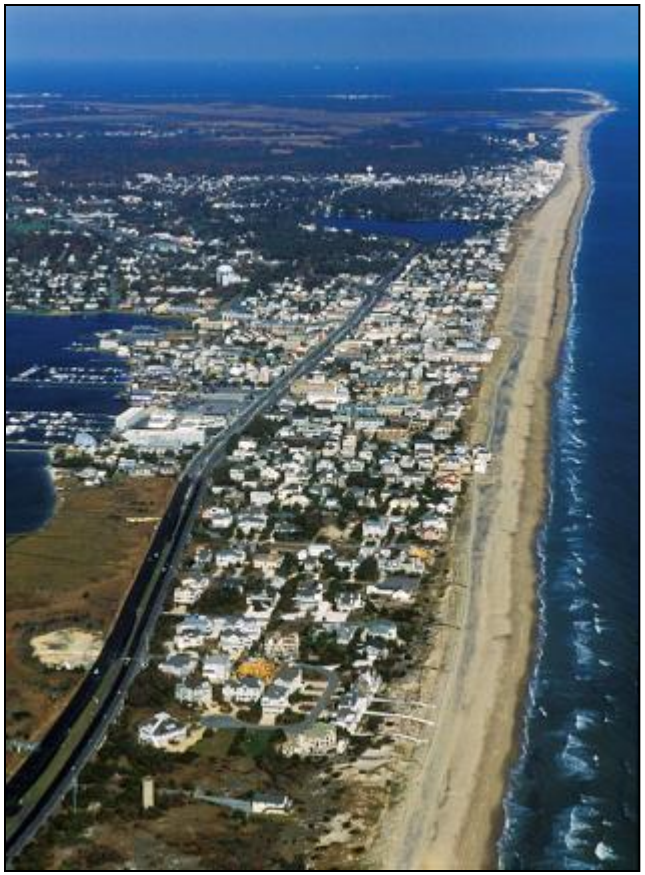
Coastal Hazards in Delaware

What are coastal hazards?

Why is Delaware vulnerable to coastal hazards?

What are the potential impacts to people, property, and natural resources?

How can risks and vulnerabilities be minimized and managed?



What are coastal hazards?

Introduction

Delaware's coastal areas are dynamic environments that are susceptible to a broad range of processes that can create and generate potentially hazardous conditions.

Much of Delaware's populated coast is vulnerable to the effects of coastal storms (high winds , wave action, overwash, storm surge), flooding, sea-level rise, and both episodic and chronic shoreline erosion.

If coastal hazards are not considered in the process of community planning and development, homeowners and property may be subject to unnecessary and increased risks from waves, storm surge, flooding and erosion.

Photo courtesy Kevin Fleming

What are coastal hazards?

Coastal hazards can pose threats to communities including people, property, infrastructure, and economies, as well as coastal environments such as beaches, dunes, and marshes.

Photo courtesy Delaware DNREC

This presentation provides an overview of natural coastal hazards such as storms, coastal flooding and storm surge, erosion, and sea-level rise.

