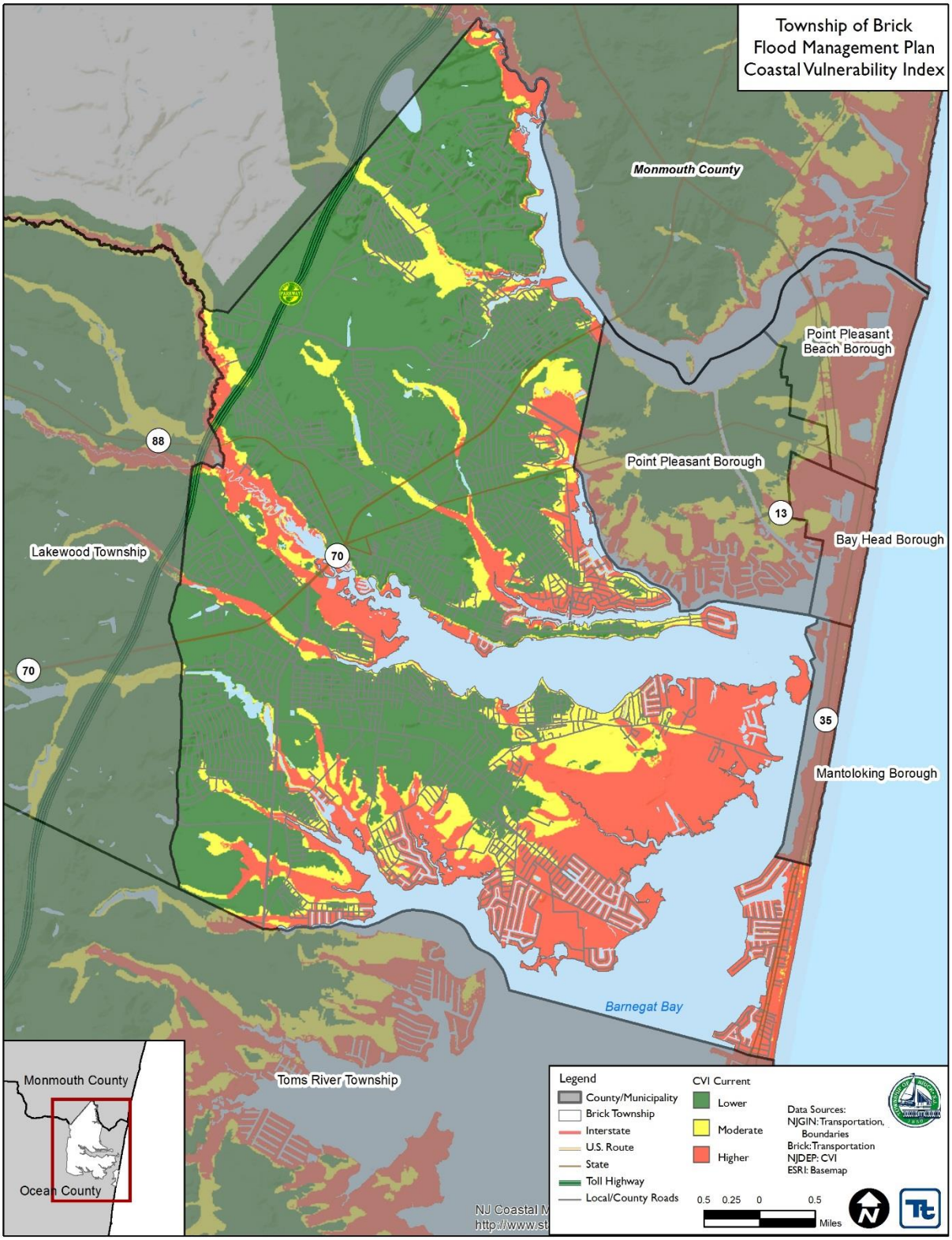
Figure 18. Coastal Vulnerability Index in the Township of Brick



Source: NJDEP

Sea Level Rise Warning Time

Through NOAA, the Center for Operational Oceanographic Products and Services has measured sea level heights and rates for more than 150 years. The center calculates the mean sea level. This is calculated with sea level rises and falls, at 128 long-term water level stations, with a minimum span of 30 years' worth of data to ensure as much accuracy as possible. The center averages results at a monthly level to remove the effect of higher frequency phenomena and to determine a linear sea level trend.

NOAA identifies multiple factors that influence both short- and long-term sea level changes. While short-term variations fluctuate daily and include waves, tides, or flood events, long-term variations occur on a larger scale, most typically months to years. Long-term sea level changes can include gradual trends, repeatable cycles, or intermittent anomalies, and they may be influenced by seasonal weather patterns, variations in the Earth's declination, changes in coastal and ocean circulation, anthropogenic influences (such as dredging), vertical land motion, and the El Niño Southern Oscillation. Thus, while short-term sea level rises may have little warning time, long-term and consistent sea level rises are gradual and can be predicted through detailed observations, typically allowing for ample warning.

Sea Level Rise Secondary Hazard

According to NOAA, sea level rise can amplify factors that currently contribute to coastal flooding: high tides, storm surge, high waves, and high runoff from rivers and creeks. All of these factors change during extreme weather and climate events (NOAA 2012). Other secondary hazards that could occur along the mid-Atlantic coast in response to sea-level rise include:

- *Bluff and upland erosion* – shorelines composed of older geologic units that form headland regions of the coast will retreat landward with rising sea level. As sea level rises, the uplands are eroded and sandy materials are incorporated into the beach and dune systems along the shore and adjacent compartments (Gutierrez et al. 2007).
- *Overwash, inlet processes, shoreline retreat, and barrier island narrowing* – as sea-level rise occurs, storm overwash will become more likely. Tidal inlet formation and migration will become important components of future shoreline changes. Barrier islands are subject to inlet formation by storms. If the storm surge produces channels that extend below sea level, an inlet may persist after the storm. The combination of rising sea level and stronger storms can create the potential to accelerate shoreline retreat in many locations. Assessments of shoreline change on barrier islands have shown that barrier island narrowing has been observed on some islands over the last 100 years (Gutierrez et al. 2007).
- *Threshold behavior* – changes in sea level rise can lead to conditions where a barrier system becomes less stable and crosses a geomorphic threshold; making the potential for rapid barrier-island migration or segmentation/disintegration high. Unstable barriers may be defined by rapid landward recession of the ocean shoreline, decrease in barrier width and height, increased overwashing during storms, increased barrier breaching and inlet formation, or chronic loss of beach and dune sand volume. With the rates of sea-level rise and climate change, it is very likely that these conditions will worsen (Gutierrez et al. 2007).
- *Loss of critical habitat* – natural ecosystems may be impacted by warmer temperatures and associated changes in the water cycle. The changes could lead to loss of critical habitat and further stresses on some threatened and endangered species (Rutgers 2013).
- *Threatened coastline* – New Jersey is vulnerable to significant impacts due to geologic subsidence, topography of its coastline, current coastal erosion, and a high density of coastal development. According to median projections of current sea level rise, it would threaten the majority of the state's coastal areas (Rutgers 2013).

Previous Occurrences and Losses

Many sources provided flooding information regarding previous occurrences and losses associated with flooding events throughout the Township of Brick. With multiple sources reviewed for the purpose of this Flood Management Plan, loss and impact information for many events could vary depending on the source and the accuracy of monetary figures is based on information available at the time of development of this plan.

Between 1954 and 2015, FEMA included the State of New Jersey in 36 flood-related disasters (DR) or emergencies (EM) classified as one or a combination of the following disaster types: hurricane, tropical storm, Nor'easter, severe storms, flooding, inland and coastal flooding, coastal storm, high tides, heavy rain, and severe storms. Generally, these disasters cover a wide region of the state; therefore, they may have impacted many counties. Ocean County was included in 14 of these flood-related declarations.

Known flood events, including FEMA disaster declarations, which have impacted the Township of Brick between 1950 and 2015 are identified in Table 5-6. It is noted that not all events that have occurred in the Township of Brick are included due to the extent of documentation and the fact that not all sources may have been identified or researched. Loss and impact information could vary depending on the source. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this Flood Management Plan.

