objective 1 Questions: 25,27,28	Change in CO_2 concentration, measured at NOAA Mauna Loa Observatory.	Mean CO_2 concentration, reported as dry air mole fraction	Annually	1958 to present	NOAA Earth System Research Laboratory, Global Monitoring Division	Monthly	Data shared on NOAA website. Indicator in *State of the Delaware Inland Bays* report.	Continue status quo. Local carbon emissions data desirable.
Climate Characteristics ◆	–	CCMP: Planning for Climate Change, Objective 1 Questions: 26,28	Average annual air temperature, annual rainfall, growing season length	Weather characteristics (temperature, precipitation, frost dates)	Hourly	Air temperature, precipitation: 1895 to present Growing Season Length: 1946 to present	Delaware Environmental Observing System (DEOS)	Daily	DEOS website. Indicator in *State of the Delaware Inland Bays* report.	Few stations in the watershed provide inadequate resolution for microclimate variations.

DATA MANAGEMENT AND QUALITY CONTROL

The data managers identified for each monitoring program (Table 1) are responsible for the following:

- Collection and analysis of data according to existing or updated monitoring plans. Changes in monitoring frequency or protocols must be communicated to the CIB, and included in any updates to the *Environmental Monitoring Plan for Delaware's Inland Bays.*
- Providing data to the CIB and/or its partners upon request for use in indicator reports or research projects.
- Quality Assurance Plans must be kept up to date and provided to data users (including the CIB) upon request.
- All monitoring programs funded partially or in whole by the U.S. EPA must have an up to date, approved Quality Assurance Project Plan (QAPP). QAPPs are to be updated every three years. A copy of the approved QAPP must be provided to the CIB for its records.

RECOMMENDATIONS AND SUPPORTING PROGRAMS

The previous section of this plan describes ongoing monitoring programs in the Inland Bays that exist currently. Many of these existing programs provide data that are used to develop the long-term indicators for the *State of the Delaware Inland Bays* reports that are published every five years by the CIB.

This section of the plan provides recommendations for new monitoring programs, or enhancement of existing programs. These recommendations, developed with the original IBEMP in 2018, are made based upon critical data gaps (identified in Table 1), the availability of new methods or technologies, and/or changes needed to make programs sustainable over the long term. Table 2 summarizes priority recommendations, and each is described more fully on pages following the table.

For the 2020 biannual update, a summary of progress made to date is included with each recommendation. Timelines and funding estimates also were adjusted, as appropriate, in Table 2.

Table 2 - Recommendations for Monitoring in the Inland Bays (Categorized according to relative priority (*** = highest priority).

Objectives	Data to be Collected / Contribution to Other Programs	Responsible Entity/Entities	Future Frequency of Reporting/Use	How Future Data Will Be Shared / Reported	Funding and Timeline	Priority Level
1. DEVELOPMENT OF A NEW HYDRODYNAMIC/WATER QUALITY MODEL FOR THE INLAND BAYS						
Build a well-calibrated hydrodynamic/water quality model for the Inland Bays in order to address water quality threat of dissolved oxygen (DO).	1) Will collect more recent sediment flux measurements, a sediment flux model, and explicit incorporation of benthic algae; 2) Will collect lag times for groundwater and soil phosphorus loads to be incorporated; 3) Will incorporate primary production and respiration rates into model calibration; 4) Will collect increased spatial resolution particularly in tidal headwaters; 5) Will incorporate meteorological records that were unavailable during calibration years (1998-2000); 6) Will incorporate re-assessment of nutrient loading to include potential groundwater discharge being explored by many DIB researchers since 2000.	Recommended partners: CIB STAC, University of Delaware, DNREC Division of Watershed Stewardship.	X	A watershed loading model – Delaware Targeted and Planning Tool (DTAP) that provides edge of stream estimates is being developed by DNREC and will be available as a publicly available online scenario tool.	Building a well-calibrated HD/WQ model will take significant data, funding, and time. STAC has determined that the effort will likely require at least $500,000 to $1.5 million and 2-5 years of effort. A funding strategy will be developed by STAC by early 2021. In 2020, DNREC funded development of DTAP, a two-year effort costing $532,500. Cost to include climate change scenarios not included in this model is $150,000 to $180,000.	***
2. UPGRADE CITIZEN MONITORING PROGRAM DATABASE AND SERVE DATA TO PUBLIC ONLINE THROUGH STORET AND STATE WATER QUALITY PORTAL						
Develop a CMP data entry template and database processing tools that will allow submission of data to STORET through the EPA's Water Quality Exchange (WQX).	1) Will ensure long-term sustainability of the Inland Bays Citizen Monitoring Program; 2) Will fill critical data needs for effective restoration and management of the estuary.	CIB, CMP, EPA Region 3, Center for Environ. Monitoring and Analysis (CEMA).	Data synthesized and reported by CIB every five years in State of the Bays reports. Included in biannual 305(b) reports.	Publicly available and searchable through EPA's WQX and the Delaware Water Quality Portal.	Data base tools completed, and a portion of 2019 CMP data were available online in early 2020. Remaining 2019 and 2020 data due to be uploaded by end of 2020. Focus in 2021 will be uploading legacy data. CEMA currently doing the work at no additional cost.	***

Table 2 - Recommendations for Monitoring in the Inland Bays (Categorized according to relative priority (*** = highest priority).

Objectives	Data to be Collected / Contribution to Other Programs	Responsible Entity/Entities	Future Frequency of Reporting/Use	How Future Data Will Be Shared / Reported	Funding and Timeline	Priority Level
3. LONG-TERM, CONTINUOUS MONITORING OF DISSOLVED OXYGEN AND CHLOROPHYLL						
Develop and deploy continuous monitoring networks to measure dissolved oxygen and chlorophyll in the Inland Bays, with a focus on tributaries.	1) Will increase sufficiency to detect rapidly changing or cycling conditions in the Bays or episodic events (ex. diel-cycling hypoxia, and phytoplankton blooms).	CIB, STAC, University of Delaware, DGS.	Ideally stations would include real-time telemetry.	Data to be available through WQX and Delaware WQ Portal. Telemetric data could be shared through DEOS. Annual summary reporting by CIB. Data used to develop indicator reports.	Three stations installed in Indian River and Pepper Creek in 2020. Cost dependent on methods used and # of stations monitored. Installation cost per station estimated at $50,000 to $60,000. Annual maintenance cost (labor and supplies) ~$20,000. Development of data management tools estimated at $50,000.	***
4. MONITORING OF SUBMERGED AQUATIC VEGETATION IN THE INLAND BAYS						
Monitor and document acreage and distribution of SAV in the Inland Bays.	1) Will assist protection of any existing SAV beds; 2) Will help focus restoration efforts in areas where SAV beds are known to survive; 3) Will track progress in SAV restoration.	CIB, DNREC Div. of Watershed Stewardship, EPA Region 3	At least every five years, depending on resource availability.	State of the Bays reports (every five years). Summary reports from CIB at end of surveys.	Using combination of drone and on-ground surveys, $12,000 to $20,000 per survey.	***
5. MONITORING OF LOCAL INDICATORS OF SEA LEVEL RISE, INCLUDING A FLOOD MONITORING NETWORK						
Expand the CFMS into the Inland Bays to partly fill the need for more local indicators of climate change and sea level rise	1) Will provide real-time tool to create flood inundation potential maps and time series of forecasted tidal predictions; 2) Will monitor sea-level rise and the development/validation of hydrodynamic models if maintained for an extended period of time.	CEMA, DNREC Coastal Management Program	Continuous.	Available to the public via online application.	Annual cost to maintain current CFMS network of approx. $15,000; adding more sensors will increase cost. May be able to use existing DelDOT telemetry system to expand the sensor network. Potential funding from DNREC Coastal Programs, NOAA, DEMA, Sussex County.	***

Table 2 - Recommendations for Monitoring in the Inland Bays (Categorized according to relative priority (*** = highest priority).

Objectives	Data to be Collected / Contribution to Other Programs	Responsible Entity/Entities	Future Frequency of Reporting/Use	How Future Data Will Be Shared / Reported	Funding and Timeline	Priority Level
6. CONTINUE MONITORING TIDAL FLUSHING AT THE INDIAN RIVER INLET						
Continue measurement of tidal prism at the Indian River Inlet.	1) Will evaluate the volume of water passing through the inlet; 2) Will monitor the residence time of water within Inland Bays; 3) Data required for development of hydrodynamic model for the Bays.	U.S. ACOE, Univ. of Delaware.	Every five years.	State of the Bays Report (every five years).	Estimated cost $40,000 for *in situ* surveys. ~$50,000 for modeling approach.	**
7. MONITORING OF OYSTER RECRUITMENT AND GROWTH IN THE BAYS						
Develop a monitoring plan that regularly measures oyster recruitment, populations, and growth in all three bays.	1) Will assist with understanding the dynamics of restored oyster populations and their ecosystem services under naturally variable conditions; 2) Will track progress of CCMP objective to enhance oyster populations in the Bays.	CIB, Delaware State University, DE Sea Grant, DNREC Divisions of Watershed Stewardship and Fish & Wildlife.	Annually. Future indicator of restoration success.	Project reports published by the CIB. Potential future indicator for State of the Bays reports.	Estimated cost is $30,000 annually.	**
8. SHORELINE CONDITION AND MODIFICATION MONITORING						
Build upon and update shoreline inventories conducted by VIMS in 2006 (for Indian River Bay) and 2012 (for Rehoboth Bay).	1) Update inventories for IR and Rehoboth Bays; 2) Complete inventory for Little Assawoman Bay; 3) Will help track success of Living Shoreline Initiative	CIB, DNREC Wetlands Assessment and Monitoring Program, DNREC Subaqueous Section, VIMS.	Every five to ten years.	Data made available through online mapping tool and project reports. Potential future indicator for State of the Bays reports.	$125,000 every ten years. Cost could be reduced by use of volunteers and/or drones in data collection.	**

Table 2 - Recommendations for Monitoring in the Inland Bays (Categorized according to relative priority (*** = highest priority).

Objectives	Data to be Collected / Contribution to Other Programs	Responsible Entity/Entities	Future Frequency of Reporting/Use	How Future Data Will Be Shared / Reported	Funding and Timeline	Priority Level
9. CONTINUE ANALYSES OF TIDAL MARSH ACREAGE AND CONDITION USING GIS METHODOLOGY ESTABLISHED IN 2104 RARE STUDY						
Use established methodologies for GIS analyses of aerial imagery and LULC data to monitor Inland Bays tidal marsh acreage/condition.	1) Will help understand and track status and trends in overall extent and health of tidal marshes in the estuary; 2) Will assist with prioritizing future research and areas for restoration; 3) Continue to use tidal marsh acreage and extent of fractured pooling as indicators in State of the Bays reports.	CIB, Univ. of Delaware Water Resources Agency.	Every five years.	State of the Bays Report (every five years).	Total cost per analysis estimated at $37,000. Update in 2020 was completed intern assistance at low cost.	*
10. MONITORING OF ESTUARY ACIDIFICATION						
Collect data needed to understand proton fluxes and balances in the Inland Bays.	1) Will allow assessment of long-term trends in acidification that may occur with climate change; 2) Will provide data to help model the interactions between hydrodynamics, eutrophication, and estuary acidification; 3) Will help understand potential impacts on shellfish in the Bays.	Univ. of Delaware, DNREC-DNERR, Mid-Atlantic Coastal Acidification Network	Continuous monitoring, reporting mechanism and frequency to be determined.	Continuous monitoring data could potentially be made available online. Will be shared in project technical reports and through STAC.	Estimated $30,000 per station added installation cost annually if included as a component of a continuous WQ sensor network.	*
11. MONITORING OF RECREATIONAL BLUE CRAB AND HARD CLAM HARVESTS						
Obtain estimates of recreational crab and clam landings in the Bays.	1) Data will help assess the health and status of shellfish populations and allow state to account for recreational harvest in management of these fisheries.	DNREC Div. of Fish & Wildlife, DE Sea Grant	Annually.	Annual reports from DFW. Potential future indicator for State of the Bays reports.	$40,000 to $50,000 annually.	*

Table 2 - Recommendations for Monitoring in the Inland Bays (Categorized according to relative priority (*** = highest priority).

Objectives	Data to be Collected / Contribution to Other Programs	Responsible Entity/Entities	Future Frequency of Reporting/Use	How Future Data Will Be Shared / Reported	Funding and Timeline	Priority Level
12. DEVELOP A LIST OF EMERGING CONTAMINANTS RESEARCH AND MONITORING IN THE INLAND BAYS.						
Build a baseline for determining which compounds have the highest potential for significant impact in the Bays, and prioritize future EC monitoring and research.	1) State to maintain a database of contaminants found in monitoring of water supplies; 2) STAC to build and maintain a list of research and monitoring activities investigating emerging contaminants in the Bays; 3) Will allow definition of the problem, recommendations for further monitoring, and promote source control.	STAC CCMP/monitoring subcommittee.	Biannually.	STAC white papers. Data to be evaluated and used for biannual updates to the IBEMP.	In-kind agency staff time.	*

1. HYDRODYNAMIC/WATER QUALITY MODEL

The first state-of-the-art water quality modeling program implemented in Delaware's Inland Bays used a calibration database that included data from DNREC, USGS, US Army Corps of Engineers, University of Delaware researchers, citizen monitors and others (Cerco et al. 1994). The model was calibrated using data from 1988-1990 and is largely based on the same model used to manage water quality in Chesapeake Bay (CE-QUAL-W2) (Cerco and Noel 2005). This model included a mechanistic sediment flux model and even included a benthic algal model due to the shallow nature of the bays (Cerco and Seitzinger 1997).

In 2004, Entrix, Inc. and J.E. Edinger Associates developed a TMDL model, currently used for the Inland Bays (Entrix and JEEAI 2004). The model is a fully coupled 1-D watershed and 3-D hydrodynamic-water quality model called the Generalized Environmental Modeling Surface Water System (GEMSS). That model was primarily used to calculate water quality constituents such as nitrogen, phosphorus (particulate/dissolved, inorganic/organic) and dissolved oxygen. It was calibrated using data collected from 1998-2000.

Since 2000, there has been a significant increase in both understanding and data collection in Delaware's Inland Bays. In particular, the University of Delaware and DNREC have collected continuous data records for dissolved oxygen (DO) over many years and at many locations. DO is arguably the greatest potential water quality threat to Delaware's Inland Bays, with multiple fish kills attributable to hypoxia occurring most years. Substantial research efforts have also demonstrated reduced growth rates and behavioral avoidance of hypoxia by juvenile estuary dependent fishes that rely on the Bays for essential fish habitat.

For this reason, the CIB requested an independent assessment of the DO calculation in the GEMSS model (Brady, 2014). While the report focuses on DO, it notes that improvements in the understanding of nutrient loading and biogeochemical cycling will also be necessary to improve future model formulations. The conclusions of this report are that GEMSS is not effective at simulating DO (especially in Indian River and tributaries). The calibration and validation datasets from 1998-2000 included few to no substantive continuous DO records. Assessing model performance in relation to diel-cycling hypoxia is exceedingly difficult, and that was not the original intent of that modeling effort. DO data collected since 2001 contain DO fluctuations from 0% to 200% saturation in the headwaters of major creeks/tributaries, and the model output shows no such fluctuations. Brady's explanation for this is either: (1) diel-cycling hypoxia only became a significant feature of the water quality in Delaware's Inland Bays in 2001 or (2) the monitoring program only became robust enough to detect diel-cycling hypoxia in 2001. In either case, the proliferation of data and understanding since 2001 strongly argues for re-visiting the modeling framework for the Bays.

<u>Recommendation</u>*: There is a critical need for a predictive, coupled watershed, hydrodynamic, and water quality model for the Inland Bays that uses current and high-frequency data.*

Brady (2014) provided specific recommendations for future accurate simulations of diel-cycling hypoxia. These include:

- In the shallow Inland Bays estuary, benthic pelagic coupling between the water column and sediments is potentially a large source of oxygen demand. The current GEMSS model uses fluxes measured from 1992-1993 and 2001. There is no mechanistic sediment flux model associated with this modeling effort. More recent flux measurements, a sediment flux model, and explicit incorporation of benthic algae will almost certainly be necessary to complete nutrient budgets. There is also potential for the bottom sediment to play a role in time lags between the implementation of the Pollution Control Strategy and response in the estuary that cannot be explored in the current modeling framework. Lag times for groundwater and soil phosphorus loads should also be incorporated.
- Incorporation of primary production and respiration rates into model calibration. Seasonal respiration appears well calibrated, but daily respiration rates are clearly not large enough to generate hypoxia in the early to late morning. These rates can be estimated from high-frequency DO measurements.

- Increased spatial resolution particularly in tidal headwaters where recent fish tagging evidence has highlighted potential fish exposure mechanisms reliant on spatial gradients in DO. Headwaters are where improvements will be seen first, so an improved model will be a tool to test the effectiveness of best management practices.
- Incorporation of multiple meteorological records that were unavailable or offline during the calibration years (1998-2000) made available by the Delaware Environmental Observing System.
- Re-assessment of nutrient loading to include potential groundwater discharge being explored by many DIB researchers since 2000. The operation of the Millsboro Pond Outlet Aqualab provides more complete loading and loading process information, particularly for storms and storm periods. It also identifies significant diel DO swings in the pond. This is the largest point source of fresh water to the Indian River.

Building a well-calibrated model will require significant data, funding, and time. Development of a predictive model tool will need to plan for a minimum of several years for data collection and model building/calibration. The total cost is likely to be several million dollars. Thus it is essential that the effort be broken down into subtasks. The model development should be led by the CIB's STAC and include the following immediate actions:

a. Appointment of a standing STAC CCMP/Monitoring subcommittee that will begin work in early 2018. This subcommittee will have among its responsibilities overseeing the implementation of the IBEMP recommendations, including model development as one of the highest priorities. The chair of this subcommittee will work closely with the STAC presiding officers and CIB staff to manage development of a new model.

b. The subcommittee will engage stakeholders in early 2018 in order to put together a specific plan for model development consisting of: subtasks, responsible entities, timeline, and funding strategy. The subcommittee will present this plan to the full STAC by June 2018.

2020 Update Report:

In 2018, a standing modeling subcommittee of the STAC was formed and tasked with developing a white paper that synthesizes the STAC's collective view of the requirements for an updated HD/WQ model of the Inland Bays and how its development can most practically be accomplished. That paper was completed and presented to the Board of Directors in March 2020. The paper was also presented to the CCMP Implementation Committee, which is helping guide development of a watershed nutrient loading model that can be coupled to the HD/WQ model. A copy of the white paper is included in this document as Appendix F.

The STAC and CIB staff issued a Request for Information on June 1, 2020, to gather information from potential model developers about their tools, timelines, and costs. Eight responses were received from both university teams and private firms. The responses included a variety of modeling approaches and costs. Analysis of the submissions indicates that development of a HD/WQ model most likely will require two to three years of effort at a cost of $500,000 to $1,500,000. With this information, the STAC subcommittee will develop a funding strategy to be completed in early 2021.

Progress was also made in developing a watershed nutrient loading model for the Inland Bays that is a necessary component of a HD/WQ model. In 2020, DNREC's Division of Watershed Stewardship executed an agreement with Devereux Consulting to develop a Delaware Targeting and Planning Tool (DTAP) for the entire state. The DTAP will work similarly to the CAST model for the Chesapeake watershed and will allow scenarios to be run to estimate loading rates at edge of stream. There is still a need to include the ability to run scenarios in DTAP using hydrological conditions expected with future climate change. The CIB is engaging with other potential users and stakeholders to discuss funding options for this.

The white paper produced by STAC identified key data and research needs for model development and calibration. These include:

1. Better spatial coverage of high-frequency water quality measurements in the upper Indian River and tributaries, with focus on dissolved oxygen and Chlorophyll a;
2. Changes in hydrodynamics due to changes in the bathymetry of the Indian River Inlet;
3. Exchange of nutrients and oxygen between bottom sediment and the water column and the role of benthic algae;
4. Data from additional stream gages to inform a watershed loading model.

The first two data gaps already are included in the IBEMP recommendations, and progress is being made on each. The CIB and STAC should continue to seek resources and partnerships to address the remaining needs.

2. UPGRADE OF CITIZEN MONITORING PROGRAM DATABASE

Due to funding and staffing issues, the University of Delaware Citizen Monitoring Program (CMP) has sometimes struggled to keep up with nutrient analyses and management of data. The CIB provided EPA Section 320 funds in 2015 and 2016 to assist the CMP with analysis of backlogged nutrient samples taken at nine stations that were key for producing *State of the Delaware Inland Bays* and other indicator reports.

The CIB, the CMP, EPA Region 3, and DNREC have a shared goal of creating database tools that will allow public, online access and queries of Inland Bays water quality data. Conversion would be made to a database that can export data into the EPA's Water Quality Exchange (WQX) data warehouse and thus allow sharing of data online via the Delaware Water Quality Portal (http://demac.udel.edu/waterquality/). The new database potentially could include an online site for volunteer monitors to enter their measurements directly, with data validation, including access from mobile platforms.

Recommendation: It is recommended that the University of Delaware's Center for Environmental Monitoring and Analysis (CEMA), which manages the state's Water Quality Portal, work with the CMP and the CIB to develop a CMP data entry template and database processing tools that will allow submission of data to the EPA's Water Quality Exchange (WQX). Data would then be pulled from WQX into the Delaware Water Quality Portal.

Specific recommended objectives and actions are:

1. *Development of an updated, supportable database structure for the CMP.*
    a. Creation of a mechanism and framework whereby CMP data can be submitted.
    b. Development of data ingestion software to input CMP data into a database or repository.
    c. Creation of a QA/QC reviewer access procedure for quality control purposes.
2. *Online availability of CMP data to the public.*
    a. Creation of a mechanism for automated submission of CMP data into WQX from the CMP database.
    b. Ingestion of CMP data from WQX into the Delaware Water Quality Portal as an additional "station type" for easy public access to CMP data.

Once this is complete, legacy data should be converted, if possible, for inclusion into STORET.

Successful completion of this project will help ensure long-term sustainability of the Inland Bays Citizen Monitoring Program and fill critical data needs for effective restoration and management of the estuary. A robust, high-quality water quality data set for the bays, combining both volunteer and state-collected data, will be publicly available and searchable through a common online portal. Additionally, this effort will further a goal of both the CIB and EPA to have CMP data incorporated into water quality analyses and models managed by the state.

Funding: Estimated cost to complete Objectives 1 and 2 is $40-50,000. EPA has provided supplemental funding to the CIB in the amount of $35,000 to begin this work in FY 2018, and it is included as a project in the CIB's FY 2018 workplan.

2020 Update Report:

The CIB received $35,000 in supplemental funding from EPA in FY 2018 to partner with CEMA on development of new database tools that allow export of CMP data to EPA's Water Quality Exchange (WQX, which replaced STORET) and the Delaware Water Quality Portal, with a goal of having CMP data available to the public online. The CIB provided additional funds to CEMA in FY 2019 through a subaward. CEMA completed the database design and data entry/processing tools in FY 2020. As of May 2020, data collected in 2019 from 64 CMP stations had been uploaded to WQX. Those stations that include dissolved oxygen (DO) data (53 stations) were pulled into the Delaware Water Quality Portal and are now viewable online. The parameters currently going to WQX for the 64 stations are water temperature, air temperature, DO, secchi disk depth, and water depth. Work to upload remaining parameters (nutrients, TSS, Chlorophyll a, and bacteria) and 2020 data into WQX continues. Legacy data that meet the metadata requirements for submission to STORET will begin to be added by CEMA in 2021. However, some of the legacy data does not currently meet these requirements and much of it must be pulled from paper records, so this may take some time. The CIB intends to work with Delaware Sea Grant to secure any funding needed to complete the work and/or to maintain data collection from the key Inland Bays stations.

3. CONTINUOUS WATER QUALITY MONITORING

Ambient water quality monitoring in the Bays has to date largely followed a traditional paradigm of discrete sampling to collect data from as many locations and as often as funding allows. Typical best-case sampling frequencies are weekly (for the Citizen Monitoring Program) or quarterly (for the State's GAMN network). While this type of monitoring program may be useful for long-term status and trend analyses, it does not provide sufficient resolution to detect rapidly changing or cycling conditions in the Bays or episodic events. Examples of these in the Inland Bays system include diel-cycling hypoxia (Tyler et al., 2009) and phytoplankton blooms.

Continuous monitoring is increasingly becoming a standard to characterize water quality in shallow coastal systems, where conditions can change frequently over time. Continuous monitoring is the sampling method of choice when water quality variations are to be characterized over time. Multiparameter sondes, for example, are increasingly being used to monitor water quality at fixed monitoring sites, to carry out vertical profiling, or to perform water quality mapping. Flow-through continuous monitoring stations also are developing and have been used at a few sites in the state. DNREC has deployed some continuous sensors at Millsboro Pond in the Bays watershed. New, autonomous platforms are available provide spatial resolution for parameters that cannot be sensed remotely.

Continuous monitoring in coastal environments can be challenging because of rapid biofouling from microscopic and macroscopic organisms, corrosion of electronic components from salt and high humidity, and wide ranges in values of field parameters associated with changing weather and tidal conditions. The sensors that are used to measure water-quality field parameters require careful field observation, cleaning, and calibration procedures, as well as thorough procedures for the computation and publication of final records. However, procedures and technologies for continuous water quality monitoring have evolved greatly in recent years, and continue to evolve. Emerging sensor technology broadens the variety of measurable chemical constituents and reduces the limits of detection. Because it has become possible to make near real-time water-quality monitoring data available on the Internet, continual progress is being made to improve applications and refine quality-control procedures.

Recommendation:

Continuous monitoring networks to measure dissolved oxygen and chlorophyll should be developed and deployed in the Inland Bays, with a focus on tributaries. This effort should build upon ongoing work in this area by Dr. Bill Ullman and others, and consider emerging, innovative technologies. The STAC should help guide the selection of sites and station configuration.

Funding:

Dependent upon the methods used and number of stations monitored. Annual cost to maintain the continuous monitoring station currently deployed at Massey's Ditch (USGS 01484680, measuring temperature, specific conductivity, DO, and pH) is on the order of $50,000. A real-time estuarine water quality monitoring network with 7-8 stations was implemented in New Jersey by the Barnegat Bay Partnership and the NJDEP. The network includes both shore-mounted and buoy-mounted stations. Cited costs are approximately $50,000 for installation of each new shore-based station, and $80,000-100,000 in recurring maintenance and operation costs for all sondes per year.

2020 Update Report:

In 2018, the CIB worked with the DNREC Environmental Laboratory to establish a long-term continuous water quality site in the upper Indian River near Wharton's Bluff, and to deploy a YSI EXO2 sonde for collection of high-frequency dissolved oxygen data and other water quality parameters at this location. Annual monitoring at this location now occurs from April through October. The CIB is responsible for this station. In FY 2020, the CIB and Delaware State University deployed additional sondes at three locations associated with oyster reef and aquaculture sites in Rehoboth Bay, Indian River, and Little Assawoman Bay. Data will be collected from these locations for at least two years. Support for these sondes comes from a Community Water Quality Improvement Grant to the CIB, and a Delaware EPSCoR award to DSU. It is hoped that these sondes can be redeployed to other locations in the Bays after the oyster reef project is completed.

In 2020, the CIB partnered with Scott Andres at the Delaware Geological Survey to install and maintain two additional continuous water quality stations closer to the mouth of Indian River and in Pepper Creek. Project WiCCED is providing the funding for equipment and university staff time, and CIB staff were funded to maintain the stations and manage the data collected. A new Access database was created to house the data acquired from all three Indian River/Pepper Creek stations, as well as from future stations that will be added as funding becomes available. The CIB worked with DGS to develop SOP and QAPP documents for the sondes they operate, and these have been approved by the university researchers involved and the U.S. EPA.

By early 2021, the CIB intends to develop a prioritized plan for deployment of a larger, long-term continuous monitoring network in the Bays. It is anticipated that the CIB will assemble and manage data from all of the network stations so that data can be efficiently evaluated and reporeted. A grant proposal submitted in 2020 by CIB to fund two to three additional stations was unsuccessful. However, several teams of investigators have included Inland Bays high frequency monitoring stations in research proposals recently submitted to MARACOOS.

4. MONITORING OF SUBMERGED AQUATIC VEGETATION

While listed as a major action in CCMP, submerged aquatic vegetation (SAV) restoration efforts in the Inland Bays have stalled. Due to high levels of nutrients, chlorophyll a, and macroalgae, SAV beds in the Inland Bays have all but disappeared. However, recent water quality analyses suggest that water quality has improved in many locations over the long term, and that macroalgae populations are much lower than previous levels in much of the Inland Bays. This suggests that SAV beds may be able to survive in the Inland Bays once again, and may currently exist in some areas that have seen improvements.

Recent surveys of SAV in the Bays have been limited to the Horned Pondweed meadows discovered a few years ago in Love Creek. No monitoring program currently exists for eelgrass or other baygrasses.

Recommendation:

Monitoring to document what SAV remains in the Inland Bays, and where it's located are necessary in order to protect any existing SAV beds, as well as focus restoration efforts in areas where SAV beds are known to survive. In addition, the recognition of SAV as an important carbon sink adds impetus to the need for accurate maps at a regional level.

Ideally the survey will be performed annually or biannually, but adjusted depending on resource availability. At a minimum it should be conducted every five years to correspond with indicator development for the *State of the Delaware Inland Bays* reports.

Recent technological advances present new options for monitoring and mapping SAV. Aerial surveys are one option. However, the current sparseness of SAV beds in the Inland Bays means that surveyors would be searching for much smaller patches than are typically identifiable by plane. Monitoring may also be conducted either with boats and divers, or with short-range, low elevation drone flights, checking areas for SAV presence and patch size. Divers and drone pilots could maximize their time by focusing efforts in areas where water quality meets SAV requirements as determined through the State of the Bays report and other water quality analyses. A workshop at the November 2017 conference of the Coastal and Estuarine Research Federation (CERF) will be devoted to sharing best practices for SAV monitoring, including new technology options.

Funding:

Funding needs depend upon the methodologies used and frequency of surveys. Once a particular protocol has been demonstrated to work in the Inland Bays, then a cost for ongoing surveys should be established and a funding source identified. EPA Region 3 has expressed interested in potentially collaborating on SAV monitoring.

2020 Update Report:

The CIB recently secured funding from Delaware Sea Grant to map SAV in areas of interest within Indian River, Rehoboth, and Little Assawoman Bays, piloting a drone methodology. Monitoring began in April 2020. Mapping was focused on areas where SAV was previously documented, areas where water quality was deemed of sufficient quality to potentially support SAV, and areas with possible SAV beds reported by partners and members of the public. The mapping methods use overlapping photos of the areas of interest collected with a DJI Mavic Pro drone. These images are post-processed in ArcGIS to derive spatially accurate aerial imagery, which was then inspected for benthic vegetated beds. Any potential beds greater than 0.10 acres are then verified via snorkeling surveys. Nearly nine miles of Indian River Bay shoreline were mapped in 2020, but no SAV beds have so far been identified there. Mapping will continue in 2021 in Little Assawoman Bay and Rehoboth Bay (targeting areas where seagrass has been reported by the public).

There is still a need to complete surveys for SAV in the tidal tributaries and canals. The majority of known SAV beds are in these areas. For example, a large bed of horned pondweed (*Zannichellia palustris*) is known to exist in upper Love Creek, and seed collected from widgeon grass (*Ruppia maritima*) in South Bethany canals was planted in other Inland Bays areas in recent years and has established at least one large bed in Herring Creek. The CIB will enlist the help of volunteers in 2021 to survey tributary locations by boat, targeting the locations of known beds.

5. LOCAL INDICATORS OF SEA LEVEL RISE

There is a critical need in the Inland Bays watershed to conduct monitoring geared specifically to address how sea level rise affects and is perceived by the public. The Inland Bays watershed is particularly vulnerable to sea level rise and its effect on the frequency and intensity of coastal flooding events, emphasizing the need for a modern, dependable coastal flood monitoring and warning system for the Bays' coastal communities.

The Delaware Coastal Flood Monitoring System (CFMS) was developed, jointly by the Delaware Geological Survey (DGS) and the Delaware Environmental Observing System (DEOS) at the University of Delaware, to provide water level predictions and flood potential for 15 communities on Delaware Bay (http://coastal-flood.udel.edu/). The tool serves three primary functions: to send out warning alerts up to 48 hrs in advance of potential flood conditions, to provide access to current meteorological and hydrologic conditions, and to provide local tidal predictions and map their areas of impact.

The CFMS currently covers only the Delaware Bay coastline. Expansion of the system to the Inland Bays and Atlantic Coast of Delaware is planned by DEOS. However, the NOAA DBOFS operation model used currently does not work well for the Inland Bays system. A different hydrodynamic or statistical model is required.

In 2015, DEOS partnered with DGS and the CIB to conduct a three-year study of water level conditions at various locations in the Inland Bays. Water level sensors were installed in spring of 2015 and likely will be maintained until the summer of 2018. Data collected will help inform development of a flood prediction model specific to these bays.

Recommendation:

Expansion of the CFMS into the Inland Bays will at least partly fill the need for more local indicators of climate change and sea level rise. If a successful model is developed for the Bays, it will provide a publically-accessible, real-time tool to create flood inundation potential maps and time series of forecasted tidal predications. The CFMS itself is not meant to be a sea level rise tool, but rather its continued development is contingent upon the availability of tidal water level data from a sensing network like the one currently deployed in the Inland Bays. The data from that same network can lend itself towards sea level rise monitoring and the development/validation of hydrodynamic models if maintained for an extended period of time.

It is recommended that support for developing this tool for the Inland Bays be continued and prioritized. A water level/flood monitoring network should be permanently installed throughout the Bays. These data are needed not only for flood alert tools, but also for development of a new hydrodynamic model for the Inland Bays.

Priority should also be given to long-term local monitoring of other indictors of climate change, such as precipitation, air temperature, and growing season length. The Inland Bays watershed experiences a range of microclimate effects, so data collected at the coast, for example, (or from outside the watershed) cannot easily be extrapolated to inland locations.

Funding:

The annual cost to maintain the current network of CFMS sensors is approximately $15,000, including upkeep of a borrowed (DelDOT-owned) RTK-GPS system. Installation of new sensors would add more cost, so maintaining what is there already is more cost effective, as long as the locations are answering the pertinent science questions. DelDOT's telemetry system might be used to expand the network.

Currently the CFMS is funded by the Delaware Coastal Management Program, with funding from NOAA's Office for Coastal Management. Opportunities for additional funding from NOAA, DEMA, and Sussex County should be explored.

2020 Update Report:

CEMA is currently working on an expansionof the Coastal Flood Monitoring System to cover the Inland Bays and the towns along the Atlantic coastline of Sussex County. Like the Delaware Bay tool, it will include an early warning ALERTS system, storm inundation mapping for communities and important roadways, and provide flood predictions at the community level. The anticipated date for completion is September 2021. Funding for the expansion is being provided by DNREC's Division of Climate, Coastal, and Energy.

6. INDIAN RIVER INLET TIDAL FLUSHING

Since it was stabilized in the 1930s, the Indian River Inlet has deepened over time, passing greater volumes of water and increasing the tidal range of the Bays. This has led to long-term increase in salinity of the Bays and contributed to degradation of marshes. Increased tidal flushing through the Inlet also results in greater flushing of nutrients from the system.

Inlet flushing is one of the important indicators included in the *State of the Delaware Inland Bays* reports. Flushing is estimated through tidal prism calculations. The tidal prism is defined as the volume of water leaving a channel on an ebb tide cycle. The following general equation is used:

$$P = H A$$

where H is the average tidal range and A is the average surface area of the basin. Area is calculated through a series of transects and using bathymetry data for depth.

Tidal prism calculations for the Indian River Inlet are not made with regularity. Calculations were made in 1939, 1952, 1969, 1975, 1976, 1978, 1979, 1981, 1985, 1986, 1988, and 2004. Bathymetry data was collected in 1999 and 2004. The most recent measurements were performed by Ocean Surveys, Inc. (Saybrook, CT).

Tidal prism calculations can be used not only to evaluate the volume of water passing through the inlet, but also the residence time of water within the Inland Bays. Evaluation of the Indian River Inlet flushing indicator during preparation of the *2016 State of the Delaware Inland Bays* report revealed a need for dedicated funding to regularly assess the inlet flushing. As the inlet deepens and widens the volume of saltwater will increase and leads to a cascade of ecological impacts. In addition, the change in channel morphology may lead to structural problems with the inlet bridge. 2004 data were provided by the Army Corps of Engineers, Coastal Planning Section.

Recommendation: It is recommended that the state work with the Army Corps to repeat these measurements every five years. Because of its interest in resiliency of coastal roadways and long-term integrity of the inlet and its bridge, DelDOT may be able to contribute to this effort.

Funding: The tidal prism data collected in 2004 was one portion of a larger data collection effort funded under a single contract. The Army Corps estimates the tidal prism portion of the work cost roughly $30,000. The tidal prism data collection effort involved hourly boat-mounted ADCP surveys measured over a 25-hour period along five transects, as shown in Figures 3 and 4. Today, a similar effort would likely cost closer to $40,000.

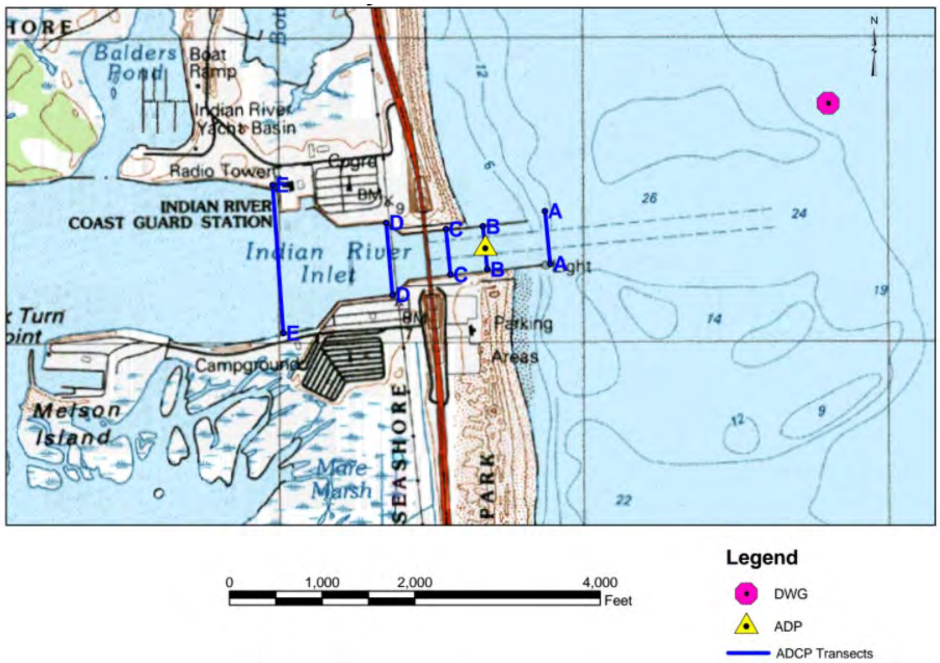

FIGURE 3– Hydraulic measurements made at the Indian River Inlet in 2004, showing current measurement transects.

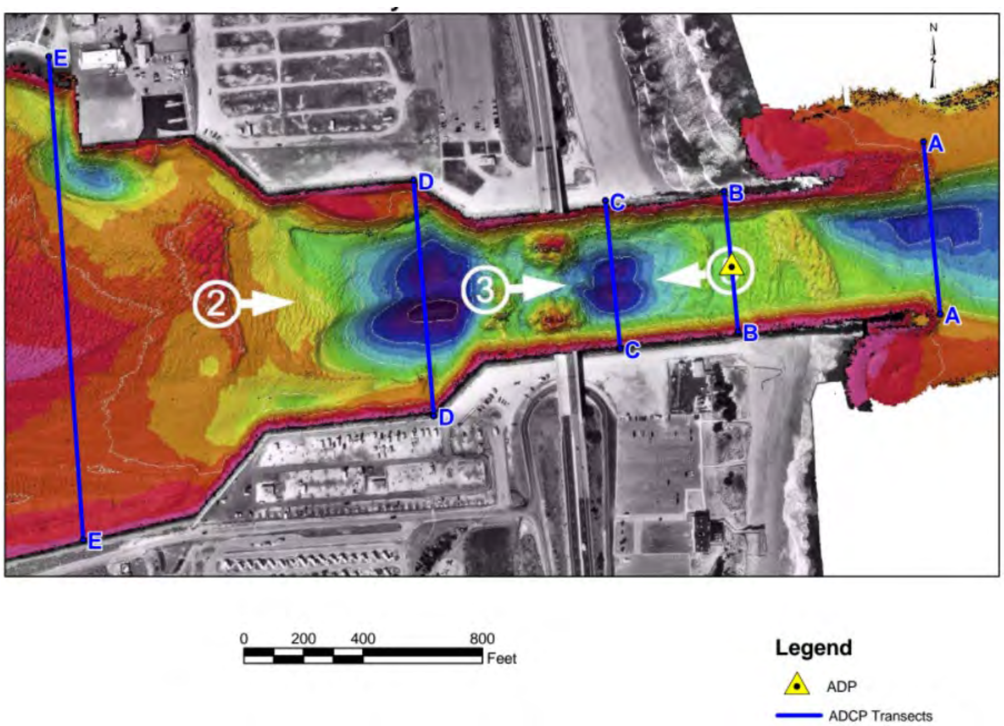

FIGURE 4 – Hydraulic measurements made at the Indian River Inlet in 2004.

<u>2020 Update Report</u>:

The CIB has been unsuccessful so far in obtaining the funding required to conduct new, *in situ* ADCP surveys of the inlet. The USACE was willing to provide partial funding through Planning Assistance to the States, but no source for the required nonfederal match was identified. At a meeting held in spring 2020, the USACE and other participants agreed that a modeling approach should be sought for estimating the prism. It was felt that this could provide an even more accurate calculation than a one-time *in situ* survey and could possibly be done using an existing model of the inlet.

The CIB is working with Prof. Fengyen Shi at the University of Delaware, who is confident that a numerical model previously developed for the Inland Bays by his group – the nearshore community model, or NearCoM – can provide an accurate estimate of the current tidal prism, and a proposal for this work was submitted by him to the CIB. The model will be re-validated against the recent tidal data measured at three USGS stations. The tidal prism will be calculated using the incoming/outgoing tidal fluxes through the inlet. The accuracy of the estimate will depend upon having appropriate bathymetry data. This work can be completed in early 2021.

7. MONITORING OF OYSTER RECRUITMENT AND GROWTH IN THE BAYS

A major goal of the Center is to restore a sustainable population of native oysters in the Inland Bays. Oyster restoration/enhancement projects (such as living shorelines, oyster reefs, and the CIB's oyster gardening program) and commencement of oyster aquaculture in the Bays will all contribute to this goal. Currently, however, no regular monitoring of oyster population, distribution, or recruitment in the Bays is occurring. Such monitoring is necessary to evaluate the effectiveness of restoration efforts.

A critical need also exists for studies on post-settlement growth and survival of oysters in the Inland Bays system. Existing literature documenting growth rates for Eastern Oysters is largely from studies of large, protected, or hatchery-spawned animals. Multi-year, population-level estimates of wild growth in local bay waters are necessary in order to understand the dynamics of restored oyster populations, and their ecosystem services, under naturally variable conditions. Such studies have very recently begun in Delaware Bay (Munroe et al., 2017).

<u>Recommendation</u>:

The CIB currently is drafting a Shellfish Enhancement Action Plan that will include recommendations for specific restoration projects such as oyster reefs. All implementation projects should, if feasible, be monitored for at least three to five years for oyster survival, growth, reef height and size (if applicable), disease, and recruitment.

In addition, however, it is recommended that regular, long-term surveys of oyster populations and recruitment be developed for all three Bays. A plan for this monitoring should be a component of the Shellfish Enhancement Action Plan.

A current research project being conducted under the guidance of Dr. Gulnihal Ozbay at Delaware State University (DSU) may provide a template for this monitoring program. The focus is to develop repeatable methods that can be used later to assess the impact that aquaculture and hatchery raised oysters have on the local wild oyster population. Components of this effort include: (a) Standardized transect surveys on riprap–armored shorelines; (b) spat collectors deployed at locations throughout the Bays; and (3) genetic analyses of spat, to determine the diversity and probable parent populations.

<u>Funding</u>:

DSU has estimated the cost of a long-term monitoring program to be approximately $30,000 annually. CIB and DSU should work together to identify funding to implement a survey in 2018.

<u>2020 Update Report</u>:

The first farmed oysters were cultivated in the Inland Bays in 2018. The state reported that in 2019, 51 total acres had been leased in the Bays, and 1,453,951 oysters were planted on commercial leases (Delaware Department of Natural Resources and Environmental Control, 2020). These were mostly, or all, nonreporductive triploid strains. In 2019, the CIB also installed and seeded three small subtidal research oyster reefs, two in Rehoboth Bay and one in Little Assawoman Bay. Funding has been secured to install and monitor additional subtidal and intertidal reefs in 2021. In the past few years, small but increasing numbers of wild native oysters have been observed in various areas of the Inland Bays. A living shoreline project installed in Indian River Bay, for example, has recruited relatively large numbers of oysters.

Thus, the importance of understanding the sources and transport of oyster larvae in the Inland Bays and the distribution and abundance of spat and adults has grown. Scott Borsum oat DSU published his master's thesis that included the results of spat surveys and intertidal riprap surveys conducted in all three bays in 2016 and 2017 (Borsum, 2018). However, other than the monitoring conducted by the CIB on the pilot research reefs, no additional surveys of oyster populations in the Inland Bays are underway or planned. The CIB intends in 2021 to recruit volunteers to assist with deployment and monitoring of spat collectors. Work will also begin in late 2021 on the final phase of a Shellfish Enhancement Action Plan that will consider monitoring needs and feasible approaches.

8. MONITORING OF SHORELINE CONDITION AND MODIFICATION

The Center is engaged in an initiative to maximize the use of living shorelines stabilization techniques in order to protect the water quality and habitat of the estuary. The initiative is a focus of the Comprehensive Conservation and Management Plan (CCMP) for the Inland Bays and is also a priority for the State.

A study to assess the shoreline conditions of Rehoboth and Indian River Bays was conducted by the Virginia Institute of Marine Science (VIMS), Center for Coastal Resources Management, with support from DNREC's Wetlands Monitoring and Assessment Program and the Center for the Inland Bays. Data for Indian River Bay were collected in 2006; data for Rehoboth Bay were collected in 2012. The spatial data collected in the study were used to build a public web-based mapping and analysis interface (http://cmap.vims.edu/ShlInv/Delaware/Delaware_shlinv.html). The assessment was not completed for Little Assawoman Bay at the time, due to funding constraints.

The data developed for the inventory were based on a three-tiered shoreline assessment approach. This assessment characterized conditions that can be observed from a small boat navigating along the shoreline. Hand-held GPS units and GPS registered videography were used to collect data on conditions observed in the field. The three tiered shoreline assessment approach divided the shore zone into three regions: 1) the immediate riparian zone, evaluated for land use; 2) the bank, evaluated for height, stability, cover and natural protection; and 3) the shoreline, describing the presence of shoreline structures for shore protection and recreational use.

A complete and up to date shoreline condition database is an important tool for evaluating success in meeting the goal of reducing hardened shorelines and increasing the extent of natural/living shorelines in the Bays. If maintained long-term, the data can be used to develop useful shoreline condition indicators for the Inland Bays. The online analysis tool can assist land owners, marine contractors, and State regulators to identify locations where shoreline restoration is needed and what type of shoreline restoration method would be most appropriate. In particular, the data may be used to help CIB and others prioritize sites for installation of living shoreline restorations in all three Inland Bays.

Recommendation:

It is recommended that a shoreline inventory be completed for Little Assawoman Bay, and that the shoreline data collected in 2006 for Indian River Bay be updated within the next one to two years. In order to use the shoreline data to develop an environmental indicator for the Bays, the data will need to be updated periodically. Ideally this would happen every five years, to correspond with release of the *State of the Delaware Inland Bay*s reports.

Funding:

Total cost for the original inventory of Rehoboth and Indian River Bays was ~$125,000. In 2015, VIMS provided a cost estimate of ~$67,000 to complete the inventory for Little Assawoman Bay and update Indian River Bay data.

The Center recommends that this work be completed more cost effectively by using in-house staff and volunteers to collect shoreline photographs and field data from boats. Use of drones may also facilitate data collection. Center staff, or a contractor, would then update the mapping layers and report the results. The Barnegat Bay Partnership recently developed a citizen science program called "Paddle for the Edge," to monitor shoreline condition. Data are collected from kayaks and canoes using a smartphone app. A similar program could easily be developed for the Inland Bays.

2020 Update Report:

As of 2020, there had been no progress on this recommendation. The CIB partnered with Barnegat Bay Partnership in 2020 on a proposal to the NEP Coastal Watersheds Grant Program for a collaborative 'Paddle for the Edge' effort that would use volunteer paddlers to collect shoreline data. That proposal was not successful.

9. CONTINUATION OF TIDAL MARSH ACREAGE/CONDITION AS ENVIRONMENTAL INDICATORS

Monitoring the extent and condition of the tidal marshes of the Inland Bays is critical for determining overall health of the estuary and to track trends in its condition. By understanding changes over time it is possible to identify potential areas of concern and prioritize future research and remediation efforts.

The *2016 State of the Delaware Inland Bays* report included new salt marsh acreage and condition (fractured pooling) indicators. These indicators were developed using data generated by a Regional Applied Research Effort (RARE) study conducted by the University of Delaware and the Center for the Inland Bays (Jo et al, 2014). The study documented the areal extent of the marshes of the Inland Bays at a number of intervals between 1937 and 2007 using geospatial analyses of aerial photography, State of Delaware wetland maps, and Landsat Thematic Mapper satellite imagery. Historic trends in the extent of vegetated marsh, fractured pooling, ditching, and wetland/upland boundary hardening provide an indication of the general health of the tide marsh system. The RARE study established a methodology for continued analysis of status and trends.

Recommendation:

In order to continue to use tidal marsh acreage and extent of fractured pooling as environmental indicators for the Bays, analyses of updated aerial imagery and land cover data should be repeated at least every five years, using the established GIS methodology. The University of Delaware Water Resources Agency (WRA) is best suited, at this time, to conduct these analyses.

Funding:

To perform the analysis, including data compilation and generation, aerial photointerpretation, GIS processing of files, generation of data for trend analysis, and reporting of status and trend results, the WRA estimates a total cost of $21,100 to $37,700.

2020 Update Report:

The CIB secured funding from Delaware Sea Grant in 2020 to support a University of Delaware student intern to update the salt marsh acreage and fractured pooling indicators for the 2021 *State of the Delaware Inland Bays* report. The intern worked under the supervision of CIB staff and Andrew Homsey, Delaware Water Resources Agency, who completed the original study. The methodology followed that of the previous salt marsh acreage and condition study, but utilized new land use, aerial imagery, and wetlands layers to derive updated acreage of fractured pooling, open water, and salt marsh. The spatial analyses were finished in the fall, and the technical report should be completed by January 2021.

10. ESTUARY ACIDIFICATION

The drivers, patterns, and ecological impacts of acidification in estuaries are not well understood, due to dramatic spatial and temporal variation in the processes that control pH in near-shore environments. Upwelling/overturn, tides, eutrophication, and watershed alteration are expected to interact with increasing atmospheric carbon dioxide and warming waters in complex ways. Proton fluxes may vary seasonally or with weather patterns. Biological impacts may also vary. Yet there is evidence that even a slight increase in acidification disrupts recruitment and growth of shellfish. Responses of other organisms to acidification are less clear.

