Atlantic Highlands Flooding Vulnerabilities Assessment

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1. INTRODUCTION AND METHODOLOGY OF OUR WORK

The goal of this report is to analyze and summarize the possible impacts of different flooding scenarios in Atlantic Highlands, New Jersey. Using various tools, the Rutgers Team (hereafter "team") has identified current vulnerabilities associated with housing, local economies, building codes, populations, significant public assets, and natural resources. This analysis also highlights the impacts to the working waterfront and water-dependent economy.

The team drew extensively on the Atlantic Highlands Municipal Coastal Vulnerability Assessment from 2016, prepared by Sustainable Jersey, in determining Atlantic Highlands' asset vulnerability. The team also considered analysis and recommendations from the 2015 Getting to Resilience Recommendations Report.

The team used NJFloodMapper to project sea level rise and flood risks for Atlantic Highlands under a moderate greenhouse gas (GHG) emission scenario and projected these impacts onto three time periods for planning purposes: 2050, 2070, and 2100 (Table 1). This was based on updated guidelines and regulations for flood planning from New Jersey Department of Environmental Protection (NJDEP) and the team's concerns about repeated damage from annual storm events, which are becoming more common with climate change and exacerbating stream flooding due to upstream development. The team was unable to project the current 500-year storm using this tool and available GIS data layers, and instead used the current 100-year flood as well as the historical storm surge extent of Hurricane Sandy to determine vulnerability to major coastal hazards. NJDEP had encouraged the team to analyze the impacts of a 500-year flood to align with anticipated future NJDEP regulations and guidance. NJDEP also advised the team to: understand the impacts of 10 and 12-feet total water level (TWL; see section 1.5 below for a description), focus on 3-feet of sea level rise (SLR) impacts for shorter time frames, and to focus on 5-feet of SLR with regard to 2100.

All of these maps are included in the appendix, although the 2070 projection with the annual storm has been used for visual reference throughout this document for ease of comparison. Maps were created using a combination of ArcGIS Desktop ArcMap and NJfloodmapper.org.

Furthermore, the team used FEMA Community Profiles and NJ Forest Adapt, total water depth data from National Oceanic and Atmospheric Administration (NOAA), the Atlantic Highlands 2019 Master Plan, and information from various departments within the Atlantic Highlands government as relevant.

1.1 Demographics

According to U.S. Census data, as of 2018, Atlantic Highlands has 4,316 residents, 93% of whom are white with a median age of 47.2 years. As a benchmark, New Jersey's population is 69% white with a median age of 39.0 years. Since the late 19th century, the population in Atlantic Highlands has been growing and reached its peak between 1940 and 1960 after World War II. Starting from the 1970s, the population growth started to flatten with a reduction of birth rate and an out-migration of the population. There has been an increasingly elderly population in Atlantic Highlands for the past 40 years, and this trend is expected to continue.

1.2 Economy

Atlantic Highlands has a median household income of $97,083. The median property value in Atlantic Highlands is $384,000 and home ownership rate is 77.3%. There are 2,320 employed residents of Atlantic Highlands as of 2018. The largest industries by number of employees are Retail Trade, Health Care and Social Assistance, and Educational Services (Xie et al. 2018).

The main commercial area in Atlantic Highlands is found along First Avenue, extending from NJ Route 36 to the waterfront. This downtown core has recently been the focus of a revitalization effort to increase its appeal to locals and visitors alike. This area is pedestrian-oriented and contains a mix of commercial and entertainment uses, such as restaurants, art galleries, shops, commercial office space, a movie theatre, and a small hotel.

There is sparse commercial use found along Route 36 to the east of First Avenue, and includes uses such as small offices, gas stations, and personal services. There is a light industrial area to the west of the downtown area, which is bounded by West Avenue, Memorial Parkway, West Highland Avenue, and Avenue A.

Additional commercial use is found along the waterfront, near the harbor. The harbor is the largest single economic driver in the municipality, and is therefore discussed later in a standalone section in this analysis.

Atlantic Highlands is involved in a regional effort (Bayshore Regional Strategic Plan) to revitalize nine bayshore communities and increase tourism and economic growth in the region. Plans for a greenway and expansion of existing trail systems are proposed to link these municipalities. These proposals are intended to boost tourism and increase awareness of the region's rich historical character and unique natural resources and scenery.

Influence of the harbor:

The harbor contributes more than a million dollars in revenue annually to the municipality through building leasing to several businesses, slip rentals, commuters, local residents, and visitors. Coastal flooding damage to the harbor would cause a loss in revenue. The loss of revenue would need to be covered through rate increases as the Harbor is a separate utility within the municipal government and raising property taxes is out of the question. Businesses located near the harbor might not recover and could potentially close down permanently. Additionally, damage to the harbor could limit the ability of evacuation into and out of the region, and the ability of regional commuters to go to and from work.

1.3 Land Cover/Use

Atlantic Highlands is made up of 970 total acres of land and completely built out with the exception of a few areas that consist of a six-acre wooded tract and a seven-acre water tract. The majority of the borough's land cover is residential, with the vast majority of this land zoned for single-family housing. There are some multifamily housing developments in the southwest and southeast parts of the borough and near the municipal harbor and the downtown.

Geographically, the town is defined by its waterways, which feature an extensive bayfront coastline and two creeks that empty into the bay. Both of these creeks run through the more developed, lower-lying areas on the western side of town. The eastern half is defined by steep slopes and coastal bluffs, reaching a maximum elevation of 266-feet. While the more elevated area is also developed, it features larger homes and lower-density construction.

In terms of its forest cover, Atlantic Highlands has stretches of deciduous forests, old field cover, and deciduous brush and shrubland, much of it close to the bayfront, though almost all of it is on private property. It has 96 acres of upland forest and 10 acres of wetland forest. In Monmouth County as a whole, most forest cover consists of oak/hickory, oak/gum/pine, oak/pine, and loblolly/shortleaf pine ecosystems.

There is no agricultural land within the borough.

1.4 Hazards

Due to Atlantic Highlands' unique location, situated between Sandy Hook Bay, the hilly Highlands, and the neighboring low lying areas of Middletown, several natural hazards pose risks to its residents and businesses. According to FEMA records, Monmouth County has been involved in 11 New Jersey disaster declarations since 1965. Nine of these 11 declarations were for coastal storms, such as hurricanes and Nor'easters, and for severe rainstorm flooding events. Therefore, this report focuses primarily on coastal storms and floods, and provides analysis of expected changes to these hazards and their associated risks with climate change considerations.

The lower lying portion of Atlantic Highlands between Wagner and Many Mind Creeks currently experiences occasional tidal flooding. Heavy precipitation events also flood both creeks, particularly when rainfall coincides with the high tide. Atlantic Highlands also faces a unique heavy rainfall-related hazard in New Jersey, shallow slumps, which impact the steep sloped coastal bluffs on the eastern side of town. Further, coastal storms such as Hurricane Sandy and yearly Nor'easters bring additional hazards of storm surges and strong winds, which impact the commonly flooded areas and municipality over all.

The hazards mentioned here are influenced by the climate in which they occur. For example, New Jersey's coastal temperature has increased by approximately 4°F since the start of the 20th century. This increase in temperature in combination with other long-term environmental trends (e.g. sea water expansion, melting glaciers, and land subsidence) have caused the sea level along the Atlantic Highlands coast to rise by one foot over the last century. By 2100, scientists expect New Jersey will experience a total of 9°F increase in temperature under a moderate emissions scenario (RCP 4.5). Sea levels in New Jersey are thus projected to rise by as much as 3-feet by 2070 and 5-feet by 2100, according to 2020 New Jersey Scientific Report on Climate Change (NJDEP 2020). Extreme precipitation events, defined as rainfalls with more than two inches per day, have increased by 50% in recent years (2010-2014) compared to any other five year period since 1900.

These events are expected to increase in intensity and frequency, and in seasonal variability over the next century.

Each of these changes have implications for the hazards above. Warming temperatures will contribute to the warming of the oceans. Warmer oceans carry the potential to increase storm intensity, thereby increasing the risks associated with tropical storms in the New Jersey region. Sea level rise will increase the frequency of tidal floods as the seas and bays creep landward, and also increase the impact of coastal storm surges on the community. More frequent intense precipitation will stress stormwater management systems and lead to more riverine and coastal flooding, and for Atlantic Highlands, more landslides. This report has been generated with these hazards and increasing risks in mind. As such, the following section contains an assessment of Atlantic Highlands' assets and vulnerabilities in terms of the hazards presented here.

Hazards causing flooding may also trigger cascading effects in multiple aspects (shown in Figure 1). It is crucial to understand and prevent potential cascading effects to lessen further damage. Environmentally, rainstorms and flooding events may induce landslides, increasing the rate of coastal erosion. These environmental events may cause structural damage, such as flood damage to harbors, destruction of buildings, creation of power and electricity outages, and disruption of transportation systems. This structural damage may further impede the efficiency of rescue efforts and slow down post-disaster recovery. Economically, flooding may further disrupt business from three months to a year. The structural and economic loss further leads to social and health issues. For instance, there are displacement issues if ancestral properties are permanently inundated; mold growing under the carpet after flooding events; deterioration of mental health from the repetitive loss and length of recovery; potential outbreak of waterborne disease; contamination of drinking water when contaminated sites and sewer systems are flooded, etc. Therefore, it is crucial to identify the most critical linkages and interdependencies of both natural hazards and anthropogenic systems.

In Atlantic Highlands, it is crucial to maintain the evacuation shelters, prevent and clean up if drinking water is contaminated, lessen the destruction at the borough’s harbor, and ensure communication and its back up system can run smoothly during a storm. These aspects may not cut the cascading chain entirely, however, these measures enable the fire, police, and emergency medical services departments to react to the situation immediately and effectively.

