Preparing for Tomorrow's High Tide

Sea Level Rise Vulnerability Assessment for the State of Delaware

July 2012

Other Documents in the Preparing for Tomorrow's High Tide Series

A Progress Report of the
Delaware Sea Level Rise Advisory Committee
(November 2011)

A Mapping Appendix to the
Delaware Sea Level Rise Vulnerability Assessment
(July 2012)

Preparing for Tomorrow's High Tide

Sea Level Rise Vulnerability Assessment for the State of Delaware

Prepared for the Delaware Sea Level Rise
Advisory Committee
by the Delaware Coastal Programs
of the Department of Natural Resources
and Environmental Control

About This Document

This Vulnerability Assessment was developed by members of Delaware's Sea Level Rise Advisory Committee and by staff of the Delaware Coastal Programs section of the Department of Natural Resources and Environmental Control. It contains background information about sea level rise, methods used to determine vulnerability and a comprehensive accounting of the extent and impacts that sea level rise will have on 79 resources in the state. The information contained within this document and its appendices will be used by the Delaware Sea Level Rise Advisory Committee and other stakeholders to guide development of sea level rise adaptation strategies.

Users of this document should carefully read the introductory materials and methods to understand the assumptions and trade-offs that have been made in order to describe and depict vulnerability information at a statewide scale. The Delaware Coastal Programs makes no warranty and promotes no other use of this document other than as a preliminary planning tool.

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Further information about this document and the Delaware Sea Level Rise Advisory Committee can be found online at http://de.gov/slradvisorycommittee/ and at the address below:

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Executive Summary

As a coastal state, Delaware's economy and quality of life have historically been linked to its shores, its vast expanses of protected tidal wetlands, and its fertile farm fields. Because of its location, low average elevation, and dependence on the coast, Delaware is particularly vulnerable to the effects of rising sea levels including loss of low-lying land and structures, saltwater intrusion into ground and surface waters, and increased coastal flooding from storm events.

Today, sea level rise is rarely, if ever, considered by governments, organizations, and individuals as they make decisions about where to develop, how to build, or what to preserve. However, changes in sea levels could impact the longevity, safety, and return-on-investment of projects that have long planning horizons or long life-spans. Accounting for changes in sea level that may be expected to occur over the lifetime of these projects will help lead to informed decisions for public and private investments by minimizing risk and potential for damage. Planning for the long-term effects of sea level rise may also help us better prepare in the short-term for flooding from coastal storms.

Delaware's Sea Level Rise Advisory Committee

Delaware's Sea Level Rise Advisory Committee (SLRAC) was established by invitation of Collin O'Mara, Secretary of the Department of Natural Resources and Environmental Control (DNREC), to help the state plan for sea level rise. The committee is composed of members from a wide variety of interest groups including state agencies, local governments, citizen organizations, business organizations, and environmental organizations. The goal of the Sea Level Rise Advisory Committee is to assess Delaware's vulnerability to current and future inundation problems that may be exacerbated by sea level rise and to develop a set of recommendations for state agencies, local governments, businesses, and citizens to enable them to adapt programs, policies, business practices and make informed decisions.

The committee's work has been split into two phases, a vulnerability assessment phase and an adaptation planning phase. This document is the culmination of the vulnerability assessment phase, during which the committee provided expert opinions to analyze and assess potential impacts of sea level rise to 79 statewide resources, ranging from roads to wetlands to tourism. This vulnerability assessment will be used as the basis for the next phase, adaptation planning. During the adaptation planning phase, the Advisory Committee will identify ways that government, businesses, and citizens can adapt their policies and business practices to reduce the impact of sea level rise on our state's citizens, economy, and natural resources. The final report of the Sea Level Rise Advisory Committee will contain recommendations to help governments, businesses and citizens prepare for sea level rise.

Results of the Sea Level Rise Vulnerability Assessment

Delaware's sea level rise vulnerability assessment demonstrates that inundation from sea level rise will occur in all three of Delaware's counties, affecting a range of resources. Although the direct impacts from sea level rise inundation will be felt primarily in areas near tidal waters, every Delawarean is likely to be affected by sea level rise whether through increased costs of maintaining public infrastructure, decreased tax base, loss of recreational opportunities and wildlife habitat, or loss of community character.

Statewide, between 8% and 11% of the state's land area (including wetlands) could be inundated by a sea level rise of 0.5 meters to 1.5 meters, respectively. Within those potentially inundated areas lie transportation and port infrastructure, historic fishing villages, resort towns, agricultural fields, wastewater treatment facilities and vast stretches of wetlands and wildlife habitat of hemispheric importance.

Peggy Schultz

The Delaware Sea Level Rise Advisory Committee discusses the issues.

Eric Crossan

The St. Jones River meeting the Delaware Bay, southeast of Dover, Delaware.

Executive Summary

Based upon the information in this vulnerability assessment, the Sea Level Rise Advisory Committee ranked each resource according to the potential impacts that could result from sea level rise and their relative statewide importance. Based upon this ranking, 16 resources emerged as being of high concern statewide:

Beaches and Dunes: Delaware's coastline is an important ecological resource—providing habitat for a variety of plants, animals, insects, migratory birds, and a multitude of other terrestrial and aquatic wildlife. Shorelines naturally shift and retreat in response to wind, waves, tides, storms and rising seas. However, natural shoreline processes are interrupted by people's desire to live and recreate near the shore. Delaware's 381 miles of shoreline, including 24 miles that front the Atlantic Ocean, provides economic benefits from tourism, coveted high-value space for commercial and residential development, and many forms of recreation, including boating, fishing, and beach-going. When combined with wind-driven waves, sea level rise can exacerbate shoreline erosion that damages dune habitat and leaves infrastructure along the coastline vulnerable to storm damage. Beach replenishment has been the predominant means to offset sand loss and protect structures to which the state has contributed considerable funding. Due to the economic value, natural resource value and significant state investment in sand replenishment, this resource was ranked as a high concern.

Coastal Impoundments: Coastal impoundments are vital resources that serve to provide important breeding, migration, and wintering habitat for a variety of birds, serve as nurseries for fish, help to control mosquitoes, and provide important recreational opportunities. Impoundments in each county are at risk from sea level rise. A sea level rise of 0.5 meters would result in the potential inundation of 81% of the state's acreage of impounded wetlands. Up to 99% of all the state's acreage of impounded wetlands could be inundated at both 1.0 and 1.5 meters of sea level rise. The impacts will be relatively local; however the areas that are affected show high levels of inundation and complete loss of function. Since the majority of the resource within the state may be affected, this resource was ranked as a high concern.

Delaware Coastal Programs

Dams, Dikes & Levees: Between 39% and 78% of the state's 50 miles of dams, dikes and levees could be inundated by sea level rise by 2100. The highest concentration of potential impact is focused in Kent County, whose dikes primarily protect wildlife areas. The majority of the dikes in New Castle County protect people, property, and, in one case, a contaminated site. These structures were built to provide a certain level of containment or protection. If a breach or structural failure were to occur, the resultant flooding could affect a large area inland of the structure. Due to these considerations, inundation of dams, dikes, and levees in the state was ranked as a high concern.

Evacuation Routes: Between 1% and 6% of the state's evacuation routes are within an area that could be inundated by sea level rise by 2100. Interstates and arterial roads tend to serve as the major evacuation routes for emergencies; substantial reliance on a single mode of transportation for evacuations may endanger many people if the highway infrastructure is made inaccessible because of sea level rise. All three counties experience exposure but the highest concentration is found in Sussex County. Because evacuations rely on automobile transportation and because flooded roadways can prevent or slow evacuation by car, inundation of evacuation routes was ranked as a high concern.

Freshwater Tidal Wetlands: Freshwater tidal wetlands occur at the upper reaches of estuaries where the water is no longer salty, but is still influenced by the rise and fall of the ocean tides. These wetlands are home to unique plant and animal communities and are known for their high species diversity. Sea level rise, over time, may introduce salinity to freshwater areas, replacing freshwater tidal marshes with brackish marshes or open water, which in turn will cause major shifts in species composition. For freshwater tidal marshes affected by sea level rise, a wetland system may still exist with increased salinity, but its unique habitat value will be lost. Sea level rise could impact between 84% and 98% of the total freshwater tidal wetland acreage statewide by the year 2100. Because of the unique habitats contained within freshwater tidal wetlands and because the majority of the resource within the state could be affected, this resource was ranked as a high concern.

Future Development Areas: Between 3% and 7% of land designated as future development areas by Delaware's Strategies for State Policies and Spending are within an area that could be inundated by sea level rise by 2100. These areas are typically rural or suburban in nature and are adjacent to the actively growing zones of Delaware's municipalities. Four-fifths of these potentially inundated areas are located in Sussex County and could be developed to meet the future demand for residential and commercial development in and around the resort areas. Careful consideration must be given to determine whether directing new development to potential inundation areas will place citizens and infrastructure at risk in the future and whether creating new building restrictions will impact citizens' freedom of choice and the regional economy. Due to the significant potential effects for development in Sussex County coupled with the potential need for state funding of infrastructure repairs and legal concerns, sea level rise within future development areas was ranked as a high concern.

Habitats of Conservation Concern: The Delaware Wildlife Action Plan, the framework for conserving the state's native wildlife, identified 27 Habitats of Conservation Concern (HCC). These habitats are rare, have special significance in Delaware, are particularly sensitive to disturbance, and/or have a high diversity of rare plants. Of these 27 unique habitat types, 15 were determined to be vulnerable to sea level rise and were analyzed to determine the extent of possible exposure. Between 55% and 65% of the total acreage of the 15 HCCs analyzed could be inundated by sea level rise by 2100. Because these exceptional habitat types often harbor rare plant and animal species and are sensitive to environmental stresses, including sea level rise, this resource was ranked as a high concern.

Delaware Coastal Programs

A driver navigates across a flooded road during a nor'easter in October 2009.

Executive Summary

Heavy Industrial Areas: Between 16% and 25% of the acreage of heavy industrial lands in the coastal area (as permitted by Delaware's Coastal Zone Act) are within an area that could be inundated by sea level rise by 2100; the majority of these areas are in New Castle County. While the inundation model shows that inundation risk to the facility buildings themselves is low, many associated structures like docks, piers, and lagoons could be affected. Because these facilities are a large economic driver for the state, reduced operational capacity could impact both the economies of the towns surrounding these facilities and the state's economy as a whole. If the lands currently zoned for heavy industry become unsuitable for industrial operations, retaining these businesses within the state could prove difficult due to lack of suitable industrially zoned land and the difficulties of rezoning land to industrial uses. Due to the significant potential statewide effects resulting from sea level rise, heavy industrial areas were ranked as a high concern.

Port of Wilmington: Between 36% and 73% of the Port of Wilmington's property is within an area that could be inundated by sea level rise by 2100. The port is based in northern New Castle County; however, the economic value to Delaware and the entire Northeast Region makes exposure to sea level rise a state and regional issue. Due to these considerations, inundation of the Port of Wilmington was ranked as a high concern.

Protected Lands Statewide: Protected lands encompass a variety of lands owned by state, local and municipal governments, conservation groups and individuals. These lands include state wildlife areas, state parks, state forests, boat ramps, nature preserves, historical sites, national wildlife refuges, municipal parks, open space, and recreational facilities and public and private conservation easements. Collectively, these properties represent a variety of habitat types and extensive opportunities for outdoor recreation. Statewide, between 37% and 44% of protected lands statewide are exposed to sea level rise under the three scenarios. Because these lands represent a significant investment to protect natural habitats and recreational use and because sea level rise could impact their intended use, protected lands were ranked as a high concern.

Roads & Bridges: Between 1% and 5% of the state's roads and bridges are within an area that could be inundated by sea level rise by 2100. Inundation of an individual segment of road could cause regional transportation disruptions, particularly if no alternative routes are available. The highest concentration of roadway exposure to sea level rise was found in Sussex County; however, potential exposure was found throughout the state. Due to the potential regional impacts, inundation of roads and bridges from sea level rise was ranked as a high concern.

Railroad Lines: Between 2% and 6% of the state's railroad lines are within an area that could be inundated by sea level rise by 2100. The highest concentration of impact is focused in New Castle County. Even with smaller amounts of exposure in Kent and Sussex Counties, it should be noted that if a single rail line segment becomes inundated, the entire functionality of the line could be lost. This may impact industries served by rail such as power plants and the Delaware City refinery. Passenger travel is also a concern; disruptions and possible restrictions to the Amtrak rail line could impact travel throughout the northeast corridor. Because disruption of rail service in Delaware could have impacts throughout the state and region, inundation of railroad lines as a result of sea level rise was ranked as a high concern.

Tidal Wetlands: Tidal wetlands are among the most productive ecosystems in the world and provide habitat, food and breeding grounds for many species of plants and animals. Delaware's tidal wetlands are an intricate part of the local, regional, national, and international ecosystems. Tidal wetlands act as sponges by soaking up floodwaters and buffering storm impacts and also act as filters by trapping sediments and removing contaminants. The potential impacts to tidal wetlands as a result of sea level rise are striking in their extensiveness, affecting the vast majority of tidal wetlands in all three counties. The exposure assessment found that 97% of the state's tidal wetlands may be impacted at the 0.5 meter scenario, and 99% at both the 1.0 and 1.5 meter scenarios. Since the majority of the resource within the state may be affected, impacts to tidal wetlands as a result of sea level rise was ranked as a high concern.

Tourism and Coastal Recreation: Tourism and coastal recreation are important components of Delaware's economy and quality of life. Significant portions of Delaware's resort areas, coastal historic sites, and natural resources could be inundated or significantly altered by sea level rise. Of specific concern is the maintenance of Delaware's beaches, which are currently replenished on a routine basis with federal and state funding. Accelerated rates of sea level rise may necessitate larger or more frequent beach replenishment projects to preserve recreational beach uses. Due to the potential for revenue losses statewide, coupled with the potential increased funding needs for maintenance or repair of tourist destinations, sea level rise impacts to tourism and coastal recreation was ranked as a high concern.

U.S. Fish and Wildlife Service Refuges: Prime Hook National Wildlife Refuge (NWR) is located in Sussex County near the town of Milton. Bombay Hook NWR is located in Kent County near the towns of Smyrna and Dover. Area residents and tourists use the refuges for passive outdoor recreation activities such as birding, wildlife watching, and photography, as well as for hunting and fishing. Refuge wetlands provide habitat for overwintering and migrating waterfowl and shorebirds, wading birds, secretive marsh birds and wetland passerines. Reduction or loss of wetland habitats within the protected boundaries of the refuges can impact populations of these species. Species may be forced to redistribute if refuge wetlands no longer meet their needs, and may relocate in wetlands that are not afforded the same protection and management that is provided by the NWR designation. Between 85% and 95% of refuge acreage could be inundated under the three scenarios. While the impacts are localized, the acreage affected (21,354 to 24,120 acres) represents a significant loss of protected habitat and was ranked as a high concern.

Wells: Residents and businesses in Kent and Sussex Counties rely on groundwater resources for drinking, irrigation and industrial purposes. Operation of wells that extract groundwater can be compromised by inundation from sea level rise, and the quality of groundwater can be compromised by saltwater intrusion resulting from sea level rise. Statewide, between 3% and 7% of domestic wells, 3% and 7% of industrial wells, 1% and 2% of irrigation wells, and 2% and 10% of public wells are within an area that could be inundated by sea level rise by 2100. Potential exposure of wells to sea level rise is focused along the coast; however, reduction in availability of groundwater in the coastal areas may increase demand on inland public wells. Because access to clean water is a necessity and because demand on inland wells may increase, sea level rise impacts to wells was ranked as a high concern.

The Sea Level Rise Advisory Committee will use the results of the Vulnerability Assessment to inform and focus efforts during the next phase of their work, the development of adaptation options.

Executive Summary

Use of this Document

This document and its appendices provides an exhaustive accounting of resources vulnerable to sea level rise of up to 1.5 meters in Delaware. It includes background information, a description of the process used to assess vulnerability, exposure assessment tables, and risk assessments for 79 resources. A comprehensive set of vulnerability maps and information on how to use them is also included as the Mapping Appendix. The vulnerabilities and risk assessment described in this document should be considered as a starting point for more detailed localized or resource-based assessments and as a starting point for prioritizing adaptation strategies.

This document is the first of its kind to provide detailed estimates of numbers or acres of resources at risk from sea level rise at a state level. It represents a significant accomplishment and positions the state well to develop and implement specific adaptation strategies for resources most important to Delaware's continued sense of community, economic well-being, and natural resource diversity.

Tony Pratt

Homes and wildlife habitat at Broadkill Beach, along the Delaware Bay.

Coastal
Heritage

Introduction

Introduction

Delaware's See Level Rise Advisory Committee

Delaware's Sea Level Rise Advisory Committee was formed to help the state plan for sea level rise, a coastal issue that could affect a wide range of quality of life and economic issues from infrastructure sustainability to crop yields to wildlife habitat. The committee was established by invitation of Collin O'Mara, Secretary of the Department of Natural Resources and Environmental Control (DNREC), to investigate Delaware's vulnerability to sea level rise and to provide recommendations about how to best prepare for higher sea levels. The committee is composed of members from a wide variety of interest groups including state agencies, local governments, citizen organizations, business organizations, and environmental organizations.

Peggy Schultz

The Delaware Sea Level Rise Advisory Committee discussing a presentation.

The Sea Level Rise Advisory Committee held their inaugural meeting in November 2010 and has met thirteen times between November 2010 and May 2012. Three workgroups were formed in February 2011 to allow in-depth discussions of priority sea level rise issues: Natural Resources; Society & Economy and Public Safety and Infrastructure.

The committee's work was split into two phases, a Vulnerability Assessment Phase and an Adaptation Planning Phase. This document is the culmination of the Vulnerability Assessment Phase, during which the committee provided expert opinions to analyze and assess potential impacts of sea level rise to 79 statewide resources, from roads to wetlands to tourism. The vulnerability assessment will be used as the basis for the next phase, adaptation. During the Adaptation Planning Phase, the Advisory Committee will identify ways that government, businesses, and citizens can adapt their policies and business practices to reduce the impact of sea level rise on our state's citizens, economy, and natural resources. The final report of the Sea Level Rise Advisory Committee will contain recommendations to help governments, businesses and citizens prepare for sea level rise.

It is the intent of the Sea Level Rise Advisory Committee to provide information and guidance to help people make informed decisions when considering activities and investments in areas that may be at risk from the effects of sea level rise; it will not oversee implementation of adaptation measures. Any recommended adaptation action that would require a change in legislation or regulations will go through the normal legislative and public processes.

Sea Level Rise Advisory Committee Member Agencies

Delaware Association of Realtors	Delaware Office of the Governor
Delaware Department of Agriculture	Delaware Office of Management and Budget
Delaware Department of Health and Social Services	Delaware State Chamber of Commerce
Delaware Department of Natural Resources and Environmental Control	Home Builders Association of Delaware
Delaware Department of Safety and Homeland Security	Kent County
Delaware Department of Transportation	League of Women Voters of Delaware
Delaware Economic Development Office	New Castle County
Delaware Farm Bureau	Positive Growth Alliance
Delaware Insurance Commissioner's Office	Sussex County
Delaware League of Local Governments	The Nature Conservancy
Delaware Legislature	Tidewater Utilities, Inc.
Delaware Nature Society	University of Delaware

Planning for Sea Level Rise

Delaware is a coastal state; its economy and quality of life have historically been linked to its shores, its vast expanses of protected tidal wetlands, and its fertile farm fields. Because of its location, low average elevation, and dependence on the coast, Delaware is particularly vulnerable to the effects of rising sea levels including loss of low-lying land and structures; saltwater intrusion into ground and surface waters; and increased coastal flooding from storm events.

Today, sea level rise is rarely, if ever, considered by governments, organizations, and individuals as they make decisions about where to develop, how to build, or what to preserve. However, changes in sea levels could impact the longevity, safety, and return-on-investment of projects that have long planning horizons or long life-spans. Accounting for changes in sea level that may be expected to occur over the lifetime of these projects will help lead to informed decisions for public and private investments by minimizing risk and potential for damage. For example, expensive retrofits or replacements of roads and buildings could be avoided by building structures that are specifically designed to withstand a certain rise in sea level. Funding and resources for shoreline stabilization, wetland restoration, and infrastructure improvements could be planned and in-place before emergency measures are necessary. Thoughtful, proactive planning for sea level rise may help Delaware's economy and natural resources continue to flourish even with the new long-term challenges sea level rise brings.

Delaware Coastal Programs

The impacts of storm surge from Hurricane Irene in August 2011 take a toll on State Highway Route 9 over Augustine Creek near Port Penn, Delaware.

Planning for the long-term effects of sea level rise may also help the state better prepare in the short-term for periodic flooding from coastal storms. Storm surges of between two and four feet frequently occur along the Delaware Bay and Atlantic coast from tropical storms and nor'easters. Delaware's largest storm on record, a nor'easter that occurred in 1962, caused a storm surge of 4.5 feet (1.4 meters) in Lewes; a nor'easter that occurred on Mother's Day in 2008 produced a storm surge of 4.0 feet (1.2 meters) in Bowers Beach. These storm surges are comparable to the sea level rise expected by 2100; any actions taken to reduce the effects of sea level rise in the future will also have the added benefit of increased protection from storm surge flooding now.

The goal of the Sea Level Rise Advisory Committee is to assess Delaware's vulnerability to current and future inundation problems that may be exacerbated by sea level rise and to develop a set of recommendations for state agencies, local governments, businesses, and citizens to enable them to adapt programs, policies, business practices and make informed decisions.

Introduction

Effects of Sea Level Rise

Sea level rise is just one of the factors that contribute to changes in the coastal landscape over time. Other factors such as storms, erosion, and sediment accretion act in concert with changes in sea level to shape the size and makeup of our sandy shorelines, wetlands, and river channels. However, as the rates of sea level rise accelerate, sea level rise may increasingly become the driving force in coastal changes. Accelerated rates of sea level rise could cause inundation of low-lying land, saltwater intrusion into groundwater and streams, and increased extent and severity of storm flooding.

Inundation of low-lying land and structures can occur when the sea level rises faster than natural forces can build up land or where shoreline protection structures are not constructed. This can cause dry land to become flooded and can cause wetlands to convert into open water (CCSP, 2009). Structures, including homes, roads, and utilities that have been built in low-lying areas can become difficult to access, suffer structural instability or become unusable. This vulnerability assessment focuses primarily on these inundation effects in Delaware.

Saltwater intrusion of groundwater and streams can also occur as sea levels increase. In rivers and streams, sea level rise may cause the “salt line” to move inland, changing the types of vegetation in and around the stream, and impacting the quality of fish spawning areas. It also may affect intake structures for drinking water and industry. In certain areas, water from the ocean and bay may turn groundwater supplies salty, affecting water used for drinking and irrigation (United States Environmental Protection Agencey & Delaware River Basin Commission, 1986). The data and information necessary to assess the potential for saltwater intrusion issues from sea level rise in Delaware is not currently available, however, throughout this document, potential impacts are discussed, and data gaps are highlighted.

Salt Line

The salt line is the location where a stream or river is no longer considered to be salty (contains less than 250 milligrams per liter of chloride). The salt line fluctuates each year depending upon tidal inputs and freshwater inflows from rain and dam releases. In the Delaware River, the salt line is currently a mile south of the Delaware Memorial Bridge, but has reached as far as 2 miles north of the Ben Franklin Bridge in Philadelphia in severe drought years.

As sea level rises, flooding from coastal storm events may become more widespread. As sea levels increase, so do the storm surge[1] heights generated by a given storm. An increased storm surge height, combined with resulting coastal erosion and loss of tidal wetlands that provide natural flood protection may result in increased flood depths in already flood-prone areas. It may also cause flooding in areas further inland that have not previously been flood-prone. Flooding from storm surges can cut off evacuation routes and cause significant damage to homes and infrastructure.

While increased storm surge heights and flooding is a very important consideration for understanding the potential range of effects caused by sea level rise, modeling specific storm surge impacts statewide is a complicated and resource-intense undertaking that was outside of the scope of this assessment. However, the general effects of increased storm surge heights with regard to resources of concern are discussed throughout this document.

Figure 1 maps shoreline retreat in the Bombay Hook area of Delaware Bay. This map demonstrates historic shoreline loss along the shoreline of Bombay Hook Delaware and was constructed using shoreline maps for 1883 and 1969 published by the National Ocean Service, and a digitized shoreline from a US Geological Survey aerial photograph taken in 2007. Rates of shoreline retreat at this location between 1883 to 2007 range from 2 to 5 meters per year. Between 1969 and 2007, the rate was 5 to 10 meters per year, among the highest rate for the wetland coast of Delaware Bay. A combination of storm-wave erosion and relative sea level rise are responsible for landward migration of the shoreline over time (CCSP, 2009).

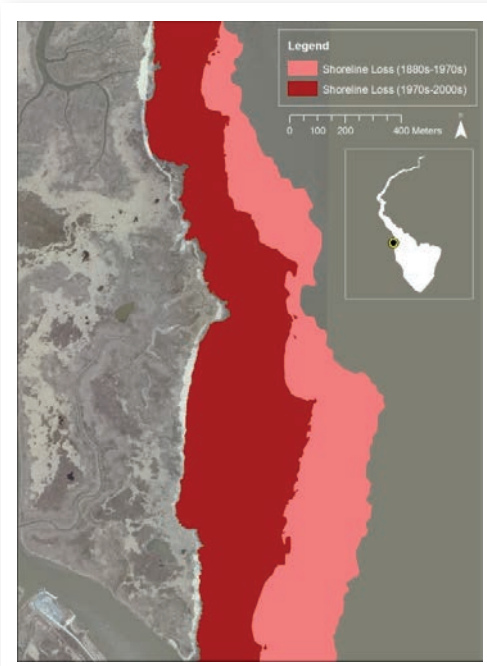


Figure 1 - Shoreline erosion
(Woods Hole Group Consulting, Inc.)

Delaware Coastal Programs

Dockside parking lot at Bowers Beach
in May 2009 after a nor'easter.

[1]Storm surge is an abnormal rise of water generated by a storm. A useful description of storm surge can be found on NOAA's website http://www.nhc.noaa.gov/surge/

Introduction

Rates and Causes of Sea Level Rise

Sea level trends are recorded by tide stations, which measure the height of water referenced to a stable point on land with a known elevation (benchmark). Tide stations are primarily installed for navigational purposes and their data are used to make tide predictions. Long term data sets from these tide stations have also been used to understand local and global sea level trends (IPCC, 2001). Globally, sea level rises for two primary reasons: expansion of saltwater as it warms and loss of ice on land. As the ocean absorbs solar radiation in excess of what it emits, the water warms. When water warms, it expands and causes the average level of the water to rise. In addition, as the Earth becomes warmer, land-based glaciers and ice-caps melt and slide into the sea. This melt-water and ice empties into oceans and causes the average level of the water to rise. In combination, these two forces constitute the eustatic (or global) rate of sea level rise[2]. The eustatic sea level rate during the twentieth century, as determined by tide gauge measurements, was about 0.07 inches per year (or about 7 inches over 100 years) (IPCC, 2001).

Tide gauges indicate that the change in the local mean sea level (LMSL)[3] in Delaware is greater than the eustatic sea level rate. The rate of change recorded at the tide gauge in Lewes is 0.13 inches per year (or 13 inches over 100 years), as compared to eustatic rate of 0.07 inches per year. This difference is due to the vertical movement of the Earth's crust, which is causing the land in Delaware to slowly sink. Tide gauges record this combined motion of the land and the sea. Figure 2 shows the local mean sea level trend from the tide gage at Lewes from 1919 to 2011. Other tide gauges throughout the Mid-Atlantic show similar trends[4].

While it cannot be proven with certainty, climatologists have predicted that the rate of sea level rise occurring today will likely become greater in the decades to come (IPCC, 2001) The extent of the increase will depend on a number of factors including future emissions of greenhouse gases (especially carbon dioxide), the rate at which the temperature of the ocean increases and the rate at which ice is lost from land-based glaciers.

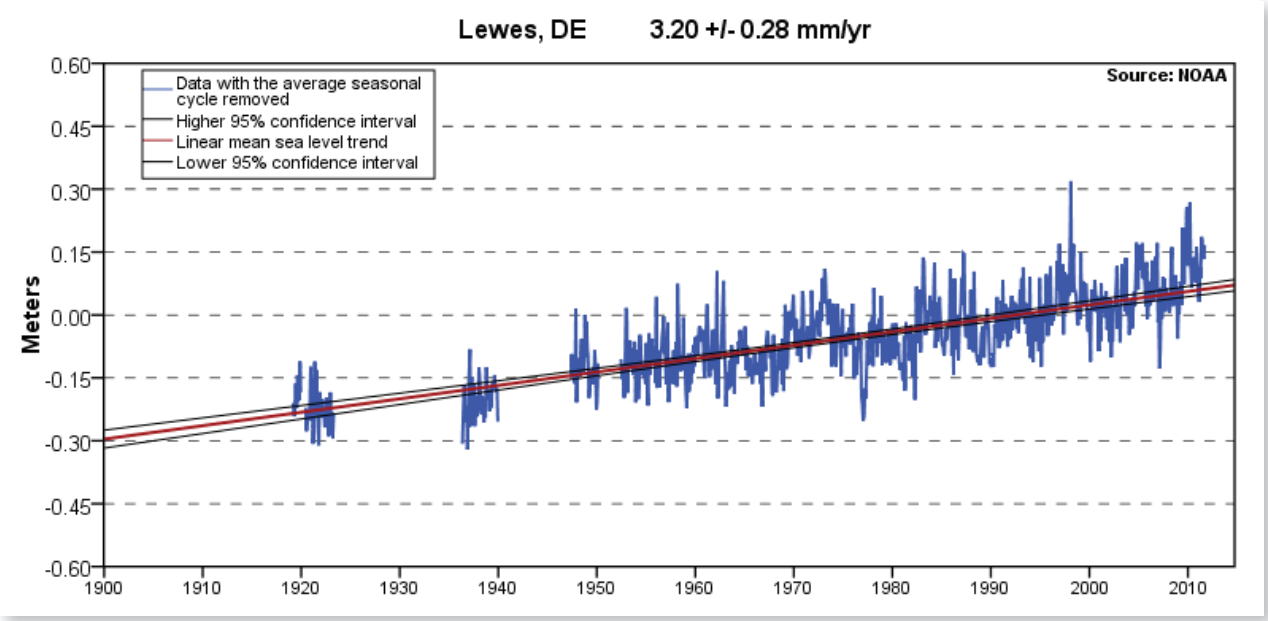


Figure 2 - Mean Sea Level Trend - Lewes, DE (NOAA, 2012)

[2]The eustatic sea level rate is a technical term for the worldwide change of sea level elevation with time

[3]Local Mean Sea Level (LMSL) is a term that describes the height of the ocean relative to land, measured hourly by a tide gauge and averaged over a nineteen year period known as the National Tidal Datum Epoch.

Future Rates of Sea Level Rise

In 2009, the DNREC formed a Sea Level Rise Technical Workgroup to provide the Department with planning scenarios for sea level rise to the year 2100. This workgroup, composed of scientists from the University of Delaware, Delaware Geological Survey, Center for the Inland Bays, Partnership for the Delaware Estuary and DNREC, reviewed historical data for local sea level rise and reviewed the findings of international and national sea level rise expert panels. Based on this information, the Sea Level Rise Technical Workgroup recommended three planning scenarios for sea level rise to 2100. The conclusions of the workgroup were then reviewed by national experts[5] and used by DNREC in the development of an internal policy that directed it to plan for sea level rise (DNREC Sea Level Rise Technical Workgroup, 2009).

The Technical Workgroup chose to recommend a range of scenarios to DNREC because it is not possible to precisely predict future rates of sea level rise (DNREC Sea Level Rise Technical Workgroup, 2009). The three scenarios can be used as a planning tool to determine a range of potential outcomes and options. The Technical Workgroup's low scenario was a sea level rise of 0.5 meters (1.6 feet) between now and the year 2100. This scenario is slightly higher than the current rate of sea level rise in Delaware and is partially based on low estimates for future global warming. The high scenario was a sea level rise of 1.5 meters (4.9 feet) between now and the year 2100. This scenario is based on higher estimates of future global warming. The intermediate scenario was 1.0 meter (3.3 feet) between now and the year 2100, and is based on moderate estimates of future global warming. Figure 3 contains a graph of the three scenarios, which can be used to estimate a range of sea level rise scenarios between now and 2100. The upward curvature of the lines indicates that the rates increase with time. The straight, or "stable," line is included for reference; it shows the sea level that would occur if today's rate of sea level rise continued into the future, rather than accelerating.

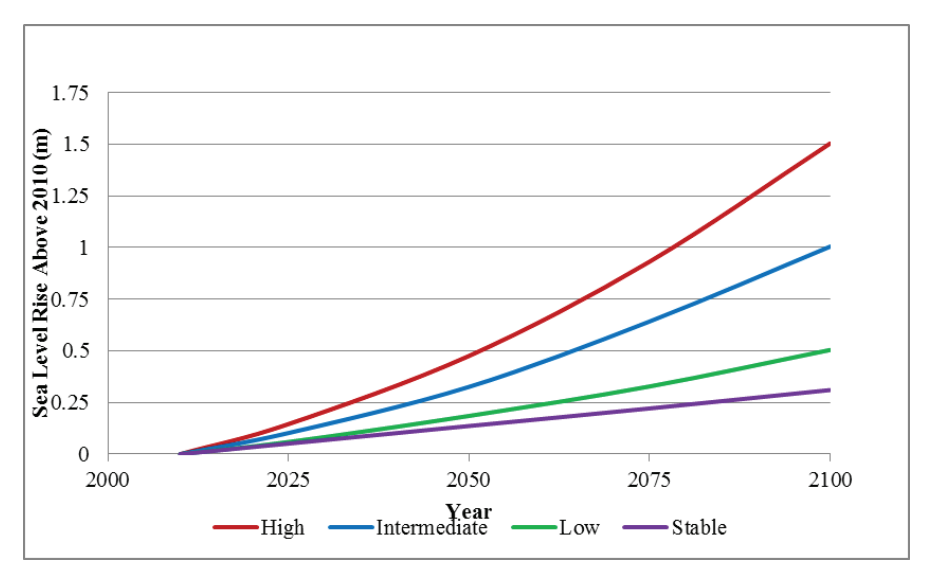


Figure 3 - Sea Level Rise Scenarios Recommended by DNREC's Technical Workgroup.

These three scenarios were provided to the Sea Level Rise Advisory Committee by DNREC and have been used throughout the vulnerability assessment to understand the potential range of impacts that sea level rise may have for the state. Evaluation and endorsement of these recommended sea level rise scenarios was outside of the purview of the Advisory Committee.

It is important to note that scientists are continually working to increase their knowledge about sea level rise and to provide better predictions of future sea levels. As new data and information become available, the planning scenarios (and associated maps) will be revised in order to reevaluate potential impacts.

[4]Tide gauge information is available from the National Oceanic and Atmospheric Administration: http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml.

[5]The scenarios were reviewed by S. Jeffress Williams, Coastal Marine Geologist at the US Geological Survey Woods Hole Science Center and Jim Titus, US Environmental Protection Agency

Introduction

Visualizing Sea Level Rise

It is difficult to reliably model how shorelines and coastal areas will change and reshape due to the combined forces of accelerated rates of sea level rise, coastal erosion, storm surges and human activities (dredging, shoreline protection), particularly at a statewide scale. However, bathtub inundation models, which assume a static shoreline, can be useful in identifying low-lying coastal areas that could be subject to inundation in the future.

Using high resolution elevation data, a bathtub model of the state was created. The bathtub model floods all land below a certain elevation, unless there is a structure that would block tidal flow (like dikes and dams). Based upon this model, a series of maps was developed to show what the recommended sea level rise scenarios would look like on the ground at mean higher-high water (see text box). Maps were created for mean higher-high water (MHHW), MHHW + 0.5 meters, MHHW + 1.0 meter and MHHW + 1.5 meters.

Mean Higher High Water (MHHW)

These sea level rise scenario maps depict potential future sea levels at mean higher-high water; a term that describes an average height of water at high tide. In Delaware, there are two high tides per day. Of those, one rises slightly higher than the other (the same is true of low tides). Mean higher-high water is calculated by taking the average of the higher of the two high tides each day, observed over a nineteen year period (the National Tidal Datum Epoch).

The maps are available online as an interactive viewer at http://de.gov/slrmap.aspx. A complete description of the process used to develop the maps is available in the Mapping Appendix document.

There are many other terms used to describe water levels at various tides (e.g. mean high tide, ordinary high water mark)6; in this document any time the term “high tide” is used, it is referring to mean higher-high water.

These maps show the level of high tide in Bowers Beach, Delaware under three different planning scenarios, which were developed using local data coupled with scenarios generated by several federal agencies.

Bowers Beach at high tide, 2011.

Bowers Beach at high tide with 1.6 feet of sea level rise.

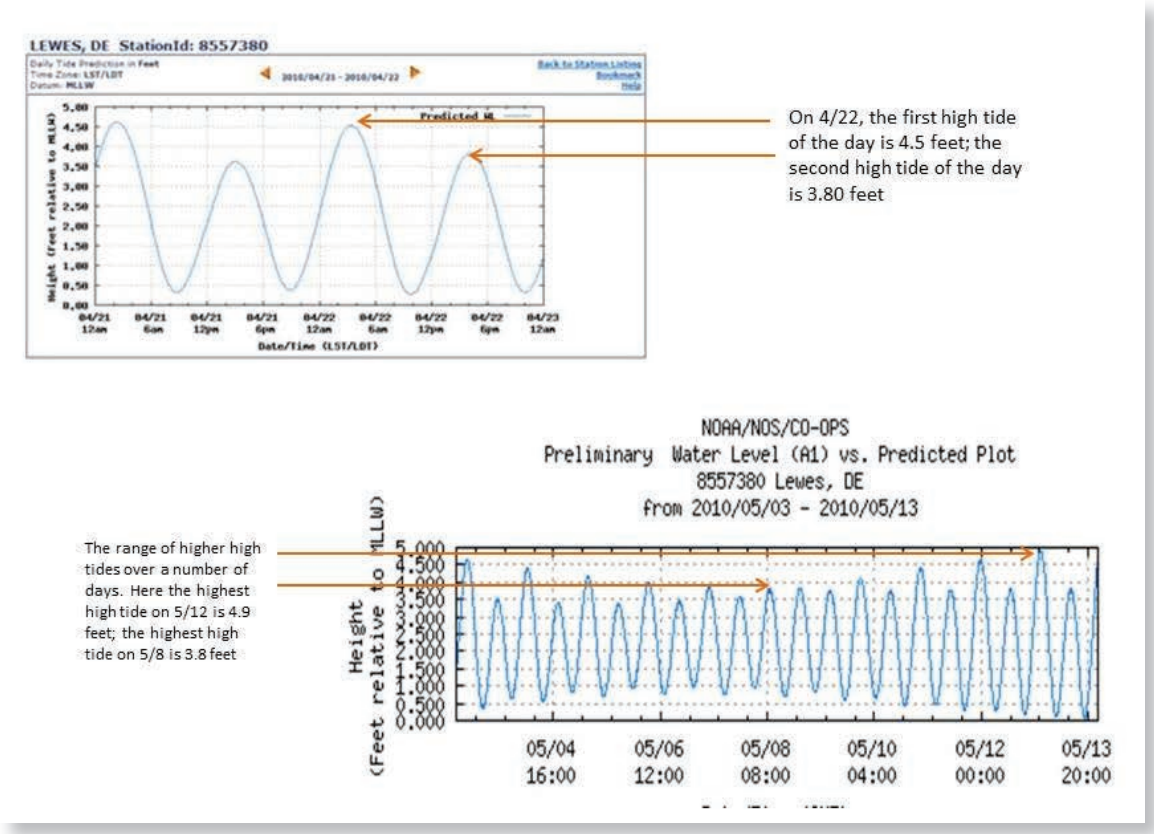
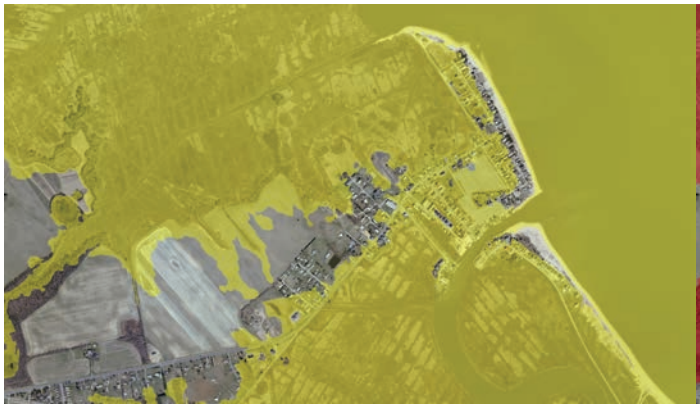


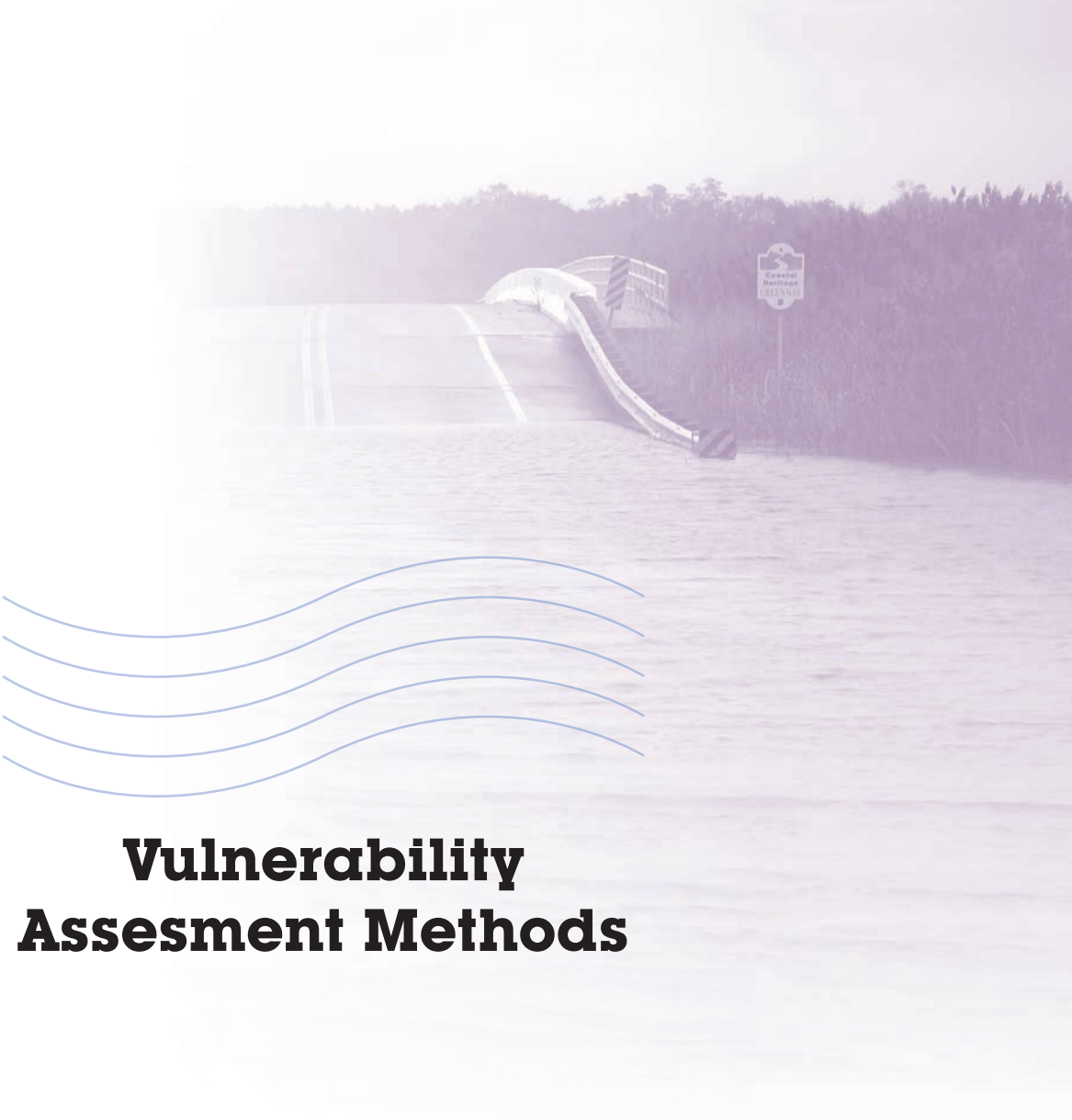
Figure 4 - Differences in high tide heights.



Bowers Beach at high tide with 3.3 feet of sea level rise

Bowers Beach at high tide with 4.9 feet of sea level rise

[6]A useful reference that briefly describes water level recording devices and tidal datums is available online from the Southeast Atlantic Coastal and Ocean Observing System (SEACOOS): http://seacoos.org/Data%20Access%20and%20Mapping/water_level_product_desc



Vulnerability Assesment Methods

Vulnerability Assesment Methods

Vulnerability assessments are conducted as a way to understand the effects of a hazardous event, whether the event is an attack by a computer hacker, a tornado or in this case – sea level rise. Vulnerability assessments identify locations and extent of impacts and often prioritize the importance of these impacts. This process can then lead to changes that may limit the negative effects should the event occur.

Completion of a statewide vulnerability assessment for sea level rise was the first major task of the Sea Level Rise Advisory Committee and represents a significant achievement. Delaware is the first state to comprehensively assess specific resource vulnerability to sea level rise at a statewide level. This document provides detailed information about what resources will be impacted, where those impacts will occur and what the likely secondary social, environmental, and economic effects will be. Because the vulnerability assessment has a very large scope and covers a large geographic area, it should be considered a screening tool for determining the need for more detailed vulnerability assessments and for development of sea level rise adaptation strategies.

The Vulnerability Assessment was developed in five stages, described in detail below:

1. Identification of Resources of Concern
2. Data Collection
3. Exposure Assessment
4. Impact Assessment
5. Risk Assessment

Additionally, a series of Public Engagement Sessions was held to inform the public of the Committee's activity and as a cross-check on the issues.

Delaware Coastal Programs

House raised above coastal flood zone in Slaughter Beach, Delaware.

Identification of Resources of Concern

Each workgroup met several times to identify issues that would result from sea level rise and to identify specific resources of concern to them. The definition of resource in this case is broad, including items from historic sites to industrially zoned land to roads to special wildlife habitats. As a result of these discussions, the three workgroups identified 140 resources that could be mapped and quantified for use in the vulnerability assessment.

Data Collection

In order to conduct an in-depth vulnerability assessment, geographic datasets are necessary. Geographic datasets are a special type of dataset that contains information so that it can be placed on a map. Delaware Coastal Programs staff spent considerable time and effort compiling geographic datasets that could be utilized with the sea level rise scenario maps to determine the location and numbers of resources at risk from sea level rise. Datasets like roads, railways and public safety facilities were relatively easy to obtain as they are maintained and routinely updated by a state or county agency. Many datasets were out of date or lacked appropriate documentation as to when the data was collected or how it was collected (metadata). A few datasets were unable to be used for this assessment due to privacy or homeland security concerns (electrical substations for example). In many other cases, the desired data did not exist or was so out of date that it could not be used.

Of 140 datasets identified as necessary to understand impacts to resources, 79 were obtained and analyzed as a part of this vulnerability assessment. In all cases, existing data was used for this assessment. Creating, improving or updating geographic datasets generated by disparate entities was outside of the scope of this assessment. However, throughout this document, all data sources are cited and any issues with the data are explained. Additional information about this is available in the Mapping Appendix.

Exposure Assessment

After the data was collected, an exposure assessment for each resource was conducted using ArcGIS. Locations of resources of concern were “overlaid” with the three sea level rise scenarios; any resource within the sea level rise scenarios was counted as “exposed.” Figure 4 shows how this was done using storage tanks as an example. The pink dots represent locations of storage tanks; the yellow areas indicate areas that could be inundated at the 1.0 meter sea level rise scenario. Any pink dot within the yellow area would be counted as exposed at 1.0 meter. Results are reported in an Exposure Table and summarized for each scenario and for each county (see Table 2 and text box description of how to use the exposure tables below). Maps were also developed for each resource that depict the geographic extent of inundation under each scenario at a statewide level (see Mapping Appendix for complete description of how statewide maps were developed and how to interpret them).

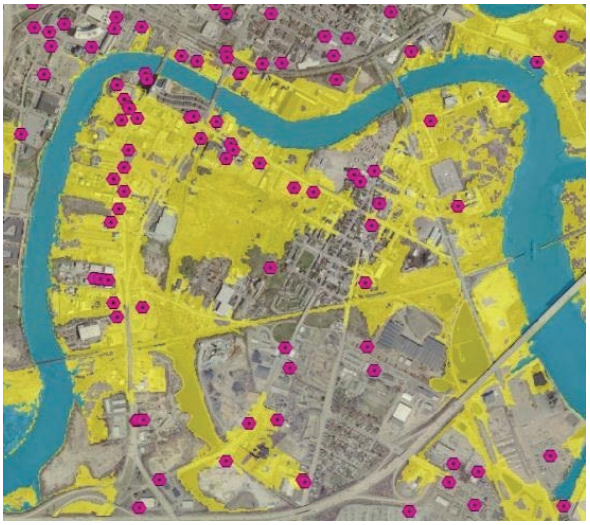


Figure 5 - Storage tanks exposed to inundation.

The exposure tables and maps are an indication of the extent and severity of inundation for a specific resource. However, a resource that is “exposed” to sea level rise may or may not be impacted. The impact of this exposure depends upon a number of factors including whether a building is elevated or flood-proofed; the type of materials utilized in construction; or use of protective structures. For example, a home that is within a mapped sea level rise area (and therefore “exposed”) but is raised on pilings may not suffer any structural damage from increased water levels. Conversely, there are also instances where resources may be affected but are not included in the exposure table. For example, structures which are not inundated but are surrounded by inundation areas become “islands” and may no longer function as intended because of access issues.

Vulnerability Assesment Methods

Impact Assessment

Using the information obtained in the exposure assessment, committee members provided input about the potential direct impacts that could result from the inundation of resources as well as the secondary economic, environmental, and social impacts that could result.

Direct impacts include

- Loss of land and wetlands from inundation
- Loss of buildings and infrastructure from inundation
- Decreased usability of structures due to flooded access roads and supporting infrastructure
- Increased structural damage from repetitive storm damages

Secondary impacts include

- Loss of jobs and revenue streams
- Loss of community or sense of place
- Contaminant releases from industrial sites or storage tanks
- Loss of habitat from increased erosion• Increased need for government services or intervention

Because this assessment was conducted at a statewide scale, all “exposed” resources were assumed to be impacted. Vulnerability assessments can be conducted in the future that focus in on a geographic area or specific resource; limiting the scope of a vulnerability assessment allows for more site specific conditions to be considered. This statewide vulnerability assessment should be considered a screening tool to determine where more focused studies should be conducted.

Information for each resource compiled in a standardized format and reviewed by workgroup members and Delaware Coastal Programs staff. The individual assessments (including exposure tables) are included in the remaining chapters of this document.

