2021 Chester-Choptank Watershed Report

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

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Executive Summary

The Delaware Department of Natural Resources and Environmental Control's (DNREC) Wetland Monitoring and Assessment Program (WMAP) documented wetland acreage trends and determined the ambient condition of non-tidal wetlands in the Chester-Choptank watershed in 2018. The goals of this project were to summarize acreage gains, losses, and changes across the Chester-Choptank watershed based on the most current state wetland maps; assess the condition of non-tidal wetlands throughout the watershed; identify prevalent wetland stressors; assess the value that non-tidal wetlands provide to the local landscape; and make watershed-specific management recommendations to different audiences, including scientists and land managers, decision makers, and landowners.

The Chester-Choptank watershed begins in Delaware and continues west into Maryland, where waters eventually drain to the Chesapeake Bay. The Delaware portion of the watershed is a combination of multiple HUC10 watersheds and is located within New Castle and Kent Counties in Delaware, where it encompasses 113,944 acres (178 square miles) of land. It is composed of 12 sub-watersheds at the HUC12 level, including Cypress Branch, Big Elk Creek, Andover Branch, Fowling Creek-Choptank River, C&D Canal West-Back Creek, Gravelly Branch-Choptank River, Tappahanna Ditch-Choptank River, Upper Elk River, Bohemia River, Cow Marsh Creek, Chapel Branch-Choptank River, and Upper Sassafras River, which were combined for this project and report. For simplicity, we refer to this watershed complex as 'Chester-Choptank'. Approximately 35% of the land area of the watershed was covered by wetlands. Of these wetlands, 78.1% were non-tidal flats, 8.9% were non-tidal riverine wetlands, and 13.0% were non-tidal depressions.

We estimated historic (prior to 1992) and more recent (1992 to 2007) wetland losses in the Chester-Choptank watershed based on historic hydric soil maps and 2007 statewide wetland mapping resources. Our analysis indicated that by 1992, approximately 24,876 acres of the watershed's historic wetlands had been filled or lost, mostly due to conversion to other land uses such as residential development. Between 1992 and 2007, the watershed lost another 148 acres of wetlands and gained approximately 157 acres, resulting in a net gain of 9 acres between those years. Most of the wetland acreage loss was due to conversion of non-tidal wetlands to development, such as rural houses or housing developments. Most of the gained acreage was attributed to the creation of ponds, usually in the form of stormwater retention ponds, which do not resemble natural wetlands and generally provide fewer ecosystem services than natural wetlands. Other wetlands changed wetland type from 1992 to 2007. Most changes were from vegetated to non-vegetated wetland types.

To assess wetland condition and identify stressors affecting wetland health, rapid assessments were conducted at wetland sites throughout the watershed during the summer of 2018. Wetland assessment sites were located on public and private property and were randomly selected utilizing a probabilistic sampling design with the assistance of the Environmental Protection Agency's (EPA) Ecological Monitoring and Assessment Program (EMAP). WMAP performed non-tidal wetland assessments in 30 flat wetlands, 27 riverine wetlands, and 19 depression wetlands using the Delaware Rapid Assessment Procedure (DERAP) Version 6.0. No tidal wetlands were assessed because there were no vegetated tidal wetlands in the Delaware portions of these watersheds.

Forested headwater flat wetlands (n=30) had a mean condition score of 77.5 ± 10.7 (median=79.0) out of a maximum possible score of 95.0, ranging from 54.0 to 92.0. Riverine wetlands (n=27) had a mean condition score of 77.4 ± 18.9 (median=84.0) out of a maximum possible score of 91.0, ranging widely from 15.0 to 90.0. Depression wetlands (n=19) received a mean score of 72.3 ± 15.2 (median=78.0) out of a maximum possible score of 82.0, also ranging widely from 19.0 to 82.0. Compared with 10 other watersheds previously assessed in Delaware, the wetlands of the Chester-Choptank watershed fell in the middle, with wetlands being healthier than those in some watersheds, but not as healthy as others. The greatest proportion of wetlands in the Chester-Choptank watershed were moderately stressed (58%), while 29% were minimally stressed and 13% were severely stressed. Buffer disturbances were the most widespread types of stressors, particularly adjacent agriculture, roads, and development. Invasive plant species and selective cut harvesting were common habitat stressors in riverine and flat wetlands, respectively. Ditching was common in flats, while microtopographic alterations were common hydrology stressors in flats and depressions.

Wetland value was also evaluated in non-tidal wetlands because wetland value to the local area may be independent of wetland condition. Value-added assessments were conducted at non-tidal sites using Version 1.1

of the Value-Added Protocol, in conjunction with DERAP v.6.0. Most flat wetlands were found to provide moderate value to the local area (63%), providing the most value in terms of habitat availability. Similarly, most riverine wetlands were rated as providing moderate value (44%) and were considered most valuable for their habitat structure and complexity. The highest proportion of depressions were rated as providing rich value to the local landscape (57.9%), mostly because of habitat availability and habitat structure and complexity.

Based on analysis and synthesis of all data collected for this report, we made several management recommendations to improve overall wetland condition and acreage by targeting specific issues in different wetland types. These recommendations were tailored to different audiences, including environmental scientists and land managers, decision makers, and landowners. We recommended that environmental scientists, researchers, and land managers work to maintain adequate wetland buffers, perform wetland monitoring, conservation, and restoration activities, and continue to increase citizen education and involvement through effective outreach. We also recommended that decision makers improve the protection of non-tidal wetlands, develop incentives and legislation for maintaining non-tidal wetland buffers, and secure funding for wetland preservation. Finally, we suggested that landowners protect and maintain vegetated buffers around wetlands on their property, protect or enhance wetlands on their property, and engage in best management practices in agricultural and suburban settings.

Introduction

Wetlands are unique, beautiful ecosystems that are intrinsically valuable and provide many important ecosystem services to communities. Wetlands can remove and retain disturbed sediments, pollutants, and nutrient runoff from non-point sources (e.g. agriculture, land clearing, and construction) from the water column before they enter our waterways, thereby improving the quality of drinking and swimming water. By retaining sediments, wetlands also help to control erosion. Wetlands minimize flooding by collecting and slowly releasing stormwater that spills over channel banks, protecting infrastructure and property. They also sequester carbon, meaning that they help remove excess carbon dioxide from the atmosphere and store it in their plant biomass and soils to potentially reduce the effects of climate change. Additionally, wetlands are biologically rich habitats and are home to many unique plant and animal species, some of which are threatened or endangered. They are critical resources for migrating shorebirds and wintering waterfowl and serve as nurseries for most commercial fish and shellfish species in Delaware. Wetlands are also valuable sources of recreation (e.g. hunting, fishing, kayaking, and birding) and livelihood (e.g. fishing, crabbing, and fur-bearer trapping).

The ecosystem services that wetlands provide supply significant contributions to local economies in Delaware that together total more than $1 billion annually. For example, flood control benefits provided by Delaware wetlands are valued at $66 million annually, and wildlife activities conducted in these areas such as birding, fishing, and hunting generate approximately $386 million annually. Additionally, Delaware’s wetlands provide an estimated $474 million annually in water quality benefits (Kauffman 2018).

Wetland acreage, condition, and diversity are all crucial to the ability of wetlands to provide these beneficial services. If wetland acreage decreases, then there are fewer wetlands to perform vital ecosystem services to people and wildlife. Wetlands provide the greatest amount of services when they are in good condition. Wetlands that have been impacted by removal of buffer habitat, altered hydrologically such as by ditching, or have been severed by a road, for example, will function at a lower capacity. Engineered solutions that are designed to replace some wetland ecosystem services, such as water treatment facilities, can be very costly to construct and maintain. Additionally, if wetland acreage decreases, it becomes more difficult for wildlife to disperse and migrate among wetland habitats, as distances between wetlands may grow larger. Such reduced dispersal and migration can reduce genetic diversity and population sizes of wildlife species (Finlayson et al. 2017). Different wetland types typically perform certain functions better than others based on factors such as position in the landscape, vegetation type, and hydrological characteristics (Tiner 2003); therefore, a variety of wetland types ensure that all services that wetlands can offer are provided.

Wetlands have a rich history across the region and their aesthetics have become a symbol of the Delaware coast. Unfortunately, many wetlands that remain are degraded by the impacts of many direct and indirect stressors and are therefore functioning below their potential. Mosquito ditches, adjacent agriculture and development, filling, and invasive species are all examples of common stressors that Delaware wetlands experience that can negatively affect their hydrology, biological community, and ability to perform beneficial functions. Many anthropogenic wetlands, such as stormwater or agricultural ponds, cannot make up for the degradation of natural wetland function. This is because most created wetlands are non-vegetated and do not resemble natural wetlands, and they perform many functions at lower levels than natural wetlands (Woodcock et al. 2010, Tiner et al. 2011, Rooney et al. 2015).

While a portion of wetlands have been degraded, many others have been lost completely; approximately half of all historic wetlands in Delaware have been lost since human settlement in the early 1700s. This decline in wetland acreage has continued in recent years; between 1992 and 2007, there was a substantial net loss of 3,126 acres of vegetated wetlands across the state. Acreage losses are particularly alarming for forested freshwater wetlands, which experienced the greatest losses of all wetland types between 1992 and 2007 (Tiner et al. 2011). These non-tidal wetland losses have largely occurred because of direct human impacts, many of which are likely the result of the lack of regulatory protection and enforcement. The state of Delaware regulates activities in tidal wetlands, but only in non-tidal wetlands that are 400 contiguous acres or more in size. Federal regulations do exist for non-tidal wetlands, but not for small wetlands <0.1 acres in size. A lack of stringent enforcement presence on the ground leaves room for unpermitted losses. Moreover, very recent changes to the definitions of the waters of the U. S. (WOTUS) have lessened federal regulations for small or geographically isolated freshwater wetlands.

Tidal wetlands in Delaware also face many different challenges. Although regulated by the state, most of the recent tidal wetland losses have been caused by subsidence and submergence, highlighting the impacts of sea level rise from climate change. Acreage losses of tidal and non-tidal wetlands have led to the reduction of many beneficial functions, such as carbon sequestration, sediment retention, wildlife habitat, nutrient transformation, and shoreline stabilization (Tiner et al. 2011).

The state of Delaware is dedicated to preserving and improving wetlands through protection, restoration, education, and effective planning to ensure that they will continue to provide important services to the citizens of Delaware (DNREC 2015a). Thus, the Delaware Department of Natural Resources and Environmental Control (DNREC) examines changes in wetland acreage over time and monitors wetland condition and functional capacity to guide management and protection efforts.

Delaware's Approach

Since 1999, DNREC's Wetland Monitoring and Assessment Program (WMAP) has been developing scientifically robust methods to monitor and evaluate wetlands in Delaware on a watershed basis using a four-tiered approach that has been approved by the U.S. Environmental Protection Agency (EPA). WMAP evaluates wetland health (i.e. condition) by documenting the presence and severity of specific stressors that are degrading wetlands and preventing them from functioning at their full potential. Wetland assessments are conducted on four tiers, ranging from landscape-level to site-specific studies (Figure 1). The landscape level assessment (Tier One) is the broadest and least-detailed and is performed on desktop computers using state wetland maps, while the rapid assessment (Tier Two), comprehensive assessment (Tier Three), and intensive assessment (Tier Four) are progressively more detailed and require active field monitoring. Of Tiers Two to Four, rapid assessments require the least amount of work and shortest field days, while intensive assessments require the most intense field work, data collection, and analysis.

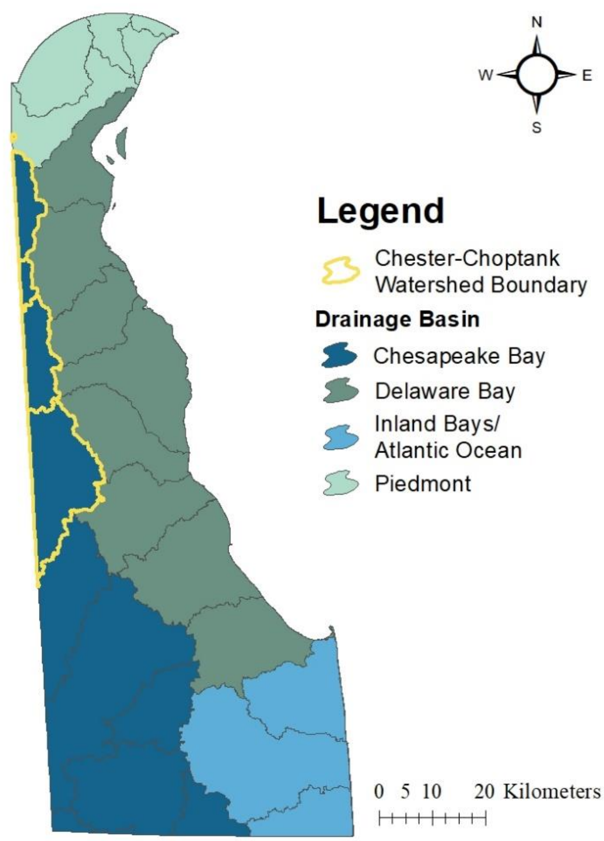
State wetland maps that are created for Delaware for desktop analyses include the two most common types of wetland classification: the Cowardin system (FGDC 2013), which is the main classification used by the U.S. Fish and Wildlife Service's (USFWS) National Wetlands Inventory (NWI; USFWS 2021), and the hydrogeomorphic (HGM) system, which describes landscape position, landform type, waterbody type, and water flow path (LLWW; USFWS 2014). WMAP considers both classification systems when performing desktop and field assessments. The Cowardin system is used for random selection of assessment points, splitting wetlands into estuarine, tidal palustrine, and non-tidal palustrine wetland types (see "Field Site Selection" in Methods section below). The HGM/LLWW system is then used in the field to differentiate among the most common non-tidal palustrine wetland types in Delaware based on hydrogeomorphic characteristics, which are flat, riverine, and depression wetlands.

Figure 1. The four-tiered approach that is used to evaluate wetland condition across the Mid-Atlantic region, including Delaware.

Once these assessments are complete, data are extrapolated to generate overall watershed condition reports that discuss trends in wetland acreage, identify common stressors by wetland type, summarize overall health of wetland types, and provide management recommendations based on these results. Information and recommendations provided by these reports can be used by watershed organizations, state planning and regulatory agencies, and other stakeholders to prioritize and improve wetland protection and restoration efforts. For example, protection efforts, such as through acquisition or easement, can be directed toward wetland types in good condition, and restoration efforts can target degraded wetland types to increase their functions and services. In this report, we discuss wetland acreage trends and wetland condition in the Chester-Choptank watershed in western Delaware, which are based on landscape (Tier One) and rapid (Tier Two) assessment data.

Watershed Overview

The Chester-Choptank watershed begins in Delaware and continues west into Maryland, where waters eventually drain to the Chesapeake Bay. The Delaware portion of the Chester-Choptank watershed that was assessed for this report is a watershed that represents a headwater region of the Chesapeake Bay and is the combination of multiple watersheds at the Hydrologic Unit Code (HUC) 10 scale, including Sassafras River, Elk River, Chester River, and Upper Choptank River (Map 1). The Chesapeake Bay drainage basin in Delaware, including the Chester-Choptank watershed, provides an estimated $3.4 billion in ecosystem goods and services. Ecosystem services of freshwater wetlands alone in the Chesapeake Bay drainage basin, such as flood control, water quality improvement, provision of fish and wildlife habitat, carbon storage, and recreation, are valued at $1.1 billion (Kauffman et al. 2011 and Kauffman 2018).



Map 1. Location of the Chester-Choptank watershed and the major drainage basins in Delaware. Watersheds at the HUC10 scale are outlined in dark gray.

The Delaware portion of this watershed encompasses 113,944 acres (178 square miles) of land in parts of Kent and New Castle County, and is composed of 12 sub-watersheds at the HUC12 level: Cypress Branch, Big Elk Creek, Andover Branch, Fowling Creek-Choptank River, C&D Canal West-Back Creek, Gravelly Branch-Choptank River, Tappahanna Ditch-Choptank River, Upper Elk River, Bohemia River, Cow Marsh Creek, Chapel Branch-Choptank River, and Upper Sassafras River (not shown on map). The entire Chester-Choptank watershed continues to the west into Maryland; however, this report only covers the Delaware portions of the watershed. Directly south and southeast of the watershed are the Marshyhope Creek and Murderkill River watersheds, respectively. Just north of the top of the Chester-Choptank watershed lies the Christina River watershed. The Chester-Choptank watershed spans a far distance from north to south; as such, many other watersheds border it to the east. These include the Red Lion Creek, Appoquinimink River, Smyrna River, Leipsic River, and St. Jones River watersheds.

Most of this watershed is rural, and the most populous sections of the watershed are part of Middletown and part of Harrington. Other municipalities are extremely small, including Farmington and

Hartly. The northern part of the watershed contains part of the man-made C&D Canal, which connects the Delaware River and the Chesapeake Bay. The southern half of the watershed, which lies entirely within Kent County, contains many tax ditches. The northern half of the watershed, which lies partially in Kent but mostly in New Castle County, contains far fewer tax ditches. Tax ditches are organizations that were formed to address drainage issues within specific land areas and are composed of landowners within those drainage areas. The physical ditches themselves vary greatly in size depending on the extent of the areas they drain. The only pond in the watershed is Mud Mill Pond, which is a dammed pond in the southwestern section of the watershed adjacent to the Maryland border. Ponds such this in the Chesapeake Bay drainage basin were often historically created to serve as a power supply for mill operations (DNREC 2001).

Hydrogeomorphology

Prior to the last ice age, most of present-day Delaware was covered by the ocean. However, as polar ice caps expanded, the sea level decreased, exposing more land. Massive amounts of sediment from the ancient Appalachians were carried down the large Delaware and Susquehanna Rivers and settled onto the coastal plains of Delmarva. Repeated continental glacier advances and retreats and subsequent melting of polar ice caps helped to shape the relative sea level and dictate stream formations that comprise current watersheds (DNREC 2001).

Today, the Chesapeake Bay basin, which includes the Chester-Choptank watershed, lies within the Atlantic Coastal Plain Physiographic Province, just south of the Appalachian Piedmont Fall Zone. It is composed of three hydromorphic regions: inner Coastal Plain, poorly-drained upland, and well-drained upland. Inner Coastal Plain represents slightly less than half of the watershed area and is present in the northern part of the watershed, while poorly-drained upland represents slightly more than half of the watershed area and is present in the southern extent. Well-drained upland is only present in very small patches within the southern half of the watershed (DNREC 2001).

Wetlands are an extremely important part of the Chesapeake Bay Basin. The ecosystem services that wetlands provide within the basin have been valued at over $1.1 billion per year, which is equivalent to $13,344 per acre per year (Kauffman 2018). The wetlands within the Chester-Choptank watershed contribute greatly to this total by performing beneficial functions such as water quality improvement, flood control, provision of fish and wildlife habitat, recreation, and carbon sequestration. Wetlands in the Delaware portion of the Chester-Choptank watershed are in the headwater region of the Chesapeake Bay drainage basin, making them particularly important for stream flow maintenance and groundwater recharge (Yeo et al. 2019a, b).