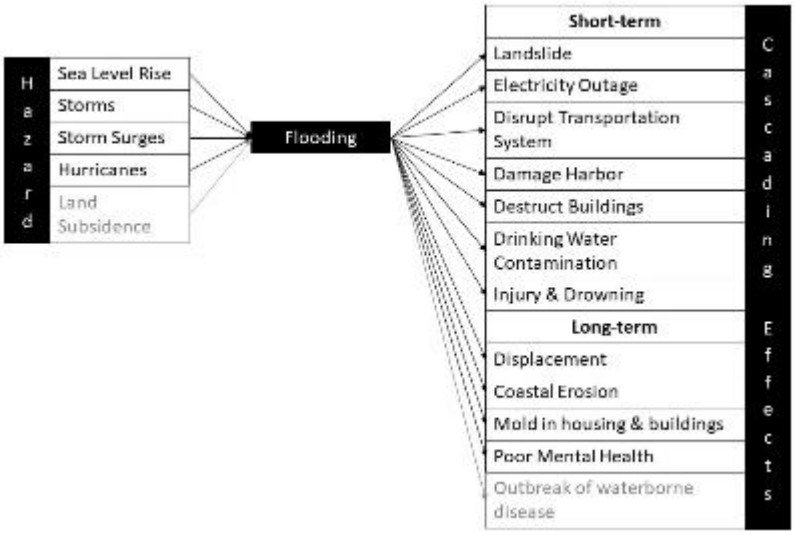

Figure 1. Cascading effects (secondary hazards) of flooding in Atlantic Highlands

1.5 Methodology for Flooding Scenarios and Mapping

The team used NJFloodMapper for this flooding vulnerability assessment to get a sense of the locations in Atlantic Highlands that will be impacted by various degrees of sea level rise and flooding. A total of nine scenarios were analyzed and are summarized in the table below (Table 1).

Each scenario was based on the following core data: tide gauge information from Sandy Hook, NJ; moderate greenhouse gas (GHG) emissions which correspond to a future consistent with current global emission policies; and above average sea level rise estimates (these estimated values have a 17% chance of being exceeded). Changes in water level are presented as TWL values as calculated through NJFloodMapper. The TWL is the sum of three water values: mean higher high water (MHHW), sea-level rise, additional water height from a flood event.

The resolution of our TWL results is limited to the user preferences on NJFloodMapper. For example, the team was only able to select from the following flood events when calculating TWL: no flood, Annual Flood (1.6-feet above MHHW), 2-year Flood (2.5-feet above MHHW), 10-year Flood (3.9-feet above MHHW), and 100-year Flood (6.80-feet above MHHW). As such, the team was not able to refine the assessment beyond the available options in NJFloodMapper. Atlantic Highlands may find it helpful to calculate water inundation from a 500-year Flood for the Plan Endorsement Process using ArcGIS, but such TWL values were not available on NJFloodMapper.

Maps presented in Appendix A were recreated using the TWL established with the NJFloodmapper.org methodology just described. Available NOAA GIS data layers for use in these re-creations included flooding extents and depths for TWLs from 0 - 10 feet. These layers can be found at coast.noaa.gov/slrdata. GIS layers from New Jersey Geographic Information Network

(NJGIN) were also used to identify municipal boundaries. Maps were created using the WGS - 1984 coordinate system. Maps with TWLs greater than 10-feet for which we did not have NOAA GIS layers (*i.e.,* 2070: Sandy; 2100: 100-year Flood and Sandy) were reproduced in this report directly from NJfloodmapper.org.

Table 1. Summary of the different scenarios analyzed in this Flood Vulnerabilities Assessment. Each row represents a different timeframe (2050, 2070, 2100) while each column represents a different flooding scenario in Atlantic Highlands. Table outputs represent TWL produced through NJFloodMapper. As such, the scenarios in column two represent TWL from Annual Flood conditions (*i.e.,* the expected sea level rise from moderate greenhouse gas emissions [there is at least a 95% chance this amount of sea level rise will be realized] and the expected increase in water height during an Annual Flood [which has a 99% Annual Exceedance Probability]). The scenarios in column three represent the TWL from 100-year Flood conditions (*i.e.,* the same as column one except this flood has a 1% AEP). The scenarios in column four represent the TWL if Hurricane Sandy were to occur at each time horizon. MHHW refers to the tidal elevation determined by averaging the highest daily tide at Sandy Hook, NJ over recorded history.

Time Horizon	Annual Flood (1.6-feet above MHHW)	100-year Flood (6.8-feet above MHHW in future year)	Hurricane Sandy storm surge extent (8.0-feet above MHHW)
2050	4-feet	9-feet	10-feet
2070	5-feet	10-feet	11-feet
2100	7-feet	12-feet	13-feet

2. SOCIAL VULNERABILITIES

2.1 Housing and Population

2.1.1 *Background Information*

Population density

Atlantic Highlands has a fairly high density of population of 3,401 inhabitants per square mile. For comparison, Monmouth County has 1,337 people per square mile. The block east to First Avenue has the highest population density, while the residential area west along First Avenue is also relatively crowded (see Figure B1, Appendix B).

Aging population

Atlantic Highlands has been experiencing a growing aging population since the 1970s. According to ACS 2018 (5-Year estimate) data, 33.7% of the population is aged 55 and older, and 16.6 % is aged 65 and over. In terms of physical location, a concentration of the elderly population was found in the coastal areas (see Figure B2, Appendix B).

Housing types

In Atlantic Highlands, according to ACS data, there are in total 1,942 units as of 2018, 76% of which are single family homes and 16% multifamily (3 or more units) housings. 733 housing units are estimated to be built pre-1940, which would be the stock most vulnerable to flooding.

Regarding physical location, the residential area with most of the old (pre-1940) homes were not identifiable based on 2014-2018 ACS data.

Table 2. Age of homes in Atlantic Highlands. (Source: ACS 2018 5-year estimate data.)

Age of Home	**Pre-1940**	**1940-1969**	**1970-1989**	**Since 1990**	**Total**
No. of units	733	613	317	279	1,942
Percent(%)	37.74	31.57	15.78	14.37	100

Poverty

Few families live in poverty in Atlantic Highlands; 58 families (4.39%) were estimated to live in poverty in 2014-2018. Only about 214 people, or 4.99% of the total population, were considered to be in poverty in 2014-2018.[1]

2.1.2 *Risk Assessment*

a. Asset Identification

Six community assets were identified in the 2016 Coastal Vulnerabilities Assessment (CVA) report that are categorized as "Districts, Neighborhoods & Population Clusters" – Bayside Neighborhood, Bowne Avenue Neighborhood, Harbor View Neighborhood, Leonard Avenue Neighborhood, Ocean Boulevard Neighborhood on the west and eastside Ocean Boulevard Neighborhood.[2]

In between Wagner Creek and Many Mind Creek, there are three residential neighborhoods – Bowne Avenue Neighborhood, Harbor View Neighborhood and Leonard Avenue Neighborhood. Bowne Avenue Neighborhood is situated next to Wagner Creek and along Bowne Avenue, which is the most western street in the borough. The neighborhood has approximately 16 single-family homes. Harbor View Neighborhood is in the coastal area along Raritan Bay and Sandy Hook Bay, which consists of 13 single-family homes. Lastly, Leonard Avenue Neighborhood can be found along the East end of Leonard Avenue with approximately 12 single-family homes. The area is situated about 0.3 miles away from Many Mind Creek, and is known for flooding. A few properties in this neighborhood have been bought out by the municipality.

[1] According to the U.S. Census, a family group is defined as any two or more people living together, and related by marriage or birth.

[2] Ocean Boulevard Neighborhood on the west was originally cited as "Bayview Avenue" in the 2016 CVA report. Following the change in name, the team will refer to this area as westside Ocean Boulevard Neighborhood instead for the analysis in this report, as Bayview Avenue is no longer used in Atlantic Highlands.

Three more residential neighborhoods are located along the Henry Hudson Trail. Bayside Neighborhood is situated along Bayside Drive with approximately 82 single-family homes. Additionally, there are two residential neighborhoods based along Ocean Boulevard. The neighborhood on the west has 75 single-family homes, and the other one on the east has approximately 39 single-family homes. The residential properties in the westside Ocean Boulevard Neighborhood are considered some of the most valuable in the borough.

b. Analysis

In the 2016 CVA report, only Harbor View Neighborhood out of the six community assets was considered vulnerable to 1.3-feet SLR (2050 mid-range projections used in the CVA report). Harbor View Neighborhood was considered to have an impact that is "insignificant," based on the vulnerability rating key used in the 2016 CVA report. The five other assets were rated to have no impact from the 1.3-feet SLR.

The team's 2020 analysis found all five residential neighborhoods are somewhat impacted depending on the flooding scenarios. The Bowne Neighborhood is the most significantly impacted community asset. The area west of Bowne Neighborhood is flooded in the 5-feet TWL (2070, Annual Flood), and the neighborhood becomes more inundated with increasing TWLs. With 10-feet TWL (2050, 100-year Flood), Leonardo Neighborhood is also significantly impacted. The neighborhood becomes completely submerged in this scenario. The Harbor View Neighborhood is also severely impacted within each scenario adhering to higher TWLs.

Figure 2. Neighborhoods under 5-feet TWL (2070, Annual Flood). (Source: NJGIN, NOAA)

Figure 3. Neighborhoods under 10-feet TWL (2050, 100-year Flood). (Source: NJGIN, NOAA)

2.2 Social Infrastructure

2.2.1 Background Information

Social infrastructure includes all public and quasi-public space that provides services to the community or improves social cohesion. Small businesses, parks and open space, schools, places of worship, senior centers, health care facilities, and historical structures are examples of social infrastructure found in Atlantic Highlands.

The central commercial district is located along First Avenue, and includes the eight block area that runs from the shopping center at NJ Route 36 to Bay Avenue and Ocean Boulevard. The second commercial hub is located bordering the harbor, and is discussed in the Harbor section of this report. There is sparse commercial use found along Route 36 to the east of First Avenue and a light industrial area to the west of the downtown area, which is bounded by West Avenue, Memorial Parkway, West Highland Avenue, and Avenue A. There are many historical structures located throughout the borough. There are two structures listed in the National Register of Historic Places: the Alexander Hamilton steamship, which is the sunken remains of a steamboat built in 1924 for the Hudson River Day Line, and The Towers, also known as Strauss Mansion, which was built in 1893 and now houses the Atlantic Highlands Historical Society and museum. Additionally, the New Jersey State Register of Historic Places recognizes the Atlantic Highlands Historical District, which is bounded by Atlantic Ocean, Chapin Avenue, East Highland Avenue and 4th Avenue.

2.2.2 Risk Assessment

Generally, social infrastructure throughout the municipality is not severely threatened by increased flooding except in the scenarios with higher TWLs. Under 5-feet TWL conditions, there is minor

flooding from the Many Mind Creek that is near the First Avenue downtown hub. There is one historic structure listed on NJ FloodMapper that is impacted by this level of flooding. The elementary school is safe at 5-feet TWL, but is at the edge of impact under the 13-feet TWL.

