2

Quantifying Water

It is a revolutionary reality
the sea is rising. slowly now
she is giving us time to adapt
if we dare look at the future

Excerpted from Sea-Rise, by John Englander @2015

Collins Waterfront Study Area | Indian Creek Dr with 39th street looking North

Investment to meet the future resiliency challenges of sea-level rise, extreme rainfall events, King Tides and storm surges is likely to be significant. Policy regarding major adaptive rehabilitation projects should therefore take into account a mid- to long term-time horizon. For the purposes of this study, roughly 60 years seems appropriate.

2.1 // INTRODUCTION

The proximity of water and land is a defining feature of Miami Beach. It is also a primary factor in the vulnerability of the city. Preservation of these districts and their associated benefits requires an understanding of present and future flooding potential and associated damage predicted by various frequency storm events.

In order to understand possible future impacts of water on Miami Beach historic districts, the following four issues were examined: anticipated sea-level rise; 10-year rainfall storm events; King Tides; and storm surge associated with hurricane events. Following the guidance of the Compact, the impact for each was calculated on a timeline of 2040, 2060, and 2080. If significant sea level rise continues past 2080, alternate adaptation and resilience strategies may need to be considered. For the purpose of this study, we have projected future water based on the projections of the South Florida Climate Change Compact. Applying the projections of the Compact, on-going sea level rise combined with other water events will increase the frequency of flooding and volume of damage to the historical properties within the Flamingo Park and Collins Waterfront Historical Districts.

Climate resilience is the capability of a community to minimize disruption and recover quickly after the occurrence of hazardous events such as hurricanes or coastal storms that cause extreme flooding. Major property damage or regular disruptions within a community will contribute to reduced property values and the loss of tax base.

The city should continue to explore the susceptibility of historical buildings to flooding during various frequency storm events and assess their long term damage potential. Damage predictions may serve as a measure for evaluating benefits of proposed resiliency guidelines and strategies. The city should consider the economic benefits of potential solutions by measuring the reduced frequency of damage of adapted buildings against the implementation cost and potential loss of neighborhood aesthetics.

2.2 // ANTICIPATED WATER LEVELS

A. Sea level rise

Global warming is contributing to the thermal expansion of seawater and the melting of land based ice sheets and glaciers, resulting in sea level rise. According to ???, mean sea level has risen 6.3 to 8.3 inches between 1900 and 2016. More precise data measurements indicate an acceleration of 3.0 inches of mean sea level rise between 1993 and 2017. Predicting sea level rise is challenging due to the many factors influencing climate change.

Organizations researching climate change and its influence on sea level rise include, the Intergovernmental Panel on Climate Change (IPCC) – an intergovernmental body of the United Nations, the U.S. Army Corps of Engineers (USACE) – a U.S. federal agency associated with flood protection, and the National Oceanic and Atmospheric Administration (NOAA) – an American scientific agency focused on oceans, waterways and the atmosphere.

In January 2009, Miami-Dade, Broward, Monroe and Palm Beach counties united to form the Southeast Florida Climate Change Compact (SFCCC or Compact) to coordinate climate change mitigation and adaptation activities. The Compact created a Regional Climate Action Plan to outline recommended mitigation and adaptation strategies, including a unified sea level rise projection for the region Specifically, the Compact formed an ad-hoc working group, identified as the Sea Level Rise Work Group, to update the 2011 Unified Sea Level Rise Projection report. The updated report was drafted and released in 2015, after the National Oceanic and Atmospheric Administration (NOAA) et al. 2012 and U.S. Army Corps of Engineers (USACE) 2013 projections were released.
The projections of the Compact have been used for the purposes of this study.

The Compact utilized the updated projections throughout their 2015 Report, and based their adaptation measures on the updated projections. According to the Compact, the 2015 Projection update shifted the sea level rise projection start date to 1992, which is the "center of the current mean sea level National Tidal Datum Epoch of 1983-2001" (Compact, 2015). Within the 2015 Report, the Sea Level Rise Work Group recommends that the updated unified sea level rise projection include three curves: the NOAA High Projection, the USACE High Projection, and a projection corresponding to the median of the IPCC AR5 RCP8.5 scenario (Compact, 2015). These recommendations are summarized in Figure 2.1.

Guidance is provided within the Regional Climate Action Plan regarding the recommended use of the curves and tables for planning of various municipal projects:

• The lower curve (blue dashed line) is recommended for use in the design of low risk projects with short design lives.

• The shaded zone (in blue, between the IPCC AR5 and the USACE High) is recommended to be applied for most projects, within a short term planning horizon. This zone is projected to reflect the most likely range of sea level rise for the remainder of the 21st century.

• The NOAA High curve (solid orange line) is recommended for projects with medium to long term applications, which are not easily replaceable or removable or have a long design life of more than 50 years.

This study has followed the Compact recommendations, using USACE high projections up to 50 years, and NOAA High curve numbers to be used for planning projects with design life of more than 50 years. As the adaptation of historic building in Miami Beach will likely require significant investment and imply a lifespan of more than 50 years, we propose the NOAA High curve projection for 2080 as a reference point for assessing alternatives and recommending code changes in the Historic Districts.

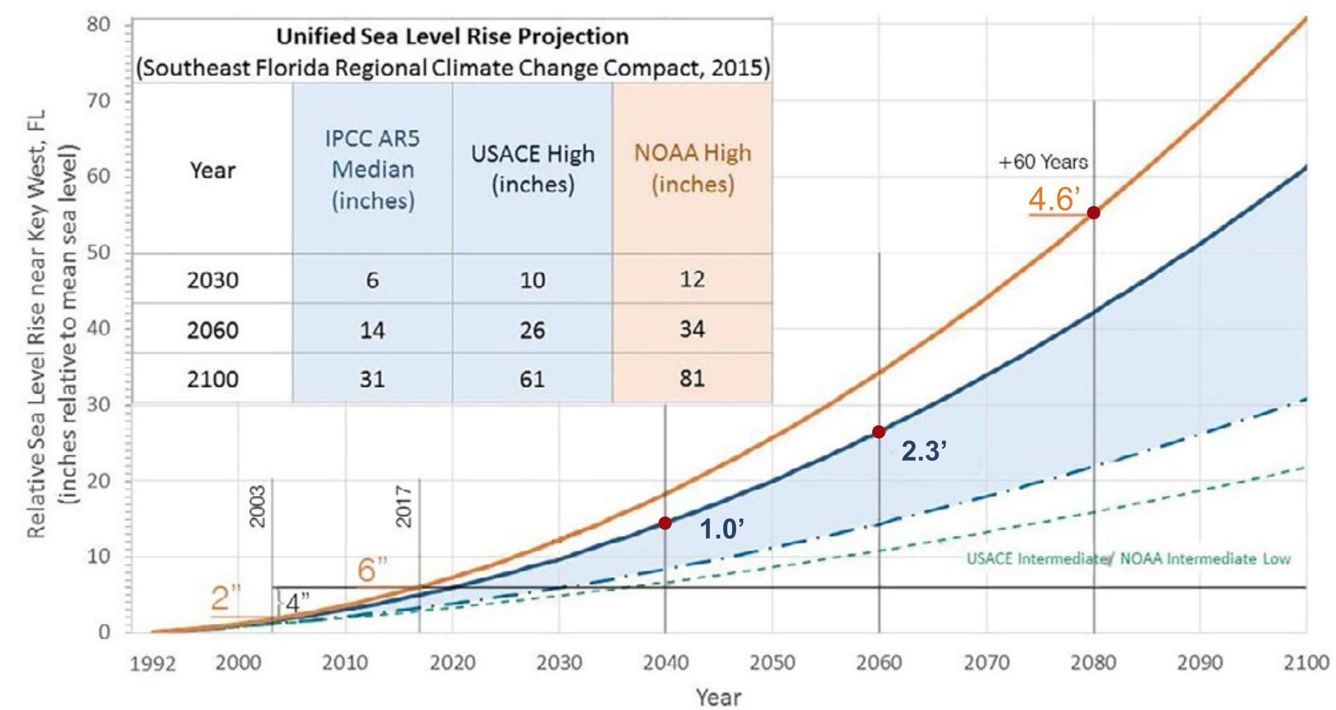


Fig. 2.1. Unified Sea Level Rise Projection, Southeast Florida Regional Climate Change Compact, 2015 annotated

