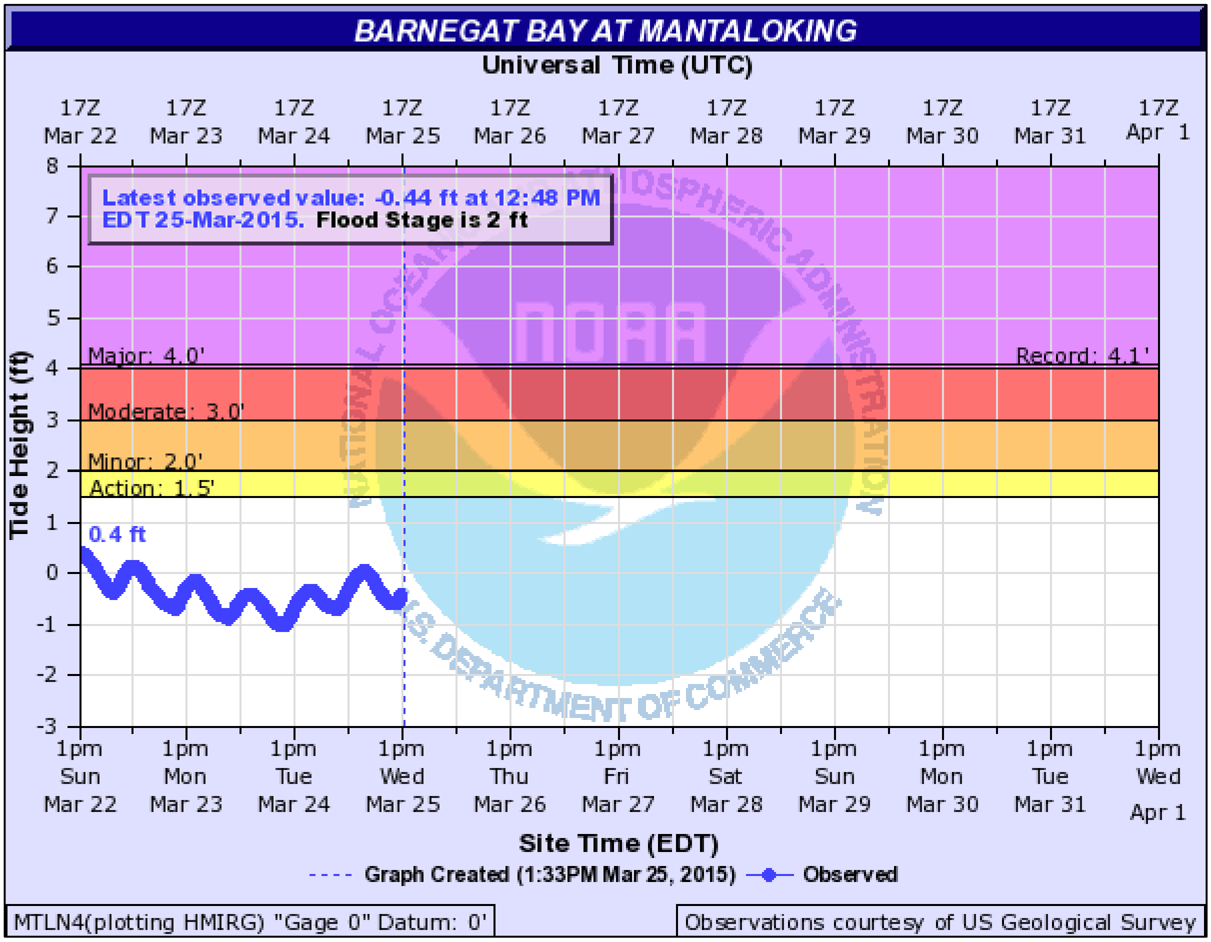
Figure 9. Barnegat Bay Hydrograph near Mantaloking, NJ



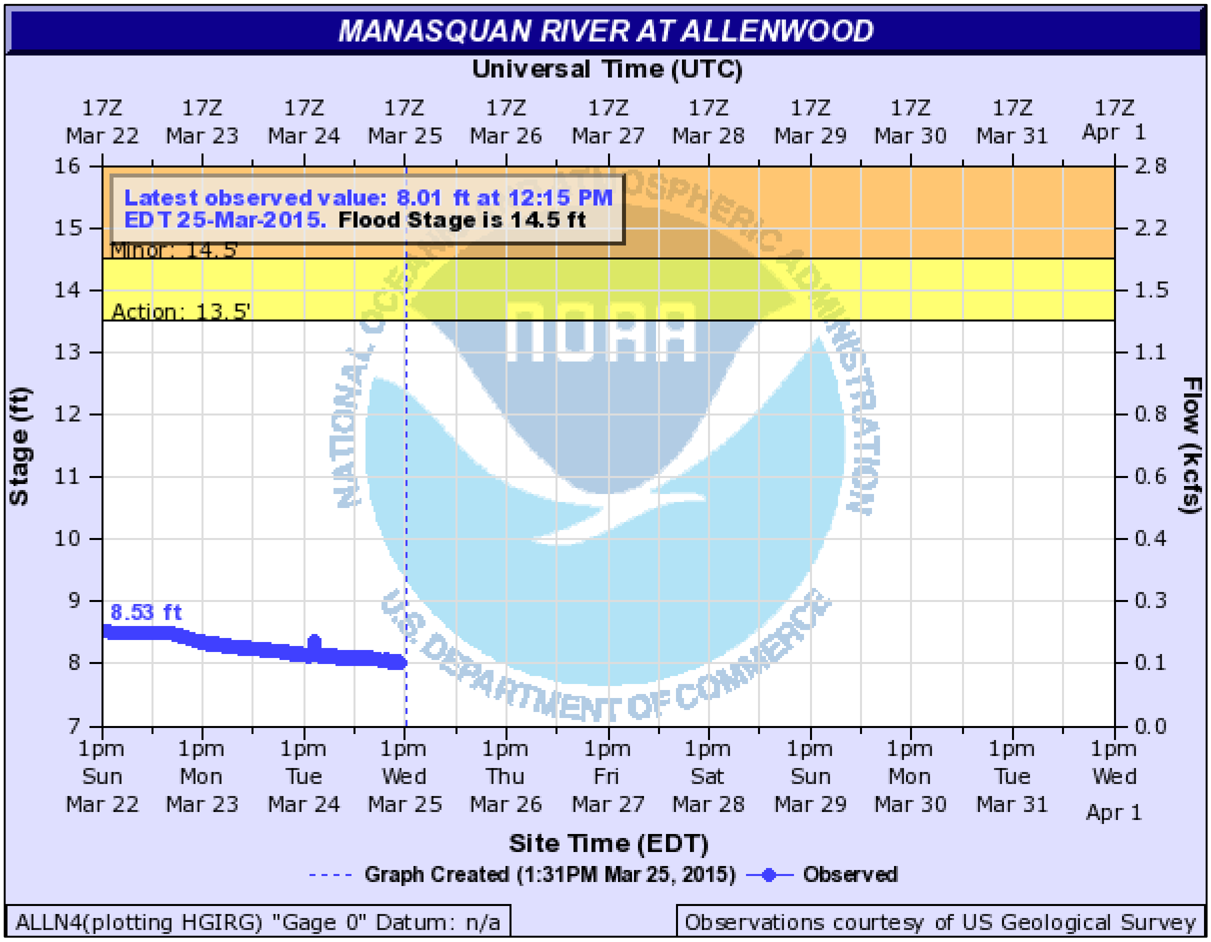
Source: NOAA NWS 2015

Notes:

EDT *Eastern Daylight Time*

ft *feet*

Figure 10. Manasquan River Hydrograph near Allenwood, NJ



Source: NOAA NWS 2015
Notes:
EDT *Eastern Daylight Time*
ft *feet*
kcfs *Kilo cubic feet per second*

The NWS issues watches and warnings when forecasts indicate rivers may approach bank-full levels. The flood extent or severity categories used by the NWS include minor flooding, moderate flooding, and major flooding. Each category has a definition based on property damage and public threat:

- Minor Flooding - minimal or no property damage, but possibly some public threat or inconvenience.
- Moderate Flooding - some inundation of structures and roads near streams. Some evacuations of people and/or transfer of property to higher elevations are necessary.
- Major Flooding - extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations (NWS 2011).

