

THE STATE OF YOUR CREEK

Dirickson Creek on Little Assawoman Bay



DELAWARE CENTER FOR THE
INLAND BAYS
Research. Educate. Restore.

The State of Your Creek: Dirickson Creek on Little Assawoman Bay

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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.

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STATE OF THE INLAND BAYS

The Inland Bays are coastal lagoons—bays that lie behind a narrow barrier island that separates them from the Atlantic Ocean (Figure 1). Travelling down Route 1, through Dewey Beach, Bethany Beach and Fenwick, the Inland Bays lie to the west.

They are unique places where ‘the rivers meet the sea’ ...where freshwater flowing off the land and down rivers and creeks mixes with seawater that enters through inlets from the ocean.

The Bays are ringed with saltmarshes and tidal flats and for thousands of years have supported an abundance of wildlife. People have always been drawn to these shores: first the Native Americans, then Dutch and English colonists and most recently in this century, a huge influx of retirees and second-home owners that have settled here and urbanized the areas around the Bays.

Fifty years ago, the Bays were thought to be generally healthy: clear waters with plentiful sea grass meadows, productive oyster reefs, and oxygen concentrations that supported diverse and plentiful fish populations.

But years of accumulated nutrient pollution from human activities, and the loss of forests and wetlands, have left our Bays and creeks polluted. Baygrass beds and oyster reefs have largely disappeared, and algae blooms are frequent in the poorly flushed areas of the bays. Oxygen concentrations frequently are too low and bacteria concentrations too high, especially in the upper creeks and canals during the warmer months.

Changes in the landscape, including conversion of land from forests and wetlands to agriculture and development, have taken a toll on the Bays. However, results from our recently published 2016 *State of the Delaware Inland Bays* report indicate that some areas of the bays are seeing improvements in water quality—demonstrating that actions taken over the past two decades are beginning to pay off.

The Inland Bays and their creeks can be healthy again, but it will take people, towns, and communities working together as though our quality of life here depends on the health of these bays. It does.



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STATE OF DIRICKSON CREEK REPORT

This State of Dirickson Creek Report is a compilation of environmental data about Dirickson Creek and its watershed.

Seven environmental indicators, including land use change, septic system permits, nutrient inputs, nutrient concentrations, baygrasses, dissolved oxygen concentrations, and bacterial concentrations were selected to provide a snapshot of the State of Dirickson Creek using the most recent data available.

This report is a product of the Delaware Center for the Inland Bays' (CIB) 'Your Creek' initiative, a project to introduce residents and property owners to their local creek, to their creek neighbors, and to the CIB as a resource of data and support for their creek. By identifying 'friends of the creek' and empowering these residents and property owners with data on water quality conditions in their creek and with information on land use conditions and practices that can affect water quality, Dirickson Creek residents can advocate for their creek.

The CIB began the Your Creek initiative with Love Creek on Rehoboth Bay in 2013. The Dirickson Creek team was the second team to be formed, in 2015,

and is working with the CIB to learn about their creek, share their knowledge with their communities, and take action to restore and protect their creek.

DIRICKSON CREEK WATERSHED

The land in the southern part of the Little Assawoman Bay Watershed, which includes Dirickson Creek, was part of the ancestral Great Cypress Swamp that extended from the middle of the Delaware to the Atlantic Ocean.

As the land was settled in the 19th and 20th centuries, ditches were dug to drain the land for farming, shaping the character of the landscape to this day. Dirickson Creek is still fed primarily by ditches that drain the farmland and communities located to the west.

In the past two decades, large swaths of the farmland located along Route 54 between Fenwick Island and Selbyville have been developed. (Figure 3). Originally, this area was very rural, with an influx of vacationers to the nearby ocean resorts in the summer. Today, while some residential communities are primarily seasonal, many are permanent residences that support a year-around business community.

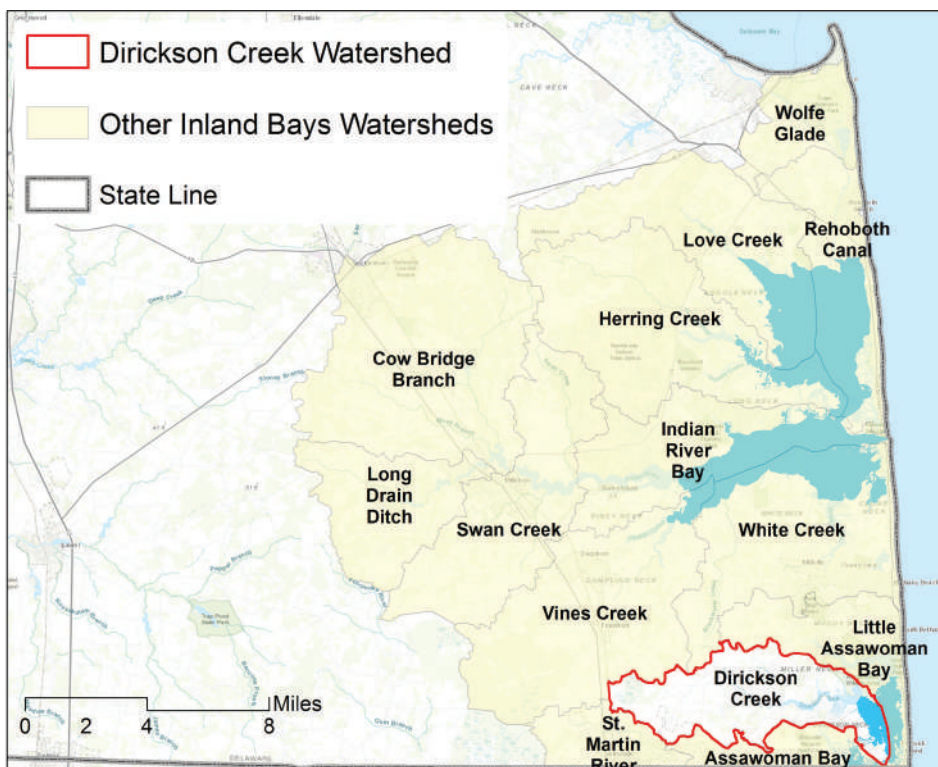


Figure 2. Location of Dirickson Creek watershed within the Inland Bays watershed.

Quick Facts About Dirickson Creek

- Dirickson Creek is a major tributary of Little Assawoman Bay, flowing into the Bay from the west, just north of the Delaware/Maryland state line. (Figure. 2)
- Dirickson Creek parallels the busy Route 54 corridor from Fenwick Island to Selbyville. The western (inland) end of the Dirickson Creek drainage area extends almost to Route 113.
- The total area of the Dirickson Creek watershed is approximately 20 square miles (Figure 3).
- The primary public access to the creek is by way of a boat ramp at Mulberry Landing in the Assawoman Wildlife Refuge, located on the north shore near the mouth of Dirickson Creek.

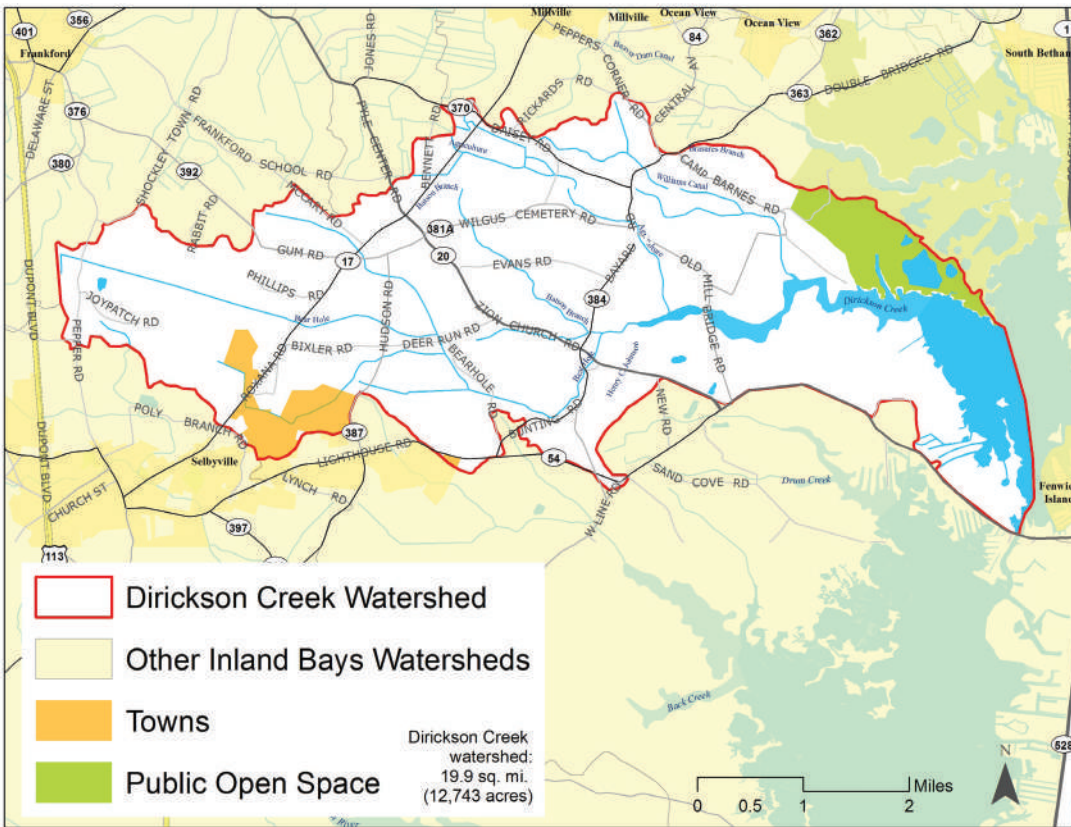


Figure 3. Map of Dirickson Creek watershed showing the location of towns and communities that are in the watershed.

POLLUTION IN DIRICKSON CREEK—WHERE DOES IT COME FROM?

There are many sources of pollution to Dirickson Creek, including legacy contaminants (contaminants that entered the watershed during an earlier period and are still there) from agricultural fertilizers and animal farming. The transport of these nutrients through groundwater can take a decade or more to enter the creek or bay, so improvements in practices may take just as long to show results.

Fortunately, there are no significant ‘point sources’ of pollution entering Dirickson Creek (i.e. industrial or wastewater outfalls discharging directly into the water). ‘Nonpoint source’ pollution from both agricultural and developed land areas, however, is an ongoing issue in the watershed.

As agricultural land is converted to residential and commercial developments, the increase in impervious cover (i.e., roads, parking lots, roofs, and driveways)

creates new pollution challenges; water running across these hard surfaces picks up bacteria, toxins, animal waste, and sediment, and carries the pollutants into nearby waterbodies. Nutrients from farms, lawn fertilizer, and septic systems on developed land also can find their way into the Creek. Development and the armoring of natural shorelines with bulkheads and stone has led to loss of tidal wetlands that filter and absorb pollutants.

Dirickson Creek and its tributaries currently are listed as ‘impaired’ under the federal Clean Water Act for bacteria and nutrients. The Little Assawoman Bay watershed as a whole has a Total Maximum Daily Load (TMDL) designation for these pollutants of concern. The TMDL regulation requires a 40% reduction in nitrogen and phosphorus, and a 40% reduction in freshwater bacteria from nonpoint sources. More information on this can be found at www.inlandbays.org.

SUMMARY OF THE FINDINGS IN THIS REPORT



- **Loss of forests, particularly forested buffers along the shorelines as new development occurs, is a significant threat to the health of the creek.** The recession and that began in 2008 slowed development across the watershed. But many projects that were on hold are now underway, many of them in the northern part of the creek watershed bordering the Assawoman Wildlife Area.
 - **The population in the area continues to grow, bringing with it commercial development, increased traffic, and the need for additional infrastructure.** While conversion of farmland to development reduces inputs of pollution from agricultural fertilizers, the conversion of forests and wetlands to residential communities and ag lands will increase nutrient inputs.
 - **Nitrogen and phosphorus continue to be major nutrient pollutants in the upper portions of Dirickson Creek.** Loads (or inputs) of nitrogen have decreased since 2009 but remain above the allowable limits (Total Maximum Daily Load) for Dirickson Creek. Concentrations of dissolved inorganic nitrogen at the Old Mill Road bridge monitoring site consistently fail to meet the state water quality standard. Loads of phosphorus entering the Creek are below the allowable limits, but concentrations in the water are at unhealthy levels, possibly due to 'legacy' phosphorus remaining in bottom sediments from previous years of nutrient pollution. The conversion of agricultural land to development may, over time, lower nutrient concentrations in the creek, but
- continued implementation of Best Management Practices (BMP's) to reduce nutrient pollution from both agricultural and suburban landscapes is essential. Cover crops on farmland, rain gardens, ponds and swales to capture stormwater in developed areas, and protective vegetated buffers along shorelines will all be important to manage nutrients.
- **No significant beds of baygrass are known to be present in Dirickson Creek.** Physical factors such as salinity and the type of bottom sediment present, along with excess nutrient pollution, makes Dirickson Creek a harsh environment for many baygrass species.
 - **Dissolved oxygen concentrations in the upper portions of the Creek remain a concern for the health of animal life.** Residential canals and upper portions of the Creek experience particularly low oxygen in warmer months. Reducing the amount of nutrients entering the creek will decrease algae growth, keep the water clearer for sea grasses and allow for healthy concentrations of dissolved oxygen.
 - **Bacterial pollution increases heading upstream from the mouth of the Dirickson Creek.** During the summer, concentrations of Enterococcus bacteria near the Old Mill Road bridge exceed safe swimming standards over 75% of the time. Identifying and removing sources of bacteria pollution to the Creek is a priority.



