

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
- DeIDOT 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.

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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.

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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.

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Emergency Services: This resource includes fire and rescue 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.

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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.

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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

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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 (Technographics), 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: DeIDOT 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: DeIDOT – 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.

Public Safety and Infrastructure

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 devices 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 adversely impacted by sea level rise. Facilities 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).

Public Safety and Infrastructure

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 DeIDOT'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 DeIDOT'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: DeIDOT, 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 adversely 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 facilities are within the 1.0 meter scenario (Table 58). No facilities will be exposed at the 0.5 meter scenario. In New Castle and Sussex County, two treatment/collection facilities in each county will be exposed to sea level rise at the 1.5 meter scenario. The wastewater treatment/collection facilities that will be potentially exposed to sea level rise are located in Delaware City, Port Penn, Lewes, and Seaford. See Map Appendix 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.

Public Safety and Infrastructure

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, 9-29-2011

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 find 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).

Public Safety and Infrastructure

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.

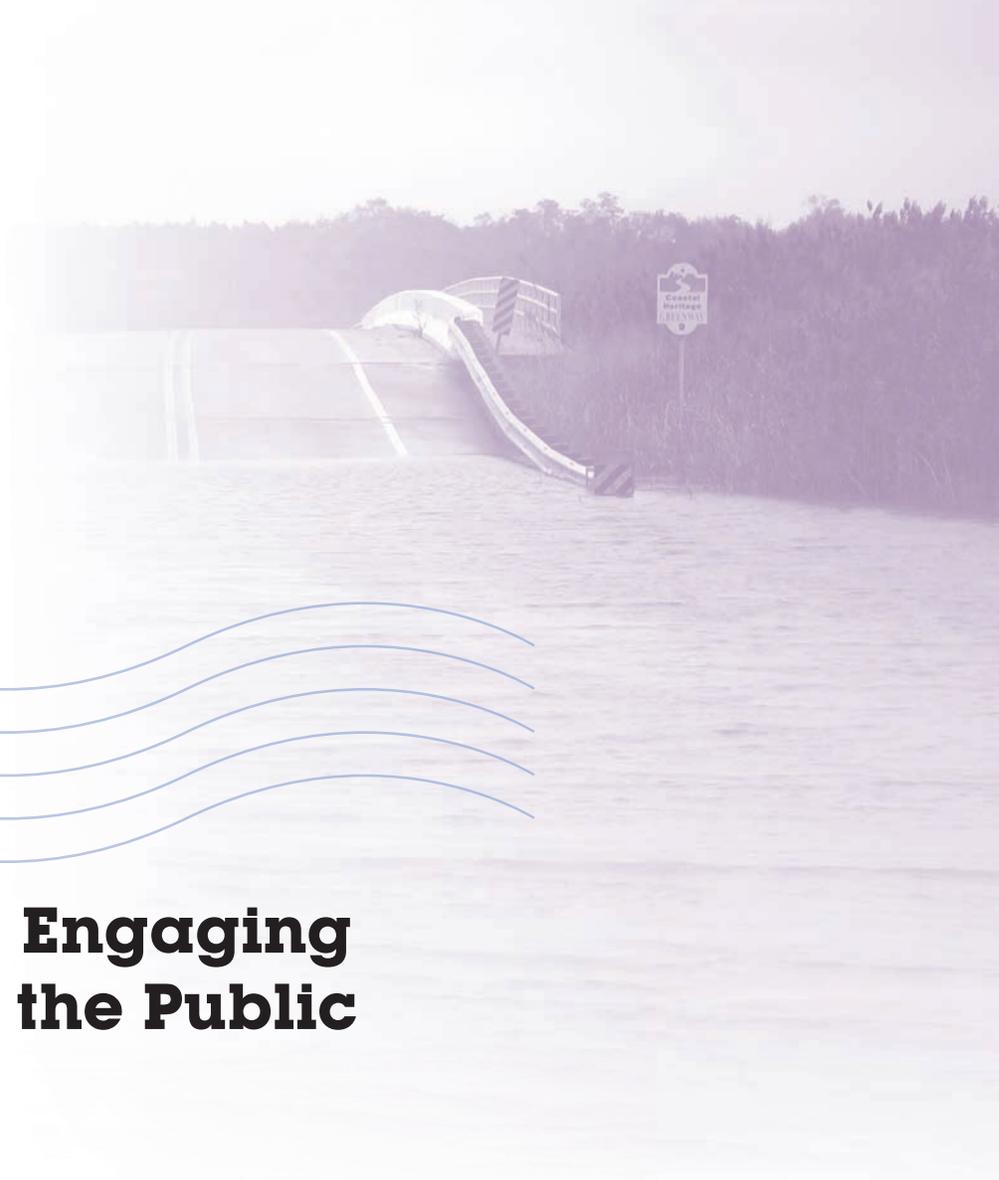
Public Safety and Infrastructure

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.







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.







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.

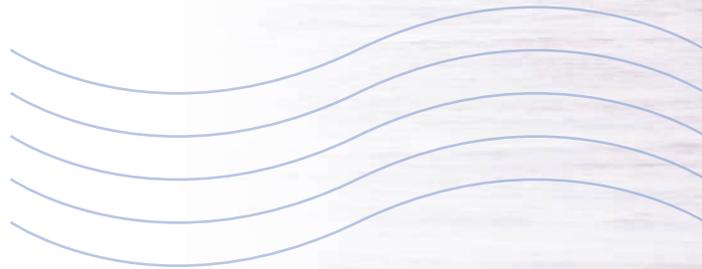
Accommodation strategies are actions that allow continued use of an area or structure without shoreline structures. Examples include drainage improvement projects, raising buildings on pilings and flood-proofing. Accommodation can also include changes in behavior like evacuating early from flood prone 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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