Currently no long-term acidification monitoring is being conducted in the Inland Bays. Whether or not it is a significant concern is unknown. Monitoring pH in estuaries is not straightforward. Other National Estuary Programs have deployed cutting-edge systems to monitor long-term coastal acidification trends, including San Francisco Bay, Santa Monica Bay, Tampa Bay, Massachusetts Bay, Casco Bay, Barnegat bay, Long Island Sound, and Corpus Christi Bay. In addition, EPA has measured acidification in the Delaware River and Estuary as well as the Mid-Atlantic waters. Dr. Bill Ullman's group at the University of Delaware currently is studying acidification in the Murderkill Estuary, using a continuous, stable, high frequency pH sensor for estuarine and marine applications.

The Mid-Atlantic Coastal Acidification Network (MACAN) effort may help inform this monitoring (http://midacan.org). MACAN intends to develop research priorities and a coastal acidification monitoring framework for the Mid-Atlantic region in the near future.

Recommendation:

Collection of data needed to understand proton fluxes and balances in the Inland Bays should be included as a component of a continuous water quality monitoring system. Efforts should be made to upgrade planned continuous monitoring stations with sensors to monitor pH and carbonate system parameters. State of the art sensors suitable for use in brackish or marine waters will be required.

Funding:

Barnegat Bay Partnership estimates an added cost of $30,000 per station to install sensors for carbonate parameters at their network stations.

2020 Update Report:

Two research groups plan to install sensors in the Inland Bays to monitor acidification. In November 2020, Wei-Jun Cai's group, University of Delaware, installed a SeapHOx pH sensor in the upper Indian River at the same station established by CIB for continuous water quality monitoring. Another sensor will be installed shortly at the Indian River Inlet Coast Guard station. Support for this comes from Delaware EPSCoR, and additional support is anticipated from the Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS). DNREC-DNERR and other partners also applied for funding through MARACOOS to build a network to monitor coastal acidification and hypoxia in Delaware and New Jersey estuaries, including the Inland Bays. In 2022 at least one pH-pCO2 sensor bundle will be installed at a location near shellfish leases to be determined in consultation with CIB staff, who will help maintain the sensors.

11. RECREATIONAL BLUE CRAB AND CLAM HARVESTS

DNREC's Division of Fish and Wildlife indicates that obtaining estimates of recreational Blue Crab and Hard Clam harvests is one of the highest priorities for fisheries research in the Inland Bays. Currently no information exists on what quantity of shellfish are being recreationally landed from the Bays. This information would be used to assess the health and status of those shellfish populations and would allow the state to better account for recreational harvest in their management.

Recommendation:

The Division of Fish and Wildlife should develop an ongoing recreational Hard Clam and Blue Crab harvest survey in the Inland Bays similar to the MRIP survey currently used by NOAA recreational fish catch. This survey would rely on a field, 'harvester-intercept' interview survey that records catch rates for species; and a telephone (or mail survey) that is designed to estimate effort. Average catch rates would be applied to the effort estimates to generate landings per year. These surveys would be conducted annually.

Funding:

In 2009, the state contracted with MARCO to conduct this type of survey to generate a recreational landings estimate for Blue Crabs in the state. The cost was $46,000. Cost for the proposed survey is expected to be similar.

2020 Update Report:

As of 2020, no progress had been made on this recommendation.

12. EMERGING CONTAMINANTS

Wastewater Management Objective #2 of the 2012 Addendum to the CCMP is "Examine emerging contaminants entering the Inland Bays and engage the regulatory community and general public in education and source reduction." Action 1A is a symposium be held that "identifies emerging contaminants, their sources, and potential effects." A statewide symposium on emerging contaminants was co-sponsored by the CIB and the University of Delaware on March 13, 2017. Proceedings are available at www.inlandbays.org/events/emerged-symposium/. Contaminants of concern discussed included pharmaceuticals, personal care products, perfluoroalkyl and polyfluroroalkyl Substances (PFAS), polybrominated diphyenyl ethers (PBDE), phytoestrogens, oxybenzone (sunscreen), microplastics, and protons (coastal and estuarine acidification). Monitoring, regulation, and research needs were also discussed. Limited monitoring of these compounds has occurred in the Inland Bays study area.

Recommendation:

DNREC's Division of Water and the Delaware Health and Social Service's Division of Public Health report contaminant s found during monitoring of water supplies to the U.S. EPA, although the EPA does not have the resources to make regulatory determination on all of them. The State of Delaware should continue to maintain a database of contaminants found and inform EPA of the findings.

The STAC's CCMP/Monitoring subcommittee should also maintain a list of research and monitoring activities investigating emerging contaminants in the Inland Bays. This will build a baseline for determining which compounds have the highest potential for significant impact in the Bays, at which point reports can be prepared to define the problem, recommend further monitoring and research efforts, and promote source control.

Funding: In-kind agency staff time.

2020 Update Report:

In 2016, Jonathan Cohen's research group at the University of Delaware obtained funding from Delaware Sea Grant to study microplastic particle distribution and transport in Delaware Bay (Cohen et al., 2019). CIB staff assisted him in collection of samples in the Inland Bays, but results have not yet been published.

Miling Li, a new faculty member at the University, is pursuing a pilot project focused on PFAS concentrations in both estuaries. CIB staff also assisted her in sample collection in summer 2020.

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APPENDIX A

2012 CCMP ADDENDUM ACTIONS AND PERFORMANCE MEASURES

2012 CCMP ADDENDUM ACTIONS AND PERFORMANCE MEASURES

Focus Area: Nutrient Management	
Objective 1. Monitor the effectiveness of the nutrient management program and CAFO regulations, and suggest and implement revisions as	
Actions	**Performance Measures**
A. Annually report on watershed agricultural BMP implementation including PCS goals for cover crop acreage, manure storage sheds, and manure relocated or put into alternative use.	Publish annual reports on agricultural BMP implementation.
B. Target and prioritize BMP implementation to areas of the watershed where they will be most efficient and effective.	
B1. Use GIS and BMP performance data to determine the locations of BMPs in the watershed by BMP type resulting in the most cost effective nutrient reductions.	A workgroup produces a report targeting BMPs by type and location.
B2. Cost share providers prioritize assistance for targeted BMPs and track implementation	Amount spent on targeted practices relative to non-targeted practices.
C. Secure and leverage funding for BMPs.	
C1. Conduct a workshop to examine and enhance BMP financing strategies.	Recommendations for improving BMP financing strategies developed.
C2. Utilize DNREC's Water Quality Improvement Project Sponsorship Program (WQIPSP) to leverage funding for BMPs.	WQIPSP dollars spent on BMP implementation.
D. Promote and reward those in the agriculture sector who are good stewards of the environment.	Members of the agricultural sector are recognized publically for their innovation and BMP implementation.
E. Improve nutrient management of developed lands through research and education to better quantify and reduce nutrient loads.	
E1. Conduct watershed specific analysis to determine nutrient loading to the Bays from developed lands under different management practices.	A report is produced on nutrient loading from developed lands including education and management recommendations.
F. Develop program to educate the general public and landscapers on the benefits of reducing fertilization and improving fertilization practices.	Number of individuals and landscapers educated on the benefits of improving fertilization practices.

Focus Area: Wastewater Management	
Objective 1. Examine, improve and update existing on-site wastewater treatment and disposal regulations and their enforcement.	
Actions	**Performance Measures**
A. Annually assess and update information on regulatory initiatives in the onsite wastewater sector.	
A1. Continue and report on DNREC holding tank inspection program.	Regular reports on the holding tank inspection program are publicly available.
A2. Report compliance with DNREC pump-out and inspection requirements for septic systems on properties that are sold.	Regular compliance reports are publicly available.
A3. Verify that all new and replacement septic systems in the Inland Bays watershed are required to meet all regulatory performance standards.	Regular reports on replacement septic systems are publicly available.
B. Promulgate and enforce revisions to DNREC's onsite wastewater treatment and disposal regulations.	Regulations are promulgated and enforced.
C. Ban permanent holding tanks in the watershed.	A ban is in place and remains as such.
Objective 2. Examine emerging contaminants entering the Inland Bays and engage the regulatory community and general public in education	
Actions	**Performance Measures**
A. Conduct a symposium that identifies emerging contaminants, their sources, and their potential effects.	Emerging contaminant symposium held and findings conveyed.
B. For emerging contaminants with the highest potential for significant environmental impact, prepare reports to define the problem and promote source control.	Number of emerging contaminants reported upon.
C. Determine the need for regulations to reduce the threat of identified emerging contaminants.	Position on regulations provided by regulatory agencies.
D. Inform the public about the potential threats, challenges, and solutions to identified emerging contaminants.	A public education campaign on emerging contaminants is developed and implemented.

Objective 3. Promote the use of regional wastewater treatment and disposal systems within designated growth zones over multiple small	
Actions	**Performance Measures**
A. Develop a wastewater planning committee comprised of DNREC, Sussex County, utility industry representatives, and other stakeholders to coordinate the treatment and disposal of wastewater from new and existing develpments based on the TMDLs of receiving waters.	The wastewater planning committee is formed and meets regularly.
B. Conduct workshop to share new technology and incentives for increasing the beneficial reuse of wastewater.	Workshop results in an increase in the number of beneficial re-use projects.
C. Require surface water assessments that clearly demonstrate how all proposed wastewater treatment and disposal systems will help to meet TMDSs for receiving waters.	Regulations or permit requirements are implemented that require consistency with TMDLs.
D. Enforce the waters of Exceptional Recreational and Ecological Significance (ERES) provisions of the State Water Quality Standards requiring the least environmentally damaging disposal alternatives for wastewater.	ERES provisions are enforced for wastewater disposal.
E. Develop a nutrient budget for wastewater to determine existing and projected total wastewater loads to receiving waters.	Nutrient budget for wastewater is developed and used for planning and permitting.
F. Research the attenuation of nutrients and contaminants released from different types of on-site wastewater systems along flowpaths to receiving waters.	Information on attenuation developed and used to guide permitting.

Stormwater Management	
Objective 1. Reduce nutrient contributions from stormwater to help achieve TMDLs.	
Actions	**Performance Measures**
A. Complete the revision and implementation of sediment and stormwater regulations.	Revised sediment and stormwater regulations are promulgated.
B. Create stormwater management facilities and source reduction strateties for 4,500 acres of urban and residential lands developed pre-1990.	Acres developed pre-1990 treated by stormwater retrofits.
C. Provide assistance to local governments and HOAs to draft ordinances that minimize new and reduce existing impervious surfaces.	The number of governments and HOAs assisted with impervious surfaces ordinances.
D. Engage corporate partners to include Green Infrastructure practices in new and redevelopment projects.	Number of corporate partners adopting Green Infrastructure practices.
E. Encourage Sussex County and/or municipalities to create a stormwater utility to fund maintenance and retrofits.	Stormwater utility(ies) created.
F. Develop and implement a lines and grades/drainage code for Sussex County.	Sussex County adopts a lines and grades/drainage code.
G. Develop impervious surface coverage targets to protect aquatic life and urge their inclusion into county and municipal comprehensive plans.	Maximum impervious surface coverage targets developed. Number of comprehensive plans including maximum impervious surface coverage targets.

Water Quality Management	
Objective 1. Update the Inland Bays estuarine and watershed models with the latest scientific understanding and best available data, and	
Actions	**Performance Measures**
A. Update the Inland Bays estuarine water quality and hydrodynamic model.	An updated model populated with the best available data is available for use.
B. Update the Inland Bays watershed nutrient loading model.	An updated model with the best available data is available for use.
C. Utilize updated estuarine and watershed models to evaluate if existing TMDLs are adequate to achieve water quality standards for nitrogen and phosphorus.	A report is produced. TMDL regulations are updated as needed.
Objective 2. Report on the implementation of the PCS, revise and prioritize remaining actions, and devise an implementation plan to meet the	
Actions	**Performance Measures**
A. Produce initial report on PCS implementation and identify barriers to implementation.	Initial report on PCS implementation is published.
B. Revise PCS goals as needed, incorporating any revisions to the TMDLs.	PCS goals revised as needed incorporating any revisions to the TMDLs.
C. Develop an implementation plan for remaining PCS actions that includes a time frame for completion, interim goals, and identified implementation funding sources.	A revised PCS with implementation plan is published.
D. Produce annual PCS progress reports including a yearly determination of the nutrient loads to the Bays and their tributaries relative to their TMDLs.	Annual PCS progress reports are generated.

Objective 3. Review and revise State and local standards for ground and surface water protection.	
Actions	**Performance Measures**
A. DNREC reviews their technical standards for ground and surface water protection at five-year intervals.	Review is publicly available.
B. Obtain and review County standards for ground and surface water protection.	Such a review is publicly available.
Objective 4. Quantify the transport of contaminants from Indian River Power Plant (IRPP) coal ash landfills to receptors in the aquatic	
Actions	**Performance Measures**
A. Study the transport of contaminants to aquatic life near the IRPP to inform the Voluntary Cleanup and the Natural Resources Damage Assessment Processes for the Burton Island coal ash landfill.	Final reports made available to the public.
B. Model transport scenarios of contaminants from the IRPP coal ash landfills to environmental receptors based on various levels of sea level rise and severe storm impacts.	A report on this scientific research is made available to the public.
Objective 5. Reduce nutrient input to residential canals and lagoons.	
Actions	**Performance Measures**
A. Treat or remove greywater discharges into tributaries, canals, and lagoons.	Number of greywater discharges treated or removed.
B. Filter runoff from roofs, driveways, and other impervious surfaces.	Number of projects implemented.
C. Provide and disseminate educational material for homeowners on reducing fertilizer inputs to tributaries, canals, and lagoons.	Materials are distributed.
D. Examine dead-end canals to determine if any could benefit from low-cost solutions to increase flushing.	Candidate sites for additional tidal flushing are identified.
Objective 6. Re-assess water quality monitoring efforts for their representativeness and capacity to detect trends, then develop recommendations	
Actions	**Performance Measures**
A. Aggregate historic and contemporary water quality monitoring data and metadata into one publicly accessible database.	Database is available and updated annually.
B. Conduct a long-term trend analysis of water quality parameters.	The trend analysis is completed and published.
C. Develop recommendations to improve efficacy of monitoring efforts to detect trends.	Recommendations report is published.

Managing Living Resources and Their Habitat	
Objective 1. Promote recurrence of bay grasses.	
Actions	**Performance Measures**
A. Conduct an education initiative on the benefits and importance of re-establishing submerged bay grasses.	Number of individuals educated about bay grasses and their restoration.
B. Map areas of the Bays that have habitat characteristics supportive of the re-establishment of bay grass species that have been identified as suitable candidates for restoration.	A report including data layers and maps is produced.
C. Convene a bay grass restoration workgroup to develop a bay grass restoration, protection, and monitoring plan.	Baygrass restoration workgroup is active. A plan is developed.
D. Implement the bay grass restoration, protection, and monitoring plan.	Number of acres successfully restored. Annual restoration and monitoring reports are produced.
Objective 2. Halt the continued loss of wetlands and reverse these loss trends by promoting projects to mitigate for previously lost wetlands.	
Actions	**Performance Measures**
A. Bring regulation of freshwater wetlands, including isolated wetlands, under State jurisdiction and permitting.	State legislation is passed and regulations are adopted.
B. Identify candidate sites for the creation and restoration of wetlands.	Numbers and acreages of sites identified.
C. In accordance with the Inland Bays Pollution Control Strategy (PCS), create or restore wetlands on areas previously converted to cropland.	The PCS goal of restoring 4,147 acres is met.
D. Protect and enhance/restore additional wetland acreage.	Number of acres protected. Number of acres enhanced/restored/created per year.
E. Encourage the planting of trees and other plants adjacent to all wetlands.	Number or acres of planted next to wetlands.
F. Revise the existing Sussex County Ordinance on water quality buffers to be in line with the CIB's Recommendations for a Water Quality Buffer System.	A revised ordinance is adopted.
G. Engage the state Natural Areas Advisory Council to help identify freshwater wetlands that should be purchased as preserves.	A prioritized list of properties to be purchased is produced.
H. Develop a living shoreline initiative to maximize the amount of natural Bay shorelines.	
H1. Assess and report on the condition of shorelines in the Inland Bays.	Shoreline assessment reports are produced.
H2. Conduct an education and outreach program on shoreline function and management alternatives for shoreline property owners.	Number of shoreline property owners informed.
H3. Conduct living shoreline demonstration projects to train installation and maintenance contractors.	Length of living shoreline enhancements or stabilizations installed. Number of contractors trained.
H4. Demonstrate innovative living shoreline stabilization techniques utilizing bay grasses, shellfish, and other native biota where feasible.	Number of demonstration projects completed.
H5. Support legislative and/or regulatory changes needed to require that living shoreline techniques be employed wherever feasible for shoreline stabilization.	Legislation is passed or regulations are updated.
Objective 3. Provide access for native migratory fish to upstream areas for use as spawning and/or nursery sites.	
Actions	**Performance Measures**
A. Conduct a migratory fish passage restoration feasibility and planning study.	The study is completed .
B. Implement fish passage restoration projects.	Number of passage projects completed. Number of miles of fish habitat restored.
C. Monitor fish passage restoration success.	Annual reports are produced that document the number or percentage of target migratory fishes utilizing the passages.
D. Conduct education and outreach efforts on the importance of migratory fishes and the benefits of fish passage restoration.	Number of people informed.
Objective 4. Eliminate once through cooling at the Indian River Power Plant (IRPP).	
Actions	**Performance Measures**
A. Track progress of IRPP compliance with DNREC agreements for removal of Unit 3 water withdrawals by January 1, 2014.	The only water being withdrawn at IRPP is to compensate for evaporative loss at the cooling tower.

Objective 5. Increase the economic and environmental benefits of shellfish.	
Actions	**Performance Measures**
A. Increase the acreage of approved shellfishing waters.	
A1. Examine water quality data for the past 5 years to determine if areas of the Bays could be re-opened to shellfish harvest.	Number of acres reclassified from closed to approved or seasonally approved.
A2. Determine the sources of contamination that presently constrain the opening of additional shellfishing areas.	A listing of the sources of contamination is available for public scrutiny.
A3. Develop and implement a strategy to address contaminant source reduction so that additional shellfishing waters may be opened.	The strategy is completed and implementation is underway .
B. Enhance populations of eastern oysters.	
B1. Create additional hard bottom areas suitable for oyster recruitment or planting of oyster spat.	Acres of suitable hard bottom areas created.
C. Promote and encourage shellfish aquaculture in the Inland Bays.	
C1. Convene a team of state and federal regulatory representatives and stakeholders to produce the scientific, educational, and policy groundwork necessary to develop legislation and regulations that govern shellfish aquaculture in the Inland Bays.	Legislation favorable to aquaculture is passed. PM C1.2 Regulations governing aquaculture are promulgated.
C2. Provide financial incentives for new aquaculturists.	Financial incentives are competitive with other states.
C3. Provide technical support and education to aquaculturists.	Technical guidance specific to the Inland Bays is published.

Objective 6. Monitor and control the spread of invasive species within the Bays and their watershed.	
Actions	**Performance Measures**
A. Map the known distributions of invasive species of concern in the watershed.	A map is created and publicized.
B. If needed, support implementation of policy designed to curb the spread of invasive species.	The legislative/and/or regulatory process is engaged to limit the spread of invasive species.

Planning for Climate Change

Objective 1. Integrate projected sea level rise into land use planning and proposed development to protect shore zone ecosystems and bay	
Action	**Performance Measures**
A. Work with the County and municipalities to incorporate sea level rise into comprehensive plans.	The County includes sea level rise in its comprehensive plan. Percentage of bayside municipalities that include the projected impacts of sea level rise in their comprehensive plans.
B. Conduct a sea level rise vulnerability analysis specific to the Inland Bays watershed that includes potential impacts to both green and gray infrastructure.	Report of analysis is publicly available.
C. Implement the recommendations of the State Sea Level Rise Advisory Committee relative to the Inland Bays when they become available.	Percentage of total recommendations implemented.
D. Model the distribution of tidal wetlands under different sea level rise scenarios to guide land use and protection decisions that maximize future tidal wetland extent.	Number of additional acres that would need to be acquired or protected.
E. Track shifts of dominant aquatic species potentially caused by climate change through the use of previous and recent surveys.	Generation of a list of species affected that is regularly updated.
F. Include climate change and sea level rise information in public outreach and education efforts.	Number of individuals informed about climate change and sea level rise.

Coordinating Land and Water Use Decisions

Objective 1. Involve all levels of government to obtain commitments for coordination of land use decisions that minimize environmental

Action	Performance Measures
A. Designate the Inland Bays watershed as a 'Critical Environmental Area' and manage the watershed for nutrient reductions consistent with TMDL load reductions or reductions attributed to best available technologies.	Designation of the Inland Bays watershed as a 'Critical Environmental Area'.
B. Request that representatives of all levels of government sign a letter of understanding that their land use decisions will minimize environmental impact to existing aquatic resources in the watershed.	Such a letter is drafted and signed by appropriate agencies represented on the CIB Board of Directors.

Objective 2. Provide maximum protection of waterways, forested stream corridors, groundwater, natural areas, open space, tidal and non-

Action	Performance Measures
A. Water quality buffers shall be clearly demarcated, designated, and recorded on final site plans or final major subdivision plats and demarcated on the ground with signs or other kinds of markers.	This requirement is included in a revised Sussex County ordinance.
B. Maintain land presently classified as open space under County or municipal ordinances or codes to minimize nutrient loading to the Inland Bays estuary.	County and municipal officials are educated on the need for such maintenance.
C. Update and implement the Inland Bays Habitat Protection Plan.	Number of acres protected through acquisition or easement.
D. Use the Delaware Ecological Network and other appropriate information source to prioritize the preservation of key habitat in the Inland Bays drainage system.	Number of acres protected.

Objective 3. Update and implement the Inland Bays Water Use Plan.

Action	Performance Measures
A. Assess implementation progress of the Water Use Plan and revise remaining and new actions.	Water Use Plan Update is published.
B. Focus outreach on increasing waterway safety and channel marking.	Waterway maintenance improves.
C. Focus on low impact water use activities.	The public is informed about the availability of low impact water use activities.
D. Continue marine spatial planning efforts to maximize aquatic resources and minimize water use conflicts.	
D1. Develop a publicly accessible marine spatial planning database.	A database is publicly available.
D2. Provide educational and planning forums on spatial aspects of water uses.	Number of individuals attending forums.

Outreach and Education

Objective 1. Increase the visibility of the CIB and its mission.

Action	Performance Measures
A. Assess the CIB brand and communications strategy to determine effectiveness.	
A1. Conduct surveys to gather data on citizen perceptions and understanding of issues of concern in the watershed.	Surveys are developed and implemented.
B. Identify and implement high priority Work Plan/CCMP actions and develop outreach and education campaigns.	Campaign(s) are developed and implemented.

Objective 2. Educate stakeholders in the watershed about their impacts on water quality in the Bays and how they can help.

Action	Performance Measures
A. Develop and deliver watershed education programs for children.	
A1. Programs for school age children are offered at the James Farm Ecological Preserve.	Number of students attending programs.
A2. Offer community outreach and education to children, families, and visitors at the Bethany Beach Nature Center.	Programs offered at BBNC.
A3. Continue to offer watershed education at schools through the Schoolyard Habitats Program.	Number of schools reached annually at their schools.
B. Administer a Speakers Bureau.	Number of speaking engagements annually.
C. Continue to promote the 1000 Rain Gardens for the Inland Bays program.	A demonstration rain garden is established in every incorporated town in the watershed. Rain Garden booklets are distributed at demonstration sites.

Objective 3. Communicate with stakeholders through a variety of media; to promote public involvement and influence behaviors, attitudes	
Action	**Performance Measures**
A. Continue to develop and administer a website as a primary vehicle for disseminating information	A comprehensive website is maintained.
B. Incorporate social marketing and enhanced use of media into CIB's communications strategy	Social media is used to maintain regular communication with Board and Board Committees, volunteers, Friends of the Bays, and elected and public officials.
C. Edit and disseminate a newsletter and annual report.	The Inland Bays Journal is published and distributed three times each year and an annual report is published annually.
D. Create and disseminate printed marketing materials such as brochures, postcards, flyer exhibits and signage to address specific education/outreach needs to target audiences.	Printed materials and exhibits are produced each year for priority issues and projects.
E. Maintain relationships with local media outlets and reporters and disseminate press releases and photos for their use.	Press releases are issued for events and selected projects.

Objective 4. Encourage more stakeholder support through volunteerism.	
Action	**Performance Measures**
A. Direct a volunteer program that provides citizens a formal track to partner with the CIB.	Volunteer opportunities are developed and volunteers receive regular invitations to assist.
B. Involve volunteers and stakeholders in demonstration projects that model desired changes in practices and citizen science research.	Number of volunteer hours worked each year.

Objective 5. Communicate environmental results to inform legislators and raise citizen awareness about the state of the Inland Bays and its	
Action	**Performance Measures**
A. Results of Inland Bays environmental studies or projects are published.	A "State of the Inland Bays Report" is published and disseminated every five years. Press releases are issued to provide new information to the media.
B. Communicate the benefits to economic development, tourism, recreation and quality of life of achieving water quality goals.	Increase in participation from the business community.

APPENDIX B

ENVIRONMENTAL MONITORING PLAN REVISION PROCESS AND MEETING NOTES

ENVIRONMENTAL MONITORING PLAN REVISION PROCESS

Ambient Water Quality Monitoring Workshop

As part of the IBEMP update, the Center for the Inland Bays (CIB) hosted a facilitated workshop on July 29, 2015 to discuss ambient water quality monitoring in the Inland Bays. The workshop was facilitated by a contractor, Jim Eisenhardt, of RK&K. Primary goals of the workshop were to:

1. Review current ambient water quality monitoring programs and identify strengths, weaknesses, and areas of improvement;
2. Develop a process to transfer existing and new University of Delaware Citizen Monitoring Program (CMP) data to a public database such as STORET;
3. Include CMP data effectively into the combined Watershed Assessment Report (305(b)) and Determination for the Clean Water Act Section 303(d) List of Waters Needing TMDLs;
4. Evaluate the effectiveness, capacity, and costs of the DNREC water quality portal (developed by DEMAC) to provide DNREC and CMP data to researchers and the public; and
5. Improve the participation of organizations in the review and interpretation of Inland Bays environmental indicator reports.

Prior to the workshop, participants were asked to provide input on key questions to help guide discussion; compiled results are included below (pages B-3 through B-17). Participants represented the following organizations/agencies: CIB, Delaware Department of Natural Resources and Environmental Control (DNREC), University of Delaware, and the United States Geological Survey (USGS). Representatives from the United States Environmental Protection Agency (EPA) Region III were not in attendance; however, Bill Richardson of the Office of Standards, Assessment and TMDLs provided input prior to the workshop.

Workshop notes are included below (pages B-18 through B-25).

Scientific and Technical Advisory Committee Input and Review

At its meeting on September 18, 2015, the STAC discussed the IBEMP update. The discussion was facilitated by Jim Eisenhardt (RK&K) and the Center's Science and Restoration Coordinator, Marianne Walch. The focus of the discussion was existing monitoring programs and anticipated monitoring needs.

A questionnaire similar to the one used for the facilitated workshop was sent to key STAC members prior to the meeting. Compiled results of that questionnaire (pages B-26 through B-32) and notes from the discussion held at the STAC meeting (page B-33) are included below.

Compiled Questionnaire for WQ Monitoring Workshop Meeting

29 July 2015

In order to gather information to help guide our discussions at the July 30th workgroup meeting, we ask that you provide answers to the following questions about your own agency/organization's monitoring programs in the Inland Bays, as well as your thoughts about improving the Center for Inland Bays (CIB) monitoring plan[1].

Attendees/Responders

- BR: Bill Richardson, EPA Region 3, Office of Standards, Assessment and TMDLs
- DW: Dave Wolanski, DNREC, Watershed Assessment
- HM: Hassan Mirsajadi, DNREC, Division of Watershed Stewardship, Watershed Assessment and Management Section
- RG: Rick Greene, DNREC, Division of Watershed Stewardship, Watershed Assessment Section
- RT: Robin Tyler, DNREC, Division of Water/Environmental Laboratory Section
- JY: Joanna York, University of Delaware, School of Marine Science and Policy
- SA: Scott Andres, Delaware Geological Survey/Chair CIB STAC
- BU: William (Bill) Ullman, University of Delaware, School of Marine Science and Policy, Oceanography Program
- JF: Joe Farrell, University of Delaware, Delaware Sea Grant, UD Citizen Monitoring Program
- EW: Edward Whereat, University of Delaware, UD Citizen Monitoring Program

[1]Per email from Chris Bason on 22 July: Is there anyway EPA can communicate its desire to have citizen science data operationally included into the determination of water quality impairment (or lack thereof)? Important role for EPA to encourage States to do this. Maybe there will still be ways in which EPA can support our effort to do this in DE and I think it would be fantastic if DE and Region III could be a national leader in this. Nancy Laurson [EPA HQ]: Monitoring Plan should fit the local needs.

Per Bill Richardson: It would be EPA's preference for any data collected by the citizen scientists working with CIB be used in DE's Integrated Reports (IRs).

1. **What areas, based on your experience/expertise, are the most important to focus on in a water quality monitoring plan for the Inland Bays and (very briefly) why?**
   - BR:
     - Eutrophication; habitat and wetland loss.
     - Bacteria for protection of recreation.
   - DW: The DNREC monitoring stations are pretty extensive and cover the largest waterbodies with enough stations to give us big picture conditions, provide some modelling data and track trends in the watershed as a whole.
   - HM:
     - Water quality monitoring at headwaters and smaller streams.
     - Groundwater quality and movement.
     - Ecological conditions including habitat and biology.
     - Wetland assessment.
     - Since we have an acceptable level of water quality monitoring of larger streams and Bays that is currently conducted by DNREC and Citizen groups, the above four areas may need additional attention.
   - RG:
     - Nutrients and algal productivity (Why: Eutrophication, dissolved oxygen, fisheries, benthic habitat and aesthetics).
     - Bacteria (Why: Shellfish harvesting and primary contact recreation).
   - RT: I think that the most important areas (factors/variables) to focus on within the water quality element of the Inland Bays Monitoring Plan are those presently being focused upon – dissolved oxygen, nutrients, chlorophyll, and pathogen indicator bacteria.
   - JY: Monitoring of chlorophyll, DO, and nutrients. Potentially also biomass of macroalgae, depending on balance between micro- and macro-algal primary producers. Could also consider light—even via Secchi disk.
   - SA:
     - Spend monitoring dollars wisely. This can be accomplished if you:
       1) Clearly articulate the goals and objectives of monitoring.
       2) Develop protocols (including QA/QC) and document metadata consistent with the protocols.
       3) Communicate 1) and 2) to the monitoring program staff and volunteers
     - Recognize and avoid mission creep. This dilutes the effort and spreads staff too thin.
     - Do what is necessary to have monitoring data incorporated in or linked to larger state, regional, or national datasets. "Spending monitoring dollars wisely" will guide the program to this objective.
   - BU:
     - Monitoring needs to yield data in a form that can be usefully related to both status and fluxes. Fluxes are harder to determine on ecologically relevant time scales, but these fluxes are needed to appropriately set goals for long term

preservation. Spot samples are easy to collect, but much harder to use as these spot analyses need to be integrated into flow models to yield fluxes.
    - We have been successfully using continuous automated sensors in the Indian River, Nanticoke River and Murderkill River watersheds to supplement spot measurements for a number of years and have been using these data to estimate fluxes and to answer specific scientific questions in these systems.
- JF:
    - Dissolved oxygen as good overall indicator of living resource and Bay health.
    - Nutrients (N and P) load and concentration - as long term indicator of whether Bay conditions are improving.
    - Pathogen indicator – for recreation water quality and safe shellfish consumption.
- EW:
    - Causes of eutrophication, i.e. nutrient levels - needed to assess trends.
    - Biological responses to eutrophication, i.e. low dissolved oxygen levels, reduced water clarity, high chlorophyll levels, (harmful algae blooms?) - needed to assess trends.
    - Recreational contact safety - total Enterococcus levels - recreational use and public interest.
    - Habitat conditions are important, but difficult to address.

2. **What monitoring activities/data collection is your organization undertaking in the Inland Bays that could be part of the CIB WQ monitoring network?**
    - BR: EPA's national survey may collect Inland Bay sites, but the survey is only conducted every five years. The data may not be sufficient to supplement CIB needs.
    - DW:
        - DNREC publishes the monitoring plans online: http://www.dnrec.delaware.gov/swc/wa/Pages/WaterQualityMonitoring.aspx
        - In lieu of Table 1, I am attaching our most up to date monitoring plan[2] which is being updated now. No significant changes are expected at this time.
    - RG:
        - Routine monitoring of selected metals at multiple stations (see monitoring plan provided by Dave Wolanski for details).
        - Toxics: Work is done when a specific need arises and is justified scientifically.

[2] State of DE Ambient Surface Water Quality Monitoring Program – FY 2015. Available online at: http://www.dnrec.delaware.gov/swc/wa/Documents/WAS/State%20of%20Delaware%20FY%202015%20Ambient%20Surface%20Water%20Quality%20Monitoring%20Program%20.pdf.

        - Toxics in Biota Monitoring Program collects and tests fish tissue and shellfish samples for chemical contaminants.
        - Toxics in Sediment Monitoring Program assesses toxic contaminants in sediment samples (mostly collected by other programs).
- SA: I cannot overstress the importance of collecting good quality data on the flow of water. Water flow is the single most important variable in computing pollutant loads.
    - Coordinate and pass funding to U.S. Geological Survey
    - Being done with DEOS/DEMAC
    - Being done with DEOS
- BH: Our group does not have any present monitoring efforts in the Inland Bays watershed.

PLEASE COMPLETE TABLE 1 AT THE END OF THE QUESTIONNAIRE. Feel free to provide additional comments here.

3. What water quality monitoring programs are planned for the future that might be applicable to the Inland Bays?

- BR: EPA funds a National Coastal Conditions Assessment (NCCA) every five years. The NCCA is ongoing this summer in 2015. The NCCA is a probabilistic survey and there are normally a few sites located within the DE Inland Bays. DNREC staff are provided grant funding to collect DE samples.
- DW: See response to question #2.
- RG: The Watershed Approach to Toxics Assessment and Restoration (WATAR) might be applicable to the Inland Bays in the future.
- RT: No knowledge of new programs.
- BU: We have no current plans for the Inland Bays watershed, although, we have submitted a proposal with Scott Andres, Delaware Geological Survey, to instrument and monitor the effects of the Wolfe Neck Regional Wastewater Treatment Plant on nutrient concentrations and loads leaving this site for surface waters of the Lewes-Rehoboth Canal. This work, if funded, would begin in Spring 2016.
- EW: Nothing applicable at this time.

PLEASE COMPLETE TABLE 2 AT THE END OF THE QUESTIONNAIRE. Feel free to provide additional comments here.

4. What areas, based on your experience/expertise, are missing from the current Inland Bays WQ monitoring plan?

- BR: EPA would recommend CIB coordinating with DNREC to ensure adequate data are collected for use in DE's biannual Integrated Report (305(b) and 303(d)). EPA can assist with DNREC-CIB discussions if needed.
- HM: The 4 areas mentioned in question #1 above.
- RG:
    - Continuous monitoring of dissolved oxygen, temperature, pH and conductivity.

    - Habitat types and quality.
- RT: Establishing bacterial source tracking as a routine element of water quality monitoring would seem to have value because it may dampen much of the present accusation/denial conflict regarding such sources and give more pointed and effective direction to pollution abatement efforts. Also, if bacteria contributions are linked to human sources then it is reasonable to assert that those sources are also accountable for some larger proportion of the loading of other factors of interest such as organic matter and associated nutrients (i.e., actions corrective to the input of pathogen indicator bacteria are also likely to yield improvements in the levels of organic matter and nutrients).
- SA: The current plan relies almost entirely on DNREC action and political pressure. There is an overwhelming influence of the TMDL, PCS, and 305b programs on monitoring and the data that are regularly assessed and reported on by DNREC staff. Changing any aspect of monitoring or assessment has consequences for hard-won progress with the TMDL and PCS. The fear of consequences has stopped ideas for new ways to collect or assess data.
- BH: I think that too little is known about the variable impacts of agricultural and domestic wastewater on total nutrient loads to the Inland Bays. With population increases, I am concerned that total loads to surface waters will increase, even as better treatment and disposal options are put into place. I think that we need to have better estimates of these loads and develop robust models for estimating future loads from these sources as population increases in the future.
- JF: Not sure.
- EW:
    - In general, inadequate frequency and spatial coverage.
    - Episodic events (extreme rain, wind and tide events).
    - Winter conditions.
    - Targeted sampling to address specific issues or determine effectiveness of BMPs.
    - Toxicity studies of fish, shellfish, and sediments are limited

5. What additional WQ monitoring activities would your organization benefit from if CIB could include in their monitoring plan? Please feel free to think outside of the box, without regard to availability of funding, including new or innovative technologies.

- BR: Continuous monitoring of DO and pH to evaluate nutrient impacts (if not on-going).
- BR: Research on possible impacts from ocean acidification.
- DW: Continuous monitors might be valuable for evaluating DO criteria in tributaries.
- RG: An innovative study of engineered denitrification of groundwater.
- RT: The DNREC Laboratory is exploring the efficacy of doing bacterial source tracking testing as one of its services. The feasibility of successfully doing so is contingent upon having a steady enough flow of samples (work) to make the venture viable. Establishing

bacterial source tracking as a routine test within long-term monitoring and special project sampling efforts is essential and a commitment from the Inland Bays Monitoring Plan would be helpful in advancing this.

- JY: Nutrient monitoring. Perhaps in situ monitoring instrument - similar to the LOBO instrument that is installed at Bowers Beach (Bill Ullman) or the instruments maintained by the DNERR. Expensive, but provides LOTs of data.
- SA: Deployment of automated WQ sensors. In addition to standard physical sensors, nitrate sensors provide invaluable data.
- BU: We have considerable and growing expertise in the use of continuous water quality monitoring devices for coastal watersheds and estuaries. I think that it is more likely that we could assist the CIB and the State than vice versa, but we would be interested in expanding the use of these systems and developing automated applications of these data for managers.
- JF: Phytoplankton/HAB monitoring plan for recreational and commercial shellfish harvesting/aquaculture.
- EW:
  - Continuous monitoring in some tributaries.
  - Bacterial source tracking.
  - Toxicity of harmful algae.

6. **Does your organization have historical WQ or other monitoring data that were not included in the original monitoring plan that would be useful for future WQ monitoring activities or for use as State of the Bays indicators?**
   - BR: Possible NCCA data, but for only a few sites.
   - DW: DNREC publishes all its data through STORET, online at: http://www.epa.gov/storet/
   - HM: We have several years of high frequency water quality and nutrient data from Millsboro Pond outlet.
   - RG: Possibly.
   - RT: Yes.
   - JY: Probably not. I assume folks from UD have been engaged with plans at the CIB and State level and would have given input.
   - SA: The Monitoring Plan does not include a concise bibliography, database, or list of data. It is possible that data held by the Delaware Geological Survey are missing, but I don't have enough time to do this detective work by July 28.
   - BU: I believe all of our data were made available to DNREC and CIB. Not all of the data collection was part of the initial Monitoring Plan. Much of the data that we collected historically, have also been published.
   - JF: More than a decade of comprehensive phytoplankton/harmful algal bloom (HAB) data for Inland Bays.
   - EW:
     - Bacteria (TE) levels.
     - Select harmful algae species.

7. **Does your organization anticipate having sufficient future funding to carry out WQ monitoring activities that CIB has included in the monitoring plan to date? Do you anticipate future funding for additional data collection parameters beyond the current monitoring criteria included in CIBs plan?**
   - BR: No.
   - DW: Funding is always challenging. The State budget is going to be interesting the next few years.
   - HM: Our surface water quality monitoring program has changed from what is in the CIB plan based on our emerging and changing needs. However, our current level of monitoring is much more than what is in the CIB plan. And, we expect to have sufficient funding to continue our current level of monitoring into the future.
   - RG: Unknown.
   - RT: The "Priority Basin Monitoring" (aka General Assessment for 305(b) Water Quality Inventory reporting) is anticipated to continue at least at the level of effort of the past 25 years. Biological (macroinvertebrate) monitoring is likely to continue, probably at five-year intervals. Other Clean Water Act mandated monitoring such as NPDES will also continue as will other permit-related programs in the Division of Water.
   - JY: Funding is dependent on successful grant applications. It is hard to anticipate beyond a two-year timespan.
   - SA: The plan has NO activities for my agency only work that might be done if resources were available. Table 2 lists potential data collection efforts.
   - BU: All of our work required extramural funding. Other than the proposal described in item 3, above, we have no additional plans for monitoring activities in the Inland Bays.
   - JF: We will need support to continue some of our past monitoring efforts that are no longer funded e.g. nutrients.
   - EW:
     - To some degree, depending on scope.
     - Doubtful at this time.

8. **Do you have any recommendations for additional funding sources for WQ monitoring activities?**
   - BR: None at this time.
   - DW: No.
   - HM: EPA, NOAA, NSF.
   - RG: No.

- RT: Increases in environmental monitoring funding levels via the government sector seem unlikely in the present economic and political climate, absent a crisis such as that triggered by Pfiesteria almost 20 years ago. More productive perhaps would be grants from the private sector, particularly large foundations or endowments.
- JY: Collaborative funding proposals to the EPA/NSF/NOAA for longer term funding, potentially including the CIB, academic researchers, and citizen groups.
- SA:
  - Private entities could purchase monitoring equipment for CIB to use or borrow for monitoring (see question #5).
  - EPA NEP funds could potentially fund migration of the CMP data into STORET. From there, the data are accessible to everyone through multiple channels.
- BU: There is very little funding available for just monitoring. However, data collected as part of scientific research can also serve a secondary monitoring objective. Both DNREC and Sea Grant have funded such dual-use projects in the past.
- JF: I wish we did.
- EW:
  - DNREC/State should devote more funds to monitoring.
  - CIB should devote more funds to monitoring.

9. Other than the University of Delaware Citizen Monitoring Program, are you aware of any volunteer organizations/programs that are currently active and could be included in future Inland Bays WQ monitoring for supplemental information?

- BR: No.
- DW: No.
- HM: No.
- RG: No.
- RT: No.
- JY: No.
- SA: No.
- BU: No.
- JF: South Bethany Water Quality Committee.
- EW: I am not aware of other volunteer organizations/programs, perhaps with exception of the South Bethany Water Quality Committee, which falls under our umbrella, but has certainly become semi-independent and has been involved in CIB BMP projects.

10. For the data you discuss in this document, is your organization just collecting raw data or are you also processing the data and developing trends from the data?

- BR: Raw data only. Reports from the NCCA are written at a national scale.
- DW: We collect and process the data for a number of programs and purposes.
- HM: Our Section develops the monitoring plan and reviews and analyzes the data.
- RG: Watershed Assessment has compiled and assessed toxics data generated through its own monitoring and monitoring performed by others to produce a better understanding of an issue (e.g., arsenic in surface water, ground water, soils, sediments, fish tissue and air).
- RT: Mostly data collection, with some analysis.
- JY: I also process the data and interpret mechanisms and trends.
- SA: We also process and interpret data.
- BU: We are only interested in projects where monitoring data can be put to scientific use.
- JF: We provide semi-monthly summary reports during summer and are working on providing trend information, but we need additional staff support and resources to develop and maintain trend data in more accessible form.
- EW: Our organization has tended to focus on collection of raw data, but we do process and report data (reports issued regularly during summer, and data summaries submitted for 305b report), and have participated in prior CIB's State of the Bays reports.

Table 1

Attendee	Program/Monitoring Activity	Purpose/users	Where? (bay(s), stream(s), watershed(s), etc.)	Years collected, frequency of sampling	Parameters measured	Current/future status	Funding Status/ Sources
HM	Surface water quality monitoring – Fixed Station, grab samples	Assessment of surface water quality conditions	About 24 stations in the tributaries and main Bays	30+ years of data with different frequencies Monitoring frequency during FY 2016 is monthly	About 30 parameters including nutrients, organic, physical, bacteria, etc.	Will monitor monthly for 2 yrs, then will monitor 6 times/yr for the next 3 yrs	State General Fund, EPA 106 grant
HM	Continuous WQ monitoring (datasonde)	To monitor short term changes of dissolved oxygen and other parameters	Millsboro Pond outlet Massey Ditch	3+ yrs 15 minutes data collection	DO, temp, salinity, pH	Will continue monitoring during FY 2016	EPA 106 grant
HM	Stream gages	Measuring stream discharge	Millsboro Pond outlet Beaverdam ditch near Millville	20+ yrs	Stream discharge	Will continue during FY 2016	State General Fund, EPA 106 grant
HM	Tide gages	Measuring	Rosedale Beach	20+ yrs	Tidal elevation	Will continue	State General

		tidal elevations	Indian River Bay near Bethany Beach Beaverdam ditch near Millville			during FY 2016	Fund, EPA 106 grant
RG	Toxics in Biota Monitoring (i.e., testing of fish and shellfish for chemical contaminants)	To determine need for fish consumption advisories	Indian River Bay Rehoboth Bay Millsboro Pond	Infrequent	PCBs, dioxins/furans, OC pesticides, PAHs, arsenic, and mercury	Low priority compared to State waters with known toxic impacts	State & Federal
RG	Toxics in Sediment Monitoring & Assessment (data collection leveraged through dredging projects and EPA Coastal Assessment Program)	Assess ecorisk to benthic aquatic life and potential human health risk through sediment to biota transfer	Indian River Bay Rehoboth Bay	Infrequent	PCBs, OC pesticides, PAHs, and metals	Low priority compared to State waters with known toxic impacts	State & Federal
RT	General water sampling	Environmental Modeling and Trend analysis – Watershed Stewardship Section.	Tidal and Nontidal waters of Indian River Bay, Rehoboth Bay and Little Assawoman Bay	Over 30 years of sampling. Frequency varies from monthly to quarterly depending upon Statewide needs of the	General Water chemistry, Field parameters, bacteria, and chlorophyll	Ongoing - stable	EPA via Watershed Stewardship

				overall Surface Water Monitoring Plan			
RT	Biology sampling (macroinvertebrates)	Status of environmental condition Environmental Laboratory Section	Nontidal waters of Indian River Bay, Rehoboth Bay, and Little Assawoman Bay	25 years of sampling Sporadic, present intent is to sample random sites within the watershed every 5 years	Macroinvertebrates, general water chemistry, field parameters, and chlorophyll	Sporadic - unstable	EPA via Watershed Stewardship
JY	Water column sampling	Research projects	Guinea Creek	1 year, sporadic	NO3, NH4, PO4, chlorophyll a	Project ends 1/31/16	DE Sea Grant/ NOAA
JY	Ground water sampling	Research projects	Indian River Bay	2 years, sporadic	NO3, NH4, PO4, N isotopes	Project ended 1/31/15	DE Sea Grant/ NOAA
SA	1) Stream and tide gaging	Ambient hydrologic monitoring	IRB, RB, LAB, tributaries	1980's - present	Tide height, stream discharge	Always a challenge to acquire funds	State and federal pass through sources
SA	2) Coastal flooding	DNERR, DEMA, DEOS,CIB	IRB, RB	2014 - 2016	Tide height	One and done	NERR
SA	3) WQ portal	DNREC	Statewide		WQ	?	DNREC
SA	4) Evapotranspiration	DEOS	RB watershed at Warrington Farm	2015-	Atmospheric Water flux	?	DNREC/DEOS/DGS

SA	5) Groundwater level and salinity	DNREC/DGS	Multiple wells	1980's - present	Water level, temperature, and salinity	?	DNREC/DGS
JF	UD Citizen Monitoring Program	DNREC, CIB, public	Inland Bays	Since 1991, year round, weekly in summer	DO, Secchi, salinity, nutrients, Chlorophyll a, and TSS	Continued nutrients is contingent on CIB or other funding support	DNREC
JF	Phytoplankton (HAB) monitoring	Public health, DNREC	Inland Bays	Since 2001	Screen and enumerate potentially harmful algal species	Continuing	DNREC
JF	Recreational Water (BEACH) monitoring	Public health, DNREC	Inland Bays	Since 2003	Total enterococcus	Continuing	DNREC/EPA
EW	Volunteer field data	Impairment in DO and water clarity/DNREC, CIB, and public	Inland Bays and tributaries	25 years	DO and Secchi depth	Ongoing	Funded/DNREC
EW	Nutrient samples	Impairment in nutrient, chlorophyll and TSS levels DNREC, CIB, volunteers, and UD researchers	Inland Bays and tributaries	20 years	Nitrate plus Nitrite Ammonium DIP Chlorophyll TSS	Ongoing, but cutting back on sites and outsourcing analysis	Funding for analyses on year to year basis/CIB

EW	Bacteria samples	Recreational contact safety/public, CIB, DNREC, and UD	Inland Bays and tributaries	11 years	Total Enterococcus	Ongoing, expect to continue	Funded/DNREC & EPA
EW	Harmful algae samples	AULS and public safety/DNREC, UD, public	Ocean beach, Inland Bays and Tributaries	14 years	HAB species, fresh and marine General phytoplankton community	Ongoing, expect to continue	Funding limited/DNREC & EPA

Table 2

Attendee	Program/Monitoring Activity	Purpose/users	Where? (bay(s), stream(s), watershed(s), etc.)	Duration, frequency of sampling	Parameters measured	Anticipated Start Date	Funding Status/ Sources
RG	Watershed Approach to Toxics Assessment and Restoration (WATAR)	See attached Work Plan	Watersheds with known toxics impacts (does not include the IBs)	One-time, comprehensive synoptic survey, with follow-up investigation if justified	PCBs, dioxins/furans, OC pesticides, PAHs, and mercury in surface water, sediment, and biota	Not scheduled within next 2 years	State & Federal
SA	DE Sea Grant proposal	Ullman, Andres	Groundwater project in RB watershed	2 yrs – multiple/day	Hydrology, nutrients, and DOC	Jan 2016	DE Sea Grant
SA	Groundwater salinity	DGS/DNREC	Multiple wells	ongoing	salinity	?	State of DE capital budget or see Table 1, SA reponse 5)

Delaware Center for the Inland Bays
Notes from Monitoring Plan Workgroup Meeting, 30 July 2015

Attendees:

CIB – Marianne Walch
RKK – Jim Eisenhardt, Larry Trout, Leslie Jamka
DNREC – Robin Tyler, David Wolanski, Michael Bott, Debbie Rouse, Hassan Mirsajadi, John Schneider
University of Delaware (UD) – Joanna York, Kevin Brinson, Tina Callahan, Ed Whereat, Bill Ullman, Joe Farrell, and Scott Andres
USGS – Judy Denver

Introduction

- Monitoring Plan for the Comprehensive Conservation and Management Plan (CCMP)
    - Measures effectiveness of CCMP
    - Written in 1995[1]
    - Revised by Robin Tyler (DNREC) in 1996
    - Charged by EPA to update by 1 Oct 2015
        - 2012 CCMP addendum: New goals and strategies to be incorporated into the Monitoring Plan
        - Changes since 1996: New data, programs, partnerships, needs, technologies, understanding of the Inland Bays, TMDLs, etc.