Eric Crossan

The community of Kitts Hummock next to the Delaware Bay.

Public Engagement

A series of five public engagement sessions was held in November 2011 to share preliminary results of the exposure and impact assessments with Delawareans and to obtain feedback about the findings and work of the committee. Additional information about public engagement strategies can be found in Appendix E.

Risk Assessment

The final step of the vulnerability assessment was a risk assessment exercise that considered the combined consequences of the sea level rise exposure and impacts documented for each resource. Using standardized questions, workgroups ranked each resource according to the statewide magnitude of potential impacts. The magnitude of impact was determined using three primary factors: the geographic scope of exposure, the geographic scope of impacts and the functionality of the resource.

In considering geographic scope of exposure, the workgroups used the vulnerability assessment maps to determine where inundation would occur. For geographic scope of impacts, the workgroups considered where direct or secondary impacts would occur. Would impacts be felt by citizens statewide, or in a limited area? Would exposure cause economic impacts to one neighborhood, or would it cause impacts statewide? For example, although the exposure of heavy industrial areas was limited primarily to New Castle County, the economic impacts of exposure could be felt statewide through loss of job opportunities and revenues.

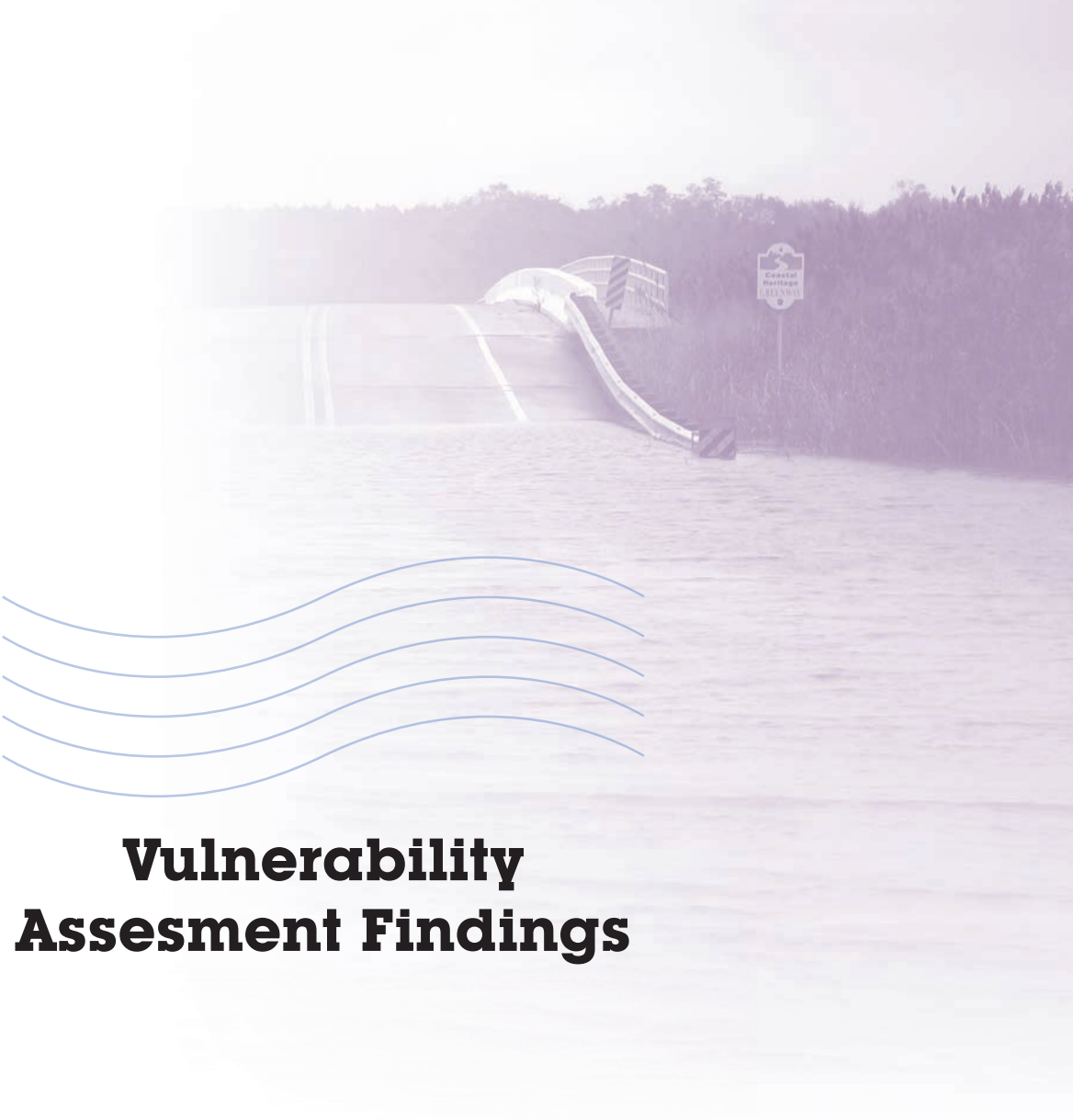
In considering functionality, the workgroups determined whether a resource could continue to meet its intended purpose when exposed to sea level rise. For example, an evacuation route functions to allow safe travel in emergency situations; a manufacturing facility functions to produce goods and provide jobs; a wetland functions to provide wildlife habitat and to attenuate storm flooding.

As a result of this discussion, each resource was ranked as a High, Moderate, Low, or Minimal Concern. In general, resources of high concern are those that if inundated, no longer meet their intended use and this loss of function would have statewide implications. Resources of low concern are those that, if inundated, would likely continue to function with modifications and whose impacts are generally of localized concern. Resources ranked as a high and moderate concern will likely become the starting point for adaptation strategy development in Delaware.

This risk assessment was subjective in nature; workgroup members used the information available to them to make a reasonable assessment of the risk to the state for inundation of each resource. The risk assessment will inform Phase II (adaptation) of the SLRAC's work. Adaptation strategies for many of the resources ranked as high and moderate concern will be discussed and developed, however, that does not preclude the development of strategies for resources that were ranked as lower concern at this time.

Table 1 - Risk Assessment Scores, Basis and Recommended Action

Score	Impact		Geographic Scope	Recommended Action
High Concern	Resource does not function or meet its intended use	And/or	Statewide	Develop adaptation strategies
Moderate Concern	Major loss of function or some failure of intended use	And/or	County-level	Evaluate further and develop adaptation strategies if necessary
Low Concern	Resource functions with modifications	And/or	Localized	Monitor and re-asses in future years
Minimal Concern	minor or no impact to function	And/or	Isolated	Re-asses in future years



Vulnerability Assesment Findings

Vulnerability Assesment Findings

This vulnerability assessment demonstrates that inundation from sea level rise will occur in all three of Delaware's counties, affecting a range of resources. Although the direct impacts from sea level rise inundation will be felt in areas near tidal waters, every Delawarean is likely to be affected whether through increased costs of maintaining public infrastructure, decreased tax base, loss of recreational opportunities, or loss of community character.

Table 2 - Total Acreage of Uplands and Wetlands Exposed to Sea Level Rise

Land Area							
County	Total Acres	Acres Inundated by SLR Scenarios			Percent of Total Inundated by SLR Scenarios		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	1,385,495	110,497	133,531	151,528	8%	10%	11%
New Castle	278,754	25,179	29,916	33,148	9%	11%	12%
Kent	510,428	50,095	57,784	63,269	6%	11%	12%
Sussex	596,314	35,223	45,831	55,111	6%	8%	9%

Source: USGS and Delaware Geologic Survey, State Outline (Area), 2007-04-01

Statewide, between 8% and 11% of the state's land area (including wetlands) could be inundated by sea level rise of 0.5 to 1.5 meters. Table 2 shows potential inundation by acreage and percent of land area for the state as a whole and for each county. The county with the lowest percentage of land area at risk is Sussex County, where between 6% and 9% of the land area could be inundated by sea level rise. This may be a surprising result to many, and emphasizes the statewide nature of the sea level rise issue.

The nature of resources at risk varies between counties. The vast majority of the land area that could be inundated within Kent County is tidal wetlands, although the surrounding uplands and communities would also be affected. Wetlands are also affected in southern New Castle County, but in the northern parts of the County, several urban residential and commercial areas are at risk, as are transportation corridors, including the Port of Wilmington. In Sussex County, low lying resort communities along the Atlantic Ocean, Delaware Bay, and Inland Bays are within potential inundation areas, as are tidal wetlands in the Inland Bays and Delaware Bay areas.

How to Use the Exposure Tables

Exposure tables are provided throughout this document to help the reader understand the number or acreage of a resource that could be inundated by 0.5, 1.0 or 1.5 meters of sea level rise and to help the reader understand where those potential impacts occur. Maps are also provided in the Mapping Appendix to assist the reader to visualize the geographic extent of potential inundation.

The "Total Acres" column in Table 2 represents that total area of the state or county. The "Acres Inundated" columns report the number of acres of land that fall within the three sea level rise scenarios. These numbers are reported cumulatively. For example, 151,528 acres of land statewide would be inundated at 1.5 meters of sea level rise; this includes the 133,531 acres of land inundated at 1.0 meter.

The Percent of Total Inundated columns provide an additional way to understand the extent of inundation. The percent is calculated by dividing the Acres Inundated by the Total Acres. Because the Acres Inundated column is reported cumulatively, the Percent Inundated column is also cumulative.

Results of Resource Risk Assessment

As outlined above, the SLRAC workgroups conducted an exercise to determine the relative level of concern for impacts to each resource assessed. The results are below and are detailed further in the following chapters.

High Concern - A high concern resource is generally a resource where inundation would cause it to no longer function as designed and/or could cause impacts statewide, whether directly to the resource itself or indirectly through disruptions in jobs or revenue streams. Additional research and development of adaptation strategies for high concern resources is strongly recommended.

The following resources were ranked as high concern by SLRAC workgroups:

Heavy Industrial Areas	US Fish & Wildlife Property	Port of Wilmington
Future Development Areas	Railroad Lines	Tourism and Coastal Recreation
Roads and Bridges	Tidal and Freshwater Tidal Wetlands	Beaches and Dunes
Evacuation Routes	Coastal Impoundments	Dams, Dikes & Levees
Habitats of Conservation Concern	Wells	Protected Lands Statewide

Moderate Concern - A moderate concern resource is generally one in which there is some impact or loss of function and/or the geographic extent of the impact is less than statewide. Further evaluation and development of adaptation strategies for moderate concern resources is recommended.

The following resources were ranked as moderate concern by SLRAC workgroups:

Residential Areas	Landfills, Nature Preserves	Septic Systems
Agricultural Land Conservation Easements	Wastewater Facilities	

Low Concern - A low concern resource is generally one in which the impacts to the resource itself would not be significant or/or the impact would be isolated to several small geographic regions. A ranking of low concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather that the impacts would not be of statewide concern. Low concern resources should be monitored and reassessed in subsequent planning activities.

Businesses and Commercial Areas	Brownfield Sites	Agriculture
Salvage Yards	Historic and Cultural Resources	Underground Storage Tank Sites
Factories	Contaminated Sites	Non-tidal Wetlands
Commodity Pipelines	Highly Productive Agricultural Soils	Agricultural Land Preservation Districts

Minimal Concern - A resource of minimal concern is generally one in which the geographic scope is isolated and/or would have minor to no loss of function. Minimal concern resources should be reassessed in subsequent planning activities.

Upland Forest	Bus Routes and Bus Stops	Adult and Child Care Facilities
Emergency Services	Cemeteries	Navigation Aids
Schools	Boat Ramps and Piers	Leaking Underground Storage Tank Sites

No Exposure - The following resources were analyzed and were found to have no exposure to sea level rise of up to 1.5 meters.

Correctional Facilities	Public Safety Access Points	Airports
Cell Towers	Hospitals	

Natural Resources

Natural Resources

Assessing Exposure of Natural Resources

The Natural Resources Workgroup was composed of members of the Sea Level Rise Advisory Committee and additional subject matter experts. A list of those who participated in this workgroup is available in Appendix C. The workgroup met six times between February 2011 and March 2012 to identify, assess, and rank issues related to environmental impacts from sea level rise.

Resources Considered

Specific resources that the Natural Resources Workgroup was concerned with included:

- Water resources (such as salinity changes and groundwater effects)
- Wetlands
- Beaches and dunes
- Upland forest
- Flora and fauna
- Protected lands
- Agricultural resources such as soils and protected lands

Assessing Exposure

As described in the introductory section, Delaware Coastal Programs staff worked with Workgroup and Committee members to collect data and information about each resource that the workgroup wished to assess. Based upon available data, tables were generated in ArcGIS that described the exposure of each resource to sea level rise under each of the three scenarios. Maps depicting location and density of this exposure were also generated in ArcGIS. Workgroup members filled out resource assessment templates based upon their own expertise and in collaboration with their colleagues. All of this information was compiled together into a comprehensive assessment for each resource, which were reviewed and edited by workgroup members. Full text of each one of these assessments follows.

Data and Information Gaps

This vulnerability assessment relied on existing data and information to complete a state level screening of resources at risk to sea level rise. In some cases, data and information that would have provided a better picture of the resource impacts of sea level rise was not available at a scale that would be useful for analysis of sea level rise. However, this did not impede our ability to understand the range of potential impacts from sea level rise and make recommendations for future studies that would help improve our understanding of specific impacts. Two resources in particular, Salinity Changes and Groundwater Effects, were difficult to assess given the unknowns about the complex hydrological and hydrogeological interactions involved. The potential impacts are discussed within the natural resources chapter however; there is not enough data to compare the level of concern about sea level rise impacts relative to the other resources.

[1]Beaches and Agricultural resources were also identified by the Society and Economy Workgroup as a concern but were evaluated from a different perspective. Whereas this workgroup was more focused on ecological significance of the resources, the Society and Economy Workgroup review of beaches concentrated more on tourism and recreational uses. For agriculture, the workgroup reviewed total acreage and types of agriculture for economic and cultural impacts.

Salinity Changes: The influence of sea level rise on salinity levels in rivers and streams depends on the increase in tidal prism and the increase in estuary surface area (its width), assuming the tide range remains unchanged. The mean depth of the estuary will increase with sea level rise only if sedimentation does not keep pace with the vertical space created. The extent to which the tide range changes with sea level rise (if at all) depends on the modified depth and width of the estuary, which is difficult to predict given the number of variables involved. For this reason it is problematic to forecast how the salinity of estuarine waters will change with sea level rise, independent of other factors such as climatic changes in freshwater runoff and human influences on the geometry of the basin.

Groundwater Effects: Rising sea levels could increase the salinity of groundwater tables in shallow coastal aquifers. As rising water levels submerge low-lying sections of land, portions of the aquifer could become saline. Aquifers recharged by fresh water regions of the Delaware River may become saline in the future as well, if salt water pushes further up the waterway. The inundation scenarios used to assess resources affected by sea level rise are ill-suited to provide a meaningful assessment of potential groundwater impacts. Hydraulic interactions between sea level, aquifers, precipitation, streams, and other surface waters are too complex to draw conclusions based on just the increase in water level assumed in the three scenarios.

Assessing Vulnerability of Natural Resources

As discussed in the Introduction, once the resource assessments were completed and maps were available, the Natural Resources Workgroup conducted an exercise to assess the vulnerability of the state to the effects of sea level rise for each resource. Using standardized questions, the workgroup considered the two primary factors: the geographic scope of impacts and whether the resource could continue to "function." For geographic scope, the workgroup considered both the discrete locations of impacts themselves and the extent to which impacts may be felt outside of those locations. For example, loss of lands protected for wildlife habitat not only affects the species that live there but may also reduce ecotourism opportunities and generated revenue. As a result of this discussion, each resource (with the exception of Salinity Changes and Groundwater Effects discussed above) was ranked as a high concern, moderate concern, or low concern. Resources ranked as high and moderate concerns will likely become the starting point for adaptation strategy development in Delaware.

High Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources are of the highest concern: tidal wetlands, freshwater tidal wetlands, coastal impoundments, habitats of conservation concern, protected lands statewide, U.S. Department of Fish and Wildlife property, and beaches and dunes. A high concern resource is generally a resource where inundation would cause it to no longer provide its typical functions, values, benefits and/or could cause impacts statewide. Additional research and development of adaptation strategies for high concern resources is recommended.

[1]The tidal prism is the volume of water that moves into and out of the estuary during a tidal cycle

[2]The tide range is the vertical difference between the high tide and the low tide

Natural Resources

Tidal Wetlands: Tidal wetlands are among the most productive ecosystems in the world and provide habitat, food and breeding grounds for many species of plants and animals. Delaware's tidal wetlands are an intricate part of the local, regional, national, and international ecosystems. Tidal wetlands act as sponges by soaking up floodwaters and buffering storm impacts and also act as filters by trapping sediments and removing contaminants. The potential impacts to tidal wetlands as a result of sea level rise are striking in their extensiveness, affecting the vast majority of tidal wetlands in all three counties. The exposure assessment found that 97% of the state's tidal wetlands may be impacted at the 0.5 meter scenario, and 99% at both the 1.0 and 1.5 meter scenarios. Since the majority of the resource within the state may be affected by sea level rise, this resource was ranked as a high concern.

Freshwater Tidal Wetlands: Freshwater tidal wetlands occur at the upper reaches of estuaries where the water is no longer salty, but is still influenced by the rise and fall of the ocean tides. These wetlands are home to unique plant and animal communities and are known for their high species diversity. Sea level rise, over time, may introduce salinity to freshwater areas, replacing freshwater tidal marshes with brackish marshes or open water, which in turn will cause major shifts in species composition. For freshwater tidal marshes affected by sea level rise, a wetland system may still exist with increased salinity, but its unique habitat value will be lost. Sea level rise could impact between 84% and 98% of the total freshwater wetlands acreage statewide by the year 2100. Because of the unique habitats contained within freshwater tidal wetlands and because the majority of the resource within the state could be affected, this resource was ranked as a high concern.

Coastal Impoundments: Coastal impoundments are vital resources that serve to provide important breeding, migration, and wintering habitat for a variety of birds, serve as nurseries for fish, help to control mosquitoes, and provide important recreational opportunities. Impoundments in each county are at risk from sea level rise. A sea level rise of 0.5 meters would result in the potential inundation of 81% of the state's acreage of impounded wetlands. Up to 99% of all the state's acreage of impounded wetlands could be inundated at both 1.0 and 1.5 meters of sea level rise. The impacts will be relatively local; however the areas that are affected show high levels of inundation and complete loss of function. Since the majority of the resource within the state may be affected, this resource was ranked as a high concern.

Habitats of Conservation Concern: The Delaware Wildlife Action Plan, the framework for conserving the state's native wildlife, identified 27 Habitats of Conservation Concern (HCC). These habitats are rare, have special significance in Delaware, are particularly sensitive to disturbance, and/or have a high diversity of rare plants. Of these 27 unique habitat types, 15 were determined to be vulnerable to sea level rise and were analyzed to determine the extent of possible exposure. Between 55% and 65% of the total acreage of the 15 HCCs analyzed could be inundated by sea level rise by 2100. Because these exceptional habitat types often harbor rare plant and animal species and are sensitive to environmental stresses, including sea level rise, this resource was ranked as a high concern.

Protected Lands Statewide: Protected lands encompass a variety of lands owned by state, local and municipal governments, conservation groups and individuals. These lands include state wildlife areas, state parks, state forests, boat ramps, nature preserves, historical sites, national wildlife refuges, municipal parks, open space, and recreational facilities and public and private conservation easements. Collectively, these properties represent a variety of habitat types and extensive opportunities for outdoor recreation. Statewide, between 37% and 44% of protected lands statewide are exposed to sea level rise under the three scenarios. Because these lands represent a significant investment to protect natural habitats and recreational use and because sea level rise could impact their intended use, protected lands were ranked as a high concern.

U.S. Fish and Wildlife Service Refuges: Prime Hook National Wildlife Refuge (NWR) is located in Sussex County near the town of Milton. Bombay Hook NWR is located in Kent County near the towns of Smyrna and Dover. Area residents and tourists use the refuges for passive outdoor recreation activities such as birding, wildlife watching, and photography, as well as for hunting and fishing. Refuge wetlands provide habitat for overwintering and migrating waterfowl and shorebirds, wading birds, secretive marsh birds and wetland passerines. Reduction or loss of wetland habitats within the protected boundaries of the refuges can impact populations of these species. Species may be forced to redistribute if refuge wetlands no longer meet their needs, and may relocate in wetlands that are not afforded the same protection and management that is provided by the NWR designation. Between 85% and 95% of refuge acreage could be inundated under the three scenarios. While the impacts are localized, the acreage affected (21,354 to 24,120 acres) represents a significant loss of protected habitat and was ranked as a high concern.

Beaches and Dunes: Delaware's coastline is an important ecological resource—providing habitat for a variety of plants, animals, insects, migratory birds, and a multitude of other terrestrial and aquatic wildlife. Shorelines naturally shift and retreat in response to wind, waves, tides, storms and rising seas. However, natural shoreline processes are interrupted by people's desire to live and recreate near the shore. Delaware's 381 miles of shoreline, including 24 miles that front the Atlantic Ocean, provides economic benefits from tourism, coveted high-value space for commercial and residential development, and many forms of recreation, including boating, fishing, and beach-going. When combined with wind-driven waves, sea level rise can exacerbate shoreline erosion that damages dune habitat and leaves infrastructure along the coastline vulnerable to storm damage. Beach replenishment has been the predominant means to offset sand loss and protect structures to which the state has contributed considerable funding. Due to the economic value, natural resource value and significant state investment in sand replenishment, this resource was ranked as a high concern.

Moderate Concern Resources

Based upon the risk assessment conducted by the workgroup, Nature Preserves and Agricultural Land Conservation Easements were categorized as having moderate concern. Resources are considered to be of moderate concern if there is some impact or loss of function and/or if the geographic extent of the impact is less than statewide.

Nature Preserves: Nature preserves are relatively undisturbed protected lands, free from development pressure and thereby provide exceptional habitat for various species of flora and fauna. These lands are unique and often fragile environments that represent some of Delaware's most important natural habitats. The percentage of affected acreage of dedicated nature preserves ranges from 34% to 43% under the three scenarios. The impact to the resource appears to be fairly local in scale; however, the habitat value of those sites may be exceptional. As a result of these factors, impacts to nature preserves from sea level rise were ranked as a moderate concern.

Agricultural Land Conservation Easements: The Delaware Department of Agriculture has a land preservation program that uses two strategies to preserve farmland, agricultural preservation districts (ranked low concern and discussed below) and agricultural conservation easements. Conservation easements provide permanent protection from development for agricultural activities. Statewide, 13% to 17% of the land in conservation easements may be exposed to rising water. The exposure is localized with a concentration in Kent County. Conservation easements are considered to be an important tool to preserve farming operations and to prevent development and infrastructure in vulnerable areas. Due to these considerations, impacts to conservation easements were ranked as a moderate concern.

Natural Resources

Low Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources were considered to be of lower concern at this time: Non-tidal Wetlands, Highly Productive Soils, Agricultural Land Preservation Districts, and Upland Forest. A ranking of low concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather the impacts will not be significant in nature and/or will be isolated to several small geographic regions. Low concern resources should continue to be monitored and re-assessed in subsequent planning activities.

Non-tidal Wetlands: Non-tidal freshwater wetlands are floodplains of natural stream channels, ditched modifications and extensions of natural streams, and isolated systems. These wetlands represent a large proportion of the forested area in Delaware and are too wet to build upon or farm without substantial draining or filling. These wetlands are classified as emergent, shrub or forested systems. When all three types are combined, 8% to 12% of the total non-tidal wetland acreage throughout the state is potentially affected under the inundation scenarios. Under the right conditions these wetlands may become tidal, thereby maintaining some of their former functions. This conversion will however, affect the uniqueness of the non-tidal wetland habitat. Given the relatively limited acreage affected, impacts to non-tidal wetlands from sea level rise were considered a low concern at this time.

Highly Productive Soils: This resource includes soil types considered to be prime farmland and farmland of statewide importance. Prime farmland is land whose soils have the best combination of physical and chemical characteristics for the production of crops. Farmland of statewide importance includes those soils that are nearly prime farmland and that produce high yields of crops when treated and managed according to acceptable farming methods. Land classified as having highly productive soils includes some areas that are not currently used for agriculture. Statewide, impacts to highly productive soils are limited, with 2% to 4% of the highly productive soils potentially exposed under the three scenarios. Localized impacts may be significant but would not negatively affect the state as a whole. As such, impacts to highly productive soils were ranked as a low concern at this time.

Agricultural Land Preservation Districts: The Delaware Department of Agriculture has a land preservation program that uses two strategies to preserve farmland, agricultural preservation districts and agricultural conservation easements. An agricultural preservation district is a voluntary agreement to use land only for agricultural purposes for at least a ten year period. There is no guarantee that the property will remain agricultural land once the 10 years expires but there is the possibility of permanent protection under the conservation easement program. Approximately 8% to 11% of acreage within Delaware's agricultural land preservation districts will be exposed to sea level rise. Because the acres affected is not a large percentage of the acres within the preservation districts program statewide, this resource was ranked as a low concern at this time.

Upland Forest: The level of exposure to upland forest resources is fairly limited. The combined impacts from the three upland forest types—deciduous, evergreen and mixed forest— range from 2% to 6% for the state as a whole under the range of inundation scenarios. Reductions in upland forest will negatively affect biodiversity and wildlife habitat, including that for migratory bird species. However, given the relatively limited acreage affected, impacts to upland forest from sea level rise were considered a low concern at this time.

Detailed Resource Assessments

The following sub-chapters contain a detailed exposure assessment for each resource and a description of the likely economic, social and environmental impacts that could result. As discussed in the introduction to this document, an exposure assessment describes how much of a particular resource is within each one of the three sea level rise scenarios. The potential effects to each resource are described within the text, along with the caveats of the analysis and data. These assessments are being used as the baseline data and information to formulate an adaptation strategy for the state, while recognizing the limitations of this method for site specific planning.

Water Resources

This section of the vulnerability assessment focuses on two primary concerns related to sea level rise with respect to water resources: the effects of changes in salinity within the Delaware Estuary and Inland Bays and the impacts to groundwater from salt water inundation. Neither issue is easily addressed as there are many unknowns. In order to evaluate the potential impact from sea level rise more information is needed, including an evaluation of the potential for intrusion of saltwater further into the Delaware River and Inland Bays and a detailed evaluation of the freshwater heads in coastal aquifers to identify potential changes in the salt content in coastal aquifers.

Salinity Changes

The salinity regime of a waterbody determines not only human uses, such as drinking water or agricultural irrigation, but also regulates habitat suitability for aquatic plants and animals. It also impacts certain aspects of water quality and flow dynamics.

Estuaries of coastal Delaware receive fresh water from rivers and saline water from the coastal ocean. In general, the salinity of estuarine waters reflects a balance between the freshwater discharge volume and the tidal prism volume. For example, fresh water enters the Delaware River and Bay estuary primarily through the Delaware, Schuylkill, and Brandywine/Christina river tributaries. Salt water is driven into the bay between Cape May and Cape Henlopen at its mouth by a combination of tidal currents and non-tidal density-driven flow. Fresh water is less dense than salt water, so freshwater runoff tends to flow over the salt water transported landward from the mouth. These waters mix with tidal energy, a process that leads to a transition from salt water at the bay mouth to fresh water in the upper estuary.

At any point along an estuary, salinity levels vary as a result of tides, storms events, and seasonal cycles in precipitation and evaporation. Over a long period of time, processes that alter the freshwater discharge or tidal prism influence the steepness of the along-estuary salinity gradient and the mean salinity of the estuary as a whole. Such a change could result from changes in weather and climate patterns and oceanographic phenomena, among other factors.

The landward limit of salt in surface water, also known as the salt line, is based on established drinking water standards of 250 milligrams per liter chloride concentration. The Delaware River and Basin Commission uses the seven day average location of the salt line to define the upper bounds of salinity intrusion in the Delaware Estuary. The salt line varies daily in response to tides, seasonally and in response to freshwater inputs—rainfall, streamflow, and reservoir releases—but is typically between Wilmington, Delaware and Philadelphia, Pennsylvania.

Exposure to Sea Level Rise: With rising mean sea level, an estuary will widen through erosion or submergence of its coasts, particularly in low-lying areas. The influence of sea level rise on salinity depends on the unit increase in tidal prism with unit increase in estuary surface area, assuming the tide range remains unchanged. The mean depth of the estuary will increase with sea level rise only if sedimentation does not keep pace with the vertical space created. The extent to which the tide range changes with sea level rise (if at all) depends on the modified depth and width of the estuary, which is difficult to predict given the number of variables involved. For this reason it is problematic to forecast how the salinity of estuarine waters will change with sea level rise independent of other factors such as climatic changes in freshwater runoff and human influences on the geometry of the basin.

Changes in salinity and sedimentation patterns from sea level rise could be a stressor to aquatic life, and will be most harmful for organisms that cannot easily migrate in response to changes like oyster beds. It should be noted that estuarine settings naturally experience a wide range of salinity, so organisms that inhabit these environments are generally well-adapted to this variability.

Potential Economic Impact: Drinking water reliability in Delaware is highly dependent on surface water withdrawal in New Castle County (the rest of the state utilizes groundwater for drinking water). An increase in salinity near drinking water intake pipes could affect the quality and reliability of drinking water for thousands of citizens. If augmentation of drinking water infrastructure is necessary to mitigate increased salinity, associated costs may be substantial.

Additionally, changes in salinity could cause changes in habitat for species that have commercial and recreational value. Industrial facilities dependent upon freshwater withdrawals may also be affected to varying degrees by salinity changes. Increased salt content in process water may affect some operations; require alternate sources of freshwater, or other economic hardship. Economic impacts to industrial facilities from sea level rise are covered in more detail in the Society & Economy chapter of this assessment.

Potential Social Impact: Changes to habitats for species with commercial or recreational value as a result of saltwater intrusion could result in impacts to local communities with historic and economic ties to those resources. Industries or municipalities that rely on fresh water for industrial processes or drinking water may be adversely affected by salt water intrusion, which in turn could lead to reduced production, fewer jobs, and resultant community impacts.

Potential Environmental Impact: Sea level rise could potentially increase the tidal prism volume of estuaries in Delaware, increasing the mean salinity of the estuaries, and causing salt to migrate landward into what is currently tidal fresh water. The combination of higher water levels and increased salinity could impact tidal wetlands by increasing the frequency of inundation and the salinity of tidal waters.

Increased salinity may impact plants and animals sensitive to changes in salt content. Sessile species such as shellfish are most vulnerable to these changes. Over time, shellfish beds may shift inland, but that requires time and appropriate bottom substrate in the new location. An additional concern specific to the Eastern oyster (Crassostrea virginica) is the correlation between increased salinity and disease prevalence. Oysters are primarily a mesohaline species whose population is limited at higher salinities by major predators (oyster drills and starfish). Although not harmful to humans, two parasitic diseases, MSX and Dermo, are extremely lethal to Delaware's native oyster population. These diseases thrive in warmer, higher salinity environments. Since MSX was introduced, it has become a second factor killing oysters at salinities above 15 ppt. The disease Dermo is less prevalent in the Delaware Bay but still a concern. Increased prevalence and infection occur in waters with salinity concentrations between 12-15 parts per thousand (Virginia Institute of Marine Science, 2012).

Changes in salinity will also affect fish species like American shad, river herring, and striped bass which live in salt water but return to freshwater rivers to spawn. These recreationally important species would be negatively affected by decreased tidal freshwater acreage that could be caused by rising sea levels and saltwater intrusion. A decrease in suitable freshwater habitat would likely result in a decrease in spawning areas and a decrease in juvenile foraging areas, leading to population declines.

Another important anadromous species is the Atlantic sturgeon, a state and federally endangered species. The spawning grounds are unknown; however, less tidal freshwater acreage reduces the potential area for spawning and early larval stage. Additionally, juvenile foraging area will be reduced and likely reduce the production capacity of the system.

Alternately, increased salt content might make the bay more suitable for other coastal species that prefer a higher salinity.

Additional Information: The Delaware Division of Fish and Wildlife have identified the Marcus Hook anchorage and Chester Island areas as potential spawning grounds at the edge of the salt to fresh transition zone based on the presence of adult male Atlantic sturgeon in May and early June. This area is currently being targeted by an ongoing Delaware State University study of sturgeon. Increased salinity could be devastating to these areas (if they are in fact used as spawning grounds or early larval staging area).

The Delaware River Basin Commission (DRBC) is the agency responsible for managing flows in the Basin. Managing releases of water from upstream dams and regulating the allocation of water is the primary tool for managing salinity levels, and the salt line is one target that the DRBC uses in its management efforts.

Extensive information on Delaware Bay oyster populations and climate change impacts can be found in Appendix O. Oysters in Delaware Bay – Climate Change of the report titled, Climate Change and the Delaware Estuary: Three Case Studies in Vulnerability Assessment and Adaptation Planning (Kreeger, et al., 2010).

Natural Resources

Groundwater

Delaware's groundwater is one of its most important natural resources. It is essential for meeting the needs of all segments of our society and for maintaining economic growth and agriculture. At this time, all water used for public and domestic supply and more than 98% of water used for irrigation south of the Chesapeake and Delaware Canal is groundwater. North of the canal, approximately 70% of public water supplies are obtained from four surface-water sources (creeks) and 30% from ground-water resources (Delaware Geologic Survey).

Exposure to Sea Level Rise: Rising sea levels could increase the salinity of rivers, bays, and the groundwater tables in the state. Shallow coastal aquifers are particularly vulnerable. As rising water levels submerge low-lying sections of land, portions of the aquifer could become saline. Aquifers recharged by fresh water regions of the Delaware River may become saline in the future as well, if salt water pushes further up the waterway.

The inundation scenarios used to assess resources affected by sea level rise are ill suited to provide a meaningful assessment of potential groundwater impacts. Hydraulic interactions between sea level, aquifers, precipitation, streams, and other surface waters are too complex to draw conclusions based on just the increase in water level assumed in the three scenarios. However, a data layer available that is related to potential groundwater impacts from rising sea levels is the Undeveloped Recharge Areas layer. A groundwater recharge area is a region where water from precipitation is transmitted through the soil layers to an aquifer. Developed parcels and impervious surface prohibit effective recharge so for the purpose of this assessment, only the undeveloped recharge areas were analyzed. This data layer was generated using impervious surface data in conjunction with the recharge areas layer to identify undeveloped areas that would infiltrate precipitation. Statewide, the percentage of undeveloped recharge areas that could be inundated by sea level rise ranges from 2% to 4% (Table 3).

Table 3 - Undeveloped Recharge Areas

County	Total Acres	Acres Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	396,107	7,788	12,682	17,358	2%	3%	4%
New Castle	16,658	31	35	40	< 1%	< 1%	< 1%
Kent	150,483	1,098	2,288	3,746	1%	2%	2%
Sussex	228,967	6,659	10,359	13,572	3%	5%	6%

Sources: DNREC, Recharge Areas, 2010-10-27, Office of State Planning Coordination, 2007 Impervious Surface Data, 2008 05 18

Table 4 - Wellhead Protection Areas

County	Total Acres	Acres			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	29,224	270	613	987	1%	2%	3%
New Castle	12,977	43	133	175	<1%	1%	1%
Kent	6,684	104	159	228	2%	2%	3%
Sussex	9,563	123	321	585	1%	3%	6%

Source: DNREC, Statewide Wellhead Protection Areas 2009, 2009-09-29

A wellhead is the physical structure of a well above ground. Wellhead data analyzed for this assessment is for public water supply sources. Private wells and irrigation wells were not analyzed because the data is not available for public use. Areas surrounding public water supplies are designated as wellhead protection areas and regulated by DNREC to control land use activities that may prove detrimental to the groundwater resource.

Statewide, 1% - 3% of the total acreage of wellhead protection areas could be inundated by sea level rise. The highest level of potential impact is in Sussex County where up to 6% of the public wellhead protection areas could be inundated by sea level rise (Table 4).

Potential Economic Impact: Saltwater intrusion to groundwater resources could affect the reliability of drinking water for hundreds of thousands of people. If augmentation of drinking water infrastructure is necessary as a result of sea level rise, associated costs may be substantial. Further, the negative economic effects of salt-contaminated groundwater can extend far beyond the costs of remediation or replacement. Many farms and neighboring communities depend on groundwater withdraws for farm operations and domestic water consumption. Salt-contaminated groundwater can discourage new businesses or residents from locating in a community. Existing businesses reliant on groundwater may be forced to move to an area with access to an uncontaminated water supply.

Potential Social Impact: Delawareans rely extensively on groundwater withdrawals for all water used for public and domestic supply. Any disruption to a society's supply of fresh, potable water has far reaching impacts. The effects would result in disruptions to daily life, public health concerns, agricultural production issues, and consequences to industrial facilities that rely on fresh water for processing. If a groundwater supply is contaminated by salt water from rising seas, there will be a pressing need to locate a clean freshwater supply, inform the public, and determine a long-term solution. Once a water supply is contaminated, replacement is often the most reasonable alternative and the costs of siting new wells, treating existing supplies, or providing bottled water are high.

Potential Environmental Impact: Impacts to aquifers similar to the potential stresses of sea level rise already occur during times of severe drought. Many shallow aquifer systems along the Atlantic coast are in direct hydraulic connection with streams and other surface waters that are often sources of recharge to the underlying ground-water system.

The USGS summarizes the impacts of sea level rise on aquifers

Perhaps most fundamentally, a landward movement of seawater would push saltwater zones in coastal aquifers landward and upward, which could accelerate rates of saltwater intrusion into aquifers already experiencing saltwater contamination. Rising sea levels also might cause upstream migration of saltwater in coastal estuaries, inundation of low-lying areas including wetlands and marshes, and submergence of coastal aquifers. In some areas, sea level rise would erode beaches and bluffs, leading to shoreline retreat, narrowing of aquifers, and diminished areas of aquifer recharge. Sea level rise also might cause increases in coastal ground-water levels, because of the overall rise in the position of the freshwater-saltwater interface.

Although sea level rise could increase saltwater intrusion into coastal surface and groundwaters, landward saltwater movement also will depend in part on changes in precipitation, runoff, and recharge that may occur within coastal watersheds. For example, increased freshwater runoff could counterbalance the landward movement of saltwater. Moreover, should saltwater intrusion into coastal aquifers occur in response to sea-level rise, it is likely that some aquifers may require hundreds to thousands of years to re-equilibrate to changes in sea level, such as has occurred in parts of the Northern Atlantic Coastal Plain aquifer system where freshwater-saltwater interfaces appear to be still responding to sea-level increases that began at the end of the last ice age. (Barlow, 2003)

Wetlands

For the purpose of this assessment, wetlands are broken into the categories tidal wetlands, non-tidal wetlands, and man-made impounded wetlands. The impact tables for tidal wetlands are further broken down by impacts to saltwater tidal wetlands and impacts to freshwater tidal wetlands; however the discussion of economic, social and environmental impacts refer to all tidal wetlands. Similarly the impact tables for non-tidal wetlands are sub-categorized by emergent, shrub, and forested wetlands, but the discussion of impacts addresses impacts from non-tidal wetlands combined.

Tidal Wetlands

Tidal wetlands are among the most productive ecosystems in the world and provide habitat, food and breeding grounds for many species of plants and animals. Delaware's tidal wetlands are an intricate part of the local, regional, national, and international ecosystems. Without these tidal wetlands, populations of migratory birds and fish would be impacted, thus shifting traditional patterns and altering ecosystems elsewhere. As a result, it can be said that while the primary users of the tidal wetlands are Delaware residents and visitors, the existence and the continued health of our tidal wetlands are important to communities throughout the United States.

Additionally, both saltwater and freshwater tidal wetlands sequester more carbon than any other habitat type in the Delaware Estuary (Kreeger, et al., 2010). Carbon sequestration is important to combating climate change—an issue of international importance.

Many different human and non-human communities use tidal wetlands and derive significant benefits from them. Human users of tidal wetlands are primarily Delaware residents and visitors. Groups of human users can be split into two categories- those who knowingly and directly benefit from being physically present in the tidal wetlands, and those who indirectly and perhaps unknowingly benefit from the existence of the tidal wetlands.

Tidal wetlands act as sponges, soaking up floodwaters and buffering storm impacts. This function provides a

valuable service to coastal communities.

Tidal wetlands also act as a sink for nutrients and pollutants to help maintain water quality. Freshwater tidal wetlands in particular are also a first line of defense for capturing contaminants flowing from urban lands to the estuary. The nutrient storage and sequestration function of saltmarshes is of particular importance to Delaware's Inland Bays and tributaries to the Delaware Bay which suffer from excess nutrient pollution. Tidal wetlands remove excess nitrogen entering the estuaries from both non-point sources and direct deposition from the atmosphere.

Saltwater Tidal Wetlands

Saltwater tidal wetlands are low flat marshlands inundated by salt water. These tidal wetlands form a continuous fringe around the Delaware Bay and Inland Bays. While it is possible that some saltwater wetlands will migrate landward and upward in response to sea level rise, due to the limitations of the bathtub model used for this assessment, the exposure values discussed below do not take into consideration natural processes of erosion, accretion and landward migration

Exposure to Sea Level Rise: Saltwater tidal wetlands are extremely vulnerable to sea level rise, as indicated by the figures in the Table 5 (and depicted on maps in the Mapping Appendix). However, the extent to which a given tidal wetland is vulnerable to sea level rise depends on several factors: the burial rate of organic and inorganic sedimentary matter; the rate of regional land subsidence relative to the rate of sea level rise; and the degree to which coastal development, topography, and other factors limit the landward migration of marshes.

Tidal wetlands grow vertically through accretion. They do this by capturing sediment brought in by the tides and by maintaining high plant production above ground and slow decomposition rates below ground. By accumulating dead plant matter and inorganic sediment, established marshes generally accrete at rate sufficient to keep pace with sea level rise. However, accelerating rates of sea level rise are likely to alter wetland accretion dynamics in some areas and the potential impact on accretion rates depends on interplay between the biotic and physical factors involved. The rate of sea level rise is critical, and we can expect many of our tidal wetlands to drown under the higher sea level rise scenarios (Kirwan, Guntenspergen et al. 2010).

Table 5 - Tidal Wetlands

County	Total Acres of Wetlands	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	73,408	71,172	72,956	73,141	97%	99%	99%
New Castle	16,113	14,614	15,755	15,877	91%	98%	99%
Kent	36,205	35,609	36,152	36,191	98%	99%	99%
Sussex	21,090	20,949	21,048	21,073	99%	99%	99%

Source: DNREC, Delaware Wetlands SWMP 20100901, unpublished

Tidal wetland acreage during periods of rising sea level is also determined by the capacity of marshes to migrate landward and upward (transgress) over adjacent uplands. The rate of marsh migration under a given rate of sea level rise is determined primarily by the slope of adjacent lands and their management. Rates of marsh migration are lower where the slopes of adjacent lands are higher (Carey, 1996). Migration can be stalled by naturally steep slopes or land management activities that raise the elevation of adjacent lands or harden the upland wetland boundary. This will stall the migration of wetlands until sea levels rise enough to push marshes past the obstructions. Where obstructions include (or are protecting) infrastructure like roads, communities will likely be inclined to prevent this process for as long as possible. Under conditions of rapidly rising sea levels, landward wetland migration is likely to be the primary process by which wetlands maintain their acreage and function, if such migration is possible (CCSP, 2009).

A recent report, Delaware Wetlands: Status and Changes from 1992-2007, identified a loss of 579.5 acres of tidal wetlands, attributing 83% of the loss to conversion to open water. However, a portion of this acreage lost was offset by gains elsewhere resulting in a net loss of 238 acres (Tiner, Biddle, Jacobs, Rogerson, & McGuckin, 2011). These trends are expected to continue and likely increase with climate change impacts, including sea level rise. Sea level rise will interact with various other stressors to push many wetlands past their sustainable threshold (Kreeger, et al., 2010).

Freshwater Tidal Wetlands

Freshwater tidal wetlands occur at the upper reaches of estuaries where the water level is influenced by the rise and fall of the ocean tides, but is beyond the salt line. Freshwater tidal wetlands were not mapped separately but the acres inundated were included within the broader category of tidal wetlands (Maps 1-3 in the Mapping Appendix). However, because freshwater tidal wetlands are ecologically important and known for high species diversity, they are addressed separately here. The tables below represent freshwater tidal wetlands combined (Table 6) as well as separated into two types: mixed broadleaf (Table 7) and forested and shrub (Table 8). This data was provided by the Delaware Natural Heritage Program and was obtained through both field verification and interpretation of aerial and satellite photographs.

Exposure to Sea Level Rise: Freshwater tidal wetlands are very vulnerable to sea level rise, as indicated by the results of the exposure assessment in Tables 6-8. The extent to which a given freshwater tidal wetland is vulnerable to sea level rise depends on the factors noted above for salt marshes. Additionally, the degree to which sea level rise increases the salinity of tide water is another factor, because salinity limits the types of flora that colonize the marshes.

Table 6 - Freshwater Tidal Wetlands

County	Total Acres of Tidal Marsh	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	11,052	9,264	10,638	10,828	84%	96%	98%
New Castle	3,368	2,351	3,202	3,306	70%	95%	98%
Kent	1,749	1,286	1,681	1,714	74%	96%	98%
Sussex	5,934	5,628	5,755	5,806	95%	97%	98%

Source: DNREC - Natural Heritage Program, Habitats of Conservation Concern (2011), unpublished

Table 7 - Mixed Broadleaf Freshwater Tidal Marsh

County	Total Acres of Tidal Marsh	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	5,933	4,683	5,797	5,887	79%	98%	99%
New Castle	3,143	2,195	3,011	3,099	70%	96%	99%
Kent	298	1	298	298	< 1%	99%	99%
Sussex	2,491	2,487	2,489	2,489	99%	99%	99%

Source: DNREC - Natural Heritage Program, Habitats of Conservation Concern (2011), unpublished

Freshwater tidal wetlands are expected to grow vertically to keep pace with accelerating rates of sea level rise in most areas, but only if they are not exposed to salt water.

Due to possible increases in salinity associated with sea level rise (and possibly other system alterations) at least some transitional brackish and freshwater tidal wetlands are expected to be exposed to increasing salinity. As salinity increases in freshwater tidal wetlands, freshwater-adapted species die, and salt-tolerant species may or may not replace them. Some new research is finding that sometimes there is insufficient time for belowground processes to shift and the soils become toxic to most vegetation due to redox changes (Carey, 1996).

Table 8 - Freshwater Tidal Forested and Shrub Wetlands

County	Total Acres of Wetlands	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	5,119	4,581	4,841	4,941	89%	95%	97%
New Castle	225	156	191	207	69%	85%	92%
Kent	1,451	1,285	1,383	1,416	89%	95%	98%
Sussex	3,443	3,141	3,266	3,317	91%	95%	96%

Source: DNREC - Natural Heritage Program, Habitats of Conservation Concern (2011), unpublished

Freshwater wetland acreage during periods of rising sea level is also determined by the capacity of these wetlands to migrate over adjacent uplands. In more landward areas upriver, it may be possible for some freshwater tidal marshes to 'out run' sea level rise by migrating inland, but this depends on the rate of change and the capacity to move into inland areas. Rates of migration are lower where the slopes are adjacent lands are higher, and migration can be stalled by natural steep slopes or land management activities that raise the elevation of adjacent lands or harden the upland wetland boundary. This will stall the migration of wetlands until sea levels rise enough to push wetlands past the obstructions. According to several studies, landward migration of freshwater tidal marshes in Delaware is very unlikely since many of these coastal areas are developed or 'hardened.' (Kirwan & Guntenspergen, 2010) Where obstructions to migration include or protect important infrastructure like roads and structures, taking action to allow migration is complicated and may be unlikely.

Because of the relative rarity of these wetlands in Delaware and their high natural capital value (described below), preventing inundation or change due to sea level rise is especially important.

Potential Economic Impact: While no specific economic data is available for economic production from tidal wetlands in Delaware, an assessment of the economic value of the state of New Jersey's natural resources determined that tidal wetlands provided $6,269 per acre per year in total goods and services to residents and visitors (State of New Jersey, 2007). These estimates can be reasonably applied to tidal wetlands in Delaware.

Natural Resources

Loss of associated ecosystem services: Associated ecosystem services include water filtration, carbon sequestration, flood protection, and habitat critical to fisheries and shellfisheries. According to an assessment by the Water Resources Agency of the University of Delaware in 2011, saltwater tidal wetlands provide an average of $7,235 per acre in ecosystem services (Kauffman, Homsey, Chatterson, McVey, & Mack, 2011). Losing 97% of Delaware's saltwater tidal wetlands, the most conservative number, would result in the loss of over $500 million of ecosystem services per year. The same study valued freshwater tidal wetlands at an average of $13,621 per acre in ecosystem services. Losing 79% of Delaware's mixed broadleaf freshwater tidal marsh, and 89% of Delaware's freshwater tidal forested and shrub wetlands (the most conservative estimate) would result in the loss of over $125 million of ecosystem services per year. This analysis does not account for many secondary economic or climate impacts. For example, the loss of more than 70,000 acres of tidal wetlands would result in a large pulse of carbon dioxide due to respiration of outwelled peat, thereby contributing a positive feedback for greenhouse gas emission.

Loss of tourism/recreation: According to the same study, the estimated economic value associated with fishing, hunting, and wildlife watching along coastal Delaware is $134 million annually. This value is derived from estimates of trip related expenditures including food and lodging, transportation, and hunting, fishing, and wildlife watching equipment (Kauffman, Homsey, Chatterson, McVey, & Mack, 2011). Given the important role of tidal wetlands in fish production and natural habitats in coastal Delaware and the unique habitat niche filled by freshwater tidal wetlands, it is likely that a large portion of this value can be attributed at least in part to tidal wetlands.

Loss of jobs: While there are no specific estimates regarding what would happen to commercial fishing operations if 97% of Delaware's saltwater tidal wetlands, 79% of Delaware's mixed broadleaf freshwater tidal wetlands and 89% of Delaware's freshwater tidal forested and shrub wetlands were inundated, it is likely that this industry would suffer some type of decline. It is estimated that anywhere from 85%-95% of our recreationally and commercially important coastal fisheries rely on tidal wetlands as a place to shelter and grow their young (Department of Natural Resources and Environmental Control, 2011).

Loss of flood protection: Though it was mentioned above during the discussion of ecosystem services, the importance of flood protection to coastal communities cannot be overstated. Without wetlands to attenuate flooding effects from storms, damage to homes, businesses and infrastructure would likely increase significantly. Coastal tidal wetlands are especially important for absorbing or dissipating storm surge effects.

Potential Social Impact: Losing significant acreage of tidal wetlands would result in quality of life impacts, including the loss of income for commercial fishers; loss of hunting and fishing opportunities; and increased flooding for coastal communities. These losses, combined with increased flooding, could affect the social fabric and sustainability of Delaware's coastal communities.