According to the 2007 Delaware Statewide Wetland Mapping Project (SWMP), the Delaware portion of the Chester-Choptank watershed had a total of 38,583 acres of wetlands, including both vegetated and non-vegetated mapped wetlands. Of those, 37,804 acres of wetlands were natural, vegetated wetlands. Delaware's Tier 2 wetland condition assessments are conducted only on natural, vegetated wetland types, so those were the focus of the assessments and this report. However, both vegetated and non-vegetated wetland types were evaluated in Tier One landscape assessment and are discussed in acreage trends (see 'Wetland Acreage' in Results section below). The Chester-Choptank watershed had several major types of natural, vegetated wetlands, including flat, riverine, and depression. Flat wetlands are non-tidal wetlands often forested and found in

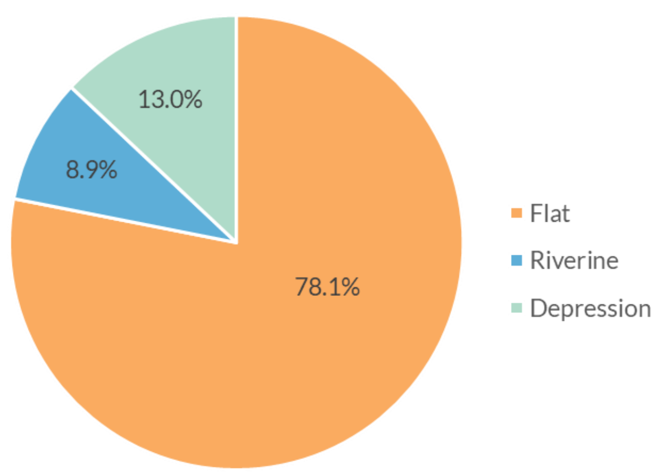
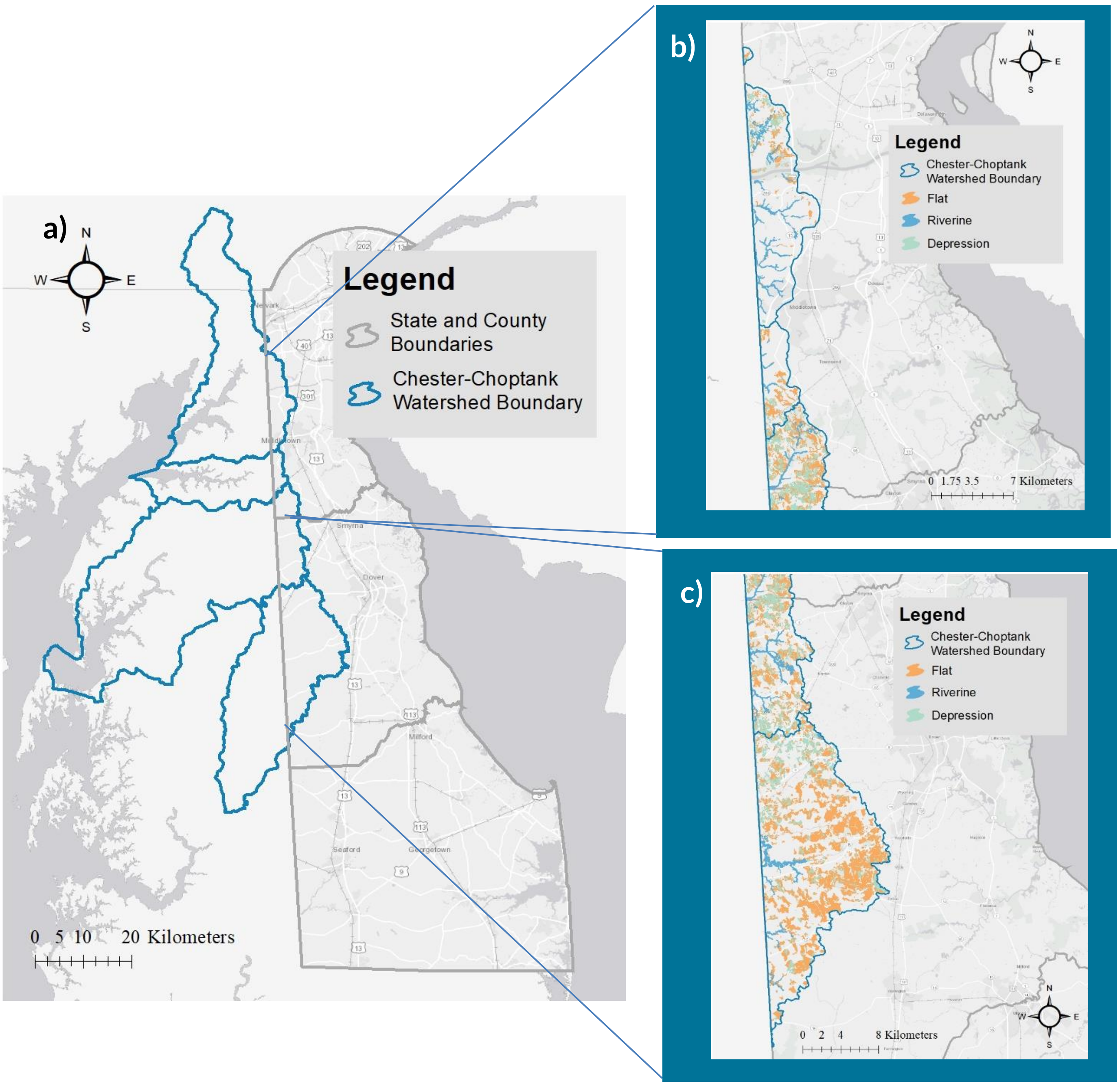


Figure 2. Proportions of major natural wetland types in the Chester-Choptank watershed based on 2007 SWMP maps. Proportions are based on acreage of vegetated wetlands only (non-vegetated wetlands not included).

headwater regions that are fed mainly by precipitation. They occur in areas with relatively flat landscapes and poor-draining soils. Riverine wetlands are non-tidal wetlands that are located within the floodplains of rivers and streams. Depression wetlands are non-tidal wetlands that occur in areas of low elevation with little flow that tend to pool water (often seasonally) from groundwater, precipitation, and overland flow. Out of the natural, vegetated wetlands in this watershed, the majority were flat wetlands (29,531.0 acres; 78.1%) followed by depressions (4,897.5 acres; 13.0%) and riverine wetlands (3,375.6 acres; 8.9%; Figure 2). Flats were scattered throughout but were most densely concentrated in the central and southern parts of the watershed. Riverine wetlands were also scattered throughout the watershed, and depressions were mostly in the central and southern portions (Map 2).



Map 2. Major vegetated wetland types in the Chester-Choptank watershed based on 2007 SWMP data. Shown in a) is the outline of the entire Chester-Choptank watershed, b) the wetlands in the New Castle County portion of the watershed, and c) the wetlands in the Kent County portion of the watershed.

Aquatic bed was the only other type of vegetated wetland, but it represented <1% of wetland area in the watershed. Therefore, it was not a target wetland type for assessments. Non-vegetated wetland types included lacustrine unconsolidated bottom, palustrine unconsolidated bottom, and estuarine unconsolidated bottom. Delaware's rapid assessment protocols are designed only for vegetated wetland types, so non-vegetated wetlands were not target wetlands and were not sampled in the field (see 'Field Site Selection' in Methods section below).

Land Use and Land Cover

The most recent land cover dataset for Delaware from 2012 was based on the 2012 National Land Cover Dataset (NLCD). This land cover dataset showed that the Chester-Choptank watershed was dominated by agriculture (44.3%), followed by wetlands (34.7%), development (11.8%), and forest (6.1%). Smaller portions of land were rangeland (2.2%), open water (0.6%), or transitional land that was cleared, likely for future development (0.3%; Table 1). As agriculture was the dominant land use type, it was scattered across the entire watershed, though was least prevalent in the northern part of the watershed where development was most concentrated. Wetlands were numerous and were scattered in patches throughout the watershed, though were more common in the center and southern portions compared with the northern part of the watershed. Forests were often found adjacent to wetlands throughout the watershed. Rangeland, open water, and transitional land were far scarcer and were scattered in very small patches (Map 3).

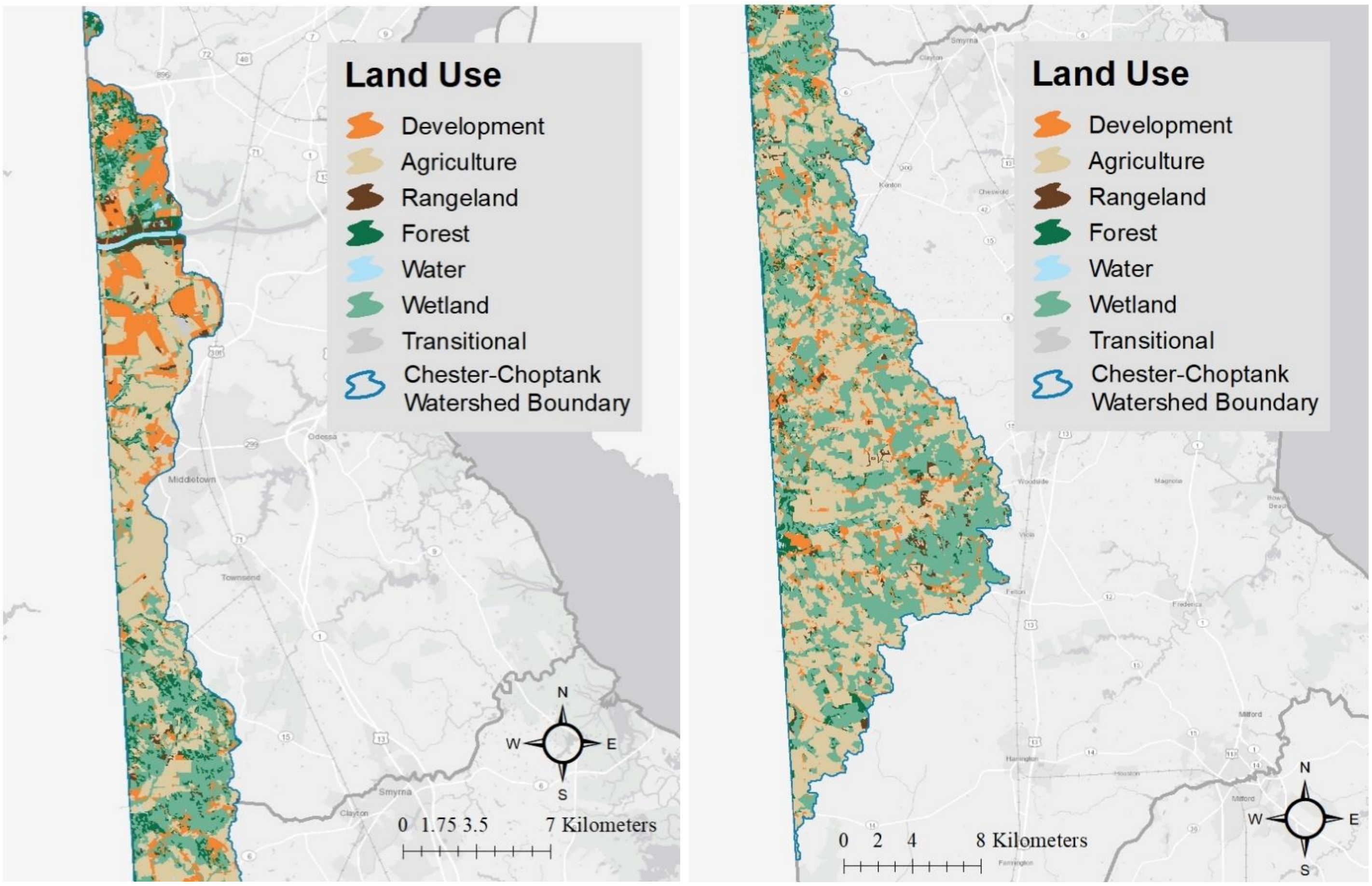
Based on a comparison between 1997 and 2012 Delaware land use and land cover datasets, the Chester-Choptank watershed experienced a substantial 9.0% increase in wetland land cover in the 15-year time frame. Also notable was that land used for agriculture decreased by 6.1%, forested land decreased by 6.5%, and developed land increased by 2.9% (Table 1). Residential development was one cause of decline in agriculture and forest land, which subsequently caused developed land cover to increase. Development also increased because transitional land that had been cleared for development in 1997 had become completely built-upon by 2012. Aside from development, other causes of decline in agricultural land were conversion of retired fields to wetlands (i.e. natural wetland re-establishment) and rangeland. Not surprisingly, those occurrences led to slight increases in rangeland and wetland land covers (Table 1).

Table 1. Land use and land cover (LULC) change in the Chester-Choptank watershed based on 1997 and 2012 Delaware datasets. Values are percentages.

Land Use	1997	2012	Change	Main Reasons for Change
Development	8.9	11.8	+ 2.9	Converted forest, agricultural land, and transitional land; map reclassifications
Agriculture	50.4	44.3	- 6.1	Residential development; conversion to wetland; conversion to rangeland; map reclassifications
Rangeland	0.9	2.2	+ 1.3	Retired agricultural lands; map reclassifications
Forest	12.6	6.1	- 6.5	Map reclassifications; residential development; conversion to agriculture
Water	0.5	0.6	+ 0.1	Construction of residential stormwater ponds; map reclassifications
Wetlands	25.7	34.7	+ 9.0	Map reclassifications; retired agricultural fields
Transitional	1.0	0.3	- 0.7	Completed residential development; map reclassifications

However, many changes in land cover type were artifacts of mapping methods, meaning that some land areas were more accurately reclassified from 1997 to 2012. For example, wetland acreage appeared to increase considerably because many areas that were incorrectly classified as upland forest in 1997 were correctly reclassified as forested wetlands in 2012 (i.e. land cover did not experience any real changes on the ground). Similarly, some areas that were incorrectly classified as agriculture in 1997 were correctly reclassified as wetlands in 2012. True increases in natural wetland land cover were therefore much smaller than 9.0%. This also means that much of the apparent forest decline, and some agriculture decline, was due to land reclassification to wetlands in mapping. Likewise, some of the decline in transitional land was explained by reclassification to wetlands, water, or rangeland, especially in spoil areas along the C & D Canal. Some developed and agricultural lands, as well as some wetlands and forests, were reclassified as rangeland. In summary, actual, meaningful changes are smaller than shown in Table 1, and this is noted for each land use category as 'map reclassifications' under the column 'Main Reasons for Change.'

Map 3. LULC in the Chester-Choptank watershed in New Castle County (left) and Kent County (right) based on the 2012 Delaware state land use and land cover data.



Surface and Groundwater

An unconfined aquifer (water table) and several deeper confined aquifers throughout the Chesapeake Bay basin support the groundwater for the basin. The unconfined aquifer flows through gravelly sands and is refilled by precipitation in areas where permeable sediments allow water to infiltrate down to the aquifer. This groundwater is extremely important, as it is the only source of drinking water in this region (DNREC 2001). Runoff from impervious surfaces or agricultural land can affect the quality of this water. Wetlands, therefore, are extremely important in this region for drinking water and for irrigation because wetlands help clean and recharge groundwater.

The state of Delaware is required by the EPA to develop a list of impaired waters under Section 303(d) of the Clean Water Act. Impaired waters are defined as waters that are not meeting clean water criteria even when current existing pollution control strategies (PCSs) are enacted. DNREC performs water quality monitoring throughout the state on a regular basis, allowing them to identify waterbodies that are not meeting water quality standards. States are required to create total maximum daily loads (TMDLs) for certain pollutants of impaired waterbodies, which set limits on the amount of those pollutants that can be discharged into those waterbodies for water quality standards to be met. Several waterbodies within the Chester-Choptank watershed are considered impaired in the state of Delaware under Section 303(d). The Chester River and Choptank River have been identified as having high levels of pollutants such as harmful bacteria or excess nitrogen or phosphorus from non-point sources. TMDLs were established for the Chester and Choptank Rivers in 2005 (DNREC 2005).

Once TMDLs are developed for impaired waterbodies, the next step is typically to create a PCS, which describes specific actions that can be taken to achieve water quality goals. In Delaware, PCSs are often made by collaboration between DNREC and Tributary Action Teams. Tributary Action Teams are specific to each impaired waterbody and include a variety of stakeholders, allowing a diverse group of public participants to play a role in the development of PCSs (DNREC n.d.-a). The Chester-Choptank watershed is part of the area that is addressed by the Upper Chesapeake Watershed Tributary Action Team, and this team created PCS recommendations in 2008. Some of those recommendations included maintaining vegetated buffers along water bodies, installing rain gardens and permeable pavement in new developments, planting cover crops on agricultural fields, and installing fence barriers to keep livestock out of tax ditches (KCI Technologies, Inc. and DNREC 2014).

Aside from state TMDLs for each waterbody, the EPA established a TMDL for the entire Chesapeake Bay and its tributaries in 2010, which includes water bodies in the Chester-Choptank watershed. This bay-wide TMDL involves all 6 states (Delaware, Maryland, Virginia, Pennsylvania, New York, and West Virginia) and Washington, DC that have waters that drain into the Chesapeake Bay. It was designed to address sediment and nutrient pollution problems by making each state have several phases of watershed implementation plans (WIPs) that describe what steps they will take to reduce bay pollution. The EPA holds each state accountable for their progress with a goal of having as many pollution-control practices in place as possible by 2025. In Delaware, the Phase I WIP was completed in 2010, Phase II in 2012, and Phase III in 2019. The most recent WIP, Phase III, describes best-management practices (BMPs) that municipalities will use to achieve pollution reduction goals. Within the Phase III WIP, the Chester River and Choptank River watersheds were both identified as areas of special interest for implementing BMPs because of their high levels of nutrient pollution (DNREC 2019).

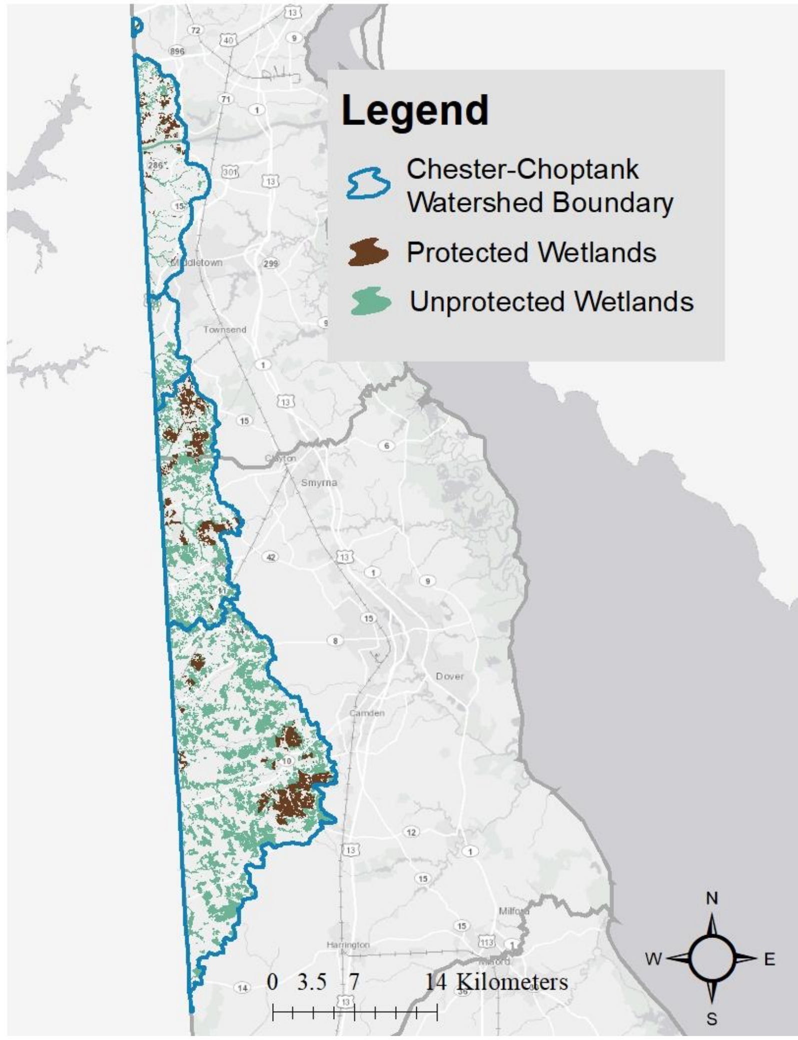
Protected Areas and Category One Wetlands

Protected areas are lands that are kept natural and are shielded from development. There are various types of protected areas, such as state forests, wildlife areas, nature preserves, open spaces, historical sites, parks, or conservation easements. According to 2007 SWMP maps and maps of Delaware's protected lands, all protected areas in the watershed combined contained 7,825.9 acres of vegetated target wetlands, which represented 20.7% of vegetated wetlands in the watershed. Of those protected vegetated wetlands, 6,150.9 acres were flat wetlands (20.8% of flats), 843.4 acres were riverine wetlands (25.0% of riverine wetlands), and 831.5 acres were depression wetlands (17.0% of depressions; Table 2). Additionally, 176.2 acres of non-vegetated or farmed wetlands were on protected land. Protected wetlands were scattered throughout the watershed (Map 4).