THE ENVIRONMENTAL INDICATORS INCLUDED IN THIS REPORT

This report is a compilation of environmental data about Dirickson Creek and its watershed. To assess the health of the Creek, a suite of environmental indicators were selected. These are specific species and conditions that are measured over time to determine how the Creek is changing and how much progress has been made toward restoration goals.

The table below summarizes the indicators used to assess the health of Dirickson Creek and its watershed. Details of data and analyses used in developing this report can be found in the Appendix. A more comprehensive report, 2016 State of the Delaware Inland Bays, assessed the health of the entire Inland Bays estuary. It can be viewed at www.inlandbays.org/wp-content/uploads/Final-CIB-State-of-the-Bays-2016-low-res.pdf.

Indicator	Data/Stations Used	Source
Land Use Change	Land Use/Land Cover data layers, Active PLUS1 Projects	State of Delaware Land Use Land Cover Program and Office of State Planning Coordination, PLUS Project inventory
Septic System Permits	Septic permits, Sussex County billing records, CPCN2 areas	DNREC Division of Water, Sussex County, and Delaware Public Service Commission
Nutrient Inputs	Modeled loading data table	DNREC Division of Watershed Stewardship, Watershed Assessment and Management Section
Nitrogen and Phosphorus Concentrations	UDCMP3 Stations	University of Delaware, Citizen Monitoring Program
Sea Grasses	Field observations	UDCMP, Center for the Inland Bays
Dissolved Oxygen Concentration	UDCMP3 Stations	UDCMP
Bacterial Concentrations	UDCMP3 Stations	UDCMP

Table 1. Summary of the indicators and sources of data used for the State of Dirickson Creek Report.

Most of the water quality data used in this report come from two stations monitored by the University of Delaware's Citizen Monitoring Program: Old Mill Road bridge (Station No. LA09) and Mulberry Landing Station No. LA03 (Figure 4).

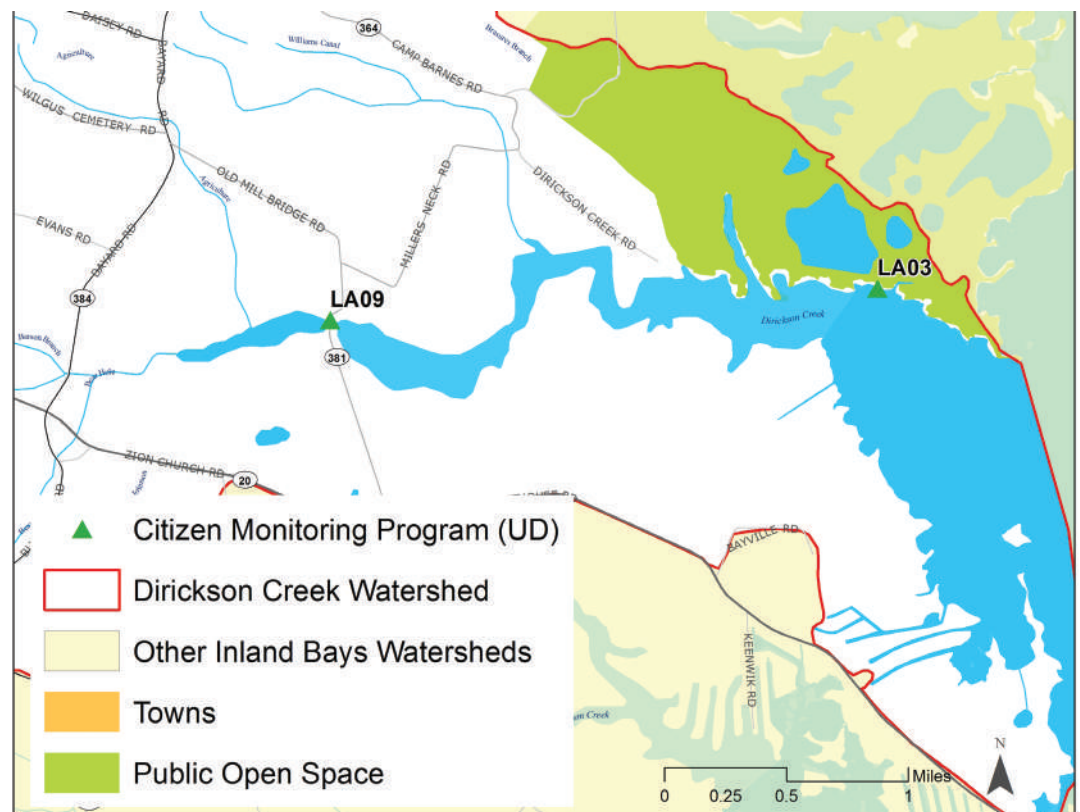


Figure 4. Map showing the location of UDCMP water quality monitoring stations in Dirickson Creek that provided data used to develop this report.

WATERSHED CONDITION

INDICATOR: LAND USE CHANGE

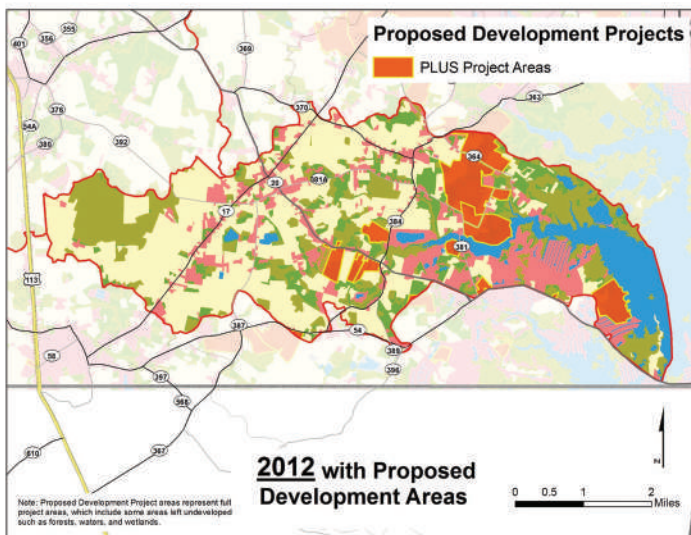
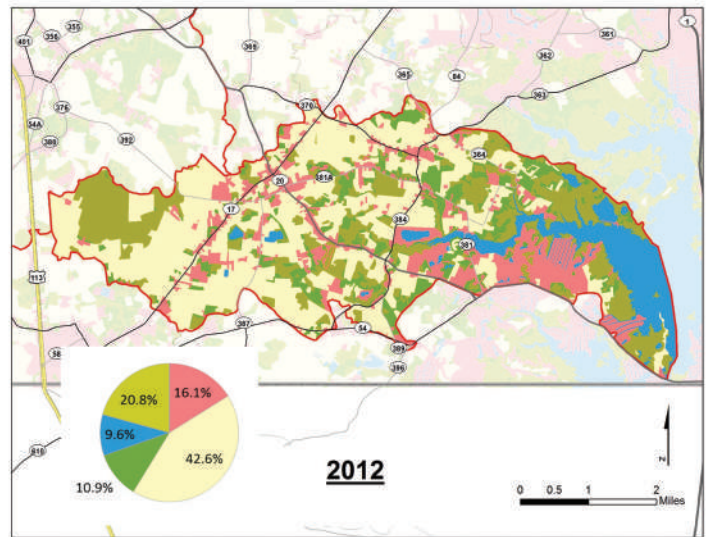
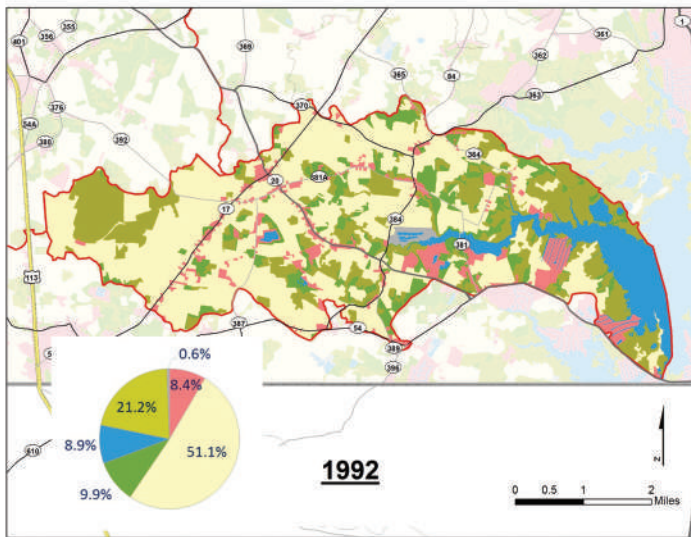
From 1992 to 2012, land use has changed significantly in the 20-square mile Dirickson Creek watershed. A decrease was seen in agricultural land, while an increase was noted in developed areas, especially along the Rt. 54 corridor and the land surrounding the Assawoman Wildlife Management Area (Figure 5).

In 2012, the most recent year for which data are available, agriculture was still the largest use of the land in the Dirickson Creek watershed (43%), followed by forested land (21%), developed/developing land (16%) and wetlands (11%) (Figure 6).

The largest changes are attributable to conversion of agricultural lands to development (Figure 7)

How humans use the land directly affects water quality in creeks and rivers that flow into the Bays. Different types of land uses, including development, agriculture, and forests, each have a characteristic contribution of pollutants to waters.

Per acre of land, cropland tends to contribute the highest loads of nutrient pollution to waters, followed by developed areas. Forests contribute few nutrients and healthy wetlands can actually remove nutrients from waters on the way to the Bays.



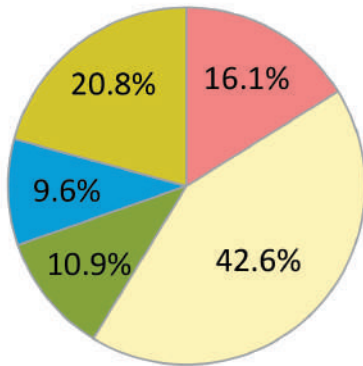
Land Use

- Developed/ Developing
- Agriculture
- Upland Forest
- Open Water
- Wetland
- Other

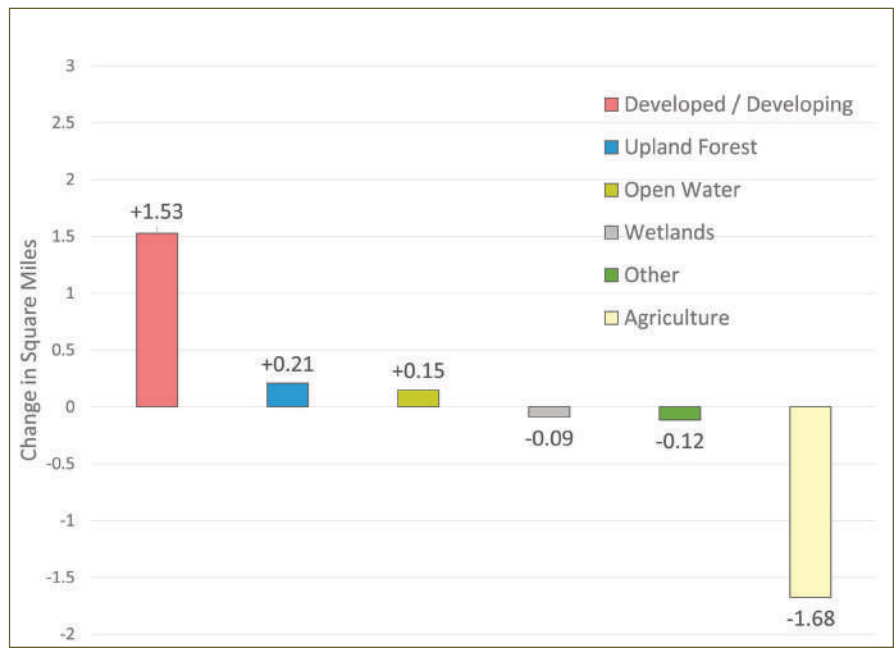
Note: Proposed Development Project areas represent full project areas, which might include some areas left undeveloped such as forests, waters, and wetlands.

Figure 5. Maps show changes in land use over time in the Dirickson Creek watershed, including proposed development areas.

Land Use in 2012 Dirickson Creek Watershed



- Developed / Developing
- Agriculture
- Upland Forest
- Open Water
- Wetlands



LOOKING AHEAD—WHAT CAN BE DONE?

- Because cropland tends to contribute the most nutrients to waterways, the conversion of croplands to development may actually result in gradually reduced nutrient loads to Dirickson Creek over time—but only if communities and homeowners manage residential fertilization and stormwater effectively. Increased impervious (hardened) surfaces in developed areas—such as roads, driveways, roofs, etc.—tend to speed the delivery of pollutants (nutrients, toxins, bacteria, sediment, etc.) to the Creek via stormwater runoff unless communities and towns adopt green infrastructure ordinances and practices that limit impervious surfaces.
- Alternately, the conversion of forests and wetlands to development will result in increased nutrient inputs to the Creek. Protecting forest buffers along shorelines can help mitigate impacts from development; filtering runoff and taking up excess nitrogen and phosphorus.
- The location of new developments near marshes and creeks along Dirickson Creek, will degrade the natural function of wetlands and shorelines unless communities protect wetland areas, opt for 'living shorelines' to manage erosion, and maintain vegetated buffers to protect waterways from runoff. Potential future development, as proposed to the State of Delaware Preliminary Land Use Service (PLUS), indicates that rapid development along the shores of Dirickson Creek, its marshes and streams, and along Little Assawoman Bay is intended. The only way to protect the quality of life that clean water affords a community is to design and build to protect water quality.