B. Rain events

Water Surface Elevation (Feet NGVD) NOAA 2012 High Curve Projections				
Rainfall Frequency	Present	(+) 20 YEAR	(+) 40 YEAR	(+) 60 YEAR
	2020	2040	2060	2080
Predicted Sea Level Rise	**0**	(+) 1.0 ft	(+) 2.3 ft	(+) 4.1 ft
1 YEAR	4.10	5.10	6.40	8.20
2 YEAR	4.30	5.30	6.60	8.40
5 YEAR	4.35	5.35	6.65	8.45
10 YEAR	4.50	5.50	6.80	8.60

source

Intense rain events, where a large volume of water overwhelms an area in a short amount of time, is an important factor of flooding in Miami Beach. When stormwater does not have anywhere to flow to when it reaches the ground, it accumulates and leads to flooding conditions. In undeveloped areas, a significant portion of stormwater infiltrates naturally into the soil when it reaches the ground, while the remainder flows by gravity over the surface to collect in low-lying areas — often wetlands, lakes, and streams. In Miami Beach and other urban areas, draining of natural wetlands, the dense coverage of buildings, and the use of impervious pavement has limited the ability for stormwater to naturally be removed from the surface. The city's low-lying elevations also makes drainage a challenge, especially given the high groundwater table in Miami's porous limestone underneath the ground.

Climate change and a warming environment are likely to lead to more rainfall and stronger storms, putting further strain on drainage systems and other infrastructure. While there is significant variability in year-to-year rainfall, average rainfall has increased about 10% for the southeast region of the United States during the last century according to Florida Climate Center at Florida State University. There has also been an increased frequency of rainfall of events of two inches or more, indicating stronger storms.x Rising tides and sea levels add additional challenges to draining stormwater as sewer systems can be inundated with tidal flooding that blocks and backs up into municipal stormwater outfalls.*

Four Largest Storms Impacting Miami Region since 1880				
Hurricane	Category	Year	Storm Surge Elevation (feet)	Comments
Great Miami Hurricane	4	1926	+15.0	
Unnamed Hurricane	4	1888	+14.0	
Andrew	5	1992	+11.8	North Portion - Biscayne Bay
			+10.0	Downtown Miami
			+17.0	Near point of landfall
Betsy	4	1965	+6.0	Impacted Miami Beach

Four Largest Storms impacting Miami region since 1880.

source

C. King tides

King Tide Elevation (Feet NGVD)				
NOAA 2012 High Curve Projections				NOAA High Curve
	Starting Point	(+) 20 YEAR	(+) 40 YEAR	(+) 60 YEAR
	2020	2040	2060	2080
Predicted Sea Level Rise	**0**	(+) 1.2 ft	(+) 2.2 ft	(+) 3.5 ft
King Tides	3.8	5.0	6.0	8.4

source

Gravitational forces between the sun and moon cause ocean waters to rise and fall in cyclical tidal patterns. In Miami, there are several times a year when the tide is especially high — known as King Tides.x A natural occurrence caused by the moon being closer to the Earth, this temporary phenomenon becomes even more extreme when coupled with permanent sea level rise induced by climate change.

Amplified tidal changes can cause coastal tidal flooding that is more frequent, more extreme, and able to travel further inland. A storm is not needed for ocean waters to encroach inland either by overtopping unprotected coasts or backing up into drainage pipes and canals. So-called "sunny-day flooding" or "high tide flooding" is not just a nuisance, but can damage infrastructure, restrict transportation options, hurt commerce, and destroy property.

Miami Beach has seen increased tidal flooding with the accelerated rate of localized sea level rise occurring in recent years.xx If sea level rise projections continue to become reality, the region could frequently see two flooding events in one day regardless of precipitation —one for each daily high tide.
xxx *
*

D. Storm surge

Storm Surge Elevation (Feet NGVD)				
NOAA 2012 High Curve Projections				NOAA High Curve
Storm Frequency	Starting Point	(+) 20 YEAR	(+) 40 YEAR	(+) 60 YEAR
	2003	2040	2060	2080
Predicted Sea Level Rise	0	(+) 1.3 ft	(+) 2.7 ft	(+) 4.6 ft
10 YEAR	8.1	9.4	10.8	12.7
20 YEAR	9.5	10.8	12.2	14.1
50 YEAR	10.8	12.1	13.5	15.4
100 YEAR	13.6	14.9	16.3	18.2
500 YEAR	17.7	19.0	20.4	22.3

source

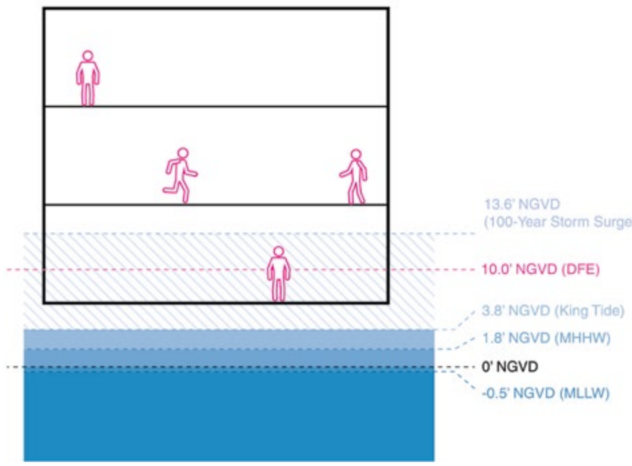
During major storm events such as hurricanes, seawater levels can rise abnormally higher than typical high tide marks. This rise in water levels, known as storm surge, is primarily caused by intense winds and by pressure changes of a storm pushing water onshore. Storm surges produce water levels beyond the normal waves that crash onto the coast. Taken together, the typical daily tidal increases and the storm surge account for the total storm tide seen during a hurricane or other major storm event. Hurricanes arriving at the same time as normal high tide cycles can make storm surge especially powerful and damaging.

Sea level rise due to climate change can make storm surge even more intense as the excess water present due to sea level rise is also able to be pushed on shore, inundating greater land area. With higher storm surge, even a low category hurricane can have a major impact, put residents at risk and damage property. Miami-Dade County locates Miami Beach in Zone B as it relates to storm surge planning, meaning that even a Category 2 storm poses significant risk for storm surge. It is important to note that a storm or hurricane does not need to make direct impact with an area for the effects of storm surge to be seen. The winds generated by a storm located miles offshore can still push water inland and upriver, as has been seen in historical hurricanes and tropical storms that have damaged Miami Beach and the surrounding region.* Hurricane Irma generated nearly 2' of storm surge in the vicinity of Miami Beach when it struck Florida in 2017.