CIB needs/goals

- Status and trends of the Inland Bays
- Identify data needs/gaps
- Identify/access best available data
- Coordination
- Public education/engagement/perception

Objectives of facilitated discussion

- Obtain input from partners
- Monitoring needs/goals
- Identify strengths/weaknesses/gaps
- How best to house/share/archive data
- Identify and prioritize funding needs/opportunities
- Maintain perspective of "importance"; everyone thinks their work is the most important

Parties that should be at the workshop, but are not represented

- Agriculture sector
    - Jennifer Volk, Environmental Quality Extension Specialist (invited)
    - Delaware Department of Agriculture (DDA)
        - Laura Torres, Delaware Nutrient Management Program
        - Laura Match

[1]Per Robin, data well pre-dated 1995.

        - Scott Blair

- Sussex County
    - Mike Izzo, County Engineer
    - Heather Sheridan, Director of Environmental Services
- EPA Region III
    - Mike Hoffman (invited)
    - Bill Richardson[2] (invited)
- DNREC Division of Fish and Wildlife
    - Initiate discussion/review of Monitoring Plan prior to 1 Oct vs. leave placeholders

History and status

- Intern updating datasets
    - Brian Glaser compiled/maintained list of historical studies/reports until 1996
        - Does CIB have this list?
- Folks in the room have considerable experience and long-term involvement
- EPA wants DE to take the lead in estuary management
- Big questions asked in 1996 and addressed with monitoring data
    - Eutrophication, habitat, and wetland loss
    - Dissolved oxygen, nutrients, chlorophyll, and pathogen indicator bacteria
- Continue to monitor for core data

Goals

- How best to dot the i's and cross the t's for EPA *and* obtain data important to DE?

    - Short-term: Submit revised Monitoring Plan to EPA by 1 October 2015[3]
        - What is needed to update the Monitoring Plan?
            - Use 2011 State of the Delaware Inland Bays as a starting point
        - Report trends; never say "we are there" – insinuates no need for funding
        - Highlight what is being done well and areas that are deficient or need improvement
            - Use the Monitoring Plan to introduce long-term needs and potential management resources

    - Long-term: What do we want to know? What are the big questions monitoring should answer? What needs to be monitored?
        - Continue current monitoring; expand to include new data, such as upper watershed
        - Identify action areas and short/medium/long-range goals
            - What data do we have/need?
                - Can we improve what we have?
                - Are there additional data that can be collected under existing monitoring?
            - Do we know target goals?

[2]Submitted questionnaire.
[3]Maintain the Monitoring Plan as a living document with opportunities to update.

            - Do we understand system enough to know goals/needs?
            - Different areas have different goals[4]
        - Monitor water quality or water quality indicators?
            - What are other monitoring criteria?
            - What are other indicators of estuary health?
        - Broader scope than just water quality: Need to capture chemical, physical, biological data
    - Changing needs
        - As initial problems are addressed and the Inland Bays improve, other/secondary problems become apparent
        - Recognize evolutionary changes
            - Is monitoring capturing data?
                - If not, how best to capture?
            - Restoration is really renovation: Bays should look better, but not necessarily what they looked like in the past
                - Do we know what they looked like?
            - Is current level of monitoring sufficient to see/show changes?
    - Big picture/think outside the box
        - Key concerns/players/milestones
        - Opportunity to really make a difference
        - Communicate information to future generations
        - Keep science going: Change the lingo, monitoring *is* the science
        - Effective mechanisms for data sharing and collaboration
        - Creative approaches to funding monitoring initiatives

Funding

- Issues
    - Identifying and obtaining funding for monitoring is difficult
        - EPA will not fund monitoring
        - Most states do limited monitoring
    - Need creative approach to fundraising
    - Science often done "EPA's way" to standardize data/collection for statistical purposes
    - Change is difficult to see
    - Key: Create strategy to motivate change
    - Market the collaborative/collective approach to increase options/opportunities/success
        - CIB is hiring a water quality manager that could manage a grant
    - Leverage research/resources of others
    - Current funding for on-going activities
        - Funding is continuously decreasing with inflation
- Entities
    - Delaware is a small state; how best to market and secure funding?
    - Corporate sponsorships: Walmart, WWTPs, power plants, artesian water, etc.

[4]For example, seeing the stream bottom can be good, but in wetlands, water clarity is bad.

    - Private parties including non-profits/foundations
    - Kickstarter
- Strategies
    - Avoid using the word monitoring in proposals
    - "Sell" scientific question that can be answered by monitoring data
    - Clearly state why data are needed/utility of data
    - Partner vs. compete with the Chesapeake Bay

Questionnaire compilation/discussion

- How might the intensity, duration, and frequency of events drive the Monitoring Plan? How have these changed over time?
    - Twenty years ago, primarily spot monitoring (exception of pH and conductivity)
        - No option for continuous monitoring
    - Important questions to answer
        - Timescales needed to answer these questions
    - "Vat" of data
        - Need to synthesize and apply to answer bigger questions such as climate change
            - Are there things we should be monitoring, such as water depth?
- How are our actions impacting the Bays?
- Would we know improvement if we saw it?
- Answered lots of questions posed in 1995/1996
- What/where are the critical needs/trends that should be monitored?
    - Bacteria
        - EPA has guidance for the protection of recreational waters
        - CIB is concerned with health risks, which are becoming increasingly important
        - Tests are expensive, but people want these data
            - Look for pathogens vs. indicators
    - Sub-watersheds
        - Streams vs. larger bodies of water
        - Use local studies to inform larger questions
    - Stressors
        - Stressors are changing; point sources have decreased
            - Implications for monitoring
        - Monitoring may lead to identification of new management issues
    - Management practices
        - Example: Monitoring of BMPs
            - Privacy concerns, lack of focus, small scale
            - Need aggregated, doable, monitoring strategy
            - Lack before and after data
    - Know Inland Bays system now much better than in 1995
        - Lots of data
        - Third generation of modelling
        - Problem: Minimal, and/or anecdotal, historical data from the 1950s/60s
    - Look for trends in all applications

        - Example: 305b reporting includes downstream monitoring that summarizes trends
        - 1999 – 2013 trends
            - Nitrogen down, phosphorus up/down
            - Slow, but steady improvement
        - New sources of contamination
            - Chemical indicators for small source monitoring
            - New technology for monitoring
            - Effect on aquatic health
        - How to handle changes/trends that have yet to hit the Inland Bays
            - What are strong indicators of health in the Inland Bays?
            - Hard to quantify if no historical data
    - Short vs. long-term monitoring
        - Limited utility of short-term monitoring; need long-term monitoring to see changes, which only manifest with time
        - Consider scale/frequency of sampling/monitoring
            - Intensive monitoring for a year vs. every five years
            - Advantages/necessity of more frequent monitoring
            - Monitoring indicators vs. trends
        - CIB monitoring interests may not match DNREC monitoring interests
            - National vs. state-specific focus
                - DNREC only has one station in the Inland Bays
            - Continue base monitoring of Inland Bays, but add more specific monitoring upland (sub-basins/watersheds)
    - Groundwater
        - Is DNREC monitoring groundwater?
        - CCMP goal: Groundwater monitoring for saltwater intrusion
        - Good assessment tools for groundwater, but expensive and difficult
            - Note in Monitoring Plan
        - Lack clear understanding of land-based wastewater; some polluter-based monitoring
        - Target groundwater collection over time
        - Could do more with base flow sampling or mine existing data for flow
        - Need to understand processes and re-sample in networks not sampled recently
        - Jen Volk (UD) does continuous stormwater monitoring
        - Other sampling efforts
            - North East Water Resources Network (NEWRNet)
                - Researchers in Rhode Island, Delaware, and Vermont are using sensors in streams to measure water depth, temperature, dissolved oxygen and organic matter, nutrients, and cloudiness
            - National Estuary Research Reserve
                - Network of 28 coastal sites designated to protect and study estuarine systems
                - NOAA funded; each site managed by state agency or university

        - Maybe options to collaborate
- Data
    - Availability, accessibility, maintenance, integrity
    - Sharing mechanisms
        - STORET (STOrage and RETrieval) data warehouse is EPA's repository for water quality, biological, and physical data
            - Available to state environmental agencies, EPA and other federal agencies, universities, private citizens, etc.
            - At this point, DNREC is the only one populating STORET
            - Historically, difficult to use
    - Greatest challenges
        - How/where to house data: STORET, Delaware Environmental Observing System (DEOS), other?
            - Accessibility is essential to long-term value/utility
            - Need solution for broader datasets
            - DEOS: Data aggregator of continuous data for Delaware
                - Provides interface
                - Mapping application for water quality data (pulls from STORET)
    - Other data considerations
        - Management
            - Who can manage? Maintain?
            - Need single entity to coordinate
            - Identify/include special/one-time studies
            - How to most effectively and efficiently share data?
            - Metadata to ensure longevity
            - How to avoid losing data/datasets?
            - How to maintain integrity?
            - How to handle studies with no digital data?
        - Utilization
            - Everyone is looking at their own data
            - How to aggregate for analysis?
                - No one is synthesizing, integrating, or compiling data; very time-intensive activity
                - How best to do this?
                - Who should/could do this?
                - CIB is only one of many users
            - Need common time stamp
            - Need universal format/standardization
            - How can CIB use data most effectively?
        - Collection
            - Define protocols in a specific way
            - Account for different collection strategies: Fixed sampling locations vs. collection within a box
        - Can existing datasets be tweaked to meet current data gaps/needs?
    - Needs
        - Continuous long-term datasets at fixed points

        - Non-continuous periodic sampling, maybe with mobile sensors
        - Automated mechanism to report continuous data results vs. raw data
        - No need to sample pH in saltwater
        - Need minimum/maximum levels of dissolved oxygen
        - Are continuous concentrations of nitrogen and phosphorus necessary?
            - What is the necessity/utility of high density data streams?
        - Climate: Groundwater flow, depth, and inundation
        - Lacking data for acute/small-scale events

- Monitoring technology
    - Technology has changed drastically over the past 20 years
        - Increasingly cost-effective option to use portable sensors for single monitoring event or leave in place for extended monitoring
        - Time and cost savings: Instruments will defray analytical costs over time
            - Data available on the spot with no analytical needs
            - In two to five years, cost-effective option to purchase mobile equipment
            - Provides option for automated, continuous sampling
        - Disadvantages
            - Equipment needs to be maintained and calibrated
            - May not get all the data, such as enterococcus
        - Scott Andres is a co-PI for water quality sampling technology project
        - Need initial start-up funds to purchase equipment
        - DNREC has pool of equipment and experiences personnel within the state
        - Sensor capability
            - Some can collect temperature and salinity data needed for the hydrodynamic model
            - Cannot collect total nitrogen/phosphorus, but can collect nitrate
            - Could equipment be modified to fit need?

- Citizen Monitoring Data (CMD)
    - Questions of variability, quality, etc.
        - Volunteers are all trained and many have years of experience
    - CMD near shore stations vs. DNREC off shore stations
        - Shoreline data are heterogeneous; need large numbers to be meaningful
    - Huge volume of data with considerable buy-in/community support
    - Beneficial to add total nitrogen and total phosphorus
    - CIB wants to include CMD in Monitoring Plan; no one else is collecting these data
    - What can be done to increase credibility?
        - Example: Community Collaborative Rain, Hail and Snow Network (CocoRaHS)
    - How best to integrate?
    - Extensive QA/QC
    - Reports archived on website
        - Volunteer monitoring reports are a good example of data compilation
        - Should data be reviewed prior to posting online?

- Need to figure out the best way to get the data into STORET
    - These data are very important to the CIB for trends
- How to expand citizen monitoring activities?
    - How best to manage and oversee activities and data?
    - Is engagement an issue?
    - Can we request volunteers do specific things?
    - How best to expand capacity?

- Non-monitoring related needs
    - Searchable library/archive of historical reports, data summaries, etc.
        - Housed at CIB; does CIB have the capacity to maintain?
        - DNREC Watershed Assessment and Management Section moving; great opportunity to scan documents and get them online
        - Need someone to sort through historical data
        - Need summaries or keywords searchable in pdf image
        - Kent Price's student maintained list of reports/datasets until 1972ish
            - Who has this list? DNREC? CIB?
        - Accuracy
            - Not a critical issue unless data are used for regulatory purposes
            - Plot data over time/space; if consistent, accuracy is good
        - Stored electronically (STORET? If not, where?) and link to historical report
            - What is in it for CIB? Trends?
    - Consider compartmentalizing tasks for internships, etc.
        - Target specific sources

Questionnaire for CIB CCMP Appendix Monitoring Plan Update - General

Responders

- DJ: Doug Janiec, Sovereign Consulting Inc., Natural Resources Program Manager, Senior Restoration Ecologist
- LT: Lauren Torres, Delaware Department of Agriculture, Nutrient Management Program
- JD/MN: Judy Denver/Mark Nardi, USGS, MD-DE-DC Water Science Center
- JC: John Clark, DNREC, Fish and Wildlife
- Jim Sadowski

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1. **Did you participate in preparation/meetings/workshops for initial 1995/1996 CCMP Monitoring Plan?**
   - DJ: No.
   - LT: No, I did not.
   - JD: Yes, to some extent, but don't remember much about it.
   - JC: No, I think Roy Miller and Jeff Tinsman participated for Fisheries.

2. **What areas, based on your experience/expertise, are the most important to focus on in a monitoring plan for the Inland Bays and (very briefly) why?**
   - DJ: Habitat loss and gain (e.g., shoreline). Habitat loss is a top of pyramid indicator, which includes the net outcome of many primary indicators working together in a complex system.
   - LT: Based on our experience, DDA believes that the most important areas to focus on in a monitoring plan for the Inland Bays are septic's, cesspools, and the expansion of sewer treatment plants based on the associated population growth in the Inland Bays watershed. DDA will continue to implement The Nutrient Management Program and the Concentrated Animal Feeding Operation (CAFO) Program to oversee nutrient handling activities associated with animal production, specifically poultry production, and on farm nutrient management practices.
   - JD/MN:
     - Monitoring to understand water quality in the tidal portion of the bays for assessing current conditions and trends where samples have been collected long-term by DNREC and others should be continued to assess the health of the Bays.
     - The addition of upstream sites for long-term monitoring of non-tidal fresh surface-water quality would be very useful to track changes in water quality related to changes in land use and land management which could lead to a better understanding of the system as a whole. A monitoring network in small sub-watersheds is suggested. To track and understand nitrogen, which is mostly from groundwater, several sites that were selected and sampled in the late 1990s and early 2000s (by USGS, DGS and UD) could be used to develop a network of non-tidal sites and sampling could be repeated during winter base-flow conditions every year. A subset of these sites could be selected as a base

for this network and, and, at a minimum, could be sampled during winter baseflow for nitrogen inputs, but it would be better to do at least season sampling and include ecological sampling at least during the warm seasons. This network could also be used to track and better understand sediment and phosphorus inputs.

- JC: My experience/expertise is with fish, so I would focus on fish and water quality, but water quality and fish habitat depend on land use in the watershed, so I would have a hard time coming up with a single most important focus.
- JS: The Indian River Power Plant has shut down three cooling units and the remaining unit, with the cooling tower, has not been running very much. It was always said that the plant was impacting the Indian River and Bay but the 316a and 316b studies showed "no appreciable harm". I think the Center should further investigate what affects, if any, shutting down of the once through units has had on the Indian River and Bay. What has happened to all the species, increased/decreased/remained the same? Are the species changing? Are they different during the different seasons due to the temperature changes? What are the effects of the temperature changes? What is the effect of the reduced flow in Island Creek? The list can go on and on, but I think the Indian River System would be a great lab to see what affects a power plant shutting down has on the ecosystem.

3. What areas, based on your experience/expertise, are missing from the current monitoring plan?

- DJ: More detailed tracking on shoreline changes and its contribution to sediment loads in the Bays.
- LT: Based on our knowledge, we think it would be helpful for an evaluation of the total number of septic systems, and cesspools that are in existence in the Inland Bays Watershed, and how many of those are planned to be converted to the city sewer systems to be included in the new monitoring plan. Additional data could include the age and types of systems, and the estimated nutrient load from those sources, and subsequent reductions from conversions. Additionally, a summary of how this monitoring plan and all of these activities relate to the State of Delaware's Watershed Implementation Plan along with the TMDL's would help explain how all these activities tie together.
- JD/MN: See above answer for surface water.
- JC: Given that the Inland Bays has one of the healthiest hard clam populations of any coastal lagoon system on the Atlantic Coast, hard clam monitoring would be a good addition.

4. What monitoring activities/data collection is your organization undertaking in the Inland Bays that could be part of the CIB monitoring network?

- DJ: None, yet.
- LT: Currently, none, but see new project below.
- JD/MN:
  - Data are currently being collected at 7 stations in the Inland Bays watershed for flow, tide, and/or real-time monitoring of specific conductance, dissolved oxygen, pH, and temp.
  - The USGS has setup an ephemeral storm surge network (deployed only during events) comprised of 7 sites. Six of the sites measure water level and specific conductance; one of the sites is a rapid deployment gage (RDG) that measures and transmits in real time water level, wind speed and direction, barometric pressure, and air temperature. We will work with DelDOT on RDG siting.

5. **What monitoring programs are planned for the future that might be applicable to the Inland Bays?**
   - LT: DDA and USGS will be beginning a new study monitoring shallow ground water wells on a 5 year basis. See details in Table 2.
   - JD/MN: Most of the current USGS monitoring in the Inland Bays is done in collaboration or cooperation with other agencies including DGS, DNREC and Del DOT and is likely to continue in the near future. Future plans depend on program directions of all agencies involved and are not known now.

6. **For the data you discuss in this document, is your organization just collecting raw data or are you also processing the data and developing trends from the data?**
   - LT: The data is being collected currently to establish baselines, and the future data will be used to develop trends.
   - JD/MN: All data currently collected by USGS are published and available on the USGS NWIS webpage under the "Atlantic Coastal Bays" tabs (http://waterdata.usgs.gov/de/nwis/current/?type=flow&group_key=basin_cd). In limited areas the USGS is working with cooperating agencies to analyze the data. All data collected by the USGS are subject to QA/QC and processing procedures prior to public release, except in limited cases where partner agencies have direct data access.
   - JC: We process our trawl data and report trends in overall catch and trends in juvenile abundance indices.

7. **What additional monitoring activities would your organization benefit from if CIB could include in their monitoring plan? Please feel free to think outside of the box, without regard to availability of funding, including new or innovative technologies.**
   - LT: Monitoring activities that would benefit the DDA, and all organizations, would be data that indicates the source of impairments and the age of the water.
   - JC: The volunteer seining survey complements our trawl survey. I think it should be continued.

8. **What do you, or your organization, feel are the critical indicators of health for the Inland Bays?**
   - DJ: Fisheries, shellfish, and SAVs, shorelines.
   - LT: Critical indicators for the health of the Inland Bays are nutrient concentrations, dissolved oxygen, bacteria counts, submerged aquatic vegetation, and water clarity.
   - JD/MN: SAV's, dissolved oxygen, water clarity, biological diversity. Underpinning all of these is water chemistry of both groundwater and surface water inputs which from a monitoring point of view are very important to the Inland Bays system that has limited exchange with the Atlantic.
   - JC: Water quality, fish and other aquatic organism communities, hard clams, etc.

9. **Does your organization have historical monitoring data that was not included in the original monitoring plan that would be useful for future monitoring activities or for use as State of the Bays indicators? Please list them.**
   - DJ: No.
   - LT: We do not have historical monitoring data.

10. **Does your organization anticipate having sufficient future funding to carry out monitoring activities that CIB has included in the monitoring plan to date? If not, what level of additional funding is needed?**
    - LT: We do not have monitoring activities currently listed in the monitoring plan.
    - JC: Fisheries will continue the trawl survey.

11. **Do you anticipate future funding for additional data collection parameters beyond the current monitoring criteria included in CIBs plan?**
    - LT: We anticipate the funding for the new project between USGS and DDA.
    - JC: No.

12. **Do you have any recommendations for additional funding sources for Inland Bays monitoring activities?**
    - DJ: No.
    - LT: Not currently.
    - JC: No.

13. **Are you aware of any volunteer organizations/programs that are currently active and could be included in future Inland Bays monitoring for supplemental information?**
    - DJ: No.
    - LT: I am not aware of any other organization or programs currently active in the Bays other than the Inland Bays, "Your Creek" projects.
    - JC: No.

Table 1

Responder	Program/Monitoring Activity	Purpose/users	Where? (bay(s), stream(s), watershed(s), etc.)	Years collected, frequency of sampling	Parameters/species measured	Current/future status	Funding Status/ Source
JC	Division of Fish and Wildlife Juvenile Finfish Trawl Survey	This survey estimates year class strength of various fish and invertebrate species and assesses abundance and community structure	12 stations sampled in Indian River and Indian River and Rehoboth Bays	1986 to present Sites are sampled monthly from April through October	Fish and invertebrates are sorted and counted by species A subsample of each species is measured Surface water quality is taken at each station	DFW plans to conduct this survey indefinitely	Secure funding through the Federal Aid in Sport Fish Restoration Program

Table 2

Responder	Program/Monitoring Activity	Purpose/users	Where? (bay(s), stream(s), watershed(s), etc.)	Duration, frequency of sampling	Parameters measured	Anticipated Start Date	Funding Status/ Source
DJ	More real-time monitoring, such as the York Canal Project		Near oyster cages and floating wetlands				
	Update the IB GIS AP and shoreline migration rates						
	Monitoring for project success/failure, not just bay-wide status/trends						
LT	USGS/DDA Shallow Ground Water Monitoring Program	Establish trends in nutrient levels in shallow ground water (40 ft or less) To test nutrient loading BMPs	Statewide, approximately 70 total wells (all dedicated established monitoring wells)	Every 5 years	N, P, age dating ions, land use tracer ions	Fall of 2014 & fall of 2015 to establish baselines First trend assessment will be Fall 2020	USGS and DDA matches
JC	Division of Fish and Wildlife hard clam density survey	Determine whether hard clam density is compatible with shellfish aquaculture on a given acre of bottom	Indian River and Rehoboth Bays	Sampling began in 2014 to determine hard clam density in acreage that DFW attempting to get permitted for shellfish aquaculture leases	Number of hard clams per square yard, bottom type	2014	DFW funds

Notes from STAC Meeting Discussion of Monitoring Plan
September 18, 2015

Suggestion to review the monitoring plans of other programs:

- Other NEPs
- Chesapeake Bay Program
- National Coastal Assessment

Areas to focus on:

- *Bill Ullman:* Figure out how people use the estuary; focus on areas of the estuary that are most used
- *Robin Tyler:* Minimizing and tracking disruptive effects on the system
- *Jenn Volk:* Land use, BMPs, sea level rise, future land use
- *Andrew Homsey:* Tidal wetlands condition
    - Sea level rise, degradation, shorelines, vegetation changes
    - Aerial photography
    - Ability of wetlands to migrate
- Habitat Loss: GIS, remote sensing
- *Scott Andres:* Population, demographics and projections; this has a large impact
- Set aside areas to protect important resources
- *Joanna York:* Must consider projections to guide monitoring plan. Use models, think strategically about monitoring needed based on projections.
- Cost/benefit analyses (economics, ecosystem services). What has been spent already, what will be lost.
- Land surface loadings, changes (agriculture, wastewater treatment, development, etc.)
- *Robin Tyler:* Long-term seaweed monitoring – an important indicator of eutrophication. Last done in 2012. Suggest doing it every five years?
- Monitoring in South Bethany:
    - ~12 Citizen Monitoring Program stations there (salinity, temp, clarity, DO); three sites monitor bacteria and nutrients; three continuous monitors
    - The town collects and analyzes data
    - Local tide gages are monitored and analyzed (sea level rise)
- *Jim Sadowski:* There has been no follow-up on actions taken in the Bays (e.g. NRG plant changes, dredging) to determine if expected impacts have happened. Only short-term studies. We must know if management actions have worked.
- Monitoring to determine the impact of oyster farming.
- *John Clark:* DFW tracks fish kills (since 1981)
- Microbial source tracking
- Phytoplankton monitoring: biomass (chl A), trends, changes in community composition

Historical Data Sources: South Bethany WQ Committee, Robin Tyler and DNREC Environmental Laboratory Section, Division of Watershed Stewardship, Bill Ullman

Key to coordination is educating all partners on what others are doing. CIB needs to do this on an ongoing basis, through workshops, symposia, special STAC meetings, etc.

APPENDIX C

DESCRIPTIONS OF EXISTING LONG-TERM MONITORING PROGRAMS IN THE INLAND BAYS STUDY AREA

APPENDIX C

DESCRIPTIONS OF EXISTING LONG-TERM MONITORING PROGRAMS IN THE INLAND BAYS STUDY AREA

C.1 Monitoring of Surface Water

C.1.1 State of Delaware Ambient Surface Water Quality Monitoring Program C-2
C.1.2 University of Delaware Citizen Monitoring Program C-7
C.1.3 State Fecal Coliform Monitoring Program C-15
C.1.4 USGS-DGS Stream and Tide Gaging Program C-15
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C.1.6 Toxics Monitoring C-20
C.1.7 Continuous Surface Water Quality Monitoring C-23

C.2 Monitoring of Groundwater

C.2.1 Delaware Groundwater Monitoring Network C-26
C.2.2 Delaware Agricultural Shallow Groundwater Monitoring Network C-28
C.2.3 Public Supply Wells C-30

C.3 Monitoring of Wastewater

C.3.1 Point Source Wastewater Discharges C-31
C.3.2 Land Application of Wastewater C-32

C.4 Monitoring of Atmospheric Deposition

C.4.1 Atmospheric Deposition of Nutrients C-34

C.5 Monitoring of Wetlands

C.5.1 DNREC Wetlands Assessment and Monitoring C-35
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C.6 Monitoring of Living Resources and Habitats

C.6.1 National Aquatic Resource Surveys C-40
C.6.2 Statewide Vegetation Community and Land Cover Mapping Project C-44
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C.6.12 Volunteer Diamondback Terrapin Survey C-57

C.1 MONITORING OF SURFACE WATER

C.1.1. STATE OF DELAWARE AMBIENT SURFACE WATER QUALITY MONITORING PROGRAM

Description/Objective(s)

The Delaware Department of Natural Resources and Environmental Control (DNREC) maintains a statewide General Assessment Monitoring Network (GAMN) of 134 stations, of which 24 are located in the Inland Bays (Figure C.1). GAMN stations are considered long-term stations, and data collected support compilation of Watershed Assessment Reports as mandated by the Clean Water Act under section 305(b).

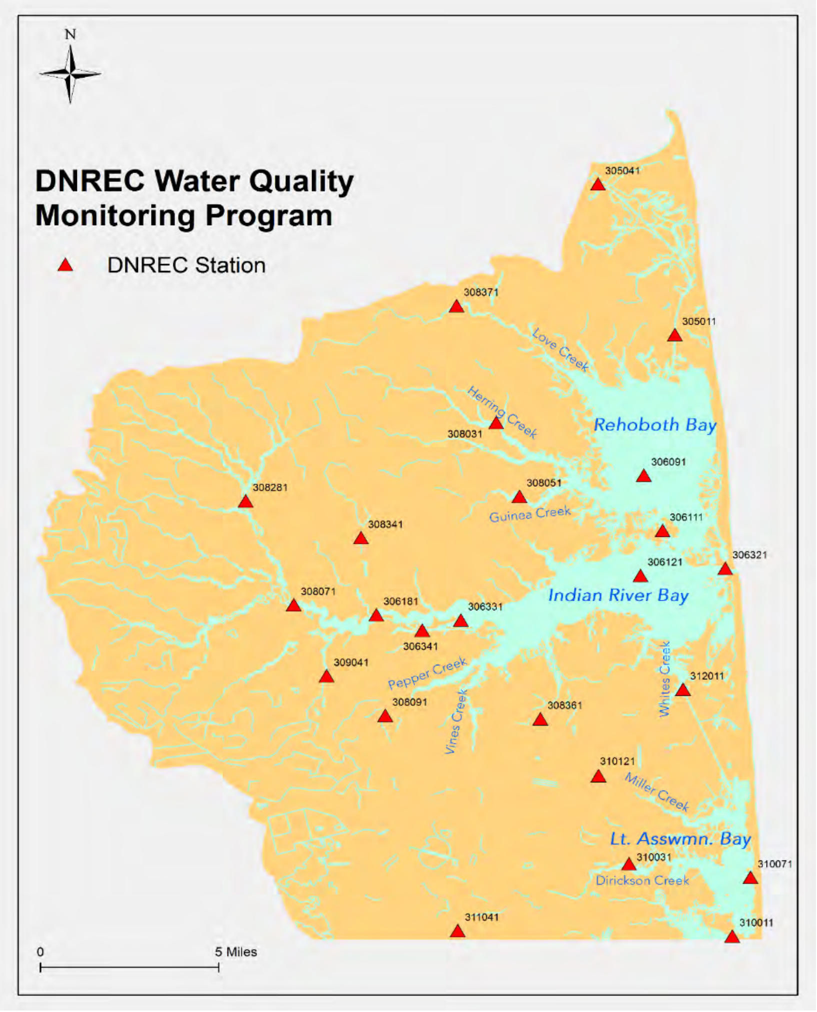


FIGURE C.1 -- Map showing DNREC GAMN monitoring stations in the Inland Bays.

All GAMN stations are monitored for temperature, salinity, dissolved oxygen, pH, alkalinity, hardness, chloride, chlorophyll, biological oxygen demand, total suspended solids, turbidity, organic carbon, nutrients, and *Enterococcus* bacteria. Tidal waters and lakes/ponds are also monitored where and when possible for water clarity (Secchi depth) and light attenuation. Some nontidal and tidal stations are further monitored for metals, while some nontidal stations are monitored for biology/habitat.

Monitoring frequency at GAMN stations usually follows a five-year rotating basin schedule in which every station is monitored monthly for two years and monitored every other month for the remaining three years. Each station is monitored for conventional parameters such as nutrients, bacteria, dissolved oxygen, pH, alkalinity, and hardness (see Tables C.1 and C.2. for a complete list of parameters). Some stations are also monitored for dissolved metals. Recently, the sampling schedules have been on hold as DNREC is working to implement the stressor identification process.

Responsible Organization and Contact

The collection of samples and field data is conducted by the DNREC, Division of Water, Environmental Laboratory Section (ELS). The analysis of samples and generation of analytical results is also done by the ELS, with exception of some tests which are outsourced to selected laboratories that have EPA-approved Quality Assurance Management Plans.

Contact: Christopher Main, DNREC Environmental Scientist
christopher.main@delaware.gov, (302) 739-9942

DNREC's Division of Watershed Stewardship, Watershed Assessment Section, analyzes the data to (1) define the water quality status and trends for each sub-basin and (2) compare the data with water quality standards to assess designated use support as mandated by Section 305(b) of the CWA.

Contact: Stephen Williams, Environmental Program Administrator
Stephen.Williams@delaware.gov, 302-729-9921

Data Collection Cost

The annual cost of water quality monitoring of sites within the Inland Bays Watershed is between $100,000 to $170,000, depending on frequency of monitoring (monthly or every other month). Frequency of monitoring follows a five-year statewide rotating basin schedule. Per this schedule, during every five years, most monitoring sites in the Inland Bays are monitored monthly for two years and are monitored every other month for three years.

Data Use

GAMN data are used to:

- Describe general water quality conditions of the State's surface waters;
- Identify long term trends in water quality;
- Determine the suitability of Delaware waters for water supply, recreation, fish and aquatic life, and other uses;
- Calculate annual nutrient loads and track progress toward achieving Total Maximum Daily Loads (TMDLs) targets; and
- Evaluate the overall success of Delaware's water quality management efforts.

The findings are reported biannually to the EPA in the Water Quality Inventory Report as mandated by Section 305(b) of the Clean Water Act (CWA), and are used to identify and prioritize water-quality limited waters as mandated by Section 303(d) of the CWA, as well as waters of high quality. Since the late 1990's the data have been used to develop and calibrate TMDL models, and in the future will be used to gage the success of TMDL-based Pollution Control Strategies.

Data from this program also are used by the Center to prepare environmental indicator reports, including the pentennial *State of the Delaware Inland Bays* reports.

Record of Collection

See Table C.1 for the record of collection at each Inland Bays station.

Collection Method

Water Sample Collection:

All water sample collections are conducted by the DNREC Field Services Branch according to the Environmental Laboratory's *Operational Procedure, Surface Water Sampling*,

Continuous Monitoring:

A portable, automated on-site laboratory was deployed from 2005-2011 at the outlet to Millsboro Pond in order to define inorganic nitrogen and phosphorus loads entering the Inland Bays via the nontidal segment of Indian River.

DNREC has been developing a network of water quality monitoring stations at which data is collected continuously for dissolved oxygen concentration and percent saturation and other parameters (temperature, specific conductivity, pH, and salinity) that exhibit substantial fluctuation over short time scales such as the diel (24-hour) cycle or in response to weather conditions. This monitoring is conducted using YSI 6-series multi-parameter sondes. Measurements are taken at least every 15 minutes when the instruments are deployed. A rotating basin approach in the state is planned by DNREC.

Currently the only continuous monitoring station is deployed in Massey's Ditch (USGS 01484680), at the Massey's Landing fishing pier. Water quality data has been collected at this site since November 2011 (https://waterdata.usgs.gov/usa/nwis/uv?01484680). It is funded jointly by USGS and DNREC.

Analysis Methods

See Table C.2 for a summary of analytical methods used for each parameter.

Data Location

The GAMN data are entered into the U.S. EPA's WQX database, and are publicly available via the EPA's Water Quality Portal (https://www.epa.gov/waterdata/water-quality-data-download#portal) and the Delaware Water Quality Portal (http://demac.udel.edu/waterquality/).

Management Goal

Management goals are defined by the TMDLs approved for each watershed.

Hypothesis and Test Statistics

Methodologies for analyses are defined in the *State of Delaware Integrated 305(b)-303(d) Report,* available from the Division of Watershed Stewardship. A copy of the methodologies section also is included in this document as Appendix D.

TABLE C.1. -- Summary of DNREC GAMN Stations in the Inland Bays

Station ID	Location		Period of Record		Sampling Frequency*
	Latitude	Longitude	Start	Latest	
312011	38.557982	-75.089363	1998	2016	b
311041	38.455828	-75.206459	1998	2016	b
310121	38.521498	-75.133453	1998	2016	a
310071	38.478040	-75.055024	1998	2016	b
310031	38.483943	-75.117882	1998	2016	b
310011	38.453054	-75.064774	1998	2016	b
309041	38.564236	-75.274149	1998	2016	b
308371	38.721514	-75.206296	1999	2016	b
308361	38.545671	-75.163470	1999	2016	b
308341	38.622818	-75.256184	1998	2016	b
308281	38.638595	-75.316098	1998	2016	b
308091	38.547228	-75.243750	1998	2016	b
308071	38.594322	-75.290992	1998	2016	a
308051	38.640505	-75.173960	1998	2016	b
308031	38.671799	-75.185884	1998	2016	b
306341	38.583450	-75.224515	1998	2016	b
306331	38.587743	-75.204563	1998	2016	b
306321	38.609540	-75.067228	1998	2016	a
306181	38.590102	-75.248384	1998	2016	b
306121	38.606510	-75.111310	1998	2016	a
306111	38.625578	-75.099793	1998	2016	b
306091	38.649121	-75.109355	1998	2016	b
305041	38.772986	-75.132947	1998	2016	b
305011	38.708891	-75.093022	1998	2016	b

* a: Station is monitored monthly every year.

b: Station is monitored six times a year for three years, then twelve times a year for two years.

TABLE C.2 -- Water quality parameters analyzed at DNREC GAMN Stations and analytical methods.

Parameter	Method Reference (EPA)	Reporting Level
Water Column Nutrients		
Total Phosphorous	EPA365.1 M	0.005 mg/l P
Soluble Ortho-phosphorus	EPA365.1	0.005 mg/l P
Ammonia Nitrogen	EPA350.1	0.005 mg/l N
Nitrite+Nitrate N	EPA353.3	0.005 mg/l N
Total N*	SM 4500 NC	0.08 mg/l N
Carbon and Organics		
Total Organic Carbon	EPA415.1	1 mg/l
Dissolved Organic Carbon	EPA415.1	1 mg/l
Chlorophyll-a (Corr)	EPA 445.0	1 µ/l
Biochemical Oxygen Demand		
BOD_5, N-Inhib (CBOD)	SM20thed-5210B	2.4 mg/l
BOD_{20}, N-Inhib (CBOD)	SM20thed-5210B	2.4 mg/l
General		
Dissolved oxygen – Winkler	EPA360.2	0.25 mg/l
Dissolved oxygen – Field	EPA360.1	0.1 mg/l
Total Suspended Solids	EPA160.2	2 mg/l
Alkalinity	EPA310.1	1 mg/l
Hardness	EPA310.2	5 mg/l
Field pH	EPA150.1	0.2 pH units
Conductivity - Field	EPA120.1	1 µS/cm
Salinity	SM20thed-2520B	1 ppt
Temperature	EPA170.1	°C
Secchi Depth	EPA/620/R-01/003	meters
Light Attenuation	EPA/620/R-01/003	%
Turbidity	EPA180.1	1 NTU
Chloride	EPA325.2	1 mg/l
Bacteria		
Enterococcus	SM20thed-9230C	1 cfu/100 ml

3.1.2 UNIVERSITY OF DELAWARE CITIZEN MONITORING PROGRAM

Description/Objective(s)

The University of Delaware Sea Grant Marine Advisory Service's Citizen Monitoring Program (CMP) was formed in 1991 to support the newly-formed Inland Bays Estuary Program (http://citizen-monitoring.udel.edu/). Through this citizen science program, more than 300 trained volunteers have collected samples at water quality monitoring sites throughout the Inland Bays, and provided important data - including dissolved oxygen, dissolved inorganic nitrogen, dissolved inorganic phosphorus, water clarity, bacteria levels, and other environmental data. Supplemental NEP grants have helped grow shorter-term special interest monitoring programs, including harmful algal species and dissolved oxygen measurements taken from boats.

Combined with the state's fixed monitoring stations, the additional resolution provided by the more than 20 years of data, from over 30 sampling sites in the Inland Bays, has resulted in a long-term, robust, high-quality data set that provides scientists and resource managers with a clearer picture of the bays' health and the trend information needed to understand and manage the ecosystem.

Responsible Organization and Contact

The program is managed by the University of Delaware Sea Grant Marine Advisory Service at the College of Earth, Ocean, and Environment in Lewes.

Contact: Dr. Edward Whereat
whereat@udel.edu, 302-645-4252

Program Funding

Original support for the CMP came through the National Estuary Program, but since 1994 the Citizen Monitoring Program has received an appropriation from the Delaware General Assembly through a Memorandum of Agreement with DNREC. Additional support has come from a variety of sources, including: Sea Grant; DNREC; the Center for the Inland Bays; U.S. EPA; the Delaware Estuary Program; the National Fish and Wildlife Foundation; and local communities.

Reported total cost of the Inland Bays program in federal fiscal year 2020 was $106,377. This included $34,177 federal funding, $45,000 state funding, and $27,200 private in-kind.

Data Use

CMP data are used by the CIB for status and trend analyses in the CIB's *State of the Delaware Inland Bays* reports, which are published every five years. In addition, CMP data are used to develop indicator reports for individual tributaries in the CIB's 'Your Creek' project.

CMP data are included in an Appendix in the State's Combined 305(b) Report and 303(d) List, submitted to the US EPA every two years, but are not used directly in listing determinations.

Bacteria and harmful algal bloom data collected by the CMP are used by DNREC to support the Delaware Shellfish Monitoring Program and to assess bacteria levels and trends in the state's coastal watersheds.

Record of Collection

See Table C.3 for the record of collection at each Inland Bays station.

Collection Method

Data are collected by trained volunteers at sites assigned to them by the CMP Program Manager. Table C.3 summarizes the CMP monitoring sites that currently are used to assess Inland Bays water quality status and trends. Figures C.2 to C.5 provide a maps of CMP sites for individual indicator parameters. Additional sites are monitored in the Bays, but only those that provide long-term data used for CIB environmental indicator reports are included here.

Sampling methods are detailed in a guidebook, *Inland Bays Citizen Monitoring Program Volunteer's Water Quality Monitoring Manual* (revised 2017). They are summarized below:

Parameter	Collection Frequency May-Sept	Oct-Apr	Method/Instrument
Temperature	Weekly	Monthly	Thermometer or meter
Turbidity	Weekly	Monthly	Secchi Disk
Dissolved Oxygen	Weekly	Monthly	Micro-Winkler Titration or meter
Salinity	Weekly	Monthly	Hydrometer or meter
pH	Weekly	Monthly	Digital Meter
Nitrate & Ammonium	Biweekly	Monthly	Grab Sample/Lab Analysis
Orthophosphates	Biweekly	Monthly	Grab Sample/Lab Analysis
Bacteria	Biweekly	Monthly	Grab Sample/Lab Analysis
Phytoplankton	Biweekly	Monthly	Grab Sample/Lab Analysis

Analysis Methods

Currently, nutrient analyses are subcontracted to the University of Maryland Chesapeake Biological Laboratory in Solomons, MD. Other laboratory analyses are conducted in-house at the University of Delaware, with assistance from trained volunteers.

See Table C.4 for a summary of analytical methods used for each parameter.

Note that DIP is labeled as Orthophosphate in the state's GAMN dataset. DIN is calculated by summing nitrate+nitrite and ammonium.

Data Location

Data are stored in a database at the University of Delaware College of Earth, Ocean, and Environment in Lewes. Semi-monthly reports are posted online at http://www.citizen-monitoring.udel.edu/reports/. Data are available by request to the CMP Program Manager.

The CIB has been working with CMP and staff of the Delaware Environmental Observing System (DEOS) to make data available for public viewing and download through the U.S. EPA's Water Quality Exchange (WQX) database (https://www.epa.gov/waterdata/water-quality-data-wqx) and the Delaware Water Quality Portal (http://demac.udel.edu/waterquality/). As of December 2020, a portion of the 2019 dataset was viewable. Work continues to upload remianing 2019 and 2020 data, as well as legacy data.

Management Goal/Hypothesis and Test Statistics

The CIB uses CMP data to develop an indicator known as the Water Quality Index (WQI) for eelgrass reestablishment. The WQI is created by relating the values of DIN, DIP, Chlorophyll a, and Secchi depth to the eelgrass restoration criteria developed in the Chesapeake Bay as refined for the Delmarva Coastal Bays (Valdes-Murtha 1997, Batuik et al. 2000). Thresholds are DIN = 0.14 mg/L, DIP = 0.01 mg/L, Chlorophyll a = 15 micrograms per liter, and Secchi depth = 2.2 ft.

All data collected for these parameters that followed the established criteria for inclusion are scaled linearly using the following Excel function:

```
=TREND(calcs!E$2:F$2,calcs!C$4:D$4,F2)
```

E2 and F2 represent the top and bottom of the scale desired (0 and 1), and C and D represent the 95th percentile of all data for that parameter and the threshold value for that parameter. F represents the actual parameter value. For Secchi depth, the 5th percentile is used instead of the 95th percentile, because a larger number represents a better Secchi depth, unlike the other parameters where a larger value indicates a worse environmental condition. After scaling linearly, any values below 0 are changed to 0, and any values exceeding 1 are changed to 1. Then, for each row, the four parameters are added together, and the sum was divided by 4 to get a mean WQI for each sampling event at each station. The mean annual WQI values are used for Mann Kendall trend analyses.

	Criteria for Indicator Status			
Indicator	**Very poor water quality**	**Does not support eelgrass reestablishment**	**May support eelgrass reestablishment**	**Supports eelgrass reestablishment**
Water Quality Index for Eelgrass Reestablishment (range=0 to 1)	<0.75	0.75 to <0.9	0.9 to <1.0	1.0

TABLE C.3 – Summary of Citizen Monitoring Program Stations in the Inland Bays. These are stations currently sampled regularly, as of 2020.
Notes: [1] Stations identified by the CIB as top priority to continue, for use in the State of the Delaware Inland Bays reporting.
[2] Station was sampled fewer than five times for any parameter in 2020.

	Location		Period of Collection		Parameters Collected									
Station ID	Latitude	Longitude	Start Date	End Date	Chl a	DIN	DIP	DO	pH	Salinity	Secchi Depth	Total *Enterococcus*	TSS	Water Temp
IR02[1,2]	38.59453	-75.20838	2000	2002	•	•	•	•		•	•		•	•
IR02a[1]	38.59453	-75.20838	2017	2020	•	•	•	•		•	•	•	•	•
IR04[1,2]	38.59583	-75.20500	2000	2015	•	•	•	•		•	•	•	•	•
IR03	38.59467	-75.17547	2017	2020				•		•	•	•		•
IR11[1]	38.61683	-75.10223	2000	2020	•	•	•	•		•	•	•	•	•
IR12	38.58853	-75.07288	2001	2020				•		•	•			•
IR20[1,2]	38.58260	-75.15509	2000	2014	•	•	•	•		•	•	•	•	•
IR24	38.58212	-75.26920	2013	2020				•		•	•	•		•
IR26	38.58323	-75.26492	2015	2020				•		•	•			•
IR32	38.57069	-75.08449	2002	2020				•		•	•	•		•
IR36	38.58125	-75.08710	2004	2020				•		•		•		•
IR38[1]	38.56158	-75.19947	2006	2020	•	•	•	•	•	•	•	•	•	•
IR39	38.60893	-75.06465	2006	2020				•		•	•			•
IR50	38.55575	-75.08852	2002	2020				•		•	•			•
IR51	38.56228	-75.20573	2010	2020				•		•	•	•		•
IR73	38.54901	-75.07046	2009	2020				•		•	•			•
LA03[1]	38.48538	-75.07735	2000	2020	•	•	•	•		•	•	•	•	•
LA09[1]	38.48362	-75.11880	2000	2020	•	•	•	•		•	•	•	•	•
LA29	38.47675	-75.13791	2015	2019				•		•	•	•		•
LA38	38.48312	-75.12968	2011	2020				•			•	•		•
LA45[1,2]	38.46103	-75.05778	2004	2013	•	•	•	•		•	•	•	•	•
LA46[1]	38.45497	-75.05833	2010	2020	•	•	•	•		•		•	•	•
LA48	38.46199	-75.05355	2011	2020				•		•	•	•		•
RB06[1]	38.63828	-75.16918	2002	2020	•	•	•	•	•	•	•	•	•	•

	Location		Period of Collection		Parameters Collected									
Station ID	Latitude	Longitude	Start Date	End Date	Chl a	DIN	DIP	DO	pH	Salinity	Secchi Depth	Total *Enterococcus*	TSS	Water Temp
RB06A	38.64065	-75.17410	2002	2020						•		•		•
RB07[1,2]	38.66194	-75.13222	2000	2015	•	•	•	•		•	•	•	•	•
RB10	38.63695	-75.19712	2011	2020						•		•		•
RB16	38.68983	-75.07748	2017	2020				•		•	•			•
RB34[1]	38.70262	-75.16075	2002	2020	•	•	•	•		•	•	•	•	•
RB38	38.67794	-75.13603	2000	2020						•	•			•
RB64	38.69909	-75.11242	2005	2020				•		•	•			•
RB90	38.66555	-75.18235	2014	2020				•	•	•		•		•
SB01	38.51901	-75.05558	2008	2020	•	•	•	•		•	•	•	•	•
SB02	38.51851	-75.06083	2006	2020				•		•	•			•
SB04	38.51793	-75.05603	2007	2020				•		•	•	•		•
SB05	38.51783	-75.06050	2009	2020				•		•	•			•
SB06	38.51744	-75.05539	2012	2020				•		•	•	•		•
SB07	38.51490	-75.05993	2006	2020	•	•	•	•		•	•	•	•	•
SB09	38.51033	-75.05633	2008	2020				•		•	•			•
SB10E	38.52083	-75.06113	2002	2020				•		•	•			•
SB10W	38.52057	-75.06350	2002	2020				•		•	•			•
SB12	38.51356	-75.06233	2002	2020				•		•	•			•
SB13	38.51025	-75.05752	2015	2020				•		•	•			•

TABLE C.4 – Summary of Citizen Monitoring Program Analytical Methods

Parameter	Method Reference (EPA)	Reporting/Quantitation Limit
Water Column Nutrients – These analyses are currently performed by the UMCES CBL NASL		
Soluble Ortho-phosphorous	EPA365.1	0.0025 mg/l P
Ammonia Nitrogen	EPA350.2	0.01 mg/l N
Nitrite + Nitrate N	EPA353.2	0.0035 mg/l N
General		
Dissolved oxygen – Winkler	EPA360.2	0.25 mg/l
Dissolved oxygen – Meter	EPA360.1	0.1 mg/l
Chlorophyll-a	EPA445.0	1 µg/L
Total Suspended Solids	EPA160.2	2 mg/l
Field pH	EPA150.1	0.2 pH units
Conductivity – Meter	EPA120.1	1 µS/cm
Salinity - Meter and Hydrometer	SM20thed-2520B and 2520C	1 ppt
Temperature	EPA170.1	0.5 °C
Secchi Depth	EPA/620/R-01/003	0.1 meters
Bacteria		
Total Enterococcus	SM20thed-9230C	1 cfu/100 ml

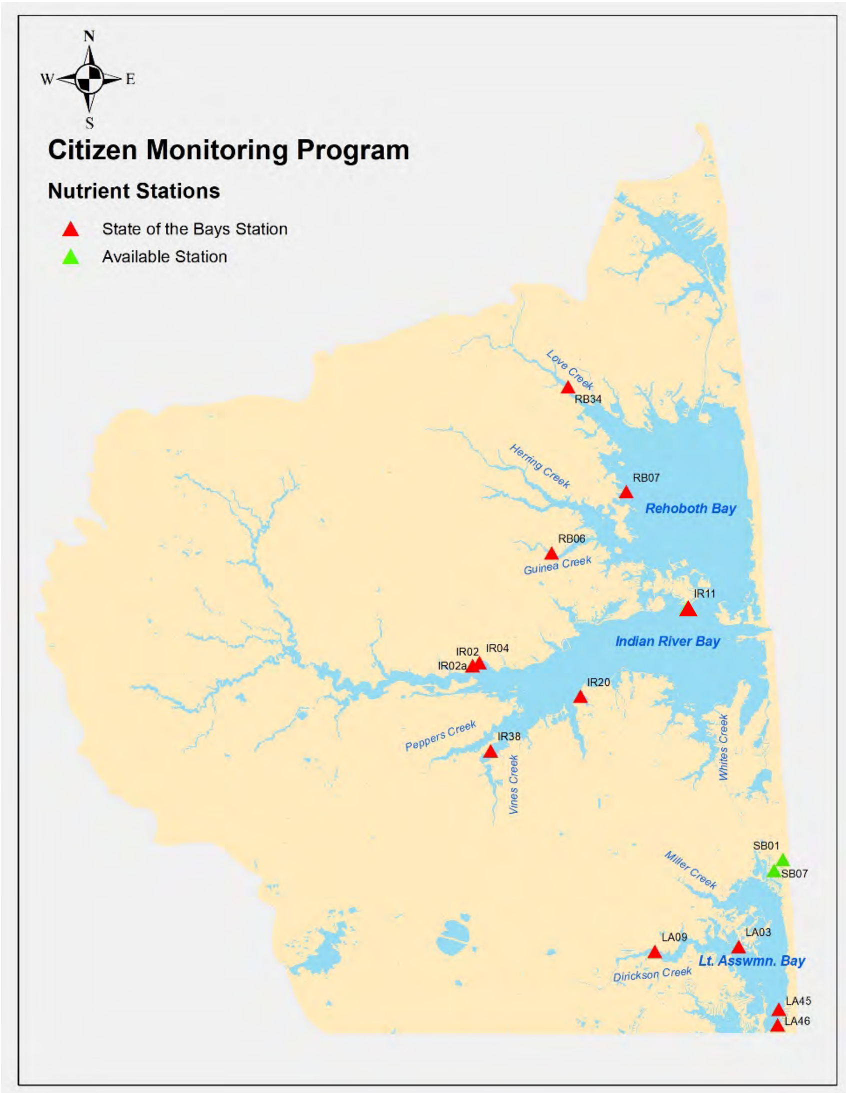


FIGURE C.2 – Map showing locations of Citizen Monitoring Program stations that collect nutrient data. (Revised 2020)

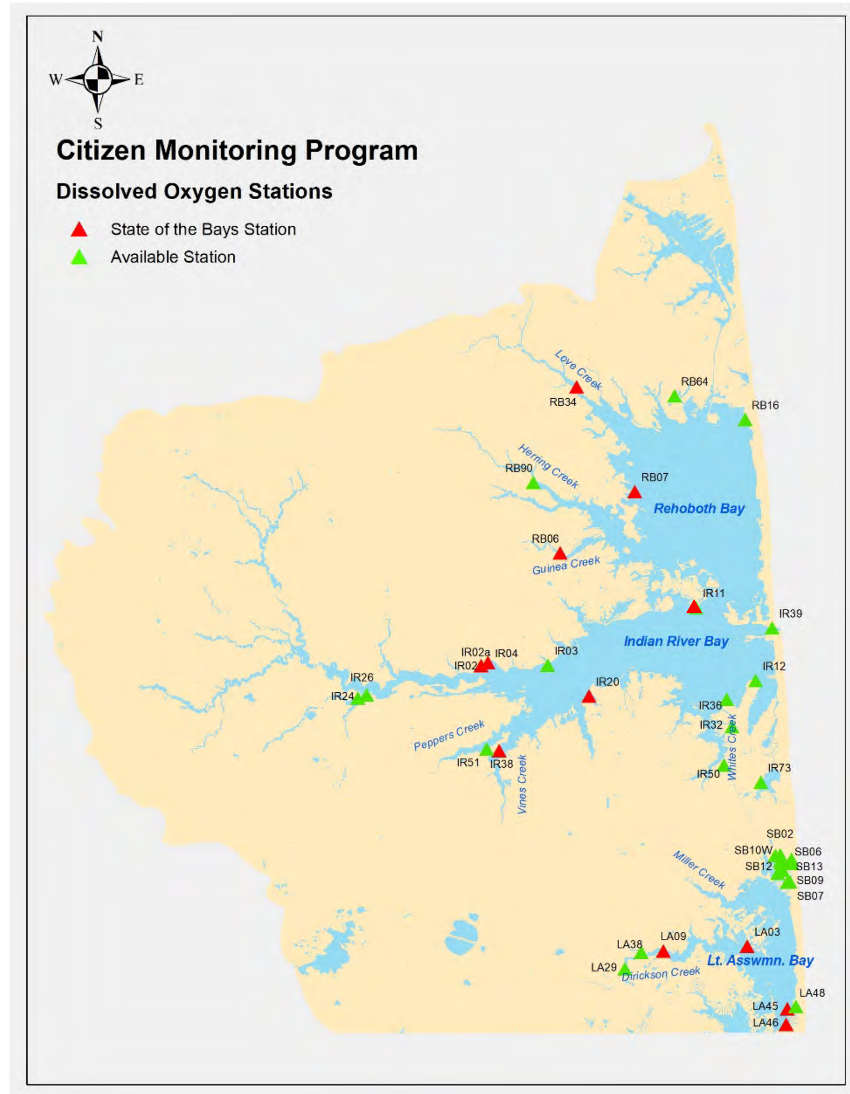


FIGURE C.3 – Map showing locations of Citizen Monitoring Program stations that collect dissolved oxygen data. (Revised 2020)

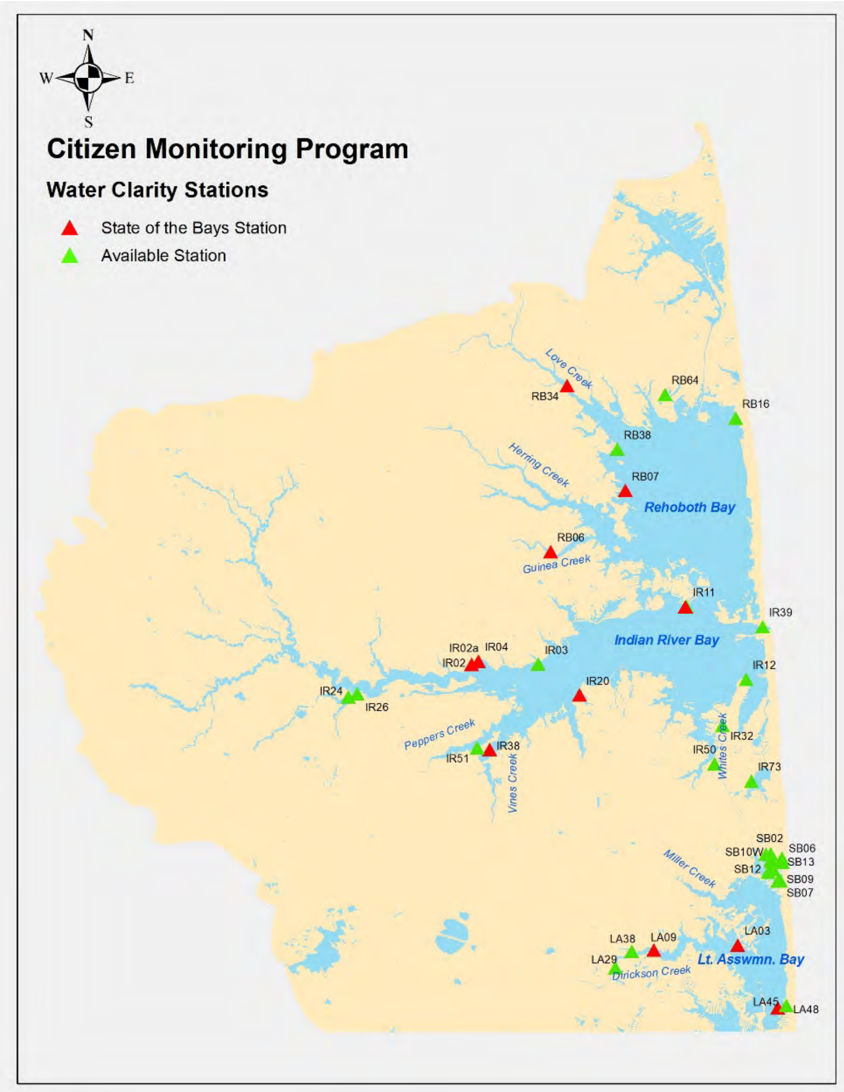


FIGURE C.4 – Map showing locations of Citizen Monitoring Program stations that collect Secchi depth data.

