THE LAND PERSPECTIVE:

Watershed health influences bay health

THE MARYLAND COASTAL BAYS 2016

This booklet provides an overview of the current science and management issues in the Maryland Coastal Bays and their watersheds in 2016. Previous assessments include the *2004 State of the Maryland Coastal Bays* and the 2009 book, *Shifting Sands: Environmental and cultural change in Maryland's Coastal Bays*. Both of these previous publications and this booklet, *Maryland Coastal Bays 2016: Land and bay perspectives* are available on IAN Press (*ian.umces.edu/press*).

Recognizing the importance of both a bay perspective and a land perspective, this booklet provides current data and insights into a) how bay health is influenced by ocean and land and b) how watershed health influences bay health. It includes two 'booklets' in one publication—one intended for those interested in the bay perspective, and the other for those interested in the land perspective. The two documents culminate in a summary centerfold which focuses on both watershed and bay issues.

Source material for this booklet is derived the 2015 Comprehensive Conservation Management Plan and the 2016 Ecosystem Health Assessment—both available at *http://mdcoastalbays.org/publications*. Data used in this publication is through 2013.

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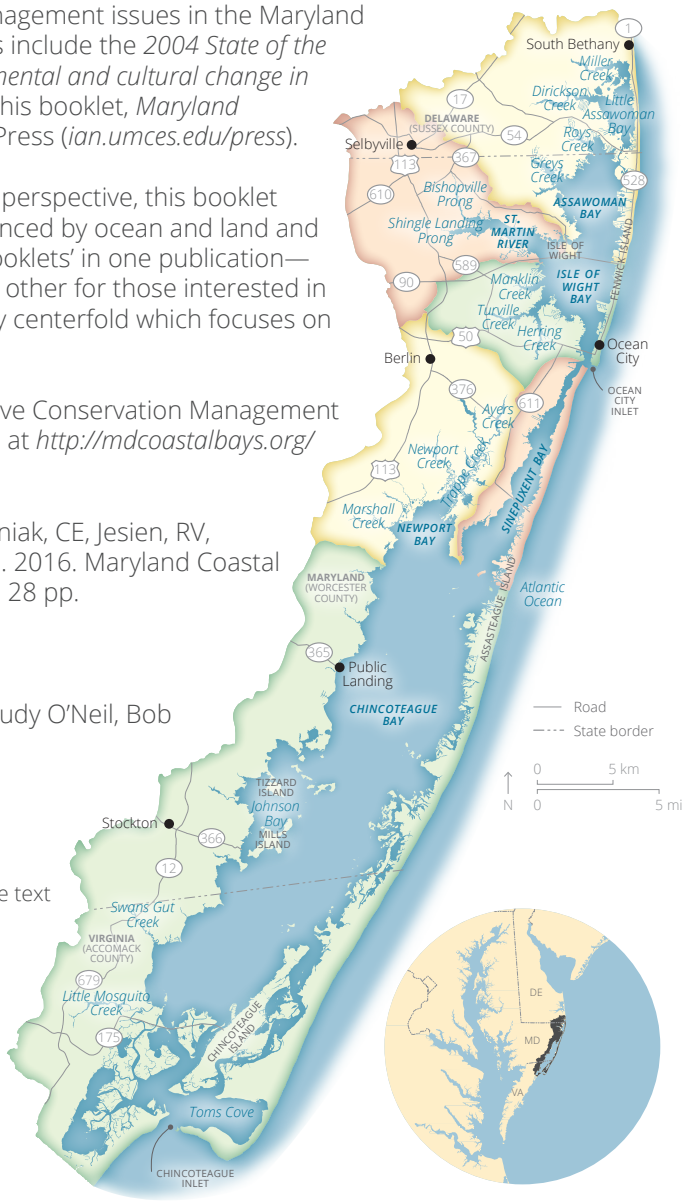

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Maryland Coastal Bays Program

Maryland Department of Natural Resources

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CITATIONS
Homer CG, Dewitz JA, Yang L, Jin S, Danielson P, Xian G, Coulston J, Herold ND, Wickham JD, and Megown K. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v.81, no.5, p.345–354.
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PHOTO CREDITS
Watershed cover: Jane Thomas and Adrian Jones.

HOW WE USE THE LAND AFFECTS COASTAL WATERS

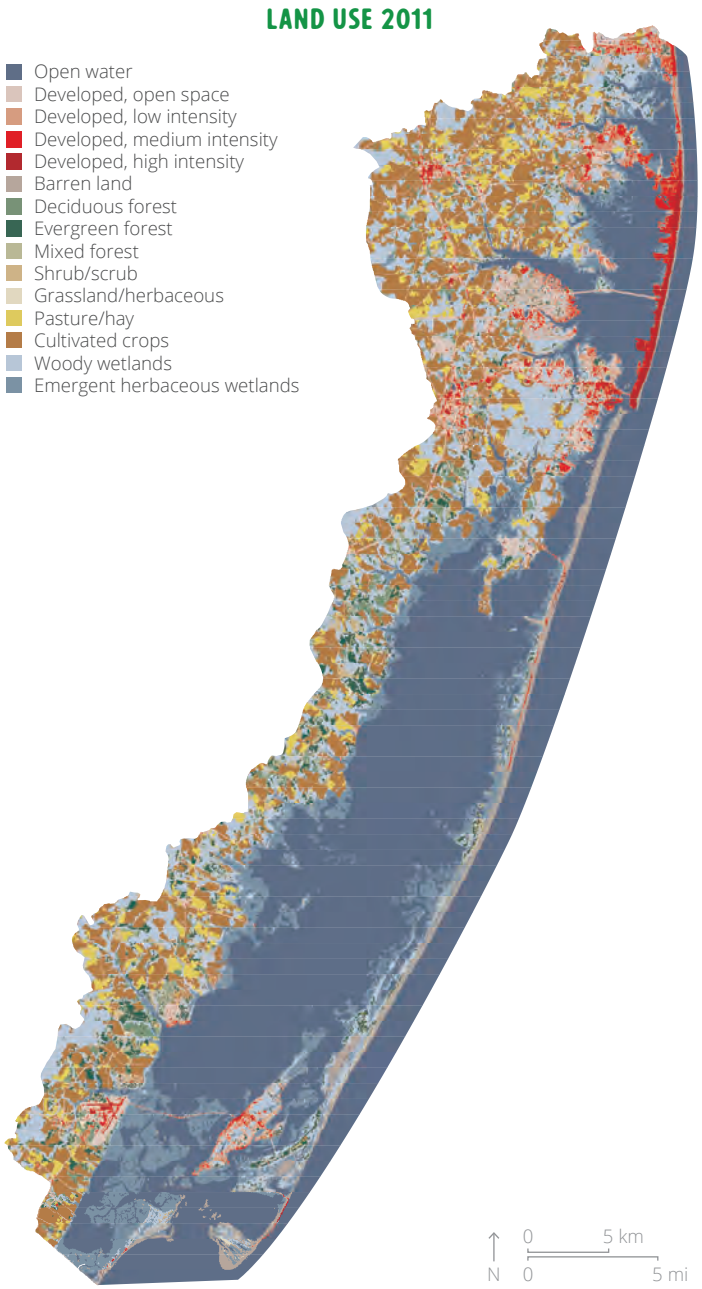
Land use decisions affect bay habitat and the fish and animals that live there. Various land uses result in nutrient runoff. Shoreline stabilization that uses hard substrate decreases habitat for many fish and other species. Hard shorelines increase wave refraction which decreases the nearby area as potential seagrass habitat. Additionally, wetlands cannot migrate up the shoreline as sea level rises. Development in the floodplain and creation of dead-end canals has led to poor habitat and fish kills.

The health of the Coastal Bays remains largely influenced by activities that occur within the watershed (the area of land that drains into the bays). Nutrients and chemicals are transported into the bays via surface runoff (water running over land to creeks, rivers and streams) and groundwater (water that flows below the earth's surface), while runoff also carries sediments. Enhancing land drainage allows runoff to reach the bays quicker than in the past and may even disrupt shallow groundwater flow. Most streams suffer from poor habitat and water quality due to septics, ditching, and increased fertilizers (lawns, golf courses, and farms) that wash nutrients into the streams and bays. The nutrient components of fertilizers have also changed over the past decade and affect what type of algae grow in the bays, which in turn impacts the fish and shellfish which need healthy algae populations to live.