WATERSHED CONDITION

INDICATOR: SEPTIC SYSTEM PERMITS

The Dirickson Creek watershed has both a lower number (581) and lower density of active septic permits (30.8 permits per sq. mi.) than other watersheds on the Inland Bays (Figure 8).

The density map of septic systems in the Dirickson Creek watershed (Figure 9) shows that they are largely concentrated in the northern and western parts of the watershed.

Most of the watershed's subdivision developments are connected to sanitary sewer. While active septic permits still exist in some of these communities, it is anticipated that as sewer service is provided, those systems will be abandoned.

Did you know?

Septic systems are a significant source of nutrients to nearby waterbodies. **Even properly maintained septic systems can leach approximately 10.6 pounds of nitrogen and 0.7 pounds of phosphorus into the groundwater each year.** There are roughly 8,292 septic systems within the watersheds of the Inland Bays; the densities and number of systems are shown on these maps (Figure 8).

In addition to nutrient pollution, septic systems that are not properly designed, constructed, or maintained can also contribute loads of bacteria to the creek, if untreated waste surfaces and runs off, or reaches the groundwater.

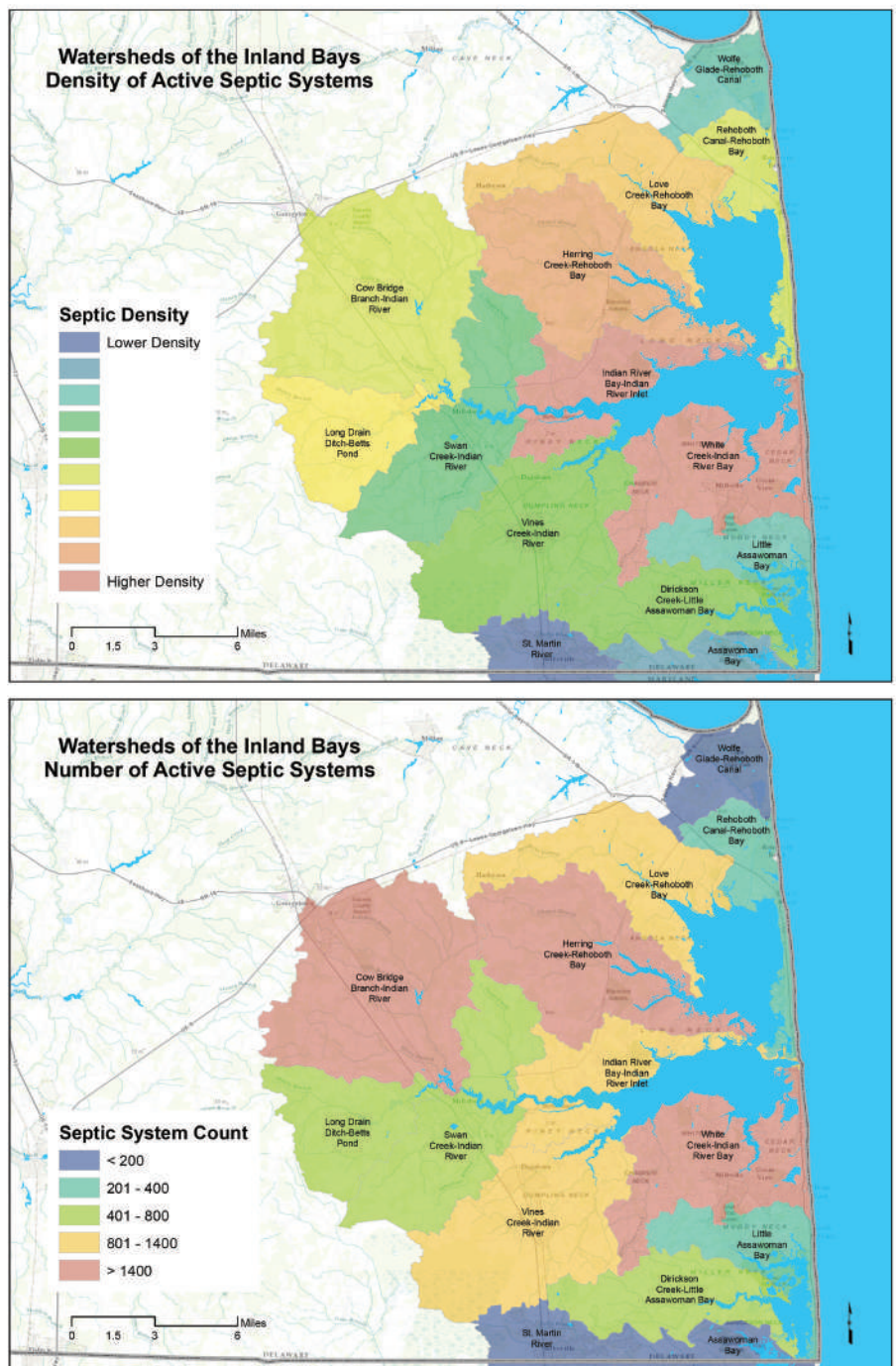


Figure 8. Relative density and numbers of septic system permits in subwatersheds of the Inland Bays, as of 2016.

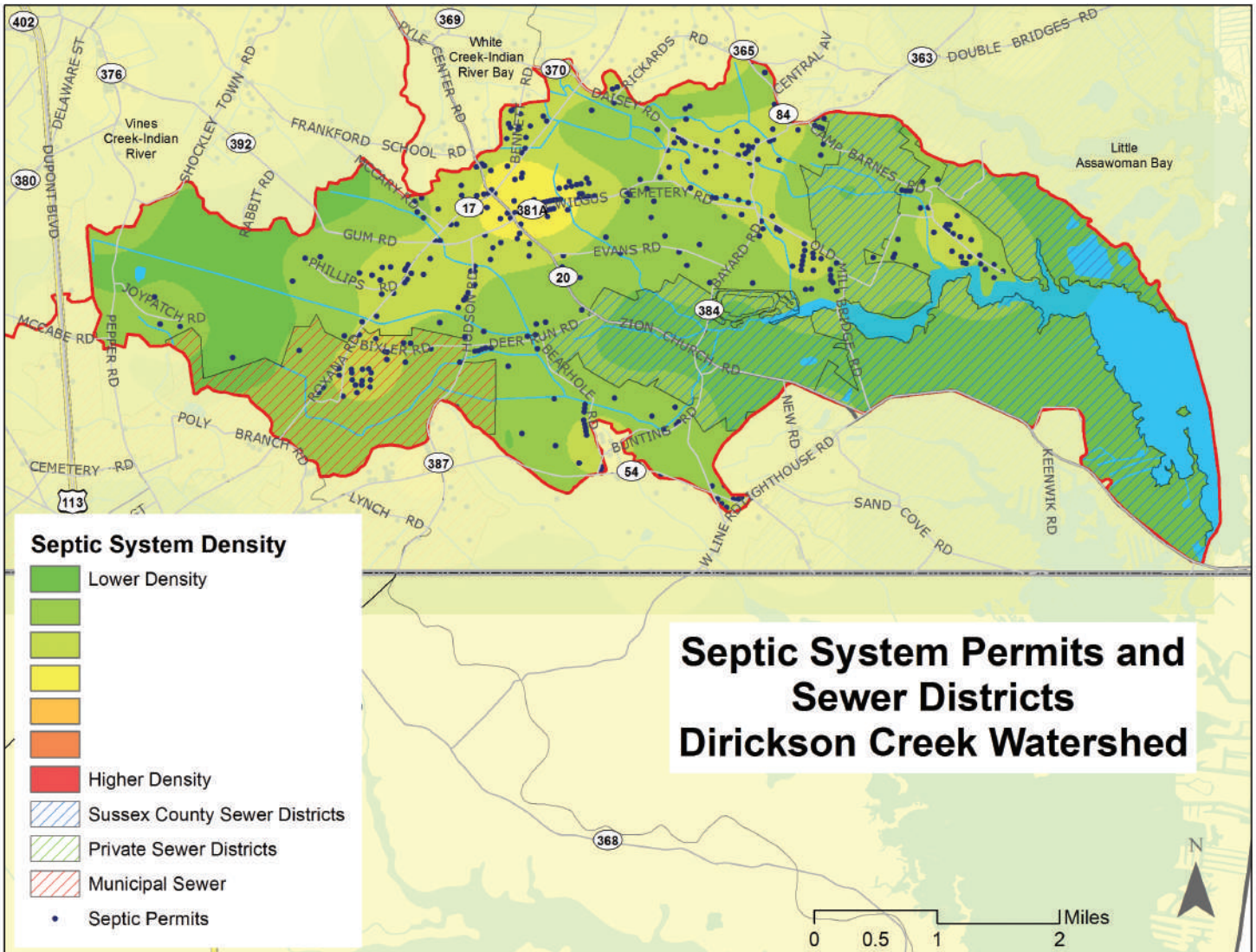


Figure 9. Density map of active septic systems in the Dirickson Creek watershed. Also shown are the boundaries of county, municipal, and private sanitary sewer districts.

LOOKING AHEAD—CHOICES WE CAN MAKE FOR CLEANER WATER

- Sussex County and private wastewater utilities are working to expand sewer service to more communities in the Dirickson Creek watershed. When they do, residents and property owners in these communities will have the opportunity to vote for cleaner water in their creeks. Central sewer provides a much higher level of sewage treatment compared to existing septic systems, and even properly maintained septic systems leach nutrients into groundwater, so over time, conversion of most existing septic systems to public sewer will result in cleaner water.
- For properties maintaining or installing septic systems—proper siting and regular pump outs and maintenance, as required by the Inland Bays Pollution Control Strategy (PCS), will reduce the risk of pollution to the Bays. New and replacement septic systems must now provide advanced waste treatment (known as 'Performance Standard Nitrogen 3' or PSN3). This regulation went into effect January 2009 for sites close to tidal waters and wetlands and extended to the entire Inland Bays watershed in 2015.

WATERSHED CONDITION

INDICATOR: INPUTS OF NUTRIENT POLLUTION

Nutrients are necessary for the growth of beneficial grasses and algae in tidal creeks. However, excessive amounts of nitrogen and phosphorus in the water cause an overabundance of algae, cloudy waters, and unhealthy dissolved oxygen concentrations. This can inhibit growth of underwater baygrass habitats and lead to deaths of fish and shellfish in creeks and canals.

Nutrient pollution—in particular, an excess of nitrogen—is the largest water quality problem facing both Dirickson Creek and Little Assawoman Bay. Nitrogen and phosphorus found in the waters of the Creek come primarily from chemical fertilizers, manure, stormwater runoff, wastewater, septic systems, and natural sources. These nutrient loads vary with the different ways that land in the watershed is used; farms, developments, and even forests to some extent, contribute nutrients to Dirickson Creek.

“Nutrient load” refers to the total amount of nitrogen or phosphorus entering the water during a given time, such as “pounds of nitrogen per day.” Nutrient loads are calculated from measurements of nitrogen and phosphorus taken over time in the creek—basically concentration times flow. The estimated nitrogen and phosphorus loads are compared with the allowable Total Maximum Daily Load (TMDL) of nutrients that a creek may receive and still remain healthy for human use and aquatic life.

The variation in nutrient loads from year to year is related to stream flow, which is in turn related to the amount of precipitation in a year. During wetter years, the increase in precipitation will cause an increase in runoff from the land. This runoff carries nutrients from farms and residential lawns, bacteria and toxins from developments, and sediment from eroding stream banks and construction sites, and delivers them to the Creek.

These impacts can be lessened. If developments are built with proper

stormwater control structures, farms and residential lawns apply nutrients only when necessary, and in the correct quantity, and shorelines are stabilized in a natural way, increases in runoff from these areas will be less harmful to the bays.

Inputs of Nitrogen

Nitrogen loads to Dirickson Creek have failed to meet water quality standards every year since 2006. In 2014, nitrogen loads were 150% that of the healthy limits for the Creek (it’s TMDL goal) (Figure 10).

There appears to have been some decrease in these loads over time, possibly due in part to improved agricultural nutrient management and a loss of agricultural lands in the watershed. However this decrease is not significant, and nitrogen loads to Dirickson Creek are still far too high.

Inputs of Phosphorus

Phosphorus loads to Dirickson Creek have been well within the health limits for the Creek (below the Total Maximum Daily Load goal) every year since 2006 (Figure 11). This is good news. As with nitrogen, phosphorus loads vary from year to year, mostly due to changes in stream flow. There is no overall trend of increase or decrease in phosphorus loads, indicating no significant increase or decrease in sources.



Figure 10. Annual loads of nitrogen to Dirickson Creek, with mean annual streamflow for comparison. The Total Maximum Daily Load (TMDL) goal for nitrogen in the Creek is indicated by the dashed red line. Nitrogen Loads consistently exceed the goal.