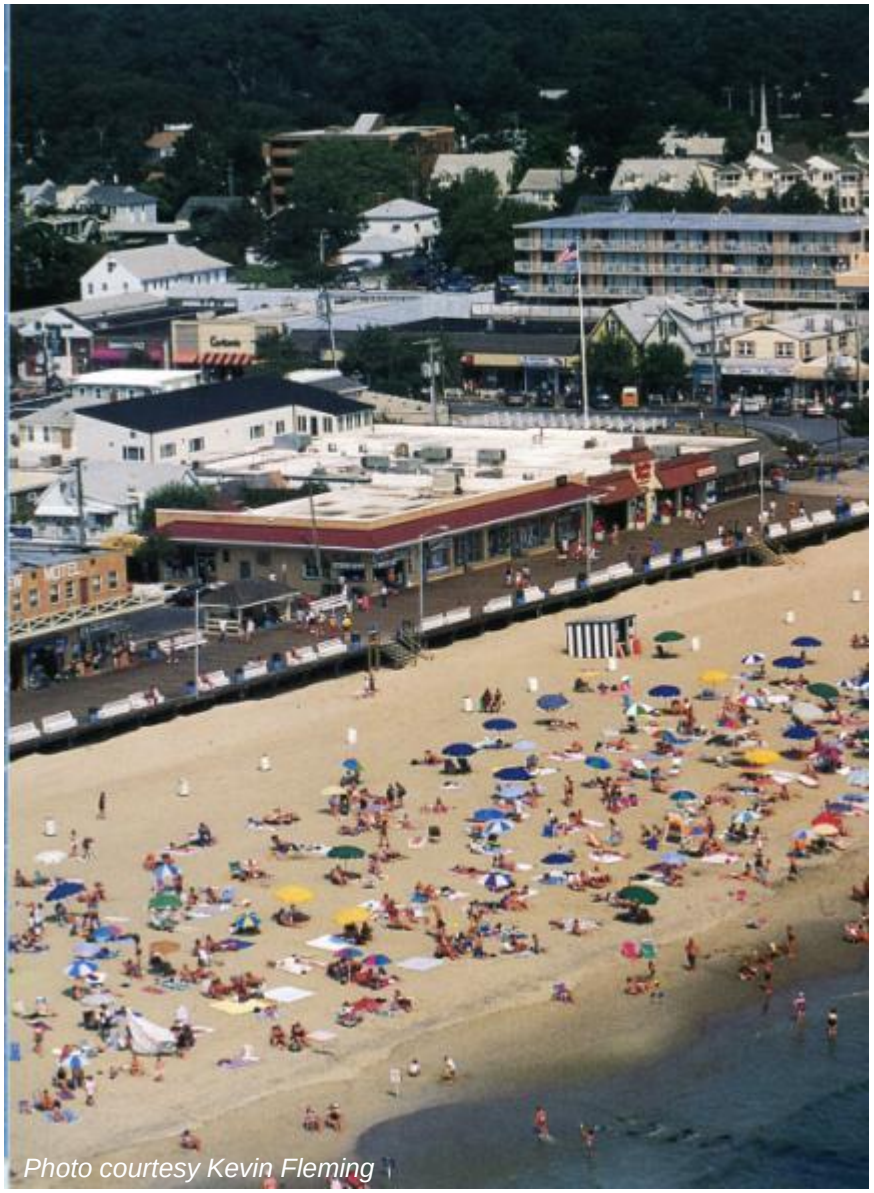


Photo courtesy Kevin Fleming

Note: there are also man-made hazards that affect coastal Delaware such as oil spills, harmful algal blooms, and pollution, but these human-induced hazards are not addressed in this overview.

What are coastal hazards?

Delaware and its communities are vulnerable to the damaging impacts of many types of hazards including:

- Coastal storms – northeasters and tropical systems
- Coastal flooding and storm surge
- Inland flooding
- Extreme wind
- Shoreline erosion – chronic and episodic
- Sea-level rise
- Tsunamis

Photo courtesy Delaware DNREC

What are coastal hazards?

Coastal storms – northeasters and tropical storm systems

Northeasters

Due to their frequency of occurrence, these intense low pressure systems are considered a primary coastal hazard in Delaware. These coastal storms are typically accompanied by high winds, waves and tides, and considerable precipitation.

Photo courtesy Delaware DNREC

What are coastal hazards?

Coastal storms – northeasters and tropical storm systems

Northeasters

If a northeaster is powerful and slow-moving along the coast, significant beach erosion can occur. Similarly, a stalled northeaster can persist through several tidal cycles. Even a one- to two-foot storm surge can result in major and extended flooding of coastal and inland properties as waves and tidal elevations continue to increase as the storm persists.

Photo courtesy Delaware DNREC

What are coastal hazards?

Coastal storms – northeasters and tropical storm systems

Tropical storm systems

Hurricanes, tropical storms and tropical depressions may also cause significant damage to Delaware communities. This type of coastal storm forms over tropical waters and is typically accompanied by high wind velocities, high waves and storm surge, and significant amounts of precipitation.

Photo courtesy Delaware DNREC


Photo courtesy Delaware Sea Grant

What are coastal hazards?

Coastal storms – northeasters and tropical storm systems

Tropical storm systems

Hurricanes and/or tropical storms that reach Delaware tend to be relatively fast-moving systems, and rarely impact the coast over multiple tidal cycles. Although they occur relatively infrequently along the Delaware coast, the associated winds, waves, storm surge and precipitation can cause significant damage to beaches, property and communities.

Even when tropical systems track south of Delaware or far offshore, large waves can be generated, resulting in impacts to our coastline. These waves can dramatically alter beach conditions, cause beach erosion, and create hazardous conditions for beachgoers and swimmers.

Photo courtesy Delaware DNREC

What are coastal hazards?

Coastal flooding and storm surge

Coastal flooding and storm surge can result from elevated tide levels, intense winds and heavy rainfall. Tidal areas subject to coastal flooding and storm surge are located along the barrier beaches and marsh shorelines of the Atlantic Coast, Delaware Bay, and Delaware's Inland Bays. Additionally, all low-lying areas adjacent to tidal tributaries are susceptible to flooding and storm surge.

Photo courtesy Delaware DNREC

What are coastal hazards?

Coastal flooding and storm surge

Along the shoreline, storm surge is the principal cause of flooding and inundation during a coastal storm event. Storm surge is caused by the low atmospheric pressure at the center of a storm and the pulling/pushing of water onto the shoreline by accompanying winds. The elevated water levels resulting from storm surge move ashore and flood adjacent land areas.

Photo courtesy Delaware DNREC

What are coastal hazards?

Coastal flooding and storm surge

Elevated water levels caused by storm surge are not only threats to human life, but can also cause extensive damage to property.

Photo courtesy Delaware DNREC

What are coastal hazards?

Coastal flooding and storm surge

Storm surge, along with associated waves and currents, can wash over or break through dunes and spill out onto the landward side of dunes, into roadways and over property and/or wetlands. This process is called overwash. Low-lying areas such as a break in the dune system are particularly vulnerable to overwash.

Photo courtesy Delaware Sea Grant

What are coastal hazards?

Inland flooding

At first glance, the link between inland flooding and coastal hazards may not be obvious. However, torrential rainfall (6 inches or more of precipitation) typically accompanies tropical storm systems and can produce deadly and destructive flooding. This is a major threat to inland areas in Delaware, and all residents should be aware that the impact of coastal storms is not limited to shoreline regions, but can be widespread throughout the region. Typically, greater rainfall amounts and flooding are associated with tropical systems that have a slow forward speed or stall over an area.

Photo courtesy Delaware DNREC

What are coastal hazards?

Inland flooding

In general, there are two types of inland flooding associated with tropical storm systems:

- *Flash Flooding* occurs in creeks, streams, and urban areas within a few minutes or hours of excessive rainfall. Rapidly rising water can overflow stream banks or containment barriers and flood adjacent properties. Streets can become swift moving rivers and underpasses can become death traps.

Photo courtesy Delaware DNREC

- *River Flooding* occurs from heavy rains associated with decaying hurricanes or tropical storms, and in extreme cases, river floods can last a week or more.