Table 2. Acres of target wetlands in public or private protected areas as of 2007, and the percentage of each wetland type in protected areas based on the total number of acres of each wetland type in the watershed.

Wetland Category	Wetland Type	Acres on Protected Land	Percent on Protected Land
Target wetlands	Flat	6,150.9	20.8
	Riverine	843.4	25.0
	Depression	831.5	17.0

Most wetlands on protected land were managed by a state agency, including DNREC Division of Parks and Recreation, DNREC Division of Fish and Wildlife, Delaware Department of Transportation (DelDOT), and Delaware Forest Service (89.5% of protected wetlands; Figure 3). Such state lands were designated as wildlife areas, state forest lands, nature preserves, or historical sites. Blackbird State Forest, Blackiston Wildlife Area, and Norman G. Wilder Wildlife Area contained the majority of protected wetlands in this watershed. Other protected wetlands were on land managed by counties (9.8%), private landowners (0.6%), or municipalities (0.1%; Figure 3). Wetlands on land managed by private landowners were protected under conservation easements, and those on land managed by counties were parts of designated open spaces and parks.



Map 4. Wetlands that were on protected and unprotected lands in the Delaware portion of the Chester-Choptank watershed.

The Chester-Choptank watershed also contained some Category One wetlands, which are rare, unique, freshwater wetland types in Delaware. The types of Category One wetlands found in this watershed were Coastal Plain ponds and groundwater seepage wetlands. Coastal Plain ponds are relatively small, circular or oval-shaped depressions that are fed by groundwater and precipitation. They are usually flooded in the wet seasons of winter and spring and are often dry on the surface in the summer and fall. Because Coastal Plain ponds are classified as depressions in the HGM classification system, they have the potential to be randomly selected for rapid assessments, as depressions are target wetlands. Groundwater seepage wetlands, or groundwater seeps, are those that occur in areas on slopes where groundwater flows out onto the surface. Groundwater seeps are typically classified as riverine or slope wetlands in the HGM classification system. Riverine wetlands are targets but slope wetlands typically are not, so groundwater seeps may or may not be randomly selected as wetland points.

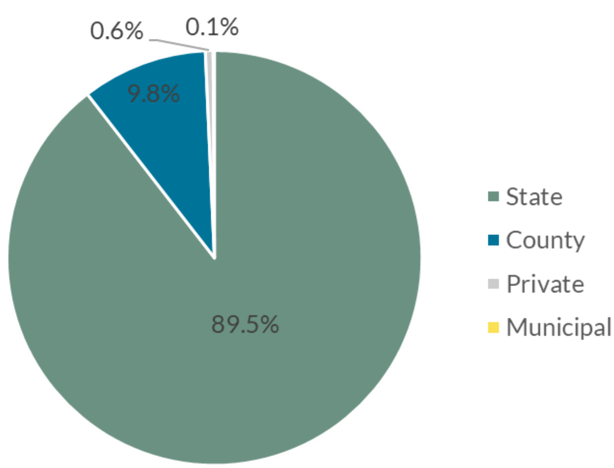


Figure 3. Management of protected wetlands in the Chester-Choptank watershed.

The 2007 SWMP maps included Category One wetland classifications as additional attributes or modifiers. Accuracy checks were performed on polygons with Category One classifications in this watershed using aerial imagery from multiple years and topographic lines. After accuracy checks, it was determined that there were an estimated 940.3 acres of groundwater seeps and 208.5 acres of Coastal Plain ponds in this watershed. Coastal Plain ponds were scattered throughout the watershed but were most heavily concentrated in the center of the watershed, while seeps were present only in the northern half of the watershed in New Castle County. Of those unique wetlands, 261.2 acres (27.8%) of groundwater seeps and 73.0 acres (35.0%) of Coastal Plain ponds were within protected areas (Table 3).

Table 3. Acres of Category One wetlands in public or private protected areas as of 2007, and the percentage of each wetland type in protected areas based on the total number of acres of each wetland type in the

Wetland Category	Wetland Type	Acres on Protected Land	Percent on Protected Land
Category 1 wetlands	Coastal Plain pond	73.0	35.0
	Groundwater seep	261.2	27.8

Wetlands that are not within protected areas are more susceptible to destruction or degradation from human impacts. Non-tidal wetlands in Delaware are only regulated by the state if they are greater than 400 contiguous acres. This leaves most non-tidal wetlands, including Category One wetlands like groundwater seeps and Coastal Plain ponds, unregulated by the state. When wetlands are unregulated, they are far more likely to be destroyed or degraded by anthropogenic activity than if a permit were required for their impacts. Non-tidal wetlands on protected lands are less likely to be impacted by human impacts, so the 20.7% of non-tidal wetlands that reside within protected areas are relatively safe. However, the other 79.3% of non-tidal wetlands that are not on protected lands are much more vulnerable.

Wildlife Habitat and Outdoor Recreation

The 2015 Delaware Wildlife Action Plan (DNREC 2015b) highlights wetlands within the Chester-Choptank watershed as important habitats for many reptile and amphibian species of greatest conservation need (SGCN), such as the spotted turtle (*Clemmys guttata*), the four-toed salamander (*Hemidactylium scutatum*), and the marbled salamander (*Ambystoma opacum*; Figure 4). It also identifies wetland types within this watershed as important habitats for bird SGCN, including the Swainson's warbler (*Limnothlypis swainsonii*), hooded warbler (*Setophaga citrina*), and Louisiana waterthrush (*Parkesia motacilla*). Many freshwater mussel and insect SGCN use wetland habitats in this watershed as well, such as the dwarf wedgemussel (*Alasmidonta heterodon*) and the rare skipper (*Problema bulenta*; DNREC 2015b).

Unique wetlands, such as Category One wetlands, can be particularly important for certain SGCN. Both groundwater seepage wetlands and Coastal Plain ponds, which are unique wetland types found within the Chester-Choptank watershed, are noted as being important for many rare plant and animal SGCN. They are also designated as habitats of conservation concern because they are threatened by factors such as human development, loss of buffers, fragmentation, draining, excess nutrients, and invasion by non-native plants (DNREC 2015b), and remain unregulated at the state level.

Just as wetlands and the areas surrounding them can be important for wildlife, they can also provide many opportunities for outdoor recreation. In Kent County, people can enjoy hunting, birding, and horseback riding in Norman G. Wilder Wildlife Area, hunting and birding in Blackiston Wildlife Area, and hunting in Tappahanna Wildlife Area. People can boat,

Figure 4. A marbled salamander found in a Delaware non-tidal wetland.

kayak or canoe, and fish in Mud Mill Pond, where there is a public boat ramp. Visitors can camp, hunt, bike, horseback ride, fish, and hike in Blackbird State Forest, which is on the border of Kent and New Castle Counties. In New Castle County, Delawareans can enjoy hunting and birding in C & D Canal Conservation Area.

Methods

Changes to Wetland Acreage

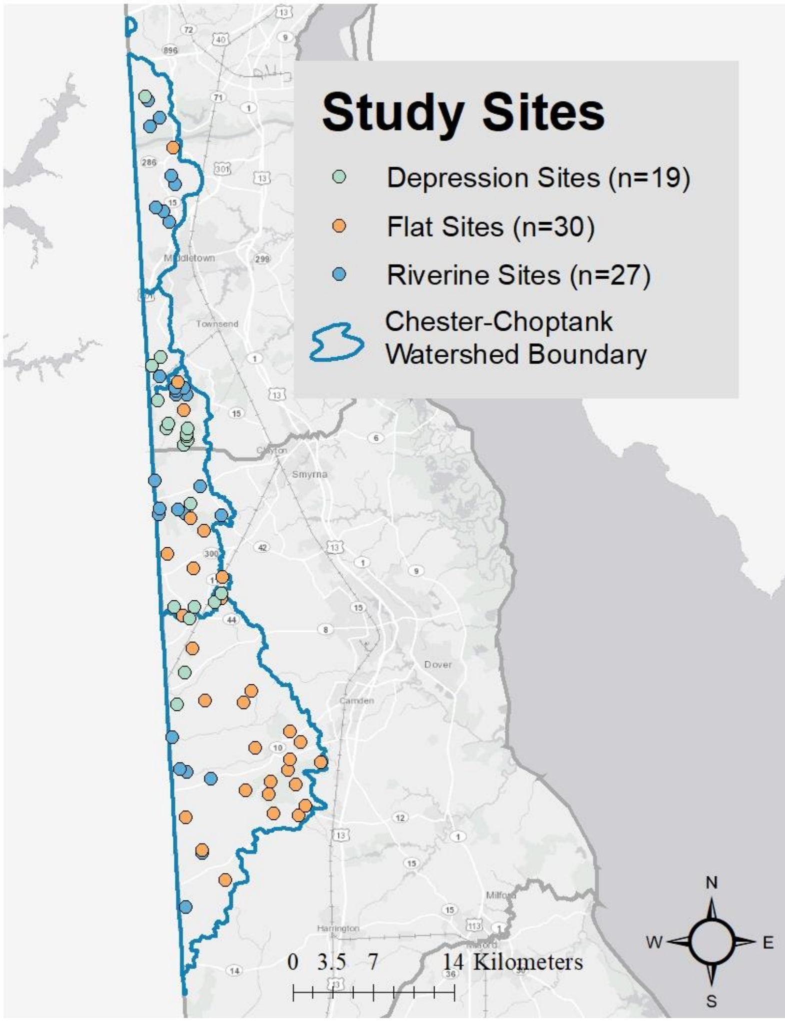
Historic wetland acreage in the Chester-Choptank watershed was estimated using a combination of U.S. Department of Agriculture (USDA) soil maps and historic soil survey maps from 1915. These maps are based on soil indicators such as drainage class, landform, and water flow, and allow for classification of hydric soils. Hydric soils occurring in areas that are currently not classified as wetlands due to significant human impacts, either through urbanization, agriculture, land clearing, or hydrologic alterations, were assumed to be historic wetlands that have been lost prior to 1992. Current wetland acreage was calculated from maps created in 2007 as part of a mapping effort by the SWMP (State of Delaware 2007). More recent trends in wetland acreage were determined from SWMP spatial data, which classified mapped wetland polygons as 'lost', 'gained', or otherwise 'changed' from 1992 to 2007 (State of Delaware 2007 and Tiner et al. 2011). Both vegetated and non-vegetated wetlands were included in this desktop analysis. Vegetated wetlands were those classified as being dominated by forest, scrub-shrub, emergent, or aquatic bed vegetation. Non-vegetated wetlands were those classified as having little to no vegetation, including unconsolidated bottom or shore.

Field Site Selection

The project goal was to sample 30 non-tidal sites in each common HGM class (flat, riverine, and depression) for a total of 90 sites. To accomplish this, the EPA's Ecological Monitoring and Assessment Program (EMAP) in Corvallis, Ore. selected 540 potential sample sites from a target population of vegetated wetlands within the Chester-Choptank watershed using the 2007 NWI maps (USFWS 2021). EMAP used a generalized random tessellation stratified design, which eliminates selection bias (Stevens and Olsen 1999, 2000). Study sites were randomly-selected points within mapped wetlands, with each point having an equal probability of being selected. Non-vegetated wetlands and farmed wetlands were not included in the target population and were not assessed because Delaware's wetland condition assessment protocols are only designed to assess natural, vegetated wetlands.

Once the full list of potential sample sites was created, sites were considered and sampled in numeric order from lowest to highest, as dictated by the EMAP design. Sites were only dropped from sampling in circumstances that prevented us from accessing the site or if the site was not actually in the target population (see 'Landowner Contact and Site Access' section below for details). Five oversample sites were assessed as reference sites because they were close in proximity to other assessment sites. In total, 30 flat, 27 riverine, and 19 depression sites were assessed in the field (Map 5). Statistical survey methods developed by EMAP were then used to extrapolate results from the sampled population of wetland sites to the whole population of wetlands throughout the watershed (see 'Wetland Condition and Value Data Analysis' section below for details). Reference sites were excluded from statistical analyses.

Data Collection



Map 5. Locations of study sites by wetland type. Sites were selected using the EMAP sampling design.

Landowner Contact and Site Access

We obtained landowner permission prior to assessing all sites. We identified landowners using county tax records and mailed each landowner a postcard providing a brief description of the study goals, sampling techniques, and our contact information. If a contact number was available, we followed the mailings with a phone call to discuss the site visit and secure written permission. If permission was denied, the site was dropped and not visited. Sites were also dropped if a landowner could not be identified or if landowner contact information was unavailable. Reasonable efforts were made to reach all points, but sites were deemed inaccessible and were subsequently dropped if the site was unsafe to visit for any reason (e.g. severe terrain, deep water, infestation with poisonous plants). Some sites that were selected using the EMAP design were determined upon visitation to be uplands or open water rather than vegetated wetlands, and such sites were dropped because they were not in the target sampling population.

Assessing Non-tidal Wetland Condition

The WMAP used the Delaware Rapid Assessment Procedure (DERAP) v.6.0 to assess the condition of non-tidal wetlands based on the presence and intensity of stressors related to habitat, hydrology, and buffer elements (Table 4; Jacobs 2010). DERAP was followed to collect data at 30 flat sites, 27 riverine sites, and 19 depression sites in the Chester-Choptank watershed in summer 2018. Prior to field assessments, we produced site maps and calculated several buffer metrics using ArcMap GIS software (ESRI 2017). All metrics measured in the office were field-verified to confirm accuracy.

Table 4. Metrics measured with the Delaware Rapid Assessment Procedure (DERAP) Version 6.0.

Attribute Group	Metric Name	Description	Measured in AA or Buffer
Habitat	Dominant Forest Age	Estimated age of forest cover class	AA
Habitat	Forest Harvesting within 50 Years	Presence and intensity of selective or clear cutting within 50 years	AA
Habitat	Forest Management	Conversion to pine plantation or evidence of chemical defoliation	AA
Habitat	Vegetation Alteration	Mowing, farming, livestock grazing, or lands otherwise cleared and not recovering	AA
Habitat	Presence of Invasive Species	Presence and abundance of invasive plant cover	AA
Habitat	Excessive Herbivory	Evidence of herbivory or infestation by pine bark beetle, gypsy moth, deer, nutria, etc.	AA
Habitat	Increased Nutrients	Presence of dense algal mats or the abundance of plants indicative of increased nutrients	AA
Habitat	Roads	Non-elevated paths, elevated dirt or gravel roads, or paved roads	AA
Hydrology	Ditches	Depth and abundance of ditches within and adjacent to the AA (flats and depressions only)	AA and Buffer
Hydrology	Stream Alteration	Evidence of stream channelization or natural channel incision (riverine only)	AA
Hydrology	Weir/Dam/Roads	Man-made structures impeding flow of water into or out of the wetland	AA and Buffer
Hydrology	Storm Water Inputs and Point Sources	Evidence of run-off from intensive land use, point source inputs, or sedimentation	AA and Buffer
Hydrology	Filling and/or Excavation	Man-made fill material or the excavation of material	AA
Hydrology	Microtopography Alterations	Alterations to the natural soil surface by forestry operations, tire ruts, and soil subsidence	AA
Buffer	Development	Commercial or residential development and infrastructure	Buffer
Buffer	Roads	Dirt, gravel, or paved roads	Buffer
Buffer	Landfill or Waste Disposal	Reoccurring municipal or private waste disposal	Buffer
Buffer	Channelized Streams or Ditches	Channelized streams or ditches >0.6m deep	Buffer
Buffer	Poultry or Livestock Operation	Poultry or livestock rearing operations	Buffer
Buffer	Forest Harvesting within 15 Years	Evidence of selective or clear cutting within past 15 years	Buffer
Buffer	Golf Course	Presence of a golf course	Buffer
Buffer	Row Crops, Nursery Plants, or Orchards	Agricultural land cover, excluding forestry plantations	Buffer
Buffer	Mowed Area	Any reoccurring activity that inhibits natural succession	Buffer
Buffer	Sand/Gravel Operation	Presence of sand or gravel extraction operations	Buffer

We navigated to the EMAP points in the field with a handheld GPS unit and established an assessment area (AA) as a 40m radius circle (0.5 ha) centered on each random point (Figure 5). Any necessary adjustments to the AA shape or location were made according to the DERAP protocol (Jacobs 2010). The entire AA was explored on foot and evidence of wetland habitat, hydrology, and buffer stressors (Table 4) were documented during one field visit during the growing season (June 1 to September 30). Field investigators collectively assigned the wetland a Qualitative Disturbance Rating (QDR) from one (least disturbed) to six (most disturbed; Appendix A) based on best professional judgement. Statistical analyses were performed using Microsoft Excel and R version 3.3.0 (R Core Team 2016).

DERAP produces one overall wetland condition score for each wetland using a model based on the presence and intensity of various stressors (Appendix B, C; Jacobs 2010). Wetland stressors included in the DERAP model were selected using step-wise multiple regression and Akaike's Information Criteria (AIC)

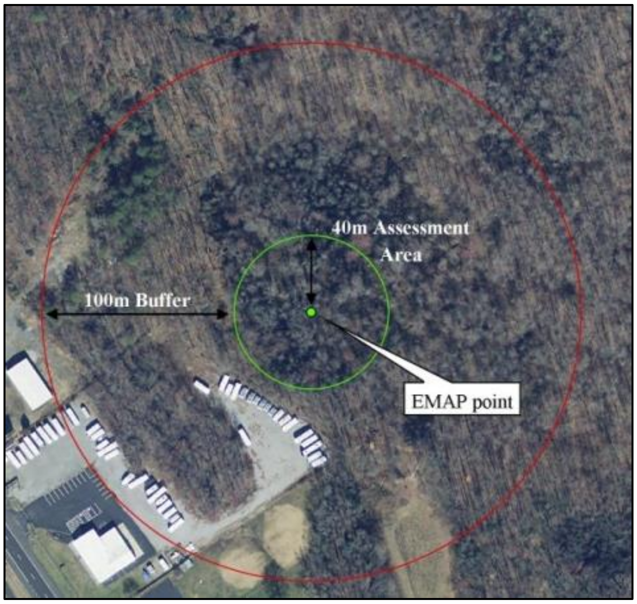


Figure 5. Standard AA (green) and buffer (red) used to collect data for DERAP v.6.0.

approach to develop the best model that correlated to Delaware Comprehensive Assessment Procedure (DECAP) data (i.e. Tier Three, more detailed assessment data) without over-fitting the model to a specific dataset (Jacobs et al. 2009). Coefficients, or stressor weights, associated with each stressor were assigned using multiple linear regression (Appendix C). This process allowed for effective screening and selection of stressor variables that best represent wetland condition for each HGM class. The DERAP Index of Wetland Condition (IWC) score was calculated by summing the stressor coefficients for each of the selected stressors that were present and subtracting the sum from the linear regression intercept for that HGM type:

$$\textbf{DERAP IWC}_{\textbf{FLATS}} = 95 - (\sum \text{stressor weights})$$
$$\textbf{DERAP IWC}_{\textbf{RIVERINE}} = 91 - (\sum \text{stressor weights})$$
$$\textbf{DERAP IWC}_{\textbf{DEPRESSION}} = 82 - (\sum \text{stressor weights})$$

As shown in these equations, the maximum condition score that flat wetlands could receive is a 95; for riverine wetlands, a 91; and for depression wetlands, an 82.

Example: Site D

Forested flat wetland with 25% of AA clear cut (weight 19), 1-5% invasive plant cover (weight 0), moderate ditching (weight 10), and commercial development in the buffer (weight 3):

DERAP condition score = 95 – (19+0+10+3)

DERAP condition score = 63

Assessing Non-tidal Wetland Value

The local values that wetlands provide may be independent of wetland condition and function (Rogerson and Jennette 2014). Thus, a value-added assessment protocol can provide additional information that, when used in conjunction with condition results from DERAP, can provide managers with a more complete picture for decision making purposes. We performed value-added assessments at non-tidal wetland sites in conjunction with the DERAP assessment using v.1.1 of the Value-Added Assessment Protocol (Rogerson and Jennette 2014). The purpose of this assessment was to evaluate the local ecological value that a wetland provides to the local landscape by assessing seven value metrics (Table 5). Metric scores were tallied to produce a final score that ranged from zero to 100. Categories and category thresholds for final scores are shown in Table 6. Statistical analysis was performed using Microsoft Excel and R version 3.3.0 (R Core Team 2016).