When a watch is issued, the public should prepare for the possibility of a flood. When a warning is issued, the public is advised to stay tuned to a local radio station for further information and be prepared to take quick action if needed. A warning means a flood is imminent, generally within 12 hours, or is occurring. Local media broadcast NWS warnings. Thresholds for flood warnings have been established on the major rivers in the Township of Brick, based on available stream gage information, as follows:

- North Branch of the Metedeconk River, near Lakewood, NJ
    - Action state is 7 feet
    - Minor flooding/Initial flood stage is 8 feet
    - Moderate flooding is 9 feet
    - Major flooding is 10 feet
- Barnegat Bay near Mantaloking, NJ
    - Action state is 1.5 feet
    - Minor flooding/Initial flood stage is 2 feet
    - Moderate flooding is 3 feet
    - Major flooding is 4 feet
- Manasquan River near Allenwood, NJ
    - Action state is 13.5 feet
    - Minor flooding/Initial flood stage is 14.5 feet
    - Moderate and major flood stages are not currently available

Coastal Flooding Secondary Hazards

The most problematic secondary hazard for flooding is bank erosion, which in some cases can be more harmful than actual flooding. This is especially true in the upper courses of rivers with steep gradients, where floodwaters may pass quickly and without much damage, but scour the banks, edging properties closer to the floodplain or causing them to fall in. Flooding is also responsible for hazards such as landslides when high flows over saturate soils on steep slopes, causing them to fail. Hazardous materials spills are also a secondary hazard of flooding if storage tanks rupture and spill into streams, rivers, or storm sewers.

Coastal Erosion Hazard

Along with flooding, coastal erosion is one of the primary coastal hazards leading to loss of lives or damage to property and infrastructure in damaged coastal areas. Coastal storms are an intricate combination of events that impact a coastal area. A coastal storm can occur any time of the year and at varying levels of severity. One of the greatest threats from a coastal storm is coastal flooding caused by storm surge. Coastal flooding is the inundation of land areas along the oceanic coast and estuarine shoreline by seawaters over and above normal tidal action.

Many natural factors affect erosion of the shoreline, including shore and nearshore morphology, shoreline orientation, and the response of these factors to storm frequency and sea-level rise. Coastal shorelines change constantly in response to wind, waves, tides, sea-level fluctuation, seasonal and climatic variations, human alteration, and other factors that influence the movement of sand and material within a shoreline system.

Unsafe tidal conditions, as a result of high winds, heavy surf, erosion, and fog, are ordinary coastal hazard phenomena. Some or all of these processes can occur during a coastal storm, resulting in an often detrimental impact on the surrounding coastline. Factors including: (1) storms such as Nor'easters and hurricanes, (2) decreased sediment supplies, and (3) sea-level rise contribute to these coastal hazards.

Coastal erosion can result in significant economic loss through the destruction of buildings, roads, infrastructure, natural resources, and wildlife habitats. Damage often results from an episodic event with the combination of severe storm waves and dune or bluff erosion.

Historically, some of the methods used by municipalities and property owners to stop or slow down coastal erosion or shoreline change have actually exacerbated the problem. Attempting to halt the natural process of erosion with shore parallel or perpendicular structures such as seawalls (groins and jetties) and other hard structures typically worsens the erosion in front of the structure (i.e. walls), prevents or starves any sediment behind the structure (groins) from supplying down-drift properties with sediment, and subjects down-drift beaches to increased erosion. Since most sediment transport associated with erosion and longshore drift has been reduced, some of the state's greatest assets and attractions—beaches, dunes, barrier beaches, salt marshes, and estuaries—are threatened and will slowly disappear as the sediment sources that feed and sustain them are eliminated.

Sandy barrier/bluff coastlines are constantly changing as the result of wind, currents, storms, and sea-level rise. Because of this, developed sandy shorelines are often stabilized with hardened structures (seawalls, bulkheads, revetments, rip-rap, gabions, and groins) to protect coastal properties from erosion. While hardened structures typically prove to be beneficial in reducing property damage, the rate of coastal erosion typically increases near stabilization structures. This increased erosion impacts natural habitats, spawning grounds, recreational activity areas, and public access (Frizzera 2011). Ocean County is home to a number of NJDEP shoreline structures, both along the Atlantic Ocean and inland bays, including 72 groins and three jetties (NJDEP 1993).

To counteract the negative impact of hard structures, alternative forms of shoreline stabilization that provide more natural forms of protection can be used. Along the New Jersey coast, beach nourishment and dune restoration are now the main forms of shoreline protection. In addition, existing groins have been notched to reestablish the flow of sediment to previously sand-starved areas of the beach. The sheltered coastlines in New Jersey consist of tidal marshlands and a few narrow, sandy beaches—all of which naturally migrate inland as the sea level rises. Experts have stated that marshes can keep pace with a 0.1 inch per year (inch/year) rate of sea level rise; however, the state's current rate is approximately 0.11 to 0.16 inch/year, a rate that is predicted to continue increasing (Frizzera 2011). Currently, bulkheads and revetments are the primary form of shore protection along these tidal areas. As the sea level rises and coastal storms increase in intensity, coastal erosion and requests for additional shoreline stabilization measures are likely to increase (Frizzera 2011).

Coastal Erosion Location

Although structural and other measures can be taken to reduce the impact or frequency of this hazard, all shorelines in the Township are vulnerable to coastal erosion. The properties most at risk to coastal erosion will be those located within 200 feet of the erodible shoreline and beaches. In the Township of Brick, this consists of 292 parcels (0.5% of total parcels in the municipality), which is consists of 1,913 at-risk parcels or 0.5% of total parcels in the county).

As noted earlier, the Township of Brick has the most privately-owned waterfront property of any municipality in New Jersey, including 1.79 miles of ocean-front property on the barrier island and 11.93 miles of bay-front property (OC HMP 2014). This creates an additional area of vulnerability, as private property may not be monitored and regulated with the same degree of care against erosion unless property owners are aware of the potential impacts of non-managed coastal erosion on their property. The 2012 NJBPN notes that elevations, low spots, placement of access stairways to the beach, and other dune maintenance measures has been at the option of individual owners and that there is little municipal oversight of general dune maintenance. The Township of Brick has begun addressing this concern through beach replenishment initiatives after this vulnerability was identified during Superstorm Sandy.

Coastal Erosion Severity

Coastal erosion is measured as the rate of change in the position or horizontal displacement of a shoreline over a period of time. It is generally caused by storm surges, hurricanes, windstorms, and flooding. Coastal erosion may be exacerbated by human activities, such as boat wakes, shoreline hardening, and dredging (FEMA 1996).

Natural recovery after erosion events can take months or years. If a dune or beach does not recover quickly enough via natural processes, coastal and upland property may be exposed to further damage in subsequent events. Coastal erosion can cause the destruction of buildings and infrastructure (FEMA 1996).

The severity of coastal erosion in the Township of Brick can be observed in the results of the post-storm survey performed by the Richard Stockton College of NJ Coastal Research Center (CRC). The analysis for the developed portion of the northern Ocean County barrier-spit compares data collected during fall 2012 (mid-September) to data surveyed post-storm (Sandy) on November 8th, 12th, and 19th 2012. Data from profile locations situated at Normandy Beach and Public Beach #3 (locations 151 and 152, respectively) indicated significant foredune removal as shown in Figures 5-11 and 5-12 below.