Potential Environmental Impact: The inundation of saltwater tidal wetlands could create major environmental changes including:

- Shifts in community species composition (including loss of rare plants)
- Changes to extent of wetland areas
- Changes to the ratio of shoreline edge to marsh area
- Changes to the rate of channel scour
- Increase in storm surge susceptibility
- Reduction in fisheries production
- Reduction in water quality

The impact of sea level rise and resulting salinity changes on freshwater tidal wetlands could create major changes to these areas. In a recent estuary-wide study, wetlands experts expressed a high concern about the following changes to freshwater tidal wetlands as a result of sea level rise and resulting salinity changes:

- Shifts in community species composition
- Saltwater intrusion to freshwater habitats
- Changes in habitat support
- Ability for wetlands to migrate landward
- Change to extent of wetland areas
- Increase in storm surge susceptibility
- Increased seaward edge erosion
- Increased salt exposure/stress/event

(Kreeger, et al., 2010)

As sea levels rise and wetlands migrate inland where they are able, there will be shifts in species composition and habitat types. Within salt marshes, low-marsh species will replace mid- and high-marsh species. Similarly, salt marshes will replace brackish marshes.

Sea level rise over time changes the salinity of freshwater tidal wetlands in Delaware. Salinity changes will replace freshwater tidal wetlands with brackish wetlands or open water, which will cause major shifts in species composition. In addition to their vulnerability to salinity, freshwater tidal wetlands are threatened by the physical effects of rising sea level, such as erosion of seaward edges. Some freshwater tidal wetlands may convert to brackish wetlands, possibly dominated by invasive species that thrive under more frequent disturbance regimes (Kreeger, et al., 2010).

Non-tidal Freshwater Wetlands

Non-tidal freshwater wetlands (also known as palustrine wetlands) in Delaware are mostly held in private ownership with the majority of the total acreage located in Kent County and Sussex County. GIS mapping indicates that there are approximately 163,000 total acres of non-tidal freshwater wetland in Delaware, of which 86% is forested. These wetlands exist as floodplains of natural stream channels, as ditched modifications and extensions of natural streams, and as isolated systems. Non-tidal freshwater wetlands represent a large proportion of the forested area in Delaware and are too wet to build upon or farm without substantial draining or filling.

Historically, non-tidal freshwater wetlands have been used for lumber production. Until the passage of laws pertaining to the handling of rubbish and other garbage in the mid-twentieth century, these wetlands were frequently used as "dumps." With the exception of some hunting and naturalist activity, usage by people is light. Habitat quality and species diversity varies and all three subcategories discussed here are used by a variety of wildlife.

Exposure to Sea Level Rise: The tables below summarize the results of the sea level rise exposure assessment for non-tidal freshwater wetlands. Results are divided into three categories: non-tidal emergent wetlands (Table 9), non-tidal forested wetlands (Table 10), and non-tidal shrub wetlands (Table 11). Inundated acreage determinations are based on data generated by the DNREC. All computer-generated numbers are rounded to two significant figures to avoid the presentation of numbers that are unrealistically precise thus slight disagreements exist between the state total and the sum of the county totals. Corresponding maps are located in the Mapping Appendix.

Table 9 - Non-Tidal Emergent Wetlands

County	Total Acres of Emergent Wetlands	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	8,873	2,236	2,950	3,140	25%	33%	35%
New Castle	2,602	635	761	818	24%	29%	31%
Kent	2,178	253	695	742	12%	32%	34%
Sussex	4,093	1,348	1,494	1,580	33%	37%	39%

Source: DNREC, De_Wetlands_20100901_PD6, 2010-09-01

Potential Economic Impact: A loss of non-tidal freshwater wetlands may result in increases in flooding and/or increased expenditure of funds for stormwater projects to prevent flooding. As the acreage of these wetlands declines, the delivery of nutrients and suspended sediments to downstream waters is expected to increase. This could lead to detrimental economic and environmental outcomes including decreased water quality, increased cost of pollutant removal and disruptions to fish and waterfowl populations.

Table 10 - Non-Tidal Forested Wetlands

County	Total Acres of Forested Wetlands	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	140,891	8,192	10,828	12,605	6%	8%	9%
New Castle	12,614	607	851	998	5%	7%	8%
Kent	53,878	2,403	3,623	4,383	4%	7%	8%
Sussex	74,399	5,181	6,354	7,224	7%	9%	10%

Source: DNREC, De_Wetlands_20100901_PD6, 2010-09-01

Potential Social Impact: The flood controlling function of these non-tidal freshwater wetlands has societal value. Intrinsic value such as catchment basin-like topography, flow-impeding roughness of the ground surface and the seasonal transpiration of the trees, shrubs, and herbaceous plants allow stormwater to be retained, with some being recharged to groundwater and the remainder being discharged relatively slowly downstream or to the atmosphere by evapotranspiration. These functions result in water quality and water quantity benefits.

Table 11 - Non-Tidal Shrub Wetlands

County	Total Acres of Shrub Wetlands	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	13,178	2,446	2,886	3,104	19%	22%	24%
New Castle	973	325	429	463	33%	44%	48%
Kent	2,624	868	1,090	1,167	33%	42%	44%
Sussex	9,581	1,253	1,367	1,474	13%	14%	15%

Source: DNREC, De_Wetlands_20100901_PD6, 2010-09-01

Flooding, whatever its cause, results in social impacts as well as economic loss. With regard to the loss of non-tidal freshwater wetlands to sea level rise, social impacts are closely intertwined with environmental impact. The loss of wetlands and associated changes in ecological character of an area may occur so slowly as to be indiscernible to anyone other than a trained ecologist. History suggests that gradual and subtle losses are unlikely to elicit much concern on the part of the general public.

Finally, these highly complex ecosystems serve as important wildlife habitat to a wide variety of species. In addition, waterfowl hunting, bird watching, and nature photography are popular activities in and around non-tidal wetlands. Therefore loss of recreational opportunities could also be considered a social impact.

Potential Environmental Impact: As water moves downstream, wetlands improve its quality by functioning as a purifying filter. Nutrients are used by the vegetation while suspended sediments settle, elevating the floodplain and thereby somewhat offsetting the coinciding sea level rise. Such retention of nutrients and sediments by wetlands of any kind reduces the quantities delivered downstream. Fisheries and migratory waterfowl populations have been disrupted by environmental conditions resulting from these pollutants including low dissolved oxygen, loss of seagrass, and blooms of undesirable algae.

The retention capacity of wetlands serves to reduce the quantity of stormwater flow carried by a stream bed. This can reduce the failure of stream banks, which leads to detrimental outcomes including the loss of riparian trees that shade the water, the elimination of pools as fish habitat due to filling with silt, sand and gravel, and the widening and shallowing of the stream channel such that summer water temperature becomes too high to support many plants and animals.

The shrinking of habitat will result in a decrease in environmental carrying capacity, cascading to a reduction in abundance at the species level and diversity at the community level. Many such impacts may be “silent” and go unnoticed by the general public.

Additional impacts are listed below:

- Alteration of species diversity (locally)
- Alteration of species diversity (landscape)
- Alteration of species composition
- Alteration of habitat structure
- Conversion of one habitat type to another
- Conversion to tidal wetlands
- Conversion to open water
- Salinization of aquifers
- Alteration of flood water retention
- Alteration of nutrient dynamics
- Alteration of sediment transport
- Alteration of land subsidence rate
- Alteration of wetland accretion rate
- Increased stress on forested communities result disease outbreaks
- Alteration of invasive community dynamics
- Introduction of and susceptibility to pathogens and parasites
- Alteration of woodlands to emergent shrub, forb, or grass species
- Shift to more salt tolerant species
- Altered susceptibility to wildfire
- Local extirpation of rare/endangered flora and fauna
- Increased human pressure on remaining land base

(Tiner R. W., 1985)

Additional Information: Many non-tidal freshwater wetlands are not regulated and can be filled or altered without permits. Because of this, losses due to sea level rise will likely be obscured by losses due to other types of human activity such as agriculture and development.

It should be noted that the exposure assessment estimates do not take into account the generation of new palustrine wetlands that can be expected to develop in some places as the water rises and the uplands retreat.

An in-depth evaluation of current landscape use and ownership within and around vulnerable wetlands may provide useful information to guide adaptation recommendations. This information coupled with current land use and zoning regulations and various sea level rise scenarios could be used to make predictions about future losses and gains in acreage and functions.

Impoundments

Coastal impoundments are man-made structures that primarily serve to provide important breeding, migration, and wintering habitat for a variety of birds. They also serve as nurseries for fish and help control mosquito populations. In addition, they provide important recreational opportunities such as bird-watching and fishing. Alongside these uses, impoundments also provide flood control for many coastal communities, roadways, and agriculture resources. The coastal impoundments have a variety of owners and management objectives which causes landscape-scale management to be a complex problem, especially in the face of sea level rise. The largest owners of impounded wetlands are the U.S. Fish & Wildlife Service, the DNREC Division of Fish and Wildlife and the city of New Castle. The U.S. Fish & Wildlife Service owns and maintains impoundments at Bombay Hook and Prime Hook National Wildlife Refuges that were created to provide habitat for waterfowl. The DNREC Division of Fish & Wildlife owns and operates several impoundments throughout the state that were created to provide habitat for waterfowl, migratory shorebirds, and to control mosquito populations. The City of New Castle owns and maintains several impoundments that were created to provide flood and storm water control for the city.

Wetland loss, whether the wetlands are natural or managed, will have dramatic consequences for wildlife populations. Therefore, management of impounded wetlands needs to be conducted in the short term to maximize the services they perform annually but also must be conducted in the long term to ensure they will be available for, and provide utility to, sea level rise adaptation. An impoundment management plan that addresses the interconnectedness of impoundments and their surrounding habitats in an adaptive way and within the context of sea level rise will help to ensure wetland habitat is available over the long term.

Exposure to Sea Level Rise: Breaching of freshwater or brackish impoundments threaten the flora and fauna within these habitats. Increasing the duration of tidal flow and salinity concentration raises the potential of permanent inundation and vegetation dieback, which could result in impoundments converting into a permanent open water body. A sea level rise of 0.5 meters could result in inundation of 81% of the state's impoundments. At 1.0 and 1.5 meters of sea level rise, 99% of all impoundments could be affected (Table 12 and maps in the Mapping Appendix).

Table 12 - Impoundments

County	Total Impoundment Acres	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	12,236	9,961	12,107	12,176	81%	99%	99%
New Castle	2,882	2,007	2,870	2,876	70%	99%	99%
Kent	2,950	1,800	2,935	2,946	61%	99%	99%
Sussex	6,403	6,154	6,302	6,354	96%	98%	99%

Source: Delaware Coastal Programs, Impoundments (2010), unpublished.

Potential Economic Impact: The economic impact is unclear. Potential losses may come indirectly as a result of reduced ecotourism and associated dollars spent on lodging, food and equipment. No economic data specific to impoundments has been generated.

Potential Social Impact: Coastal impoundments provide important breeding, migration, and wintering habitat for a variety of birds. They serve as nurseries for fish and help to control mosquito populations. In addition, they provide important recreational opportunities. Loss of impoundments could result in loss of historic and cultural connections to such activities as waterfowl hunting, trapping, and bird watching.

Potential Environmental Impact: These freshwater, brackish, and tidal impoundments fill a void in the distribution of wetlands along the coast, as human activities have resulted in a loss of freshwater and brackish wetlands. The habitat that is provided by the impoundments has become a core component of the distribution of available habitat in the Mid-Atlantic for migratory waterfowl, shorebirds, wading, and ground birds. The loss of these areas could result in a large scale shift in the distribution of birds within Delaware and the Delmarva Peninsula.

Additional Information: Detailed information on types of habitat loss may be available from data collected from each affected impoundment.

Beaches and Dunes

The coastline of Delaware is a vital economic and environmental resource. Its 24 miles of Atlantic Ocean shoreline and 357 miles of river and bay shoreline provide economic benefits from tourism, high-value space for commercial and residential development, and recreational opportunities including boating, fishing, and beach-going. Delaware's shoreline is also an important ecological resource—providing habitat for a variety of plants, animals, insects, and migratory birds.

The assessment below focuses on the ecological impacts of sea level rise to beaches and dunes. Impacts to beaches and coastal communities resulting from these impacts are also addressed within the Tourism section of the Society and Economy chapter of this document.

Operating in tandem with the Sea Level Rise Advisory Committee is another state committee focused on the communities of Delaware's Bay Beaches. The Delaware Bay Beach Work Group (also known as the Simpson Bushweller Committee) has provided the Governor with 14 short-term recommendations to help alleviate flooding and erosion problems in these areas. The Delaware Bay Beach Work Group will also provide recommendations for addressing the long term issues threatening these coastal communities including storms, rising sea levels, subsidence, beach erosion, and flooding. These recommendations will assist the State in developing a sustainable long-term strategy, including new approaches to financing restoration work (Delaware Bay Beach Work Group, 2011). This document will refer readers to their work considering these at-risk coastal communities.

Exposure to Sea Level Rise: Typically, Delaware's beaches include a berm and dune system. The berm and dune system naturally transgress or migrates landward, but infrastructure built on areas along the coast block that process. Instead, material is eroded and carried offshore. This decreases beach width and berm height, thus eliminating or damaging the dune systems, exposing coastal properties to storm damage.

Sea level rise has the potential to exacerbate the damaging effects of coastal storms by increasing the severity of flooding in coastal communities. When combined with wind-driven waves, sea level rise can cause shoreline erosion that leaves roads, boardwalks, hotels, and houses along the coastline vulnerable to storm damage.

There is no data table presented here to quantify acreage impacts to beaches. Because beaches erode and accrete naturally on a short term basis and public beaches are augmented with periodic sand replenishment projects, it may not be apparent that sea level rise is affecting beaches. Often the impacts are more obvious on the bay/wetland side of barrier beaches because without replenishment projects, as the water rises, more land is lost. The degree to which a beach would be affected by sea level rise is difficult to ascertain given the dynamic nature of the habitat. Dramatic changes can be seen annually between winter and summer beach profiles and the natural landward migration of the beach and dune habitat. Periodic beach re-nourishment efforts in developed coastal areas continually reshape the coastline.

Natural Resources

Inter-dunal wetlands are a unique coastal dune habitat type at risk from sea level rise. These small wetlands are found only among maritime dunes along the Atlantic Coast. Despite their proximity to the ocean, their seasonal flooding is driven by groundwater and precipitation. As dynamic as many other beach and dune habitats, these swales are periodically created or destroyed by major storms. Some types are wholly herbaceous vegetation, while others are dominated by shrubs. More than 20 types of rare plants are found in these wetlands. There are 72 acres of this habitat type in Sussex County, Delaware, mostly on protected state parkland. A small percentage would be affected at the 0.5 m scenario but the 1.0 m and 1.5 m scenarios indicate a more drastic impact of 81% and 94% respectively (Table 13). Impacts from predicted sea level rise, made worse by disturbance of normal coastal processes, could be substantial. Note that although inter-dunal wetlands are part of a very dynamic coastal ecosystem, their recovery from disturbance – including sea level rise – is believed to be fairly slow because a thin layer of peat must develop on the sand to establish the plant community. Note: the economic, social, and environmental impacts discussion below refers to the broader category of Beaches and Dunes, not just inter-dunal wetlands.

Table 13 - Inter-dunal Wetlands

County	Total Acres	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	72	3	58	68	5%	81%	94%
New Castle	0	0	0	0	0%	0%	0%
Kent	0	0	0	0	0%	0%	0%
Sussex	72	3	58	68	5%	81%	94%

Source: DNREC-Natural Heritage Program, Habitats of Conservation Concern (2011), unpublished

Potential Economic Impact: Based on 2008 statistics from the Delaware Tourism office, the tourism industry was the 5th largest employment sector in the state accounting for 8.3% of Delaware's total employment. The industry brought in approximately $408 million in state and local taxes and fees that year. It was estimated that 16% of total trips involved beach recreation (DEDO, 2008). Delaware's bay beaches and Atlantic coast beaches also provide ecotourism opportunities. A 2006 National Survey found that 395,000 Delaware residents and nonresidents fished, hunted, or watched wildlife in the state. Of the total number of participants, 159,000 fished, 30,000 hunted, and 285,000 participated in wildlife-watching activities, which included observing, feeding, and photographing wildlife (US DOI-FWS and US DOC-Census Bureau, 2006).

The most recent beach replenishment effort in 2011-2012 along the Atlantic coast beaches (Rehoboth, Dewey, Bethany, South Bethany and Fenwick) cost approximately $38 million. This particular sand nourishment project was paid for with federal disaster relief funding. However, the initial project was funded under the typical 35% local and 65% Federal cost share.

Along the Delaware Bay coast during the same time period, beach nourishment occurred using a truck hauling method. The bay beaches replenished were Kitts Hummock with 7,000 cubic yards of sand coasting $111,230, Bowers Beach with 13,000 cubic yards of sand costing $206,570 and South Bowers Beach with 2,000 cubic yards of sand costing $31,780. Unlike the Atlantic Ocean projects, these projects were funded exclusively with state funds.

Potential Social Impact: Coastal communities are intertwined with rising sea levels. The social fabric of these coastal towns is based around fishery activities, marina activities, and tourism. As long as these critical social factors are not affected by sea level rise, then these communities will be able to survive. However, the potential loss of beach access, and the loss of beach resort infrastructure may have impacts on their social structure. Further, as sea levels continue to rise, residents in some coastal communities may experience property damage, interrupted services, and access issues which will negatively affect their quality of life.

Potential Environmental Impact: Coastal habitats are adapted to the dynamic conditions of shifting sands, strong winds, and salt spray unique to the narrow zone along the Atlantic Ocean and Delaware Bay. They range from the beach – covered and exposed by the twice-daily tides – to the first grassy dunes and overwashes, to a complex of shrub-dominated back dunes.

These habitats have declined significantly in extent and quality during historical times primarily because of residential development and associated infrastructure, particularly artificial shoreline hardening, jetties, and groins. In recent decades, this decline has greatly slowed on the Atlantic Coast, where most remaining habitats are on public land. Losses continue along the shorelines of the Delaware Bay and Inland Bays. All of these habitats are subjected to on-going impacts from recreational activities, and Delaware Bay beaches in particular are occasionally impacted by oil spills. The long term prospect for beaches and dunes is potentially poor given predicted sea level rise, even though these disturbance-dependent habitats might be expected to accommodate sea level rise reasonably well by migrating inland. However, onshore and offshore coastal processes that would facilitate such a shift, especially sand transport, may have already been irreversibly compromised by the issues noted above.

Efforts to stabilize dunes may also further disrupt these processes in the future, despite their seeming benefits at present. Beach replenishment is a potential solution to the loss of natural sand transport, but costs are very high and nearshore habitats that serve as a sand source may be adversely impacted (DNREC-Div. of Fish and Wildlife, 2006).

Natural Resources

Upland Forest

Forests offer a wide variety of outdoor recreational activities such as hiking, jogging, biking, horseback riding, camping and hunting. They provide wildlife habitat for a variety of species and provide air quality benefits. They also provide direct economic benefits to the state through timber production.

Approximately one-third of Delaware is forested, according to the 2010 Delaware Forest Resource Assessment generated by the Delaware Forest Service. Of this, 97% is classified as potential commercial timberland and could provide benefits to the timber industry (foresters, loggers, and mills-saw timber, pulpwood, veneer, and pilings). Forests are also valuable for wildlife habitat, recreation, soil protection, water quality and quantity as well as aesthetics (Delaware Forest Service, 2010).

Exposure to Sea Level Rise: Three upland forest types were analyzed for exposure to sea level rise under the three scenarios: evergreen forest, deciduous forest, and mixed forest. However, the map (see Maps 13-15) and the discussion of impacts refers to the impact of all upland forest types combined.

The level of exposure to upland forest resources is fairly limited. The combined exposure to the three forest types represented here range from 2% to 6% of the total upland forested acreage in the state under the range of inundation scenarios (see Table 14 - 17).

Table 14 - Total Upland Forest

County	Total Forested Acres	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	177,590	4,236	7,890	11,090	2%	4%	6%
New Castle	41,305	833	1,371	1,857	2%	3%	4%
Kent	35,366	1,060	2,321	3,404	3%	7%	10%
Sussex	100,919	2,344	4,197	5,830	2%	4%	6%

Potential Economic Impact: Forests provide a wide range of social and economic benefits from timber products to recreation to aesthetics. The markets for timber products are a significant sector of our state's economy. While there is no current, statistically-valid data on the contribution of the forest products industry to Delaware, it is certainly a significant component. In 2002, more than 2,600 people were employed in the forest products manufacturing industry in Delaware. Most of these jobs were located in secondary wood processing industries. Sixty-three establishments in Delaware produce a variety of products including furniture, custom millwork, cabinets, and other wood products. Approximately 4,800 acres are harvested annually–2,400 acres by clear-cut, 1,500 acres by selection harvests, and 900 acres of pine thinning (pulpwood). The Delaware Forest Service estimates that these harvests generate at least $4 million of income for landowners annually. Furthermore, urban forests also contribute jobs to Delaware's economy. The number of tree-care companies is growing as Delaware continues to urbanize. There are now 81 certified arborists in Delaware. Nursery farms generate an estimated $47 million in sales annually (Delaware Forest Service, 2010).

Maintaining and growing these markets is vital not only to Delaware's economy but also to sustain the forest land base; owners need to generate sufficient income from their forests to retain their forests. Furthermore, it is important to develop new markets, such as wood energy, to maintain a robust and diverse forest products economy so it is not overly dependent on a single market. Public investment in forests, forest markets, and forest research is also necessary to ensure a sustainable land base and the best information is available to landowners and decision-makers. Addressing all of these issues is necessary to help ensure that Delaware's forests will continue to meet society's needs in the future.

Table 15 - Deciduous Forest

County	Total Deciduous Acres	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	58,625	1,250	2,427	3,383	2%	4%	6%
New Castle	38,219	744	1,205	1,641	2%	3%	4%
Kent	16,000	445	1,098	1,549	3%	7%	10%
Sussex	4,406	61	123	194	1%	3%	4%

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

Table 16 - Evergreen Forest

County	Total Evergreen Acres	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	29,190	612	1,290	1,833	2%	4%	6%
New Castle	656	5	9	14	1%	1%	2%
Kent	2,366	145	326	485	6%	14%	21%
Sussex	26,168	463	955	1,334	2%	4%	5%

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

Table 17 - Mixed Forest

County	Total Mixed Forest Acres	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	89,775	2,374	4,173	5,874	3%	5%	7%
New Castle	2,430	84	157	202	3%	6%	8%
Kent	17,000	470	897	1,370	3%	5%	8%
Sussex	70,345	1,820	3,119	4,302	3%	4%	6%

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

Natural Resources

Potential Social Impact: Forests offer a wide array of outdoor recreation activities. Losses from sea level rise could reduce opportunities for hiking, jogging, biking, horseback riding, camping, hunting, and wildlife observation whether on private or publicly owned lands.

Potential Environmental Impact: Delaware has a large variety of forest communities in a relatively small geographic area. Delaware's bottomland forest species (oak, gum, cypress) may be particularly impacted by sea level rise. However, some of the rarer forests such as the Inland Dune Ridge Forest found in the Nanticoke River area, the Southern New England Red Maple Seepage Swamp found in the Piedmont, and the North Atlantic Coastal Oak-Holly Forest found in the Nanticoke and Choptank River watersheds could potentially be impacted. The loss of these unique forest communities will negatively impact biodiversity, buffering capacity, and wildlife habitat including migratory bird species.

While there is considerable research needed, several potential issues relating to forests and habitat include:

- Migration of maritime forests/riparian areas inland
- Shifts in species range (migration)
- Changes in species composition and/or disappearance of species
- Increases in invasive/nuisance species and disease
- Loss of rare plant species

Additionally, there is need to establish baseline risk assessment for species and habitats and to consider methods to move low-lying riparian forest buffers inland with any rise in sea level to ensure that these buffers are not lost. It is important that these baseline risk assessments account for possible changes from sea level rise in the future.

Flora and Fauna

Habitats of Conservation Concern

The Delaware Wildlife Action Plan, the framework for conserving the state's native wildlife, identifies 27 unique Habitats of Conservation Concern (HCC). These habitats are rare, have special significance in Delaware, are particularly sensitive to disturbance, and/or have a high diversity of rare plants. Of these 27 habitat types, 15 were determined to be vulnerable to sea level rise and were analyzed to determine the extent of possible exposure.

Exposure to Sea Level Rise: Fifteen of the 27 Habitats of Conservation Concern (HCC) identified in the Delaware Wildlife Action Plan will be exposed to sea level rise. Under the 1.5 m scenario for sea level rise, approximately half of all HCC's will be inundated and potentially lost (Table 18 and maps in the mapping appendix). The analysis indicates that habitats in Kent and New Castle Counties have a higher level or exposure than those in Sussex County.

Of those HCC's that are exposed to sea level rise, seven types (each a unique type of wetland) could experience inundation of more than 90%. However, it is unknown if, how, and where HCC's and other wetland habitats might migrate to as water levels rise.

Table 18 - Habitats of Conservation Concern (HCC)

County	Total HCC Acres	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	31,340	17,088	19,470	20,342	55%	62%	65%
New Castle	3,945	2,480	3,334	3,441	63%	85%	87%
Kent	7,039	5,911	6,460	6,555	84%	92%	93%
Sussex	20,357	8,698	9,676	10,346	43%	48%	51%

Source: DNREC - Natural Heritage Program, Habitats of conservation Concern (2011), unpublished

Potential Economic Impact: The impact of sea level rise on HCC's and their associated wetlands is enormous. Delaware, being a coastal state, relies heavily on its coastal wetlands for part of its economy. There are many ways that coastal wetlands benefit the state. For example, coastal wetlands are extremely important for providing flood protection to houses, roads and other infrastructure from storm surges resulting from hurricanes and nor'easters. They efficiently sequester nutrients and trap sediments to improve water quality. Finally, they provide spawning and nursery habitat for many of our economically important commercial fisheries including the blue crab.

Potential Social Impact: The high intrinsic value of coastal wetlands and their predicted loss from sea level rise will undoubtedly have impacts on society. A substantial loss of habitats of conservation concern is an indicator of overall coastal wetland loss. We have become accustomed, even complacent, about the benefits of our coastal wetlands and the protections to infrastructure, health and the economy they provide. Once those protections are removed, the citizens of Delaware may have to think differently about a variety of issues from how they will get around in the state to where they will find clean water.

Potential Environmental Impact: Intrusion of saltwater into freshwater is an important environmental impact of losing coastal HCC's and their associated wetlands from sea level rise. As waters push further inland, hydraulic pressure at the land/water interface will increase. That pressure will cause saline surface water to move inland underground, salinizing shallow freshwater aquifers. This interaction between saline surface water and fresh and saline groundwater would potentially lead to saltwater contamination of freshwater resources. This interaction is an area that needs further investigation to fully quantify the threats posed to freshwater resources. Other sections (salinity changes, groundwater, freshwater tidal wetlands, and non-tidal freshwater wetlands) within this assessment also identify saltwater intrusion as a pertinent issue.

Additional Information: The amount of each habitat type needs to be monitored with aerial imagery set. These maps can then be updated with each aerial imagery set in order to see whether they are decreasing or increasing. More research needs to be conducted on the resource use of the animals and whether there is a trend of their populations following the trends of the habitat or whether they are adapting to other habitats.

Native Vegetation

Native vegetation discussed within this section includes rare, uncommon, and common species that occur in upland, tidal, and non-tidal habitats near or adjacent to the coast. Specifically, the following Delaware Wildlife Action Plan habitats are considered: beach and dune (overwash, foredune, grassland, inter-dunal wetland, shrubland, forests & woodlands); freshwater tidal (shorelines & mudflats, herbaceous, shrub, forested); peat wetlands (acidic fens); submerged aquatic beds (fresh and brackish); brackish tidal wetlands (herbaceous and shrub); tidal salt water wetlands (salt panne, high wetland, low wetland).

Exposure to Sea Level Rise: An analysis of the flora of Delaware, focusing on the habitats mentioned above (Table 19), found that a total of 631 native species of plants that typically occur within these habitats have the potential to be affected by sea level rise. This figure includes 172 that are state rare and uncommon (11% of the overall state native flora), 7 that are globally rare, and one that is listed as threatened by the U.S. Fish and Wildlife Service. In addition, 22 species that are at the northern limit of their natural geographic distribution and 9 species that are at their southern limit could be potentially affected by sea level rise. If these edge-of-range species, (the majority of which are freshwater species) were to become extirpated, then critical genotypes of the species will become extinct and the genetic diversity of the species will be degraded. Results specific to certain habitat types can be found in the spreadsheet below.

Potential Economic Impact: Unknown.

Potential Social Impact: Unknown.

Potential Environmental Impact: See discussion above.

Table 19 - Flora that may be affected by sea level rise and associated habitat type

DELAWARE WILDLIFE ACTION PLAN HABITAT	Total Taxa	S1	S1.1	S2	S3	Total Rare & Uncommon	% of overall flora	G1, G2, G3	U.S.F.W.S Listed	Northern Limit	Southern Limit
BEACH AND DUNE HABITATS (Overwash, Foredune, Grassland, Interdunal Wetland, Shrubland, Forests & Woodlands)	218	14	3	18	25	57	26	2	1	6	1
FRESH WATER TIDAL (Shorelines & Mudflats, Herbaceous, Shrub, Forested)	170	16	3	15	7	41	24	4	0	6	4
PEAT WETLANDS (Acidic Fens)	122	4	2	21	15	40	33	1	0	5	2
SUBMERGED AQUATIC BEDS (Fresh & Brackish)	35	5	0	3	5	13	37	0	0	0	2
BRACKISH TIDAL WETLANDS (Herbaceous and Shrub)	54	6	3	3	4	13	24	0	0	4	0
TIDAL SALT WATER WETLANDS (Salt Panne, High Marsh, Low Marsh)	32	3	0	2	3	8	25	0	0	1	0
TOTALS	**631**	**48**	**11**	**62**	**59**	**172**	**28**	**7**	**1**	**22**	**9**

Conservation Status Ranks- S1: Extremely rare and of conservation concern; typically 5 or fewer extant occurrences or populations in the state; or only a few remaining individuals; may be especially vulnerable to extirpation. S1.1: To date, only a single extant occurrence or population of this species is known to exist in the state. S2: Very rare and of conservation concern; typically between 6 and 20 known occurrences or populations; may be susceptible to becoming extirpated. S3: Uncommon not of conservation concern; typically 21 to 50 known occurrences or populations. Global Status Ranks-G1: Critically imperiled globally because of extreme rarity (5 or fewer occurrences) or because of some factor(s) making it especially vulnerable. G2: Imperiled globally because of rarity (6-20 occurrences) because of some factor(s) making it especially vulnerable. G3: Either very rare or local throughout its range (21 to 100 occurrences), or found locally in a restricted range, or because of some other factor making it vulnerable to extinction throughout its range.

Native Fauna

Sea level rise impacts to Delaware's fish and wildlife species is a complex issue. Species have evolved to become dependent on habitats and habitat conditions over the millennia. As sea level rises, those habitats could be degraded or lost at a rate faster than species are able to adapt. Indeed, some of the species that are dependent on our coastal resources may already be experiencing population declines due to sea level rise. In particular, spartina high salt marsh (a habitat of conservation concern) harbors black rails, one of the rarest bird species both within the state as well as along the Atlantic coast. Black rail populations have declined by as much as 85% over the last twenty years and there is real concern for this species and its vulnerability to sea level rise. Greater than 99% of its habitat is predicted to be lost under the most conservative sea level rise scenario of 0.5 m by the 2100. This is just one of many examples of species that might be lost in the very near future.

Natural Resources

Exposure to Sea Level Rise: Approximately 20% of the state's native fauna is considered rare and uncommon. Of the rare and uncommon species, 54% could be impacted at the 1.5 m sea level rise scenario which represents 11% of the entire state fauna. In addition, there are species that are currently considered common that may become rare or extirpated as a result of habitat changes from sea level rise. Therefore, 11% of the fauna is a conservative estimate of what could be impacted by sea level rise as this number only accounts for those species currently identified as rare and uncommon. Animals do have the ability to move and adapt with changing conditions and the bathtub inundation model used for this assessment does not take into account habitat that may be created or replaced. Regardless, sea level rise is anticipated to have significant impacts to our fauna. The level to which species populations will decline or become extirpated requires species-specific vulnerability assessments.

Potential Economic Impact: According to a report by the U.S. Fish and Wildlife Service, approximately one out of every three Americans over the age of 16 participates in wildlife watching. This has significant economic impact for Delaware where wildlife watching generates $131 million in retail sales, $77 million in salaries, wages, and business-owner income, and $19.5 million in state and local tax revenue. It also creates 1,975 jobs within the state (Leonard, 2008). While these are state-wide figures, the economic impact from sea level rise would be significant considering that the habitats within the Delaware Bay coastal area are highly vulnerable to sea level rise and are a significant natural resource due to the extent and completeness of its ecological system.

Potential Social Impact: Sea level rise has the potential to result in significant social impacts as a result of wildlife population declines. Although not well understood, there is the possibility that the loss of species that help to control pest or pathogens associated with pests might increase disease transmission. Combined with a warming climate, more pests and pathogens that were once restricted to warmer tropical climates might become established in Delaware (Logan, Regniere, & Powell, 2003). Sea level rise may also impact harvested fish and wildlife to the extent that recreational or commercial hunting and fishing opportunities are no longer available. Finally, many people simply enjoy wildlife viewing. There may be physical and emotional consequences for individuals if opportunities to be outdoors and enjoy nature are limited. The loss of the salt marsh environment in Delaware, the most extensive natural system in the state, may have a negative impact on people and communities who can no longer utilize the habitat for flood attenuation, recreational or commercial purposes.

Potential Environmental Impact: The loss of just one species could be a significant environmental impact that has far reaching consequences. In most cases, it is unknown exactly what a species contributes to the environment around it or what ecological services it may provide. One example is control of pests and pathogens. However, there is also species inter-dependence. The loss of a nectar plant may extirpate a moth that then reduces food for another species and so on. If it were not for horseshoe crabs, red knots and other shorebirds may not find the food they need during a critical period of their life cycle.

Natural Resource Conservation Lands

This section of the assessment focuses on protected lands of conservation and recreational value. The first heading, Protected Lands Statewide, considers lands protected for various purposes and by various agencies. Of this broader category, two sub-heading of protected lands are discussed, Nature Preserves and National Wildlife Refuges. Nature Preserves are discussed because of the unique habitat types and significant ecological of these areas. The National Wildlife Refuges within the state, Bombay Hook and Prime Hook, are also of significant ecological value and represent a large portion of protected land in Delaware.

Protected Lands Statewide

Protected lands statewide are lands that are protected from development by a variety of different organizations and through a variety of different measures. They include state-owned properties such as wildlife areas, state parks, state forests, boat ramps, nature preserves, and historical sites. Protected lands also includes two federally-owned wildlife refuges, Bombay Hook and Prime Hook. Municipal land holdings such as municipal parks, open space, and recreational facilities are also included. Privately-owned land with a permanent and legally binding conservation easement are also included. These easements prohibit future development and in some cases, limit the use of the land to specific purposes (like wildlife habitat) and are "held" by either a state or local government or private conservation organization. Collectively, these properties represent a variety of habitat types and extensive opportunities for outdoor recreation.

Exposure to Sea Level Rise: Sea level rise will bring changes to many of the places and amenities that people visit and enjoy in Delaware. Parks, natural areas and wildlife areas may lose ground to inundation and erosional forces, and wildlife populations may relocate or shrink as a result of changing habitats. Statewide, 37% to 44% of the state's permanently protected land could be inundated by sea level rise under the three planning scenarios (Table 20 Protected Lands (2009)). Geographically, these areas are concentrated in areas adjacent to the Delaware Bay in Kent and Sussex Counties (Maps in Mapping Appendix). Impacts resulting from sea level rise to these lands could affect the tourism industry and recreational opportunities in the first state.

Table 20 - Protected Lands (2009)

County	Total Acres	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	168,384	61,989	70,003	74,653	37%	42%	44%
New Castle	45,553	11,407	12,681	13,428	25%	28%	29%
Kent	54,399	30,289	34,336	36,388	56%	63%	67%
Sussex	68,433	20,294	22,986	24,837	30%	34%	36%

Source: DNREC- Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished

Natural Resources

Potential Economic Impact: Outdoor recreation opportunities in Delaware are a large component of the tourism industry, as well as a way of life for Delaware residents. A 2006 national survey of wildlife recreation found that 395,000 people who live in or visited Delaware fished, hunted, or watched wildlife in the state. Of the total number, 159,000 people fished, 30,000 people hunted and 285,000 participated in wildlife-watching activities, which includes observing, feeding, and photographing wildlife (US DOI-FWS and US DOC-Census Bureau, 2006). During this time period, state residents and non-residents spent $299 million on wildlife recreation in Delaware. Of that total, trip-related expenditures were $75 million and equipment purchases totaled $204 million. The remaining $20 million was spent on licenses, contributions, land ownership, and leasing, and other items (Caudill & Henderson, 2005). Inundation of the habitats within protected areas in the state may lead to a reduction in opportunities for fishing, hunting and wildlife-watching and a loss of the associated economic benefit of these activities.

Potential Social Impact: The social fabric of many of Delaware's small coastal towns is based upon fishing, boating, hunting, and other outdoor recreational activities. Reductions in the availability of these amenities as a result of sea level rise may affect tourism levels and local business revenues, leading to loss of business services and sense of community.

Potential Environmental Impact: The environmental impact is difficult to quantify as the lands discussed in this section represent various habitat types statewide. Reduction or loss of habitat within the protected lands can impact populations of the species that inhabit them. Wildlife may be forced to redistribute if habitats within the protected areas no longer meet their needs and may relocate to areas that are not afforded the same protection and management. Species that are unable to relocate may experience population decline.

Additional information about environmental impacts specific to nature preserves and national wildlife refuges are discussed in the following sections.

Nature Preserves

Nature preserves are relatively undisturbed protected lands, free from development pressure that thereby provide exceptional habitat for various species of flora and fauna. The designation of nature preserve is the highest level of land protection afforded by the State of Delaware. These lands are unique and often fragile environments that represent some of Delaware's most important natural habitats. There are currently 28 dedicated nature preserves composed of 65 tracts of both public and private land and water. The total acreage of nature preserves in the state is 4,774 acres.

Exposure to Sea Level Rise: Between 34% and 43% of the total acreage of natural preserves within the state could be inundated by sea level rise of up to 1.5 meters (Table 21). The level of exposure varies based on location and types of habitats within each nature preserve. Within New Castle County, there are four nature preserves that could lose up to half of their area as a result of inundation of up to 1.5 meters of sea level rise. One, Pea Patch Island, could be completed inundated by 1.5 meters of sea level rise. Kent County's Murderkill River Nature Preserve and Mispillion Harbor.

Reserve could also be completely inundated with up to 1.5 meters of sea level rise. In Sussex County, there are eight preserves that could be impacted, one that is approximately 50% inundated (Nanticoke River Nature Preserve) and one that is marginally affected (Doe Bridge Nature Preserve). The percent of each nature preserve that could be subject to sea level rise is presented graphically in the Mapping Appendix.

Table 21 - Nature Preserves (2009)

County	Total Acres	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	4,774	1,633	1,874	2,031	34%	39%	43%
New Castle	1,626	414	482	512	25%	30%	32%
Kent	476	197	204	206	41%	43%	43%
Sussex	2,673	1,022	1,188	1,313	38%	44%	49%

Source: DNREC Division of Parks and Recreation, Nature Preserves (2009), unpublished

Potential Economic Impact: The potential economic impact from inundation of nature preserves is unclear. Potential economic losses may come indirectly as a result of reduced ecotourism and associated dollars spent on lodging, food, etc. No economic data specific to nature preserves is available.

Potential Social Impact: Loss of nature preserves as a result of sea level rise would deprive residents and visitors of access to these sites of ecological significance resulting in potential “quality of life” type social impacts and fewer passive recreation opportunities. It is essential that people retain the opportunities to maintain close contact with thriving ecological communities and environmental systems and to benefit from the scientific, educational, esthetic, recreational, and cultural values they possess. The benefit to the public is to have permanently protected unspoiled natural areas to enjoy.

Potential Environmental Impact: As stated above, nature preserves are unique and often fragile environments that represent some of Delaware’s most important natural habitats. Sites selected for dedication as a nature preserve often have an outstanding vegetation community and habitat, species rarity, outstanding geological features or outstanding archaeological features. The environmental impact resulting from sea level rise is difficult to quantify as the preserves represent various habitat types statewide. In general, reduction or loss of unique habitats within the protected boundaries of the preserves can impact wildlife populations and plant communities. If habitats within the preserves no longer meet their needs, wildlife may relocate, sometimes to areas that do not afford the same protection and management that is provided by the nature preserve designation.

Additional Information: Detailed information on types of habitat loss may be available from data collected from each affected preserve. This data is likely available from the Natural Areas Program or may be captured under other land use data layers.

National Wildlife Refuges

Prime Hook National Wildlife Refuge (NWR) is located in Sussex County near the town of Milton. Bombay Hook NWR is located in Kent County near the towns of Smyrna and Dover. Area residents and visitors use the refuges for passive outdoor recreation activities such as birding, wildlife watching, and photography, as well as for consumptive wildlife uses such as hunting and fishing. In 2004, 63% of visitors to Prime Hook NWR were residents of Delaware; the remainder were visitors to the state. The vast majority of those visitors were there for non-consumptive (passive) outdoor recreation. Classes and school groups from area schools and colleges also use the refuges for environmental education programs.

Exposure to Sea Level Rise: The sea level rise inundation maps show that between 85-95% of the total acreage of NWRs in Delaware could be inundated by sea level rise (Table 22 USFWS Property). Up to 94% of the over 16,000 acres of marsh, forest and agricultural fields at Bombay Hook NWR could be inundated by sea level rise of 1.5 meters. Up to 98% of the habitats and land at Prime Hook NWR could be inundated by sea level rise of 1.5 meters.

Table 22 - USFWS Property

County	Total Acres of USFWS Property	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	25,266	21,354	23,478	24,120	85%	93%	95%
New Castle	0	0	0	0	0%	0%	0%
Kent	16,137	13,010	14,769	15,152	81%	92%	94%
Sussex	9,129	8,344	8,709	8,969	91%	95%	98%

Source: DNREC- Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished.

In addition to the results of the inundation maps that serve as the basis for this vulnerability assessment, the sea level rise risk for Bombay Hook NWR and Prime Hook NWR have been analyzed using the Sea Level Affecting Marshes Model (SLAMM). SLAMM analysis has limitations which are discussed in more detail within each specific SLAMM report (Scarborough, 2009). However, the results provide further indication of the magnitude of threat facing the two National Wildlife Refuges in Delaware and demonstrate the potential associated land cover changes.

For Prime Hook NWR, a SLAMM analysis was conducted by the Delaware Coastal Programs, utilizing SLAMM version 5 combined with more accurate elevation data than was typically relied upon for that version of the model (Scarborough, 2009). The model was applied utilizing inputs representing a range of possible future scenarios. It is anticipated that the reality could fall anywhere within these predicted outcomes. For example, under the 0.5 meter sea level rise scenario, if the model assumes that salt marsh accretion keeps pace with current sea level rise rates, and that there is full tidal influence along the coast, then the refuge is predicted to lose more than half of its marsh, and the amount of open water and tidal mudflat (combined) will more than quadruple. If the model assumes that salt marsh accretion will increase to 5.0 mm/year, keeping pace with sea level rise as salt marshes often can, then the reduction of marsh acreage is small and conversion to open water and tidal mud flat are not as pronounced. In both cases, more than half of the upland is predicted to be lost. The primary difference is whether or not the remaining areas are maintained in some form of wetland cover, or are converted to open water. Under each sea level rise and marsh accretion scenario, if the model assumes that coastal dunes will instead be maintained, these predictions do not change appreciably. Results for additional scenarios, such as increased rates of sea level rise, can be found in (Scarborough, 2009).

For Bombay Hook NWR, this effort was conducted in 2010 by a contracting firm on behalf of the USFWS Washington Office (Clough & Larson, 2010). Input values (e.g., elevation, sea level rise, accretion, erosion) were based on the available local or regional estimates. Under this analysis, Bombay Hook is predicted to lose more than three quarters of its regularly flooded (salt) marsh in scenarios higher than 1.0 meter. This model predicted that saltmarsh will increase with sea level rise scenarios less than 1.0 meter due to the conversion of irregularly flooded marshes. The refuge is predicted to lose between 23% and 62% of its upland, and between 15% and 97% of its irregularly flooded marsh across all scenarios. Maps of model results seem to predict that the refuge is fairly resilient to rates of eustatic sea level below 1.0 meter by 2100. However, there are concerns regarding the accuracy of the elevation data covering the refuge (Clough & Larson, 2010). New elevation data obtained during spring 2011 may allow for a new, more accurate, SLAMM analysis of Bombay Hook NWR.

Potential Economic Impact: Refuge management activities and influences contributing to the economy of the surrounding communities include Refuge purchases of goods and services within the local community, Refuge personnel salary spending, revenues generated by Refuge Revenue Sharing, and spending in the local community by Refuge visitors. The effects of sea level rise on Delaware's National Wildlife Refuges could have significant indirect economic impacts to the communities near the refuge, and thus to the state, from loss of recreational opportunities, and therefore loss of economic activity generated by recreation on Refuges. Potentially, changes in Refuge habitats could lead to changes in management that would alter other economic activities of the Refuges, but this cannot be estimated. For both Refuges, the "Banking on Nature" reports provide information on the economic input of the Refuge to the surrounding economy (Caudill & Henderson, 2005). This report examines expenditures by people visiting Refuges, and also calculates the "final demand" associated with each Refuge. Final demand is defined as the total spending by final consumers on all goods, in a given region, attributable to refuge visitation. Final demand includes spending by people who earn income from refuge visitors' activities as well as spending by refuge visitors themselves.

According to "Banking on Nature," the total visitor recreation expenditures for Bombay Hook NWR in 2004 were $3,166,800, with non-residents accounting for $3,009,800 (95 percent of total expenditures). Expenditures on non-consumptive activities accounted for 99 % of the total with hunting accounting for one percent. Total final demand was $4,316,600. This is the total monetary value of economic activity generated in the 2-county area by refuge visitor spending. In turn, this final demand generated 37 jobs (both full-time and part-time) with total job income of $1,387,400. Total tax revenue generated (county, state, and federal) amounted to $855,000.

At Prime Hook NWR, "Banking on Nature" reports that visitor recreation expenditures in 2004 were $1,043,600 with non-residents accounting for $795,000, or 76%, of the total Refuge visitor recreational expenditures. Dollars spent by non-consumptive users totaled $771,900, fishing expenditures accounted for $222,100, or 21% of the total, and hunting expenditures totaled $49,700, or 5% of total recreation expenditures. The final demand was calculated as $1,456,000. This amount reflects the total monetary value of economic activity generated in the three counties of Delaware by Prime Hook NWR visitor spending. In turn, the final demand generated 13 jobs (both full-time and part-time) with a total job income of $419,400. Total tax revenue generated (county, state, and federal) amounted to $291,000.

At Prime Hook NWR, the Regional Economic Impacts of Current Management for the Refuge were also estimated using the "Impacts Analysis for Planning" (IMPLAN) regional input-output modeling system (Koontz, 2010), providing an updated refuge-specific report. Refuge management activities directly related to Refuge operations generate an estimated $2.7 million in local output, 25 jobs, and $742,000 in labor income in the local economy. Including direct, indirect, and induced effects, Refuge activities are estimated to generate total economic impacts of $3.9 million in local output, 33 jobs, and $1.1 million in labor income.

More specifically, non-consumptive uses (such as birding and general refuge visits) directly related to Refuge operations are estimated to generate $2.1 million in local output, 21.3 jobs, and $602,700 in labor income in the local economy. Including direct, indirect, and induced effects, non-consumptive uses are estimated to generate total economic impacts of $3.1 million in local output, 29.3 jobs and $875,000 in labor income. Fishing activities directly related to Refuge operations are estimated to generate $180,4000 in local output, 1.8 jobs, and $50,400 in labor income in the local economy. Including direct, indirect, and induced effects, fishing activities are estimate to generate total economic impacts of $252,500 in local output, 2.1 jobs, and $72,100 in labor income.

Overall hunting activities directly related to Refuge operations are estimated to generate $73,500 in local output, 0.6 jobs, and $21,000 in labor income in the local economy. Including direct, indirect, and induced effects, overall Refuge hunting activities are estimated to generate total economic impacts of $103,600 in local output, 0.9 jobs, and $30,100 in labor income. A further breakdown of hunting activities on the Refuge, including direct, indirect, and induced effects, reveals that big game hunting on the Refuge would generate total economic impacts of $45,500 in local output, 0.4 jobs, and $13,00 in labor income. Waterfowl hunting on the Refuge is estimated to generate total economic impacts of $60,000 in local output, 0.5 jobs, and $16,600 in labor income. Small game hunting on the Refuge would generate total economic impacts of $2,000 in local output, 0.02 jobs, and $500 in labor income.

Impacts from sea level rise would likely result in a conversion of large areas of Refuges to different habitat types, and/or open water. The Refuges will still provide wildlife habitat, even if the nature of that habitat has changed, so, it is possible that outdoor recreation opportunities would remain. However, it is reasonable to expect that the quality or accessibility would be reduced, resulting in economic impacts for the nearby area.

Potential Social Impact: Social impacts will stem from the loss of recreational opportunities, as well as from the loss of quality wildlife habitat. As described above, recreation at the Refuges provides significant and measurable economic benefit to the local economy by encouraging tourism from outside Delaware. The loss of such benefits will have considerable societal impact. Area residents, in particular, will suffer from the loss of a treasured natural area. Residents who use the Refuges for convenient source of recreation and a place to relax in the outdoors will be deprived of those opportunities, as access to the Refuges is likely to decrease following inundation. Regardless of how frequently they may visit, the mere presence of highly regarded National Wildlife Refuges in the area can be a sense of pride for some residents.

Far more difficult to quantify, but worth noting, is the loss of ecosystem services provided by the habitats, particularly the wetlands, that comprise both Refuges. These impacts are discussed in more detail under the assessment for each habitat resource (e.g., tidal emergent wetlands, forested wetlands). In summary, healthy wetlands provide a measure of flood protection by absorbing run-off from uplands as well as storm surge from the Delaware Bay. Healthy wetlands also improve water quality in areas downstream. The coastal wetlands of the Refuges, which are likely first to be inundated, provide important nursery habitat for fish species that are an important component of the local seafood economy. Indirect society impacts of inundation of the Refuges include loss or degradation of these important ecosystem services provided by Refuge lands.

Potential Environmental Impact: National Wildlife Refuges are an incredibly important environmental resource in Delaware, and sea level rise is anticipated to have many significant environmental consequences. Both NWRs were established primarily for migratory birds, due to their position within the Atlantic flyway. Birds in various guilds concentrate at both Refuges at different stages of their life history. For example, both Refuges are important for migrating and overwintering waterfowl in the fall and winter, and for migrating shorebirds in the spring and late summer. Refuge wetlands also provide habitat for wading birds, secretive marsh birds, wetland passerines, and other landbirds. Reduction or loss of wetland habitats within the protected boundaries of the Refuges can impact populations of these species. They may be forced to redistribute if Refuge wetlands no longer meet their needs, and relocate in wetlands that are not afforded the same protection and management that is provided by the NWR designation.

Natural Resources

Further details about the environmental consequences of the reduction or loss of specific habitat types found on the Refuges, especially wetlands, can be found elsewhere in this vulnerability assessment.