However, as water levels rise, they steadily move closer to the downtown core. At 13-feet TWL, West Avenue is virtually completely inundated with water from Many Mind Creek. West Ave is only one block west of First Avenue, which comprises the downtown business district. Some of the perpendicular blocks between West and First Avenues are also inundated under the 13-feet TWL scenario, which will impact any businesses and storefronts that are located just off of First Avenue. Additionally, several blocks to the west of Many Mind Creek are also completely inundated.

One unique aspect of Atlantic Highlands' social infrastructure is its wealth of historical structures. Unlike homes or commercial buildings, historical structures cannot be rebuilt or replaced if they are irreparably damaged. Therefore, extra precautions must be taken to protect these sensitive structures from flood damage.

Open space is somewhat threatened by future flooding scenarios. There are currently plans to enhance the greenway near Many Minds Creek, and this area is also a component of a regionally-planned greenway effort. Many Mind Creek is projected to flood extensively, which would reduce the space safely available to develop parkland. If a greenway concept is implemented, it will have to consider future flooding projections in its design. Establishing parkland around Many Mind Creek may help prevent future development in this very vulnerable area. Parkland would have to be designed to accommodate the creek's flooding; for example, passive use such as raised walkways and scenic overlooks would be preferred to active use like sports fields.

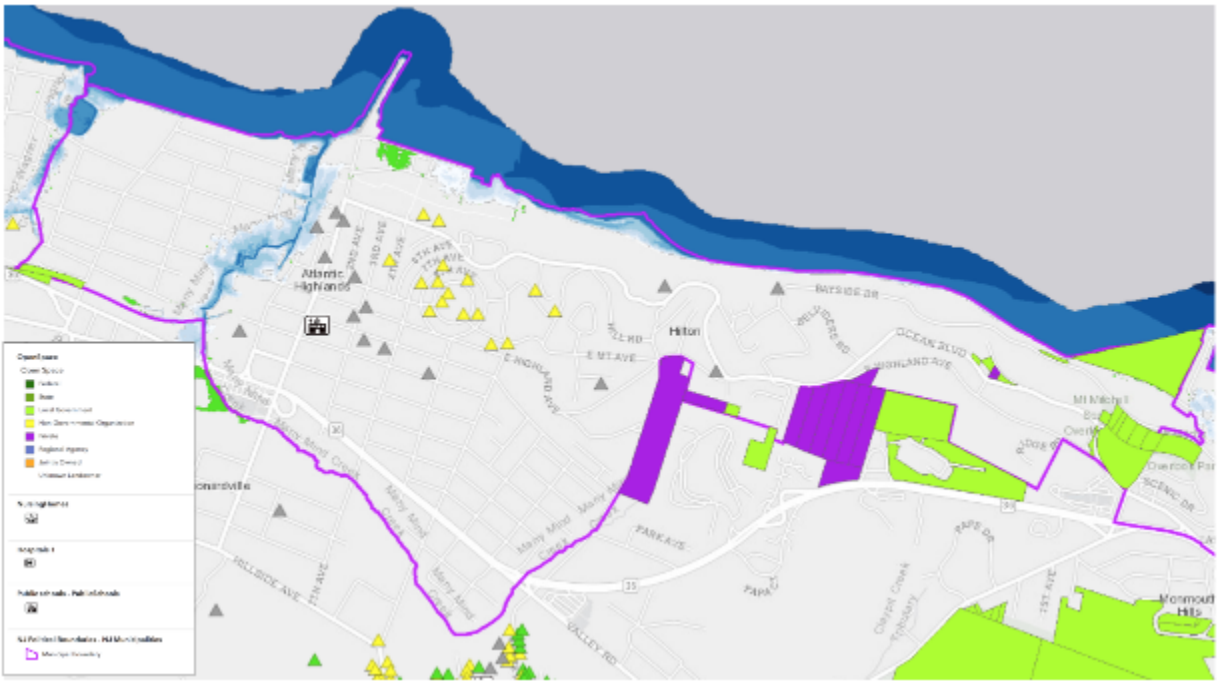

Figure 4. Atlantic Highlands' social infrastructure under 5-feet TWL (2070, Annual Flood).

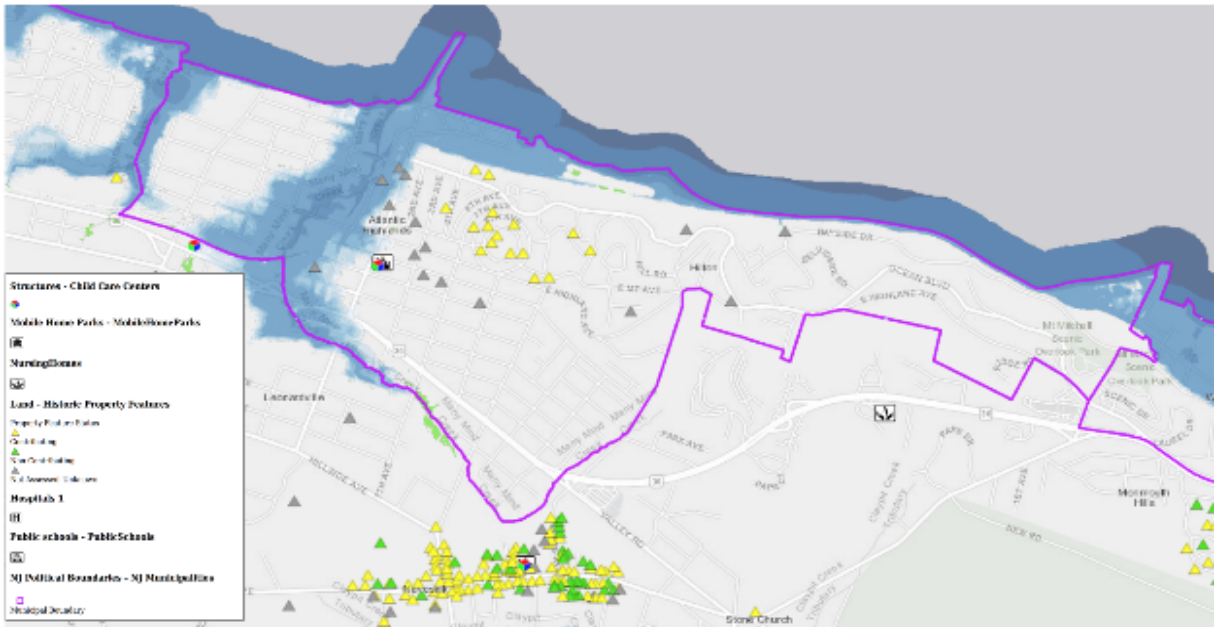

Figure 5. Atlantic Highlands' social infrastructure under Hurricane Sandy conditions in 2100 (13-feet TWL).

2.3 Health

2.3.1 *Background Information*

The storm danger message document shows great understanding of potential adverse health risks during and after a flooding event. Guidelines were posted on preventing skin contact with debris as well as potential polluted water and soil; prevention of inhaling mold from housing. A detailed self-assessment on mold in housing is also provided on the Atlantic Highlands Office of Emergency Management webpage.

2.3.2 *Risk Assessment*

Overall health impacts of flooding include but are not limited to poor mental health, increased risk of waterborne and mosquito-borne disease, mold, and injury. Routes of exposure include dermal, oral, and inhalation. Potential hazardous sources might include debris, exposed soil, contaminated drinking water or tap water, and air pollution that contains heavy metal, E. coli, etc. Elderly children are the vulnerable populations.

In 2050, 4-feet TWL is predicted. Business along Many Mind Creek and R-1 residential housing would be impacted the most. Business owners might be exposed to potential contaminated soil and debris when cleaning up its environment. While R-1 residential housing that has carpets has higher risk of mold in their housing. The TWL of 5-feet in 2070 will exacerbate the health risks in 2050. Additionally, the elevated and expanded flooded area will also increase pockets of stagnant water that may become mosquito breeding hotspots. This may encourage the spread of water-borne and mosquito-borne disease. By 2100, a TWL of 9-feet is estimated. Public sewer system will be flooded under this elevation, increasing the risk of drinking water contamination within the municipality and downstream users. Furthermore, an elementary school and day care center will be inundated under this elevation. Children, a vulnerable population, will have increased risk of exposure to potential contaminated soil or debris in their playgrounds.

3. PHYSICAL VULNERABILITIES

3.1 Critical Infrastructure

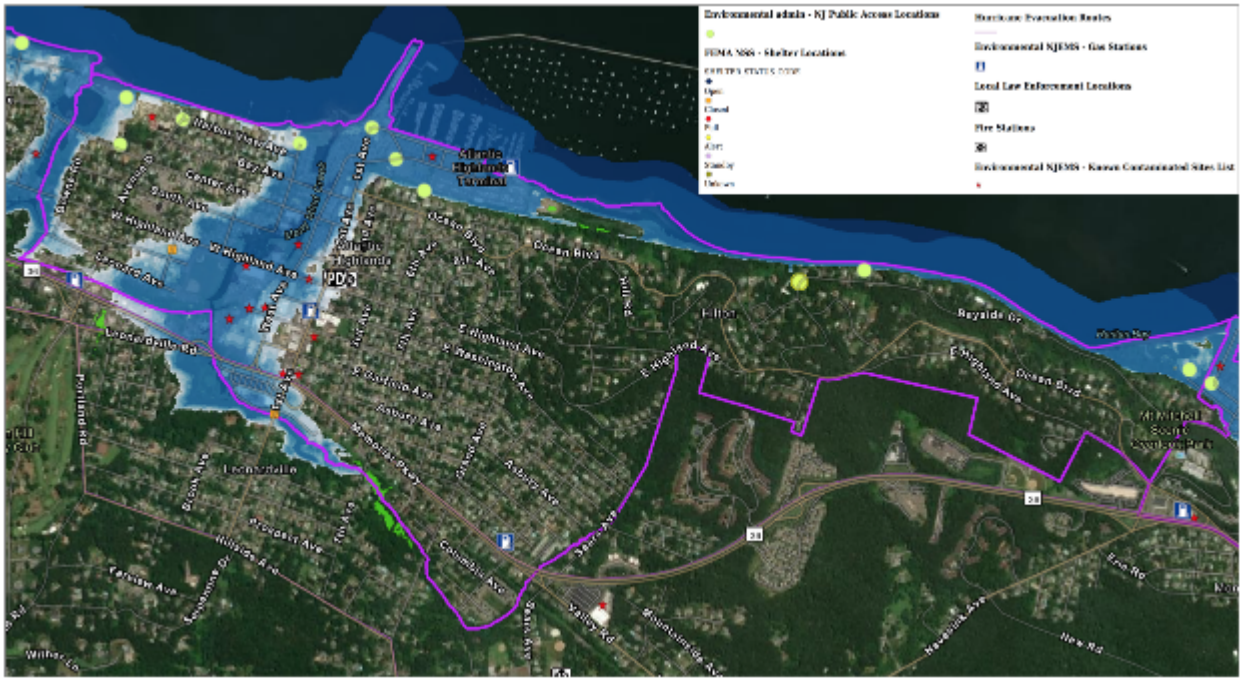

Figure 6. Critical infrastructure under 5-feet TWL (2070, Annual Flood).