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
September 4, 1971	Heavy Rains, Flooding	DR-310	Yes	Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan. The following counties were designated under the FEMA DR for this event - Atlantic, Bergen, Burlington, Camden, Cape May, Cumberland, Essex, Gloucester, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Passaic, Salem, Somerset, Sussex, Union, and Warren.
August 21, 1976	Severe Storms, High Winds, Flooding	DR-519	Yes	Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan. The following counties were designated under the FEMA DR for this event - Atlantic, Cape May, Monmouth, and Ocean.
April 12, 1984	Coastal Storms, Flooding	DR-701	Yes	Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan. The following counties were designated under the FEMA DR for this event - Atlantic, Bergen, Cape May, Essex, Monmouth, Morris, Ocean, and Passaic.
March 3, 1992	Severe Coastal Storm	DR-936	Yes	Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				The following counties were designated under the FEMA DR for this event - Atlantic, Cape May, Cumberland, Monmouth, and Ocean.
December 18, 1992	Coastal Storm, High Tides, Heavy Rain, Flooding	DR-973	Yes	Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan. The following counties were designated under the FEMA DR for this event - Atlantic, Bergen, Cape May, Cumberland, Essex, Hudson, Middlesex, Monmouth, Ocean, Salem, Somerset, and Union.
January 7, 1996	Coastal Flood	N/A	N/A	Estimated regional property damage of $6.5 million. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
June 17, 1996	Flash Flood	N/A	N/A	A cluster of thunderstorms with torrential downpours dropped as much as 4 inches of rain (reported in Tuckerton Borough in Ocean County) during the afternoon of June 17. This caused considerable urban and poor drainage flooding, especially in the Township of Stafford (Ocean County). Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
August 29, 1996	High Surf	N/A	N/A	Rough surf, associated with Hurricane Edouard affected the coastal areas of New Jersey around the Labor Day Weekend and caused two drownings and one serious injury. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
September 17, 1996	Flash Flood	N/A	N/A	Heavy rain, associated with the remnants of Pacific Hurricane Fausto impacted Ocean County. The heavy rain from this event caused flooding throughout the county. Flooding led to road and bridge closures. Rainfall totals ranged from 2.97 inches to over 6 inches. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
October 19, 1996	Coastal Flood	N/A	N/A	In Ocean County, bay flooding was reported around Seaside Park and Ship Bottom. In Harvey Cedars several north-south roads were closed. In Toms River, back bay/river flooding approached several homes. In Point Pleasant Beach flooding was reported over the seawall and onto the Inlet Drive parking lot.
December 8, 1996	Coastal Flood	N/A	N/A	A low pressure system developed over South Carolina and Georgia the morning of December 7 and moved quickly northeast passing over the Delmarva Peninsula during the late afternoon of December 7 and just east of the New Jersey coast during the evening of December 7.

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				The onshore flow accompanying the low pressure system kept the tide from receding overnight and the ensuing high tide the morning of December 8 was about 2 feet above normal south of Manasquan Inlet. Only minor tidal flooding was reported along New Jersey's coast. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
December 13, 1996	Coastal Flood	N/A	N/A	In Ocean County, back bay flooding inundated Ship Bottom's Central Avenue from 26th through 29th Streets. Eight blocks in Ocean City were closed due to flooding.
June 2, 1997	Coastal Flood	N/A	N/A	A series of low pressure systems moving east off the North Carolina coast and a relatively strong high pressure system over Eastern Canada brought a strong and persistent northeast flow from June 2 through 4. The onshore flow peaked during the evening of June 2 and the morning of June 3 and produced some minor tidal flooding at times of high tide. The heavy surf also caused some minor beach erosion. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
July 16, 1997	Flash Flood	N/A	N/A	Thunderstorms dropped torrential rains within about 90 minutes over southern parts of Ocean County in Barnegat, Ocean, and Stafford Townships. Four inches of rain fell in Barnegat. This caused considerable urban flooding as well as flooding of some of the creeks in Southern Ocean County. Lower Shore Road had considerable flooding in Barnegat Township.
July 24, 1997	Flood	N/A	N/A	Heavy rain, associated with weak low pressure systems riding along a nearly stationary frontal boundary in the southern Delmarva Peninsula, caused urban flooding, especially on the back bay sides of the barrier islands of Atlantic, Cape May, and Ocean Counties.
August 20, 1997	Coastal Flood	N/A	N/A	Very strong onshore winds coupled with torrential rain, that nearly coincided with the high tide along the back bays caused moderate tidal flooding along the barrier islands of Atlantic, Cape May, and Ocean Counties.
August 20, 1997	Flash Flood	N/A	N/A	Torrential rain fell across southeast New Jersey as a low pressure system developed over the Delmarva Peninsula and slowly moved northeast across southern New Jersey. A series of thunderstorms developed along this low pressure system's frontal boundaries and trained or moved over the same areas. This caused

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				extremely heavy rain to fall over several hours especially across southern parts of Ocean County. Rainfall totals in the county ranged from 4.75 inches in East Dover to over 10 inches in Little Egg Harbor Township. No injuries or fatalities were reported for this event. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
September 1, 1997	Flash Flood	N/A	N/A	A severe thunderstorm produced frequent lightning and torrential downpours. This caused small stream flooding and urban flooding in parts of Ocean County. It was estimated that rain fell at three inches within one hour over parts of northern Ocean County.
November 14, 1997	Coastal Flood	N/A	N/A	In Ocean County, Harvey Cedars reported severe erosion and also lost some dune fencing. Barnegat Bay tidal flooding also occurred on Cedar Bonnet Island, Little Egg Harbor Township and Tuckerton. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
December 29, 1997	Coastal Flood	N/A	N/A	This low pressure system brought heavy rain to a large part of the state, high winds to Monmouth and Ocean Counties as it was intensifying, and some minor tidal flooding at the times of the evening high tide on December 29. The heavy rain in most places coincided with the incoming tide and this exacerbated the poor drainage flooding along the coastal communities. In Ocean County, the tides and heavy rain forced the closure of several main roadways and one traffic circle in Long Beach Township, Ship Bottom, and Surf City. In addition to the heavy rain and tides, wind gusts reached around 60 mph and knocked down trees and power lines. GPU Energy reported about 6,300 homes and businesses lost power from Middletown Township in Monmouth County south through Toms River in Ocean County. Peak wind gusts included 61 mph in Brighton Beach and 57 mph in Harvey Cedars (both in Ocean County). Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
February 4, 1998	Coastal Flood	N/A	N/A	The strongest Nor'easter of the winter battered Coastal New Jersey, especially from Ocean County southward, with damaging winds, moderate to severe coastal flooding, extensive beach erosion, several dune breaches, and heavy rain.
February 17, 1998	Coastal Flood	N/A	N/A	A low pressure system moved from coastal North Carolina the morning of February 17 to about 150

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				miles east of Manasquan Inlet, New Jersey the morning of February 18. A strong high pressure system was anchored over Maine and the Canadian Maritimes at the same time. The difference in surface pressure between them produced strong gusty winds mainly during the afternoon of February 17. This also prevented the tide from receding during the low tide cycle around 6:00 p.m. Winds diminished by the time of the late evening/early morning tide on February 17 and 18. Nevertheless, the onshore flow helped produce some minor tidal flooding. The onshore winds lasted only one tide cycle and the astronomical tides were low. Thus, in spite of tidal departures of about 3 feet above normal, tidal flooding was only at the low end of the minor range. No serious damage was reported.
February 24, 1998	Coastal Flood	N/A	N/A	In Ocean County, the pounding surf ate away at the dune line in Bay Head and ate away much of the sand that was replaced at the foot of the 48th Street Beach in Brant Beach. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
March 3, 1998	Coastal Storm	DR-1206	Yes	No further details provided.
April 9, 1998	Coastal Flood	N/A	N/A	The onshore flow during the evening of April 9 produced minor tidal flooding in Atlantic, Cape May, and Ocean Counties and minor to locally moderate tidal flooding in Monmouth County.
May 11, 1998	Coastal Flood	N/A	N/A	The worst tidal flooding and erosion problems were reported in Ocean County. Isolated flooding was reported at Point Pleasant Beach. The erosion was described as substantial at Seaside Park. In Barnegat, the wind-driven waves were crashing onto East Bay Avenue and Bayshore Drive. On Long Beach Island, Long Beach Boulevard was flooded several times. Bayside road flooding occurred in Beach Haven and Harvey Cedars. In Brant Beach, the dunes were chopped along 53rd Street. In Ship Bottom and Surf City cliffs were formed. In Ship Bottom dune fencing dangled down a 20-foot drop that extended for several blocks. Shifting sands exposed an old barge. In Tuckerton Beach, minor flooding occurred the evening of May 11. In Stafford Township on Mallard Island minor flooding occurred as waves crashed onto the decks and docks on East Bay Avenue. Minor back bay flooding extended westward along Toms River into Avon Beach. Tidal flooding also occurred around Raritan Bay. On the evening of May 11, the police had to block off several roads in Woodbridge in Middlesex County.

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
January 3, 1999	Coastal Flood	N/A	N/A	On the evening of January 2, as one low pressure system headed into the Great Lakes, a second low pressure system formed along its frontal boundary along the coastal plains of the south Atlantic states. This second low increased the pressure gradient (or surface pressure difference between it and a strong high pressure system over the Canadian Maritimes) along the coast and increased the onshore flow. The low passed through New Jersey the morning of January 3. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
March 21, 1999	Coastal Flood	N/A	N/A	The onshore flow preceding a strong low pressure system that moved north along the Atlantic Seaboard during the evening of March 21 produced pockets of minor flooding along the New Jersey shore. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
August 20, 1999	Flash Flood	N/A	N/A	Thunderstorms with torrential downpours dropped a radar estimated 2.0 to 3.5 inches of rain across Eastern Ocean County within a two-hour period during the late afternoon of August 20. This caused considerable urban and poor drainage flooding on Long Beach Island and on the mainland. Flooding of some creeks also occurred on the mainland in Eastern Ocean County. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
August 26, 1999	Flash Flood	N/A	N/A	During the late afternoon and early evening of August 26 thunderstorms with torrential downpours caused considerable poor drainage flooding as well as flooding of some of the smaller creeks and streams. In Ocean County, part of New Jersey State Route 35 was washed away in Point Pleasant Beach. First floor flooding occurred in the Bricks Estate in the Township of Brick. In Burlington County, several roads in Browns Mills were under water. Reported storm totals included 2.90 inches in New Lisbon and 2.19 inches at the McGuire Air Force Base.
August 30, 1999	Coastal Flood	N/A	N/A	Erosion occurred in Brant Beach (Ocean County). In Ocean County, elderly residents of Laurelton Gardens in the Township of Brick were evacuated after a creek flooded. Scattered trees and wires were knocked down throughout the county. A tree damaged a house in Toms River.
September 16, 1999	Hurricane/Typhoon, Flash Flood	N/A	N/A	Less rain and flooding occurred farther southeast than in other areas, with less urban and poor drainage flooding and only minor beach erosion and back bay