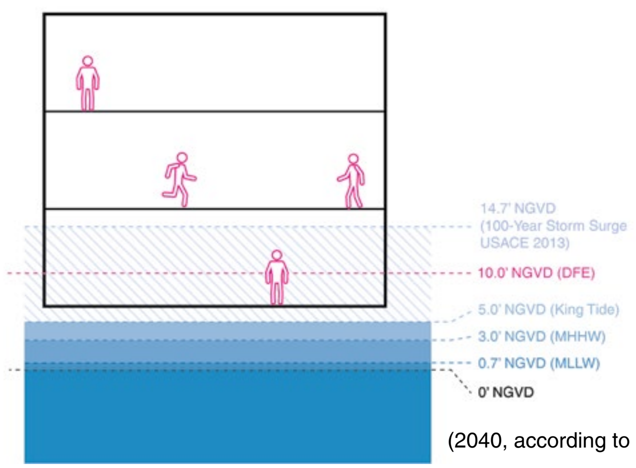
https://www.elnuevoherald.com/noticias/sur-de-la-florida/article108612152.html

2.3 // WATER & BUILDINGS

Today

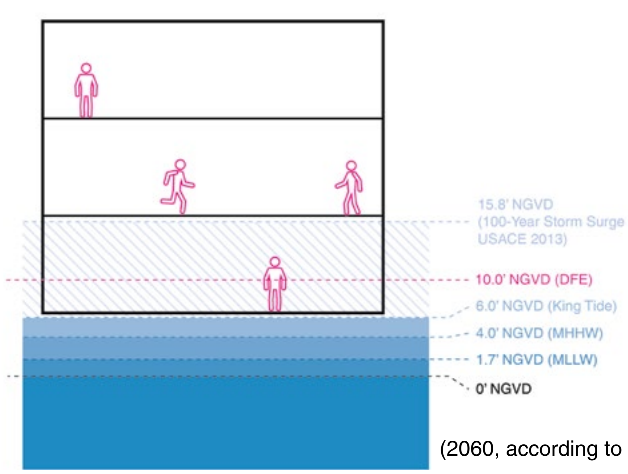


1.2' Sea Level Rise



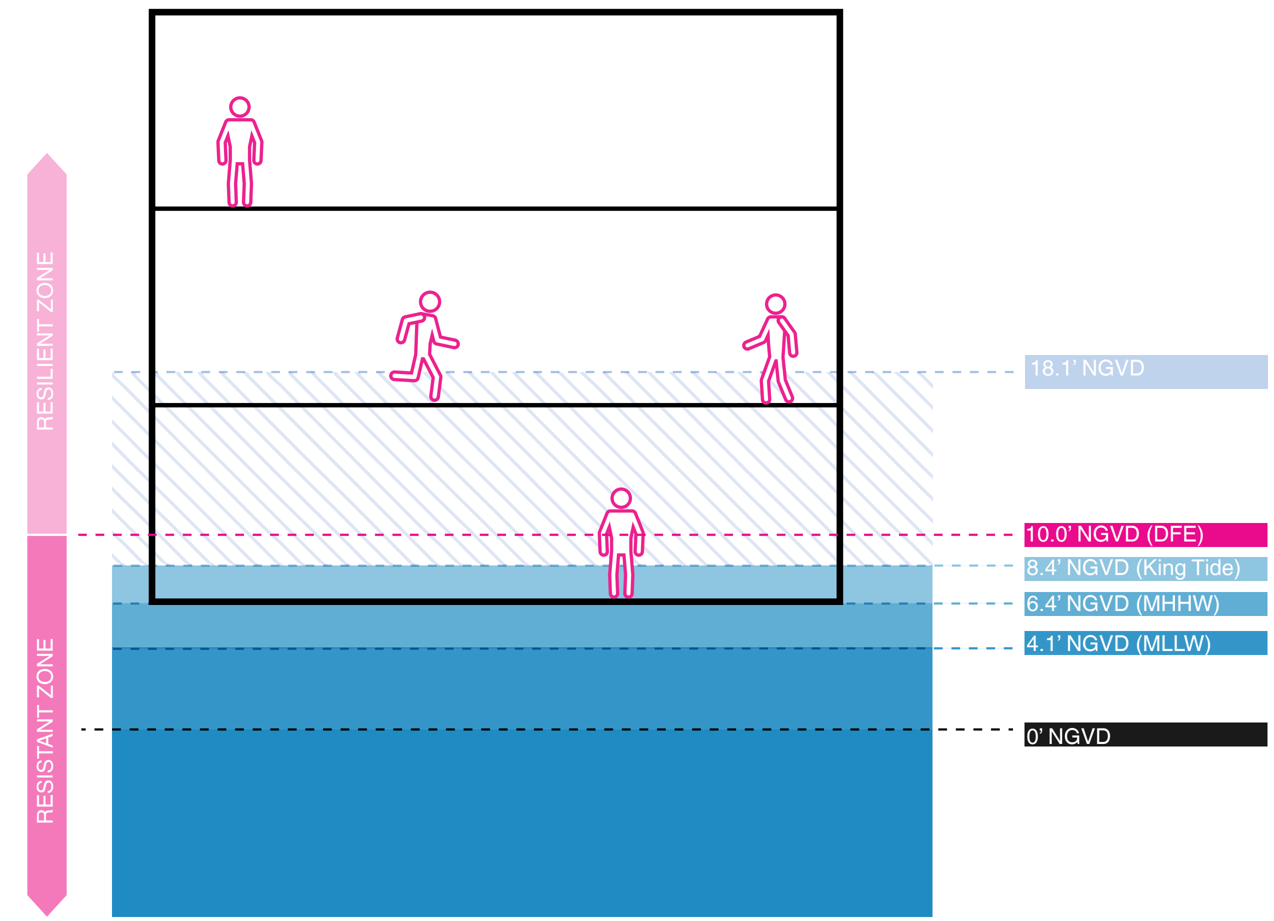
(2040, according to the Southeast Florida Regional Climate Change Compact, 2015)

2.2' Sea Level Rise



(2060, according to the Southeast Florida Regional Climate Change Compact, 2015)

4.6' Sea Level Rise



(2080, according to the Southeast Florida Regional Climate Change Compact, 2015)