Photo courtesy Delaware Geological Survey

Types of coastal hazards

Wind

The most significant coastal wind hazards in Delaware originate from tropical storm systems, northeasters, and storm-spawned tornadoes. Tropical storms are characterized by sustained winds of 39-73 mph, while hurricanes can generate sustained winds ranging from 74 mph (Category 1) to greater than 155 mph (Category 5). Northeasters typically generate sustained winds of 35-45 mph that can last for several days.

Because winds can blow across the ocean without interference, high winds are unimpeded by friction and can impose extremely large forces on structures along the coast. Consequently, coastal buildings can suffer extensive structural damage when they are improperly designed and constructed, or when wind speeds exceed design levels.

Photo courtesy FEMA Coastal Construction Manual

Types of coastal hazards

Wind

During coastal storms, damage from strong winds can be extensive. High velocity winds can blow shingles off of roofs and knock down trees and power lines. Large objects can be lifted and hurled through the air, causing additional destruction.

Recently Sussex County adopted an updated IBC/IRC building code that includes a special high wind zone (110 mph wind) for structures located along the Delaware coast – from Lewes to Fenwick Island, seaward of the Lewes/Rehoboth Canal and the Inland Bays (Rehoboth, Indian River and Little Assawoman Bay).

Photo courtesy FEMA Coastal Construction Manual

Types of coastal hazards

Shoreline erosion – chronic (long-term) and episodic (short-term)

Shoreline erosion is considered to be both a chronic and episodic hazard to Delaware coastal environments and communities. Shoreline erosion is a natural coastal process with a number of contributing factors including waves, longshore currents, sediment supply, storm events, and sea-level rise. Because the magnitude and relative importance of these factors differs along various shoreline segments, the rate of coastal erosion often varies throughout the state.

Photo courtesy Delaware DNREC

Types of coastal hazards

Shoreline erosion – chronic (long-term) and episodic (short-term)

Coastal erosion occurs when there is a net loss of sand from the beach system – either via alongshore or offshore transport, or through the process of overwash and landward migration of the beach system. The loss may be temporary or permanent, and estimates of shoreline change over the past 100 years or so show that much of the Delaware coast has been eroding at average rates of approximately two to three feet per year. However, these rates vary widely along Delaware's beaches, and averaged erosion rates must be used with caution.

Photo courtesy Delaware DNREC

Types of coastal hazards

Shoreline erosion – chronic (long-term) and episodic (short-term)

The location of the shoreline fluctuates on several time scales. The position of the land/water interface can change horizontally by 50 feet or more over a single 6-hour tidal cycle, due to the rise and fall of the tide on a gently-sloping beach. There can be a 100-foot or greater seasonal change from summer to winter, as sand moves onshore and offshore in response to changes in wave conditions. During storms, the location of the coastline and dune line can move dramatically landward in a period of hours to days. Over the long-term (centuries to millennia), sea-level rise results in encroachment of the sea onto the land.

Photo courtesy E. M. Maurmeyer

Photo courtesy E. M. Maurmeyer

Types of coastal hazards

Shoreline erosion – chronic (long-term) and episodic (short-term)

Coastal sediments are constantly in motion, moving along shore, offshore and onshore at differing time scales. The long-term evolution of the shoreline in response to sediment transport processes, sediment supply, and sea-level rise may not be evident on a day-to-day or year-to-year time frame. However, cumulative changes imposed on the beach by these forces can have a dramatic effect over the 50- to 100-year lifetime of most coastal structures.

In contrast, short-term coastal changes generated by extreme storm events are immediately recognizable, as storm surge and waves can rapidly transform the coast by moving a large volume of sand over a relatively short duration.

Photo courtesy T. Pratt

Types of coastal hazards

Shoreline erosion – chronic (long-term) and episodic (short-term)

Long-term erosion is the gradual recession of the coast over a period of decades.

Short-term erosion is the rapid recession of the shoreline in response to coastal storms and flood events.

While major storms are extreme events, they are relatively short in duration and occur infrequently. However, they play a major role in contributing to episodic erosion, shaping how the coast looks and behaves over time. The immediate erosional impact of a single storm is apparent to everyone, but it is the cumulative effects of these storms and the daily movement of sand along the beach that determines how the shoreline moves and changes over time.