As the major source of freshwater to the bays, groundwater is also the dominant source of nutrients. Groundwater flows much slower than surface runoff (several years to decades compared to hours to days); therefore, nutrients entering the bays may be from actions that happened on land many years ago. Long-term impacts of farming and development have led to an accumulation of nutrients in groundwater that can impact the bays 10–20 years later.

The biggest concern for the health of the bays is eutrophication resulting from the high nutrient loading. Phosphorus levels in the bays are high. High soil phosphorus levels are typically found on farms that have used manure or poultry litter as a crop nutrient over an extended period. The amount of phosphorus that can be applied to fields that exceed specified thresholds will be limited under new phosphorus requirements. The new requirements utilize the best science and emphasizes that Maryland farmers are committed to restoring our Bays.

Remember that many of YOUR activities affect fish and other resources in the bays! Actions like fertilizing your lawn properly, cleaning out your septic regularly, picking up after your dog, not feeding wildlife like geese, planting natural gardens and trees to decrease runoff, decreasing driving, supporting local farmers, using soft shoreline stabilization methods, and staying off bay islands that have nesting birds have positive effects.



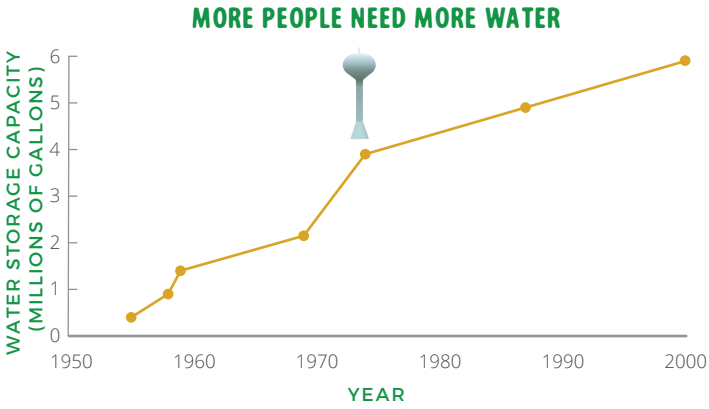
This map shows the diverse land use of the Coastal Bays watershed. Agriculture is the dominant land use, and heavy development can be seen on Fenwick Island/ Ocean City. Data: Homer et al. 2015.

THE FORGOTTEN BAYS HAVE BEEN REDISCOVERED

The Coastal Bays were known as the 'Forgotten Bays'. This reference was in relation to the better-known, nearby Chesapeake and Delaware Bays and to the main attraction of the region—the beaches of Assateague and Fenwick Islands. While the term the 'Forgotten Bays' may have indeed characterized the Coastal Bays in the past, now the Coastal Bays are an attraction in and of themselves. People have rediscovered the natural beauty of the Coastal Bays and their accessibility for boating, fishing, swimming, and bird-watching.

The increased activity in the Coastal Bays watershed is reflected in the growth of water consumption in the region. This growth in water consumption is reflected in the water storage capacity (e.g., water towers), which is needed to support more people spending time in the Coastal Bays watershed. The year-round population does not have to increase, but it can result from people spending more time (e.g., longer weekends, longer summer season) in the region. The population demographics indicate a significant increase in retirees, which could swell the population since the region is popular for retirees who desire access to the beach and a more rural lifestyle.

As a result of the increased presence of people in and around the Coastal Bays, there are more pressures currently and projected into the future. Increased recreational activities (e.g., fishing, crabbing, boating) serve as a pressure on the Coastal Bays ecosystems. In addition, rural shoreline development increase the number of septic systems, fertilized lawns and hardened shorelines can lead to more nutrient runoff, and reduced marsh vegetation means less area to intercept nutrient runoff and provide wildlife habitat.



This graph shows cumulative water storage capacity for the Town of Ocean City. Water storage capacity has increased, reflecting increases in the number of residents and visitors to Ocean City. Source: Town of Ocean City.

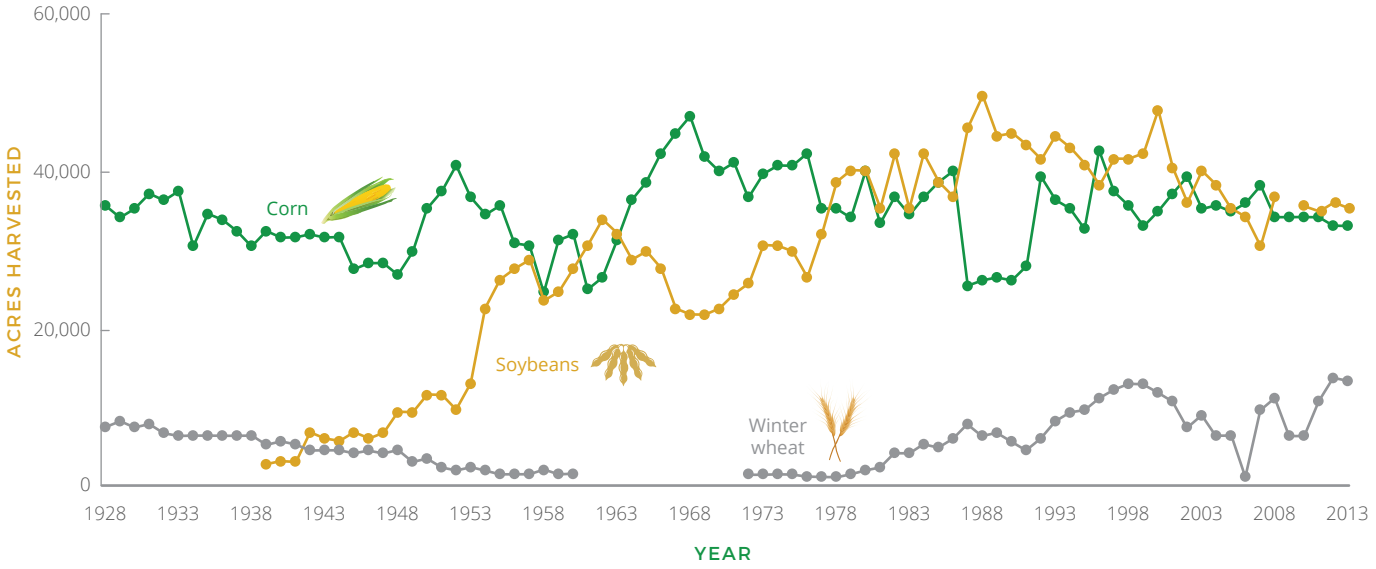
Ecotourism is just one of the ways that people use the Coastal Bays, and it has increased in recent years. Photo by Maryland Coastal Bays Program.

Fishing for blue crabs, or 'chicken-necking' (left) and jetskiing (right) are popular activities in the Coastal Bays. Photos by Sandi Smith and Adrian Jones.