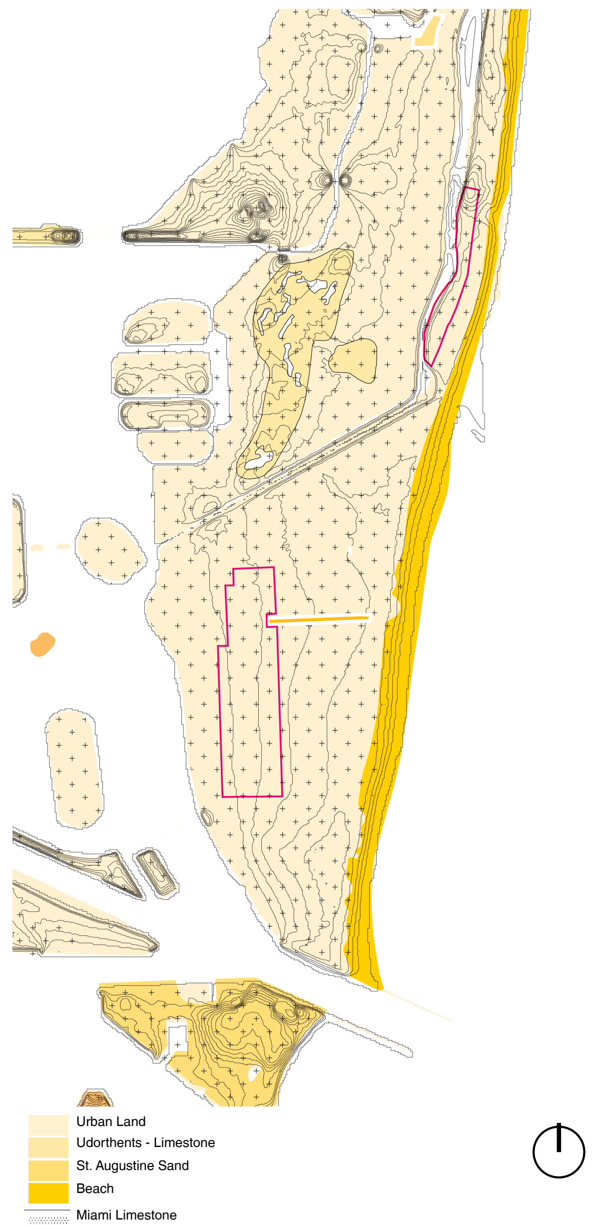
In order to preserve the historic character of the two districts, and to preserve their low-lying landscape, the City of Miami Beach should consider a flexible standard of application of anticipated flood elevation. Adaptation of historic buildings should be divided into two categories: resistance and resilience. In order to preserve these historic districts, a combination of both resistance and resilience strategies will need to be implemented and a phased approach may need to be taken.

2.4 // MAPPING WATER

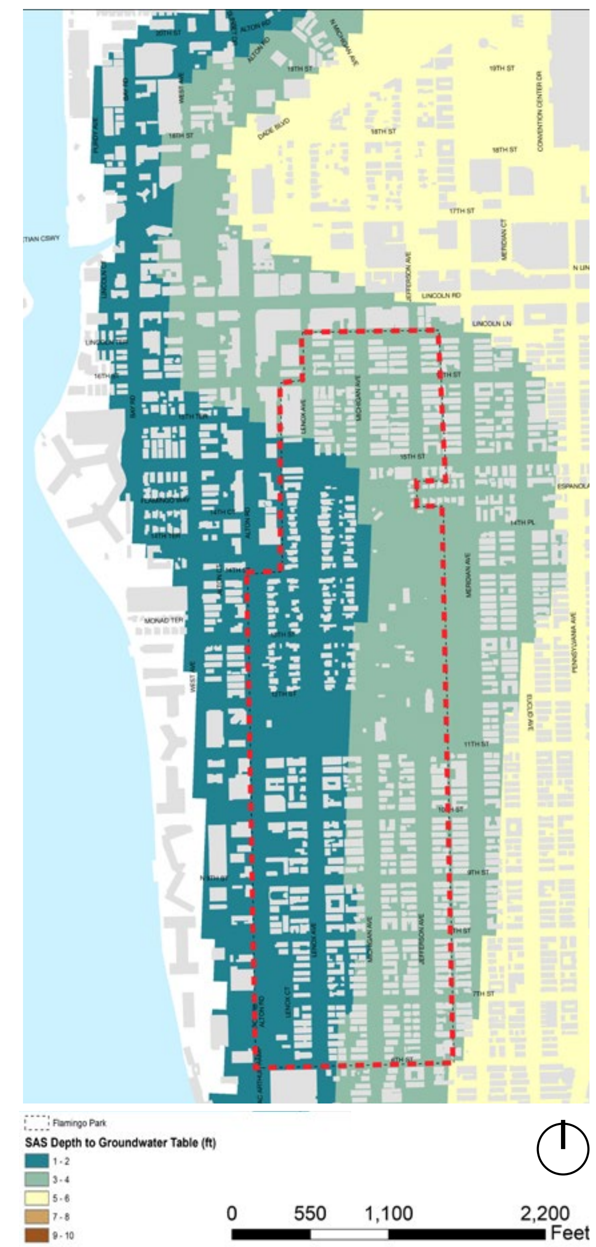
Depth to Groundwater and Geology

Flamingo Park & Collins Waterfront District

One of the challenging natural features of the Miami Beach area is the shallow depth to groundwater throughout the city. As shown in the map above, for the Flamingo Park District the groundwater table lies only at most four feet below the surface for most of the area. Because of this, sea level rise not only poses a threat from water encroaching inland from the shore, but also elevated groundwater rising up from below. This shallow groundwater is due in part to the relatively low elevation of the land area compared to sea level. Additionally, the presence of porous limestone below grade allows water to percolate through the rock layers beneath Miami Beach. As sea levels rise, there is a greater likelihood of saltwater intrusion from the ocean into the freshwater aquifer beneath the city that also serves a vital source of drinking water. A higher groundwater table also will mean less space available for infiltration of stormwater runoff into soil/rock that is already saturated.



Geology (Environmental), Florida Geographic Data Library, Scale 1:250000, Florida Department of Environmental Protection, Publication Date 2001, https://www.fgdl.org/metadataexplorer/full_metadata.jsp?docId=%7B43653D67-07B3-42E7-BA1E-BC732947DB83%7D&loggedIn=false (Referenced 6/24/2019)



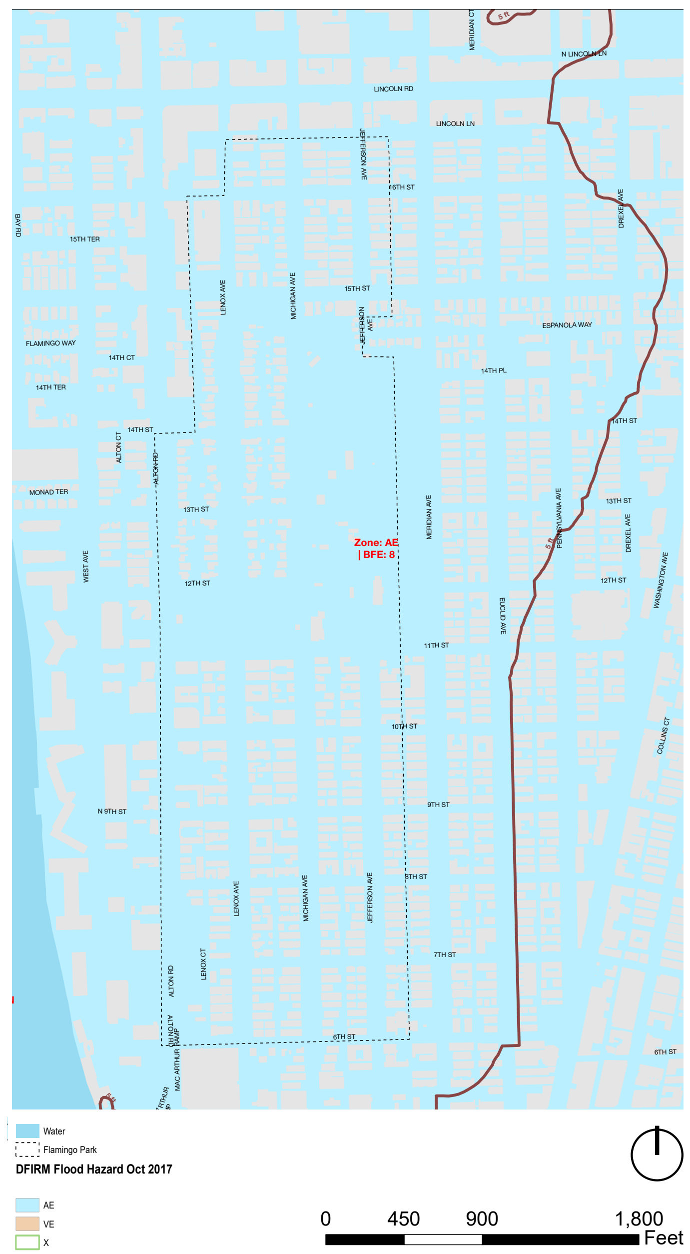
Flamingo Park Depth to Groundwater, South Florida Water Management District