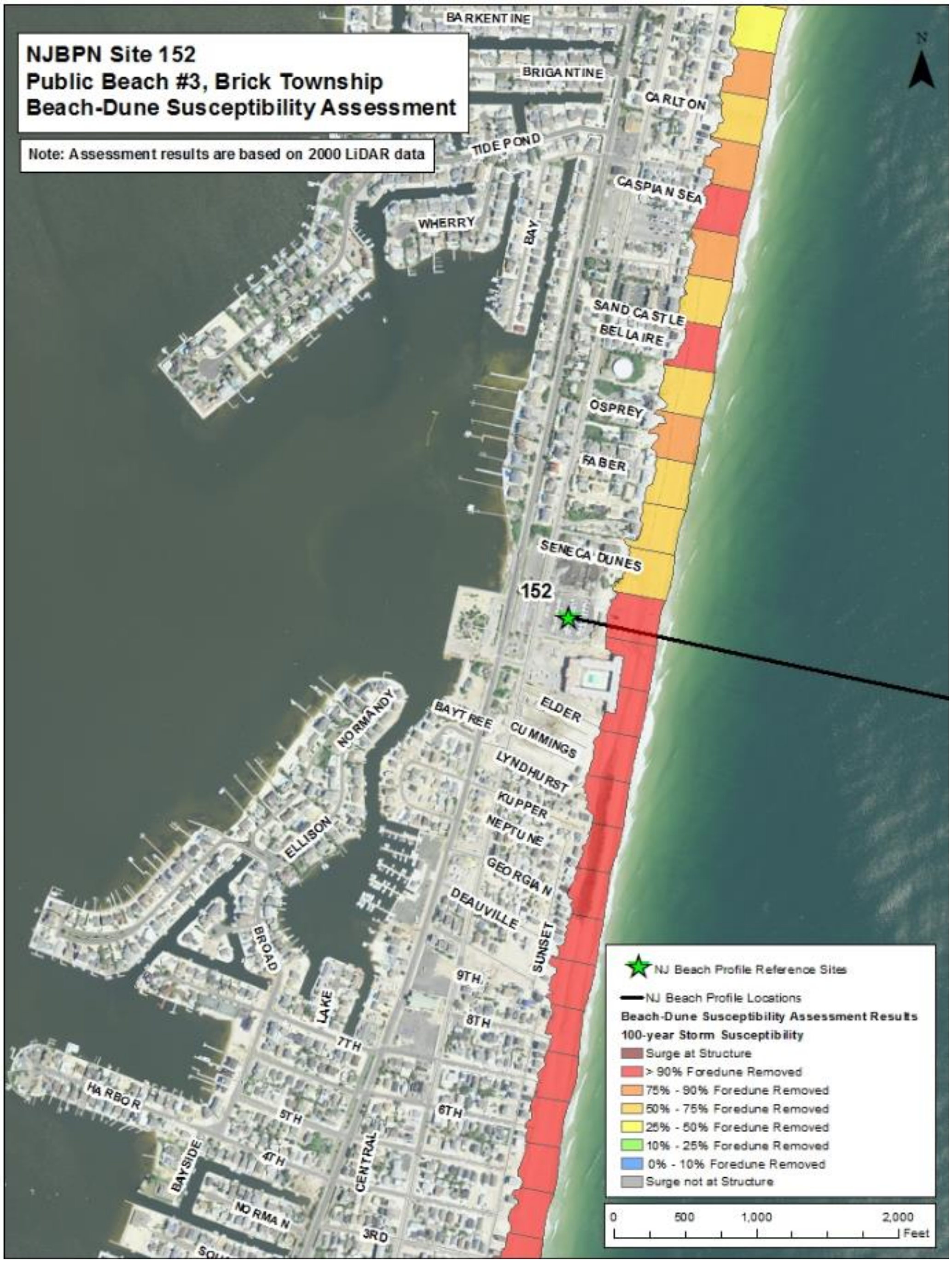
Figure 11. Predicted Impacts from a 100-Year Storm Surge at Public Beach in Brick Township

The photographs above were taken on September 14, 2012 (left) and November 8, 2012 (right).

This figure shows the predicted impacts from a 100-year storm surge at the Public Beach in Brick Township. The predicted suseptibility was based upon the moderate berm width. Also shown is the comparison plot between the pre- and post-storm surveys. The plot depicts the changes caused by the storm and the losses of theberm and moderate dune were 42.0 yds3/ft. of sand were removed during the storm. Prior to Sandy, the bulkhead was buried at least 10 feet below the dunes. Sand was transported landward in overwash deposits and several landward homes were damaged.

Source: Getting to Resiliency Recommendations Report, 2015

Figure 12. Public Beach #3 – Brick Township – Before & After Hurricane Sandy



Source: Getting to Resiliency Report, 2015

Coastal Erosion Warning Time

Meteorologists can often predict the likelihood of weather events that can impact shoreline communities in the short term and ultimately the shoreline. NOAA's NWS monitors potential events, and provides forecasts and information, sometimes several days in advance of a storm, to help prepare for an incident. With the number of structures increasing along the coast, the shoreline becomes increasingly modified. Impact from weather incidents will continue to influence the state's coastal areas, intensifying and exacerbating the coastal erosion situation.

Coastal Erosion Secondary Hazard

Coastal erosion is typically a sporadic event and most typically associated with another hazard event, such as a hurricane. Additionally, erosion rates are influenced by local geographic features and man-made structures. Although most typically associated with flooding, coastal erosion can also be caused by windstorm events, which can blow beach and dune sand overland into adjacent low-lying marshes, upland habitats, inland bays, and communities. If related to a flood event, erosion is typically seen when extreme rainfall scours and erodes dunes and when inland floodwaters return through the dunes and beach face into the ocean (FEMA 1996).

Shore protection structures such as seawalls and revetments often are built to attempt to stabilize the upland property. However, typically they eliminate natural wave run-up and sand deposition processes and can increase reflected wave action and currents at the waterline. Increased wave action can cause localized scour in front of structures and prevent settlement of suspended sediment (FEMA 1996).

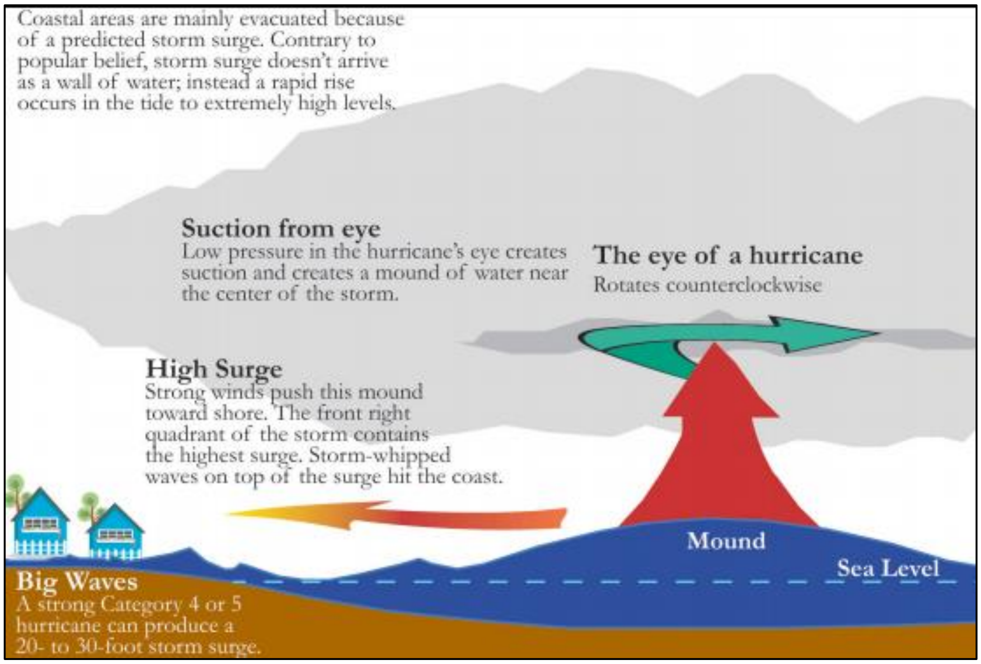
Coastal erosion is a frequent secondary hazard during coastal flooding events in Ocean County and the Township of Brick. Although not usually listed as an isolated event, coastal erosion is frequently included in a summary of damages.

Storm Surge Hazard

Storm surges inundate coastal floodplains by dune overwash, tidal elevation rise in inland bays and harbors, and backwater flooding through coastal river mouths. Strong winds can increase in tide levels and water-surface elevations. Storm systems generate large waves that run up and flood coastal beaches. The combined effects create storm surges that affect the beach, dunes, and adjacent low-lying floodplains. Shallow, offshore depths can cause storm-driven waves and tides to pile up against the shoreline and inside bays.