AGRICULTURAL PRACTICES HAVE INTENSIFIED

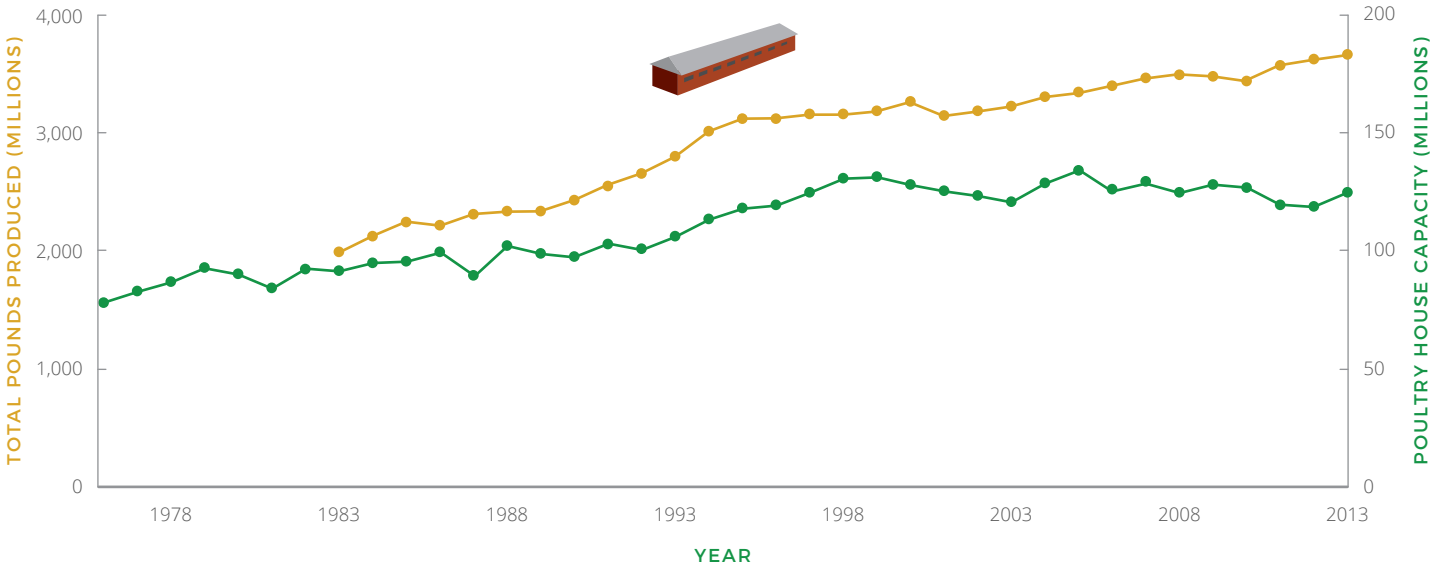
Agriculture has been a mainstay of the Worcester County economy for many years. Corn, soybeans, winter wheat, and poultry have been the major components of this industry. The amount of acres in corn has ranged between 30,000 and 40,000 acres since the late 1920s. Soybean acres increased shortly after World War II and has generally tracked the amount of corn since then. Winter wheat acreage fluctuated the most. The poultry industry expanded rapidly during World War II because of the shortage of beef and pork, which require a much longer time to develop—only seven weeks are required to produce a broiler and five months to produce a laying hen. The industry started on a commercial scale on the Delmarva Peninsula and then spread farther south and southwest. Total pounds of poultry in Delmarva increased steadily from 1983, reflecting the increase in production capacity of each poultry house. The recent increase of winter wheat is related to its use as a winter cover crop to help protect soils and prevent erosion.

AGRICULTURAL YIELDS IN WORCESTER COUNTY



Crop agriculture—in particular, corn, soybeans, and winter wheat—have long been a mainstay of the Coastal Bays economy. Source: USDA.

POULTRY PRODUCTION ON DELMARVA



Poultry production across the whole of Delmarva has been increasing over time, due to the increasing capacity of poultry houses. Note: this data is for the whole Delmarva peninsula, not just the Coastal Bays watershed. Source: Delmarva Poultry Industry, Inc.

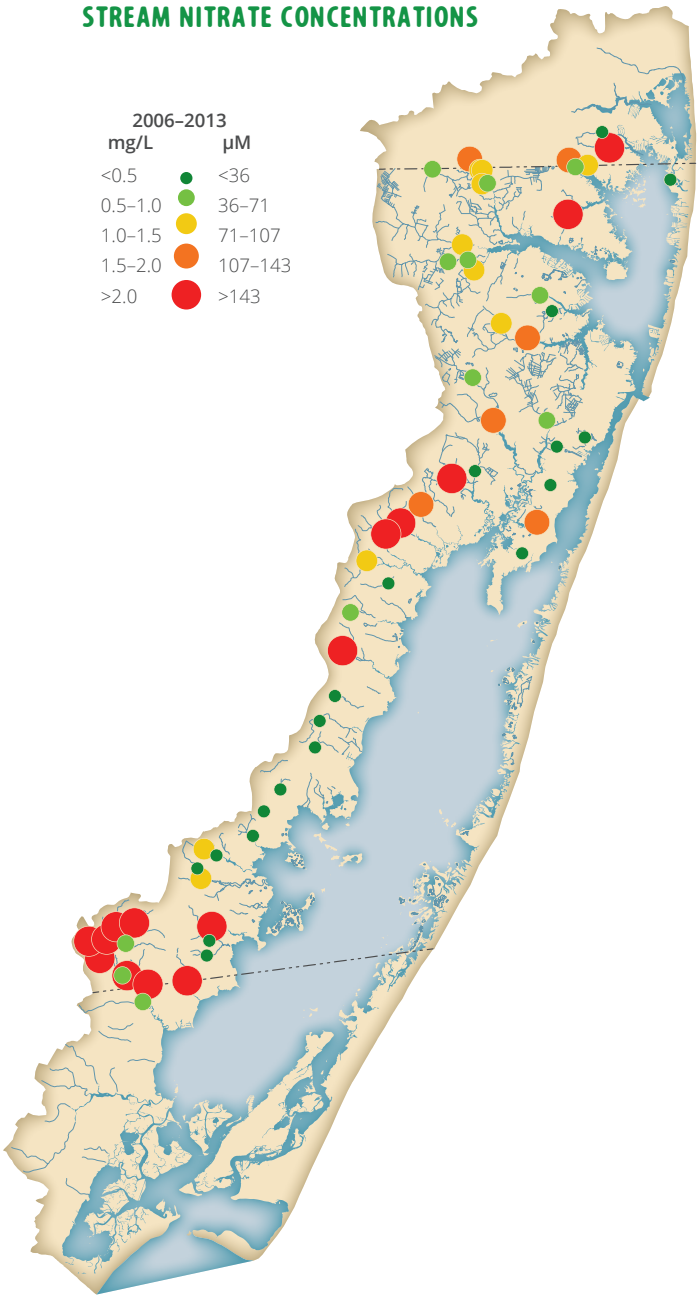
LOCALIZED CONDITIONS IMPACT STREAM HEALTH

Unlike the neighboring estuaries such as Chesapeake and Delaware Bays, the Coastal Bays have few large freshwater rivers that transport nutrients and sediments. In contrast, the Coastal Bays have small streams that drain small watersheds. As a result, surface waters (and shallow groundwater) are affected almost solely by the adjacent land use. The assessment of stream health is a reflection of conditions very close to each stream.

In Chesapeake Bay, large-scale sewage treatment upgrades have led to major improvements in water quality. This will not likely be the case for the Coastal Bays since there are few large treatment facilities. The largest, in Ocean City, discharges offshore but some fraction may make its way back into the Coastal Bays. Other small sewage treatment facilities discharge to the Coastal Bays, and one has land application outside the watershed. The majority of the watershed has diffuse non-point sources of nutrient input from residential areas and agriculture, so there are no easy fixes to curbing nutrient enrichment in the Coastal Bays. Elevated stream nitrate concentrations are attributable to groundwater input as well as surface runoff. Because of the gently sloping topography and sandy soils of the watershed, most rainwater infiltrates rather quickly into the shallow groundwater picking up nutrients and the rest moves downstream as it picks up sediment. Natural background concentrations of nitrate in streams is 0.6 mg/L with concentrations greater than 1.0 mg/L indicative of human—termed anthropogenic—input (USGS).

Concentrations that are above thresholds for healthy streams may impact stream biota as well as contribute to total nitrogen loads in the bays. Continual monitoring is necessary to determine changes in stream health based on land uses. Enrichment of specific streams in the small watersheds is being used to focus management practices to reduce the nutrient impacts to the downstream bay waters.

Urban streams, which can get choked with trash after storm events, can contribute sediments, toxicants, and nutrients to downstream areas. Photo by Roman Jesien.



Average stream nitrate concentrations in Coastal Bays streams between 2006 and 2013.

HOW WE USED THE LAND IN THE PAST AFFECTS CURRENT CONDITIONS

The history of the land is written in the bays. The remnants of historic inlets caused by oceanic storms to old river deltas from the last ice age are still recognized in the bay sediments. Long-term removal of forests and wetlands has led to increased nutrient and sediment runoff to the bays. Nearly all the headwaters of streams feeding the Coastal Bays have been ditched and are poor habitat for fish and other important animals. Phosphorus bans in the mid-1980s decreased blue-green algae blooms and allowed seagrass to flourish in the bays providing habitat for clams, crabs, and fish.