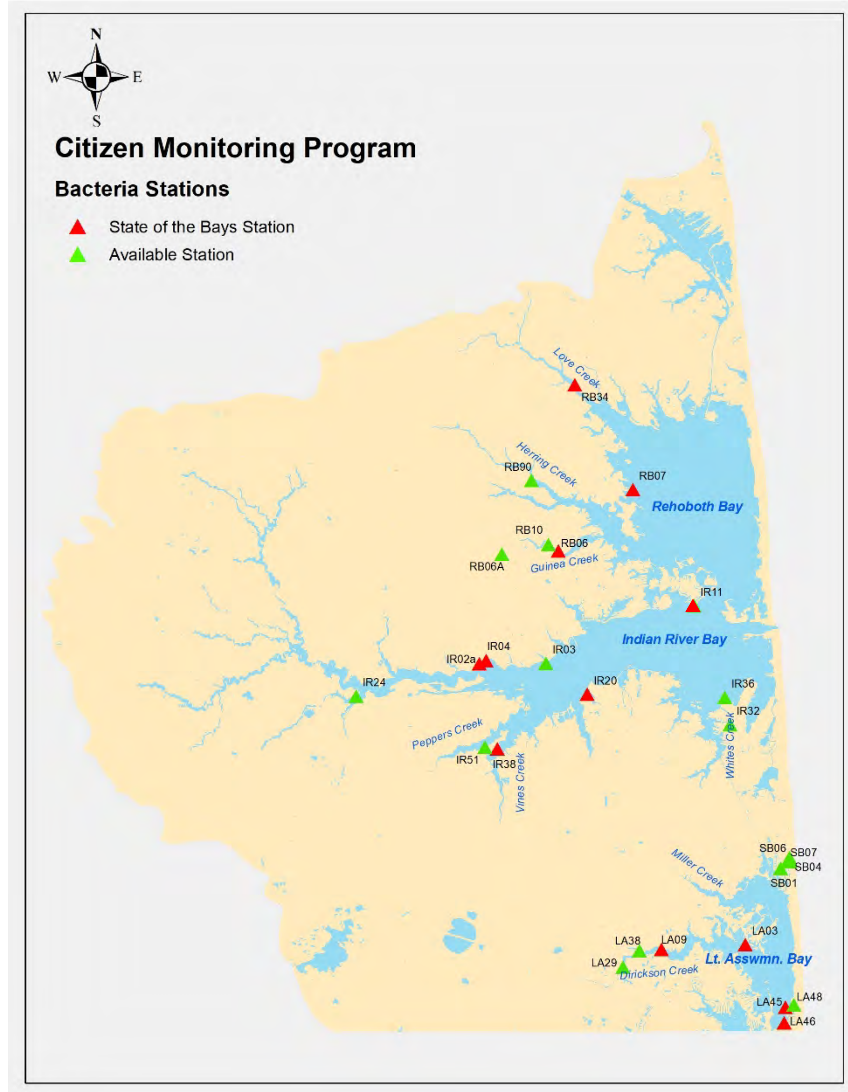


FIGURE C.5 – Map showing locations of Citizen Monitoring Program stations that collect Total *Enterococcus* data. (Revised 2020)

C.1.3 STATE FECAL COLIFORM MONITORING PROGRAM

In order to regulate shellfish harvest areas, the State has monitored levels of total coliform bacteria and, beginning in 2016, fecal coliforms in all three Inland Bays. The goal of this program is to ensure that waters that are ap`proved for shellfish harvest meet water quality standards based on routine water quality assessments. Additionally, this program can be used to justify the opening of previously closed areas for harvest should the data reflect the area is safe, and close previously open areas in the event of high coliform levels. DNREC maintains an interactive, online map showing where the harvest of shellfish is approved, seasonally approved, or prohibited.

Responsible Organization and Contact

DNREC Division of Watershed Stewardship

Contact: Michael Bott, Environmental Scientist
Michael.Bott@delaware.gov, 302-739-9939

Data Collection Cost

Not available.

Data Use

Data are used primarily by DNREC Division of Watershed Stewardship's Shellfish Program to assess the suitability of the Inland Bays waters for shellfish harvest.

Record of Collection

2008 to present. Fecal coliform collection began in 2016, with plans to succeed total coliforms as the method to assess the suitability of waters.

Collection Method

Ten times per year, 52 sites in Rehoboth and Indian River Bay are sampled and analyzed for fecal coliforms. Little Assawoman Bay is sampled nine times a year at nine sites.

Analysis Methods

Analyses use mTEC agar (M-198) membrane filter medium, for enumerating fecal coliforms in marine and estuarine waters (FDA, 1998).

Data Location

Data are managed and stored by the DNREC Division of Watershed Stewardship Shellfish Program

Management Goal

Standard for total coliforms: no more than 10% or 90th percentile, of past 30 samples exceed 330 mpn/100mL; geometric mean shall not exceed 70mpn/100mL over the past 30 samples.

C.1.4 USGS-DGS STREAM AND TIDE GAUGE PROGRAM

Description/Objective(s)

The US Geological Survey (USGS), in cooperation with the Delaware Geological Survey (DGS) through a State-Federal partnership program, operates and maintains stream and tide gauges throughout Delaware. The stream gauge network is a component of the National Streamflow Information Program (NSIP), a program that provides real-time and long-term current and historical streamflow information that is not only accurate and unbiased, but also meets the needs of many users.

Currently there are nine station locations in the Inland Bays; three of these measure fresh water stream discharge (Table C.5 and Figure C.6).

Responsible Organization and Contact

The stations located in the Inland Bays are managed by the MD-DE-DC Water Science Center, 1289 McD Drive, Dover, DE 19901, Telephone 302-734-2506

Data Collection Cost

Funding for the three stream discharge stations is provided by DNREC through the DGS. Funding for the operation of the Inland Bays tidal stations are funded by DNREC through the DGS, and the Delaware Department of Transportation. The USGS provides match funding for the stream gage portion of the program.

Data Use

The Delaware Stream and Tide Gauge network provides the hydrologic and water quality information necessary to aid in defining, using, and managing deletion here water resources. The data are used for a multitude of purposes, including, but not limited to, long-range water resources planning and management, short-term resource management, evaluation of drought-no drought conditions, allocation of water resources for public, industrial, commercial, and irrigation water supplies, flood forecasting and warning, bridge and culvert design, hazard spill response and mitigation, analysis of sea level rise, recreation, and floodplain mapping. The stream and tide data are also utilized in existing real-time early warning systems related to potential flooding, and storm/coastal erosion throughout Delaware. The warning systems are used by the DGS, Delaware Emergency Management Agency, all three county emergency management offices, most municipalities, the National Weather Service, the Office of the State Climatologist, and others.

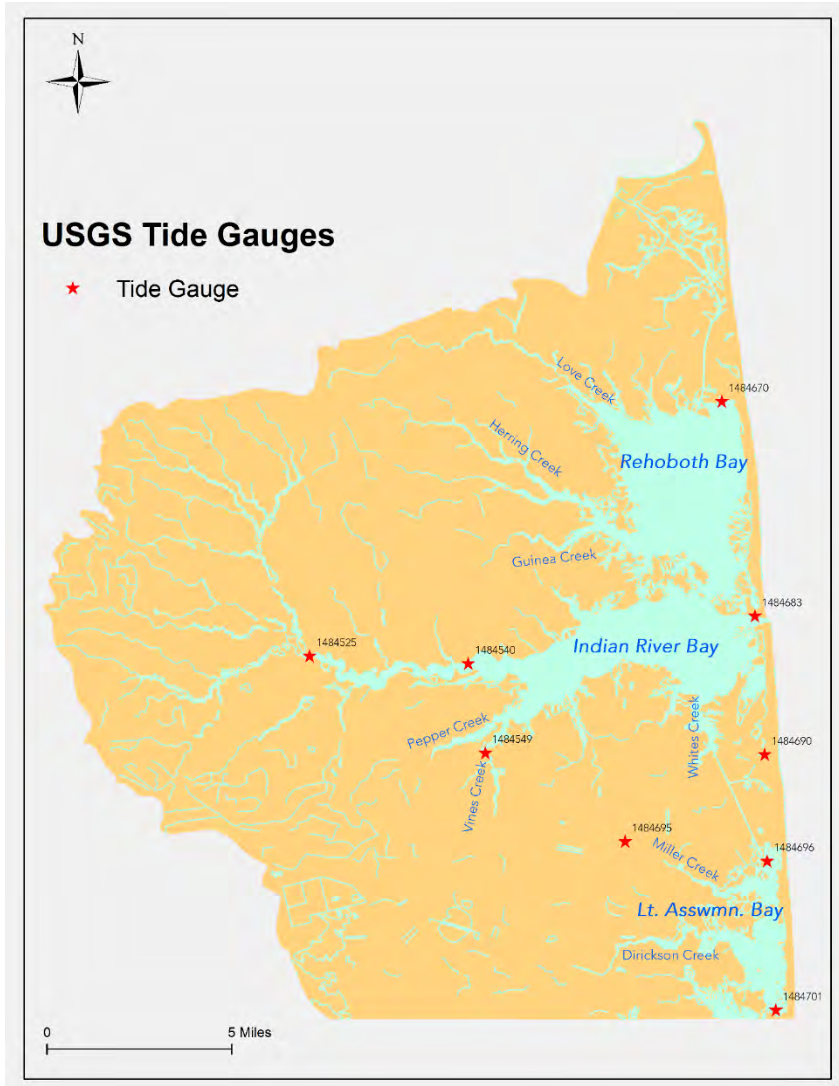


FIGURE C.6 – Map showing locations of Tide Gauges in the Inland Bays.

Record of Collection

See Table C.5.

Collection Method

Water-stage recorder gauges. The peak tidal stage that is recorded by each gauge is the elevation of water above the North American Vertical Datum of 1988. Stations have USGS data telemetry systems.

Analysis Methods

Once a complete day of readings are received from a site, daily summary data are generated and made available online. USGS finalizes data at individual sites on a continuous basis as environmental conditions and hydrologic characteristics permit. These statements are not 100% accurate but are close enough.

Data Locations

Stream and tide gauge information are available at https://waterdata.usgs.gov/de/nwis/rt. Data from USGS stream and tide gauge networks in Delaware are also available through the Delaware Environmental Observing System (DEOS) site: http://www.deos.udel.edu/data/.

TABLE C.5 – Inland Bays Stream and Tide Gauge Stations

Station No.	Station Name	Latitude	Longitude	HUC-8	Parameters	Period of Record
01484525	Millsboro Pond Outlet	38°35'40.4"	75°17'27.7"	02060010	Discharge, Gauge height	May 1986 to September 1988. March 1991 to current year.
1484695	Beaverdam Ditch near Millville	38°31'17.2"	75°08'00.2"	02040303	Discharge, Gauge height	August 1998 to current year.
01484540	Indian River at Rosedale Beach	38°35'29.5"	75°12'41.7"	02040303	Discharge, Gauge height	April 1991 to current year.
01484549	Vines Creek near Dagsboro	38°33'23.0"	75°12'11.4"	02040303	Tide elevation	Annual maximum, water years 1985-97. May 2015 to current year.
01484670	Rehoboth Bay at Dewey Beach	38°41'39.2"	75°05'03.2"	02040303	Gauge height, tide elevation	April 1985 to September 1997; November 2000 to current year.
01484683	Indian River Bay Inlet near Bethany Beach	38°36'35.4"	75°04'04.8"	02040303	Guage height, tide elevation	June 1988 to June 1989, April 1991 to December 2010, November 2011 to current year.
01484690	Unnamed Ditch on Fred Hudson Rd at Bethany Beach	38°33'19.6"	75°03'48.4"	02040303	Tide elevation	May 2015 to current year.
01484696	Jefferson Creek at South Bethany	38°30'48.8"	75°03'44.4"	02040303	Gauge height, tide elevation	July 1999 to current year.
01484701	Little Assawoman Bay at Fenwick Island	38°27'17.9"	75°03'30.0"	02040303	Gauge height, tide elevation	October 1999 to current year.

C.1.5 STATE BIOLOGICAL ASSESSMENT OF STREAMS PROGRAM

Description/Objective(s)

This long-term project collects biological and habitat data from nontidal wadable streams in order to relate water quality conditions with biological integrity. Eligible stations must (1) be completely nontidal, (2) have perennial flow, and (3) be uninfluenced by elevated temperature resulting from lentic discharge (e.g., millpond, stormwater pond). The biological data consists of two instream matrices: macroinvertebrate, and periphyton (first initiated in spring - 2005). The habitat data consists of instream and riparian zone matrices.

Beginning in 2001, and most other autumns thereafter until 2016, biological (macroinvertebrate), habitat and chemical sampling has occurred under baseflow conditions at 50 stations located along streams that have been placed on the 303(d) list due to impaired biology or habitat. Sampling of the Inland Bays occurred in six of those years. This bi-annual sampling rotates by county, major basin, or both. Conjunctional chemical sampling will be conducted. The data are evaluated to determine whether any form of impairment still exists at each respective station. If impairment is concluded, then effort will be made to identify the cause/s. The procedure for identifying causation is not yet fully outlined but will likely follow the EPA Stressor Identification Guidance Document (Cormier et al, 2000).

In years between 303(d) sampling, up to 50 GAMN stations are be sampled. The biological and habitat methodology is the same as used for the 303(d) sampling.

The immediate objective of this sampling is to determine the overall biological condition of nontidal streams in Delaware. The extended objective is to identify trends in biological condition in these waters.

Responsible Organization and Contact

DNREC Division of Water, Environmental Laboratory Section

Contact: Christopher Main, DNREC Environmental Scientist
christopher.main@delaware.gov, (302) 739-9942

Data Collection Cost

Not available.

Data Use

All analytical results are provided to the Watershed Assessment Section (WAS). The biological assessment data are used to:

- Define current water quality conditions.
- Identify and define long-term trends in water quality.
- Determine the suitability of Delaware waters for designated uses (e.g. water supply; recreation; fish, aquatic life and wildlife) as specified in the Delaware Surface Water Quality Standards.
- Determine whether the water quality standards are being met.
- Identify and prioritize high quality and degraded waters.
- Support the Total Maximum Daily Load Program.
- Evaluate the overall success of Delaware's water quality management efforts.

The 305(b) Report is submitted biannually by the WAS to the EPA as mandated by the Clean Water Act (CWA), and the findings are used to identify and prioritize water-quality limited waters as mandated by Section 303(d) of the CWA, as well as waters of high quality. Since the late

1990's the data have been used to develop and calibrate TMDL models, and in the future will be used to gage the success of TMDL-based Pollution Control Strategies.

Record of Collection

2001 to present

Collection Method

Biology and habitat sampling is done in accordance with methods defined in USEPA (1997). Biology samples are collected at coastal plain sites using a D-framed net.

Periphyton sampling is conducted according to the USGS, National Water Quality Assessment Program (Moulton et al. 2002). Samples will be collected from natural substrates, sticks and/or macrophytes (coastal plain), and rocks (piedmont). Only sticks that have obviously been in the water for an extended period (weeks to months) will be sampled.

Analysis Methods

The field preserved macroinvertebrate samples are outsourced for subsampling and identification to the lowest practical taxon. Level of identification for each phylum is as follows;

- *Arthropod*a genus / some species
- *Annelida* genus / some species
- *Mollusca* genus / some species
- *Bryozoa* family / some genus (statoblasts)
- *Platyhelminthes* genus / some species
- *Cnidaria* genus

For analytical purposes, the species composition and abundance data will be reduced to the genus level. A multi-metric approach will be used to calculate a biological index (BI) for each sample which is expressed as a percentage of the ecoregion reference values (see Gibson 1996). Based on the BI, the site will then be categorized according to condition (i.e. excellent, good, moderately degraded, severely degraded).

The periphyton samples also are outsourced for identification.

Data Location

All completed field-generated and laboratory-generated data are entered into the DNREC ELS Laboratory Information Management System (LIMS).

Management Goal

The data are evaluated to determine whether any form of impairment still exists at each respective station. If impairment is concluded, then effort will be made to identify the cause/s. The procedure for identifying causation is not yet fully outlined but will likely follow the EPA Stressor Identification Guidance Document (USEPA, 2000).

Hypothesis and Test Statistics

From each set of triplicate results (three stations sampled in triplicate for macroinvertebrates and periphyton) a coefficient of variation is developed. The range of these three coefficients of variation is regarded as the within-station spatial variability of the biological community across the entire study area.

C.1.6 TOXICS MONITORING

Ambient Water Quality Monitoring, Heavy Metals

Ongoing monitoring of toxics in the Inland Bays includes sampling and analysis of copper, lead, zinc, and arsenic as part of the state's Ambient Surface Water Quality Monitoring Program (Table C.6). This table is current as of FY 2016. Other more intensive monitoring and assessment of toxics in water, sediment and biota in the Inland Bays has occurred in the past, but these programs have not been continued long-term.

Delaware's Surface Water Quality Monitoring Program for Fiscal Year 2020 as conducted by Delaware Department of Natural Resources and Environmental Control (DNREC) includes Toxics in Biota Monitoring, Toxics in Sediment Monitoring, and Monitoring under the Watershed Approach to Toxics Assessment and Restoration (WATAR) Plan. This program has focused on Delaware Bay and Chesapeake Bay watersheds. However, the program is relevant to the Inland Bays, because the PCBs that are the major cause for issuing fish consumption advisories for the Bays are picked up elsewhere by the fish. More information on this program and copies of reports are available at https://dnrec.alpha.delaware.gov/waste-hazardous/remediation/watar/.

EPA Environmental Monitoring and Assessment Program

The EPA has some data available on toxics for fish samples and sediment samples from the Inland Bays. Those samples were collected as part of the Environmental Monitoring and Assessment Program (EMAP), which was a research program run by EPA's Office of Research and Development to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP collected field data from 1990 to 2006. Data are available online (https://archive.epa.gov/emap/archive-emap/web/html/index-37.html). Monitoring of the nation's aquatic resources is now being routinely conducted by the National Aquatic Resource Surveys, run by EPA's Office of Water (https://www.epa.gov/national-aquatic-resource-surveys). More information on this program is available in this appendix (Section C.1.6).

Monitoring of Burton Island Coal Ash Disposal Area

The Center collected biota and sediment samples from the Inland Bays in 2012 to assess whether material eroding off and/or transported from the Burton Island former coal ash disposal site in upper Indian River is contributing to significant accumulation of toxic trace elements in the local aquatic environment. Mummichogs (*Fundulus hereoclitus*), ribbed mussels (*Geukensia demissa*), and surface sediment were collected from five locations along the southern shoreline of Burton Island within Island Creek. Sites were purposely selected to coincide with locations where previous sampling or observations indicated release from Burton Island through either erosion or shallow groundwater transport. Locations within Pepper Creek were sampled for sediment and biota to serve as controls against which the Burton Island results could be compared.

The study concluded that existing conditions and concentration levels of trace elements found in the *Geukensia, Fundulus*, and sediment samples currently did not warrant an expansion of sampling to evaluate the potential ecological impacts of bioaccumulation (Riedel and Wilson, 2013). The future conditions of the island could change due to rising water levels and/or changes in the rate of pore water movement; because of this, it is recommended that tissue and sediment samples be periodically sampled and analyzed (in methods consistent with this study) to evaluate any changes in the prevalence and concentration of trace elements and metals through bioaccumulation in the surrounding biota.

TABLE C.6 – State monitoring of toxics in surface water the Inland Bays.

Station Location	Station ID	Cu, Pb & Zn	As
Burton Pond @ Rt. 24	308031	●	
Millsboro Pond @ Rt. 24	308071	●	
Pepper Creek @ Rt. 26 (Main St.)	308091	●	
Blackwater Creek @ Omar Rd. (Rd. 54)	308361	●	
Dirickson Creek @ Old Mill Bridge Rd. (Rd. 381)	310031	●	
Buntings Branch @ Rt. 54 (Polly Branch Rd.)	311041	●	
Guinea Creek @ Banks Rd. (Rd. 298)	308051	●	
Whartons Branch @ Rt. 20 (Dagsboro Rd.)	309041	●	
Lewes & Rehoboth Canal @ Rt. 9	305041	●	
Little Assawoman Bay @ Rt. 54 (The Ditch)	310011	●	
White Creek @ mouth of Assawoman Canal	312011	●	
Bundicks Branch @ Rt. 23	308371	●	
Beaver Dam Ditch @ Beaver Dam Rd. (Rd. 368)	310121	●	
Cow Bridge Branch @ Zoar Rd. (Rd. 48)	308281	●	
Swan Creek @ Mount Joy Rd. (Rd. 297)	308341	●	
Lewes & Rehoboth Canal @ Rt. 1	305011	●	
Indian River Inlet @ Coast Guard Station	306321	●	●
Rehoboth Bay @ Buoy 7	306091	●	●
Masseys Ditch @ Buoy 17	306111	●	●
Indian River Bay @ Buoy 20	306121	●	●
Indian River @ Buoy 49 (Swan Creek)	306181	●	●
Indian River @ Island Creek	306331	●	●
Island Creek upper third	306341	●	●
Little Assawoman Bay Mid-bay (Ocean Park Lane)	310071	●	

Monitoring of Burton Island Coal Ash Disposal Area

The Center collected biota and sediment samples from the Inland Bays in 2012 to assess whether material eroding off and/or transported from the Burton Island former coal ash disposal site in upper Indian River is contributing to significant accumulation of toxic trace elements in the local aquatic environment. Mummichogs (*Fundulus hereoclitus*), ribbed mussels (*Geukensia demissa*), and surface sediment were collected from five locations along the southern shoreline of Burton Island within Island Creek. Sites were purposely selected to coincide with locations where previous sampling or observations indicated release from Burton Island through either erosion or shallow groundwater transport. Locations within Pepper Creek were sampled for sediment and biota to serve as controls against which the Burton Island results could be compared.

The study concluded that existing conditions and concentration levels of trace elements found in the *Geukensia, Fundulus*, and sediment samples currently did not warrant an expansion of sampling to evaluate the potential ecological impacts of bioaccumulation (Riedel and Wilson, 2013). The future conditions of the island could change due to rising water levels and/or changes in the rate of pore water movement; because of this, it is recommended that tissue and sediment samples be periodically sampled and analyzed (in methods consistent with this study) to evaluate any changes in the prevalence and concentration of trace elements and metals through bioaccumulation in the surrounding biota.

A Long-Term Stewardship (LTS) Plan for the ash disposal area was prepared for Indian River Power LLC in 2014 (CB&I Environmental and Infrastructure, Inc., 2014). The LTS Plan includes monitoring requirements for the remedial actions at the site. Field and laboratory data are to be provided electronically to DNREC-SIRS. The monitoring requirements are:

- Annual groundwater monitoring to assess any changing physical conditions from those used to develop the site conceptual model of groundwater flow and to assess any changing chemical conditions used to evaluate the potential for human health and ecological risk.
- Annual monitoring of sediment quality immediately offshore of the site. Shoreline sediment sampling events will consist of a visual shoreline survey near the time of low tide, sample collection and documentation, and laboratory analysis. Shoreline sediment samples will be analyzed for arsenic, barium, and selenium as these metals were identified as sediment constituents of concern (COCs) in the risk assessment (Shaw, 2008).

Requests from the Center for sampling of additional heavy metals in groundwater and sediment, as well as for biological sampling, were not included in the Plan. Nor were numeric criteria based on ecological standards for all constituents of concern, or what might constitute an increase from baseline conditions in these parameters that would require any further remedial action.

<u>Fish and Shellfish Tissue Monitoring</u>

Statewide fish tissue monitoring has been conducted since 1992, and data have resulted in issuance of consumption advisories for Striped Bass and Bluefish caught in the Inland Bays. Delaware's Atlantic Coastal waters include the mouth of Delaware Bay and extend three miles out into the Atlantic Ocean between Cape Henlopen and Fenwick Island. Delaware has fish consumption advisories for striped bass and bluefish caught from these waters, including the tidal portions of Delaware's Inland Bays, which have a direct connection to the Atlantic Ocean along this stretch of coastline. Advisories for striped bass and bluefish for these waters are identical to those for Delaware Bay. Based on the migratory habits of these species, the new advice for striped bass and bluefish caught in the Delaware Bay is being extended to Delaware's coastal waters, including the tidal portions of Delaware's Inland Bays. Specifically, the maximum number of meals of striped bass caught from Delaware's Atlantic Coastal Waters is three 8-oz. servings per year. Women of childbearing age and young children are still advised to avoid consuming striped bass caught from these waters. For bluefish larger than 20 inches, the new advisory is to limit consumption to three 8-oz. meals or less per year. This advice applies to the general adult angler. The advice for women of childbearing age and children younger than 6 years old remains "Do not eat" for bluefish larger than 20 inches. PCBs and mercury are the primary contaminants of concern for the larger bluefish, while PCBs are the contaminant of concern for the smaller bluefish.

DNREC conducts three types of monitoring in support of its chemical contaminants in fish and shellfish program. Tier I screening samples are collected in areas where data gaps exist, or where the existing data are very old. Tier II intensive samples are collected in situations where the results of Tier I monitoring indicate a need to better characterize the extent and magnitude of contamination (and support a risk assessment/advisory decision); and last, advisory follow-up sampling after an advisory has been issued and there's a need to track changes over time. DNREC has performed both Tier I and Tier II sampling of contaminants in fish and shellfish in the Inland Bays. Finally, the EPA, as part of its National Coastal Assessment program, has collected and analyzed fish samples from the Inland Bays for toxics.

None of the data and assessments to date have led the State to conclude that an advisory is needed in the Inland Bays as a result of contaminant sources within the Inland Bays. There is, however, an advisory on coastal species such as Bluefish and Striped Bass that migrate in and out of the Inland Bays.

C.1.7 CONTINUOUS SURFACE WATER QUALITY MONITORING

Description/Objective(s)

As part of the Water in the Changing Coastal Environment in Delaware effort (Project WiCCED), two continuous water quality monitoring stations have been established within Indian River Bay (Table C.7). These stations monitor a variety of surface water quality parameters and operate from April through October annually.

Table C.7 – Long-term continuous water quality monitoring stations managed by CIB and the University of Delaware, as of December 2020.

Site Name	**Delaware Cultured Seafood**	**Fishers Dock on Pepper Creek**
Bay	Indian River Bay	Indian River Bay
Waterbody	Indian River	Pepper Creek
Sonde Type	EXO2	EXO2
Latitude	38.591313	38.562639
Longitude	-75.214765	-75.205600
Deployment Depth (from bottom)	1.5 ft	1 ft
Water Depth at Site (@ high tide)	6 ft	4 ft
Parameters Measured		
Dissolved Oxygen	Y	Y
Water Temperature	Y	Y
Specific Conductance/Salinity	Y	Y
pH	Y	Y
Turbidity	Y	Y
Chlorophyll a/Phycoerythrin	Y	Y

Responsible Organization and Contact

The Delaware Center for the Inland Bays is responsible for this monitoring.

Contact: Andrew McGowan, Environmental Scientist
environment@inlandbays.org, 302-226-8105, x112

Data Collection Cost

Maintenance costs are roughly $7,500 annually combined for both stations.
Initial Equipment costs are roughly $18,000 for one long-term sonde, and each station typically uses two sondes
Annual labor costs are roughly $12,000, combined, for both stations.

Data Use

The data are used primarily by the Center for the Inland Bays, researchers with project WiCCED, and DNREC. Data can be used to assess the true conditions within upper tributaries in the Inland Bays, and can be used for 305(b) reports.

Record of Collection

April 2020 - present

Collection Method

Parameters are collected using YSI EXO2 sondes. Both sites are equipped with conductivity/temperature, dissolved oxygen, pH, total algae, and turbidity sensors. Parameters are measured once every 30 minutes. Each station has two YSI EXO2 probes, which are swapped out roughly once per week.

Analysis Methods

Data are checked according to an EPA Quality Assurance Project Plan. Briefly, all data are checked for drift either as a result of sensor drift since calibration, or drift caused by fouling. Each parameter must fall within an established range (Table C.8) from a standard or side-by-side check with a cleaned calibration sensor. Data must also fall within an established minimum or maximum for each parameter or else it is manually checked against other environmental parameters such as rainfall. All data that meets QA standards are preserved. Preserved data is then analyzed for each parameter. Common indicators derived from the data are listed in Table C.9.

Data Location

Data are managed by the Center for the Inland Bays and are available upon request.

Table C.8 – Parameters collected and data quality.

Parameter	Accuracy
Specific Conductivity	± 3% of the measured value or ±5 µS/cm or, whichever is greater
Temperature	±0.2°C
Dissolved Oxygen	±0.3 mg/L
pH	±0.3 units
Turbidity	± 0.5 turbidity units or ± 5% of the measured value, whichever is greater
Chlorophyll a	± 10% of the measured value
Phycoerythrin	± 10% of the measured value

Table C.9 - Common indicators examined with the annual data are pictured In the table below.

Specific Conductance/Salinity	Water Temperature	DO	pH	Turbidity	Chlorophyll a
Range throughout the season	Range throughout the season	% of summer mornings with DO below state standard (4 mg/L)	Range throughout season	Range throughout season	Range throughout season
Correlation to rainfall events	Temperature thresholds exceeded for species of interest and time over these limits	Duration of hypoxic or anoxic conditions per month	Spiking events and possible reasons	# of extreme turbidity events ("extreme" to be defined after discussions with stakeholder groups)	% of time over state standard (15 µg/L)
		Correlations to chlorophyll or rainfall		Correlations to chlorophyll or rainfall	Correlations to salinity, water temperature and rainfall
					# of and duration of extreme bloom events. ("extreme" to be defined after discussions with stakeholder groups)

C.2 MONITORING OF GROUNDWATER

C.2.1. DELAWARE GROUNDWATER MONITORING NETWORK

Description/Objective(s)

Long time-series of water levels and quality in major aquifers serve as critical baseline data for resource management and analyses of aquifer response to pumping, climatic variability, drought hazards, seawater intrusion, and interaction with streams and their ecosystems. The Delaware Geological Survey (DGS) currently monitors groundwater levels in a network of 90 plus wells and monitors water quality in over 25 wells covering 13 aquifers in Delaware (Figure C.7). At this time, 13 of the wells are located in the Inland Bays watershed. The data are maintained in an in-house relational database and made available to the public through internet channels.

DGS has automated water level and salinity data collection, reduction, and archiving to increase efficiency and quality control while supporting expansion of the statewide network into unmonitored areas over time. For example, DGS installed salinity sensors in 2015 in wells at Indian River Inlet and Fenwick Island Seashore State Park. This supports evaluation of the long-term availability and sustainability of the groundwater supply, management of the resource, and a myriad of uses by the environmental management, engineering, and science communities. DGS participates in the National Ground Water Monitoring Network (NGWMN) and provides data from 64 Delaware wells to the NGWMN web portal (https://cida.usgs.gov/ngwmn/).

Responsible Organization and Contact

Delaware Geological Survey

Contact: A. Scott Andres, Changming He, DGS
asandres@udel.edu, hchm@udel.edu302-831-2834

Data Collection Cost

The lack of reliable, dedicated funding, (e.g., 303d 305b) has greatly affected data collection. For the past 10 years funding from several state and federal sources have been braided together to support operations and expansion of the network. Federal sources (NGWMN) support data distribution costs. Federal sources (Clean Water, Source Water) routed through the DE Division of Public Health and the Division of Water partially support operations. State appropriations to the DGS partially support operations. State capital appropriations have funded deep well construction in New Castle and Kent Counties (approximately $1.3M) and more are needed to install future new deep wells in Sussex County (estimated $1.5M).

Data Use

This monitoring program supports evaluation of the long-term availability and sustainability of the groundwater supply, management of the resource, and other uses by the environmental management, engineering, and science communities.

Record of Collection

The oldest water level data extend back as far as 1957. Details on each well, along with records of collection, are available on the DGS website at http://www.dgs.udel.edu/datasets/recent-and-historical groundwater-level-data. Project-based monitoring of groundwater quality extends back to the same timeframe as the water level data. Routine monitoring of groundwater quality started in the early 1980s at a few locations and expanded to the current network configuration in 2018.

Collection Method

The DGS database holds over 39 million instrument-measured groundwater level, temperature, and salinity records and 35,000 manually measured groundwater levels. The database holds records of more than 5000 groundwater samples collected by traditional pump or bailer methods. People needing specific information about sampling methods should contact the DGS directly.

Analysis Methods

Water quality test data are generated by a wide variety of analytical methods and multiple laboratories. Sampling and analytic methods metadata are stored with each sample and test record. People needing specific information about laboratories and methods should contact the DGS directly.

Data Location

DGS manages and stores the data. Groundwater level data and monitoring program information can be viewed or downloaded at http://www.dgs.udel.edu/datasets/recent-and-historical-groundwater-level-data. At this time, groundwater quality data are most easily accessed through the NGWMN portal https://cida.usgs.gov/ngwmn/). Users needing data access through web services should contact the DGS directly for instruction.

Management Goal

The network supports evaluation of the long-term availability and sustainability of the groundwater supply, management of the resource, models of sea-level rise impacts, and many other uses by the environmental management, engineering, and science communities.

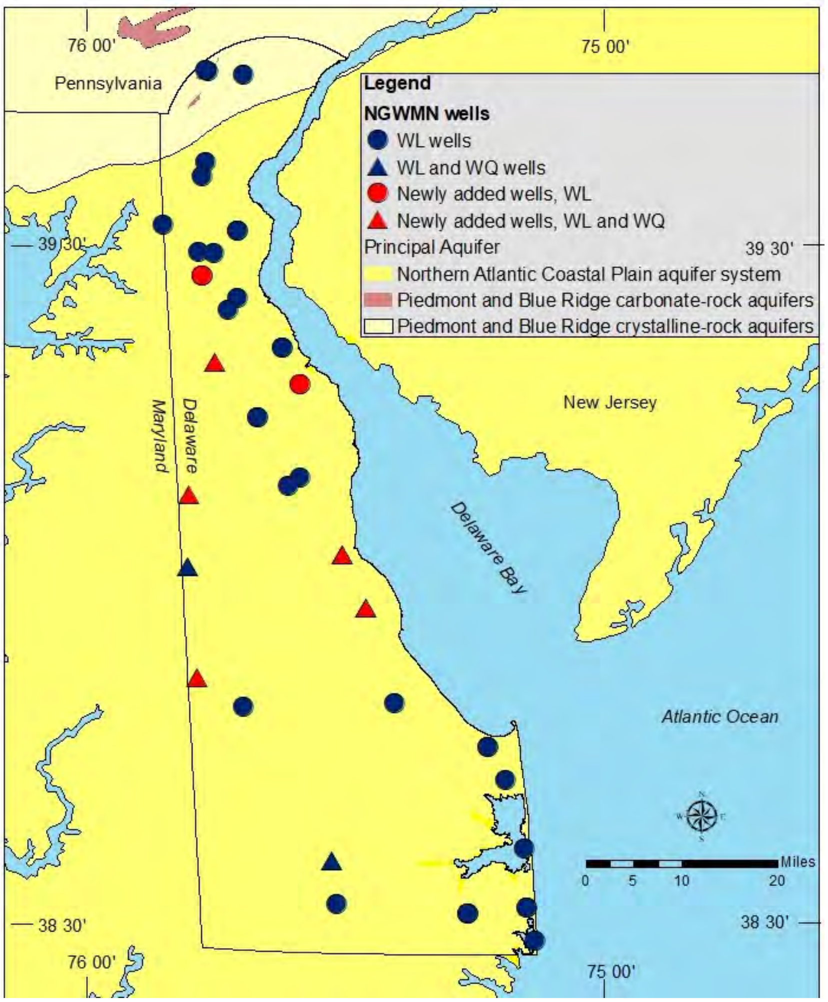


FIGURE C.7 - Monitoring sites in the Delaware Groundwater Monitoring Network. Many sites have multiple wells monitoring different aquifers.

C.2.2 DELAWARE AGRICULTURAL SHALLOW GROUNDWATER MONITORING NETWORK

Description/Objective(s)

Studies in the Delmarva Peninsula have demonstrated that groundwater in shallow unconfined aquifers near agricultural lands is susceptible to contamination from chemicals, including nutrients, applied at the land surface. The agricultural community in Delaware has been working with various State and Federal government agencies to apply a number of conservation practices intended to reduce the amount of nitrate reaching the water table beneath agricultural land in support of Delaware's nutrient reduction goals. However, changes in nutrient management practices on the land surface may take decades to improve water quality in groundwater discharge to Delmarva streams because of groundwater residence times.

To understand if these changes in agricultural practices are reducing nitrate concentrations in shallow groundwater, and eventually in drinking water and streams, a long-term groundwater monitoring program is being implemented by the USGS, in partnership with the Delaware Department of Agriculture. This network of wells is located in areas with young, oxic, shallow groundwater, overlain by agricultural land, where change will be seen most clearly in a relatively short timeframe.

Much of the documented variability in nitrate concentrations on the Delmarva Peninsula included results from networks with wells in both oxic and anoxic aquifer condition. To maximize the discriminatory power of the statistical tests, the network will have a large sample size (up to 50 wells) and only include wells in oxic aquifer conditions.

Responsible Organization and Contact

USGS and Delaware Department of Agriculture

Contact: Chris Brosch, Program Administrator - Delaware Department of Agriculture
(302) 698-4555

Data Collection Cost

Not available.

Data Use

Results of nitrate analysis from this study are intended to provide a baseline data set which, if supplemented by sampling results collected under similar hydrologic conditions in future studies, could be used to observe trends in nitrate concentrations.

Record of Collection

October 2014 to present. Data report - https://doi.org/10.3133/sir20175054.

Collection Method

A groundwater monitoring network (Figure C.8), consisting of existing shallow wells from the Delaware Department of Agriculture's Pesticide network and USGS networks, has been established based on geochemical and land-use characteristics including:

- The presence of oxic aquifer conditions
- Geochemical indicators of agricultural land use based on major ion and nutrient concentrations
- Location of wells with respect to agricultural lands
- Depth of wells, and
- Available age dates for groundwater.

Analysis Methods

Samples have been collected for analysis of nutrients, major ions, and groundwater age and the results will be used to characterize groundwater quality and compare to existing groundwater quality data.

Data Location

U.S. Geological Survey, 5522 Research Park Drive, Baltimore, MD 21228

Management Goal

Results of nitrate analysis from this study are intended to provide a baseline data set which could be used to observe trends in nitrate concentrations.

Hypothesis and Test Statistics

To evaluate changes in nitrate concentrations between 1980 and 2014, statistical matched pair tests will be applied to new nitrate analyses from wells sampled during the study and historical analyses (where available).

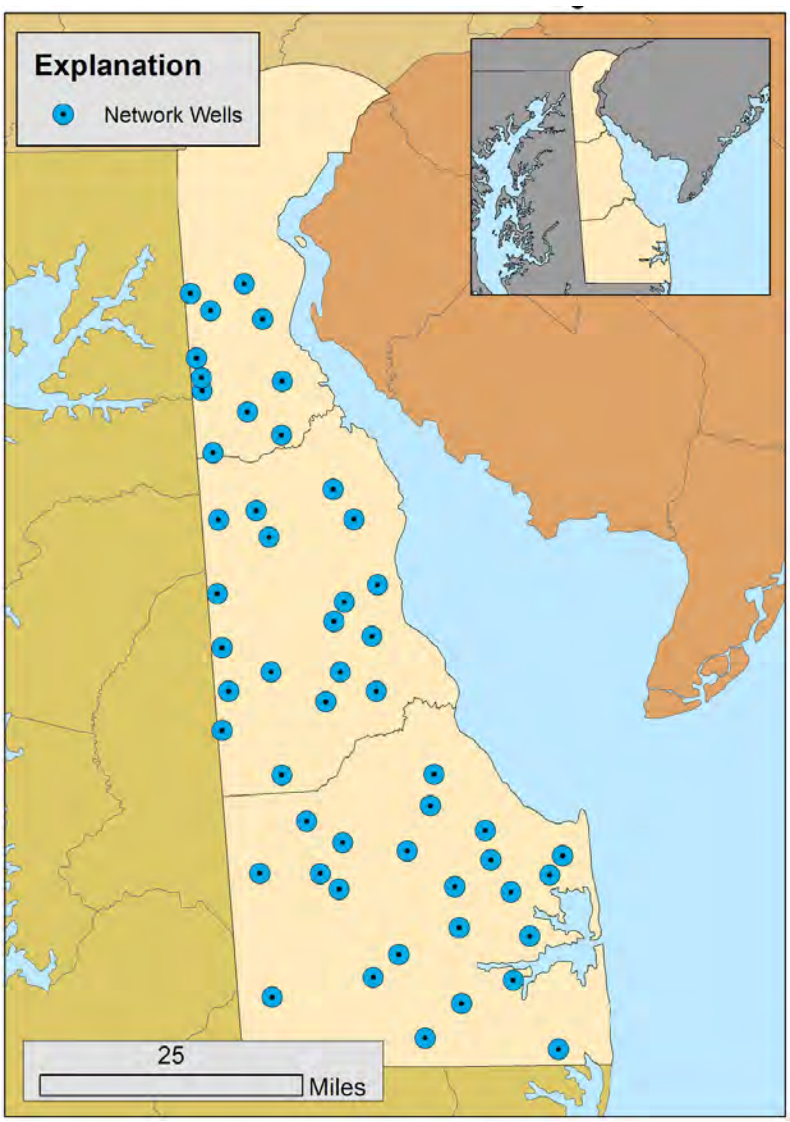


FIGURE C.8 - Map of wells included in the Delaware Agricultural Shallow Groundwater Monitoring Network.

C.2.3 PUBLIC SUPPLY WELLS

Description/Objective(s)

Groundwater is the primary source of drinking water in the Inland Bays watershed. Although the Clean Water Act focuses primarily on the quality of navigable [surface] waters, Section 106(e) requires that groundwater quality be reported "…to the extent practicable." Thus, along with the biannual Combined 305(b) Report and 303(d) List developed for Delaware, a concurrent 305(b) Groundwater-Quality Assessment Based on Public-Well Data report is produced. The primary purpose of this report is to summarize and report raw or apparently raw groundwater-quality data collected from public water-supply.

Per U.S. EPA guidance, data are evaluated with respect to hydrogeologic setting and water-quality criteria where possible. The scope is limited to available data obtained from two primary sources: the Department of Health and Social Services (DHSS) Safe Drinking Water Information System (SDWIS) database and DNREC's Source Water Assessment and Protection Program (SWAPP) database. These databases are supplemented with data collected by Tidewater Utilities, Inc.

Responsible Organization and Contact

DNREC Division of Water, Water Supply Section, Groundwater Protection Branch

Contact: Matthew Grabowski, Branch Manager
Matthew.Grabowski@delaware.gov 302-739-9945

Data Collection Cost

Not available.

Data Use

Biannual reporting on ambient groundwater quality in compliance with the Clean Water Act.

Record of Collection

2001 to present.

Collection Method

Groundwater quality is assessed based on pre-existing information stored in the SDWIS and SWAPP databases. Queries extract SDWIS records of raw or apparently raw groundwater-quality data collected from public water-supply systems during the reporting period. For the most recent (2016) assessment, supplemental groundwater-quality data for 90 public wells were obtained from a private water utility, Tidewater Utilities, Inc. The records include well details such as DNREC ID, depth, geographic coordinates, geologic formation, aquifer, and aquifer type.

Analysis Methods

Access is used to link and extract data from SDWIS and the SWAPP databases. For wells with more than one analysis of a given analyte, results are averaged. Analytes not detected above laboratory quantitation limits ("nondetects") are treated as zeros in all calculations.

Results are evaluated with respect to Primary Maximum Contaminant Levels (PMCLs), Secondary Maximum Contaminant Levels (SMCLs), and Health Advisories (HAs) for public water-supply systems. Because only raw or apparently raw groundwater-quality data are evaluated, the results may not be representative of finished or treated water delivered to consumers. Therefore, an exceedance of a drinking-water standard does not necessarily indicate that a public water-supply system is not in compliance.

Data Location

DNREC's Source Water Assessment and Protection Program (SWAPP) database.

Hypothesis and Test Statistics

Where possible, data are evaluated with respect to aquifer type (i.e., unconfined, confined, semi-confined, fractured-rock, or karst). Some data also are evaluated with respect to sample depth. Evaluation of trends (e.g., concentration vs. depth) in this assessment are qualitative and not statistically derived. ArcMap is used for the spatial analysis of groundwater data. Tabulated statistics are the result Excel calculations. Golden Software, Inc.'s Grapher version 11 is used to construct percentile diagrams. Values plot as outliers on percentile diagrams if either of the following criteria are met:

$$\text{Value} < QL - 1.5 \times IQR \quad \text{or} \quad \text{Value} > QU + 1.5 \times IQR$$

Where:

IQR is the interquartile range (i.e., the difference between the 75th and 25th percentiles)
QL is the lower quartile or 25th percentile (i.e, the bottom of the box in Figure 4)
QU is the upper quartile or 75th percentile (i.e., the top of the box in Figure 4)

Differences between tabulated statistics and corresponding percentile diagrams are the result of differences in the computational methods of Excel and Grapher.