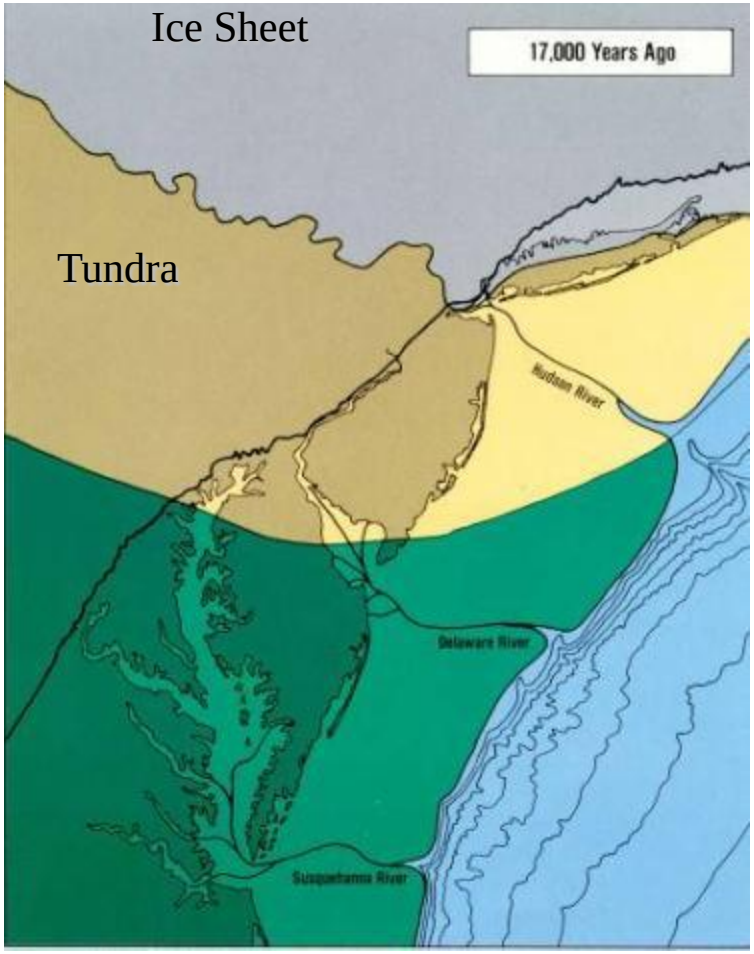
Photo courtesy Delaware DNREC

Types of coastal hazards

Sea-level rise

Because Delaware's coastal environments have evolved and responded to increases in sea level over the past 12,000 years, the impact of sea-level rise is considered to be a long-term or chronic coastal hazard.

Seventeen thousand years ago, during the peak of the last ice age, sea level was approximately 400 feet lower than it is today, and Delaware's ocean coastline was located 75 miles offshore.



Graphic courtesy Delaware Estuary Atlas and J.C. Kraft

Types of coastal hazards

Sea-level rise

As the climate became warmer and ice in the glaciers melted, sea level rose and the shoreline migrated landward to its present position. Geological studies indicate that sea level along the Delaware coast has been rising at varying rates over the past 10,000 years.

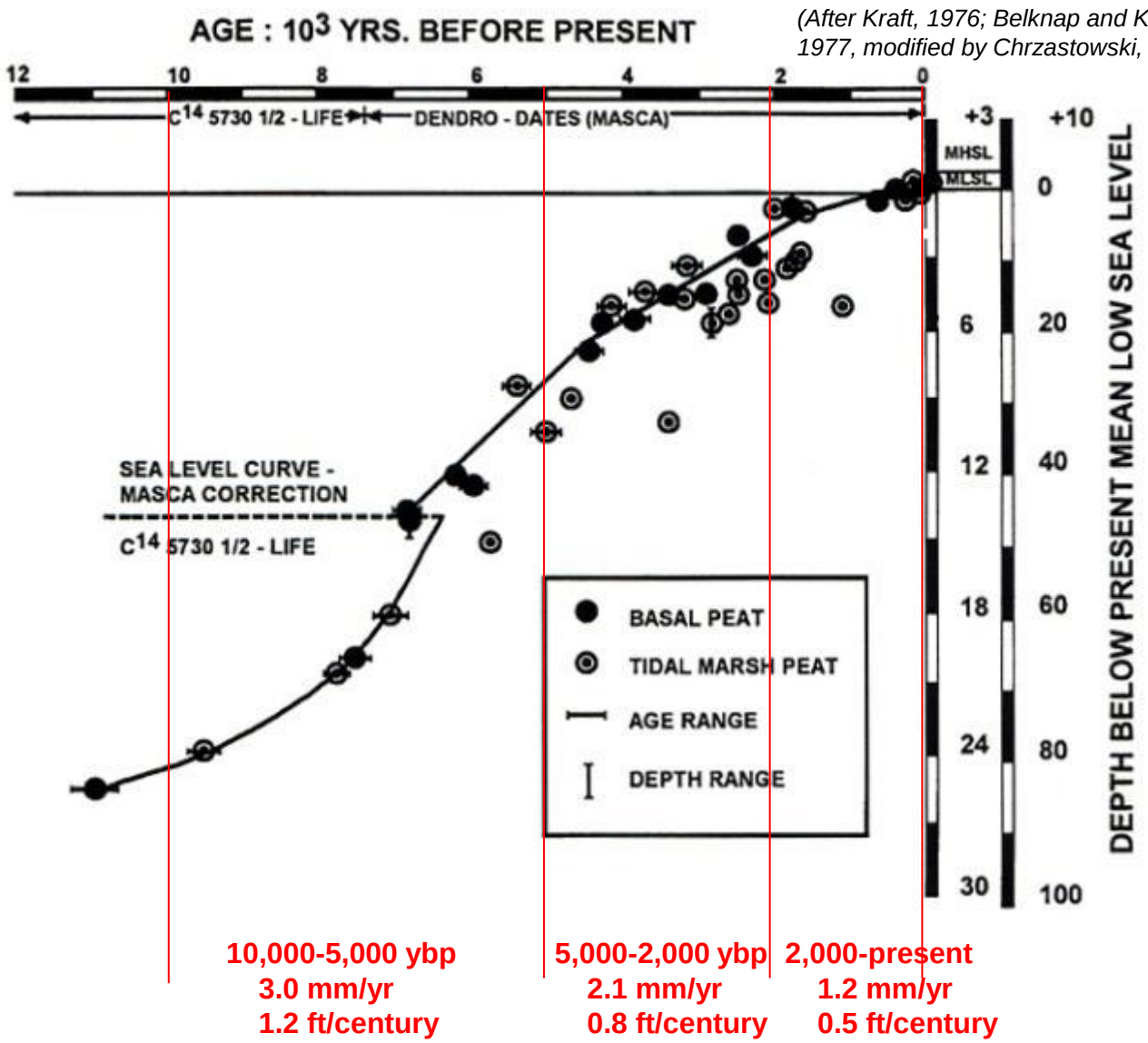
Graphic courtesy Delaware Estuary Atlas and J.C. Kraft

Graphic courtesy Delaware Estuary Atlas and J.C. Kraft

Types of coastal hazards

Sea-level rise

From 10,000 to 5,000 years before present, sea level rose at a rate of 1.2 feet per century. The rate decreased to 0.8 feet per century from 5,000 to 2,000 years before present, and to 0.5 feet per century during the past 2,000 years. Tide gage records at Breakwater Harbor, Delaware, show that sea level has been rising at a rate of approximately one foot per century since the 1920s.



