

Under Water

How Sea Level Rise Threatens the Tri-State Region



Time	Destination	Train Status
5:20	Suffern	1167
5:23	Montclair Univer	267 Boarding
5:27	Waldwick	1269 Boarding
5:28	Lake Hopatcong	807 Boarding
5:30	Spring Valley	1629 Pascadi
5:31	Summit	337 Boarding
5:35	Spring Valley	1631 Pascadi
5:38	Gladstone	433 Morris
5:41	Port Jervis	57 Throu
5:43	Bay Head	2311 North

PLEASE WATCH YOUR STEP.
"EWR" Indicates Train Service to Newark



Acknowledgments

This paper belongs to a series of reports that lay the groundwork for the policy recommendations of the fourth regional plan, *A Region Transformed*. Subsequent papers due in early 2017 will address housing and transportation issues. The full plan will appear next fall.



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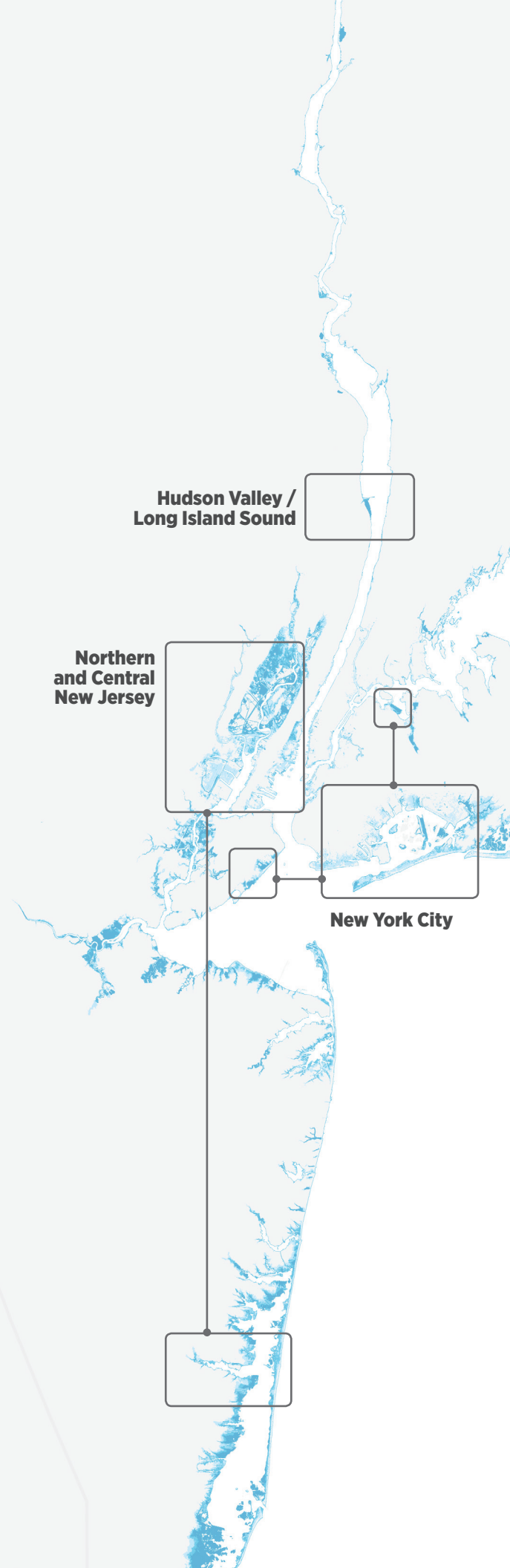
Summary

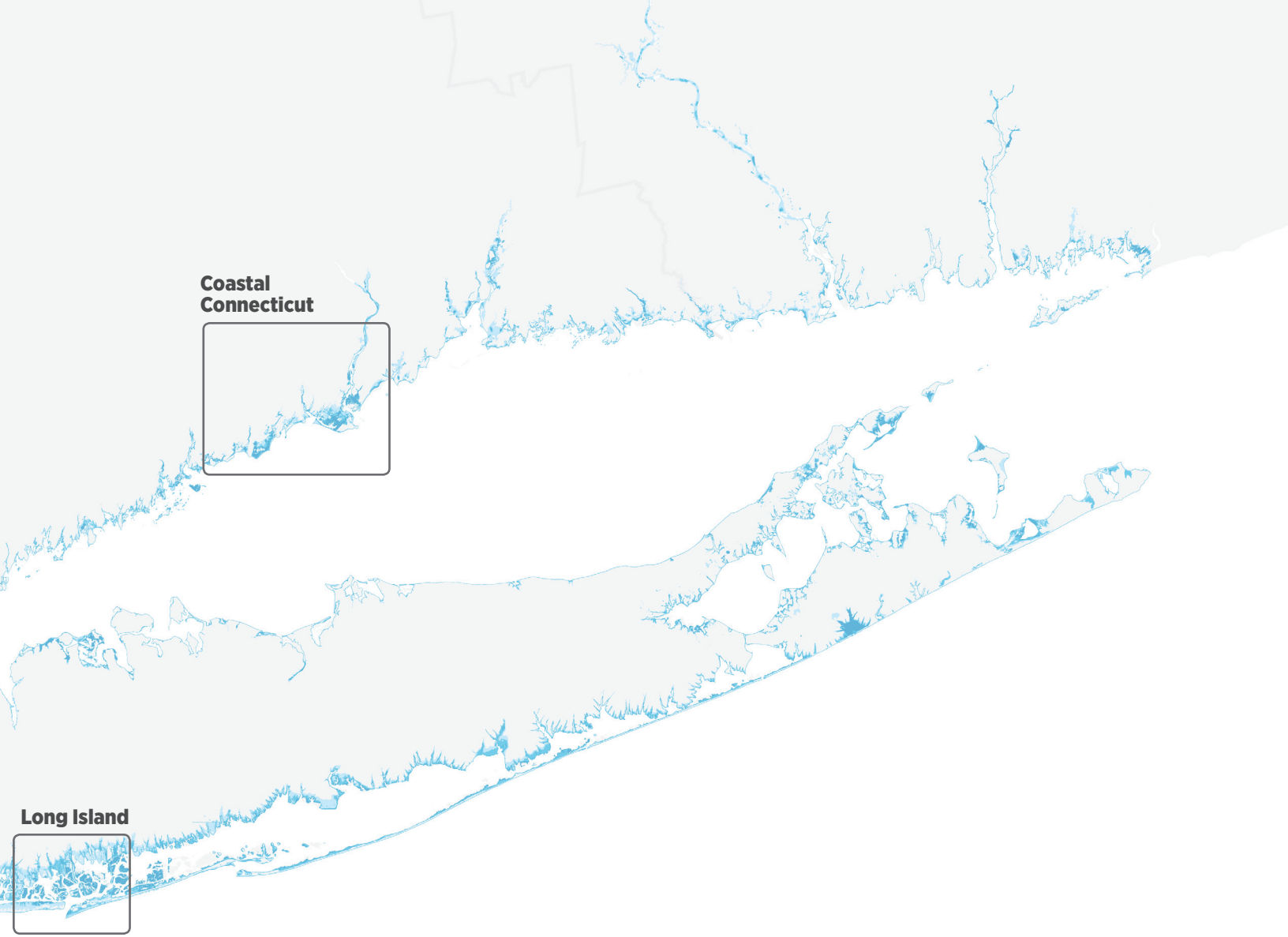
Coastal regions around the world are struggling to adjust to the gradual but relentless encroachment of ocean waters caused by climate change. The New York metropolitan area, with 23 million residents and some 3,700 miles of tidal coastline, faces a severe threat from sea level rise, yet relatively little has been done to address the inevitable permanent inundation of buildings, infrastructure and communities.

Permanent flooding from sea level rise is different than the intermittent flooding from storm surge or precipitation. Intermittent flooding recedes once a storm passes while sea level rise flooding is permanent and can be expected to encroach further inland over time. Sea level rise not only permanently alters the coast line. It also widens the area vulnerable to storm surge.

This report identifies the places in the New York, New Jersey and Connecticut metropolitan area that are most at risk of being permanently flooded, and describes the effects of 1, 3 and 6 feet of sea-level rise on neighborhoods, employment centers and infrastructure.¹ Taking into account the latest scientific findings on sea level rise and climate change, the study finds that many of the major resilience policies, plans and projects under development today fall short of adequately addressing the long term, existential threat of permanent flooding from sea level rise.

¹ One, three and six feet of sea level rise in this report refer to measurements of sea levels above a 1991-2009 baseline and the probable timing is based on RPA's interpretations of research carried out by the New York Panel on Climate Change (NPCC), New York State and the New Jersey Climate Adaptation Alliance, which are based on Kopp et al (2014).





The region could see at least **one foot** of sea level rise by 2050, possibly as soon as the 2030s. **Three feet** could be realized by the end of the century, possibly as soon as the 2080s. **Six feet** of sea level rise is possible early in the next century.

Key Findings

- ▶ Sea level rise has begun to permanently affect communities and critical infrastructure in the New York-New Jersey-Connecticut region, requiring tough choices for what we can and must protect, and where we will need to begin the process of returning the land to nature.
- ▶ The pace at which seas are rising is accelerating. Sea levels could rise around one foot as soon as the 2030s. Three feet could occur as early as the 2080s. Six feet of sea level rise could come early in the next century.
- ▶ The communities and infrastructure with the most at risk are those located in the region's bay areas (including the Great South Bay and South Oyster Bay on Long Island, Flushing Bay and Jamaica Bay in New York City, and Raritan Bay and Barnegat Bay in New Jersey), and the region's tidal estuaries (including the Hackensack Meadowlands and the Navesink and Shrewsbury Rivers).
- ▶ Large portions of the New Jersey Meadowlands - home to over 30,000 at-risk residents, Teterboro Airport, the Secaucus rail station, Giants Stadium, the American Dream entertainment project, thousands of industrial jobs and several critical roads and rail lines - could be significantly affected at three feet and largely inundated at six feet. Because of its size and complex ecology, comprehensive planning for the entire Meadowlands will be needed to determine where the water can be kept out and how to adapt to permanent flooding where it cannot.
- ▶ The communities of the Rockaways, Jamaica Bay, Coney Island and the East Shore of Staten Island are amongst the most threatened in New York City. With 3 feet of sea level rise, the communities of Broad Channel, Arverne, Edgemere and Howard Beach are particularly affected by flooding. With 6-feet of sea level rise, much of the Rockaway peninsula is under water, Jamaica Bay will have extended its reach deeper into its waterfront communities and more than half of Coney Island's current population could be at risk of permanent inundation. While any transition will take place over several decades, planning needs to give priority to the large number of low and moderate-income renters and homeowners in these communities.
- ▶ The barrier beach and back bay communities of the Jersey Shore and Long Island's south shore are among the most difficult to protect. Many of these could begin to be affected by one foot of sea level rise, and nearly all will be impacted by 6 feet. Most will need some combination of elevated structures, moving to higher ground or transitioning to seasonal communities.
- ▶ The region's airports are in areas that are most threatened. Most of Teterboro Airport could be permanently flooded with as little as one foot of sea level rise, potentially grounding its more than 165,000 annual General Aviation flights. Parts of LaGuardia could be affected at one foot as well and with three feet, more than half of the airport could be permanently flooded, threatening to disrupt service for over 28 million annual passengers. Newark Liberty and its 35 million annual passengers could be minimally affected by three feet and is more vulnerable at six feet. JFK and its nearly 57 million annual passengers are likely to be able to withstand both three and six feet, but will need to be hardened for the more severe future storm surges.
- ▶ Without additional protection measures, one foot of sea level rise will inundate nearly 60 square miles, where more than 19,000 residents in 10,000 homes live today, and where approximately 10,000 people work.
- ▶ Three feet of sea level rise could inundate close to 133 square miles where nearly 114,000 residents in 68,000 homes live today. Some 62,000 jobs are currently located in these areas.
- ▶ Six feet of sea level rise could inundate 280 square miles with 619,000 residents, 308,000 homes and more than 362,000 of today's jobs.
- ▶ Six feet of sea level rise will also threaten 20% of the region's power generating capacity and around 12,000 units of public housing.
- ▶ Cities and towns with the greatest number of residents living in areas at risk from six feet of sea level rise include New York City (203,000); Town of Hempstead, NY (80,000); Hoboken, NJ (28,000); City of Long Beach, NY (18,000); Town of Babylon, NY (17,000); Town Of Oyster Bay, NY (14,000); Jersey City, NJ (13,000); Town of Brookhaven, NY (13,000); and Town of Islip, NY (12,500)
- ▶ While New York City's 2013 Special Initiative for Rebuilding and Resiliency Report and New York State's Community Risk and Resiliency Act make efforts to address sea level rise, current resilience approaches mainly focus on storm surge and do not adequately tackle the challenge of long term permanent flooding. None of the projects currently pursue a regional approach.