3.1.1 *Background Information*

Critical infrastructure for the purposes of this analysis consists of assets that are crucial to the day-to-day functioning of the municipality as well as during extreme weather events. The Borough of Atlantic Highlands has expressed concern for the impact of climate change on nine critical infrastructure assets in the municipality's 2016 Coastal Vulnerability Assessment. These include: the Dredge Pit used for Municipal Harbor spoils (this Confined Disposal Facility is located to the east of the Marina and is sandwiched between Ocean Boulevard and Sandy Hook Bay), the drinking water treatment facility and recycling center, NJ Natural Gas Treatment Facility, the Public Works Yard, the Sewer Transfer Station (these five assets are located at W Lincoln Avenue), Many Minds Creek culvert (under State Highway 36 where Many Mind Creek runs under the highway), the Seastreak Ferry Terminal (2 First Avenue), the Sewer Main (along Henry Hudson trail), and the U.S. Post Office (25 Railroad Avenue).

3.1.2 *Risk Assessment*

a. *Asset Identification*

The critical infrastructure in Atlantic Highlands is concentrated along the waterfront and beyond the southern end of the commercial district. Specifically regarding the latter area, W Lincoln Avenue contains many of the core public works facilities for the Borough. The public works facilities are approximately 2,300-feet from the coastline, but are only 350-feet from Many Minds Creek which runs to the west of the facility.

In addition to the assets identified in the 2016 Coastal Vulnerability Assessment, several assets were also identified through NJ Flood Mapper (Figure 6 above). These additional elements

include: gas stations, hurricane evacuation routes, evacuation shelters, law enforcement facilities, fire stations and tidal water public access points.

b. *Analysis*

Generally, critical infrastructure for Atlantic Highlands starts to be impacted at 5-feet TWL with minor flooding (less than 1 foot) which could be seen as early as 2070 during an annual flooding event. With 10-feet TWL, the critical infrastructure assets start to see 3-4 feet of flooding along the coast and at W Lincoln Avenue. Based on this analysis, this level of flooding would be expected under Hurricane Sandy conditions if they occurred in the year 2050.

Focusing in on the critical infrastructure assets listed in 2016, our team's findings support the 2016 conclusions. The two "hubs" of critical infrastructure (those assets along the coast and those located at W Lincoln Avenue) are impacted more than other areas of Atlantic Highlands due to their proximity to the shore and Many Minds Creek which is subject to frequent flooding.

Of note are the following additional findings. First, at 4-feet TWL, a gas station located adjacent to the Atlantic Highlands Municipal Harbor would be under 1-2 feet of water which could prove to be a safety and environmental hazard. Furthermore, at 7-feet TWL, about 0.25 miles of the hurricane evacuation route will be under 1-2 feet of water which would cut off the western side of Atlantic Highlands to the evacuation shelter farthest inland. The second evacuation shelter, located on Avenue C, will be impacted at 10 to 11-feet TWL. Five known contaminated sites would also be affected by the 7-feetTWL which could add to local contamination of water bodies. The Atlantic Highlands Recycling Center would also be impacted.

3.2 Economy

Economic vulnerability can be measured through two aspects, one is infrastructure and building damage, the other is business interruption[2.1]. Business interruption refers to the supply-chain reaction that "radiates outwards from the disaster site"[2.1]. In Atlantic Highlands, critical economic infrastructure and buildings include the harbor, shops situated at the commercial district and along the harbor. Due to analytical constraints, the team is not able to assess the actual vulnerability of business interruption. But the team will look at the vulnerability of major transportation assets as potential indicators of business interruption. This section will first look at the economy background of Atlantic Highlands, present influence of harbor within the economy. The infrastructure mentioned above will be assessed individually in the following sections of critical infrastructure and harbor.

3.3 Building Codes and Zoning

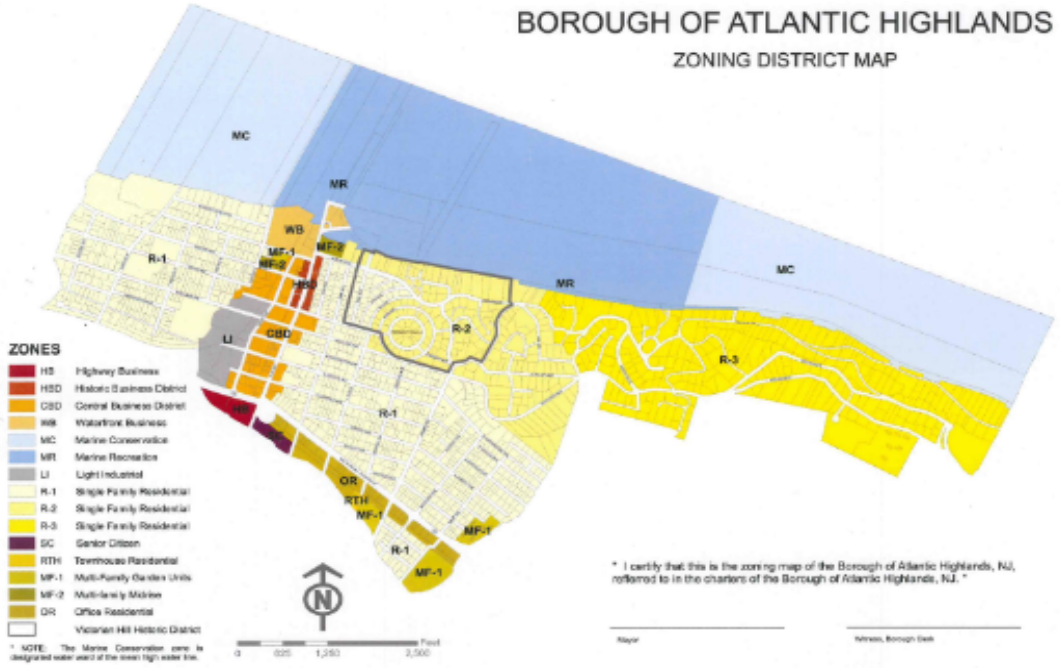

Figure 7. Atlantic Highlands zoning map.

In the 2070 TWL projections, Atlantic Highlands has some vulnerability to flooding along its two creeks. Along Wagner Creek, inundation risk is in the eastern R-1 zone, which consists of residential properties. Costs for potential losses are higher along the Many Mind Creek, where there are many businesses central to the local tourism economy, including the waterfront and historic central business district, as well as a light industrial area. Newer multi-family developments would also be impacted. Bayshore properties in R-2 and R-3 zones also have some flood risk.

The more significant risk for Atlantic Highlands is coastal storms. As pictured, Hurricane Sandy-like storm surge would cause extensive damage structures at the heart of the town, and force of flooding may threaten older buildings' ability to withstand inundation. According to FEMA Community Profiles, 75% of the borough's buildings were constructed before 1970 or after 2000, making them more susceptible to storm damage. In the storm surge scenario, there is additional flood vulnerability for the R-2 zone and extensive potential damage for eastern R-1 zone between the two creeks.

Though it was a recommended change in the 2016 Getting to Resilience report, Atlantic Highlands' building code does not reflect its flood and coastal erosion vulnerabilities. Its code is based on the New Jersey Universal Construction Code (UCC) from 2006, which focuses on standard building, plumbing, fire and electric practices for the state. Notably, the universal code does not have floodproofing standards. The borough does, however, have some building standards that are specific to its geographic challenges, as R-2 and R-3 zones require steep slope permitting for any new construction or structure alteration in areas containing or adjoining slump blocks. As previously indicated, flood-responsive building codes could include design, construction, and

landscaping standards, including outlining specifics for setbacks, retrofitting, and infrastructure protection.

Despite its shortcomings in flood-resilient construction, Atlantic Highlands has relatively high participation in the National Flood Insurance Program (NFIP). According to FEMA Community Profiles, the borough's NFIP penetration rate is 17.81%, which is slightly above the advisory penetration rate. It has seven total properties with repetitive losses or severe repetitive losses. However, it is unclear whether Atlantic Highlands' policies correspond with changes in FEMA flood maps, and whether there are ongoing awareness efforts for changes in flooding.

To better understand protective measures, it would be helpful to analyze more recent changes to growth and development management in the borough, including strategies in zoning, easements, acquisition, and relocation, that may be under consideration.

4. HARBOR VULNERABILITIES

4.1 *Background Information*

After Hurricane Sandy in 2012, FEMA gave the borough financial assistance to help rebuild the damaged waterfront. The harbor docks were destroyed in Sandy and public buildings on the shoreline were heavily damaged. The Harbor Commission convinced FEMA to make an exception to the 'replace to pre disaster conditions' and allowed the destroyed fixed docks to be replaced by a floating dock system with tall piles. The floating docks can withstand a Category 3 hurricane (2019 Master Plan).

4.2 *Risk Assessment*

a. *Asset Identification*

The Atlantic Highlands Municipal Harbor is the largest municipally owned and operated marina in New Jersey. The harbor also includes the Shore Casino, Shore Casino Banquet Hall, Seastreak Ferry Terminal, head and charter boat fleet, 12 personal watercraft dock slips, two restaurants, a catering business, senior center, active recreation park, and a fishing pier. It has 482 boat slips, 172 moorings, land storage for 140 boats on trailers, and a six-vehicle wide boat launch.

Figure 8. Photo of Atlantic Highlands Harbor.

Figure 9a. Current aerial view of Harbor.

Figure 9b. Harbor under 5-feet TWL (2070, Annual Flood).