Agriculture

Agricultural land used in Delaware ranges from local crop and vegetable farms to large poultry producers and food processors. Support businesses, such as grain, fertilizer, and irrigation supply businesses, also fall in the agricultural use category. Many groups throughout Delaware benefit from the strength of the agricultural economy. State and local government agencies use funds generated by agricultural taxes to support other programs. This section discusses the potential impact from sea level rise on highly productive soils, agricultural preservation districts and conservation easements. The Society and Economy section of this document includes additional information about agricultural impacts.

Highly Productive Soils

The category of highly productive soils includes prime farmland and farmland of statewide importance. Prime farmland is land which has the best combination of physical and chemical characteristics for the production of crops. It has the soil quality, growing season, and moisture supply needed to economically produce sustained high yields of crops when treated and managed, including water management, according to current farming methods. Prime farmland does not include publicly owned lands for which there is an adopted policy preventing agricultural use (NRCS). Farmland of statewide importance is land other than prime farmland which has a good combination of physical and chemical characteristics for the production of crops. Farmlands of statewide importance include those that are nearly prime farmland and that produce high yields of crops when treated and managed according to acceptable farming methods. It does not include publicly owned lands for which there is an adopted policy preventing agricultural use (NRCS).

Exposure to Sea Level Rise: According to the inundation maps, exposure of highly productive soils to sea level rise are low, with only 2% to 4% of the highly productive soils potentially exposed under the three scenarios (Table 23 and maps in Mapping Appendix). An additional consideration is that highly productive soils data only considers the soil type; it does not consider whether or not the land area is used for agriculture. Localized impacts from sea level rise may be significant but would not likely negatively affect the state as a whole.

Table 23 - Highly Productive Soils

County	Total Acres of Highly Productive Soils	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	693,128	12,564	22,699	32,361	2%	3%	4%
New Castle	147,779	2,538	4,366	5,934	2%	3%	4%
Kent	279,976	4,111	7,969	11,865	2%	3%	4%
Sussex	265,373	5,916	10,364	14,562	2%	4%	5%

Source: Delaware Coastal Programs, Prime Farmland (2011) and Farmland of Statewide Importance, unpublished

Potential Economic Impact: Prime farmland and farmland of statewide importance are the areas of Delaware where the highest crop production rates could occur (if the soils are in agricultural production). These soils are the state's economic drivers for agriculture; in 2009, net farm income was estimated at $193 million (Awokuse, Ilvento, & Johnston, 2010). Inundation of highly productive soils could render them unsuitable for agricultural purposes and decrease farming income to individuals and throughout the state, however, the percentage of highly productive soils potentially impacted is low and not all of these soils are in agricultural production. In addition to inundation, saltwater intrusion as a result of sea level rise could impact agricultural activities in general by decreasing crop yield, completely eliminating the capability of growing certain crops, and impacting the health of domestic livestock.

Potential Social Impact: Many communities in Delaware developed due to relative proximity to prime farmland. The potential loss of productive agricultural fields and resulting losses in employment may cause farmers and farm workers to relocate to areas not affected by sea level rise, causing losses to the local agricultural heritage of a community.

Potential Environmental Impact: Agriculture in Delaware often relies on irrigation which may be impacted by the intrusion of seawater pushing further up into fresh water stream and rivers. In coastal areas, the increased water withdrawal, combined with sea level rise, may increase saltwater intrusion into the groundwater or aquifers. Additionally, in agricultural locations near the coast, the seaward boundary for agriculture often is the point where saltwater penetrates inland far enough to prevent crops from growing (IPCC, 2007). As sea level rises, this boundary could move farther inland causing increased amounts of farmland to become too salty for traditional crop cultivation. Once seawater has invaded to a distance beyond that is tolerable, restoration of water quality in the invaded zone is generally an expensive or ineffective proposition. (Bear, Cheng, Sorek, Ouazar, & Herrera, 1999). Concerning prime farmland and farmland of state-wide importance, these soil types will lose their high production characteristics as salinity increases. The land may still allow for cultivation however, crop yields will begin to diminish well before inundation occurs.

Natural Resources

Preservation Districts and Conservation Easements

The Delaware Department of Agriculture implements a preservation program that uses two strategies to preserve farmland, agricultural preservation districts and agricultural conservation easements. A district is a voluntary agreement to use land only for agricultural purposes for at least a ten year period. Land must yield a minimum farm income, satisfy a scoring system standard, and undergo a review and approval process. Almost any size farm anywhere in the state can qualify. Permitted agricultural uses include but are not limited to: crop production, herd animal and poultry operations, horse operations, forest production, non-commercial hunting, trapping and fishing, and agricultural eco-tourism operations, as well as farm markets and roadside stands. In order to permanently preserve farmland, the development rights are purchased from landowners and a permanent agricultural conservation easement is placed on the land. Land must first be in an agricultural preservation district before the owner can apply to sell the development rights.

Exposure to Sea Level Rise: Approximately 8% -11% of acreage within Delaware's agricultural land preservation districts will be exposed to sea level rise (Table 24 and maps in the Mapping Appendix). The largest percentage of impact will be felt in New Castle County where 14% -16% of district farmland will be inundated under the 3 scenarios. Kent County has a similar range of 11% -16% of the total acreage impacted; however this percentage represents the largest acreage of impact within any of the counties. Impacts in Sussex County, where development has largely replaced farmland in coastal areas, range from 2% - 4% of the total district farmland.

Table 24 - Agricultural Land Preservation Districts

County	Total Acres of Land Preservation	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	55,907	4,307	5,281	6,218	8%	9%	11%
New Castle	6,264	847	940	1,028	14%	15%	16%
Kent	26,676	2,995	3,656	4,287	11%	14%	16%
Sussex	22,967	464	685	904	2%	3%	4%

Source: Del. Dept. of Agriculture, State Ag Easements, 2010-09-17

Approximately 13% - 17% of acreage of Delaware's agricultural land conservation easements could be exposed to sea level rise under the 3 scenarios (Table 25 and maps in the Mapping Appendix). Again, the largest percentage impact will be felt in New Castle County where 25% - 31% of preserved farmland within the county will be inundated. Kent County has a range of 14% - 19% of the total area impacted; however, this percentage represents the largest acreage of impact within the three counties. Impacts in Sussex County, where development has largely replaced farmland in coastal areas, range from 5% - 8% of the total farmland under conservation easement.

Table 25 - Agricultural Land Conservation Easements

County	Total Acres of Land Conservation	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	94,401	11,826	13,864	15,920	13%	15%	17%
New Castle	11,693	2,950	3,317	3,652	25%	28%	31%
Kent	52,139	7,334	8,532	9,687	14%	16%	19%
Sussex	30,569	1,542	2,015	2,582	5%	7%	8%

Source: Del. Dept. of Agriculture, State Ag Districts, 2010-09-17

Potential Economic Impact: As mentioned in the previous section, net farm income for Delaware was estimated at $193 million in 2009 (Awokuse, Ilvento, & Johnston, 2010). Agriculture is a major driver of the state's economy. However, it is difficult to gauge the specific impacts to farms in the preservation program from sea level rise with the general information available for this assessment.

Potential Social Impact: Many communities in Delaware developed due to relative proximity to prime farmland. The potential loss of productive agricultural fields and resulting losses in employment may cause farmers and farm workers to relocate to areas not affected by sea level rise, causing losses to the local agricultural heritage of a community.

Potential Environmental Impact: Agriculture in Delaware often relies on irrigation which may be impacted by the intrusion of seawater pushing further up into fresh water stream and rivers. In coastal areas, the increased water withdrawal, combined with sea level rise, may increase saltwater intrusion into the groundwater or aquifers. Additionally, in agricultural locations near the coast, the seaward boundary for agriculture often is the point where saltwater penetrates inland far enough to prevent crops from growing (IPCC, 2007). As sea level rises, this boundary could move farther inland causing increased amounts of farmland to become too salty for traditional crop cultivation. Once seawater has invaded to a distance beyond that is tolerable, restoration of water quality in the invaded zone is generally an expensive or ineffective proposition (Bear, Cheng, Sorek, Ouazar, & Herrera, 1999). Concerning prime farmland and farmland of state-wide importance, these soil types will lose their high production characteristics as salinity increases. The land may still allow for cultivation however, crop yields will begin to diminish well before inundation occurs.

Additional environmental impacts may come from the loss of open space and actively farmed acreage which could result in habitat losses, decreases in water quality and increased erosion.

Society and Economy

Society and Economy

Properties with a tax-assessed value of nearly $1.5 billion are located within areas potentially inundated by 1.5 meters of sea level rise (Laznik, 2012). The potential loss or devaluation of these properties will affect homeowners, businesses owners, communities, and tax revenues at all levels of government.

The Society and Economy Workgroup was formed to collaboratively investigate the potential effects of sea level rise on the residents, communities, and economy of Delaware. Its results are presented below and in the following sections. The socioeconomic effects of sea level rise issues are complex and interrelated; the Society and Economy Workgroup recognizes that the information that has been gathered and presented through this vulnerability assessment process is not complete in many cases; much more research will need to be conducted to answer many of the questions posed by the workgroup in its discussions.

Assessing Exposure of Society & Economy Resources

The Society & Economy Workgroup was composed of members of the Sea Level Rise Advisory Committee and additional subject matter experts. A list of those who participated in this workgroup is available in Appendix C. The workgroup met seven times between February 2011 and March 2012 to identify, assess, and rank issues related to sea level rise, society, and the economy.

Resources Considered

Specific resources that the Society and Economy Workgroup was initially concerned with included:

- Municipalities and future development areas
- Residences
- Businesses
- Tourism
- Real estate taxes
- Insurance claims
- Agriculture, including highly productive soils and easements
- Demographic information and vulnerable communities
- Historic resources
- Impermeable surfaces
- Hospitals
- Day care facilities
- fire and EMS stations
- Wastewater infrastructure
- Landfills

After discussion, initial data collection, and analysis by Delaware Coastal Programs staff, the workgroup narrowed their focus to the following topics:

- Businesses
- Industrial and manufacturing facilities
- Residences
- Future development areas
- Agriculture (acreage and structures)
- Tourism and coastal recreation
- Historic and cultural resources
- Socially vulnerable communities

Several resources of concern were initially identified by more than one workgroup, including agriculture, care facilities, wastewater, and landfills. Agriculture acreage and buildings were assessed in the Society and Economy Workgroup because of the strong economic implications of these resources. Conversely, the Natural Resources Workgroup assessed highly productive soils and agricultural preservation areas due to their stronger resource implications. Hospitals, day care facilities, emergency services, wastewater infrastructure, and landfills were assessed in the Public Safety and Infrastructure Workgroup.

Assessing Exposure

As described in the Vulnerability Assessment Methods chapter, Delaware Coastal Programs staff worked with Workgroup and Committee members to collect data and information about each resource that the workgroup wished to assess. Using available data sets, tables were generated in ArcGIS that described the exposure of each resource to sea level rise under each of the three scenarios. Maps depicting location and density of this exposure were also generated in ArcGIS. Workgroup members filled out resource assessment templates based upon their own expertise and in collaboration with their colleagues. All of this information was compiled together into a comprehensive assessment for each resource, which was reviewed and edited by workgroup members. Full text of each one of these assessments follows this introduction.

Data and Information Gaps

This vulnerability assessment relied on existing data and information to complete a statewide level screening of resources at risk to sea level rise. In many cases, data and information that would have provided a better picture of the economic and social ramifications of sea level rise impacts was not available at a scale that would be useful for analysis of sea level rise. For example, tourism data is available statewide, but not broken down by town or region, so definitive conclusions about inundation of certain areas of the state could not be made. This is also the case for employment, payroll, and sales revenue data which is not available at a site specific basis. Demographic information was also not available at a scale that would allow site specific assessments of very small areas of inundation due to sea level rise. These data gaps do limit our ability to provide specific economic losses and social ramifications for each resource assessed. However, they do not impede our ability to understand the range of potential impacts from sea level rise and make recommendations for future studies that would help improve our understanding of specific impacts.

Property Tax Impact

As discussed above, data and information useful for understanding the wide range of interrelated economic impacts resulting from sea level rise was not available and additional studies are recommended. One readily available dataset is the tax assessment value. A study conducted by the University of Delaware indicated that the current tax assessed value for all parcels (regardless of use category) exposed to sea level rise in New Castle County is $582 million and $55.6 million in Kent County. The assessed “improved value” of parcels exposed to sea level rise in Sussex County is $857.7 million (Laznik, 2012). Although tax rates per assessed value vary by county and some parcels have tax-exempt status, properties that are abandoned, de-valued or inundated could have an impact to local property tax revenues.

Society and Economy

Assessing Vulnerability of Society & Economy Resources

As discussed in the Introduction, once the resource assessments were completed and maps were available, the Society and Economy Workgroup conducted an exercise to assess the state's vulnerability to the effects of sea level rise for each resource. Using standardized questions, the workgroup considered two primary factors: the geographic scope of impacts and whether the resource could continue to "function". For geographic scope, the workgroup considered both the discrete locations of impacts themselves and the extent to which impacts may be felt outside of those locations. For example, although the exposure of heavy industrial areas was limited primarily to New Castle County, the effects of exposure could be felt statewide through loss of job opportunities and revenues. For "function," the committee considered the extent to which a resource could continue to meet its intended purpose, whether that purpose is recreational opportunities, manufacturing items and/or revenue generation. As a result of this discussion, each resource was ranked as a High Concern, Moderate Concern, Low Concern, or Minimal Concern. Resources ranked as a high and moderate concern will likely become the starting point for adaptation strategy development in Delaware.

High Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources are of the highest concern: Heavy Industrial Areas, Future Development Areas, and Tourism & Coastal Recreation. A high concern resource is generally a resource where inundation of a resource would cause it to no longer function and/or could cause impacts statewide, whether directly to the resource itself or indirectly through disruptions in jobs or revenue streams. Additional research and development of adaptation strategies for high concern resources is recommended.

Heavy Industrial Areas: Between 16% and 25% of the acreage of heavy industrial lands in the coastal area (as permitted by Delaware's Coastal Zone Act) are within an area that could be inundated by sea level rise by 2100; the majority of these areas are in New Castle County. While the inundation model shows that inundation risk to the facility buildings themselves is low, many associated structures like docks, piers, and lagoons could be affected. Because these facilities are a large economic driver for the state, reduced operational capacity could impact both the economies of the towns surrounding these facilities and the state's economy as a whole. If the lands currently zoned for heavy industry become unsuitable for industrial operations, retaining these businesses within the state could prove difficult due to lack of suitable industrially zoned land and the difficulties of rezoning land to industrial uses. Due to the significant potential statewide effects, sea level rise impacts to heavy industrial areas in the state were ranked as a high concern.

Future Development Areas: Between 3% and 7% of land designated as future development areas by Delaware's Strategies for State Policies and Spending are within an area that could be inundated by sea level rise by 2100. These areas are typically rural or suburban in nature and are adjacent to the actively growing zones of Delaware's municipalities. Four-fifths of these potentially inundated areas are located in Sussex County and could be developed to meet the future demand for residential and commercial development in and around the resort areas. Careful consideration must be given to determine whether directing new development to potential inundation areas will place citizens and infrastructure at risk in the future and whether creating new building restrictions will impact citizens' freedom of choice and the regional economy. Due to the significant potential effects for development in Sussex County coupled with the potential need for state funding of infrastructure repairs and legal concerns, sea level rise within future development areas was ranked as a high concern.

Tourism and Coastal Recreation: Tourism and coastal recreation are important components of Delaware's economy and quality of life. Significant portions of Delaware's resort areas, coastal historic sites, and natural resources could be inundated or significantly altered by sea level rise. Of specific concern is the maintenance of Delaware's beaches, which are currently replenished on a routine basis with federal and state funding. Accelerated rates of sea level rise may necessitate larger or more frequent beach replenishment projects to preserve recreational beach uses. Due to the potential for revenue losses statewide, coupled with the potential increased funding needs for maintenance or repair of tourist destinations, sea level rise impacts to tourism and coastal recreation were ranked as a high concern.

Moderate Concern Resources

Based upon the risk assessment conducted by the workgroup, only residential areas were categorized as having moderate concern. Resources are considered to be of moderate concern if there is some impact or loss of function and/or if the geographic extent of the impact is less than statewide.

Residences: Statewide, 1% to 5% of residences are within an area that could be inundated by sea level rise by 2100. The highest concentration of those at risk homes are in Sussex County along the barrier island south of Bethany Beach and around the Inland Bays. Although the majority of at-risk residences are in Sussex County, residences within small coastal towns in Kent County are at risk of inundation from sea level rise, as are homes in the cities of Wilmington, New Castle, and Delaware City. In already flood-prone areas, some of these homes may be elevated above the current 100-year flood zone or have other flood-proofing mechanisms installed which would limit structural damage from sea level rise. However, road access to homes subject to inundation may be limited whether the homes are flood-proofed or not. Several impacted residential areas are within socially vulnerable communities (see below) and may lack resources to repair flood damages, flood-proof, or relocate. Because potential impacts are concentrated in Sussex County but exist statewide, sea level rise impacts to residential addresses were ranked as a moderate concern.

Low Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources were considered to be of lower concern at this time: Businesses and Commercial Areas, Agriculture (acreage and structures), Historic Resources, and Factories. A ranking of low concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather that the impacts will not be significant in nature and/or will be isolated to several small geographic regions. Low concern resources should continue to be monitored and re-assessed in subsequent planning activities.

Society and Economy

Businesses and Commercial Areas: Between 1% and 5% of the state's commercial addresses are within an area that could be inundated by sea level rise by 2100. The effects to impacted businesses could include increased flood damage costs, increased insurance premiums, and reduced profitability; indirect impacts could include reduced employment opportunities and reduced goods and services for communities impacted. However, the business cycle may minimize these potential impacts as the life-span of most business ventures is much shorter than our planning horizon of 88 years and adequate commercially zoned land is likely to exist outside of the sea level rise inundation areas in the future should business owners need to relocate. While the overall impact to the state's businesses may be a small percentage, Delaware's commercial fishing and seafood industry may be particularly affected by loss of supporting infrastructure like docks and boat ramps and potential challenges to fish populations. In addition, individual business owners who rely upon waterfront access or proximity to the coast may be particularly impacted. Because of the small percentage of potentially impacted businesses and because the life-span of most commercial enterprises is less than our planning horizon, sea level rise impacts to businesses and commercial areas are of low concern at this time.

Agriculture (acreage and structures): Between 1% and 4% of currently farmed acreage in the state could be inundated by sea level rise by 2100. Inundation of agricultural land could result in decreased crop yields as a result of salt contamination and/or soils that are too wet to till. While the loss of a few thousand acres of tillable land is not likely to have a perceptible impact on the state's agricultural economy as a whole (residential development takes more land out of agricultural production), impacts to individual or regional agribusinesses could be significant. Because of the small percentage of potentially impacted land statewide, sea level rise impacts to agriculture are of low concern at this time.

Factories: Between 1% and 8% of industrial and manufacturing facilities in the state (as represented by sites listed on the toxic release inventory) are within areas that could be inundated by sea level rise. These facilities could experience repetitive flood damages, supply disruptions, and reduced production as a result of sea level rise. While facilities may experience effects of sea level rise, existing plants could become functionally obsolete during our planning horizon. Because of the small number and limited life-span of potentially impacted factories, sea level rise impacts to manufacturing and industrial facilities are of low concern at this time.

Historic Resources: Between 2% and 4% of the known historic sites (including up to 32 national historic register sites) in the state are within areas that could be inundated by sea level rise. Inundation could result in the permanent loss of these sites and their cultural value, including loss of historic information that could have been garnered from them. Because of the relatively small number of buildings at risk, historic resources are of low concern at this time.

Social Vulnerability and Social Justice

Throughout the deliberations of the Society and Economy Workgroup, issues of social vulnerability and social justice were discussed and considered. Socially vulnerable communities are neighborhoods or groups that are less likely to have the resources to respond to environmental threats like sea level rise due to a variety of factors including educational level, economic standing, age, family status, and access to services. Citizens in areas identified as socially vulnerable may lack the resources to flood-proof their homes or relocate if sea level rise begins to affect their neighborhood. They may also lose access to transportation should bus routes or bus stops be relocated due to road flooding in the region; this could also affect their ability to travel to and from work. In addition, these communities are often near or within areas of already poor environmental quality and may disproportionally be affected by indirect impacts of sea level rise such as contaminant releases from underground storage tanks or contaminated sites.

A detailed sub-chapter on socially vulnerable populations is included within this document (pg. 2) but this issue was not ranked with the other resources analyzed in this document because assessment of these communities will need to be conducted at a more localized scale and with consideration of the interaction of numerous direct and indirect sea level rise impacts. Attention to and the fair treatment of socially vulnerable communities should be at the forefront in the minds of decision-makers as plans are made to adapt to the effects of sea level rise.

Detailed Resource Assessments

The following sections contain a detailed exposure assessment for each resource and a description of the likely economic, social, and environmental impacts that could result. As discussed in the Introduction to this document, an exposure assessment describes how much of a particular resource is within each one of the three sea level rise scenarios; not whether that resource will be impacted. For example, a house that has been elevated above the floodplain is counted within the sea level rise inundation area, but that particular house may be unaffected by sea level rise because it has been flood-proofed. The potential effects to each resource are described within the text, along with the caveats of the analysis and data. These assessments are being used as the baseline data and information to formulate an adaptation strategy for the state, while recognizing the limitations of this method for site specific planning.

Businesses and Commercial Areas

Commercial business enterprises form the backbone of Delaware's economy, communities, and sense of place. Many of Delaware's towns were established in waterfront locations to take advantage of shipping opportunities, and many business districts in Delaware remain in close proximity to tidal water.

Businesses within areas potentially inundated by sea level rise may experience increased operational costs as a result of repetitive flood damage and reduced access for customers and product shipments as a result of flooded roads. In addition, businesses dependent upon waterfront access may experience increased costs for dock and pier maintenance and upgrades as well as a lack of adequate space for operations as water encroaches inland. Although many businesses can relocate when lease terms end and so may be resilient to the effects of sea level rise, waterfront and water-dependent businesses, like commercial fishing operations and marinas, may not have as many choices when deciding how to respond to the effects of sea level rise.

Society and Economy

As demonstrated by several large coastal storms, temporary flooding causes little or no long term disruption to businesses if an area is economically viable. If more permanent inundation occurs as a result of sea level rise, history indicates that human populations have been able to adapt to these changes by moving to higher ground over a period of time. These potential impacts will depend greatly upon a business's ability to adapt to new conditions, the maintenance of supporting infrastructure and upon availability of suitably zoned areas to relocate if necessary.

Exposure to Sea Level Rise: In order to determine the potential vulnerability of Delaware's businesses to sea level rise, two data sources were used, the statewide 911 address database and the Delaware Division of Revenue's business license database. The 911 address database provides address information by type of address, including commercial. The state business license database provides an address for business licenses that are issued within the state. Both databases contain inherent errors and inaccuracies. For example, the commercial addresses from the 911 database include rental properties, which are also residences. The business license database contains addresses that were not able to be mapped in our computer system, which may underestimate the number addresses affected. Conversely, some addresses have multiple businesses licenses in one location, which may overestimate the number of addresses affected. Fixing the inherent data problems within these datasets was outside of the scope of this assessment; however, using both of these databases together provides a reasonable estimate of the extent and location of potential impacts to businesses resulting from sea level rise (see Table 26 and Table 27 below).

Statewide, over a thousand individual businesses are within an area that could be inundated by 1.0 meter of sea level rise, representing 2% - 3% of the total businesses in the state. Over two thousand businesses are within an area that could be inundated by 1.5 meters of sea level rise, representing about 5% of the total businesses in the State. Sussex County has both the highest number and highest percentage of businesses at risk, with between 9% - 11% of its businesses within a mapped sea level rise area.

At the 0.5 meter sea level rise scenario, the highest concentration of businesses with the potential to be inundated is found in South Wilmington, New Castle, Milton, and Fenwick Island. At higher levels of sea level rise, the geographic extent of businesses potentially inundated expands to include Delaware City, Dover, Milford and more areas along the Delaware Bay and Inland Bays (see maps in the Mapping Appendix).

Further evaluation of the types of businesses affected and their average life-spans, employment figures, and revenue figures are outside of the scope of this vulnerability assessment, but the Sea Level Rise Advisory Committee recognizes the importance of obtaining and analyzing this data for a more comprehensive understanding of potential business impacts from sea level rise.

Table 26 - Number of Commercial Addresses

County	Total Number of Addresses	Total Addresses Inundated			Percent of Tota Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	45,873	395	1,182	2,094	1%	3%	5%
New Castle	31,479	248	625	1,143	1%	2%	4%
Kent	4,714	21	73	93	< 1%	2%	2%
Sussex	9,680	126	484	858	1%	5%	9%

Source: University of Delaware CADSR 9-1-1 Address Database

Table 27 - Number of Business Licenses within the Sea Level Rise Scenario Areas

County	Total Number of Licenses	Total Bus. Liscenses Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	51,302	237	1,072	2,556	0.5%	2%	5.%
New Castle	29,258	120	349	777	0.4%	1%	3%
Kent	8,823	14	149	323	0.2%	2%	4%
Sussex	13,221	103	574	1,456	0.8%	4%	11.0%

Source: Delaware Division of Revenue and University of Delaware CADSR.

Potential Economic Impact: For property owners, sea level rise may result in increased costs of maintaining existing commercial structures whether from repetitive flood damages or flood-proofing measures. Other associated costs of doing business, like insurance premiums, may also rise. Costs for construction of a new business or redevelopment of an existing business could also rise as a result of decreased availability of coastal real estate or costs of complying with regulations.

On a regional scale, a reduced number of businesses or reduced profitability of businesses impacts business revenues, business reinvestment, and employment opportunities. It may also affect local and regional tax revenues.

The commercial fishing and seafood industry in Delaware may be particularly impacted by sea level rise. In 2009, this industry employed 407 people, creating $57 million dollars in sales. The total economic impact of recreational fishing the same year as measured by fishing trips and durable equipment expenditures was 1,270 jobs and $193 million in sales (National Marine Fisheries Service, 2010). The commercial fishing fleet is located primarily in small coastal towns and inlets in Kent County, with additional sites in Indian River and Cedar Creek (near Slaughter Beach). These places are within areas expected to experience inundation with 0.5 meters of sea level rise; additionally, salt-water intrusion could result in degradation of fish spawning grounds, leading to a reduction in the abundance of commercially important fish species.

Potential Social Impact: The potential social impact of commercial property exposed to sea level rise includes, but is not limited to: loss of employment centers and opportunities, loss of gathering locations for the public, potential reduction in local businesses and small town charm, and potential increase in travel distance for basic necessities. These potential social impacts will depend greatly upon the business's rental or lease agreements and ability to adapt to new conditions.

Potential Environmental Impact: The potential environmental impacts associated with commercial properties and structures exposed to sea level rise primarily include release of contaminants, coastal debris, and loss of natural shorelines.

Pollution and release of contaminants may occur if commercial properties are abandoned without first removing underground or above ground storage tanks or remediating historic soil contaminants. Over time, storage tanks may leak, leaching their contents into the surrounding area. Certain contaminants in soil can also be released into the water column if repeatedly or permanently inundated. In addition, any structure left on a property that is subject to routine flooding may be transported off-site, and become a hazard or nuisance to surrounding landowners.

Society and Economy

The hardening of natural shorelines in response to increased inundation is a concern for both commercial and residential properties. Natural, vegetated shorelines provide fisheries habitat, bird foraging areas, and water quality improvements. Natural shorelines in commercial and residential areas can erode as a result of rising sea levels coupled with boat wakes and wave action and landowners may wish to build a stone revetment or bulkhead to avoid additional erosion. When natural shorelines are replaced by hard structures, habitat and water quality benefits decrease significantly.

Industrial and Manufacturing

Delaware has a rich history of industrial and chemical manufacturing, beginning with the DuPont family who manufactured gunpowder along the banks of the Brandywine River in the 1800's. Since that time, Delaware's economy and quality of life have been closely tied to industrial and chemical manufacturing and processing. Industrial and manufacturing facilities provide jobs for Delaware residents, goods for the region, and tax revenue for state and local governments. The Bureau of Labor Statistics reports that production occupations (largely those from industrial and manufacturing facilities) accounted for 20,709 jobs in Delaware as of May, 2010. These jobs have a mean annual salary of $32,810 (Bureau of Labor Statistics, 2010).

Map 1 - Delaware Coastal Zone Industrial Area.

Many of Delaware's largest industrial and chemical manufacturing facilities are located along the Delaware River and generally require direct access to navigable water for docking of ships carrying materials and supplies, or export of manufactured products. Many also rely on the Delaware River for cooling water or to discharge treated effluent. These facilities are large economic drivers for Delaware; for example, a 2002 analysis of the Motiva Refinery in Delaware City (now Delaware City Refinery) found that the refinery had a wage and salary impact of $186 million per year, and a total economic impact of $379 million per year (Condliffe, 2002).

The location of waterfront heavy industry in Delaware is limited to areas that were already in industrial use prior to the passage of Delaware's Coastal Zone Act, which prohibited new industrial development in the Coastal Zone, a strip of land generally east of Route 13 in New Castle County, Route 9 in Kent County and Route 1 in Sussex County. It also includes land along the Chesapeake & Delaware Canal, and around Delaware's Inland Bays.

Sea level rise can affect Delaware's industrial and manufacturing facilities in several primary ways. Rising sea levels could permanently inundate facilities and supporting infrastructure like parking areas, wastewater lagoons and storm-water treatment areas. Temporary flooding from coastal storm events could also damage these structures. Increased rates of shoreline erosion could also occur, coupling with rising sea level to cause structural issues for associated docks and piers.

In addition, the structure and function of intake and discharge pipes could be impacted either through increased water levels, increased salinity, or a combination of both.

Exposure to Sea Level Rise: To assess impacts to waterfront industrial areas, a database containing parcel information for permitted industrial facilities under the Coastal Zone Act was obtained from DNREC. This database contains the name, location, and property boundaries of each industrial facility within the areas regulated by the state's Coastal Zone Act. All major waterfront industrial facilities are included in this database. This database was analyzed to determine the acreage and location of permitted industrial facilities within the three sea level rise scenarios (Table 28).

Statewide, approximately 20% of the land comprising the facilities permitted by the Coastal Zone Act is within an area potentially inundated by sea level rise of 1.0 meter, a total of 781 acres. However, although industrial land is exposed to sea level rise, it is important to note that there are no industrial facility buildings within the three future sea level rise inundation areas.

In New Castle County, approximately 19% of the acreage permitted under the Coastal Zone Act is exposed with a sea level rise of one meter. At this level of sea level rise, docking facilities at Sunoco, Ocean Port and DuPont Edgemoor are exposed, as is a limited area of shoreline. Intake and/or discharge pipes and channels could also be affected at these facilities, as well as the Delaware City Refinery and Croda/Atlas Point. The remainder of impacts to lands within these facilities is wetlands and in some cases, parking areas.

There is only one heavy industrial facility permitted under the Coastal Zone Act in Kent County; Delaware Storage and Pipeline, a dock and tank facility where jet fuel is delivered. In this case, the dock, pipeline and tank facility are almost entirely inundated under the 0.5 meter scenario, as is the road to the site.

The Indian River power plant is the only heavy industrial facility permitted by the Coastal Zone Act in Sussex County. This facility's disposal area, shoreline, and intake structures are within areas that will be inundated by sea level rise, but the power plant itself is not within a potential inundation area.

Table 28 - Coastal Zone Heavy Industrial Acreage Exposed to Sea Level Rise

County	Total Acres of Industrial Land Permitted by CZA	Total Acres Inundated			Percent of Total Acres Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	4,141	676	863	1,041	16%	21%	25%
New Castle	3,861	583	746	913	15%	19%	24%
Kent	37	30	36	37	83%	97%	100%
Sussex	243	63	81	91	26%	33%	38%

Source: DNREC Office of the Secretary, Coastal Zone Heavy Industrial Facilities (20110321), unpublished

Society and Economy

To capture potential exposure from sea level rise at facilities that are not considered to be heavy industry in addition to those permitted through the Coastal Zone Act, a database containing names and locations of facilities which are required to report emissions to the state through the Toxic Release Inventory was obtained and overlaid with the sea level rise scenarios. Because the geographic location in this database is reported as a "point" instead of as a parcel, the results of the analysis more closely aligns with potential exposure to a facility or building (instead of to the parcel). This data also contains information for those facilities permitted through the Coastal Zone Act, but is more inclusive of smaller industrial and manufacturing facilities, and those not within the Coastal Zone Act area (such as facilities along the Nanticoke River).

Statewide, one facility is located in an area potentially inundated at 0.5 meters, six facilities are within an area inundated at 1.0 meter and twelve facilities are potentially inundated with a sea level rise of 1.5 meters (Table 29). The geographic extent of these potential impacts is limited to Wilmington and the surrounding area, Lewes, and Seaford (see map in the Mapping Appendix).

Table 29 - Number of Factories (as represented by Toxic Release Inventory sites)

County	Total Number of Factories	Total Factories Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	145	1	6	12	1%	4%	8%
New Castle	85	1	4	8	1%	5%	9%
Kent	26	0	0	0	0%	0%	0%
Sussex	34	0	2	4	0%	6%	12%

Source: EPA, EPA Facilities Toxics Release Inventory, 20080212

Potential Economic Impact: Direct loss of land acreage zoned as industrial as a result of inundation from sea level rise or as a result of access or transportation issues resulting from sea level rise could constitute a significant economic issue for the state. Industrial facilities are an important component of Delaware's statewide economy; moreover, land zoned as industrial with access to water and rail is a limited resource in the state. Should industrial acreage be inundated, there is limited potential for zoning new areas for industrial use within the state due to siting issues related to environmental, noise, and traffic concerns.

Operators of industrial and manufacturing facilities could experience increased costs from repetitive flood damage to buildings and associated structures, costs to relocate or elevate docking facilities, costs to relocate or raise intake/discharge pipes and increased insurance costs.

The Delaware Department of Labor reported 25,400 manufacturing jobs in the state as of March, 2012. If facilities were to shut down or reduce operations due to inundation and have no place to relocate, there could be a loss of employment and associated state and local tax revenues. Jobs within the industrial/manufacturing sector are often well paid, and have multiplier effects within the community and region.

From a regional perspective, it is also possible that a loss of one major sector or client to a railway company could result in a rail-line being financially unviable, resulting in the loss of that transportation network for other smaller users.

Potential Social Impact: Reduction in operational capacity of the industrial and manufacturing sector in Delaware from the effects of sea level rise could result in the loss of well-paying jobs in the affected communities listed above, and may also result in migration out of those locations as people search for new employment opportunities. Lack of local customers could also impact the surrounding local businesses and service providers in those communities.

Potential Environmental Impact: The potential environmental impacts associated with commercial properties and structures exposed to sea level rise primarily include release of contaminants and loss of natural shorelines.

As industrial land is inundated, there is the potential for contaminants contained within soil to be released into the water column. This is a concern for both existing facilities as well as for facilities that have been shut down or abandoned (see Public Safety and Infrastructure Section for additional details regarding brownfield and hazardous waste sites).

The hardening of natural shorelines in response to increased inundation may also occur in industrial or manufacturing areas. Natural, vegetated shorelines provide fisheries habitat, bird foraging areas and water quality improvements. Natural shorelines in industrial or manufacturing areas can erode as a result of rising sea levels coupled with boat wakes and wave action; facilities may wish to build a stone revetment or bulkhead to avoid additional erosion. When natural shorelines are replaced by hard structures, habitat and water quality benefits decrease significantly. However, industrial shorelines are often already severely degraded. The extent of habitat impact will vary dependent upon a facilities particular location and shoreline use.

Residences

Delaware is home to nearly 900,000 people, living in 325,000 households, primarily owner-occupied (74%) (US Census Bureau, 2012). Between 2000 and 2010, Delaware's population increased by 15%, and many regions experienced unprecedented growth, particularly Southern New Castle County and Eastern Sussex County. Many of the residential construction projects that were planned during this time have stalled or have been abandoned due to the financial credit crises.

Sea level rise can affect housing units and residential communities through increased storm damage, permanent inundation of lots and through degradation of supporting infrastructure like roads, septic systems, and sewer systems (please see the Public Safety and Infrastructure Section of this document for more information on these impacts). Many newer subdivisions were established with community open spaces and stormwater facilities, managed and maintained by a maintenance corporation composed of residents. Sea level rise may also impact these community facilities in a similar way.

Exposure to Sea Level Rise

In order to determine the number of homes located within a potential inundation area, the Delaware 911 database was used. This database provides a point for each residential address in the state, whether it is an apartment building, a townhouse, a manufactured home, or a single-family home. Although every point in the database does not necessarily fall exactly on a structure, this database provides a reasonable estimate of potentially affected structures at the state level.

Society and Economy

Results of this analysis (Table 30) indicate that 1% of the residential units in the state are within the 0.5 meter inundation area and that 5% are within the 1.5 meter scenario. Although this is a small percentage statewide, it represents potential impacts to between 4,000 and 20,000 residences within our state. Geographically, potential impacts to residences are clustered in developed areas, particularly coastal towns and the areas surrounding the Inland Bays (See maps in the Mapping Appendix).

In New Castle and Kent Counties, the potential number of housing units affected is very small (in most cases less than 1%), regardless of type (single-family, multi-unit or manufactured). A higher percentage of the total housing stock in Sussex County is within potential inundation areas than in either Kent or New Castle, largely due to the different development patterns in the resort areas which have resulted in high density residential development close to tidal water. Bethany Beach, South Bethany and Fenwick Island and the areas surrounding the Assawoman Bay have the highest concentration of potential residential impacts in both Sussex County and the state. The address data did not allow us to discern how many structures were second homes or seasonal rentals.

Table 30 Residential Addresses affected by sea level rise

County	Total Number of Addresses	Total Addresses Inundated			% of Total Addresses Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	346,574	3,571	9,988	17,095	1%	3%	5%
New Castle	166,569	131	409	923	< 1%	< 1%	1%
Kent	60,010	140	500	824	< 1%	1%	1%
Sussex	119,974	3,300	9,079	15,348	3%	8%	13%

Source: University of Delaware CADSR 9-1-1 Address Database, 2011

Table 31 Number of Residential Multi-Unit Addresses Exposed to Sea Level Rise

County	Total Number of Addresses	Total Addresses Inundated			% of Total Addresses Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	46,777	119	243	328	<1%	1%	1%
New Castle	37,022	0	0	12	0%	0%	<1%
Kent	1,770	0	0	0	0%	0%	0%
Sussex	7,985	119	243	316	1%	3%	5%

Source: University of Delaware CADSR 9-1-1 Address Database, 2011

Table 32 Number of Residential Manufactured Home Addresses Exposed to Sea Level Rise

County	Total Number of Addresses	Total Addresses Inundated			% of Total Addresses Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	18,526	350	2,201	3,318	2%	12%	18%
New Castle	3,772	0	0	0	0%	0%	0%
Kent	4,485	0	0	3	0%	0%	<1%
Sussex	10,269	350	2,201	3,315	3%	21%	32%

Source: University of Delaware CADSR 9-1-1 Address Database, 2011

Potential Economic Impact: Homeowners, property managers, and community associations could experience increased costs from repetitive flood damage to homes and associated structures and increased insurance costs. In some severely affected areas, property values could eventually decrease as structures become more difficult to access or experience frequent flooding and as surrounding homes are abandoned.

A study conducted by the University of Delaware indicated that the current tax assessed value for all parcels (regardless of use category) exposed to sea level rise in New Castle County is $582 million and $55.6 million in Kent County. The assessed “improved value” of parcels exposed to sea level rise in Sussex County is $857.7 million (Laznik, 2012). Although tax rates per assessed value vary by county and some parcels have tax-exempt status, properties that are abandoned, de-valued or inundated could have an impact to local property tax revenues.

The availability and cost of flood insurance and homeowner’s insurance for residences in areas exposed to sea level rise is also a significant economic consideration. Forty-seven communities in Delaware participate in the National flood Insurance Program (NFIP), which makes federally-backed flood insurance available to their residents through the Federal Emergency Management Agency (FEMA). In order to participate, communities are required to adopt at least the minimum floodplain regulations and sign a resolution to adopt and enforce these regulations. Private (not federally-subsidized) flood insurance is also available to communities that do not participate in the program, and in coastal areas where the NFIP is prohibited from writing flood insurance policies by the Federal Coastal Barrier Resources Act. While sea level rise is not in itself a peril covered by the NFIP, the impacts of sea level rise related to higher flooding levels during storms may be felt by property owners and would be lessened by the continued availability of flood insurance.

Recently, the NFIP has been financially strained due to devastating storms, leading to speculation that fundamental changes are needed to make the NFIP financially solvent. At the same time, NFIP insurance premiums have increased annually by 10% each year, the maximum increase allowed by law. A few insurance companies have periodically stopped writing new homeowners’ insurance policies in coastal Delaware, but this is not due to flood risk; rather it is because their dense portfolio of policies in the region exposes them to unacceptable levels of payout in one weather event.

Potential Social Impact: The potential social impact to residential structures and property exposed to sea level rise largely depends on the type of adaptation measure(s), if any, that are employed. A significant amount of the residential property exposed to sea level rise is in small coastal towns along the Delaware Bay and Inland Bays as well as in Delaware City, the town of New Castle, and South Wilmington. As a result of both an increase in existing residential development and future residential development land exposed to sea level rise, the quality of life, neighborhood fabric, and cultural character of Delaware's small coastal and bay towns may be significantly affected.

Potential Environmental Impact: The potential environmental impacts associated with residential properties and structures exposed to sea level rise include: introduction of contaminants from increased flooding and inundation of developed properties; coastal debris from the abandonment or loss of structures; pollution from residential septic systems and the inundation of community wastewater systems; and the loss of shoreline and wildlife habitat and the general reduction in habitat quality of the developed land that is inundated.

Future Development Areas

The Delaware Population Consortium projects that by the year 2040, Delaware will be home to 1,120,523 residents – an increase of over 225,000 persons. These projections are routinely used by State, County and municipal governments to plan how and where future residential and commercial development will occur (Delaware Population Consortium, 2010).

Delaware encourages proactive planning for the state's future growth needs through a variety of mechanisms, including the Strategies for State Policy and Spending, implemented by the Office of State Planning Coordination. These strategies set forth guidelines and maps for where the state plans to make investments of public funds for roads, sewer, schools, and other infrastructure. It also outlines those areas where the state will direct funding for investments in agriculture and natural resource preservation. The strategies incorporate the zoning and future land use desires of county and municipal governments as outlined in their comprehensive development plans. The Strategies were first approved in 1999 and were updated in 2004 and 2010. Executive Order 26 states that "All state departments and agencies shall use the Strategies document and maps as a guide to making all decisions on policy, infrastructure and other investments, and resource management."

Inundation as a result of sea level rise could affect the availability and suitability of designated future growth areas for development. This could, in turn, drive the need for changes to development patterns in areas not subject to inundation from sea level rise to accommodate necessary growth.

Exposure to Sea Level Rise: Level 3 development areas, as designated by the Strategies for State Policy and Spending, were used to determine exposure of future growth areas to sea level rise. Level 3 areas are lands within the long-term growth plans (greater than five years) of county and municipal governments and/or are adjacent to already developed or developing areas. Some of these planned growth areas will be exposed to sea level rise under the three planning scenarios (See Table 33) and may be unsuitable for development to meet future growth needs.

Statewide, between 3% - 7% of Level 3 land is within an area that could be inundated by sea level rise. In New Castle County, these areas are generally in the areas surrounding the towns of New Castle, Delaware City and Port Penn as well as areas along the Christina River near the I-95 corridor. In Kent County, these areas are generally growth areas designated by coastal towns like Bowers Beach, Leipsic, and Little Creek for future growth. Fringes of land designated as Level 3 adjacent to the St. Jones River, Murderkill River and Mispillion River in Kent County are also exposed to future sea level rise under these scenarios (See maps in the Mapping Appendix).

In Sussex County, approximately 7 % of level 3 areas within the county would be inundated under the 1 meter sea level rise scenario. The coastal development patterns in Sussex County starkly contrast with Kent County's development patterns in large part because of the resort nature of coastal Sussex County. To meet the demand for homes and services near the Atlantic Coast and Inland Bays, future growth areas surround existing development around the Inland Bays. Many of these areas, particularly Angola Neck, Long Neck, and Fenwick along Route 54 will be exposed to future sea level rise. In addition, future growth zones in and around Rehoboth Beach, Lewes and Slaughter Beach will also be exposed.

Table 33 - State Strategy Level 3 Areas Inundated by Sea Level Rise

County	Total Acres of Level 3 Land	Total Acres of Land Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	152,001	3,907	7,777	11,178	3%	5%	7%
New Castle	43,480	428	783	1,107	1%	2%	3%
Kent	25,487	566	815	1,059	2%	3%	4%
Sussex	83,034	2,912	6,178	9,012	4%	7%	11%

Source: Delaware Office of State Planning Coordination, Investment Levels, Delaware State Strategies for State Policies and Spending (2010), 2010-10-01

Potential Economic Impact: Inundation of land within future growth zones could result in a reduction in potential tax base generated by new commercial and residential properties. In addition, development within future growth zones that have the potential to be inundated by sea level rise may be limited by the willingness of purchasers to assume risk, and it may be made more expensive if local communities enact stricter zoning or building codes.

New development in areas that may be exposed to sea level rise may create the expectation that government assistance for infrastructure improvements, flood control and/or buy-outs will be made available if necessary. The cost of these actions could have significant future cost to government entities. A recent report that assessed and proposed solutions for flooding problems in Bowers Beach estimated a total cost of over $469,000 (KCI Technologies, 2011) for implementation of these solutions. This cost does not include the larger cost of state-provided sand for Bowers Beach for the past 50 years, a protective strategy necessitated by shoreline erosion and long term relative sea level rise, nor does it include costs for flood mitigation at an increased sea level.

Society and Economy

It is important to note that costs to individuals and government entities from flood mitigation projects and relocation or elevation of structures conducted as a response to sea level rise will vary depending on individual response to the rising tides. Many people residing or doing business within an inundation zone will accept a certain amount of risk and inconvenience and some may choose to relocate or raise their structures before inundation becomes problematic.

Potential Social Impact: Small coastal towns along the Delaware Bay like Bowers Beach, Leipsic, and Slaughter Beach may choose to limit the extent of their future growth areas, or change the location of their future growth areas based upon these sea level rise scenarios. If unable to find suitable areas to direct their growth, existing commercial and residential areas could fail to meet the needs of nearby residents.

Loss of land due to inundation without adequate planning or nearby land to rebuild could result in abandonment of properties within Delaware's small coastal towns and a reduction in the quality of life within them. In addition, the inundation scenarios indicate that both existing development and future development zones around Delaware's Inland Bays could be significantly affected by sea level rise. Quality of life in and around the Inland Bays may be reduced as a result, but it is important to note that the timeline for anticipated impacts is long and may allow adequate time for adjustments in development areas.

Potential Environmental Impact: Environmental impacts will vary depending upon how land use planners and developers choose to respond, and whether development is discouraged (whether by government action or personal risk tolerance) within potential future inundation zones. Development within these zones could result in a reduced opportunity for land preservation that would allow for tidal marshes to naturally migrate landward and could necessitate the hardening of natural shorelines, among others.

Agriculture

Agriculture is a major component of the economic and social backbone of Delaware. The total economic contribution of the agriculture industry to the state is $7.95 billion per year, supporting about 30,000 jobs. The overwhelming majority of the market sales are poultry (77.3%), followed by corn (6.3%), soybeans (2.9%), and milk and other dairy products (2.0%) (Awokuse, Ilvento, & Johnston, 2010).

According to the United States Department of Agriculture (2012), in 2007, 40% of the land mass in Delaware was classified as agricultural; many of these farms are located in coastal areas. Sea level rise can impact farming operations through permanent inundation of agricultural land, but it can also lead to salt contamination of soil from temporary flooding impacts during storms. Conversations with farmers at public meetings held in November, 2011 indicate that these impacts are already being seen in coastal agricultural areas. In addition, sea level rise can lead to saltwater intrusion into groundwater resources, contaminating irrigation wells with salt water unsuitable for irrigation of crops.

Exposure to Sea Level Rise: Exposure of the agriculture industry and community to sea level rise was assessed by using the State's Land Use/Land Cover maps. These maps outline areas that are used for specific types of land use, classified from aerial photographs. These maps were analyzed with respect to the sea level rise inundation areas to provide a gross indication of the extent and location of potential agricultural impacts.

Statewide, 1% - 4% of the 47,000 acres of mapped agricultural land is within areas that could be inundated by sea level rise (Table 34). Potential for the most concentrated impacts is in a region from southern New Castle County to Lewes, with coastal areas of northern Sussex seeing the most significant potential for concentrated impacts (see maps in the Mapping Appendix). While less than 5% of agricultural land could be potentially inundated from sea level rise, saltwater intrusion may present problems to a larger region; additional studies on saltwater intrusion are necessary before potential impacts can be characterized. It is also important to note that many of the farms within the sea level rise areas are also enrolled in agricultural conservation programs (additional discussion of these areas can be found in the natural resources section of this document).

Table 34 - Acres of Actively Farmed Land Exposed to Sea Level Rise

County	Total Acres of Farmed Land	Total Acres Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State		4,910	10,935	17,199	1%	2%	4%
New Castle	63,729	834	1,812	2,759	1%	3%	4%
Kent	166,506	1,248	3,747	6,511	1%	2%	4%
Sussex	243,562	2,828	5,376	7,928	1%	2%	3%

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

To understand potential impacts to farm structures, the Land Use/Land Cover maps were also analyzed with respect to the sea level rise scenarios to determine acreage and location of confined animal feeding facilities and farm buildings (Table 35 and Table 36). In general, less than 1% of Delaware's confined animal feeding operations are within areas that could be inundated by sea level rise. Up to 2% of farmsteads and related buildings could be inundated by sea level rise. The largest impact to farmsteads would be in Sussex County where 2% could be inundated at both the 1.0 meter and 1.5 meter scenarios. Due to the nature of the Land Use/Land Cover maps and the way in which structures are classified, the acreages reported in these tables are likely overestimated.

Table 35 - Acres of Confined Animal Feeding Operations Exposed to Sea Level Rise

County	Total Acres of Confined Feeding Operations	Total Acres Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	9,672	6	24	74	<1%	<1%	1%
New Castle	156	0	1	1	0%	<1%	<1%
Kent	1,554	1	4	11	<1%	<1%	1%
Sussex	7,964	5	20	62	<1%	<1%	1%

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19

Table 36 - Acres of Farmsteads and Related Buildings Exposed to Sea Level Rise

County	Total Acres of Farmsteads and Related Buildings	Total Acres Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	14,060	54	149	238	<1%	1%	2%
New Castle	2,781	6	23	36	<1%	<1%	1%
Kent	5,389	13	34	66	<1%	1%	1%
Sussex	5,890	35	92	136	1%	2%	2%

Source: Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008 05 19

Potential Economic Impact: The loss of productive agricultural land to inundation and salt contamination decreases the profitability of individual farms and may make it increasingly difficult for family farmers to stay in business. It could also reduce the number of employment opportunities in the agricultural sector. The loss of local corn and soybean crops could also affect local feed sources and costs for the poultry industry. Landowners wishing to protect tillable acreage may also bear costs of shoreline protection strategies.