We are past the point where sea level rise can be ignored in the hope that future technology will provide an easy solution.

With the first damaging consequences of sea level rise already affecting some of the region's neighborhoods, our current generation of elected officials, policy makers, planners, advocates, scientists, developers and residents are the only ones that can choose a different course from the one we're on. We are the only ones who can choose not to purchase, approve or develop in places that will be flooded in a matter of decades. There is no future generation left to figure this out.

Broadly speaking, there are three ways to protect ourselves from rising seas in the places most at risk:

1. We can develop engineering solutions, continually pumping more sand onto beaches or building higher berms and sea walls around communities and infrastructure, installing pumps to keep the water out;
2. We can learn to live with the water, elevating more structures and infrastructure and adjusting to a new life on less dry ground; or
3. We can phase out new development and retreat from at risk places over the coming decades, returning the land to nature.

All of these options present significant obstacles, raise tough questions and would require substantial investment and political leadership. We will need to figure out what combination of these approaches is best for each community at risk — and what policy and fiscal tools will be needed.

We can neither wall off the region's entire 3,700 mile coast from the sea, nor can we retreat from every future flood zone. The many resilience projects being implemented today will help us weather the storms, but most will not eliminate the threat of sea level rise. Difficult choices will need to be made in every community with a developed waterfront.

Significant adaptation investments, changes in future development policies and comprehensive buyout programs across the region will be required to ensure we are adequately planning for and confronting sea level rise.

RPA's fourth regional plan, *A Region Transformed*, will propose specific policies and investments to allow the region to mitigate climate change and confront its effects. But some immediate actions are clear:

- ▶ The 2015 international Paris agreement to limit future greenhouse gas emissions must be implemented if we are to have any hope of avoiding catastrophic effects from sea level rise and other outcomes of global warming. While the primary responsibility is at the federal level, state and local governments can have a substantial impact through land use, energy and transportation policies.
- ▶ Federal, state and local efforts to make us more resilient to future storms should also include funding and planning to address the effects of sea level rise.
- ▶ Vulnerable communities should begin having conversations about how best to adapt to sea level rise. There is time to prepare if we start now, but the conversations can be difficult and will take time to address multiple concerns and complicated options including social vulnerability.

Sea Level Rise Is Accelerating

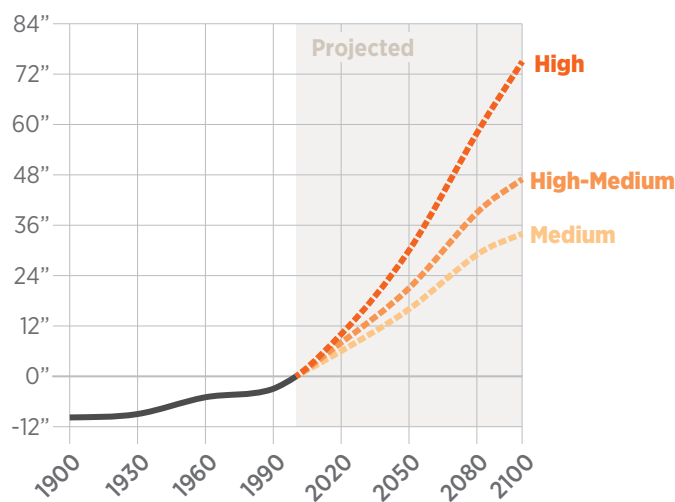
Sea levels across the planet are on the rise. In the New York metropolitan region, sea levels already have risen by about a foot since 1900. That rate, which is ahead of the global average, is expected to accelerate over the course of this century.² The rising waters pose an enormous threat to the safety, prosperity and quality of life of the tri-state area. By the first half of the next century, over 600,000 of today's residents and critical regional infrastructure such as power plants, wastewater treatment plants, LaGuardia airport and low lying rail lines could be permanently inundated by flood waters

Predicting how much sea level rise will occur by certain dates in certain places is complicated. Because there are so many factors at play — the number of emissions generated and rate of warming, the amount of ice melt, the topography of the land and integrity of coastal infrastructure, subsidence and compaction of land over time and changes in natural climate patterns — it is impossible to predict sea level rise for a particular time period with precision. As a result, scientists have developed models that provide ranges of sea level rise at varying levels of probabilities. A common methodology for projections first adopted by the New York City Panel on Climate Change and since adopted by New York State is providing the clearest picture for how much sea level rise will happen by when. The New Jersey Climate Adaptation Alliance of Rutgers University also has adopted the methodology to develop projections for New Jersey. RPA has reviewed the projections of each and assumes the following as the most probable of sea level rise projections for our region:

The region could see at least one foot of sea level rise by 2050, possibly as soon as the 2030s. Three feet could be realized by the end of the century, possibly as soon as the 2080s. Six feet of sea level rise is possible early in the next century.

The primary cause of sea level rise is global warming caused by the release of greenhouse gases like carbon dioxide into the atmosphere from burning fossil fuels for electricity, heat and transportation.³ Average global

Historic sea level rise observations and future projections for New York City / Lower-Hudson Region.



Source: Adapted from NPCC and New York State projections.
Note: The Low scenario developed by the NPCC is not included in this chart. That scenario is dependent on a radical and immediate reduction in carbon emissions reduction that is considered by many experts to be unrealistic, and most consider the Medium scenario to be the lower range of what may occur.

temperatures rose 0.87°C between 1880 and 2015. The last three decades were the warmest 30 years of the last 1,400 years.^{4,5}

As ocean waters are heated by rising temperatures, they physically expand, extending their reach inland. At the same time, glaciers and ice sheets are melting, adding to the volume of the ocean. The New York region is also prone to the slow sinking of our land, known as subsidence, as well as compaction from the removal of groundwater, both of which further the inland reach of the sea.

The Paris Agreement of 2015 to limit future greenhouse gas emissions to a measure that would level off warming at 2°C is a critical step toward avoiding catastrophic warming. But warming of our planet by 2°C still locks in around 3 feet of sea level rise by the end of this century, and at least 20 feet in the long term.⁶ If emission trends continue unabated, we are on track for 4.5°C of warming, with devastating con-

² New York City Panel on Climate Change (NPCC). 2015
³ U.S. Environmental Protection Agency. 2014

⁴ NASA's Goddard Institute for Space Studies (GISS). 2015
⁵ IPCC Synthesis Report Summary for Policymakers. 2014
⁶ Svetlana Jevrejeva et al. 2016. Coastal sea level rise with warming above 2 °C

sequences. So while this report serves as a call-to-action to begin planning for the sea level rise that we know is coming, the greatest urgency remains to find ways locally, regionally, nationally and globally to reduce our carbon emissions.

Permanent vs. Intermittent Flooding

The developed coastal areas of the tri-state metropolitan region are at significant risk of flooding from sea level rise, storm surge and their cumulative effect over time. There has been substantial progress in planning for recovery and resilience against future storms in the aftermath of Hurricanes Irene and Sandy. But it is important to distinguish between the flooding caused by catastrophic storms and sea level rise.

Large and catastrophic storms like Sandy happen occasionally and unpredictably, producing large increases in tidal height, or storm surge, coupled with destructive wave action and — in some storms — heavy precipitation, all of which leave behind a wake of disaster and initiate a long period of recovery across large portions of the coastal region. The process is traumatic and painful, but it is ultimately temporary. Residents and businesses can evacuate and then come back to rebuild, even if it takes years. Technology and engineering may even allow for flood proofing that prevents major disruptions.

Sea level rise, on the other hand, is happening slowly and steadily over time with serious and permanent consequences for a growing number of places. The flood waters of sea level rise won't recede once a storm passes. They will be permanent and over time will inundate our streets and homes, intrude into our drinking water aquifers, fill our tunnels, basements and storm drains, saturate our brownfields and other contaminated sites and eventually overwhelm low-lying rail lines and wastewater treatment and power plants. They will permanently change our coastline.

What's more, sea level rise exacerbates the impact of storm surge, extending its reach inland. A catastrophic storm today could produce a surge that affects up to one million residents in the region. With a two to three foot rise in sea levels, a catastrophic storm could produce a surge that doubles the vulnerable population to more than two million.

RPA Sea Level Rise Mapping Methodology

RPA's sea level rise maps are based on the "bathtub model" and methodology developed by NOAA. The sea level is represented by the Mean Higher High Water (MHHW) which is measured relative to the NAVD88 vertical datum. Elevation data comes from the USGS National Elevation Dataset (NED) at a resolution of $\frac{1}{3}$ arc-second. The difference in sea level is added to the MHHW, which is subtracted from the NED to obtain the depth and extent of sea level rise inundation. Areas below the new sea level that are non-contiguous with the sea are classified as "Low-lying Areas" and not assumed to be inundated for the purposes of the analysis.

Methodology

RPA's sea level rise inundation estimates are based on the methodology developed by NOAA for estimating the extent of sea level rise inundation (NOAA 2012). This so-called "bathtub model" approach, in which sea level behaves like the water level rising in a bathtub, is also the basis for the sea level rise mapping methods used by Climate Central (Strauss et al. 2012), TNC (Gilmer 2011), and Scenic Hudson (Scenic Hudson 2015).