(After Kraft, 1976; Belknap and Kraft, 1977, modified by Chrzastowski, 1986)

Types of coastal hazards

Sea-level rise

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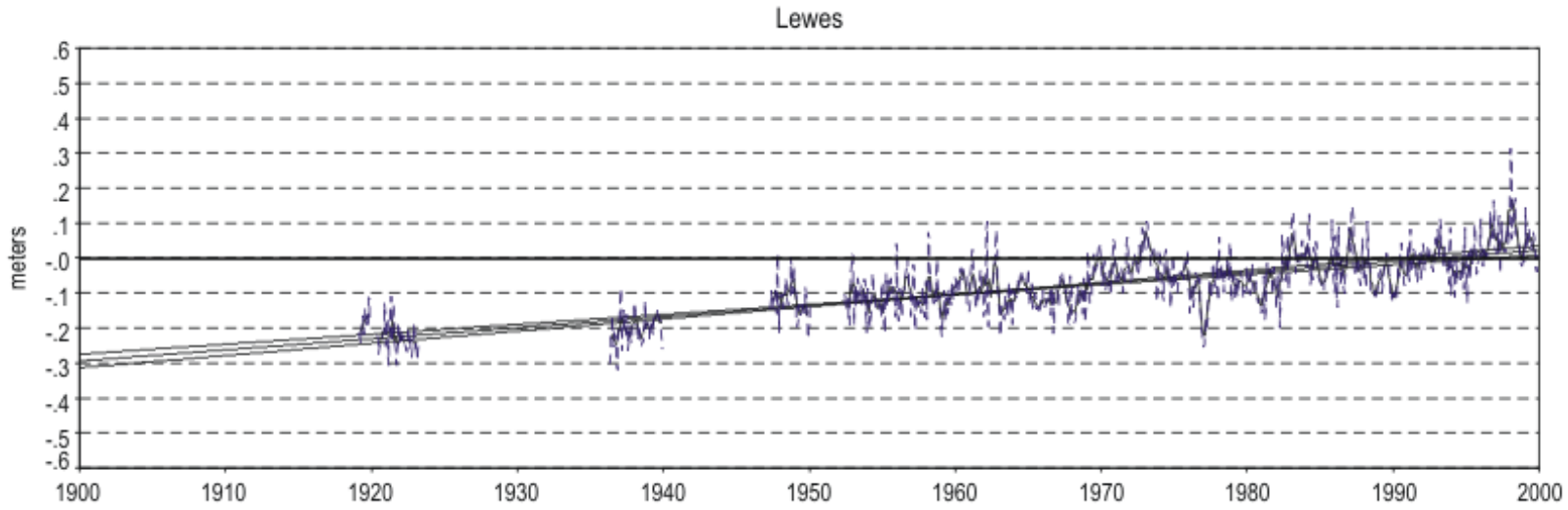


Delaware Relative Sea Level Trends: 3.2 mm/yr (1.0 ft/century)

Source: http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

Types of coastal hazards

Sea-level rise

There is considerable agreement among scientists that the rate of sea-level rise will increase in the next 100 years. The Intergovernmental Panel on Climate Change report (IPCC 2007) recently suggested that rates of sea-level rise are accelerating, and by the year 2100, there may be in an increase in sea level of 2-3 feet along the Delaware coast.

Long-term relative sea-level rise is important in that it ultimately controls the position of the shoreline. An increasing sea level means we will be faced with continued and possibly exacerbated erosion, inundation and flooding problems in the future. Additionally, coastal wetlands may also be affected by long-term sea-level rise, particularly if they do not rise vertically at the same pace as the rising sea.