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				flooding reported in Atlantic, Cape May, and Ocean Counties. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
September 16, 1999	Hurricane	EM-3148	Yes	Hurricane Floyd caused the largest flood on record along the Raritan River. Extensive flooding occurred throughout central and northern New Jersey. Rainfall totals exceeded 12 inches in several locations, with 8- to 10-inch totals widespread.
January 1, 2000	Flood	N/A	N/A	The worst wind damage occurred on the New Jersey State Route 72 Causeway between Long Beach Island and Stafford Township in Ocean County. Total accumulations included 10 inches in the Township of Brick.
March 21, 2000	Flood	N/A	N/A	The tight gradient (difference in surface pressures between a low pressure system along the mid-Atlantic coastal waters and a strong high pressure system in the Canadian Maritimes) produced isolated pockets of minor flooding the morning of March 21 and more widespread, but still minor tidal flooding during the evening of March 21. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
April 18, 2000	Flood	N/A	N/A	The combination of a low pressure system exiting the North Carolina coast, a large high pressure system over the Canadian Maritimes and higher than normal astronomical tides because of the approaching full moon produced some minor tidal flooding at the times of high tide during the evening of April 18. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
July 26, 2000	Flash Flood	N/A	N/A	In Ocean County, the heavy rain led to the closure of the causeway leading to the J. Stanley Tunney Bridge. Large parts of New Jersey State Route 35 were closed. The worst flooding occurred in Seaside Heights, Seaside Park, Lavallette, Bay Head, Point Pleasant, and Point Pleasant Beach and most of the flooding occurred near Barnegat Bay. In Point Pleasant alone, nine streets were closed. Farther south, the heavy rain led to flooding near the bay in Beach Haven and Beach Haven Crest. Flood problems also occurred on the mainland. In the Township of Brick, two roads were closed and there was a voluntary evacuation of Laurelton Village. The rising Toms River flooded the beach and the flood waters reached behind the pine trees in South Toms River.
August 28, 2000	Flood	N/A	N/A	The combination of a weak onshore flow around a high pressure system building into New England and

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				the adjacent coastal waters, a weak low pressure system off the south Atlantic coast, and the spring astronomical tides by the new moon caused some minor tidal flooding around the times of high tide the evening of August 28 and the evening of August 29. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
September 25, 2000	Flood	N/A	N/A	The combination of spring tides near the new moon, a high pressure system over New England and a low pressure system over the mid-Atlantic states produced widespread minor tidal flooding during the times of high tide from the evening of September 25 through the evening of September 26. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
November 10, 2000	Coastal Flood	N/A	N/A	Strong southeast winds combined with high astronomical tides to produce areas of minor tidal flooding around the time of high tide the morning of November 10. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
March 5, 2001	Flood	N/A	N/A	In Ocean County, significant erosion occurred in the Township of Brick as 50 feet of beach was lost.
June 16, 2001	Flash Flood	N/A	N/A	The remnants of Tropical Storm Allison produced showers and thunderstorms with heavy rain during the morning of June 17. This caused small stream and poor drainage flooding in the county with the worst reported flooding near and along the shore. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
August 13, 2001	Flash Flood	N/A	N/A	Thunderstorms with heavy downpours caused flooding of streams as well as urban and poor drainage flooding in Ocean County. Flooding was also reported along U.S. Route 9 in Lacey Township and on several roadways in the Township of Brick.
August 27, 2001	Flash Flood	N/A	N/A	Three-foot deep "lakes" formed in neighborhoods in Dover and the Township of Bricks. Sewers were overflowing. Basement flooding was also reported in the county. No serious injuries were reported.
September 14, 2001	Flood	N/A	N/A	The combination of spring tides around the new moon and onshore flow around a high pressure system produced minor tidal flooding around the times of the evening high tides from September 14 through 16. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
October 1, 2001	Flood	N/A	N/A	The onshore flow around a Nor'easter brought minor to locally moderate tidal flooding along the New Jersey coast from September 29 through the morning of October 1. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
July 19, 2002	Flash Flood	N/A	N/A	Thunderstorms with torrential downpours dropped an adjusted Doppler Radar storm total estimate of 5 to 6 inches of rain in Lakewood and Jackson Townships. This caused considerable urban and poor drainage flooding as well as flooding of streams in northern Ocean County. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
October 16, 2002	Flood	N/A	N/A	A strong Nor'easter caused minor to locally moderate tidal flooding along the New Jersey coast and in the back bays, wind gusts to around 50 mph, and beach erosion. Tides, winds, and erosion were worse in Ocean and Monmouth Counties than farther south. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
February 23, 2003	Flood	N/A	N/A	The combination of heavy rain during the day on February 22 and snow melt run-off led to minor flooding along the North Branch of the Metedeconk River on February 23. The North Branch of the Metedeconk River in Lakewood was above its 7-foot flood stage from 1 p.m. through 6:43 p.m. on February 23. It crested at 7.18 feet at 6:15 p.m. on February 23.
December 6, 2003	Storm Surge, Tide	N/A	N/A	A Nor'easter caused erosion, minor tidal flooding, and dune damage along coastal New Jersey on December 5 and 6. The combination of the low pressure system moving northeast along the nearby Atlantic Ocean and a high pressure system in nearby Canada kept an onshore flow for two days along the New Jersey Coast. The worst erosion was reported in Bay Head and Mantoloking Boroughs in Ocean County. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
February 7, 2004	Flood	N/A	N/A	The combination of heavy rain and snow melt caused poor drainage flooding and eventually flooding along the Metedeconk River in Ocean County.
July 12, 2004	Flash Flood	N/A	N/A	A series of thunderstorms with torrential rain caused widespread poor drainage flooding and flooding of some of the streams in Ocean County. Nearly every municipality within the county reported flooding. New Jersey State Route 37 near Toms River was flooded. Doppler Radar storm total estimates exceeded one

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				inch throughout the county and reached between 6 to 8 inches in Berkeley and Lacey Townships. Storm totals included 5.46 inches in Lakewood.
October 21, 2004	High Surf	N/A	N/A	Roadways along Barnegat Bay (Ocean County) had several inches of water during the times of high tide. Flooded streets were reported in Bay Head, Beach Haven, Seaside Park, and the Normandy Beach section of the Township of Brick.
October 24, 2004	Storm Surge, Tide	N/A	N/A	Roadways along Barnegat Bay (Ocean County) had several inches of water during the times of high tide. Flooded streets were reported in Bay Head, Beach Haven, Seaside Park, and the Normandy Beach section of the Township of Brick.
September 19, 2005	Hurricane Evacuation	EM-3257	Yes	No further details provided. This event is related to Hurricane Katrina and not a direct flooding event to the township.
October 12, 2005	Flood	N/A	N/A	Periods of heavy rain associated with a series of low pressure systems southeast of New Jersey fell across Ocean County (particularly the northern half) on October 12 and 13. This caused considerable poor drainage flooding as well as flooding of creeks and rivers as well as one lake. Three-day storm totals ranged from around one inch in the southern part of the county to around ten inches in the northern part of the county. The Metedeconk River flooded in Brick and Lakewood Townships. New Jersey State Route 88 was closed in Lakewood Township. Lake Carasaljio flooded nearby streets in the township. Roads were closed in Dover and the Township of Brick.
February 12, 2006	High Surf, Coastal Flood	N/A	N/A	Coastal Ocean County took a major hit from this winter storm. There was significant to severe damage to dunes across several locations, including Bayhead, Bricktown, Ortley Beach, Harvey Cedars, and Long Beach Township. Vertical cuts across most of the beaches ranged from 2- to 4-feet high by 50- to 75-feet wide. Minor to moderate coastal flooding was fairly widespread as a direct result of this potent winter storm.
June 23 to 28, 2006	Heavy Rain	N/A	N/A	Rainfall amounts of 2.1 inches were recorded at Point Pleasant and 2.09 inches were recorded at Barnegat Light.
October 6, 2006	Coastal Flood	N/A	N/A	A Nor'easter brought tidal flooding, heavy rain, strong winds, and beach erosion to coastal New Jersey. Widespread minor tidal flooding with areas of moderate tidal flooding occurred during the high tides on October 6 and 7. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
April 15, 2007	Flood	N/A	N/A	The heavy rain and Metedeconk River flooding forced road closures in the Township of Brick. Flooding along the Toms River caused road closures in Island Heights Borough. The North Branch of the Metedeconk at Lakewood was above its 7-foot flood stage from 9:39 p.m. on April 15 through 7:45 p.m. on April 17. It crested at 8.28 feet at 12:00 p.m. on April 16. Precipitation totals included 3.76 inches in Beachwood, 3.04 inches in Point Pleasant, 2.65 inches in Brick, 1.90 inches in Berkeley, 1.76 inches in Seaside Heights, and 1.38 inches in Harvey Cedars.
May 11 to 13, 2008	Nor'easter	N/A	N/A	Peak wind gusts recorded near Barnegat were 59 mph. Heavy rain combined with high astronomical tides caused several roads to close in southern New Jersey and Delaware. Coastal flooding in New Jersey was comparable to the October 2006 floods. Beach erosion in Delaware and New Jersey due to the high surf was also attributed to this storm. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
September 25, 2008	High Surf	N/A	N/A	In Monmouth and Ocean Counties, the vertical cuts on the beaches averaged 2 to 4 feet with the sloping cuts around 40 feet. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
December 12, 2008	Flood	N/A	N/A	The North Branch of the Metedeconk River at Lakewood was above its 7 foot flood stage from 4:30 a.m. on December 12 through 8:15 a.m. on December 13. It crested at 7.86 feet at 10:45 a.m. on December 12. There was also minor tidal flooding at the time of the morning high tide along the ocean front. Event precipitation totals included 5.05 inches in Lavallette, 4.98 inches in Stafford Forge, 4.69 inches in the Township of Brick and 4.34 inches in Little Egg Harbor.
November 11, 2009	High Surf	N/A	N/A	A powerful Nor'easter produced wind gusts of nearly 60 mph, widespread moderate tidal flooding, heavy rain, and severe beach erosion along the New Jersey coast from November 12 through November 14. Initial damage estimates were placed at $180 million. By several measures this was one of the worst Nor'easters to affect New Jersey since 1990. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
December 9, 2009	Flood	N/A	N/A	The runoff from heavy rains produced flooding along sections of the North Branch of the Metedeconk River during the night of December 9. The North Branch of the Metedeconk River near Lakewood was above its 7-foot flood stage from 7:09 p.m. on December 9