Two datasets were used for the sea level rise analysis. For land elevation, the National Elevation Dataset (NED) from USGS, a digital elevation model (DEM) with a resolution of $\frac{1}{3}$ arc-second. Tidal elevation comes from NOAA's VDatum tool, which converts tidal elevation data to the NAVD88 for compatibility with the NED. The extent of the sea is based on Mean Higher High Water (MHHW), which is the average elevation of the higher of the two daily high tides. MHHW represents the average extent of the tide in any given day. Similar sea level rise inundation analyses either used MHHW (NOAA 2012; Scenic Hudson 2015) or Mean High Water (MHW) (Strauss et al. 2012; Gilmer 2011).

The level of sea level rise (e.g. +1ft, +3ft, and +6ft) was added to the MHHW level to project a future sea level. The DEM land elevation was then subtracted from the projected sea level layer to produce a depth grid. Values equal or less than zero, which represent dry land, were excluded from the layer. The remaining areas contiguous to the sea were considered inundated, while remaining non-contiguous areas were classified as "Low Lying Areas", which are below the projected sea level and may or may not be subject to flooding, depending on geophysical and hydrostatic factors beyond the scope of the analysis.

The population and jobs analysis applies to "SLR Inundation Areas" only and does not include "Low Lying Areas" non-contiguous with the sea. The population and jobs analysis is based off current (2010-2011) figures and does not necessarily represent the number of people who will still be living in inundated areas in 50-100 years. Block-level population and housing data originated from the 2010 decennial US Census. Block-level jobs numbers came from the 2011 US Census Longitudinal Employment-Housing Dynamics Survey. Data related to infrastructure came from the Metropolitan Transportation Authority, Port Authority of New York and New Jersey, Amtrak, the US Department of Transportation, Environmental Protection Agency, US Department of Housing and Urban Development, and the US Energy Information Administration.

References

Gilmer, Ben. 2011. "TNC's SLR and Storm Surge Mapping Methods"

NOAA Coastal Services Center. 2012. "Detailed Methodology for Mapping Sea Level Rise Inundation."

Scenic Hudson. 2015. "Scenic Hudson GIS Methodology for Mapping Sea Level Rise."

Strauss, Benjamin H., Remik Ziemiński, Jeremy L Weiss, and Jonathan T Overpeck. 2012. "Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States." Climate Central.

The New York Region at One, Three and Six Feet of Sea Level Rise

The following narratives provide hypothetical scenarios of what our region might face as sea levels rise. They are followed by a summary of geospatial analysis that estimates the current population, number of housing units, total area, jobs and critical infrastructure in areas projected to be affected by sea level rise.

Approaching a foot of sea level rise - Canaries in the Coal Mine

The shift to one foot of sea level rise was neither immediate nor dramatic. Still contained by bulkheads, seawalls and other coastal infrastructure for much of this time, the sea inched higher and higher, occasionally overflowing into yards or onto streets at the highest tides, causing nuisance flooding. Streets would be closed for a day or two, storm water infrastructure would become temporarily overwhelmed and sometimes the levels would get high enough to damage personal property such as cars, basements or ground floors of homes and businesses. Then the tide would go back out, the water would recede and life would return to normal.

But at some point along the way in particularly vulnerable areas, the water began to stay around even longer, until it stopped receding altogether. A few inches remained at all times, rising with

high tide and retreating to a few inches at low tide. Some roads became unusable and a number of homes and businesses experienced standing water in their basements. Street and yard trees began to die, unable to process the salt water now surrounding their roots. Suburban septic systems began to fail. In the hardest hit places, sections of neighborhoods along the waterfront became uninhabitable, and some people chose to leave. Where it could be afforded, states and municipalities invested in higher bulkheads, elevated streets and hard-working pumps to send the water back out to the sea. But it was becoming clear that sea level rise was real and having an impact in a growing number of places.

Area Flooded: **60 square miles**
(about 0.5% of the entire region's land)

People affected*

Residents: **nearly 19,000**

Housing Units: **more than 10,000**

Jobs: **10,000** (more than half of which are in New Jersey)

Places most affected

Communities directly adjacent to the waterfront along the region's bays and tidal rivers, in many cases where wetlands and marshes were filled for development decades ago.

* Based on 2010 Census data for population, housing units and 2011 Census data for jobs.

From 1 to 3 feet - Reality Sets In

By the time sea levels had risen to three feet, it became clear that sea level rise was having enormous consequences in the region. At one foot of sea level rise, the relatively few sections of places with permanent flooding had become curiosities for others to see. At two feet, nuisance flooding became a more regular occurrence for more communities whose residents now knew that this was the sign they would be next. The coast was becoming an unpleasant and unnerving place to live. Three feet of sea level rise began to wreak havoc across the region, flooding runways of major airports, lapping up against extensive rail networks and storage yards, expanding floodwaters deeper into the suburbs and beginning to turn some urban streets into canals. More waterfront parks were becoming submerged, and waterfront infrastructure - including treatment plants, storm drains and combined sewer overflows backed up during storms. Even in the dry parts of the region, quality of life was suffering as encroaching waters made travel difficult, curtailed recreation and affected more families and co-workers.

Area Flooded: **133 square miles**
(about 1% of the entire region's land)

People affected*

Residents: **nearly 114,000**
Housing Units: **more than 67,000**
Jobs: **62,000** (more than half of which are in New Jersey)

Places most affected

Communities directly adjacent to the waterfront along the region's bays and tidal rivers, with further reach in the suburbs and the beginning of more significant impacts in some urban places.

The region at Six Feet - A New Coastline

With six feet of sea level rise, the region's coast became unrecognizable. So many developed places were reclaimed by the sea, taking with it entire communities, vital infrastructure and natural systems that had served as protection. As sea level rise approached six feet, what had been primarily a suburban disaster became a force of destruction in our urban centers where many more people were affected. Entire sections of the region, including coastal beaches, tidal rivers and estuaries, were lost. Nearly every mile of the region's coastline was now penetrated by a deeper and more unpredictable sea.

Area Flooded: **280 square miles**
(about 2% of the entire region's land)

People affected*

Residents: **nearly 620,000**
Housing Units: **more than 308,000**
Jobs: **363,000** (more than half of which are in New York City)

Places most affected

Now include urban centers such as Hoboken and Jersey City, the communities around Jamaica Bay and the Rockaways in New York City and the iconic beach towns of the Jersey Shore.

New York City

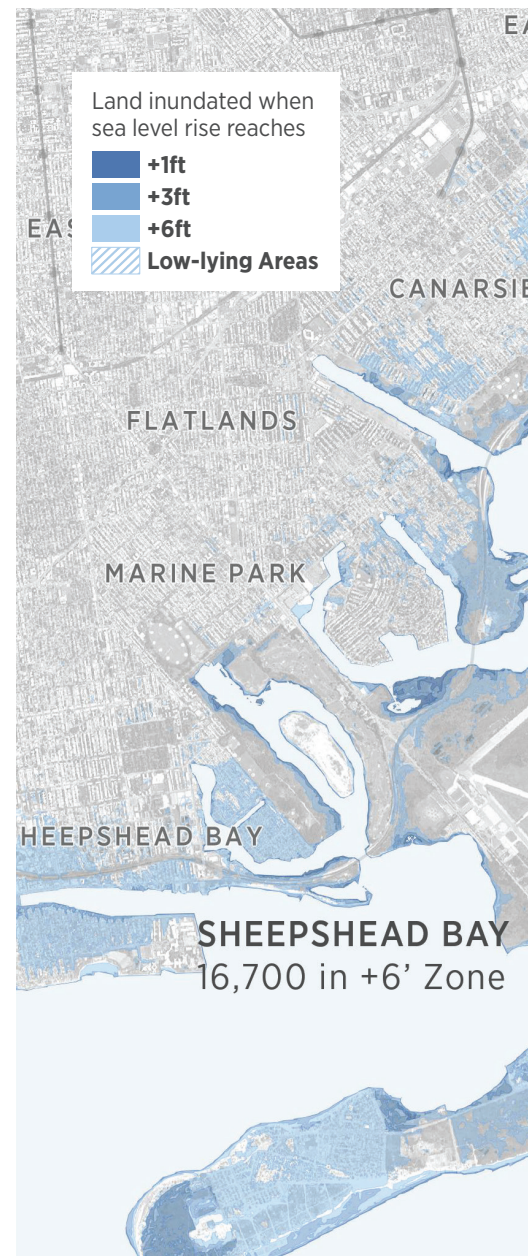
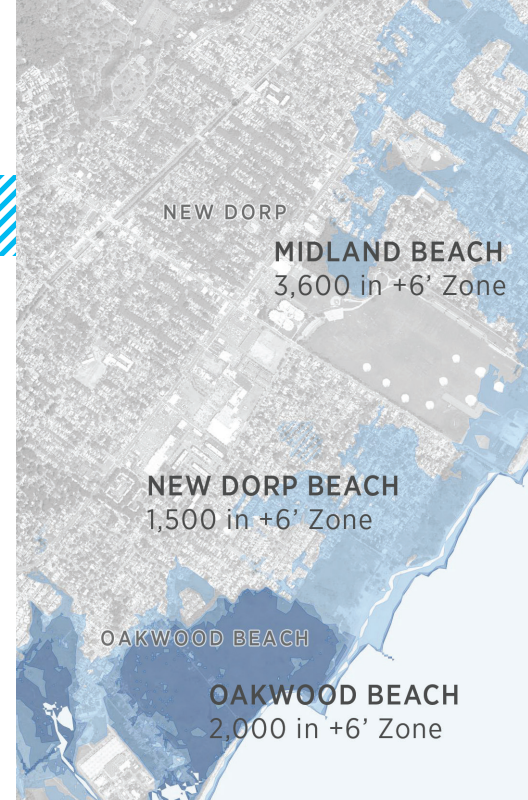
Residents Inundated **+1': 1,278** **+3': 12,275** **+6': 202,784**