Collins Waterfront Depth to Groundwater, South Florida Water Management District

Flood Risk Map | Current conditions

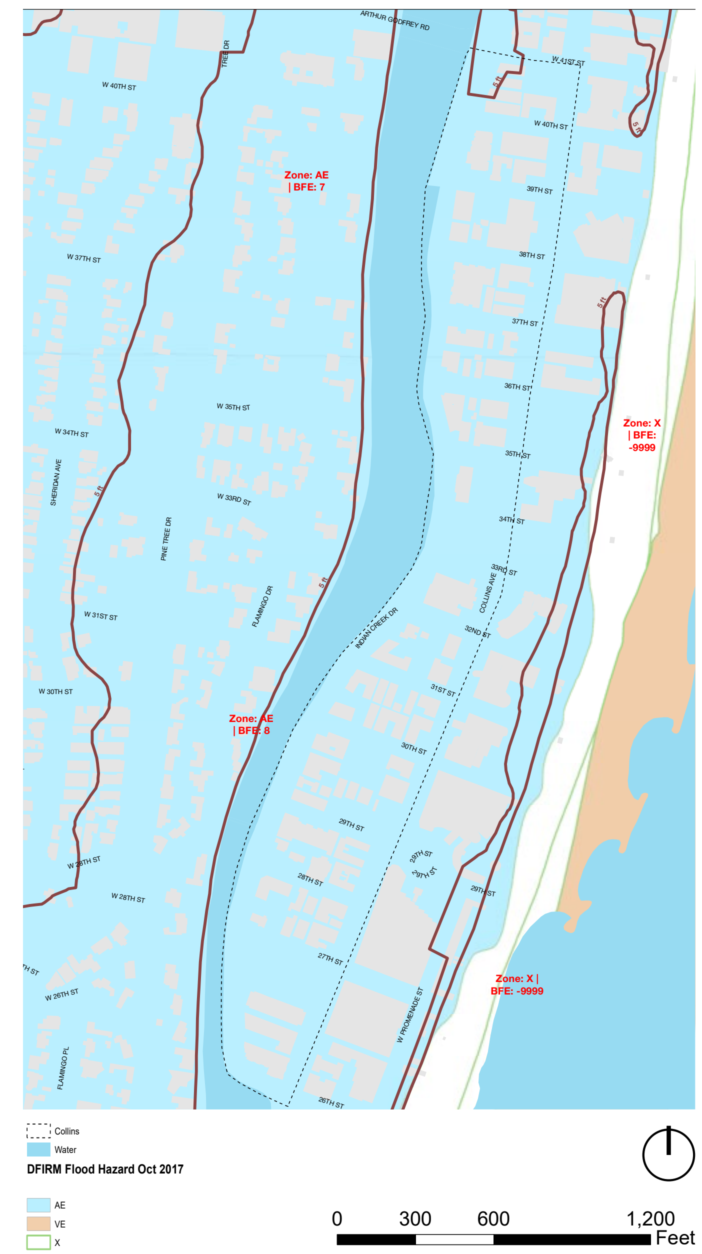
Flamingo Park District

Shown on these maps is the current 100-year storm floodplain and storm surge risk zones as provided by the Federal Emergency Management Agency (FEMA) Digital Flood Insurance Rate Maps (DFIRM) database. These are flood maps current as of October 2017 and show that currently both Flamingo Park and Collins Waterfront Districts fall within areas subject to inundation by the 1-percent-annual-chance flood event as determined by FEMA.



Flamingo Park 100-Year Flood 2017 DFIRM Map, FEMA and University of Florida GeoPlan Center

Collins Waterfront District



Collins Waterfront 100-Year Flood 2017 DFIRM Map, FEMA and University of Florida GeoPlan Center

SLR High Tide Projections 2040 | 2060 | 2080

Flamingo Park District

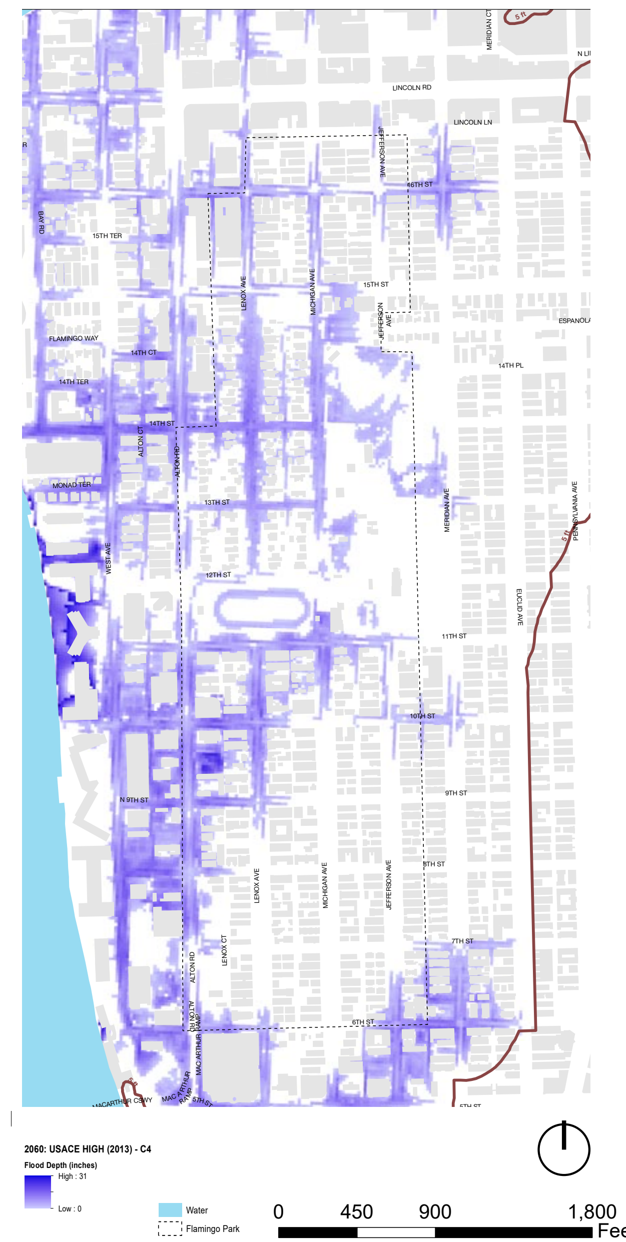
The following maps illustrate the potential extents and depth of inundation from sea level rise (SLR) projections in a given year. The darker shade of purple in a given map indicates a deeper level of inundation (higher water levels on land). These SLR estimates are based on Mean Higher High Water (MHHW) levels. The east cost typically sees two high tide events and two low tide events in a given day. MHHW levels refer to the average of the higher of the two high tides seen each day.