Specific studies to determine the economic impact of sea level rise to the agricultural industry are outside the scope of this assessment, but the workgroup acknowledges the importance of collecting this information.

Potential Social Impact: The potential loss of productive agricultural fields and resulting losses in employment may cause farmers and farm workers to move outside of the inundation zone, causing losses to the local agricultural heritage of a community. Delaware takes pride in having locally grown food sources; these sources have the potential to become lost as prime farmland becomes inundated with rising sea levels.

While the social impact may be significant in small geographic areas, the statewide exposure of agricultural acreage ranges from only 1-4% of the total agricultural area in the state. Based on this small statewide exposure, the farming community in Delaware is likely to be resilient to these changes.

Potential Environmental Impact: Agriculture in Delaware often relies on irrigation; groundwater withdrawals in coastal areas, combined with sea level rise, may increase saltwater intrusion into groundwater or aquifers and affect adjoining properties. Additional information about groundwater intrusion is available in the Natural Resources section of this document.

Inundation of agricultural land may also result in decreased areas for wildlife to forage or rest. Migratory geese in particular, utilize farm fields heavily during their winter stopover in Delaware.

As with residential and commercial areas, there is potential for loss of vegetated shorelines and their associated habitat, if landowners choose to protect the shoreline with rock or bulkheads to reduce flooding.

Tourism and Coastal Recreation

Tourism is a critical part of the economy for the state of Delaware; tax-free shopping, family-friendly beaches, excellent restaurants, sporting events, and slot machines all draw non-Delawareans into the state to recreate and spend money. In 2010, the last year for which tourism data is available, 7.1 million people visited Delaware, generating $400 million in state and local government taxes and fees and 39,000 jobs. Of those visiting Delaware from outside of the state, 24% dined in Delaware, 25% came here to shop, 16% to gamble, and 19% for beach activities (DEDO, 2012).

Coastal recreation opportunities in Delaware are a large component of the tourism industry, as well as a way of life for Delaware residents. A 2006 national survey of wildlife recreation found that 395,000 people who live in or visited Delaware fished, hunted, or watched wildlife in the state. Of the total number, 159,000 people fished, 30,000 people hunted and 285,000 participated in wildlife-watching activities, which includes observing, feeding, and photographing wildlife. During this time, state residents and nonresidents spent $299 million on wildlife recreation in Delaware. Of that total, trip-related expenditures were $75 million and equipment purchases totaled $204 million. The remaining $20 million was spent on licenses, contributions, land ownership and leasing, and other items (U.S. Department of the Interior, 2006).

Sea level rise will bring changes to many of the places and amenities that people visit and enjoy in Delaware. Waterfront restaurants and retail shops could experience increased frequency of flooding and eventual inundation. Scenic coastal routes like Delaware Route 9 may become difficult to travel on as a result of inundation or ground saturation may damage its structural integrity. Parks, natural areas and beaches may lose ground to inundation and erosional forces, and wildlife populations may relocate or shrink as a result of changing habitats. All of these changes may impact the tourism industry and recreational opportunities in the first state.

Exposure to Sea Level Rise: To assess the potential impact of sea level rise to tourist attractions in the state, the Society and Economy Workgroup attempted to obtain data that contained the locations of tourist attractions, including restaurants, shopping destinations, and hotels, and associated economic data. However, this data is not currently available statewide; therefore impacts to specific tourist attractions and tourist amenities could not be conducted. An analysis of impacts to the business sector in the state (inclusive of hotels and shops) was conducted as part of the statewide vulnerability assessment; those results are available in the Business chapter in this section.

Since gambling is a large component of tourism revenues in the state, the sea level rise scenario maps were compared to the locations of existing gambling sites; none of the three existing gambling sites are exposed to future sea level rise under the three planning scenarios.

Society and Economy

Delaware's State Parks provide visitors with many recreational and educational opportunities, from playing in the waves on the Atlantic Ocean to ghost tours at Fort Delaware. To assess potential impacts to these recreational opportunities, park boundary information was obtained from Delaware's Division of Parks and Recreation and used to determine the number and percentage of acres of parks within each of the three sea level rise planning scenarios (Table 37). Statewide, 25% of State Park land is within an area that could be inundated by sea level rise of 0.5 meters, up to 35% of State Park land is within areas that could be inundated by sea level rise of 1.5 meters. Potential inundation is most significant along the Atlantic Coast and Inland Bays in Sussex County; however, parks along the Delaware River in New Castle County could also be significantly affected. The Mapping Appendix indicates the state parks that could experience inundation, and provides a pie-graph indicating the extent of potential inundation at each scenario.

Additional resources that could impact outdoor recreational opportunities are discussed in the Natural Resources Section of this document.

Table 37 - Acres of Delaware State Parks Exposed to Sea Level Rise

County	Total Acres	Total Acres Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	25,164	6,348	7,865	8,865	25%	31%	35%
New Castle	8,766	279	450	550	3%	5%	6%
Kent	1,601	0	0	0	0%	0%	0%
Sussex	14,796	6,069	7,415	8,316	41%	50%	56%

Source: Delaware Division of Parks and Recreation, 2011

Potential Economic Impact: Because many coastal resort areas contain land or amenities that could be inundated in the future and because many of the natural places that visitors seek out will experience inundation or habitat changes, alterations to tourism patterns could be expected as a result of sea level rise. If these patterns lead to decreased numbers of visits or decreased spending by visitors, tourism revenue will decrease, impacting business owners, employees of coastal businesses and tax revenues. However, should sea level rise result in entrepreneurial opportunities and expansion of amenities, tourism revenues may increase. For example, deeper water could allow some rivers, harbors, or marinas to accommodate boats with deeper DRAFTs, and could reduce the need for maintenance dredging of accumulated sediments.

In addition to changes in tourism revenue, sea level rise is expected to increase the costs of maintaining amenities and tourist destinations. For example, as sea level rises and flooding becomes more frequent, business owners may need to flood-proof or raise their buildings, parking lots, and docks. The cost to maintain sandy beaches may also increase. Delaware routinely partners with federal and local partners to replenish (or add sand to) its publically accessible Atlantic Ocean and Delaware Bay beaches, a strategy that has ensured that visitors and residents have space to enjoy a day at the beach while simultaneously protecting buildings, infrastructure and natural resources behind the dune from storm damage. Boardwalks, trails and viewing platforms that provide eco-tourism opportunities throughout the state may also require additional funding for maintenance or relocation to remain available and useful.

Potential Social Impact: The social fabric of many of Delaware's small coastal towns is based around fishing, boating, beach access, and the tourism that those activities bring. Reductions in the availability of these amenities as a result of sea level rise may affect tourism levels and local business revenues, leading to loss of business services and sense of community.

Potential Environmental Impact: Tourism and outdoor recreation contributes directly to environmental stewardship and natural resource conservation in the state of Delaware through financial contributions to restoration and through increased environmental awareness.

For example, one percent of the state's accommodation tax goes directly into the Beach Preservation Program of the Department of Natural Resources and Environmental Control, where it is used to help meet federal match requirements for beach replenishment projects. A reduction in the number of hotels and hotel guests could reduce this revenue stream, and thus the ability of the State to have the financial resources to conduct beach replenishment projects. However, seasonal rental homes are currently exempt from the accommodation tax; had seasonal home rental spending been subject to the tax, and addition $72 million in state revenue would have been generated in one year (DEDO, 2012).

Similarly, many of the state's wildlife conservation programs are supported by a federal excise tax on hunting equipment and ammunition and by the Federal Duck Stamp, which migratory waterfowl hunters must purchase each year. Losses or changes to important wildlife habitat could reduce the number of hunting opportunities, and thus reduce the revenue stream for conservation programs.

Historic and Cultural Resources

Historic resources are the physical places that embody Delaware's past, contain important information about the lives and history of our ancestors, and preserve the past for Delaware's future generations. Historic resources include buildings, structures, archaeological sites, landscapes, objects, and historic districts (areas with multiple numbers of individual resources) generally built before 1961. Historic resources can be found on land, in the water, and submerged on subaqueous lands.

Most historical resources are in private ownership. The public though, can enjoy the historic landscape around them as they drive, particularly on Delaware's Scenic and Historic Byways, and when they visit Delaware's historic towns, such as New Castle and Lewes, both of which have large historic districts. In addition, historians and researchers use and interpret these resources. Various historic museums are run by the state, as well as a number of private non-profits around the state, that provide historic interpretations and educational experiences for the public and for students at all grade levels. State parks also include many historic resources, for instance, the Fort Miles Historic District at Cape Henlopen State Park, and provide educational and recreational experiences for the public.

Sea level rise can affect historic and cultural resources in several ways. Damage to buried archaeological resources begins with a rise in the water table, leading to leaching of chemical and organic contents of the site. This results in loss of the information potential of the site to archeologists and historians. Inundation can cause structural damage or loss of historic buildings, historic vistas, and artifacts.

Society and Economy

Exposure to Sea Level Rise

The Delaware State Division of Cultural and Historic Affairs' State Historic Preservation Office maintains a database of known historic and cultural sites in Delaware (State Historic Sites) and a database of National Historic Register Sites. The sea level rise scenario areas were overlaid with this database to determine the number and location of historic resources that are within areas potentially inundated by sea level rise. The Division of Cultural and Historic Affairs continually updates these databases, but not all areas in Delaware have been surveyed for historic resources and errors do exist in their data.

Table 38 and Table 39 below indicate the number of State Historic Sites and National Register Sites that could be inundated by sea level rise. Because of incomplete mapping, the summaries in the analysis table are likely an underrepresentation of the potential exposure of historic resources to sea level rise.

Between 2% - 4% of the 14,316 known historic sites in the state of Delaware are within areas that could be inundated by sea level rise. Between 2% - 5% of the state's 640 National Historic Register sites are within areas that could be inundated by sea level rise. Geographically, potentially impacted historic resources are widespread throughout the state (Map in the Mapping Appendix). Note that the maps show no impacts in northern and western Sussex County; this is due to lack of historic data collection in these areas and not necessarily because no historic resources exist in these areas.

Table 38 - Number of State Historic Sites Exposed to Sea Level Rise

County	Total Number of State Historic Sites	Total Number of Historic Sites Inundated			Percent of Historic Sites Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	14,316	244	441	634	2%	3%	4%
New Castle	6,645	79	137	181	1%	2%	3%
Kent	5,429	113	206	298	2%	4%	5%
Sussex	2,242	52	98	155	2%	4%	7%

Source: Delaware State Historic Preservation Office, CRS Inventory, 2011, unpublished.

Table 39 - Number of National Register Sites Exposed to Sea Level Rise

County	Total Number of National Register Sites	Total Number of National Register Sites Inundated			Percent of National Register Sites Inundateds		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	640	14	24	32	2%	4%	5%
New Castle	380	4	6	9	1%	2%	2%
Kent	141	5	10	14	4%	7%	10%
Sussex	119	5	8	9	4%	7%	8%

Source: Delaware State Historic Preservation Office,
National Register of Historic Places for Delaware, 1997-12-01

Potential Economic Impact: Economic impacts of permanent inundation of historic resources include direct loss of buildings, structures, and landscapes as well as the revenues that are generated from them, whether home business, farms, or tourism. In addition, tax revenue to state and local governments could be affected by direct loss of property, although some of these properties may be tax-exempt.

In addition to direct losses, there are significant costs associated with moving historic buildings, structures, and cemeteries, raising historic buildings and structures above flood levels, providing flood protection for historic resources, repairing flood damage to historic resources, and/or conducting data recovery excavations of significant archaeological sites. In certain circumstances, some owners of historic resources may have a legal obligation to relocate or document the resource if loss is imminent, such as in the case of permanent inundation. Indirectly, loss of tidal marshes and other natural communities that provide natural flood mitigation to upland properties may exacerbate inundation impacts to inland historic resources.

Potential Social Impact: While not immediately visible to the public, the loss of archaeological sites means the irrecoverable loss of information that may be significant to understanding Delaware's past, representing a serious loss for researchers, archaeologists, historians, and even environmentalists interested in reconstructing past ecologies. Damage to archaeological sites begins with rises in the water table, leading to leaching of chemical and organic contents of the site, thereby damaging the information potential of the site well before a site is permanently inundated.

Additionally, property owners could experience loss of their historic homes and commercial properties such as stores and farms. Quality of life for all Delawareans could be impacted because historic resources are a large part of the community character of Delaware's towns as well as the look and feel of its rural areas, creating pleasing view-sheds, walkable neighborhoods, interesting streetscapes, and recreational and cultural opportunities.

Potential Environmental Impact: Some historic buildings may still contain lead-based paints and asbestos and there may be other chemicals and contaminants remaining in historic farms, mills, and industrial sites. Inundation of these sites could release hazardous materials into the water column. In addition, inundation of cemeteries may result in the release of lead and other toxins that are used in burial materials.

Socially Vulnerable Populations

Socially vulnerable populations are neighborhoods or groups that are less likely to have the resources to respond to environmental threats like sea level rise due to a variety of factors including educational level, economic standing, age, family status, and access to services.

Citizens in areas identified as socially vulnerable may lack the ability or resources to adapt to sea level rise. They may not have the financial resources to flood-proof their homes or relocate if sea level rise begins to affect their neighborhood. They may also lack their own transportation or lose access to transportation should bus routes or bus stops be relocated due to road flooding in the region; this could also affect their ability to travel to and from work. In addition, these communities are often near or within areas of already poor environmental quality and may disproportionally be affected by indirect impacts of sea level rise such as contaminant releases from underground storage tanks or contaminated sites.

Socially vulnerable populations were discussed and considered throughout this document but were not ranked with the other resources analyzed because assessment of these communities will need to be conducted at a more localized scale and with consideration of the interaction of numerous direct and indirect sea level rise impacts. Attention to fair treatment of socially vulnerable communities should be forefront in the minds of decision-makers as plans are made to adapt to the effects of sea level rise. Strategies that are developed for sea level rise should seek to avoid disproportionate effects to socially vulnerable populations as described below.

Society and Economy

Exposure to Sea Level Rise: To understand the location and extent of populations that could be particularly susceptible to the effects of sea level rise, two social vulnerability indicators were utilized: The Wilmington Planning Area Council's (WILMAPCO) Environmental Justice (EJ) areas and the Social Vulnerability Index (SoVI).

Environmental Justice entails the fair treatment and meaningful involvement of people from all races, cultures, and incomes regarding the development of environmental laws, regulations and policies. An outgrowth of Title VI of the Civil Rights Act of 1964, EJ is a policy to ensure the non-discriminatory distribution of federal funds in the U.S. During his terms, President Clinton issued a pair of Executive Orders (EO) which detailed the EJ responsibilities of federal agencies. EO 12898, signed in 1994, requires agencies to identify and avoid disproportionately high and adverse effects on low-income and minority populations. Six years later, EO 13166 called for outreach and involvement of persons with Limited English Proficiency (LEP). A decade later, President Obama reinvigorated the federal government's commitment to EJ. Strategies across federal agencies were revamped, with weight added to the following areas: public engagement, implementation of the National Environmental Policy Act (NEPA) and Title VI, the relationship of climate change to EJ, and the impacts of freight movement.

EJ areas in Delaware were identified by WILMAPCO for use in transportation planning projects. Using data from the 2000 Census, block groups were given points based on the percentage of low-income, black, Hispanic, and Asian persons. Based upon the number of points, block groups were scored as either having a Low, Moderate or Significant concentration of at-risk residents (WILMAPCO, 2009).

A Social Vulnerability Index is a quantitative measure of social vulnerability to environmental hazards. Social vulnerability focuses on demographic and socioeconomic factors that increase or attenuate the impact of environmental hazards (like sea level rise) on local populations. The Social Vulnerability Index (Cutter, Bryan, & Shirley, 2003) uses a similar strategy to identify block groups that are particularly susceptible to environmental hazards, but uses 32 variables to score each block group. These variables include race and income like the WILMAPCO method, but also includes percentage of elderly residents, percent female headed households, hospitals per capita, housing values, percent employment, education level, and others. Vulnerable block groups are identified as those whose scores are greater than one standard deviation above the mean (Cutter, Bryan, & Shirley, 2003). SoVI data at a block group level was obtained from the National Oceanic and Atmospheric Administration for use in this assessment.

Due to recent changes in the way in which demographic data is collected through the US Census, the most robust and useable dataset for social vulnerability analysis is the 2000 Census. This analysis should be updated as new demographic data is available.

Using these two methods, block groups whose boundaries were within any sea level rise scenario were identified; these block groups were further analyzed to determine if there were any residences that would be exposed to sea level rise. Block groups with at least one affected residence were included in the results below. It is important to note that in many cases, only a small sliver of each block group is exposed to sea level rise, and the remainder of the block group is outside of the area of concern. Additional analysis will be necessary to discern the social vulnerability within affected parcels.

Results of the two different techniques for identifying at-risk populations varied widely, likely as a result of the increased number of variables used by the SoVI versus the WILMACPO method. The SoVI, likely due to its inclusion of age and infrastructure factors, identified more rural and resort areas as vulnerable, but also included areas of dense development in Wilmington, Dover, and Milford. The Environmental Justice Areas, because of the focus on race and income, was more likely to identify urban areas in Wilmington, Milford, Dover, and Seaford. However, smaller towns and rural areas were also identified as vulnerable.

Block groups identified as environmental justice areas or socially vulnerable areas by this analysis are listed below. Block groups in italics indicate that the block group was identified by both methods.

WILMAPCO Environmental Justice Areas - Significant

- North of Wilmington, east of 13 (Tract 101700, Block Group 4)
- South Wilmington, East of Christina River and West of Heald Street (Tract 1900, Block Group 2)
- Milford, North of Mispillion River and west of 113 (Tract 042500, Block Group 2)

WILMAPCO Environmental Justice Areas – Moderate

- Wilmington, North of Brandywine River (Tract 000700 Block Group 2, Tract 000602 Block Group 2 & 3)
- City of Wilmington, northwest of Christina River (Tract 002700, Block Group 1)
- City of Wilmington, north of Christina River (Tract 002000, Block Group 1)
- North of Delaware City (Tract 0163303, Block Group 1)
- Bear, west of 7 (Tract 014902, Block Group 1)
- Southeast of Middletown (Tract 016802, Block Group 1)
- Eastern Kent County (Tract 040400, Block Group 1)
- East of Dover (Tract 041000, Block Group 1)
- Downtown Dover, along the upper St. Jones River and Silver Lake (Tract 040900, Block group 1)
- West Milford (Tract 050102, Block Group 3)
- Milton and vicinity (Tract 050801, Block Group 2)
- Seaford, North of Nanticoke River (Tract 050402, Block Group 2)
- Laurel and South of Laurel (Tract 051802, Block Group 2)

Social Vulnerability Index – High Vulnerability

- East of Christiana River (Tract 012900, Block group 2)
- Downtown Dover, along the upper St. Jones River and Silver Lake (Tract 040900, Block group 1)
- Lewes along the L&R Canal (Tract 050900, Block Group 3)
- Seaford, North of Nanticoke River (Tract 050402, Block Group 2)
- Millsboro, along Indian River (Tract 050602, Block Group 1)
- Sussex County along north side of Indian River (Tract 050702, Block Group 1)

Social Vulnerability Index – Moderate Vulnerability

- City of Wilmington, northwest of Christina River (Tract 002700, Block Group 1)
- West of Route 13 in Smyrna and Kent County (Tract 040203, Block Group 2)
- Milford west of Route 113 (Tract 042500 Block Group 2, Tract 050102, Block Group 1)
- Milton and vicinity (Tract 050801, Block Group 2)
- East of Millsboro, north side of Indian River (Tract 050702, Block Group 2)
- East and South of Dagsboro, including Frankford (Tract 051500, Block Group 2)
- East of Selbyville (Tract 051302, Block Group 1)

Society and Economy

These results should be considered as a screening upon which to base additional investigations into the potential impact that sea level rise may have on communities. Americans have proven to be highly economically mobile throughout their lifetimes, and community composition is likely to change over our 88 year planning horizon. In addition, these methods identified some block groups as vulnerable based upon age and fixed incomes; these individuals may actually have sizeable assets and wealth to use as resources to adapt.

Potential Economic Impact: The potential economic impacts associated with exposure of socially vulnerable populations to sea level rise include costs associated with home maintenance, employment opportunities, and social services. Although it can be assumed that many socially vulnerable individuals rent their homes; flooding of residences may result in increased or unplanned costs for home repair or relocation. For homeowners, this may result in increased insurance costs or repairs after flood events. There could also be unanticipated costs for renters as well; including relocation costs (first and last month's rent, security deposits etc.) should this become necessary due to safety or structural issues. Alternate housing options may also be limited for those using subsidized housing programs.

In some neighborhoods, flooding of buildings could also result in loss of employment within the vicinity; those residents who do not have a car may lose employment opportunities within walking distance and may have difficulty with the costs associated with traveling by car. In addition, the nature of social services needed for residents of these areas may evolve in the future, requiring more government resources to help them respond, recover, or adapt to sea level rise.

Potential Social Impact: The potential social impact associated with the exposure of socially vulnerable populations to sea level rise includes the loss of housing, of 'local' identity, loss community structure, and character, loss of employment opportunities, and the loss of a social network. In many small communities, neighbors support neighbors through emergency babysitting, rides to work, and block watches. Any action that would result in the relocation of families could have an isolating affect, particularly in multi-generational communities or communities with long tenure. Increased flooding and structural damages will also impact quantity and quality of social service resources needed and available for these populations.

Potential Environmental Impact: The potential environmental impacts associated with the exposure of socially vulnerable populations to sea level rise include exposure to contaminants, water quality and health effects. Some socially vulnerable communities are located near industrial sites and brownfields (formerly industrial sites suspected of having contamination). Inundation of these sites may release contaminants (mercury, arsenic, PCBs etc.) into the water column, increasing the likelihood of these contaminants coming into contact with humans through a variety of means.

Sea level rise may also affect the function and safety of septic systems and drinking water wells; persons and communities unable to bear the costs of repair or replacement will be particularly affected. Increased water tables or inundation could cause septic systems to no longer drain properly or to back up into homes; this exposes humans and the water supply to bacteria, pathogens, and other pollutants. Increased water tables and inundation could also cause well-water to become salty affecting the quality and quantity of drinking water supplies.

Sea level rise may also increase the number of people at risk for health conditions related to standing water, wet building materials, and sustained high indoor humidity. Standing water can result in increased mosquito populations and exposure to mosquito borne disease. Wet or damp basements and high indoor humidity can result in increased mold spores and increased incidences of asthma and allergies.

Coastal
Heritage

Public Safety and Infrastructure

Public Safety and Infrastructure

The Public Safety and Infrastructure Workgroup was formed to collaboratively investigate the potential effects of sea level rise on the public safety, transportation, utility, service, and industrial infrastructure of Delaware. Its results are presented below and in the following sections. The effects of sea level rise on infrastructure is relatively straight-forward; with facilities exposed to sea level rise subject to damage or reduced usefulness. When the economic, environmental, and social impacts are taken into consideration the issue becomes more complex and interrelated; the workgroup recognizes that the information that has been gathered and presented through this vulnerability assessment process is not complete in many cases; much more research will need to be conducted to answer many of the questions posed by the workgroup in its discussions.

Assessing Exposure of Public Safety & Infrastructure Resources

The Public Safety and Infrastructure Workgroup was composed of members of the Sea Level Rise Advisory Committee, additional subject matter experts, and members of the public. A list of those who participated in this workgroup is available in Appendix C. The workgroup met five times between February 2011 and March 2012 to identify, assess, and rank issues related to sea level rise, public safety, and infrastructure.

Resources Considered

Specific resources that the Public Safety and Infrastructure Workgroup was initially concerned with but which were not included in the assessment due to a lack of information or impact include the following:

Lack of Information:

- Emergency shelters
- DelDOT maintenance yards
- Electric generation stations
- Electric distribution stations
- Telephone switching stations
- Electricity and communication utilities
- Governmental buildings
- Water lines
- Sewer lines

No Impact:

- Correction facilities
- Airports
- Hospitals
- 911 call centers
- Public schools
- Cell towers

After discussion , initial data collection, and analysis by Delaware Coastal Program staff, the workgroup narrowed their focus to the following topics: dams, dikes & levees; emergency service facilities; evacuation routes; DART bus routes & stops; navigation aids; The Port of Wilmington; railroad lines; public boat ramps & piers; roads & bridges; septic tanks & disposal fields; underground pipeline utilities; wastewater facilities; wells; adult & child care facilities; cemeteries; public and private schools; brownfields; landfills & salvage yards; DNREC SIRS contaminated sites; and underground storage tanks.

Assessing Exposure

As described in the Introduction section, Delaware Coastal Programs staff worked with workgroup and committee members to collect data and information about each resource that the workgroup wished to assess. Based upon available data, tables were generated in ArcGIS that described the exposure of each resource to sea level rise under each of the three scenarios. Maps depicting location and density of this exposure were also generated in ArcGIS. Workgroup members filled out resource assessment templates based upon their own expertise and in collaboration with their colleagues. When possible, regional studies on sea level rise, such as WILMAPCO's Transportation Vulnerability Assessment of the Wilmington, Delaware Region, were used to compare and contrast results (WILMAPCO, 2011).

All of this information was compiled together into a comprehensive assessment for each resource, which was reviewed and edited by workgroup members. Full text of each one of these assessments follows.

Data and Information Gaps

This vulnerability assessment relied on existing data and information to complete a statewide level screening of resources at risk to sea level rise. In many cases, the data that was provided showed the impact to the physical structure but was unable to fully convey the economic, social, and environmental ramifications of sea level rise on a given resource. For example, wastewater facility data showed the number of facilities that are exposed to sea level rise but did not detail the number of residents that would be affected if these structures lost functionality. Dam/levee data also ran into this issue with only the physical structure being analyzed. Data overlap was another issue for the Public Safety and Infrastructure workgroup. Some resources, such as brownfields and salvage yards, were subsets of other resources like SIRS contaminated sites. These overlaps lead to the development of multiple exposure assessments for a similar resource. However, these data issues do not impede our ability to understand the range of potential impacts from sea level rise and make recommendations for future studies that would help improve our understanding of specific impacts.

Assessing Vulnerability of Public Safety & Infrastructure Resources

As discussed in the Introduction, once the resource assessments were completed and maps were available, the Public Safety and Infrastructure Workgroup conducted an exercise to assess the vulnerability of the state to the effects of sea level rise for each resource. Using standardized questions, the workgroup considered the two primary factors: the geographic scope of impacts and whether the resource could continue to "function". For geographic scope, the workgroup considered both the discrete locations of the impacts themselves and the extent to which impacts may be felt outside these locations. For example, although the exposure of wells is concentrated along the coast, the effects of exposure could be felt statewide due to an increase in demand pressure on inland wells. For "function," the committee considered the extent to which a resource could continue to meet its intended purpose, whether that purpose is to provide emergency services, wastewater treatment, or public services. As a result of this discussion, each resource was ranked as a High Concern, Moderate Concern, Low Concern, or Minimal Concern. Resources ranked as high and moderate concern will likely become the starting point for adaptation strategy development in Delaware.

Public Safety and Infrastructure

High Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources are of the highest concern: Dams, Dikes and Levees, Port of Wilmington, Railroad Lines, Roads and Bridges, Wells, and Evacuation Routes. A high concern resource is generally a resource where inundation of a resource would cause it to no longer function and/or could cause impacts statewide, whether directly to the resource itself or indirectly through disruption of services. Additional research and development of adaptation strategies for high concern resources is recommended.

Dams, Dikes & Levees: Between 39% and 78% of the state's 50 miles of dams, dikes and levees could be inundated by sea level rise by 2100. The highest concentration of potential impact is focused in Kent County, whose dikes primarily protect wildlife areas. The majority of the dikes in New Castle County protect people, property, and, in one case, a contaminated site. These structures were built to provide a certain level of containment or protection. If a breach or structural failure were to occur, the resultant flooding could affect a large area inland of the structure. Due to these considerations, inundation of dams, dikes, and levees in the state was ranked as a high concern.

Port of Wilmington: Between 36% and 73% of the Port of Wilmington's property is within an area that could be inundated by sea level rise by 2100. The port is based in northern New Castle County; however, the economic value to Delaware and the entire Northeast Region makes exposure to sea level rise a state and regional issue. Due to these considerations, inundation of the Port of Wilmington was ranked as a high concern.

Railroad Lines: Between 2% and 6% of the state's railroad lines are within an area that could be inundated by sea level rise by 2100. The highest concentration of impact is focused in New Castle County. Even with smaller amounts of exposure in Kent and Sussex Counties, it should be noted that if a single rail line segment becomes inundated, the entire functionality of the line could be lost. This may impact industries served by rail such as power plants and the Delaware City refinery. Passenger travel is also a concern; disruptions and possible restrictions to the Amtrak rail line could impact travel throughout the northeast corridor. Because disruption of rail service in Delaware could have impacts throughout the state and region, inundation of railroad lines as a result of sea level rise was ranked as a high concern.

Roads & Bridges: Between 1% and 5% of the state's roads and bridges are within an area that could be inundated by sea level rise by 2100. Inundation of an individual segment of road could cause regional transportation disruptions, particularly if no alternative routes are available. The highest concentration of roadway exposure to sea level rise was found in Sussex County; however, potential exposure was found throughout the state. Due to the potential regional impacts, inundation of roads and bridges from sea level rise was ranked as a high concern.

Wells: Residents and businesses in Kent and Sussex Counties rely on groundwater resources for drinking, irrigation and industrial purposes. Operation of wells that extract groundwater can be compromised by inundation from sea level rise, and the quality of groundwater can be compromised by saltwater intrusion resulting from sea level rise. Statewide, between 3% and 7% of domestic wells, 3% and 7% of industrial wells, 1% and 2% of irrigation wells, and 2% and 10% of public wells are within an area that could be inundated by sea level rise by 2100. Potential exposure of wells to sea level rise is focused along the coast; however, reduction in availability of groundwater in the coastal areas may increase demand on inland public wells. Because access to clean water is a necessity and because demand on inland wells may increase, sea level rise impacts to wells was ranked as a high concern.

Evacuation Routes: Between 1% and 6% of the state's evacuation routes are within an area that could be inundated by sea level rise by 2100. Interstates and arterial roads tend to serve as the major evacuation routes for emergencies; substantial reliance on a single mode of transportation for evacuations may endanger many people if the highway infrastructure is made inaccessible because of sea level rise. All three counties experience exposure but the highest concentration is found in Sussex County. Because evacuations rely on automobile transportation and because flooded roadways can prevent or slow evacuation by car, inundation of evacuation routes was ranked as a high concern.

Moderate Concern Resources

Based upon the risk assessment conducted by the workgroup the following resources are of moderate concern: Septic Systems and Disposal fields, Landfills, and Wastewater Facilities. Resources are considered to be of moderate concern if there is some impact or loss of function and/or if the geographic extent of the impacts is less than statewide.

Septic Systems & Disposal Fields: Statewide, between 1% and 4% of septic systems are within an area that could be inundated by sea level rise by 2100. The highest concentration was found in Sussex County, with a focus around the Inland Bays. Functionality issues may arise well before inundation due to rising water tables. This may result in the potential for significant environmental and public health issues related to groundwater contamination. Since potential impacts are concentrated in Sussex County but exist statewide, sea level rise impacts to septic systems were ranked as a moderate concern.

Landfills: Sites included for this resource range from large state permitted landfills operated by major companies such as NRG, Waste Management, and Delaware Solid Waste Authority to small privately or municipally owned sites, some of which are no longer in operation. Between 1% and 3% of landfill acreage is within an area that could be inundated by sea level rise by 2100. It should be noted that state permitted landfills are expected to see little to no direct exposure to inundation. While the impact to the resource is relatively small and the scale is localized with a focus in northern New Castle County, landfill disruption is still considered to be a statewide concern. These sites service a large area and the need for future rezoning may be an issue. The possibility of contamination migration was another factor considered when determining risk. Due to these considerations, inundation of landfills was ranked as a moderate concern.

Wastewater Facilities: Sites included for this resource included sewer pumping stations, spray irrigation fields, and public treatment/collection facilities. Statewide, between 7% and 21% of sewer pumping stations, 0% and 17% of spray irrigation fields, and 0% and 13% of public treatment/collection facilities are within an area that could be inundated by sea level rise by 2100. The majority of the exposure will be focused in eastern Sussex County; however, New Castle and Kent Counties have wastewater facilities that are also affected but to a lesser extent. These facilities service a large number of people so the potential impacts will be much larger than the percentages indicate. In some cases, impacts may be experienced before inundation occurs due to rising water tables. Taking all available information into account, inundation of wastewater facilities was ranked as a moderate concern.

Public Safety and Infrastructure

Low Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources were considered to be of lower concern at this time: Brownfield Sites, Salvage Yards, Underground Storage Tanks, DNREC Site Investigation & Remediation Section (SIRS) Contaminated Sites, and Underground Pipeline Utilities. A ranking of low concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather that the impacts will not be significant and/or isolated to several small geographic regions. Low concern resources should continue to be monitored and re-assessed in subsequent planning activities.

Brownfields: Between 9% and 25% of brownfield sites throughout the state are within an area that could be inundated by sea level rise by 2100. Geographically, the exposure is focused in the Wilmington area with only one site being located outside of New Castle County. If sites become inundated, the release of contaminants may lead to serious health and environmental complications for the surrounding community; however, some sites have been or are currently being remediated. Due to the limited geographic extent of impacts, the inundation of brownfield sites is of low concern at this time.

Salvage Yards: Between 11% and 26% of salvage yards throughout the state are within an area that could be inundated by sea level rise by 2100. Geographically, the exposure is focused in Northern New Castle County with only 1 site being located in a different county. Salvage yards contain a variety of contaminants; however, many sites are currently in the process of being remediated. Due to these considerations, inundation of salvage yards is of low concern at this time.

Underground Storage Tanks (UST): Between 2% and 6% of UST sites throughout the state are within an area that could be inundated by sea level rise by the year 2100. While sites are exposed in all three counties, the scale appears to be localized in nature with a focus on the Wilmington area and the beach communities. If sites are inundated, the release of contaminants may lead to health and environmental impacts for the surrounding community. Due to the limited geographical extent of impacts, the inundation of UST sites is of low concern at this time.

DNREC Site Investigation & Remediation Section (SIRS) Contaminated Sites: Between 41% and 54% of SIRS sites throughout the state are within an area that could be inundated by sea level rise by the year 2100. Geographically, the exposure is focused in the Wilmington area, Bombay Hook, and the beach communities. If these sites become inundated, the release of contaminants may lead to health and environmental complications; however, SIRS sites have already been identified, evaluated, and in many cases, remediation is complete or currently taking place. Due to these considerations, inundation of SIRS contaminated sites is of low concern at this time.

Underground Pipeline Utilities: This resource includes natural gas and petroleum pipelines. Workgroup members also initially considered water and sewer pipelines; however, data was unavailable due to privacy and homeland security concerns. Between 4% and 6% of pipeline utilities throughout the state are within an area that could be inundated by sea level rise by the year 2100. While sections of pipeline are exposed in all three counties, the highest concentration is found in New Castle County. The results from the analysis showed that major supply lines will not be affected; however, distribution along with pipeline corrosion may become issues in the future. Due to these considerations, inundation of underground pipeline utilities is of low concern at this time.

Minimal Concern Resources

Based upon the risk assessment conducted by the workgroup, the following resources were considered to be of lower concern at this time: Adult and Child Care Facilities, Cemeteries, Schools, Leaking Underground Storage Tanks, DART Bus Routes and Stops, Navigation Aids, Public Boat Ramps and Piers, and Emergency Services. A ranking of minimal concern does not necessarily mean that a resource is not important or that impacts from sea level rise will not be felt, rather the impacts will be minor in nature or isolated to a small geographic region. Minimal concern resources should be re-assessed in subsequent planning activities.

Adult & Child Care Facilities: Between 0% and 1% of adult and child care facilities throughout the state are within an area that could be inundated by sea level rise by the year 2100. Due to the sporadic nature and low number of potentially exposed sites, adult and child care facilities are of minimal concern at this time.

Cemeteries: Between 2% and 4% of cemeteries are within an area that could be inundated by sea level rise by the year 2100. All cemetery sites that are potentially exposed are located in Sussex County. Due to the local nature and small number of impacted sites, cemeteries are of minimal concern at this time.

Schools: This resource includes both private and public schools. Statewide, only one school is within an area that could be inundated by sea level rise by the year 2100. Due to the small number of potentially impacted facilities statewide, sea level rise impacts to schools is of minimal concern at this time.

Leaking Underground Storage Tanks (LUST): Between 1% and 5% of LUST sites are within an area that could be inundated by sea level rise by the year 2100. All three counties have exposed sites with slight concentrations in Wilmington and along the Inland Bays. The geographic scale is localized and many of the sites are still active. These LUST sites are known to be sources of contamination and are currently being remediated. Due to these considerations, inundation of LUST sites is of minimal concern at this time.

DART Bus Routes & Stops: Between 1% and 3% of DART bus routes and stops are within an area that could be inundated by sea level rise by the year 2100. It should be noted that Kent and Sussex Counties do not rely on mass transit the way that New Castle County does. Bus routes and stops constantly shift with demand and there is little to no cost involved with these shifts. Due to these considerations, inundation of DART routes and stops is of minimal concern at this time.

Navigation Aids: Since navigation aids are situated on or near the water, 100% are within an area that could be inundated by sea level rise by the year 2100. Most navigation aids are designed to withstand the effects of sustained wave action meaning the majority of devices will only see minor impacts. Due to these considerations, inundation of navigation aids is of minimal concern at this time.

Public Boat Ramps & Piers: Between 60% and 69% of public boat ramps and piers are within an area that could be inundated by sea level rise by the year 2100. Since ramps and piers are built along the waterfront, impacts from sea level rise should be expected. Impacted ramps and piers are found throughout the state; however, adapting to a higher water level should not be difficult or costly to accomplish. Due to these considerations, inundation of public boat ramps and piers is of minimal concern at this time.

Public Safety and Infrastructure

Emergency Services: This resource includes fire and rescues stations, ambulance and paramedic stations, police stations, and emergency operation centers. Statewide, between 0% and 9% of fire and rescue stations, 0% and 3% of ambulance and paramedic stations, 0% and 8% of police stations, and 0% and 14% of emergency operation centers are within an area that could be inundated by sea level rise by the year 2100. All emergency facilities already have a mutual aid backup plan in place. Secondary stations are spread throughout the state and coastal stations routinely move equipment to higher ground in the case of a storm event. This statewide backup network will require little adaptation in the future. Due to these considerations, inundation of emergency services is of minimal concern at this time.

Detailed Resource Assessments

The following sub-chapters contain a detailed exposure assessment for each resource and a description of the likely economic, social, and environmental impacts that could result. As discussed in the Introduction section of this document, an exposure assessment describes how much of a particular resource is within each one of the three sea level rise scenarios; not whether the resource will be impacted. For example, a house that has been elevated above the floodplain is counted within the sea level rise inundation area, but that particular house may be unaffected by sea level rise because it has been flood-proofed. The potential effects to each resource are described within the text, along with the caveats of the analysis and data. These assessments are being used as the baseline data and information to formulate an adaptation strategy for the state, while recognizing the limitations of this method for site specific planning.

Public Safety

Dams, Dikes & Levees

Dams and levees, also referred to as dikes, are manmade structures constructed of earth or other materials designed to contain or direct water in a river, lake or other water bodies for purposes including, but not limited to, flood control or power generation. Historically, dams in Delaware have been used in the operation of mills for processing agricultural products and irrigation. Likewise, levees in Delaware were initially constructed for agricultural purposes allowing for arable lands, along the Delaware River and Bay, to be farmed. As time passed and development spread, these structures served increasingly as flood control structures, protecting homes and infrastructure placed in flood prone areas.

While these structures provide a certain level of containment or protection and provide great opportunities to Delaware communities, they are not without risk. Levees are continually impacted by wind, waves and tides; natural forces that can gradually erode, and weaken the face of these structures or that can cause significant damage during coastal storm events. High wind and heavy rains can cause wave heights and water levels to increase. Overtopping can result in water moving at a high velocity down an embankment slope which may lead to failure of the structure. Seepage can also result in the instability and failure of these structures. Seepage through a levee or dam may occur when the water level on one face rises, resulting in increased water pressure. This pressure forces water a) through weakened areas of the structure, like those created by animal borrows or cracking from settlement, or b) under the structure as evidenced by boils appearing along the opposing bank. Erosion, overtopping, and seepage are all factors that may lead to collapse and each are exacerbated by sea level rise.

Exposure to Sea Level Rise: Exposure of dams, dikes, and levees to future sea level rise was assessed by using GIS line layers obtained from the Delaware Department of Natural Resources and Environmental Control Dam Safety Program. The layers marked the locations of dams, dikes, and levees throughout the state and were used in to analyze data with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a structure is within an area that is potentially exposed to sea level rise and should not be used to determine if a structure will be able to function. To fully assess the impact sea level rise will have on dams, dikes, and levees, additional criteria will be needed including: construction and materials used; current condition of structure and associated facilities; amount and/or source of water behind the structure; inventory of infrastructure; population; and other resources protected by the structure.

Statewide, approximately 31 miles of dams, dikes, and levees are within an area that could be inundated by 1 meter of sea level rise, representing 63% of the total miles of the dams, dikes, and levees in the state. Kent County has both the highest number of miles and highest percentage of constructed structures at risk, with between 15% - 88% of its structure being located within a mapped sea level rise area. New Castle and Sussex Counties are both projected to have approximately 7 miles of dams, dikes, and levees exposed at the 1.5 meter scenario. In New Castle County, the majority of the dikes are used to protect communities such as the city of New Castle, whereas dikes in Kent County are primarily wildlife impoundments. See Map Appendix.

Table 40 - Miles of Dams & Levees Exposed to Sea level Rise

County	Total Miles	Miles Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	49.6	19.2	31.4	38.7	39%	63%	78%
New Castle	10.7	2.4	5.1	7.2	22%	48%	67%
Kent	27.9	4.1	19.5	24.5	15%	70%	88%
Sussex	10.9	6.6	6.8	7.0	61%	62%	64%

Source: DNREC – Dam Safety Program, Dams and Dikes of Delaware, unpublished

Potential Economic Impact: Poorly maintained dams and levees may lead to damage or failure of these structures and the increased risks resulting from sea level rise may put infrastructure, such as homes and businesses protected by these structures, at high risk of flooding and flood damage. The economic impact of structural failure depends on what is being protected. A 2011 study for the city of New Castle was conducted on the four levees that protect the city and surrounding area (Greenstone Engineering, 2011). A cost-benefit analysis for each levee was used to project the results of overtopping or breaching during a 100-year storm event. The water elevation during a 100-year flood event in this area is 9 feet. Damages resulting from this type of event would range from $8-80 million. The water elevation with 0.5 meter sea level rise in this area is 10.6 feet.

Knowing such risks exist could have economic impacts to an area. Insurance companies may raise flood insurance rates for properties protected by inadequate structures. Understanding the risk and potential impacts, business owners may decide to move their operations to a safer location which could mean a loss of tax revenue for local coastal communities.

Potential Social Impact: Limited or changed functionality of dams, dikes, and levees may put a greater percentage of people and property at risk from flooding. As sea levels continue to rise, the threat of overtopping or structural failure could also increase coastal communities' risk of flooding.

Potential Environmental Impact: As with potential economic impacts, the degree of environmental impacts resulting from levee failure depends on what is being protected. Most structures in Delaware protect some amount of marsh habitat. This habitat can be greatly affected through changes in the geomorphology resulting from tidal flushing, and fauna and flora impacts due to salinity changes. Failure of dikes that are part of a wetland impoundment system may result in the loss of globally important habitat for migratory bird species.

By controlling tidal exchange, some structures currently prevent the release of hazardous materials trapped in the marsh sediment as a result of chemical spills and pollution. These toxins could potentially be carried away from flooded properties and distributed throughout the flood plain. Additionally, industrial, municipal, and agricultural operations that are flooded could release pollutants such as chemicals, solid wastes, raw sewage, and petroleum products and common household substances into the flood waters.

Emergency Service Facilities

Emergency service facilities include fire and rescue stations, ambulance and paramedic stations, police stations, and emergency operation centers.

Fire and rescue stations are structures that house and maintain fire and rescue equipment and may contain communication centers and ancillary equipment storage. Ambulance and paramedic stations are structures that house and maintain EMS apparatuses and may contain communication centers and ancillary equipment storage. These structures may or may not be co-located with fire stations. Police stations are structures that house and maintain police operations, including offices, communications, and equipment storage. These structures include any Federal, Delaware Department of Natural Resources and Environmental Control, or U. S. Fish and Wildlife enforcement locations. Emergency operation centers are structures that house emergency operation personnel, communication centers, and data links.

Emergency service facilities may be adversely impacted by sea level rise. Facilities may initially be subject to intermittent flooding from lunar high tides. This may cause short-term operational and access problems. However, as sea levels continue to rise; the problem could become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of emergency service facilities to future sea level rise was assessed by using GIS point layers obtained from the United State Department of Homeland Security and the Delaware Emergency Management Agency. The layers marked the locations of emergency facilities throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a facility is within an area that is potentially exposed to sea level rise and should not be used to determine if a facility will be able to function. To fully assess the impact sea level rise will have on emergency service facilities, additional criteria will be needed including: surrounding road elevations to determine accessibility to facilities; floor elevations to determine level of inundation within structures; critical equipment elevations to determine exposure of ancillary equipment.

Statewide, eight fire & rescue stations are within an area that could be inundated by 1.5 meters of sea level rise, representing 9% of the stations in the state (Table 41). Sussex County has the highest number of fire & rescue stations at risk, with four facilities being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with only one station being exposed at the 1.5 meter scenario. The fire & rescue stations that will be potentially exposed to sea level rise are Wilmington Fire Station 2, Leipsic Fire Station, Bowers Fire Station, Little Creek Fire Station, Indian River Fire Station, Memorial Fire Station, and Bethany Beach Stations 1 & 2. See Map Appendix for map.

Table 41 - Number of Fire & Rescue Stations Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	88	0	0	8	0%	0%	9%
New Castle	40	0	0	1	0%	0%	3%
Kent	19	0	0	3	0%	0%	16%
Sussex	29	0	0	4	0%	0%	14%

Source: DHS (TechniGraphics), Delaware fire Stations Q1, 2008-04-02

Statewide, two ambulance & paramedic stations are within an area that could be inundated by 1.5 meters of sea level rise, representing 3% of the stations in the state (Table 42). Both stations are located in Kent County and are only potentially exposed at the 1.5 meter scenario. New Castle and Sussex Counties have no impacted facilities. The ambulance & paramedic stations that will be potentially exposed to sea level rise are Bowers EMS/Fire Station and Leipsic EMS/ Fire Station. See Map Appendix for map.

Table 42 - Number of Ambulance & Paramedic Stations (EMS) Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	68	0	0	2	0%	0%	3%
New Castle	34	0	0	0	0%	0%	0%
Kent	15	0	0	2	0%	0%	13%
Sussex	19	0	0	0	0%	0%	0%

Source: DHS (TechniGraphics), Delaware Emergency Medical Services Q108, 2008-04-02

Public Safety and Infrastructure

Statewide, five police stations are within an area that could be inundated by 1.5 meters of sea level rise, representing 8% of the stations in the state (Table 43). Sussex County has both the highest number and highest percentage of police stations at risk, with between 9% - 14% of its stations being located within a mapped sea level rise area. Both New Castle and Kent Counties are projected to each have one police station impacted. The police stations that will be potentially exposed to sea level rise are Dewey Beach, Bethany Beach, South Bethany, USFWS Office of Law Enforcement, and DNREC Fort Delaware State Park Ranger Station. Other police stations with the potential to be exposed to sea level rise not included in the assessment are Fenwick Island and the City of New Castle. See Map Appendix for map.

Table 43 - Number of Police Stations Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	63	0	3	5	0%	5%	8%
New Castle	24	0	0	1	0%	0%	4%
Kent	17	0	1	1	0%	6%	6%
Sussex	22	0	2	3	0%	9%	14%

Source: DHS (Technigraphics), Delaware Law Enforcement 2009 O4, 2009-12-18

Statewide, one emergency operation center is within an area that could be inundated by 1.0 meter of sea level rise, representing 14% of the centers in the state (Table 44). The site is in New Castle County and is the location for the new Wilmington emergency operation center which is currently under construction. See Map Appendix for map.

Table 44 - Number of Emergency Operation Centers Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	7	0	1	1	0%	14%	14%
New Castle	5	0	1	1	0%	20%	20%
Kent	1	0	0	0	0%	0%	0%
Sussex	1	0	0	0	0%	0%	0%

Source: DEMA, EOC shapefile, 2011-04-03 [edit by Delaware Coastal Programs]

Potential Economic Impact: Limited or changed functionality of emergency service facilities could impact emergency response times and thus could cause more damage to property and possessions and increase the cost of insurance. Sea level rise may also alter governmental funding allocated to stations based on response times. Property values in impacted communities may decrease due to the lack of emergency service coverage.

Potential Social Impact: The role of emergency services facilities is to be multifaceted first responders, answering fire, rescue, hazardous materials, medical, and criminal calls. Limited or changed functionality of emergency services facilities will impact the response times of personnel and thus could increase the risk of loss of life and possessions. Delaware communities rely on these facilities and sea level rise may prevent responders from aiding residents during times of need. Fire stations sometimes serve as town gathering locations for social events and local government meetings. The loss of such facilities may erode the sense of community for many towns throughout Delaware.

Potential Environmental Impact: Limited or changed functionality of emergency service facilities will impact response times of personnel and thus could increase times to contain spills and other detrimental environmental impacts from fires, accidents, or chemical spills. A reduced ability to respond to hazardous waste emergencies may harm the surrounding natural habitat and contaminate water sources.

Evacuation Routes

Included in this section are roadways that are listed as evacuation routes by the Delaware Department of Transportation. Interstates and arterials tend to serve as major evacuation routes for emergencies. This substantial reliance on a single mode of transportation may endanger many people if the highway infrastructure is damaged or made inaccessible because of sea level rise. If the relative sea level increases such that portions of evacuation routes are under water then the essential connectivity and evacuation provided by those highways would be lost (CCSP, 2008).

Evacuation routes that lie in the path of sea level rise may be adversely impacted. Routes may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access and congestion problems as well as flood damage if evacuation routes are not adequately elevated or flood protected. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of evacuation routes to future sea level rise was assessed by using GIS line layers obtained from the Delaware Department of Transportation's Traffic Management Team. The layers marked the locations of evacuation routes throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a route is within an area that is potentially exposed to sea level rise and should not be used to determine if a road will be able to function. To fully assess the impact sea level rise will have on evacuation routes, additional criteria will be needed including: road construction materials and structures; traffic count; and the availability of other evacuation routes.

Statewide, approximately 50 miles of designated evacuation routes are within an area that could be inundated by 1.0 meter of sea level rise, representing 4% of the evacuation routes in the state (Table 45). Sussex County has the highest amount of evacuation routes at risk, with approximately 40 miles being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with only 2% of its evacuation routes being exposed at the 1.5 meter scenario. See Map Appendix for map.