Photos courtesy Delaware Sea Grant

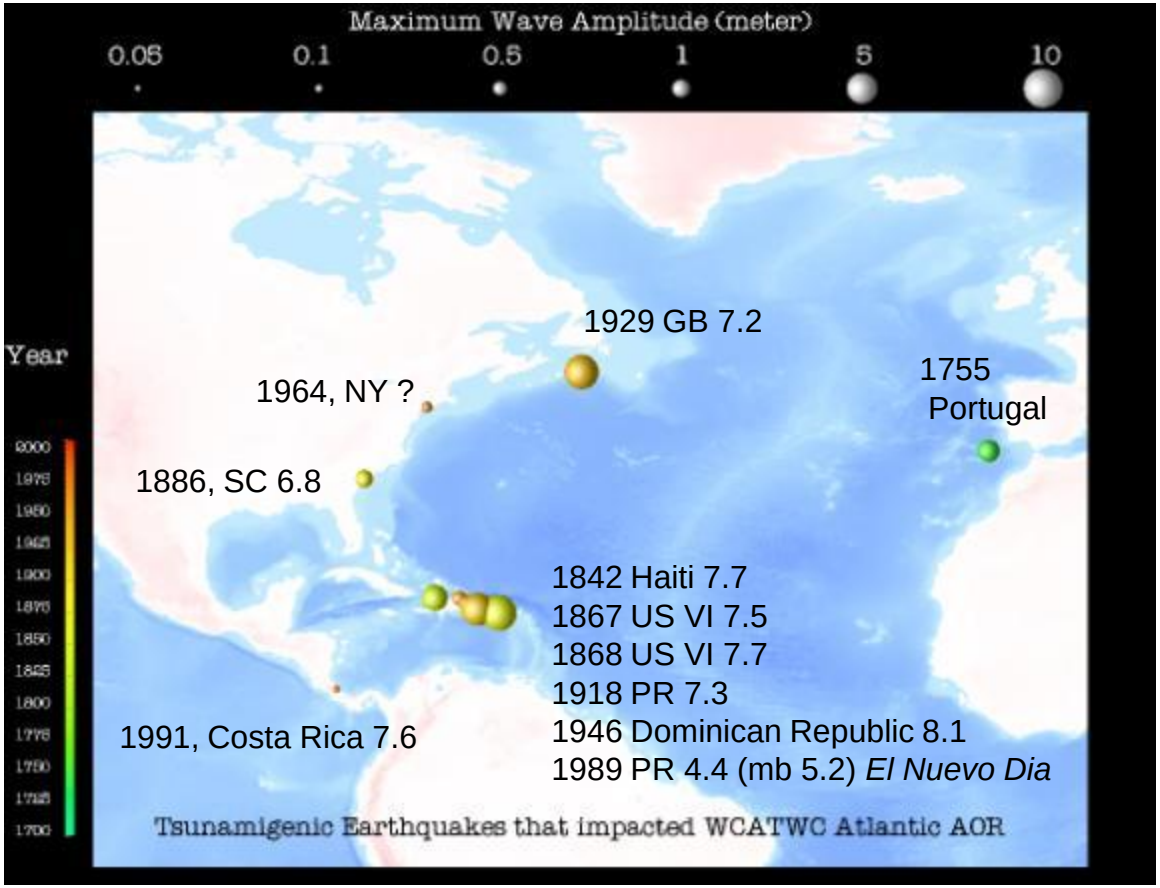
Types of coastal hazards

Tsunami

While tsunamis are not considered to be a high risk coastal hazards, it is possible that a tsunami could impact the Delaware coast. There are many causes of tsunamis, including earthquakes, landslides, volcanic eruptions, explosions, and meteorite impacts – any disturbance that displaces a large water mass can generate a tsunami.

Wave and tide gauge records have documented the relative magnitude of tsunamis reaching the east coast. In 1918 and 1946, tide gauges recorded waves just a few inches high generated by earthquakes in Puerto Rico and the Dominican Republic, respectively.

More recently, Atlantic basin gauges recorded 5-10 inch waves generated by the December 2004 Indian Ocean tsunami.



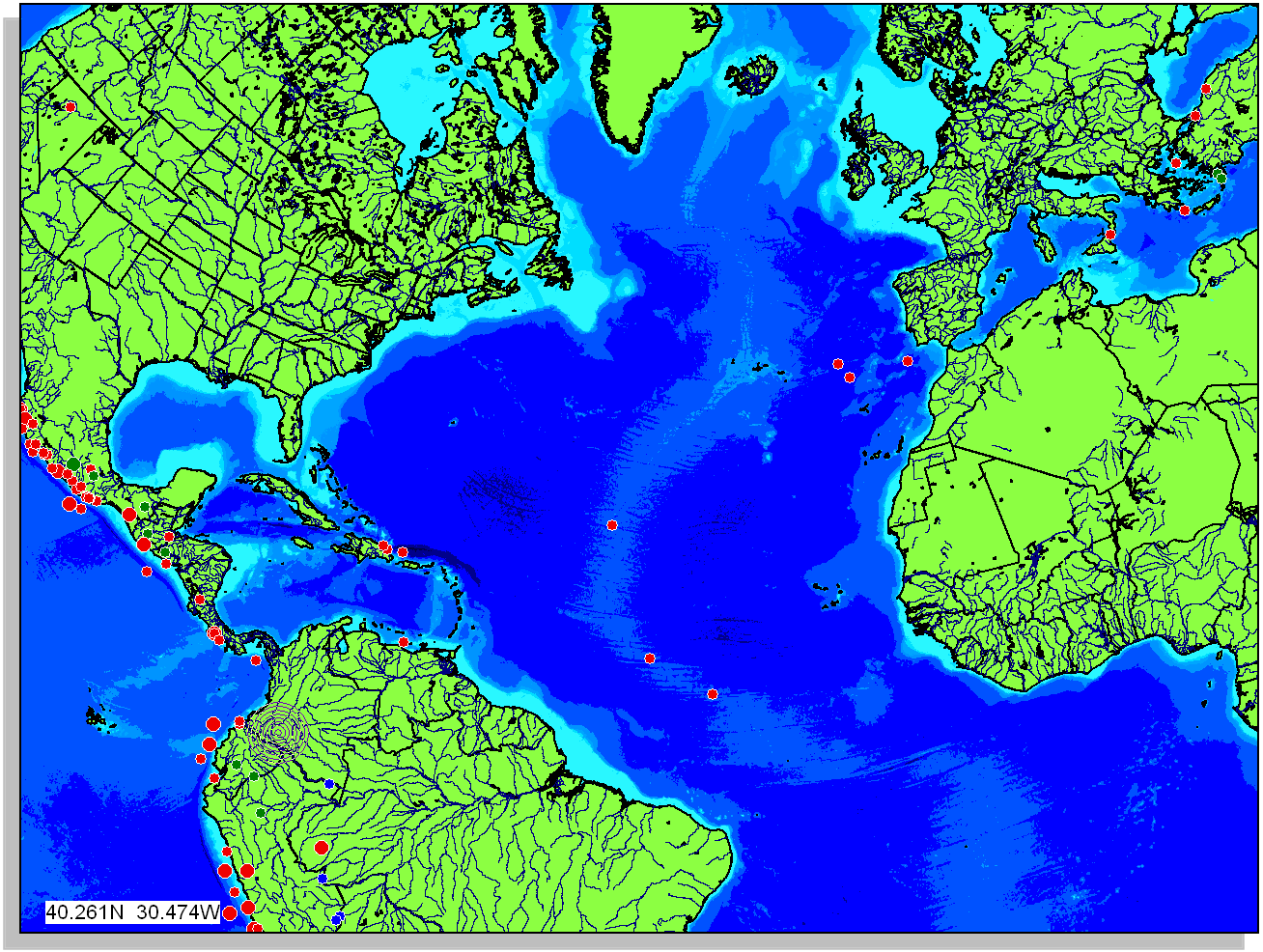
Any place on the coast is at risk of tsunamis, and the East Coast is no exception.
Graphic courtesy of NOAA West Coast and Alaska Tsunami Warning Center