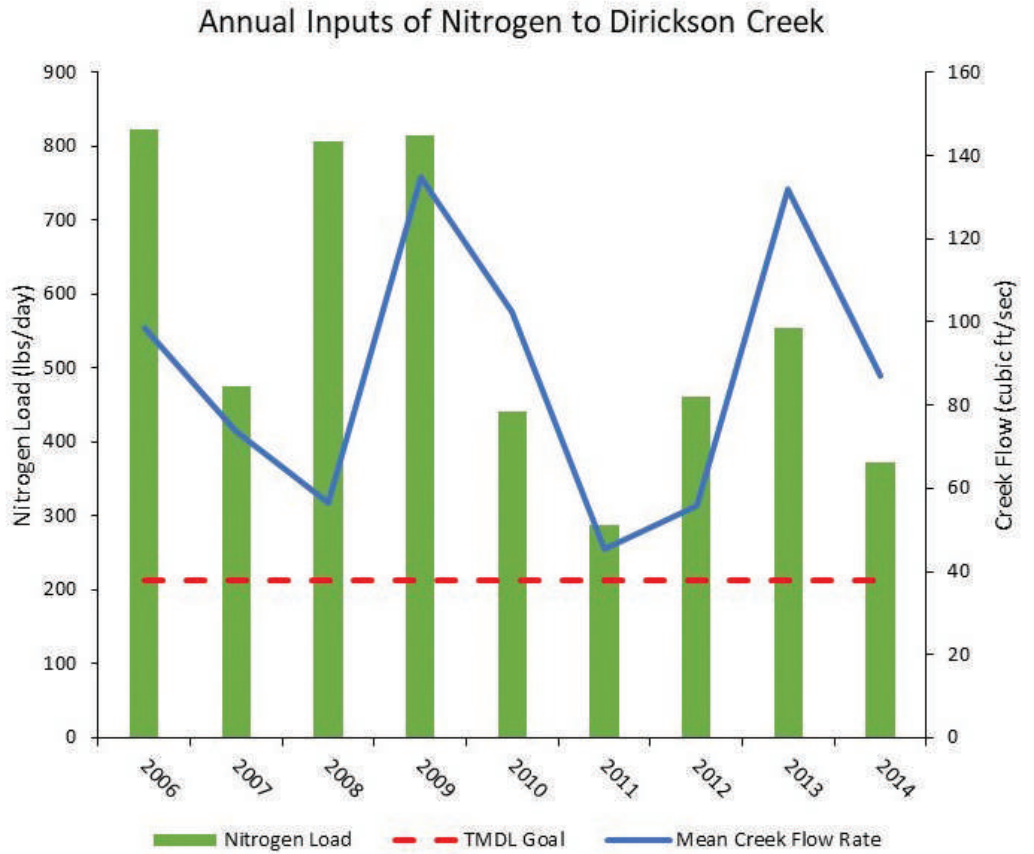
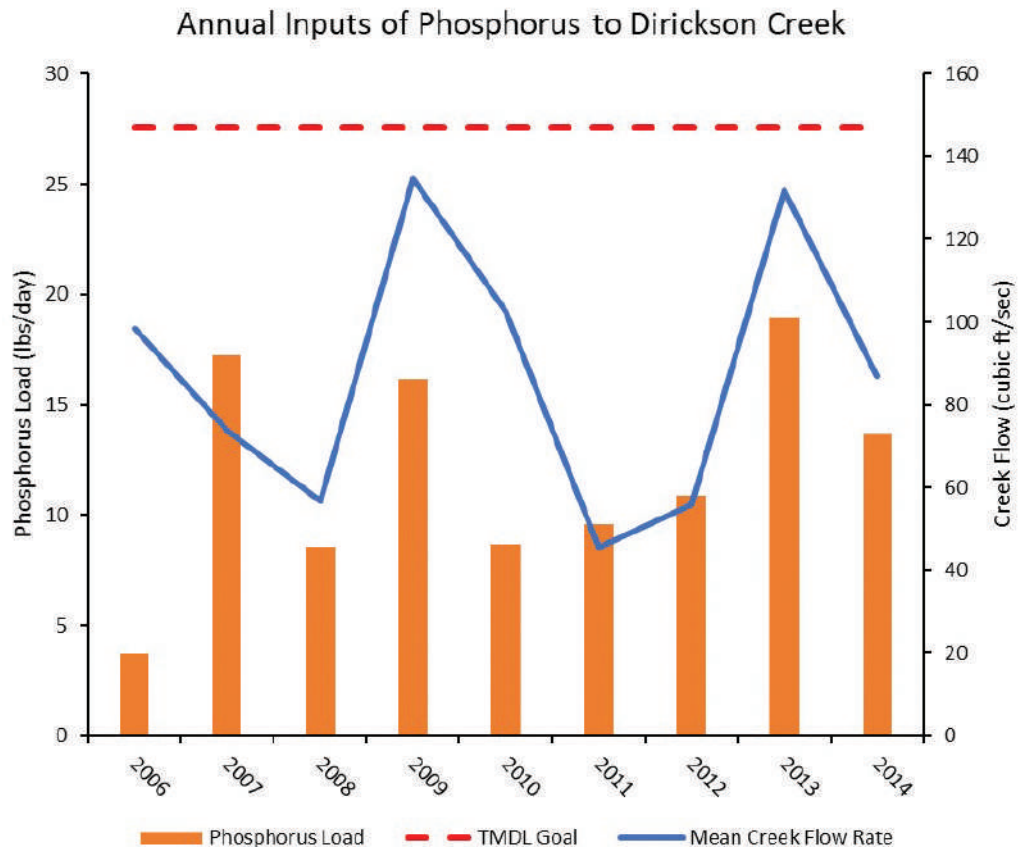


Figure 11. Annual loads of phosphorus to Dirickson Creek, with mean annual streamflow for comparison. The Total Maximum Daily Load (TMDL) goal for phosphorus in the Creek is indicated by the dashed red line. Phosphorus Loads consistently meet that goal.



WATER QUALITY

INDICATOR: CONCENTRATIONS OF NITROGEN AND PHOSPHORUS IN THE WATER

The 'loads' (or inputs) of nitrogen and phosphorus are a measure of what is entering the creek and can change depending on how the land is managed and used. 'Concentration' is the amount of a dissolved pollutant actually measured in a certain volume of water (for example, milligrams of dissolved nitrogen per liter).

The concentrations of nutrients in Dirickson creek reflect the loads, but they also are affected by other factors including uptake by plants and algae, and release of 'legacy' nutrients from sediments. Both nitrogen and phosphorus take different forms once they enter the water column, leading to varying concentrations. The concentration of these nutrients in the water, and their chemical forms, directly impacts algae growth.

Annual median concentrations of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) in Dirickson Creek were determined from water samples taken at two monitoring stations: the bridge crossing at Old Mill Road and the boat launch at Mulberry Landing (Figure 4, Stations LA09 and LA03). Both stations have been monitored continuously by the University of Delaware's Citizen Monitoring Program (CMP) since 1999.

With a goal of reducing nutrients to concentrations at which sea grasses can reestablish in our Bays, the State has established water quality standards for nitrogen and phosphorus (0.14 mg/L and 0.01 mg/L, respectively). Concentrations of nitrogen and phosphorus measured in the Creek are compared against these goals.

Nitrogen Concentrations

At the monitoring station upstream of the Old Mill Road bridge, nitrogen concentrations exceed the

state water quality standard during most years. No consistent trend is evident over time, and the data show tremendous variability at this site. At the station downstream of Mulberry Landing, near the mouth of the creek on Little Assawoman Bay, waters meet the nitrogen standard most of the time (Figure 12).

The difference in the two stations likely is likely attributable to the land use surrounding the monitoring stations. The Mulberry Landing station is located at the Assawoman Wildlife Area, where the many acres of forests and wetlands result in fewer pollutants running off the land compared to the Old Mill Road bridge station, which is surrounded by developed lands and agriculture, and is therefore closer to sources of nitrogen pollution. In addition to land use, increased tidal flushing at the mouth of Creek results in increased dilution near the Mulberry Landing station.

Phosphorus Concentrations

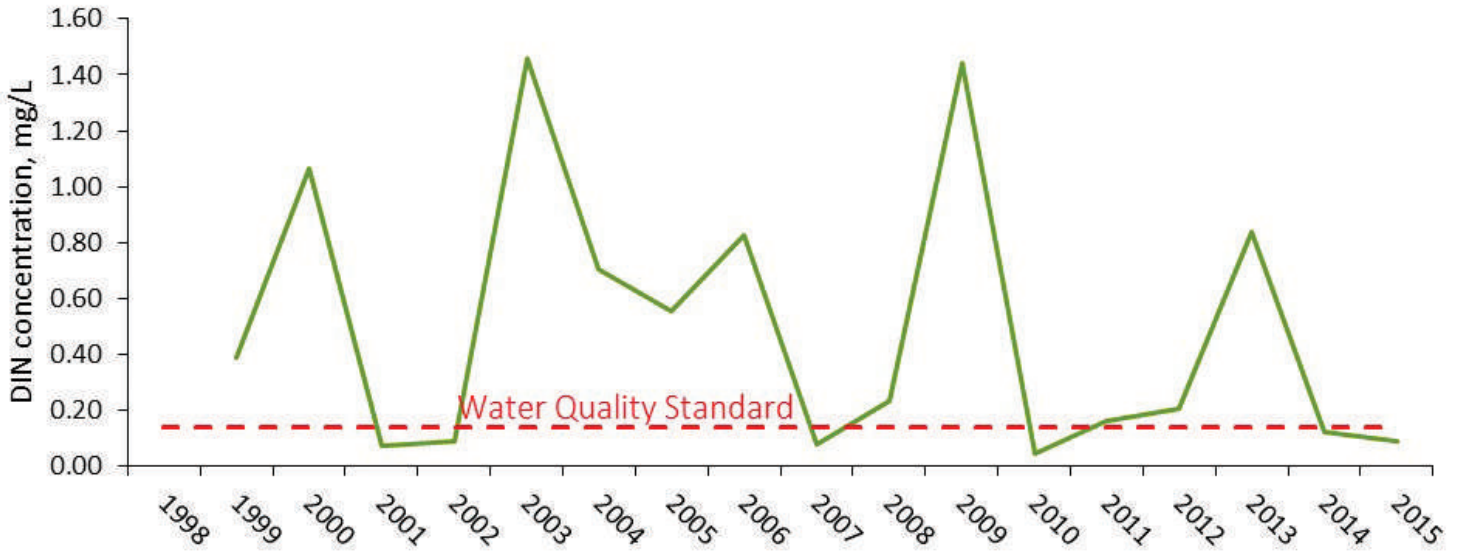
Phosphorus concentrations in Dirickson Creek follow a pattern similar to that for nitrogen (Figure 13). Median concentrations of phosphorous at the upstream monitoring station have consistently failed to meet the water quality standard, and show no overall trend over time.

At the station downstream of Mulberry Landing, however, phosphorus concentrations do meet the water quality standard. Again, this reflects a pattern typical in the Inland Bays that was revealed in the 2016 State of the Delaware Inland Bays report. While water quality improvements over time have been observed in open waters of the Bays, the tributaries and canals continue to have poorer water quality, algae blooms, and unhealthy oxygen concentrations due to their proximity to nonpoint sources and poor tidal flushing.

LOOKING AHEAD—

- Loads of both nitrogen and phosphorus to Dirickson Creek will be affected by the projected changes in land use in the watershed. The net effect of conversion of crop lands to housing is not completely clear and should be closely monitored.
- Conversion of communities from septic systems to central sewer will continue to have a positive impact on nutrient loads to the Creek from groundwater. But increased stormwater runoff from development and roads may have a negative impact unless communities and residents work together to protect against runoff into waterways.

Median Nitrogen Concentration Station LA09 - Old Mill Road Bridge



Station LA03 - Mulberry Landing

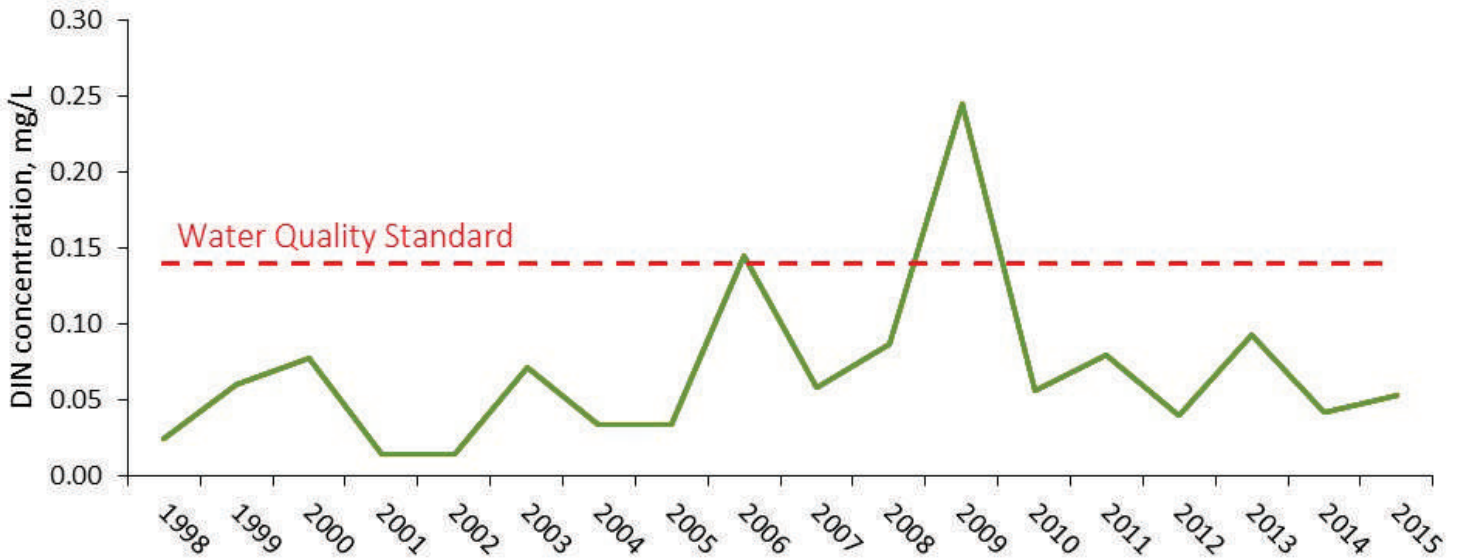
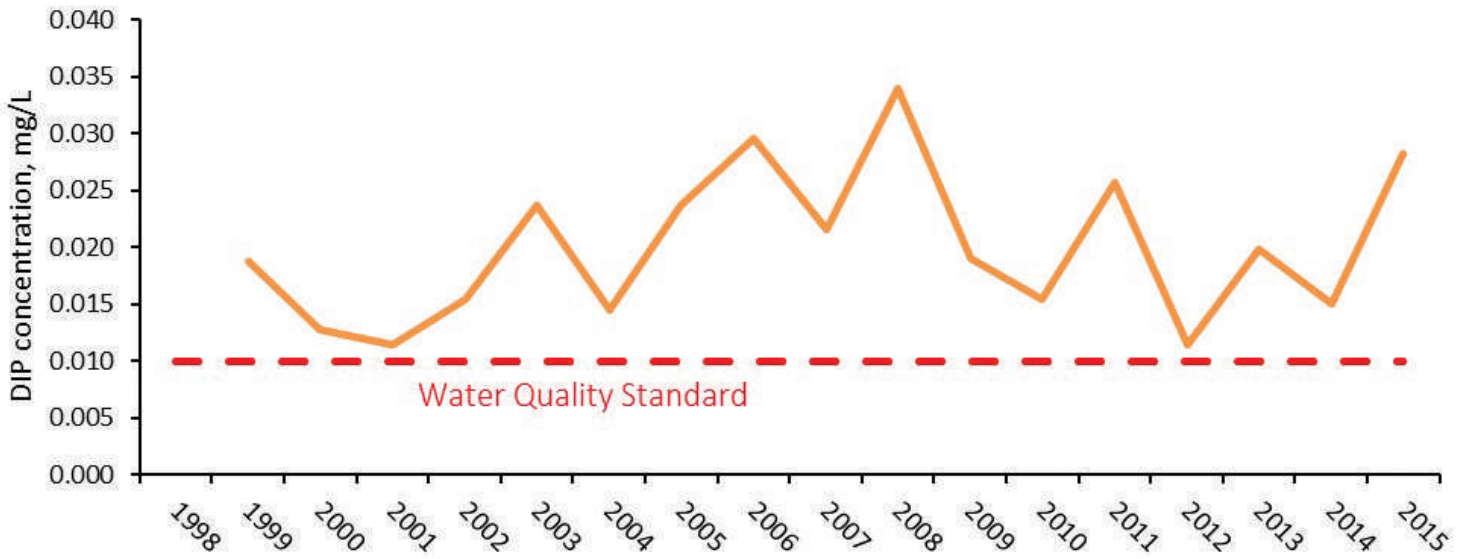