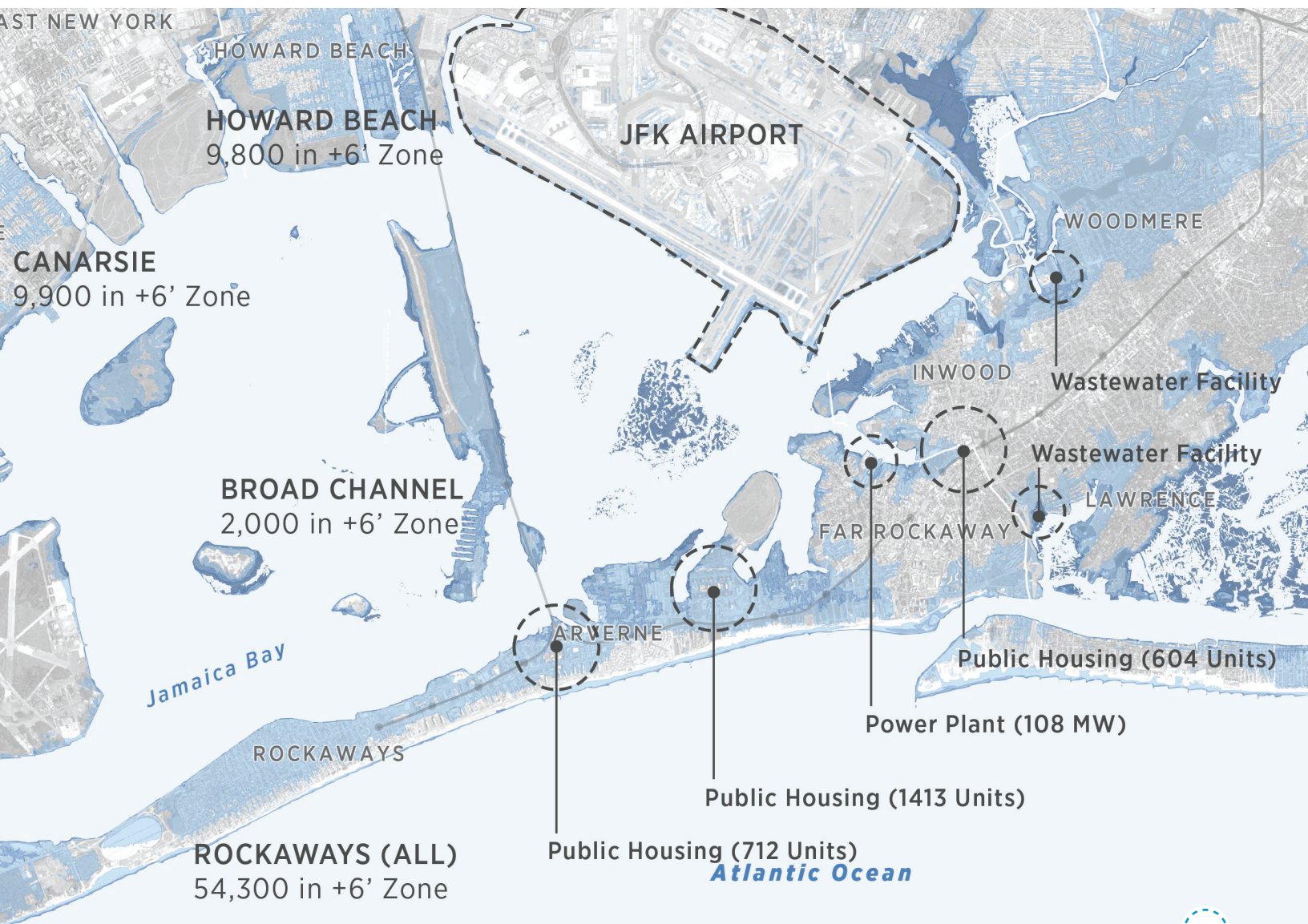
+1' Because so much of the city's shoreline is hardened against flooding, the vast majority of neighborhoods in New York City are expected to experience few consequences from one foot of sea level rise, save a handful of places in and around Jamaica Bay, Flushing Bay and the particularly vulnerable eastern shore of Staten Island. The community of Broad Channel in Queens is significantly threatened with one foot of sea level rise. LaGuardia Airport will likely begin to experience periods of nuisance flooding at particularly high tides that could disrupt operations from time to time. At one foot of sea level rise, a number of waterfront parks around the city begin to face partial inundation.

+3' With three feet of sea level rise, places that were experiencing smaller incidents of flooding at one foot will likely face greater or more permanent inundation. More than 12,000 of today's New York City residents live in places that could be permanently flooded by a rise of three feet, the vast majority along the shores of Jamaica Bay, Flushing Bay and eastern Staten Island. The flooding in Broad Channel is likely to become even more significant, also affecting the subway connection between the Rockaways and Howard Beach. LaGuardia Airport's 13/31 runway and portions of its terminal areas begin to become permanently inundated around two feet of sea level rise, with more coverage at three feet. Waterfront parks, coastal protection infrastructure and topography continue to buffer much of the rest of New York City's neighborhoods from permanent flooding, though stormwater and drainage infrastructure could become prone to backups at high tides and low-lying neighborhoods may experience increased incidents of nuisance flooding.

+6' At six feet of sea level rise, portions of New York City begin to look very different than they do today. The coastal protection infrastructure and waterfront parkland that had buffered much of the city through three feet of sea level rise is no longer enough to hold back water from places where more than 200,000 residents live today. Over 150,000 of those residents are located in the boroughs of Brooklyn and Queens, the majority residing in communities around Jamaica Bay and the Rockaways, Coney Island, Brighton Beach and Sheepshead Bay. Broad Channel is completely inundated at six feet. Flushing Bay communities as well as Red Hook and Sunset Park also could see permanent flooding of portions of their waterfronts. The industrial areas of Sunset Park and the Brooklyn Navy Yard are two major employment centers that face near total inundation. At six feet of sea level rise, both runways and the terminals of LaGuardia airport could become fully inundated. JFK airport is likely not to be affected by six feet of sea level rise but will be more susceptible to storm surge.

In Manhattan, close to 30,000 residents today live in places that could be permanently flooded in particularly vulnerable neighborhoods such as Harlem, Battery Park City, Hudson Yards and Chelsea, and the Lower East Side and East Village. The Bronx could see flooding in places where over 5,000 of today's residents live, primarily in Schuylerville, Throgs Neck, Edgewater Park and University and Morris Heights. The east shore communities of Oakwood Beach, Midland Beach, and South Beach account for about 80% of the close to 15,000 Staten Island residents who live in places today that could be permanently flooded.





Long Island

Residents Inundated +1': 7,122 +3': 41,023 +6': 164,592

+1' The south shore of Long Island is one of the region's most susceptible areas to one foot of sea level rise, and unlike other similarly threatened places, it is more developed and more populous. Nassau County and Suffolk County combined account for more than 7,000 of the 9,000 New York State residents in the region expected to be permanently flooded by one foot of sea level rise. Most are located along the Great South Bay and South Oyster Bay in the Towns of Brookhaven, Islip, Babylon and Hempstead.

+3' At three feet of sea level rise, the south shore remains New York's most affected area. Water that had penetrated communities along the Great South Bay and South Oyster Bay expands its reach inward and gets deeper in places it had already flooded. Close to 40,000 of today's residents on Long Island live in places that could be permanently inundated with a rise of three feet of sea levels, nearly six times the population affected at one foot.

+6' At six feet of sea level rise, nearly 165,000 Long Island residents today live in places that could be permanently flooded. No community along the south shore is left untouched and the long stretches of sandy barrier beaches that today are one of the region's most popular destinations likely will be reduced to thin slivers of sand interspersed with frequent inlets.

The additional flooding brought on from three to six feet affects Nassau County communities more significantly than those in Suffolk. Over 113,000 Nassau County residents today could be affected, nearly 80,000 alone in the Town of Hempstead. Particularly vulnerable communities include Baldwin Harbor, Freeport, Long Beach, Merrick, Oceanside, Seaford, Valley Stream and Woodmere. Places that face community-wide inundation could include Barnum Island, Bay Park, Island Park and Lido Beach. The neighboring Town of Oyster Bay could see flooding that affects places where over 14,000 residents live today.

In Suffolk County, much of the additional flooding occurs in places where 51,000 residents live today and that were already flooded at three feet of sea level rise, primarily in the towns of Babylon, Islip and Brookhaven along the Great South Bay. Communities on Fire Island are nearly all lost to the sea. It is also notable that at six feet of sea level rise, communities on Long Island's north shore are likely to see higher levels of inundation in places like Bayville, where about a third of today's population could see permanent flooding.

Land inundated when sea level rise reaches

+1ft

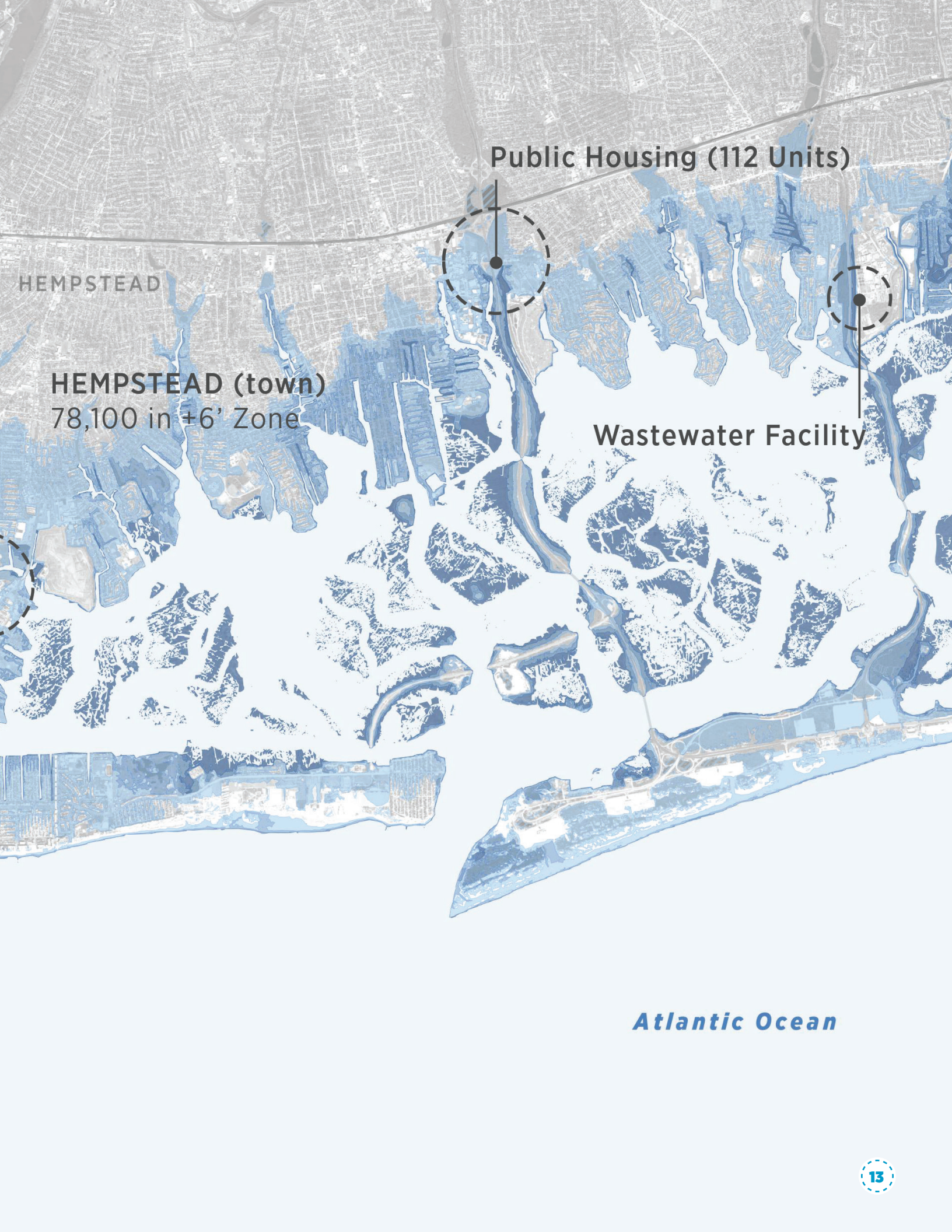
+3ft

+6ft

Low-lying Areas



LONG BEACH
18,100 in +6' Zone



HEMPSTEAD

Public Housing (112 Units)

HEMPSTEAD (town)
78,100 in +6' Zone

Wastewater Facility

Atlantic Ocean

Hudson Valley / Long Island Sound

Residents Inundated +1': 659 +3': 2,454 +6': 6,652

+1' Because of topography and historical development patterns, Hudson River communities, many of which are developed on higher ground, are less at risk from sea level rise than other communities in the region. Still, places like Yonkers, Piermont and Stony Point, whose waterfront edges are more developed or are developed on fill, begin to see permanent flooding. Sections of Long Island Sound towns to the east including New Rochelle, Rye and Mamaroneck town are also likely to see permanent flooding.