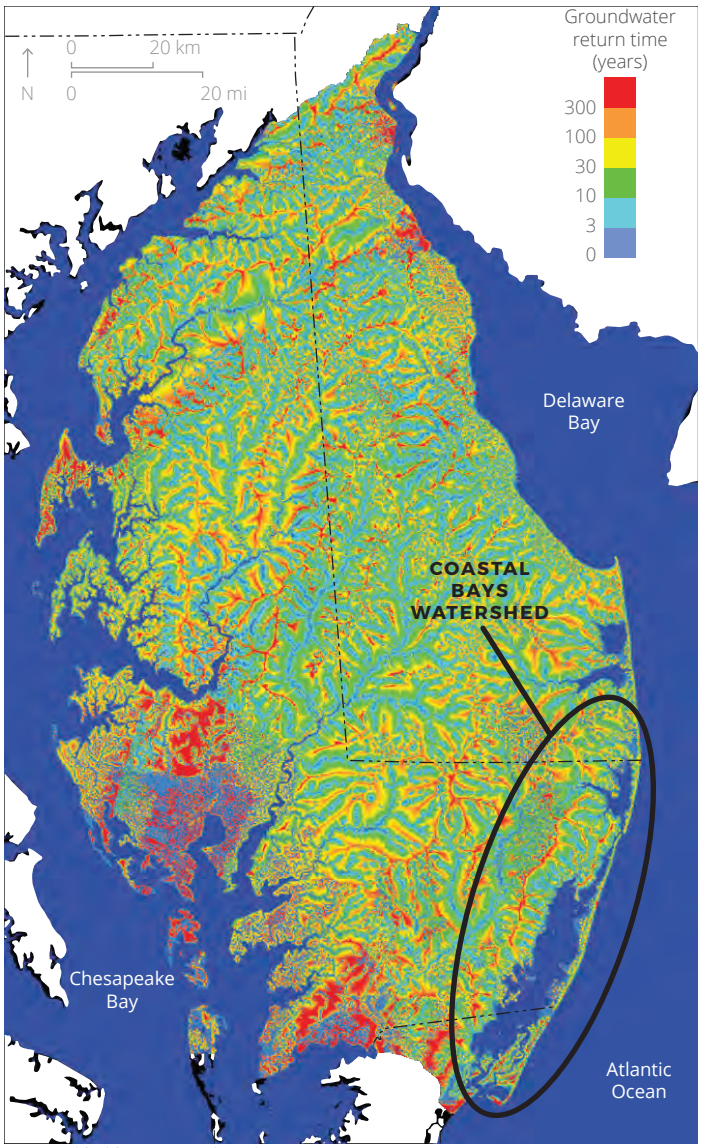
The watershed of the Maryland Coastal Bays has very little relief and very sluggish groundwater movement. As a result of this topography, there are substantial time lags between when nutrients (e.g., fertilizer, chicken manure) are applied to the watershed and when the groundwater containing these nutrients reaches the Coastal Bays. This means that management practices instituted previously will not be manifested in the Coastal Bays until years to decades later.

Furthermore, one of the major agricultural best management practices that has been increasingly implemented is winter cover crops to soak up excess fertilizer at the end of the growing season. Research has shown that it takes up to five successive years of cover crop application before reductions in groundwater nitrate levels are fully realized. This adds more lag times to the realization of impacts of this best management practice.

The exception to the long groundwater lag times is on the sandy barrier islands including Fenwick, Assateague, and Chincoteague Islands. Rapid groundwater percolation through the sandy soils reduces groundwater lag times.

The installation of wells to allow monitoring of groundwater gives information about the concentration of nutrients in the groundwater. Photo by Roman Jesien.

GROUNDWATER FLOW IN THE DELMARVA PENINSULA



Base modified from U.S. Geological Survey 1:100,000-scale digital data

Simulated return time of groundwater travelling from the water table to its discharge location. Groundwater from the Coastal Bays watershed may take decades to reach the bays themselves. Source: Sanford et al. 2012.

Ecological lag times in response to environmental changes also contribute to inertia in ecosystem processes. A build-up of organic matter can lead to nutrient remineralization where the organic matter is slowly decomposed, releasing nutrients and consuming oxygen. The microbial community in sediments and soils will reflect the history of organic and nutrient loading for an undetermined period.

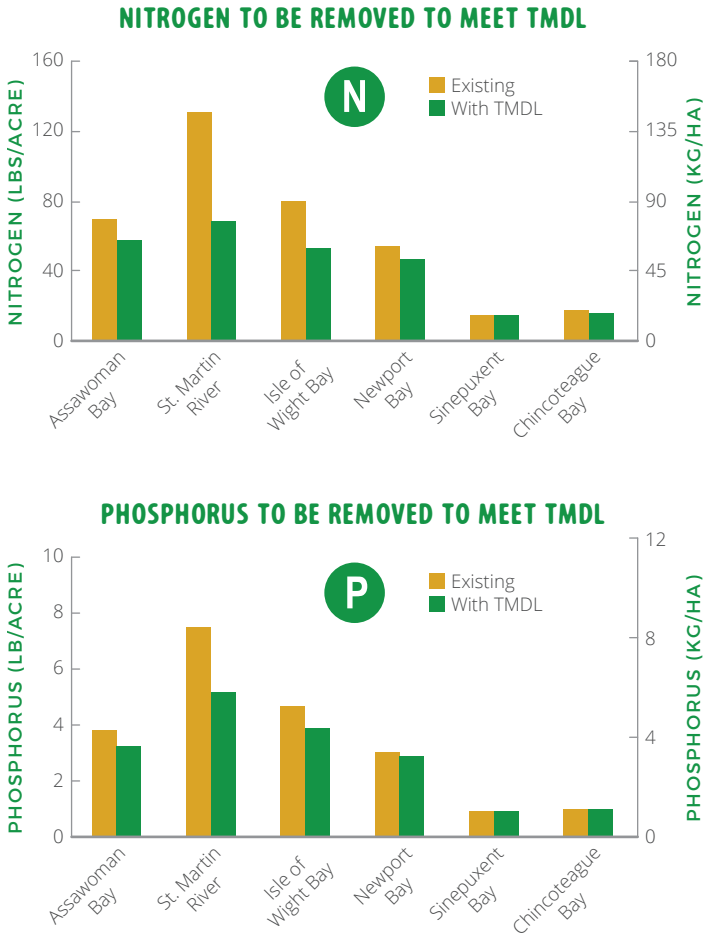
In summary, we cannot expect rapid responses to some of our management actions so patience and persistence will need to be exercised.

THE WATERSHED IS ON A NUTRIENT DIET

Waterways in the United States that are listed as impaired under the federal Clean Water Act have an opportunity for voluntary clean-up. Following a period of voluntary efforts, if the waterways are still listed as impaired, the U.S. Environmental Protection Agency is authorized to impose a regulatory clean-up. For nutrient impairments, like in the Maryland Coastal Bays, the regulatory clean up is known as a Total Maximum Daily Load, or TMDL. The TMDL does not prescribe how the nutrient reductions are achieved, but it sets the limit on the total amount of nitrogen and phosphorus that can enter the waterways. The TMDL is also known as a 'nutrient diet'. The TMDL targets and allocations are set by a hydrodynamic and eutrophication model developed with consultation with the research and monitoring scientists.

Nutrient targets are set by the relevant state agencies (e.g., Maryland Department of Environment), who are delegated the authority to impose the TMDL through their Watershed Implementation Plans (WIPs). The Maryland Coastal Bays have watershed area in three states: Maryland, Virginia, and Delaware. Thus, the TMDL applies to these portions of those states and the relevant state agencies for implementation. The TMDL sets the geographic and jurisdictional nutrient loads through the WIPs, which must be approved by the U.S. Environmental Protection Agency. The TMDL also has a timetable for nutrient reductions, with interim and end-point goals.