Based on an area's topography, a storm surge may inundate only a small area (along sections of the northeast or southeast coasts) or a storm surge may inundate coastal lands for a mile or more inland from the shoreline. Figure 5-13 depicts a storm surge.

Figure 13. Storm Surge



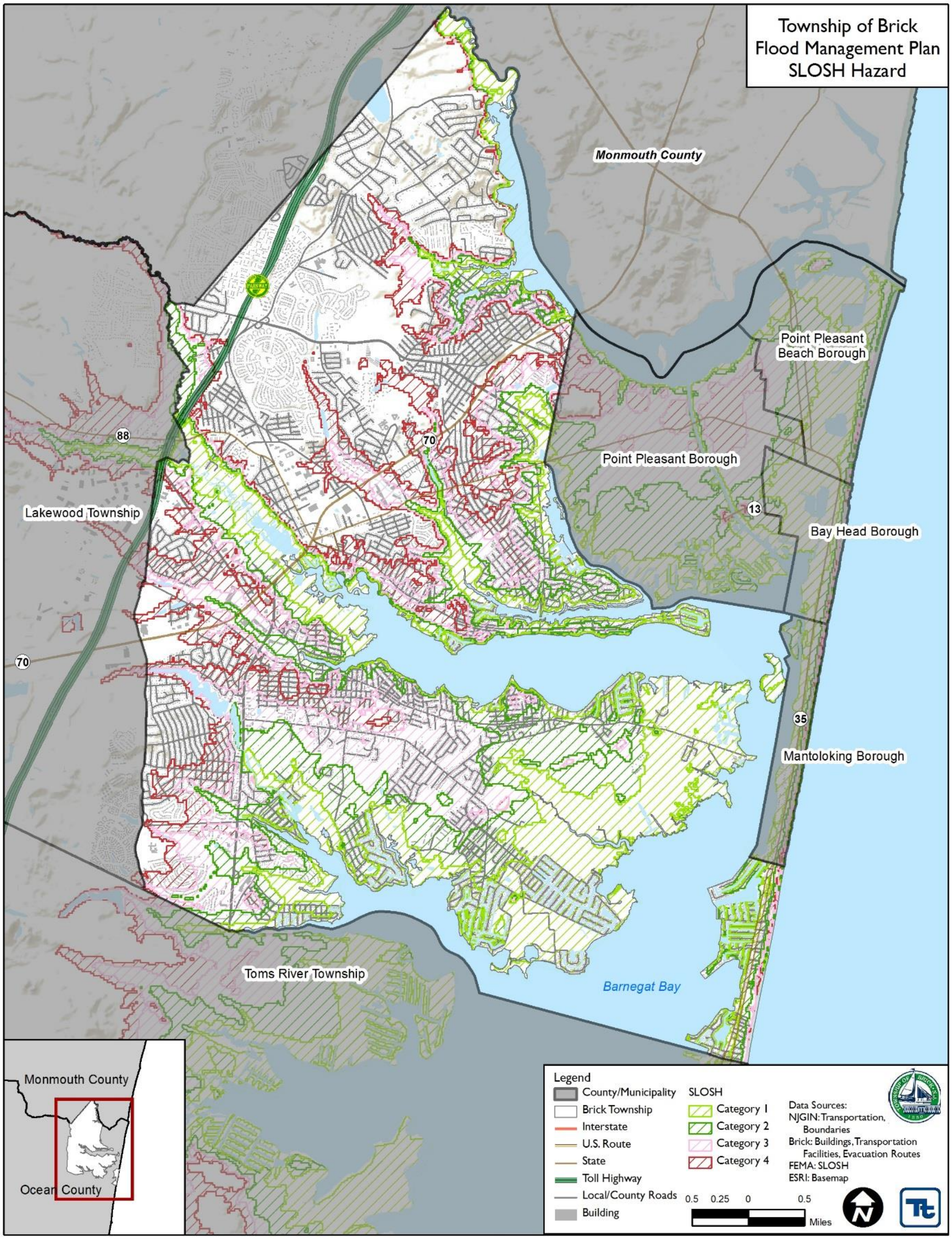
Source: FEMA 2010

Storm Surge Location

As noted above, inundation from storm surge has devastating impacts on coastal communities. The USACE, in cooperation with FEMA, initially prepared Sea, Lake and Overland Surge from Hurricanes (SLOSH) inundation maps. SLOSH maps represent potential flooding from worst-case combinations of hurricane direction, forward speed, landfall point, and high astronomical tide. It does not include riverine flooding caused by hurricane surge or inland freshwater flooding. The mapping was developed for the coastal communities in New Jersey using the computer model to forecast surges that occur from wind and pressure forces of hurricanes coastline topography. In New Jersey, hurricane category is the predominant factor in worst-case hurricane surges. The resulting inundation areas are grouped into Category 1 and 2 (dangerous), Category 3 (devastating), and Category 4 (catastrophic) classifications. The hurricane category refers to the Saffir/Simpson Hurricane Intensity Scale, summarized below.

FEMA Region IV Risk Analysis Team developed storm surge inundation grids for the State of New Jersey in a spatial format from the maximum of maximums outputs from the SLOSH model. These represent the worst-case storm surge scenarios for each hurricane category (1 through 4). To assess the Township's exposure to the hurricane/tropical surge, a spatial analysis was conducted using the SLOSH model. Refer to the 'Vulnerability Assessment' presented later in this section. The SLOSH boundaries do not account for any inland flash flooding. Figure 5-14 illustrates the SLOSH zones in the Township of Brick.

Figure 14. FEMA Region IV SLOSH Model



Source: FEMA 2012, NJGIN 2015

Storm Surge Frequency

Like coastal erosion, storm surge frequencies are tied to other hazard events. Storm surge most often occurs as a secondary threat from a hurricane or severe storm. In general, the severity of a storm can be used to roughly predict the existence of storm surge (in that a very severe storm or hurricane will likely lead to storm surge), although specific factors and details, such as the storm's intensity, approach, and angle to the shoreline, and the local coastline's geography, also play a significant role in the occurrence of storm surge.

Storm Surge Severity

Typically, storm surge is estimated by subtracting the regular/astronomical tide level from the observed storm tide. Typical storm surge heights range from several feet to more than 25 feet. The exact height of the storm surge and which coastal areas will be flooded depends on many factors: strength, intensity, and speed of the hurricane or storm; the direction it is moving relative to the shoreline; how rapidly the sea floor is sloping along the shore; the shape of the shoreline; and the astronomical tide. Storm surge is the most damaging when it occurs along a shallow sloped shoreline, during high tide, in a highly populated, and developed area with little or no natural buffers (for example, barrier islands, coral reefs, and coastal vegetation).

The most common reference to a return period for storm surges has been the elevation of the coastal flood having a 1-percent chance of being equaled or exceeded in any given year, also known as the 100-year flood. Detailed hydraulic analyses include establishing the relationship of tide levels with wave heights and wave run-up. The storm surge inundation limits for the 1-percent annual chance coastal flood event are a function of the combined influence of the water surface elevation rise and accompanying wave heights and wave run-up along the coastline.

The risk of storm surge elevations higher than seven feet exists in every coastal state from Texas to New Jersey. A storm surge associated with storms of longer recurrence intervals may result in more storm surge flooding, higher water levels, larger waves, and an increased likelihood of dune overwash, wave damage, and possible breaching of barrier islands.

Storm Surge Warning Time

Storm surge is most frequently associated with severe coastal storms and hurricanes. Although suggestions for storm surge-specific scales have been raised, NOAA currently does not believe that a system would effectively help convey the appropriate threat level of any impending storm surge. This is most specifically due to storm surge being significantly influenced by local coastal elevations (e.g., where shallow waters increase surge, the coastline can focus and amplify surge, and waterways can carry surge further inland). NOAA is currently working on enhancing storm surge analysis and prediction tools to create more accurate prediction and height tools. Currently, storm surge probabilities are available through the National Hurricane Center during hurricane watches and warnings.