Figure 12. Median annual concentrations of dissolved inorganic nitrogen (DIN) measured by the Old Mill Road bridge (Station LA09) and further downstream at Mulberry Landing (Station LA03). The state water quality standard for DIN, 0.14 mg/L, is indicated by the dashed red line. (Data Source: University of Delaware Citizen Monitoring Program)

Median Phosphorus Concentration Station LA09 - Old Mill Road Bridge



Station LA03 - Mulberry Landing

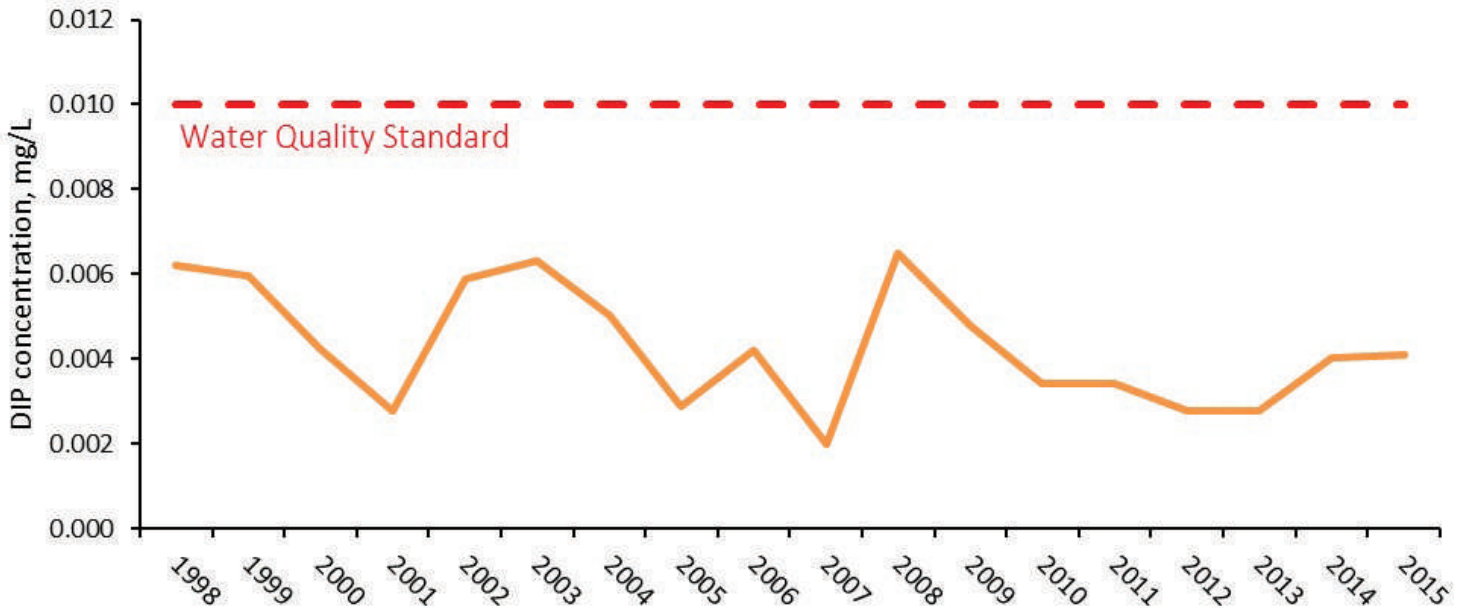


Figure 13. Median annual concentrations of dissolved inorganic phosphorus (DIP) measured by the Old Mill Road bridge (Station LA09) and further downstream at Mulberry Landing (Station LA03). The state water quality standard for DIP, 0.01 mg/L, is indicated by the dashed red line. (Data Source: University of Delaware Citizen Monitoring Program)

WATER QUALITY

INDICATOR: BAYGRASSES

Baygrass meadows are a key habitat found in healthy bays. These underwater grass beds are important nursery areas for fish and crabs, provide food and protection to young marine life, add oxygen to the water, remove nutrient pollution, trap sediment, reduce erosion, and carpet the shallows with verdant green color.

The presence of baygrasses in bays and tributaries is a good indicator of water quality, since they require relatively clear water to grow and survive and many species need water with low nutrient concentrations. Run off and erosion of sediment, and high concentrations of algae, caused by excess nutrients in creeks, can cloud the water and block sunlight from reaching from the bottom, preventing the growth of sea grasses. Disturbance from boat propellers and clam rakes can also destroy existing beds, or rip new growth from the bottom. Improving water clarity is the most important step in sea grass restoration, because sea grasses need sunlight to grow.

No recent studies have taken place to document the presence and size of underwater grass beds in Dirickson Creek or Little Assawoman Bay, but it is not believed that any substantial baygrass beds are present in these areas.

LOOKING AHEAD—BAYGRASSES

- Sediment washing into the creek from stormwater runoff and eroding shorelines has the potential to further reduce water clarity.
- Protection and reestablishment of forested and wetland buffers along the shores of Dirickson Creek is critical to restoring water quality and water clarity that would allow for the growth of sea grasses.
- Surveys to document the distribution and presence of sea grasses within Dirickson Creek, as well as the entire Inland Bays, should be implemented.



Figure 14. Submerged eelgrass (*Zostera marina*).

Eelgrass (*Zostera marina*) is one of the most valued species of baygrasses (Figure 14). By the late 1970s, eelgrass and most other baygrass species had disappeared from the Inland Bays, due to disease and increasing nutrients. When it seemed that water quality might be improving in the 1990s, some attempts were made to reestablish eelgrass in parts of the Inland Bays. However, nutrient concentrations were still too high for eelgrass survival in much of the Bays, and macroalgae such as sea lettuce, smothered restoration attempts. Eelgrass grows in firm sandy substrates, and primarily in medium to high salinity waters. Due to restricted flushing between Dirickson Creek and the Ocean City Inlet, Dirickson Creek experiences large fluctuations in salinity, ranging from fresh to high salinity depending on the amount of rainfall. Along with these fluctuations, Dirickson Creek primarily has a soft sediment bottom. These physical factors make Dirickson Creek an unlikely environment for eelgrass to grow and thrive in.

Widgeon grass (*Ruppia maritima*) is another species of baygrass more suited to the environmental conditions present in Dirickson Creek. Capable of surviving in both fresh and saline waters, widgeon grass also grows in soft sediment bottoms. While it is unlikely that eelgrass meadows will flourish in Dirickson Creek, the presence of widgeon grass meadows would be an encouraging sign of improved water quality.

WATER QUALITY

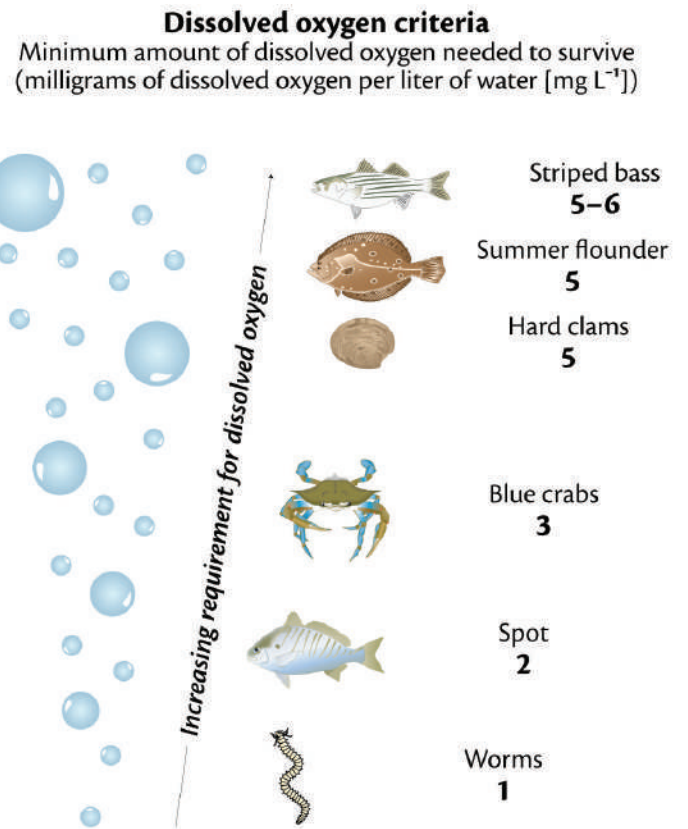
INDICATOR: DISSOLVED OXYGEN CONCENTRATION

All aquatic life needs healthy concentrations of oxygen in the water (Figure 15). Healthy concentrations of oxygen are especially important in tidal creek nursery grounds where young fish and shellfish are found.

Delaware has a minimum standard of 4 milligrams of dissolved oxygen per liter of water (mg/L) for a tidal creek to be considered healthy. If the minimum daily concentration falls below this standard too often, water quality is considered impaired, and aquatic life may be harmed.

Excess algal growth fueled by nitrogen and phosphorus creates high concentrations of oxygen during the day (while the algae photosynthesizes), but also causes oxygen to plummet during the night and early mornings (when the algae stops photosynthesizing and consumes oxygen during respiration). These swings in dissolved oxygen are characteristic of waters which have unhealthy amounts of algae. Eventually, the algae blooms die and decompose, which consumes even more of the dissolved oxygen in the water.

Between 1999 and 2016 at the Old Mill Road Bridge station, 45 percent of the observed summer months had mean dissolved oxygen values below the water quality standard of 4 mg/L (Figure 16). At Mulberry Landing, only 5% of the summer months had mean values that failed to meet the dissolved oxygen standard. This difference is due largely to increased tidal flushing at the creek mouth and lower nutrient concentrations compared to the Old Mill Road bridge station.