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				through 1:07 a.m. on December 10. It crested at 7.2 feet at 9:15 p.m. Event precipitation totals included 3.09 inches in Bayville, 2.75 inches in Stafford Township, 2.43 inches in Barnegat Township, 2.32 inches in Little Egg Harbor Township, 2.25 inches in Berkeley Township, 2.05 inches in the Township of Brick, 2.02 inches in Toms River, and 1.95 inches in Point Pleasant.
December 22, 2009	Severe Storms and Flooding	DR-1867	Yes	This event is associated with Tropical Depression Ida and a Nor'easter. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
December 26, 2009	Flood	N/A	N/A	The North Branch of the Metedeconk at Lakewood was above its 7-foot flood stage from 5:15 p.m. on December 26 through 1:22 p.m. on December 28. It crested at 8.59 feet at 6:00 a.m. on December 27. Event precipitation totals included 2.78 inches in South Toms River, 2.10 inches in Berkeley Township, 2.02 inches in the Township of Brick, and 1.98 inches in Lavallette.
February 25, 2010	Flood	N/A	N/A	The North Branch of the Metedeconk River at Lakewood was above its 7-foot flood stage from 2 a.m. on February 24 through 2:15 a.m. on February 25. It crested at 7.31 feet at 11 a.m. on February 24. Precipitation totals included 2.57 inches in Stafford Township, 2.53 inches in Point Pleasant, 2.43 inches in Pine Beach, 2.29 inches in Berkeley Township, 2.28 inches in the Township of Brick, and 1.95 inches in South Toms River.
March 29, 2010	Flood	N/A	N/A	The North Branch of the Metedeconk River at Lakewood was above its 7-foot flood stage from 4:30 p.m. on March 29 through 10:15 a.m. on April 1. It crested at 8.27 feet at 3 a.m. on March 31. Event precipitation totals included 4.61 inches in Lavallette, 4.60 inches in Oakwood, 4.50 inches in the Township of Brick, and 3.96 inches in Toms River.
April 2, 2010	Severe Storms and Flooding	DR-1897	Yes	FEMA distributed over $33 million to flood survivors from this event. Specific and detailed damages and/or losses for the Township of Brick were not readily available at the time of this plan.
March 11, 2011	Flooding	N/A	N/A	This event included 1.52 inches of rain falling in a 24-hour period at 2 N in the Township of Brick.
August 27 to 31, 2011	Hurricane	EM-3332, DR-4021	Yes	Hurricane Irene produced torrential downpour rains that resulted in major flooding and a number of record-breaking crests on area rivers, tropical storm force wind gusts with record-breaking outages for New Jersey utilities, one confirmed tornado, and a three-to-five foot storm surge that caused moderate to severe tidal flooding with extensive beach erosion over the weekend of August 27 and 28. The highest wind gusts in the Township of Brick were 58 mph.
October 28 to 30, 2012	Hurricane	EM-3354, DR-4086	Yes	Very high wind gusts were recorded due to Superstorm Sandy, with the strongest winds north and east of the center of the hurricane. Superstorm Sandy

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				provided some areas of the mid-Atlantic region with their highest wind gusts since Hurricane Hazel 58 years earlier (October 1954), especially in New Jersey and eastern Pennsylvania. Several wind gusts in Ocean County, New Jersey were close to 90 mph, with many regions reporting gusts over 50 mph. The highest wind gust reported in the Mount Holly area was 89 mph in Surf City (Ocean County). Winds gradually began to increase Monday, peaking as the storm passed through the region Monday night. Many trees and power lines were taken down as a result of these wind gusts. A 61-year-old male drowned in his house on Vanders Drive by the Kettle Creek in the Township of Brick (Ocean County), and a 61-year-old male died in the Township of Brick (Ocean County) after a tree stump fell on him as he was trying to remove it. Peak wind gusts were recorded at 78 mph in the Township of Brick.
December 27, 2012	Coastal Flood	N/A	N/A	An intense low pressure system brought strong to high northeast winds into central and eastern New Jersey mainly during the evening of December 26. Peak wind gusts reached hurricane-force gusts in Ocean County. The strong to high winds caused some structural damage as well as knocked down trees, tree limbs and wires, causing power outages. Jersey Central Power and Light reported approximately 7,000 of its customers lost power in Ocean and Monmouth Counties. Peak wind gusts were recorded at 74 mph in the Township of Brick. The Township of Brick closed off its part of the barrier islands to traffic and Toms River Township reported some ocean breaches on its barrier islands. In Barnegat Bay, tidal flooding caused the closure of Mandalay and Drum Point Roads.
March 7, 2013	Coastal Flood	N/A	N/A	An intense Nor'easter brought strong to high winds across most of central and southern New Jersey on March 6 and 7 with minor to moderate tidal flooding along Raritan Bay, lower Delaware Bay, and on the ocean side. The coastal flooding was exacerbated by wave action as waves off of Barnegat (Ocean County) reached 15 feet and seas offshore reached 25 feet. The coastal flooding caused new breaches in Mantoloking and flooded roadways. Voluntary evacuations were recommended in Toms River, the Township of Brick, and Long Beach Townships. Wind gusts of 56 mph were recorded in the Township of Brick.
May 1, 2014	Flood	N/A	N/A	The North Branch of the Metedeconk River at Lakewood had minor flooding and was above its 8-foot flood stage from 5:54 a.m. through 7:45 p.m. on May 1. It crested at 8.37 feet at 12:45 p.m. on May 1. Event precipitation totals included 4.25 inches in the Township of Jackson, 3.28 inches in the Township of

Table 5-7. Flooding Events in the Township of Brick, 1950 to 2015

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Ocean County Designated?	Estimated Damages and/or Losses
				Brick, 3.19 inches in the Township of Stafford, 3.12 inches in the Township of Whiting and 3.04 inches in the Township of Toms River.
July 15, 2014	Flood	N/A	N/A	The runoff from thunderstorms with very heavy rain caused minor flooding along the North Branch of the Metedeconk River during the early morning of July 15. The North Branch of the Metedeconk River near Lakewood was above its 8-foot flood stage from 3:05 a.m. through 6:45 a.m. on July 15. It crested at 8.08 feet at 4:15 a.m. Event precipitation totals included 3.42 inches in the Township of Jackson, and 2.95 inches in the Township of Brick.
July 15, 2014	Flash Flood	N/A	N/A	Thunderstorms with very heavy rain caused poor drainage and small creek flash flooding in the Township of Brick. Flash flooding closed the northbound exit to the Township of Brick off of the Garden State Parkway near the Cedar Bridge Branch. Event precipitation totals included 3.73 inches in the Township of Brick, one of the highest amounts to fall in New Jersey on July 15.
August 13, 2014	Flash Flood	N/A	N/A	Thunderstorms with torrential downpours caused flash flooding in eastern Ocean County, including the Township of Brick. Rainfall totals reached up to 9 inches in the impacted areas. Rainfall totals in the Township of Brick was 5.87 inches.
October 21, 2014	Flash Flood	N/A	N/A	Heavy rain from thunderstorms caused flash flooding within the Township of Brick. Motor vehicles were stuck in flood waters on Princeton Avenue and several motorists had to be rescued. Event precipitation totals included 2.34 inches in the Township of Brick.

Notes:
FEMA *Federal Emergency Management Agency*
mph *miles per hour*
N/A *Not Applicable*

Significant Flooding Events in the Township of Brick

Reviewing the events and losses discussed below helps identify targets for risk reduction and ways to increase the township's capability to avoid large-scale events in the future. Still, many flood events do not trigger federal disaster declaration protocol but have significant impacts on their communities. These events are also important to consider in establishing recurrence intervals for flooding. The following section provides an overview of some of the more significant floods in the Township.

Ash Wednesday Storm, March 6 to 8, 1962

Until a few years ago, the Ash Wednesday Storm was one of the most impactful storms to hit Ocean County's shoreline in recent history. From March 6 to 8, 1962, the storm pelted the entire coastline of New Jersey with gale force winds, high tides, and heavy snow/precipitation. The storm lasted for about 60 hours in Ocean County and Township of Brick, at times generating winds of 70 miles per hour (mph). The storm's impacts were augmented by the five successive high spring tides, leading to many river docks being underwater for several

days after the storm. The storm caused severe flooding not only in Ocean County, but also along the entire New Jersey shoreline.