Storm Surge Secondary Hazard

Storm surge is considered the greatest threat to life and property from a hurricane. In fact, storm surge is usually the cause behind most hurricane-related deaths. Although Hurricane Katrina did not occur in New Jersey, it provides a powerful example of the potential effect of storm surge indicating the potential extensive impact on life safety during similar events in New Jersey and specifically the Township of Brick. According to the National Hurricane Center, at least 1,500 people lost their lives either directly or indirectly from the storm surge associated with Hurricane Katrina. Storm surge can cause significant property damage both by power and momentum of waves crashing into property and by eroding, undermining, and weakening structural foundations. This second form also contributes to additional coastal erosion and the destruction of roadways.

The National Hurricane Center notes that the maximum potential for storm surge depends on a number of locational and event factors, including storm intensity, forward speed of the storm, size of the storm, the storm's angle of approach to the coast, central pressure, the width and slope of the continental shelf, and the shape and characteristics of coastal features.

Storm surge is a frequent secondary hazard during coastal flooding events in Ocean County and the Township of Brick. Although this event is sometimes categorized individually by NOAA and other hazard-tracking databases, it may also be included under a general flooding event in the summary of damages.

Stormwater and Urban Drainage Flooding

Stormwater flooding is a result of local drainage issues and high groundwater levels. Locally, heavy precipitation, especially during high lunar tide events may produce flooding in areas other than delineated floodplains or along recognizable channels due to the existence of storm system outfalls which are inadequate to provide gravity drainage into the adjacent body of water. If local conditions cannot accommodate intense precipitation through a combination of infiltration and surface runoff, water may accumulate and cause flooding problems. During winter and spring, frozen ground and snow accumulations may contribute to inadequate drainage and localized ponding. Flooding issues of this nature generally occur in areas with flat gradients and generally increase with urbanization which speeds the accumulation of floodwaters because of impervious areas. Shallow street flooding can occur unless channels have been improved to account for increased flows (FEMA 1997). There are numerous areas within the Township that experience Stormwater flooding and contribute to street and structure inundation several times a year within the Township.

High groundwater levels can be a concern and cause problems even where there is no surface flooding. Basements are susceptible to flooding from high groundwater levels. Seasonally high groundwater is common in many areas, while elsewhere high groundwater occurs only after a long periods of above-average precipitation (FEMA 1997).

Urban drainage flooding is caused by increased water runoff due to urban development and drainage systems. Drainage systems are designed to remove surface water from developed areas as quickly as possible to prevent localized flooding on streets and other urban areas. These systems make use of a closed conveyance system that channels water away from an urban area to surrounding streams and bypasses the natural processes of water filtration through the ground, containment, and evaporation of excess water. Since drainage systems reduce the amount of time the surface water takes to reach surrounding streams, flooding in those streams can occur more quickly and reach greater depths than prior to development in that area (FEMA 2008).

Dam Failure Hazard

A dam is an artificial barrier that has the ability to store water, wastewater, or liquid-borne materials for many reasons (flood control, human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, recreation, or pollution control. Many dams fulfill a combination of these stated functions (Association of State Dam Safety Officials 2013). Dams are an important resource in the United States.

Man-made dams can be classified according to the type of construction material used, the methods used in construction, the slope or cross-section of the dam, the way the dam resists the forces of the water pressure behind it, the means used for controlling seepage, and, occasionally, the purpose of the dam. The materials used for construction of dams include earth, rock, tailings from mining or milling, concrete, masonry, steel, timber, miscellaneous materials (plastic or rubber), and any combination of these materials (Association of State Dam Safety Officials 2013).

Dam failures typically occur when the spillway capacity is inadequate and excess flow overtops the dam, or when internal erosion (piping) through the dam or foundation occurs. Complete failure occurs if internal erosion or overtopping results in a complete structural breach, releasing a high-velocity wall of debris-filled waters that rush downstream damaging and/or destroying anything in its path (FEMA 1996).

Dam failures can result from one or a combination of the following reasons:

- Overtopping caused by floods that exceed the capacity of the dam
- Deliberate acts of sabotage
- Structural failure of materials used in dam construction
- Movement and/or failure of the foundation supporting the dam
- Settlement and cracking of concrete or embankment dams
- Piping and internal erosion of soil in embankment dams
- Inadequate maintenance and upkeep

(FEMA 2013a)

Dam Failure Severity

The principal factors affecting flood damage are flood depth and velocity. The deeper and faster flood flows become, the more damage they can cause. Shallow flooding with high velocities can cause as much damage as deep flooding with slow velocity. This is especially true when a channel migrates over a broad floodplain, redirecting high velocity flows and transporting debris and sediment. Flood severity is often evaluated by examining peak discharges.

Dam Failure Location

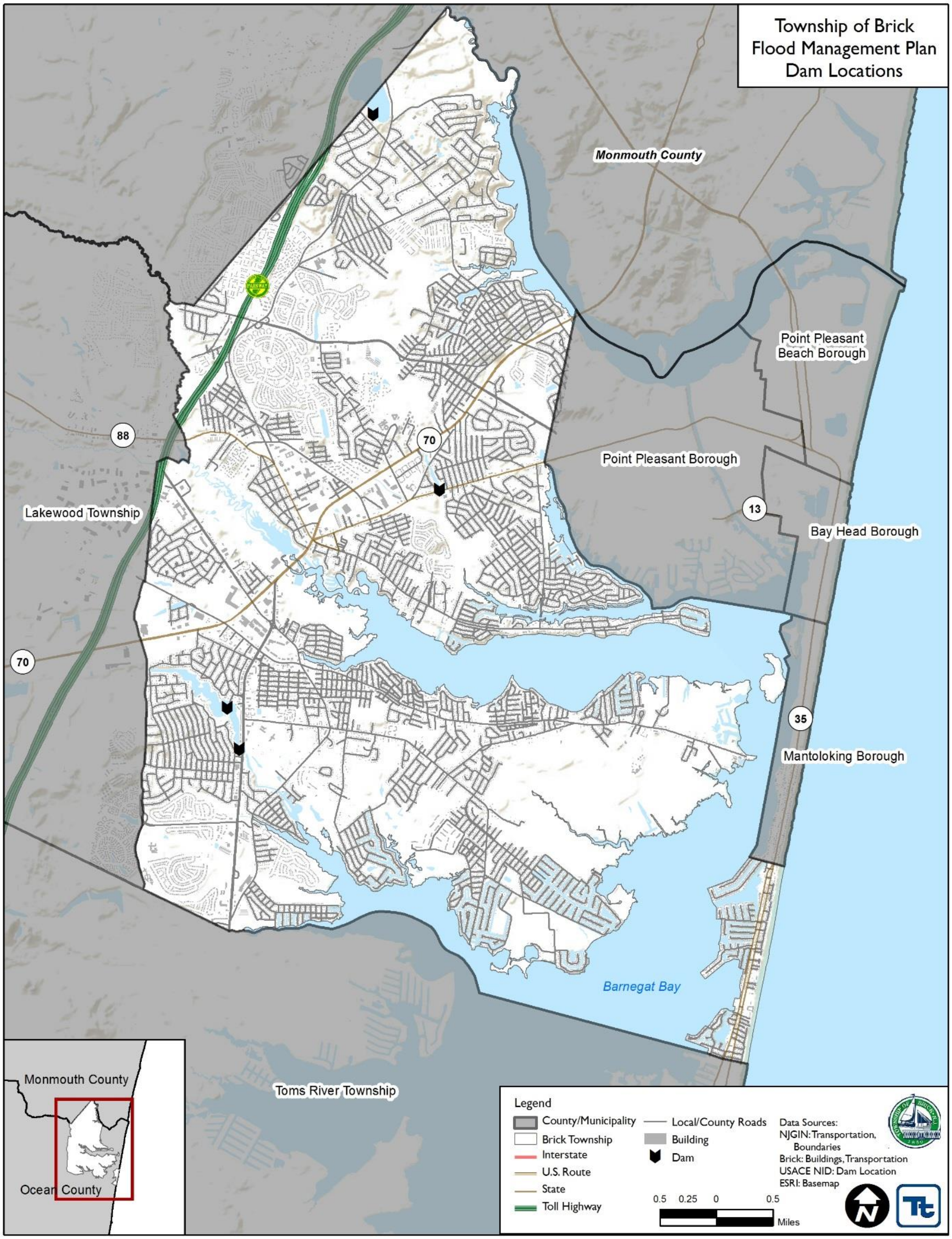
According to the U.S. Army Corps of Engineers (USACE) National Inventory of Dams (NID), there are over 87,000 dams in the country; however, this inventory only covers dams that meet minimum height and impoundment requirements. In addition to those identified by the USACE, there are numerous small dams not identified in the NID. The NID reported 825 dams in the State of New Jersey, of which 48 are located in Ocean County (4 are located in the Township of Brick as displayed in Figure 5-4). However, this total differs from that provided by the NJDEP, which identifies 99 dams in the county. For the purpose of this Flood Management Plan, the NJDEP data will be used. Table 5-4 summarizes the number of dams and their hazard classifications in the Township of Brick.