Public Safety and Infrastructure

Table 45 - Miles of Evacuation Routes Exposed to Sea Level Rise

County	Total Miles	Miles Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	1,185	12.60	48.2	65.8	1%	4%	6%
New Castle	359	2.2	4	6.8	1%	1%	2%
Kent	307	8.8	16.5	20.5	3%	5%	7%
Sussex	519	1.6	27.7	38.5	< 1%	5%	7%

Source: DelDOT Traffic Management Team (Edwards and Kelcey), 2007 Evacuation Routes, 2010-15-04

Potential Economic Impact: Limited or changed functionality of evacuation routes may impact the cost of repairs and increase insurance rates of coastal towns that could be isolated due to road inundation. Property values may also decline and industries may decide to relocate due to the potential of residents and workers getting stranded during an emergency situation. The result will be an erosion of tax revenue for the local communities impacted.

Potential Social Impact: Socially, limited or changed functionality of evacuation routes may increase the potential for loss of life or property damage due to accessibility issues. It is worth noting that the loss of a small individual segment of a given highway may make significant portions of that evacuation route impassable. Further, even if a particular interstate or arterial is passable, if the feeder roads are flooded, then the larger roads become less usable (CCSP, 2008). The result would be entire communities cut-off from access to evacuation routes. Many coastal towns in Delaware have only one major road, Route 1, which also serves as the primary evacuation route. Limited access to the roadway would isolate residents and prevent help from entering the town.

Potential Environmental Impact: Concerning the environment, limited or changed functionality of evacuation routes may delay the removal of hazardous materials and other items from areas that are exposed to sea level rise increasing the risk for contamination. Also, permanent inundation may force the relocation of evacuation routes causing habitat destruction where these new routes are constructed.

Transportation

DART Bus Routes & Stops

DART First State provides transportation services statewide with over 400 buses, 57 year- round bus routes, and paratransit services. DART also provides bus route services in the beach resort section of Sussex County during the summer months.

Many Delawareans rely on public transportation to get to and from work, school, or daily activities. If relative sea level increases to an extent that transit service would pass through areas under water in the future, either the connectivity provided by that transit would be lost or corrective actions to reroute the transit would be needed (CCSP, 2008). DART bus routes and stops that lie in the path of sea level rise may be adversely impacted. Routes and stops may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access problems as well as flood damage if stops are not adequately elevated or prepared for flooding conditions. However, as sea levels continue to rise; the problem will become chronic, meaning adaptation will likely be required to maintain fully functionality of the public transportation system.

Exposure to Sea Level Rise: Exposure of DART bus routes and stops to future sea level rise was assessed by using GIS line and point layers obtained from the Delaware Department of Transportation. The layers marked the locations of routes and stops throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a route or stop is within an area that is potentially exposed to sea level rise and should not be used to determine if a route or stop will be able to function. To fully assess the impact sea level rise will have on bus routes and stops, additional criteria will be needed including: route ridership; ridership numbers at individual stops; alternate route possibilities; and whether served communities will also be affected by sea level rise.

Since the vast majority of transit service is provided by buses, schedules and routes can be modified easily, though the same is not true for terminals and maintenance facilities. Therefore, minimal impact on bus systems is expected from relative sea level rise (CCSP, 2008).

Statewide, approximately 70 miles of DART bus routes are within an area that could be inundated by 1.0 meter of sea level rise, representing 2% of the bus route mileage in the state (Table 46). New Castle County has the highest number of bus routes at risk, with approximately 94 miles being located within a mapped sea level rise area. Kent and Sussex Counties are projected to have a minimal impact from sea level rise with less than 1% of the bus routes in each county being exposed at the 1.5 meter scenario; however, the miles of bus routes analyzed in Sussex County does not include seasonal beach resort routes providing service to Rehoboth Beach, Dewey Beach, Bethany Beach, and Fenwick Island during the summer months. See Map Appendix for map.

Table 46 - Miles of DART Bus Routes Exposed to Sea Level Rise

County	Total Miles	Miles Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	4,408	37	70	101	1%	2%	2%
New Castle	3,299	36	66	94	1%	2%	3%
Kent	652	0.8	2	4	< 1%	< 1%	<1%
Sussex	456	0.5	2	3	< 1%	< 1%	<1%

Source: DelDOT – DART, DTC TRAPESE Routes and Stops, 2010-10-01

Statewide, 69 DART bus stops are within an area that could be inundated by 1.0 meter of sea level rise, representing approximately 2% of the bus stops in the state (Table 47). Sussex County has the highest amount of bus stops at risk with approximately 48 stops being located within a mapped sea level rise area. Kent County is projected to have the smallest impact with only 2 stops potentially exposed at the 1.5 meter scenario. The DART bus stops exposed in Sussex County include seasonal beach resort stops providing service to Rehoboth Beach, Dewey Beach, Bethany Beach, and Fenwick Island during the summer months. See Map Appendix for map.

Table 47 - Number of DART Bus Stops Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	3,409	24	69	108	1%	2%	3%
New Castle	2,550	14	28	58	1%	1%	2%
Kent	555	0	2	2	0%	< 1%	< 1%
Sussex	304	10	39	48	3%	13%	16%

Source: DelDOT – DART, DTC TRAPESE Routes and Stops, 2010-10-01

Potential Economic Impact:

Changes to or elimination of DART bus routes and stops due to sea level rise would potentially cause added expenses to passengers if other means of transportation must be arranged. Additionally, alternate routes may be more costly to operate for the state and may lead to longer travel times resulting in a decrease in ridership and revenue. Allowing buses to continue to operate in known inundated areas may increase service requirements due to salt corrosion to vehicles.

Potential Social Impact: Socially, changes to or the elimination of DART bus routes and stops may impact the ability of members of the public to commute due to stops being moved away from coastal communities. Diverted routes may also increase travel time along routes causing individuals to miss appointments and have less time to perform daily tasks.

The majority of DART services are provided by buses which allows for schedules and routes to be modified easily. Therefore minimal impact on bus systems is expected from sea level rise.

Potential Environmental Impact: While minimal impact from sea level rise is expected, limited or changed functionality of DART bus routes may increase air pollution from longer altered bus routes. Additionally, contaminants, that accumulate on the pavement at bus stops, such as transportation fuel, may migrate and enter water supplies due to inundation of the impervious surfaces.

Navigation Aids

A navigation aid is any device external to a vessel specifically intended to assist navigators in determining their position or safe course, or to warn of dangers or obstructions to navigation. Buoys, lights, and other devices are used to aid in the navigation of Delaware waterways. Since navigation aids are situated on the water, impacts from sea level rise should be expected. Infrastructure may initially be subject to intermittent flooding from lunar high tides. This may cause short-term usage problems if navigation aids are not properly elevated. The problem may become more chronic as sea levels continue to rise; however, adaptation may not be required if full functionality of the devises remains.

Exposure to Sea Level Rise: Exposure of navigation aids to future sea level rise was assessed by using GIS point layers obtained from the U.S. Department of Homeland Security. The layers marked the locations of navigation aids throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a navigation aid is within an area that is potentially exposed to sea level rise and should not be used to determine if a navigation aid will be able to function. To fully assess the impact sea level rise will have on navigation aids, additional criteria will be needed including: type of navigation aid (floating or non-floating aid), type and length of mooring or other method of securing, and water depth at location.

Statewide, approximately 456 navigation aids are within an area that could be inundated by 0.5 meters of sea level rise, representing 100% of the aids in the state (Table 48).

Table 48 - Number of Navigation Aids Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	456	456	456	456	100%	100%	100%
New Castle	287	287	287	287	100%	100%	100%
Kent	62	62	62	62	100%	100%	100%
Sussex	107	107	107	107	100%	100%	100%

Source: Department of Homeland Security, HSIP Freedom, 2011.

Potential Economic Impact: Concerning the economy, limited or changed functionality of navigation aids may increase the risk of property damage. Most navigation aids are designed to withstand the effects of sustained sea water attack meaning the majority of devices will only see minor impacts from sea level rise. It is not expected that sea level rise will have an impact on floating navigation aids such as light vessels and buoys. The only issue may be the need to lengthen the anchor chain and strengthen the mooring. An increase in sea level may deepen and open new channels allowing for additional shipping traffic which will require the installation of more navigation aids.

Potential Social Impact: Socially, limited or changed functionality of navigation aids may increase risk of injury due to the loss of devices.

Potential Environmental Impact: Concerning the environment, limited or changed functionality of navigation aids may increase the risk of cargo losses or fuel leaks from ships running aground. As sea level rises, new shipping routes may open but also affect the movement of sub-surface sandbanks. If and when change occurs, it may require the relocation of floating navigation buoys to a new position impacting the surrounding natural habitat.

Public Safety and Infrastructure

Port of Wilmington

The Port of Wilmington is a full-service deep-water port and marine terminal capable of handling all types of cargo with customized logistics. Today, the port is the busiest terminal on the Delaware River handling about 400 vessels annually with a yearly import/export cargo tonnage of over 4 million tons (Port of Wilmington, 2006).

The Port is considered the nation's leading gateway for imports of fresh fruit, juice concentrate, and is one of the world's largest banana hubs. Companies such as Dole Fresh Fruit Company and Chiquita Fresh North America are major importers and take advantage of the on-site cold storage complex (Port of Wilmington, 2006). Wilmington is also a leading automobile export hub to Central America, the Middle-East, and West Africa shipping vehicles for companies such as General Motors.

In addition, a variety of break bulk and bulk cargos move through the Port including forest products, steel, bulk materials, and petroleum products (Port of Wilmington, 2006). In recent years, Wilmington has also become a gateway for livestock, project cargo, and wind energy shipments.

Located at the confluence of the Delaware and Christina Rivers, 65 miles from the Atlantic Ocean, the Port of Wilmington is owned and operated by the Diamond State Port Corporation, a corporate entity of the state of Delaware (Port of Wilmington, 2006). The property includes docks, cargo transfer areas and some warehouses. Adjoining properties are used to support port operations including dredge disposal sites, warehouses, and cargo holding areas.

Port of Wilmington infrastructure may be adversly impacted by sea level rise. Facilites and equipment may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access problems as well as flood damage if facilities are not adequately elevated or flood proofed (Deyle, Bailey, & Matheny, 2007). However, as sea levels continue to rise, the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of the Port of Wilmington to future sea level rise was assessed by using GIS polygon layers obtained from New Castle County tax parcel maps. The layers marked the locations of Diamond State Port Corporation property throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a section of the Port of Wilmington is within an area that is potentially exposed to sea level rise and should not be used to determine if the port will be able to function. To fully assess the impact sea level rise will have on the Port of Wilmington, additional criteria will be needed including: layout of facility including warehouses, offices, storage, parking, and work areas; type and location of cargo storage areas; floor and critical equipment elevations; surrounding road and rail elevations to determine accessibility; and geotechnical information to determine soil load bearing capacities.

Approximately 128 acres of the Diamond State Port Corporation's core property are within an area that could be inundated by 1.0 meter of sea level rise, representing 59% of the port's land area (Table 49). All exposure to sea level rise is concentrated in New Castle County with approximately 158 acres being located within a mapped sea level rise area.

Table 49 - Acres of the Diamond State Port Corporation Property Exposed to Sea Level Rise

County	Total Acres	Acres Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
New Castle	216	78	128	158	36%	59%	73%

Source: New Castle County, NCC Tax Parcels, 2010-09-01

Approximately 362 acres of the Port of Wilmington's operations and supporting activity properties are within an area that could be inundated by 1.0 meter of sea level rise, representing 29% of the port's supporting activity land area (Table 50). The Port of Wilmington's core property (Table 50) is also included in this assessment.

Table 50 - Acres of Port Operations and Supporting Activity Exposed to Sea Level Rise

County	Total Acres	Acres Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
New Castle	1,234	251	362	462	20%	29%	37%

Source: DNREC – Office of the Secretary, Coastal Zone Heavy Industry, unpublished

Potential Economic Impact: Limited or changed functionality of the Port of Wilmington and supporting facilities may temporarily or permanently affect the needed workforce causing a loss of jobs to the region. The port may also see a decrease in revenues due to sea level rise impacting importing/exporting operations which will have an effect on city, county, and state tax revenues.

For facilities that are not appropriately protected, either by elevation or by structures, rising water levels pose an increased risk of chronic flooding, leading in the worst case to permanent inundation of marine terminal facilities, either completely or in part, and rendering them inoperable (CCSP, 2008).

Navigable depths are likely to increase in many harbors and navigation channels as a result of rising sea levels. This could lead to reduced dredging costs, but higher costs where rising water levels require changes to terminals (CCSP, 2008). Transportation costs may also increase due to impacts to supporting businesses (auto, chemical, food, minerals, etc.) which may impact the prices consumers pay for products.

One impact of sea level rise not generally mentioned is the decreased boat clearance under bridges. Even with precise timing of the stage of tide and passage under fixed bridges, sea level rise will affect the number of low water windows available for the large vessels now being built (Gill, Wright, Titus, Kafalenos, & Wright, 2009).

Potential Social Impact: Socially, changed functionality of the Port of Wilmington may impact the safety of workers due to flooding and/or compressed loading/unloading windows. The possibility remains that as sea levels rise, Diamond State Port Corporation may have to decrease the number of people employed at the port which could result in the deterioration of neighboring communities. Since the Port of Wilmington is a major part of the Delaware economy, measures to keep the facility operational will be of great importance; however, sea level rise may force the relocation of port services. Impacts on highways and rail connections could also affect the ability to utilize and transport goods to and from the Port of Wilmington (CCSP, 2008).

Potential Environmental Impact: Along with fruit and vehicle imports and exports, the Port of Wilmington also ships and stores hazardous materials such as petroleum products. Inundation from sea level rise may allow stored materials to escape into the surrounding area. These products may contaminate drinking water supplies, natural habitat, and residential properties that border port facilities.

Railroad Lines

Railroad lines, including both passenger and freight, are infrastructure that is vital to the economic and social wellbeing of Delaware. Rail lines serve as a mode of transporting people across the Mid-Atlantic and are essential for moving freight throughout Delaware and to other parts of the United States. Impacts to the State's rail network could serve as choke points to both passenger and freight traffic that originates in and flows through Delaware (CCSP, 2008). Transportation routes serve as the lifeline to communities, and inundation of even the smallest component of a rail system can result in a much larger system shutdown (Gill, Wright, Titus, Kafalenos, & Wright, 2009).

Railroad lines are often found in low-lying areas, and therefore, are at risk for interruptions in service due to inundation and coastal erosion resulting from sea level rise. In addition, railroads often run through marsh areas in coastal zones and as the low-lying tracks become flooded; the marsh beds become vulnerable to sinking from the compaction of marsh peat (Titus, 2002). These impacts may cause short-term access and congestion problems as well as flood damage if railroad tracks are not adequately elevated. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of railroad lines to future sea level rise was assessed using GIS line layers obtained from the United States Geological Survey's 7.5 minute Digital Rail Line Graphs. The layers mark the locations of rail lines throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a rail line is within an area that is potentially exposed to sea level rise and should not be used to determine if a rail line will be able to function. To fully assess the impact sea level rise will have on railroad lines, additional criteria will be needed including: geo-technical information on soils; weight of trains; speed of trains/ rail/tie/ballast construction materials and methods; and depth of standing water (relates to axle heights).

Statewide, approximately 17 miles of rail lines are within an area that could be inundated by 1.0 meter of sea level rise, representing 4% of the railroad lines in the state (Table 51). New Castle County has the highest amount of rail lines at risk, with approximately 21 miles being located within a mapped sea level rise area. Kent County is projected to have the least impact from sea level rise with less than 1% of the rail lines being exposed at the 1.5 meter scenario. See Map Appendix for map.

When compared to the WILMAPCO regional study, at the 1.5 meter scenario, New Castle County was projected to have 8.7 miles of rail lines potentially inundated by sea level rise, representing approximately 5% of the total (WILMAPCO, 2011). The data discrepancies can be attributed to different methodologies used for each study. The SLRAC vulnerability assessment used data appropriate for the statewide scale of the study, while the WILMAPCO vulnerability assessment used more regionally specific data.

Table 51 - Miles of Railroad Lines Exposed to Sea Level Rise

County	Total Miles	Miles Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	418	9	17	25	2%	4%	6%
New Castle	235	8	14	21	3%	6%	9%
Kent	76	0	0.03	0.1	0%	< 1%	< 1%
Sussex	107	1	3	4	1%	3%	4%

Source: USGS, 7.5 minute Digital Line Graphs – Rail, 2010-09-30

Potential Economic Impact: Damage to railroad lines resulting from sea level rise may increase shipping costs of freight and prices for passenger travel. Since goods are transferred to and from facilities by rail, service interruptions on selected segments of infrastructure are likely to affect a larger percentage area due to the distribution to network connectivity (CCSP, 2008). This may cut-off industries served such as the Edgemoor and Indian River power plants, the Delaware City refinery, and the Edgemoor Rail Yard bulk transfer. Concerning passenger travel, disruptions and possible restrictions to the Amtrak Northeast Corridor rail line will potentially disrupt travel between Washington D.C. – Philadelphia – New York City – Boston forcing commuters and business travelers to find other means of transportation.

For rail line systems in Delaware, sea level rise could potentially be a serious issue. Relocating tracks and permanent facilities is a major undertaking; tracks would need to be protected or moved to higher ground to remain functional (CCSP, 2008). The engineering costs of such a project may force the permanent abandonment of some routes. Some industries, such as the Port of Wilmington, need to remain at or near the water's edge to send and receive shipments. There will be a continued need for rail service into these locations. Other rail customers, however, may begin to relocate to higher ground or to different regions entirely. This will have an impact on state tax income, jobs in impacted communities, and affect the type and scale of the rail network needed to meet the demand for inbound and outbound freight shipments.

Potential Social Impact: Damage to railroad lines from sea level rise may impact the prices and amount of products available to consumers. If rail lines are inundated, more freight and passengers may have to use cars, buses, and trucks as an alternate form of transportation. The disruption of commuter lines may have an impact on job opportunities in Delaware due to individuals not being able to commute to their place of employment.

An issue related to moving rail lines further away from coastal areas is that it will, in most cases, move passenger rail services further away from population centers. The highest density populations tend to occur along coastal regions, making it the most desirable location for passenger rail stations. If the rail line is moved further inland to areas with lower population density, it would have a negative impact on the amount of patrons the rail line can service and the potential of any future commuter passenger rail line that might be warranted by population growth along the coast (CCSP, 2008).

Public Safety and Infrastructure

Potential Environmental Impact: Sea level rise impacts to railroad lines may cause added air pollution from alternate forms of shipping or public transit. Hazardous materials, such as creosote, originating from rail bed materials may contaminate ground and surface waters due to an increase in migration potential from inundation. Another factor is the extent to which rising sea levels create a higher water table that leads to additional flooding during periods of normal precipitation. As the water table rises, the ground is less able to absorb normal rainfall. This could cause frequent flooding of rail track and facilities (CCSP, 2008).

Public Boat Ramps & Piers

Delaware is home to miles of coastline, ponds, and streams making the state an exceptional destination for all types of boating and fishing. The Delaware Department of Natural Resources and Environmental Control's Division of Fish and Wildlife provides public access to boat ramps and piers throughout the state. Since ramps and piers are built along the waterfront, impacts from sea level rise should be expected. Infrastructure may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access problems to parking as well as flood damage if ramps and piers are not adequately elevated. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation may be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of ramps and piers to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resources and Environmental Control's Division of Fish & Wildlife. The layers marked the locations of state owned ramps and piers throughout Delaware. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a ramp or pier is within an area that is potentially exposed to sea level rise and should not be used to determine if a ramp or pier will be able to function. To fully assess the impact sea level rise will have on ramps and piers, additional criteria will be needed including: type of construction of ramp or pier; type and location of parking area; location of access roads to boat launch site.

Statewide, approximately 46 ramps or piers are within an area that could be inundated by 1.0 meter of sea level rise, representing 64% of the state owned ramps and piers in the state (Table 52). Percentage wise, New Castle County has the greatest amount of ramps or piers at risk, with approximately 94% of the County's ramps and piers being exposed at the 0.5 meter scenario. Kent and Sussex Counties have the greatest number of ramps and piers at risk, with approximately 17 affected ramps or piers. See Map Appendix for map.

Table 52 - Number of Ramps and Piers Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	72	43	46	50	60%	64%	69%
New Castle	17	16	16	16	94%	94%	94%
Kent	28	14	15	17	50%	54%	61%
Sussex	27	13	15	17	48%	56%	63%

Source: DNREC – fish and Wildlife, Ramps and Piers 2008-06-03, unpublished.

Potential Economic Impact: Inundation from sea level rise of public boat ramps and piers may cause a reduction in water activities (fishing, birding, etc.) due to accessibility issues, resulting in a loss in state and retail revenues. Additional funds may be needed to build new structures to keep pace with rising water levels.

Sea level rise may lead to some economic benefits by exploiting new opportunities. Deeper waters may allow certain rivers and harbors to become more practical for recreational use.

Potential Social Impact: Socially, limited or changed functionality of public boat ramps and piers may impact the ability of the public to access certain waterways safely. To many coastal communities in Delaware, life is based around fishing and boating. Limiting access to these recreational opportunities may reduce the quality of life residents and visitors expect.

Potential Environmental Impact: Economically, limited or changed functionality of public boat ramps and piers may harm the surrounding environment from the use of unauthorized access locations. Boating and fishing infrastructure may be damaged or destroyed by sea level rise, allowing materials to become an environmental hazard to surrounding wildlife and natural habitats.

Roads & Bridges

Roads and bridges are essential infrastructure that can guide development patterns for centuries. The ability of Delaware to adapt to sea level rise in the years to come may be helped or hindered by the decisions state transportation officials make today (Titus, 2002). Transportation infrastructure is designed to perform for a wide range of service lives. Roads are among the shortest-lived facilities, with surfaces that must be repaved every 10-20 years (Transportation Research Board, 2008). Due to the limited lifespan of roads, future decisions need to be based on the cost/benefit of continued road upgrades in flood-prone areas. Transportation routes serve as the lifeline to communities, and inundation of even the smallest component of a road system can result in a much larger system shutdown (Gill, Wright, Titus, Kafalenos, & Wright, 2009).

Roads provide the public access to services and act as the major source of transportation in Delaware. In many low-lying communities, roads are lower than the surrounding lands, so that land can drain into the streets. As a result, the streets are the first to flood. As sea level rises, these drainage systems become less effective, causing additional flooding (Titus, 2002).

Sea level rise directly affects travel on roadways as a result of flooding, inundation, erosion of road bases, removal of sediment around bridge abutments or piers, and reduced bridge clearance. Roads and bridges that lie in the path of sea level rise may be adversely impacted. A road system may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access and congestion problems as well as flood damage if roadways are not adequately elevated. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of roads and bridges to future sea level rise was assessed using GIS line layers obtained from the Delaware Department of Transportation's road centerline file. The layers marked the locations of all roads and bridges throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

Public Safety and Infrastructure

It is important to note that this simple assessment tells us only whether a road or bridge is within an area that is potentially exposed to sea level rise and should not be used to determine if a road or bridge will be able to function if inundated. To fully assess the impact sea level rise will have on roads and bridges, additional criteria will be needed including: road/bridge construction, geo-technical data, traffic counts, availability of other routes, and infrastructure along the route.

Statewide, approximately 484 miles of roads and bridges are within an area that could be inundated by 1.5 meter of sea level rise, representing 4% of the roads in the state (When compared to the WILMAPCO regional study, at the 1.5 meter scenario, New Castle County was projected to have 27.9 miles of roadway potentially inundated by sea level rise, representing 2.7% of the total (WILMAPCO, 2011). While the miles exposed for each assessment differ, the percentage of total inundated are relatively similar with 2% - 2.7% of the resource impacted. The data discrepancies can be attributed to different methodologies used for each study. The SLRAC vulnerability assessment used DelDOT's road centerline file which includes all roads in the state while the WILMAPCO vulnerability assessment only considered roadways that had corresponding traffic data. This included all major roads but left out some local roadways accounting for the difference in the number of miles inundated.

Table 53Sussex County has the highest amount of roads and bridges at risk, with approximately 357 miles being located within a mapped sea level rise area. Percentage-wise, New Castle County is projected to have the least impact from sea level rise with 2% of the County's roads being exposed at the 1.5 meter scenario. See Map Appendix for map.

When compared to the WILMAPCO regional study, at the 1.5 meter scenario, New Castle County was projected to have 27.9 miles of roadway potentially inundated by sea level rise, representing 2.7% of the total (WILMAPCO, 2011). While the miles exposed for each assessment differ, the percentage of total inundated are relatively similar with 2% - 2.7% of the resource impacted. The data discrepancies can be attributed to different methodologies used for each study. The SLRAC vulnerability assessment used DelDOT's road centerline file which includes all roads in the state while the WILMAPCO vulnerability assessment only considered roadways that had corresponding traffic data. This included all major roads but left out some local roadways accounting for the difference in the number of miles inundated.

Table 53 - Miles of Roads & Bridges Exposed to Sea Level Rise

County	Total Miles	Miles Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	8,990	116	317	484	1%	4%	5%
New Castle	3,431	21	46	72	1%	1%	2%
Kent	2,003	16	35	55	1%	2%	3%
Sussex	3,556	79	237	357	2%	7%	10%

Source: DelDOT, Road Centerline file, 2008-06-01

Potential Economic Impact: Concerning the economy, road networks exist to facilitate the movement of goods and are an integral part of Delaware's economic fabric. The need for these networks, or transportation demand, therefore, is defined by economic considerations that connect population centers and provide access to resources (CCSP, 2008). Since goods are transferred to and from locations via trucks, service interruptions on selected segments of road infrastructure are likely to affect a larger percentage area due to the distribution in network connectivity. Limited or changed functionality of roads may affect the amount of income and subsequent taxes paid by businesses situated along transportation routes.

Potential Social Impact: Limited or changed functionality of roads and bridges may increase the potential for loss of life or property damage and may force the re-location of land uses due to loss of access. As residential populations relocate from affected areas, demand for transported goods would decline. Similarly, as commercial activities relocate, transportation services would shift with them causing labor shortages for transportation and commercial facilities along the coast (CCSP, 2008). It is worth noting that the potential loss of a small individual segment of a given highway may make significant portions of the road network impassable. Further, even if a particular interstate or arterial is passable, if the feeder roads are flooded, then the larger roads become underutilized possibly isolating communities along the Delaware coastline. Highways are the chief mode for transporting people across Delaware. Impacts to the highway network could serve as choke points to passenger traffic that emanates in or flows through the region causing more traffic congestion (CCSP, 2008).

Potential Environmental Impact: Sea level rise may have an increased impact of coastal erosion on roadways. The effect of increased wave action, tidal currents and extreme storm surges can cause the removal of sediment in and around roadways, making them inaccessible (Transportation Research Board, 2008). Limited or changed functionality of roads and bridges may increase the risk of environmental damage from hazardous materials being transported on alternate roads due to flooding. Inundation of roadways may also result in the dispersion of paving materials into water sources. As the sea level rises, the coastline will change. Bridges that were not previously at risk may be exposed in the future. Additionally, bridges with decks at an elevation below the likely crest of storm surges, based on experience from previous storms, will be below water during the storm event and not subject to wave damage (CCSP, 2008).

Utilities

Septic Tanks & Disposal fields

A septic system is a self-contained underground wastewater treatment system that treats and disposes of household wastewater onsite. The system consists of two main parts: a septic tank and the drainfield. Septic systems are often more economical than centralized sewer systems in rural areas where lot sizes are larger and houses are spaced widely apart. By using natural processes to treat wastewater onsite, septic systems do not require the installation of miles of sewer lines, making them less disruptive to the environment (WVU, 2012).

Public Safety and Infrastructure

Three primary components govern the placement of a septic system: (1) the elevation of the site above groundwater, (2) the lateral distance between the leaching component of the facility and a point of water use (well, surface water, etc.), and (3) the suitability of the soils or sediments to receive and treat the liquid effluent from the wastewater disposal system (Buzzards Bay National Estuary Program, 1991). Pathogens in septic tank effluent are removed primarily through physical retention or straining through soil and adsorption onto soil particles. The efficiency of these processes decreases as the moisture in the soil increases and drops drastically if the soil is saturated (Buzzards Bay National Estuary Program, 1991). Septic systems that lie in the path of sea level rise may be adversely impacted. Systems may initially be subject to intermittent flooding from lunar high tides. This may cause short-term operational problems. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of septic systems to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of septic systems throughout the state. The tank location was identified as the location of the housing structure. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a tank is within an area that is potentially exposed to sea level rise and should not be used to determine if a tank will be able to function. To fully assess the impact sea level rise will have on septic systems, additional criteria will be needed including: exact locations of septic tanks and disposal fields; and groundwater elevations to determine pre-inundation effects.

Statewide, 1,600 septic systems are within an area that could be inundated by 1.0 meter of sea level rise, representing 2% of the septic systems in the state (Table 54). Sussex County has both the highest number and highest percentage of septic systems at risk, with 1– 7% of its septic systems being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with less than 1% of its septic systems being exposed at the 1.5 meter scenario. See Map Appendix for map.

Table 54 - Number of Septic Systems Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	78,109	485	1,675	3,185	1%	2%	4%
New Castle	15,460	7	18	44	< 1%	< 1%	< 1%
Kent	21,095	63	243	393	< 1%	1%	2%
Sussex	41,554	415	1,414	2,748	1%	3%	7%

Source: DNREC, Delaware Septic Systems (last update 2010-11-23), unpublished

Potential Economic Impact: Concerning the economy, the failure of septic systems is a major challenge that property owners exposed to sea level rise will have to address. If this issue is not remedied, a home is rendered uninhabitable, and the property loses its value. In most cases, the property cannot be sold for other uses due to the level of development that has already altered the land (Maryland DNR, 2008). Above-ground facilities, such as bermed infiltration ponds, or in-ground sewage holding tanks are possible alternatives. These methods are expensive and have a limited capacity (Maryland DNR, 2008). Holding tanks must be pumped out, requiring the services of companies that specialize in sewage tank removal. This will add to the already high costs but may provide new employment opportunities. Failing septic systems may also force local governments to install costly central sewer systems for coastal communities.

Potential Social Impact: The changed functionality of septic tanks and disposal fields may impact the health and safety of communities that are exposed to untreated or partially treated waste. Sea level rise may cause some properties in coastal towns that rely on septic systems to become uninhabitable due to sewage backups. Microbial populations from septic waste that is able to enter the surface water may exceed the U.S. Environmental Protection Agency's body contact standards, abruptly halting recreational use of beaches, lakes, and streams and possibly contaminating groundwater supplies.

Potential Environmental Impact: The presence of groundwater levels near the surface will affect the integrity of on-site septic disposal systems. Saturated ground conditions impair the soil's ability to infiltrate and filter sewage effluents. Sea level rise will decrease the soil filtration process allowing for additional contaminants to enter water resources.

It is estimated that every failing septic system can discharge more than 76,650 gallons of untreated wastewater into Delaware's groundwater and surface waters per year (Lee, Jones, & Peterson, 2005). Untreated wastewater contains excessive nutrients (nitrogen and phosphorus) that can harm native plant and fish populations in surface waters. Wastewater's excessive organic matter content also can choke off the oxygen supply in streams and rivers.

Underground Utilities (Pipelines)

Underground pipelines for this section are designated infrastructure that carries oil or natural gas to Delaware residents and industries. These materials are transported via a network of underground pipelines running throughout the state. Pipelines are considered a safe and economical mode of transporting large volumes of product. Aging steel pipes, especially for natural gas, are being constantly replaced with high strength Polyethylene plastic pipes which are less likely to corrode; however, these new pipes may be more prone to damage associated with sea level rise such as the force of wave action.

Underground utilities that lie in the path of sea level rise may be adversely impacted. Pipelines may initially be subject to intermittent flooding from lunar high tides. This may cause short-term supply issues as well as flood damage if pipelines are not adequately protected. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Public Safety and Infrastructure

Exposure to Sea Level Rise: Exposure of underground pipeline to future sea level rise was assessed by using GIS line layers obtained from the United States Department of Transportation's National Pipeline Mapping System. The layers marked the locations of oil and natural gas pipeline throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a pipeline is within an area that is potentially exposed to sea level rise and should not be used to determine if a pipeline will be able to function. To fully assess the impact sea level rise will have on underground utilities, additional criteria will be needed including: material conveyed in pipeline; construction of pipeline; surrounding road elevations to determine accessibility to pipelines; elevations of pipelines and groundwater surface levels; and elevation of access points.

Statewide, approximately 17 miles of pipeline are within an area that could be inundated by 1.0 meter of sea level rise, representing 5% of the underground pipeline in the state (Table 55). New Castle County has both the highest number of miles and highest percentage of pipeline at risk, with between 7% - 9% of its pipeline being located within a mapped sea level rise area. Sussex County is projected to have the least impact from sea level with less than 1% of its pipeline being exposed at the 1.5 meter scenario. A map showing underground pipelines is not available due to the sensitive nature of the information.

Table 55 - Miles of Pipeline Exposed to Sea Level Rise

County	Total Miles	Miles Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	347	14	17	20	4%	5%	6%
New Castle	162	11	13	15	7%	8%	9%
Kent	100	3	4	5	3%	4%	5%
Sussex	84	0.18	0.34	0.47	< 1%	< 1%	< 1%

Source: National Pipeline Mapping System, U.S. Dept. of Transportation – Pipeline and Hazardous Materials Safety Administration, 2011-07-12.

Potential Economic Impact: Concerning the economy, limited or changed functionality of underground pipelines may prevent expansion of networks and future development because of the inability to connect to current line infrastructure. Companies that manage the utility infrastructure may incur additional expenses due to the need to service damaged lines. The requirement for alternate transport methods may also increase expenses for individuals and businesses that rely on underground pipelines.

Potential Social Impact: Socially, limited or changed functionality of underground utilities may impact the amount of material that is able to be transported to consumers. Communities impacted by service disruptions could see businesses close and residential areas become uninhabitable due to the lack of energy sources.

Potential Environmental Impact: Concerning the environment, An increase in the frequency of inundation will affect soil structure, water table levels, soil stability, and the vulnerability of pipelines to normal wave action as well as storm surge. Sea level rise will cause increases in the elevation of fresh groundwater that overlies saltwater in surficial aquifers in coastal areas. This may expose buried utility lines and pipelines to corrosion and may affect the structural stability of the buried pipelines (Deyle, Bailey, & Matheny, 2007). Where significant subsidence has occurred, pipeline segments will be exposed to wave action. High-energy waves may subject a pipeline to stress levels it was not designed to withstand, causing possible fractures (Committee on Environment and Natural Resources, 2008). Spills of hazardous substances would result, leading to detrimental impacts on surrounding natural areas.

Wastewater Facilities, Pumping Stations, & Spray Irrigation Fields

Wastewater facilities are a critical type of infrastructure in Delaware. Preserving the operational integrity of these facilities will be a key component to maintaining the quality of life and environmental quality that many Delawareans have come to expect.

Much of the water used by homes, industries, and businesses in Delaware must be treated before it is released back into the environment. The infrastructure used during wastewater treatment include: pumping stations, spray irrigation fields, and treatment/collection facilities. Pumping stations are structures that contain pumps and associated equipment that are used to move wastewater to treatment facilities. Spray irrigation fields are land areas used for the application of treated wastewater. Treatment facilities are structures and surrounding facilities (aeration basins, etc.) which are used in the processes to treat wastewater. Collection facilities are structures that collect wastewater and then move the waste to treatment facilities.

Wastewater infrastructure that lies in the path of sea level rise may be adversly impacted. Facilities may initially be subject to intermittent flooding from spring tides. This may cause short-term access problems as well as flood damage if facilities are not adequately elevated or flood proofed (Deyle, Bailey, & Matheny, 2007). However, as sea levels continue to rise, the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality. Concerning spray irrigation fields, future flooding may inhibit the treatment ability of these land areas.

Exposure to Sea Level Rise: Exposure of wastewater facilities to future sea level rise was assessed by using GIS point data layers obtained from New Castle, Kent, and Sussex Counties. The layers marked the locations of publically owned pumping stations, spray irrigation fields, and treatment/collection facilities throughout the state. The layers were analyzed with respect to the future sea level rise inundation areas. This assessment did not include private, community, and investor owned and operated wastewater facilities.

Public Safety and Infrastructure

It is important to note that this simple assessment tells us only whether a facility is within an area that is potentially exposed to sea level rise and should not be used to determine if a facility/field will be able to function. To fully assess the impact sea level rise will have on wastewater infrastructure, additional criteria will be needed including: surrounding road elevations to determine accessibility to facilities; floor elevations to determine the level of inundation within structures; Critical Equipment Elevations to determine exposure of pumps, controls, backup generators, and other ancillary equipment; groundwater elevations to determine changes in the depth of the vadose zone for irrigation; soil type to determine saturation rates for irrigation fields; construction of structures to determine stability if surrounding ground becomes saturated.

While the number of wastewater facilities exposed to sea level rise is an important consideration, understanding of the amount of homes and businesses these facilities serve is critical. With this in mind, the impact of sea level rise will extend far beyond just the limit of inundation.

Statewide, approximately 17% of pumping stations are within the 1 meter sea level rise scenario (Table 56). In New Castle and Kent County, approximately 5% - 6% of each county's pumping stations will be exposed to sea level rise at the 1.5 meter scenario. Sussex County is projected to have the greatest number of facilities impacted with approximately 13% - 37% of the county's pumping stations being exposed to sea level rise. See Map Appendix for map.

Table 56 - Number of Public Pumping Stations Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	648	44	111	136	7%	17%	21%
New Castle	156	3	8	10	2%	5%	6%
Kent	176	1	5	9	1%	3%	5%
Sussex	316	40	98	117	13%	31%	37%

Source: New Castle County Special Services, NCC Sewers Geodatabase, 9-01-2010; Kent County Public Works, Kent Sewer Geodatabase, 10-05-2009; Sussex County GIS, Sussex Sewer Pump Stations Points, 6 -12-2009.

Only one spray irrigation field is projected to be impacted by sea level rise in Delaware. The spray irrigation field is located in Sussex County near Wolfe Neck and will be potentially exposed at the 1.5 meter scenario (Table 57).

Table 57 - Number of Public Spray Irrigation fields Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	6	0	0	1	0%	0%	17%
New Castle	4	0	0	0	0%	0%	0%
Kent	0	0	0	0	0%	0%	0%
Sussex	2	0	0	1	0%	0%	50%

Source: DNREC – financial Assistance Branch (TetraTech), Spray Irrigation fields, 1 -11-2010.

Statewide, approximately 7% of public wastewater treatment/collection facilites are within the 1.0 meter scenario (Table 58). No facilites will be exposed at the 0.5 meter scenario. In New Castle and Sussex County, two treatment/collection facilites in each county will be exposed to sea level rise at the 1.5 meter scenario. The wastewater treatment/collection facilites that will be potentially exposed to sea level rise are located in Delaware City, Port Penn, Lewes, and Seaford. See Map Apendix for map.

Table 58 - Number of Public Treatment/Collection Facilities Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	30	0	2	4	0%	7%	13%
New Castle	9	0	1	2	0%	11%	22%
Kent	6	0	0	0	0%	0%	0%
Sussex	15	0	1	2	0%	7%	13%

Sources: DNREC – financial Assistance Branch (TetraTech), POWWTP, 1-11-2010; New Castle County Special Services, NCC Sewers Geodatabase, 9-01-2010; Kent County Public Works, Kent Sewer Geodatabase, 10-05-2009; Sussex County GIS, Sussex Sewer Pump Stations Points, 6 -12-2009.

Potential Economic Impact: Concerning the economy, limited or changed functionality of wastewater infrastructure may prevent the expansion of the state's sewer network. Development in such areas could become stagnant and businesses may have to suspend operation if wastewater facilities become non-functional.

If businesses are forced to suspend operations and development opportunities become limited, the result will be a loss of state and local tax revenue. Employment may also be impacted if wastewater facilities are impacted by sea level rise. While the number of public facilities impacted by sea level rise is relatively small, the cost of adaptation and flood prevention to maintain functionality may put a financial strain on local municipalities. These economic strains may include the cost of retrofits to facilities, the construction of new infrastructure, and an increase in the amount of funds used for storm damage.

Potential Social Impact: Limited or changed functionality of wastewater infrastructure may impact the amount of waste that is able to be moved, which may cause sewer line backups into houses. The backups may lead to home damage and health issues due to bacteria and increased dampness. In some cases when a facility is inundated, operators may be forced to bypass the treatment process and release untreated waste into nearby rivers and streams impacting water quality and recreational opportunities. The release of untreated waste may necessitate the need for wastewater storage basins which will cause odors and unpleasant views impacting the aesthetic value of the surrounding area.

Potential Environmental Impact: A wastewater facility that is being flooded, or has been flooded, can suffer structural damage due to the weight of the floodwaters. The structural damage may cause untreated wastewater to be diverted into nearby fields or bodies of water which could have a damaging effect to the local environment (Kane County, 2005). Environmental impacts may include harm to fish and wildlife populations, oxygen depletion in water, beach closures, restrictions on fish and shellfish harvesting, and contamination of drinking water (USGS, 2011). Concerning spray irrigation, the sprayed wastewater evaporates into the air, soaks into the soil, or percolates through the soil and recharges the groundwater (USGS, 2005). Sea level rise would cause an increased threat of flooding which will prevent wastewater from entering the soil profile allowing for the potential of wastewater runoff.

Wells - Domestic, Industrial, Irrigation & Public

Groundwater is a significant water supply source for Delaware. The amount of groundwater storage dwarfs our present surface water supply. At any given time groundwater is about 20 to 30 times greater than the amount of water in all the lakes, stream, and rivers of the United States (USGS, 2000). Groundwater is tapped through wells placed in water-bearing soils and rocks beneath the surface of the earth. Wells in Delaware supply water for domestic, industrial, irrigation, and public uses. Domestic wells constitute the largest share of all water wells in the state; however, irrigation wells account for the largest use of groundwater.

Wells that lie in the path of sea level rise may be adversely impacted. Wells may initially be subject to intermittent flooding during lunar high tides. This may cause short-term water usage problems due to salt water intrusion. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of wells to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resources and Environmental Controls' Division of Water wells database. The layers marked the locations of domestic, industrial, irrigation, and public wells throughout the state. The layers were analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a well is within an area that is potentially exposed to sea level rise and should not be used to determine if a well will be able to function. To fully assess the impact sea level rise will have on wells, additional criteria will be needed including: depth of well; construction of well; height of well casing; grouting of well; location and type of pump; geo-hydrology of area in regard to salt water intrusion.

Statewide, 2,985 domestic wells are within an area that could be inundated by 1.0 meter of sea level rise, representing 5% of the domestic wells in the state (Table 59). Sussex County has both the highest number and highest percentage of domestic wells at risk, with between 1,701 and 3,541 (5% - 10%) of its domestic wells being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with 2% of its domestic wells being exposed at the 1.5 meter scenario. See Map Appendix for map.

Table 59 - Number of Domestic Wells Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	61,285	2,051	2,985	4,183	3%	5%	7%
New Castle	6,507	85	119	129	1%	2%	2%
Kent	19,871	265	413	513	1%	2%	3%
Sussex	34,907	1,701	2,453	3,541	5%	7%	10%

Source: DNREC, Division of Water. Wells Database, 2010.

Statewide, 21 industrial wells are within an area that could be inundated by 1.0 meter of sea level rise, representing 6% of the industrial wells in the state (Table 60). Sussex County has the highest number of wells at risk with between 8 and 15 of its industrial wells being located within a mapped sea level rise area. New Castle County has the highest percentage of industrial wells at risk, with 11% of the county's wells being exposed at the 1.5 meter scenario. Kent County is projected to have the least impact with only 2 industrial wells being exposed to sea level rise. See Map Appendix for map.

Table 60 - Number of Industrial Wells Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	335	11	21	25	3%	6%	7%
New Castle	74	3	6	8	4%	8%	11%
Kent	82	0	1	2	0%	1%	2%
Sussex	179	8	14	15	4%	8%	8%

Source: DNREC, Division of Water. Wells Database, 2010.

Statewide, 48 irrigation wells are within an area that could be inundated by 1.0 meter of sea level rise, representing 1% of the irrigation wells in the state (Table 61). Sussex County has the highest number of wells at risk with between 12 and 39 of the county's irrigation wells being located within a mapped sea level rise area. New Castle County has the highest percentage of irrigation wells at risk (3%), but this represents only four wells being exposed at the 1.5 meter scenario. See Map Appendix for map.

Table 61 - Number of Irrigation Wells Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	3,501	25	48	66	1%	1%	2%
New Castle	145	2	3	4	1%	2%	3%
Kent	1,006	11	17	23	1%	2%	2%
Sussex	2,350	12	28	39	1%	1%	2%

Source: DNREC, Division of Water. Wells Database, 2010.

Public Safety and Infrastructure

Statewide, 75 public wells are within an area that could be inundated by 1.0 meter of sea level rise, representing 6% of the public wells in the state (Table 62). Sussex County has both the highest number and highest percentage of public wells at risk, with between 18 and 105 (3% - 15%) of its public wells being located within a mapped sea level rise area. New Castle County is projected to have the least impact from sea level rise with seven (3%) of the County's public wells being exposed at the 1.5 meter scenario. See Map Appendix for map.

Table 62 - Number of Public Wells Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	1,312	25	75	129	2%	6%	10%
New Castle	264	1	3	7	< 1%	1%	3%
Kent	341	6	15	17	2%	4%	5%
Sussex	707	18	57	105	3%	8%	15%

Source: DNREC, Division of Water. Wells Database, 2010.

Potential Economic Impact: Concerning the economy, limited or changed functionality of domestic and public water wells may prevent the expansion of water supply networks and future development due to system capacity limits. Also, the movement of groundwater in an aquifer is typically slow making it difficult and expensive to flush saltwater contamination from a groundwater source and re-establish an original freshwater/ seawater interface (USGS, 2000). Once polluted, an aquifer may remain contaminated for decades. Additional costs would arise from providing alternate water supplies to the impacted communities.

Impacts to irrigation wells may have an impact on crop production. The diminished crop yield and possible loss of agricultural land will mean a potential loss of tax revenue, primarily for state and indirectly to local governments, in the form of businesses which support the agricultural industry.

Potential Social Impact: Socially, limited or changed functionality of domestic and public water wells may impact the amount and quality of potable water available for coastal communities. A decrease in supply would cause certain areas of Delaware to become uninhabitable without an outside source of potable water. Health concerns may also arise from unsafe potable water. The U.S. Public Health Service drinking water standards indicate that a 2% concentration of seawater in fresh groundwater will make the water source unusable. Above this level, the water is considered to be contaminated and is no longer safe for public supply purposes (USGS, 2000).

Potential Environmental Impact: Concerning the environment, as sea level rises and shorelines recede landward, saltwater intrusion into coastal surficial aquifers will increase. Saltwater intrusion is the shoreward movement of water from the ocean into confined or unconfined coastal aquifers and the subsequent displacement of freshwater from these aquifers (USGS, 2000). Communities that draw water from surficial aquifers in various parts of Delaware have already experienced problems with saltwater intrusion from the sea due to excessive withdrawals. Sea level rise will exacerbate these problems. The "salt front" of the tidal saltwater wedge in coastal rivers also will move further upstream with the potential to affect both surface water intakes and well fields in aquifers that are recharged by river water (Deyle, Bailey, & Matheny, 2007).

Services

Adult & Child Care Facilities

Adult care facilities, such as nursing homes and assisted living facilities provide temporary or long-term, non-medical residential care services for adults who are unable to live independently. Resident dependence may be the result of physical or other limitations associated with age, physical or mental disabilities or other factors. Most residents of adult care facilities are in need of supervision and personal care services necessary to enable the resident to maintain good personal health and to carry out the basic activities of daily living (New York State, 2005).

Child care facilities are licensed day care centers that provide care for children typically under the age of 13. Day care is typically an ongoing service during specific periods, such as the parents' time at work.

Adult and child care facilities that lie in the path of sea level rise may be adversely impacted. Facilities may initially be subject to intermittent flooding during lunar high tides. This may cause short-term operational and access problems. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of adult and child care facilities to future sea level rise was assessed by using GIS point layers obtained from the University of Delaware's Center for Applied Demography and Survey Research. The layers marked the locations of facilities throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a facility is within an area that is potentially exposed to sea level rise and should not be used to determine if a facility will be able to function. To fully assess the impact sea level rise will have on adult and child care facilities, additional criteria will be needed including: surrounding road elevations to determine accessibility; floor and critical equipment elevations; facility property layout to determine areas of use and emergency exit locations; and facility use criteria (age, number, mobility of users).

Statewide, only one adult care facility is within an area that could be inundated by 1.5 meters of sea level rise, representing 1% of the facilities in the state (Table 63). The facility is a nursing home located in the Governor Bacon Health Center, near Delaware City in New Castle County.

Table 63 - Number of Adult Care Facilities Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	81	0	0	1	0%	0%	1%
New Castle	50	0	0	1	0%	0%	2%
Kent	11	0	0	0	0%	0%	0%
Sussex	20	0	0	0	0%	0%	0%

Source: UofD – CADSR, Current Adult Care Facilities, unpublished.

Public Safety and Infrastructure

Statewide, nine child care facilities are within an area that could be inundated by 1.5 meters of sea level rise, representing 1% of the facilities in the state (Table 64). Sussex County has the highest number of facilities at risk, with 4 buildings being located within a mapped sea level rise area. Kent County is projected to have the least impact from sea level rise with only 1 child care facility being exposed at the 1.5 meter scenario. The only county to have child care facilities potentially exposed to sea level rise at the 0.5 and 1.0 meter scenarios is Sussex County.

Table 64 - Number of Child Care Facilities Exposed to sea level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	1,532	2	2	9	< 1%	< 1%	1%
New Castle	932	0	0	4	0%	0%	< 1%
Kent	297	0	0	1	0%	0%	< 1%
Sussex	303	2	2	4	1%	1%	1%

Source: UofD – CADSR, Current Day Care Centers, unpublished.

Potential Economic Impact: Adult and child care facility owners may need to make repairs to maintain accessibility. Also, costs for adult and child care services could increase if facilities within the sea level rise areas are forced to close. The result would be greater demand at other facilities that are not threatened by inundation.

Potential Social Impact: Socially, limited or changed functionality of adult and child care facilities could mean longer commutes for family members and less convenient care services.

Potential Environmental Impact: Environmental impacts will be limited.

Cemeteries

A cemetery is a land area that has been specifically designated as a burial ground for the remains of deceased individuals. The remains may be interred in a grave, a tomb, an above-ground grave, or a mausoleum. This resource does not include archeological sites or privately owned family plots.

Cemeteries that lie in the path of sea level rise may be adversely impacted. Sites may initially be subject to intermittent flooding during lunar high tides. This may cause short-term operational and access problems. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation or site movement will likely be required to maintain full functionality.

Exposure to Sea Level Rise: Exposure of cemeteries to future sea level rise was assessed by using GIS point layers obtained from the United States Geologic Survey's Geographic Names Information System. The layers marked the locations of cemeteries throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a cemetery is within an area that is potentially exposed to sea level rise and should not be used to determine if a cemetery will be able to function. To fully assess the impact sea level rise will have on cemeteries, additional criteria will be needed including: soil type; layout of cemetery; type of burial and locations; and groundwater levels.