Figure 9c. Harbor under Annual Flood conditions in 2100 (7-feet TWL).

b. *Analysis*

The harbor risks mentioned in the 2016 Municipal Assessment discuss the possible inundation of the facility, which would impact the edge of the parking lots near the harbor, as well as boat ramps and fixed docks, during high tide. Additionally, major inundation would occur during a Category 1 storm event. In such an event, the boats in the harbor would be destroyed and structures throughout the harbor that are not elevated could cause damage to nearby businesses. This assessment is consistent with the TWLs from 2070 Annual Flood conditions, in which water levels rise about 5-feet by 2070. According to the 2016 assessment, inundation of nearby land could also make traveling to the harbor difficult. All other flooding scenarios show the harbor being completely submerged. While floating docks do help with hazard mitigation, there are still many fixed docks and structures that would be greatly impacted in events below a Category 3 hurricane. For example, Figure 9c shows a TWL of 7-feet with moderate emissions in the year 2100. Therefore, in a likely sea level rise scenario, the harbor will be underwater within the next 80 years.

5. NATURAL RESOURCES VULNERABILITIES

5.1 *Background Information*

Natural resources are at the heart of Atlantic Highlands, supporting the community and local economy. These natural resources, such as dunes and wetlands, protect the community in the face of natural hazards, such as storm surge, by providing a buffer to reduce impact. Although these features are part of the natural systems of the Bayshore area, they are also threatened by repeated natural hazards, including coastal storms. Drowning of wetlands and oversaturation of forest soils can damage these resources and reduce their ability to provide protection. By building upon its natural resources to strengthen ecosystem services in the area, Atlantic Highlands can protect its physical and social infrastructure using existing assets. To inform this effort, this section of the report details key natural assets in Atlantic Highlands and analyzes their risks with respect to rising sea levels and increased precipitation intensity in various storm scenarios.

5.2 *Risk Assessment*

a. *Asset Identification*

Natural assets in Atlantic Highlands include both land and waterways, as well as some at their intersection, such as wetlands. The shoreline stretches 2.5 miles along the bay, providing beauty and supporting recreation and economic activity. The Avenue A paper street extension to the bay, along the Many Mind Creek and bounded by private property to the east, is one of two stretches of public beach in Atlantic Highlands and supports light recreational activities. Looking out at New York City, this stretch of beach is an aesthetic asset to residents and visitors alike. This beach also has a small dune system that protects the borough's central business district directly behind it.

On the other side of the marina to the east of the beach, the Henry Hudson bike path runs along the bay. It is protected by riprap, or rock piling that functions as a breakwater, along the bay slope. The east end of the Henry Hudson path in Atlantic Highlands ends at Popamora Point Park, which contains the second segment of public beach in the municipal boundary. This park serves as a buffer zone for the eastern side of town and the neighboring Highlands. Additionally, the park provides a rare quiet New Jersey beach for residents and visitors to enjoy. Several other parks in Atlantic Highlands, including Center Avenue Park, South Avenue Park, Fireman's Field Park, and

Many Mind Avenue Park, provide outdoor spaces for community recreation. Some of these spaces also serve as open spaces without many structures in which stormwater can safely overflow.

The creeks running through the municipality, Many Mind Creek and Wagner Creek, serve as stormwater collection systems for Atlantic Highlands and its neighbors in Middletown. Although these creeks currently overflow when rainfall storms meet high tides, they have the potential to protect the community and businesses in the area, along with their surrounding wetlands and retention ponds.

The Lenape Woods Nature Preserve, a 51-acre plot of woodlands and wetlands, has 3 acres within Atlantic Highlands and serves as the headwater for the Many Mind Creek. As such, it protects water quality in the creek. This nature preserve also provides access to a uniquely high point along the coast, Mount Mitchell, offering residents and visitors the ability to immerse themselves in nature by hiking, walking, birdwatching, and overlooking the bay.

b. *Analysis*

With future sea levels and precipitation intensities in mind, the assets identified remain subjected to various levels of risk depending on their location and the scenario. In 2016, with only 1.3-feet of sea level rise analyzed, the risks for each of the natural assets identified ranged from "non-applicable" to "low" under simple high tide conditions. Under Category 1 hurricane conditions, both creeks and the Henry Hudson Trail were assessed to have high vulnerability with high consequences.

Looking at the shortest time frame included in this 2020 assessment, by the year 2050 with sea level rise and an annual flood, 4-feet TWL is predicted. At that level, five identified assets are under water. Between 0.5-feet and 4-feet of water cover the Avenue A paper street extension and both creek outflows, including their surrounding wetlands. For the beach-dune system, flooding and associated wave energy can lead to erosion, potentially worsening outcomes of future events.

Under 4-feet of TWL, approximately 1500-feet of the Henry Hudson Trail is subject to slight flooding, between 0.5-feet and 1 foot. This could higher maintenance costs, and likely decline use of the trail. Additionally, in this scenario, 3-feet of water inundates the sandy beach at Popamora Point Park, with another 0.5 feet to 1 foot of water covering nearly 400-feet of the inland park. South Avenue Park, located directly behind the Many Mind Creek, floods with up to 3-feet of water in this scenario. While this level of flooding will temporarily render the park unusable for recreation, it will protect the surrounding neighborhood from the worst flooding impacts. It is also worth noting that in this scenario in the year 2050, precipitation intensity will likely increase, meaning that the slump blocks may be at greater risk for landslides.

Figure 10a. Many Mind and Wagner Creeks overflow at 5-feet TWL (2070, Annual Flood).

Figure 10b. Popamora Point Park at 5-feet TWL (2070, Annual Flood).

By the year 2070, the TWL with an Annual Flood is estimated at 5-feet. With this slightly higher water level, the portion of the Avenue A paper street extension to the bay in front of the dune system is inundated with up to 5-feet of water, and the area immediately behind the dunes spills over with 0.5 feet to 1 foot of water. Dune protection is key to keeping flooding within the beach area. At this water level, close to 5000-feet of the Henry Hudson trail are subject to 0.5 feet to 1 foot flooding. Similar to Avenue A, the Popamora Point Park beach in this scenario experiences up to 5-feet of water, and the portion of park behind the beach floods with 0.5-feet to 2-feet of water (Figure 10c). The Many Mind Creek in this scenario spills over up to 4-feet into the neighborhood behind it, including into the South Avenue Park (Figure 10a). The Wagner Creek on the other side of town also spills up to 4-feet into the surrounding areas (Figure 10b), which are largely buffer zones. These scenarios highlight the strength of natural barriers, such as dunes and buffer zones, while underscoring the level of stress they will likely experience in the future.

The maps included in Appendix A include flooding scenarios for 2100, as well as for 2050 and 2070. Each of those scenarios illustrates greater risks for the natural assets than those detailed here. When considering this, the risks can appear overwhelming. However, an advantage of natural resources is that they offer protective value to the humans and critical infrastructure around them, even if they themselves are at risk of the same hazards. Dunes, for example, offer wave energy reduction, thereby helping to stabilize the coast and reduce erosion. Wetlands adjacent to the creeks help prevent excessive flooding in surrounding areas, and with restoration and enhancement, they could perform even better. The key consideration for natural asset vulnerability is not just what is at risk, but what protective capabilities these assets have to offer.

6. EMERGENCY RESPONSE COMMUNICATION SYSTEM

6.1 *Background Information*

Good communication can help to effectively allocate resources as well as save lives. According to the Monmouth County Sheriff's Office Communications Center, 27,000 of 170,000 calls were non-emergency in nature. This limits emergency resources to assist life threatening events but also costs tax dollars. If residents are given proper information and trained to know basic responses when flooding occurs, it is less likely they will be in serious danger in the event of a flood. This section assesses the current flood warning system, evacuation plans, and communication strategies to determine potential improvements to the emergency response communication system.

6.2 *Risk Assessment*

a. *Asset Identification*

Residents and business owners in flood evacuation zones are the primary audience for communication in a disaster or emergency. Evacuation zones show the potential storm surge areas. In Atlantic Highlands, evacuation zone A (color red) coincides with flooding inundated areas of Many Mind Creek, Wagner Creek and the marina in 5-feet TWL scenario (2070, Annual Flood) and the 9-feet TWL scenario (2100, 100-year Flood). In the 2070 5-feet TWL scenario, floods a few contaminated sites. Evacuation zone A encompasses the 2100 9-feet TWL scenario, which overlays the commercial district and governmental facilities. The flooded area includes 12 known contaminated sites, one publicly-owned wastewater pumping station, one elementary school, one

fire department/EMS station, multiple historic properties, and residential housing along the harbor with over 22.8% of the senior population.

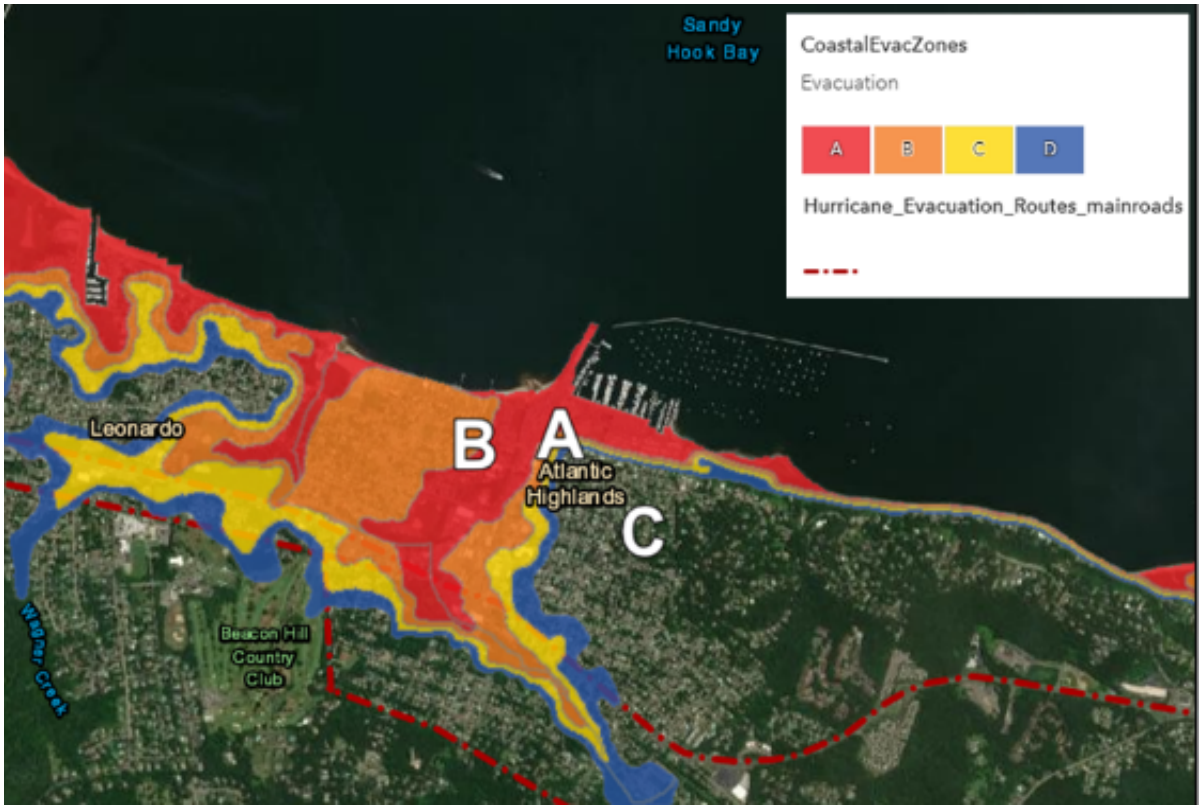

Figure 11. Coastal Evacuation Zones in Atlantic Highlands (Source: Monmouth County Sheriff's Office).

