Design Studio:

MIAMI BEACH

Resiliency and Adaptations by Design

May 2016

Design Studio

Rutgers
Edward J. Bloustein School
of Planning and Public Policy

Miami Beach
Resiliency and Adaptations by Design

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ACKNOWLEDGEMENT

We thank Susanne M. Torriente, Chief Resiliency Officer/Assistant City Manager, City of Miami Beach, Florida for her time and effort to direct us to the issues facing the city throughout this century. We would like to acknowledge AECOM, especially Marcia Tobin and Jason Bird, for their attention and responses to our questions and design solutions. We would also like to thank all of the faculty members at the Edward J. Bloustein School of Planning and Public Policy, particularly Professors Juan Ayala and Barbara Faga, for their feedback throughout the length of our project.

For April 26, 2016 Student presentation go to: https://ru-stream.rutgers.edu/media/Faga+Studio+Presentation+April+2016+-+Clipped/1_8wy7tejk

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EXECUTIVE

Once a mangrove swamp and built on unstable limestone of a barrier island, Miami Beach is learning to "Live With The Water." The City is sometimes waterlogged by king tides, sunny day flooding, and faces a serious threat from Sea Level Rise (SLR). The City is working to combat water from seeping in -- Miami Beach is proactively working to address SLR. With its economy, culture, and diversity is at risk the City of Miami Beach is acting now to ensure its future.

This document is the final product of the Rutgers, Edward J. Bloustein School of Planning and Public Policy's Spring 2016 Graduate Design Studio. The 14-student Studio Team, working with AECOM and led by Professor Barbara Faga, compiled creative solutions for solving the SLR problem specifically for the City of Miami Beach. Goals of this project are; 1) to implement adaptation and protection strategies to keep the city of Miami Beach dry, 2) create designs that work with water, and 3) create a sustainable culture for the community Within this document is a unique methodology that prioritizes flood areas where risks and vulnerabilities are high, 16 out-of-the-box and place-based SLR solutions, several zoning recommendations, and estimated phasing as well as possible funding sources. The Studio also studied the City and researched similar national and international case studies. It is the Design Studio's hope that Miami Beach will be inspired by our recommendations as they continue to ensure the island's sustainability into the next century.

The 16 SLR design solutions are designed specifically for four neighborhoods, herein referred to as "Adaptation Action Areas" or "AAAs". These AAAs were identified as having high flood risks that could expose local vulnerabilities such as traditionally underrepresented populations, evacuation routes, or major economic developments, among others. The four AAAs are comprised of North Beach, Mid-Beach, and two South Beach locations. Some solutions are purposefully located in multiple AAAs while others are uniquely situated.

Elevate

Elevated Buildings are one of the most common design combatants to flood waters. The Studio proposes the City utilize this popular mitigation strategy. However, the Design Studio also proposes out-of-the-box approach to elevated buildings -- not as a mitigation strategy, but as an adaptation strategy. Amphibious Structures are buildings situated on land that adapt to flooding by elevating and floating as the tide rises. The same concept for Elevated Buildings can be applied to Elevated Streets - the same concept for Amphibious Structures can be applied to Hydraulic Streets. One other elevation strategy designed by students is the Pedestrian Bridge, inspired by Hamburg, Germany and Isaac Stein in his University of Miami student

AND ADAPTATIONS BY DESIGN

SUMMARY

project. This bridge interlinks economic centers via an active elevated sidewalk.

Defend
Like the pedestrian bridge, the Multi-Purpose Levee or the "Bay Line" is an active outdoor pedestrian oriented-space. This design solution proposes a large 200-foot-wide-based levee on the Bay Side of the island that can integrate additional land uses. This unique linear waterfront park will act as a natural buffer to the Bay. Mangrove Piers and Land Moats will also act as a buffer to the City, where mangrove piers will be planted with the intent of mangroves "filling in" between piers and land moats, or landscaped buffers, protecting shoreline homes. The Land Moat Embankment Hybrid is another defense mechanism to mitigate SLR. This design utilizes a hard-engineered core in a landscaped embankment in combination with the above mentioned land moats. Lastly, the uniquely situated Indian Creek Drive Design System is a complex embankment barrier that utilizes mangrove nurseries and permeable planters across both sides of Indian Creek Drive of Mid-Beach.

Living With the Water
Defending against water isn't the only solution. Miami Beach must also learn to "Live With the Water." One way the City could do this is by integrating a modern Water Moat - yes, the type of moat you typically see around castles. By locating this moat around a city block beneath a grated sidewalk, the City can increase its water storage. At a grander scale, a Park Reservoir, involves reconstructing Flamingo Park so that it could store water in an engineered system beneath. A canal would funnel the water to the Bay. Another canal, the 34th Street Canal, would also funnel water from Indian Creek to Oceanside and doubly act as Miami Beach's own piece of Venice.

Out-of-the-Box.
Additional out-of-the box solutions were creatively designed. A Green Roof Parking Structure System is integrated throughout many of the AAAs in which a rooftop "greenway" links several structures together. Others, like the Water Tower solution, can act as a gateway into the City since the Tower is a tall structure that not only stores water, but is also uniquely designed- like an art piece or well-known destination. Depending on size, the Tower could accommodate a viewpoint from the top for citizens. A Flood Defense Barrier inspired by Dutch flood solutions was also designed for the Bay. Proposed Limestone Solutions is one of the most interesting designs since it attacks the problem at the core. This solution involves either a vertical or horizontal layer of clay to be integrated into the porous limestone bedrock in which the City sits.

METHODOLOGY

A resilient city:

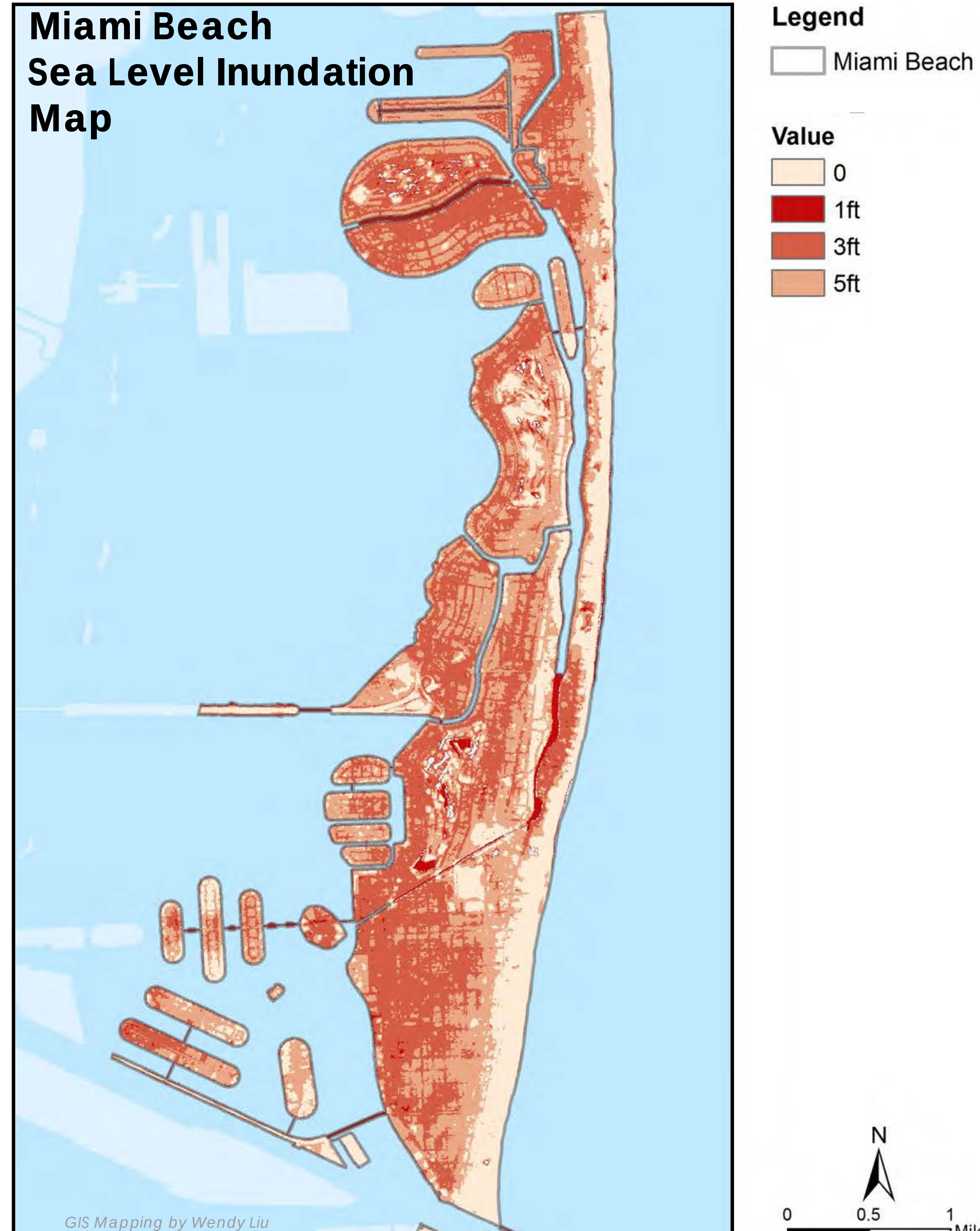
- *Delivers basic needs;*
- *Safeguards human life;*
- *Protects, maintains and enhances assets;*
- *Facilitates human relationships and identity;*
- *Promotes knowledge;*
- *Defends the rule of law, justice, and equity;*
- *Supports livelihoods;*
- *Stimulates economic prosperity*

Arup - City Resilience Framework, pg 4

The intent of this methodology is to illustrate Miami Beach's priority areas based on key risk and resiliency factors. Resilience planning promotes a city that survives and functions as a whole regardless of future shocks and stresses.[1] Therefore, The Design Studio created a broad based resilience risk vulnerability priority methodology for determining which areas were most important to the functioning of Miami Beach as well as most at risk of future shocks and stresses.

The resilience priority risk methodology drew from two key sources: ARUP's Resilience Index Framework as part of the Rockefeller Institute's 100 Resilient Cities program, and the National Oceanic and Atmospheric Administration's Coastal Resilience Index for the Gulf Coast. The resilience risk priority methodology attempts to cover the physical assets required for Miami Beach to survive and thrive. However, it is important to consider that social infrastructure is also required to create a resilient city including effective leadership, empowered stakeholders, social stability & security, and collective identity & support.[2]

Using these resources as a starting point, the Design Studio formed a methodology based on seven criteria. These criteria reflected Miami Beach's future threats, key cultural and economic considerations, population demographics, and service provisions. These criteria are: Sea Level Rise, Population Density, Traditionally Underrepresented Populations which includes minorities, low income populations, and the elderly, Proximity to Green Space, Historic Cultural Assets, Critical Infrastructure which additionally includes evacuation routes, and Assessed Property Values. The Design Studio chose not to include several categories in the methodology, including environmentally sensitive areas and soil types due to the high percentage of urban land uses (91%) and the lack of detailed soil data (listed as urban). Each of the selected criteria are discussed in detail. We used a double weighted methodology for risk and priority for each of the key resiliency criteria outlined above. Each criterion were rated on a 5-point risk vulnerability scale, 1-point represented a low risk for the category, and 5 a high risk. We applied a multiplier based on the category's priority level -- low (x1), medium (x2), high (x3), and critical (x4). A low priority level reflects Miami Beach's priorities and considerations -- such as green space. A medium priority level represents important concerns, but not the City's critical needs. A high priority level represents physical assets and priorities that are required for the functioning of the City. A critical priority level represents concerns that require immediate



NOAA Sea Level Rise Estimate Comparisons

1 foot SLR **3 foot SLR** **5 foot SLR**

Source: NOAA Sea Level Rise and Coast Flooding Impact Maps

attention. The Design Studio used the methodology to apply the weighted risk vulnerability score to the entire island for a complete overlay analysis in ArcGIS. This methodology was discussed and adjusted through several conversations with AECOM. Sea Level Rise (20% weight) Miami Beach sits on a barrier island, most of which is below a 6-ft elevation. Sea Level Rise will dramatically change the landscape of Miami Beach, inundating the majority of the City, as seen in the inundation map. This is a change that cannot be ignored; the City is working to adapt. The Studio created an inundation map using Florida Digital Elevation Modeling tiles at a 5-meter resolution, with a scale of <1 ft., <3ft, and <5ft. Our compiled data matched the National Oceanic and Atmospheric Administration (NOAA) predictions for SLR in Miami Beach, as seen to the left. These inundation levels were assigned a risk score based on their inundation level, as seen in the Risk Priority Methodology table. Population Density (10% weight) The Design Studio recognizes that one of the factors in protecting a community is mitigating human losses, whether in the form of injury or death. High population densities pose higher risks for human losses in the event of a disaster. Moreover, these areas require more services to guarantee a quality standard of living, and are more sensitive to disruptions, such as long term flooding. These rationales directly relate to ARUP's mitigating human vulnerability requirement -- ensuring that everyone's minimum needs are met.[3] However, the Design Studio recognizes that high population densities tend to live in less flood prone mid- to high-rise building typologies. Therefore, this data was assigned a medium priority level, to reflect the importance of preventing service disruptions. The risk weight was determined based an area's population density quintile, with the highest density areas assigned a risk score of 5, and the lowest density areas assigned a risk score of 1.