Statewide, three cemeteries are within an area that could be inundated by 1.5 meters of sea level rise, representing 4% of the cemeteries in the state (Table 65). The only county in the state that has cemeteries potentially exposed to sea level rise is Sussex County.

Table 65 - Number of Cemeteries Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	82	2	2	3	2%	2%	4%
New Castle	23	0	0	0	0%	0%	0%
Kent	18	0	0	0	0%	0%	0%
Sussex	41	2	2	3	5%	5%	7%

Source: USGS, Geographic Names Information System, 2011-06-15

Potential Economic Impact: Limited or changed functionality of cemeteries may incur added expenses to reinter bodies. There are significant costs also associated with moving cemeteries to better situated sites. Another consideration is that previously sold plots may have to be refunded if a cemetery becomes permanently inundated.

Potential Social Impact: Many of Delaware's cemeteries are considered to be culturally important. Inundation of historic cemeteries will decrease the opportunity for people to learn about historical figures and Delaware's cultural heritage. Also changed functionality of cemeteries may impact the ability of relatives to visit gravesites.

Potential Environmental Impact: Concerning the environment, limited or changed functionality of cemeteries due to rising groundwater or inundation may leach substances from older unsealed coffins. Inundation of cemeteries may result in the release of lead and other toxins that are used in burial materials contaminating surrounding natural habitats and water sources.

Private & Public Schools

A private school is any institution for which the facilities are not provided by the federal, state, or local government. The majority of private schools in Delaware are operated by religious institutions and organizations. Funding is generally provided through student tuition, endowments, scholarship funds, and donations and grants from sponsoring organizations. Private schools typically provide education from kindergarten through 12th grade.

A public school is an institution that is administered by the local, state, or federal government. School funding is provided through taxation and school performance is monitored by the Delaware Department of Education. The public school system provides education from kindergarten through 12th grade. The schools are structured as elementary schools, middle schools, and high schools.

Public Safety and Infrastructure

Schools that lie in the path of sea level rise may be adversely impacted. Facilities may initially be subject to intermittent flooding during lunar high tides. This may cause short-term operational and access problems. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality. The statewide exposure of schools is relatively minor with only 1 private school and no public schools projected to be impacted by sea level rise. Based on this small exposure, Delaware is likely to be resilient to any changes.

Exposure to Sea Level Rise: Exposure of private and public schools to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Education. The layers marked the locations of schools throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a school is within an area that is potentially exposed to sea level rise and should not be used to determine if a school will be able to function. To fully assess the impact sea level rise will have on private and public schools, additional criteria will be needed including: floor and critical equipment elevations; facility property layout to determine areas of outdoor use and emergency egress; facility use criteria (age, number, mobility of users); and surrounding road elevations to determine access.

Only 1 school (including both private and public) is projected to be impacted by sea level rise in Delaware. The school is St. Peters, located in the City of New Castle, and will be potentially exposed at the 1.0 meter scenario. This one school accounts for 1% of the private schools in both New Castle County and the entire state (Table 66).

Table 66 - Number of Private Schools Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	149	0	1	1	0%	1%	1%
New Castle	107	0	1	1	0%	1%	1%
Kent	25	0	0	0	0%	0%	0%
Sussex	17	0	0	0	0%	0%	0%

Source: Delaware Department of Education, Delaware Private School Layer, 9-29-201

Table 67 - Number of Public Schools Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	252	0	0	0	0%	0%	0%
New Castle	136	0	0	0	0%	0%	0%
Kent	55	0	0	0	0%	0%	0%
Sussex	61	0	0	0	0%	0%	0%

Source: Delaware Department of Education, Delaware Public School Layer, 9-29-2010

Potential Economic Impact: Inundation resulting from sea level rise may increase the costs and expenses to maintain the impacted schools. Also, missed school days, as a result of access issues, could impact the guardians of the students by increasing the need to find alternative supervision.

Potential Social Impact: Inundation of schools resulting from sea level rise may impact the safety and learning environment of the students. Also, missed school days, as a result of access issues, could impact the guardians of students by increasing the need to finder alternative supervision.

Potential Environmental Impact: Inundation of schools resulting from sea level rise may impact the environment by allowing more pollutants to be emitted from vehicles due to longer travel times needed to reach alternate facilities.

Industrial

Brownfields

Brownfields are a subset of SIRS (Site Investigation and Remediation Section) contaminated sites. A Brownfield is defined as "any vacant, abandoned, or underutilized real property, the development or redevelopment of which is hindered by the reasonably held belief that the real property may be environmentally contaminated."[7 Del. C. §9102(3)]. The majority of brownfield sites are associated with former industrial or commercial facilities, such as gas stations, factories, and salvage yards, and are usually located in a community's commercial zone. Many brownfields in the City of Wilmington represent wetlands or subaqueous lands filled with industrial wastes that contain hazardous substances, as well as commercial and residential refuse. Brownfield sites may contain hazardous wastes that are dangerous or potentially harmful to human health and the environment. Contaminants may be found in a solid, liquid, or gaseous form contained in discarded commercial products, waste spill residues, or by-products of manufacturing processes. Contamination may be present in surface and subsurface soils, groundwater, surface water, and sediments.

Brownfields that lie in the path of sea level rise may be adversely affected. Sites may initially be subject to intermittent flooding from lunar high tides. This may cause short-term access problems as well as flood damage if sites are not adequately protected. However, as sea levels continue to rise; the problem will become more chronic. Depending on the site, contaminants could be released into the water column, change form (reduced vs. oxidized, solid and immobile vs. dissolved and mobile), and lead to potential groundwater contamination.

Exposure to Sea Level Rise: Exposure of brownfield sites to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of brownfields, registered in the State Brownfield Program, throughout Delaware. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a site is within an area that is potentially exposed to sea level rise and should not be used to determine if a site will function or release contaminants. To fully assess the impact sea level rise will have on brownfields, additional criteria will need to be analyzed including: contaminants that are still present at the site; groundwater elevations at a given site; soil type and other geo-technical data; technical and economic feasibility of additional remediation; and proposed re-development use of a site.

Public Safety and Infrastructure

Statewide, 23 brownfield sites are within an area that could be fully or partially inundated by 1.0 meter of sea level rise, representing 17% of the brownfield sites in the state (Table 68). In New Castle County, nearly 30% of the county's brownfields will be potentially exposed to sea level rise at the 1.5 meter scenario. Sites located in Kent County will experience no impacts while in Sussex County only one brownfield will be potentially affected by sea level rise. See Map Appendix for map.

Table 68 - Number of Brownfield Sites Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	139	12	23	35	9%	17%	25%
New Castle	114	11	22	34	10%	19%	30%
Kent	12	0	0	0	0%	0%	0%
Sussex	13	1	1	1	8%	8%	8%

Source: DNREC, Brownfields GIS Layer, 2010-10-27

Potential Economic Impact: When communities convert brownfield sites, such as parking lots or vacant properties, into vibrant mixed-use developments, they can strengthen their local tax base, concentrate growth, and reduce pressure to convert undeveloped land, potentially yielding significant air and water quality benefits. Redevelopment of brownfield sites removes environmental hazards from Delaware communities and provides new investment opportunities in areas already well served by infrastructure. New development and investment in these site locations can re-energize lagging commercial corridors, providing new stimulus to preserve traditional uses and promote recreational opportunities that strengthen the local economy (NOAA, 2011). If sea level rise changes the usefulness of brownfield sites, redevelopment, and the related income produced may be prevented, reducing tax revenues for coastal towns and economic development potential.

Potential Social Impact: Sea level rise may impede the remediation and redevelopment of brownfield sites within port and coastal communities. This would have a deleterious effect in social terms. The redevelopment of brownfield sites in these locations promotes eco-tourism and eco-friendly recreational activities. These include fishing, camping, picnicking and water related activities. Brownfield sites can serve as educational facilities as well, instructing youth and non-locals as to the qualities of the natural environment. Without the opportunity to redevelop these brownfields, these sites could remain blighted areas on the landscape possibly contributing to poverty, health problems, crime, and urban sprawl in communities impacted by sea level rise. Many brownfield sites are near or adjacent to low-income communities. Sea level rise may prevent site cleanup or result in increased contamination in the community, representing a significant social and environmental justice issue.

Potential Environmental Impact: Inundation may allow above-ground contaminants to dissolve in the surface water and then seep into the soil. In a brownfield site, water is most often the media that displaces hazardous chemicals. Since saltwater is heavier than freshwater, it has a greater potential to displace contaminated groundwater plumes, pushing non-aqueous contaminants that are less dense than water upward to ground level. Sea level rise, especially saltwater intrusion, will increase this factor. Depending on the geological characteristics of a site, the direction of plume migration may be difficult to predict without a comprehensive geophysical analysis (Barnett, 2010).

Coastal communities can serve as stewards of natural resources and are better positioned to understand the ecological balance of lands comprising the public trust. These communities often share insights and knowledge of local habitats. Additionally, the changed functionality and hydrologic conditions of brownfield sites may impact the environment by allowing contaminants to escape into the surrounding media. Contaminated runoff may have a negative impact on neighboring or downstream natural habitats and wildlife species.

Landfills & Salvage Yards

A landfill is defined as: "A natural topographic depression and/or man-made excavation and/or diked area, formed primarily of earthen materials, which has been lined with man-made and/or natural materials or remains unlined and which is designed to hold an accumulation of solid wastes." State of Delaware Regulations Governing Solid Waste 1301:3.0

Sites included in this assessment range from state permitted landfills operated by major companies such as NRG, Waste Management and Delaware Solid Waste Authority (DSWA) to small privately or municipally owned sites, some of which are no longer in operation. Many of the smaller landfills and salvage yards are not permitted and are regulated by the DNREC Site Investigation & Remediation Section (SIRS).

The major potential effects of sea level rise on landfills and salvage yards are inundation, waste solution migration, physical erosion, and saltwater intrusion. Sites may initially be subject to intermittent flooding from lunar high tides, which may cause erosion of berms resulting in a release of contaminants. As sea levels continue to rise, inundation will become more chronic and saltwater intrusion of groundwater may occur. Both may result in structural instability and contaminant release. However, the severity of the effects of inundation is dependent on many specific factors, so this issue needs to be evaluated on a site-specific basis.

Exposure to Sea Level Rise: Exposure to landfills and salvage yards to future sea level rise was assessed by using GIS point and polygon layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of landfills and salvage yards throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a site is within an area that is potentially exposed to sea level rise and should not be used to determine if a site will be able to function. To fully assess the impact sea level rise will have on landfills and salvage yards, additional criteria will be needed including: surrounding soil type; landfill construction including liner and cap material; status (i.e. active or capped); layout of facility including storage areas and work areas; and materials stored on-site; groundwater elevations.

Currently most of Delaware's permitted landfills are not anticipated to experience significant impacts from sea level rise. Some along water bodies could require engineering controls such as heightened barrier walls to combat storm surges, or a groundwater extraction system to prevent groundwater from coming in direct contact with the waste mass, if there was significant risk to human health or the environment to justify such measures. However, many of the non-permitted landfills/dump sites and salvage yards that have been closed are located in areas that are vulnerable to the future impacts of sea level rise.

Public Safety and Infrastructure

The following tables represent both state permitted landfills and small landfills regulated by SIRS. Statewide, approximately 18% of landfills are within the 1.0 meter scenario (Table 69), however, only 2% of the total landfill acreage will be possibly impacted (Table 70). In New Castle and Kent Counties, approximately 1% to 4% of the designated landfill areas will be potentially exposed to sea level rise. Sussex County is projected to have no impacts to landfills under any scenario. The greatest number of landfills impacted by sea level rise will occur in New Castle County with the potential for 16 landfill sites to be exposed. See Map Appendix for map.

Statewide, approximately 22% of salvage yards are within the 1.0 meter sea level rise scenario (Table 71). New Castle County is projected to have approximately 11% - 45% of the county's salvage yards potentially exposed to sea level rise. Sussex County will have no salvage yards exposed to sea level rise, while Kent County only has one salvage yard potentially exposed. See Map Appendix for map.

Table 69 - Number of Landfills Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	73	11	13	16	15%	18%	22%
New Castle	43	9	11	14	21%	26%	33%
Kent	9	2	2	2	22%	22%	22%
Sussex	21	0	0	0	0%	0%	0%

Table 70 - Acres of Landfills Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	943	7	16	26	1%	2%	3%
New Castle	726	7	14	23	1%	2%	3%
Kent	84	0.5	1	3	1%	2%	4%
Sussex	133	0	0	0	0%	0%	0%

Source: DNREC, Landfills GIS Layers, 2010-09-28

Table 71 - Number of salvage Yards Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	143	16	31	37	11%	22%	26%
New Castle	80	16	30	36	20%	38%	45%
Kent	19	0	1	1	0%	5%	5%
Sussex	44	0	0	0	0%	0%	0%

Source: DNREC, Salvage Yards GIS Layer, 2010-10-27

Potential Economic Impact: In some cases for operating landfills, engineering controls could be put in place to minimize or prevent impacts attributed to sea level rise. Installation and ongoing operation of engineering controls would be an additional cost to the landfill operators. This could lead to higher tipping fees at operating commercial or DSWA landfills, and shortfalls in post-closure financial assurance at closed landfills. Sea level rise may also reduce the safe holding capacity of certain sites leading to the need for acquisition of additional disposal sites. If a site is potentially exposed and engineering measures are not cost effective, the waste from these disposal areas will need to be removed and relocated to inland landfills, salvage yards, or recycled. The cost of relocation would range from thousands of dollars, to many millions depending upon the size of the site (Cwlth of Australia, 2009). Additionally, some closed landfill and salvage yard sites may have been owned or operated by municipalities or counties. Increased remedial or maintenance costs at these facilities will potentially add to the tax burden on residents.

Potential Social Impact: Many local landfills and salvage yards are located in places that were undesirable or not suitable for the then-recognized community needs and were cheap to procure. As a result, many older sites were placed in or adjoining flood prone and low-lying lands, including wetlands and subaqueous lands. A changed functionality of landfills or salvage yards due to sea level rise may impact the health and safety of local residents with release of waste material. Also, increased tipping fees and construction of new sites could increase rates for residents which tend to promote increases in illegal dumping.

Potential Environmental Impact: Inundation of a landfill or a salvage yard can result as sea levels rise. A ponding effect may cause increased leachate (liquid that moves through or drains from a landfill) production by adding water to the volume of wastes in the landfill or salvage yard and causing varying degrees of saturation (which may affect structural stability). Waste solution due to floodwater may result in increased leachate production and the potential migration of these wastes onto neighboring properties. Active sites that are not capped are particularly vulnerable (Flynn, Walesh, Titus, & Barth, 1984).

Waves can cause extensive erosion of any loose cover material. Erosion is particularly significant at landfills constructed so that the waste is above ground level. Salt water intrusion from sea level rise may affect landfills with clay caps and/or liners. In coastal areas, where the extent of saltwater intrusion inland may be significant, it is common to have shallow unconfined aquifers with depths that respond rapidly to fluctuations in sea level. Changing water tables could threaten wastes stored in surface impoundments, landfills, and salvage yards. Furthermore, saltwater can permeate clay liners that are impervious to freshwater. As a result, the risk of wastes leaching through the liners would increase (Flynn, Walesh, Titus, & Barth, 1984).

It is difficult to specify the types of materials disposed into landfills and salvage yards or the quantity that may be released back into the environment by sea level rise. Most disposal sites contain quantities of petroleum products, demolition waste, asbestos, pesticides, plastics, and heavy metals fixed into the soil/waste matrix (Cwlth of Australia, 2009). If these materials were released back into the environment it would constitute a significant environmental hazard. However, the potential for increased release of contaminants is site-specific and requires evaluation of each facility individually.

Public Safety and Infrastructure

DNREC Site Investigation & Remediation Section (SIRS) Contaminated Sites

The DNREC Site Investigation and Restoration Section (SIRS) is responsible for the identification, evaluation, and remediation of sites within the state that have had releases of hazardous substances. A hazardous substance, as defined by the Delaware Hazardous Substance Cleanup Act and Federal Regulations, is any compound that presents a risk to the public health, welfare, or the environment.

A hazardous substance may be a solid, liquid, or gas, and may be radioactive, flammable, explosive, toxic, or corrosive. Hazardous substances also include substances that can be biohazards, oxidizers, or irritants.

A SIRS site is any location which has been identified by DNREC Site Investigation and Remediation Section where a hazardous substance has or may have been released that can have the potential to harm humans, animals, or the environment. Sites vary in origin, size, and the toxicity and bioavailability of the contaminants present. Accordingly, the hazard levels posed by unremediated sites also vary widely. In order to protect the public from the potential environmental and health results of hazardous substances, government agencies at all levels are required to expend resources on moving, mitigating, or protecting these sites.

The major impacts of sea level rise on SIRS sites are erosion, inundation, waste solution (leachate) migration, saltwater intrusion, and in the worst cases, potential damage to remedial structures, e.g., dikes, bulkheads, caps, liners, and leachate control systems through erosion, flooding, or wave action. Sites may initially be subject to intermittent flooding from lunar high tides, which may cause an increased rate of release of contaminants. As sea levels continue to rise, inundation will become more chronic and saltwater intrusion of groundwater may occur increasing the potential for waste solution migration.

Exposure to Sea Level Rise: Exposure of SIRS sites to future sea level rise was assessed by using GIS point and polygon layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of SIRS sites throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether a site is within an area that is potentially exposed to sea level rise and should not be used to determine if a site will be able to function. To fully assess the impact sea level rise will have on SIRS sites, additional criteria will be needed including: surrounding soil type; site construction including liner and cap material; remediation status and methods; contaminants present at the site; materials stored on-site; and groundwater hydrology.

Statewide, approximately 39% of SIRS sites are within the 1.0 meter sea level rise scenario (Table 73) which comes to a total of nearly 30,200 acres that are potentially exposed (Table 72). In New Castle County, 285 SIRS sites are within the 1.5 meter scenario (Table 73), however only 27% of the total acreage of SIRS sites will be potentially exposed to sea level rise. Kent County is projected to have the greatest amount of acreage impacted with approximately 67% - 80% acres exposed (Table 72) on 16 – 21 SIRS sites. Fifty sites in Sussex County are within the 1.5 meter scenario with 5,827 acres potentially inundated by sea level rise. See Map Appendix for map.

Table 72 - Acres of SIRS Sites Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	60,088	24,586	30,202	32,669	41%	50%	54%
New Castle	20,148	3,021	4,487	5,487	15%	22%	27%
Kent	26,816	17,909	20,750	21,356	67%	77%	80%
Sussex	13,125	3,656	4,966	5,827	28%	38%	44%

Table 73 - Number of SIRS Sites Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	785	262	308	345	33%	39%	44%
New Castle	543	213	252	285	39%	46%	52%
Kent	103	16	20	21	16%	19%	20%
Sussex	139	41	45	50	29%	32%	36%

Source: DNREC – SIRS Investigation and Remediation Database, unpublished.

Potential Economic Impact: Reduced functionality of remedial measures DNREC SIRS Contaminated Sites may increase the remediation costs and influence the type of practices that are viable. If sea level rise changes the functionality of these sites, any redevelopment and the related income that would be produced may be unobtainable, thereby affecting tax revenues for coastal towns. If a site is potentially exposed and engineering measures are not cost effective, the waste and contaminants from these sites will need to be removed and relocated inland adding to the cleanup and maintenance costs.

Potential Social Impact: Socially, inundation of DNREC SIRS Contaminated Sites may threaten the health and safety of the neighboring public due to the release of hazardous substances. Without the opportunity to redevelop, these sites will remain unusable and unproductive, possibly raising concerns about poverty, health, crime, and urban sprawl in communities subject to sea level rise. Many SIRS sites are near or adjacent to low-income communities. Sea level rise may make site cleanup more expensive, less feasible, or impair the ability to control contamination in the community, representing a significant social and environmental justice issue.

Potential Environmental Impact: Environmentally, inundation or saltwater intrusion of DNREC SIRS contaminated sites may affect surrounding areas by increasing the potential for movement of hazardous substances. This may also have an influence on the effectiveness of current remedial practices. Some remediation sites incorporate or are associated with constructed wetlands, re-vegetated areas, or other mitigation/restoration projects. The usefulness of these projects will likely be impaired or lost along with their environmental benefits if sites are inundated or even occasionally exposed to flooding.

Increased risk from storms is an important factor on SIRS sites. A rise in sea level would bring new sites into floodplains and result in more severe flood levels for those already in floodplains. Furthermore, the risks from damaging waves would increase as deeper water will allow these waves to penetrate further inland (Flynn, Walesh, Titus, & Barth, 1984).

In a SIRS site, water is most often the media that displaces hazardous substances. Since saltwater is heavier than freshwater, it has a greater potential to displace contaminated groundwater plumes, pushing wastes upward to ground level. Sea level rise, especially saltwater intrusion, will increase this factor. Depending on the geological characteristics of a site, the direction of plume migration may be difficult to predict without a comprehensive geophysical analysis (Barnett, 2010).

Underground Storage Tanks (UST) & Leaking Underground Storage Tanks (LUST)

Underground storage tanks (UST) systems are tanks including connected underground pipes, which are used to contain an accumulation of regulated substances, and the volume is 10% or more beneath the surface of the ground. Septic tanks, regulated pipelines, surface impoundments, storm or waste water collection systems, and tanks in an underground area such as a basement are not included as an UST. A UST facility may consist of a property containing one or more USTs.

Leaking underground storage tanks (LUST) are underground storage tanks that have had a confirmed release of a regulated substance to the environment. Typically if a LUST is found, the Delaware Department of Natural Resources and Environmental Control requires the owner/operator to remove the tank and then holds the responsible parties accountable for performing further corrective actions. Once a release has been confirmed the DNREC Tank Management Section refers to the property as a LUST site. It is important to note that the same property can have multiple confirmed releases that require a cleanup over several years.

UST facilities and LUST sites that lie in the path of sea level rise may be adversely affected. Sites may initially be subject to intermittent flooding from lunar high tides resulting in the corrosion of tanks and the movement of leaking contaminants. This may cause short-term functionality problems as well as flood damage if sites are not adequately protected. However, as sea levels continue to rise; the problem will become more chronic, meaning adaptation will likely be required to maintain full functionality.

It is worth noting that UST regulation excludes smaller tanks such as those used for residences. It has not been determined how many home fuel oil or propane USTs may exist in the state and in what areas. Because residential USTs are not regulated, these tanks may be less rigorously maintained and inspected than regulated USTs and may actually have a higher rate of deterioration or failure.

Exposure to Sea Level Rise: Exposure of UST facilities and LUST sites to future sea level rise was assessed by using GIS point layers obtained from the Delaware Department of Natural Resource and Environmental Control. The layers marked the locations of UST facilities and LUST sites throughout the state. The data was analyzed with respect to the future sea level rise inundation scenarios.

It is important to note that this simple assessment tells us only whether an underground storage tank facility is within an area that is potentially exposed to sea level rise and should not be used to determine if a site will be able to function. To fully assess the impact sea level rise will have on UST facilities and LUST sites, additional criteria will be needed including: material stored in tank; volume of tank and pipes; construction of tank and pipes; connecting pipe network; surrounding soil type; floatation potential of tank and pipes; and groundwater elevations to determine pre-inundation effects. Moreover, UST sites in coastal or other low-lying areas may already be in contact with groundwater. If groundwater rises due to SLR, USTs could be affected by saltwater intrusion even if the site surface is not inundated.

Statewide, approximately 6% of UST facilities are within the 1.5 meter sea level rise scenario (Table 74). In New Castle and Kent County, nearly 3% of each county's UST facilities will be potentially exposed to sea level rise at the 1.0 meter scenario. Sussex County is projected to have the greatest number of tanks impacted with approximately 3%–11% of the county's UST facilities being exposed to sea level rise. See Map Appendix for map.

Table 74 - Number of UST Facilities Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	3601	65	145	208	2%	4%	6%
New Castle	2107	29	58	94	1%	3%	4%
Kent	639	9	16	17	1%	3%	3%
Sussex	855	27	71	97	3%	8%	11%

Source: DNREC Underground Storage Tanks, 2010-10-27.

Statewide, approximately 2% of LUST sites are within the 1.0 meter sea level rise scenario (Table 75). In all three counties, nearly 5% of LUST sites will be potentially exposed at the 1.5 meter scenario. Sussex County will not see any potential impacts until the 1.5 meter scenario. In New Castle County, potential exposure to sea level rise will occur at the 1.0 meter scenario while Kent County LUST sites will potentially be impacted at the 0.5 meter scenario. See Map Appendix for map.

Table 75 - Number of LUST Sites Exposed to Sea Level Rise

County	Total Number	Number Inundated			Percent of Total Inundated		
		0.5 m	1.0 m	1.5 m	0.5 m	1.0 m	1.5 m
State	166	2	3	8	1%	2%	5%
New Castle	61	0	1	3	0%	2%	5%
Kent	42	2	2	2	5%	5%	5%
Sussex	63	0	0	3	0%	0%	5%

Source: DNREC, Leaking Underground Storage Tanks, 2010-11-15.

Potential Economic Impact: Reduced function or increased rate of deterioration of underground storage tanks, resulting from sea level rise, may impact operating costs of facilities. Certain industries that are heavily dependent on underground storage tanks, such as gas stations, may have costly repairs or have to close or move operations. This would cause a loss of income for the facility owners. Concerning leaking underground storage tanks, sea level rise may allow contaminants to migrate from the surrounding soil to water resources increasing the cost and scope of site remediation.

Public Safety and Infrastructure

Potential Social Impact: Socially, changed functionality of underground storage tanks may impact the views and safety of neighboring properties by requiring surface placement of tanks. If sea level rise allows contaminants from leaking tanks to spread into surrounding areas, health and environmental impacts may also occur. Local communities may see a drop in property desirability due to contamination risk which would impact property values.

Potential Environmental Impact: Concerning the environment, underground storage tank facilities would have the options of either developing emergency plans to remove contents prior to flooding from sea level rise or incorporating structural engineering solutions. But, if these measures failed, the consequences could be serious. Tanks could overflow, containers could float or spill if not properly secured, structural damage to above-ground or partially above-ground tanks could be caused by floating debris or by increased hydrostatic pressure, and saltwater could corrode tanks and containers (Flynn, Walesh, Titus, & Barth, 1984). Spills, structural damage, and corrosion would increase the risk of soil and water contamination. Surrounding natural habitats would be exposed to hazardous substances causing harm to the local wildlife and plant community.

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Engaging the Public

Engaging the Public

Transparency and public involvement is important to the members of Sea Level Rise Advisory Committee. All Advisory Committee Meetings are posted to the State Meeting Calendar, are open to the public and time is reserved during each meeting for public comment. In addition, meeting agendas, meeting summaries, handouts, and presentations are publically accessible on the committee website at http://de.gov/slradvisorycommittee.

In order to obtain initial feedback on the work of the committee and its preliminary findings, a series of public engagement sessions was held during the month of November 2011. These sessions were held in the late afternoon through early evening to attempt to accommodate the schedules of as many interested citizens as possible. Engagement sessions were held at the following locations:

November 9: Middletown High School, Middletown
November 15: Georgetown Public Library, Georgetown
November 17: William Penn High School, New Castle
November 21: Kent County Administration Building, Dover
November 29: Cape Henlopen High School, Lewes

The engagement sessions were designed to be participatory and interactive. Sea Level Rise Advisory Committee members and Delaware Coastal Programs staff manned six different displays where participants could learn about sea level rise, its potential effects on Delaware and view maps of sea level rise inundation areas. An overview presentation was also given twice during each session. Participants provided feedback directly to advisory committee and staff members and/or filled out comment forms that asked participants the following questions:

For persons unable to attend in person, meeting display boards, presentations, and comment forms were available online on the Advisory Committee's website at http://de.gov/slradvisorycommittee. A total of 196 persons attended the five public engagement sessions. Forty-four comment forms were received. Comments received during this process were compiled for use by the Advisory Committee in the vulnerability assessment and are available in Appendix E.

In addition to these efforts, Delaware Coastal Programs staff have made themselves available for presentations to community groups about sea level rise, its effects, and the work of the Sea Level Rise Committee. More than a dozen such presentations were given during 2011 to a variety of audiences statewide, providing additional opportunities for citizens to become aware and involved with the work of the Advisory Committee.

The Sea Level Rise Advisory Committee will continue to work to engage the public in its decision-making process during the next phase of its work.

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Next Steps

Next Steps

The Sea Level Rise Vulnerability Assessment will be used by SLRAC and workgroup members to prioritize and inform the development of adaptation strategies. It may also be used to identify resources or geographic areas for which more in-depth, site-specific vulnerability assessments should be conducted.

Phase II of this project will develop an adaptation plan for the state. Adaptation is a term used to refer to any action that decreases vulnerability to new or emerging conditions, like sea level rise. There are three primary mechanisms for sea level rise adaptation: Protection; accommodation and retreat.

Protection strategies are actions that would keep rising water out of a specific area. Examples include construction of sea-walls, building up dunes and beaches through beach replenishment projects and shoreline armoring among others.

Accommodation strategies are actions that allow continued use of an area or structure without shoreline structures. Examples include drainage improvement projects, raising buildings on pilings and flood-proofing. Accommodation can also include changes in behavior like evacuating early from flood prone areas and changing driving patterns to avoid frequently flooded roadways.

Retreat strategies are actions that plan for the eventual removal of structures and uses from an area that will be subject to inundation from sea level rise. Examples include relocation of infrastructure and flood prone buildings inland, purchase of land or conservation easements in at-risk areas and siting new structures outside of vulnerable areas.

In order to employ any of these strategies, existing programs, plans, policies and funding mechanisms in the state must be investigated for their ability to support adaptation actions. Policy and funding gaps that could hinder adaptation must also be identified. The SLRAC will conduct this assessment with the assistance of subject matter experts and make recommendations for improvements. The SLRAC will not oversee the implementation of recommendations, however it is envisioned that a committed group will coordinate to obtain funding, resources and support to implement recommendations over several years.

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Works Cited

Works Cited

Awokuse, T., Ilvento, T., & Johnston, Z. (2010). The impact of agriculture on Delaware's Economy. University of Delaware, College of Ag. and Natural Resources. Newark, DE: Dept. of Food and Resource Economics.

Barlow, P. M. (2003). Ground Water in Freshwater-Saltwater Environments of the Atlantic Coast. Retrieved from USGS Circular 1262: http://pubs.usgs.gov/circ/2003/circ1262/#heading152526608

Barnett, A. (2010). Coastal Brownfields and Adaptation to Climate Change: Discussion on Potential hazards from Contaminated Groundwater Displacement Due to Saltwater Intrusion. University of Washington, School of Marine Affairs.

Bear, J., Cheng, A. H., Sorek, S., Ouazar, D., & Herrera, I. (1999). Seawater Intrusion in Coastal Aquifers: concepts, methods, and practices. Kluwer Academic Publishers.

Bureau of Labor Statistics. (2010). Occupational employment statistics. Retrieved from http://www.bls.gov/oes/current/oes de.htm#00-0000

Bushek, D., Quirk, T., & Philipp, K. (2010). Appendix F: Tidal Wetlands Case Study. In D. Kreeger, J. Adkins, P. Cole, R. Najjar, V. D, P. Conolly, et al., Climate Change and the Delaware Estuary. Wilmington: Partnership for the Delaware Estuary.

Buzzards Bay National Estuary Program. (1991). Action Plan: managing on-site wastewater disposal systems.

Carey, W. L. (1996). Transgression of Delaware's finging tidal salt marshes: surficial morphology, subsurface stratigraphy, vertical accretion rates, and geometry of adjacent and antecedent surfaces. Lewes, DE: University of Delaware-College of Marine Studies.

Caudill, J., & Henderson, E. (2005). Banking on Nature 2004: The economic benefits to local communities of National Wildlife Refuge visitation. Washington DC: Div. of Economics - USFWS.

CCSP. (2008). Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I. In M. J. Savonis, V. R. Burkett, & J. R. Potter (Ed.), A Report by the US Climate Change Science Program and the Subcommittee on Global Change Research (p. 445). Washington DC: US Dept of Transportation.

CCSP. (2009). Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region. In J. G. Titus, K. E. Anderson, D. R. Cahoon, D. B. Gesch, D. B. Gill, B. T. Gutierrez, et al., Final Report—Synthesis and Assessment Product 4.1. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research (pp. 11-24). Washington DC: U.S. Environmental Protection Agency.

Center for Applied Demography and Survey research. (2012). TBD. Newark, DE: University of Delaware.

Clough, J. S., & Larson, E. C. (2010). Application of the Ses-level Affecting Marshes Model (SLAMM 6) to Bombay Hook NWR. Dr. Brian Czech, Warren Pinnacle Consulting, Inc. Arlington, VA: US Fish and Wildlife Service - Conservation Biology Program.

Committee on Environment and Natural Resources. (2008). Scientific Assessment of the Effects of Global Change on the United States.

Condliffe, S. (2002). Economic Impact of Motiva Enterprises LLC Delaware City Refinery. Retrieved from Uniiv. of Delaware - Center for Applied Demography and Survey Research: http://www.cadsr.udel.edu

Cutter, S. L., Bryan, B. J., & Shirley, L. W. (2003). Scial Vulnernability to Environmental Hazards. Social Science Quarterly, 84(2), 242-261.

Cwlth of Australia. (2009). Climate Change Risks to Australia's Coast: a first pass national assessment. The Commonwealth of Australia, Dept. of Climate Change.

DEDO. (2008, 02 01). Tourism Economic Impact Reports. Delaware Tourism Satellite Account-February 2008. Retrieved from Delaware Economic Development Office: http://dedo.delaware.gov/information/tourism/Delaware-TSA-final Feb2008.pdf

DEDO. (2012). Value of Tourism in Delaware. Retrieved from Delaware Economic Development Office: http:www.visitdelaware.com/includes/content/images/MEDIA/docs/The-Value-of-Tourism-2010-final-9.30.11-w-seasonal-homes.pdf

Delaware Bay Beach Work Group. (2011, 02 01). Delaware Bay Beach Workgroup. Retrieved 02 23, 2012, from DNREC : Division of Watershed Stewardship : Shoreline and Waterway Management: http://www.dnrec.delaware.gov/swc/Shoreline/Documents/DE%20Bay%20Beach%20Workgroup/Recommendations%20of%20the%20De%20Bay%20Beach%20Work%20Group.pdf

Delaware Forest Service. (2010). Delaware forest resource assessment. Dover, DE: Delaware Department of Agriculture.

Delaware General Assembly. (2009, May 26). Title 7 Natural Resources and Environmental Control 7500 Wetlands and Subaqueous Lands. Retrieved May 2011, from Delaware Regulations Administrative Code: http://regulations.delaware.gov/AdminCode/title7/7000/7500/7502.shtml

Delaware Geologic Survey. (n.d.). Hydrogeologic Resources for Delaware. Retrieved from DGS: http://www.dgs.udel.edu/water-resources

Delaware Population Consortium. (2010). Annual Population Projections. Retrieved 06 06, 2011, from http://128.175.63.72/projects/DOCUMENTS/DPC2010.pdf

Department of Natural Resources and Environmental Control. (2011). What good are Wetlands? Retrieved May 2011, from Wetland Values: http://www.dnrec.delaware.gov/Admin/DelawareWetlands/Pages/Wetlandvalues.aspx

Deyle, R., Bailey, K., & Matheny, A. (2007). Adaptive Responsive Planning to Sea Level Rise in Florida and Implications for Comprehensive and Public-Facilities Planning. Tallahassee: Florida State Univ. - Dept of Urban and Regional Planning.

DNREC Division of Water Resources. (2011). What is Regulated and Where is it Regulated? Retrieved May 2011, from Wetlands and Subaqueous Land Section: http://www.wr.dnrec.delaware.gov/Information/regulations/Pages/WLSL%20What%27s%20Regulated.aspx

DNREC Sea Level Rise Technical Workgroup. (2009). Sea Level Rise. Retrieved from DNREC: http://de.gov/coastal/Documents/SeaLevelRise/final%20and%20Signed%20SLR%20scenarios.pdf

DNREC-Div. of Fish and Wildlife. (2006). Delaware Wildlife Action Plan. Dover, DE: Department of Natural Resources and Environmental Control.

EPA. (2011). Hazardous Waste. Retrieved from US Environmental Protection Agency: http://www.epa.gov/waste/hazard/index.htm

Flynn, T., Walesh, S., Titus, J., & Barth, M. (1984). Implications of Sea Level Rise for Hazardous Waste Sites in Coastal Floodplains. Washington DC: US Environmental Protection Agency.

Gill, S. K., Wright, R., Titus, J. G., Kafalenos, R., & Wright, K. (2009). Population, Land Use and Infrastructre. In J. G. Titus, K. E. Anderson, D. R. Cahoon, D. B. Gesch, S. K. Gill, B. T. Gutierrez, et al., Coastal Sensitivity to Sea Level Rise: A focus on the Mid-Atlantic Region (pp. 105-116). Washington DC: US Environmental Protection Agency.

Works Cited

Greenstone Engineering. (2011). Dike Maintenance and Emergency Planning Report for the City of New Castle: Coastal Flood Control Dikes. Retrieved from DNREC - Delaware Coastal Programs: http://de.gov/coastal/Pages/CityofNewCastle.aspx

Industrial Economics. (2010). Appendix G: Application of Ecological and Economic Models of the Impacts of Sea Level Rise to the Delaware Estuary. In D. Kreeger, J. Adkins, P. Cole, R. Najjar, V. D, P. Conolly, et al., Climate Change and the Delaware Estuary. Wilmington: Partnership for the Delaware Estuary.

IPCC. (2001). Global Climate Projections. In S. S. al. (Ed.), Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the IPCC (pp. 749-845). Cambridge, UK: Cambridge University Press.

IPCC. (2001). Observations: Oceanic Climate Change and Sea Level. In S. S. al. (Ed.), Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the IPCC (pp. 387-432). Cambridge, UK: Cambridge University Press.

IPCC. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the International Panel on Climate Change. (M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson, Eds.) Cambridge, UK: Cambridge University Press.

Kane County. (2005). Stormwater Management, Flood Information. Retrieved from Kane County, Illinois: http://www.co.kane.il.us/kcstorm/flood/health.htm

Kauffman, G., Homsey, A., Chatterson, S., McVey, E., & Mack, S. (2011). Socioeconomic Value of the Delaware Estuary Watershed. Newark: University of Delaware.

KCI Technologies. (2011). Town of Bowers beach final drainage report. Retrieved 10 2008, from Kent County Planning: http://www.co.kent.de.us/documents/AdoptedCompPlan-Full.pdf

Kirwan, M. L., & Guntenspergen, G. R. (2010). Limits on the adaptability of coastal marshes to rising sea level. Geophysical Research Letters, 23.

Koontz, L. (2010). Regional econonmic impacts of current and proposed management alternatives for Prime Hook NWR. Washington DC: US Geological Survey.

Kreeger, D., Adkins, J., Cole, P., Najjar, R., D, V., Conolly, P., et al. (2010). Climate Change and the Delaware Estuary: Three Case Studies in Vulnerability Assessment and Adaptation Planning. Wilmington: Partnership for the Delaware Estuary.

Laznik, J. (2012). Development of Datasets and local case studies in support of a sea level rise vulnerability assessment for Delaware. Newark, DE: University of Delaware.

Lee, B., Jones, D., & Peterson, H. (2005). Septic System Failure. West Lafayette, IN: Dept. of Agronomy and Dept of Agricultural and Biological Engineering. Purdue University.

Leonard, J. (2008). Wildlife Watching in the U.S.: The Economic Impacts on National and State Economies in 2006. Washington D.C.: US Fish and Wildlife Service.

Logan, J. A., Regniere, J., & Powell, J. A. (2003). Assessing the impact of global warming on forest pest dynamics. Forest Ecology and Management, 246(1), 130-137.

Mandelker, D. R., Payne, J. M., Salsich, P. W., & Stroud, N. E. (2008). Planning and Control of Land Development: Cases and Materials (7th Edition ed.). New York: Matthew Bender & Company, Inc.

Maryland DNR. (2008). Sea Level Rise: Technical Guidelines for Dorchester County. Annapolis, MD: Maryland Dept of Natural Resources, Coastal Zone Management Division.

Masters, J. P. (2011). Storm Surge Reduction by Wetlands. Retrieved May 2011, from Weather Underground: http://www.wunderground.com/hurricane/surge_wetlands.asp

McMahon, E. (2004). Better Models for development in Delaware: ideas for creating more livable and prosperouscommunities. Arlington: The Conservation Fund.

National Marine Fisheries Service. (2010). Fisheries Economics of the United States, 2009. Retrieved from https://www.st.nmfs.noaa.gov/st5/publication/index.html

New York State. (2005). About the Adult Care Facility Directory. Retrieved from New York State, Department of Health: http://www.health.ny.gov/facilities/adult care/about.htm

NOAA. (2011). Coastal and Waterfront Smart Growth. Retrieved from National Oceanic and Atmospheric Administration: http://coastalsmartgrowth.noaa.gov/elements/strengthen.html

NRCS. (n.d.). Retrieved from http://soils.usda.gov/technical/handbook/contents/part622.html

Port of Wilmington. (2006). Port of Wilmington. Retrieved from Diamond State Corporation: http://www.portofwilmington.com

Scarborough, R. (2009). Application of the Sea Level Affecting Marsh Model (SLAMM) using high resolution data at Prime Hook NWR. DNREC. Dover, DE: Delaware Coastal Programs.

State of New Jersey. (2007). Valuing New Jersey's Natural Capital: An assessment of the economic value of the State's resources. Trenton, NJ: New Jersey Department of Environmental Protection.

Tiner, R. W. (1985). Wetlands of Delaware. Newton Corner, MA and Dover, DE: USFWS and Delaware Department of Natural Resources and Environmental Control.

Tiner, R. W., Biddle, M. A., Jacobs, A. D., Rogerson, A. B., & McGuckin, K. G. (2011). Delaware Wetlands: Status and Changes from 1992-2007. A Cooperative National Wetlands Inventory Publication. Hadley, MA and Dover, DE: US Fish and Wildlife Service - Northeast Region and Delaware Dept. of Natural Resources and Environmental Control.

Titus, J. (2002). Does Sea Level Rise Matter to Transportation along the Atlantic Coast? In C. f. Forcasting, The Potential Impacts of Climate Change on Transportation. Washington DC: US Dept of Transportation.

Transportation Research Board. (2008). Potential Impacts of Climate Change on US Transportation. TRB Special Report 290. Washington DC: National Research Council of the National Acadamies.

U.S. Department of the Interior, F. a. (2006). 2006 National Survey of Fishting, Hunting and Wildlife Associated Recreation. Washington, DC.

United States Environmental Protection Agencey, & Delaware River Basin Commission. (1986). Greenhouse Effect, Sea Level Rise, and Salinity in the Delaware Estuary. Retrieved from http://www.epa.gov/climatechange/effects/downloads/delaware.pdf

US Census Bureau. (2012). American Fact Finder. Retrieved from http://factfinder2.census.gov/faces/nav/jsf/pages/index.html

US DOI-FWS and US DOC-Census Bureau. (2006). National Survey of Fishing, Hunting, and Wildlife-associated Recreation. Washington DC: GPO.

US EPA. (2003). Voluntary national guidelines for management of on-site and clustered (decentralized) wastewater treatment systems. Washington DC: US Environmental Protection Agency.

USDA. (2012). State Fact Sheets: Delaware. Retrieved 2012, from http://www.ers.usda.gov/StateFacts/DE.htm

Works Cited

USGS. (2000). Is Seawater Intrusion Affecting Groundwater on Lopez Island, Washington? Washington DC: United States Geologic Survey.

USGS. (2005). Effects of Spray-Irrigated Municipal Wastwater on a Small Watershed in Chester County, Pennsylvania. Retrieved from United States Geologic Survey: http://pubs/usgs.gov/fs/2005/3092/fs2005-3092.pdf

USGS. (2011). Wastewater Treatment Water Use. Retrieved from USGS Water Resources: http://ga.water.usgs.gov/edu/wuww.html

Virginia Institute of Marine Science. (2012). Dermo Fact Sheet. Retrieved 01 24, 2012, from VIMS-Virginia Institute of Marine Science: http://www.vims.edu/research/departments/eaah/programs/shellpath/Research/perkinsus_marinus/index.php

WILMAPCO. (2009). Environmental Justice: Transportation Equity Report. Newark: Wilmington Area Planning Council.

WILMAPCO. (2011). Sea-Level Rise A Transportation Vulnerability Assessment of the Wilmington, Delaware Region. Newark: Wilmington Area Planning Council.

WILMAPCO. (2011). Sea-level Rise: A Transportation Vulnerability Assessment of the Wilmgton, Delaware Region. Newark, DE: Willmington Area Planning Council.

WVU. (2012). National Environmental Services Center. Retrieved from West Virginia University: http://www.nesc.wvu.edu/subpages/septic.cfm

Coastal
Heritage

Appendix

A - Acronyms

CZA – Coastal Zone Act

DFS – Delaware Forestry Service

DNREC – Delaware Department of Natural Resources and Environmental Control

DCP – Delaware Coastal Programs

DelDOT – Delaware Department of Transportation

DRBC – Delaware River Basin Commission

DSWA – Delaware Solid Waste Authority

EPA – United States Environmental Protection Agency

FEMA – Federal Emergency Management Agency

GIS – Geographic Information Systems

HCC – Habitats of Conservation Concern

HSIP – Homeland Security Infrastructure Protection

IMPLAN – Impacts Analysis for Planning

IPCC – Intergovernmental Panel on Climate Change

LiDAR – Light Detection and Ranging

LMSL – Local Mean Sea Level

LUST – Leaking Underground Storage Tank

MHHW – Mean Higher High Water

NFIP – National Flood Insurance Program

NOAA – National Oceanic and Atmospheric Administration

NWR – National Wildlife Refuge

PDE – Partnership for the Delaware Estuary

SIRS – Site Investigation & Remediation Section

SLAMM – Sea Level Affecting Mashes Model

SLR – Sea Level Rise

SLRAC – Sea Level Rise Advisory Committee

SoVI – Social Vulnerability Index

UD – University of Delaware

USDA – United States Department of Agriculture

USFWS – United States Fish & Wildlife Service

USGS – United States Geologic Survey

UST – Underground Storage Tank

WILMAPCO – Wilmington Planning Area Council

B - Glossary

Adaptation – An action that can be taken to adjust to new or emerging conditions. With respect to sea level rise, adaptation can include a variety of actions including raising structures, building sea walls, restoring natural areas, relocating structures and avoiding investments in high risk areas.

Anadromous Fish – A fish species that is born in fresh water, spends most of its life in the ocean, and returns to fresh water to spawn. Examples would be salmon, striped bas, and sturgeon.

Bathtub Model – A water surface model that floods all land below a certain elevation, unless there is a structure that would block the tidal flow.

Biodiversity – The number and variety of organisms found within a specified geographic region.

Brownfield – Any vacant, abandoned, or underutilized real property the development or redevelopment of which is hindered by the reasonably held belief that the property may be environmentally contaminated.

Chronic – Persisting for a long time or constantly recurring.

Coastal Impoundment – A topographic depression, excavation, or diked area, primarily formed from earthen materials and designed to hold accumulated water and provide storm water control.

Conservation Easement – Legal agreement between a landowner and a land trust (or other organization) which places protective environmental restrictions on the property.

Corrosion – The gradual destruction of a material, usually metal, by a chemical reaction with the surrounding environment.

Domestic Well – A privately owned well that supplies groundwater for human consumption and other household uses.

Effluent – Liquid waste or sewage discharged into surface water or groundwater.

Environmental Justice – The fair treatment and meaningful involvement of people from all races, cultures, and incomes regarding the development of environmental laws, regulations, and policies.

Estuary – A partly enclosed coastal body of water with one or more rivers or streams flowing into it with a free connection to the open sea. Estuaries form a transition zone between river environments and ocean environments and are subject to both marine influences and riverine influences.

Eustatic Sea Level Rate – The worldwide change of sea level elevation with time. The changes are due to such causes as glacial melting or formation, thermal expansion or contraction of sea water, etc.

Exposure – Refers to the presence of people, livelihoods, environmental resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by sea level rise and which, thereby, are subject to potential future harm, loss, or damage.

Farmland of Statewide Importance – Land other than prime farmland with a good combination of physical and chemical characteristics for crop production.

B - Glossary

Feeder Road – A secondary road used to bring traffic to a major road or highway.

Functionality – Determines whether a resource can continue to meet its intended purpose.

Future Development Areas – Lands within the long-term growth plans (greater than five years) of county and municipal governments and/or are adjacent to already developed or developing areas.

Geographic Information System – A system of hardware and software used for the storage, retrieval, mapping, and analysis of geographic data.

Geomorphology – The scientific study of landforms and the processes that shape them.

Groundwater Recharge Area – The area where an aquifer is replenished from natural processes, such as the infiltration of rainfall and snowmelt or from human interventions, such as the use of storm water management systems.

Habitats of Conservation Concern – Types of environments (habitats) identified in the Delaware Wildlife Action Plan that are rare, sensitive to disturbance, have a high density of rare plants, or have special significance to the state.

Hydraulic – denoting a liquid moving in a confined space under pressure.

Hydrogeology/ Hydrogeological – Branch of geology that deals with the occurrence, distribution, and effect of groundwater.

Hydrology/Hydrological – Properties, distribution, and effects of water on the earth's surface, in the soil, and the atmosphere.

Local Mean Sea Level – The height of the ocean relative to land, measured hourly and averaged over a nineteen year period known as the National Tidal Datum Epoch.

Intermittent – Occurring at irregular intervals.

Inundation – Movement of coastal water over land as a result of sea level rise.

LiDAR (Light Detection and Ranging) – An optical remote sensing technology that can measure the distance to, or other properties of a target by illuminating the target with light, often using pulses from a laser.

Land Subsidence – The lowering of a portion of the earth's crust.

Mean Higher High Water – The long-term average of the higher of the daily high tides.

Mean Sea Level – The average level of the sea observed over a period of time and referenced to a water or land elevation benchmark. Tide gauges are frequently used to measure sea level.

Non-point Source Pollution – Pollution source that is not fixed or specific. Instead the source is mobile or widely scattered.

Preservation District – A voluntary agreement to use land only for agricultural purposes for at least a ten year period.

Prime Farmland – Land with the optimal combination of physical and chemical characteristics for crop production.

Public Well – A privately or publicly owned well that provides water to a public water system including: (1) community water systems, such as municipalities, mobile home parks, or nursing homes; (2) transient non-community water systems, such as campgrounds, motels, and gasoline stations; and (3) non-transient, non-community systems, such as schools, factories, and hospitals.

Remediation - The removal of pollution or contaminants from environmental media such as soil, groundwater, sediment, or surface water for the general protection of human health and the environment.

Saltwater Intrusion – Occurs in coastal freshwater aquifers when the different densities of both the saltwater and freshwater allow the ocean water to intrude into the freshwater aquifer due to its greater density.

Sea Level – The level of the sea after averaging out short-term variations due to wind and waves.

Sea Level Rise – long-term increases of mean sea level. At a coastal site, sea level rise can occur both as a consequence of worldwide increases in sea level due to an increased volume of water in the oceans and due to local sinking of land surfaces.