Types of coastal hazards

Tsunami

Tsunamis in the Atlantic Basin are most commonly generated by earthquakes and landslides. Primary sources of tsunami-producing earthquakes in the Atlantic are located near Puerto Rico, Portugal, and the Canary Islands.

Tsunamis in the Atlantic Ocean may also be caused by underwater landslides, usually occurring near the continental shelf and slope.



Instrumental earthquakes with magnitude greater than 7.5

Graphic courtesy of NOAA West Coast and Alaska Tsunami Warning Center

What parts of Delaware are vulnerable to coastal hazards?

The geographic area that encompasses Delaware's entire coastal zone is vulnerable to coastal hazards. This includes not only the shorelines along the Atlantic Ocean and Delaware Bay, but also more sheltered coasts along the Inland Bays (Indian River, Rehoboth and Little Assawoman Bays).

Additionally, risks and vulnerabilities associated with coastal hazards extend along all tidal tributaries and throughout watersheds, including the Nanticoke. Communities located adjacent to non-tidal tributaries and streams are vulnerable to flooding caused by torrential rainfall associated with coastal storms.

Photo courtesy Delaware DNREC

Photo courtesy Delaware DNREC

What parts of Delaware are vulnerable to coastal hazards?

Essentially, communities in all three Delaware counties – New Castle, Kent, and Sussex – are part of the coastal zone, and are vulnerable to risks posed by coastal hazards and flooding.

Photo courtesy Delaware DNREC

Photo courtesy Delaware DNREC

Examples of impacts of coastal hazards and severe flood events in various Delaware communities can be found in PowerPoint presentations included within this website.

Why are Delaware communities vulnerable to coastal hazards?

There are many reasons why communities are vulnerable and exposed to coastal hazards, including:

General characteristics of the coastal plain –

- Proximity to waterways – ocean, bays, tributaries;
- Low-lying topography (low ground elevation);
- Unconsolidated soils (sandy soils are more vulnerable to erosion than hard rock)

Photo courtesy E. M . Maurmeyer

Why are Delaware communities vulnerable to coastal hazards?

Construction of property and infrastructure in vulnerable areas –

- Property located along barrier beaches, bay shores and tributaries;
- Development in flood-prone areas (low-lying areas, floodplains);
- Properties and infrastructure constructed without incorporating hazard mitigation measures (e.g. elevation, etc.).

Why are Delaware communities vulnerable to coastal hazards?

Population growth and associated increases in development –

- Greater number of people living at the coast;
- Subsequent growth of coastal communities causes intensive development pressures.

Photo courtesy Delaware Sea Grant

What are the potential impacts to people, property, and natural resources?

Manifestations of various coastal hazards occur at broadly different rates –

1) *Short-term (days/hours) and catastrophic hazards*

Short term and/or catastrophic impacts – tropical systems, northeasters, storm surge – shoreline change is measured in terms of days or hours.

Short-term effects – alteration of beaches, dunes, wetlands; threats to life and property.

2) *Long-term (years/decades) and gradual/chronic hazards*

Long-term and/or gradual impacts – sea-level rise and chronic erosion – shoreline change is measured on a decadal time-scales.

Long-term effects – more predictable; allow for long-range planning and measured preparation.

What are the potential impacts to people, property, and natural resources?

What are the potential impacts to people, property, and natural resources?

Photo courtesy Delaware DNREC

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Photo courtesy Delaware DNREC

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What are the potential impacts to people, property, and natural resources?

Photo courtesy Delaware City Flood Mitigation Plan Report

What are the potential impacts to people, property, and natural resources?

Photo courtesy Delaware Geological Survey

What are the potential impacts to people, property, and natural resources?

Photo courtesy Delaware DNREC and Delaware State Highway Dept.

How can risks and vulnerabilities be minimized and managed?

One of the first steps a community can take towards becoming more resilient to hazards is to perform an assessment of risks and vulnerabilities.

A risk and vulnerability assessment helps to identify people, property, and resources that are at risk of injury, damage, or loss from hazardous incidents or natural hazards. This information is important to help determine and prioritize the precautionary measures that can make a community more disaster-resistant.

NOAA's Coastal Services Center offers many training opportunities and tools that can help communities assess risks and vulnerabilities.

For example:

Risk and Vulnerability Assessment Tool

Hazard Assessment Tool

How can risks and vulnerabilities be minimized and managed?

General characterization of Delaware coastal hazards and associated risks

Hazard	High Risk	Medium Risk	Low Risk
Hurricane		X	
Northeaster	X		
Storm Surge	X		
Flooding	X		
Wind		X	
Episodic Erosion	X		
Chronic Erosion		X	
Sea-level Rise		X	
Tsunamis			X

How can risks and vulnerabilities be minimized and managed?

After community risks and vulnerabilities are assessed, appropriate measures can be taken – local regulations and ordinances; planning and implementation.

Photo courtesy Delaware DNREC

How can risks and vulnerabilities be minimized and managed?

Communities and coastal resource managers may use various measures to reduce coastal hazards and flood-related risks.