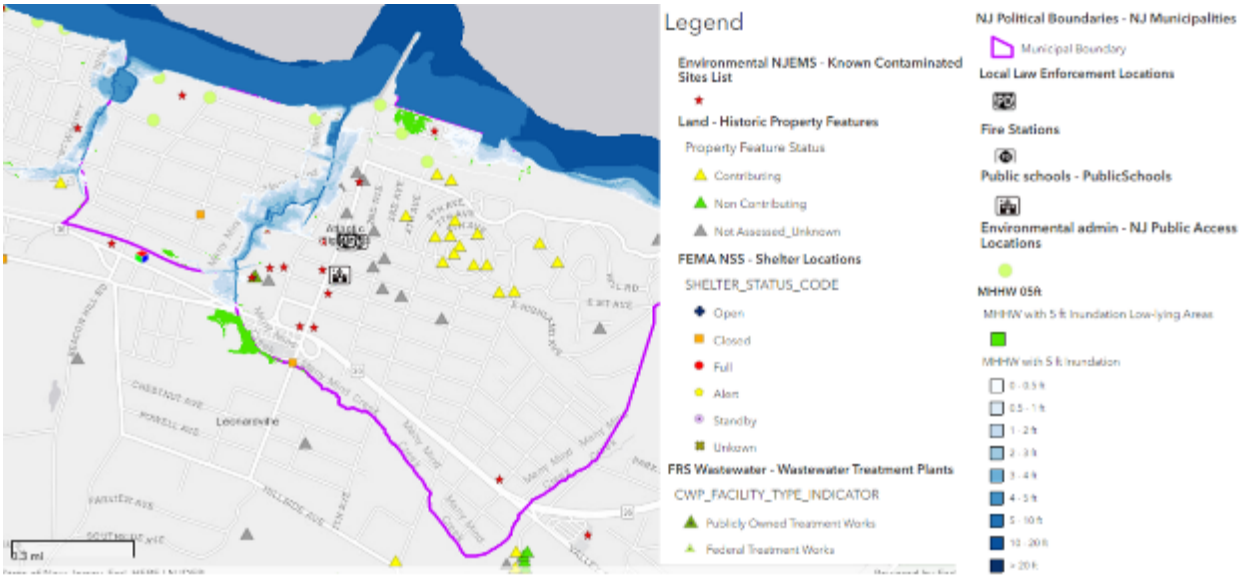

Figure 12. Critical Infrastructure and Contaminated Sites within Evacuation Zones 5-feet TWL (2070, Annual Flood) (NJFloodmapper).

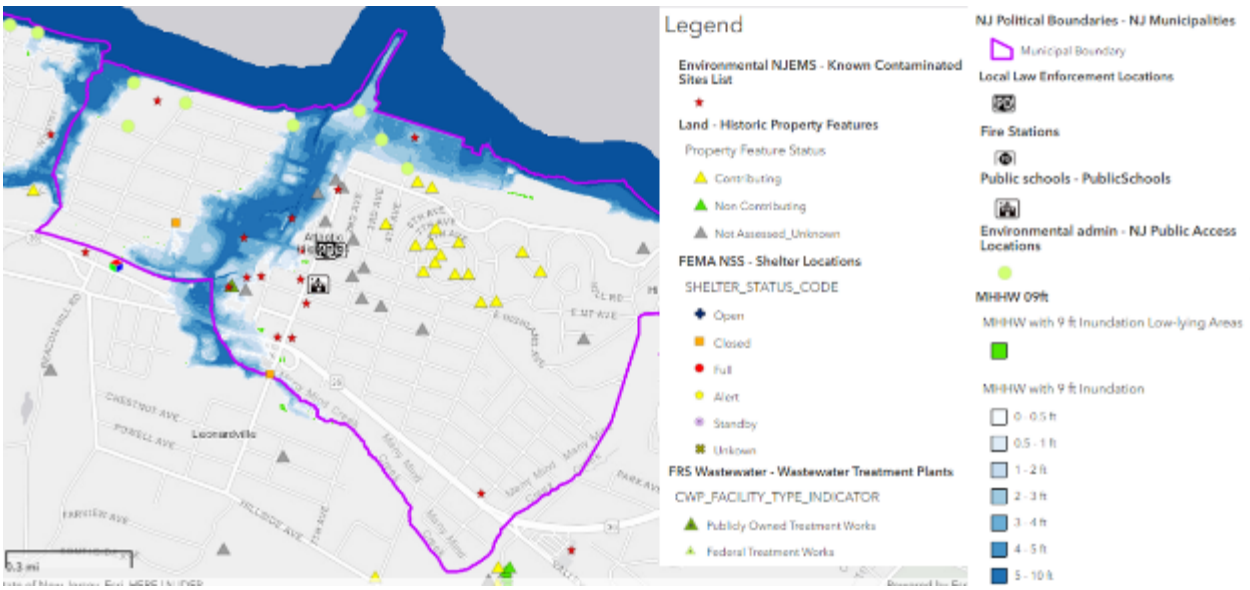

Figure 13. Critical Infrastructure and Contaminated Sites within Evacuation Zones 9-feet TWL (2100, Annual Flood) (NJFloodmapper).

b. *Analysis*

Atlantic Highlands website is well-organized with crucial and detailed information on its webpage[3]. Currently, communication is mainly done by putting up flyers, posters, electronic documents, social media, and holding community meetings. However, the older population might not go through the municipal official webpage frequently. Also, if there is disruption in electricity or internet services, the public will be unable to receive information online. Therefore, it is crucial to develop multiple methods to convey information to the public as well as do it in a timely manner.

Atlantic Highlands Office of Emergency Management has clear and detailed instruction on preparing households for hazards, especially hurricanes. The Atlantic Highlands Office of Emergency Management webpage includes pre-disaster preparation for hurricanes, post-disaster awareness and tips, evacuation zone-check, health-related awareness on mold and mosquitoes, emergency contact information, and hazard mitigation plan archives. Moreover, the borough provides assistance on evacuation for those with special needs. Though the evacuation plan suggested by Monmouth County Sheriff's Office was not as detailed as those in Atlantic Highlands, it also stressed the importance of having residents and business owners prepare well in advance in the case of a hurricane.

Although instructions and itineraries are well articulated in the documents, it is unclear if residents are prepared for different hazard scenarios. Thus, it is crucial to develop public outreach and communication strategies to better convey information to residents and implement mitigation efforts through awareness.

[3] The 2013 Monmouth County Hazard Mitigation Plan does not include Atlantic Highlands evacuation or outreach strategies.

6.3 *Suggestions*

a. Education

Schools should implement lessons to address what to do in flooding emergencies specific to Atlantic Highlands response to Atlantic Highlands and how they can give and receive information. These sessions should be open to the public as well as provide recorded or summarized documents for those who were unable to make it.

b. Communication Methods

Phone calls and emails are effective ways to deliver information to older populations. These can act as alternative communication methods in Atlantic Highland