Table 5-4. Dams in the Township of Brick by Hazard Ranking

Dam Name	River	Hazard	Use
Rainbow Dam	Kettle Creek	High	Recreation
Lake Riveria Dam	Kettle Creek	Significant	Recreation
Route 88 Dam	Beaverdam Creek	Significant	Recreation
BTMUA Reservoir Dam	Brick Twp Reservoir	High	Water Supply

Source: NJDEP 2013

Figure 15. Dams Located in the Township of Brick



Source: USACE 2015, NJGIN 2015

Dam Failure Frequency

Dam failures are difficult to predict and do not necessarily have an associated frequency. While large or catastrophic dam failures tend to be of greater concern to planners, municipal officials, and local residents, an analysis by the Nuclear Regulatory Commission (NRC) has indicated that causes for catastrophic failures are about the same as those due to the entire dam population. This means that planners and municipal officials should concentrate on mitigating the same types of potential damage causes for dams at greater risk of catastrophic failure as for those with lower risk failure. These causes include overtopping due to the exceedance of the reservoir level (often due to severe storms or heavy rainfall), foundation effects and internal erosion, poor design and maintenance, operational and mechanical failures, or seismic events and earthquakes.

Frequency cannot be determined as a consistent probability since dam failures are a non-natural hazard. Although probabilities can be estimated, vulnerability is unique to each dam in question (in regards to dam type, age, and previous incident information). While anecdotal and historical events are typically used as a basis for calculating risk and frequency, it must be recognized that these events may lack clarity or detailed information and data (NRC, no date [n.d.]).

Dam Failure Severity

The extent or magnitude of a dam failure event can be measured in terms of the classification of the dam. Additionally, the two factors that influence the potential severity of a full or partial dam failure are: (1) the amount of water impounded; and (2) the density, type, and value of development and infrastructure located downstream (City of Sacramento Development Service Department 2005). There are several classification tools used to identify the hazards of dam. FEMA, USACE, and NJDEP all have a form of classifying hazards. For the purpose of this Flood Management Plan, the NJDEP hazard classification will be explained in this section. Refer to the *Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams* (2004) and *Safety of Dams – Police and Procedures* (2014) for an explanation of the FEMA and USACE classifications, respectively.

The NJDEP has four hazard classifications for dams located in New Jersey. The classifications relate to the potential of property damage and/or loss of life should a dam fail. The classifications are as follows:

- Class I (High-Hazard Potential) - Failure of the dam may result in probable loss of life and/or extensive property damage.
- Class II (Significant-Hazard Potential) - Failure of the dam may result in significant property damage; however loss of life is not envisioned.
- Class III (Low-Hazard Potential) - Failure of the dam is not expected to result in loss of life and/or significant property damage.
- Class IV (Small-Dam Low-Hazard Potential) - Failure of the dam is not expected to result in loss of life or significant property damage. Dam must also meet the requirements of a Class III dam above.

It is required by the State of New Jersey that all High Hazard and Significant Hazard dams must have NJDEP-approved Emergency Action Plans (EAP) in place. It is the responsibility of the dam owner to review and update the EAP on an annual basis. The New Jersey Dam Safety Standards also require that dams are periodically inspected to identify conditions that may adversely affect the safety and functionality of a dam and its appurtenant structures; to note the extent of deterioration as a basis for long-term planning, periodic maintenance or immediate repair; to evaluate conformity with current design and construction practices; and to determine the appropriateness of the existing hazard classification. Inspection guidelines, as identified in the NJ HMP, are reproduced in Table 5-5 in brief. Complete inspection and operating requirements for dams can be found in the New Jersey Dam Safety Standards (N.J.A.C 7:20-1.11).

Table 5-5. New Jersey Dam Inspection Requirements

Dam Size/Type	Regular Inspection	Formal Inspection
Class I (High Hazard) Large Dam	Annually	Once every 3 years
Class I (High Hazard) Dam	Once every 2 years	Once every 6 years
Class II (Significant Hazard) Dam	Once every 2 years	Once every 10 years
Class III (Low Hazard) Dam	Once every 4 years	Only as required
Class IV (Zero Hazard) Dam	Once every 4 years	Only as required

Source: NJ HMP 2014

In New Jersey, every dam in the state, as defined in the Safe Dam Act, N.J.S.A. 58:4, is required to meet state dam safety standards. The State dam safety laws and regulations provide the NJDEP with enforcement capabilities and powers to achieve statewide compliance with dam safety standards. This includes issuing orders for compliance to dam owners, and pursuing legal action if the owner does not comply (with the goal of compliance and possible fines levied on a per-day basis for violations). Of the four dams in the Township of Brick, the Brick Township Municipal Utilities Authority (BTMUA) Reservoir Dam and Rainbow Dam are classified as Class I dams, while the Lake Riviera Dam and Route 88 Dam are considered Class II dams.

Flood severity from a dam failure can be measured with a low, medium, or high severity level, which are further defined as follows:

- **Low severity -** No buildings are washed off their foundations; structures are exposed to floodwater depths of less than 10 feet.
- **Medium severity -** Homes are destroyed but trees or mangled homes remain for people to seek refuge in or on; structures are exposed to floodwater depths of more than 10 feet.
- **High severity -** Floodwaters sweep the area and nothing remains. Locations are flooded by the near instantaneous failure of a concrete dam, or an earthfill dam that turns into "jello" and washes out in seconds rather than minutes or hours. In addition, the flooding caused by the dam failure sweeps the area clean and little or no evidence of the prior human habitation remains after the floodwater recedes (Graham 1999).

Dam Failure Warning Time

Dams can fail with little warning. Intense storms may produce a flood in a few hours or even minutes for upstream locations. Flash floods can occur within six hours of the beginning of heavy rainfall, and dam failure may occur within hours of the first signs of breaching. Other failures and breaches can take much longer to occur, from days to weeks, as a result of debris jams, the accumulation of melting snow, buildup of water pressure on a dam with deficiencies after days of heavy rain, and other factors. Flooding can occur when a dam operator releases excess water downstream to relieve pressure from the dam (FEMA 2013d).

Warning time for dam failure varies depending on the cause of the failure. In events of extreme precipitation or massive snowmelt, evacuations can be planned with sufficient time. In the event of a structural failure because of an earthquake, there may be no warning time. A dam’s structural type also affects warning time. Earthen dams do not tend to fail completely or instantaneously. Once a breach is initiated, discharging water erodes the breach until either the reservoir water is depleted or the breach resists further erosion. Concrete gravity dams also tend to have a partial breach as one or more monolith sections are forced apart by escaping water. The time of breach formation ranges from a few minutes to a few hours (USACE 1997).

High and significant hazard dam owners are required to prepare and maintain an EAP. The EAP is to be used in the event of a potential dam failure or uncontrolled release of stored water. Owners are also required to have established protocols for flood warning and response to imminent dam failure in the flood warning portion of its adopted emergency operations plan (EOP). These protocols are tied to the EAPs also created by the dam owners. These documents are customarily maintained as confidential information, although copies are required to be provided to the NJDEP for response purposes. State and local offices of emergency management also have copies of the approved EAPs.