In practice, the federal TMDL agency—the U.S. EPA—delegates the authority to the relevant state agencies, who in turn mandate the local jurisdictions to implement the WIPs. So the counties, towns, and cities are required to come up with solutions, often without funding allocations. This can cause conflict due to 'unfunded mandates'. At the local level, there is considerable opportunity for innovation and creative solutions.



These graphs show the amount by which nitrogen (top) and phosphorus (bottom) loads would need to be reduced to meet the Total Maximum Daily Load requirements.

It is helpful to visualize the provisions of the Clean Water Act as a train, with water quality standards as the 'engine' and each car dependent on the one preceding it. Modified from Georgia Legal Watch.

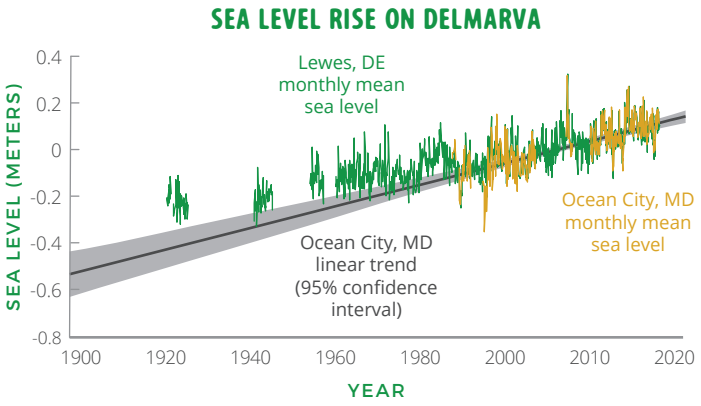
ADAPTATIONS TO STORM SURGE AND SEA LEVEL RISE ARE NECESSARY

The mid-Atlantic Bight region is subject to rapid rates of relative sea level rise. Relative sea level rise accounts for both subsidence of land as well as gains in elevation of the ocean surface. Long-term rebound from the continental glaciers of North America results in land subsidence in Delmarva, which can be exacerbated by groundwater extraction. Global sea level rise is particularly acute in the North Atlantic Ocean due to greenhouse gas-related surface water warming. In addition, the weakening of the Gulf Stream offshore results in accelerated rates of sea level rise.

Given the pressing nature of relative sea level rise in this region, there is an urgency to develop strategies to adapt to these accelerated rates. Inundation maps reveal the vulnerability of the human infrastructure in the region. In addition, Assateague Island has been temporarily breached in recent storm events. A direct hit by a storm of the magnitude of Hurricane Sandy in 2012 could be devastating to the region.

Currently, beach replenishment from offshore sand dredging is conducted north of Ocean City inlet to maintain swimming beaches, but also to protect Ocean City from storm surge. Assateague Island National Seashore transports sand to maintain the north end of the island from washing away due to storm surges and erosion. Additionally, the National Park Service is experimenting with sand berms and sand dune stabilization to protect the island from storm surge.

Maryland escaped major damage during Hurricane Sandy. However, we recognize that the greatest change to the bays could occur during an intense storm event that lasts only a few days, but changes the shape and function of the system for several decades. The ongoing impacts in other areas from Hurricane Sandy are just a glimpse into how climate change and sea level rise alter ecosystem processes and coastal communities. To face these challenges, the Maryland Coastal Bays Program will continue to use the best available science to work towards restoring and protecting this unique ecosystem that we all treasure.



Shown here is mean sea level at the Ocean City inlet, MD and Lewes, DE. Sea level at Ocean City is rising at a rate of 5.6 mm (nearly a quarter-inch) per year which is equivalent to a change of 1.84 feet in 100 years. Source: NOAA.

The top photo shows an intact southern end of Assateague Island prior to the blizzard of 22–24 January 2016. That storm breached Assateague Island in several places, as seen in the bottom photo. Photos by Patrick J. Hendrickson/Highcamera.com

Ocean City suffered severe flooding during Hurricane Sandy, which impacted Maryland on October 29–30, 2012. Photo by Ricky Kerrigan.

DAM REMOVAL RESTORES STREAM HABITATS

The goal of the Bishopville Stream Corridor Enhancement Project was to replace the existing dam with a nature-like fish passageway, consisting of a series of shallow step pools, to allow fish to move upstream. The removal of the Bishopville Dam allows access to more than seven miles of freshwater spawning habitat for anadromous fish species such as alewife (*Alosa pseudoharengus*), blueback herring (*A. aestivalis*), and white perch (*Morone americana*)—these species live in salt water but require fresh water to reproduce. Herring populations are of special concern throughout the East Coast due to loss and degradation of habitat. The project maintained a portion of the existing pond, at the request of local residents, while creating fish passage through a series of step pools that serve as a gently sloping stream corridor to transition from non-tidal to tidal waters.

The non-tidal portion of the project was completed in December 2014, making spring 2015 the first time the area has been accessible to anadromous fish since 1959. The project was deemed successful with alewife, white perch, American eel (*Anguilla rostrata*), and gizzard shad (*Dorosoma cepedianum*) passing upstream in its first season. In addition to fish passage, the project provides increased contact time with bacteria and vegetation to allow for nutrient removal as water flows over the series of vegetated weirs and shallow pools.

From top right, this series of photographs shows the Bishopville Dam before its removal; the restoration project under construction; and the final restored stream with three rock weirs. Photos by Roman Jesien/Maryland Coastal Bays Program.

IMPROVEMENTS TO SEPTIC AND SEWAGE DISCHARGES ARE ONGOING

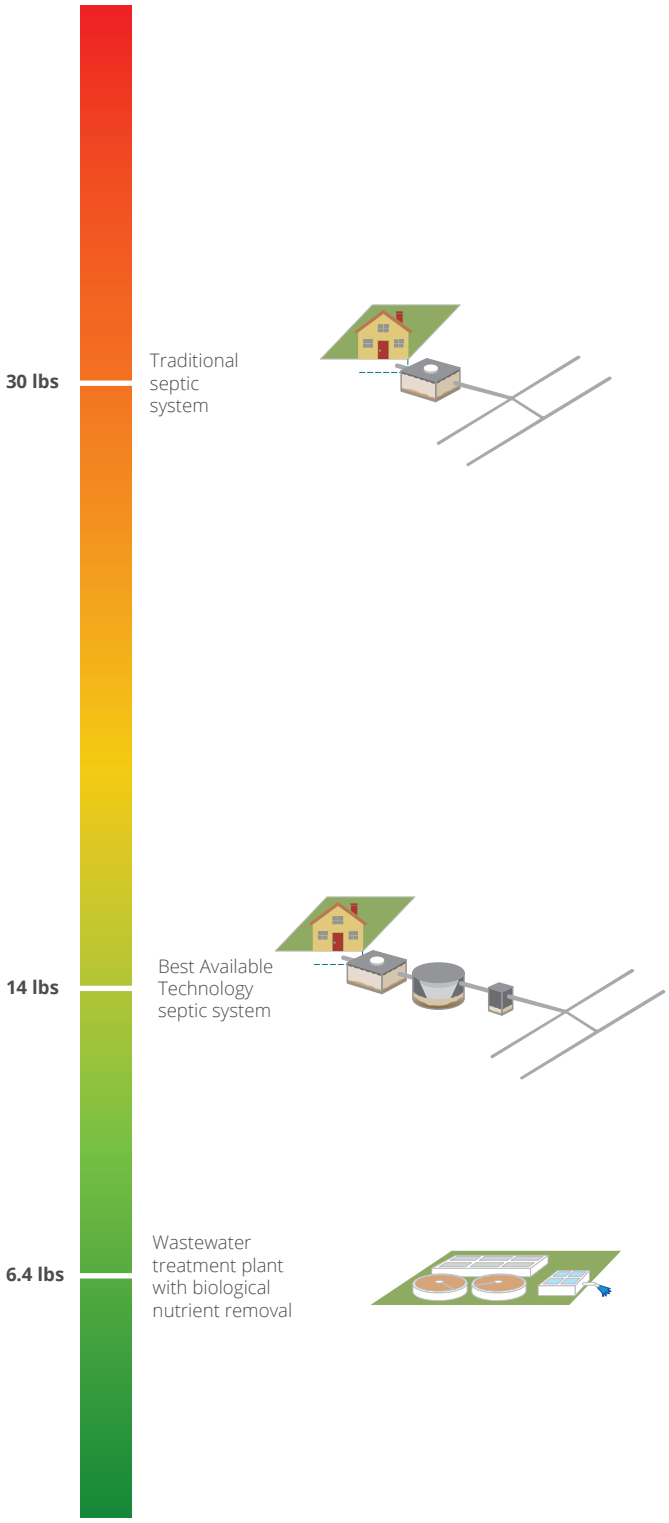
Through the Bay Restoration Fund in Maryland, a $60 annual fee is collected from each home served by an on-site septic system. The total estimated program income is $27 million per year. Sixty percent of these funds are used for septic system upgrades and 40 percent are used for cover crops. There are 420,000 on-site septic systems in Maryland. With priority given to failing septic systems in the Critical Area (all land within 1,000 feet of Maryland's tidal waters and tidal wetlands), Bay Restoration funds can be provided for upgrades of existing septic systems to best available technology for nitrogen removal.