Table 5. Value metrics scored according to v.1.1 of the Value-Added Assessment Protocol.

Value Metric	Description
Uniqueness/Local Significance	Significance of wetland based on ecology and surrounding landscape
Wetland Size	Size of the wetland complex the site falls within
Habitat Availability	Percentage of unfragmented, natural landscape in AA and buffer
Delaware Ecological Network (DEN) Classification	Identification of ecologically important corridors and large blocks of natural areas
Habitat Structure and Complexity	Presence of various habitat features and plant layers important for species diversity and abundance
Flood Storage/Water Quality	Wetland ability to retain water and remove pollutants
Educational Value	Ability of wetland to provide education/recreation opportunities based on public accessibility and aesthetic qualities

Table 6. Categories and thresholds for value-added final scores from v.1.1 of the Value-Added Assessment Protocol.

Value Category	Value Score Range
Rich	≥ 45
Moderate	< 45, ≥ 30
Limited	<30

Wetland Condition and Value Data Analysis

The EMAP sampling method is designed to allow inference about a whole population of resources from a random sample of those resources. In accordance with EMAP design statistical procedures, we used a cumulative distribution function (CDF) to show wetland condition on the population level (Diaz-Ramos et al. 1996). A CDF is a visual tool that extrapolates assessment results from a sample to the entire watershed population. It can be interpreted by drawing a horizontal line anywhere on the graph and reading that as: 'z' proportion of the area of 'x wetland type' in the watershed falls above (or below) the score of 'w' for wetland condition. Points can be placed anywhere on the graph to determine the percent of the population that is within the selected conditions. For example, in Figure 6, approximately 55% of the wetland area scored above 81 for wetland condition. A CDF also highlights cliffs or plateaus where either a large or small portion of wetlands are in similar condition. In the example, there is a condition cliff around 73 and 74, illustrating that a relatively large proportion of the population had condition scores in this range. In contrast, the plateau from about 67 and below indicates that a small proportion of the wetland population scored in this range.

Medians of DERAP final scores are presented in addition to means in this report, as the final scores of riverine and depression wetlands were not normally distributed (Shapiro-Wilk normality test, α=0.05; flat: W=0.95, p=0.15; riverine: W=0.65, p<0.01; depression: W=0.64, p<0.01). When data are not normally distributed, the median is a better descriptor of the central tendency of the data than the mean. All value-added scores were normally distributed (Shapiro-Wilk normality test, α=0.05; flat: W=0.95, p=0.15; riverine: W=0.93, p=0.08; depression: W=0.94, p=0.25), but means and medians are both still reported for consistency.

Sites in each HGM subclass were placed into three condition categories: minimally stressed, moderately stressed, or severely stressed (Table 7). Condition class breakpoints were determined by applying a percentile calculation to the QDRs and condition scores from sites in several watersheds that were assessed previously

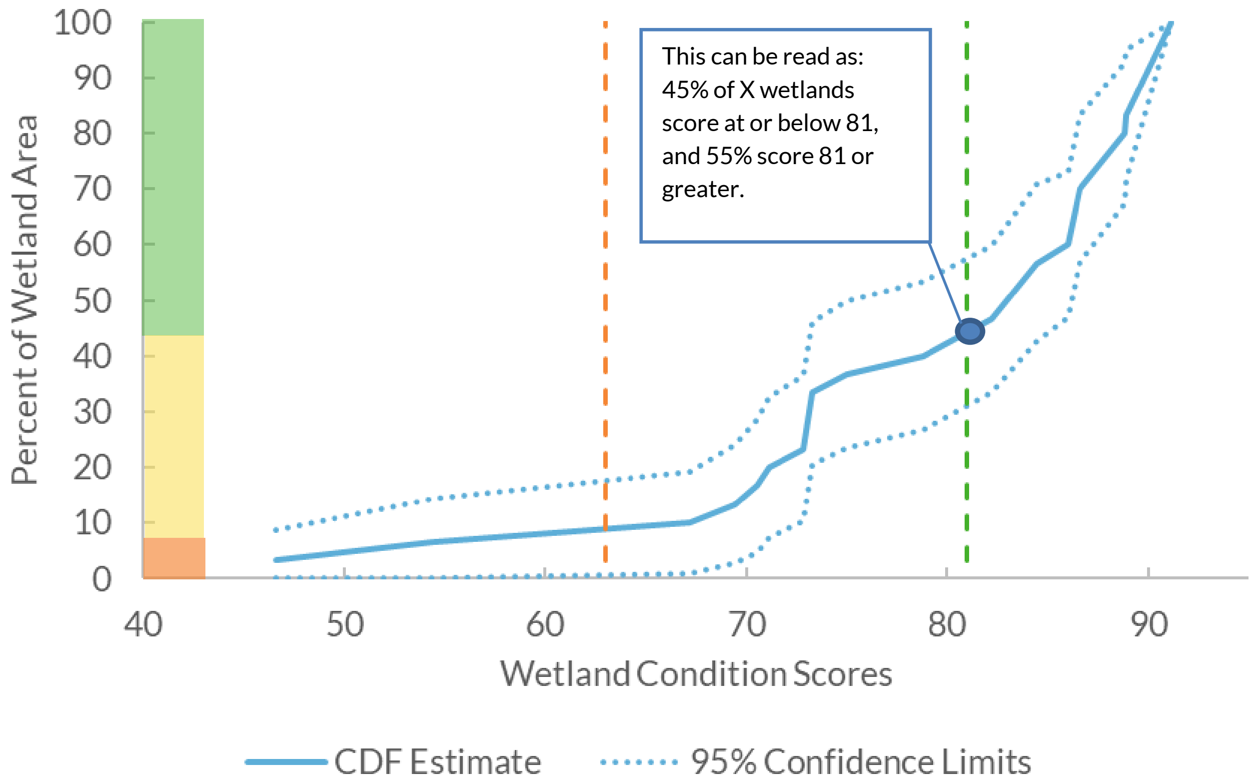


Figure 6. An example CDF showing wetland condition. The solid blue line is the population estimate and the dashed blue lines are 95% confidence intervals. Colored blocks on the y-axis show percent of wetlands within each condition category, where orange is severely stressed, yellow is moderately stressed, and green is minimally stressed. The orange and green dashed lines show the numeric breakpoints between condition categories.

(Jacobs 2010, Rogerson and Haaf 2017). Minimally stressed sites are those with a condition score greater than the 25th percentile of sites assigned a QDR of one or two. Severely stressed sites are those with a condition score less than the 75th percentile of sites assigned a QDR of five or six. Moderately stressed sites are those that fall in between. The condition breakpoints that we applied in the Chester-Choptank watershed are provided in Table 7.

Table 7. Condition categories and breakpoint values for non-tidal wetlands in the Chester-Choptank watershed as determined by wetland condition scores, where 'x' denotes a condition score in each listed inequality.

Wetland Type	Method	Minimally Stressed	Moderately Stressed	Severely Stressed
Flat	DERAP	x ≥ 88	88 > x ≥ 65	x < 65
Riverine	DERAP	x ≥ 85	85 > x ≥ 47	x < 47
Depression	DERAP	x ≥ 73	73 > x ≥ 53	x < 53

Wetland Health Report Card

Information in this technical report was used to create a wetland health report card. The report card provides a clear, concise summary of wetland health and management recommendations in the Chester-Choptank watershed for the general public. It is easily accessible online (see pg. 52 for link). In the report card, wetland health was portrayed in a symbolic and colorful manner to make the data clear and understandable for the general public. This involved converting wetland health scores from this report into letter grades, symbols, and color-coded health categories.

Letter grades (A - F) were assigned to each wetland type based on condition scores, with A being the highest grade for wetlands in the best health, and F being the lowest grade for wetlands in the worst health. These overall grades were calculated by dividing average final DERAP scores for each HGM type by the maximum possible DERAP score for each type. Flat wetlands achieved a letter grade of B; riverine wetlands, a B; and depressions wetlands, a B+. The whole watershed was assigned a letter grade of B, which was calculated by multiplying overall report card grades for each wetland type by the acreage proportion for each type in the watershed (i.e., weighting based on acreage), and then summing those values. All report card grades are listed in Table 8, and the letter grade scale used can be seen in Appendix D.

Table 8. Report card grades by wetland type and overall watershed. Grades are listed as final overall grades for each type, as well as by attribute category.

Wetland Type	Overall Grade	Habitat Grade	Hydrology Grade	Buffer Grade
Flat	B	A	B-	D
Riverine	B	A-	A-	D
Depression	B+	A	B+	B
Overall Watershed	B	.	.	.

Table 9. Symbols and their meanings for each attribute category.

Category	Symbol
Habitat	
Hydrology	
Buffer	

The habitat and hydrology attribute categories for each non-tidal wetland type were also given letter grades by dividing total stressor weight sums for each category by the total possible stressor category weight sum, and then converting it to a zero to 100 scale. Letter grades were assigned to non-tidal buffers by averaging the buffer stressor tally for each wetland type (i.e., the number of buffer stressors rather than stressor weights) and comparing that average to a grading scale that was designed specifically for non-tidal buffers (see Appendix D). The symbols used in the report card to depict habitat, hydrology, and buffer were also used in the results section (see 'Results' below) of this report (Table 9).

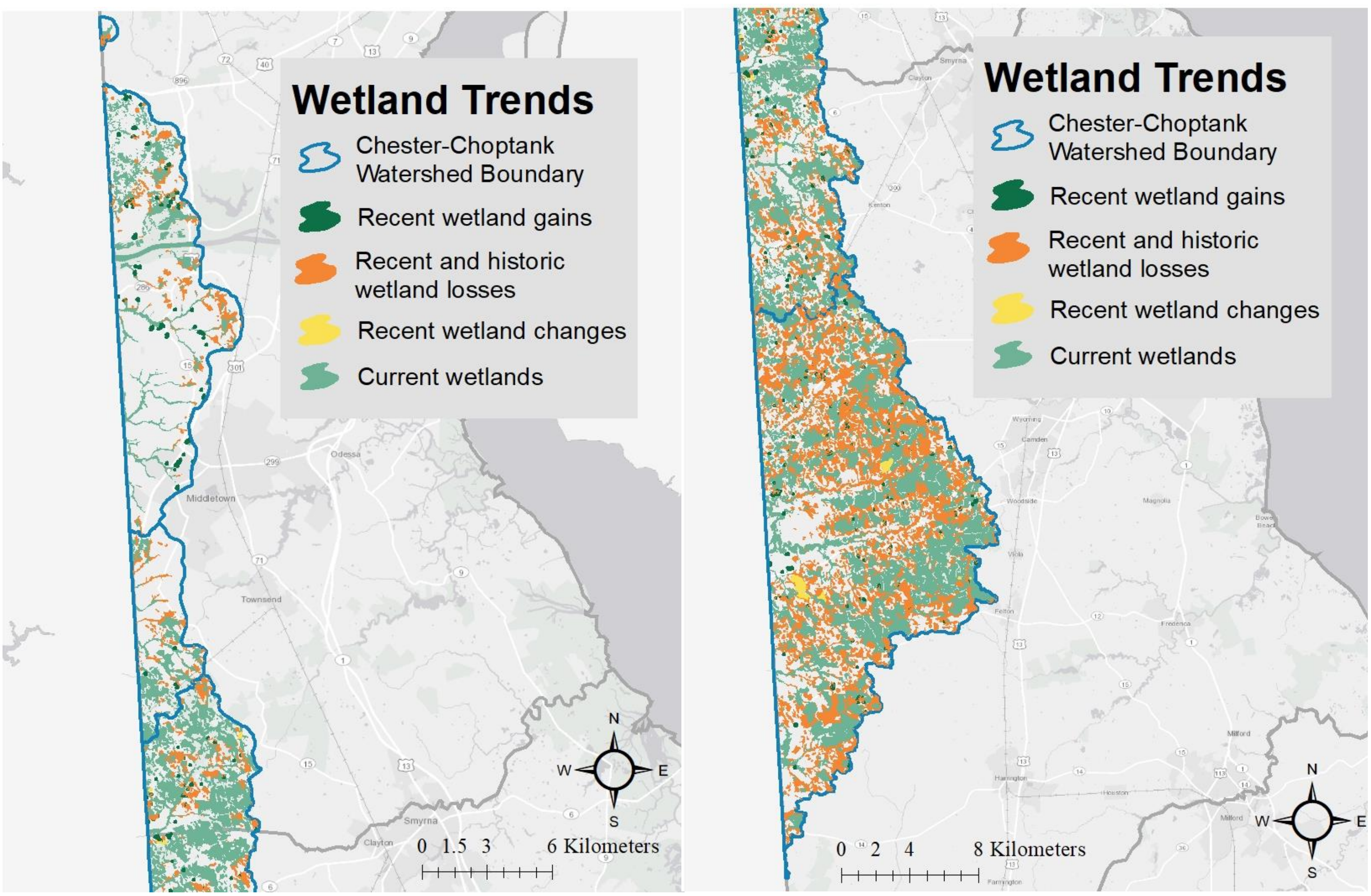
Results

Wetland Acreage

The Chester-Choptank watershed contained an estimated 63,608 acres of wetlands prior to human settlement in the early 1700s. Approximately 24,876 acres were lost or destroyed prior to 1992, while an additional 148 acres were lost between 1992 and 2007. Altogether, this indicates that about 39.3% of historic wetland acreage has been lost in this watershed up to 2007. These wetland losses were due mainly to human development scattered

Table 10. Wetland acreage gains, losses, and changes in the Chester-Choptank watershed between 1992 and 2007. Values and categories are based on those in 2007 SWMP spatial datasets.

Wetland Type	Gain (acres)	Loss (acres)	Change (acres)
Flat	2.2	105.8	125.0
Riverine	1.7	3.9	9.0
Depression	12.9	34.2	3.8
Ponds (Non-vegetated)	140.1	4.5	0.1
Total	156.9	148.4	137.9



Map 6. Wetland trends over time in the Chester-Choptank watershed in New Castle County (left) and Kent County (right). Recent wetland types changes and wetland acreage gains are those that occurred between 1992 and 2007. Historic and recent wetland losses are all estimated losses that occurred over time up to 2007. Current wetlands include all vegetated and non-vegetated wetlands as of 2007.

throughout the watershed (Map 6, Table 10). Losses have been particularly staggering in the Kent County portion of the watershed (Map 6).

Most wetlands that were lost between 1992 and 2007 were destroyed because of development (103.3 acres; 69.6% of losses), including the construction of rural houses and housing developments (Figure 7). The other major source of wetland loss was agriculture, which included row crops (24.4 acres; 16.5%), pastureland for livestock (13.4 acres; 9.0%), and poultry operations (7.3 acres; 4.9%). Most wetlands that were lost were vegetated flats (105.8 acres; 71.3% of losses) or depressions (34.2 acres; 23.1%). Others were non-vegetated ponds (4.5 acres; 3.0%) or riverine wetlands (3.9 acres; 2.6%).

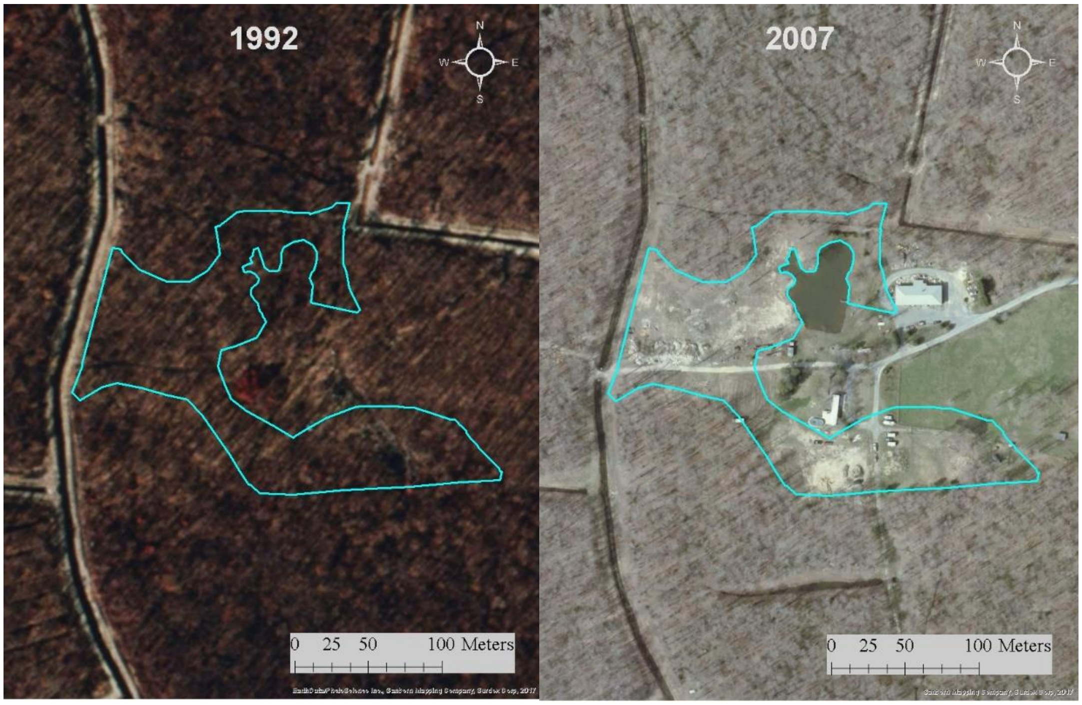


Figure 7. An example of a wetland loss that occurred between 1992 and 2007. In 1992, there was a forested wetland present, outlined in light blue (left). By 2007, the wetland was lost to rural development (right).

In the same time frame, the Chester-Choptank watershed gained 156.9 acres of wetlands, which was slightly more than was lost (Table 10). This resulted in an overall watershed net gain of 8.5 acres. Many gained wetlands were constructed in developed areas (69.6 acres; 44.4% of gains) as ponds associated with houses or housing developments, golf courses, or landfills. Similarly, many wetlands were created in agricultural areas (68.0 acres; 43.3%), such as within or adjacent to row crop fields, within pasturelands for livestock, or adjacent to chicken houses. Functional gain was likely very limited in these created wetlands because they were all non-vegetated ponds with unconsolidated bottom. On the other hand, 19.3 acres (12.3%) of gains were because of wetland restoration or creation, most of which were restored on agricultural lands. Some restoration was the result of natural reforestation on sections of agricultural fields that were no longer active, while other restoration activity was from man-made wetlands. Restored wetlands varied greatly from non-vegetated to forested; 50.3% of them were classified as excavated, non-vegetated ponds, while 49.7% were forested or had emergent vegetation.

A total of 137.9 acres were classified as 'changed' in the Chester-Choptank watershed between 1992 and 2007 (Map 6, Table 10). Such areas changed from one wetland type to another within that time frame. Most documented changes occurred to flats (125.0 acres; 90.6% of changes). Changes to flats were in large part explained by logging activities that changed the vegetation from trees to emergent plants once trees were felled. A few non-vegetated ponds were also constructed in forested flats, changing natural, vegetated wetlands to man-made, non-vegetated wetlands. Riverine wetlands that underwent alterations (9.0 acres; 6.5%) changed from natural, forested wetlands to non-vegetated excavated or impounded wetland (Figure 8). All depressions that experienced changes (3.8 acres; 2.8%) went from being natural, forested wetlands to excavated, non-vegetated ponds. A very small proportion of wetland changes in the watershed (0.1 acres; 0.1%) were because of non-vegetated ponds being drained, allowing them to grow emergent vegetation.