Local damage from the storm was mostly due to extensive flooding in developed areas along the 30-mile reach from Barnegat Bay and the Manasquan River (the Townships of Brick and Barnegat). Floodwaters reached depths of 1.5 feet over several streets in Seaside Park and 2 feet over portions of Ortley Beach in Township of Toms River (formerly the Township of Dover). While other parts of the state experienced more severe flood depths, the storm still caused significant damage to the township and county. A total of 5,759 residences and commercial establishments in this reach were damaged by inundation. Of these properties, 163 residences were structurally damaged. Additionally, beaches, dunes, and boardwalks throughout the area received substantial damage from storm surge and coastal flooding (FEMA FIS 2014).

Tropical Storm Doria, August 26 to 27, 1971

From August 26 to 27, 1971, New Jersey experienced significant amounts of flooding from the combined effects of Tropical Storm Doria and a heavy frontal storm. Flood damage was substantial enough to lead to a Presidential Disaster Declaration for the state, and the high water mark survey results from this storm were filed with the USGS Division of Water Resources.

The damage from the event was exacerbated by heavy rain on August 27, 1971, the day prior to Tropical Storm Doria's passage. Intense storm activity throughout the 3-day period led to 32 hours of rainfall in south-central, central, and northeastern New Jersey. Total stormfall amounts from this event ranged between 3 to 11 inches, depending on the location in the state. Storm runoff increased and led to record flows at all 47 gaging stations in New Jersey (FEMA FIS 2014).

Hurricane Floyd, September 16, 1999

On September 16, 1999, Hurricane Floyd made landfall in Cape Fear, North Carolina as a Category 2 hurricane. It then crossed over North Carolina and southeastern Virginia, briefly entering the Atlantic Ocean. New Jersey felt the impacts of the storm on September 17, 1999. Hurricane Floyd is most notable for its record-breaking flooding throughout the State of New Jersey. In addition to the Raritan River Basin experiencing record floods 4.5 feet higher than any previously recorded flood crests, the areas of Bound Brook and Manville were also severely impacted. Hurricane Floyd is estimated to have caused about $250 million in damage to the State of New Jersey, causing the President to issue an emergency declaration (FEMA FIS 2014).

Specifically in Ocean County, the damage estimates were about $5.5 million. Across the state, 3,900 homes, 1,208 apartments, and 1,683 businesses sustained major damaged along with 23,235 homes, 1,758 apartments, and 1,043 businesses which suffered minor damaged. Approximately 616,400 homes and businesses lost power throughout the state for up to five days and some municipalities had limited water use while sewage treatment plants were overwhelmed with runoff (OC HMP 2014).

Hurricane Irene, August 28, 2011

Having earlier been downgraded to an extra-tropical storm, Hurricane Irene came ashore in Little Egg Inlet in southern New Jersey; on August 28, 2011. In anticipation of the storm Governor Chris Christy declared a state of emergency of August 25, with President Obama reaffirming the declaration on August 27. Mandatory evacuations were ordered throughout the Ocean County barrier islands. Wind speeds were recorded at 75 mph and rain totals reached over 10 inches in many parts of the state. Long Beach Boulevard, the main road on Long Beach Island, was reportedly under 6 to 8 inches of water in Beach Haven. In Mantoloking, the eastern foot of the Mantoloking Bridge was completely submerged underwater. The bay has spilled out on to streets in Mantoloking, Bay Head, and further south into Normandy Beach and Chadwick Beach. In Ocean County 45,000

customers lost power during the storm. Overall damage estimates, for the State of New Jersey, came to over $1 billion; with over 200,000 homes and buildings sustaining damaged (FEMA FIS 2014).

In the Township of Brick, officials met prior to the storm to prepare the response necessary for storm management. The mayor was recorded in local media on advising local residents, particularly those in low-lying and back-bay areas, to prepare for all scenarios, including evacuations, and to have a basic emergency supply kit accessible (Brick Township 2011).

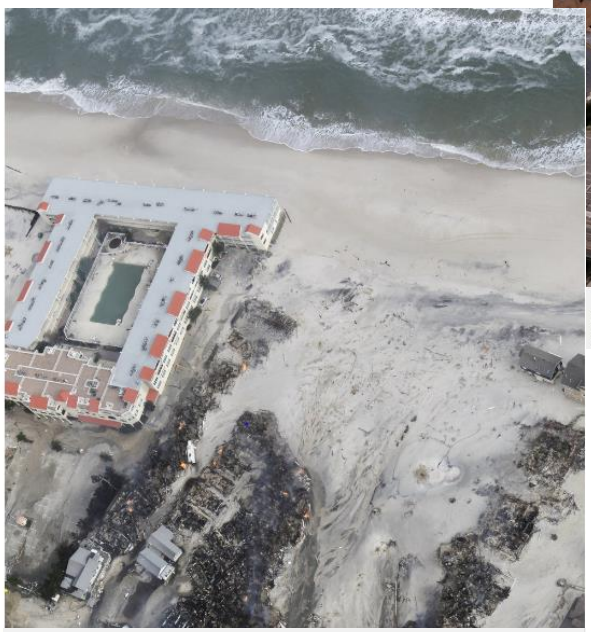
It is important to note that during this storm, the Metedeconk River experienced unprecedented flooding due to rainfall during this event.

Superstorm Sandy, October 29, 2012

Superstorm Sandy came ashore as an immense tropical storm in Brigantine, New Jersey, on October 29, 2012. Superstorm Sandy dropped heavy rain on the area; almost a foot in some areas. Wind gusts were recorded at 90 mph. A full moon made the high tides 20% higher than normal and amplified the storm surge. The New Jersey shore suffered the most damage. Some barrier island communities suffered severe "wash over" including the creation of two temporary inlets. At NOAA's gage #8534720 in Atlantic City, the high water mark (which is considered as a stillwater elevation without waves) reached 8.76 feet. At NOAA's gage #8531680 at Sandy Hook, the high water mark reached 9.21 feet. Seaside communities were damaged and destroyed up and down the coastline. Some 252,000 households in Ocean County lost power. Initial reports suggest that well over 24,000 homes and businesses were damaged or destroyed by the storm. Governor Chris Christy declared a state of emergency on October 31. Superstorm Sandy is estimated to have cost the State of New Jersey over $36 billion (FEMA FIS 2014).

Link to this photo | Comments about this photo essay

BEFORE - The Thunderbird Hotel and smaller, bungalow-style ocean block homes just south in Brick Township as the Jersey Shore prepares for Hurricane Irene's arrival Sunday morning August 26, 2011. This area was completely destroyed by Hurricane Sandy 14 months later. (Andrew Mills/The Star-Ledger)



Link to this photo | Comments about this photo essay

2 of 10 AFTER - A community of bungalow-style ocean block homes in Brick Township was completely destroyed by Hurricane Sandy just south of the Thunderbird Hotel October 31, 2012. (Andrew Mills/The Star-Ledger)

The Township of Brick was particularly hard hit by Superstorm Sandy. The existing bulkheads along the Manasquan River were too low to protect against the storm surge, as were the existing bulkheads against the dredged lagoons. The dredged lagoons also did not have surge barriers. In addition, the residents in the southern area of the township are located in a low-lying area. All of this contributed to a greater vulnerability to Superstorm Sandy, particularly in the area of Barnegat Bay and along the Atlantic Ocean (Rutgers 2014).

The township experienced property damage, infrastructure damage, and severe impacts to its economy, community, and housing. In early 2014, 202 homes were reported as abandoned in the Township of Brick. Many of these homes, despite being primary residences, were abandoned as the owners were disqualified from most types of financial aid. Many residents were displaced by the storm, and there has been a small increase in the township's homeless population since Superstorm Sandy.

The township also experienced significant beach erosion and loss of dunes, further limiting the community's ability to protect itself from future coastal flooding and hazard events. In regards to economic and community impact, many businesses suffered interruption of operations from power outages and road closures. Even upon reopening, these businesses continued to be negatively impacted by a decrease in local and regional tourism (Brick Township SRPR 2014).

Probability of Future Occurrences

Given the history of flood events that have impacted the Township of Brick, it is apparent that future flooding of varying degrees will occur. The fact that the elements required for flooding exist and that major flooding has occurred throughout the county in the past suggests that many people and properties are at risk from the flood hazard in the future. It is estimated that the township will continue to experience direct and indirect impacts of flooding events annually that may induce secondary hazards such as coastal erosion, storm surge in coastal areas, infrastructure deterioration or failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents, and inconveniences.

Floods are typically described in terms of their extent and their recurrence interval. The recurrence interval or return period is the average number of years between floods of a certain size. The actual number of years between floods of any given size varies because of the naturally changing climate (USGS 2013). Table 5-7 describes the recurrence intervals and probabilities of occurrences for flood events.

Table 5-8. Recurrence Intervals and Probabilities of Occurrences

Recurrence Interval (in years)	Probability of Occurrence in Any Given Year	Percent Chance of Occurrence in Any Given Year
100	1 in 100	1
50	1 in 50	2
25	1 in 25	4
10	1 in 10	10
5	1 in 5	20
2	1 in 2	50

Source: USGS 2013

Dam Failure

Dam failure events are infrequent and usually coincide with events that cause them, such as earthquakes, landslides, and excessive rainfall and snowmelt. As noted in the Previous Occurrences and Losses section, dam failures typically occur in New Jersey as a result of heavy rains or other precipitation. There is a "residual risk" associated with dams. Residual risk is the risk that remains after safeguards have been implemented. For dams, the residual risk is associated with events beyond those that the facility was designed to withstand. However, the probability of any type of dam failure is low in today's dam safety regulatory and oversight environment.