Appendix A. Maps for Nine Flooding Scenarios Analyzed

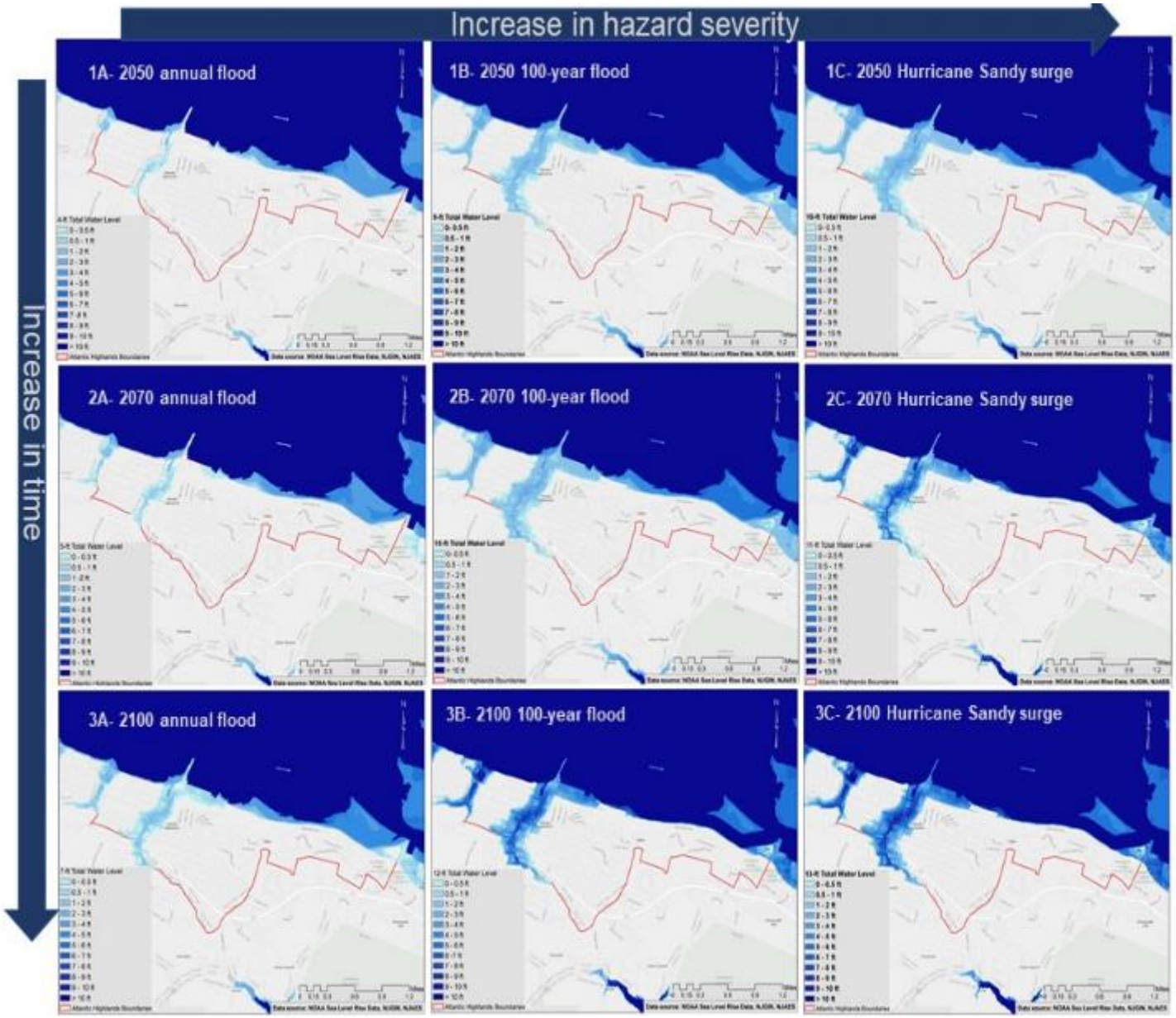

Figure A1. Matrix of flooding scenarios evaluated. The scenarios pictured here follow the flooding events detailed in Table 1. In short, scenarios chosen represent sea level rise projections that have a 17% chance of being exceeded at the years 2050, 2070, and 2100. Flooding events chosen represent typical floods (Annual Floods, A scenarios), relatively rarer floods (100-year, B scenarios), and severe historical floods (based on Hurricane Sandy, C scenarios). All scenarios assume moderate emissions, or a scenario in which global greenhouse gas emissions begin to decline around the middle of the twenty-first century. Data for the maps were generated using ArcGIS ArcMap software with NOAA Sea Level Rise Depth data, available here. All flooding scenarios were first understood using NJfloodmapper TWL tools and were subsequently recreated based on the TWLs that each scenario resulted in, as shown in NJfloodmapper's online software.

Appendix B. Maps for Demographics and Housing

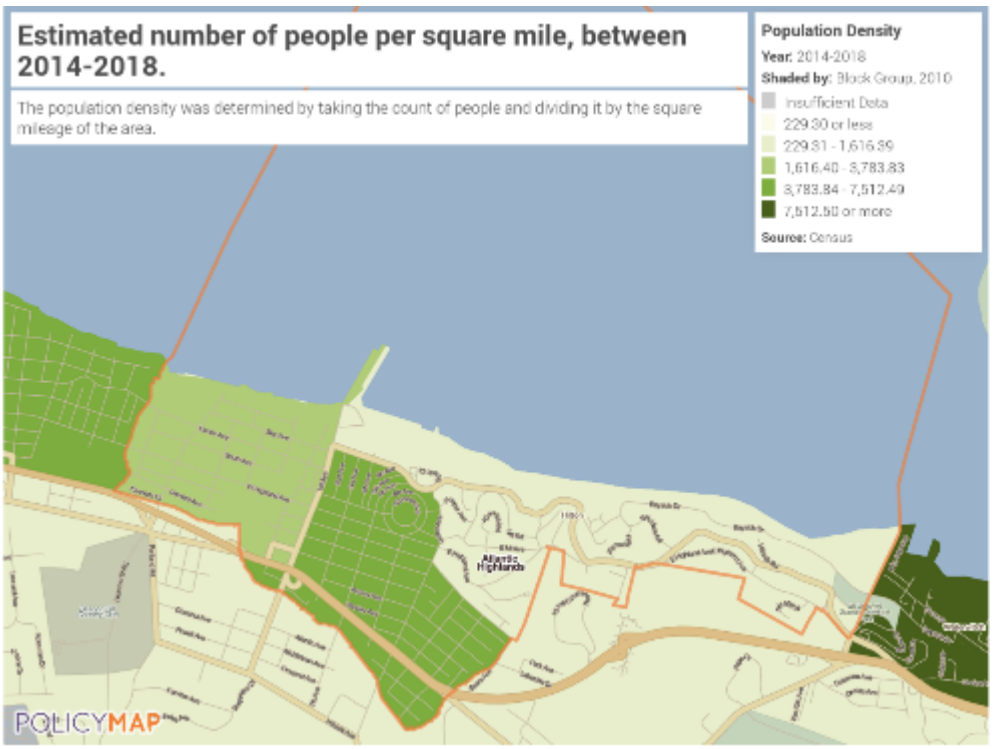

Figure B1. Estimated number of people per square mile (2014-2018). Source: Policy Map

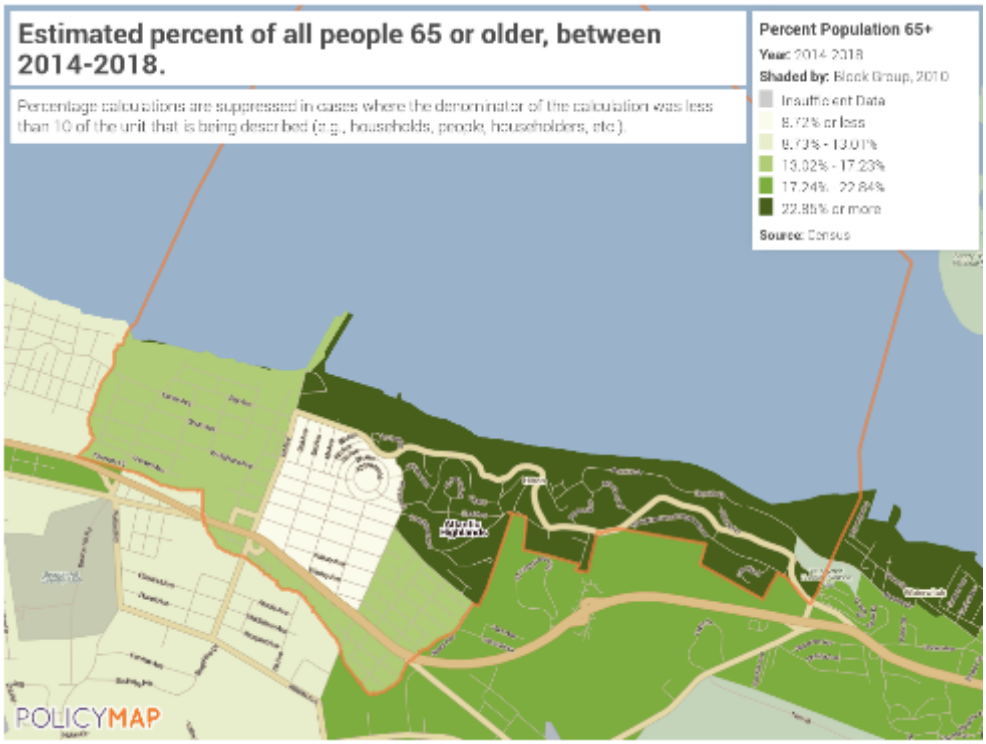

Figure B2. Estimated percent of all people 65 or older (2014-2018). Source: Policy Map

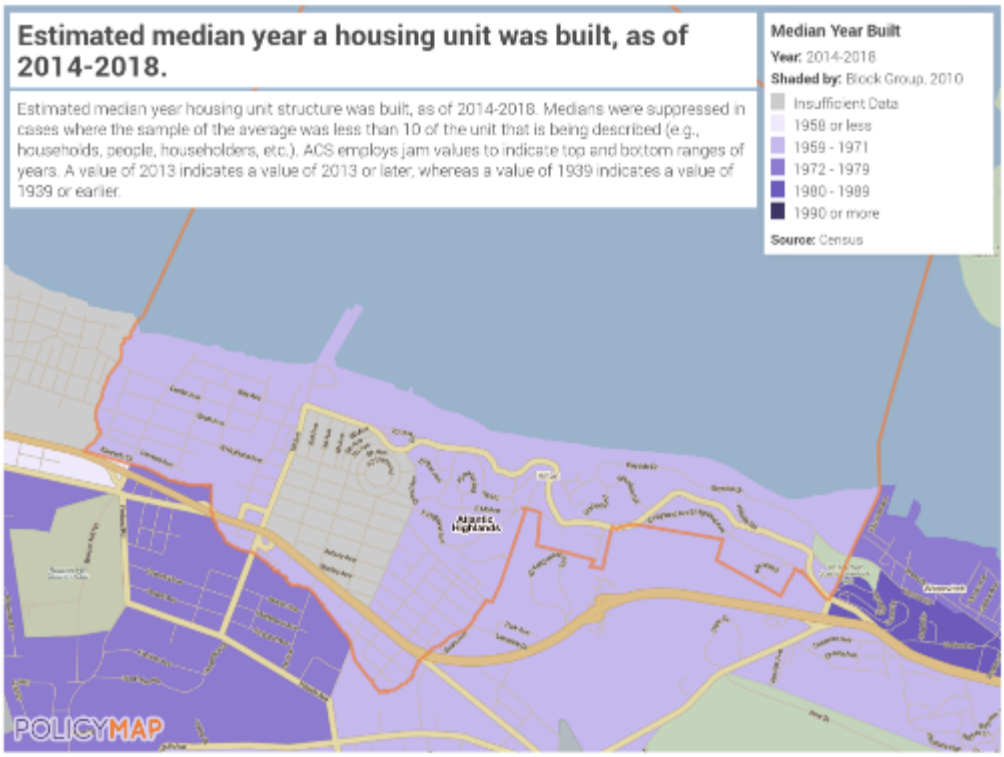

Figure B3. Estimated median year a housing unit was built (2014-2018). Source: Policy Map