Traditionally Underrepresented Populations (25% weight)

In order to address environmental justice issues, traditionally underrepresented populations were included in the methodology -- median household income, racial minorities, and the elderly. The justification of each category is similar, resulting in a combined grouping. These categories were weighted independently of each other and therefore have differing priority weights. The Studio referenced the Miami-Dade Metropolitan Planning Organization's 2040 Long Range Transportation Plan to identify vulnerable populations. The MPO lists disadvantaged populations including minorities, the elderly, youth, persons with disabilities, and individuals residing in low-income households. Using 2014 American Community Survey data, the Studio obtained elderly and youth data by age, median household income data, and minority data by race and ethnicity. Persons with disabilities data does not exist through the census. Due to a lack of source data, the Studio opted not to include persons with disabilities in the methodology. Minorities and median household income were perceived to be important but not critical to city needs or risks (Medium - 10%), where the elderly and youth were identified as a priority and consideration for the City (Low) and were assigned a weight of 5%. The risk level weighting for each category is seen in Table 1. Green Space (5% weight) Green spaces represent areas that can absorb flooding without major economic or population disruption. After an extreme flood or large-scale disaster event, potential environmental consequences include losses of native vegetation, alteration of habitat, loss of biodiversity, water quality degradation, loss of shoreline habitat, loss of recreational opportunities, loss of land and decreased landscape appeal, among others.[4] More importantly, green space can act as a natural buffer and a short-term rainwater storage solution. This is extremely important in Miami Beach, where according to USDA NRCS data, 91% of land (excluding beaches) is classified as urban. Therefore, those geographies located further away from green space are at higher risk for flooding and received a higher risk value. The precise weighting of the risk values is seen in Table 1.

Historic and Cultural Assets (10% weight)

Historic sites and districts in Miami Beach are important resources that reflect the City's rich historic character and legacy. As such, it is essential to protect these cultural assets and preserve the City's heritage for future generations to enjoy as well as establish a context for future development. Moreover, these historical assets provide a tourist draw for the city of Miami Beach -- a vital component of the local economy. Protecting these assets contributes to the maintenance of a resilient, diverse, and stable economic system.[5] The methodology counted any parcel that either contained a historic building or was within a historic district to be a historic and cultural asset. Therefore, we assigned these areas a risk value of 5, and all other areas a value of 1. critical infrastructure (15% weight) Critical infrastructure is broken up into two subcategories, in order to graphically organize data -- critical infrastructure and evacuation routes. Together, these two sub-

METHODOLOGY

categories have a critical priority rating. However, each category is weighted based on their relative importance to the day-to-day functioning of Miami Beach.

Critical Infrastructure (15% weight)

Critical infrastructure is broken up into two subcategories, in order to graphically organize data -- critical infrastructure and evacuation routes. Together, these two subcategories have a critical priority rating. However, each category is weighted based on their relative importance to the day-to-day functioning of Miami Beach.

Critical infrastructure are the facilities and services required to keep a city running. These facilities include hospitals, police stations, fire stations, emergency shelters, electrical substations, sewer pumps, sewage treatment facilities, and potable water pumps.[6] The facilities were mapped and assigned risk based on proximity to the critical infrastructure locations. Protecting these assets is necessary for Miami Beach to continue providing basic services for the community.[7] Moreover, it would take a significant investment to relocate these resources. Therefore Critical Infrastructure is assigned a high level of prioritization, weighted at 15%. The risk values were assigned based on proximity to critical infrastructure, so as to create a buffer zone to protect the key pieces of infrastructure, as seen in the Risk Priority Methodology table to the right.

Evacuation Routes (5% weight)

The Southeast Florida Compact Inundation Map and Vulnerability Work Group mapped vulnerable locations for 13 municipalities in Broward County, Florida using SLR models produced from the Southeast Florida Regional Climate Assessments. The Vulnerability Work Group specifically focused on the potential impacts of SLR on municipal infrastructure using 1-foot and 2-foot scenarios. One of the criteria used were evacuation routes. The Studio, using the Regional Climate Action Plan as a base, looked at the accessibility of these routes under each SLR scenario. Evacuation routes are vital to emergency response plans, but are less important in identifying the long term vulnerability of neighborhoods. Therefore, evacuation routes have a weight of 5%, reflecting the need to protect these assets from SLR.

Assessed Property Values (10% weight)

Market based economic impacts resulting from physical destruction affect the lives of individuals, businesses, governments, and the regional economy. Whether a direct loss in asset value or a loss in income or production, protecting high value properties is an important factor in planning for the City's fiscal resilience.[8] Fiscal resilience allows Miami Beach to plan for and react to future climate impacts and weather events through retrofit payments, or float capital improvement bonds. Therefore, the Design Studio has applied a medium weight of 10% to this criteria, to ensure the City's fiscal flexibility. The risk values were determined based on the property value's relative quintile. Properties within the high quintile of values were assigned a 5, and properties in the lowest quintile were assigned a 1.

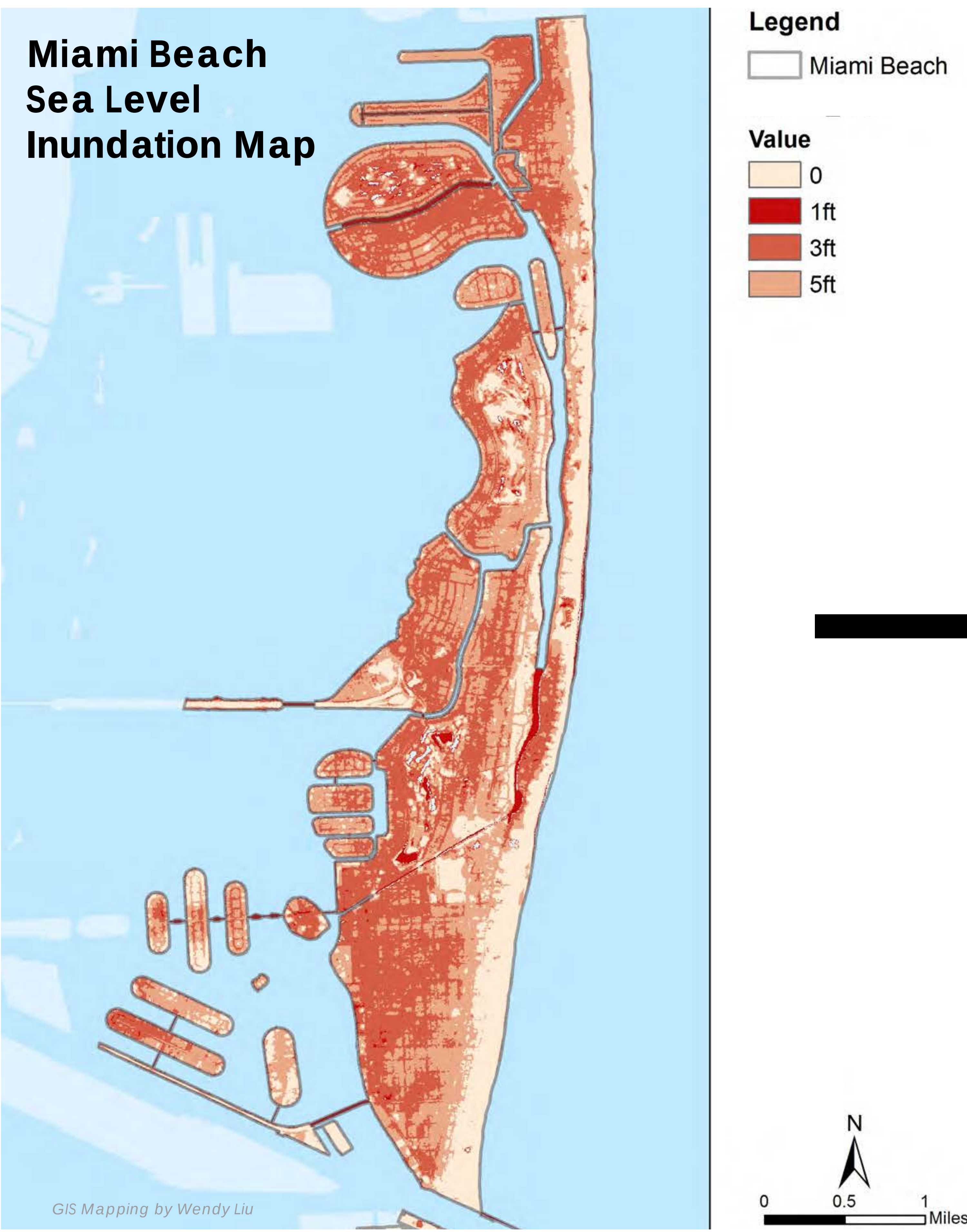
The most vulnerable neighborhoods to SLR economically, socially, and environmentally were identified as Adaptation Action Areas (AAAs) as a result of this methodology