Similarly, a $5 monthly fee is collected from each home served by a wastewater treatment plant, with funds reaching an estimated $100 million per year. These funds are directed towards upgrading wastewater treatment plants to enhanced nutrient removal (ENR) technologies.

The average properly functioning septic system delivers about 30 lbs of nitrogen per year to groundwater. Septic systems that have been upgraded to the best available technology for nitrogen removal contribute about 14 lbs of nitrogen per household per year to groundwater. Wastewater treatment plants with biological nutrient removal contribute about 6.4 lbs per household. In the Maryland Coastal Bays watershed, there are 4,484 septic systems, most of which are in the Critical Area. In the Coastal Bays, 454 new septic systems are proposed to be added by 2025 with an additional 683 systems connected to existing wastewater treatment plants by 2025.

The town of Berlin has diverted all of the effluent from its sewage treatment plant from stream discharge to land application. Trees, shrubs, and grasses take up the nutrients from the treated effluent. Photo by Roman Jesien.

POUNDS OF NITROGEN DELIVERED TO GROUNDWATER ANNUALLY PER HOUSEHOLD



Wastewater treatment plants with biological nutrient removal contribute the least amount of nitrogen to groundwater annually per household—less than 25% of the nitrogen that traditional septic systems contribute to groundwater.

STRATEGIES ARE BEING DEVELOPED FOR CHICKEN WASTE DISPOSAL

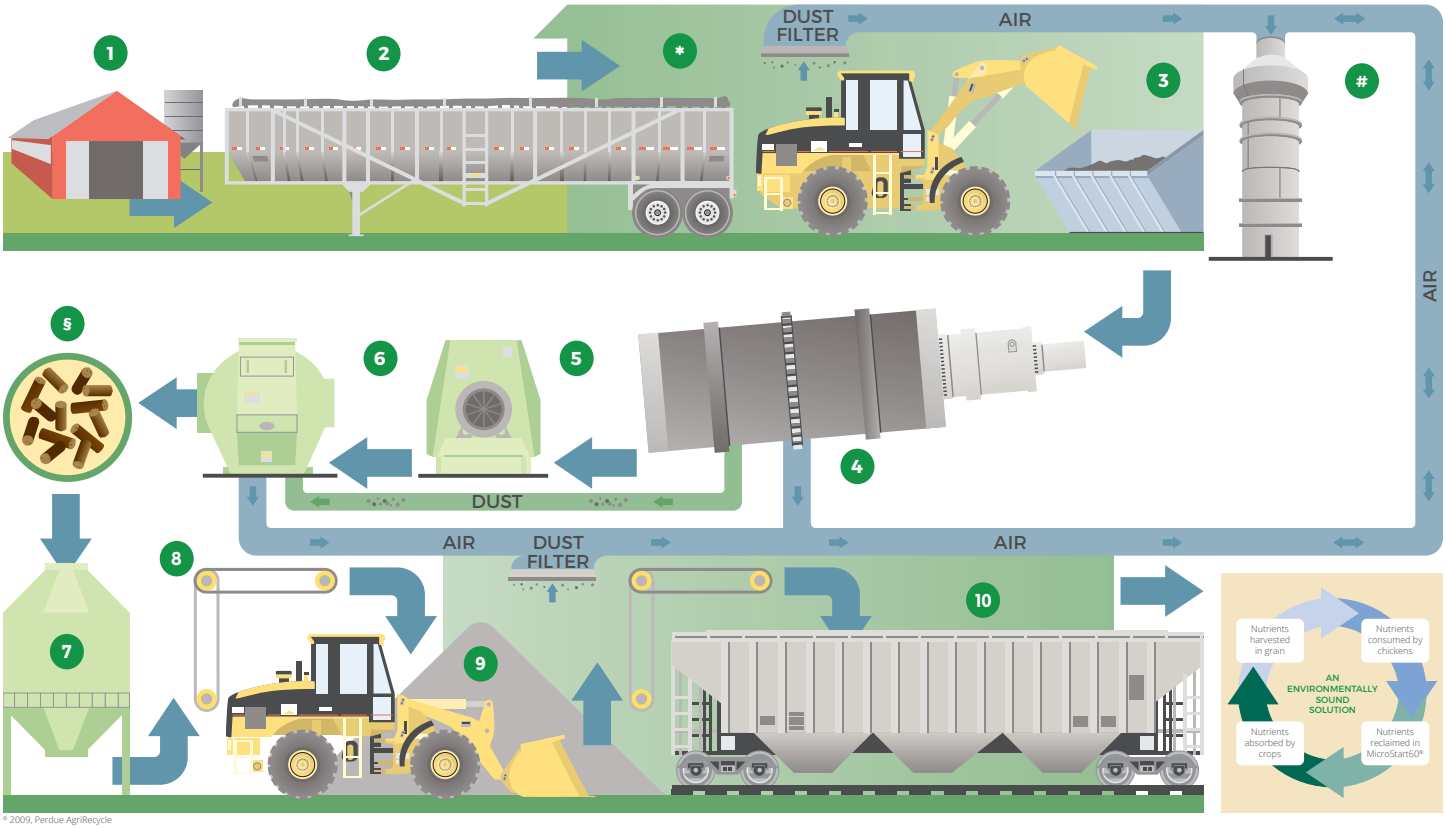
To combat the excess of chicken waste on the Eastern Shore, alternative disposal methods are being developed. A pilot program developed by Planet Found Energy Development LLC began in 2014 at Millennium Farms in Pocomoke, Maryland. The program is designed to transform chicken waste into usable energy while removing excess nutrients through three anaerobic digesters. The chicken manure is heated up inside concrete towers where bacteria begin to decompose the waste, releasing methane in the process. The collected methane can provide enough energy to power the digesters; excess energy will help generate electricity for the farm. Dissolved nutrients are reduced from the manure byproduct before it is applied to the fields as fertilizer. If successful, this program is projected to remove more than 18 tons of phosphorus per year from poultry waste.

Since 2001, Perdue's AgriRecycle plant has been transforming chicken waste into organic fertilizer. Raw manure is transported to the plant and heated to kill any bacteria and seeds remaining in the waste. The treated manure is processed through a pelletizing machine to produce slow-release fertilizer. The fertilizer is then sold to organic farms and home fertilizer companies such as Espoma and Scott's. About half of the fertilizer is exported out of the Coastal Bays and Chesapeake Bay watersheds.

Two other methods are reducing the amount of phosphorus reaching the Coastal Bays. One is to transport the manure out of the Coastal Bays watershed for disposal. The other is to feed the enzyme, phytase, to the chickens to increase their ability to absorb phosphorus, reducing the amount available in the manure and thus applied to fields.

From left to right, Amanda Poskaitis (Maryland Coastal Bays Program), Jeff Smith (Perdue), Jennifer Rafter, Roman Jesien (Maryland Coastal Bays Program), and Wayne Hudson (Perdue) at the Perdue AgriRecycle plant. Photo by Katherine Phillips.