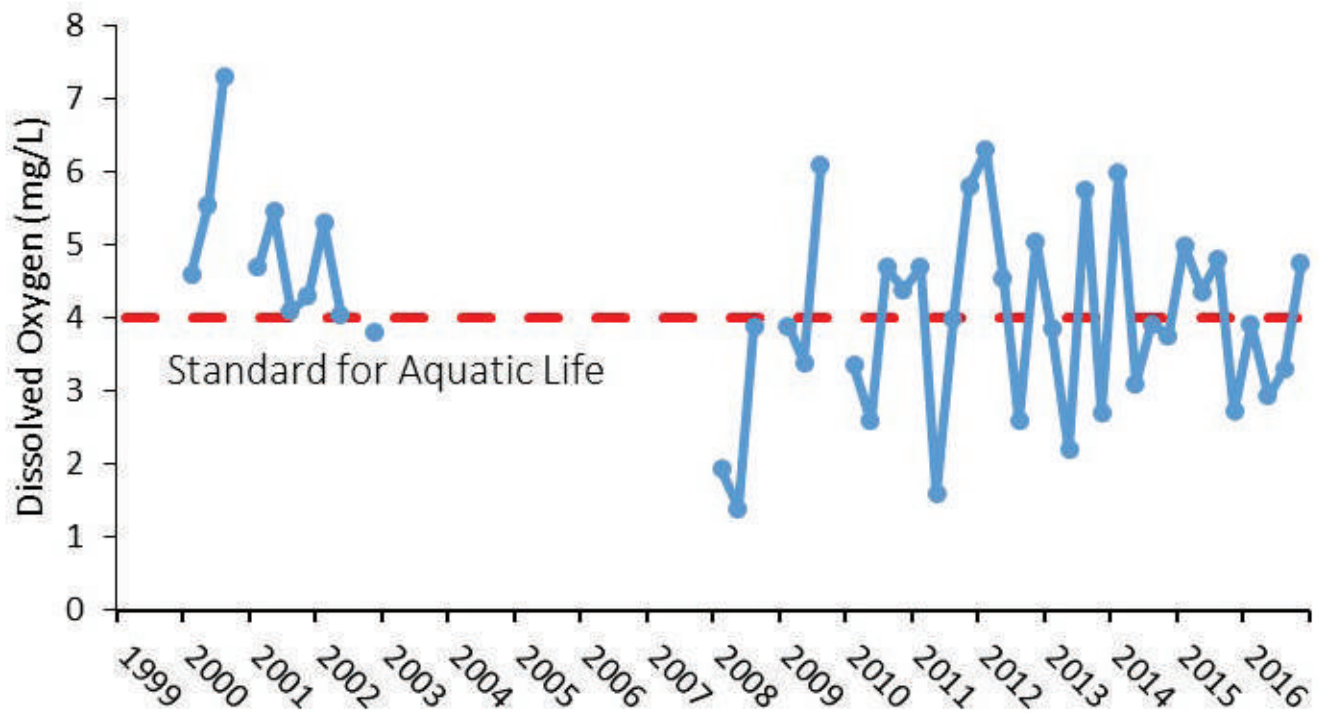
Different organisms require different levels of dissolved oxygen in the water to survive. Dissolved oxygen is a useful indicator of water quality. Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Donikow, M.C., J.B. Thomas, C.L. Carr, T.B. Carothers, R.R. Holt, IV, J. Jassby, C.F. Phlips, and D.E. Wilcox. 2009. Shifting Goals: Environmental and cultural change in Maryland's Coastal Bays. IAN Press, University of Maryland Center for Environmental Science.

Figure 15. Various organisms require different concentrations of dissolved oxygen (DO) to survive. In general, higher DO concentrations are preferable and indicate higher water quality. Courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

LOOKING AHEAD— DISSOLVED OXYGEN

Low dissolved oxygen is directly tied to excess nutrients and water clarity, so control of nitrogen and phosphorus loads to Dirickson Creek will continue to be critical for the survival and health of aquatic life there.

Station LA09 - Old Mill Road Bridge



Station LA03 - Mulberry Landing

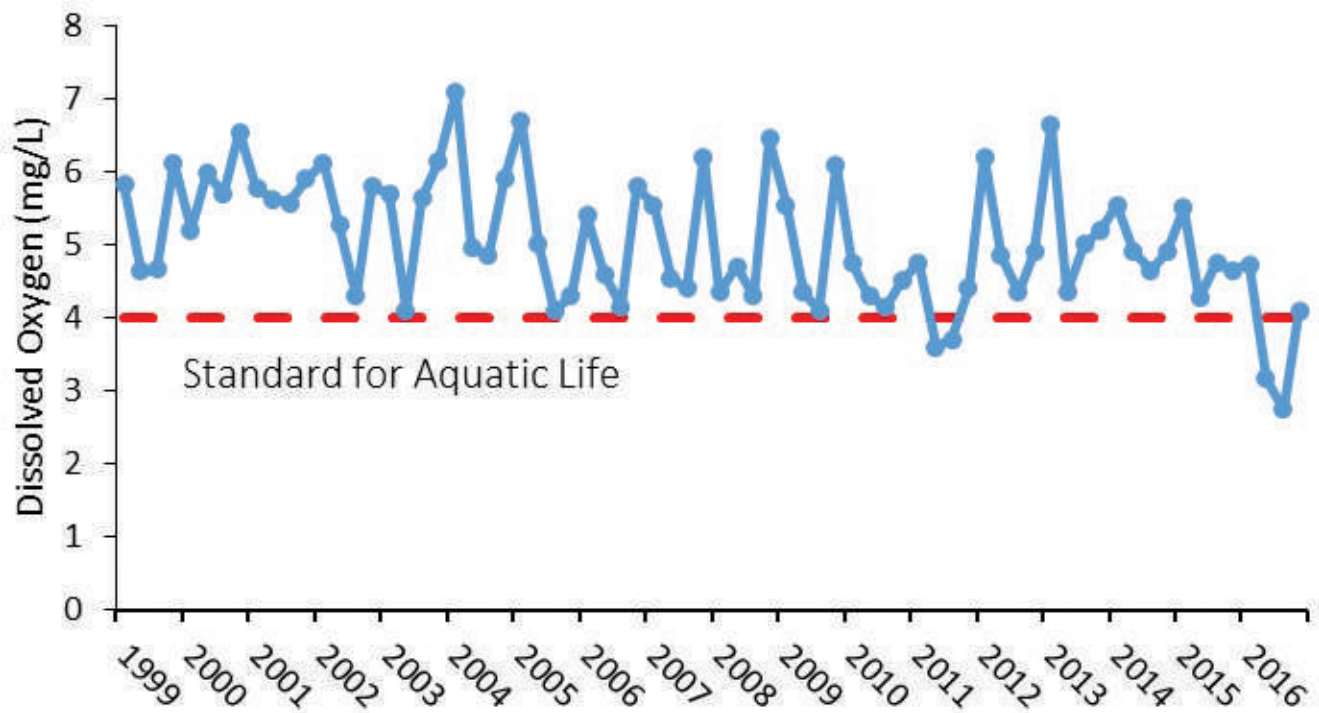


Figure 16. Monthly mean dissolved oxygen concentrations measured on summer mornings by the Old Mill Road bridge (Station LA09) and further downstream at Mulberry Landing (Station LA03). The DO standard to support aquatic life is indicated by the red dashed line (4.0 mg/L). (Data Source: University of Delaware Citizen Monitoring Program)

WATER QUALITY

INDICATOR: BACTERIA CONCENTRATIONS

The Inland Bays are a playground for so many who love boating, fishing, swimming and other water activities. Unfortunately, bacterial concentrations often exceed the safe swimming standards in the Bays' creeks, canals, and marinas—including in Dirickson Creek.

Potentially harmful waterborne bacteria and pathogens can enter waterways from many sources, including waste from wildlife, pets, septic systems, manure, and marine sanitation devices. Impervious surfaces such as roofs, roads, and parking lots in developed areas accumulate bacteria that wash into creeks and the bay with stormwater. With more impervious surface comes more bacteria.

In Dirickson Creek, the monitoring of recreational water quality is conducted by the University of Delaware Citizen Monitoring Program. They measure concentrations of *Enterococcus*, a type of bacteria that can indicate the presence of other harmful bacteria and pathogens.

A maximum standard of 104 colony forming units (CFUs) of *Enterococcus* in a single 100 milliliter sample of water is used to assess the health of individual water samples and close waters for swimming. Over the long term, a geometric mean safe swimming standard of 35 colony forming units (CFUs) of *Enterococcus* per 100 milliliters of water is used to advise water users. Varying advisory standards are provided to prevent unnecessary beach closures due to variation from a single sample.

Upstream, at the Old Mill Road bridge monitoring station, summertime *Enterococcus* concentrations failed to meet the single-sample safe swimming standard of 104 CFU/100 mL nearly 80% of the time. Closer to the mouth of the Creek, at Mulberry Landing, bacteria concentrations were far lower and only 6% of the samples failed to meet the safety standard. Since 2004, average annual

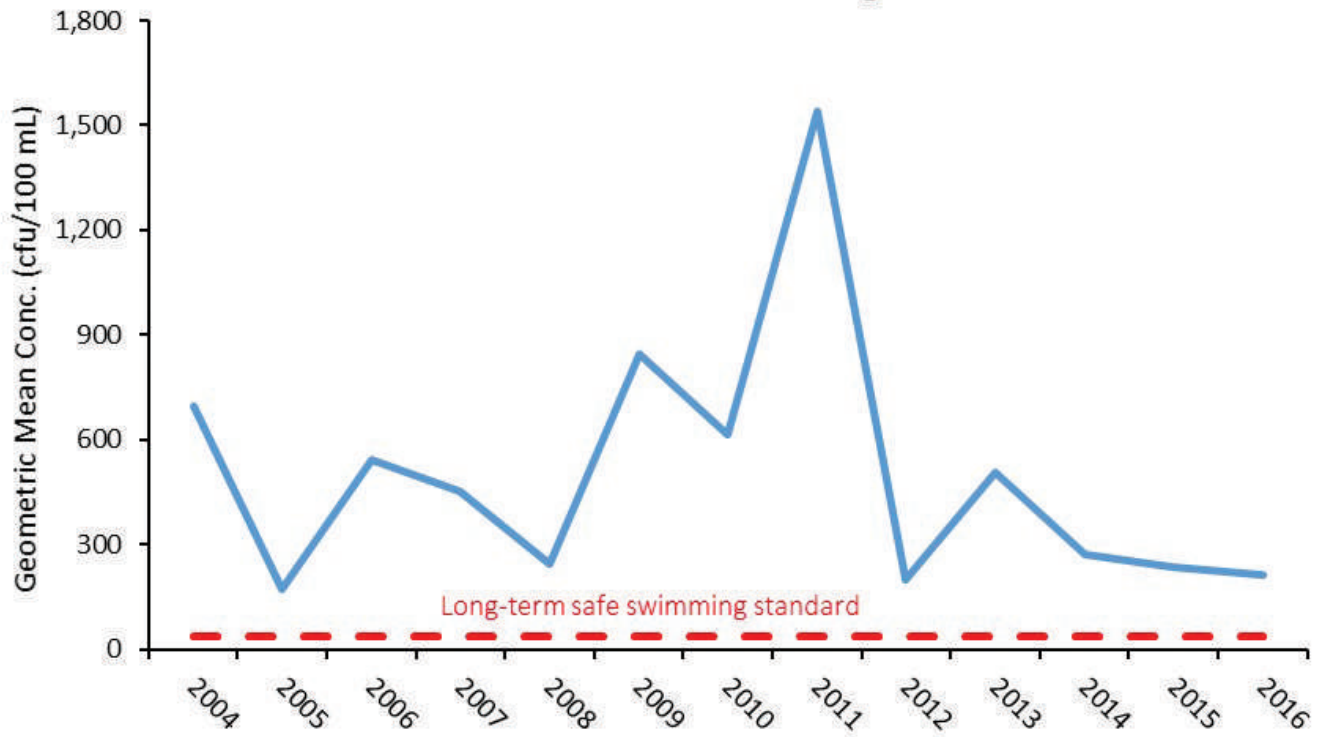
concentrations of *Enterococcus* bacteria at Old Mill Road bridge also have consistently remained above the long-term safe swimming standard, while the standard is generally met at the Mulberry Landing site (Figure 17). Dirickson Creek's bacteria concentrations have neither increased nor decreased significantly over time, but many areas routinely fail to meet standards for safe recreational use of the water.

Bacteria concentrations can vary by location within a tributary, typically increasing upstream and decreasing downstream where there is more mixing and dilution with saltier bay water. As with nutrient concentrations, dilution and tidal flushing at the mouth of the Dirickson Creek results in much lower concentrations of bacteria there. The downstream Mulberry Landing sampling site is also located much further away from some potential sources of fecal bacteria, such as farms and septic systems, while the station upstream of the Old Mill Road bridge is closer to these sources.

DNREC's Delaware Shellfish Program has closed all of Dirickson Creek to commercial and recreational harvest of clams, mussels and oysters, due to high bacteria concentrations and the potential for food-borne illness.



Enterococcus Bacteria, Summer Means
Station LA09 - Old Mill Rd Bridge



Station LA03 - Mulberry Landing

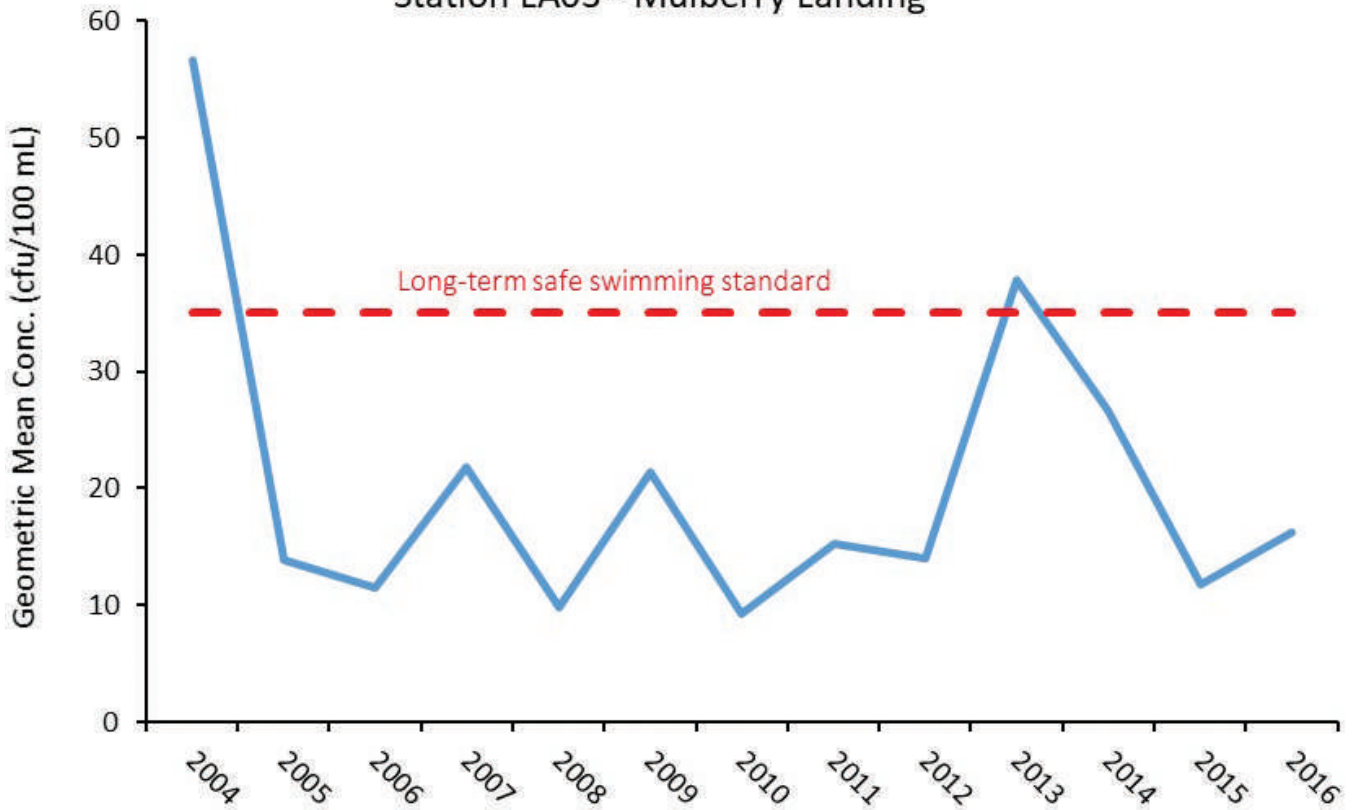


Figure 17. Average summertime concentrations of Enterococcus indicator bacteria measured by the Old Mill Road bridge (Station LA09) and further downstream at Mulberry Landing (Station LA03). The long term safe swimming standard for Enterococcus, 35 colony forming units (cfu) per 100 milliliters, is indicated by the dashed red line. (Data Source: University of Delaware Citizen Monitoring Program)