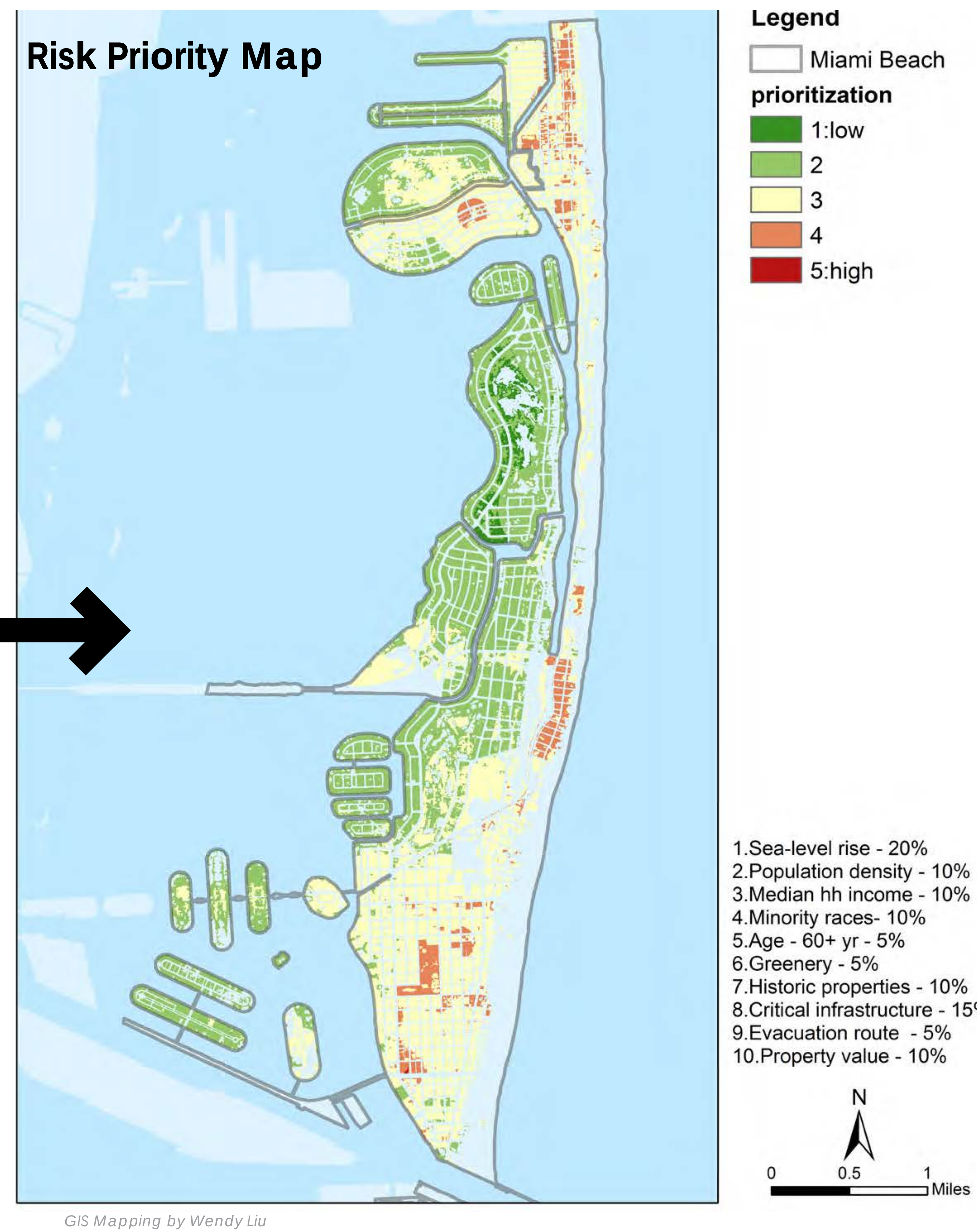
Conclusions

In addition to pinpointing the Adaptation

Risk Priority Methodology

Criteria	Scale	Risk Score	Priority Level	Weight
Sea Level Rise	1 ft	5	High	20 %
	3 ft	3		
	5 ft	1		
	Other	0		
Population Density	<20% Quintile	1	Medium	10 %
	21-40% Quintile	2		
	41-60% Quintile	3		
	61-80% Quintile	4		
	>80% Quintile	5		
Median Household Income	<20% Quintile	5	Medium	10 %
	21-40% Quintile	4		
	41-60% Quintile	3		
	61-80% Quintile	2		
	>80% Quintile	1		
Racial Minorities	<20% of population	1	Medium	10 %
	21-40% of population	2		
	41-60% of population	3		
	61-80% of population	4		
	>80% of population	5		
Age - 60+ years	<20% of population	1	Low	5 %
	21-40% of population	2		
	41-60% of population	3		
	61-80% of population	4		
	>80% of population	5		
Greenery	1-500 ft	1	Low	5 %
	500-1000 ft	3		
	>1000 ft	5		
Historic Properties	Historic Building/District	5	Low	10 %
	Non Historic Building/District	1		
Critical Infrastructure	<500 ft	5	High	15 %
	500-1000 ft	3		
	> 1000 ft	1		
Evacuation Route	<500 ft	5	low	5 %
	500-1000 ft	3		
	> 1000 ft	1		
Assessed Property Value	<20% Quintile	1	Medium	10 %
	21-40% Quintile	2		
	41-60% Quintile	3		
	61-80% Quintile	4		
	>80% Quintile	5		


Miami Beach
Sea Level
Inundation Map
Legend
Miami Beach
Value
0
1ft
3ft
5ft
N
0 0.5 1
Miles
GIS Mapping by Wendy Liu


Risk Priority Map
Legend
Miami Beach
prioritization
1:low
2
3
4
5:high
1.Sea-level rise - 20%
2.Population density - 10%
3.Median hh income - 10%
4.Minority races- 10%
5.Age - 60+ yr - 5%
6.Greenery - 5%
7.Historic properties - 10%
8.Critical infrastructure - 15%
9.Evacuation route - 5%
10.Property value - 10%
N
0 0.5 1
Miles
GIS Mapping by Wendy Liu

ADAPTATION ACTION AREAS

Action Areas (AAAs)through the use of the methodology, additional qualitative criteria was taken into consideration. Specifically, the Design Studio identified State Roads in each of the AAAs since the state does not recognize SLR. Therefore, considering the above quantitative methodology in combination with qualitative information obtained from AECOM, the Design Studio identifies the following AAAs:

North Beach - North Shore (16 Blocks) - 75th to 79th St. & west of Abbott Ave.
The North Beach AAA was chosen for its lack of State Roads, its residential landscape and the presence of a school that the Studio believes will provide a key community anchor. However, North Beach in general is an area that has a high resiliency risk priority level, and should not be ignored.

Mid-Beach (18 Blocks) - 26th to 41st St.
The Mid-Beach AAA was chosen due to the presence of 2-3 pieces of critical infrastructure, high assessed property values, high population densities, elderly representation, historic district properties, and high SLR. As a critically important commercial area, despite the presence of State Roads, this area also protects the bay-side.

South City Center (20 Blocks) - South to 14th St. from Washington to Euclid & west to Jefferson Ave.
This South Beach AAA was chosen for its iconic Lincoln Road portion, other cultural assets, presence of

Legend

- Miami Beach

prioritization

- 1:low
- 2
- 3
- 4
- 5:high

1.Sea-level rise - 20%
2.Population density - 10%
3.Median hh income - 10%
4.Minority races- 10%
5.Age - 60+ yr - 5%
6.Greenery - 5%
7.Historic properties - 10%
8.Critical infrastructure - 15%
9.Evacuation route - 5%
10.Property value - 10%

N
0 0.5 1 Miles

Mid Beach

GIS Mapping by Wendy Liu

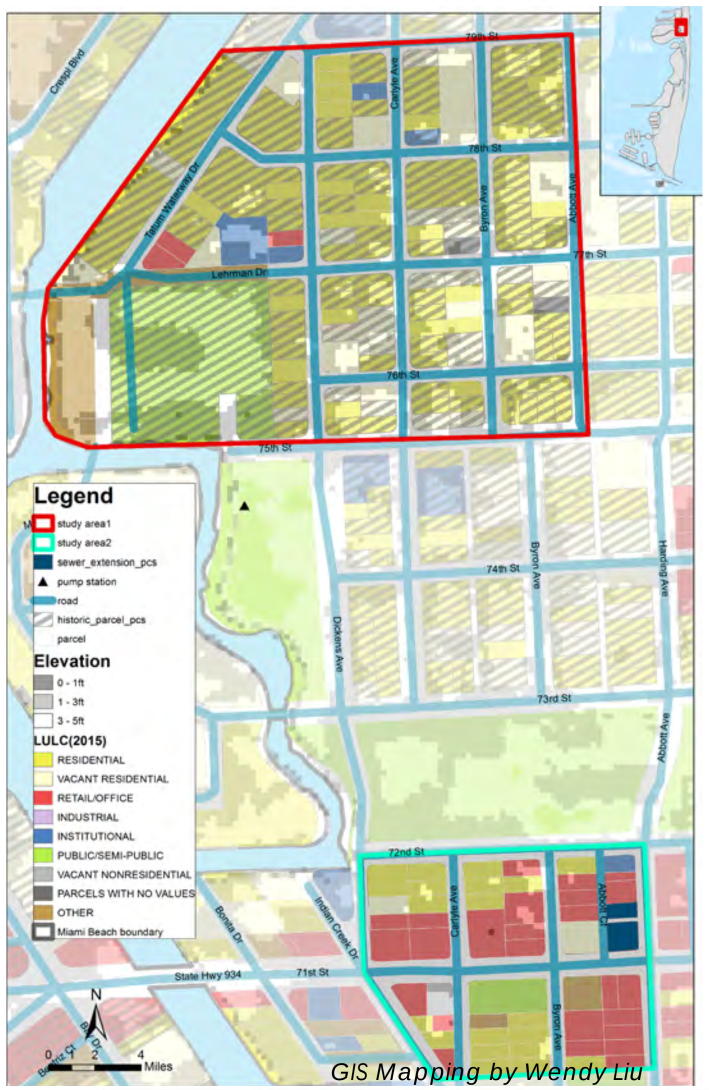
green space, high assessed property values, flooding hot spots, mixed-use landscape, and lack of state roads.

Flamingo/Lummus (12 Blocks) - 5th to 9th St. & Jefferson Ave. to West Ave.
The South Beach AAA was chosen due to its high risk score, proximity to the bay, low elevation, and mixed residential character.

Recommendations

The Design Studio recommends re-running this methodology every 10 years, in order to respond

North Beach

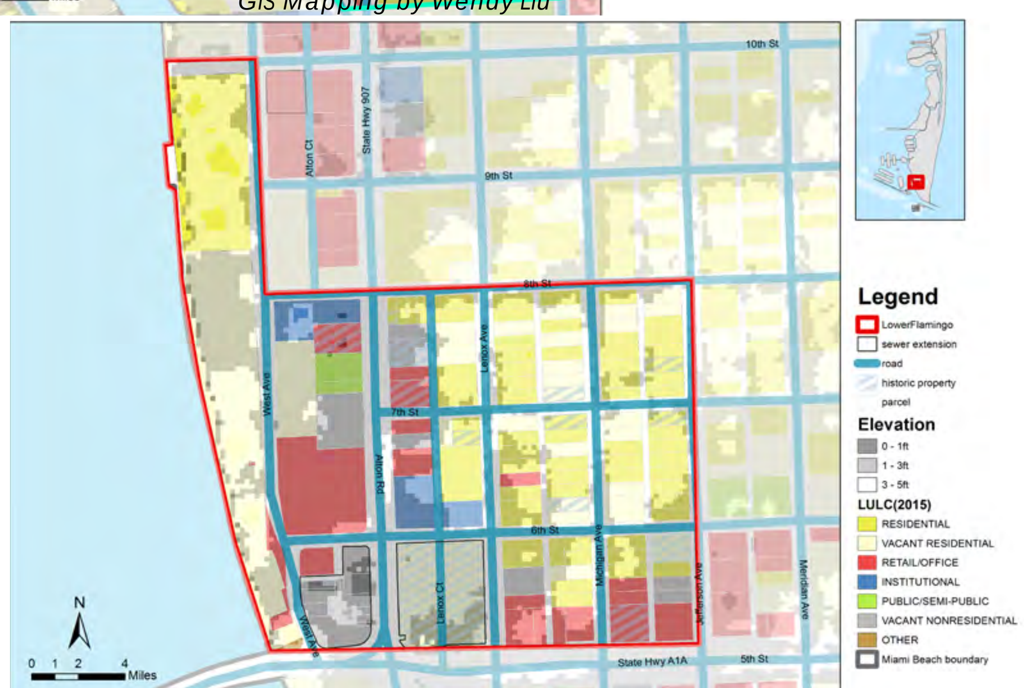


GIS Mapping by Wendy Liu

City Center

GIS Mapping by Wendy Liu

Lummus/ Flamingo



GIS Mapping by Wendy Liu

Neighborhood Risk Priority Scores

Diagram by Jenny Mei

ENVIRONMENTAL ANALYSIS

Limestone is a sedimentary rock made of calcium carbonate from the remains of old coral, molluscs, or forams. Limestone is also soluble in slightly acidic water, causing sinkholes.