Coastal Erosion

Coastal erosion is measured as the rate of change in the position or horizontal displacement of a shoreline over a specific period of time, measured in units of feet or meters per year. Erosion rates vary as a function of shoreline type and are influenced primarily by episodic events. Monitoring of shoreline change based on a relatively short period of record does not always reflect actual conditions and can misrepresent long-term erosion rates due to storm frequency.

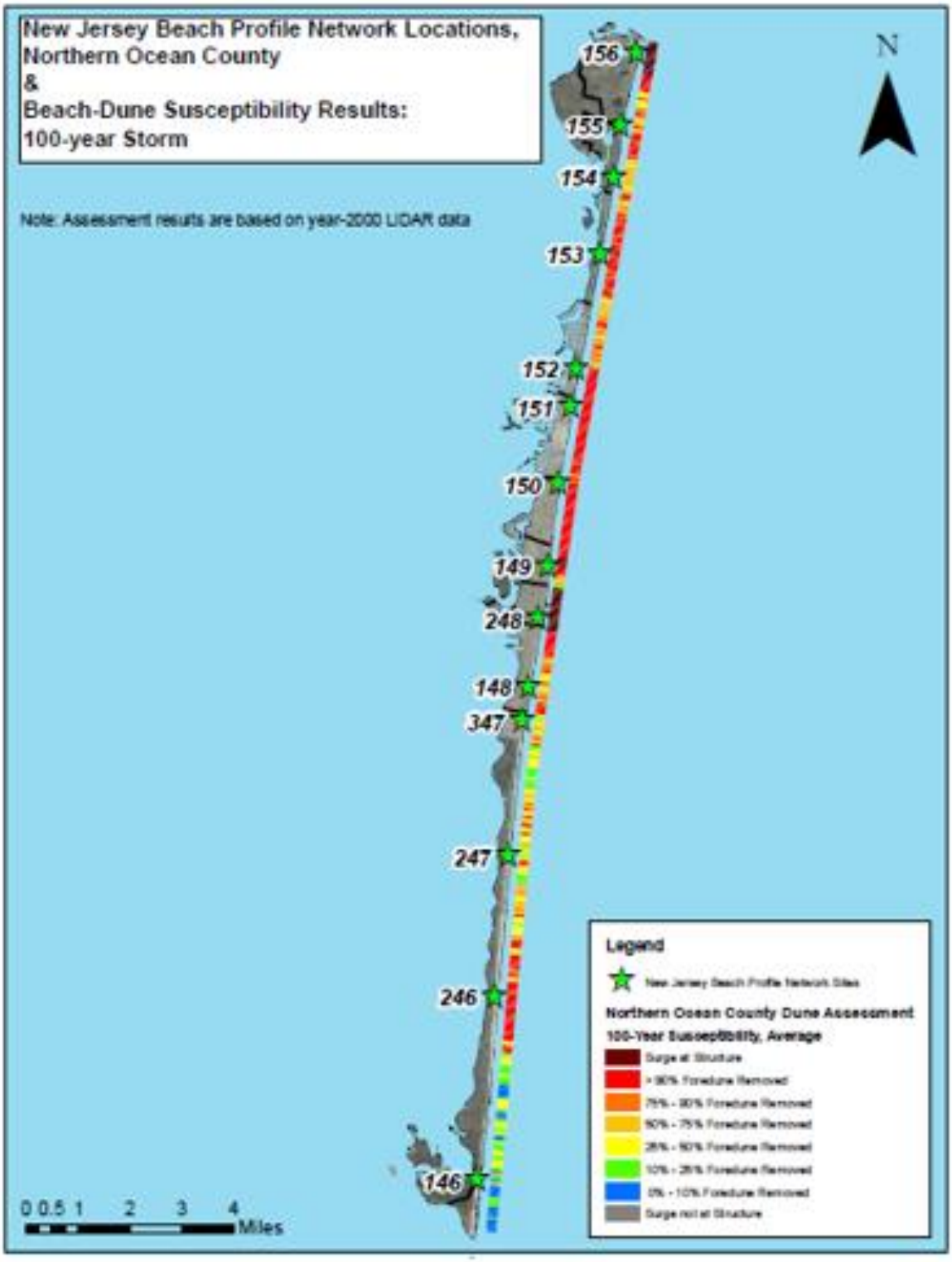
A number of factors determine whether a community exhibits greater risk of long-term erosion or accretion:

- Exposure to high-energy storm waves
- Sediment size and composition of eroding coastal landforms feeding adjacent beaches
- Near-shore bathymetric variations that direct wave approach
- Alongshore variations in wave energy and sediment transport rates
- Relative sea-level rise
- Human interference with sediment supply (such as revetments, seawalls, and jetties) (Woods Hole Sea Grant 2003)

The long-term patterns of coastal erosion are difficult to detect because of substantial and rapid changes in coastlines in the short-term (that is, over days or weeks from storms and natural tidal processes). It is usually severe short-term erosion events, occurring either singly or cumulatively over a few years, that cause concern and lead to attempts to influence the natural processes. Analysis of both long- and short-term shoreline changes are required to determine which is more reflective of the potential future shoreline configuration (FEMA 1996).

In the Township of Brick, coastal erosion will continue to be an on-going problem along many areas of coastline. It is difficult to assign a probability to the near constant small on-going erosion that may occur over a continuous period of time. However, a probability can be assigned to larger storm events such as Nor'easters and hurricanes, which can result in significant, rapid coastal erosion. The period of time suggest the probability of coastal erosion will be about the same in the future, with year-to-year variations (Gutierrez et al. 2007). The figure below indicates those areas of the township with greater coastal erosion vulnerability.

Figure 19. Coastal Erosion Vulnerability in the Township of Brick



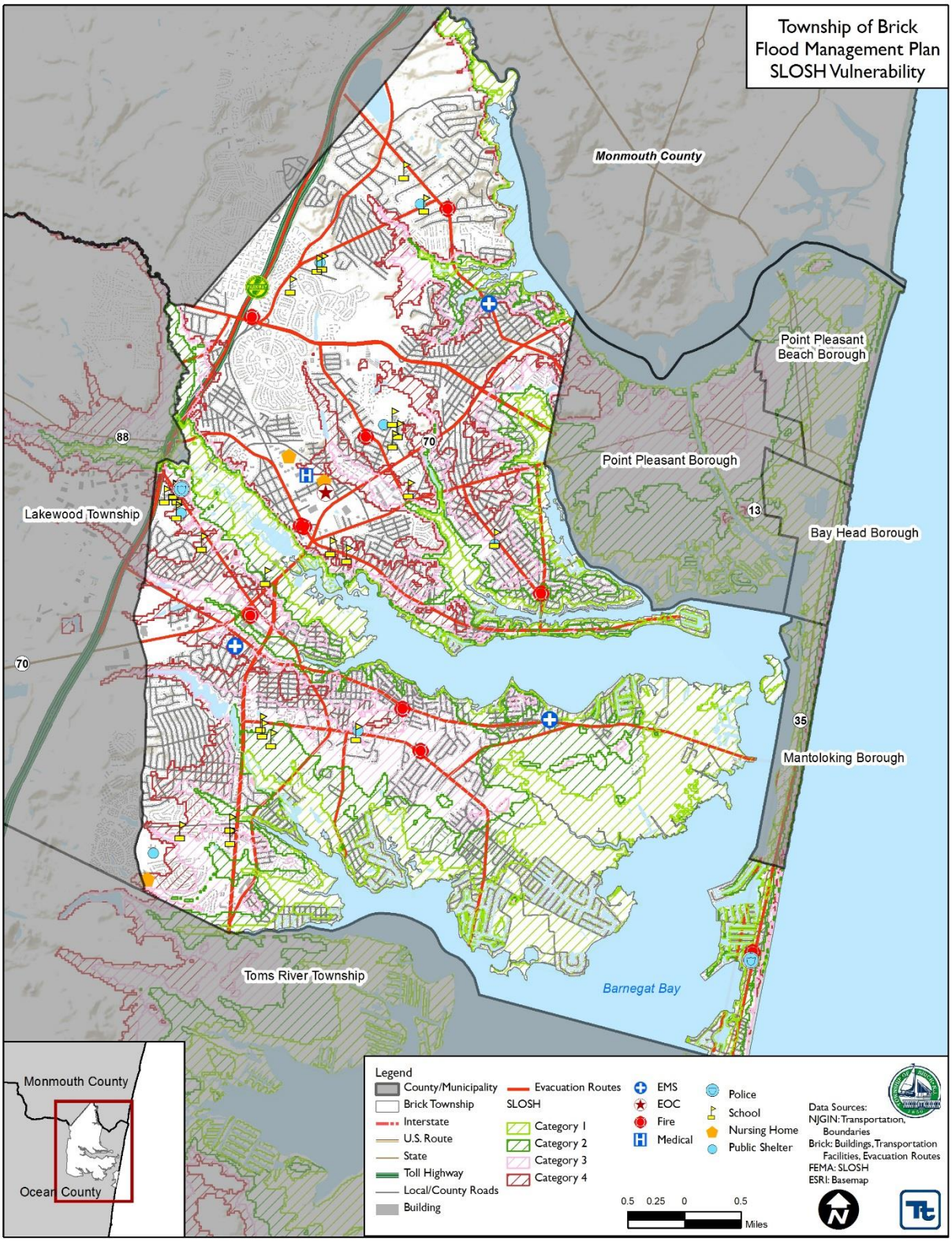
Source: NJ Beach Profile Network

Storm Surge

As noted earlier, no storm-surge specific scales exist due to the concern that no scale can adequately represent the storm surge's potential impact. Because of the threat posed by storm surge, the National Hurricane Center continues to develop more accurate methods of analyzing and predicting storm surge, particularly those associated with tropical storms, hurricanes, and Nor'easters. The National Hurricane Center also includes the probability of surge heights to be exceeded. The New Jersey coastal weather forecast offices typically provide impact graphics during tropical cyclone watches and warnings. These graphics will indicate expected storm surge impacts, if that information has been calculated.