+3' Those New York communities along the Hudson River and Long Island Sound that saw flooding affecting sections of town at one foot sea level rise are likely to see the area and depth of flooding increase at three feet. Portions of the Metro-North Hudson rail line could become threatened at three feet of sea level rise. More than 2,000 of today's Westchester and Rockland County residents live in places along the Hudson and the Sound that could be permanently flooded at three feet of sea level rise, with the greatest numbers in Yonkers, Rye, New Rochelle and Mamaroneck town. Nearly 9% of Piermont's population today faces inundation at three feet.

+6' At six feet of sea level rise, the Hudson River is likely to have reclaimed many of the areas that had been filled in over time, affecting over 2,500 residents as well as critical infrastructure including waterfront parks, wastewater treatment plants and power generating facilities. The Metro-North Hudson rail line and its 12 stations between New York City and Poughkeepsie along with Amtrak's Empire Corridor line is at risk of inundation in a number of low lying sections along the Hudson's eastern shore. On the western shore, the River Subdivision — a freight line owned by CSX — runs north along the shoreline to Selkirk, just south of Albany and has low lying sections at risk in places as well.

About one third of the Town of Mamaroneck's population today could be inundated at six feet of sea level rise, making it one of the hardest hit Long Island Sound towns. Rye and New Rochelle continue to lose land to the Sound at six feet.

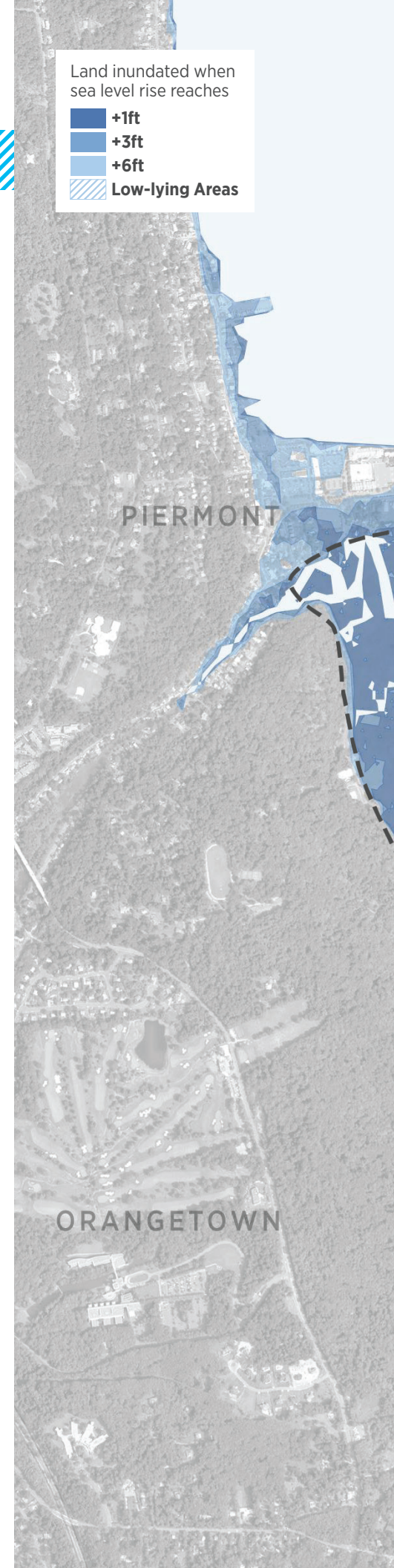
Land inundated when sea level rise reaches

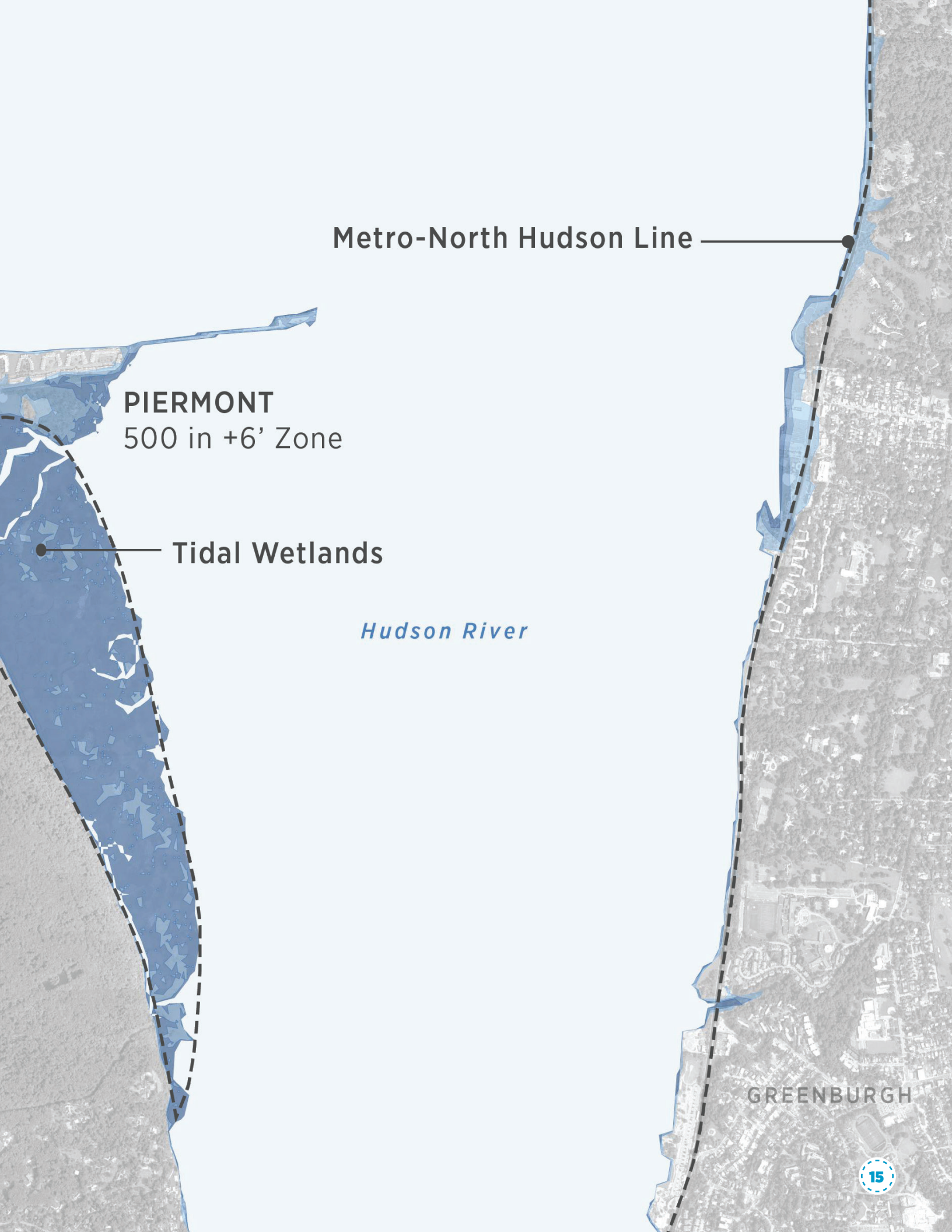
+1ft

+3ft

+6ft

Low-lying Areas





Metro-North Hudson Line

PIERMONT
500 in +6' Zone

Tidal Wetlands

Hudson River

GREENBURGH

Northern and Central New Jersey

Residents Inundated +1': 7,833 +3': 47,208 +6': 197,681

The Harbor and Its Tributaries

+1' New Jersey communities along the shores of the Hudson River, Arthur Kill, Hackensack, Passaic and Raritan rivers and Newark and Raritan Bay, in general are more urbanized than in other parts of New Jersey and thus have more protective infrastructure in place to minimize the flooding of one foot of sea level rise. In the Hackensack Meadowlands however, a few communities such as Moonachie and parts of Secaucus as well as Teterboro Airport begin to see inundation at one foot. Communities along the Raritan Bay and the Raritan River are more affected with more than 1,000 of today's population facing inundation in towns like Middletown, Sayreville and Union Beach.

+3' The permanent flooding that had begun at one foot of sea level amplifies broadly to affect a growing number of residents at three feet. The more Urban areas - Jersey City, Hoboken, Perth Amboy - still remain minimally affected, though notably Hoboken rail terminal is likely to become partially flooded. The towns within the Meadowlands and around Raritan River and Bay that saw flooding at one foot now could see thousands more of today's residents permanently flooded. The Meadowlands town of Moonachie could experience flooding that affects nearly 70% of its total population today.

Critical infrastructure, including the numerous passenger and freight rail lines and warehouse and distribution facilities in the Meadowlands become threatened at three feet, and Teterboro is likely to be completely inundated, rendering it unusable.

+6' Like New York City, New Jersey's more urban communities are more significantly affected by six feet of sea level rise. The most significantly impacted city in the region is Hoboken, where more than half of today's 50,000 residents live in places that will be permanently flooded. Historically, Hoboken was an island separated from mainland New Jersey, but over time was filled in with dense uses. As floodwaters crest the protective infrastructure along the city's waterfront, the low-lying fill areas are likely to fill back in with water, affecting more than 28,000 of today's residents. The Hoboken rail terminal and yards are also likely completely inundated at six feet, affecting NJ Transit, PATH and Hudson Bergen Light Rail lines.

Neighboring Jersey City's waterfront is also likely to see significant inundation, affecting areas where more than 13,000 residents live today. More than 6,000 residents of Newark currently live in places that could become permanently inundated and both the Port of New York and New Jersey and Newark Liberty International Airport face significant risk of permanent flooding across vast sections..