In accordance with the Southeast Florida Climate Change Compact guidance, the maps were created using the sea level rise projections as follows:

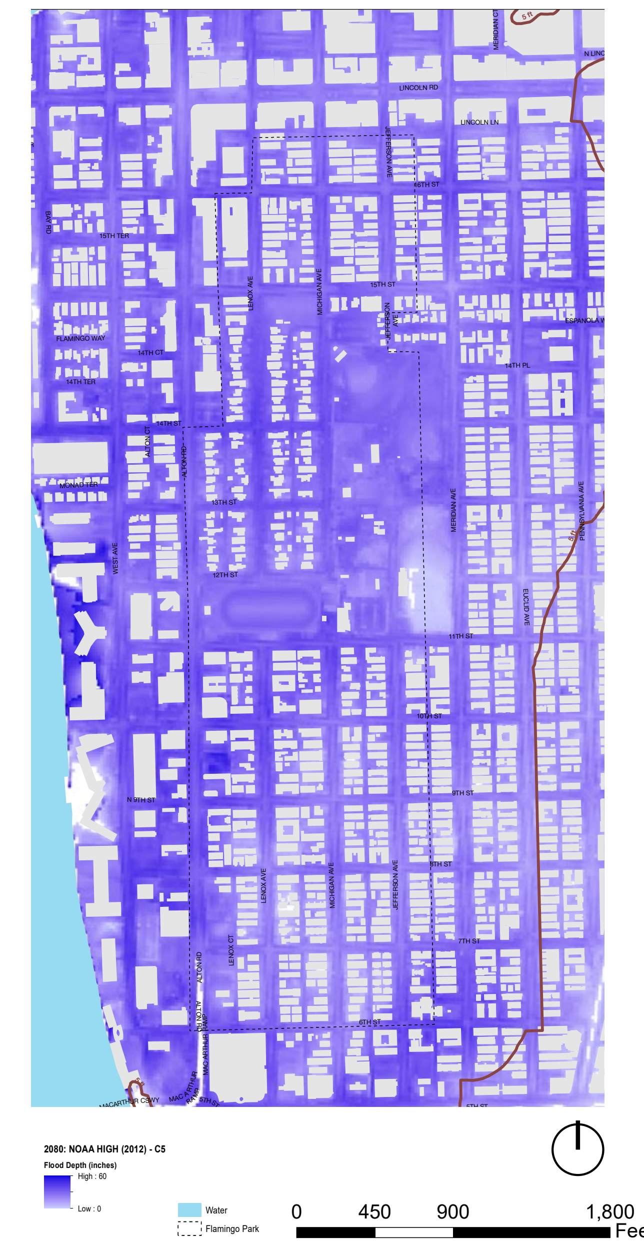
2040: USACE HIGH (2013)
2060: USACE HIGH (2013)
2080: NOAA HIGH (2012)

Data was gathered from GIS mapping information available from the University of Florida GeoPlan Center.

Flamingo Park 2040 USACE Sea Level Rise Projection (2013-High), USACE and University of Florida GeoPlan Center



Flamingo Park 2060 USACE Sea Level Rise Projection (2013-High), USACE and University of Florida GeoPlan Center



Flamingo Park 2080 NOAA Sea Level Rise Projection (2012-High), NOAA and University of Florida GeoPlan Center

SLR High Tide Projections 2040 | 2060 | 2080

Collins Waterfront District

The following maps illustrate the potential extents and depth of inundation from sea level rise (SLR) projections in a given year. The darker shade of purple in a given map indicates a deeper level of inundation (higher water levels on land). These SLR estimates are based on Mean Higher High Water (MHHW) levels. The east cost typically sees two high tide events and two low tide events in a given day. MHHW levels refer to the average of the higher of the two high tides seen each day.