Social Vulnerability – The inability of people, organizations, and societies to withstand adverse impacts from multiple stressors to which they are exposed. A person's vulnerability to environmental hazards is determined by access to resources, diversity of income sources, and by the economic status of the person or household.

Storm Surge – The local change in the elevation of the ocean along a shore due to high winds and low atmospheric pressure experienced during a storm. The storm surge is measured by subtracting the astronomic tidal elevation from the total elevation. Storm surge can be potentially catastrophic, especially on low lying coasts with gently sloping offshore topography.

Tidal Prism – The difference between the mean high water volume and the mean low water volume in an estuary.

Tide Gauge – A water measurement device used to continuously record coastal sea level and referenced to an elevation benchmark.

Vulnerability – Susceptibility of a resource to negative impacts from sea level rise.

Wellhead – The principal source of a well or stream.

Wellhead Protection Area – The surface and subsurface area surrounding a water well or well-field, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water wells or well-fields.

C - Advisory Committee and Workgroup Members

Sea Level Rise Advisory Committee Members

Sarah Cooksey ..... Delaware Department of Natural Resources and Environmental Control
Richard Collins ..... Positive Growth Alliance
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Pam Thornburg-Bakerian ..... Delaware Farm Bureau
Robin Tyler ..... Delaware Department of Natural Resources and Environmental Control

D - Data layers requested and used in the Vulnerability Assessment

Public Safety and Infrastructure Layers Used in Analysis	Workgroup Requesting Data			Source Notes
	PS&I	S&E	NR	
Schools (K-16)	X			Del. Dept. of Education, Delaware Public School Layer, 9-29-2010
Fire and Rescue stations	X	X		TechniGraphics, Inc., Delaware Fire Stations 2008 Q1, 2008-04-02
Police stations	X	X		Department of Homeland Security (Technigraphics), Delaware Law Enforcement 2009 Q4, 20091218
Communication/cell towers	X	X		FCC, Cellular Tower Locations , 20030427
Roads	X	X		Del. Dept. of Transportation, Road Centerline File, 2008-06-01
Bridges	X	X		Del. Dept. of Transportation, Road Centerline File, 2008-06-01
Bus Routes	X			Del. Dept. of Transportation - DART, DTC TRAPESE Routes and Stops, 20101001
Airports	X			HSIP Freedom (Department of Homeland Security); Del. Dept. of Transportation - Aviation
Railroads - Stations/Lines/Holding areas	X			USGS, 7.5 minute Digital Line Graphs - Rail, 20100930; HSIP Freedom (Department of Homeland Security)
Ports and Ferry Terminals	X	X		DNREC - Office of the Secretary, Coastal Zone Heavy Industries, unpublished.
Sewer pump stations	X	X	X	Kent County Engineering, New Castle County Special Services and Sussex County GIS
Sewer lines	X	X	X	Kent County Engineering, New Castle County Special Services and Sussex County GIS
Waste Water Facilities	X	X	X	DNREC - Financial Assistance Branch (TetraTech), POWWTP, 1/11/2010 Kent County Engineering, New Castle County Special Services and Sussex County GIS
Septic Systems	X	X	X	DNREC, Delaware Septic Systems (last update 20101123), unpublished
Hospitals and medical facilities	X	X		DE Div. of Public Health (UofD - CADSR), Delaware Hospitals, 2011-05-31
Emergency Operation Centers	X	X		Delaware Emergency Management Agency, EOC shapefile, 2011-04-03 [edit by Delaware Coastal Programs]

Public Safety and Infrastructure Layers Used in Analysis	Workgroup Requesting Data			Source Notes
	PS&I	S&E	NR	
Evacuation Routes	X			Del. Dept. of Transportation Traffic Management Team (Edwards and Kelcey), 2007 Evacuation Routes, 2010-15-04
Pipelines	X			DOT-PHMSA-National Pipeline management System
Wells - domestic, public, irrigation, industrial	X	X		DNREC-Water Resources-Doug Rambo
Navigation Aids	X			HSIP Freedom (Department of Homeland Security)
Correctional Facilities	X			TechniGraphics, Inc., Delaware Correctional Institutions 2007 Q4, 2007-11-05
Day Care centers	X			UofD - CADSR, Current Day Care Centers, unpublished.
Senior Centers	X			Del. Div. of Public Health (UofD - CADSR)
Nursing Homes	X			Del. Div. of Public Health (UofD - CADSR)
Refineries	X	X		DNREC - Office of the Secretary, Coastal Zone Heavy Industrial Facilities (20110321), unpublished.
Factories	X	X		EPA, EPA Facilities Toxics Release Inventory, 20080212
Site Investigation and Restoration Section (superfund, HSCA)	X	X		DNREC - SIRS, Site Investigation and Remediation Database, unpublished.
Leaking Underground Storage Tanks	X			DNREC, Leaking Underground Storage Tanks, 2010-11-15
Underground Storage Tanks	X			DNREC, Underground Storage Tanks, 2010-10-27
Brownfields	X			DNREC, Brownfields GIS Layer, 2010-10-27
Salvage Yards	X			DNREC, Salvage Yards GIS Layer, 2010-10-27
Hazardous Waste Generator	X			DNREC, Hazardous Waste Generator GIS layer, 2010-11-16

D - Data layers requested and used in the Vulnerability Assessment

Public Safety and Infrastructure Layers Requested but not Used in Analysis	Workgroup Requesting Data			Source Notes
	PS&I	S&E	NR	
Emergency Shelters	X			Data unavailable for Public Use
Public Utilities	X	X		Unspecific request. Several specific utility data layers collected and listed elsewhere
Private Utilities	X	X		Unspecific request. Several specific utility data layers collected and listed elsewhere
Wind Generation	X			Data unavailable for Public Use
Combined Sewer Overflows	X			Data Incomplete
Spray irrigation fields	X			Data Unavailable in GIS format
Community treatment facilities	X			Data unavailable for public use
Telephone switching stations	X			Data unavailable for public use
Water Supply Intakes	X			Data unavailable for public use
DelDOT Maintenance Yards	X			Data Incomplete
School Bus Storage	X			Data Unavailable in GIS format
Emergency Shelters	X			Data unavailable for Public Use
Public Utilities	X	X		Unspecific request. Several specific utility data layers collected and listed elsewhere
Private Utilities	X	X		Unspecific request. Several specific utility data layers collected and listed elsewhere
Wind Generation	X			Data unavailable for Public Use
Combined Sewer Overflows	X			Data Incomplete

Society & Economy Layers Used in Assessment	Workgroup Requesting Data			Source Notes
	PS&I	S&E	NR	
Social Vulnerability Index		X		NOAA Coastal Services Center (2000 Census)
Housing Units -Housing Units in mobile homes, trailers, others		X		UD CADSR - 911 Addressing
Income - Median Household and Per Capita		X		2010 Census (UofD - CADSR)
Delaware Environmental Justice Communities		X		WILMAPCO (2000 Census)
Heavy Industrial Sites		X		DNREC-Coastal Zone Act permitted sites; DNREC Toxic Release Inventory
Land use/land cover		X		datamil.delaware.gov
Agriculture Preservation/Easements		X	X	Del. Dept. of Agriculture, State Ag Easements, 2010-09-17
State Planning Investment Layers		X	X	Delaware OSPC, Investment Levels, Delaware State Strategies for State Policies and Spending (2010), 2010-10-01
Historic and Cultural resources			X	Delaware State Historic Preservation Office, CRS Inventory, unpublished, and National Register Properties, SHPO
Residential Addresses		X		UD CADSR - 911 Addressing
Inundated State Landmass		X		USGS and Delaware Geologic Survey, State Outline (Area), 2007-04-01
Tourist Destinations	X	X		DNREC Facilities-parks, beaches - DE Division of Parks and Recreation
Commercial Buildings		X		County 911 Databases [digitized by UofD - CADSR]
Agriculture Data - acreage and crop/animal types and economic impact		X	X	Del. Dept. of Agriculture, Ed Ratledge-UD, DEDO, Conservation districts Productive Soils data from USDA, LandUse/LandCover
Agriculture facilities/infrastructure		X	X	Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19
Business Licenses		X		Delaware Division of Revenue, through University of Delaware CADSR

D - Data layers requested and used in the Vulnerability Assessment

Society & Economy Layers Requested but not Used in Assessment	Workgroup Requesting Data			Source Notes
	PS&I	S&E	NR	
Date structure was built		X		Data unavailable
Tax Ditches		X		Data available but later deemed not necessary for inclusion
Impermeable Surfaces		X	X	OSPC-OMB, 2007 Impervious Surface Data, 2008-05-18
Zoning		X		Statewide data not available.
Water Franchises		X		Data requested by later deemed not necessary for inclusion
Special Overlay Zones		X		Data requested by later deemed not necessary for inclusion
Floodplains		X		Not 'at-risk' per se. Information more suited to adaptation.
Maps where insurance is available		X		Data requested by later deemed not necessary for inclusion
Recurring Damage Claims		X		Data unavailable statewide
Rating Schedules		X		Data requested by later deemed not necessary for inclusion
"Pre-FIRM" maps		X		Data requested by later deemed not necessary for inclusion
Affordable Housing communities		X		Data unavailable statewide
Senior Housing		X		Data unavailable statewide
Manure Sheds		X		Data unavailable statewide
Buffer Regulations		X		Data unavailable statewide
Large Employers		X		Data requires analysis beyond scope of current project

Natural Resources Layers Used in Assessment	Workgroup Requesting Data			Source Notes
	PS&I	S&E	NR	
Wetlands			X	DNREC, De_Wetlands_20100901_PD6, 2010-09-01
State Protected Areas			X	DNREC - Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished
Recharge Areas			X	DNREC, Recharge Areas, 2010-10-27
Wellhead Protection Areas			X	Sources: DNREC, Statewide WHPA 2009, 2009-09-29
Natural Areas			X	DNREC - Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished
Habitats of Conservation Concern			X	DNREC - Natural Heritage Program, Habitats of Conservation Concern (2011), unpublished
Nature Preserves			X	DNREC Division of Parks and Recreation, Nature Preserves (2008), unpublished
Coastal Impoundments			X	Delaware Coastal Programs, Impoundments (2010), unpublished
Public Access Sites (ORI2009)			X	DNREC - Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished
Conservation Easements			X	DNREC Division of Parks and Recreation, Conservation Easements (2010), unpublished
Forests			X	Delaware Geographic Data Committee, 2007 Delaware Land Use and Land Cover, 2008-05-19
DNERR			X	Delaware Coastal Programs, DNERR Boundary (2010), unpublished
Wetlands			X	DNREC, De_Wetlands_20100901_PD6, 2010-09-01
State Protected Areas			X	DNREC - Parks and Recreation, Outdoor Recreation Inventory (2009), unpublished
Recharge Areas			X	DNREC, Recharge Areas, 2010-10-27
Wellhead Protection Areas			X	Sources: DNREC, Statewide WHPA 2009, 2009-09-29

D - Data layers requested and used in the Vulnerability Assessment

Natural Resources Layers Requested but not Used in Assessment	Workgroup Requesting Data			Source Notes
	PS&I	S&E	NR	
Depth to Water Table			X	Data requires analysis beyond scope of current project
Stormwater Management Structures			X	Data unavailable in GIS format
Salt Line/Salt water intrusion		X	X	Data requires analysis beyond scope of current project
Turbidity, nutrient changes, salinity			X	Data requires analysis beyond scope of current project
Head of tide			X	Data unavailable
Increased Extent of storm surges and habitat changes			X	Data requires analysis beyond scope of current project
Fisheries, EFH, nursery habitat			X	Data not at scale suitable for vulnerability assessment
Shellfish maps			X	Data requires analysis beyond scope of current project
Freshwater mussels			X	Data unavailable in GIS format
Site Specific species migration studies			X	Data requires analysis beyond scope of current project
Map physical barriers to wetland migration			X	Data requires analysis beyond scope of current project
Marsh Vulnerability Index			X	Data requires analysis beyond scope of current project
Model marsh response to SLR			X	Data requires analysis beyond scope of current project
Wetland to Forest migration maps from The Nature Conservancy			X	Data requires analysis beyond scope of current project
Economic Value of hunting and fishing			X	Data requires analysis beyond scope of current project
Depth to Water Table			X	Data requires analysis beyond scope of current project

E - Sea Level Rise Public Engagement Session Comments Received

The Delaware Sea Level Rise Advisory Committee hosted a series of five public engagement sessions in November 2012, as described in the Public Engagement Section. All comments received in writing or by phone in response to these sessions are below:

Do you have concerns about sea level rise not mentioned today that you would like the sea level rise advisory committee to consider? Please describe.

- Should have a chart that draws a month by month continuous curve of tide gauge data.
- Yes, the actual impacts on homes in the vulnerable areas. For instance, South Bethany is greatly affected by 0.5 meter SLR. Can we project when these areas are going to be impacted to the point that the homes will be unusable?
- This information needs to be shared with the local coastal communities in Sussex County so that they can plan their new construction projects with this information in mind. I believe that future construction should be severely restricted along the coast.
- It would be helpful to describe: (a) impacts of SLR on those living in high elevations (b) Delaware's SLR efforts vs. those of surrounding states, USA, global.
- Impacts on underground utilities and water supply.
- Require the deed or lease to describe possibility of flooding and make the realtor liable if they do not show it to the customer. Deny federal flood insurance to properties that flood repeatedly. Stop beach replenishment which is a waste of taxpayer money. At Fowlers Beach the replenished beach lasted only a month. Avoid waivers for waterfront lots. Bulkheads do not work well. Levees also have problems.
- More community outreach efforts – target city and town councils.
- No, DNREC is getting too powerful and is infringing on private citizens rights.
- I am not concerned at all about sea level rise.
- Impact of increased salinity on oysters?
- Impact at local levels/ municipalities
- No, covered well and everything was explained in detail. Everyone took time to answer questions about localized areas of concern. Good presentation and exhibits. Thank you.
- Pollutant transfer particularly from contaminated areas. This was alluded to in the presentation but should be addressed more specifically and would help underscore the public health impacts of SLR.
- I believe the projections concerning sea level rise may not be accurate. Temperatures have fluctuated over history. If the only reasonable action given the economy, is to move to higher ground. Humanity is not going to stop natural rhythms. Constructing dikes throughout the state is impractical. Regulations should prohibit development in at risk areas and all funding for stop gap measures, such as beach replenishment, should cease or be funded totally by the landowner.
- Not sure that there is a clear well articulated state policy or initiative.
- I am very concerned about (1) insuring the accuracy and integrity of the data upon which any SLR conclusions are based, and (2) the inevitable conflict between contemplated regulatory initiatives and existing property uses and private property rights.

E - Sea Level Rise Public Engagement Session Comments Received

- Please discuss in subsequent presentations the effects of the unexpected rapidly rising rate of the melting of surface ice in Greenland and Western Antarctica.
- You have a long awareness challenge! Look for ways to get more information to more people such as newspaper articles and community meetings.
- Recommendation for financial incentives to mitigate or abate impact of SLR from both the private property owner as well as municipalities. At the same time, do not mandate or intrude into personal property issues.
- Would like to see more of this information in the local newspapers.
- Please consider the fact that your committee may be being used to promote an agenda not known to the members, as a means to insure local compliance to the U.N. Convention on Biological Diversity, wetlands project, as a vital step in attaining sustainable development. This is set forth in the U.N. "Agenda 21" program. If you are not familiar with it, look it up!
- No, except possibly how will we deal with the impacts to sequestered toxins at existing landfills and disposal areas that will be inundated.
- The presentation needed, I think, 3 areas of more in-depth analysis:
  1) The potential economic/financial impact
  2) A 25 -50 year scenario in the presentation. It is truly hard for the public to grasp 100 years
  3) Impact of climate change: increased storm activity, storm surge, etc.
- I think the best and cheapest way to fix Primehook's problem is to dredge the beach and bay. The sand and filler could be dumped on the beach benefitting the citizens and commerce. Actually, it would help all of Delaware's beach area.
- No, you have a very dynamic and diverse background to consider the problem.

Did you find any inaccuracies or problems with the information displayed today? Please describe.

- What causes global temperatures to change?
- Poster: What causes Sea Levels to Change? The section dealing with global temperature change seems to indicate that most of climate change is resulting from natural forces and therefore there is little we can do to mitigate it.
- I struggled (as you did) with the maps. They do not readily convey the information. A possibility would be to start with what questions (5) the maps should answer and design the maps with that in mind.
- No – very well presented.
- No, I thought the computer models and available displays were accurate.
- We now know some information being presented is based on false science.
- I do not agree with your findings that the sea will rise and swallow us up!
- fire/Ems stations- seemed to be a lot of Ems stations. Need to distinguish between the two. Police station ids. Business impacts need to be more detailed.
- No, very informative.

- Did not review in enough detail, though the 2 computer stations were a great idea.
- No, but I have little or no ability to question the data or the conclusions drawn from the data. That is why I came, to learn more and educate myself.
- Display 4 contains the statement “approximately 3% of Delaware’s 411,000 homes could be inundated by 3.3 feet (1 meter) of SLR”. My comment is that SLR inundates land that is low, not homes. Codes exist along the coast which requires homes to be elevated more than 3.3 feet above sea level.
- I am not keen on the display that shows the reasons for SLR. The Milankovitch cycles and sunspot activity are relatively minor factors which take away from the main threat.
- Because the projections are on a gross scale, actual local elevations do not show.
- No, Committee seems to be using an even handed approach.
- No, but a cost study would have enhanced the presentation along with some short term analysis. You have bent over backwards to make a scientific presentation without using panic ideology.
- I found the presentation very professional. The DelDOT people were very friendly as were the volunteers. It was just a depressing subject.
- No, it was reflective of a balanced approached to addressing a complex problem.

Please tell us what aspects of sea level rise might impact you, your home, or your community.

- I’ll be gone by the time SLR gets really bad, but I worry about my grandchildren and their children.
- None to my home, at least for another 284 years according to my calculations however, it will have an impact on my community. Things will change the question is how well will we change with SLR?
- If Delaware makes taxpayers pay for risky investments, specifically homes that should not have been built so close to the water, I will have less money. Where is the County responsibility?
- Sea level rise will affect all of us living in areas adjacent to coastal Sussex County. It will affect tourism, agriculture, and real-estate.
- I live and work in a coastal town. SLR could affect my home, job, and recreational opportunities.
- flooding of our business community in Milton.
- 1.0 meter SLR, Delaware is sinking.
- Infrastructure availability.
- I live in Georgetown; your maps show that my house will stay high and dry no matter what.
- I live inland but my family has a beach house so I am concerned about storm surge. But I am also concerned about all regional impacts especially on natural resources and infrastructure.
- I am from Primehook, so the roadway for emergency need is impacted plus the loss of dunes and beach front.
- Habitat migration/ adaptation, impacts on drinking water, and impacts on wastewater treatment.
- Wells, septic, damage from storms pushing water further inland.
- No but the material presented is fairly dense.

E - Sea Level Rise Public Engagement Session Comments Received

- Loss of home very shortly.
- Not much, fortunately, as I live on relatively high ground.
- I till 3 farms in South Bowers. We used to see saltwater intrusion onto our land once every 5-6 years. Now it happens 3-5 times a year. Changes have been seen over the past 15 years. We have lost about 30 acres that are no longer tillable because the soil is too salty. flooding by saltwater is so frequent that salt never has a chance to be flushed out of the soil.
- I will probably have to pay taxes to make up for the stupid land use decisions county officials have made. They are so keen to get real-estate transfer taxes that they ignore SLR.
- I live in a relatively low lying area in Kent County. Concerned about community water and wastewater utilities.
- Loss of property, economic decline, loss of quality of life, environmental changes.
- A significant point of vulnerability in Lewes is the bridge over Canary Creek. It currently is too low! The bridge floods regularly and a strong northeast wind can keep water, from storms, in the creek for days. This bridge, when built, was not properly constructed and the approaches sink quickly after they are repaired by DELDOT. This bridge has served as a crabbing and fishing point for 75-100 years. Please do not eliminate this local feature of the bridge if you choose to rebuild a better bridge over the Canary Creek.
- I live in South Bethany on a canal!
- I live in South Bethany and my home is about 8 feet above sea level.
- I live in the back of Primehook Beach. That marsh and strip of land has been our barrier island but it is dissolving quickly. It is very frightening, as we have worked for 25 years for our home and property.
- Land value decrease as it will become less desirable to come to the beach areas.
- SLR will significantly reduce our opportunity for recreational benefits, damage the ecosystem, put our homes at risk for flooding, and cause economic hardship.
- My home may be completely destroyed. The value has declined drastically and it is scary. I see sale signs going up with asking prices cut to the bone. They are good people and deserve better. Our road to Primehook is really dangerous but we are thankful for it.
- Communities will need infrastructure for roads and schools. For me personally and for my family, we are outside of the impact zone.

Please tell us what aspects of sea level rise you are most concerned about.

- Port Mahon – roadway is problem already; Bombay Hook NWR.
- Dealing with SLR is going to cost a lot of money. The Committee needs to hold more discussions about the value of vulnerable assets.
- Being smart about our adaptation methods. Who is responsible? If I buy a home that in 100 years will be under water and I am ok with that because it is on the beach and I am only looking 10-15 years ahead, then So What! The problem is 40 years from now, the owner of that home is screaming for a buyout at top dollar. Personal responsibility has to play into the strategy.
- Loss of wetlands!
- Be able to adjust in the future as new info about SLR becomes available.

- According to the models the community where I work is in big trouble.
- What can we do as individuals beyond AWARENESS?
- Economic impacts
- Little
- I have no concerns about sea level rise.
- All of them!
- Road inundation and critical infrastructure inundation.
- Engulfing our cottage with no option of relocation. Loss of property will impact us financially and our family sentiment since we built the cottage ourselves.
- Habitat migration and affects on surface water and groundwater resources.
- I would like to thank you for the information. Everyone involved is doing a good job and the State of Delaware should be proud to have people who are industriously applying themselves to their jobs.
- How will adaptation be paid for? Will emerging solutions be considered.
- Revert back to a beach replenishment agreement in exchange for public assistance. Then go for long range solutions.
- Why are we spending millions of dollars on Indian River Inlet Bridge when the roads to and from it will be under water?
- Future regulatory initiatives.
- Spending taxpayer money to benefit a small portion of people who live along the coast.
- I am most concerned about economically disadvantaged people who are without choices in dealing with SLR.
- flooding/inundation and salt water intrusion.
- Loss of property and the ability to provide health and safety services for the community.
- The government, through regulation and restriction of personal property use and denying citizens their right to private property i.e. the 4th Amendment the U.S. Constitution.
- Inundation of wetlands and existing infrastructure. Will the taxpayers have to bail out flooded homeowners in the coastal zone? Example: Primehook Beach?
- Impact on beach communities. When preparing public information after the recommendation phase, be mindful of how such information may impact property value and tourism in Delaware which is a substantial revenue source for the State.
- Should I move? Should we build dikes? Should we bring in a lot of sand? I could still get around in my boat.
- It is clear that our town will be inundated due to sea level rise. Our issue will be how do we plan for SLR now and not later. (Mayor of South Bethany)
- flooding. May allow for the distribution and spreading of toxic and carcinogenic chemicals.
- The increasing impact on groundwater and the drinking water around my house and the flooding potential.
- That people can ignore this issue. SLR is happening whether you believe it or ignore it!
- Risk of damage and flooding to property, degradation of the community from economic hardship,

infrastructure damage, and potential danger to evacuation routes and possibly even to overall evacuation.

- Complete flooding in the area which will happen and to a degree has happened several times recently.
- Cost to me and the community.

Please tell us if you feel that the Delaware Sea Level Rise Advisory Committee is on the right track or on the wrong track with its approach to planning for sea level rise.

- Right track x 12
- Right track. I will be interested to hear the solutions now that I know the issues.
- Right track with proper government representation.
- Wrong track. Reduce DNREC budget or eliminate department, it is getting too political.
- Wrong track. I think we are wasting a lot of money on studying sea level rise.
- Right track. Hope for rapid answers but know that research must be done.
- Right track. Bravo for taking this issue on and focusing the public's attention.
- Right track for the long range. Wrong direction for the short range.
- Do not know enough yet to say for sure. It appears that the Committee is doing a good job of studying the issue.
- Right track. There is a need to reassess what is going on along the coast and change what we are doing.
- Right track. Could be less conservative
- You did not make any suggestions for solutions. Should we move or spend a lot of money?
- Right track. Thank you for the great presentation and displays.
- This is a great track. You are carefully building the case for adaptation.
- Right track. This is going to be of upmost importance to all of Delaware in time, not just the coastal areas. All options should be investigated and evaluated.
- You are on a good track. I encourage you to continue to maintain your diverse group.

What information presented today was most useful to you?

- TV info and the SLR map viewer.
- The ability to see the areas that will be potentially affected.
- Rate and extent of change.
- Computer availability
- Knowing your direction so citizens can resist.
- I enjoy looking at maps.
- It's very useful to listen to simple explanations of sea level rise. It's helpful for explaining to friends and family without putting them to sleep.

- All. Nice job by the presenter and facilitators.
- Scenarios/mapping
- All of it.
- The GIS maps and infrastructure display
- Maps
- Very good. The information was well presented.
- Include below-water-level sewer outlets for the Wilmington sewer system.
- Information on mapping
- Computer map overlay showing flooding at various elevations of SLR.
- Local information about my community provided by the computer maps.
- The website that allows us to look at the SLR maps on our home computer.
- Visuals showing potential inundation.
- Both the presentation and the displays.
- The data presented has been around for some time. I am waiting for the strategies and recommendations.
- Seeing what the Committee is doing.
- Computer maps that show the potential effects on our property.
- Everything. It was great to see that people are actually trying to address this issue.
- Computer maps and scenarios, well done.
- The information simply confirmed my thoughts.
- Social and economic impacts.

Do you have additional information or concerns you would like to share?

- The general public needs to understand SLR and be challenged to live more efficiently and use less energy. Please offer a plan to educate the public on what they can do and what we all must do to lower the impacts over time. We need our government to be proactive on this as well. Thanks for your efforts.
- Need to add wastewater plant in Milton.
- I am wondering why you are scaring people with this stuff when the sea is barely rising at all if at all. I do not believe in global warming which has now been renamed climate change. It is a hoax. I am sorry we are wasting so much time and money on this.
- Keep up the good work.
- Integration between the State and County governments regarding hazard mitigation plans.
- Perhaps your group could come to our Primehook Beach organization meetings with your exhibits on SLR or contact the Board chair, she is great at dispensing information to us non-residents by email.
- Many questions about how this research/data will be used. Could have been addressed during the presentation.
- You should have been more forceful with this information years ago to advise other agencies to pass zoning

and building codes to stop people from building in areas that will be under water. Laws could have been made to say if you build you cannot be bailed out by taxpayers.

- Support not allowing people to build in certain areas. Want the amount of sand on the beach to be reduced so that the shoreline can change naturally.
- Availability of GIS layers for 3rd party users to evaluate.
- Sussex County Government should participate.
- Why is Sussex County not listed as a member of the Advisory Committee?
- If the plan is that I should move then I should do it soon so that I can sell my property. I am 68 so I probably do not need to do anything but my children will have to worry about it.
- What should towns in the impact zone do? As more and more information about SLR “gets out”, town officials will be asked to provide what we have in place to combat SLR. So the sooner the better in getting out the recommended solutions. Thank you for holding these public engagement sessions. I believe SLR is happening and I came tonight with the hope that the Committee would provide solutions with how to handle the impacts of SLR. (Mayor of South Bethany)
- The town oflewes would like the SLR maps to download.
- Your maps should show:

  A) the range of static sea level rise

  B) the range of storm surge

  C) the combination of A + B, which would be the real world worst case scenario
- Why are the Sussex County municipalities and Sussex County not represented on the Advisory Committee? Most of the ocean shoreline is in Sussex County! It is very disconcerting that many DNREC employees do not know the municipalities in Delaware, such as Henlopen Acres. What procedures are being developed to keep all municipalities involved and informed?
- Why is Sussex County not directly represented on the Advisory Committee? We should stop wasting time with determining why SLR is happening. It is happening and we need to keep moving forward.
- The public will have difficulty attempting to mitigate risk, increasing protection, or taking on other costly measures without a cost/benefit analysis. The Committee must continue to build the scientific argument that SLR is real and then add in the cost of adaptation options. Also we probably need to emphasize the rapidly changing trends - this is so important- since the situation is accelerating and we do not want the maps to lead to panic. We need to build this into our UD campus tours. Can we build in the ecosystem changes that are likely to occur?

Comment Letter from Steve Callanen
Chair, Southern Delaware Group, Sierra Club

38986 Bayfront Drive
Ocean View, DE 19970
December 2, 2011

Susan E. Love, Resource Planner, Delaware Coastal Programs
DNREC, Division of Soil & Water Conservation
5 E. Reed Street, Suite 201
Dover, Delaware 19901

Subj: Reduction of Indian River Inlet Depth Needed to Curtail Bay flooding

Attachments:
a) Tidal Prism Graph, CCMP, Appendix F, p. 2-1, June 1995.
b) Tidal Prism Graph, 2011 State of the Delaware Inland Bays, 23 Sep. 2011.
c) Indian River Bay Shoreline flooding, Callanen Photo 5109, 5-12-08.
d) Indian River Bay Shoreline flooding, Callanen Photo 5115, 5-12-08.
e) Indian River Bay Shoreline flooding, Callanen Photo 5125, 5-12-08.
f) Indian River Bay Shoreline flooding, Callanen Photo 5130, 5-12-08.
g) Indian River Inlet - ACOE Multi-beam survey data - Mar 1999 Slide42
h) IR Inlet Cross Section, figure 3.14
i) IR Inlet Cross Section, figure 3.15
j) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, Sep. - Oct. 2008.
k) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, Oct. 2009.
l) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, May - Aug. 2011.
m) USGS 01484540 Indian River at Rosedale Beach, DE, Tide height, Aug. - Nov. 2011.
n) USGS 01484540 Indian River at Rosedale Beach, DE, Location Data & Photo.

Dear Ms. Love,

I enjoyed talking with you after your Sea Level Rise Engagement Session presentation on November 29th in Lewes. Please consider the comments in this letter as my “Comment Form” reply.

My primary concern, which has not been addressed by the Sea Level Rise Advisory Committee, which astonishingly has no representative from Sussex County, is the rise in water levels around the shores of Delaware’s Inland Bays due to self-scouring of Indian River Inlet. According to Robert Scarborough, DNREC Research Coordinator & Environmental Scientist, whom I also spoke to on Tuesday evening, it is unlikely that this problem will be addressed for at least two years. This delay in taking action on this serious problem is inappropriate and downright foolish.

It is submitted that tidal-prism data (Attachments (a) & (b)) indicates that the rate of water level rise on the shorelines of the Inland Bays exceeds future flooding rate increase estimates attributed strictly to global warming.

The 320-square-mile Inland Bays watershed has experienced well documented severe flooding on numerous occasions, including in November 2009 during tropical storm Ida and in May 2008 (Attachments (c), (d), (e) & (f)). Bay flooding is adversely impacted not only by major storms and sea-level rise, but also by the extreme self-scouring of Indian River Inlet, which provides the primary connection between Delaware’s Inland Bays and the Atlantic Ocean.

A greater volume of water exchange between the ocean and the Bays now occurs on each tide cycle, due to extreme self-scouring of the Inlet (Attachments (g), (h) & (i). The cross-sectional area of Indian River Inlet, 500-feet east of the bridge, increased from approximately 800 square feet in 1936 to nearly 22,000 square feet in 1991. The cross-

sectional area of the channel, 600-feet west of the bridge, increased from approximately 900 square feet to over 31,000 square feet during this same time period.[11] The volume of water flowing through the Inlet on each tide cycle roughly tripled from 1939 to 1969, then almost doubled from 1969 to 1988. The depth of the Inlet has dramatically increased from 15-feet to over 100-feet in some places; and as a result, high tides in the bays are higher and low tides are lower. Low tide water levels in Indian River Bay are 12-inches lower than they were 50 years ago. (Delaware Inland Bays Comprehensive Conservation and Management Plan (CCMP), Appendix F, p. 7, June 1995.) As the Inlet's cross-sectional area has increased, it has become less effective as a deterrent of excessively high water levels in the Bays.

The attached Indian River Bay and Rehoboth Bay "tidal prism" graphs illustrate the increasing tidal action, and hence the corresponding higher high tide and lower low tide water levels. (Delaware Inland Bays Comprehensive Conservation and Management Plan (CCMP), Appendix F, p. 2-1, June 1995.) This same "tidal prism" data was recently published in the 2011 State of the Delaware Inland Bays.

Because of the significant progress made over the past decade in eliminating large point sources of pollution around the Bays, it seems highly doubtful that significantly reducing, or halting, further scouring of the Inlet will detrimentally impact adequate flushing action, which transports excess harmful nitrogen and phosphorus nutrients from the Bays to the ocean.

Sea-level rise and typical nor'easter storms increase flooding impacts, not only on private property and public roads surrounding the Bays, but also on the leaching of toxic heavy metals into Bay waters from the unlined 144-acre Burton Island coal ash landfill adjacent to the Indian River Power Plant.

The Burton Island site is now mostly surrounded by riprap; however, U. S. Geological Survey tide height measurements taken at Rosedale Beach, almost directly across Indian River from the power plant, show that on numerous occasions in 2008, 2009 and 2011, for which data is available (Attachments (j), (k), (l) & (m)), water levels have exceeded the top of the pier on which the USGS water height gage is located. In October 2009 and August 2011 the excessively high water levels caused the water height gage to malfunction, thereby preventing accurate recording of these events. The USGS indicates that a maximum water elevation of 6.99 feet occurred at this site on Feb. 5, 1998, (Attachment (n)).

It was shocking and disturbing to learn at a 2008 DNREC public hearing that 26 years after Delmarva Power and Light ceased dumping coal ash from the Indian River Power Plant onto Burton Island, 26 of 26 offshore sediment samples were discovered to contain seven heavy metal pollutants identified as "Constituents of Potential Concern for either human or ecological receptors."

These metals include aluminum, arsenic, barium, cobalt, copper, mercury and nickel. Delaware Toxic Release Inventory Reports identify compounds of arsenic, cobalt and nickel as carcinogens.

An ecological risk assessment published by Shaw Environmental Inc. in March 2008 states, "There is a potential for adverse affects to benthic invertebrates in the sediment along the shoreline of Burton Island due to arsenic and barium."

NRG's remediation plan for Burton Island has thus far consisted of leaving contaminated offshore sediment in place and adding riprap along the shoreline. Although this riprap helps inhibit erosion of shoreline embankments, the synthetic fabric underlay is permeable, and therefore does not prevent leaching of the landfill pollutants into bay waters. The riprap fails to eliminate the long-term pollution problem, which is exacerbated by high water levels and wave action, especially during typical Nor'easter storms.

To the best of my knowledge, the impact of sea level rise has not even been considered in the ongoing Burton Island remediation analysis or discussed in the reports developed to date. The Sea Level Rise Advisory

Committee should focus attention on this omission.

To prevent long-term worsening of Inland Bay flooding impacts, it is necessary for DNREC and/or the Army Corps of Engineers to reduce the volume of water entering the Bays on each tide cycle by reducing the Inlet's depth and hence its cross-sectional area.

According to an ACOE report, "inlet scour continues and presently poses what may prove to be the most difficult and costly of the coastal engineering challenges presented in the 100 plus years since locals first petitioned the Government for a jettied inlet." Assuming this statement to be correct, it is respectively submitted that the time to start working on remediation of this worsening problem is NOW.

Sincerely,

Steve Callanen, Chair, Southern Delaware Group, Sierra Club

302-539-0635 (h)

Copy to: Senator George H. Bunting, Jr., 20th Senatorial District, Senator F. Gary Simpson, 18th Senatorial District, Joan R. Deaver, Sussex County Council, District 3, Collin O'Mara, DNREC Secretary, Sarah W. Cooksey, DNREC Administrator, Delaware Coastal Programs, Robert W. Scarborough, Ph.D., DNREC, Research Coordinator & Environmental Scientist, Kelly Valencik, DNREC, Coastal Programs, Chris Bason, Acting Director, the Delaware Center for the Inland Bays, Doug Parham, Chair, CIB, Citizens Advisory Committee

[11]"Delaware Inland Bays Comprehensive Conservation and Management Plan," Appendix F, figure 3.16, p. 3-130, Jun 1995.

[12]The DE Center for the Inland Bays, '2011 State of the DE Inland Bays,' p. 15, September 23, 2011.

[13]http://waterdata.usgs.gov/de/nwis/uv?cb_00065=on&format=gif_default&period=21&site_no=01484540

[14]The USGS tide gage was not installed until April 1991.

[15]"57 YEARS OF COASTAL ENGINEERING PRACTICE AT A PROBLEM INLET: INDIAN RIVER INLET, DELAWARE," by Jeffrey A. Gebert, Keith D. Watson, A. M., ASCE and Augustus T. Rambo.

E - Sea Level Rise Public Engagement Session Comments Received

Responses to Steve Callanen Letter

Point of Clarification,

The item that I referred to that would not happen for probably two years is the expansion of the DEOS (Delaware Environmental Observing System) Coastal Storm Early Warning System. The system is now in place for Kent County (http://www.deos.udel.edu/coastal_flood) and researchers from the University of Delaware are currently expanding the coverage to go from Lewes to the City of New Castle. The next phase if funded will include the piedmont area of northern New Castle County and the Inland Bays. These two areas are last because of the complications and extra research required due to increased surface runoff in the piedmont region and difficulty in predicting flooding in the Inland Bays due to restricted tidal flows through the Inlet combined with runoff.

Thank you,

Robert W. Scarborough, Ph.D.DNREC//Delaware Coastal Programs/DNERR

Steve,

Thank you for your comments – we will include them for consideration by the sea level rise advisory committee.

You already received and email from Dr. Scarborough regarding the expansion of the Delaware Environmental Observing System Coastal Storm Early Warning System into the Inland Bays area, if funded.

I also wanted to let you know that modeling of the impact of sea level rise on the NRG ash disposal area was conducted as part of the recent remedial investigation by DNREC Site Investigation and Restoration Section. The reports are available here:

http://www.dnrec.delaware.gov/whs/awm/Info/Pages/NRGIndianRiver.aspx

The impacts of sea level rise are specifically addressed in the third document listed – NRG's Response to DNREC's comments. If you have questions about the results, please call Greg DeCowsky at SIRS who will be able to explain the technical details much better than I can.

Again, thanks for your comments.

Regards,

Susan E. Love

Delaware Coastal Programs

E - Sea Level Rise Public Engagement Session Comments Received

Comment Letter from Claudine Bodin

Wednesday, November 16, 2011 - 12:20 PM

Subject: Government Inaction or Sea Level Rise?

From: Claudine Bodin

To: Valencik Kelly J. (DNREC); Senator Simpson; Kenton Harvey (LegHall); Hill Jennifer A. (Governor); Dan ASHE; Glen Robert A (DOS)

Cc: brenda.l.schillaci@mssb.com; Ron; Tena Alexander; Devores; trainster@aol.com; Diane McConnell

Sent: Monday, November 14, 2011 8:18 PM

Government Inaction or Sea Level Rise?

Because of an injunction brought forth by PEER, there has been massive, destructive flooding at Primehook Beach. Is this a case of “sea level rise” or “deferred maintenance”? The only reason this sort of flooding is not a current crisis at Rehoboth or Dewey Beach is because those communities can count on dune and beach replenishment done paid for by the state of Delaware, whenever needed. I clearly remember the Rehoboth boardwalk being destroyed by a storm . . . and then fixed. If those repairs had been neglected where would Rehoboth Beach be now?

What we are witnessing and experiencing at Primehook is a breach of duty by the state and federal governments -a matter of neglect and deferred maintenance in a National Wildlife Refuge abutting a great community. Primehook tax payers are in a constant crisis of being flooded, stranded, and their very lives left in peril. They must deal with this crisis mostly on their own. Some government agencies and representatives have helped and are currently seeking justice for the community. But the crux of the problem, the breached dunes, is not being addressed. I believe this has more to do with breach of duty, exacerbated by the PEER lawsuit (that was finally defeated late this summer) than a matter of sea level rise.

Primehook property owners have been left with properties that cannot be sold. Even if someone wanted to buy one of the houses currently for sale, mortgage lenders would require flood insurance; but that is no longer available at Primehook because of the neglect –not neglect by the Primehook property owners --they have been fighting to fix this problem for years!

At this point one of two things should happen:

1) The breached dunes should be fixed and consistently maintained, or;

2) The government must accept their breach of duty and buy the land from the owners who have been left to confront flooding as no other property owners in Delaware have had to.

What is Happening at Primehook is an Out-of-Control Short-Term Problem that has Left Residents in a Horrible Quandary

I have faith that what is happening at Primehook can be resolved. The former fresh water refuge is at a fragile, irreparable tipping point. I hope that the state of Delaware and the National Wildlife Refuge system (Department of the Interior) can appreciate that and take swift action for both the migratory birds and other wildlife dependent on that habitat as well as the property owners on beautiful Primehook Beach.

Sincerely,

Claudine Bodin

F - Dissenting Opinion Statements

Expertise, opinions and advice from members of the Sea Level Rise Advisory Committee was essential to the development of this sea level rise vulnerability assessment. Advisory Committee members outlined desired information, helped obtain datasets, drafted individual sections of the document, and reviewed draft and final products. Committee members also voted to finalize and publish the document.

Voting procedures approved by the Sea Level Rise Advisory Committee require the affirmative vote of 2/3 of the total committee membership to pass any motion. Committee members also recognize that dissenting opinions add context to a discussion and should be documented for consideration in future work. As a result, the voting procedures also outlined a process to allow Advisory Committee members who do not agree with a recommendation to have their opinions included in committee products as a dissenting opinion.

Two Advisory Committee member organizations have submitted dissenting opinion statements for inclusion in this vulnerability assessment, the Home Builders Association of Delaware and the League of Women Voters of Delaware. The Home Builders Association of Delaware registered the sole “no” vote for the finalization and publication of the Vulnerability Assessment. The League of Women Voters of Delaware voted to approve this document with the inclusion of the additional information contained within their dissenting opinion.

The two dissenting opinions are presented on the following pages.

MINORITY STATEMENT BY THE HOME BUILDERS ASSOCIATION OF DELAWARE

The Home Builders Association of Delaware (HBADE) appreciates the work effort of the Sea Level Rise Advisory Committee toward addressing the potentials of sea level rise. Our Board of Directors has approved the following position statement, and have asked our representative Keith Rudy to submit this on the behalf of HBADE.

Over the last 110, the rate of Sea Level Rise and Subsidence in Delaware has averaged about 3.35 mm per year. Over the next 100 years, at this rate, we expect that an addition 0.34 meters of rise. Accounting for an increased rate of sea level rise that some feel may occur over the next 100 years and in order to plan conservatively, the Home Builders Association of Delaware supports the planning for 0.5 meters of sea level rise over the next 88 years at the current time.

One half meter is consistent with the conservative estimates by the International Panel on Climate Change (IPCC) and NOAA for global sea level rise over the next 100 years. Additionally, the HBADE supports a close monitoring of the actual sea level rise over the next twenty years in order to determine if the 100 years trend will exceed 0.5 meters of rise. Even at the most catastrophic estimates of sea level rise being considered by DNREC, we would not exceed 0.5 meters in 30 years and we would still have adequate time to plan for this level if it appears that the trend is towards more than 0.5 meters of rise in the next 100 years.

We appreciate the opportunity to submit our position and hope that it is helpful to the Advisory Committee.

Submitted by Howard Fortunato, Executive Vice President, HBADE on April 26, 2012

MINORITY STATEMENT BY THE LEAGUE OF WOMEN VOTERS OF DELAWARE ON THE SEA LEVEL ADVISORY COMMITTEE VULNERABILITY ASSESSMENT REPORT

1 The DNREC Coastal Programs Staff did a good job of writing the first draft of the 244-page Vulnerability Assessment Report and of including most of the suggestions made by Advisory Committee members, including a number made by the League, in the second draft. There are however three important issues that should be addressed on which we were unable to reach a consensus with the staff and Advisory Committee to include. We describe them, with references to our information sources, in this Minority Statement. The first set of three summarizes the issues; the second set gives more detail with references. The page numbers in parentheses refer to the Coastal Programs' second pdf draft of the report.

1. Delaware has the lowest average elevation of any state in the U.S., so that it is especially vulnerable to sea level rise.

2. The evidence that the rate of sea level rise is increasing and is very likely to keep increasing for many decades to come was downplayed in the report as adopted by the Committee, in spite of evidence that the rate of ice loss from both Greenland and Antarctica is increasing and that the loss of ice from these two huge ice sheets will dominate the future rate and extent of sea level rise.

3. The report fails to mention that Delaware's vulnerability to climate change is caused not only by sea level rise using the "bathtub model" adopted by the Committee, but by storm surges and wave heights that are likely to increase in a warming world.

1. Delaware is particularly vulnerable to the effects of SLR not only because of its location and dependence on the coast, but also because it has the lowest average elevation of any state in the U.S., only about 60 ft or 18 m.[1] (Pages xi and 3)

We suggested inserting on Page 3 right after the sentence starting with "Delaware is particularly vulnerable …"Delaware has the lowest average elevation of any state in the U.S., only about 60 ft or 18 m."

2. We strongly dislike the sentence on Page 7, "While it cannot be proven with certainty, climatologists have predicted that the rate of sea level rise occurring today will likely become greater in the decades to come." (emphasis added) We can't understand the reasons for not simply replacing it with, "Climatologists have predicted that the rate of sea level rise will likely become greater in the decades to come." The new wording provides the reader with the idea of uncertainty with the words, „predict" and „likely.„ We object to the phrase, "While it cannot be proven with certainty, ..." because it may give the lay reader the mistaken impression that the expectation of increasing rates of future sea level rise is quite uncertain, and that therefore adaptive action can be put off.

The U.S. Army Corps of Engineers (USACE) issued a circular in October 2011 providing guidance for incorporating the direct and indirect physical effects of projected future sea-level rise across the life cycle of USACE projects and systems.[2] The USACE guidance predicts an accelerating rise at least until 2100. The form of an equation describing the acceleration was taken from a 1987 NRC report.[3] At that time (25 years ago) it was not known whether the mass of ice on Antarctica was increasing or decreasing; it was thought that the snow and ice added by more annual snowfall in a warming world might exceed ice loss due to melting and calving.

A recent paper published in 2011 by research scientists E. Rignot et al.[4] - including two from the Cal Tech Jet Propulsion Laboratory and one from the National Center for Atmospheric Research - who have studied the ice sheet mass balance for Greenland and Antarctica over the last two decades, reports that both Greenland and Antarctic ice sheets are losing mass at accelerating rates,[5] and that the combined acceleration is 3 times larger than that of other glaciers. They write: "If this trend continues, ice sheets will be the dominant contributor to

sea level rise in the 21st century." The acceleration of ice loss from Greenland, which is caused in part by the increased rates of sliding and calving of glaciers, is supported by earlier papers from NASA.[6]

3. The report focuses too narrowly on its "bathtub" model of sea level rise and fails to point out that the vulnerability of some resources - like people's homes - depends not only on the gradual increase in the mean higher high water (MHHW) of high tides, but also on episodic storm surges and waves that are likely to increase in height with global warming and that need to be added to relative sea level rise to assess vulnerability along the coast. The U.S. Global Change Research Program states: "There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures."[7] We would like to have seen a figure in the report, similar to the one defining MHHW (Page 10), showing tide gauge measurements on the Delaware coast covering a number of days that include a period of storm activity. One example would be the passage of Hurricane Irene up the Delaware coast last year. In that case the damage was much less than feared because the highest storm surge was short-lived and came at an especially low tide (new moon).[8] Another possibility would be the nor"easter of 1962, which lasted through five high tides, produced waves 20-40 feet high, and devastated the Delaware coast.[9]

A study of the intensity of wave action in the northeast Atlantic, using microseismometers to measure the shaking of the coast, indicates that wave action has been increasing as the water temperature has been increasing.10 The same may be true of our Mid-Atlantic coast. More energetic wave action is expected to increase the rate of coastal erosion and make it harder to protect coastal resources like marshes.

Submitted by Chad Tolman on June 4, 2012 for the LWV of Delaware

[1] U.S. Census Bureau, Statistical Abstract of the United States, Chapter 6, Geography and Environment, p. 216, 2004-2005.
At: http://www.census.gov/prod/2004pubs/04statab/geo.pdf

[2] SEA-LEVEL CHANGE CONSIDERATIONS FOR CIVIL WORKS PROGRAMS, U.S Army Corps of Engineers, Circular No. 1165-2-212, Oct. 1, 2011.
At: http://planning.usace.army.mil/toolbox/library/ECs/EC11652212Nov2011.pdf

[3] Responding to Changes in Sea Level: Engineering Implications, NRC, 1987. At: http://www.nap.edu/openbook.php?record_id=1006&page=30

[4] E. Rignot, I. Velicogna, M. R. van den Broeke, A. Monaghan and J. Lenaerts, Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise, Geophysical Research Letters, Vol. 308, 2011. At: http://www.agu.org/pubs/crossref/2011/2011GL046583.shtml

[5] The measured combined acceleration from Greenland and Antarctica corresponds to an annual increase in the rate of global sea level rise of 0.10 mm/yr, so that in 2100, if the trend continues, these ice sheets by themselves will contribute 10.7 mm to the sea level rise that year. This can be compared with the average annual global rate of 1.7 mm during the last century from both water warming and ice on land melting.

[6] Greenland Ice Loss Doubles in Past Decade, Raising Sea Level Faster, NASA Jet Propulsion Laboratory, Feb, 16, 2006. At: http://www.jpl.nasa.gov/news/news.cfm?release=2006-023
Jacobshavn Glacier Retreat, NASA Earth Observatory, July 15, 2010. At: http://earthobservatory.nasa.gov/IOTD/view.php?id=44625

[7] Hurricanes and Climate Change, in Hurricanes - a Compendium of Hurricane Information, USGCRP, updated Sept. 15, 2008. At: http://www.usgcrp.gov/usgcrp/links/hurricanes.htm
For a good book on hurricane history and science by an MIT professor see Kerry Immanuel, Divine Wind – The History and Science of Hurricanes, Oxford University Press, New York, 2005.

[8] Hurricane Irene "Looking Bad" for U.S.—Moon May Make It Worse, National Geographic Daily News, Aug. 25, 2011.
At: http://news.nationalgeographic.com/news/2011/08/110825-hurricane-irene-outer-banks-storm-tracker-weather-nation-major-path/

[9] The Great Nor'easter of 1962 - Delaware's Storm of the Century, published by the UD Sea Grant College Program in cooperation with DNREC.
At: http://www.deseagrant.org/sites/deseagrant.org/files/product-docs/1962_storm_of_the_century.pdf

[10] Grovmeyer, R. Herber and H.H. Essen, Microseismological evidence of a changing wave climate in the northeast Atlantic Ocean, Nature, Vol. 408, 16 November 2000, pages 349-352.
At: http://www.geo.uni-bremen.de/sensorik/publikationen/nature408_349.pdf

Coastal
Heritage

Delaware Sea Level Rise Advisory Committee

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