The rising sea levels continue to drastically affect communities in the Meadowlands and along the Hackensack River. Six feet of sea level rise threatens the viability of this transportation, energy and warehousing hub. Nearly all of Little Ferry's and Moonachie's residents today live in places that would become permanently flooded as does more than half of Kearny's population. The areas around Raritan Bay and its tributaries have around 20,000 residents living in places today that could become permanently inundated in the towns of Hazlet, Keansburg, Middletown, Sayreville, South River and Woodbridge alone. Highlands borough could see nearly half of its current population inundated.

Land inundated when sea level rise reaches

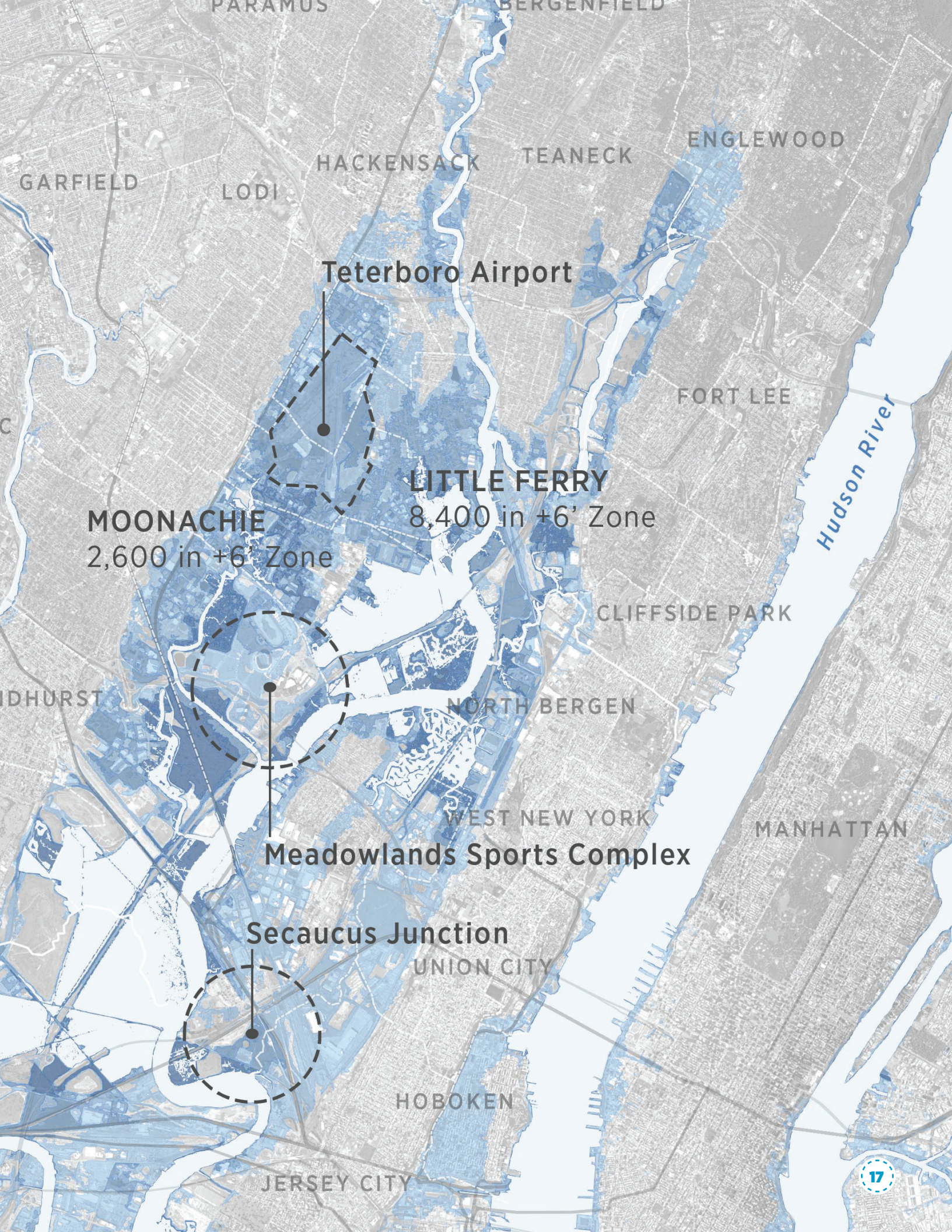
+1ft

+3ft

+6ft

Low-lying Areas





Teterboro Airport

LITTLE FERRY
8,400 in +6' Zone

MOONACHIE
2,600 in +6' Zone

Meadowlands Sports Complex

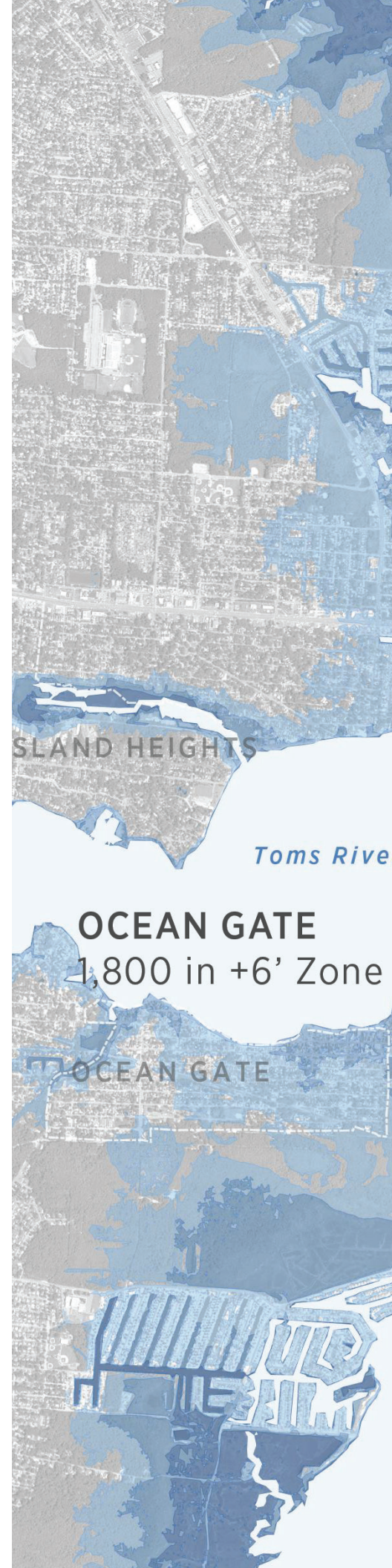
Secaucus Junction

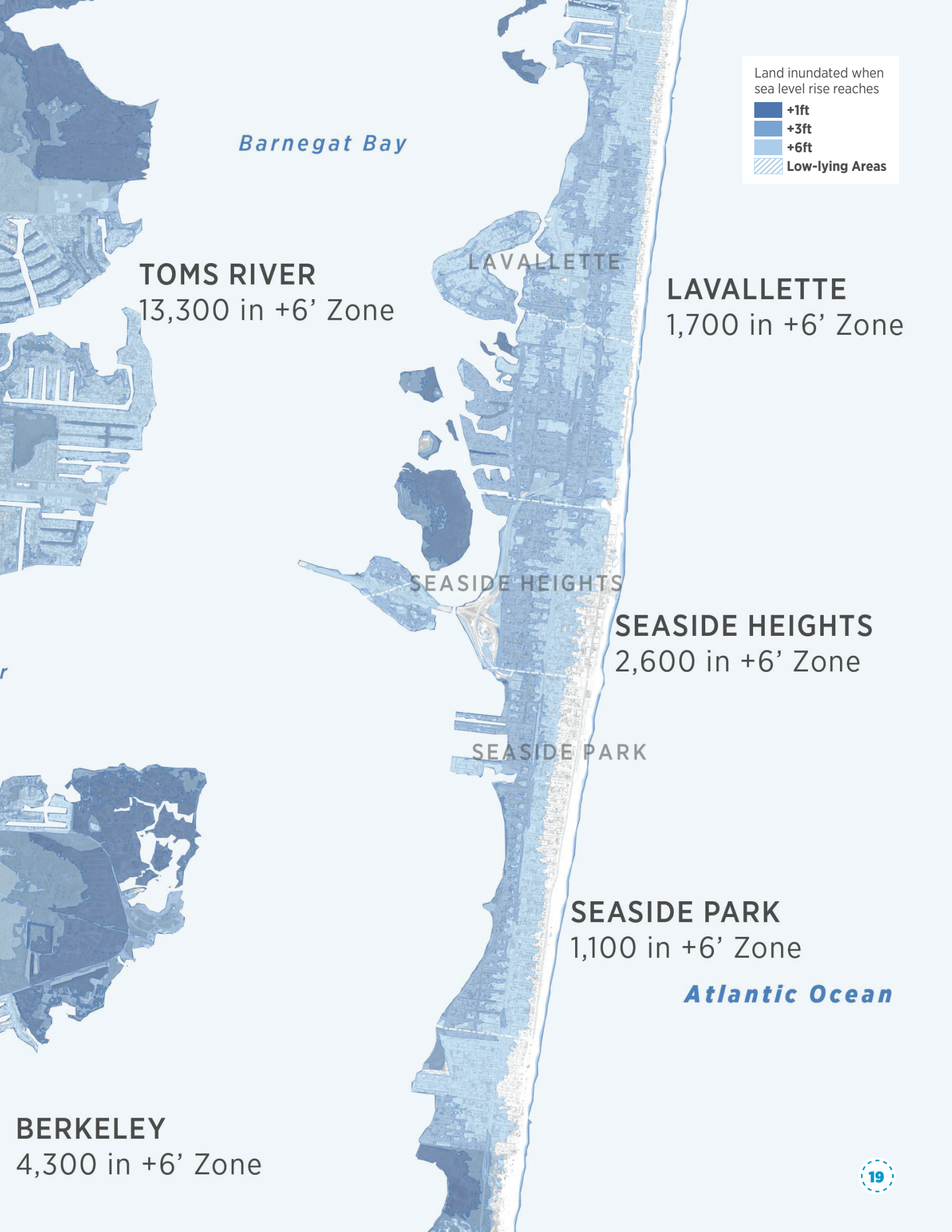
The Jersey Shore

+1' At one foot of sea level rise, the Jersey Shore is particularly vulnerable to permanent flooding, with much of the initial inundation in communities that line its back bays, tidal rivers and estuaries. Particularly affected are the Ocean County communities around Barnegat Bay and Toms River, where over 3,000 of today's residents live in places that could be inundated.

+3' As sea levels rise to three feet, the bay and tidal river portions of the shore will continue to be the hardest hit in the state. Permanent flooding is likely to inundate many more towns than were affected at one foot and those places already flooded will likely experience worse and more far reaching inundation. The areas around the Navesink and Shrewsbury rivers could see flooding that affects thousands in Highlands, Oceanport, Rumson and other towns. Sea Bright could see almost half of today's population permanently flooded. Further down the shore, the beach and coastal river towns of Monmouth County including Long Branch, Manasquan, Monmouth Beach, Ocean and Point Pleasant Beach will likely see flooding affect over 10,000 of today's residents. While in Ocean County, the communities along Barnegat Bay and Toms River are likely to continue to experience the greatest amount of flooding in New Jersey with nearly 23,000 residents living in places today that could be permanently flooded in towns such as Berkeley Township and Seaside heights where more than half of the current population will be affected.