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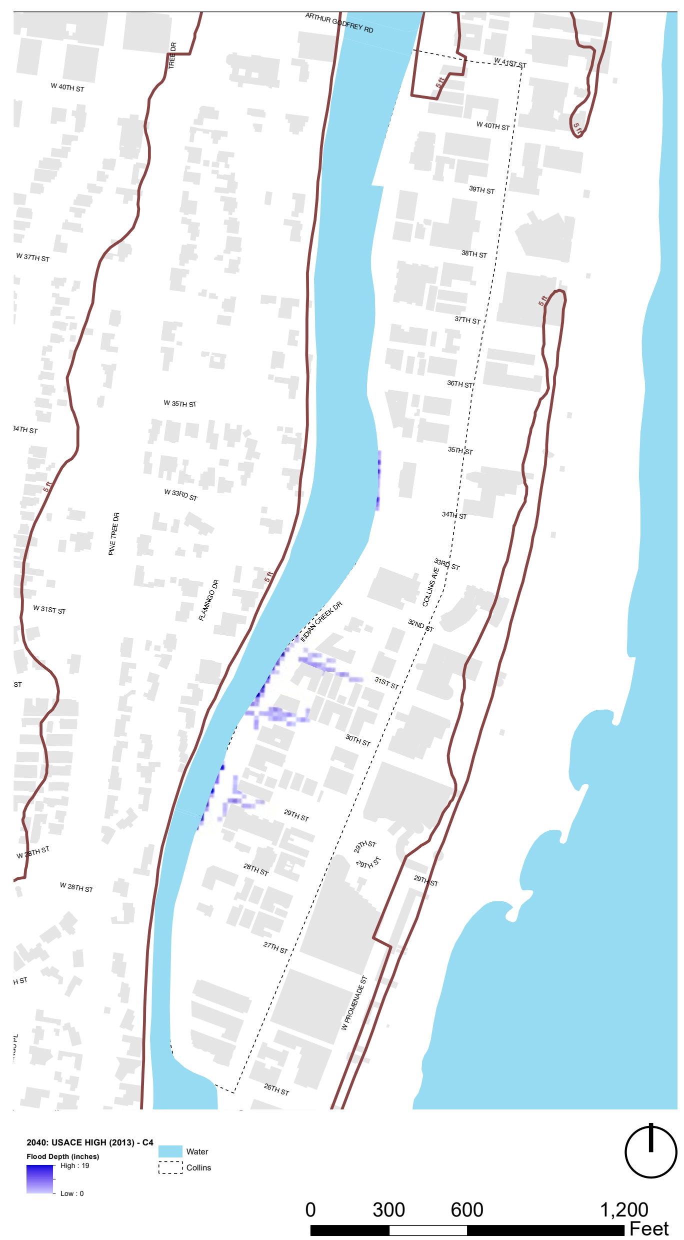
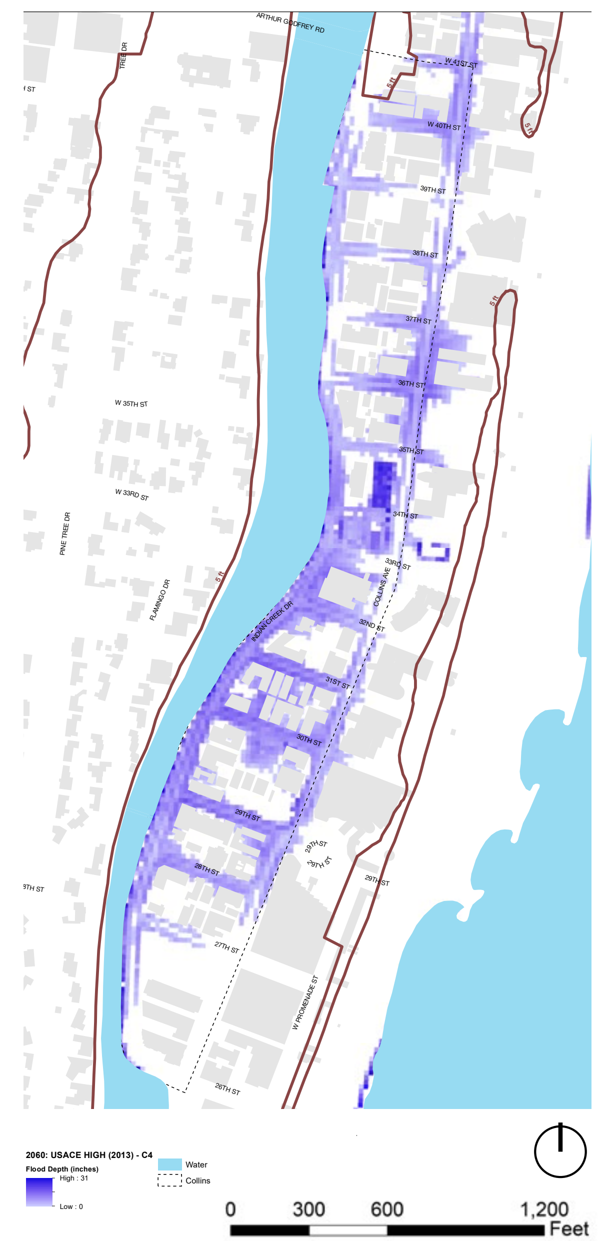
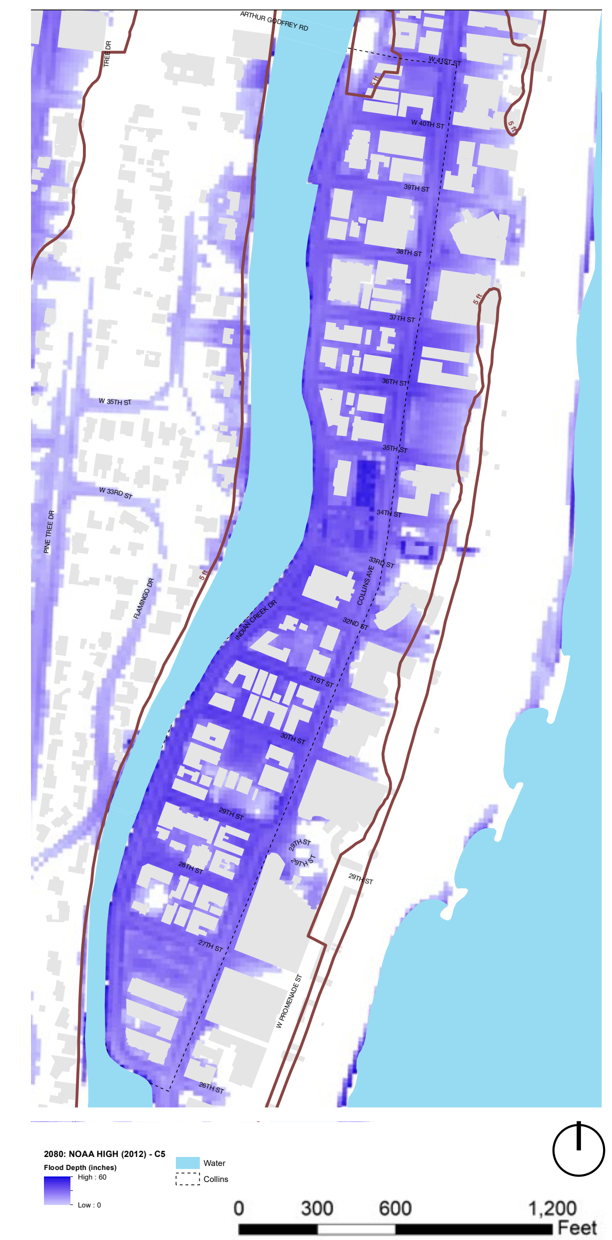


Collins Waterfront 2040 USACE Sea Level Rise Projection (2013-High), USACE and University of Florida GeoPlan Center



Collins Waterfront 2060 USACE Sea Level Rise Projection (2013-High), USACE and University of Florida GeoPlan Center



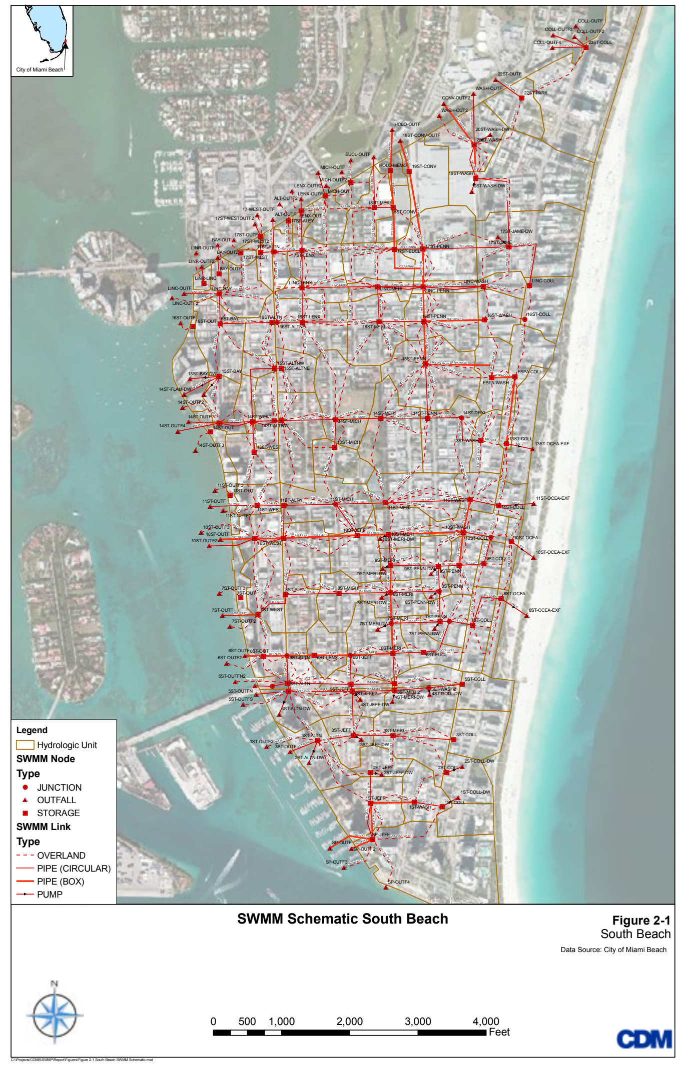
Collins Waterfront 2080 USACE Sea Level Rise Projection (2013-High), USACE and University of Florida GeoPlan Center

Stormwater Managment

Flamingo Park District

The Flamingo Park Historic District is approximately 355 acres in area with an existing stormwater management system that has been in place for many years. The storm sewer networks flow from the north towards the south along the alleys and Avenues; and from east towards the west along Streets. This stormwater system discharges into Biscayne Bay through approximately 14 outfall pipes, all of which are located along the western bulkheaded shoreline of Miami Beach. There are several stormwater pump stations along Alton Road that collect water runoff from these streets.