Indicator Bacteria

Members of two bacteria groups, coliforms and fecal streptococci (the genus *Enterococcus*), are used as indicators of sewage contamination because they are commonly found in human and animal feces. Although generally not harmful themselves, the presence of these “indicator” bacteria in water suggests that pathogenic microorganisms might also be present and that swimming and eating shellfish might be a health risk. Since it is difficult and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for indicator bacteria instead.

The U.S. EPA recommends *Enterococcus* as the best indicator of health risk in salt water used for recreation and as a useful indicator in fresh water as well.

LOOKING AHEAD—BACTERIA

- Dirickson Creek has many likely sources of fecal bacteria, including humans, wildlife, farmed animals and pets. The projected increase in development in the Dirickson Creek watershed may increase the proportion of human sources.
- The conversion from septic to central sewer service has the potential to reduce the amount of bacteria entering the Creek. Particularly if improperly functioning, older septic systems are converted.
- Controlling concentrations of fecal bacteria in the creek will require a better understanding of the specific sources responsible for the high concentrations seen in summer months in the mid- to upper portions of the tributary.
- Communities located on Dirickson Creek could reduce their input of bacteria in the water through improved stormwater management, for instance, through the construction of vegetated stormwater ponds, or stormwater retrofits and control measures.

CONCLUSIONS

The condition and trends within the Dirickson Creek watershed tend to mirror those of the Inland Bays as a whole. These include:

- Land use changes are urbanizing the landscape and increasing stormwater pollution; but conversion from agricultural lands to development may reduce nutrient loads.
- Flow of excess nutrients into the waterways cause algae growth and decreases in oxygen concentrations;
- Loss of wetlands and forested buffers that filter water, provide habitat for native plants and animals, and help prevent flooding.

POSITIVE TRENDS

- The nutrient and bacteria impacts to Dirickson Creek from the use of septic systems will lessen as even more communities are converted to central sewer.

- Nitrogen concentrations continue to meet water quality standards at the Mulberry Landing station.
- Phosphorus concentrations in the Creek meet the water quality standard at Mulberry Landing and phosphorus loads remain below the TMDL.
- Concentrations of fecal bacteria generally meet the safe swimming standard at Mulberry Landing.

NEGATIVE TRENDS

- Nitrogen pollution remains a major problem in Dirickson Creek. While loads of nitrogen have been reduced over the last several years, they remain above the healthy limit. Correspondingly, concentrations of nitrogen remain above water quality standards at the Old Mill Road bridge station during most years.
- Concentrations of fecal bacteria farther up the Creek far exceed standards for safe swimming and shellfishing.



Recommendations for a Cleaner Dirickson Creek

- Forested buffers that remain along Dirickson Creek and its tributaries must be protected to protect water quality in the creek. Re-forestation should be done where possible to protect water quality and wildlife habitat.
- Natural shorelines and tidal marshes that still exist on Dirickson Creek should be protected. Wherever feasible, living shoreline stabilization techniques should be used instead of riprap or bulkheads in areas where shoreline management is planned, and when shoreline armoring is being repaired or replaced.
- Owners of agricultural properties within the watershed must be encouraged to follow best practices for nutrient management and to adopt more effective pollution control practices whenever feasible. Stabilization of the sediment along the banks of tax ditches can be achieved through vegetating these areas, which would also serve to mitigate nutrient pollution entering from the fields in route to the Creek.
- Communities along Dirickson Creek should adopt best practices for stormwater management, lawn care, and pet waste, in order to reduce inputs of nutrients and bacteria to the waterway.
- Sampling at the existing water quality monitoring stations in Dirickson Creek should be continued and expanded through the Citizen Monitoring Program. Long-term data from multiple stations would provide a clearer picture of trends in nutrient concentrations. Continuous dissolved oxygen monitoring should be implemented in Dirickson Creek.
- Studies to identify the main sources of bacteria pollution in the Creek will allow targeted controls to be implemented.
- Sea grass distribution, and marsh plant communities should be monitored, as they are good indicators of the health of the creek and provide important habitat for many aquatic species. Preservation of these important habitats should be a high priority.
- Financing for clean water projects is needed in order to help implement these crucial projects.



The Dirickson Creek Team, a group of citizens from communities in the Dirickson Creek watershed, are working with each other and the DE Center for the Inland Bays to improve water quality in Dirickson Creek through community action, informing and educating neighbors, and serving as advocates for the creek and the land around it.



APPENDIX

Data and Methods Used
in This Report

LAND USE DATA

To determine land use changes in the Dirickson Creek watershed, data were acquired from the State of Delaware Land Use Land Cover (LULC) Program and the Office of Planning Coordination, PLUS Project Inventory. LULC information is derived from aerial photography acquired every five years during early spring/late winter. The data layers are available

through Delaware’s First Map site (<http://firstmap.delaware.gov/>). 1992 and 2012 LULC data were used for this report. Data layers were clipped to include only land areas within the Dirickson Creek watershed.

The state’s LULC data classifies parcels on a more detailed scale than was needed for this report, so land use categories were combined into broader categories (Figure A-1).

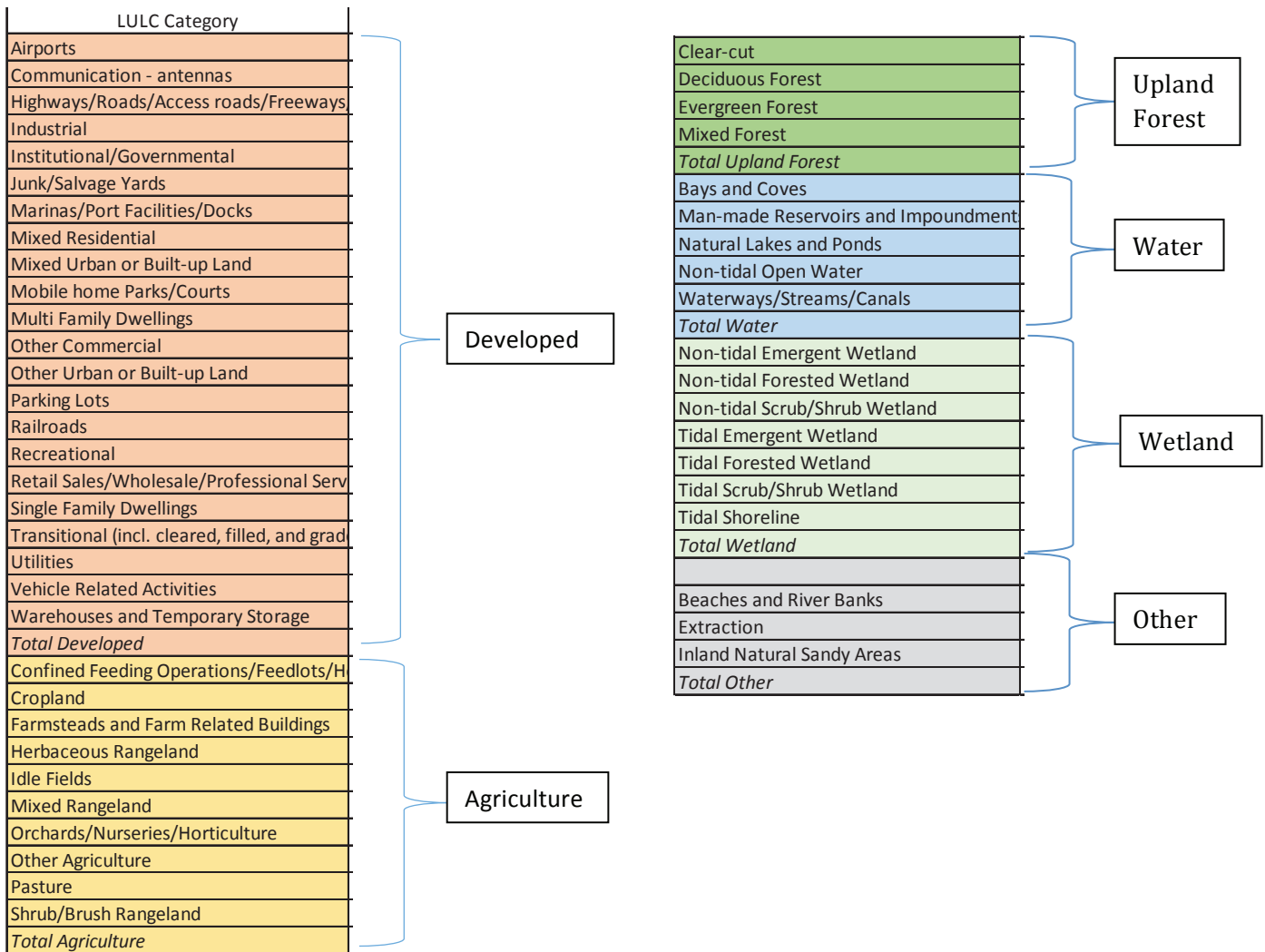


Figure A-1. Correspondence of LULC categories to simplified land use classes.

Dirickson Creek Land Use by Year

Figure A-2 summarizes the changes across the six categories, within the Dirickson Creek watershed, for each of the five-year periods. The percent of land use for each broad category from 1992 was compared to the current percent in the 2012 land use data.



Figure A-2. Land use change in the Dirickson Creek watershed, 1992 – 2012.

The raw land use data in 2012 indicates a relatively large increase in wetlands within the watershed; however, this was not likely due to real changes on the ground, but rather to an increase in the amount of forested wetlands identified. Information from the State’s 2009 National Wetlands Inventory project identified a significant number of forested wetland areas that had previously been classified as upland forest, based on ground verification and the use of hydric soils data. In the derivation of the 2012 dataset information from the 2009 wetlands project was used to alter the later land use data, leading to an increase in land area identified as wooded wetlands. To account for this, we reclassified forested wetland areas in the 2012 data that had been classified upland forest in the 2007 dataset back to upland forest. Even though this processing step might potentially lead to under-representation of actual freshwater wooded wetlands in the bays, it was necessary to enable comparisons across years.

Another apparent anomaly in the data is an increase in the amount of forest identified between 2007 and 2012. These changes do not represent a significant increase in intact, high-value forest land in the watershed, but rather transition to early-growth forest in areas previously classified as “scrub-shrub” and in developing lands which remained vacant (potentially due to the economic slowdown).

Other potential discrepancies in the classification among years include variation in the quality, spectral characteristics, or spatial resolution of the base imagery, differences in photo interpretation methodology, and varying priorities within the agencies funding the interpretation.

Addition of Development Project Areas

Polygon shapefiles of development projects proposed to the State of Delaware’s Office of Planning’s Preliminary Landuse Service from 2007 to 2012 were obtained from Delaware First Map. Project areas were clipped to the Dirickson Creek watershed outline. Developed & Developing land uses from the 2012 land use layer were then erased from the proposed development layer to exclude proposed developments that were already built or under construction. This resulted in proposed projects intended for construction.

Project areas are the entire outline of the parcels to be developed. They include lands to be developed as well as lands to be left in the existing land use as open space. The percentage of open space for a proposed development is variable depending on a number of factors. Therefore, project areas cannot be used as an accurate estimate of land use conversion to development. However, they can be used as a more general approximation of the level of intended development intended in the watershed.

SEPTIC SYSTEM PERMIT DATA

Septic information was acquired from DNREC and from Sussex County. DNREC tracks all active septic permits within the Ground Water Discharge Section of the Division of Water, while the County maintains an inventory of all tax parcels that receive a sewer bill from them. In some cases, active septic permits may fall within properties receiving a sewer bill from the County. This could indicate that there is a lag between when a septic system is abandoned and when the State's database is updated to reflect that, or that a property owner chooses to maintain a septic field, even though receiving sewer service.

Lots with public sewer provision through the county should have their septic systems abandoned within a short time-frame. The density of active septic permits, therefore, should drop significantly once these systems are abandoned. Net septic permits are calculated from the total number of permits minus the number of septic permits on properties with sewer service provided by Sussex County (based on Sussex County billing records).