Dam Failure Secondary Hazard

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure are landslides around the reservoir perimeter, bank erosion on the rivers, and destruction of downstream habitat. Dam failures can occur as a result of structural failures, such as progressive erosion of an embankment or overtopping and breaching by a severe flood. Earthquakes may weaken dams. Floods caused by dam failures have caused loss of life and property damage (FEMA 1996). To date, there have been no recorded incidents or events at any of the dams located in the Township of Brick.

Sea Level Rise Hazard

There is evidence that the global sea is rising at an increased rate and will continue rising over the next century. The two major causes of sea level rise are thermal expansion caused by the warming of the oceans and the loss of land-based ice (glaciers and polar ice caps) due to increased melting. Thermal expansion can account for 50% of sea level rise and is a result of warming atmospheric temperatures and subsequent warming of ocean waters causing the expansion. Since 1900, records and research have shown that the sea level has been steadily rising at a rate of 0.04 to 0.1 inches per year (National Oceanic and Atmospheric Administration [NOAA] 2013).

There are two types of sea level: global and relative. Global sea level rise refers to the increase currently observed in the average global sea level trend (primarily attributed to changes in ocean volume due to ice melt and thermal expansion). The melting of glaciers and continental ice masses can contribute significant amounts of freshwater input to the earth’s oceans. In addition, a steady increase in global atmospheric temperature creates an expansion of salt water molecules, increasing ocean volume.

Local sea level refers to the height of the water as measuring along the coast relative to a specific point on land. Water level measurements at tide stations are referenced to stable vertical points on the land and a known relationship is established. Measurements at any given tide station include both global sea level rise and vertical land motion (subsidence, glacial rebound, or large-scale tectonic motion). The heights of both the land and water are changing; therefore, the land-water interface can vary spatially and temporally and must be defined over time. Relative sea level trends reflect changes in local sea level over time and are typically the most critical sea level trend for many coastal applications (coastal mapping, marine boundary delineation, coastal zone management, coastal engineering, and sustainable habitat restoration) (NOAA 2013).

Short-term variations in the sea level typically occur on a daily basis and include waves, tides, or specific flood events. Long-term variations in the sea level occur over various time scales, from monthly to yearly and may be repeatable cycles, gradual trends, or intermittent differences. Seasonal weather patterns (changes in the Earth’s declination), changes in coastal and ocean circulation, anthropogenic influences, vertical land motion, and other factors may influence changes in the sea level over time. When estimating sea level trends, a minimum of 30 years of data are used in order to account for long-term sea level variations and reduce errors in computing sea level trends based on the monthly mean sea level (NOAA 2013).

Sea Level Rise Location

Generally speaking, sea level rise is an important factor to consider when reviewing future flood impact on coastal communities. It will impact any area in the Township of Brick that is vulnerable to coastal flooding. However, there are two specific mechanisms which influence the location and extent of sea level rise. First, sea level rise can result in the permanent submergence of low-lying coastal areas. At the most basic level, one can assume that a one-foot rise in sea level will inundate areas with an elevation of one foot or less. This assumption does not consider any natural processes such as coastal erosion or marsh migration that may occur due to sea level rise nor does it take into account any increased rates of coastal erosion, although these rates typically increase with sea level rise. Second, in addition to permanent submergence, sea level rise can exacerbate the impact of temporary severe coastal flood events. In addition to affecting the frequency and duration of coastal flood events, sea level rise increases the inland extent of coastal floodplains.

The National Oceanic and Atmospheric Administration (NOAA) has identified four scenarios for global mean sea level rise in its 2012 report, "Global Sea Level Rise Scenarios for the United States National Climate Assessment". NOAA's scenarios were based on four estimates of global sea level rise, using mean sea level in 1992 as a starting point, that reflect different degrees of ocean warming and ice sheet loss by 2100. Based on these scenarios, labeled "Lowest", "Intermediate -Low", "Intermediate-High" and "Highest", NOAA generally has estimated, factoring in future potential conditions, global sea level rise by the year 2100 at the following four levels, respectively: 0.7 feet; 1.6 feet; 3.9 feet; and 6.6 feet (NOAA 2012).

In accordance with the 2014 NJ State Hazard Mitigation Plan Update, the NOAA model is used as the basis of mapping and vulnerability analysis. This mapping was developed under a partnership between NOAA, FEMA, USACE, the U.S. Global Change Research Program (USGCRP), and the White House Council on Environmental Quality (CEQ) in 2013 to create a set of map services and related tools to help communities, residents, and other stakeholders consider risks from future sea level rise in planning for reconstruction following Superstorm Sandy. Various sea level rise projections were incorporated with present day floodplain mapping to identify the potential horizontal expansion of the 1-percent annual chance coastal floodplain due to various increases in the sea level at the year 2050 and 2100. The data can be viewed in detail using the online "Sea Level Rise Planning Tool" viewer at: http://www.globalchange.gov/browse/sea-level-rise-tool-sandy-recovery#overlay-context (OC HMP 2014).

Table 5-6 below summarizes the four NOAA sea level rise scenarios available for New Jersey. For the purposes of this plan, two sea level rise scenarios are presented to indicate potential location and impacts of sea level rise.

The Township, with input from Jacques Cousteau National Estuarine Research Reserve and to align with the State of New Jersey Hazard Mitigation Plan, selected two NOAA sea level rise scenarios to examine. The 2050 Intermediate-High and the Highest NOAA sea level rise scenarios were selected to account for the full range of potential impacts understanding that other knowledgeable agencies have adopted sea level rise projects for NJ based on alternate geological perspectives (NJ sea level rise projection ranges and best estimates. Miller AK, Kopp RE, Horton BP, Browning JV and Kemp AC. 2013. A geological perspective on sea-level rise and its impacts along the U.S. mid-Atlantic coast. Earth's Future 1(1):3-18) which indicate much higher rates of sea level rise pending potential glacial ice sheet collapse beginning in Antarctica (Jacques Cousteau Estuarine Research Reserve). For impacts, refer to the 'Vulnerability Assessment' portion found later in this plan.

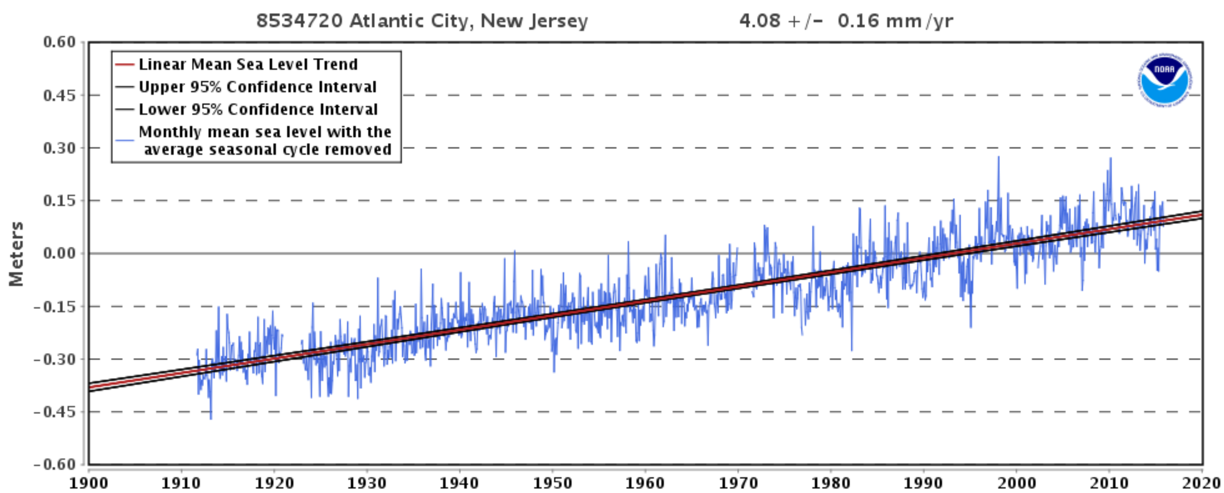
Table 5-6. NOAA Sea Level Rise Scenarios for New Jersey