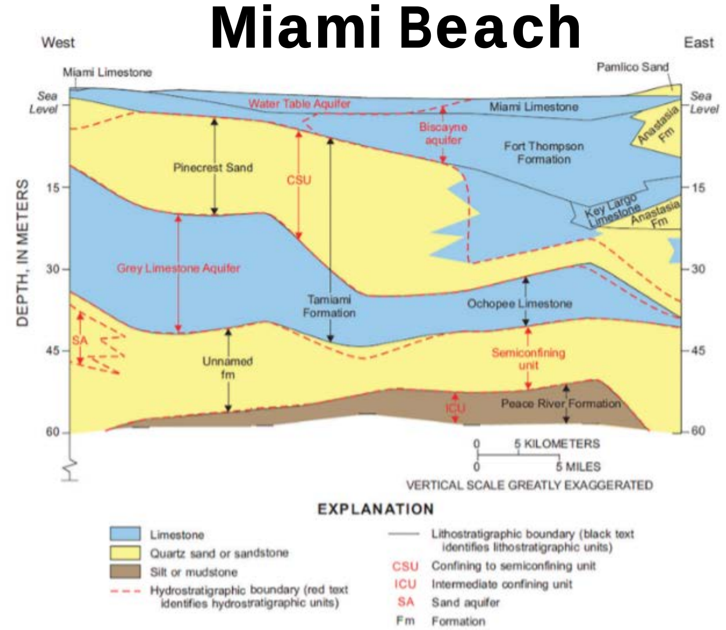
Miami Beach is a series of natural and man made barrier islands on the eastern side of Biscayne Bay. Ninety-one percent of the city is classified as urban, with little natural or green spaces left to react to sea level rise, which increases the number of days of tidal flooding, hastens erosion effects and slowly submerges the city. **By 2100, approximately 90% of Miami Beach will be inundated** The breadth of the physical, economic and social issues Miami Beach will bear as a direct link to Sea Level Rise are so significant that the City of Miami Beach is takingimmediate action. The City simply cannot afford to repeatedly repair and increase sea armaments to keep pace with the anticipated 5 feet of sea level rise over the next 100 years. These simple facts necessitate an environmental call to action. This section outlines the environmental challenges Miami Beach faces including soil and geological conditions, elevation, and the lack of prior ecological functions. Environmental case studies are additionally provided for Southern Florida as a whole with targeted environmental solutions for Miami

Soil, Hydrology, and Geology

The barrier island is made up of sand above porous coraline key largo limestone.[2] These geological conditions provide the City of Miami Beach with two challenges. First, the sand soil layer does not trap and hold water well; it rapidly drains water into the high and variable Biscayne Aquifer below, raising the water table.[3] This results in a groundwater storage capacity of a mere 0.3" across the entire city.[4] Unfortunately, the lack of ground water capacity limits Miami Beach from considering ground-storage solutions for temporary flooding such as green infrastructure solutions like stormwater trees and trenches. [5]

Second, the porous nature of the limestone bedrock means that water, as a result of sea level rise, is slowly seeping up through the ground into urban Miami Beach. Miami Beach is unlike other low lying areas, like the Netherlands, which have a less permeable clay soil layer, preventing the ocean

Water Table, Miami Beach



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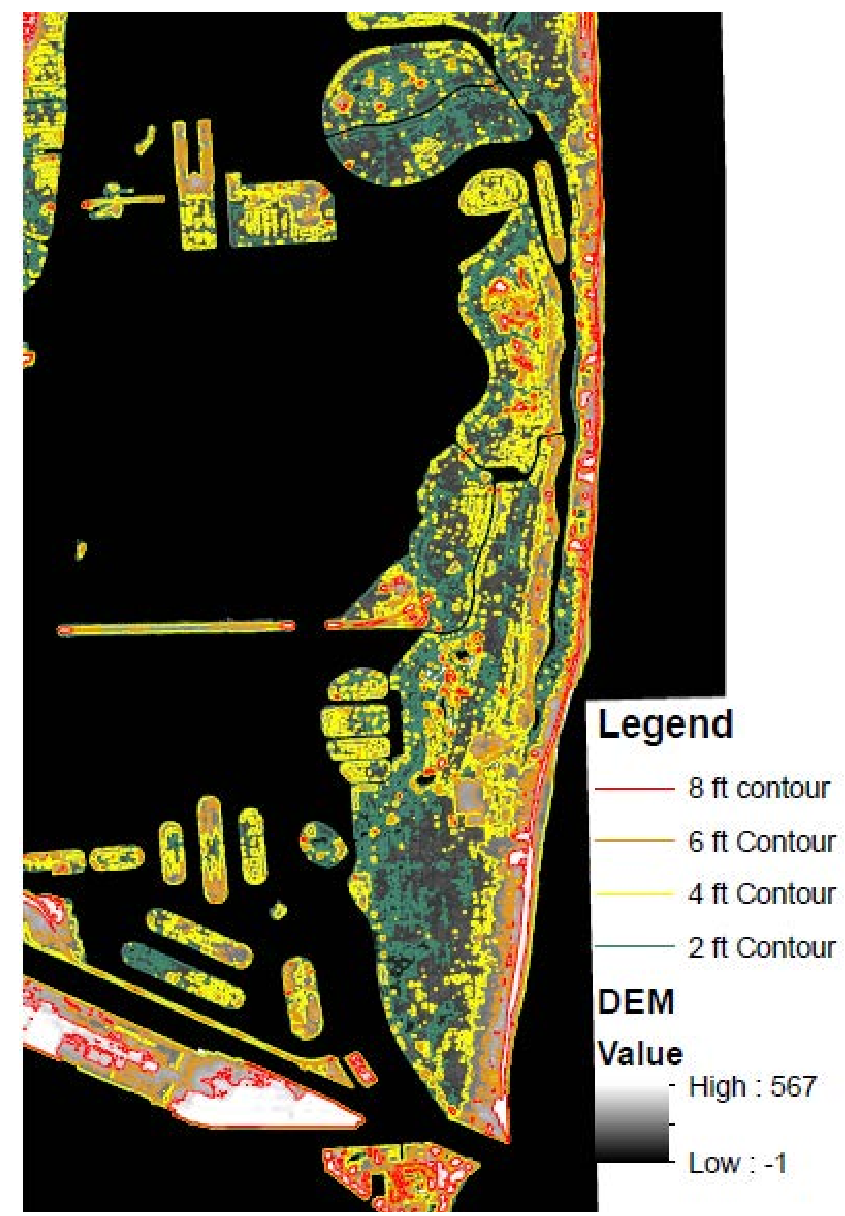
from marching further in.[6] Miami Beach's limestone presence means that even if the inevitable sea level rise is held back, the city will still flood unless something is done to "plug" the limestone. Limestone is a sedimentary rock made of calcium carbonate from the remains of old coral, molluscs, or forams. Limestone is also soluble in slightly acidic water, causing sinkholes.[7]

The confluence of climate change and sea level rise will literally dissolve the bedrock that Miami Beach sits on. Currently, the ocean absorbs around 25% of all CO_2 emissions.[8] The CO_2 then reacts with other chemicals in the sea to lower the ocean's pH and carbonate ions, and carbonate minerals.[9] In fact, since the industrial revolution, the ocean has seen a .01 pH drop - becoming approximately 30% more acidic over the past 150 years. Together, these limit the amount of carbonate available to reefs, increasing the erosion levels around Miami Beach. More importantly, it increases the key largo limestone dissolve rate. This may lead to sinkholes opening up underneath Miami Beach.[10]

Miami Beach Contour Map



GIS Map by Andrew Pagano

Environmental Transect

Miami Beach is almost completely urbanized. Only 9% of the city approaches a natural condition. We cannot design for long term solutions without understanding what interventions might work for a floridian barrier island. It is essential to understand the barrier island environmental transect and apply it to Miami Beach.

Floridian barrier islands have four distinct types of vegetation zones -- dune grasses, salt marshes, hardwood hammocks and mangroves. Each zone is differentiated by distance from the ocean and the elevation of the terrain. How each of these ecosystems work is outlined in the Miami Beach Natural Environments diagram.

Miami Beach Natural Environments

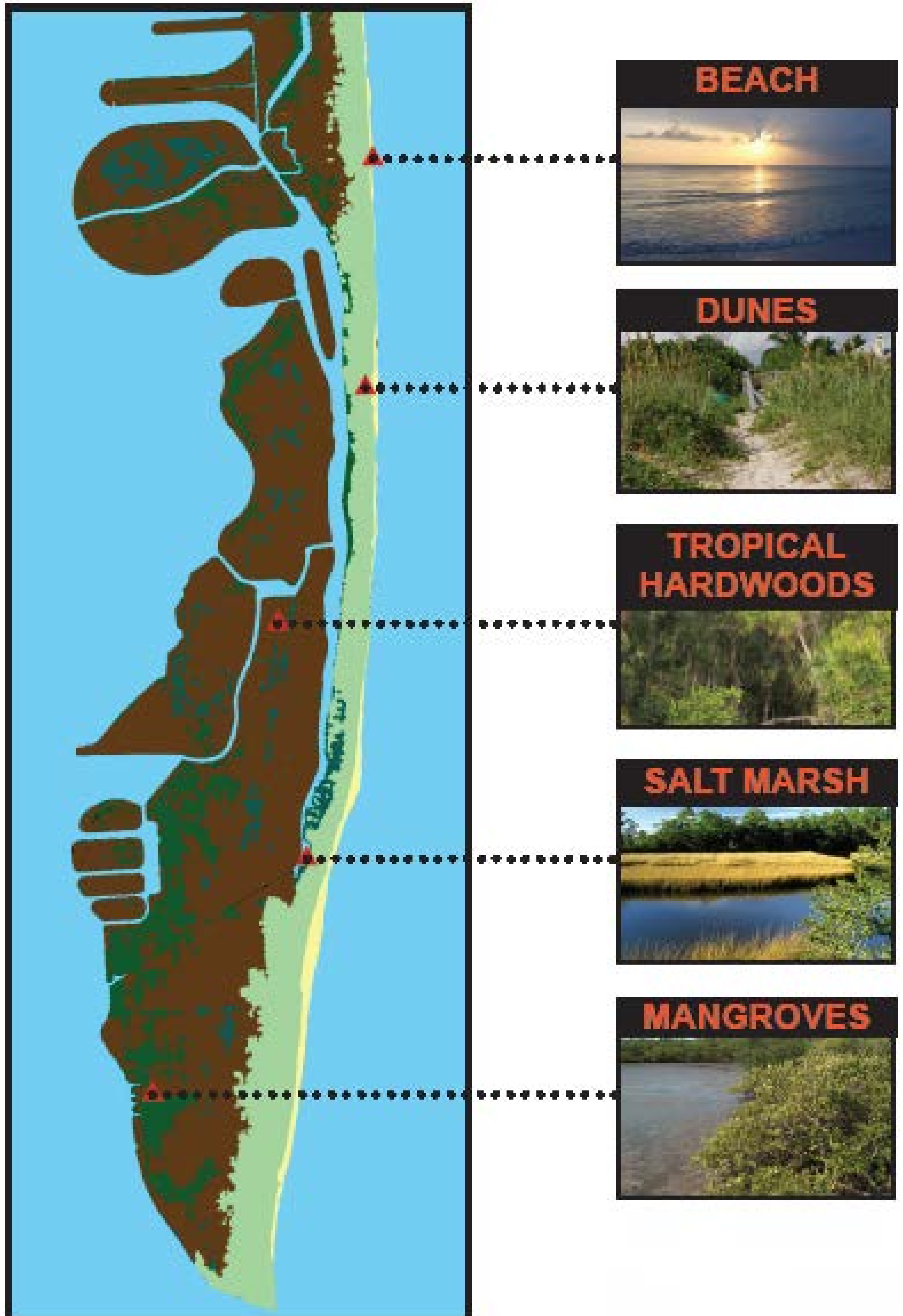
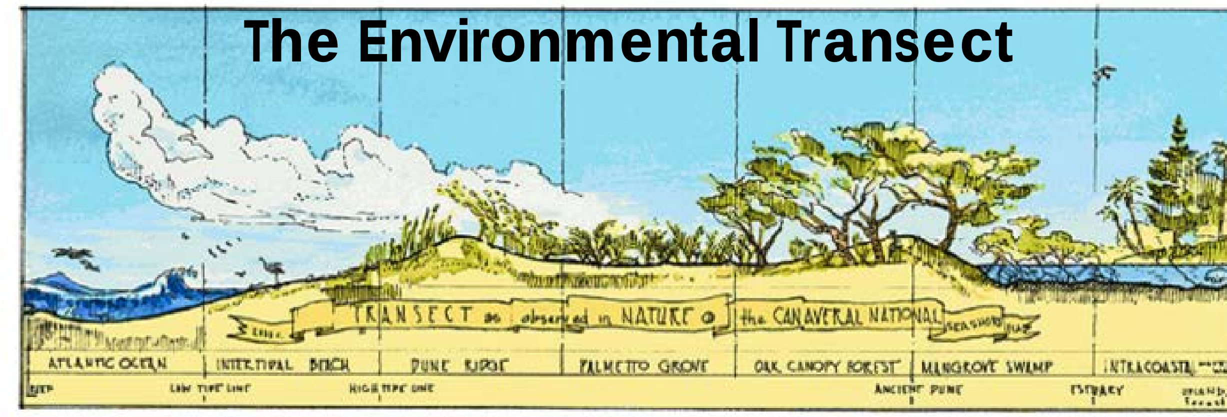


Diagram by Dan Cahalane



Source: http://www.miami21.org/TheTransect.asp

Elevation: > 0ft

Dunes and Beaches mark the ecosystems on the edge of the ocean. They are made up of sand washed onto the shore by tides, storm surges, and winds through the process of accretion. [11] The sand piles up, creating a natural stormwater and tidal protection zone.[12]

The higher elevations in the sandy zone are occupied by dune grasses and shrubbery evergreens such as sea grapes, silverwood buttonwoods, Sea oats and Saw palmetto.[13] These plants dominate the dune ecosystem due to their hardiness to strong salty breezes while anchoring the dune sands into place, preventing erosion. Protecting and maintaining these areas will be crucial to limiting the effects of sea level rise while continuing to generate tourism revenue.