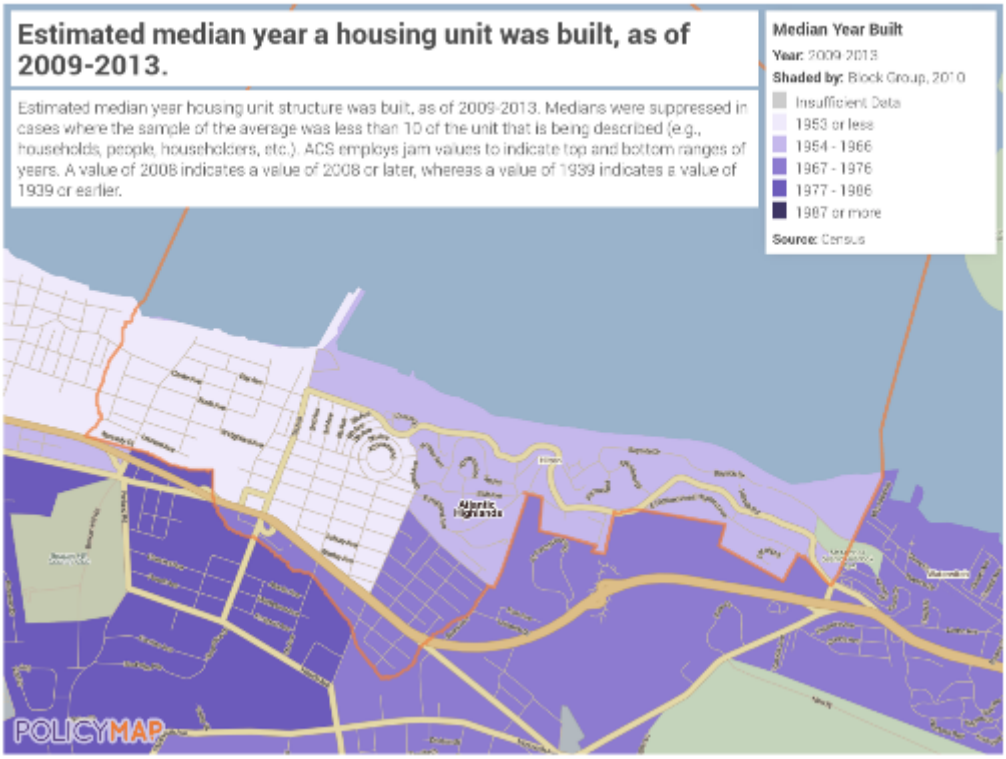

Figure B4. Estimated median year a housing unit was built (2009-2013). Source: Policy Map

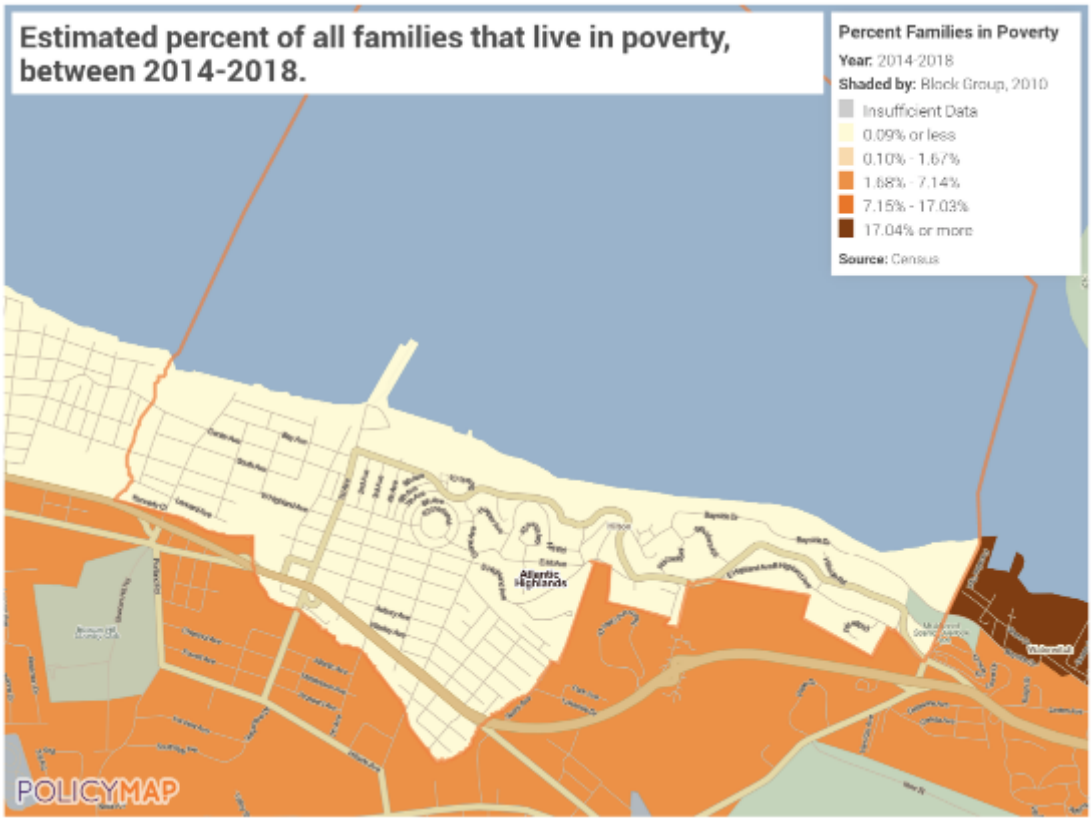

Figure B5. Estimated percent of all families that live in poverty (2014-2018). Source: Policy Map

Appendix C. Summary of assets and vulnerabilities under 4-feet (2050, Annual Flood) and 10-feet (2050, Sandy) flooding scenarios.

Table C1. **Detailed assets & corresponding vulnerabilities to two flooding scenarios.**

Asset name	Function (as defined in 2016 Coastal Vulnerabilities Assessment)	Asset Category	Impacted by Scenario 1A (4-ft) Y/N	Impacted by Scenario 1C (10-ft) Y/N
Avenue A Paper Street Extension	Small local beach bounded by private property to the east used for fishing and passive recreation.	Natural resources	Y	Y
Bayshore Plaza	Retail shopping center	Social infrastructure	N	Y
Bayside Neighborhood	A residential neighborhood located along Bayside Drive and along the Henry Hudson Trail.	Housing types & population centers	N	N
Bayview Neighborhood	A residential neighborhood located along Bayview Avenue on the hills above the Henry Hudson Trail.	Housing types & population centers	N	N
McConnell Tract (formerly Blackfoot Mobile Marine Services)	A 7 acre plot of land likely to develop with single family homes & open space	Housing types & population centers / Natural Infrastructure	N	Y
Bowne Avenue Neighborhood	A residential neighborhood located along Bowne Avenue and next to Wagner Creek	Housing types & population centers	N	Y

Center Avenue Park	An active recreation park located along Center Avenue, which contains a soccer field.	Social infrastructure / Natural Infrastructure	N	N
Central Business District	The Central Business District is the downtown area of Atlantic Highlands and includes several blocks along 1st Avenue from Bayview Avenue to State Highway 36.	Social infrastructure	N	Y
Commercial & Industrial District	The Commercial & Industrial District is located along several blocks of West Avenue / Hennessey Boulevard from Bayview Avenue to State Highway 36.	Social infrastructure	Y	Y
Detention Pond	A stormwater retention facility for the west side of the borough at Many Mind Creek. The facility is currently not functional as it is filled in with silt.	Natural resources	Y	Y
Dredge Pit	The Municipal Harbor is dredged on a 5-8 year cycle. The dredge pit contains the dredge spoils from the harbor.	Critical infrastructure	Y	Y

Drinking water treatment facility & recycling center	A municipally owned drinking water treatment facility for the borough.	Critical infrastructure	N	Y
Fireman's Memorial Field	Fireman's Memorial Field is an active recreation park used for community-wide organized sports.	Social Infrastructure	N	Y
Fireman's field building	A community rental hall. Used as polling for Districts 2 and 3 during elections	Social infrastructure	N	Y
Harbor View Neighborhood	A residential neighborhood located along Harbor View Drive and Sandy Hook Bay.	Housing Types and Population Centers	Y	Y
Henry Hudson Trail	The Henry Hudson Trail is a 10 foot wide former rail track converted to recreation trails that runs 24 miles in length with a mixture of paved and primitive areas. Through Atlantic Highlands 1.2 miles of trail run along Sandy Hook Bay and the Municipal Harbor.	Social infrastructure and Natural resource	Y	Y
Jaspan Brothers Hardware	Family-owned and operated hardware store.	Social Infrastructure	N	N

Lenape Woods Nature Preserve	3 acres of a 51-acre nature preserve at the headwaters of Many Mind Creek	Natural Resources	N	N
Leonard Avenue Neighborhood	A residential neighborhood located along the Southeast end of Leonard Avenue.	Housing Types and Population Centers	N	Y
Many Mind Ave Park	A park towards the south end of Atlantic Highlands adjacent to Many Mind Creek	Social infrastructure and Natural resources	N	N
Many Mind Creek	Many Mind Creek is a natural waterway which receives rain water that drains from a large land area of Atlantic Highlands and parts of neighboring Middletown.	Natural Resources and Critical Infrastructure	Y	Y
Many Mind Creek Culvert	A culvert located under State Highway 36 where Many Mind Creek runs under the state highway.	Critical Infrastructure	Y	Y
Municipal Harbor	The municipal harbor is the largest harbor in the state of New Jersey.	Harbor	Y	Y
NJ Natural Gas (NJNG) Treatment Facility and Offices	The offices and facility are used as part of a coal tar remediation project. The facility is treating	Critical Infrastructure	N	Y

	contaminated soils from Many Mind Creek.			
Ocean Boulevard Neighborhood	A residential neighborhood located along Ocean Boulevard on the hills above the Henry Hudson Trail.	Housing Types and Population Centers	N	Y
Popamora Point Park	Popamora Point Park is a Monmouth County Park which contains open park area, wetlands, and beaches.	Natural Resources and Social Infrastructure	Y	Y
Public Works Yard	The public works yard includes offices, equipment, a drinking water well (No. 7), salt storage shed, and street sweeping shed.	Critical Infrastructure	Y	Y
Sandy Hook Bay Catamaran Club	Gazebo, clubhouse, lined with catamarans in summer.	Social Infrastructure	Y	Y
Seastreak Ferry Terminal	Seastreak Ferry is a high speed passenger service that runs a daily commuter service between Atlantic Highlands and NYC.	Critical Infrastructure	Y	Y

Sewer Main (Along Henry Hudson Trail)	The Monmouth County Bayshore Outfall Authority (MCBOA) serves the Bayshore area of the county and provides collective means of effluent disposal for 13 municipalities carried over 14 miles of pipeline.	Critical Infrastructure	Y	Y
Sewer Transfer Station	A municipally-owned and operated sewer transfer station.	Critical Infrastructure	N	Y
South Avenue Park	A small passive recreation park with a small playground area.	Natural Resources and Social Infrastructure	Y	Y
St. Paul Baptist Church	A Baptist Church.	Social Infrastructure	N	Y
U.S. Post Office	Atlantic Highlands branch of the U.S. Post Office.	Critical Infrastructure	N	N
Wagner Creek	Wagner Creek is a natural waterway which receives stormwater that drains from a small land area on the western boundaries of Atlantic Highlands and from a large area of Middletown.	Natural Resources	N	Y

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