Scenario	2050 (feet of rise)*	2100 (feet of rise)*
Lowest	SFHA + 0.3 feet	SFHA + 0.7 feet
Intermediate - Low	SFHA + 0.7 feet	SFHA + 1.6 feet
Intermediate - High	SFHA + 1.3 feet	SFHA + 3.9 feet
Highest	SFHA + 2.0 feet	SFHA + 6.6 feet

Source: NOAA 2012; NOAA Map Service (Sea Level Rise Planning Tool - New Jersey and New York State, 2050)
**1992 mean sea level is used as a starting point for sea level rise projections*
SFHA Special Flood Hazard Area

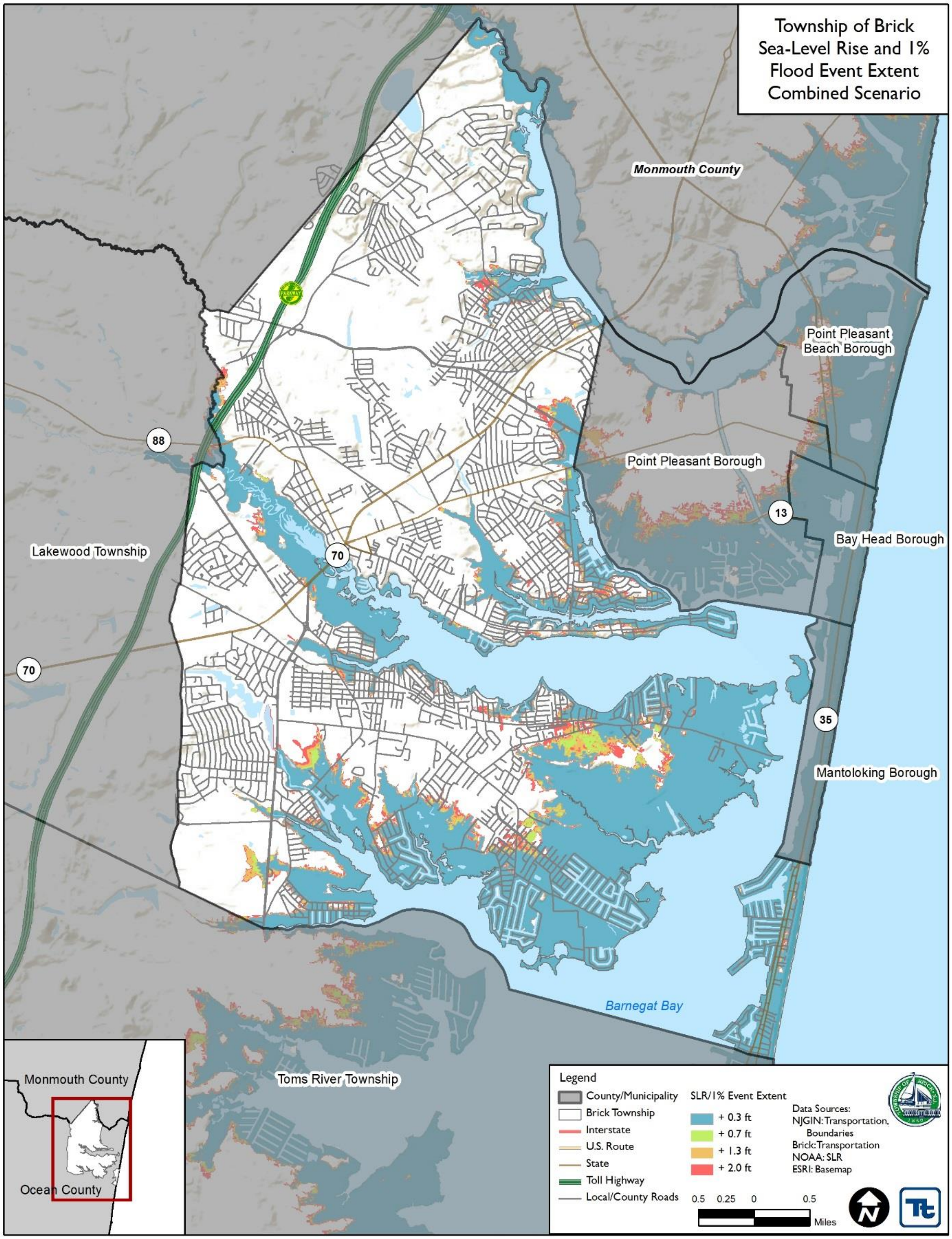
The sea level rise trend is more clearly indicated by the graph in Figure 16.

Figure 16 Linear Mean Sea Level Trend-Atlantic City NJ



NOAA Tide Gage Website (http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8534720) 2015

Figure 17. Sea Level Rise Scenarios for the Township of Brick



Source: NOAA

Per the Township of Brick 'Getting to Resiliency Recommendations Report' (2015), even the relatively low end scenario of one foot of sea level rise will require adaptation as numerous streets and low lying bayside communities will see fairly regular tidal inundation including the Island Drive community, the David Beaton & Sons Boatyard, Jersey Shore Marina and Boat Sales, and western portions of Shore Acres. Scientists anticipate the arrival of one foot of sea level rise before 2050. As sea level rise is expected to accelerate this century, three feet of sea level rise is very likely before 2100.

Furthermore, two feet of sea level rise would result in regular tidal flooding slowly impacting more of the bayside communities resulting in the isolation of the Mandalay section of the Township. Portions of Baywood, the eastern section of the Metedeconk community, properties bordering Beaverdam Creek, Bay Harbor Estates, the end of Tunes Brook Drive, and the Sandy Point community would begin to flood. The Island Drive community, the David Beaton & Sons Boatyard, Jersey Shore Marina and Boat Sales, and western portions of Shore Acres would experience heavy flooding. Three feet of sea level rise would result in regular tidal inundation near the shorelines of almost all waterfront communities. Shore Acres, Baywood and West Mantaloking would be impacted. The Cherry Quay community would experience street flooding along Royal Drive, Perch Creek, Captains Drive, and Seagoin Road. A three feet rise would also begin to impact the evacuation route of Mantaloking Road. However, the barrier island area of Brick appears to be one of the last waterfront areas impacted by sea level rise. Any level of inundation due to regular tidal flooding would have large scale impacts on emergency response. Sea level rise would also result in greater impact of storm events as a surge atop a higher sea level will be more dramatic than the same surge atop a lower sea level (Brick Township "Getting to Resilience" Recommendations Report, 2014).

Sea Level Rise Frequency

Sea level change is an ongoing process and can be monitored on both long-term and shorter-term scales. Global sea level changes are due to the changes in the volume of water in ocean basins through thermal expansion, glacial melt, or net changes in the size of ocean basins. In fact, global sea rise has been occurring for the past 20,000 years as a natural result of glacial maximum decline.

Local and shorter-term sea level rise frequency is not as continuous but can still be predicted by surrounding factors. Permanent sea level rise will be more noticeable and frequent in low-lying areas already close to sea level or bayside locations. The landward side of open-coast barrier island communities are more likely to experience sea level rise as they are at a greater vulnerability for coastal erosion, which can impact sea levels near land. Sea level rise frequency can be partially predicted by nearby human activity, as mitigation measures like sea walls, levels, or dikes can affect the location and extent of the sea level rise (OC HMP 2014).

Sea Level Rise Severity

According to the USGS, the coastal vulnerability index (CVI) provides a preliminary overview, at a national scale, of the relative susceptibility of the nation's coast-to-sea-level rise. This initial classification is based upon variables including geomorphology, regional coastal slope, tide range, wave height, relative sea-level rise, and shoreline erosion and accretion rates. The combination of these variables and the association of these variables to each other furnish a broad overview of coastal regions where physical changes are likely to occur due to sea-level rise. The figure below provides a visual representation of the Township's CVI, and the areas along the coast have much higher vulnerability ratings than those areas further inland. The figure was developed by the NJDEP Coastal Management Program and the Bureau of GIS (BGIS) as a way to help assess the vulnerability and resiliency of coastal communities in New Jersey to coastal hazards. It was developed using the 'Coastal Community Vulnerability Assessment and Mapping Protocol (CCVAMP)' developed by the NJDEP Coastal Management Program. The protocol is based on work initiated by the USGS.