In the Township of Brick, storm surge will remain a concern for many coastal flooding and hurricane events. Although the level of severity for storm surge may not always be accurate, the events are usually easy to predict since they are often a secondary effect from another hazard event (most typically hurricanes, severe storms, and coastal flooding). The figure below indicates those areas of the township with greater storm surge vulnerability.

Figure 20. Storm Surge Vulnerability in the Township of Brick



Source: FEMA 2012, Brick Township, NJGIN 2015

Sea Level Rise

The CVI, as described earlier in this section, uses physical characteristics of the coastal system to classify the potential impact of sea-level rise on open coasts. This approach combines the coastal system's susceptibility to change with its natural ability to adapt to changing environmental conditions, yielding a quantitative measure of the shoreline's natural vulnerability to the effects of sea-level rise (Gutierrez et al. 2007).

Climate Change Impacts

Climate change refers to changes over a long period of time in patterns of temperature, precipitation, humidity, wind, and seasons. Climate change is expected to have significant impacts on the mid-Atlantic and Northeast regions by the mid-21st century. Climate plays a fundamental role in shaping ecosystems and the human economies and cultures that depend on them. It is generally perceived that climate change will have a measurable impact on the occurrence and severity of flooding. As hydrology changes, what is currently considered a 100-year flood may strike more often, leaving many communities at greater risk. Planners will need to factor a new level of safety into the design, operation, and regulation of flood protection facilities such as dams, floodways, bypass channels and levees, as well as the design of local sewers and storm drains. Climate change impacts have the potential to affect the Township of Brick, as well as the entire New Jersey coastal region.

The climate of New Jersey is already changing and will continue to change over the course of this century. Since 1900, temperatures in the northeastern U.S. have increased an average of 1.5 degrees Fahrenheit (°F). The majority of this warming has occurred since 1970. From 1970 to 2010, average temperatures in New Jersey have increased 1.2°F (Office of the New Jersey State Climatologist [ONJSC] 2013). In terms of winter temperatures, the northeast region has seen an increase in the average temperature of 4°F since 1970 (Northeast Climate Impacts Assessment [NECIA] 2007).

In addition to the effect of increased temperatures, precipitation is expected to increase over the next several decades. Average annual precipitation is projected to increase in the region by 5% by the 2020s and up to 10% by the 2050s. Most of the additional precipitation is expected to come during the winter months, where a 20% to 30% increase is expected late in this century (New York City Panel on Climate Change [NYCPCC] 2009). Although precipitation is expected to increase, extreme precipitation is the most likely concern for New Jersey. Extreme precipitation has the potential to cause significant flooding and in the winter produce heavy snowfall. While exact projections are not available, it is estimated that the New York City region will see an increase of 10% to 25% of the frequency of intense precipitation events (Sustainable Jersey Climate Change Adaptation Task Force 2013).

Precipitation during 2012 was slightly below normal, averaging 43.21 inches statewide. It ranked as the 8th driest calendar year of the past 30 years. The central coastal area was wettest in 2012, with several stations in Ocean and Burlington Counties receiving more than 53 inches. Over the long term, there has been an upward trend in annual precipitation in New Jersey. Since 1895, annual precipitation has increased at a rate of 4.1 inches per century. Heavy precipitation events have increased in the past 20 years and it is expected that this trend may continue (Rutgers Climate Institute 2013).

With this increase in frequency of precipitation, New Jersey, Ocean County, and the Township of Brick may experience more flooding events. More intense, frequent flooding could lead to significant habitat loss for wildlife. Salt marshes and estuaries that serve as critical feeding grounds for birds and waterfowl, and as nursery habitats for commercial fish, could be lost (State of New Jersey 2010). Climate change may also lead to sea level rise which will lead to more frequent and extensive flooding (NJDEP 2013c).

Dam Failure

Dams are designed partly based on assumptions about a river's flow behavior, expressed as hydrographs. Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hygrograph changes, it is conceivable that the dam can lose some or its entire designed margin of safety, also known as freeboard. Loss of designed margin of safety may cause floodwaters more readily to overtop the dam or create unintended loads. Such situations could lead to a dam failure.

Coastal Erosion

Coastal areas may be impacted by climate change in different ways. Coastal areas are sensitive to sea level rise, changes in the frequency and intensity of storms, increase in precipitation, and warmer ocean temperatures. According to National Aeronautics and Space Administration (NASA), warmer temperatures may lead to an increase in frequency of storms, thus leading to more weather events that cause coastal erosion.

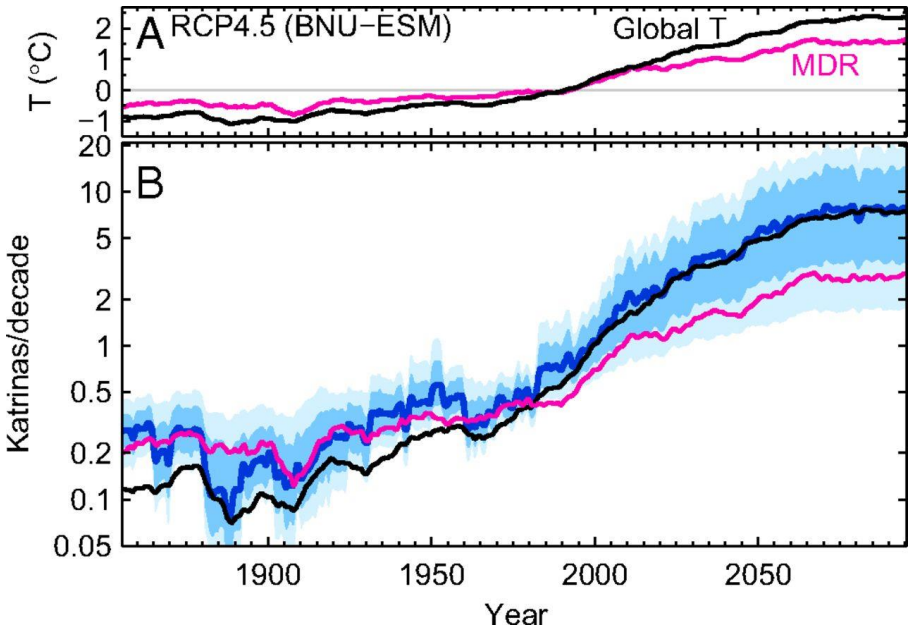
A study on increased storm wave heights from climate change indicated that coastal erosion and flooding may occur twice as fast from sea level rise alone and up to four times as fast as a doubling of the frequency of major El Niño events. Should all these potential subsequent events from climate change occur simultaneously, there could be up to an order of magnitude increase in both coastal erosion and flood frequency (compared against the current rate of those processes). While erosion rates would still be partially dependent on beach slopes and dune crest elevations, this possibility highlights the importance of incorporating climate change and climate control into mitigation practices (Ruggiero 2008).

Storm Surge

Storm surges are generated by the strong winds and intense low pressure associated with tropical cyclones, hurricanes, and severe storms. While not all severe storms will have devastating impacts or create significant levels of storm surge, the surge index record shows a significant positive trend between warmer years and extreme events (i.e., Hurricane Katrina-level events). While surge levels will vary because of situational factors, projected changes in hurricane surge levels above the mean sea level are more likely to increase than decrease. In fact, one study projects that category 4 and 5 frequency in the Atlantic basin could increase by 40% to 90% in the 21st century, for a sea surface temperature increase of about 1.7 degrees Celsius (3.1 degrees Fahrenheit). (Knutson et al, 2013).

More extreme projections have been postulated as shown in the figure below which provides a visual representation of the number of Hurricane Katrina-magnitude surge events per decade hindcast (i.e., past events are modeled to see how well the output matches known results) and projected changes. Each line shows the results based off different modeling techniques and data contributions. Although there is some variation depending on the model, the results show an overall positive correlation between temperature/climate increase and storm surge frequency (Grinsted 2013). This information is provided to indicate the more extreme projections of the scientific community and not the probability of occurance.

Figure 21. Surge Event Frequency over Time and Climate Changes



Source: Grinsted 2013

Sea Level Rise

Changes in global temperatures, hydrologic cycles, coverage of glaciers and ice sheets, and storm frequency and intensity are captured in long-term sea level records. Sea levels provide a key to understanding the impact of climate change (NOAA 2013).

Sea level rise increases the risks coastal communities face from coastal hazards (floods, storm surges, and chronic erosion). It may also lead to the loss of important coastal habitats. In fact, sea level rise may have a stronger influence on hazard occurrences than an increase in El Niño events (Ruggiero 2008).