C.3 MONITORING OF WASTEWATER

C.3.1. POINT SOURCE WASTEWATER DISCHARGES

Description/Objective(s)

Point source discharges directly to surface water are regulated under the National Pollutant Discharge Elimination Systems (NPDES) Permits Program. Monitoring of these discharges is required by law.

The NPDES Program controls point source discharges to surface waters and land, respectively, by means of a permit which establishes the parameters, limits, schedules, and conditions for each discharge. Also included in this program are the compliance/monitoring reports prepared by the permittee; the surveillance, sampling and inspection of facilities; and an enforcement element. Limits are established based on minimum technology-based standards set pursuant to federal and State laws and regulations. More restrictive controls may be established, if deemed necessary, to meet surface water quality standards.

At this time, there are two point source wastewater facilities discharging to the Inland Bays: the City of Lewes WWTP (discharging to the Lewes-Rehoboth Canal), and the Allen Harim facility near Millsboro (discharging to Wharton Branch). The City of Lewes discharges only 2.5% of its effluent to the Inland Bays. The City of Rehoboth Beach WWTP, which formerly discharged to Rehoboth Bay, now has an ocean discharge.

Responsible Organization and Contact

The DNREC Division of Water, Surface Water Discharges Section

Contact Bryan Ashby, Section Manager, Surface Water
(302) 739-9946
Bryan.Ashby@delaware.gov

Data Collection Cost

The costs of monitoring and reporting of results are borne by the permitted facilities. Funding sources for DNREC operations include Federal Section 106 and 205(g) excess funds, as well as State funding and permit fees. Total cost is not available.

Data Use

Discharge monitoring data are used to ensure that point source discharges into the Bays and tributaries of any pollutant, or combination of pollutants, meet all the applicable requirements under Clean Water Act Sections 301, 302, 306, 307, 308 and 403.

Record of Collection

Varies by permitted facility.

Collection Method

The effluent limitations, frequency of monitoring, parameters tested, and other special conditions vary between the individual facilities according to the requirements specified within their permits. Requirements may also vary between individual outfalls within a given facility. The permits are valid for five years but may be administratively extended.

All of the discharge facilities monitor flow, and eutrophication indicators such as biological oxygen demand, total suspended solids, total phosphorus, total nitrogen, pH and dissolved oxygen. Some facilities also monitor fractions of phosphorus and nitrogen. Information concerning collection frequency and the type of samples collected is found in the excerpts from the permits of individual discharge facilities.

Analysis Methods

Each discharge facility and the contractors which they select to provide monitoring and laboratory services must adhere to all the USEPA-approved Methodology and Quality Assurance requirements specified within the permit. Delaware requires NPDES and Land Treatment permit holders to maintain records of all information resulting from any monitoring activities that are required in their permit.

Data Location

Previously data were accessible through the Delaware Environmental Navigator; however, data must now be requested directly through DNREC staff.

Management Goal

The data generated via NPDES monitoring also are used to calibrate and run the point source pollution component of the Hydrodynamic and Water Quality Model. These results determine the progress toward meeting the goals that were set by the TMDL for the Inland Bays of reducing loads of point source nitrogen by 10-15 percent and point source phosphorus by 60 percent.

C.3.2 LAND APPLICATION OF WASTEWATER

Description/Objective(s)

Land application of wastewater (spray irrigation or rapid infiltration basins) is increasingly being used within the Inland Bays watershed in lieu of point source discharges. This treatment approach uses the soil and terrestrial vegetation as a filter and storage system for wastewater constituents such as nutrients and bacteria.

Since land application has the potential to impact surface waters of the State, the Division of Water Resources, Ground Water Discharges Section, is responsible for facilitating and overseeing this activity. Land application facilities, like their NPDES counterparts, operate under a permit which establishes the parameters, limits, schedules, and conditions for each facility.

DNREC also requires compliance/monitoring reports prepared by the permittee; the surveillance, sampling and inspection of facilities; and an enforcement element. The primary objective of this monitoring is to ensure compliance with permit conditions.

Responsible Organization and Contact

The DNREC Ground Water Discharges Section, Large Systems Branch, reviews and approves spray irrigation wastewater systems, onsite wastewater treatment and disposal systems with daily flows greater than 2,500 gallons per day, Experimental/Alternative Technologies, Advanced Treatment Units, underground injection wells, and other means associated with land application wastewater treatment.

Contact: Ping Wang, Section Manager
Ping.Wang2@delaware.gov, 302-739-9948

Data Collection Cost

The costs of monitoring and reporting of results are borne by the permitted facilities. Funding sources for DNREC operations include Federal Section 106 and 205(g) excess funds, as well as State funding and permit fees. Total cost is not available.

Data Use

Monitoring data are used to verify that the wastewater treatment process for a facility is functioning properly and that the land application activity does not adversely impact surface and groundwater quality in the area, or soils under the site.

The loading route to the Bays of constituents contributed by Land Treatment facilities is considered to be nonpoint source. Presently, nonpoint source loadings to the Bays are estimated using concentration and flow data collected at the tidal/nontidal interface. The land application monitoring data has not been used to estimate the percentage of the total nonpoint source load that is attributable to these facilities.

Record of Collection

Varies by permitted facility.

Collection Method

Following treatment at a wastewater treatment facility, the reclaimed water is tested for a variety of parameters to ensure that the reclaimed water meets appropriate treatment standards. Then, when weather conditions are suitable for irrigation, the reclaimed water is applied to the field at agronomic rates. Agronomic loading rates are determined by the nutrient levels of the reclaimed water and the nutrient needs of the crops being grown and should be incorporated into the farm managers Nutrient Management Plan.

The effluent limitations, frequency of monitoring, parameters tested, and other special conditions vary between the individual facilities according to the requirements specified within their permits. This specific information is available for each facility within Attachment 8. Land Treatment permits also require groundwater and soil monitoring, in addition to the limitations an individual permit excerpts (Attachment 8). For one facility (the Town of Georgetown) surface water monitoring is also required in two adjacent streams. The parameters typically monitored in sprayed effluent are similar to NPDES requirements, including eutrophication indicators such as total suspended solids, biological oxygen demand, total phosphorus, total nitrogen (and fractions of nitrogen), pH and dissolved oxygen. Groundwater monitoring includes measurement of water table depth and constituents that are highly soluble and do not readily adhere to soil (under and adjacent to the spray site). Soil monitoring is done to ensure that normal soil functioning is maintained so that expected levels of effluent treatment can occur.

Analysis Methods

Each discharge facility and the contractors which they select to provide monitoring and laboratory services must adhere to all the USEPA-approved Methodology and Quality Assurance requirements specified within the permit. Delaware requires NPDES and Land Treatment permit holders to maintain records of all information resulting from any monitoring activities that are required in their permit.

Data Location

Data must be requested from the Groundwater Discharges Section at DNREC.

Management Goal

Limits are established based on minimum technology-based standards set pursuant to federal and State laws and regulations. More restrictive controls may be established, if deemed necessary, to meet Federal or State drinking water quality standards. If background conditions exceed the drinking water standards, then there shall be no concentration increase above the background levels.

C.4 Monitoring of ATMOSPHERIC DEPOSITION

C.4.1 ATMOSPHERIC DEPOSITION OF NUTRIENTS

Description/Objective(s)

Nutrients are deposited from the atmosphere directly into the Bays during both wet and dry weather. Deposition of nitrogen is the most significant.

Data from the National Atmospheric Deposition Program/Atmospheric Integrated Research Monitoring Network (NADP/AIRMoN) site at Cape Henlopen, available through August 2017, can be used to estimate wet deposition rates (fluxes associated with rainfall) of nitrate (NO_3^-), ammonium (NH_4^+), and phosphate (PO_4^{3}) to the open waters and the tidal marshes of the Inland Bays on a daily basis. These daily measurements may be summed to determine wet deposition over other time periods.

There are other species in wet deposition, and atmospheric inputs due to another set of chemical and physical processes, collectively described as dry deposition, that deliver N and P to land and water surfaces in the absence of rainfall. These species and processes may also contribute significantly to nutrient delivery to the Bays and their watersheds.

At present, the Cape Henlopen site is no longer an active site for the Inland Bays watershed. The Assateague Island NTN site is the next closest active site, but it only measures the nitrogenous components in precipitation. A correlation analysis will be performed for historical data from the Lewes site and the Assateague site to assess how this choice may affect deposition estimates. This will also be done for P (and N) at the Pennsylvania State University (PA15) site. This site may not be representative, however, due to its proximity to fossil fuel burning power plant sources.

Procedures to calculate the wet and dry deposition rates of N and P species directly to the Inland Bays are described in Ullman et al. (2010).

Responsible Organization and Contact

University of Delaware, College of Earth, Ocean, and Environment

Contact: Andrew Wozniak
awozniak@udel.edu, 302-645-4318

Data Collection Cost

Not available.

Data Use

Data are used to calculate the wet and dry deposition rates of nitrogen and phosphorus species to open waters and contiguous marshes in the Inland Bays, and elsewhere in Delaware for use in mass balance studies.

Record of Collection

1993 to 2017 for data from the Lewes station.

Collection Method

Samples are collected daily within 24 hours of the start of precipitation, often providing data for all or part of a single storm. The AIRMoN sites are equipped with a wet-only deposition collector and precipitation gage. Each site also has a National Weather Service standard gage for reporting storm total precipitation.

Samples are refrigerated after collection and are sent in chilled insulated shipping containers to the Central Analytical Laboratory (CAL) at the Illinois State Water Survey, where they are kept refrigerated until analysis.

Analysis Methods

The CAL measures free acidity (H^+ as pH), conductance, calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), and ammonium (NH_4^+). The CAL also measures orthophosphate, but only for quality assurance as an indicator of sample contamination.

The CAL reviews field and laboratory data for completeness and accuracy, and flags samples that were mishandled, compromised by precipitation collector failures, or grossly contaminated. The CAL delivers all data and information to the NADP Program Office, which applies a final set of checks and resolves remaining discrepancies. Data then are made available on the NADP Web site.

Methods to calculate N and P deposition are described in detail in Ullman et al., 2010.

Data Location

Data from the Lewes NADP/AIRMoN site (DE02; located in Cape Henlopen State Park, Lewes), Assateague, Island NTN, and from Penn State NADP/AIRMoN site (PA15) located in Centre PA are accessed through the main NADP/AIRMoN website at http://nadp.sws.uiuc.edu/airmon/ or from the AIRMoN Data Retrieval Site at http://nadp.sws.uiuc.edu/AIRMoN/. Additional information about the sites and data request forms, can be found there.

Management Goal

Despite significant uncertainties in the absolute values of the deposition rates calculated (Ullman et al., 2010), temporal trends may still be revealed. Based on a comparison with samples collected simultaneously on the north shore Indian River Bay, it is understood that extrapolating from Cape Henlopen rain data to the entire Inland Bays represents a conservative (minimum) estimate of wet N deposition rates for this system.

C.5 MONITORING OF WETLANDS

3.5.1. STATE WETLANDS MONITORING AND ASSESSMENT PROGRAM

Description/Objective(s)

The goal of DNREC's Wetland Monitoring and Assessment Program (WMAP) is to assess the condition, function, and services of wetlands in the state, and to integrate the latest research to understand the connection between the metrics and measures that are evaluated and the actual processes and implications on services that wetlands provide. This information is used to inform the citizens of Delaware and to improve existing education, restoration, protection, and land use planning efforts. The Delaware Wetland Monitoring Strategy (Delaware Department of Natural Resources and Environmental Control, 2011) guides the WMAP's efforts in the areas of protocol development, wetland monitoring and assessment activities, research, and application of information. The goals and objectives outlined in the monitoring strategy support many of the goals of the Delaware Wetland Conservation Strategy (Delaware Department of Natural Resources and Environmental Control, 2008).

The Program works closely with other states through the Environmental Protection Agency's Mid-Atlantic Wetlands Program to establish and conduct research methods and share information.

Objectives include:

- Develop scientifically valid wetland assessment methods.
- Assess the current condition of wetlands by watershed and identify major stressors that are impacting wetlands.
- Perform research to improve our understanding of wetland functions, the impact of stressors, and the ecosystem services provided by wetlands to humans and the environment.
- Evaluate the performance of wetland restoration and other compensatory wetland mitigation in replacing wetland acreage and function.

- Educate other state agencies, conservation partners, and the general public to improve efforts to protect and restore wetlands.
- Integrate monitoring and assessment data into watershed restoration plans and other conservation strategies.
- Meet requirements of the Clean Water Act.

The watersheds of the state were prioritized for wetlands monitoring based largely on the TMDL implementation schedule (Figure C.9). The intent of the state is to monitor these watersheds using a rotating basin approach once an initial assessment of the wetlands within each watershed has been performed. Monitoring of nontidal wetlands in the Inland Bays occurred in 2005-2006; tidal wetlands were monitored in 2008 (Jacobs et al., 2008; Rogerson et al., 2008).

Responsible Organization and Contact

DNREC Wetland Monitoring and Assessment Program

Contact: Alison Rogerson
Alison.Rogerson@delaware.gov, (302) 739-9939

Data Collection Cost

Not available.

Data Use

Final reports documenting the condition of tidal and nontidal wetlands in the Inland Bays were completed in 2009 (Jacobs et al., 2009; Rogerson et al., 2009). The data obtained by DNREC from assessing wetlands is being used to design wetland restoration plans for watersheds and to better understand how certain land use decisions affect the health of our wetlands.

Record of Collection (Inland Bays)

Nontidal wetlands: 2005-2006
Tidal wetlands: 2008

Collection and Analysis Methods

Nontidal riverine sites and flats in the Inland Bays are surveyed using a combination of comprehensive and rapid assessment procedures:

DECAP - The Delaware Comprehensive Assessment Procedure is a comprehensive assessment method for collecting data that can be used to determine the condition of a wetland site relative to reference condition (closest to natural and undisturbed). DECAP can be used to assess flat, riverine and depressional nontidal wetland subclasses in the Coastal Plain of Delaware and Maryland. The comprehensive procedure can produce scores for certain wetland functions (services), including habitat, plants, hydrology, buffers, and soil cycling.

DERAP - The Delaware Rapid Assessment Procedure is a rapid field method for determining the general condition of a wetland site. The DERAP can be used in flat, riverine, and depressional wetlands in Delaware and Maryland.

Tidal wetland surveys use a rapid assessment protocol:

MidTRAM - The MidAtlantic Tidal Rapid Assessment Method is a rapid protocol for assessing the condition of estuarine emergent tidal wetlands in Delaware, Maryland, and Virginia. The MidTRAM is validated with intensive biological data based on the bird community and biomass levels.

Data Location

Data are managed and retained by the DNREC Wetland Monitoring and Assessment Program. All data are entered into an Access computer database that has been developed to consistently store wetland assessment data. Data are now available online through the Delaware Open Data Portal (https://data.delaware.gov/).

Management Goal

DNREC's goal is to achieve an annual net gain in wetland acreage and condition. The *Delaware Wetland Conservation Strategy* highlights recommends approaches with measurable outcomes for enhancing and improving wetland protection.

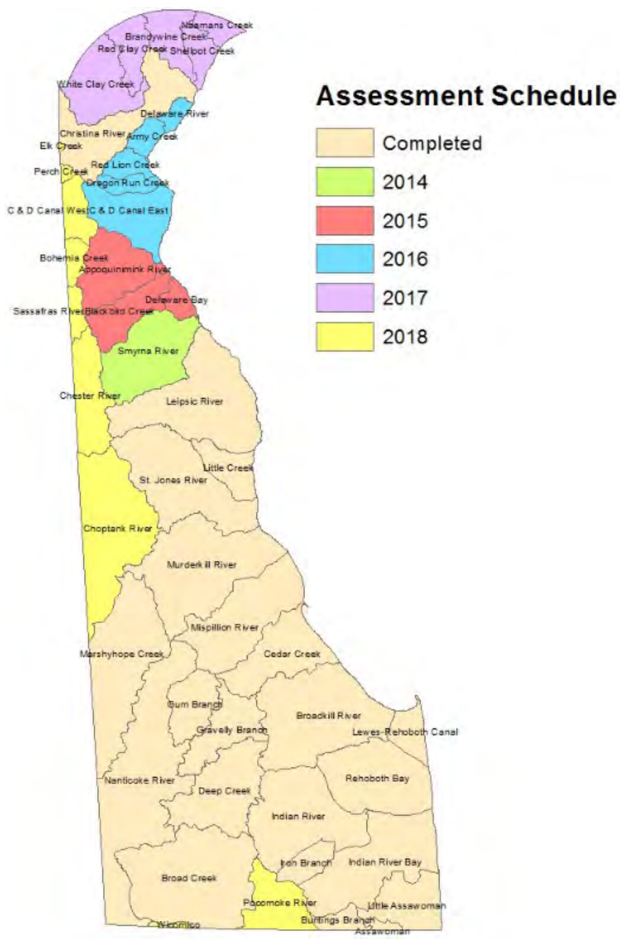


FIGURE C.9 - DNREC's current schedule for statewide wetland assessments.

C.5.2 LONG-TERM SALT MARSH MONITORING

Description/Objective(s)

Three representative salt marshes in the Inland Bays were each instrumented with triplicate Sediment Elevation Tables (SETs) in order to provide high intensity baseline information on sediment elevation changes in salt marshes of the Inland Bays. Locations of the SETs are provided in Figure C.10. In addition, one marsh (Angola Neck) was outfitted with continuous water level loggers to determine water depth at marsh surface locations. These data can be used to assess whether Inland Bays marshes are keeping pace with sea level rise, and can provide information on potential causal or influential factors of sudden wetland dieback events.

Responsible Organization and Contact

The Delaware Center for the Inland Bays is responsible for this monitoring program in the watershed.

Contact: Andrew McGowan, Environmental Scientist
environment@inlandbays.org, 302-226-8105, x112

Data Collection Cost

Costs for each SET platform are roughly $900 for initial installation, not including labor costs, and $50 annually for maintenance. The SET arm costs $2,000 but can be used at all sites because it is portable. Water loggers cost approximately $2,200 each.

Labor cost is roughly $5,000 a year to monitor the SET tables and water loggers.

Data Use

The information will be used to better understand the variation among processes that result in fringing marsh maintenance or conversion to open water, and will be included in the development of saltmarsh restoration and protection strategies for the watershed.

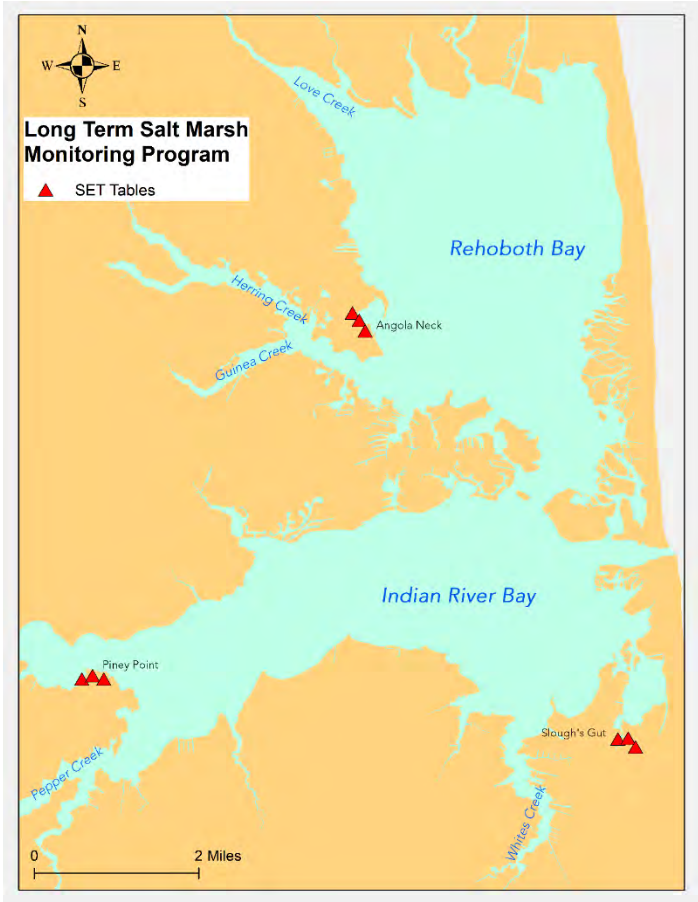


FIGURE C.10 - Locations of sediment elevation tables in the Inland Bays.

Record of Collection

Angola Neck: 2008 – present
Piney Point: 2010 – present
Slough's Gut: 2011 - present

Collection Method

Data are collected twice annually, within 5 days of the full moon in October and April. Each SET table has both a deep SET, which measures overall marsh height change, and a shallow SET, which measures changes in the marsh height as a result of both surface accretion/erosion, and changes in the root zone. Sampling is conducted by attaching the SET arm to a SET table and placing nine SET pins into the corresponding holes on the SET arm. The pins are gently lowered to the marsh surface, and the height each pin extends above the SET arm is recorded for all nine pins to the nearest millimeter. The pins are then removed, the SET arm is rotated 90 degrees and the process if repeated until all four directions are sampled. Both the shallow SET and the deep SET are measured in this way. Additionally, each SET table has three feldspar clay accretion plots, which are sampled by cutting away a plug with a knife and measuring the height of sediment above the top of the clay layer at three different locations on the plug.

Water level data are downloaded from each logger and corrected for barometric pressure using Win-Situ software.

Analysis Methods

Data are analyzed to determine if each SET platform is keeping pace with the current rate of sea level rise by first determining the slope of the change in height for each individual pin at each direction at each SET over time with a linear regression (e.g., 9 slopes for direction A at Angola Neck site 1, one for each pin, then 9 slopes for direction B at Angola Neck site 1, one for each pin). Only the deep SET measurements are used as these reflect all changes in marsh height, as opposed to the shallow SET which only reflects root zone and surface layer changes. The coefficient of each slope is then averaged together for all 4 directions at each SET location (e.g., 36 slope coefficients averaged at Angola Neck site 1) to determine the average rate of change at a particular SET location. The standard error is also calculated. These values are compared to the mean sea level rise rate from the Lewes DE NOAA station. This follows the protocol recommended by the National Park Service.

To assess what specific processes are driving the changes in marsh height, each SET table is analyzed separately using the shallow SET readings, the deep SET readings, and accretion data. As described previously, a slope is calculated for each pin at each position for each SET for the shallow and deep platforms. The slopes are averaged together at each SET to determine the overall slope for a particular SET table. This procedure is performed for both the deep SET readings and the shallow SET readings. The shallow SET readings capture changes occurring only in the root zone and surface layer, or roughly the first 0.6 m of the marsh surface. These changes include root zone growth, compaction, and accretion. By subtracting the shallow SET slope from the corresponding deep SET slope, the changes occurring below the 0.6 m root zone are separated from the overall deep SET measurements. In this way, we are able to determine what is occurring below the root zone.

To determine accretion rate, the nine accretion measurements are averaged together to get the average accretion height. If the height reading is the first reading since laying down a new layer of clay, this height is divided by the number of days since the clay was laid onto the marsh. If the height value is not the first measurement since laying the clay onto the marsh, the height value is subtracted from the previous sampling event's average height value and divided by the number of days since the last measurement. This is done to prevent previous accretion events from influencing the current measurements. Each average change in height is averaged together to determine the overall average accretion rate. The average accretion rate for each SET table is then subtracted from the shallow slope values to determine the changes occurring solely in the root zone.

Data Location

Located at the Delaware Center for the Inland Bays, available upon request.

Management Goal

Inform decision makers on how salt marshes in the Inland Bays are faring with respect to sea level rise, and what processes are responsible for maintenance of marsh elevation or conversion to open water.

Hypothesis and Test Statistics

Elevation at each SET table and each marsh as a whole is compared to current sea level rise rates. If changes rates at the SET are lower than the sea level rise rates the SET Is considered to not keep pace with sea level rise.

C.6 MONITORING OF LIVING RESOURCES AND HABITATS

C.6.1 NATIONAL AQUATIC RESOURCE SURVEYS

Description/Objective(s)

The National Aquatic Resource Surveys (NARS) are statistical surveys designed to assess the status of and changes in quality of the nation's coastal waters, lakes and reservoirs, rivers and streams, and wetlands. Using sample sites selected at random, these surveys provide a snapshot of the overall condition of the nation's water. Because the surveys use standardized field and lab methods, results can be compared from different parts of the country and between years. EPA works with state, tribal and federal partners to design and implement the NARS.

The surveys are designed to answer questions such as:

- What percent of waters support healthy ecosystems and recreation?
- What are the most common water quality problems?
- Is water quality improving or getting worse?
- Are investments in improving water quality focused appropriately?

These surveys are providing nationally consistent water quality information. Additionally, the national surveys are helping to build stronger water quality monitoring programs across the country by fostering collaboration on new methods, new indicators and new research.

The NARS are made up of four individual surveys that are implemented on a rotating basis. Stations in the Inland Bays watershed during previous field seasons are shown in Figure C.11. A summary of the indicators used in each survey is provided in Table C.10.

- National Coastal Condition Assessment (NCCA)

    Goals: (1) What percent of the Nation's coastal waters are in good, fair, and poor condition for key indicators of water quality, ecological health, and recreation? (2) What is the relative importance of key stressors such as nutrients and contaminated sediments?

    Design: The NCCA sampling is comprised of coastal waters extending from the shoreline to the nearshore boundary of the open water of the oceans and Great Lakes. The assessment is limited to the fringing, shallow band of coastal waters most heavily used by humans and most vulnerable to activities within adjacent coastal watersheds.

- National Lakes Assessment (NLA)

    Goals: (1) What is the current biological, chemical, physical and recreational condition of lakes? (2) Is the condition of lakes getting better, worse, or staying the same over time? (3) Which environmental stressors are most associated with degraded biological condition in lakes?

    Design: The NLA sampling is comprised of natural lakes, ponds, and reservoirs across the lower 48 states. Starting with the NLA2012, to be included in the survey, a water body had to be a natural or man-made freshwater lake, pond or reservoir, greater than 2.47 acres (1 hectares), at least 3.3 feet (1 meter) deep, and with a minimum quarter acre (0.1 hectare) of open water. Lakes had a minimum retention time of 1 week. The Great Lakes and the Great Salt Lake were not included in the survey, nor were commercial treatment and/or disposal ponds, brackish lakes, or ephemeral lakes. The NLA 2007 assessed only those lakes greater than 10 acres (4 hectares) in size.

- National Rivers and Streams Assessment (NRSA)

    Goals: The goals of the NRSA are to determine the extent to which rivers and streams support a healthy biological condition and the extent of major stressors that affect them. The survey supports a longer-term goal: to determine whether our rivers and streams are getting cleaner and how we might best invest in protecting and restoring them. Additionally, the survey compares the condition of streams to those of an earlier study that focused on small streams (the Wadeable Streams Assessment or WSA) conducted by the U.S. Environmental Protection Agency and its partners in 2004.

Design: The NRSA assesses the ecological condition of the full range of flowing waters in the conterminous U.S. (lower 48 states). The target population includes the Great Rivers (such as the Mississippi and the Missouri), small perennial streams, and urban and non-urban rivers. Run-of-the-river ponds and pools are included, along with tidally influenced streams and rivers up to the leading edge of dilute sea water.

- National Wetland Condition Assessment (NWCA)

  Goals: The NWCA is designed to answer basic questions about the extent to which U.S. wetlands support healthy ecological conditions and the prevalence of key stressors at the national and regional scale. It is intended to complement and build upon the achievements of the U.S. Fish and Wildlife Service Wetland Status and Trends Program, which characterizes changes in wetland acreage across the conterminous United States. Paired together, these two efforts provide government agencies, wetland scientists, and the public with comparable, scientifically defensible information documenting the current status and, ultimately, trends in both wetland quantity (i.e., area) and quality (i.e., ecological condition).

  Design: The survey design is developed in partnership with the US FWS Wetlands Status and Trends Program. The NWCA sampling is comprised of all wetlands of the conterminous U.S. The survey encompasses both tidal and nontidal wetlands ranging from the expansive marshes of our coasts to the forested swamps, meadows, and waterfowl-rich prairie potholes of the interior plains.

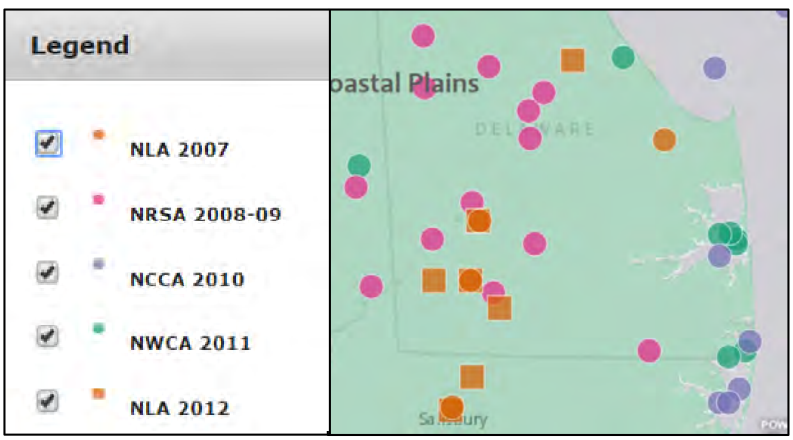


FIGURE C.11 – Southern Delaware sites at which NARS data were collected for published reports to date.

Responsible Organization and Contact

U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds
National Aquatic Resource Surveys
1200 Pennsylvania Avenue, NW (Mail code 4503T), Washington, DC 20460
https://www.epa.gov/national-aquatic-resource-surveys

Data in Delaware are collected by DNREC Environmental Laboratory Section.
Contact: Christopher Main, 302-739-9942

Data Collection Cost

Not available.

Data Use

The U.S. EPA publishes reports for each survey. In addition, the data are publicly available for use in research.

Record of Collection

NCCA: The first NCCA sampling field season was conducted in 2010. The most recent field season was conducted in 2015.

NLA: NLA field season sampling is conducted every five years. Previous field seasons were conducted in 2007 and 2012.

NRSA: NRSA sampling field seasons were conducted in 2008-2009 and 2013-2014. The next field season will be conducted in 2018-2019.

NWCA: The 2011 National Wetland Condition Assessment (NWCA) was the first sampling season. The second field sampling season was conducted in 2016.

Collection Method

Samples for Delaware sites are collected by the DNREC Division of Water, Environmental Laboratory Section.

Field Operations Manuals are available on the EPA website: https://www.epa.gov/national-aquatic-resource-surveys/manuals-used-national-aquatic-resource-surveys.

Analysis Methods

Field, laboratory, quality assurance and site evaluation manuals are available on the EPA website: https://www.epa.gov/national-aquatic-resource-surveys/manuals-used-national-aquatic-resource-surveys.

Data Location

NARS data are available for download on the EPA website: https://www.epa.gov/national-aquatic-resource-surveys/data-national-aquatic-resource-surveys.

Management Goals

Within each survey, the goals are:

- For each indicator of condition, estimate the proportion of the nation's waters in degraded condition within a ± 5% margin of error and with 95% confidence.
- For each indicator of condition, estimate the proportion of waters or resources in a specific ecoregion that fall below the designated threshold for good conditions for selected measures within a ± 15% margin of error and with 95% confidence.
- Estimate the proportion of waters (± 7%) that have changed condition classes for selected measures with 95% confidence.

Hypothesis and Test Statistics

These are detailed in the respective Quality Assurance Project Plans, available at https://www.epa.gov/national-aquatic-resource-surveys/manuals-used-national-aquatic-resource-surveys.

TABLE C.10 - Indicators Evaluated for the National Aquatic Resource Surveys.

BIOLOGICAL	CHEMICAL/TOXICITY	PHYSICAL	RECREATIONAL/HUMAN HEALTH
National Coastal Condition Assessment (NCCA)			
• Benthic macroinvertebrates • Chlorophyll a • Ecological fish tissue contaminants	• Dissolved oxygen • Nitrogen • Phosphorus • Salinity • Sediment contaminants • Sediment toxicity	• Water clarity	• Human health fish tissue contaminants* (Great Lakes only)
National Lakes Assessment (NLA)			
• Benthic macroinvertebrates • Chlorophyll a • Zooplankton	• Acidification • Atrazine • Dissolved oxygen • Nitrogen • Phosphorus • Sediment mercury	• Drawdown • Human disturbance • Lakeshore habitat • Physical habitat complexity • Shallow water habitat	• Algal toxin (microcystin) • Cyanobacteria
National Rivers and Streams Assessment (NRSA)			
• Benthic macroinvertebrates • Periphyton (algae) • Fish community	• Phosphorus • Nitrogen • Salinity • Acidity	• Streambed sediments • In-stream fish habitat • Riparian vegetative cover • Riparian disturbance	• Enterococci (fecal indicator) • Mercury in fish tissue
National Wetland Condition Assessment (NWCA)			
• Benthic macroinvertebrates • Chlorophyll a • Fish assemblage • Fish tissue contaminants • Macrophytes • Phytoplankton • Sediment diatoms • Wetland vegetation (introduced species) • Wetland vegetation (plant community) • Zooplankton	• Acidification • Atrazine • Conductivity • Dissolved oxygen • Nitrogen • Phosphorus • Salinity • Sediment enzymes • Sediment mercury • Soil chemistry	• Lakeshore habitat/riparian vegetative cover • Human disturbance • Physical habitat complexity • Shallow water habitat/in-stream fish habitat • Streambed sediments • Water clarity	• Algal toxins (microcystin) • Cyanobacteria • Enterococci • Fish tissue contaminants

C.6.2. STATEWIDE VEGETATION COMMUNITY & LAND COVER MAPPING PROJECT

Description/Objective(s)

The Delaware Statewide Vegetation Community Mapping Project seeks to map all of the vegetation communities and land covers present in the state of Delaware. Delineations are drawn to the finest extent possible (no defined minimum mapping unit) using aerial imagery analysis, field observations, and data obtained from others. Approximately 10-20% of the state has been field checked. The project began with a map of the Brandywine Creek and was extended to include the entire state of Delaware.

Responsible Organization and Contact

DNREC Wildlife Species Conservation and Research Program

Contact: Joseph Rogerson, Environmental Program Manager
joseph.rogerson@delaware.gov, 302-735-3600

Data Collection Cost

Not available.

Data Use

Currently, the maps are used for determining the rarity and status of vegetation communities in Delaware, environmental reviews, and management plans on public lands. These maps can be used as a baseline for sea level rise studies, climate change, and change over time studies from historical imagery.

Record of Collection

Historical analyses and maps of vegetation communities, land covers, and habitats have been published for the following areas in the Inland Bays:

- Thompson Island Nature Preserve (Coxe, 2011)
- Assawoman Wildlife Area (Coxe, 2012a)
- Delaware Seashore State Park (Coxe, 2012b)
- Fenwick Island State Park (Coxe, 2012c)
- Cape Henlopen State Park (Coxe, 2012d)
- James Farm Ecological Preserve (Coxe, 2013)

Collection Method

Field data is obtained primarily from environmental reviews and surveys of public lands in Delaware. Land covers are obtained from the same methods and impervious surfaces are from 2007 impervious surface layer, except for the Brandywine and Red Clay Creek watersheds which were digitized from 2002 aerial imagery. Vegetation communities are determined using the *Guide to Delaware Vegetation Communities* which is derived and linked to the National Vegetation Classification System (NVCS). The NVCS is a national effort by The Nature Conservancy and Natureserve to standardize the names and classification of vegetation communities in North America. Common names of the vegetation communities in Delaware are the same as those used in the NVCS.

Analysis Methods

All shapefiles for the Delaware Statewide Vegetation Community Map are organized by watershed. Each watershed file has a year after (i.e. 1997, 2002, or 2007) that signifies the imagery that the map is based on. About once a month a complete map will be produced which will be called Delaware Statewide Vegetation Community Map with the date after it.

Data can be used to map a particular vegetation community for a watershed, or to query how much acreage of a vegetation community is present in a watershed.

Data Location

DNREC Wildlife Species Conservation and Research Program, and the University of Delaware Water Resources Agency.

C.6.3 SEAWEED MONITORING

Description/Objective(s)

Small to medium amounts of macroalgae are healthy for estuarine systems. They provide habitat for blue crabs, as well as numerous species of fish, especially in the absence of seagrass beds. However, excess macroalgae can have the opposite effect by smothering benthic organisms and creating hypoxic zones particularly during the early summer mornings before photosynthetic activity resumes. In order to assess levels of macroalgae over time, particularly in response to efforts to reduce nutrient pollution to the Inland Bays, 12 locations in Rehoboth and Indian River Bay are monitored for macroalgae.

The objectives of this study are to see if macroalgae types, distribution, and density appear remarkably different than previously observed levels, and to assess the abundance and distribution of macroalgae over a full growing season in Indian River Bay and Rehoboth Bay. Furthermore, the rapid macroalgae sampling approach employed in this study can be investigated for its feasibility as a means for more regular monitoring of macroalgae abundance and distribution using citizen volunteers.

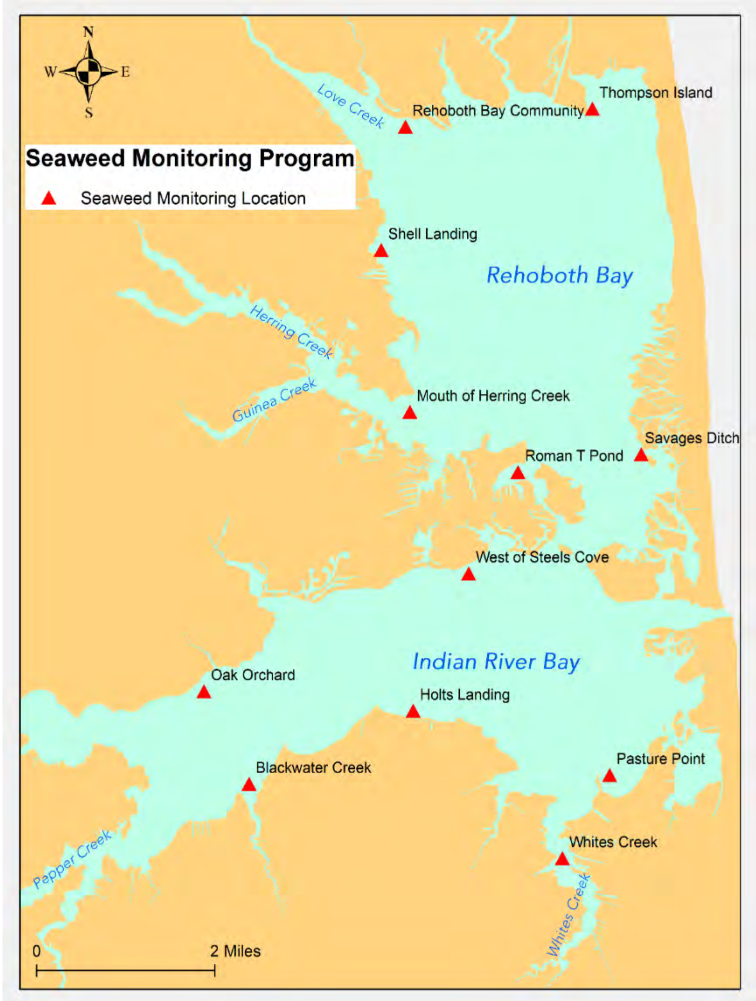


FIGURE C.12 - Map showing location of seaweed monitoring stations in Rehoboth and Indian River Bays.

Responsible Organization and Contact

The Delaware Center for the Inland Bays is responsible for this monitoring program beginning in the spring of 2017. Previous to this, DNREC Division of Water was in charge of the monitoring program.

Contact: Andrew McGowan, Environmental Scientist
environment@inlandbays.org, 302-226-8105, x112

Data Collection Cost

Roughly $2,000 for CIB staff time per year
Equipment: $100 in fuel and supplies

Data Use

Data are used to track macroalgae abundance over time, and to assess seasonal abundance and distribution.

Record of Collection

Original data collected by DNREC was been collected irregularly, with sampling occurring in 1999, 2009, 2011, and 2012. Currently DCIB staff sample monthly from May through September.

Collection Method

Macroalgal density is determined using a stainless steel grappling hook tossed off the windward side of a boat. Sampling occurs once a month at 12 sites from May through September (Figure C.12). The hook is 25 cm long, has a width of 24.3 cm with six tines spaced about 9 cm apart and is attached to a 10 m length of 0.95 cm diameter nylon line. The hook is tossed off the windward side of the boat and allowed to settle to the bottom, at which time the line is given five steady tugs and then the hook is hauled into the boat. It was determined that the five tugs result in the hook covering a distance across the bottom of about 3 to 4 m. Three tosses will constitute a single sample that will be placed into a sieve bucket graduated in liters. The bucket will then be shaken from side-to-side a few times to settle and uniformly distribute the algae.

Analysis Methods

The approximate amount of area covered by the grappling hook during the three tosses is 2.5 m. (3.5 meters per toss x width of hook, 0.24m x 3 tosses). The sample of algae collected is reported as liters of algae. Density is categorized as light (0 to 3 liters), moderate (4 to 7 liters) and heavy (> 8 liters). Dominant groups of macroalgae (e.g. Ulva, Gracilaria, and Agardhiella) are sorted while remaining non-dominant groups are lumped together. Relative percentages of the groups are determined visually.

Data Location

Located at the Delaware Center for the Inland Bays, available upon request.

Management Goal

Document the abundance of macroalgae in the Inland Bays over time, including seasonal patterns of abundance and distribution. Data generated through this program can be used to gauge the potential success of sea grass restoration in areas near sampling locations and can be used in conjunction with water quality measurements to gauge the success of nutrient pollution reduction efforts.

Hypothesis and Test Statistics

Abundance between sites as well as between years for macroalgae in general, along with each dominant group, can be compared using ANOVA or Kruskal Wallis tests ($\alpha = 0.05$).

C.6.4 COASTAL FINFISH ASSESSMENT SURVEY

Description/Objective(s)

The relative abundance and distribution of a number of recreationally important finfish species are assessed using trawl sampling in the Delaware Estuary and Delaware's Inland Bays (Indian River and Rehoboth Bays). The 16-foot trawl survey used in the Inland Bays is primarily intended to monitor juvenile fish abundance.

Responsible Organization and Contact

DNREC Division of Fish and Wildlife, Fisheries Section

Contact: Michael Greco
Michael.Greco@delaware.gov, 302-735-6780

Data Collection Cost

Not available.

Data Use

The indices generated from these surveys are used in the development of interstate fishery management plans and stock assessments. In particular, the surveys are used in the Weakfish (*Cynoscion regalis*), Striped Bass (*Morone saxatilis*), Bluefish (*Pomatomus saltatrix*), Atlantic Menhaden (*Brevoortia tyrannus*), Black Drum (*Pogonias cromis*) and Summer Flounder (*Paralichthys dentatus*) fishery management plans and stock assessments. In addition, data from the surveys are used in establishing time of year restrictions for beach replenishment and dredging. The CIB uses the data to develop fish abundance indicators.

The surveys also serve as platforms for providing specimens to researchers studying life history and biology of fishes. These surveys have provided samples for use in genetics, tissue contaminants, age and growth, food habits, reproduction, and many other studies.

Record of Collection

The Delaware Bay trawl surveys were expanded in 1986 to include monthly sampling (April to October) in the Indian River and Rehoboth Bays.

Collection Method

Sampling with a 16-foot semi-balloon otter trawl is conducted monthly from April through October at 12 fixed stations in the Inland Bays (Figure C.13).

Sampling at each station consists of a ten-minute trawl tow, typically made against the prevailing tide. Occasionally, tows less than ten minutes are made in cases of unforeseen gear conflicts, draft considerations, etc. In such cases, tows are required to be at least five minutes in duration to be considered valid. Catches from short tows are standardized to ten minutes.

The trawl is hauled over the stern and the catch emptied on a sorting table upon completion of each tow. Finfish were sorted by species and enumerated. A representative subsample of 30 specimens per species is measured for fork length to the nearest half centimeter; the remainder are enumerated. Surface temperature, salinity, and dissolved oxygen, tidal stage, weather conditions, water depth, and engine speed are recorded at the beginning of each tow.

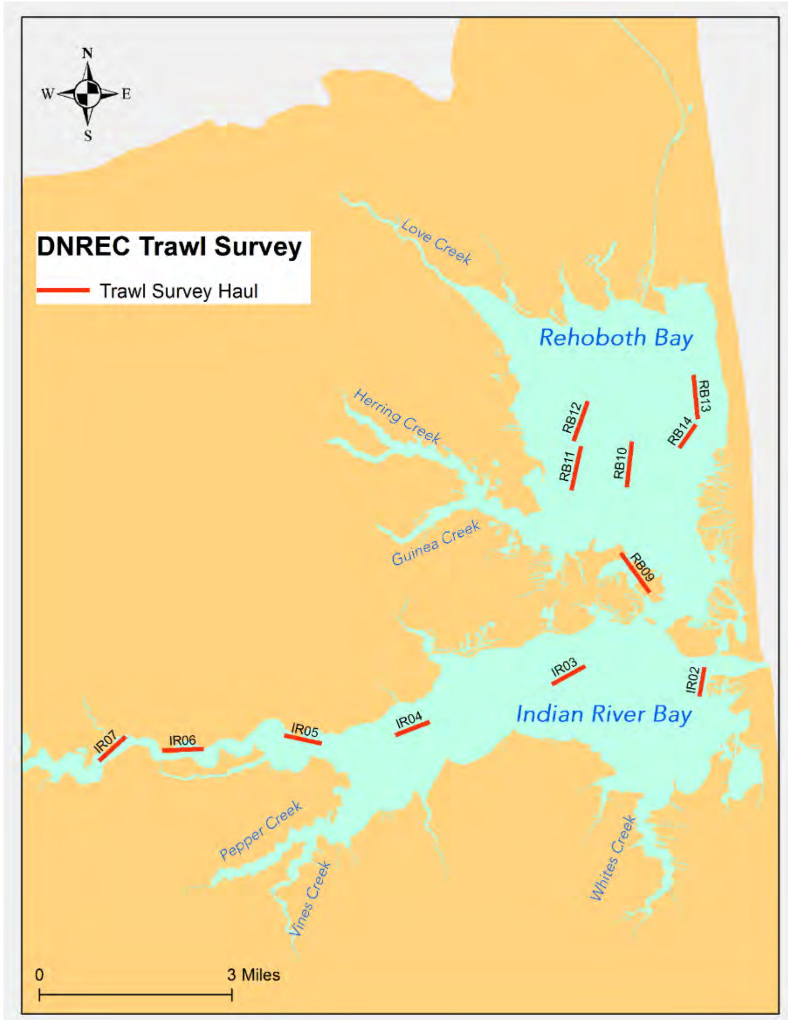


FIGURE C.13 - Map showing DNREC otter trawl survey locations in the Inland Bays.

Analysis Methods

Data analysis includes monthly and annual summaries of the catch including a listing of species collected, total number of each species taken, mean catch per tow, and standard deviations. Mean surface salinities and temperatures are calculated similarly by month, station or subarea. Annual young-of-the year index values are calculated, as geometric mean catch per tow, for target species.

Data Location

Data are maintained by the Division of Fish and Wildlife Fisheries Section.

Management Goal/Hypothesis and Test Statistics

Species-specific Stock Assessment Subcommittees test geometric means for individual assessments. First, the relative prevalence for that particular species is determined to see if the survey interacts with it enough to warrant inclusion in the assessment. Next, the survey may be standardized using a generalized linear model. Further, trend analyses are conducted on the survey itself (using ARIMA, Mann-Kendall tests), and combined with age, growth (Von Bertalanffy), maturity F, M (Lorenzen) data for analyses.

C.6.5 VOLUNTEER SHOREZONE FISH AND BLUE CRAB SURVEY

Description/Objective(s)

The shorelines of the Inland Bays provide critical habitat to many juvenile and young-of-the-year fish species along with blue crabs. In an effort to obtain fish population and diversity data from these inshore areas, an Inland Bays volunteer fish monitoring program was implemented collect data that can be used to create fish indices that complement the data being collected by the DNREC Division of Fish and Wildlife Trawl Survey. The objectives of this program are to conduct seining surveys to determine the abundance, species diversity, and body lengths of the near-shore fish communities in the Delaware Inland Bays and to measure physical and biological parameters to determine which conditions are favorable for nearshore fish and blue crabs in the Inland Bays.

Responsible Organization and Contact

The Delaware Center for the Inland Bays is responsible for this monitoring program.

Contact: Andrew McGowan, Environmental Scientist
environment@inlandbays.org, 302-226-8105, x112

Data Collection Cost

Equipment: $700 for nets, buckets, first aid kits, tongs, miscellaneous gear
Staff time: $5,400

Data Use

The data collected from this project are used primarily by the Delaware Division of Fish and Wildlife and the Center for the Inland Bays. These data will be used to help document trends, seasonality, and annual variability in fish populations over time. Additionally, this data will be used to assess the importance of the shorezone waters for commercially and recreationally important species.

Record of Collection

2011 to present. No data were collected in 2020 due to the COVID-19 pandemic.

Collection Method

16 shoreline sites are monitored once in April and twice a month from May through October using a 30-foot-long 4-foot-tall seine net (Figure 3.10). To sample a beach, one volunteer holds one end of the seine net along the beach while another volunteer wades out with the opposite end until the net is fully extended (30 ft). Both volunteers drag the net for 70 feet along the shoreline, with the volunteer in the deeper water walking slightly ahead of the shallow water volunteer. At the 70-foot mark, the inshore volunteer stops and the deep water volunteer swings inshore with the net, at which point both volunteers drag the net ashore having seined 100 feet of shoreline. All fish are identified to species and counted, and the first 25 fish of each species are also measured to the nearest millimeter. The number of blue crabs is

also counted. In addition, physical parameters such as dissolved oxygen, water temperature, salinity, wave height, amount of rain in the last 24 hours, and wind speed are also recorded prior to each seine.

Analysis Methods

To assess species abundance over time, geometric mean catch for each species is calculated each year. Differences in catch between the bays are assessed with pairwise Wilcoxon rank sum tests (α = 0.05). To assess which variables are important to inshore fish species, correlations to physical variables are assessed for recreationally or commercially important species using Kendall'sTwi Tau correlation tests (α = 0.05).

Data Location

Data are stored at the Center for the Inland Bays and are made available online at [www.inlandbays.org.](http://www.inlandbays.org)

Management Goal

Data generated through this program can be used to document trends in fish species abundance over time. These data can also be used to inform decision makers on the relative importance of shorelines on various species of fish.