This system also includes approximately 203 drainage wells and an estimated 4,000 linear feet of exfiltration trenches. Drainage wells and exfiltration trenches are two types of stormwater management practices that provide pre-treatment and drainage for individual (or isolated) drainage basins. Drainage wells collect stormwater in perforated chambers and slowly release it to the surrounding soil. An exfiltration trench also collects water for release into the surrounding soil, but uses buried perforated pipes.



Flamingo Park Stormwater Management System, City of Miami Beach Map from COASTAL

Collins Waterfront District

The Collins Waterfront District includes an area of 80 acres consisting of condominiums and hotels between Collins Avenue and Indian Creek Drive. The existing stormwater system consists of a collection of pipes and manholes (known as a network) that discharges into the Indian Creek Canal. Storm water from many of the streets flows west into this network, and discharges under Indian Drive into the Indian Creek Canal through 6 outfall pipes.

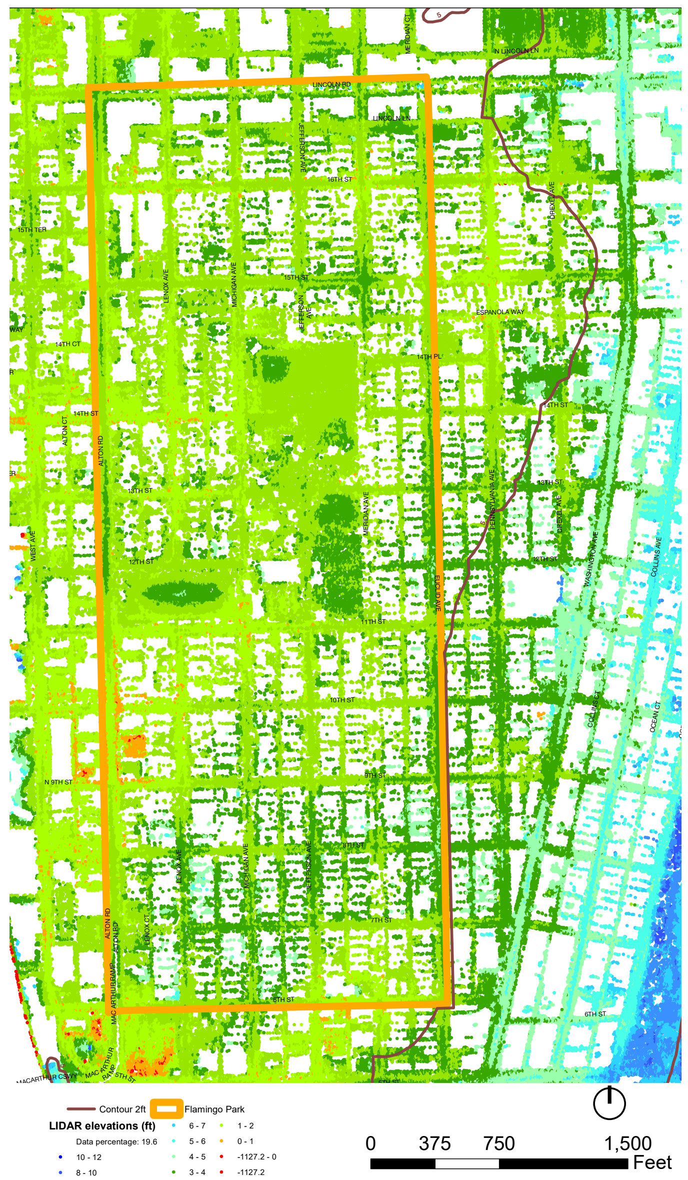
In general, as sea level rises, the capacity of the existing stormwater management system will diminish; stormwater management systems utilize the available dry soil above the aquifer to absorb the excess water, and an increase in water levels will decrease the natural drainage capacity of the area, resulting in more frequent flooding. Thus, future stormwater management systems will have to depend on pump-driven systems rather than gravity-driven systems.

Collins Waterfront Stormwater Management System, City of Miami Beach Map from COASTAL

Lidar Study Elevations

Flamingo Park & Collins Waterfront District

One of the challenging natural features of the Miami Beach area is the shallow depth to groundwater throughout the city. As shown in the map above, for the Flamingo Park District the groundwater table lies only at most four feet below the surface for most of the area. Because of this, sea level rise not only poses a threat from water encroaching inland from the shore, but also elevated groundwater rising up from below. This shallow groundwater is due in part to the relatively low elevation of the land area compared to sea level. Additionally, the presence of porous limestone below grade allows water to percolate through the rock layers beneath Miami Beach. As sea levels rise, there is a greater likelihood of saltwater intrusion from the ocean into the freshwater aquifer beneath the city that also serves a vital source of drinking water. A higher groundwater table also will mean less space available for infiltration of stormwater runoff into soil/rock that is already saturated.



Flamingo Park Elevations, City of Miami Beach LiDAR

Collins Waterfront Elevations, City of Miami Beach LiDAR

2.5 // RECOMMENDATIONS | WATER RELATED

2.5.1 // DESIGN FLOOD ELEVATION

Following projections from the South Florida Climate Change Compact (SFCCC) out to 2080, data suggests that water levels during cyclical and repetitive events like King Tides and rain events will exceed current standard of BFE +1 (9.0 NGVD) in the Flamingo Park and Collins Waterfront districts. Tracking current data, King Tides may reach 7.9' NGVD and 10-year rain event flooding may reach 8.6' NGVD.City of Miami Beach should re-examine the determination and application of Base Flood Elevation in order to promote and facilitate new development that preloads anticipated water conditions.

- Explore whether a more flexible standard for adapting historic properties is appropriate.
- Consider a new standard: Design Flood Elevation.
- Consider at what point the application of Design Floor Elevation to existing historic buildings is counterproductive.
- Agree provisionally on a set of flood projections, either following SFCCC or other projections. For the purpose of this study, 10.0 NGVD is used as a project DFE.

2.5.2 // RESISTANCE VS RESILIENCE

- By 2080, SFCCC projects that water levels during a 100-year Storm Surge will exceed current standard of BFE +1 (9.0 NGVD) in the Flamingo Park and Collins Waterfront districts. Tracking this data, a 100-year storm surge may reach 18.1' NGVD.
- Storm surge flooding raises complex issues, because raising ground floor levels and their underlying structure to meet these flood levels might imply an extraordinary and unreasonable amount of raising.
- As preliminary indications show the current average ground floor elevation in Flamingo Park district at 6.5' NGVD and the current ground floor elevation in Collins Waterfront district at 5.5, and using an average floor to floor elevation of 10', this would put even the second floor of most buildings at risk.
- Adapting historic building by raising floors would imply raising floor levels between 11.7' and 12.7' above current elevation, or more.

Resistance

- Adapted building structures should positively resist cyclical and frequent occurrence water events (King Tide, High Tide, Low Tide, rain events, etc.). This will involve either raising floor levels, or dry- or wet-floodproofing ground floors and their structures to the city's new DFE.
- This work may include reconstructing floor levels, changing the materiality of the ground floor, and at times altering ground floor use.

Resilience

- Adapted buildings should be upgraded to be resilient to infrequent storm surges (100-year storm surge). This means accepting the water and bouncing back as quickly as possible.
- This would certainly indicate upgrading the structure and shell of the building to withstand storm surge impacts.
- It may involve wet-floodproofing buildings to anticipated storm surge levels (for instance by incorporating flood vents), material change in structure, and the use of flood resistant materials in construction and finishes.