Elevation: >2ft

Hardwood hammocks are a dense stand of broad-leafed trees, shrubs, palms, ferns, and epiphytes that grow in elevated areas of barrier islands.[16,17] This ecosystem is usually found on limestone, sand, or shell elevation geology that do not usually flood.[18] However, they are usually the second line of defense for flooding as they grow slightly higher than that of surrounding marshes, wet prairies, cypress forests, and mangroves.[6] [19]

Elevation: 0-2ft

Salt marshes are coastal wetlands that are flooded and drained by salt water brought in by the tides, serving as the transition from the ocean to the land, where fresh and saltwater mix. Plants within salt marshes are adaptable to fluctuating water levels that result from tides. With the tides, nutrients are carried in that facilitate growth in these marsh plants while organic material that feeds fish and other organisms are carried out. After a time, the accumulation of organic material within the marsh forms into a dense material known as peat. [14] Aside from providing the essential food, refuge or nursery habitat for over 75% of fisheries species, salt marshes protect shorelines from erosion by buffering wave action and trapping sediments. Salt marshes also reduce flooding by both slowing down and absorbing rainwater, as well as filter runoff water to protect water quality.[15]

Elevation: 0-3ft

Mangroves are a family of trees species that are salt water tolerant. Three mangrove species currently exist in Florida: red mangrove , black mangrove , and white mangrove, according to the Florida Department of Environmental Protection. Mangrove forests provide a variety of ecosystem benefits to adjacent coastal populations, as well as coastal defense services by reducing risk from coastal hazards, such as wind and swell waves, storm surges, waves, tides and tsunamis.[20] They also provide three useful ecological functions: reducing storm surge impacts, reducing peak flooding impacts and reducing erosion.

The amount of protection that mangroves can provide depends on the width of the mangrove forest. A mangrove belt several hundred meters wide, for instance, creates a dense forest that is most effective in reducing wind and swell waves.[21] Additionally, mangroves act as a buffer for the water surface from the effects of wind, therefore reducing wind waves and the height of wind waves.[22] In fact, a study led by a Danish ecologist found that areas with mangroves were remarkably less damaged during the Indian Ocean tsunami of 2004 than areas without mangroves.

Evidence suggests that mangroves can reduce the height of wind and swell waves over short distances: wave height can be

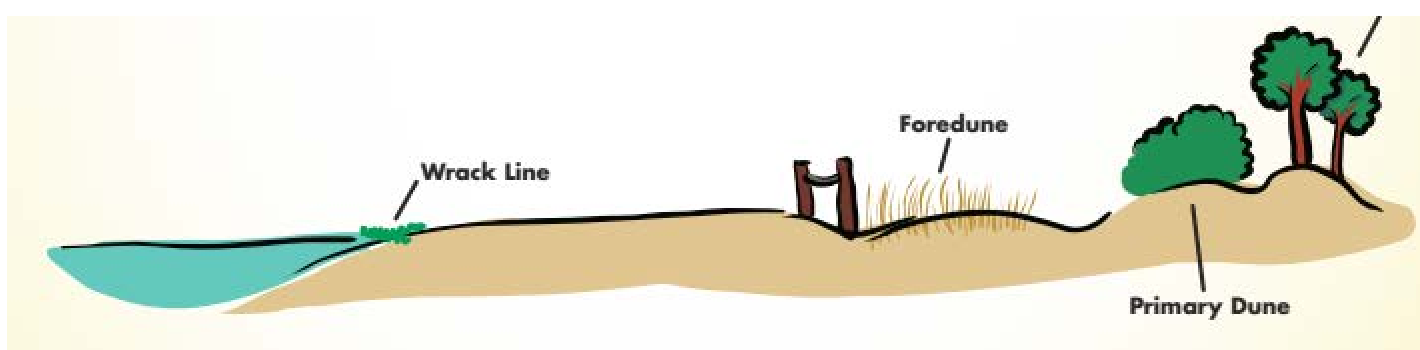
ENVIRONMENTAL ANALYSIS

reduced by between 13 and 66% over 100 meters of mangroves, while over a 500-meter-wide mangrove belt, they can reduce wave height by 50 to 100%.[23] Additionally, mangroves also have a large influence in reducing storm-surge peak water levels.[24] Mangroves can minimize damages from storm surges by reducing flood depths and reducing the height of wind and swell waves.[25] Moreover, evidence that mangroves can reduce storm surge flood depths is supported by direct observations of water heights, the use of well-validated numerical models that simulate storm surge behavior in the presence or absence of mangroves and observations of the damage caused and the numbers of lives lost from storm surges.[26]
Studies of the mangrove forests in Hurricane Wilma, a category 3 hurricane that hit the Gulf Coast of South Florida in 2005, found that mangrove forests with widths of 6-30 kilometers prevented inundation.[27] According to numerical simulations, the inundation caused by Hurricane Wilma would have extended 70% further inland without the mangrove forest.[28] The dense root systems of mangroves stabilize the coastline by trapping sediment, thus preventing erosion.

Transect Compilation

Using the ecosystem information, the Design Studio mapped what Miami Beach would look like in its "natural state." This map quickly identifies at risk areas and the types of interventions that would work best in each. Dune grasses should be protected to maintain their natural erosion and flood protection. Salt Marshes and Mangroves are both important to limit the negative effects of erosion as sea level rises, making them excellent areas to give back to nature. Tropical Hardwood forests mark the best interior areas to build, given their elevated nature and distance away from damaging salted winds. These ecosystems are the bedrock for a more natural and more resilient Miami Beach.

Dune Section



Miami Beach Dune Mangrove Signage

Endnotes

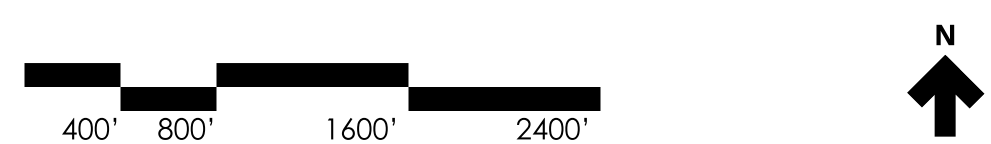
1 Re.invest Miami Beach City Report
2 http://www2.fiu.edu/~whitmand/Courses/Fl_geo_notes.html
3 Re.invest Miami Beach City Report
4 AECOM_MiamiBeachFloodingMitigation_LOS Presentation_30SEP2014 (1).pdf
5 Re.invest Miami Beach City Report pp 5
6 http://www.newyorker.com/magazine/2015/12/21/the-siege-of-miami
7 https://en.wikipedia.org/wiki/Limestone
8 http://www.pmel.noaa.gov/co2/story/Ocean+Acidification
9 http://www.pmel.noaa.gov/co2/story/What+is+-Ocean+Acidification%3F
10 http://www.pmel.noaa.gov/co2/file/Ocean+Acidification+Illustration
11 Miami Beach Dune Mangrove Signage
12 Miami Beach Dune Mangrove Signage
13 Miami Beach Dune Mangrove Signage
14 http://des.nh.gov/organization/commissioner/pip/factsheets/cp/documents/cp-06.pdf
15 http://oceanservice.noaa.gov/facts/saltmarsh.html
16 https://www.nps.gov/ever/learn/nature/hardwoodhammock.htm
17 http://sofia.usgs.gov/publications/papers/pp1011/hardhammocks.html
18 https://edis.ifas.ufl.edu/uw206
19 http://sofia.usgs.gov/publications/papers/pp1011/hardhammocks.html
20 (World Bank, 2016)
21 (World Bank, 2016)
22 (World Bank, 2016)
23 (World Bank, 2016)
24 (World Bank, 2016)
25 (World Bank, 2016)
26 (World Bank, 2016)
27 http://sofia.usgs.gov/publications/papers/mang_storm_surges/conclusions.html
28 http://sofia.usgs.gov/publications/papers/mang_storm_surges/conclusions.html

KEY

- Green Space
- Commercial
- Major Road
- Minor Road
- Marina
- Flood Direction
- Tree Lined Street
- Parking
- Green Flows
- Beach

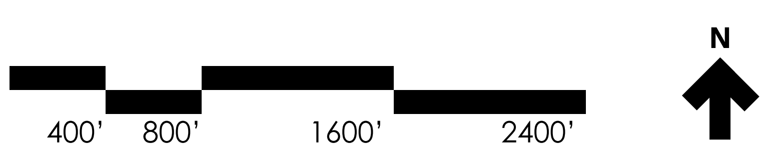
Site Analysis: North Beach

Site Analysis by Mouli Luo



Site Analysis: Mid Beach

Site Analysis by Mouli Luo



Site Analysis: South Beach

Site Analysis by Mouli Luo

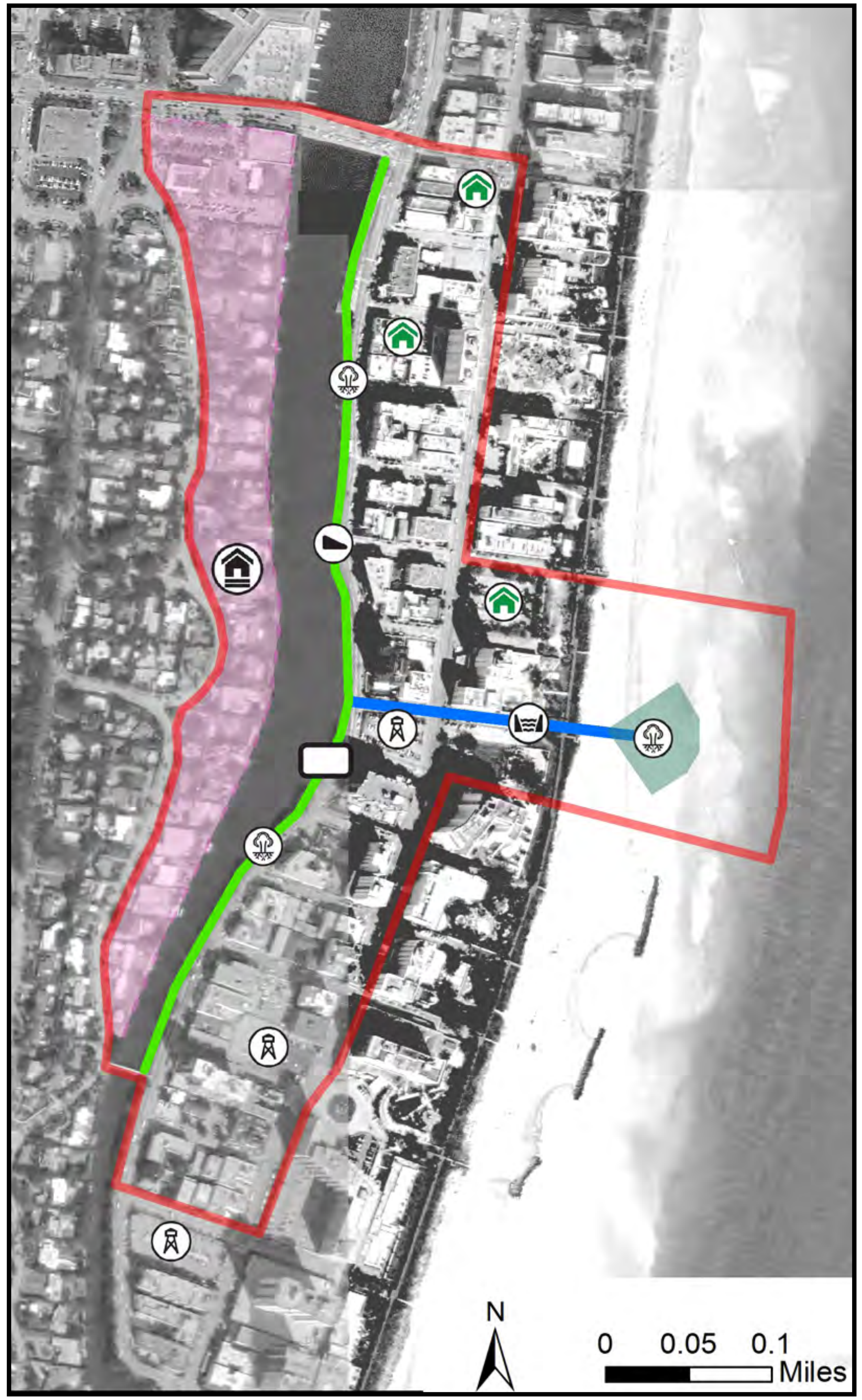
DESIGN SOLUTIONS KEY

North Beach

Key

- Elevated Buildings
- Amphibious Structures
- Elevated Streets
- Elevated Streets- Hydraulic
- Pedestrian Bridge
- Multi-Purpose Levee
- Land Moat
- Indian Creek Drive
- Water Moat
- 34th Street Canal
- Park Reservoir/Canal
- Mangrove Piers & Land Moats
- Parking Structures/ Green Roofs
- Water Towers
- Flood Defense Barrier
- Limestone Solutions