Policies and regulatory tools:

Setback lines and zoning restrictions can be used to control development in hazardous locations along coastlines and in floodplains.

Building codes can be used to improve likelihood a structure will survive an extreme storm or flood event (home elevation, increasing freeboard, etc.);

Prohibition of reconstruction of structures that are destroyed in flood or storm events;

Relocation of buildings and communities at risk of severe damage;

Implement hazard mitigation planning initiatives and incentives.

Photo courtesy Delaware DNREC

How can risks and vulnerabilities be minimized and managed?

Elevation and relocation of a flood-prone home on the Delaware Bay

Kent County – DNREC – FEMA partnership

Photo courtesy Delaware DNREC

Photo courtesy Delaware DNREC

Slide and data courtesy of Mike Powell, Delaware DNREC

How can risks and vulnerabilities be minimized and managed?

Coastal resource managers may use various measures to reduce coastal hazards and flood-related risks.

Management strategies:

Beach nourishment and regional sediment management;

Continue to evaluate adequacy of existing coastal hazards data, tools and regulations;

Develop and communicate best management practices for development in areas prone to coastal hazards and floods.

How can risks and vulnerabilities be minimized and managed?

There are many ways that local, state and federal agencies and organizations can work together to reduce the impacts of coastal hazards and flooding on Delaware communities, including:

Enhance and improve community-wide awareness about hazards, risks, and vulnerabilities.

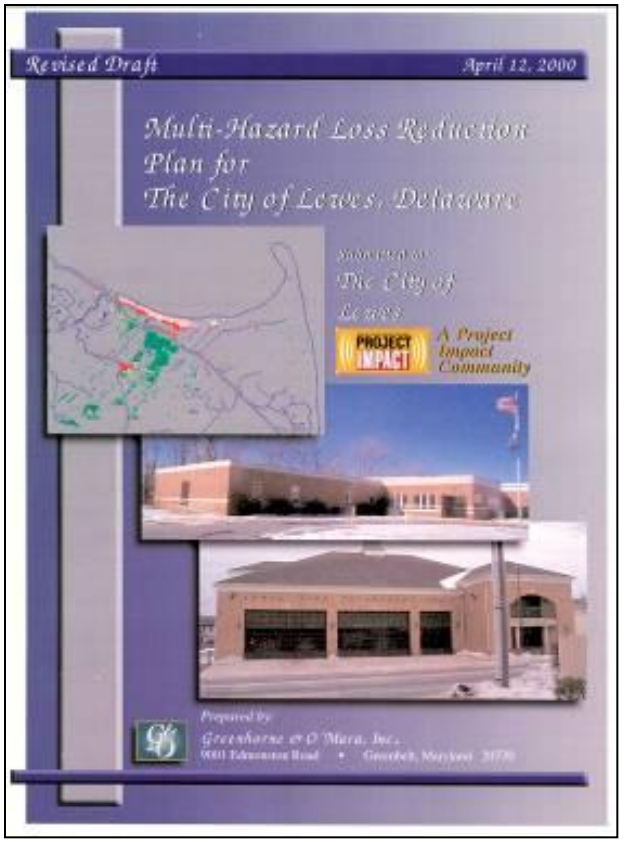
Ensure that all communities have the capacity to prepare for and respond to hazardous events.

Coordinate with community officials to develop training/education programs that will enhance opportunities to adopt best practices and ordinances that will minimize risks and vulnerabilities.

Continue to conduct research on hazards and related risks.

Increase availability and usefulness of hazard-related information and forecasting for citizens and community leaders.

Enhance ability of all communities to apply best available hazards information, tools and technologies to maximize community resiliency to coastal hazards and flooding.



How can risks and vulnerabilities be minimized and managed?

In the wake of hurricanes Katrina, Rita and Ike, concerns of coastal resiliency and sustainability have become prominent in discussions of hazard planning and coastal management.

Coastal communities can benefit from comprehensive vulnerability planning to deal with potential coastal hazards and associated damages.

How can risks and vulnerabilities be minimized and managed?

Community Resiliency Questionnaire – Preliminary Self-Evaluation

Have you evaluated the coastal natural hazards that may impact your community? ❑ Yes ❑ No
What are your community's primary coastal hazards? (please list)

Has your community been introduced to the concept of community resiliency? ❑ Yes ❑ No ❑ Unsure

Does your community have a comprehensive/strategic plan that includes a "Natural Hazard" section?
❑ Yes ❑ No ❑ Unsure

Does your community have a natural hazard mitigation plan? ❑ Yes ❑ No ❑ Unsure
If yes, has it been revised within the past two years? ❑ Yes ❑ No ❑ Unsure
Does your community have a hazard mitigation committee? ❑ Yes ❑ No ❑ Unsure

Does your community:
Participate in the National Flood Insurance Program (NFIP)? ❑ Yes ❑ No ❑ Unsure
Participate in the Community Rating System? ❑ Yes ❑ No ❑ Unsure
Have a Certified Floodplain Manager on staff? ❑ Yes ❑ No ❑ Unsure

Has your community implemented mitigation measures? For example:

Elevation of buildings to local NFIP standards ❑ Yes ❑ No ❑ Unsure
Relocation of buildings and infrastructure ❑ Yes ❑ No ❑ Unsure
Flood proofing non-residential structures ❑ Yes ❑ No ❑ Unsure
Education programs ❑ Yes ❑ No ❑ Unsure
Acquisition of repetitive loss structures or infrastructure ❑ Yes ❑ No ❑ Unsure
Incentive-based mitigation measures ❑ Yes ❑ No ❑ Unsure

Are your community's evacuation route(s) flood-prone? ❑ Yes ❑ No ❑ Unsure