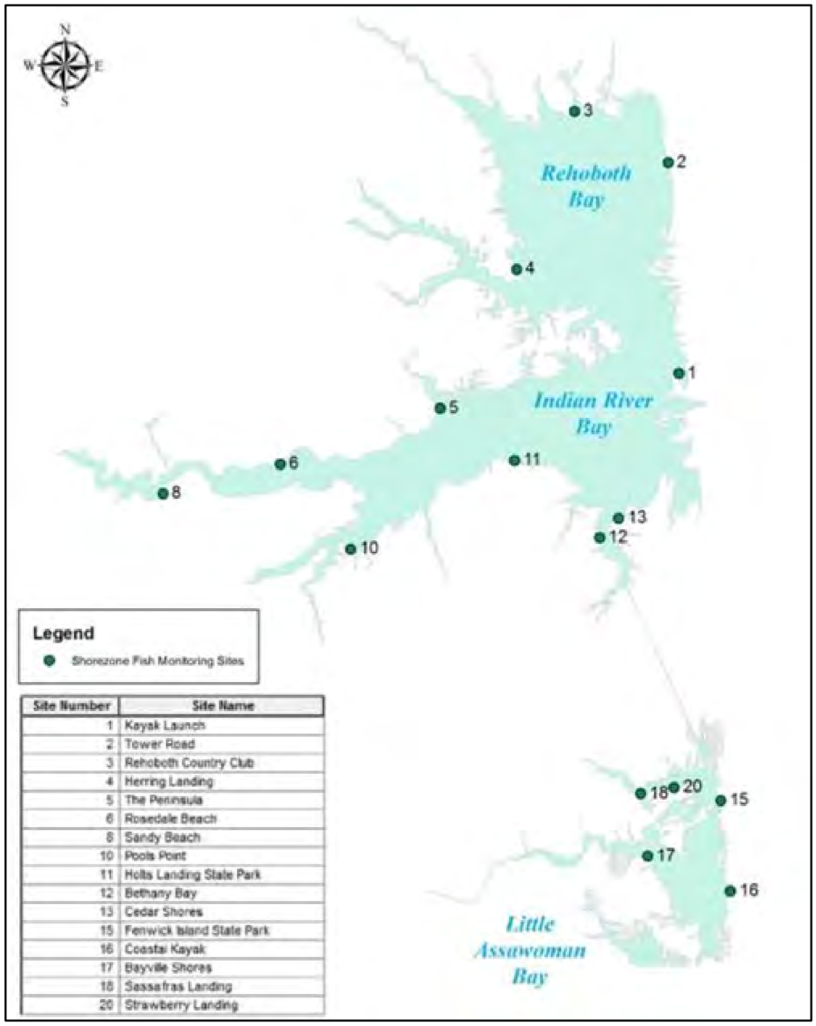


FIGURE C.14 - Map of Shorezone Fish and Blue Crab Survey seining sites.

Hypothesis and Test Statistics

Differences between bays are assessed using pairwise Wilcoxon rank sum tests (α = 0.05). The null hypothesis is that there are no differences in fish abundance between the Inland Bays. Correlations between physical parameters and recreationally or commercially important species' abundance are assessed with a Kendalls Tau correlation tests (α = 0.05). Geometric mean catch per year are calculated for each fish species caught, and these data will be used to assess species trends over time.

C.6.6 RECREATIONAL FISHING SURVEYS

Description/Objective(s)

The Marine Recreational Information Program (MRIP) survey is used by NOAA Fisheries to quantify and report marine recreational fishing catch and effort. These surveys document pounds of fish caught per trip, number of fishing trips, and pounds of individual fish species caught per year. Data for the Inland Bays are based on surveys conducted by NOAA at the Indian River Inlet.

Responsible Organization and Contact

NOAA Fisheries Service has overall responsibility for this program. DNREC's Division of Fish and Wildlife requests and analyzes local data each year.

Contact: Gordon Colvin, NOAA
301-427-8118, Gordon.colvin@noaa.gov

John Clark, DNREC Environmental Program Administrator
(302) 739-9914, john.clark@delaware.gov

Data Collection Cost

Not available.

Data Use

Locally, the data are used primarily by DNREC Division of Fish and Wildlife Fisheries Section to assess the impact of recreational fishing on Delaware's fish species and adjust management decisions accordingly.

Record of Collection

2004 to present. Recreational fishing survey data exist prior to 2004, but collection used a method differing from MRIP.

Collection Method

Data are collected through field, harvester-intercept interview surveys that record catch rates for species from anglers, and a telephone (or mail survey) that is designed to estimate effort. Average catch rates are applied to the effort estimates to generate landings per year. The MRIP survey also takes into account potential bias due to differences in catch rate at high-activity or low-activity sites, or the amount of fishing occurring at different parts of the day.

Analysis Methods

Each estimate is a combination of catch rates and effort in a particular waterbody. Previously, all fishing locations were treated equally, and in some cases high activity sites were sampled much more than low activity sites in an effort to maximize the amount of data being collected. However, the MRIP survey takes into account site activity and other bias associated with the time the survey was conducted to more accurately arrive at a catch estimate.

Data Location

Data are available from DNREC Division of Fish and Wildlife Fisheries Section upon request.

Management Goal

To incorporate the data into stock assessments, thereby accounting for the impact recreational fishing has upon each species.

Hypothesis and Test Statistics

N/A

C.6.7 HARD CLAM SURVEYS

Description/Objective(s)

The hard clam is the most important commercial resource in the Inland Bays, and along with the blue crab, is the most important recreational shellfishery. To enhance the wellbeing of this shellfishery and maintain optimum levels of sustainable harvest an adequate knowledge of the hard clam stock and its variability are necessary. A vacuum suction dredge survey of Rehoboth Bay and Indian River Bay over two years were performed to support these goals and provide information with which to evaluate overall bay health and this important living resource. Objectives of this survey were to determine density and distribution of hard clams and bay scallops within Delaware's Inland Bays, evaluate clam recruitment and survival since previous surveys were conducted, and evaluate study results and effort in light of management and monitoring objectives. This survey was last conducted in 2011, and no plans are in place for future bay-wide surveys.

Responsible Organization and Contact

DNREC Division of Watershed Stewardship

Contact: Michael Bott, Environmental Scientist
Michael.Bott@delaware.gov, 302-739-9939

Data Collection Cost

$10,000 per survey.

Data Use

Data are used primarily by DNREC Division of Fish and Wildlife and the Center for the Inland Bays. Data generated by this survey can be used to infer the health of the Inland Bays hard clam shellfishery, and inform the shellfish aquaculture program of potential conflicts in aquaculture sites due to high hard clam densities.

Record of Collection

1967, 1976, 2011

Collection Method

The Venturi Suction Dredge survey method was used for this survey. The dredge was fabricated from aluminum with a mesh net attached capable of capturing clams greater than 8mm. The dredge was powered by a 4”, water pump with a 4” reinforced intake hose and 3” effluent hose attached to the Venturi dredge. The sample quadrat was a $1m^2$ frame constructed from 1” PVC piping with holes drilled into the material to allow the pipe to fill with water and stay weighted on the sediment. The sample stations duplicated the survey points used for the 1667 and 1976 surveys. Sample stations which were located near the Indian River Inlet or in navigational channels were either eliminated or moved to adjacent locations due to safety hazards. In the event a sample location was to near to a shore line to allow operation of the dredge, the quadrat was located as near to the original point as possible and the new coordinates were recorded. Sample stations were located using a hand held GPS to get within 3m of the location, and a weighted buoy was thrown randomly to mark the specific site. Two divers would place the quadrat on the northern side of the buoy weight and remove and record any macro-algae present. One diver would operate the Venturi dredge, excavating all substrate to a minimum depth of 12”. The second diver stabilized the quadrat to prevent movement and verified the station was completely sampled before surfacing. If the substrate could not be excavated to a depth of 12”, the actual depth and limiting factors were recorded. Any clams which were partly located within the inside portion of the quadrat were included in the sample. Clams were included if the diver could run a finger along the inside edge of the PVC pipe and feel the shell within the quadrat. To avoid sampling additional substrate which caved into the sample area, the diver did not re-dredge any portions which were already sampled. Once samples were brought to the surface, all live bi-valve molluscan shellfish were sorted from the material, and measurements of the shell width and length, along with species were recorded. Qualitative sediment type was also recorded for each site, along with water depth. All calipers used were frequently calibrated on a known standard.

Analysis Methods

The data were analyzed using the Kolmogorov-Smirnov test to measure differences in clam distributions between the 1976 survey and the 2011 survey in the Rehoboth Bay, and Indian River Bay. Differences were also assessed between Rehoboth Bay and Indian River Bay for the 2011 survey.

Data Location

Upon request to DNREC Division of Fish and Wildlife.

Management Goal

This survey can be used to inform decision makers on the current status of hard clams in the Inland Bays in reference to historical levels. Data generated through this survey details the current health of the hard clam population, if restoration efforts are needed, how current management efforts are impacting hard clams, and where the highest densities of hard clams reside in the Inland Bays. This data can also be used to prevent conflicts between aquaculture sites and high density hard clam beds.

Hypothesis and Test Statistics

Kolmogorov-Smirnov tests were used to assess differences between the 1976 survey and the 2011 survey, along with differences in hard clam abundance between bays in the 2011 survey.

C.6.8 VOLUNTEER HORSESHOE CRAB SURVEY AND TAGGING PROGRAM

Description/Objective(s)

Due to their importance to both the medical industry and migratory birds, horseshoe crab spawning activity is monitored through a volunteer spawning survey, at five sandy beaches in the Inland Bays from May through June (Figure C.15). The objectives of the survey are to assess the importance of the Inland Bays' horseshoe crab population in regards to the regional population, track the number of spawning crabs over time, and monitor horseshoe crab movement through a long-term tagging program.

Responsible Organization and Contact

The Delaware Center for the Inland Bays is responsible for this monitoring.

Contact: Andrew McGowan, Environmental Scientist
environment@inlandbays.org, 302-226-8105, x112

Data Collection Cost

Equipment costs: $150 annually to support five teams - Staff time: $5,400 annually

Data Use

Data from this survey is used primarily by the Center for the Inland Bays and DNREC Division of Fish and Wildlife. The data generated through this survey can help determine the size of the Inland Bays' horseshoe crab population, relative to the regional population, measure if their numbers are increasing or decreasing over time and identify important spawning areas that need to be managed and protected.

FIGURE C.15 - Map of Inland Bays horseshoe crab survey and tagging sites.

Record of Collection

2015 - present (Surveys began in 2008, but the protocol was modified in 2015 to facilitate comparisons with the Delaware Bay Survey).

Collection Method

Sampling occurs on five beaches in the Inland Bays two nights prior to, the night of, and two nights following the new and full moons from May through June. Sampling begins during the nighttime high tide as the tide begins to recede. Teams begin by randomly selecting one end of the beach to start from using a coin flip. Once the end of the beach is determined, the team will walk to that end and extend a pull rope with markings every 1m, at the high tide line towards the opposite end of the beach. The length of the pull rope is dependent on the length of the beach and is designed to systematically allow the placement of 100 $1m^2$ quadrats along the beach. The length of the rope is determined by dividing the overall length of the beach by 50. James Farm and Tower Road use a 4-meter pull rope. Bay Colony uses a 6-

meter pull rope. Peninsula does not use a pull rope because the length of the beach is only 100m; and therefore all quadrats along the beach are counted. The Fenwick Island Site Is monitored once every five years. A new site In Rehoboth Bay at Camp Arrowhead will be monitored annually starting In 2021.In addition to randomizing the direction of travel, the placement of the quadrats within each rope pull is randomized for a single night. Two quadrats are sampled per rope pull, for a total of 100 quadrats. The same two randomized locations along the pull rope are used for the duration of the night. Once the pull rope has been extended, the $1m^2$ quadrat is placed at the first random quadrat location for that given night. The quadrat is positioned so that one end is even with the line of crabs, and the other end is towards the bay. All crabs which have at least half their body inside the quadrat are sexed and counted. Upon completion of the first quadrat, the team moves the quadrat to the second randomly selected location and repeats the counting process. Once the two quadrats have been counted for the first rope pull, the rope is extended along the next portion of the beach, and the same two random quadrat locations are sampled. This is repeated until 100 quadrats have been sampled. The 'Horseshoe Crab line' that is followed is not a straight line, and it may be above or below the water line, however, it is never more than $1m^2$ away from the high tide line.

At each of the sites, salinity samples are also taken for each night. These samples are later tested for salinity. Air and water temperature are also taken with a thermometer.

In addition to counting crabs, 1,000 crabs are also tagged with US Fish and Wildlife Service tags on the left posterior portion of the prosoma. The tagged crabs are sexed and measured for carapace width.

Analysis Methods

Average spawning densities per $1m^2$ are calculated for each beach by dividing the total number of crabs per night by 100 (the number of quadrats), and averaging each night to obtain one spawning density per beach. The cumulative spawning density for the Inland Bays represents the average of the five beaches' averages. Spawning index is calculated in the same manner but includes only females.

Total crab abundance is compared between sites using a pairwise Wilcoxon rank sum test ($\alpha = 0.05$).

Data Location

Located at the Delaware Center for the Inland Bays, available upon request.

Management Goal

The data generated through this survey can be used to identify important areas for horseshoe crab spawning activity, assess overall trends in horseshoe crab spawning activity over time, and inform decision makers on the movements of horseshoe crabs over the course of a single spawning season or multiple years.

Hypothesis and Test Statistics

Correlations between physical parameters and crab abundance are assessed with Kendall's tau correlation tests ($\alpha = 0.05$). Differences in crab abundance between sites is assessed with pairwise Wilcoxon rank sum tests ($\alpha = 0.05$).

C.6.9 DELAWARE BREEDING BIRD ATLAS

Description/Objective(s)

The Delaware Breeding Bird Atlas is primarily a volunteer citizen science project. From 1983 through 1987, over 100 volunteers participated in compiling data for Delaware's first breeding bird atlas, Delaware's largest and most comprehensive ornithological project. This effort, incorporated in *The Birds of Delaware* (Hess et al., 2000), summarized the distribution of the breeding birds during those years along with species accounts and data about all birds that occurred, or thought to have occurred, in the State. A second Atlas project was conducted between 2008 and 2012.

Responsible Organization and Contact

DNREC Division of Fish and Wildlife, Wildlife Species Conservation & Research Program

Contact: Anthony Gonzon, Project Coordinator
302-735-8673 Anthony.Gonzon@delaware.gove

Data Collection Cost

The second Atlas project was funded through the Delaware Division of Fish and Wildlife with funding from the State Wildlife Grants Program, Division of Federal Assistance, United States Fish & Wildlife Service.

Data Use

The data are useful for tracking trends in populations and diversity that occur with changes in land use, habitats, and climate.

Since being published, the first atlas has become an important resource, providing much of the distribution data about Delaware's breeding avifauna. It is often used by researchers, scientists, government officials, and birders. The first Delaware breeding bird atlas established the baseline data that will be used to compare and examine changes in the distributions of breeding species upon completion of future atlas projects.

Record of Collection

Surveys for the first Breeding Bird Atlas project were conducted from 1983-1987. The second set of surveys were conducted from 2008-2012.

Collection Method

Volunteer atlasers are assigned to a geographic "block" to survey. Within that block, the atlaser attempts to confirm breeding for as many species as possible. A block is approximately 10 sq. miles and is created using a standardized grid that is overlaid onto a map of Delaware. Delaware has over 265 blocks divided into six regions in the State. Each of the six regions contains more than 40 blocks.

Each atlaser spends time in their block surveying during the breeding season (for most birds, March - July), and observing and recording data about the birds they encounter on field cards. Volunteer atlasers report this data using an online, interactive data entry application or by submitting their field cards for entry. Once the data are entered the volunteers "save" it to the database for verification. A regional compiler serves as the primary contact for each region and verifies data. The project coordinator is responsible for maintaining communications between volunteers, compilers, project supporters, landowners, and others, and also handles all of the financial and logistical issues of the atlas, including reports and data analyses.

Analysis Methods

Maps are produced for each breeding species along with other important information such as breeding safe dates, nesting dates, and arrival and departure estimates.

Data Location

Data are kept by the DNREC Wildlife Species Conservation & Research Program. Data may be accessed online through the Breeding Bird Atlas Explorer, maintained by the USGS Patuxent Wildlife Research Center (http://www.pwrc.usgs.gov/bba).

C.6.10 MID-WINTER WATERFOWL SURVEYS

Description/Objective(s)

For almost 40 years, the Division of Fish and Wildlife has conducted four aerial waterfowl surveys annually to measure long-term trends in duck and goose populations. Surveys are carried out via a small plane with a pilot and biologist aboard, taking similar routes and using the same techniques each time. Each survey is flown using the same east-west transects to minimize data bias and allow for across year comparisons.

Flights are usually made in mid-October, mid-November, mid-December and the second week in January, subject to weather and mechanical delays. The January flight is part of a coast-wide effort to survey waterfowl throughout the Atlantic Flyway at approximately the same time. The state surveys cover the primary waterfowl habitat in Delaware, approximately the eastern half of the state, and are divided into 11 zones. From 2010 to 2019, aerial surveys were flown twice monthly, but only in the zones that coincide with greatest waterfowl abundances as identified from analyzing 40 years of survey data.

Not all ducks and geese can be seen equally well from a plane. The surveys give fairly accurate information about geese, but duck populations such wood ducks and sea ducks are almost impossible to count.

The important feature of these counts is that they augur for long-term trends that are useful to measure changes in waterfowl management strategies and the environment. In most cases no single survey count is especially important in itself, but cumulative counts have revealed important changes over the years.

Responsible Organization and Contact

DNREC Wildlife Species Conservation and Research Program

Contact: Justyn R. Forth, PhD, Gamebird Biologist
Justyn.foth@delaware.gov, 302-735-3600

Data Collection Cost

Not available.

Data Use

Data are used by the US Fish and Wildlife Service and the Delaware Division of Fish and Wildlife to adjust hunting regulations in response to population trends.

Data from both the state and Atlantic Flyway counts are used to produce a winter waterfowl indicator for the *State of the Delaware Inland Bays* reports.

Record of Collection

1974 to present.

Collection Method

These surveys are carried out via a small plane with a pilot and biologist aboard, taking similar routes and using the same techniques each time.

Analysis Methods

Waterfowl counts are summarized within the following zones:

Zone 1 - (Width of the State) Pennsylvania Line to the Delaware Memorial Bridge.
Zone 2 - (Width of the State) Delaware Memorial Bridge to the C&D Canal.
Zone 3 - (Width of the State) C&D Canal to a Line from Liston Point to Kenton.
Zone 4 - (Width of the State) Liston Point to Route 6 (Smyrna).
Zone 5 - (Width of the State) Route 6 to Route 8 Port Mahon.
Zone 6 - (East of 113) Route 8 to Big Stone Beach.
Zone 7 - (East of Route 1) Big Stone Beach to Broadkill River.
Zone 8 - (East of Route 1) Broadkill River to Bend in Lewes Rehoboth Canal South of Gordon's Pond.
Zone 9 - South of Gordon's Pond and All of Rehoboth Bay.
Zone 10 - All Indian River Bay West to Millsboro and South to Salt Pond.
Zone 11 - Salt Pond South to Maryland Line and West to Route 17.

Zones 9, 10, and 11 fall within the Inland Bays watershed.

Data Location

DNREC Division of Fish and Wildlife. Data also are posted to the Delaware Open Data Portal (https://data.delaware.gov/).

C.6.11 BALD EAGLE & OSPREY NESTING SURVEYS

Description/Objective(s)

The Delaware Division of Fish and Wildlife's Species Conservation and Research Program (SCRP) monitors bald eagle populations and nesting locations in the state. Until 2014, the Division also monitored osprey nesting. Monitoring of osprey nests was suspended at that time. The only nesting data collected since then has been through volunteer programs. As of 2016, the volunteer monitoring data are submitted to the OspreyWatch program (www.ospreywatch.org). Because osprey nesting is an important indicator used in the *State of the Delaware Inland Bays* reports, the CIB will manage a volunteer effort to collect data for the report's 2021 update. If successful, this may become a long-term citizen science program managed by CIB.

The U.S. Geological Survey biologists tested eggs and chicks for contaminants in 2001. Historically, osprey surveys were concentrated in the Inland Bays and Nanticoke River system, but the entire state of Delaware was surveyed in 2003, 2007 and 2014.

Responsible Organization and Contact

DNREC Division of Fish and Wildlife, Wildlife Species Conservation & Research Program

Contacts: Osprey Project Coordinator
302-735-3600

Data Collection Cost

Not available.

Data Use

The data for Delaware are analyzed by SCRP staff to improve understanding of arrival dates, nest success and other aspects of the species' biology in the state. Information supports conservation decisions and assists the state in identifying any new or emerging issues.

Bald Eagle and Osprey nesting are used as indicators in the *State of the Delaware Inland Bays* reports. Both species are high on the food chain and eat foods - primarily fish - that accumulate toxins. Bald eagle nesting is influenced by habitat disturbance. Ospreys also rely mostly on coastal habitats and may be affected by climate change and sea level rise.

Record of Collection

Data used for indicator reports: Bald Eagles: 1987 to 2018.
Ospreys: 1991 to 2014.

The Division has conducted surveys in some form since 1970 to document Osprey nest success. The SCRP decided to end state-wide Osprey surveys on an annual basis in 2007, with the intention of returning to it every five years or so.

Collection Method

Eagle nests are counted by aerial survey. The only state-wide Osprey nest survey conducted since 2007 was in 2014, and it was done entirely from helicopter. Each site was visited only once between June 20th and July 10th. In prior years, nest sites were visited at least twice, so the number of nests documented in 2014 likely is low, as any early season failed nesting attempts would have missed.

Analysis Methods

Starting in 2016, volunteers provide osprey nest observations to the OspreyWatch online reporting application, hosted by the Center for Conservation Biology at http://www.osprey-watch.org/. The data for

Delaware are analyzed by SCRP staff to improve understanding of osprey arrival dates, nest success and other aspects of osprey biology in the state. The data collected by CIB volunteers in 2021 will be submitted to the OspreyWatch database.

Data Location

Data collected by the state are managed by the SCRP, and are available upon request to the Program.

Starting in 2016, volunteers provide osprey nest observations to the OspreyWatch online reporting application, hosted by the Center for Conservation Biology at http://www.osprey-watch.org/. Delaware and Inland Bays data may be viewed on this site.

C.6.8 VOLUNTEER DIAMONDBACK TERRAPIN SURVEY PROGRAM

Description/Objective(s)

In 2020 the Center for the Inland Bays began a long-term population survey of diamondback terrapins, modeled after that conducted by the Maryland Coastal Bays Program. The objectives of the survey are to: (1) understand terrapin population size, annual changes, relative abundance, and distribution throughout the Inland Bays over time; (2) engage members of the public in meaningful science; and (3) provide data for targeted enhancement projects to increase terrapin numbers.

Responsible Organization and Contact

The Delaware Center for the Inland Bays is responsible for this monitoring.

Contact: Andrew McGowan, Environmental Scientist
environment@inlandbays.org, 302-226-8105, x112

Data Collection Cost

Labor costs for staff to manage program and volunteers. $5,000-$7,000 annually.

Data Use

Data from this survey is used primarily by the Center for the Inland Bays and DNREC Division of Fish and Wildlife. The data generated through this survey is used determine status and trends of the Inland Bays' diamondback terrapin population, reported as an environmental indicator, and as support for conservation projects.

Record of Collection

2020 - present

Collection Method

Surveys are conducted by volunteers in two ways – through water-based kayak transect surveys and land-based point counts. Surveys are conducted between the last week of May and the first two weeks of June. All surveys are restricted to days with wind < 8 mph, cloud cover < 50%, air temps > 50º Fahrenheit, and within two hours of low tide.

Because diamondback terrapins are primarily found within salt marsh creeks, the kayak transects are placed within each major marsh system with accessible launch points and navigable, shallow creeks. For each major marsh section one 1.5- to 3-mile paddling transect was established (Figure C.16). These transects cover a majority of the major marsh areas of the Inland Bays, and therefore the data generated is representative of the majority of the terrapin population within the Inland Bays. Surveyors work in pairs, paddling the assigned transect, recording GPS locations and numbers of turtles observed. The number of terrapins will be combined between the out and return paddle to derive one number of terrapins for each route.

In order to cover less optimal habitat, and to open the survey to volunteers who do not possess a kayak, point count sites were been selected (also indicated in Figure C.16). These are public access points with at least a 180º view of the water, and they were chosen to cover habitat types other than complex marsh

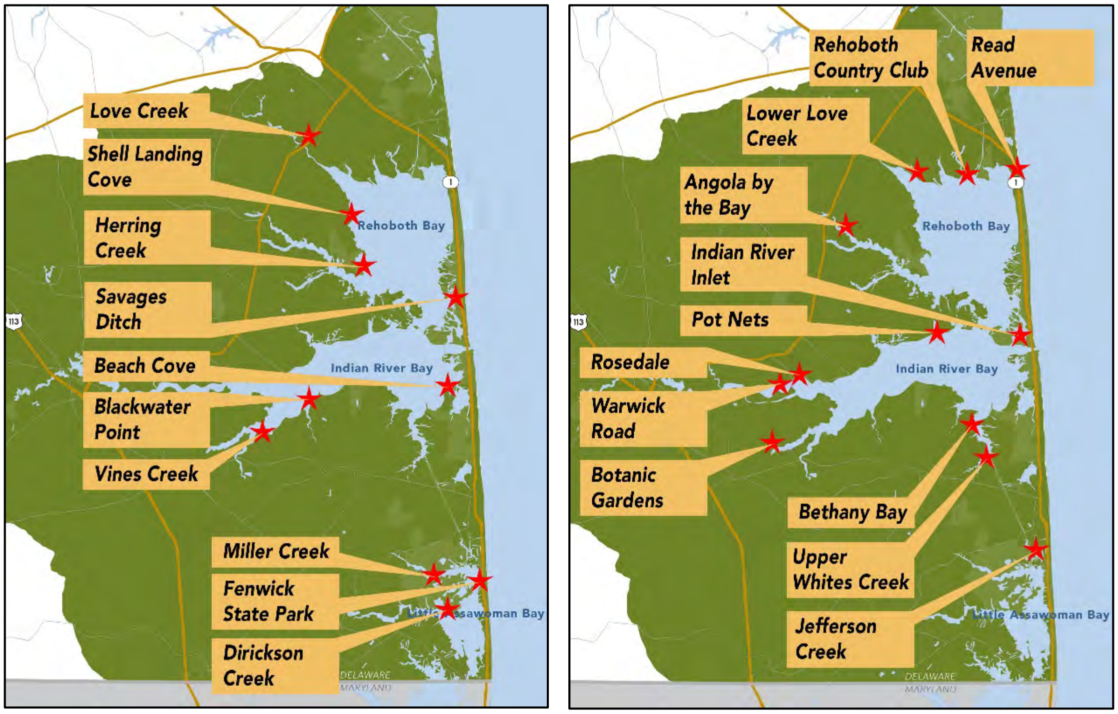


FIGURE C.16 - Map of Inland Bays diamondback terrapin survey locations. Kayak transect locations (left map) and land-based point count locations (right map).

creek areas. These areas include sandy shorelines, shorelines that have open water, and developed shorelines. Volunteers can also submit point counts from other locations of their choice. Surveyors perform a left to right sweep of the area using binoculars or scopes, counting all terrapins visible. During the left to right sweep of the water, all terrapins are counted during the sweep, but the observer does not count terrapins if they appear in an area they have already passed during their left to right sweep. The sweep should not take longer than around a minute. After counting, the observer waits five minutes and repeats the left to right sweep. This process is repeated again for a total of three left to right sweeps per site.

Analysis Methods

Total abundance from water-based kayak transects is divided by the total length of the transect to derive the mean number of terrapins per kilometer along each transect. Once the survey has taken place for enough years (5-10), trend analyses can be performed on the densities over time. These densities can also be compared to surrounding land use changes and available nesting habitat as determined through GIS analyses.

For land-based point counts the average of the three replicate counts is recorded as the abundance for that site. These abundances can be compared over time using the same methods as the water-based kayak sites. Point count surveys are also being used to observe areas not covered by the kayak transects.

Data Location

Located at the Delaware Center for the Inland Bays, available upon request.

Management Goal

The data generated through this survey will be used to help identify areas for targeted restoration or conservation projects. Overall trends in terrapin distribution and abundance over time will be assessed.

APPENDIX D

ASSESSMENT, LISTING, AND REPORTING METHODOLOGIES FOR 305(B) REPORT AND 303(D) LIST DEVELOPMENT, 2016

DRAFT

State of Delaware 2020 Combined Watershed Assessment Report (305(b)) and Determination for the Clean Water Act Section 303(d) List of Waters Needing TMDLs

(The Integrated Report)

Delaware Department of Natural Resources and Environmental Control

Division of Watershed Stewardship

Watershed Assessment and Management Section

May, 2020

PART C. SURFACE WATER MONITORING AND ASSESSMENT

C1. Monitoring Program

The purpose of the Delaware's Surface Water Quality Monitoring Program is to collect data on the chemical, physical and biological characteristics of Delaware's surface waters. The information that is collected under this program is used to:

- Describe general surface water quality conditions in the State;
- Identify long term trends in surface water quality;
- Determine the suitability of Delaware surface waters for water supply, recreation, fish and aquatic life, and other uses;
- Monitor achievement of Surface Water Quality Standards;
- Identify and prioritize high quality and degraded surface waters;
- Calculate annual nutrient loads and track progress toward achieving Total Maximum Daily Loads (TMDLs) targets; and
- Evaluate the overall success of Delaware's water quality management efforts.
- Inform decisions by other stakeholders and programs

Delaware maintains a General Assessment Monitoring Network (GAMN) of ~ 139 stations. Twenty three of the stations are monitored monthly and the remaining stations are monitored either six or twelve times per year. Each station is monitored for conventional parameters such as nutrients, bacteria, dissolved oxygen, pH, alkalinity, and hardness. Some stations are monitored for dissolved metals. The data from this monitoring is entered into EPA's STORET database and used for this report and other uses by interested parties.
More information about Delaware's Water Quality monitoring is available online at:
http://www.dnrec.delaware.gov/swc/wa/Pages/WaterQualityMonitoring.aspx
In addition to uploading data to STORET, the Department also works in co-operation with the University of Delaware to share available water quality data in a more user friendly format in the Delaware Water Quality Portal at this URL: http://demac.udel.edu/waterquality/.

C2. Assessment Methodology

General Provisions

Data Considered**:**

Readily available data and information for the period of January 1, 2014 through December 31, 2018 was considered for the assessment of most designated uses. Given that adequate water quality data may not be available in all cases, determinations of use attainment were made with an abundance of caution.

Data Quality and Quantity

Data from the Department of Natural Resources and Environmental Control's (DNREC's) Environmental Laboratory Section (ELS) was considered for use if it is collected and analyzed in accordance with the DNREC ELS Quality Assurance Project Plan. For data from sources other than the DNREC ELS, the Department considered the quality controls used in collection and analysis to determine if it was appropriate for use in this assessment. The Department routinely currently collects water quality samples at more than 130 stations throughout the State. That data makes up the bulk of the data available for use in 305(b) assessments. The Department considers data from the most recent five-year period, thus, at each station, there are usually data from 20 sampling dates or more. Some stations are in place for a more limited time period and have smaller data sets. Other readily available data and reports were requested in advance of each assessment from parties outside of the Department and used when they were made available. In addition to electronic mail requests from specific organizations, a notice was be published in the Delaware State News and the News Journal.
For the 2020 assessment, the Department considered data and information received before March 2020 from the following sources:

- Reports of ambient water quality data including State ambient water quality monitoring programs, citizen volunteer monitoring programs, complaint investigations, and other readily available data sources (e.g., EPA's Storage and Retrieval System (STORET), the United States Geological Survey, and research reports), and data and information provided by the public;
- Reports prepared to satisfy Clean Water Act (CWA) Sections 305(b), 303(d) and 314 and any updates;
- Fish and shellfish advisories
- Restrictions on water sports or recreational contact

Coordination with Delaware River Basin Commission (DRBC) and Chesapeake Bay Program Assessments

The DRBC prepares 305(b) assessment reports every two years for the Delaware River and Delaware Bay. Delaware will incorporated the most recent use attainment determinations made by DRBC for the shared waters of the Delaware River and Delaware Bay into its 2018 303(d) list. Delaware expects to work cooperatively with the DRBC, member states and stakeholders to develop and implement TMDLs in waters of the Delaware River and Bay that the DRBC determines to be impaired.

The Chesapeake Bay Program (CBP) is doing assessments for waters in the Chesapeake Bay and nearby waters that drain into the bay in co-operation with Maryland, Virginia, Washington D.C. and Delaware. Delaware incorporated the most recent use attainment determinations for waters of the state that use criteria developed by the CBP for waters that drain to the Chesapeake Bay.

Use of Environmental Protection Agency Integrated Assessment Guidance

US EPA has guidance online for preparation of Integrated Reports at the following URL: https://www.epa.gov/tmdl/integrated-reporting-guidance

The core recommendation of the guidance is to categorize all waters of the state according to the following five categories:

Category 1: All designated uses are met;

Category 2: Some of the designated uses are met but there is insufficient data to determine if remaining designated uses are met;

Category 3: Insufficient data to determine whether any designated uses are met. Either no data is available or some data is available, but it is insufficient to make a determination

Category 4: Water is impaired or threatened but a TMDL is not needed;

- 4A: All TMDLs for this segment have been completed and EPA approved. Class 4A waters have all necessary TMDLs approved, but one or more impairments exist, despite the approved TMDLs.
- 4B: Other required control measures are expected to result in the attainment of WQSs in a reasonable period of time
- 4C: The impairment or threat is not caused by a pollutant

Category 5: Water is impaired or threatened and a TMDL is needed for at least one pollutant or stressor

The Department has created a sub-category of Category 5 waters based on recommendations in a March 2018 report prepared by the Department titled “An Evaluation of Clean Water Act Section 303(d) listings of Delaware Waters Affected by Fish Consumption Advisories”. That evaluation recommends that for some waters where trends indicate a downward slope in fish tissue contaminant concentrations that should be below fish tissue target levels within five to ten years without implementing a TMDL a subcategory of impaired waters be created. That subcategory is 5(MNR) in which MNR stands for “Monitored Natural Recovery”. As implied by the name, the Department plans to continue monitoring fish tissue in those waterbodies in accordance with the Fish Tissue Advisory program protocols until such time as the contaminants in the fish are no longer above levels of concern and beyond. When the data supports removing the fish tissue advisories, the Department will consider that information for delisting decisions with stakeholder input. For more information about the Fish Tissue Advisory process see section C6 of this report. The Department also plans to pursue remediation efforts in affected watersheds in accordance with the WATAR program and process as discussed in other sections of this report and online at http://www.dnrec.delaware.gov/dwhs/SIRB/Pages/WATAR.aspx. If trends analyses at later dates show that trends in 5(MNR) waters are not in fact trending downward, or reaching their target levels, the Department will reclassify those waters as Category 5 and TMDLs for those pollutants will be developed.

The Department has worked with US EPA to move Delaware's 303(d) listing information into EPA's Assessment, Total Maximum Daily Load (TMDL) Tracking and Implementation System (ATTAINS) database which allows EPA and stakeholders to track the conditions of the Nation's surface waters. As part of that effort, the Department has converted the list of impaired waters into a format more compatible with the ATTAINS database and geographical information systems (GIS). The new format is significantly longer than the older format, but much easier to use in those environments. Future Integrated Reports are expected to be compiled largely within the ATTAINS system and reports for stakeholders will be prepared as needed for the public comment period.

The Department assessed data for a number of parameters in each segment that sufficient data was readily available for, and then assigned them the codes listed above for each parameter and segment combination. This gives the Department more information about specific parameters of concern and allows more detailed tracking of those concerns over time. Each of Delaware's monitored waterbody segments were assigned to the appropriate category for each designated use and then 'rolled up' into a final categorization for the segment.

Dissolved Oxygen (DO) Aquatic Life Use Support (ALUS)

The following types of DO data were available for analysis:

- Field measurements taken by personnel using handheld DO probes; and
- Continuous monitoring data collected using multiparameter monitoring systems that are typically deployed for several days, weeks, or months. In order to get a more accurate picture of dissolved oxygen dynamics and other water quality parameters, the Department continues to increase its use of continuous monitoring systems.

To determine ALUS with regard to Dissolved Oxygen (DO), the following methodology was used to compare measured DO concentrations to two different standards, the minimum at all times and daily average concentrations. Average DO concentrations were considered to be met if the 10^{th} percentile of available data is above the applicable criteria of 5.0 mg/l for marine waters and 5.5 mg/l for fresh waters. The statewide minimum DO concentration for surface waters is 4.0 mg/l at any time. Stations were judged to be in compliance with this criterion if the minimum is not violated by more than 1% of continuous monitoring data and no more than two field samples are below the minimum. Dissolved oxygen criteria in the Murderkill River are different from the Statewide averages for the period of May 16 to September 30^{th} and the data from that period was considered in the same way as the rest of the State against the lower criteria.

Assessments of Average DO Criteria Attainment:

If sampling events occurred on at least ten different days during the assessment period for each station, attainment of the DO average criteria were assessed using the method that follows. Stations where monitoring has been discontinued that have data from fewer than 10 days were not be considered for further evaluation.

For purposes of DO compliance with the daily average criteria in a segment, continuous monitoring data, if available, was averaged on a daily basis for each station. If no continuous data is available, then the field measurements (as available) were considered to be representative of the daily average for that day. Any type of sample (continuous or field measurement) was considered to be representative for that station at the time of collection. Once the daily average for each station (station daily average, SDA) has been determined, the SDAs for each station will be pooled and the upper confidence limit (UCL) of the nonparametric 10th percentile confidence interval was determined using methods described in Section 3.7 of Helsel and Hirsch . That UCL was compared to the applicable standard. If the UCL was above the applicable average criteria for all stations in a segment, the segment will be considered to be fully supporting (Category 1) for the DO average portion of ALUS. If the UCL from any station in a segment was below the applicable average, the segment was considered not fully supportive of the aquatic life use (Category 5)

Formally stated, the following hypotheses will be tested:

H_0: at the 90% Confidence level, $X_{10} \geq$ Standard

H_1: at the 90% Confidence level, $X_{10} <$ Standard

Where X_{10}= Non parametric estimate of the 10th percentile of available data.

Assessments of Minimum DO Criteria Attainment:

Attainment of the minimum DO criteria was assessed based on all available data (note that ten samples in 5 years are not needed for the comparison to the minimum). For stations for which no continuous DO monitoring data are available, two or more SDAs in five years below the applicable minimum was sufficient evidence to show that the aquatic life use was not supported (Category 5).

Nutrient Enrichment Assessment

From a state-wide perspective, nutrient overenrichment is one of the leading causes of water quality impairment in Delaware. While nutrients are essential to the health of aquatic ecosystems, excessive nutrient loadings to surface waters can lead to an undesirable proliferation of aquatic weeds and algae, which in turn can result in oxygen depletion and associated impacts to fish and macroinvertebrate populations. Excessive aquatic plant growth can also preclude or seriously curtail water dependent activities such as fishing and boating when plant densities become so great that uses are not physically possible.

For tidal portions of the Indian River, Rehoboth Bay and Little Assawoman Bay watersheds, the water quality criterion for dissolved inorganic nitrogen is a seasonal average of 0.14 mg/l as N, and for dissolved inorganic phosphorus a seasonal average of 0.01 mg/l. For those stations where sampling events occurred on at least ten different days during the assessment period, the available data for the months of March to October from each station was averaged and confidence intervals on the averages were determined. The lower confidence limit on the averages was compared to the above values to assess attainment of desired nutrient levels in these waters. Segments with one or more stations whose lower confidence limit on their seasonal average were above the criteria were considered to be not fully supporting the aquatic life use (Category 5).

For the remaining waters of the State, the Department has been developing and implementing nutrient and dissolved oxygen TMDLs using target values for total nitrogen of 2-3 mg/l and total phosphorus levels of 0.1 to 0.2 mg/l. These target values were developed in order to implement the narrative provisions in the Surface Water Quality Standards. For those stations with sampling events on at least ten different days during the five-year assessment period the data were averaged and lower confidence limits on the averages were calculated and compared to the maximum values above. Stations whose lower confidence limit on the 5 year average total nitrogen or total phosphorus levels were above those levels were considered to be not fully supporting the aquatic life use (Category 5). Segments with one or more stations whose lower confidence limit on their average nutrient concentrations were above the target values were considered to be not fully supporting the aquatic life use (Category 5).

The following conditions would have also resulted in segments being listed in Category 5. None of them were used in this listing cycle.

1. There were documented cases of nuisance algal blooms or excessive macrophyte growth. These cases violate Section 4.1.1.3 of Delaware’s Standards which require waters of the State to be free from substances that may result in a dominance of nuisance species;
2. Detailed, site-specific monitoring studies indicated a strong linkage between nutrient levels and indicators of eutrophication such as high chlorophyll-a concentrations, extreme daily variation in dissolved oxygen levels, and high sediment oxygen demand; or
3. For ERES waters, a long-term trend analysis indicates a statistically significant increase in nutrient levels over time. Such increases are inconsistent with the short-term goal of “holding the line” on water quality in ERES waters. Such increases are also inconsistent with the long-term goal of restoring those waters, to the extent feasible, to their natural state.

Assessments of Total Suspended Solids in the Tidal Inland Bays Watershed

For tidal portions of the Indian River, Rehoboth Bay and Little Assawoman Bay watersheds, the water quality criterion for total suspended solids (TSS) is a seasonal average of 20mg/l from March 1 to October 31. For those stations where sampling events occurred on at least ten different days during the assessment period, the available data for the months of March to October from each station were averaged and confidence intervals on the averages were determined. The lower confidence limit on the averages was compared to the above values to assess attainment of desired TSS levels in these waters. Segments with one or more stations whose lower confidence limit on their seasonal average were above the criteria were considered to be not fully supporting the aquatic life use (Category 5).

Primary Contact Recreation Use Assessments

Generally, total enterococcus bacteria water quality samples are collected several times each year at each monitoring station. In addition, for all guarded beaches and many unguarded beaches, samples are collected much more frequently from mid-May through mid-September as part of beach monitoring activities pursuant to the Beaches Environmental Assessment and Coastal Health (BEACH) Act. Assessment of the above two situations for primary contact recreation use support was as follows.

For segments with no beach monitoring, if sampling events occurred on at least ten different days during the assessment period, the geometric mean of the available enterococcus (colonies/100 ml)data for each station was compared to the geometric mean values shown in the table below. For segments with no beach monitoring, one or more station geometric means above the values in the table were considered to not be in support of the Primary Contact Recreation designated use (Category 5).

Water Type	Geometric Mean (Enterococcus colonies/100 ml) Criteria for Primary Contact Use
Fresh	100
Marine	35

Temperature Assessments

Delaware surface water quality criteria indicate that, in freshwaters, no human induced increase of the daily maximum temperature above 86^{o}F (30.0 ^{o}C) shall be allowed and in marine waters the maximum human induced temperature is 87 ^{o}F (30.6 ^{o}C). Stations for which two or more sampling events were above the criteria and whose segments receive thermal discharges would have been deemed not in support of the aquatic life use. There were no such segments receiving thermal discharges.

Assessment of Harvestable Shellfish Waters Use Support

Delaware is a member of the Interstate Shellfish Sanitation Conference (ISSC), the administrative body of the National Shellfish Sanitation Program (NSSP). Delaware's Shellfish Sanitation Regulations are administered as per ISSC / NSSP standards and practices. Section 3.2.1.3 of said Regulations specifies data collection / closure criteria for Delaware shellfish waters, which include parameters constituting administrative closure of shellfish waters. Parameters that would trigger administrative closures in compliance with ISSC/NSSP standards may include theoretical pollution loading, sanitary shoreline survey information, and numerical total coliform data. All Delaware shellfish waters designated as other-than-Approved, which may include Prohibited, Seasonally Approved, Conditionally Approved, or restricted, are so designated on the basis of administrative decisions. Specifically, these criteria include: 1) theoretical pollution loading, which is determined to be the potential for intermittent pollution discharges, making detection of said theoretical releases non-detectable via conventional sampling methodology; 2) sanitary shoreline survey findings which indicate potential for theoretical pollution loading, also non-detectable via conventional sampling methodology; and 3) may include dilution of theoretical virus discharges from point sources; however, not corresponding to increases in total coliform levels. In order to comply with ISSC / NSSP requirements, Delaware samples all shellfish waters not administratively closed for other reasons for total coliform bacteria. Delaware's Shellfish Program is assessed under the auspices of the U.S. Food and Drug Administration, as per ISSC/NSSP standards and practices, and submits bacteriological water quality data to the U.S. Food and Drug Administration to demonstrate compliance.

To assess the harvestable shellfish designated use, the Department considered the data and reports to FDA for waters that are not administratively closed. Waters that were administratively closed for shellfish harvesting as a result of total coliform exceedances during the assessment period would have been assessed as category-5. No waters were administratively closed in the assessment period.

Listing Criteria for Waters with Fish Consumption Advisories

For purposes of developing Delaware's Integrated 305(b) Report and 303(d) List, the issuance of a "no consumption" or "limited consumption" fish advisory will be interpreted as a violation of Section 4.5.9.2.3 and Section 4.1.1.3 of Delaware's Surface Water Quality Standards. Those two narrative provisions provide, respectively, that:

1) waters of the State shall be maintained to prevent adverse toxic effects on human health resulting from ingestion of chemically contaminated aquatic organisms; and
2) waters of the State shall be free from pollutants that may endanger public health.

Any segment for which fish consumption advisories were place as of the publishing of the Integrated Report would have been placed in Category 5 for each of the chemicals of concern included in each advisory. In the event that fish consumption advisories were lifted, or any chemical of concern has been removed from an advisory, any requirements to develop a TMDL for that chemical in that segment will be removed if the fish tissue data was originally the sole cause for placement of the segment on the 303(d) list. In waters impaired by toxic pollutants, with both fish consumption advisories and water column data, both fish tissue and water column data were assessed independently against the applicable criteria.

For the 2020 assessments, the Department incorporated the Fish Tissue Advisories that were issued by the Delaware Departments of Health and the Department of Natural Resources and Environmental Control on February 20th, 2018. As those advisories were incorporated into the 2018 listing decisions, there were no changes in this cycle to listing decisions previously made.

Ammonia assessments

In fresh waters, ammonia's toxicity is known to be controlled by both the temperature and pH of the water. Delaware's ammonia criteria are based on the presence or absence of early life stages of fish and specify that the criterion should not be exceeded more than one time in a three-year period. The applicable criterion is calculated for each sampling event.

For stations whose average salinity during the assessment period is below 5 ppt, total ammonia as nitrogen, temperature and pH data was used to compare the total ammonia data to the criterion calculated according to the following formulas:

When fish early life stages are present:

$$\text{Criterion} = \frac{0.0577}{1 + 10^{7.688-pH}} + \frac{2.487}{1 + 10^{pH-7.688}} * \text{MIN}\left(2.85,\ 1.45 * 10^{0.028*(25-T)}\right)$$

When fish early life stages are absent:

$$\text{Criterion} = \frac{0.0577}{1 + 10^{7.688-pH}} + \frac{2.487}{1 + 10^{pH-7.688}} * \left[1.45\ 10^{0.028*(25-\text{MAX}\ (T,7))}\right]$$

If two or more sampling events from the same station resulted in exceedances of the calculated criteria within three years, the station was deemed not supported for aquatic life use support based on ammonia toxicity.

Assessments of Aquatic Life Use Support Using Site-Specific Data That Results from Environmental Assessments and Other Programs

The Department may use the following methodology in any IR cycle, but did not do so for the 2020 IR. "*In the normal course of business, the Department requests, receives and evaluates water quality data for various environmental programs. Similar data may also come from other parties (e.g., State, Federal, or local agencies). The Department will use those site-specific studies to compare water quality data to the applicable water quality standard(s) and make assessment and listing decisions for the affected segments. If the data show no water quality criteria are exceeded and no uses are impaired, no further listing action will be taken. If the data are ambiguous or inconclusive, the segment will be listed in Category 3. If water quality criteria are exceeded or uses are impaired as a result of a contaminated site, and the owners of the site are making substantial progress (as determined by the Department) toward correcting the pollution problem, the segment will be listed in Category 4 if an enforceable regulatory mechanism has been identified and implemented. If it appears that there is a water quality* *problem related to a contaminated site, and that substantial progress is not likely in the near future, the segment will be listed in Category 5. "*

Assessments of Biology and Habitat

The Department has been working with the EPA to address prior listings for Biology and Habitat. As new stressor analyses and other data and information become available, appropriate measures will be taken to address these listings. Where no specific pollutant can be determined, the Department will delist those segments (move to category 4b or 4c as needed) and address water quality issues through restoration and other efforts as funding is available. If specific pollutants can be determined, TMDLs or other actions will be taken to address those pollutants.

Setting Priorities for Water Quality Limited Segments Still Needing TMDLs

The Department has set priorities for upcoming TMDLs in waters that remain in Category 5 or 5(MNR) according to the following protocol. Waters where TMDL development is not expected for five or more years were assigned to the "Low" priority group. For 2020 that includes waters listed for Habitat or Biology TMDL development. It also includes waters in Category 5(MNR) where waters are expected to be attaining for toxics in fish tissues within five to ten years as discussed above. As discussed above, the Department will change the priority of 5(MNR) waters if, for some reason, data shows that attainment of the use is not expected in a short period of time. The Department is working with EPA Region 3 to develop stressor analysis tools to try to resolve longstanding listings for Habit or Biology. Finally, there are some Delaware waters that are part of the DRBC waters and for which the DRBC and EPA will be taking the lead for TMDL development. Those are also listed as Low priority.

For waters the Department expected to develop TMDLs in more than 2 years, but less than 5 or more, the Department would have shown them as "Medium" priority. In those waters, plans are underway to collect data and other information to develop appropriate TMDLs. At this time, there are no waters in the Medium category.

If the Department expects to develop TMDLs in the next two years or less, those waters have been shown as "High" priority. The Department moved three waters from Medium to High priority in this cycle.

Rationale Used to Designate a Lower Category for Segments Previously Designated for TMDL Development

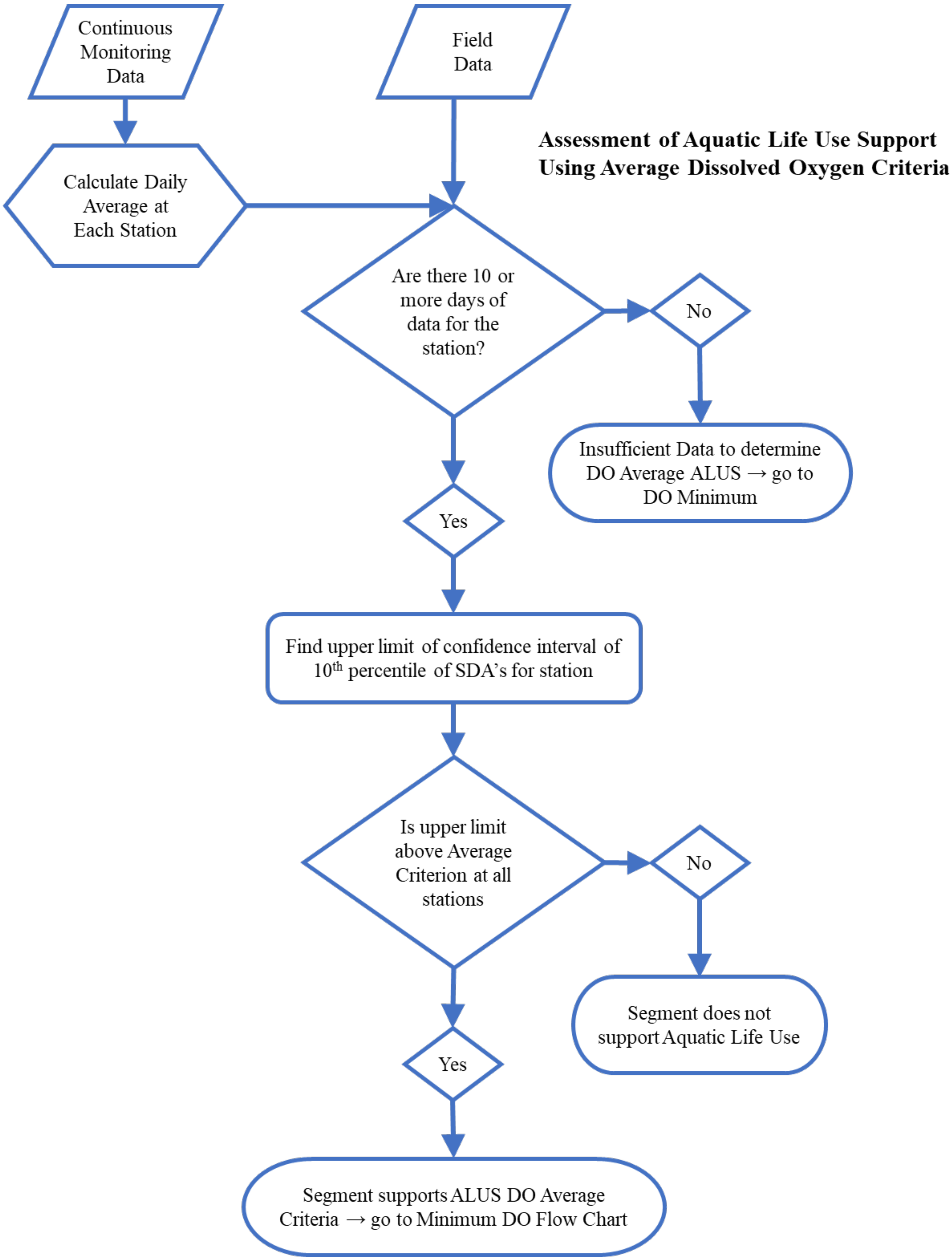
The Department may move segments from prior 303(d) Lists (equivalent to Category 5) to another category based on any of the following factors, and will document the reasons for doing so on a case-by-case basis. Once a TMDL has been promulgated and approved by the EPA, it is in place until it has been rescinded by the Department following applicable Departmental procedures.