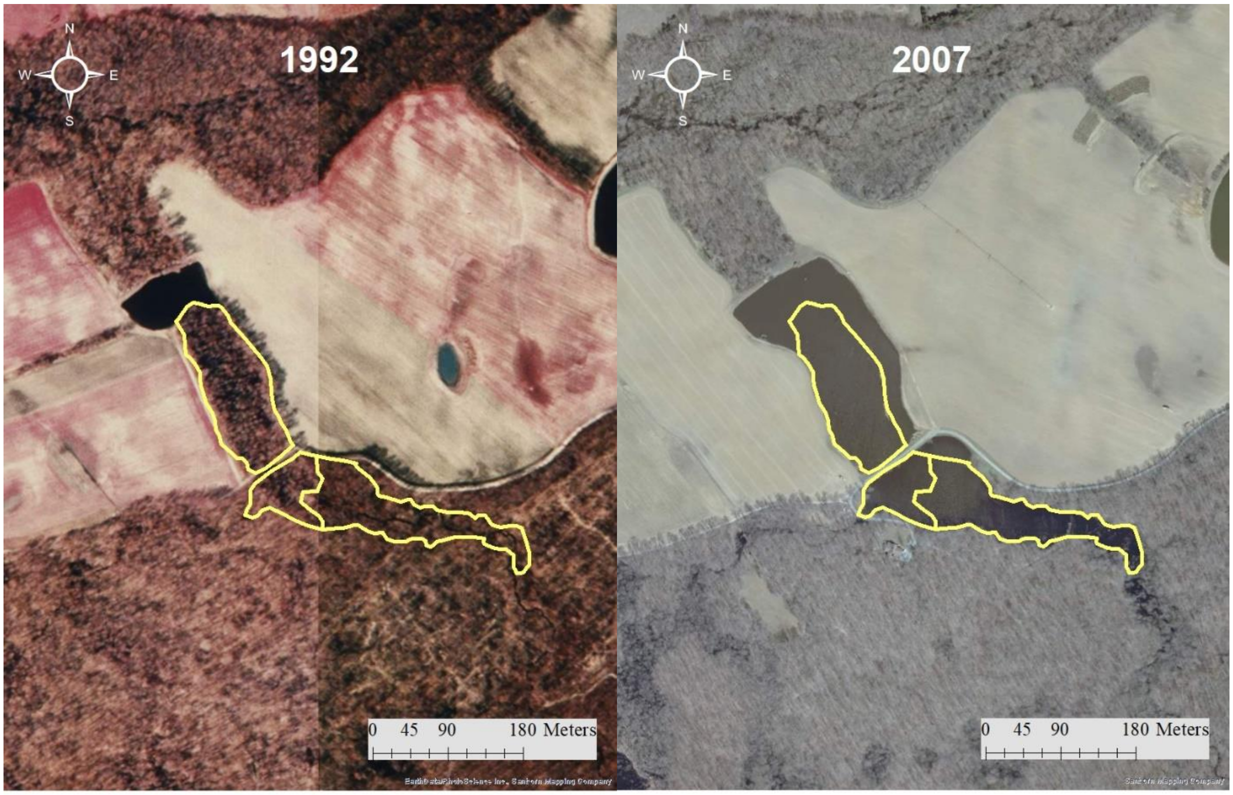


Figure 8. An example of a riverine wetland change that occurred between 1992 and 2007. In 1992, there was a forested wetland present, outlined in yellow (left). By 2007, the wetland was further impounded, causing increased flooding and vegetation loss (right).

Landowner Contact and Site Access

In total, 197 non-tidal sites were considered, where 116 sites were dropped (58.9%) and 81 sites were assessed (41.1%). Five of the 81 sites that were assessed were reference sites; data was collected there, but reference sites were dropped from condition analyses. Sites were usually dropped because of denied landowner permission (23.9%) or because they were deemed inaccessible (27.4%) either because of unsafe conditions or because the landowner could not be contacted. Some other sites were dropped because they were not wetlands (7.6%; Figure 9).

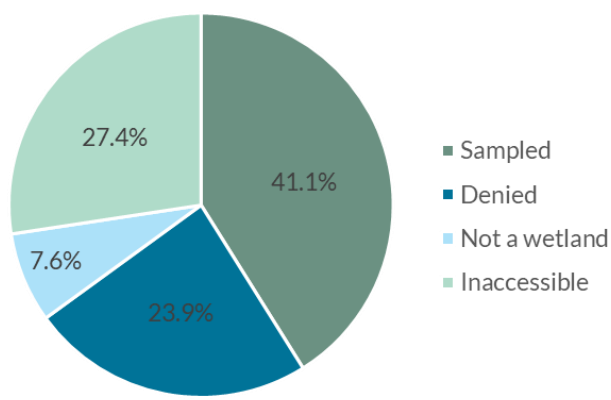


Figure 9. Sampling success for non-tidal wetlands in the Chester-Choptank watershed. Shown are percentages of the total number of sites where sampling was attempted (n=197).

Table 11. Ownership of wetland sites that were assessed and analyzed in the Chester-Choptank watershed (n=76; does not include reference sites).

Wetland Type	Public (%)	Private (%)
All combined	38.2	61.8
Flat	46.7	53.3
Riverine	29.6	70.4
Depression	36.8	63.2

A total of 76 wetland sites were assessed and analyzed in the Chester-Choptank watershed. Most of these sites were privately owned (61.8%). Ownership percentages varied greatly by wetland type. Flat wetlands were the most evenly split between private (53.3%) and public ownership (46.7%). Depressions were less evenly split in terms of private (63.2%) and public (36.8%) ownership, and riverine wetlands were even less so (private: 70.4%; public: 29.6%; Table 11).

Wetland Condition and Value

Non-tidal Flat Wetlands

Sampled flat wetlands in the Chester-Choptank watershed (n=30) all had mineral soils. Nearly all flats (96.7%) were in old growth forests, with tree age estimated to be > 50 years old; all others were forested, but younger. Flats had final DERAP scores that ranged from 54.0 to 92.0, with a mean score of 77.5 ± 10.7 (median=79.0) out of a maximum possible score of 95.0. The highest proportion of flats was moderately stressed (66.7%), followed by minimally stressed (20.0%) and severely stressed (13.3%; Figure 10). Minimally stressed flats (Figure 11) were predominantly affected by buffer stressors such as channelized streams or ditches, agriculture, development, and roads in the surrounding landscape. In addition to those stressors, moderately and

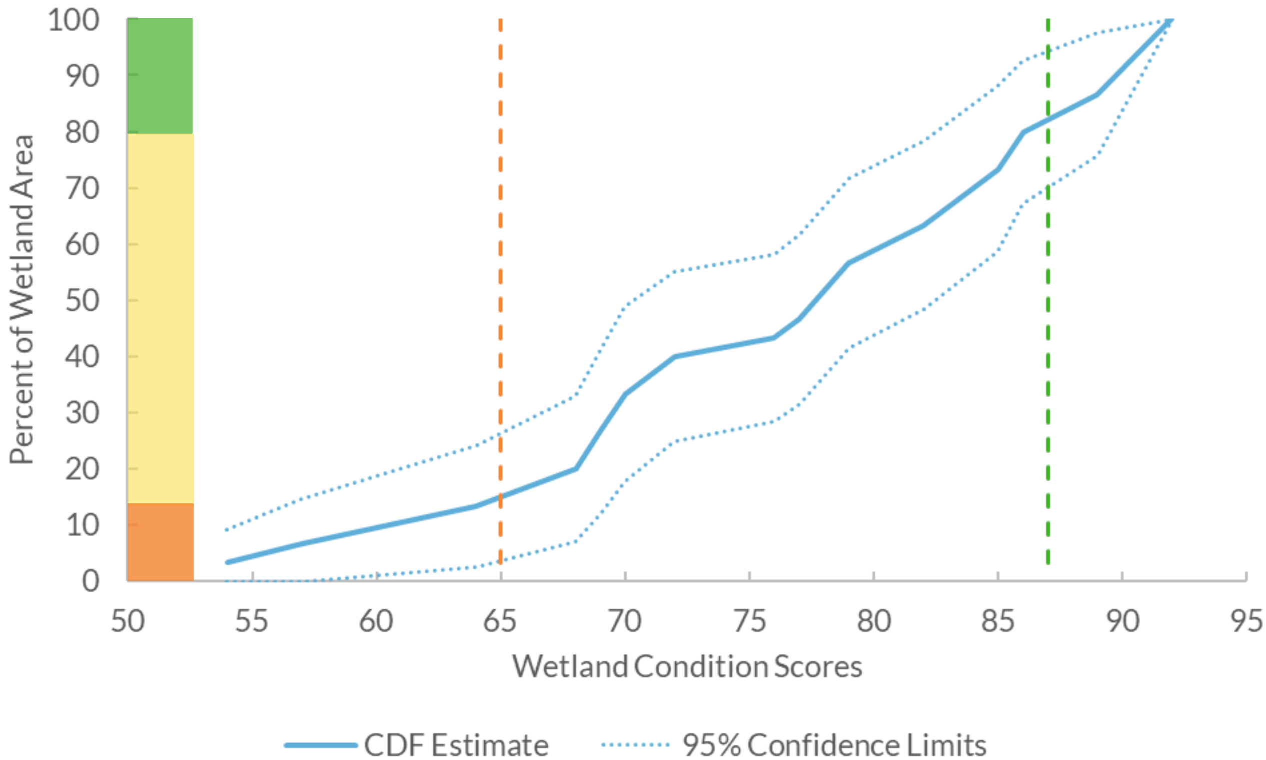


Figure 10. Cumulative distribution function (CDF) for non-tidal flat wetlands in the Chester-Choptank watershed. The solid blue line is the population estimate and the dashed blue lines are 95% confidence intervals. Colored blocks on the y-axis show percent of wetlands within each condition category, where orange is severely stressed, yellow is moderately stressed, and green is minimally stressed. The orange and green dashed lines show the numeric breakpoints between condition categories.

severely stressed wetlands commonly had mowing in the surrounding landscape (Table 12). Moderately and severely stressed flats were also characterized by selective cutting of trees, ditching, and microtopographic alterations. Data for all sampled flat wetlands for all assessed metrics can be viewed in Appendix E.

The most common habitat stressor found in flat wetlands was selective cutting of trees (Table 12). Other somewhat prevalent habitat stressors were invasive species, roads, and mowing, which were all found in 20.0% of flats. The only invasive species that was found in flats was Japanese stiltgrass (*Microstegium vimineum*). A much less common habitat stressor was the presence of pine plantations, which was only seen in 3.3% of flat wetlands. No chemical defoliation, excessive herbivory, or dense algal mats were seen.

Figure 11. A flat wetland in the Chester-Choptank watershed.

Ditching was the most widespread hydrology stressor, and of flats that were ditched, 50% were slight ditches (shallow and conveying little water), 30% were moderate, and 20% were severe (Table 12). Microtopographic alterations, likely related to tree cutting, were also common, most of which occurred on <10% of the wetland area (62.5% of flats with microtopographic alterations) and the rest of which occurred on 10 - 75% of the wetland area. Less common hydrology stressors included weirs, dams, or roads either reducing flooding or impounding water, and fill, all of which were found in 16.7% of flats. No stormwater inputs, point sources, or excessive sedimentation were detected.

Buffer stressors were widespread around flat wetlands in the Chester-Choptank watershed. The most common buffer stressors in landscapes surrounding flats were channelized streams or ditches, agriculture, mowing, development, and roads (Table 12). Poultry or livestock operations and forest harvesting were far less common and were both found nearby 3.3% of flat wetlands. Landfill or waste disposal operations, golf courses, and sand or gravel operations were not found in landscapes surrounding flats.

Table 12. Listed are the most common stressors (>20% occurrence) in flat wetlands (see Table 9 for symbol category meanings). Also shown are the occurrence of stressors in each condition category (%min = % minimally stressed; %mod = % moderately stressed; %sev = % severely stressed).

Category	Stressor	% Total (n=30)	% Min (n=6)	% Mod (n=20)	% Sev (n=4)
	Selective cut harvesting	23.3	0.0	30.0	25.0
	Ditching	33.3	0.0	30.0	100.0
	Microtopographic alterations	26.7	0.0	35.0	25.0
	Channelized streams or ditches in surrounding landscape	53.3	33.3	50.0	100.0
	Agriculture in surrounding landscape	43.3	33.3	50.0	25.0
	Mowing in surrounding landscape	33.3	0.0	35.0	75.0
	Development in surrounding landscape	26.7	33.3	25.0	25.0
	Roads in surrounding landscape	26.7	33.3	30.0	0.0

Most flat wetlands provided moderate value to people and wildlife in the watershed (63.3%), followed by limited value (36.7%). No flats were rated as providing rich value (Figure 12). Flat wetlands provided the most value in terms of habitat availability. On average, 87.8% ± 14.8% of the area within flat wetland buffers were natural and unfragmented. They also offered some value in terms of wetland size, habitat structure and complexity, and being part of the DEN network. Flats had a mean size of 131.4ha ± 105.5ha and ranged widely from 6.2ha to 339.9ha. The most common habitat features found within flats were coarse woody debris, tree and shrub or sapling cover, large downed woody, and snags. The majority of flat wetlands were located entirely, with buffers partially, within the DEN network. This means that many flats, and parts of their buffer areas, were within large corridors of ecologically important natural land. Flats were rated as providing very little value in education potential because very few were viewable from public roads, had parking for more than two vehicles, or had trail systems or boardwalks. Additionally, flat wetlands offered very little value for flood storage and water quality because very few were adjacent to surface waters, had pooling water, or had evidence of stormflow. Most flats were also classified as A or B water regimes, meaning that they were relatively dry. Flat wetlands in this watershed provided no value in terms of uniqueness or significance, as none sampled were classified as being rare in the landscape or as being restored, established, or enhanced wetlands.

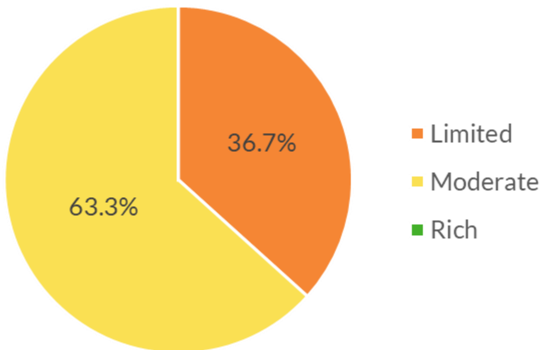


Figure 12. Proportion of flat wetlands in each value-added category.

Non-Tidal Riverine Wetlands

Riverine wetlands in the Chester-Choptank watershed that were sampled (n=27) were classified as being along first, second, or third order upper perennial streams. Most (96.3%) were in old growth forests, with average tree age estimated to be >50 years old. Riverine wetlands had final DERAP scores that ranged widely from 15.0 to 90.0, with a mean score of 77.4 ± 18.9 (median=84.0) out of a maximum possible score of 91.0. The highest proportion of these wetlands was minimally stressed (48.1%), followed by moderately stressed (40.7%), leaving a smaller proportion severely stressed (11.1%; Figure 13). Minimally stressed riverine wetlands were mostly affected by invasive species, agriculture in the surrounding landscape, and mowing in the surrounding landscape. In addition to those same stressors, moderately and severely stressed riverine wetlands were also heavily affected by development and roads in the surrounding landscape (Table 13). Data for all sampled riverine wetlands for all assessed metrics can be viewed in Appendix F.

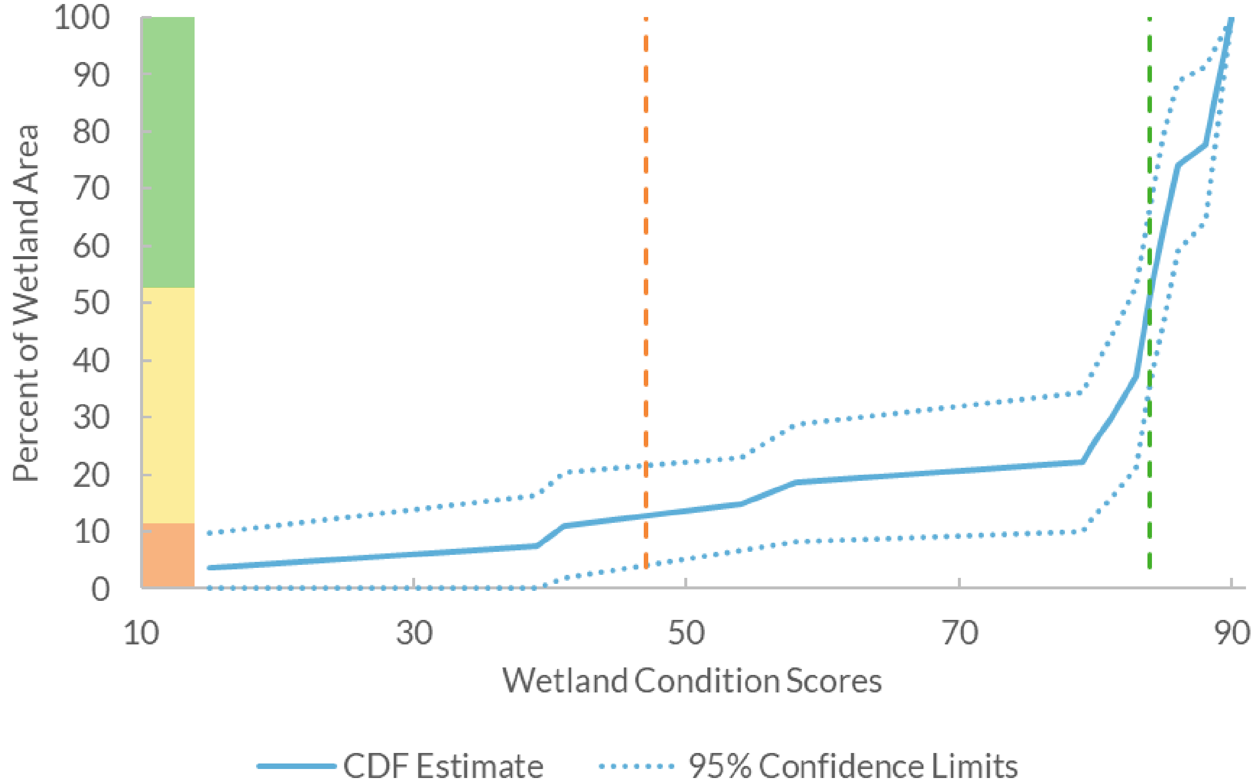
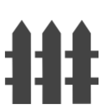


Figure 13. Cumulative distribution function (CDF) for non-tidal riverine wetlands in the Chester-Choptank watershed. The solid blue line is the population estimate and the dashed blue lines are 95% confidence intervals. Colored blocks on the y-axis show percent of wetlands within each condition category, where orange is severely stressed, yellow is moderately stressed, and green is minimally stressed. The orange and green dashed lines show the numeric breakpoints between condition categories.

The presence of invasive plant species was the most widespread of all stressors and was the most common habitat stressor (Table 13). Of riverine wetlands that had invasive species, most (52.6%) had 6 - 50% cover, followed by 1 - 5% cover (31.6%), <1% cover (7.4%), and >50% cover. Invasive species that were detected were multiflora rose (*Rosa multiflora*), Japanese stiltgrass (*M. vimineum*), Japanese honeysuckle (*Lonicera japonica*), Callery pear (i.e. Bradford; *Pyrus calleryana*), and European reed (*Phragmites australis*). Other habitat stressors that were less common were selective tree cutting (14.8% of riverine wetlands), mowing (7.4%), and roads (11.1%). Pine plantations, chemical defoliation, excessive herbivory, and dense algal mats were absent from riverine wetlands in this watershed.

Hydrology stressors were relatively uncommon in riverine wetlands in this watershed. The most prevalent hydrology stressor was stream alteration, which was found in 18.5% of riverine wetlands. Fill was a

Table 13. Listed are the most common stressors (>20% occurrence) in riverine wetlands (see Table 9 for symbol category meanings). Also shown are the occurrence of stressors in each condition category (%min = % minimally stressed; %mod = % moderately stressed; %sev = % severely stressed).

Category	Stressor	% Total (n=27)	% Min (n=13)	% Mod (n=11)	% Sev (n=3)
	Invasive species	70.4	46.2	90.9	100.0
	Agriculture in surrounding landscape	48.1	46.2	54.5	33.3
	Development in surrounding landscape	40.7	7.7	72.7	66.7
	Mowing in surrounding landscape	37.0	30.8	45.5	33.3
	Roads in surrounding landscape	22.2	7.7	36.4	33.3

stressor in 7.4% of wetlands, covering 10 - 75% of the wetland area when detected. Microtopographic alterations were also found in 7.4% of wetlands, though alterations covered <10% of such wetlands. Weirs, dams, or roads were impounding water in only 3.7% of riverine wetlands, and within those wetlands, water was impounded over 10 - 75% of wetland area. Stormwater inputs, point sources, and excessive sedimentation were absent from riverine wetlands in this watershed.