STEP BY STEP THROUGH THE PELLETIZATION PROCESS



1 ON THE FARM. Perdue AgriRecycle has signed contracts with poultry producers to remove surplus litter from their farms.

2 TRANSPORTING LITTER. Litter is loaded into specially designed, covered, and leak-proof 23-ton capacity aluminum trailers dedicated for transport to the 68,000-square-foot pellet plant, which is the length of 2.5 football fields.

3 SEPARATING LITTER. Wet and dry litter is segregated into designated feed hoppers with a front-end loader before moving to the dryer.

4 DRYER. The litter, heated from 180 to 225 degrees Fahrenheit to destroy bacteria and weed seed.

INNOVATIONS IN STORMWATER MANAGEMENT ARE BEING IMPLEMENTED

BERLIN INITIATIVES

The town of Berlin passed historic legislation in January 2013 that helps reduce flooding and clean up local rivers and streams. The new ordinance created a stormwater utility that divided the cost of managing stormwater among the town's property owners and helps the town leverage federal and state grants for additional, related enhancements. It is expected that the utility would generate $570,000 annually for capital projects to help curb flooding, reduce erosion and polluted runoff, and combat property damage. Maryland Department of Natural Resources (DNR) and its partners recognized that some jurisdictions don't have the capacity to create large-scale, non-point source restoration and protection efforts. DNR, along with other state and federal agencies, created the Watershed Assistance Collaborative in 2008 to provide services and technical assistance to communities to advance restoration activities and projects. Projects have been identified and prioritized. Upcoming projects include culvert replacement and an offline wetland along Flower Street.

This sequence of photos shows the before (top) and after (bottom) refitting a stormwater culvert in Berlin. The rocks help to slow down the flow of stormwater while plants among the rocks help to reduce the amount of nutrients in the stormwater. Photos by Roman Jesien.

OCEAN CITY INITIATIVES

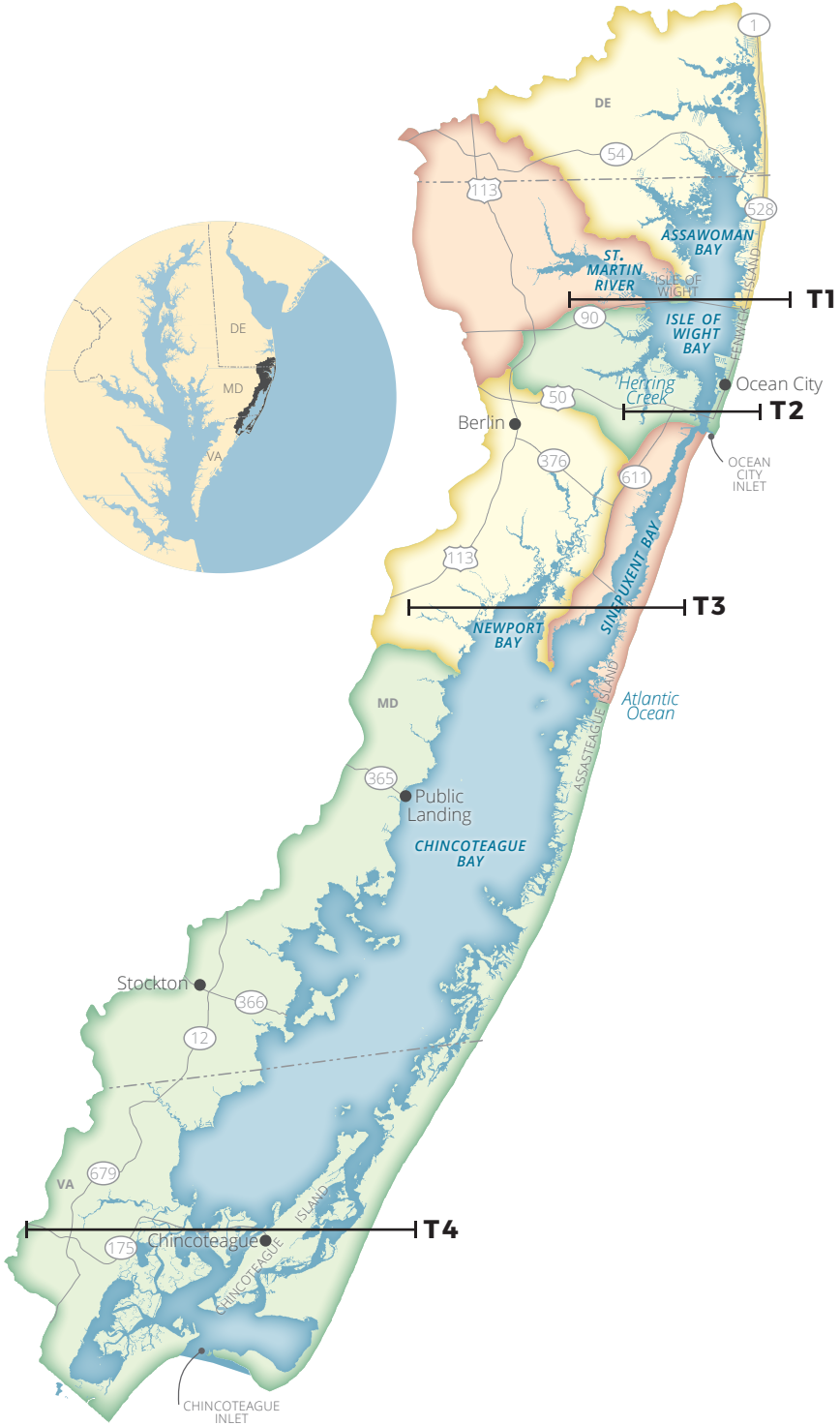
The Town of Ocean City is delegated the review authority for the State's stormwater and critical area regulations. The entire town is under the re-development umbrella and therefore has the ability to require mitigation and fee-in-lieu on projects not meeting the full intent of the regulations. Considering the existing development, hydrology, and geology of the barrier island, full compliance on-site would not be as beneficial as using the mitigation fees collected to install stormwater Best Management Practices elsewhere throughout the Town.

The mitigation fees have been used to include pervious surfaces on Town projects. Funds have been used to retrofit the storm drain system and outfalls with inserts, baffle boxes, and outfall improvements. The Town also uses the funds to offer programs in order to install native landscaping. The Beach District and BayScape programs have been going on for 11 years—beach plants and grasses are given to residents to help with water quality, habitat, and erosion control in the beach block areas where the environment is harsh and hardier plants are needed. Rain barrels are also subsidized using these mitigation fees.

Dune Patrol has been active in Ocean City for over 20 years, with supplies provided by the Town. In addition, the Town hosts two clean-ups a year—one in April around Earth Day and the other in September for the International Coastal Clean-Up. Trash bags, gloves, t-shirts, and other supplies are provided to the volunteers.

A stormwater baffle box being installed in Ocean City. The primary function of baffle boxes is to remove trash, sediment, suspended particles, and associated pollutants from stormwater. Photo by Town of Ocean City.