The historical rate of sea level rise along the New Jersey coast over the past 50 years was 0.12 to 0.16 inches per year. Future rates are predicted to increase to 0.5 inches per year (Miller and Kopp 2013). By 2050, the sea level is expected to rise 16 inches from the current mean (Rutgers 2013).

Future Trends

The Township of Brick has established a clear commitment to furthering hazard mitigation and resilience efforts in the community, a goal furthered by a review of the substantial impacts from Superstorm Sandy in 2012. The township has already begun securing additional backup generators for power redundancy, implementing beach erosion and stabilization control projects in high risk areas and areas subject to storm surge scouring, implementing resilient (i.e., greater than pre-Superstorm Sandy levels) beach replenishment measures, installing man-made flood control structures in coastal risk areas, and more. The Township of Brick plans to continue these efforts through additional infrastructure upgrades and enhancements, a Master Plan update to incorporate more mitigation integration, economic development, housing, communication and education, capital improvement, and an application to the Community Rating System (CRS) program.

The Township of Brick Master Plan already identifies general goals and objectives for natural hazard planning, which the township plans to keep as high-priority initiatives. These include implementing the Open Space and Recreation Plan, encouraging the continued municipal acquisition and recreational development of vacant

waterfront property, implementing the conservation plan for environmentally sensitive lands, improving surface and groundwater quality through the completion of the Sewerage Infrastructure Improvement Act requirements, and more. The township's participation and adoption of the Ocean County HMP also contributes to its interest in flood management, as the HMP includes goals, objectives, policies, and actions focused on frequently flooded areas. The township also has several other plans and initiatives designed to promote healthy watersheds and manage stormwater. These plan components strive to steer future trends in development away from increasing flood risks in the Township of Brick. The Township of Brick's critical areas regulations guide how development and redevelopment can safely occur on these important lands. Additionally, the Township of Brick participates in the NFIP and has adopted flood damage prevention regulations in response to its requirements. The Township of Brick has committed to maintaining its good standing under the NFIP through initiatives identified in this plan.

The Township of Brick has a population of 75,072, based on the 2010 U.S. Census. Although this is a decrease of 1.4% from the township's 2000 U.S. Census population, the township has conducted several studies to determine population projects for the next 15 years and has determined its population will increase by approximately 2,000 by 2030. A build-out analysis completed in 2005 identified all properties in the township that are available for development. The township contrasted this information with geographic information system (GIS) parcel layers, tax assessor data, and tax maps to determine that 760 new households can be built on current buildable vacant land. The cumulative implementation of these plans and regulations will reduce the impacts of future growth in the floodplains and high-risk areas of the Township of Brick, as well as lessen the impacts of flooding on future development.

Scenario

The primary waterways and the coastline in the planning area have the potential to flood at regular intervals, generally in response to hurricanes, Nor'easters, or other severe storms. Storm patterns of warm, moist air usually occur between early November and late March; Nor'easters are most typical during winter months; and hurricane season officially runs from June 1 to November 30. A series of such weather events can cause severe flooding in the planning area. The worst-case scenario is an event similar to Superstorm Sandy, i.e., a severe hurricane or a series of storms that leads to both coastal flooding and riverine or flash flooding. In addition to rain falling faster than the ground and waterways can absorb it, this type of event would cause secondary effects of coastal erosion and storm surge. This could overwhelm response and floodplain management capabilities within the planning area. Major roads could be blocked, preventing evacuation and critical access for many residents and critical functions. High in-channel flows could cause water courses to scour, possibly washing out roads and creating more isolation problems. In the case of a series of storms, the Township of Brick may not be able to make repairs quickly enough to restore critical facilities and infrastructure. The floodplains mapped and identified by the Township of Brick will continue to be impacted by these floods.

Issues

Important issues associated with flood hazards in the planning area include but are not limited to the following issues identified by the planning team:

- Many developed areas in the township are located in close proximity to tidal bodies of water. This could lead to significant problems in the case of sea level rise.
    - Example: Mantoloking Road runs parallel to the Metedeconk River, over the Barnegat Bay, and Route 35 runs next to the Atlantic Ocean (additionally preventing evacuation through this route during a Category 1 Hurricane).
- Some evacuation routes are in the floodplain or conflict with response service areas.

  - Example: In addition to the Route 35 concern listed immediately above, two fire stations are in the direct path of an evacuation route. This not only prevents residents from using this route, but also impacts rescue workers who may not be able to assist residents in high vulnerability areas.
- Superstorm Sandy increased the vulnerability of homeowners and businesses in low-lying areas.
- Sewer infrastructure in the Township of Brick is particularly vulnerable to coastal flooding and severe storms. This leads to additional public health and ecosystem concerns about untreated sewage.
- The township experiences annual variances in populations from summer tourism, leading to challenges in adequately determining the number of people in need during a hazard event.
  - In addition, the Township of Brick is projecting a population increase of approximately 2,000 more people by 2030, many of whom may move to flood-prone areas.
- Degraded wetlands in Barnegat Bay may contribute to greater vulnerability to flood events in the Township of Brick.
- Ongoing flood hazard mitigation will require funding from multiple sources.
- There needs to be a coordinated hazard mitigation effort between the town, county, state, and local agencies.
- Floodplain residents need to continue to be educated about flood preparedness and the resources available during and after floods.

5.3 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed and vulnerable in the identified hazard area. For the flood hazard, the hazard areas include the 1-percent and 0.2-percent annual chance flood zones, Category 1-4 Sea-Lake Overland Surge from Hurricane (SLOSH), and the NOAA 2050 Intermediate-High and High sea-level rise scenarios. The following text evaluates and estimates the potential impact of these hydrologic hazards for the Township of Brick including:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, health and safety of residents, (2) general building stock, (3) critical facilities, (4) economy, and (5) future growth and development
- Effect of climate change on vulnerability
- Further data collections that will assist understanding this hazard over time

Overview of Vulnerability

The flood hazard is a significant concern for the Township of Brick. As discussed, this includes riverine and coastal flooding, storm surge, flooding from dam failure, and sea level rise. In addition, coastal erosion is a significant coastal hazard to the Township as well. To assess flood vulnerability, exposure to the 1- and 0.2-percent annual chance flood events was examined using the FEMA preliminary FIRM released in January 2015. Potential losses were also calculated for 1- percent annual chance flood event. The flood hazard exposure and loss estimate analysis is presented below.

For the Township of Brick, storm surge from coastal storm events is a major concern. Storm surge along the coast and river inlets may cause erosion and damage to the Township's infrastructure and buildings. The SLOSH hazard exposure and loss estimate analysis is presented below.

Lastly, sea level rise was evaluated. Based on discussions with the Township and Jacques Cousteau National Estuarine Research Reserve, as well as to align with the State of New Jersey Hazard Mitigation Plan, two NOAA sea level rise scenarios were examined to estimate exposure in the Township.

Data and Methodology

The 1- and 0.2-percent annual chance flood events were examined to evaluate the Township's risk to the flood hazard. These flood events are generally those considered by planners and evaluated under federal programs such as the NFIP. The FEMA preliminary flood maps released in January 2015 were used to evaluate the Township's exposure to this hazard. The data used for this analysis is shown in Figure 5.5.

To estimate potential losses, the FEMA Hazards U.S. Multi-Hazard (HAZUS-MH) flood model was used. The default building inventory in HAZUS-MH 2.2 was updated and replaced with a custom building inventory developed for the Township of Brick. The most current Township-provided parcel shapefile was joined to post-Hurricane Sandy tax data. The attributes from these files were aligned with HAZUS-MH's Comprehensive Data Management System's required building stock fields. Where data was not available, reasonable assumptions were made. The user-defined table in HAZUS-MH was updated and a building-specific analysis was conducted. The 1-percent annual chance depth grid generated by NJDEP for Ocean County was integrated into the HAZUS-MH flood model and then run to estimate potential losses at the structure level using the HAZUS-MH default damage functions.

The National Hurricane Center's SLOSH model, which represents potential flooding from worst-case combinations of hurricane direction, forward speed, landfall point, and high astronomical tide was used to estimate exposure. The model forecasts surges that occur from wind and pressure forces of hurricanes, considers only storm surge height and does not consider the effects of waves. The FEMA Coastal Flood Loss Atlas storm surge inundation depth grids generated in GIS format from SLOSH Maximum of Maximums (MOMs) outputs per hurricane category were integrated into the HAZUS-MH flood model to estimate losses. Figure 5.9 illustrates the data used for this analysis.

To assess the Township's vulnerability to sea level rise, a spatial analysis was conducted with the NOAA sea level rise scenario polygon data. The 2050 Intermediate-High and the Highest NOAA sea level rise scenarios were selected to account for the full range of potential impacts. There are no depth grids associated with these scenarios, so estimated losses were not calculated in HAZUS-MH. This sea-level rise data set was generated by combining the best available SFHA at the time with the various sea-level rise scenarios; it displays a combination hazard of potential flooding hazards as a result of different sea-level rise scenarios.

- Intermediate-High [Best Available Special Flood Hazard Area (SFHA) + 1.3 feet]
- Highest (Best Available SFHA + 2.0 feet)

Figure 5-21 illustrates the flood hazard vulnerable location and critical facilities in the Township of Brick. It is noted that regarding fresh water intakes not identified in the figure, there is a long-term planning concern that sea-level rise may affect the Township fresh water supply, ultimately bringing brackish water further upstream and on a more frequent basis, making salt water presence at the water utility intake a more common occurrence.