Riverine wetlands had a wide variety of buffer stressors, the most predominant of which were agriculture, development, mowing, and roads in the surrounding landscape (Table 13). Channelized streams or ditches were also somewhat common and were found in landscapes surrounding 18.5% of riverine wetlands. A rarer buffer stressor was landfill or waste disposal, which was only found around 3.7% of wetlands. Poultry or livestock operations, recent forest harvesting, golf courses, and sand or gravel operations were all absent around riverine wetlands.

Figure 14. A large, open-canopy riverine wetland in the Chester-Choptank watershed.

Most riverine wetlands (Figure 14) in this watershed provided moderate value to people and wildlife (44.4%), followed by rich value (33.3%) and limited value (22.2%; Figure 15). Of the attributes assessed, riverine wetlands offered the most value in habitat structure and complexity. All of them had tree cover and surface water suitable for amphibians or macroinvertebrates, and many of them had shrub or sapling cover, herbaceous cover, and coarse woody debris. Riverine wetlands also provided some value for flood storage and water quality, DEN network, habitat availability, and wetland size. Most riverine wetlands were adjacent to surface waters and were capable of moderate to high sediment retention. Some wetlands and their buffer areas were entirely or partially within the DEN network of ecologically significant corridors. On average, 73.9 ± 26.1% of buffer area around riverine wetlands was natural and unfragmented, and wetlands were 124.2 ± 116.3ha in size, ranging widely from 3.5ha to 339.8ha.

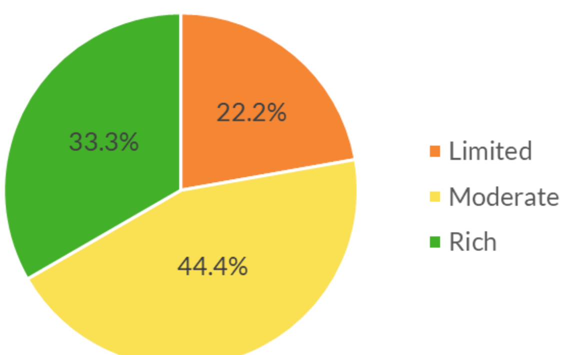


Figure 15. Proportion of riverine wetlands in each value-added category.

In contrast, riverine wetlands overall offered very little value in terms of education potential and uniqueness or local significance. This was because very few were viewable from a public road or had a trail or boardwalk system. Additionally, very few were considered ecologically significant or rare in the landscape, and none were classified as restored, established, or enhanced wetlands.

Non-Tidal Depression Wetlands

The non-tidal depression wetlands in the Chester-Choptank watershed (Figure 16) that were assessed (n=19) all had mineral soils and were all in old growth forests (tree age > 50 years). Depression wetlands had final DERAP scores that ranged widely from 19.0 to 82.0, with a mean score of 72.3 ± 15.2 (median=78.0) out of a maximum possible score of 82.0. The highest proportion of these wetlands was minimally stressed (73.7%), followed by moderately stressed (15.8%) and severely stressed (10.5%; Figure 17). Minimally stressed depressions were mostly affected by microtopographic alterations. Moderately stressed depressions suffered from microtopographic alterations and from development and agriculture in the surrounding landscape. Severely stressed depressions were mostly impacted by

Figure 16. A very wet depression wetland in the Chester-Choptank watershed.

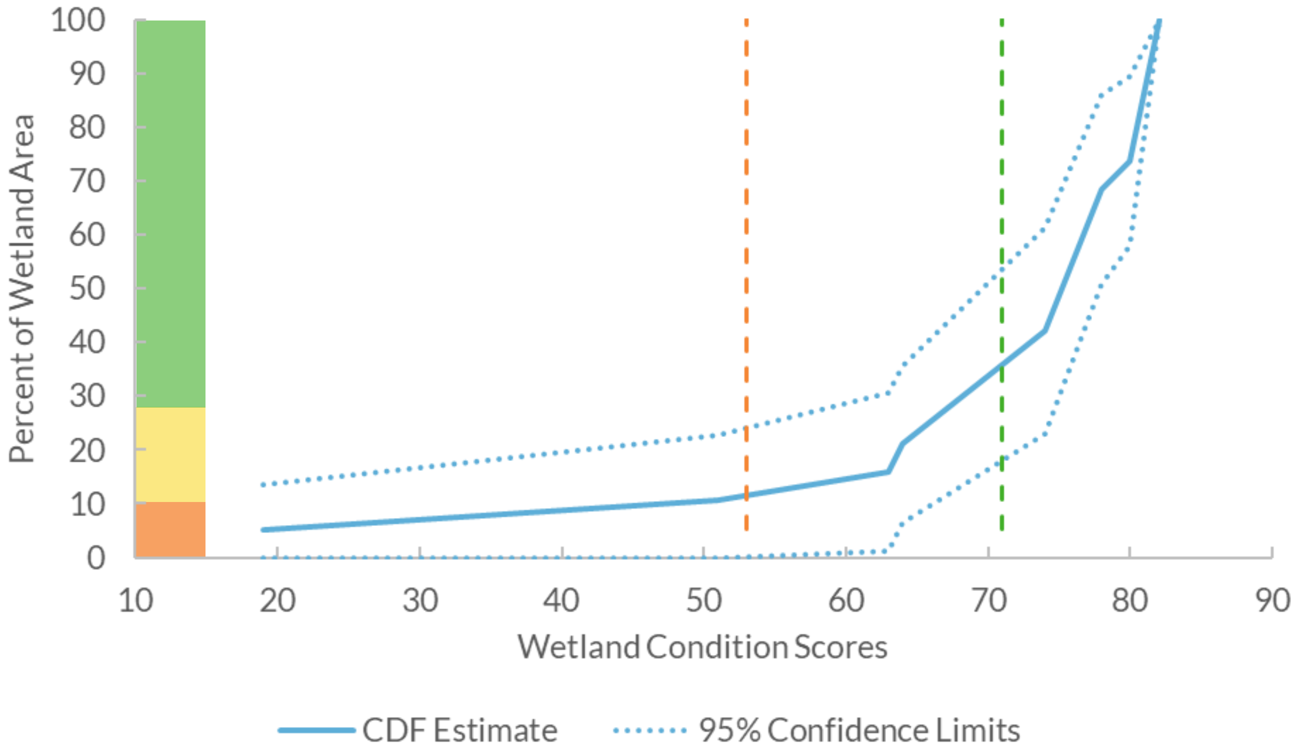
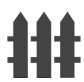


Figure 17. Cumulative distribution function (CDF) for non-tidal depression wetlands in the Chester-Choptank watershed. The solid blue line is the population estimate and the dashed blue lines are 95% confidence intervals. Colored blocks on the y-axis show percent of wetlands within each condition category, where orange is severely stressed, yellow is moderately stressed, and green is minimally stressed. The orange and green dashed lines show the numeric breakpoints between condition categories.

Table 14. Listed are the most common stressors (>20% occurrence) in depression wetlands (see Table 9 for symbol category meanings). Also shown are the occurrence of stressors in each condition category (%min = % minimally stressed; %mod = % moderately stressed; %sev = % severely stressed).

Category	Stressor	% Total (n=19)	% Min (n=14)	% Mod (n=3)	% Sev (n=2)
	Microtopographic alterations	36.8	35.7	33.3	50.0
	Roads in surrounding landscape	21.1	14.3	0.0	100.0
	Development in surrounding landscape	21.1	14.3	66.7	0.0
	Agriculture in surrounding landscape	21.1	7.1	66.7	50.0

microtopographic alterations and roads and agriculture in the surrounding landscape (Table 14). Data for all sampled depression wetlands for all assessed metrics can be viewed in Appendix G.

Habitat stressors were uncommon in depressions in this watershed. The most common habitat stressor was the presence of nutrient indicator species, which was found in 10.5% of depressions. Of those depressions, half were dominated (>50%) by nutrient indicator species, and the other half were not dominated (<50%). Only 5.3% of depressions contained invasive species, farming, and selective cutting of trees. The only invasive species detected was *P.australis*, and where it was present, it covered 6 - 50% of wetland area. Pine plantations, chemical defoliation, excessive herbivory, roads, and dense algal mats were absent from depressions.

Microtopographic alterations were common hydrology stressors (Table 14). Of wetlands with such stressors, most (85.7%) only had <10% cover of alterations, while the rest (14.3%) had 10 - 75% cover. Fill was found in 15.8% of depressions. In all those cases, fill covered 10 - 75% of wetland area. Ditching was far less common and was detected in only 5.3% of depressions, and all ditches were considered slight. No depressions contained weirs, dams or roads, stormwater inputs, point sources, or excessive sedimentation.

Roads, development, and agriculture were the most common buffer stressors surrounding depression wetlands in this watershed (Table 14). Less common buffer stressors included channelized streams or ditches (15.8% of depressions), mowing (15.8%), and recent forest harvesting (10.5%) in the surrounding landscape. Poultry or livestock operations, golf courses, landfill or waste disposal, and sand or gravel operations were not found immediately around depressions.

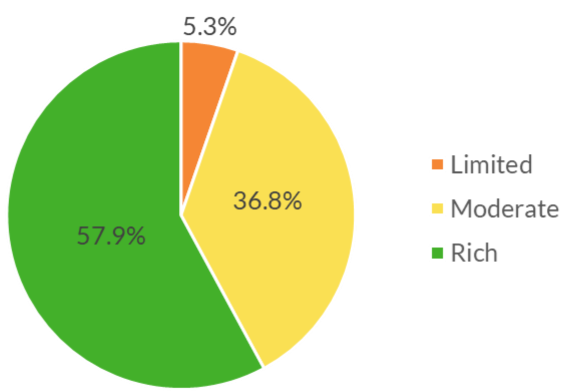


Figure 18. Proportion of depression wetlands in each value-added category.

The highest proportion (57.9%) of depressions were rated as providing rich value to people and wildlife in the watershed. Many were also rated as providing moderate value (36.8%), while few were rated as providing limited value (5.3%; Figure 18). Out of the attributes assessed, depressions offered the most value in terms of habitat structure and complexity and habitat availability. All depressions had shrub or sapling and tree cover, coarse woody debris, and surface water suitable for amphibians or macroinvertebrates. Many also had snags, large downed wood, and natural microtopographic relief. Buffer areas surrounding depressions were, on average, 91.4% ± 14.5% natural and unfragmented.

Depression wetlands also provided some value for flood storage and water quality, DEN network, and wetland size. All depressions had moderate to high sediment retention potential, and many had wet water regimes (i.e. C or wetter in Cowardin classification) and significant water pooling. Some depressions and their buffer areas were entirely or partially within the DEN network of ecologically significant corridors. On the other hand, depressions in this watershed offered low education potential because very few were viewable from a public road, had parking for 2 or more vehicles, or had trails or boardwalk systems. They also offered little in terms of uniqueness and local significance, as few were considered ecologically significant and none were considered rare in the local landscape or enhanced, established, or restored.

Overall Condition and Watershed Comparison

Overall wetland condition in the Chester-Choptank watershed was compared to 10 other watersheds that were previously assessed. To do this, condition proportions were combined (minimally, moderately, and severely stressed) for all major assessed wetland types (flat, riverine, and depression) and were weighted by the acreage of each type in each watershed. Overall, the highest proportion of wetlands in the Chester-Choptank watershed were moderately stressed (58%), followed by minimally stressed (29%) and severely stressed (13%). In terms of overall condition breakdown, the Chester-Choptank watershed was most similar to the Appoquinimink, Inland Bays, and Broadkill watersheds (Figure 19).

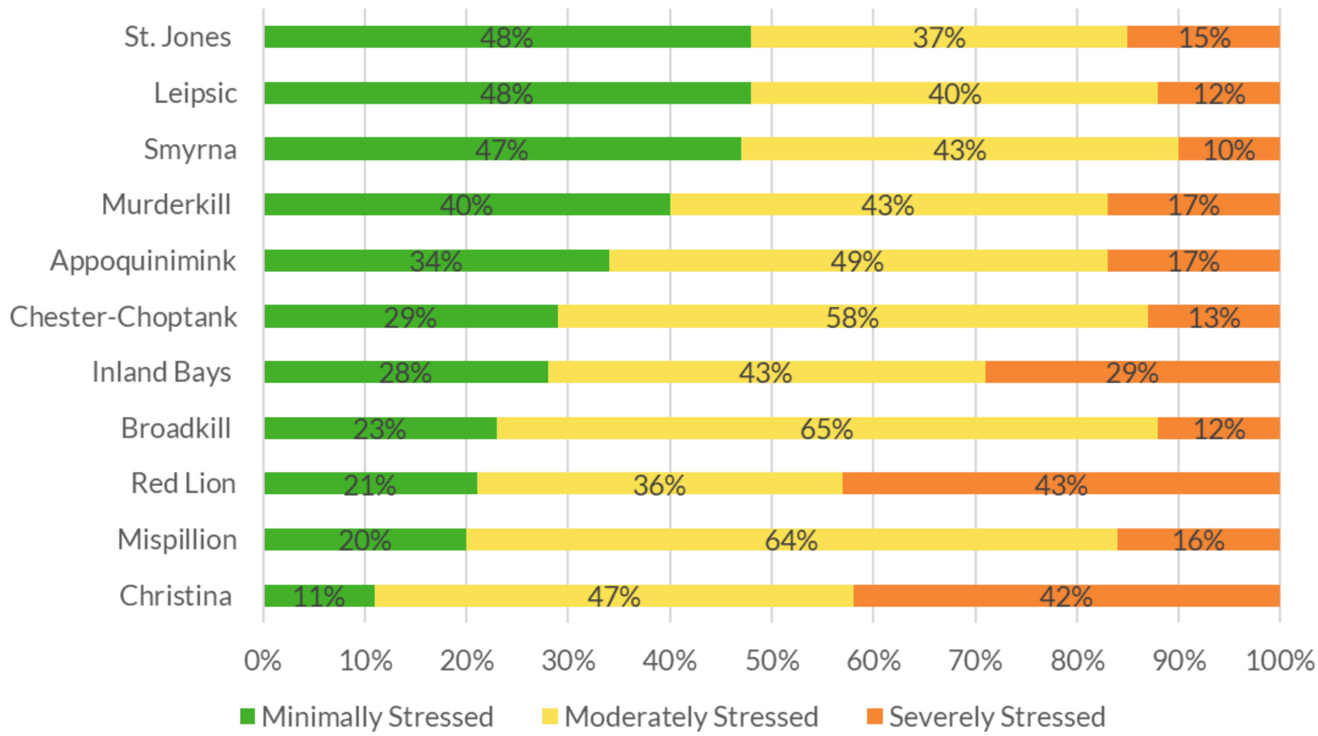


Figure 19. Comparison of overall condition categories for assessed watersheds throughout Delaware. Watersheds are listed in decreasing order of minimally stressed wetlands. Overall percentages shown are based on combined condition category percentages for all assessed wetland types that are weighted based on wetland type acreage for each watershed.

Discussion

Acreage Trends

The Chester-Choptank watershed experienced a small net gain in wetland acreage between 1992 and 2007. However, a high proportion of gained wetland acreage (89.3%) was not natural, vegetated wetlands, but was instead non-vegetated ponds for residential or agricultural uses (see example in Figure 20). These ponds usually had little to no natural buffer area around them, making them very vulnerable to indirect impacts such as polluted runoff and sedimentation. Most of these ponds were classified as unconsolidated bottom, areas of which have less than 30% aerial vegetative cover (FGDC 2013).

The Chester-Choptank watershed also gained a small amount of non-tidal palustrine wetlands that were classified as flats, riverine wetlands, or depressions, though these only represented 10.7% of total gained acreage. Most of these gained wetlands had emergent vegetation, with fewer having forest or scrub shrub vegetation. The fact that they were vegetated likely increased their chances of providing moderate to high function levels in services such as nutrient transformation, retention of sediments and pollutants, conservation of biodiversity, climate mitigation, and provision of wildlife habitat (Tiner 2003; Howard et al. 2017). However, all of these were partially bordered or entirely surrounded by housing developments or agriculture. Such stressors can reduce wetland condition through polluted runoff or reduced wetland habitat connectivity (Faulkner 2004; Brand et al. 2010), thereby reducing the ability of those wetlands to perform beneficial functions fully.

Figure 20. An example of a gained non-vegetated pond (outlined in blue) in an agricultural field between 1992 (left) and 2007 (right).

Approximately 12% of the wetlands gained in this watershed from 1992 to 2007 were because of wetland restoration or creation. Some were passive and were the result of inactivity on old agricultural fields, while other restored wetlands were man-made near active agricultural operations. The functionality of restored wetlands varies greatly depending on characteristics such as vegetation and hydrologic regime. Wetland restoration should continue, but care should be taken for restored wetlands to resemble natural wetland types and functions in the local landscape as closely as possible. This could help ensure that some of the wetland types and functions that have been lost are being replaced. However, it is extremely difficult to mimic natural wetland characteristics in wetland restoration and it may take a long time or never reach natural conditions (Moreno-Mateos et al. 2012). It has also been noted that many wetlands that have been created in response to unavoidable impacts in Delaware have not been the same wetland types as those that were lost, which suggests that wetland functions being lost are not being appropriately replaced (Haywood et al. 2020). It is therefore essential to not only continue to carefully restore wetlands but to curb losses of natural wetlands as well.

Wetland losses that occurred between 1992 and 2007 were because of construction of rural houses or housing developments, or because of agriculture (i.e. row crops, livestock, or poultry). Nearly all the wetlands lost were natural non-tidal wetlands, particularly flat and depression wetlands, that were in a headwater region of the Chesapeake Bay. Because these wetlands were lost completely and converted to another land use, all functions that these headwater wetlands performed were also lost entirely, including stream flow maintenance and groundwater recharge (Yeo et al. 2019a, b). This indicates that the lack of non-tidal wetland regulation in the state of Delaware, along with weak or inconsistent federal regulation and relaxed county requirements, have resulted in the continued destruction of non-tidal wetlands. These results aligned closely with trends seen statewide, as agriculture and residential development were noted as being the leading causes for losses of vegetated palustrine wetlands throughout all of Delaware (Tiner et al. 2011). It is possible, however, that some losses were permitted losses that were mitigated in some way. Wetland mitigation can, if done properly, help offset some functional losses.

When relating gains and losses, it is important to note that most losses were flat or depression wetlands, yet the majority of wetlands gained were man-made ponds. Headwater forested flats and depressions are valuable for their water filtration capacity and ability to provide habitat. The functions being offered by open water ponds do not match those being lost by destruction of flats and depressions. Non-vegetated agricultural or residential ponds can be beneficial to some generalist species by providing habitat where natural wetlands are scarce (Brand and Snodgrass 2009; Tiner et al. 2011). However, such wetlands most often do not provide the same functional value as natural wetlands, in part because they are largely non-vegetated, usually occur in a developed or agricultural landscape, and may be disconnected from groundwater because of liners. They may provide lower levels of certain functions, such as nutrient transformation, carbon sequestration, and sediment retention (Tiner 2003; Brand et al. 2010; Tiner et al. 2011; Howard et al. 2017).

Stormwater retention ponds have been shown to support fewer wetland-dependent plant and bird species compared with natural wetlands; this may in part be a result of their physical dissimilarities with natural wetlands, including steeper slopes and different and less variable hydroperiods (Rooney et al. 2015). Stormwater ponds may also have different water chemistry, organic matter, and invertebrate communities compared with natural wetlands (Woodcock et al. 2010). Agricultural ponds may also provide wildlife habitat that is lower in quality than natural wetlands. For example, tadpoles may suffer reduced survival or growth rates in agricultural ponds because of polluted runoff from agricultural land (Peltzer et al. 2008). Thus, created ponds usually do not resemble natural wetlands and do not replace lost natural wetland functions. Non-tidal wetlands that changed from natural wetlands to non-vegetated, excavated ponds experienced a relative decrease in ecosystem function for this same reason.