+6' At six feet of sea level rise, the flooding of bay, river and estuary communities continues to expand, but the biggest shift between three and six feet is the devastating impact to New Jersey's beach towns. The coastal waterfronts of Monmouth and Ocean counties have a combined current population of over 80,000 residents that could become permanently flooded. Thousands in Long Branch, Manasquan, Monmouth Beach, Oceanport and Rumson are at risk, while in Sea Bright more than 80% of today's population could be permanently flooded. The area around Barnegat Bay and Toms River accounts for the majority of the 80,000 residents at risk. There, the string of towns that form the popular summer destination of Long Beach Island faces near complete inundation as do many of the places that form the iconic postcard images of the Jersey Shore, like Point Pleasant Beach, Seaside Heights and Seaside Park. Toms River's barrier beach communities also face near complete inundation. At six feet of sea level rise, the story of the Jersey Shore is the loss of the arcades, boardwalks, amusement parks and sands that fuel New Jersey's tourism economy.





Land inundated when sea level rise reaches

- +1ft
- +3ft
- +6ft
- Low-lying Areas

Barnegat Bay

TOMS RIVER
13,300 in +6' Zone

LAVALLETTE

LAVALLETTE
1,700 in +6' Zone

SEASIDE HEIGHTS

SEASIDE HEIGHTS
2,600 in +6' Zone

SEASIDE PARK

SEASIDE PARK
1,100 in +6' Zone

Atlantic Ocean

BERKELEY
4,300 in +6' Zone

Coastal Connecticut

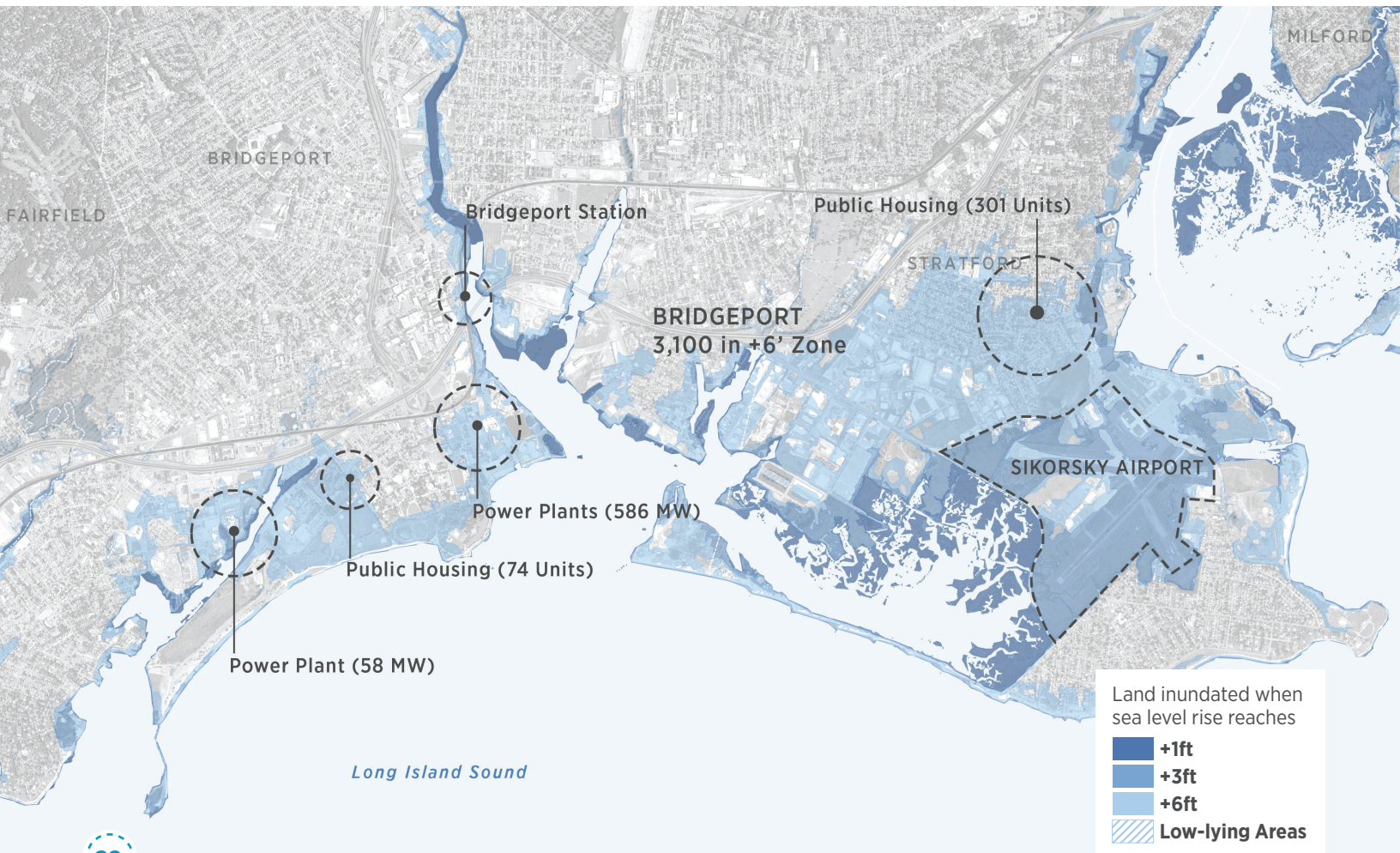
Residents Inundated +1': 2,295 +3': 10,901 +6': 47,182

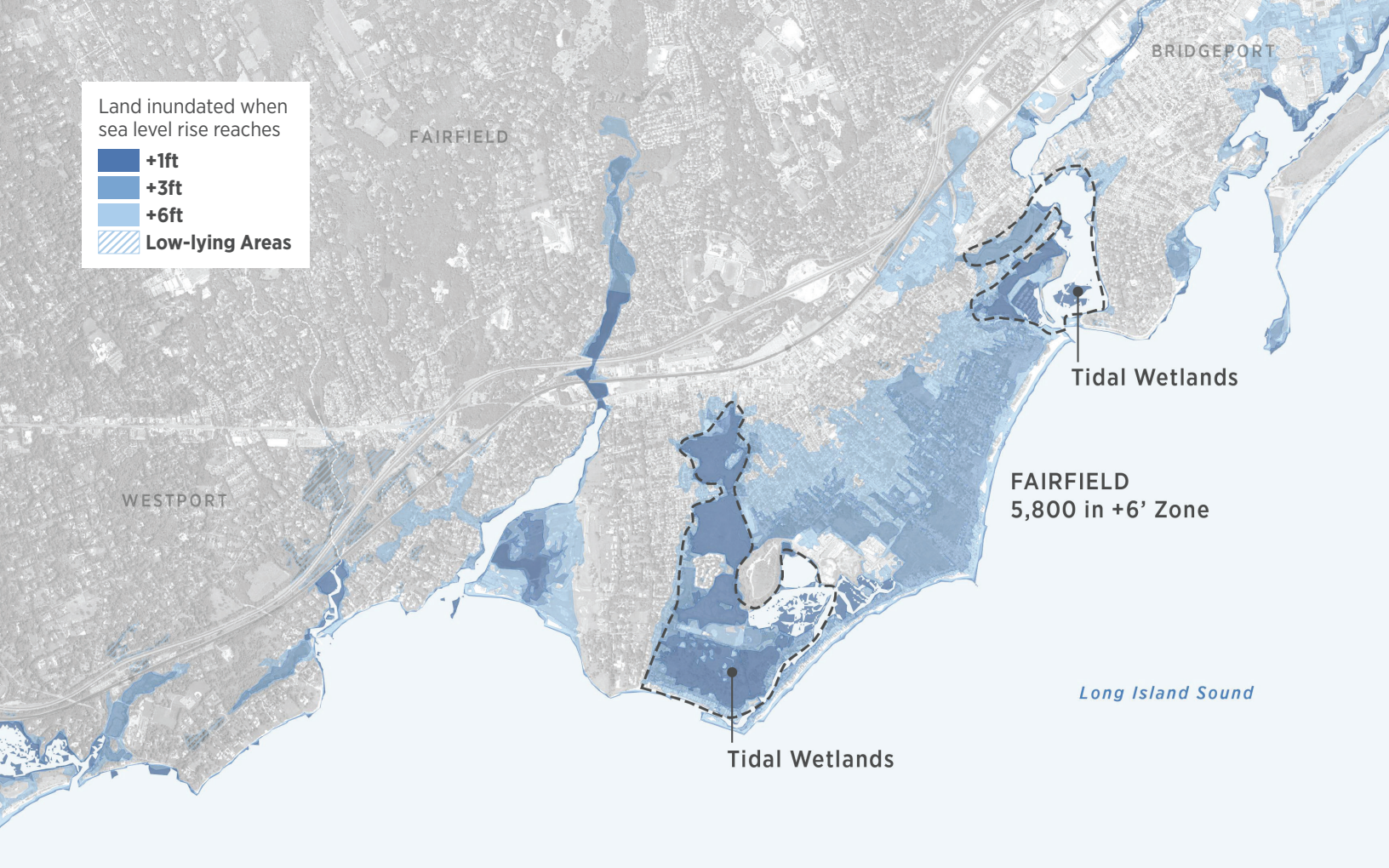
Long Island Sound Cities

+1' Connecticut's coastal cities — Stamford, Bridgeport and New Haven — are only minimally affected by one foot of sea level rise with small sections inundated and just over one hundred of today's residents in places at risk.

+3' The cities remain largely protected from a three foot rise in sea levels, with some areas more threatened than others. Hundreds of residents live in places today that could be affected by permanent flooding in Bridgeport and New Haven, while close to 2,000 of Stamford's waterfront residents could experience inundation at three feet, a significant jump from the flooding at one foot.

+6' With six feet of sea level rise, Connecticut's coastal cities start to see more dramatic effects from permanent flooding. In total, over 12,000 Bridgeport, New Haven and Stamford residents currently live in places that could become permanently flooded, nearly half of them located along the Stamford waterfront.





Long Island Sound Suburbs

+1' With one foot of sea level rise, suburban development along Connecticut's coast faces greater threats from permanent flooding than do the urban centers. In particular, portions of Fairfield, Milford and Branford account for more than half of the state's total population at risk with 1,200 of today's population living in places that could become permanently flooded.

+3' The majority of Connecticut residents affected by three feet of sea level rise continues to be in the waterfront suburban towns of Fairfield and Milford where close to 4,000 residents today live in places that could be permanently flooded. Meanwhile, communities including Branford, East Haven, Greenwich, Norwalk, Stratford and Westport are likely to see an increasing number of residents permanently flooded.