- The assessment and interpretation of more recent or more accurate data demonstrate that the applicable WQS(s) is being met. (Move to category 1)
- The results of more sophisticated water quality modeling demonstrate that the applicable WQS(s) is being met. (Move to category 1)
- Demonstration that flaws in the original analysis of data and information led to the water being incorrectly listed. (Move to category 1)

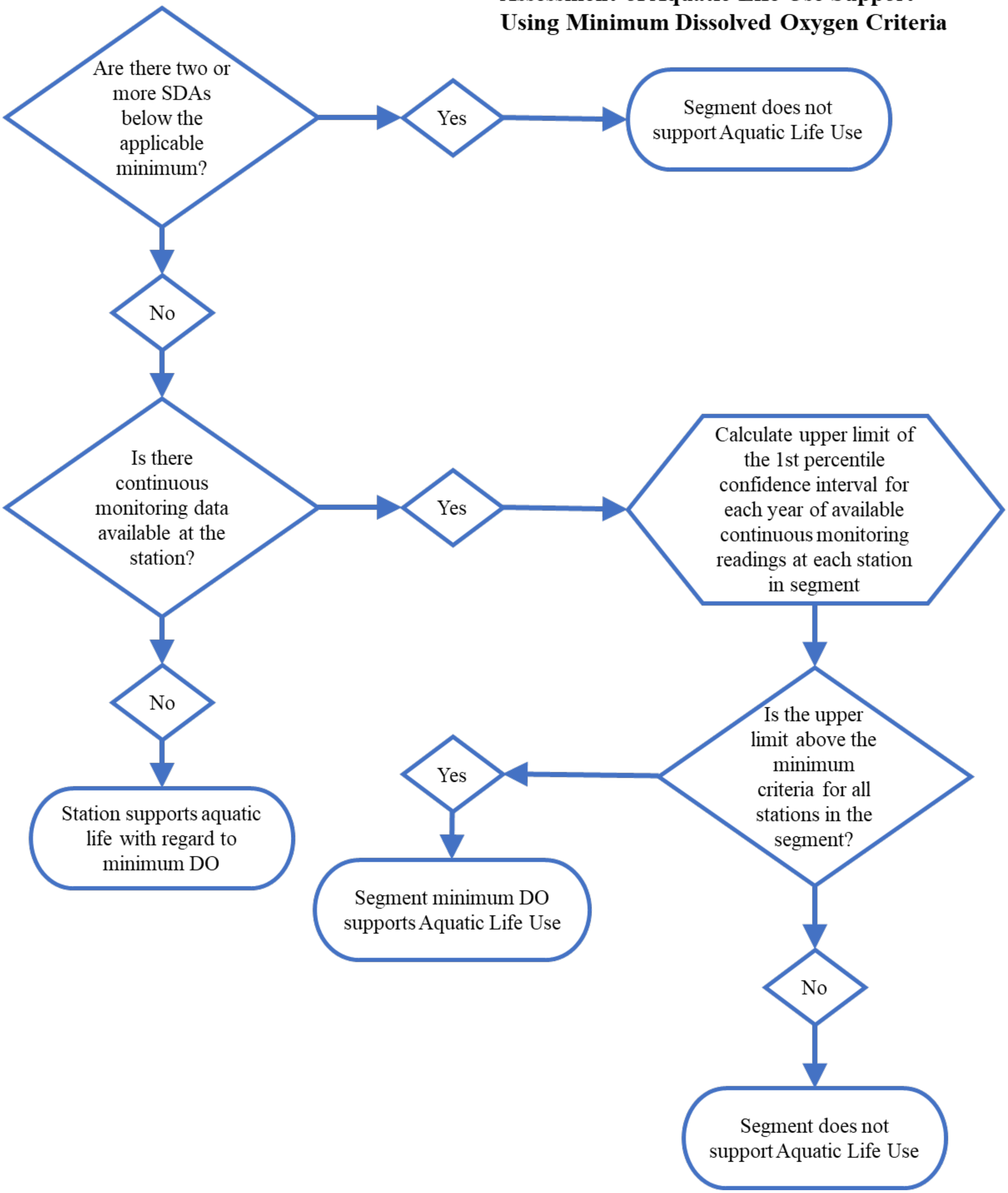
- The development of a new listing methodology, consistent with State WQSs and federal listing requirements, and a reassessment of the data that led to the prior listing, concluding that WQSs are now attained. (Move to appropriate category)
- A demonstration pursuant to 40 CFR 130.7(b)(1)(ii) that there are effluent limitations required by State or local authorities that are more stringent than technology-based effluent limitations required by the CWA and that these more stringent effluent limitations will result in the attainment of WQSs for the pollutant causing the impairment. (Move to category 4A or 4B until data and analysis support move to Category 1)
- A demonstration pursuant to 40 CFR 130.7(b)(1)(iii) that there are other pollution control requirements required by State, local, or federal authority that will result in attainment of WQSs for a specific pollutant(s) within a reasonable time. (Move to category 4A or 4B until data and analysis support move to Category 1)
- Documentation that the State included on a previous Section 303(d) List an impaired water that was not required to be listed by EPA regulations; e.g., waters where there is no pollutant associated with the impairment. (Move to category 1 or 4C as appropriate)
- Approval or establishment by EPA of a TMDL since the last Section 303(d) List. (Move to category 4A or 4B until data and analysis support move to Category 1)

Other factors may also be used to change categories on a case by case basis, subject to EPA approval and appropriate stakeholder involvement.

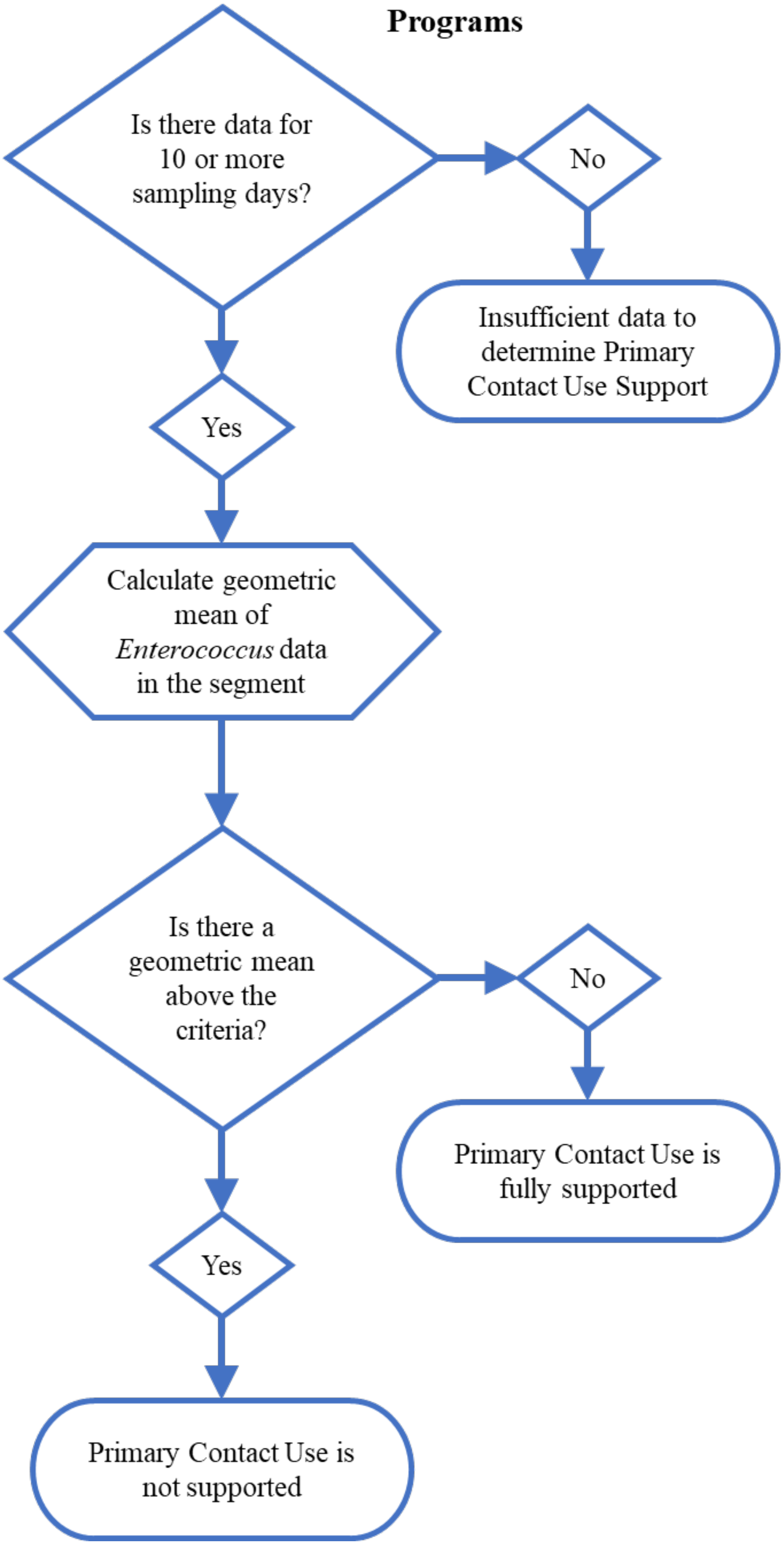
Flow Charts for Designated Use Attainment


Continuous Monitoring Data
Field Data
Assessment of Aquatic Life Use Support Using Average Dissolved Oxygen Criteria
Calculate Daily Average at Each Station
Are there 10 or more days of data for the station?
No
Insufficient Data to determine DO Average ALUS → go to DO Minimum
Yes
Find upper limit of confidence interval of 10th percentile of SDA's for station
Is upper limit above Average Criterion at all stations
No
Segment does not support Aquatic Life Use
Yes
Segment supports ALUS DO Average Criteria → go to Minimum DO Flow Chart

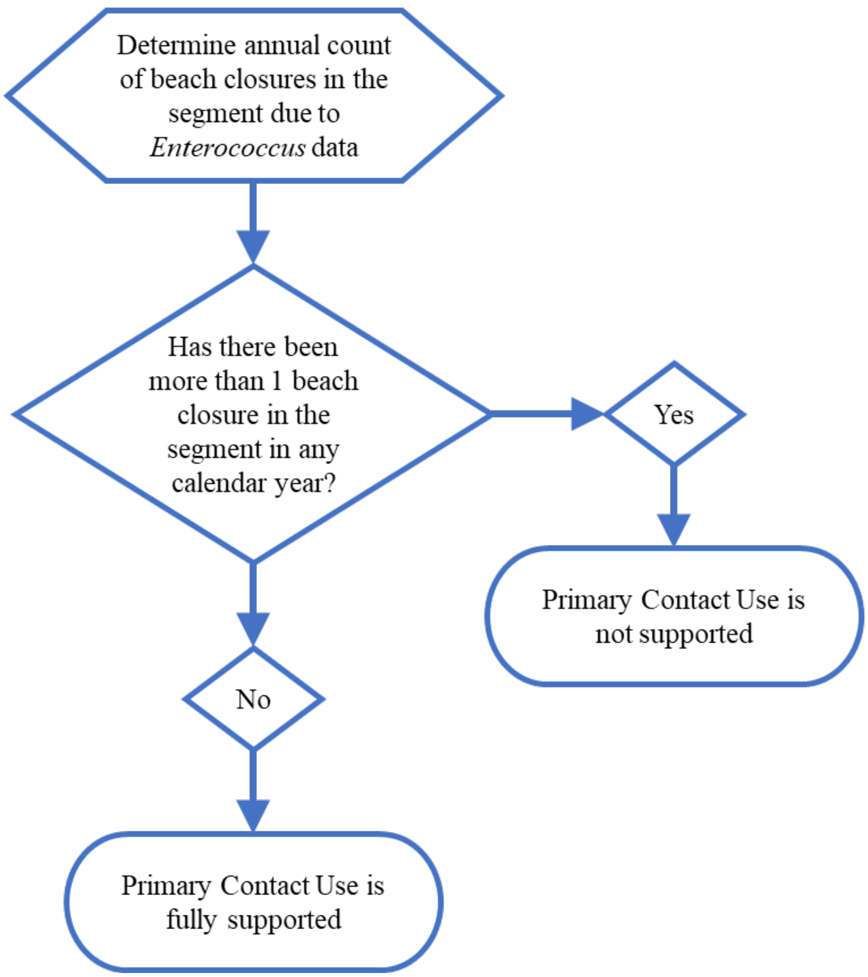
Assessment of Aquatic Life Use Support Using Minimum Dissolved Oxygen Criteria



Assessment of Primary Contact Use Support in Segments that do not have Beach Monitoring Programs



Assessment of Primary Contact Use Support in Segments with Beach Monitoring Programs



APPENDIX E

STATE OF DELAWARE AMBIENT SURFACE WATER QUALITY MONITORING PROGRAM FY 2020

State of Delaware Ambient Surface Water Quality Monitoring Program FY 2020 (July 1, 2019-June 30, 2020)

Department of Natural Resources and Environmental Control

Division of Watershed Stewardship

Watershed Assessment and Management Section

June 17, 2019

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Executive Summary

Delaware's Surface Water Quality Monitoring Program for Fiscal Year 2020 as conducted by Delaware Department of Natural Resources and Environmental Control (DNREC) is described in this report. Elements of Delaware's monitoring program include: General Assessment Monitoring, Chesapeake Non-tidal Monitoring, Continuous Water Quality Monitoring, Biological Assessment Monitoring, Toxics in Biota Monitoring, Toxics in Sediment Monitoring, and Monitoring under the Watershed Approach to Toxics Assessment and Restoration (WATAR) Plan. Each element of the monitoring program is briefly described below:

- Delaware maintains a General Assessment Monitoring Network (GAMN). GAMN stations are considered long term stations whose data is used to perform long term status and trend assessments of water quality conditions of the State's surface waters and support compilation of Watershed Assessment Reports as mandated by the Clean Water Act under section 305(b). In addition, the data is used to calculate annual nutrients and other pollutants loads and to track progress toward achieving the targets established by the Total Maximum Daily Loads (TMDLs) for many of the watersheds of the State. Furthermore, the data will be used to identify effect of land use on N and P concentrations. The State's GAMN currently has a total of 139 stations. 23 of the monitoring stations are considered category 1 stations (C1) and are monitored monthly. These stations are co-located with a United States Geological Survey (USGS) stream gaging station or are located at the mouth of a tidal river. The remaining 116 monitoring stations are Category 2 (C2) stations and are monitored monthly for 2 years and bi-monthly for 3 years according to a 5-year rotating basin schedule. 4 storm samples (one per season) are collected annually at 12 C1 and C2 sites statewide shown at the end of Table One. During FY 2020, Piedmont and Chesapeake Bay Drainage Basins are the priority basins and all stations in these two basins are monitored every month. Monitoring frequency at stations in the other 3 basins (Inland Bays, Upper Delaware Bay, and Lower Delaware Bay) will be bi-monthly.
- Delaware DNREC is participating in the Chesapeake Bay Program's Non-tidal Monitoring Program and collects samples from two of the non-tidal sites located in Delaware. These two sites are Nanticoke River near Bridgeville and Marshyhope Creek at Fishers Bridge Rd. Samples at these two sites are collected according to sample collection protocol developed by the Chesapeake Bay Program Non-tidal Monitoring Workgroup. Monthly samples and 8 storm samples per year (2 storm samples per season) are collected at these two sites. The data collected at these two sites are provided to the Chesapeake Bay Program and are used for calibrating the Chesapeake Bay Watershed Model. The data are also used to monitor water quality status and to perform trend analysis.
- Delaware DNREC, in cooperation with the Delaware Geological Survey (DGS) and the United States Geological Survey (USGS), is maintaining 6 continuous water quality monitoring sites in the State. Monitoring of water temperature, dissolved oxygen (DO), pH, and specific conductance at these sites are conducted

at fifteen minute intervals by using multi-parameter water-quality sondes (YSI sondes).

- During FY 2020, Delaware DNREC will not conduct any new habitat/biological survey. Instead, it will review the results of surveys conducted during the past several years to evaluate the condition of habitat/biota and to identify any areas where data gap exist and where additional monitoring is needed. Future habitat/biological monitoring will be based on the findings of this data review and analysis.
- During FY2020 DNREC's WATAR Team plans to continue to focus its ongoing efforts to characterize watersheds that flow from Delaware to the Chesapeake Bay. This focus started in FY2018. During the past two reporting periods, water, sediment and fish samples were collected from 18 locations within 15 watersheds, including the Elk Creek watershed, Perch Creek watershed, C&D Canal West watershed, Bohemia Creek watershed, Sassafras River watershed, Chester River watershed, Choptank River watershed, Marshyhope Creek watershed, Nanticoke River watershed, Gum Branch watershed, Gravely Branch watershed, Deep Creek watershed, Broad Creek watershed, Pocomoke River watershed and the Wicomico watershed. Data analysis and assessment is ongoing, and summary reports are in the process of being prepared.

Ambient Surface Water Quality Monitoring Program - FY 2020

The purpose of the Ambient Surface Water Quality Monitoring Program is to collect data on the chemical, physical and biological characteristics of Delaware's surface waters. The information that is collected under this Program is used to:

Describe surface water quality conditions in the State;

Identify long term trends in surface water quality;

Determine the suitability of Delaware surface waters for water supply, recreation, fish and aquatic life, and other uses;

Monitor achievement of Surface Water Quality Standards;

Identify and prioritize high quality and degraded surface waters;

Calculate annual nutrient and select metal loads and track progress toward achieving Total Maximum Daily Load (TMDL) targets; and

Evaluate the overall success of Delaware's water quality management efforts.

Major components of Delaware's Surface Water Quality Monitoring Program include the following:

General Assessment Monitoring

Chesapeake Non-tidal Monitoring

Continuous Water Quality Monitoring

Biological Assessment Monitoring

Toxics in Biota Monitoring

Toxics in Sediment Monitoring

Monitoring under the Watershed Approach to Toxics Assessment and Restoration (WATAR) Plan.

This report discusses the General Assessment Monitoring in detail. In addition, it briefly discusses other components of the Delaware's Surface Water Quality Monitoring Program including the Biological Assessment Monitoring, Toxics in Biota Monitoring, Toxics in Sediment Monitoring, and WATAR monitoring.

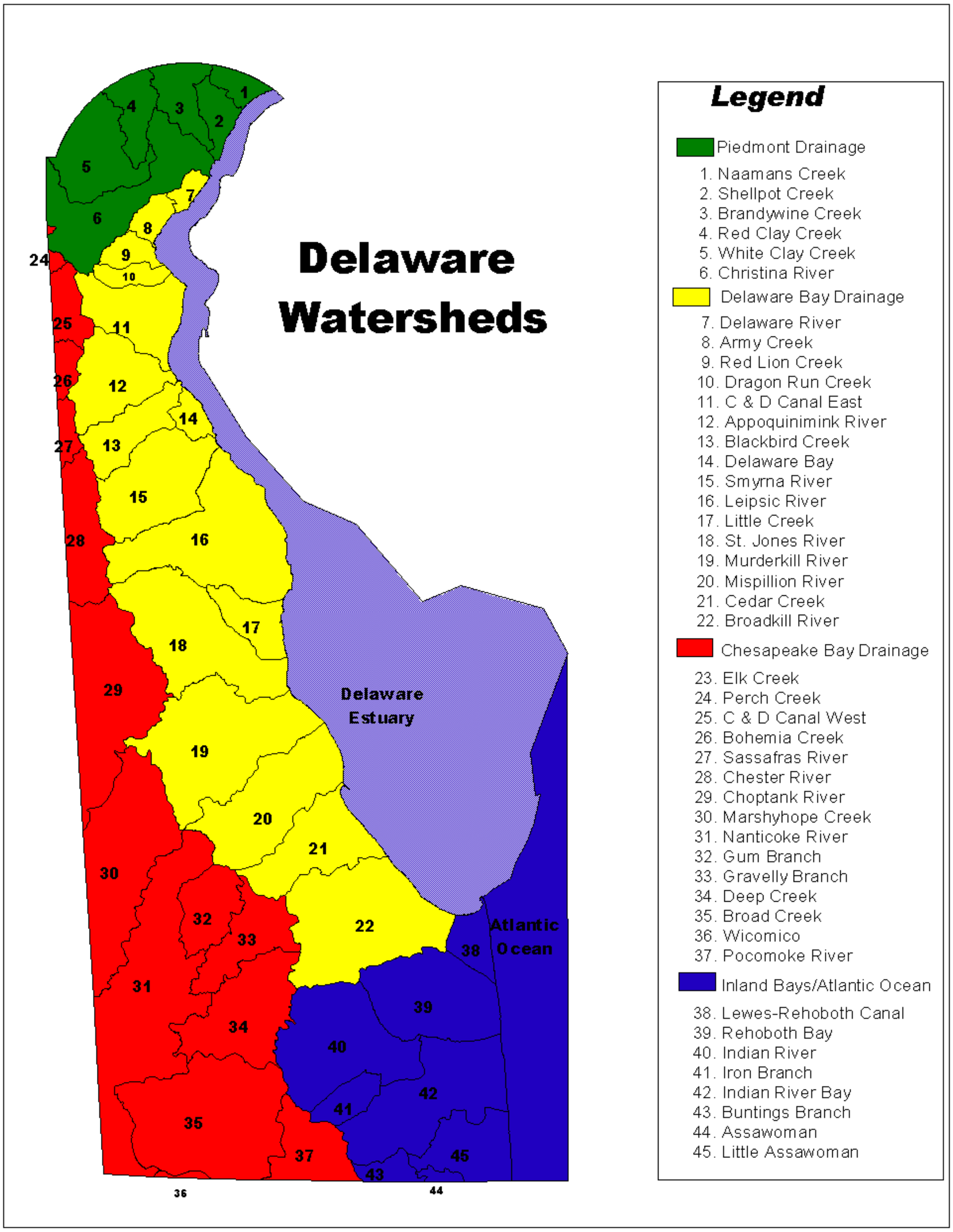

Figure 1 – State of Delaware Watersheds and Basins

The General Assessment Monitoring Network (GAMN)

The General Assessment Monitoring Network (GAMN) provides for routine water quality monitoring of surface waters throughout the State of Delaware. Currently the monitoring network includes 139 monitoring stations (see Table 1). Each station is monitored for conventional parameters such as nutrients, bacteria, dissolved oxygen, pH, alkalinity, and hardness (Table 2). Some stations are monitored for dissolved metals as well as the parameters that are needed to conduct Biotic Ligand Model (BLM) analysis for metals toxicity (see Tables 1, 3 and 4).

The data collected as part of this effort is entered into the EPA's STORET database. In addition, the data is reviewed and analyzed to assess water quality condition of the State's waters to be included in the Integrated Watershed Assessment Report (CWA Sections 305 (b)/303(d) Report) which Delaware Department of Natural Resources and Environmental Control produces every 2 years. Furthermore, the data is used to assess water quality status and trends as well as tracking progress toward achieving water quality standards and TMDL targets.

As stated earlier, the GAMN currently has a total of 139 stations. These stations fall into 2 categories:

a. C1 - Category 1 stations are high priority stations. Currently GAMN contains 23 Category 1 sites. Data collected at C1 Stations are used for calculating annual loads and long-term trends. These stations are generally co-located with a United States Geological Survey (USGS) stream gaging station or are located at the mouth of a tidal river. Monitoring at these stations is conducted monthly, regardless of rotating priority basin schedule. In addition, annually 4 storm samples (1 per season) are collected at these sites.

b. C2 - The remaining 116 stations are Category 2 stations and are monitored monthly for 2 years and bi-monthly for 3 years according to a 5-year rotating priority basins schedule.

Figure 2 shows the location of monitoring sites and C1 and C2 stations. During FY 2020, the Piedmont and Chesapeake Bay Drainage Basins are priority basins and all stations in these two basins are monitored monthly. Stations in the 3 remaining basins are monitored 6 times per year (bi-monthly). Figure 3 shows Delaware's Priority Rotating Basins.

Data collected as part of this monitoring effort is archived in the US EPA's STORET data base. In addition, the data can be viewed or downloaded from the University of Delaware's Environmental Observatory System (DEOS) Water Quality Data Portal site at the following url: http://demac.udel.edu/waterquality/

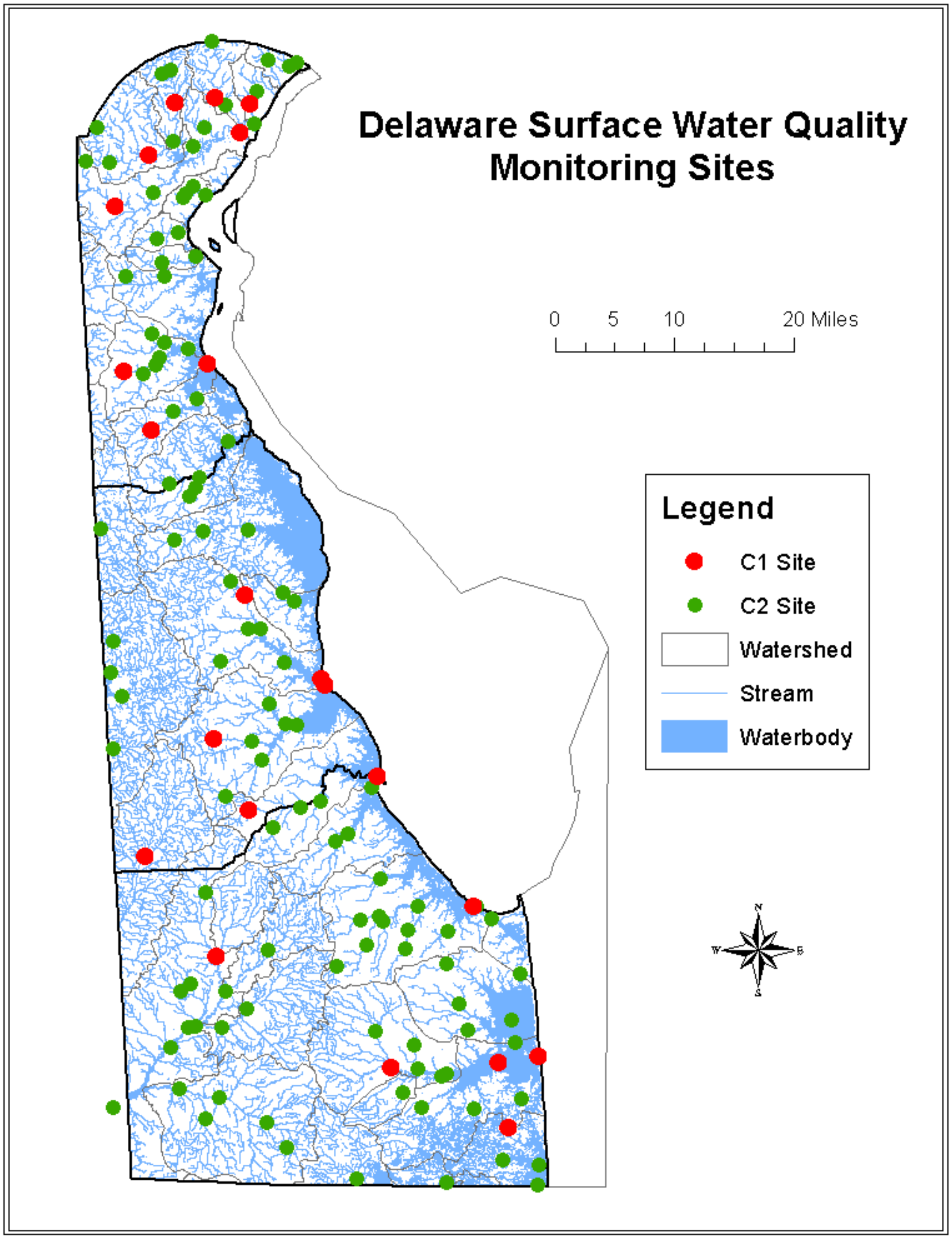

Figure 2 - Delaware's Surface Water Quality Monitoring Sites

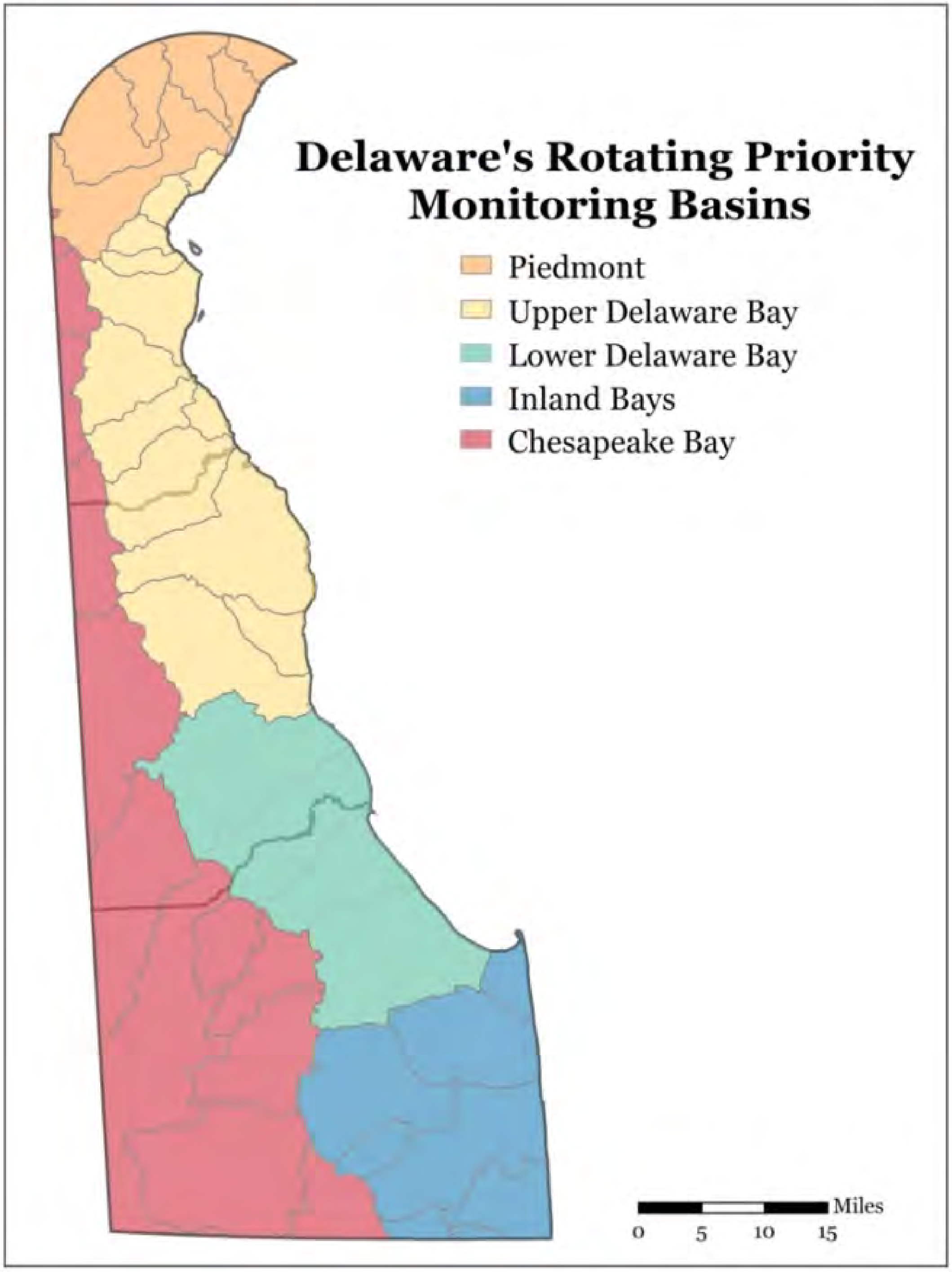

Figure 3 - Delaware's Rotating Priority Monitoring Basins

Chesapeake Bay Non-tidal Monitoring

Delaware DNREC is participating in a multi-State non-tidal monitoring Program conducted by the Chesapeake Bay Program and other jurisdictions including Maryland, Virginia, West Virginia, Pennsylvania, New York, and the District of Columbia. The Chesapeake Bay Non-tidal Monitoring Network has about 120 monitoring sites and the following two sites are in Delaware:

1. Nanticoke River near Bridgeville
2. Marshyhope Creek at Fishers Bridge Rd

Location of the Chesapeake Bay Non-tidal monitoring sites in Delaware is shown in Figure 4. Monitoring at the above two sites is conducted monthly using sample collection protocol developed by the Chesapeake Bay Program Non-tidal Monitoring Workgroup (1). In addition to monthly sampling, 8 storm samples per year (2 per season) are collected at these sites.

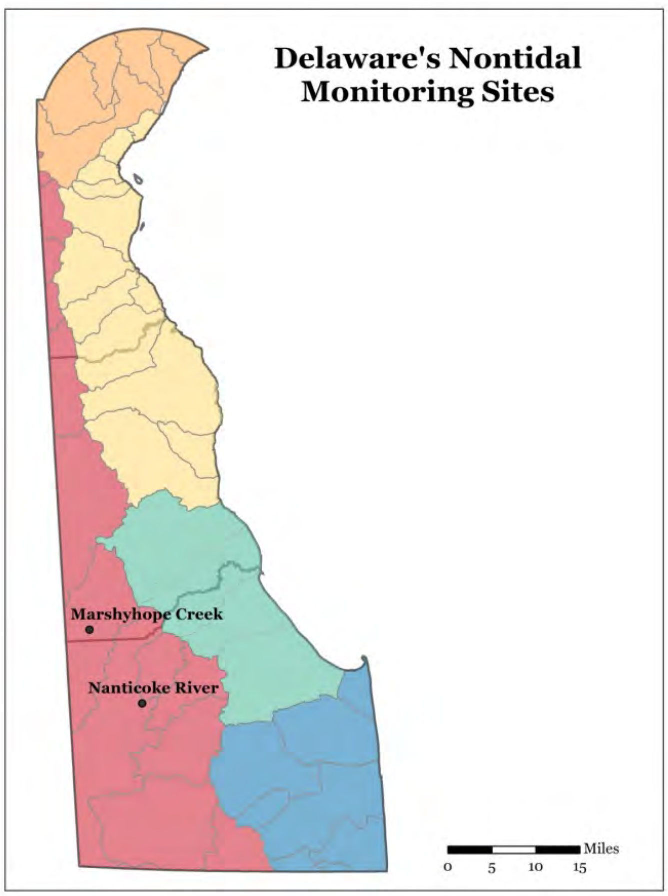

Figure 4 - Delaware's Non-tidal Monitoring Sites

Continuous Water Quality Monitoring

Delaware DNREC, in cooperation with the Delaware Geological Survey (DGS) and the United States Geological Survey (USGS), is maintaining a number of continuous Monitoring sites in the State. During FY 2020, six sites in Delaware are being monitored continuously. These sites include:

1. Brandywine Creek at Wilmington
2. Christina River at Newport
3. Appoquinimink River near Odessa
4. Millsboro Pond Outlet at Millsboro
5. Broadkill River near Milton
6. Massey Ditch at Massey Landing

Figure 5 shows the location of the above continuous monitoring sites. Measurements of water temperature, dissolved oxygen (DO), pH, and specific conductance at these sites are conducted at every fifteen minutes interval by using multi-parameter water-quality data sondes (such as YSI sondes). All data are collected following USGS protocols and are stored in USGS National Water Information System (NWIS) databases, http://waterdata.usgs.gov/de/nwis/current/?type=quality

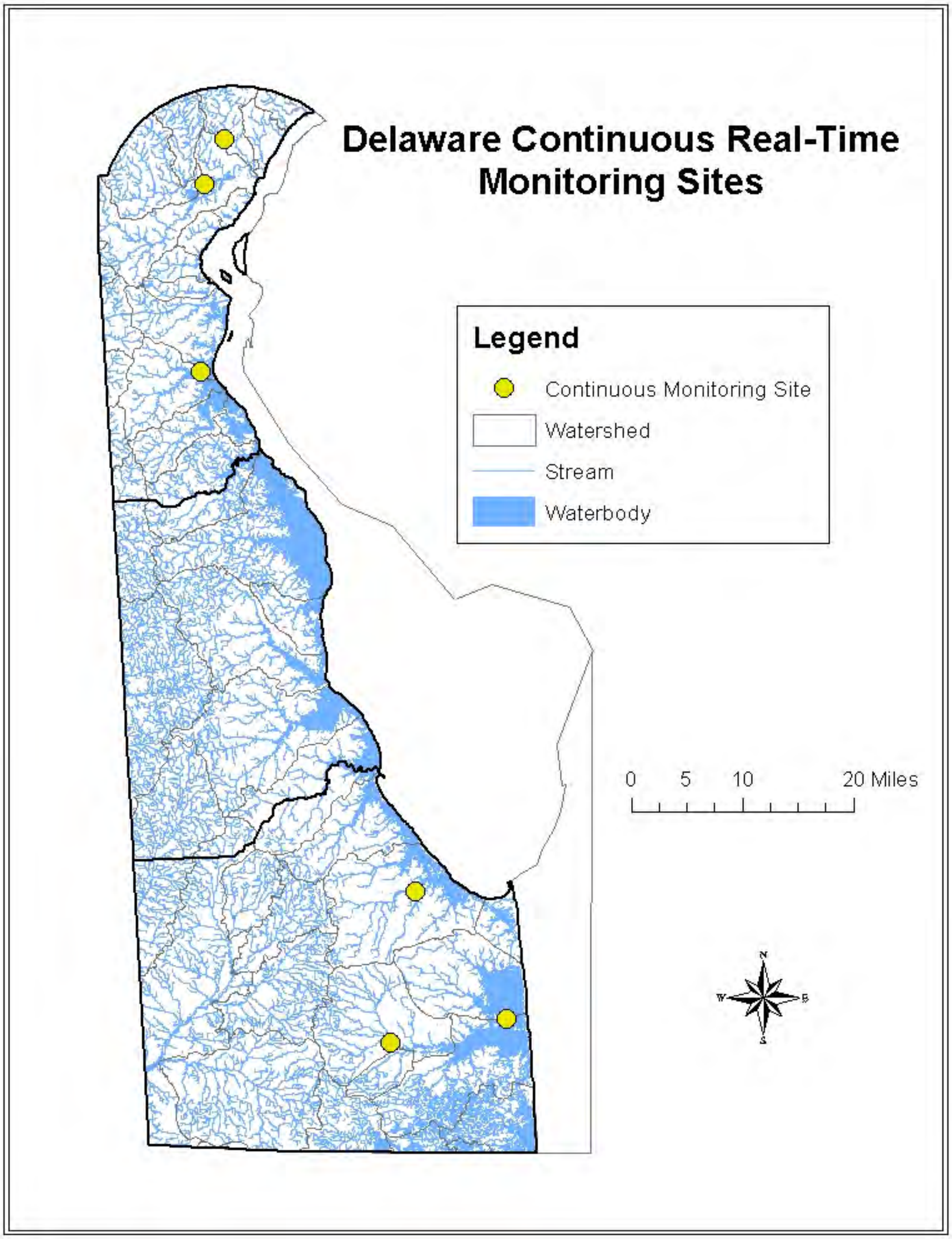

Figure 5 - Delaware's Continuous Monitoring Sites

Biological Assessment Monitoring

To assess habitat and biological integrity of Delaware's surface waters, Delaware DNREC conducts habitat and biological monitoring of its streams. Macroinvertebrate and habitat assessments are generally performed at perennial, non-tidal, wadable streams throughout the State of Delaware using a probabilistic design. Random sites are selected through the assistance by the Environmental Protection Agency (EPA) using an EMAP approach. Randomization of sites will allow for a statewide, unbiased probability-based estimate of stream conditions throughout the state. Data from this survey will be used for 305(b) analysis.

During FY 2020, Delaware DNREC is not conducting any new habitat/biological survey. Instead, it will review the results of surveys conducted over the past several years to evaluate the condition of habitat/biota and to identify any areas where data gap exist and where additional monitoring is needed. Future habitat/biological monitoring will be based on the findings of this data review and analysis.

Toxics in Biota Monitoring

The FY 2020 Toxics in Biota Monitoring program is being incorporated into the WATAR monitoring effort (see below).

Toxics in Sediment Monitoring

The FY 2020 Toxics in Sediment Monitoring program is being incorporated into the WATAR monitoring effort (see below).

Monitoring under the Watershed Approach to Toxics Assessment and Restoration (WATAR) Plan

During FY2018 and FY2019, DNREC's WATAR Team focused its monitoring efforts on watersheds that flow from Delaware to the Chesapeake Bay. Water, sediment and/or fish samples were collected from 18 locations within 15 watersheds, including the Elk Creek watershed, Perch Creek watershed, C&D Canal West watershed, Bohemia Creek watershed, Sassafras River watershed, Chester River watershed, Choptank River watershed, Marshyhope Creek watershed, Nanticoke River watershed, Gum Branch watershed, Gravely Branch watershed, Deep Creek watershed, Broad Creek watershed, Pocomoke River watershed and the Wicomico watershed (see Figure 6).

All water samples collected during the first year were analyzed for total suspended solids (TSS), particulate carbon (PC), particulate organic carbon (POC), dissolved organic carbon (DOC), and chlorophyll-a (Chl a). In addition to these conventional water quality parameters, samples were analyzed for polychlorinated biphenyls (PCBs), dioxins and furans (DxF), organonitrogen (ON) pesticides, MRES pesticides (organochlorine (OC) pesticides, organophosphate (OP) pesticides, triazine herbicides, total pyrethroids and ON herbicides), polyaromatic hydrocarbons (PAHs), carbamates, glyphosates, AMPA, glufosinate, and acid extractable herbicides.

All sediment samples collected during the first year were analyzed for total organic carbon/black carbon (TOC/BC), grain size, moisture content, bulk density, and specific gravity. In addition to these physical parameters, samples were analyzed for PCBs, DxF, TAL metals including mercury and cyanide, MRES pesticides, ON pesticides, PAHs, carbamates, glyphosates, AMPA and glufosinate.

All fish samples collected during the first year were analyzed for PCBs, DxF, MRES pesticides, ON pesticides, PAHs, and lipid content.

The second year of sampling focused on select "emerging contaminants" and included analysis of surface water and surficial sediments for neonicitinoids; specific pyrethroids (depending on whether total pyrethroids are detected in year 1); plus hormones and sterols. Additional fish tissue samples were analyzed from 12 ponds located within Delaware's Chesapeake Bay drainages. These samples were analyzed for the same parameters as noted above for the first year's fish tissue samples.

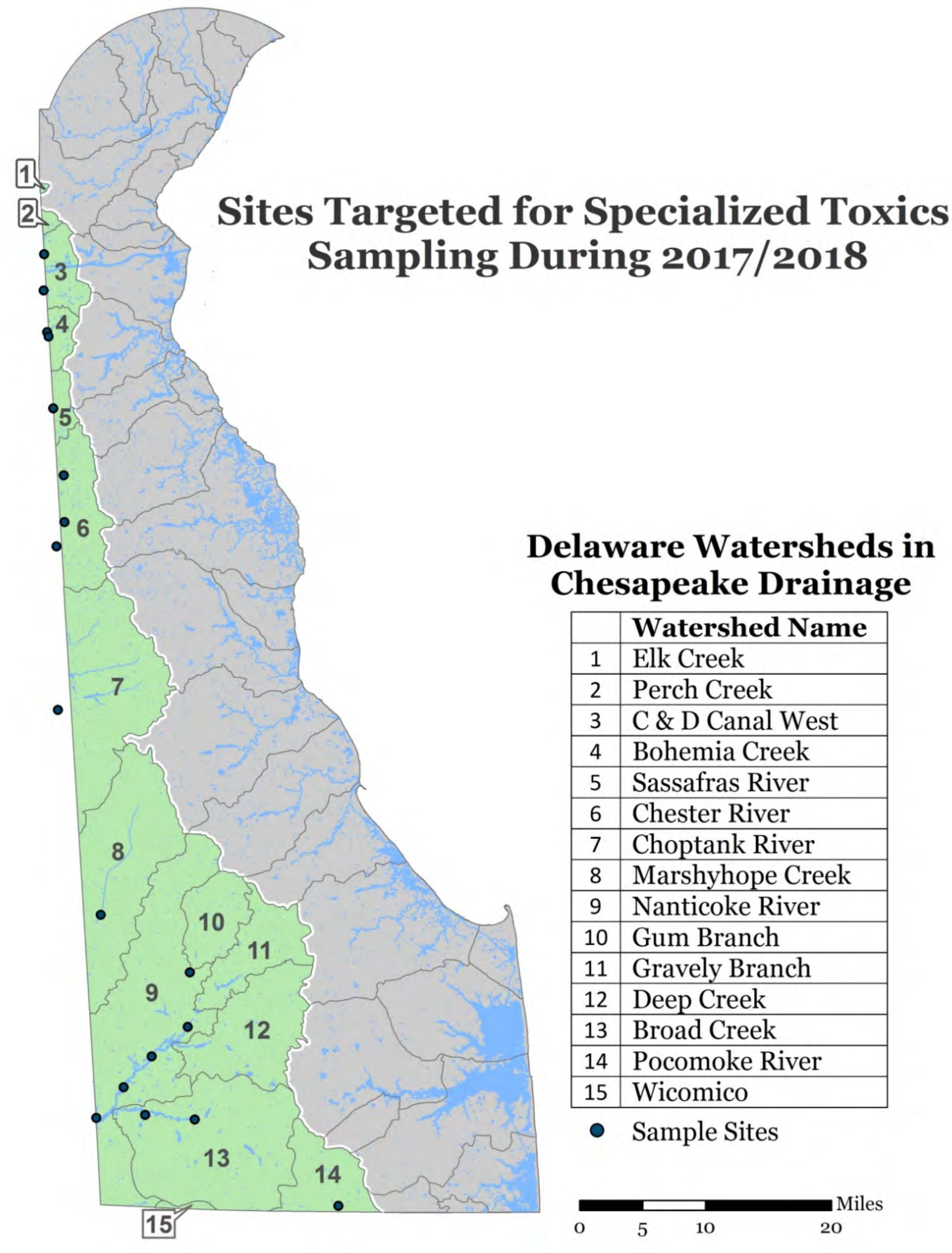

Figure 6 - WATAR Sampling sites

A comprehensive Quality Assurance Project Plan for the above WATAR work was approved by the USEPA Chesapeake Bay Office in September 2017. Sampling work was conducted in the fall of CY 2017 and CY 2018. Data evaluation and a summary report will be prepared, beginning in FY20 (CY 2019). For additional details about the scheduled work, please see the approved QAPP (2).

In addition to the Chesapeake Bay drainage summary report preparation in FY20, the WATAR team plans to focus its annual sampling efforts on fish tissue within the Saint Jones River, C&D Canal, and Red Lion Creek. The data collected will inform trend assessments submitted to USEPA in CY 2018. Additional surface water and/or sediment sampling will be conducted in support of potential TMDL development for DxF TEQs in the upper Saint Jones and Silver Lake. For more detailed information on planned activities, please refer to the WATAR 5-year workplan for 2018-2022 (5).

Field and Laboratory Procedures

Field procedures for sample collection activities are detailed in DNREC's Environmental Laboratory Services Quality Manual (3). Method references, STORET codes and reporting levels for parameters listed in Table 2 are provided by the DNREC's Environmental Laboratory Section. Any deviation from standard field, laboratory procedures, or this sampling plan shall be documented with a complete description of the alteration.

Quality Assurance, Documentation, Data Usage and Reporting

The quality assurance objectives and quality control procedures for these surveys are documented in the Quality Assurance Project Plan prepared by the Watershed Assessment and Management Section, Division of Watershed Stewardship (4).

A duplicate water column sample will be collected and analyzed on 10% of the samples from this project. All analytical results from the duplicate analyses shall be reported with the other data.

All analytical results shall be reported to the Watershed Assessment and Management Section digitally (using standard Environmental Laboratory Section's data report forms).