Increased protection, regulation, enforcement, and mitigation in non-tidal wetlands are necessary to prevent further acreage and function losses. Stricter regulations should prevent as much non-tidal wetland loss as possible. Where impacts are permitted, mitigation requirements should be strongly enforced, and significant effort should be made to replace wetland types and functions lost. Regulations should encompass all non-tidal palustrine wetlands, regardless of size. Although some palustrine wetlands tend to be small and geographically isolated, these types of wetlands often have specific characteristics, such as hydroperiod, that are crucial to the survival and reproduction of amphibians (Babbitt 2005), making them just as important to protect as larger wetlands. These geographically isolated wetlands are also important for base stream flow, groundwater recharge, and sediment retention and can in some cases perform such functions better than other wetland types (Cohen et al. 2016, Yeo et al. 2019a, b).

Non-tidal wetland losses also indicate that more education and outreach is needed for private landowners. In 2007, most unregulated non-tidal wetlands were under private ownership (unpublished). By understanding the benefits that wetlands provide, landowners may be more willing to participate in voluntary conservation efforts. This idea is supported by results from a recent survey conducted in Delaware that showed that landowner perception of wetlands became more positive once landowners were presented with facts about wetlands (DNREC and OpinionWorks 2017).

Some wetlands changed type between 1992 and 2007 in this watershed. Some riverine and depression wetlands changed from natural, vegetated wetlands to non-vegetated excavated or impounded ponds. As discussed above, created ponds do not resemble natural wetlands and do not replace natural wetland functions, meaning that riverine and depression wetlands that experienced these changes likely experienced declines in ecosystem functions. Most wetland changes (88.3%) in this watershed, however, were caused by forestry activities that clear-cut blocks of forested flat wetlands, shifting many flats from forest to emergent vegetation (Figure 21). This may not be surprising, as wet forests in the Chesapeake Bay drainage basin have often been used for timber supply if they cannot be farmed (DNREC 2001). If those forests recover, they may regain their functional capacity over time. However, if they are not allowed or able to recover following clear-cutting, they

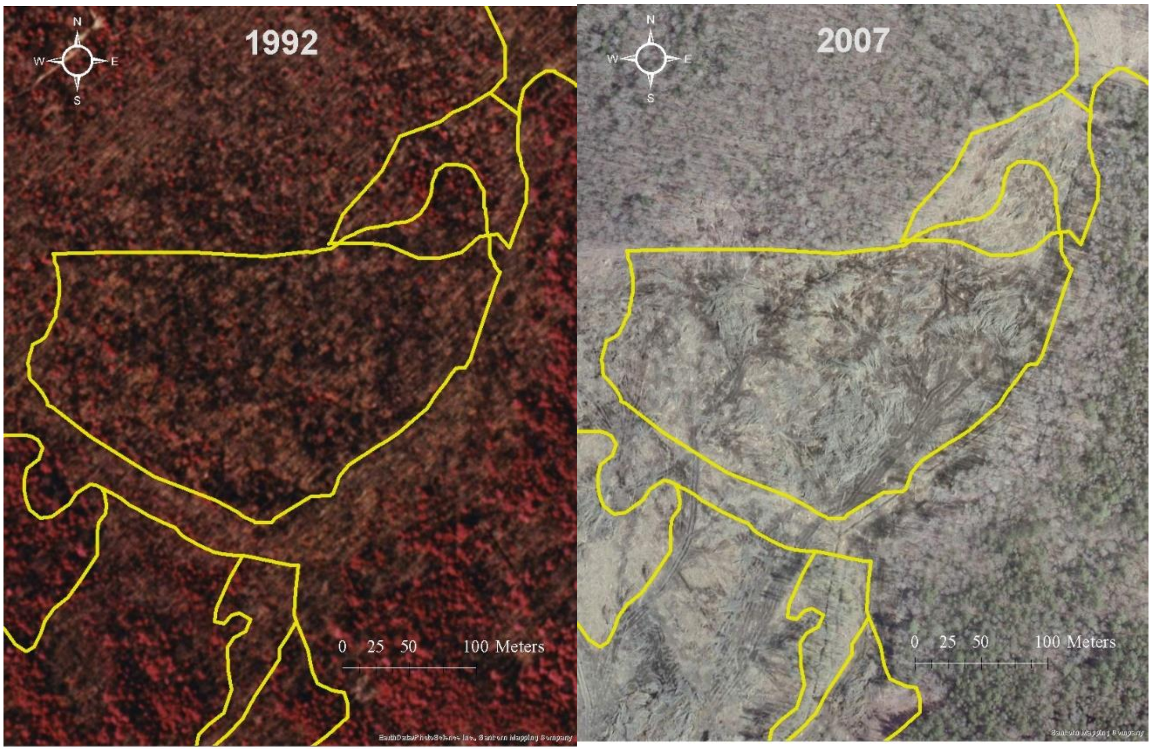


Figure 21. Example of a cluster of non-tidal flat wetlands (outlined in yellow) that changed from forested in 1992 (left) to emergent in 2007 (right) due to clear cutting.

may suffer either reduced or different functionality. For example, dramatic changes in vegetation can strongly affect the wildlife that use wetlands, as different species specialize in forest versus emergent habitat. Large vehicles and equipment associated with clear-cutting may cause irreversible soil compaction and microtopography, which could negatively affect plant regrowth, water filtration and water pooling. Furthermore, loss of tree canopy can lead to a higher water table as more precipitation is able to reach the ground and less is transpired through tree leaves (Jiang 2016). Clear cutting in wetlands should be avoided wherever possible because of these potential consequences. Selective or partial cutting may reduce negative effects on wetland ecosystems in cases where forestry impacts are inevitable. Also, efforts to restore soil condition and encourage healthy plant community regrowth is encouraged.

Non-Tidal Wetland Condition and Value

Buffer stressors were the most widespread types of stressors across all three non-tidal wetland types in the Chester-Choptank watershed. Agricultural activities, development, and roads were common in the landscapes surrounding wetlands of all three types. Mowed areas were also present around numerous flats and riverine wetlands, and channelized streams or ditches were fairly common around flats. Such unnatural land uses adjacent to non-tidal wetlands indicated that buffer zones around these wetlands were degraded. Buffers are natural areas adjacent to wetlands that can provide wildlife habitat and help shield wetlands from indirect impacts. Natural buffer areas surrounding wetlands can be just as important as wetlands, if not more so, to amphibians and reptiles, many of which require forested habitats adjacent to wetlands for foraging, overwintering, and habitat corridors for movement among wetlands (Semlitsch and Bodie 2003; Quesnelle et al. 2015; Finlayson et al. 2017).

Runoff polluted with chemicals and excess nutrients and sediment from agricultural fields, development, roads, or mowed areas can enter wetlands directly if natural buffers do not separate wetlands from anthropogenic activities. Stream channelization in buffers surrounding wetlands can affect wetland hydrology by influencing water flow into or away from the wetland. These data identify a clear need to conserve and improve buffers around non-tidal wetlands. Additionally, the prevalence of agriculture and development near wetlands highlights the importance of utilizing BMPs. Such responsible practices, including things like cover crops, limited mowing, vegetated riparian buffers, reduced fertilizers, and agricultural waste containment, would dampen effects of indirect impacts by reducing harmful runoff of waste, excess nutrients, and chemicals (EPA 2003, 2005).

Overall, non-tidal wetlands were in good habitat condition. Despite this, invasive plant species were fairly common in riverine wetlands. Invasive species can rapidly displace the native species that characterize high-functioning wetlands and that provide vital habitat for wildlife, thus decreasing wetland condition. It is also incredibly difficult to eradicate many invasive plant species once they are established. Therefore, invasive species should be removed or controlled as soon as possible both within and adjacent to riverine wetlands.

The most pervasive habitat stressor in flats was selective cut harvesting. While not as damaging as clear cutting, selective cut harvesting can still affect the quality of wildlife habitat provided by wetlands. All habitat stressors had relatively low occurrence (i.e. present in ≤20% of wetlands) in depressions. Wetland preservation efforts in this watershed should aim to keep natural habitat features of non-tidal wetlands intact, while restoration activities should target the specific issues highlighted here.

Non-tidal wetlands were in good or fair condition for hydrology with the exception of some ditching and microtopographic alterations in flats and microtopographic alterations in some depressions. All of these stressors can degrade natural wetland hydrology by increasing, decreasing, or altering the flow of water through wetlands. When hydrology is disturbed, soil moisture and groundwater levels may be reduced (Faulkner 2004). Such disturbances have the potential to affect wetland plant communities, which are adapted to live in certain hydrologic conditions. Therefore, rehabilitation efforts in flats and depressions should target these hydrological issues to reestablish natural functions. Riverine wetlands were in the best hydrological condition, as hydrology stressors were relatively rare. Wetland preservation efforts in this watershed should aim to keep natural hydrology of non-tidal riverine wetlands intact.

Over half of all wetland types were privately owned. With so many wetlands on private property, it is clear that state non-tidal wetland regulation and enforcement needs to be established to prevent further wetland loss and degradation, particularly because palustrine wetland condition was reduced largely by human impacts in this watershed. The high proportion of private ownership also highlights the need for more education and outreach for private landowners. By understanding the benefits that wetlands provide and simple ways to conserve wetlands, landowners may be more willing to participate in conservation efforts voluntarily.

A combination of wetland restoration and conservation is needed in the Chester-Choptank watershed. Most riverine and depression wetlands were characterized as minimally stressed, so conservation should be the focus for those wetland types. If intact wetlands are maintained, communities will continue to benefit from the functions they provide, and money will not need to be spent on their restoration or the replacement of beneficial services in the future. Most flat wetlands were moderately stressed, so restoration should be the focus for flats. Projects should pay special attention to common stressors that were detected in flats this watershed. For example, habitat conditions should be restored as soon as possible post-timbering, and microtopographic alterations should be reduced to help promote natural hydrology. It is easier and cheaper to restore wetlands that are moderately stressed compared with those that are severely stressed or destroyed, so rehabilitation activities should be conducted as soon as possible to ensure that condition of flat wetlands does not decline further. Preservation of flats should also occur where possible as well because preserved wetlands are less likely to be destroyed or impacted by human activities.

Highlighting the specific local values that non-tidal wetlands provided in this watershed, such as habitat availability and habitat structure and complexity, makes the case for increased protection of non-tidal palustrine wetlands even more compelling. Value-added data can also be used to inform wetland restoration and enhancement projects by focusing on improving value characteristics that were rated poorly in this watershed, such education potential, to heighten their value to the local landscape. Moreover, many moderately and severely stressed non-tidal wetlands were still rated as providing moderate to rich value to the local landscape. This shows that in some ways even unhealthy wetlands can be very valuable to local communities and wildlife, which strengthens the case for conservation and restoration of wetlands, even those in poor or declining condition.

Management Recommendations

20 Years of Progress in the Chesapeake Basin

In 2001, DNREC compiled the Chesapeake Basin Report (DNREC 2001). Part of that report highlighted wetland data gaps and identified recommendations to improve wetland knowledge, condition, and protection. Since that time, DNREC's WMAP has addressed some of these gaps and recommendations. For example, DNREC described a need to investigate the sources and locations of wetland losses in the Chesapeake Bay basin (DNREC 2001). This current report addresses much of that need by showing that wetland losses in recent years in the Chester-Choptank watershed have been caused mainly by agriculture and development, and that most losses have occurred in the Kent County portion of the watershed. DNREC also recommended adopting a wetland plan. Beginning in 2008, DNREC has continued to lead the compilation of a Delaware Wetland Strategy or Management Plan, which WMAP currently updates every five years with their partners (DNREC 2015a).

This Chester-Choptank assessment and reporting effort was an action item in that wetland plan. Another recommendation was to reach out to landowners to educate them about things such as wetland ecosystem services, the effects of ditching and draining, planting native instead of invasive species, using BMPs to reduce nonpoint source pollution, and how to protect and restore wetlands on private property (DNREC 2001). Part of WMAP's current mission is to educate the public about the benefits of wetlands as well as the harms of wetland impacts, meaning that wetland public outreach is continuously occurring and being improved upon. For instance, a wetland health report card was created to accompany this Chester-Choptank report that was designed to educate the public about local wetlands and ways they can help improve wetland condition in the watershed. All of these examples show that significant progress has been made to address wetland management gaps over the past 20 years in the Chesapeake Basin in Delaware.

Looking Forward

Despite positive steps forward, wetland loss and degradation have continued in the Chesapeake Bay basin, such as in the Chester-Choptank watershed. In this section, information was synthesized about wetland acreage trends, ambient wetland condition, and value-added characteristics to identify explicit wetland conservation and management goals for the Chester-Choptank watershed. Management recommendations were developed that identify specific actions that can be taken to accomplish the major goals that were outlined in the discussion (see 'Discussion' section above). Wetland conservation is most likely to be effective when many audiences with different backgrounds and interests are collaboratively involved, and when a variety of different approaches are used (Calhoun et al. 2014, 2017). Thus, a wide range of actions were tailored to several different audiences, including environmental scientists, researchers, and land managers, decision makers, and landowners, all of whom play an important role in protecting and restoring wetlands. Management recommendations and associated action items are summarized in Table 15 and are described in more detail below. Many recommendations made in this report are consistent with those identified in the 2001 Chesapeake Basin Report (DNREC 2001), the 2008 PCS developed by the Upper Chesapeake Watershed Tributary Action Team (KCI Technologies, Inc. and DNREC 2014), and Delaware's Phase III WIP (DNREC 2019). For example, Delaware's Phase III WIP (DNREC 2019) strongly emphasizes the use of long-term practices to benefit the Chesapeake region, including wetlands and riparian buffers. This coincides with the recommendations to protect and restore wetlands and their buffers in this watershed.

Table 15. Summary of management recommendations and associated action items for different audiences.

	Recommendation	Action Summary
Environmental Scientists, Researchers, and Land Managers	Support vegetated buffers for non-tidal wetlands	1. Secure funding for improving and protecting buffers.
	Continue to increase citizen education and involvement through effective outreach.	1. Create outreach materials tailored to specific audiences.
		2. Encourage hands-on public participation in wetland stewardship activities.
	Perform wetland monitoring, conservation, and restoration activities.	1. Continue to monitor wetland condition and stressors to guide restoration efforts.
		2. Preserve or restore wetlands through land acquisitions or conservation easements.
	Improve coordination of watershed-based efforts both within and among agencies and municipalities	1. Evaluate results from wetland, stream, and water quality studies with a whole-watershed framework.
Decision Makers (State, County, Local)	Improve regulatory protection of non-tidal wetlands through state, county, and local programs.	1. Create a state regulatory program for non-tidal wetlands that includes small and geographically isolated wetlands.
		2. Create incentives to encourage landowners to protect wetlands on their property.
		3. Enforce mitigation requirements where wetland impacts are unavoidable.
	Develop incentives and legislation to establish, maintain, or improve natural wetland buffers.	1. Increase buffer width to at least 75ft around non-tidal wetlands and regularly enforce regulations.
		2. Create incentives to encourage landowners to protect wetland buffers on their property.
		3. Encourage the use of BMPs in development and agriculture to reduce nonpoint source pollution to nearby wetlands.
	Secure funding for wetland rehabilitation and preservation.	1. Support and expand programs in Delaware that conserve wetlands.
Landowners	Protect and maintain the buffers around wetlands.	1. Plant native plants in buffer areas along wetlands and waterways.
		2. Avoid activities like mowing, development, grazing, etc. in buffer areas along wetlands and waterways.
	Preserve or restore wetlands that are on private property.	1. Protect wetlands in their natural states through conservation easements.
		2. Remove invasive plants and plant only native species.
		3. Avoid ditching and draining, mowing, and driving heavy equipment through wetlands.
	Utilize best management practices (BMPs) in agricultural operations and in suburban settings.	1. Use BMPs in agricultural practices to reduce nonpoint source pollution and indirect impacts to wetlands.
		2. Use BMPs in suburban areas to reduce nonpoint source pollution and indirect impacts to wetlands.

Environmental Scientists, Researchers, and Land Managers

1. **Support vegetated buffers for non-tidal wetlands.** There is a clear need to establish, improve, and maintain adequate natural, vegetated buffers around non-tidal wetlands in this watershed. Such work would help minimize indirect impacts and ensure that wetlands can persist and function. Currently, New Castle County requires 50ft buffers and Kent County requires 25ft buffers around non-tidal wetlands. Buffer width around non-tidal wetlands should increase to at least 75ft, and all buffer regulations should be more strongly and regularly enforced. Funding should be secured for improving buffers on currently protected lands, and for acquiring buffer land to extend riparian habitat corridors and connect more habitat hotspots.

2. **Continue to increase citizen education and involvement through effective outreach.** Over half of all sites that were sampled in the Chester-Choptank watershed were privately owned, and wetland loss and degradation were largely caused by human impacts. By increasing wetland education to landowners and informing them about the benefits wetlands can provide, landowners may be more willing to take part in voluntary stewardship activities that can benefit wetlands around them, thereby decreasing wetland loss and degradation. To accomplish effective public outreach, it is incredibly important to identify your audience, create an active dialogue with landowners, to encourage active, hands-on participation in discussions and activities, and to create an understanding of how wetlands are relevant to the public (Calhoun et al. 2014, Varner 2014). For example, in order to address the goal of increased landowner wetland stewardship, DNREC's WMAP created a website called the Freshwater Wetland Toolbox in 2017 that allows landowners to look up their property and locate wetlands, highlighting ways to care for backyard wetlands (see link on pg. 52). More outreach tools and programs should be created to address other specific public education goals. Such tools and programs should constantly be evaluated to gauge their effectiveness in addressing goals and to improve outreach efforts (Varner 2014).

3. **Perform wetland monitoring, conservation, and restoration activities.** It is essential to monitor wetland condition to detect common stressors and address them as quickly as possible. Because most wetlands were moderately or minimally stressed in this watershed, a combination of rehabilitation and preservation can greatly increase the overall health of these wetlands. When possible, environmental organizations can work to preserve or restore wetlands that are not currently protected through land acquisition or conservation easement, particularly because only 20.7% of vegetated wetlands in this watershed were on protected lands. This would help curb wetland acreage losses in this watershed while also protecting their health. Projects should account for watershed-specific conditions. For example, the overall intact habitat features of non-tidal wetlands should be kept in place, while the buffer stressors of all wetland types should be addressed. Value added results can also strengthen cases for wetland conservation and restoration and inform wetland enhancement goals. For instance, the fact that all non-tidal wetland types provided significant value in terms of habitat availability and habitat structure and complexity in this watershed could fortify arguments for wetland conservation. Care should be taken when restoring wetlands to have them resemble natural, vegetated wetlands as closely as possible. Professionals can use landscape-level screening tools such as the Delaware Watershed Resources Registry (WRR) to help locate highly suitable areas for wetland restoration and preservation (WRR 2017).

4. **Improve coordination of watershed-based efforts both within and among agencies and municipalities.** It has been demonstrated from thorough data collection that non-tidal wetlands, as well as many waterbodies, within the Chester-Choptank watershed are degraded from direct and indirect human impacts. To best improve water quality, habitat quality, and wetland function in this watershed, state and local environmental agencies and municipalities should better coordinate efforts. Water resources should not be assessed and reported independently of one another but should rather be viewed as parts of the whole watershed. Improved coordination could help maximize funding opportunities, reduce any

redundancy of data collection efforts, and make clearer management recommendations.