Mid Beach



Key

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- Amphibious Structures
- Elevated Streets
- Elevated Streets- Hydraulic
- Pedestrian Bridge
- Multi-Purpose Levee
- Land Moat
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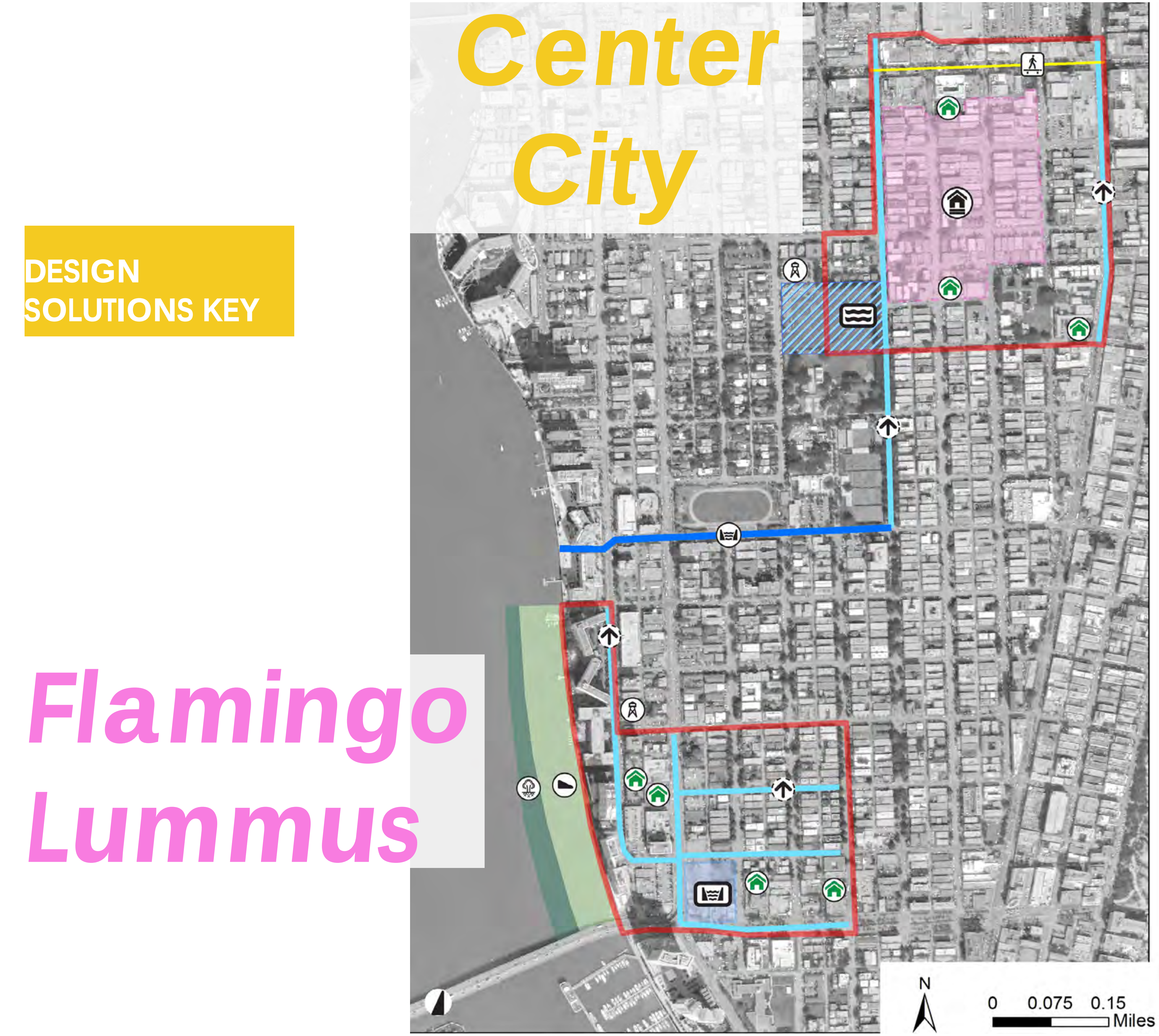
DESIGN SOLUTIONS KEY



Key

- Elevated Buildings
- Amphibious Structures
- Elevated Streets
- Elevated Streets- Hydraulic
- Pedestrian Bridge
- Multi-Purpose Levee
- Land Moat
- Indian Creek Drive
- Water Moat
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- Park Reservoir/Canal
- Mangroves
- Parking Structures/ Green Roofs
- Water Towers
- Flood Defense Barrier
- Limestone Solutions

ELEVATED BUILDINGS

3D Modeling by Mouli Luo
Greenery Rendered by MaryDena Apodaca
Cityscape Rendered by Romon Titov

Design Description

Elevated Buildings are a micro-level approach to reducing SLR. The specific designs for Miami Beach would be incorporated in the Mid Beach and City Center locations. Elevating structures off the ground can significantly reduce damage to personal property during storm surge. The Studio proposes that these buildings be elevated three to six feet from the baseline to mitigate as much damage as possible. This may be difficult for structures with a basement floor. In most circumstances, the lower level may have to be sacrificed during the elevation process.


After
3d Modeling by Mouli Luo
Greenery Rendered by MaryDena Apodaca
Cityscape Rendered by Romon Titov

AMPHIBIOUS STRUCTURES

Design Description

An amphibious structure is a building built on dry land that can float in the event of the site being flooded. Unlike other floating structures, amphibious structures are positioned on dry land. These buildings are designed with a buoyant foundation and pile supports to allow the entire structure to float up when the site is flooded. As site is flooded, the building will respond by floating on top of the rising waters and as flood waters recede, they will settle back down to original placement on land. A primary advantage to amphibious structures is that they avoid the issues concerning elevating the ground floor of a house. Amphibious structures allow for flexibility in design flood elevation and thus, greater resiliency to flooding. 1 This innovative type of building construction has been explored in Great Britain and Thailand and implemented in New Orleans, LA. Proposed location for amphibious structures is in Mid Beach, west of Indian Creek along Flamingo Drive.

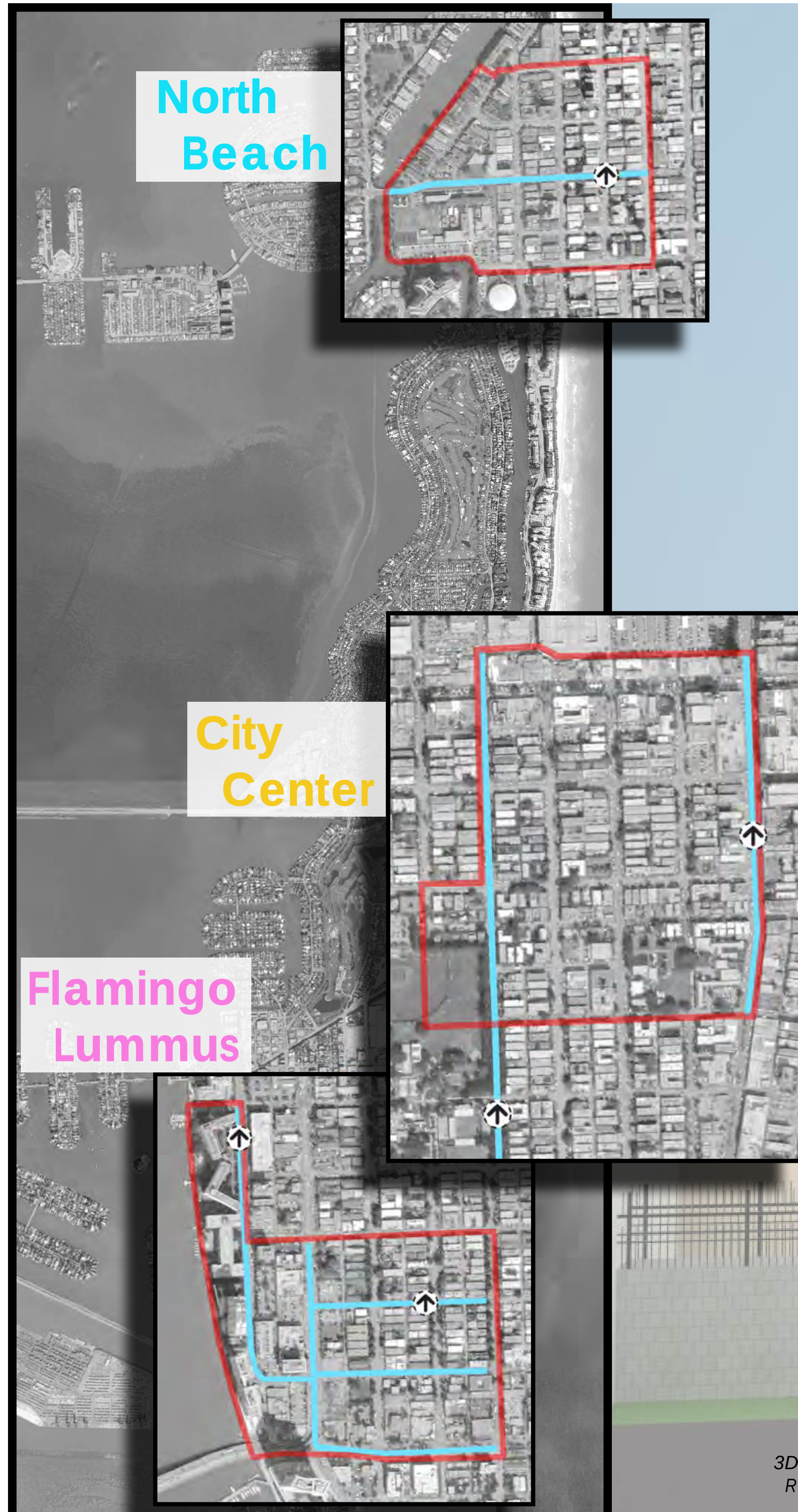
Endnotes

Hanson, Ian & Dar, Stephanie.What exactly is an "amphibious" home? Retrieved from http://amphibioushomes.weebly.com/references-- links.html