Table 1 - Station Locations, Descriptions, Parameters, and Sampling Frequency

BASIN	PROJECT	SITE DESCRIPTION	STORET	Category	Freq.	Arsenic (As)	Iron (Fe)	Copper, Lead and Zinc	BLM Parameters
PIEDMONT	North Piedmont	Little Mill Creek @ DuPont Rd.	**106281**	**C2**	12			**X**	**X**
		Christina River near Conrail Bridge	**106291**	**C1**	12			**X**	**X**
		Brandywine Creek @ Foot Bridge in Brandywine Park	**104011**	**C2**	12			**X**	**X**
		Brandywine Creek @ New Bridge Rd. (Rd. 279)	**104021**	**C1**	12			**X**	**X**
		Red Clay Creek @ Lancaster Pike (Rt. 48)	**103031**	**C1**	12			**X**	**X**
		Red Clay Creek @ Barley Mill Rd. (Rd. 258A)	**103041**	**C2**	12			**X**	**X**
		Burroughs Run @ Creek Rd. (Rt. 82)	**103061**	**C2**	12			**X**	**X**
		Brandywine Creek @ Smith Bridge Rd. (Rd. 221)	**104051**	**C2**	12			**X**	**X**
		Christina River beneath Rt. 141 Bridge	**106021**	**C2**	12			**X**	**X**
		Red Clay Creek @ W. Newport Pike (Rt. 4)	**103011**	**C2**	12			**X**	**X**
		White Clay Creek @ Delaware Park Blvd.	**105151**	**C1**	12			**X**	**X**
		White Clay Creek @ McKees Lane	**105171**	**C2**	12			**X**	**X**
		Christina River @ Nottingham Rd. (Rt. 273)	**106191**	**C2**	12			**X**	**X**
		White Clay Creek @ Chambers Rock Rd. (Rd. 329)	**105031**	**C2**	12			**X**	**X**
		Christina River @ Sunset Lake Rd. (Rt. 72)	**106141**	**C1**	12			**X**	**X**
		Smalleys Dam Spillway @ Smalleys Dam Rd.	**106031**	**C2**	12			**X**	**X**
	Northeast Piedmont	Naaman Creek S. Branch @ Darley Rd. (Rd. 207)	**101031**	**C2**	12				
		Naaman Creek @ State Line near Hickman Rd.	**101021**	**C2**	12				
		Naaman Creek South Branch @ Marsh Rd. (Rt. 3)	**101061**	**C2**	12				
		Shellpot Creek @ Carr Rd.	**102081**	**C2**	12				
		Shellpot Creek @ Market St. (Rt. 13 Bus.)	**102051**	**C1**	12				
		Shellpot Creek @ Hay Rd. (Rd. 501)	**102041**	**C2**	12		**X**		
UPPER	North Delaware	Army Creek @ S. DuPont Hgwy. (Rt. 13)	**114021**	**C2**	6				

BASIN	PROJECT	SITE DESCRIPTION	STORET	Category	Freq.	Arsenic (As)	Iron (Fe)	Copper, Lead and Zinc	BLM Parameters
DELAWARE BAY	Bay	Army Creek @ Rt. 13 near Rt. 40	**114051**	**C2**	6				
		Trib Army Crk. @ Rt. 13 near Airport Ind. Park	**114041**	**C2**	6				
		Army Creek @ River Rd. (Rt. 9)	**114011**	**C2**	6				
		Red Lion Creek @ Rt. 9	**107031**	**C2**	6				
		Dragon Creek @ Wrangle Hill Rd. (Rt. 9)	**111011**	**C2**	6				
		C & D Canal @ DuPont Pkwy. (Rt. 13) N. side	**108021**	**C2**	6				
		Dragon Creek @ S. DuPont Hwy. (Rt. 13)	**111031**	**C2**	6				
		Red Lion Creek @ Bear Corbitt Rd. (Rt. 7)	**107011**	**C2**	6				
		Lums Pond @ Boat Ramp	**108111**	**C2**	6				
	Appoquinimink River	Drawyer Creek off Rt. 13 @ parking area	**109071**	**C2**	6			**X**	**X**
		Shallcross Lake @ Shallcross Lake Rd. (Rd. 420)	**109191**	**C2**	6			**X**	**X**
		Deep Creek Branch @ Summit Bridge Rd. (Rt. 71)	**109251**	**C1**	12			**X**	**X**
		Noxontown Pond @ Noxontown Rd. (Rd. 38)	**109131**	**C2**	6			**X**	**X**
		Appoquinimink River @ DuPont Pkwy. (Rt. 13)	**109041**	**C2**	6			**X**	**X**
		Appoquinimink River @ MOT Gut (west bank)	**109171**	**C2**	6			**X**	**X**
		Appoquinimink River @ Silver Run Rd. (Rt. 9) NE	**109121**	**C2**	6			**X**	**X**
		Appoquinimink River @ Mouth	**109091**	**C1**	12			**X**	**X**
	Delaware Bay Drainage	Little River @ Bayside Dr. (Rt. 9)	**204031**	**C2**	6				
		Little River @ N. Little Creek Rd. (Rt. 8)	**204041**	**C2**	6				
		Leipsic River @ Denny St. (Rt. 9)	**202031**	**C2**	6				
		Smyrna River @ Flemings Landing (Rt. 9)	**201041**	**C2**	6				
		Blackbird Creek @ Taylors Bridge Rd. (Rt. 9)	**110041**	**C2**	6				
		Blackbird Creek @ Blackbird Station Rd. (Rd. 463)	**110011**	**C1**	12				
		Blackbird Creek @ Blackbird Landing Rd. (Rd. 455)	**110031**	**C2**	6				
		Duck Creek @ Smyrna Landing Rd. (Rd. 485)	**201051**	**C2**	6				
		Mill Creek (Lake Como outfall) @ Rt. 13	**201011**	**C2**	6				
		Providence Creek @ Duck Creek Rd. (Rt. 15)	**201161**	**C2**	6				
		Mill Creek @ Carter Rd. (Rd. 137)	**201021**	**C2**	6				
		Garrisons Lake @ DuPont Hwy. (Rt. 13)	**202021**	**C2**	6				

BASIN	PROJECT	SITE DESCRIPTION	STORET	Category	Freq.	Arsenic (As)	Iron (Fe)	Copper, Lead and Zinc	BLM Parameters
		Leipsic River @ Mt. Friendship Rd. (Rt. 15)	**202201**	**C2**	6				
	St. Jones River	St. Jones River @ mouth, Bowers Beach	**205011**	**C1**	12				
		St. Jones River @ Barkers Landing	**205041**	**C2**	6				
		St. Jones River @ East Lebanon Rd. (Rt. 10)	**205091**	**C2**	6				
		Derby Pond @ Boat Ramp (Rt. 13A)	**205211**	**C2**	6				
		Moores Lake @ S. State St. (Rd. 27)	**205181**	**C2**	6				
		Fork Branch @ State College Rd. (Rd. 69)	**205151**	**C2**	6				
		Silver Lake @ Spillway (Dover City Park)	**205201**	**C2**	6				
LOWER DELAWARE BAY	Murderkill River	Murderkill River @ Rt. 13	**206011**	**C1**	12			**X**	**X**
		Browns Branch @ Milford-Harrington Hwy. (Rt. 14)	**206041**	**C2**	6			**X**	**X**
		McColley Pond @ Canterbury Rd. (Rt. 15)	**206361**	**C2**	6			**X**	**X**
		Coursey Pond @ Canterbury Rd. (Rt. 15)	**206451**	**C2**	6			**X**	**X**
		Double Run @ Barratts Chapel Rd. (Rd. 371)	**206561**	**C2**	6			**X**	**X**
		Murderkill River @ Bowers Beach Wharf (mouth)	**206101**	**C1**	12			**X**	
		Murderkill River near levee @ MNWA (RM 3.25)	**206141**	**C2**	6			**X**	**X**
		Murderkill Rv. @ confl. of KCWWTF discharge ditch	**206231**	**C2**	6			**X**	**X**
		Murderkill River @ Bay Rd. (Rt. 1/113)	**206091**	**C2**	6			**X**	**X**
	South Delaware Bay	Beaverdam Branch @ Deep Grass Ln. (Rd. 384)	**208231**	**C1**	12				
		Abbotts Pond @ Abbotts Pond Rd. (Rd. 620)	**208181**	**C2**	6				
		Silver Lake @ Maple Ave.	**208211**	**C2**	6				
		Mispillion River @ Rt. 1	**208021**	**C2**	6				
		Mispillion River @ Cedar Creek confluence	**208061**	**C1**	12				
		Cedar Creek @ Cedar Beach Rd. (Rt. 36)	**301091**	**C2**	6				
		Cedar Creek @ Coastal Hwy. (Rt. 1)	**301031**	**C2**	6				
		Swiggetts Pond @ Cedar Creek Rd. (Rt. 30)	**301021**	**C2**	6				
	Broadkill River	Savannah Ditch @ Savannah Drive (Rd. 246)	**303011**	**C2**	6				
		Ingram Branch @ Gravel Hill Rd. (Rd. 248)	**303021**	**C2**	6				
		Beaverdam Creek @ Carpenter Rd. (Rd. 259)	**303181**	**C2**	6				
		Beaverdam Creek @ Cave Neck Rd. (Rd. 88)	**303171**	**C2**	6				

BASIN	PROJECT	SITE DESCRIPTION	STORET	Category	Freq.	Arsenic (As)	Iron (Fe)	Copper, Lead and Zinc	BLM Parameters
		Round Pole Branch @ Cave Neck Rd. (Rd. 88)	**303311**	**C2**	6				
		Broadkill River @ Union St (Rt. 5)	**303031**	**C2**	6				
		Pemberton Branch @ Gravel Hill Rd. (Rt. 30)	**303341**	**C2**	6				
		Red Mill Pond @ Rt. 1	**303051**	**C2**	6				
		Broadkill River 0.10 Miles From Mouth	**303061**	**C1**	12				
		Broadkill River @ Rt. 1 Bridge	**303041**	**C2**	6				
		Waples Pond @ Rt. 1	**303331**	**C2**	6				
INLAND BAYS	Inland Bays w/ Pocomoke & Delaware Bay	Indian River Inlet @ Coast Guard Station	**306321**	**C1**	12	**X**		**X**	
		Little Assawoman Bay Mid-Bay (Ocean Park Lane)	**310071**	**C2**	6	**X**		**X**	
		Little Assawoman Bay @ Rt. 54 (The Ditch)	**310011**	**C2**	6	**X**		**X**	
		Dirickson Creek @ Old Mill Bridge Rd. (Rd. 381)	**310031**	**C2**	6	**X**		**X**	**X**
		Beaver Dam Ditch @ Beaver Dam Rd. (Rd. 368)	**310121**	**C1**	12	**X**		**X**	**X**
		Blackwater Creek @ Omar Rd. (Rd. 54)	**308361**	**C2**	6	**X**		**X**	**X**
		White Creek @ mouth of Assawoman Canal	**312011**	**C2**	6	**X**		**X**	
		Bundicks Branch @ Rt. 23	**308371**	**C2**	6	**X**		**X**	**X**
		Pocomoke River @ Bethel Rd. (Rd. 420)	**313011**	**C2**	6				
		Whartons Branch @ Rt. 20 (Dagsboro Rd.)	**309041**	**C2**	6	**X**		**X**	**X**
		Pepper Creek @ Rt. 26 (Main St.)	**308091**	**C2**	6	**X**		**X**	**X**
		Buntings Branch @ Rt. 54 (Polly Branch Rd.)	**311041**	**C2**	6	**X**		**X**	**X**
		Millsboro Pond @ Rt. 24	**308071**	**C1**	12	**X**		**X**	**X**
		Cow Bridge Branch @ Zoar Rd. (Rd. 48)	**308281**	**C2**	6	**X**		**X**	**X**
		Swan Creek @ Mount Joy Rd. (Rd. 297)	**308341**	**C2**	6	**X**		**X**	**X**
		Guinea Creek @ Banks Rd. (Rd. 298)	**308051**	**C2**	6	**X**		**X**	**X**
		Burton Pond @ Rt. 24	**308031**	**C2**	6	**X**		**X**	**X**
		Indian River @ Buoy 49 (Swan Creek)	**306181**	**C2**	6	**X**		**X**	
		Indian River @ Island Creek	**306331**	**C2**	6	**X**		**X**	
		Island Creek upper third	**306341**	**C2**	6	**X**		**X**	
		Indian River Bay @ Buoy 20	**306121**	**C1**	12	**X**		**X**	
		Massey Ditch @ Buoy 17	**306111**	**C2**	6	**X**		**X**	
		Rehoboth Bay @ Buoy 7	**306091**	**C2**	6	**X**		**X**	

BASIN	PROJECT	SITE DESCRIPTION	STORET	Category	Freq.	Arsenic (As)	Iron (Fe)	Copper, Lead and Zinc	BLM Parameters
		Lewes & Rehoboth Canal @ Rt. 1	**305011**	**C2**	6	**X**		**X**	
		Lewes & Rehoboth Canal @ Rt. 9	**305041**	**C2**	6	**X**		**X**	
		Roosevelt Inlet, mouth	**401011**	**C2**	12				
CHESAPEAKE	Nanticoke River	Raccoon Prong @ Pepperbox Rd. (Rd. 66)	**307371**	**C2**	12			**X**	**X**
		Hitch Pond Branch @ Pepper Pond Rd. (Rd. 449)	**307081**	**C2**	12			**X**	**X**
		Nanticoke River @ Rt. 13	**304471**	**C2**	12			**X**	**X**
		Concord Pond @ German Rd. (Rd. 516)	**304311**	**C2**	12			**X**	**X**
		Deep Creek @ Old Furnace Rd. (Rd. 46)	**304741**	**C2**	12			**X**	**X**
		Gravelly Branch @ Coverdale Rd. (Rd. 525)	**316011**	**C2**	12			**X**	**X**
		Gravelly Branch @ Deer Forest Rd. (Rd. 565)	**316031**	**C2**	12			**X**	**X**
		Nanticoke River @ Beach Hwy. (Rt. 16)	**304681**	**C2**	12			**X**	**X**
		Clear Brook @ Cannon Rd. (Rt. 18)	**304371**	**C2**	12			**X**	**X**
		Bucks Branch @ Conrail Rd. (Rd. 546)	**304381**	**C2**	12			**X**	**X**
		Williams Pond @ East Poplar St.	**304321**	**C2**	12			**X**	**X**
		Broad Creek @ Bethel Rd. (Rd. 493)	**307031**	**C2**	12			**X**	**X**
		Records Pond @ Willow Street	**307011**	**C2**	12			**X**	**X**
		Horsey Pond @ Sharptown Rd. (Rt. 24)	**307171**	**C2**	12			**X**	**X**
		Nanticoke River @ Sharptown	**304011**	**C2**	12			**X**	**X**
		Nanticoke River @ Buoy 66 (mouth of DuPont Gut)	**304151**	**C2**	12			**X**	**X**
	Chesapeake Drainage	Sewell Branch @ Sewell Branch Rd. (Rd. 95)	**112021**	**C2**	12				
		Tappahanna Ditch @ Sandy Bend Rd. (Rd. 222)	**207081**	**C2**	12				
		Culbreth Marsh Ditch @ Shady Bridge Rd. (Rd. 210)	**207091**	**C2**	12				
		Cow Marsh Creek @ Mahan Corner Rd. (Rd. 208)	**207021**	**C2**	12				
		White Marsh Br. @ Cedar Grove Church Rd. (Rd. 268)	**207111**	**C2**	12				
	Chesapeake Bay Nontidal	Nanticoke River @ Rifle Range Rd. (Rd. 545)	**304201**	**C1**	12			**X**	**X**
		Marshyhope Creek @ Fishers Bridge Rd. (Rd. 258)	**302031**	**C1**	12			**X**	**X**
	Chesapeake Bay Nontidal Storm	Nanticoke River @ Rifle Range Rd. (Rd. 545)	**304201**	**C1**	8			**X**	**X**
		Marshyhope Creek @ Fishers Bridge Rd. (Rd.	**302031**	**C1**	8			**X**	**X**

BASIN	PROJECT	SITE DESCRIPTION	STORET	Category	Freq.	Arsenic (As)	Iron (Fe)	Copper, Lead and Zinc	BLM Parameters
		258)							
State-Wide Storm		Shellpot Creek @ Market St. (Rt. 13 Bus.)	**102051**	**C1**	4				
		Brandywine Creek @ New Bridge Rd. (Rd. 279)	**104021**	**C1**	4			**X**	**X**
		Red Clay Creek @ Lancaster Pike (Rt. 48)	**103031**	**C1**	4			**X**	**X**
		White Clay Creek @ Delaware Park Blvd.	**105151**	**C1**	4			**X**	**X**
		Christina River @ Sunset Lake Rd. (Rt. 72)	**106141**	**C1**	4			**X**	**X**
		Deep Creek Branch @ Summit Bridge Rd. (Rt. 71)	**109251**	**C1**	4			**X**	**X**
		Blackbird Creek @ Blackbird Station Rd. (Rd. 463)	**110011**	**C1**	4				
		Murderkill River @ Rt. 13	**206011**	**C1**	4			**X**	**X**
		Millsboro Pond @ John Williams Hwy. (Rt. 24)	**308071**	**C1**	4	**X**		**X**	**X**
		Silver Lake @ Spillway (Dover City Park)	**205201**	**C2**	4				
		Beaver Dam Ditch @ Beaver Dam Rd. (Rd. 368)	**310121**	**C1**	4				
		Beaverdam Branch @ Deep Grass Ln. (Rd. 384)	**208231**	**C1**	4				

Table 2 - Water Quality Parameters to be monitored at all stations - FY 2020

Parameter	*Method Reference*[1]	*Reporting Level*[2]
Water Column Nutrients		
Ammonia Nitrogen	EPA 350.1, Rev. 2.0 (1993)	0.010 mg/l N
Nitrite+Nitrate Nitrogen	EPA 353.2, Rev. 2.0 (1993)	0.010 mg/l N
Nitrogen, Total, Alkaline Persulfate	SM 4500-P J-2011	0.100 mg/l N
Soluble Ortho-phosphorus	EPA 365.1, Rev. 2.0 (1993)	0.005 mg/l P
Phosphorus, Total, Alkaline Persulfate	SM 4500-P J-2011	0.010 mg/l P
Carbon and Organics		
Total Organic Carbon	SM 5310 B-2011	1 mg/l
Dissolved Organic Carbon	SM 5310 B-2011	1 mg/l
Chlorophyll-a (Corr)	EPA 445.0, Rev. 1.2 (1997)	1 µg/l
Biochemical Oxygen Demand		
BOD_5, N-Inhib (CBOD)	SM 5210 B-2011	2.4 mg/l
BOD_{20}, N-Inhib (CBOD)	SM 5210 B-2011	2.4 mg/l
Field Measurements		
Conductivity	SM 2510 B-2011	1 µS/cm
Dissolved oxygen	SM 4500-O G-2011 or ASTM D888-09 (C)	0.1 mg/l
pH - Field	SM 4500-H+ B-2011	0.2 pH units
Salinity	SM 2520 B-2011	0.1 ppt
Temperature	SM 2550 B-2010	Water -5.00 ^{o}C Air -10 ^{o}C
Secchi Depth[3]	EPA-841-R-14-007	0.1 meters
Light Attenuation[4]	EPA-841-R-14-007	0.1 µmol/s/m2
General		
Alkalinity	SM 2320 B-2011	2.3 mg/l
Chloride	SM 4500-Cl^- E-2011	3 mg/l
Hardness	SM 2340 C-2011	5 mg/l as $CaCO_3$
Total Suspended Solids	SM 2540 D-2011	2.5 mg/l[5]
Turbidity	SM 2130 B-2011	1 NTU
Bacteria		
Enterococcus	Enterolert®	1 mpn/100 ml

[1] SM refers to Standard Methods.

[2] The Environmental Laboratory Section defines the Limit of Quantitation (LOQ) as the lowest standard in the calibration curve or, in instances where a standard curve is not specified by the procedure, LOQ represents the limitations of the method. For those tests where reference spiking material exists, the ELS measures Method Detection Limit (MDL), as defined in the Federal Register 40 CFR Part 136 Appendix B. MDL values are generated or verified once per year. Results less than the MDL are considered to be not detected and "< MDL" is reported. Results greater than the MDL but less than the LOQ are qualified with a J to indicate a result that is extrapolated or estimated. For tests where MDL is not applicable, results less than the LOQ are reported as "< LOQ". ELS MDLs meet or exceed (i.e., are lower than) the reporting level requirements listed in Table 3. The reporting levels listed represent the LOQ or method defined limit.

[3] Secchi Depth to be measured at designated stations. The reappearance depth is recorded.

[4] Light attenuation to be conducted as practical to obtain correlation with Secchi disk readings. PAR at the surface and at one meter depth is recorded and reported.

[5] Reporting Limit based on 1000 ml filtration volume. The reporting limit will be adjusted according to actual volume filtered. The method specifies to decrease volume if complete filtration takes more than 10 minutes.

Table 3 - Metal Parameters

Dissolved Metals (dissolved and total)	***Method Reference (EPA)***	***Reporting Level[6]***
Copper	EPA 200.8, Rev. 5.4 (1994)	1.0 ug/l
Lead	EPA 200.8, Rev. 5.4 (1994)	1.0 ug/l
Zinc	EPA 200.8, Rev. 5.4 (1994)	2.0 ug/l
Iron	EPA 200.7, Rev. 4.4 (1994)	100 ug/l
Arsenic	EPA 200.8, Rev. 5.4 (1994)	1.0 ug/l

[6] High levels of dissolved solids in the sample may cause analytical interferences. For example, EPA method 200.8 recommends that the dissolved solids levels not exceed 0.2% (w/v) (~2,000 mg/L) to reduce such effects. Samples may be diluted during analysis to minimize the instrument interferences associated with high salinity/conductivity. The reported MDLs and LOQs for the parameters will be adjusted due to the sample dilution.

Table 4 - Additional parameters needed for freshwater stations with Biotic Ligand Model Sampling for Copper (BLM Parameters)

Dissolved Parameters	***Method Reference (EPA)***	***Reporting Level***
Alkalinity	SM 2320 B-2011	2.3 mg/l
Chloride	SM 4500-Cl^- E-2011	3 mg/l
Calcium	EPA 200.7, Rev. 4.4 (1994)	1000 ug/l
Magnesium	EPA 200.7, Rev. 4.4 (1994)	1000 ug/l
Potassium	EPA 200.7, Rev. 4.4 (1994)	1000 ug/l
Sodium	EPA 200.7, Rev. 4.4 (1994)	1000 ug/l
Sulfate	EPA 300.0	0.75 mg/l

References:

1. Chesapeake Bay Program. 2008. Chapter V, Non-tidal Water Quality Monitoring. Annapolis, MD.
2. DNREC. 2017. Quality Assurance Project Plan - Collection and Analysis of Surface Water, Sediment and Fish Tissue Samples for Toxics in Delaware Watersheds that Flow to the Chesapeake Bay. Division of Watershed Stewardship, Delaware Department of Natural Resources and Environmental Control, Dover, DE.
3. DNREC. 2019. Quality Manual for DNREC Environmental Laboratory and Field Operations, Environmental Laboratory Section, Division of Water.
4. DNREC. 2019. Delaware Ambient Surface Water Quality Monitoring Program Quality Assurance Program Plan (QAPrP), Division of Watershed Stewardship, Watershed Assessment and Management Section.
5. DNREC. 2018. Watershed Approach to Toxics Assessment and Restoration 2018-2022. DNREC Division of Watershed Stewardship and Division of Waste and Hazardous Substances.

APPENDIX F

WHITE PAPER: DEVELOPING A HYDRODYNAMIC/WATER QUALITY MODEL FOR THE INLAND BAYS: IMPLEMENTATION PLAN

Developing a Hydrodynamic/Water Quality Model for the Inland Bays: Implementation Plan

Prepared by:

Delaware Center for the Inland Bays
Scientific and Technical Advisory Committee

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FINAL 2/21/2020

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LIST OF ACRONYMS

CAST	Chesapeake Assessment Scenario Tool
CCMP	Comprehensive Conservation and Management Plan
CIB	Center for the Inland Bays
DO	Dissolved Oxygen
GEMSS	Generalized Environmental Modeling Surface Water System
HD/WQ	Hydrodynamic/Water Quality
HEM3D	Hydrodynamic Eutrophication Model 3-D
HSPF	Hydrological Simulation Program-Fortran
NEP	National Estuary Program
NOAA	National Oceanic and Atmospheric Administration
RFI	Request for Information
ROMS	Regional Ocean Modeling System
SPARROW	SPAtially Referenced Regression On Watershed attributes model
STAC	Scientific and Technical Advisory Committee
TMDL	Total Daily Maximum Load
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WASP	Water Quality Analysis Simulation Program
WiCCED	Water in the Changing Coastal Environment of Delaware

INTRODUCTION

In 2017, the Delaware Center for the Inland Bays (CIB) finalized an updated Environmental Monitoring Plan for the Inland Bays. The purposes of the plan are: (a) to guide monitoring and research to track the status and trends of key environmental indicators used to assess the chemical, physical, and biological integrity of the estuary and surrounding study area; and (b) to evaluate whether the goals of the Inland Bays Comprehensive Conservation and Management Plan (CCMP) are being met. The CIB's Scientific and Technical Advisory Committee (STAC) is responsible for ensuring the implementation of this plan and tracking progress.

Of primary importance in the plan are prioritized recommendations for new monitoring programs, or enhancement of existing programs. These recommendations were based upon critical data gaps (including emerging issues), the availability of new environmental monitoring methods or technologies, and/or changes needed to make programs sustainable over the long term. They were the result of facilitated panel discussions held with stakeholders/partners and the STAC on July 29, 2015 and September 18, 2015, respectively. Additional input was provided through written questionnaires, follow-up STAC meeting discussions, and reviews by the U.S. Environmental Protection Agency (USEPA).

Among the highest priority recommendations is the development of a predictive, coupled watershed, hydrodynamic/water quality (HD/WQ) model for the Inland Bays that uses current and high-frequency data. Update of watershed nutrient loading, estuarine water quality, and hydrodynamic models for the Inland Bays is a specific objective included in both the 2012 CCMP Addendum (Water Quality Management - Objective 1, Actions A, B and C) and the draft CCMP revision that is currently under development by the CIB and its partners (Healthy Bay Ecosystems - Objective 1, Actions 1, 2, and 3). A number of other actions may be facilitated or supported through use of these updated models (Table 1).

In 2018 and 2019, a standing CCMP/Monitoring Subcommittee of the STAC met to discuss priorities and potential approaches for developing new models for the Inland Bays. Several meetings of the full STAC were devoted to presentations from practitioners who have developed models of various types for estuarine systems. This white paper is the result of these meetings and discussions. It synthesizes the STAC's collective view of the requirements for an updated HD/WQ model of the Inland Bays and how its development can most practicably be accomplished.

THE NEED FOR MODELS

Multiple presentations from modeling practitioners to the STAC made clear the need for, and best uses of, updated and maintained models of the Inland Bays system. Professor Dominique DiToro of the University of Delaware, in particular, summarized well the usefulness of good models for understanding how the estuary functions and for making predictions about the outcomes of management actions. Models are data analysis tools; comparison of expected and observed distributions of monitoring data provides invaluable information about the system. He emphasized that:

- Models are needed to demonstrate that funding for management actions is spent in the most effective manner. That is, predictions can be made about the types and locations of practices that will result in the greatest pollutant load reductions to particular water bodies per dollar spent. In fact, decades of work to reduce nutrient loads to the Bays have not produced the sought after reductions in eutrophication. Using well-calibrated models to guide our investments will likely improve the outcomes. The newly formed Inland Bays CCMP Implementation Committee, a standing committee of the CIB Board, has identified development of an updated watershed nutrient loading as a top priority for its work in Fiscal Years 2020 and 2021.

- Models provide information to guide monitoring efforts and interpret monitoring data. Models can help target monitoring efforts and eliminate unnecessary stations or identify areas of the estuary that need better coverage. When observed water quality concentrations fail to agree with predicted values, we learn something significant about the functioning of the system and may indicate that the model is not properly calibrated. Although monitoring provides data on current water quality status and past trends, predictions about future status cannot be made based upon monitoring alone. A well calibrated model can be used for predicting future conditions and those future conditions may happen only if all other conditions in the model prediction scenario remain constant.
- Models help us to understand the chemical mass balance in the estuary and the physical, geochemical, and biological processes that influence nutrient fluxes. Unless the mass balance is well understood, then the outcome of remediation practices cannot be predicted.
- Models can be used to better understand the relationship between nutrient loads and water column concentrations.

BACKGROUND ON INLAND BAYS MODELING & RELATED MONITORING

The first state-of-the-art water quality modeling program implemented in Delaware's Inland Bays was calibrated using data collected from 1988-1990 (Cerco et al., 1994). This tool included a mechanistic sediment flux model; it even included a benthic algal model due to the shallow nature of the bays (Cerco and Seitzinger, 1997). In 2004, Entrix, Inc., and J.E. Edinger Associates developed a Total Maximum Daily Load (TMDL) model for the Inland Bays (Entrix and JEEAI, 2004). The model is a fully coupled 1-dimensional watershed and 3-dimensional HD/WQ model called the Generalized Environmental Modeling Surface Water System (GEMSS). That model was used primarily to calculate water quality constituents such as nitrogen, phosphorus (particulate/dissolved, inorganic/organic) and dissolved oxygen (DO). It was calibrated using data collected from 1998-2000.

Since 2004, there has been a significant increase in understanding of nutrient loading from the watershed and how the Bays respond to nutrient loads, as documented in Hydrological Simulation Program-Fortran (HSPF) models of watershed loading (Gutierrez-Magness, 2006) and a HD/WQ model (Brady, 2014). Advances in monitoring, as documented by studies that used high-frequency data collection (Tyler, 2004; Ullman and Andres, 2004-2010) have also occurred.

The HSPF and process models represent large and fairly expensive data collection and modeling efforts. They were calibrated from watershed-specific baseflow and storm flow data and provide edge-of-stream nutrient and sediment loads on daily time steps. This is exactly the type of input needed to improve HD/WQ modeling capabilities. The tool also has the capability to model the ecosystems response to a changing climate.

Ullman and Andres (2004-2010) operated an automated on-site laboratory at the Millsboro Pond outlet that determined physical and nutrient values every six hours for nearly six years. As the Millsboro Pond outlet is the single largest input of water and nutrients to the Indian River, these data are critical for accurately determining the impact of nutrient inputs. Tyler (2001) and Tyler et al. (2009) found significant diel DO swings at multiple locations in the Bays from operation of automated, high-frequency DO monitoring sensors. Diel hypoxia and anoxia is arguably the greatest uncertain water quality threat to Delaware's Inland Bays, with multiple fish kills attributable to hypoxia occurring most years, and likely significant impacts on the cycling of nutrients between bottom sediment and the water column. Substantial research efforts have also demonstrated reduced growth rates and behavioral avoidance of hypoxia by juvenile estuary dependent fishes that rely on the Bays for essential fish habitat.

For this reason, the CIB requested an independent assessment of the DO calculation in the GEMSS model (Brady, 2014). Damien Brady also presented a summary of his assessment to the STAC at its February 2019 meeting. While the report focuses on DO, it notes that improvements in the understanding of nutrient loading and biogeochemical cycling will also be necessary to improve future model formulations. It is of course important to note that the original model was a tool to establish nutrient TMDLs that would provide protection of the Inland Bays under average conditions. The conclusions of this assessment were:

- Bay hydrodynamics have significantly changed since the Cerco et al. (1994) and Entrix and JEEAI (2004) GEMMS modeling efforts and will continue to change with rising sea level and modification to the Indian River Inlet. Volumetric flow through the inlet has changed drastically over the years and is a major driver of nutrient flushing from Rehoboth and Indian River Bays.
- The model simulates physical parameters such as tide and temperature well. However, GEMSS is not effective at simulating diel DO cycling (especially in the Indian River and tributaries).
- Calibration and validation used datasets only from 1998-2000, and 1998 was a particularly wet year. We now have 19 additional hydrographs (along with long term discharge data at Millsboro Pond and water quality data, though collected less frequently) to incorporate into the model. Furthermore, the calibration and validation datasets included few to no substantive continuous DO records. Assessing performance of the GEMMS in relation to diel-cycling hypoxia is difficult, and was not the original intent of that modeling effort.
- The model needs to incorporate sediment fluxes of nitrogen and phosphorus; it also does not incorporate any rate information such as respiration and primary productivity.

DO data collected since 2001 contain DO fluctuations from 0% to >200% saturation in the headwaters of major creeks/tributaries, and the model output shows no such fluctuations. Brady's explanation for this is either: (1) diel-cycling hypoxia only became a significant feature of the water quality in Delaware's Inland Bays in 2001; or (2) the monitoring program only became robust enough to detect diel-cycling hypoxia in 2001. In either case, changes to Bay hydrodynamics, proliferation of data and understanding of important processes since 2001 strongly argues for re-visiting the modeling framework for the Bays. In his report, Brady provided specific recommendations for future accurate simulations of diel-cycling hypoxia.

Brady's recommendations carry additional importance with consideration of recent research on sediment-water column interactions in Barnegat Bay (Wilson and DePaul, 2016; Paudel et al., 2017), Chesapeake Bay (Cornwell et al., 2016), and elsewhere. These studies build upon a long history of sediment-water column research showing that hypoxic and anoxic conditions exacerbate release of phosphorus from sediments and alter how sediments process nitrogen. The studies conclude that loads of nutrients from sediment-water column interactions in some poorly flushed coastal bays are on the same order of magnitude as watershed-delivered loads. Similar studies have not yet been completed for the Delaware Inland Bays. Sawyer et al. (2013) and Russoniello et al. (2016) have demonstrated in studies of the Inland Bays the importance of understanding watershed hydrology and groundwater-surface water exchange for identifying sources of nutrients and critical targets for management. Coupling these types of physics-based models to geochemical models would advance understanding and predictive capacity to the next level.

Finally, the CIB is currently seeking funds through the U.S. Army Corps of Engineers to collect updated data on the bathymetry of and tidal flow through the Indian River Inlet. The most recent previous tidal prism calculation was 2004. Inlet bathymetry has no doubt changed significantly in response to removal of the old Route 1 bridge, completed in 2013. The inlet is the largest single source of water flux in and out of the Bays. This information is critical to predicting impacts of long-term sea level rise on water flow and salinity in the Bays as well as storm events.

EVALUATION OF MODEL NEEDS & OPTIONS

The CIB organized and hosted a series of presentations and panel discussions by regional modeling experts for CIB staff, STAC members, and other interested parties between May 2018 and April 2019 (Table 2). In addition, the then STAC chair, Scott Andres of the Delaware Geological Survey, and other subcommittee members held meetings with other modeling experts who could not attend STAC meetings.

These meetings and presentations clarified what models are, how they are best used, and identified several potential service providers. More importantly, experts described how models are instrumental for quantifying how the estuary works, a trait that tests our understanding of estuarine processes and permits forecasting of outcomes of management and mitigation activities. Dr. Dominic DiToro's statement accurately captured the current situation -- "…without a modeling tool, you are just guessing."

The Chesapeake Bay Model is often cited in discussions of potential modeling approaches for the Delaware Inland Bays. The Chesapeake Bay Program's integrated suite of modeling tools includes an airshed model, a land use change model, a Phase 6 Watershed Model (the Chesapeake Assessment Scenario Tool, or CAST), and an estuary model that predicts the effects that calculated pollutant loads will have on water quality. The development and ongoing improvement of the Chesapeake models is led by a collaborative working group consisting of multi-state, federal, academic, and private partners, stakeholders and experts. The suite of tools can be accessed online for free for use by local and regional planners. The high cost and complexity of the Chesapeake Bay Model has been raised by some as a reason to avoid similar effort in the Inland Bays. However, the Chesapeake Bay and its 64,000-square-mile watershed is a very different system from the Inland Bays' shallow, poorly flushed coastal lagoons, and the level of effort required to model them is not directly comparable.

Olivia Devereux (KCI Technologies) and Mark Nardi (USGS) discussed with the STAC, for example, how CAST and the USGS's Sparrow model both include information that could be used to inform a terrestrial and management model for the Inland Bays that determines the nitrogen, phosphorus, and sediment loads delivered to the edge of small streams and to the Bays. The Inland Bays tool would simply use data from Sparrow and CAST, rather than work like or be add-ons to those existing models.

Modeling tools developed for other shallow, eutrophic mid-Atlantic coastal lagoons that connect to the ocean only through narrow inlets probably provide more relevant comparisons for what could be accomplished for the Delaware Inland Bays. Modeling projects conducted for NEP partners in Barnegat Bay, New Jersey and the Coastal Bays of Maryland not only demonstrate successful model-derived quantitative assessments of management practices and resulting changes in their estuaries, but their models and associated monitoring projects also can provide key data that can be used to fill in data gaps currently present in the Inland Bays. In short, not having data on local processes up front should not derail work to create similar tools for the Inland Bays; though adequate water quality monitoring data will still be necessary to calibrate and validate models.

A Hydrological Simulation Program-Fortran (HSPF) framework was used to model watershed hydrological and nutrient transport processes of the Maryland Coastal Bays watershed (Maryland Department of the Environment and Virginia Institute of Marine Science (VIMS), 2013), for the purpose of developing TMDLs. In addition, a Hydrodynamic Eutrophication Model 3-D (HEM3D) was developed by VIMS and used as a tool to simulate the dynamics of physical-biological-chemical processes in the receiving bay waters, using the nutrient loads generated by the HSPF watershed model (Wang et al., 2013). The HEM3D modeling system was calibrated and compared very well with intensive water quality data collected during 2001- 2004. The predicted daily mean DO from the HEM3D was further adjusted to incorporate the diel cycle of DO using a statistical analysis developed for the Maryland Coastal Bays (Perry, 2012). A continuous water quality monitoring network established in these bays (http://eyesonthebay.dnr.maryland.gov/) provided data for calibration and validation.

In New Jersey, USGS partners recently worked with the NJ Department of Environmental Protection to couple a hydrodynamic model, the Regional Ocean Modeling System (ROMS), with the USEPA's Water Quality Analysis Simulation Program (WASP) in a comprehensive analysis of water quality in the Barnegat Bay-Little Egg Harbor estuary (Defne et al., 2017). The need for a comprehensive understanding of the relation between watershed land use and water quality in the bay required a bay-wide monitoring effort supported by an advanced modeling approach. Model development relied upon data and results from a number of studies, including sea floor mapping, continuous stage and discharge measurements, water quality monitoring, sediment characterization and chemistry, light attenuation, sediment oxygen demand and sediment nutrient flux, phytoplankton characterization, and wetlands denitrification research. Data collection was facilitated by a well-supported continuous water quality monitoring network established in Barnegat Bay. The model is being used to develop a TMDL for the estuary, to test a variety of water quality management scenarios, and to provide input to other ecosystem models.

PRIORITIZATION OF MODEL GOALS & KEY MANAGEMENT QUESTIONS TO BE ADDRESSED

Development of a well-calibrated, predictive model or models for the Inland Bays will require significant data, funding and time. Thus it is important that the effort be focused by clarifying and prioritizing overall goals for and key management questions to be addressed by the tool(s).

The key management questions for the Inland Bays are driven by a complex interrelated set of water quality issues. These include eutrophication in many bay segments, diel-cycling hypoxia in the upper reaches of the Indian River and other tidal tributaries, sediment-water column nutrient and oxygen exchange, focused (stream) and diffuse (groundwater and atmospheric) inputs of nutrients, and changes in hydrodynamics and inlet bathymetry. These questions are not new, and, despite investments of hundreds of millions of dollars in many types of pollution abatement practices and the efforts of countless people, long-term monitoring data show mixed success in improving water quality. Do we know the impacts of maintenance dredging activities on flow patterns and nutrient concentrations? Can we predict, for example, how the removal of the point source at Rehoboth Beach Wastewater Treatment Plant will impact nutrient and phytoplankton dynamics and concentrations in Rehoboth Bay over the next 10 years? Can we quantify the direct links between changes to the Rehoboth Beach wastewater discharge, annual fluctuations in watershed and ocean inputs, and observed changes to Bay water quality? Currently, experts can only say it appears that changes to the Rehoboth Beach wastewater discharge have improved water quality. With the lack of clear understanding and assessment tools, the complex web of government incentives for pollution abatement and economic development built over the past 20 years serves to perpetuate the status quo.

The CIB seeks to disrupt this inertia by establishing and supporting the partnerships necessary to construct, operate, and maintain two types of modeling tools for the Inland Bays: (1) a nutrient loading tool for the Rehoboth Bay, Indian River Bay, and Little Assawoman Bay watersheds; and (2) a fully coupled HD/WQ simulation tool for Rehoboth and Indian River Bays and their tidal tributaries.

Although subcommittee members agreed that updated modeling tools to be used for assessing and prioritizing management responses to critical water quality issues in the Bays are a high priority, there was no consensus that either the watershed loading or HD/WQ model had a greater priority. From a practical standpoint, each of these modeling projects can proceed independently of the other.

There are many potential approaches and types of model tools, with varying cost and time implications. Thus, defining and prioritizing goals and key questions to be answered is critical to the success of this effort. Following all of the presentations and panel discussions, the STAC subcommittee identified the following prioritized list of criteria for the model(s) to be developed for the Inland Bays:

A. Model(s) must predict the impacts of changes in nutrient loadings on water quality in the Bays and their tributaries, including effective simulation of diel-cycling hypoxia. This includes understanding impacts of past and future land use change and wastewater loadings.

B. Model(s) must predict the most effective types and locations of best management practices and management actions to reduce nutrient loads to the Bays.

C. Model(s) should serve to understand the effects of the Indian River tidal prism volume on water quality and flooding endpoints.

D. Model(s) should serve to understand effects of climate change (sea level rise, extreme events, increased salinity, warming) on water quality parameters.

E. Model(s) should serve to predict where habitats will be most impacted by climate change, including sea level rise and pollutant impacts.

Project priorities should be commensurate with the objectives and actions of the CCMP. This means that the most relevant timescale for predictions is on the order of five to ten years, rather than many decades.

POTENTIAL MODELING APPROACHES

The model for the estuary will be a fully coupled HD/WQ simulator. The watershed loading model could be a process-based numerical simulator, such as HSPF, or an analytic/spreadsheet tool such as SPARROW. Rather than prescribing specific computer codes or modeling approaches, prospective service providers should be solicited through Request(s) for Information (RFIs) and asked to describe the methods with which they would conduct the studies, how their methods have been successful in other estuaries or watersheds, estimated costs, and how their individual organizations are suited to work with the CIB and its partners on modeling projects. Selection of providers and tolls will consider criticality, expedience, and costs.

Service providers for these projects would likely be universities, research institutes, the consulting industry, or the federal government (USGS, NOAA). Several potential providers participated in the meetings, presentations, and panel discussions organized by the STAC. They would be invited to submit proposals that would be fairly competed with those of other practitioners.

The HD/WQ model project cycle is anticipated to be up to five years, with two to three years for model development and reporting, followed by two years of maintenance and updates. The watershed loading model project cycle is anticipated to be two years or less. Both projects will require input from CIB staff, STAC members, and partner agencies and organizations. Potential funding sources for the work still need to be identified.

The STAC subcommittee identified the following list of additional criteria for modeling approaches and tasks:

- Model(s) will have long-term usefulness and would be validated and updated as appropriate with new data generated by environmental monitoring programs and research (annually or biennially).
- Model(s) should be easily updated. Living/breathing modules could be replaced in future as new approaches or updates become available.
- Code used should be open source and proposed by potential service provider(s).
- Model scenarios must be able to be easily run in a cost-effective manner.
- A model maintenance agreement must be included as part of the contract.

It is recommended that the CIB be responsible for contracting and managing the service provider. The CIB would also be responsible for coordinating partners. The CCMP Implementation Committee will play a key role in both areas. The STAC is the obvious group to coordinate exchange of technical information, interact with the service provider on technical issues, and review the findings of the work.

DEFINITION OF DATA GAPS & A PLAN FOR COLLECTION OF DATA REQUIRED FOR MODEL CALIBRATION

In contrast to other nearby estuaries (i.e., Chesapeake, Barnegat Bay) the Delaware community of scientists and engineers is very small, and problems of data access are minimal. It should be understood that any competent service provider will know what data they need to do their work and already know where to acquire and make those data usable in their project. Providers that have worked in Delaware before will likely know who to ask questions about data. When necessary, CIB and STAC will be the points of contact for coordinating access to data and pointing the model service provider to the most appropriate contacts for answering questions.

The background section of this document and the Environmental Monitoring Plan identify the most important historic datasets available for development and calibration of a HD/WQ model. Nearly all of these datasets are available online for download or can easily be acquired by contacting the project managers. CIB staff will contribute data from the high-frequency DO observing systems that they now operate. Ongoing research by Project WiCCED (https://projectwicced.org/about/) investigators may be available for a modeling project. Several STAC members are members of Project WiCCED, and installation of at least two continuous monitoring sondes in the Inland Bays is planned under that project.

The choice of a watershed nutrient loading model platform will dictate which data are needed for that tool. FirstMap (https://firstmap.delaware.gov/) houses the vast majority of geospatial data on land cover, topography, hydrography, etc. for either model platform.

The subcommittee has identified several important data and research gaps but did not reach consensus on priorities. Several presentations and panel discussions among regional experts concluded that data gaps do not preclude modeling work, and that model results will assist in prioritizing work to fill data and research gaps, though keeping in mind adequate water quality monitoring data is still necessary for model calibration and validation. Thus, these research needs are not expected to delay initiation of or progress on model development. Model development can proceed using existing local and regional data and then be updated with new data and research findings in the future; this is an iterative process.

The key data and research gaps identified, with time and cost estimates to fill them, are:

- Exchange of nutrients and oxygen between bottom sediment and the water column and the role of benthic algae (2.5 years and $150-500K estimate from Jeff Cornwell).
- Diel cycling of dissolved oxygen in the upper Indian River and tributaries. Better spatial coverage of high-frequency measurements is needed. Chlorophyll a data may be important in tributaries as well. (3 to 5 years; and $250K estimated installation cost, plus $80-100K annual maintenance, based upon estimates for five continuous monitoring stations).
- Changes in hydrodynamics due to changes in the bathymetry of the Indian River Inlet (1 year, $50-80K estimate from USACE).
- Additional stream gages are desirable for the watershed loading model. Currently only two are in place (Millsboro Pond and Beaver Dam Creek). Re-activation of stations at Bundicks Branch, Swan Creek, and Blackwater Creek that supported the GEMMS and HSPF models would provide information about how changes in the watershed over the past 20 plus years have impacted hydrology and nutrient loading. Annual operational costs currently are approximately $16K per station. Installation costs can range from a few hundred to a few thousand dollars per station.

NEXT STEPS

The STAC recommends to the CIB the following actions:

1. Submit this document to the CIB Board of Directors for consideration at its March 2020 meeting.
2. Share this document with the CCMP Implementation Committee. Coordinate with the IC on

watershed loading model development.

3. Develop and distribute Request(s) for Information to model service providers to determine feasibility, interest, and/or available capabilities to develop and maintain watershed loading and HD/WQ models for the Inland Bays. Responses will provide information on practitioners available, timelines, and costs.
4. Identify potential funding sources for each component of the work (e.g., watershed loading model, hydrodynamic model, water quality model, research to address data gaps). At least one STAC meeting or workshop in 2020 should be devoted to this.
5. Develop a detailed funding strategy and timeline for development of both models. This strategy must include a plan and funding to allow future updates to the model(s). The STAC subcommittee and CIB staff will work together to develop this plan.

The STAC will be responsible for developing Requests for Proposals, reviewing responses, and ensuring that the selection process is transparent and neutral.

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Table 1. Delaware Inland Bays CCMP actions directly or potentially addressed through use of updated watershed, hydrodynamic, and/or water quality models. Table 1A lists actions in the 2012 Addendum. Relevant actions included in the draft CCMP revision being prepared by the CIB are listed in Table 1B, next page.

Table 1A - 2012 CCMP Addendum Actions

Focus Area: Nutrient Management
Objective 1, Action E1: Conduct watershed specific analysis to determine nutrient loading to the Bays from developed lands under different management practices.
Focus Area: Wastewater Management
Objective 3, Action E: Develop a nutrient budget for wastewater to determine existing and projected total wastewater loads to receiving waters.
Objective 3, Action F: Research the attenuation of nutrients and contaminants released from different types of on-site wastewater systems along flowpaths to receiving waters.
Focus Area: Water Quality Management
Objective 1, Action A: Update the Inland Bays estuarine water quality and hydrodynamic model.
Objective 1, Action B: Update the Inland Bays watershed nutrient loading model.
Objective 1, Action C: Utilize updated estuarine and watershed models to evaluate if existing TMDLs are adequate to achieve water quality standards for nitrogen and phosphorus.
Objective 2, Action B: Revise PCS goals as needed, incorporating any revisions to the TMDLs.
Objective 5, Action D: Examine dead-end canals to determine if any could benefit from low-cost solutions to increase flushing.
Objective 6, Action C: Develop recommendations to improve efficacy of monitoring efforts to detect trends.
Focus Area: Managing Living Resources and Their Habitat
Objective 1, Action B: Map areas of the Bays that have habitat characteristics supportive of the reestablishment of bay grass species that have been identified as suitable candidates for restoration.
Objective 2, Action B: Identify candidate sites for the creation and restoration of wetlands.
Objective 5, Action B1: Create additional hard bottom areas suitable for oyster recruitment or planting of oyster spat.
Focus Area: Planning for Climate Change
Objective 1, Action B: Conduct a sea level rise vulnerability analysis specific to the Inland Bays watershed that includes potential impacts to both green and gray infrastructure.
Objective 1, Action D: Model the distribution of tidal wetlands under different sea level rise scenarios to guide land use and protection decisions that maximize future tidal wetland extent.

Table 1B – Draft CCMP Revision (October 2019)

Focus Area: Living with a Changing Climate
Objective 2, Action 1: Develop a Coastal Flood Monitoring System for the Inland Bays to provide a publicly-accessible, real-time tool to create flood inundation potential maps and time series of forecasted tidal predictions.
Focus Area: Clean Waters: Heathy Agricultural Landscapes
Objective 2, Action 2: Develop and implement a project plan to achieve the Agricultural Actions of the Inland Bays Pollution Control Strategy.
Focus Area: Clean Waters: Reducing Pollution from the Developed Landscape
Objective 2, Action 3: Develop a nutrient budget for wastewater to determine existing and projected loads to receiving waters and report biannually.
Objective 2, Action 6: Research the attenuation of nutrients and contaminants released from County-owned wastewater systems along flow paths to receiving waters.
Objective 3, Sub-Action 2b: Develop a plan to create stormwater retrofits to work toward a goal of treating 4,500 acres of urban and residential lands developed pre-1990.
Objective 3, Action 4: Develop a nutrient budget for stormwater to determine existing and projected loads to receiving waters and report biannually.
Focus Area: Healthy Bay Ecosystems: Protect and Restore Thriving Habitats for Abundant Fish & Wildlife
Objective 1, Action 1: Update the Inland Bays estuarine water quality and hydrodynamic model.
Objective 1, Action 2: Update the Inland Bays watershed nutrient loading model.
Objective 1, Action 3: Utilize updated estuarine and watershed models to evaluate if existing TMDLs are adequate to achieve water quality standards for nitrogen and phosphorus.
Objective 1, Action 4: Continue research on potential for reestablishing bay grasses.
Focus Area: Coordinated Land and Water Use Management
Objective 1, Sub-Action 2c: Develop an Inland Bays regional sediment management project plan for Indian River and Little Assawoman Bay.

Table 2. Record of meetings and decisions. Copies of STAC meeting agendas, notes, and presentations may be viewed at https://www.inlandbays.org/stac-meeting-agenda-notes-reports-presentationspublication-science-technical-advisory-committee-presentations/.

Date	Meeting/Decision	Agenda, Relevant Presentations
2/27/18	STAC CCMP/Model Subcommittee Scoping Meeting – CIB/STAC leadership	Develop scope of work, goals, and potential members
4/19/18	STAC Subcommittee Meeting	First meeting
7/19/18	STAC Subcommittee Leadership Meeting	Discussion of modeling needs and options
9/12/18	STAC Subcommittee Leadership Meeting	Clarified subcommittee goals
10/26/18	Full STAC Meeting	Jeremy Testa, UMCES (*Using ecosystem models to explore eutrophication, hypoxia, and acidification in estuarine ecosystems*) Joseph Zhang, VIMS (*A seamless modeling system on unstructured grids for hydrodynamics and water quality*)
2/1/19	Full STAC Meeting	Damien Brady, Univ. of ME (*Water Quality Modeling in Delaware's Inland Bays: Lessons Learned*) Dominic DiToro, Univ. of DE (*The Importance of water quality and eutrophication models in understanding the causes of improving and degrading water quality*) Jeffrey Cornwell, UMCES (*Benthic biogeochemistry in shallow coastal ecosystems: Lessons learned from East Coast estuaries*) Olivia Devereux, KCI Technologies, & Mark Nardi, USGS (*Developing a Terrestrial and Management Model*) Panel Discussion
4/1/19	STAC Subcommittee Meeting	Prioritization of model goals, approaches, and data gaps
5/10/19	Full STAC Meeting	Tye Pettay, Univ. of DE (*Improving resolution and accessibility of real-time water quality data using low-cost, high-frequency sensors maintained by citizen scientists*) Update to full STAC on subcommittee progress
7/26/19	Full STAC Meeting	Report to STAC on draft document and next steps.
8/26/19	Review of draft document by STAC and CIB Executive Director completed	---
2/13/20	Revised, final draft sent for STAC approval	---
2/17/20	STAC vote held to approve document for submission to CIB Board of Directors	---