+6' Despite the additional areas of Connecticut's cities affected by six feet of sea level rise, the vast majority of residents facing increased permanent flooding at six feet remain in the waterfront suburbs. Fairfield remains the most affected of Connecticut towns with nearly 6,000 residents at risk, followed closely by Stratford and Milford with each over 5,000. Norwalk, Westport, Branford, East Haven and Milford together have close to 12,000 people living in places that could be permanently flooded.

What's Being Done

New York State Community Risk and Resilience Act (CRRA)

CRRA was signed into law on September 22, 2014 with the aim to ensure that certain state funding, facility-siting regulations and permits consider the effects of climate change and extreme weather events. Five major provisions of the law include:

1. The state adopting its own official sea level rise projections, adjusted for sub-regions of the state and based on New York City's methodology carried out by the New York City Panel on Climate Change.
2. Requiring applicants for permits or funding in specified programs to demonstrate that they have considered the risks of sea level rise, storm surge and flooding and that they are factored into facility-siting regulations.
3. Ensuring that mitigation of sea level rise, storm surge and flooding risks are added to the list of smart-growth criteria for public infrastructure.
4. Requiring the NYC Department of State (DOS) and the Department of Environmental Conservation (DEC) to develop model local laws that consider risk from sea level rise, storm surge and flooding.
5. Requiring DEC and DOS to develop guidance for how to use natural resources and processes to enhance resilience.

While many of the final details for implementation are currently being worked out at many levels, this law represents a proactive and forward-looking approach to tackle climate change risks, including sea level rise. The details of implementation will determine how effective and replicable the law could be for the rest of the region.

New York City's Special Initiative for Rebuilding and Resiliency

Following Superstorm Sandy, New York City under Mayor Michael Bloomberg responded to the disaster by building off of the already strong approaches it had been crafting around recovery and resilience, with a focus on preparing for the long term. The City released a final report in June 2013 that summarized the threats from climate change to neighborhoods and vital infrastructure and laid out an ambitious set of recommendations to meet the challenges posed by those threats. Projects in the plan include an estimated \$20 billion worth of projects ranging from hard infrastructure such as sea walls to living shorelines and everything in between.

Under Mayor DeBlasio, a number of the plan's projects have made good progress in places like Red Hook, Hunts Point, Sea Gate, Staten Island's East Shore, the Rockaways and Jamaica Bay and along Manhattan's Lower East Side where coastal defences are being planned and implemented. Funds are being secured for coastal protection projects and new policies have been adopted to support coastal protection. The SIRR report looked ahead to 2050 to consider the risk of sea level rise on City neighborhoods and infrastructure. The ambitious actions the City is taking to become more resilient are similarly focused more on threats for the next few decades, than those beyond, meaning higher levels of sea level rise will need to be addressed in future planning.

Rebuild by Design

The innovative and imaginative Rebuild by Design competition process grew out of a unique partnership of the Rockefeller Foundation and the U.S. Department of Housing and Urban Development. Together, along with key partnerships with Regional Plan Association, the Municipal Art Society, the Institute for Public Knowledge and the Van Alen Institute, the competition brought together designers, planners,

architects and scientists to dream a new vision of resilience for our region. The resulting set of projects are at various points of implementation and represent the vanguard for resilience planning. RPA looked specifically at four to evaluate the degree to which they will protect against sea level rise, separate from extreme storms.

Big U/East Side Coastal Resiliency



Source: BIG (Bjarke Ingels Group)

Originally conceived as “the Big U,” the East Side Coastal Resiliency project is the first segment of an integrated flood protection system around the southern tip of Manhattan, and is a signature project of New York City’s SIRR report. It aims to fuse structural protection with public amenities such as open space to provide protection for neighborhoods that include over 9,000 NYCHA housing units, critical networks of the City subway system, Con Edison substations, the Manhattan pump station and the FDR Drive. Ultimately, the primary purpose of the project is to protect these places from the storm surge that comes with extreme storms. It is being designed for the “100-year flood plus sea level rise.” Because it cannot seamlessly seal off every section from the Harbor, flood waters could eventually find inlets into some neighborhoods and depending on the final height of the structure could top the structure in the long run.

Resilient Bridgeport



Source: WB Unabridged

Focusing on Connecticut’s most dense, diverse and socially vulnerable city, Resilient Bridgeport aims to tackle the flooding from rainfall and storm surge that will be made worse by sea level rise. The project also aims to boost habitat restoration, economic development and community revitalization in the South End neighborhood of the city by elevating a critical road, building a waterfront berm and

establishing offshore breakers to mitigate surge. While the project focuses largely on surge and rainfall flooding, final designs include adaptable space to adjust for sea level rise.

New Meadowlands/Rebuild by Design-Meadowlands



Source: MIT CAU + ZUS + URBANISTEN

As a pilot of a larger vision, this project intends to protect the five municipalities in the New Jersey Meadowlands region of New Jersey. Originally conceived as a network of protective berms to keep out floodwaters, provide developable space and create room for wetland restoration, the project has been scaled back and as part of an environmental impact statement process underway is considering three alternatives, 1) structural flood protection; 2) stormwater drainage and management to minimize flooding from extreme precipitation; and 3) a hybrid approach. The project as it is being studied, looks to the year 2075 to develop and evaluate anticipated flooding conditions, which should account for more than a foot of sea level rise. It is unclear how future increases in sea level rise will be factored into the final project.

Resist, Delay, Store and Discharge/Rebuild by Design-Hudson River



Source: OMA

The proposed project for Hoboken is squarely focused on taking a comprehensive water management approach to address flooding from periodic major storms and high tides and from periodic extreme rainfall events. It combines hard infrastructure to protect against storm surge and high tides, including berms and levees, with new green infrastructure and improvements to existing stormwater infrastructure. The coastal protection components of the proposal are being designed for a 500-year flood event, but does not specifically discuss the permanent implications of flooding from sea level rise.

Taking Action

With the first damaging consequences of sea level rise projected to affect our neighborhoods as soon as the next 15-20 years, we can no longer put off preparing. The purpose of this report is to put sea level rise at the forefront of policy discussions that will determine how well we adapt to a new environment and coastline. Using the best data available, it paints a picture of the future we could see if we fail to reduce our carbon emissions and change the way we plan, develop and adapt along our waterfronts.

The following offers some overarching tenets, many of which will be explored in greater detail in RPA's fourth regional plan due out next year, that should inform what we can do to do address sea level rise today.

1. Follow through on commitments to reduce carbon emissions

As we accept and brace for a future with dramatically rising seas, we must remain steadfast in doing everything we can to reduce our carbon emissions, locally, regionally and nationally. Our nation has committed to reduction goals and our region can lead the way in meeting and exceeding those levels. Reducing our carbon emissions is the only way for us to slow the rate and minimize the amount of sea level rise around us.

2. Plan now for sea level rise at the state, municipal and community level.

It might seem obvious, but the first step in confronting sea level rise is to acknowledge that it is happening and take the necessary steps to plan for it. All too many communities in our region aren't fully aware of the threat and aren't planning for its consequences. While 85, or 50 or even 15 years seems like a long way off, the planning and development decisions we make today have long-term effects. A new apartment building approved for development today and built in an area that will eventually be submerged by the sea will be fine in the short term, but as difficulties arrive, from initial nuisance flooding at high tides to the eventual inundation of the property, the challenges for how to ensure the safety and well-being of people living in these places there will multiply.

There will be places where we will need to cease development because of sea level rise, others that we will need to reclaim as open space and habitat and some places where it

will make sense to reinforce and redevelop. Those decisions will happen today in master plans, zoning updates, hazard mitigation plans, open space protection plans and other policies that set the table for growth in our region. New York State has taken a bold step with the Community Risk and Resiliency Act that ensures that state funding, facility-siting regulations and permits account for climate risks and extreme weather events. New Jersey and Connecticut should enact similar legislation. And local municipalities will need support, both funding and knowledge, to begin planning for sea level rise.

3. Know what's at risk.

The numerous web-based tools available from federal, state and local government, universities and non-profit organizations allow all of us to use the latest science, projections and models to pinpoint areas at greatest risk from sea level rise. What's essential in planning for sea level rise is knowing where those areas are and what is in them. This report has taken a first look at our region and has identified the people, jobs and some of the major infrastructure at greatest risk, but it is incumbent upon each community to do a more exhaustive analysis. New York City has taken stock of who and what is at risk from catastrophic storms as well as from sea level rise through 2050. Properly scaled versions of their approach looking to the longer term should be emulated in municipalities across the region to so that action can be taken to confront this growing risk.

4. Fund sea level rise adaptation.

Adapting to sea level rise will require varied investments depending on the context. Some areas will need investments in hard infrastructure and pumps to keep water out; others will need to elevate homes, infrastructure, perhaps entire facilities; still others may require a more natural approach with restored wetlands and other living shorelines; some areas eventually might need to move away from the water's edge and return the land to nature. All of these measures will require levels of funding that are currently insufficient. There will be no adaptation steps taken to confront sea level rise unless there is funding to do so, and requirements to ensure it is done. New funding sources will be needed, and all existing sources of adaptation funding, from federal to state to local and philanthropic, need to address sea level rise in addition to intermittent, storm related flooding.

5. Implement resilience projects for the short and long term.

In the wake of Hurricanes Irene and Sandy in our region, funding has been dedicated to plan, design and implement multiple resilience projects. These projects, as they are completed, will provide necessary protection and improved practices in the face of catastrophic storms. These projects should continue to be implemented with no interruption. At the same time, there should be an acknowledgment that many of these projects will offer limited or - at best – short-term protection from sea level rise, and additional projects will be needed in the long term. Many of these existing projects can be leveraged to maximize their usefulness in the long term to best protect against sea level rise.

6. Pay special attention to the most socially and economically vulnerable.

The consequences of sea level rise will affect many of our region's residents, but the poor, elderly, renters and others who are vulnerable for economic or social reasons will be hit harder. About one-third of residents at risk of flooding from sea level rise could be considered socially vulnerable. With lower incomes, fewer job choices, less ability to be mobile and a limited supply of affordable housing, the challenges faced by socially vulnerable populations will be exacerbated by sea level rise. Even the adaptation tools available to confront sea level rise will need to be tailored to different populations. For example, buyout programs work best for homeowners of single family homes and are not adequately structured to fairly acquire multi-family buildings with renters. Municipal leaders, policy makers and adaptation funders will need to develop adaptation programs for and effectively communicate with those who are socially vulnerable.



Regional Plan Association

Regional Plan Association is America's most distinguished independent urban research and advocacy organization. RPA improves the New York metropolitan region's economic health, environmental sustainability and quality of life through research, planning and advocacy. Since the 1920s, RPA has produced three landmark plans for the region and is working on a fourth plan that will tackle challenges related to sustained economic growth and opportunity, climate change, infrastructure and the fiscal health of our state and local governments. For more information please visit, www.rpa.org.

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