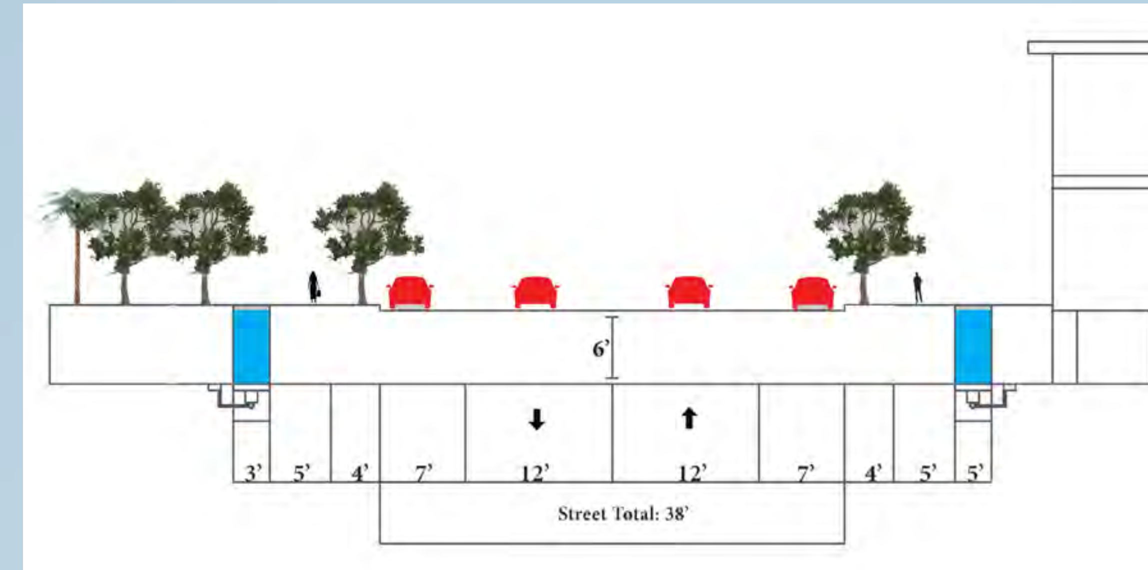
3D Modeling by Jenny Mei
Greenery Rendered by MaryDena Apodaca
Cityscape Rendered by Romon Titov

3d Modeling by Jenny Mei
Greenery Rendered by MaryDena Apodaca
Cityscape Rendered by Romon Titov

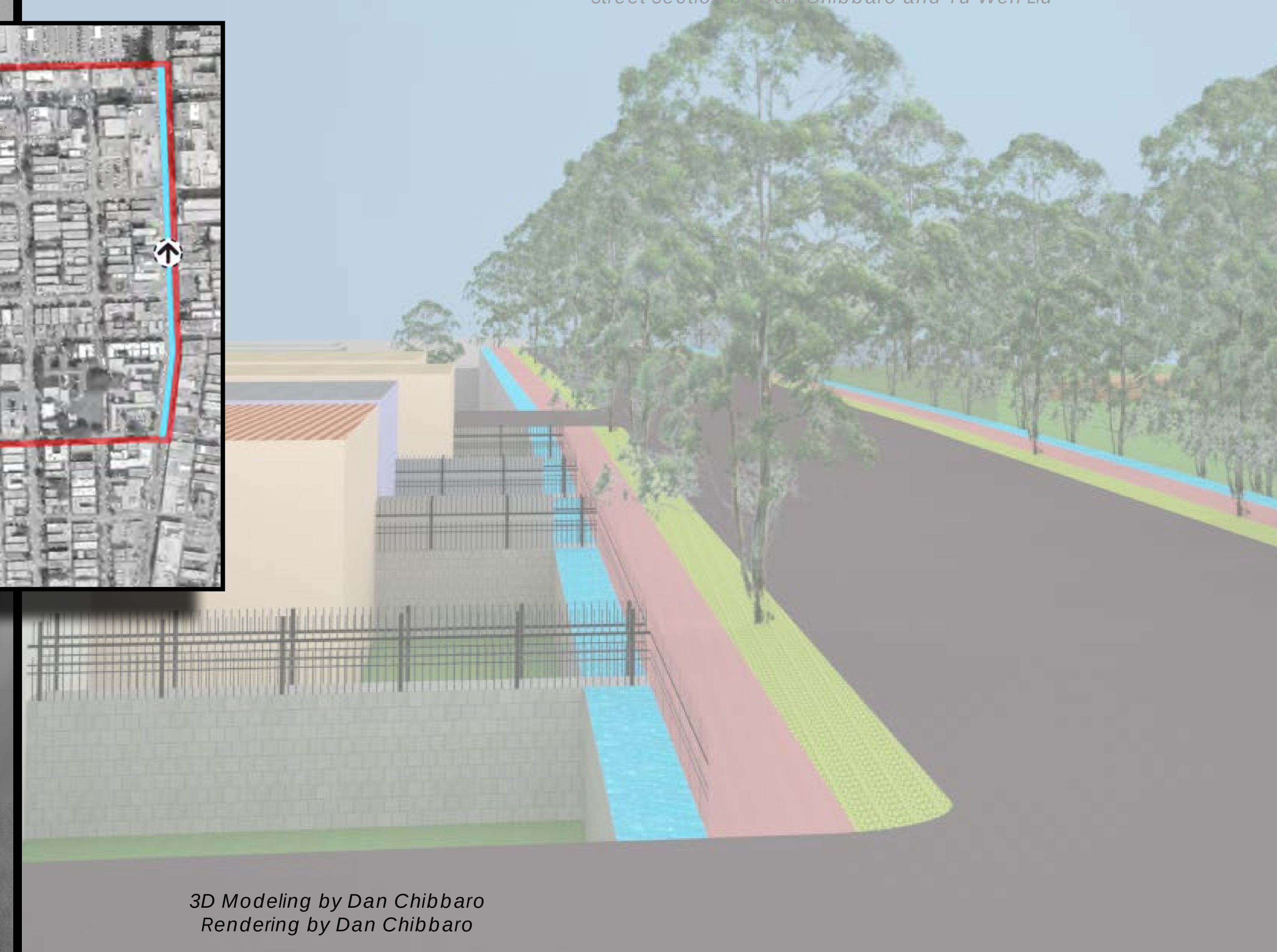
ELEVATED STREETS



Proposed Meridian Ave Street Section



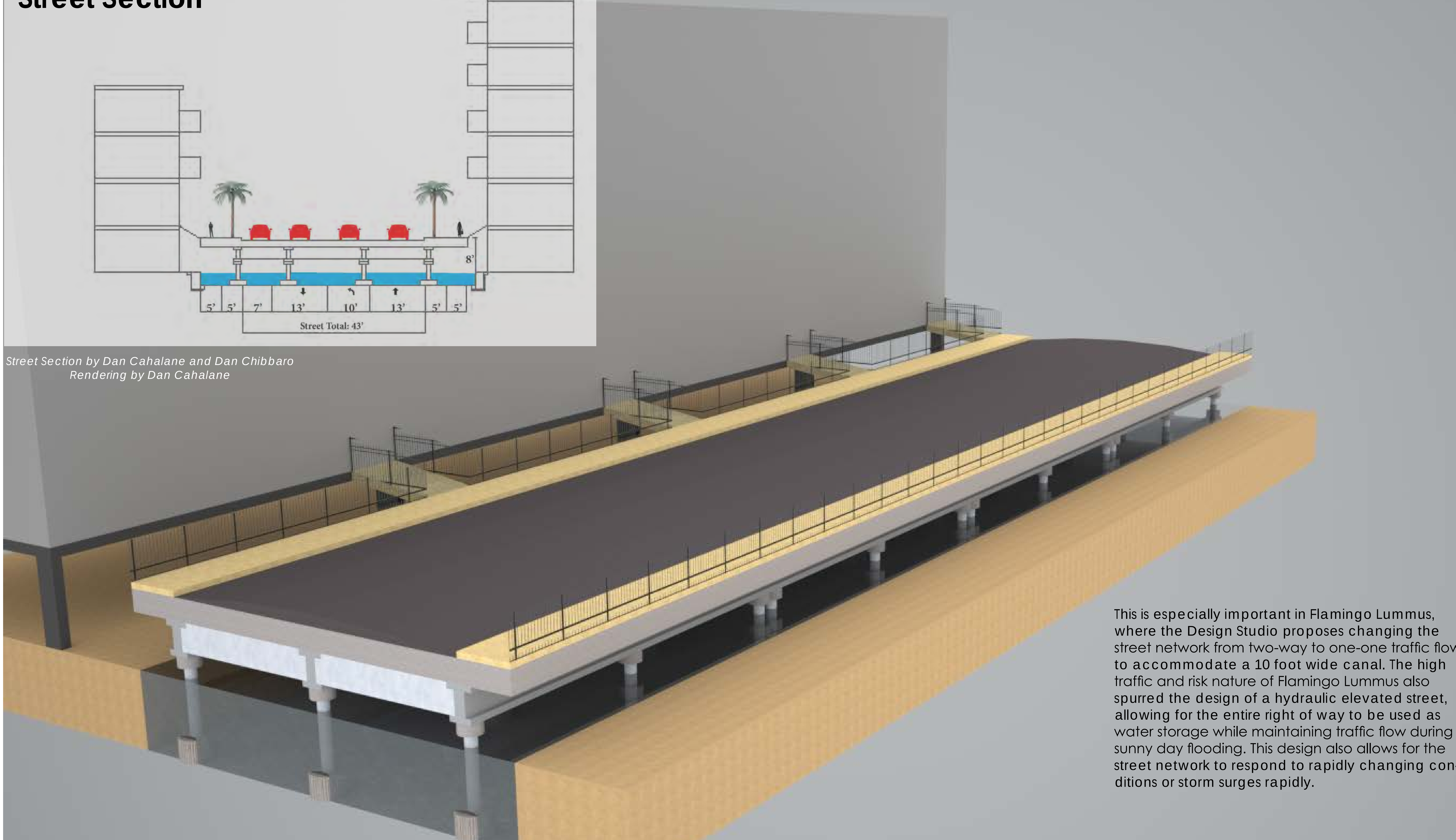
Street Section by Dan Chibbaro and Yu-Wen Liu



3D Modeling by Dan Chibbaro
Rendering by Dan Chibbaro

Design Description
Miami Beach is implementing elevated street sections throughout the City. The Design Studio proposes fleshing out an elevated street network based on high priority roads and the potential for flood water storage. Therefore the Design Studio recommends elevating 77th Street in North Beach, Meridian and Washington Avenues in City Center, and creating a flood mitigation network in Flamingo Lummus. These will allow for continued traffic flow throughout the city while providing inundation and storm water a place to temporarily combine before draining to the ocean at low tide.

Proposed West Avenue Street Section



Street Section by Dan Cahalane and Dan Chibbaro
Rendering by Dan Cahalane

This is especially important in Flamingo Lummus, where the Design Studio proposes changing the street network from two-way to one-one traffic flow to accommodate a 10 foot wide canal. The high traffic and risk nature of Flamingo Lummus also spurred the design of a hydraulic elevated street, allowing for the entire right of way to be used as water storage while maintaining traffic flow during sunny day flooding. This design also allows for the street network to respond to rapidly changing conditions or storm surges rapidly.