Decision Makers (State, County, and Local)

1. **Improve regulatory protection of non-tidal wetlands through state, county, and local programs.** Without increased regulatory protection, loss of non-tidal wetlands in the Chester-Choptank watershed will probably continue, especially because all losses in this watershed were because of direct human impacts (i.e. development and agriculture). Acreage losses will translate into loss of ecosystem services and values. Wetland type and function changes associated with clear cutting of forested wetlands may continue without increased protection as well. Degradation of non-tidal wetlands from anthropogenic stressors, such as those commonly found in the Chester-Choptank watershed (e.g. ditching, selective cut harvesting, or microtopographic alterations), will likely also continue without increased protection. In addition, fewer than 25% of all non-tidal wetland types were located on protected land, leaving them vulnerable to impacts. These facts highlight the need for improved protection to fill the gaps left by very recent changes to the definitions of the WOTUS and to address the lack of state regulation. Conservation of non-tidal palustrine wetlands will likely be most effective if state regulation is combined with smaller-scale efforts from counties, local governments and organizations, stakeholders, and landowners. Such collaborative efforts can make everyone feel involved and informed, while successful solutions can be reached that simultaneously conserve wetlands and integrate interests of many parties (Calhoun et al. 2014, 2017). A state regulatory program in concert with county and local programs would reduce the ambiguity surrounding non-tidal wetland regulation and provide a comprehensive and clear means to protect these wetlands in the entire state. Regulations should aim to protect palustrine wetlands of all sizes and should include geographically isolated wetlands. Local regulations can be incorporated into municipal and/or county code and homeowner associations to protect wetland areas of special significance. In addition, the development of incentives programs could attract landowner interest in conserving wetlands and the beneficial ecosystem services that they provide. Where impacts are permitted, mitigation requirements should be strongly enforced, and effort should be made to replace wetland types and functions lost.

2. **Develop incentives and legislation to establish, maintain, or improve natural wetland buffers.** The data presented in this report demonstrate a clear need for establishment, improvement, or maintenance of natural buffers around non-tidal wetlands. To further improve wetland condition, buffers need to be kept as wide as possible, and development, agriculture, and roads within buffer areas needs to be prevented. Currently, New Castle County requires 50ft buffers and Kent County requires 25ft buffers around non-tidal wetlands. Buffer width around non-tidal wetlands should increase to at least 75ft, and all buffer regulations should be more strongly and regularly enforced. Incentive programs could also attract landowner interest in maintaining natural buffers between non-tidal wetlands and human activity to reduce negative indirect impacts to wetlands and provide crucial wildlife habitat. Development of incentives or legislation or improvements to any existing local legislation for buffer setbacks would help to prevent further buffer degradation or destruction. Additionally, municipalities and developers should be encouraged to use BMPs to reduce indirect impacts to wetlands from nonpoint source pollution. Aside from maintaining natural buffers, BMPs could include preserving open space in urban areas, using permeable paving materials, rebuilding in areas that were previously constructed, and enacting slope restrictions for building to discourage erosion (EPA 2005).

3. **Secure funding for wetland rehabilitation and preservation.** Overall, 58% of wetlands were moderately stressed and 13% of wetlands were severely stressed in the Chester-Choptank watershed, meaning that restoration can make a large impact on improving wetland health in this watershed. Specifically, efforts should focus on rehabilitation, or the restoration of lost features and functions within existing wetlands. As 29% of wetlands were minimally stressed in this watershed, it is important to prioritize wetland preservation as well. Preservation of wetlands that are already healthy will ensure that they continue to provide beneficial ecosystem services in the future, while preservation of less healthy wetlands can

reduce the likelihood of further degradation and increase the likelihood that rehabilitation actions will occur. Funding should be secured to continue and expand programs that already exist in Delaware that can help conserve wetlands, including the Delaware Open Space Program (DNREC n.d.-b) and the Delaware Forestland Preservation Program (DE DDA n.d.). New funding opportunities should also be explored. If new wetlands are created, care should be taken to replace the same type of wetland and to replicate natural features and processes as much as possible. Note that storm water wetlands and ponds are not functional substitutes for natural, vegetated wetlands.

Landowners

1. **Protect and maintain the buffers around wetlands.** Buffers are natural, vegetated areas adjacent to wetlands that can help wetlands stay in good condition. Wetland buffers trap sediments and excess nutrients and filter pollutants before they reach wetlands. Buffers also slow storm water runoff from nearby impervious surfaces, such as roads. In this way, buffers can protect wetlands from some of the negative indirect impacts associated with roads, development, and agriculture that prevent wetlands from functioning at their fullest capacity. Buffers are also vital for the survival of wetland wildlife, including many species of reptiles and amphibians. In the Chester-Choptank watershed, wetland buffers were degraded or entirely absent due mostly to development, agricultural activities, and roads. When buffers are degraded in this way, they do not perform ecosystem services to the same degree as when buffers are undisturbed. To maintain natural wetland buffers, avoid anthropogenic activities (e.g., development, stream channelization, ditching, agriculture, or mowing) adjacent to and within existing buffers. Buffers can also be maintained by planting native plant species between open spaces and waterways.

2. **Preserve or restore wetlands that are on private property.** Over half of the wetlands in the Chester-Choptank watershed were located on privately-owned land, and less than a quarter of vegetated wetlands were on protected land. This means that landowners play an important role in maintaining wetland acreage and function through wetland protection and stewardship. There are many ways that landowners can engage with the natural wetlands right in their backyards whether they have a small property or own a large area. For large landholdings, one of the best ways to do so is to protect or restore wetlands through conservation easements, which can be accomplished through programs such as the Agricultural Conservation Easement Program (ACEP; NRCS n.d.-a) or the Delaware Forestland Preservation Program (DE DDA n.d.). Easements can protect wetlands in their natural state from future development for a number of years or permanently. One potential resource to identify other wetland preservation or restoration options is the Wetlands Work website by the Chesapeake Bay Program (CBP 2021). For smaller property owners, planting native species and removing invasive species are two other important actions, especially because invasive species were common in riverine wetlands in this watershed. They can also avoid mowing grasses and picking up downed logs and branches within wetlands because those features provide important habitat for wildlife. In addition, leaving the hydrology intact by allowing waterways to flow naturally without being dug out or straightened and by not adding ditches or trenches to drain wet areas will help ensure that wetlands will remain healthy and fully functioning. Landowners can also avoid driving vehicles or heavy equipment through wetlands to minimize negative effects on hydrology. WMAP's Freshwater Wetland Toolbox website allows landowners to see if wetlands exist on their property and to discover more ways in which they can benefit wetlands on their land (see link on pg.52).

3. **Utilize BMPs in agricultural operations and in suburban settings.** In this watershed, agriculture, development, and roads were found near many non-tidal wetlands, suggesting that indirect effects on wetlands were occurring from surrounding land use. Utilizing BMPs in agricultural operations can greatly reduce the amount of waste, sediments, chemicals, and nutrient runoff from fields, thereby reducing the potential for indirect wetland impacts from non-point source pollution. Some examples of beneficial

BMPs include use of cover crops, precision farming, exclusion of animals from waterways, crop rotation, tree planting, proper animal waste management, and avoidance of over-grazing (EPA 2003). Similarly, BMPs can also be used in suburban settings to limit effects of non-point source pollution. These include practices such as washing cars on grass, properly disposing of pet waste and chemicals, minimizing use of fertilizers and pesticides on lawns, installing rain barrels or gardens, and installing pervious pavement at home (EPA 2005). Not surprisingly, the Upper Chesapeake Watershed Tributary Action Team identified many of these BMPs in their pollution control strategy in 2008 to reduce water pollution (KCI Technologies, Inc. and DNREC 2014), and results highlighted in this report further support their pollution control strategy. Utilizing BMPs would also be consistent with Delaware's Phase III WIP for the Chesapeake Bay, where the Chester-Choptank watershed was highlighted as an area of special interest for installing BMPs to reduce nutrient pollution (DNREC 2019). DNREC's Non-Point Source Program provides some funding opportunities to help landowners and other public or private entities reduce non-point source pollution, such as the Section 319 grant (DNREC n.d.-c) and the Chesapeake Bay Implementation grant program (DNREC n.d.-d). Funding for BMPs is also available through several programs administered by the Natural Resources Conservation Service (NRCS n.d.-b). Delaware's Livable Lawns program is another great resource for landowners as it provides information about how to make lawncare more friendly to waterways (Delaware Livable Lawns 2020).

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Acronyms

All acronyms used in this report are defined in the table below. Acronyms are listed in alphabetical order.

Acronym	Definition
AA	Assessment Area
ACEP	Agricultural Conservation Easement Program
AIC	Akaike's Information Criteria
BMP	Best Management Practice
CDF	Cumulative Distribution Function
DECAP	Delaware Comprehensive Assessment Procedure
DelDOT	Delaware Department of Transportation
DEN	Delaware Ecological Network
DERAP	Delaware Rapid Assessment Procedure
DNREC	Department of Natural Resources and Environmental Control
EMAP	Ecological Monitoring and Assessment Program
EPA	Environmental Protection Agency
GIS	Geographic Information Systems
HGM	Hydrogeomorphic
HUC	Hydrologic Unit Code
IWC	Index of Wetland Condition
LLWW	Landscape Position, Landform Type, Waterbody Type, Waterflow Path
LULC	Land Use and Land Cover
NLCD	National Land Cover Dataset
NRCS	Natural Resources Conservation Service
NWI	National Wetland Inventory
PCS	Pollution Control Strategy
QDR	Qualitative Disturbance Rating
SGCN	Species of Greatest Conservation Need
SWMP	Statewide Wetland Mapping Project
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
WIP	Watershed Implementation Plan
WMAP	Wetland Monitoring and Assessment Program
WOTUS	Waters of the United States
WRR	Watershed Resource Registry

Appendix A: Qualitative Disturbance Rating (QDR) Category Descriptions

Qualitative Disturbance Rating: Assessors determine the level of disturbance in a wetland through observation of stressors and alterations to the vegetation, soils, and hydrology in the wetland site, and the land use surrounding the site. Assessors should use best professional judgment (BPJ) to assign the site a numerical Qualitative Disturbance Rating (QDR) from least disturbed (one) to highly disturbed (six) based on the narrative criteria below. General description of the minimal disturbance, moderate disturbance, and high disturbance categories are provided below:

A) **Minimal Disturbance Category (QDR one or two):** Natural structure and biotic community maintained with only minimal alterations. Minimal disturbance sites have a characteristic native vegetative community, unmodified water flow into and out of the site, undisturbed microtopographic relief, and are in a landscape of natural vegetation (100 or 250m buffer). Examples of minimal alterations include a small ditch that is not conveying water, low occurrence of invasive species, individual tree harvesting, and small areas of altered habitat in the surrounding landscape, which does not include hardened surfaces along the wetland/upland interface. Use BPJ to assign a QDR of one or two.

B) **Moderate Disturbance Category (QDR three or four):** Moderate changes in structure and/or the biotic community. Moderate disturbance sites maintain some components of minimal disturbance sites such as unaltered hydrology, undisturbed soils and microtopography, intact landscape, or characteristic native biotic community despite some structural or biotic alterations. Alterations in moderate disturbance sites may include one or two of the following: a large ditch or a dam either increasing or decreasing flooding, mowing, grazing, moderate stream channelization, moderate presence of invasive plants, forest harvesting, high impact land uses in the buffer, and hardened surfaces along the wetland/upland interface for less than half of the site. Use BPJ to assign a QDR of three or four.

C) **High Disturbance Category (QDR five or six):** Severe changes in structure and/or the biotic community. High disturbance sites have severely disturbed vegetative community, hydrology, and/or soils as a result of ≥ 1 severe alterations or > 2 moderate alterations. These disturbances lead to a decline in the wetland's ability to effectively function in the landscape. Examples of severe alterations include extensive ditching or stream channelization, recent clear cutting or conversion to an invasive vegetative community, hardened surfaces along the wetland/upland interfaces for most of the site, and roads, excessive fill, excavation or farming in the wetland. Use BPJ to assign a QDR of five or six.

Appendix B: DERAP Stressor Codes and Definitions

Habitat Category (within 40m radius of sample point)	
Hfor50	Forest age 31-50 years
Hfor30	Forest age 16-30 years
Hfor15	Forest age 3-15 years
Hfor2	Forest age ≤2 years
Hcc10	<10% of AA clear cut within 50 years
Hcc50	11-50% of AA clear cut within 50 years
Hcc100	>50% of AA clear cut within 50 years
Hforsc	Selective cutting forestry
Hpine	Forest managed or converted to pine
Hchem	Forest chemical defoliation
Hmow	Mowing in AA
Hfarm	Farming activity in AA
Hgraz	Grazing in AA
Hnorecov	Cleared land not recovering
Hinv1	Invasive plants cover <1% of AA
Hinv5	Invasive plants cover 1-5% of AA
Hinv50	Invasive plants cover 6-50% of AA
Hinv100	Invasive plants cover >50% of AA
Hherb	Excessive Herbivory/Pinebark Beetle/Gypsy Moth
Halgae	Nutrients dense algal mats
Hnis50	Nutrient indicator plant species cover <50% of AA
Hnis100	Nutrient indicator plant species cover >50% of AA
Htrail	Non-elevated road
Hroad	Dirt or gravel elevated road in AA
Hpave	Paved road in AA
Hydrology Category (within 40m radius of sample point)	
Wditchs	Slight Ditching; 1-3 shallow ditches (<0.3m deep) in AA
Wditchm	Moderate Ditching; 3 shallow ditches in AA or 1 ditch >0.3m within 25m of edge of AA
Wditchx	Severe Ditching; >1 ditch 0.3-0.6 m deep or 1 ditch > 0.6m deep within AA
Wchannm	Channelized stream not maintained
Wchan1	Spoil bank on one or both sides of stream
Wchan2	Spoil bank on same side of stream as AA
Wincision	Natural stream channel incision
Wdamdec	Weir/Dam/Road decreasing site flooding
Wimp10	Weir/Dam/Road impounding water on <10% of AA
Wimp75	Weir/Dam/Road impounding water on 10-75% of AA
Wimp100	Weir/Dam/Road impounding water on >75% of AA
Wstorm	Stormwater inputs
Wpoint	Point source (non-stormwater)
Wsed	Excessive sedimentation on wetland surface

Hydrology Category (continued)	
Wfill10	Filling or excavation on <10% of AA
Wfill75	Filling or excavation on 10-75% of AA
Wfill100	Filling or excavation on >75% of AA
Wmic10	Microtopographic alterations on <10% of AA
Wmic75	Microtopographic alterations on 10-75% of AA
Wmic100	Microtopographic alterations on >75% of AA
Wsubsid	Soil subsidence or root exposure
Landscape/Buffer Category (within 100m radius outside site/AA)	
Ldevcom	Commercial or industrial development
Ldevres3	Residential development of >2 houses/acre
Ldevres2	Residential development of 1-2 houses/acre
Ldevres1	Residential development of <1 house/acre
Lrdgrav	Dirt or gravel road
Lrd2pav	2-lane paved road
Lrd4pav	≥4-lane paved road
Llndfil	Landfill or waste disposal
Lchan	Channelized streams or ditches >0.6m deep
Lag	Row crops, nursery plants, or orchards
Lagpoul	Poultry or livestock operation
Lfor	Forest harvesting within past 15 Years
Lgolf	Golf course
Lmow	Mowed area
Lmine	Sand or gravel mining operation

Appendix C: DERAP IWC Stressors and Weights

Category/Stressor Name*	Code	Stressor Weights**		
*DERAP stressors excluded from this table are not in the rapid IWC calculation.		Flats	Riverine	Depression
Habitat Category (within 40m radius site)				
Mowing in AA	Hmow	15	3	24
Farming activity in AA	Hfarm			
Grazing in AA	Hgraz			
Cleared land not recovering in AA	Hnorecov			
Forest age 16-30 years	Hfor16	5	4	2
≤10% of AA clear cut within 50 years	Hcc10			
Forest age 3-15 years	Hfor3	19	7	12
Forest age ≤2 years	Hfor2			
11-50% of AA clear cut within 50 years	Hcc50			
>50% of AA clear cut within 50 years	Hcc100			
Excessive Herbivory	Hherb	4	2	2
Invasive plants dominating	Hinvdom	2	20	7
Invasive plants not dominating	Hinvless	0	5	7
Chemical Defoliation	Hchem	5	9	1
Managed or Converted to Pine	Hpine			
Non-elevated road in AA	Htrail	2	2	2
Dirt or gravel elevated road in AA	Hroad			
Paved road in AA	Hpave			
Nutrient indicator species dominating AA	Hnutapp	10	12	10
Nutrients dense algal mats	Halgae			
Hydrology Category (within 40m radius site)				
Slight Ditching	Wditchs	10	0	5
Moderate Ditching	Wditchm		0	
Severe Ditching	Wditchx	17	0	
Channelized stream not maintained	Wchannm	0	13	0
Spoil bank on one or both sides of stream	Wchan1	0	31	0
Spoil bank on same side of stream as AA	Wchan2	0		0
Stream channel incision	Wincision	0	21	0
WeirDamRoad decreasing site flooding	Wdamdec	2	2	2
WeirDamRoad/Impounding <10%	Wimp10			
WeirDamRoad/Impounding 10-75%	Wimp75			
WeirDamRoad/Impounding >75%	Wimp100			
Stormwater Inputs	Wstorm	2	2	2
Point Source (non-stormwater)	Wpoint			
Excessive Sedimentation	Wsed			

Appendix C: DERAP IWC Stressors and Weights

Hydrology Category (continued)	Code	Flats	Riverine	Depression
Filling, excavation on <10% of AA	Wfill10	2	0	8
Filling, excavation on 10-75% of AA	Wfill75	16	11	2
Filling, excavation on >75% of AA	Wfill100			
Soil Subsidence/Root Exposure	Wsubsid	7	0	0
Microtopo alterations on <10% of AA	Wmic10			
Microtopo alteations on 10-75% of AA	Wmic75	16	11	2
Microtopo alterations on >75% of AA	Wmic100			
Buffer Category (100m radius around site)				
Development- commercial or industrial	Ldevcom	1 buffer stressor = 3	1 buffer stressor = 1	1 buffer stressor = 4
Residential >2 houses/acre	Ldevres3			
Residential ≤2 houses/acre	Ldevres2			
Residential <1 house/acre	Ldevres1			
Roads (buffer) mostly dirt or gravel	Lrdgrav	2 buffer stressors = 6	2 buffer stressors = 2	2 buffer stressors = 8
Roads (buffer) mostly 2- lane paved	Lrd2pav			
Roads (buffer) mostly 4-lane paved	Lrd4pav			
Landfill/Waste Disposal	Llndfil			
Channelized Streams/ditches >0.6m deep	Lchan			
Row crops, nursery plants, orchards	Lag			
Poultry or Livestock operation	Lagpoul	≥ 3 buffer stressors = 9	≥ 3 buffer stressors = 3	≥ 3 buffer stressors = 12
Forest Harvesting Within Last 15 Years	Lfor			
Golf Course	Lgolf			
Mowed Area	Lmow			
Sand/Gravel Operation	Lmine			
Intercept/Base Value		95	91	82
Flats IWCrapid= 95 -(∑weights(Habitat+Hydro+Buffer))				
Riverine IWCrapid= 91 -(∑weights(Habitat+Hydro+Buffer))				
Depression IWCrapid= 82 -(∑weights(Habitat+Hydro+Buffer))				

**Stressors with weights in boxes were combined during calibration analysis and are counted only once, even if more than one stressor is present.

Appendix D: Report Card Grading Scales

The following is the letter grade scale used in wetland health report cards for overall watershed grades, overall wetland type grades, and habitat and hydrology grades within wetland types (left), and the letter grade scale used for buffer grades within wetland types (right):

Score Range	Letter Grade
97-100	A+
93-96	A
90-92	A-
87-89	B+
83-86	B
80-82	B-
77-79	C+
73-76	C
70-72	C-
67-69	D+
63-66	D
60-62	D-
0-59	F

Average Stressor Tally Range	Letter Grade
0-0.60	A
0.61-1.2	B
1.21-1.8	C
1.81-2.4	D
2.41-3.0	F

Once letter grades are determined, wetland types as well as their attribute categories (habitat, hydrology, and buffer) are color-coded and placed on a qualitative wetland health scale shown below. This color-coded wetland health scale is designed to make public interpretation of wetland health as clear as possible.

Letter Grade	Wetland Health Scale	Color
A	Excellent	
B	Good	
C	Fair	
D	Poor	
E	Very Poor	

Appendix E-G are stored as a separate file and can be found online within the Delaware Wetlands Library of Wetland Health Reports.

This report and other watershed condition reports, assessment methods, scoring protocols, and wetland health report cards can be found on the Wetland Monitoring and Assessment Program's website:

Data collected for this report are publicly available for viewing and downloading for non-tidal wetlands.

Other helpful resources described in this report include the Freshwater Wetland Toolbox and the Delaware Watershed Resources Registry.