A LOOK ACROSS THE COASTAL BAYS



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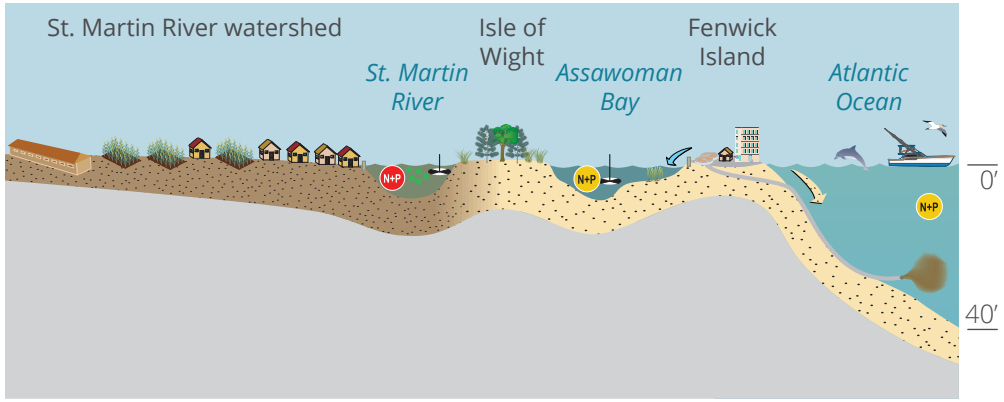
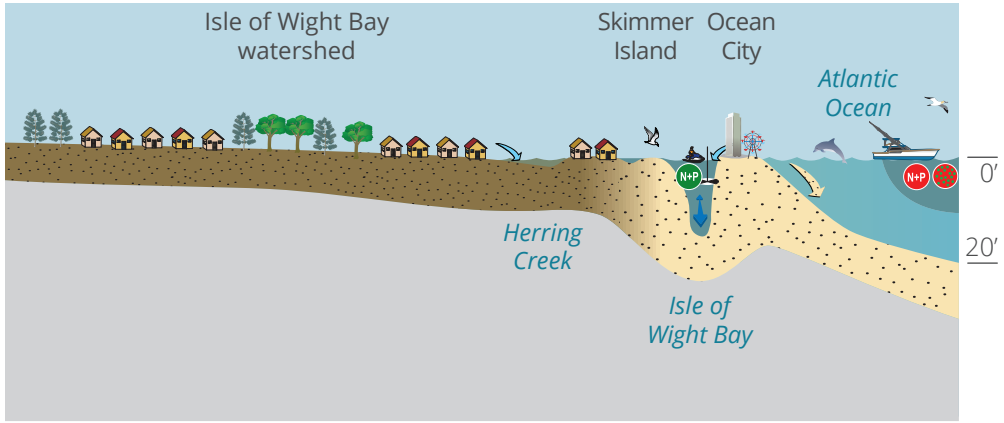


- St. Martin River watershed is highly developed leading to degraded water quality in St. Martin River.
- Ocean City sewage treatment effluent discharges offshore (~30' water depth).
- Assawoman Bay has moderate water quality with remnant seagrasses.

T2: ROUTE 50 TRANSECT

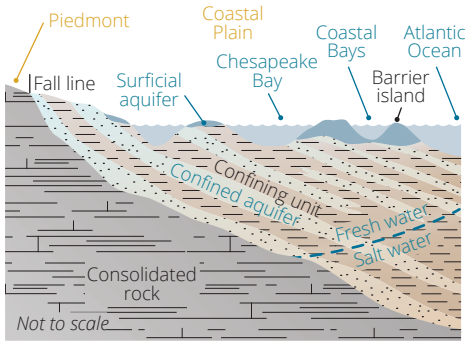


- Isle of Wight Bay watershed is residential and commercial; Isle of Wight Bay is well flushed with clams and fishing, Skimmer Island supports waterfowl.
- Ocean City inlet is maintained by dredging and tidal scouring.
- Ocean City is highly urbanized for summer tourism with impervious surfaces and stormwater runoff.

Four parallel east–west transects were established to provide insights into the features of the Maryland Coastal Bays. From north to south, these transects were the following:

T1: Route 90 bridge transect
T2: Route 50 bridge transect
T3: Verrazano Bridge transect
T4: Chincoteague Island transect

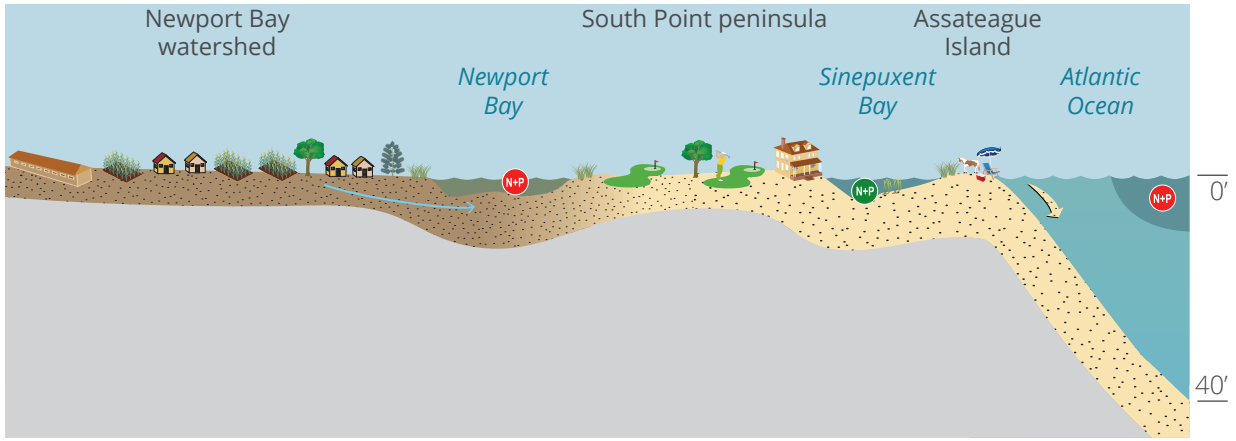
CROSS SECTION OF THE ATLANTIC COASTAL PLAIN



LEGEND

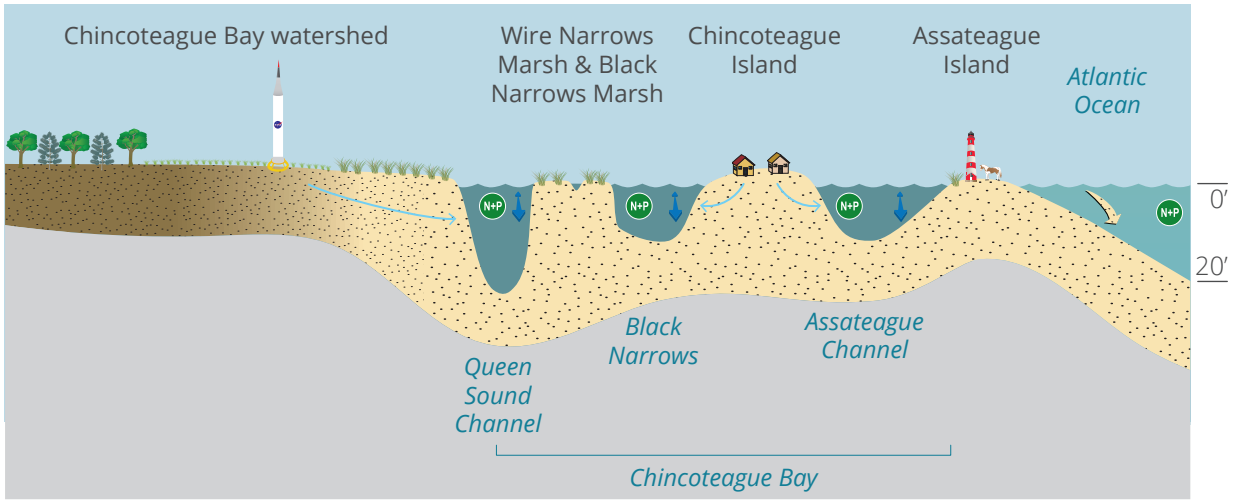
- Sandy bottom
- Muddy bottom
- Water clarity
- Nutrient concentration—low
- Nutrient concentration—moderate
- Nutrient concentration—high
- Chlorophyll concentration—high
- Algal bloom
- Seagrass
- Stormwater runoff
- Longshore sediment transport
- Tidal flushing
- Groundwater flow
- Hardened shoreline

T3: VERRAZANO BRIDGE TRANSECT



- Newport Bay watershed is rural with forest and agriculture leading to nutrient runoff into poorly flushed Newport Bay.
- Sinepuxent Bay is shallow and well flushed, supporting extensive seagrass meadows.
- Assateague Island is managed with the National Park Service for natural geomorphological processes, with herds of iconic feral ponies.

T4: CHINCOTEAGUE ISLAND TRANSECT



- Southern Chincoteague Bay watershed includes housing developments and Wallops Island Flight Center, as well as forest and agriculture.
- Southern Chincoteague bay is well flushed with low ambient nutrient concentrations.
- Chincoteague Island supports the town of Chincoteague which is on septic systems on sandy soil which leads to nutrient discharge to Southern Chincoteague Bay via groundwater.