The Delaware Public Service Commission manages private company sewer service areas for the Inland Bays, which indicate where sewer service is being provided, or will be provided when development occurs in the future. Sussex County also provides sewer service, primarily in the eastern half of the Dirickson Creek watershed.

The following table summarizes the number of active septic permits by Inland Bay watershed in Delaware, along with the density, in number of septic permits per square mile. Net septic permits are calculated from the total number of permits minus the number of septic permits on properties with sewer service provided by Sussex County (based on Sussex County billing records). Note that the density of active septic permits does not necessarily reflect which areas have the highest nutrient loading due to septic systems. Depending on the age of the septic system the wastewater is subjected to varying levels of treatment. A denser area of new septic systems may leach less nutrients into the ground compared to a less dense system of older septic systems. The density map presented in the report should be used only to infer areas where numerous permits exist, and not "hot spots" for nutrient leaching.

Watershed	Land Area, Sq. Mi.	Septic Permits	Permit Density (per sq. mi.)	Permits w/ County Sewer	Net Septic Permits
Assawoman Bay	6.8	172	25.4	84	88
Cow Bridge Branch-Indian River	44.8	1470	32.8	21	1449
Dirickson Creek-Little Assawoman Bay	18.9	581	30.8	179	402
Herring Creek-Rehoboth Bay	33.8	2093	61.9	509	1584
Indian River Bay-Indian River Inlet	17.6	1124	63.7	453	671
Little Assawoman Bay	13.1	254	19.4	124	130
Long Drain Ditch-Betts Pond	17.6	753	42.8	3	750
Love Creek-Rehoboth Bay	24.2	1340	55.5	486	854
Rehoboth Canal-Rehoboth Bay	11.4	382	33.5	382	0
St. Martin River	7.8	61	7.8	3	58
Swan Creek-Indian River	29.4	797	27.1	25	772
Vines Creek-Indian River	35.7	1117	31.3	62	1055
White Creek-Indian River Bay	26.9	1749	65.1	904	845
Wolfe Glade-Rehoboth Canal	10.0	155	15.5	149	6
TOTAL	298.0	12048	40.4	3384	8664

Table A-1. Septic permit density summary for watersheds in the Inland Bays. Data from 2015.

NUTRIENT LOADS FROM NONPOINT SOURCES

Data for nonpoint source loads of total nitrogen and total phosphorus to the Inland Bays were provided by DNREC’s Division of Watershed Stewardship. Annual loading data were available for the years from 2006 through 2014. Prior to 2006, the state’s monitoring focused on TMDL development; hence, they many more stations were monitored, but with less frequency. The low frequency of monitoring in those periods did not allow calculation of annual loads with sufficient confidence.

The loads are provided in pounds per year for total nitrogen (TN) and total phosphorous (TP), as well as loading rate per acre of watershed area. Flow information is provided based on the annual mean flow in cubic feet per second at the Millsboro Pond Outlet at Millsboro (USGS 01484525). The daily mean was obtained for each day between 2006 and 2014, and then the yearly mean was calculated using each year’s daily mean data.

Table A-2 summarizes the loads and loading rates, for each year (2006–2014) for TN and TP in Dirickson Creek, based on monitoring data. The first row shows the 2004 TMDL baseline.

Year	Annual Load, TN (lb/yr)	Annual Load, TP (lb/yr)	Loading Rate, TN (lb/yr/ac)	Loading Rate, TP (lb/yr/ac)	Net Septic Permits
2004 TMDL Baseline	129,643	16,749	11.8	1.5	88
2006	300,714	1,361	27.2	0.1	1449
2007	173,784	6,299	15.8	0.6	402
2008	294,380	3,127	26.7	0.3	1584
2009	297,102	5,898	26.9	0.5	671
2010	161,182	3,157	14.6	0.3	130
2011	104,850	3,499	9.5	0.3	750
2012	168,603	3,973	15.3	0.4	854
2013	202,354	6,914	18.3	0.6	0
2014	136,208	4,998	12.3	0.5	58

Table A-2. Loads and loading rates for TN and TP in Dirickson Creek, 2006–2014.

DISSOLVED NUTRIENT CONCENTRATION DATA

To assess the status and trends of water quality in the Dirickson Creek tributary, dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) trends were considered using data from University of Delaware Citizen Monitoring Program (CMP) stations at the Old Mill Bridge (LA09) and Mulberry Landing (LA03).

Data for both stations were subdivided by year, and annual medians calculated and graphed, to assess the status over time relative to state standards (0.14 mg/L for DIN and 0.01 for DIP).

DISSOLVED OXYGEN DATA

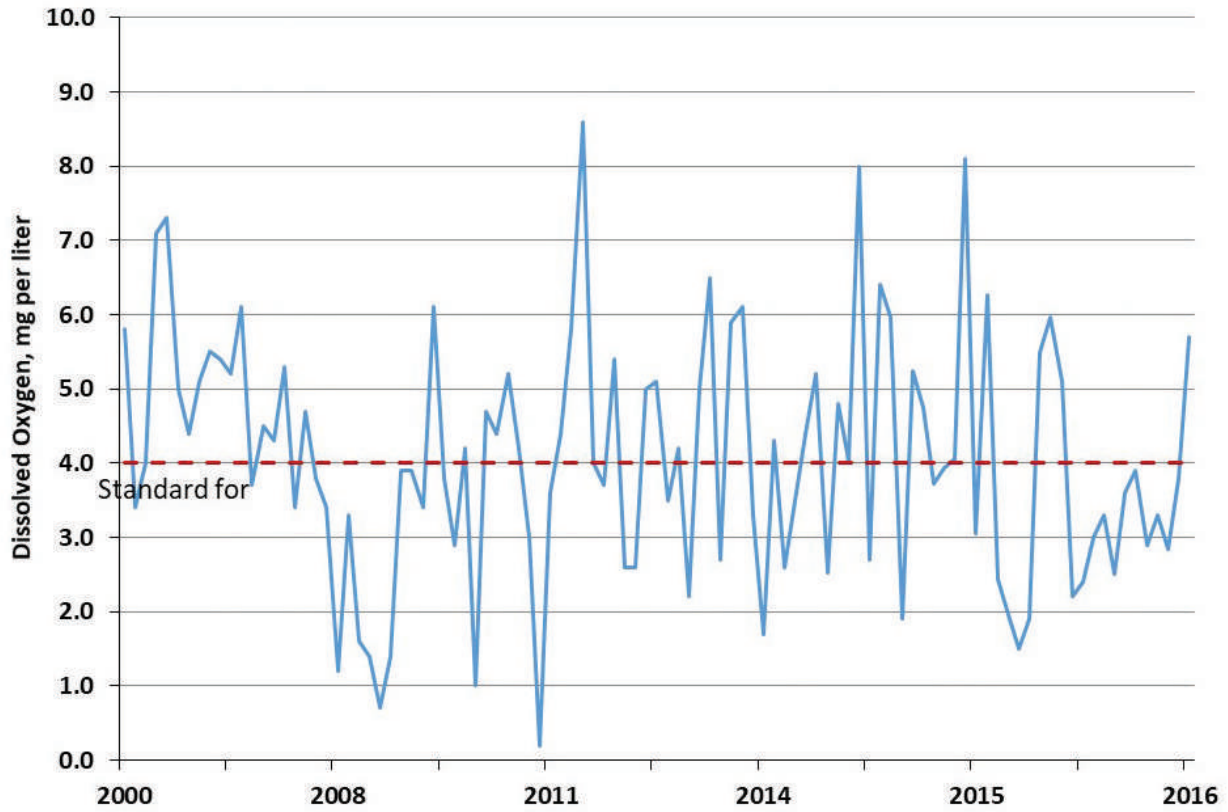
Dissolved Oxygen (DO) concentrations in Dirickson Creek were obtained for the period from the CMP datasets for stations LA09 and LA03. Since it was important to obtain data only during summer months

(June through September) and before 9:00 AM (at which time photosynthetic activity would tend to raise oxygen concentrations), data for both sampling locations were filtered to meet those criteria.

For each month, the mean dissolved oxygen value was calculated for each station, and this monthly mean was plotted on the graph. It was found that 20 out of 44 (45%) monthly means fell below the water quality standard of 4 mg/L at LA09. 4 out of 72 (5%) monthly means fell below the 4 mg/L standard at LA03.

To provide further clarity, each individual observation was plotted and results are pictured below (Figure A-3). It was found that of the samples at LA09 that met the seasonal and time-of-day criteria (i.e., summer mornings), 51 out of 101 (50.5%) samples did not meet the water quality standard for DO of 4 parts per million (mg/L). At station LA03, 26 of 178 (14.6%) samples failed to meet this standard. These results are similar to the monthly mean results used in the report.

Station LA09 - Old Mill Rd Bridge



Station LA03 - Mulberry Landing

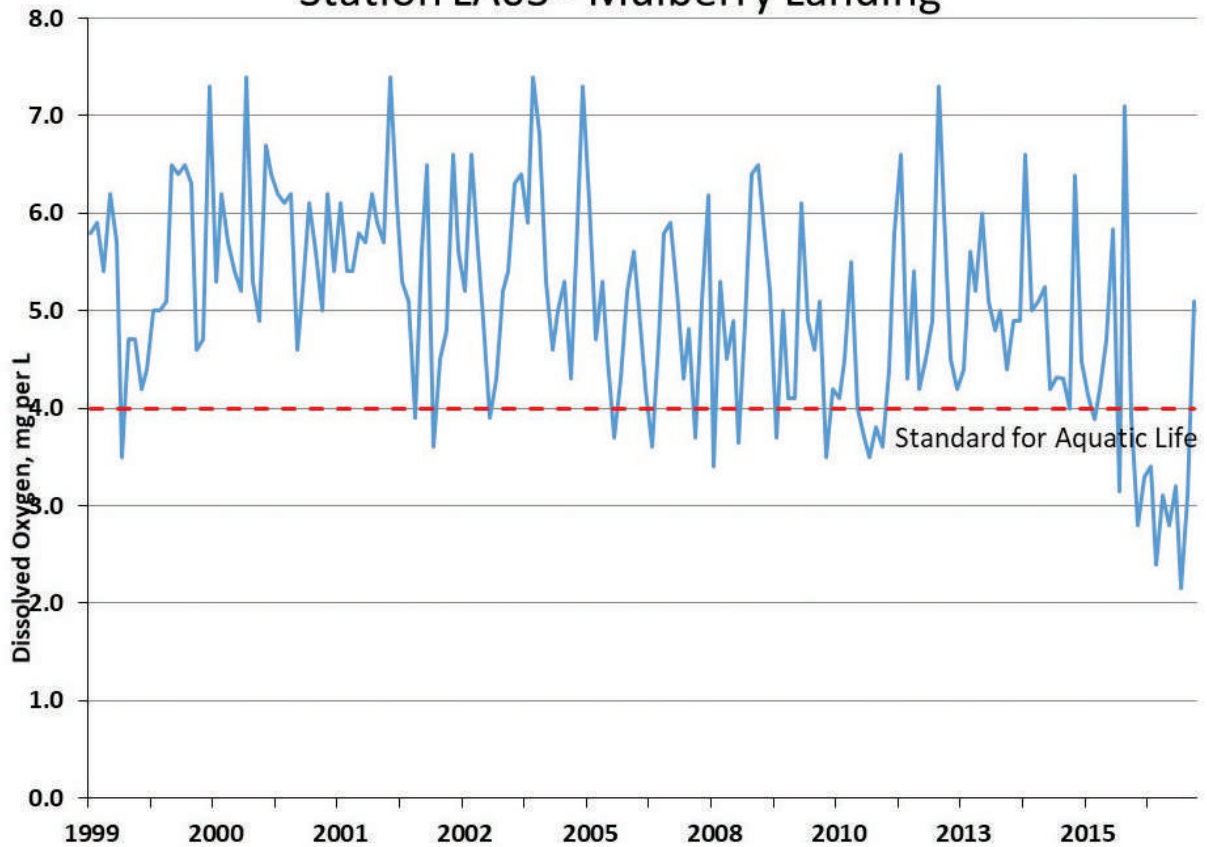


Figure A-3. Dissolved oxygen concentrations for each summer observation to better show the variability in samples.

RECREATIONAL WATER QUALITY/BACTERIA DATA

Recreational contact safety in Delaware is determined by measuring the number of colony forming units (CFUs) of Enterococcus bacteria per 100 mL of water. The EPA considers Enterococcus to be the best fecal indicator bacteria; it has the strongest correlation with the risk of people acquiring gastroenteritis from inadvertent ingestion of water.

Bacteria data for CMP sampling sites LA09 and LA03 were available from 2003 to 2014, of which only samples from the summer swimming months (June through September) were considered.

The University of Delaware Citizens Monitoring Program routinely monitors concentrations of Enterococcus at numerous sites in the Inland Bays, twice a month from May through September. Locations include bridges, docks, and marinas.

Enterococcus concentrations are assessed either through the single sample limit (104 cfu/100mL), or by calculating a geometric mean which must fall below 35 cfu/100mL. The single sample limit is higher to account for the natural variation when taking a sample for Enterococcus, and to prevent unnecessary closures and advisories based upon a single sample's variation. Data were subset to only include the months of June through September since the majority of human recreation in the Inland Bays takes place during these months. Furthermore, only years with at least five samples between June and September were preserved. The percent of samples that exceeded the single sample safe swimming standard of 104 Enterococcus colony forming units per 100 mL was calculated for both LA03 and LA09. In addition, the geometric mean was calculated for each year at both stations and compared to the long term geometric swimming standard of 35 cfu/100mL.

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