PEDESTRIAN BRIDGE

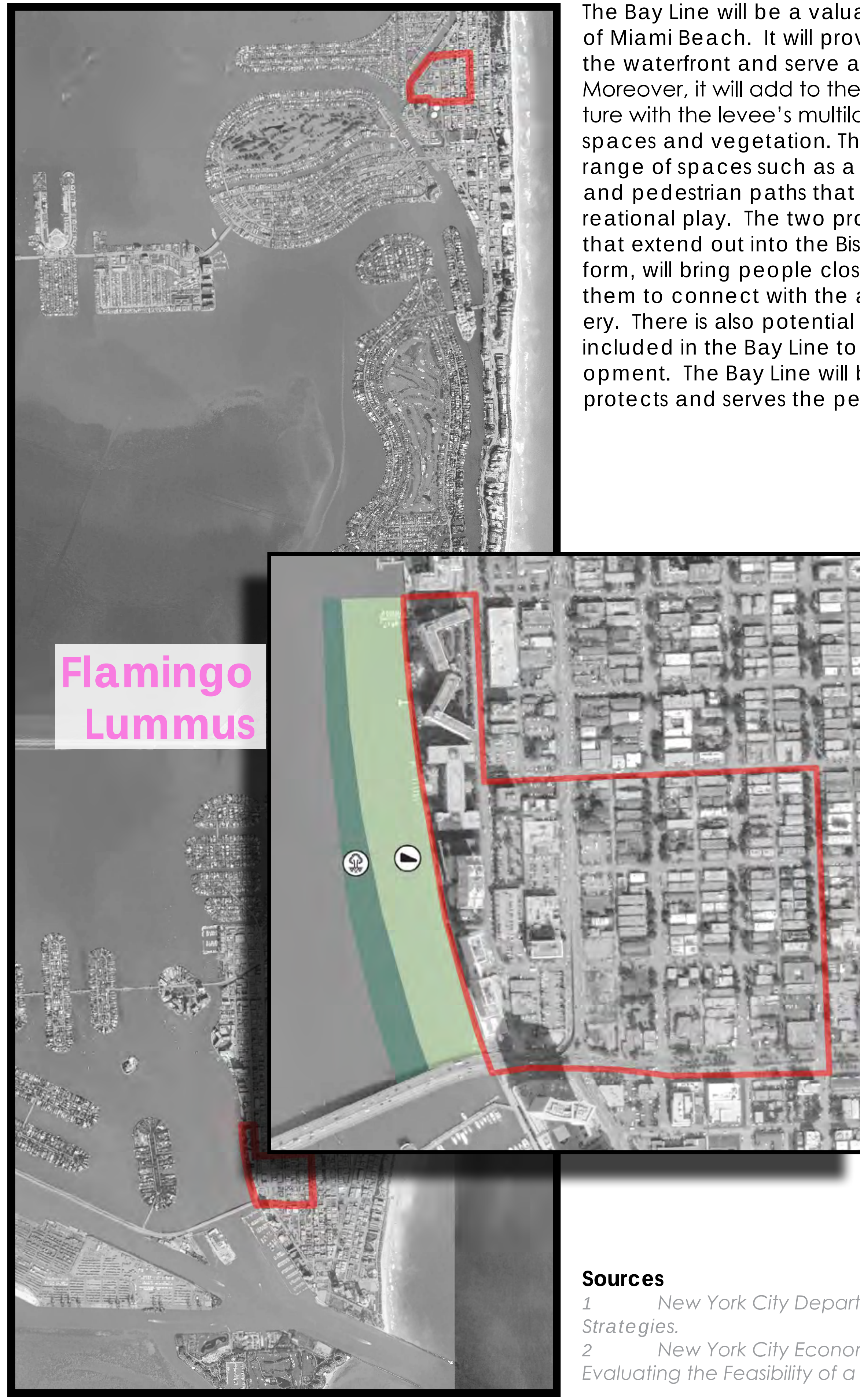
Design Description

The Design Studio proposes a 15 foot wide elevated pedestrian walkway along Lincoln Road. This will maintain the pedestrian nature of Lincoln Road during sunny day flooding and future SLR. This space will be a great place for locals and tourists alike to people watch while enjoying the beautiful South Florida weather.
In the short term, it will also increase the amount of high value commerical space within the City, helping pay for future SLR adaptation design strategies. In the long term, this design will ensure the continued commercial vitality of Lincoln Road.


3D Modeling by Wendy Liu
General Rendering by Roman Titov
Greenery Rendered by Jenny Mei

MULTIPURPOSE LEVEE

A multi-purpose levee (MPL) is a broad river embankment that combines other functions, such as buildings or parks either on top or within its structure.[1] Also referred to as a "super levee," a MPL serves as a preventive measure to inundation and is resistant to overflow even if the barrier is overtopped. They are wider that the traditional levee and has a gradual slope that can be developed into new public spaces or other urban uses. Its multifunctional design allows for seamless integration with existing urban development, as well as, the maximum utility of waterfront resources. MPLs have a demonstrated ability to achieve coastal resiliency over the long term and are less likely to experience structural failure when compared to a traditional levee, which can be breached if overtopped.[2] This type of levee have been explored extensively by cities in the Netherlands and implemented in Japan. A MPL is proposed to be located in South Beach along the waterfront bounding Biscayne Bay from 5th Street to 10th Street. Named, The Bay Line, the levee will not only provide protection against flooding, but will also serve as a waterfront park and promenade for the community of South Beach to enjoy. The curvilinear design is inspired by natural forms and designed to better integrate the network of mangrove trees with the levee aesthetically. The network of mangroves that line the exterior periphery of the Bay Line will stabilize the coastline and provide additional protection from storm surges and erosion.



The Bay Line will be a valuable resource to the City of Miami Beach. It will provide residents access to the waterfront and serve as a recreational area. Moreover, it will add to the City's green infrastructure with the levee's multilayer network of green spaces and vegetation. The Bay Line will have a range of spaces such as a trails system, bike paths, and pedestrian paths that support exercise and recreational play. The two prominent pedestrian paths that extend out into the Biscayne Bay in an arc-like form, will bring people closer to the water and allow them to connect with the abundance of greenery. There is also potential for retail spaces to be included in the Bay Line to support economic development. The Bay Line will be an iconic place that protects and serves the people of Miami Beach.

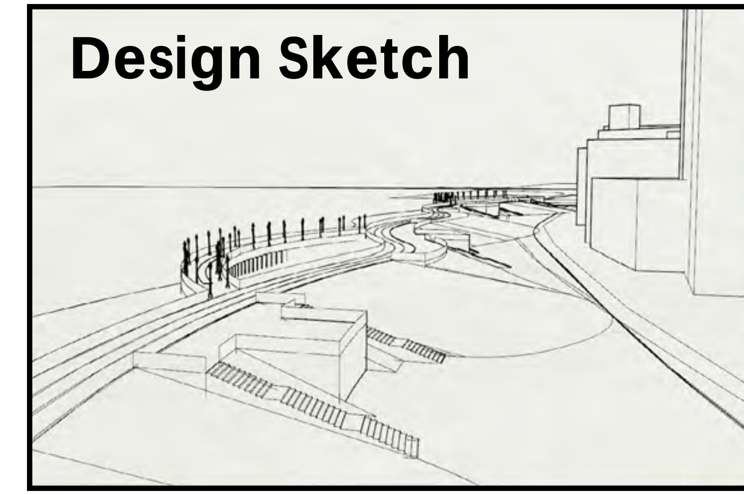


Illustration by Jenny Mei

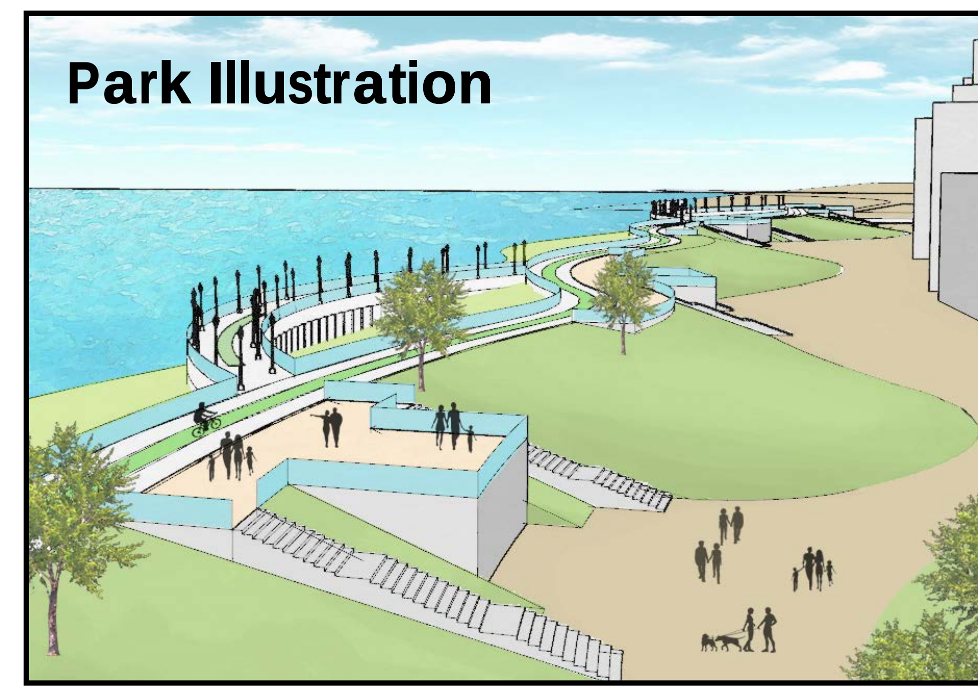


Illustration by Jenny Mei

Sources

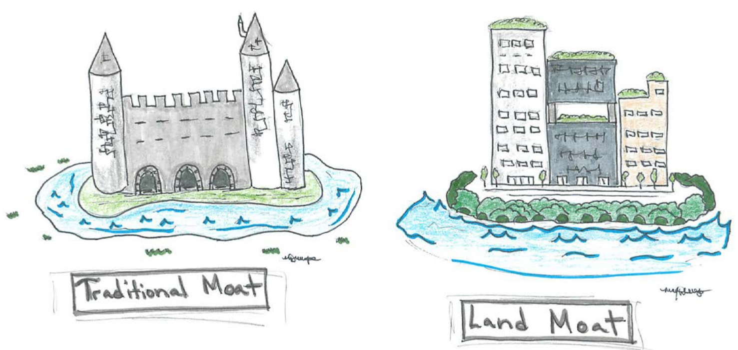
1 New York City Department of City Planning. (2013). Coastal Climate Resilience: Urban Waterfront Adaptive Strategies.

2 New York City Economic Development Corporation. (2014). Southern Manhattan Coastal Protection Study: Evaluating the Feasibility of a Multi-purpose Levee (MPL)


3D Model by Jenny Mei
Greenery Rendering by Jenny Mei
Cityscape Rendered by Roman Titov

LAND MOAT EMBANKMENT HYBRID

Concept Sketch



Sketch by MaryDena Apodaca

The concept of the land moat derived from the traditional moat as a part of medieval fortifications preventing an attack on the foundations of a castle. Instead of a channel in the land that contained water, we reversed the concept so that the land acts as a barrier against encroaching water. Land Moats differ from traditional embankments in two ways. First, they are not a community level sea aramament, but a block level armament — designed to keep water from entering a building if a primary embankment fails. Second, they are specifically designed as a to mimic natural topography to allow for native vegetation to keep the design in place.

Design Description

The Hybrid is a design solution proposed for Mid Beach along the full extent of Indian Creek Drive. The land moat is a design variation of the traditional water moat. As illustrated in the sketch provided, the contrast between the traditional moat and land moat can be seen. With the function of the land moat in mind, we wanted to further its water barrier capacity by taking an embankment and covering it with several layers of the land moats. Instead of having a bare embankment, you will instead see lush landscaping composed of land moats, palm trees, and mangroves along Indian Creek's water edge. The Hybrid provides lovely greenery while simultaneously defending against sea level rise.

Land Moat Conceptual Sketch

Sketch by MaryDena Apodaca


3D Modeling by MaryDena Apodaca
Greeny Rendered by MaryDena Apodaca
Cityscape Rendered by Roman Titov

INDIAN CREEK DRIVE DESIGN SYSTEM

We also propose the Water System for Mid Beach along Indian Creek Drive. We designed an interconnected system composed of three different micro-designs. The Hybrid, in fact, is the first of the three designs. The second design, located on the inside of the Hybrid along the edge of Indian Creek Drive next to the water, is the Mangrove Nursery. The Mangrove Nursery is a network of five small canals: three for rainwater capture and two for saltwater flow. The saltwater canals are designed for mangrove cultivation, hence the need for saltwater access to nurse mangrove seedlings to maturity. In the longrun, the mangroves will serve as an additional natural line of defense to pair with the Hybrid. The last of the three designs in this system is the Permeable Planter. We observed few street planters throughout Miami Beach and wanted to remedy that while maintaining our flood and sea level rise prevention aims.

The Permeable Planter is a three foot tall planter placed outside the sidewalk to 1) safeguard pedestrians, 2) provide for a more pleasant walking experience, and 3) prevent a certain amount of water from entering into homes and other important structures located within the Indian Creek Drive area of Mid Beach. Addiionally, these planters will be filled with forms of vegetation that are highly effective at absorbing rain water.

The technical street section below demonstrates the mechanics and engineering behind the Water System design. The three designs can be seen creating a large system that directs different water sources away from streets and buildings – each design is connected by an underground pipe that helps funnel rainwater and saltwater back to the ocean.

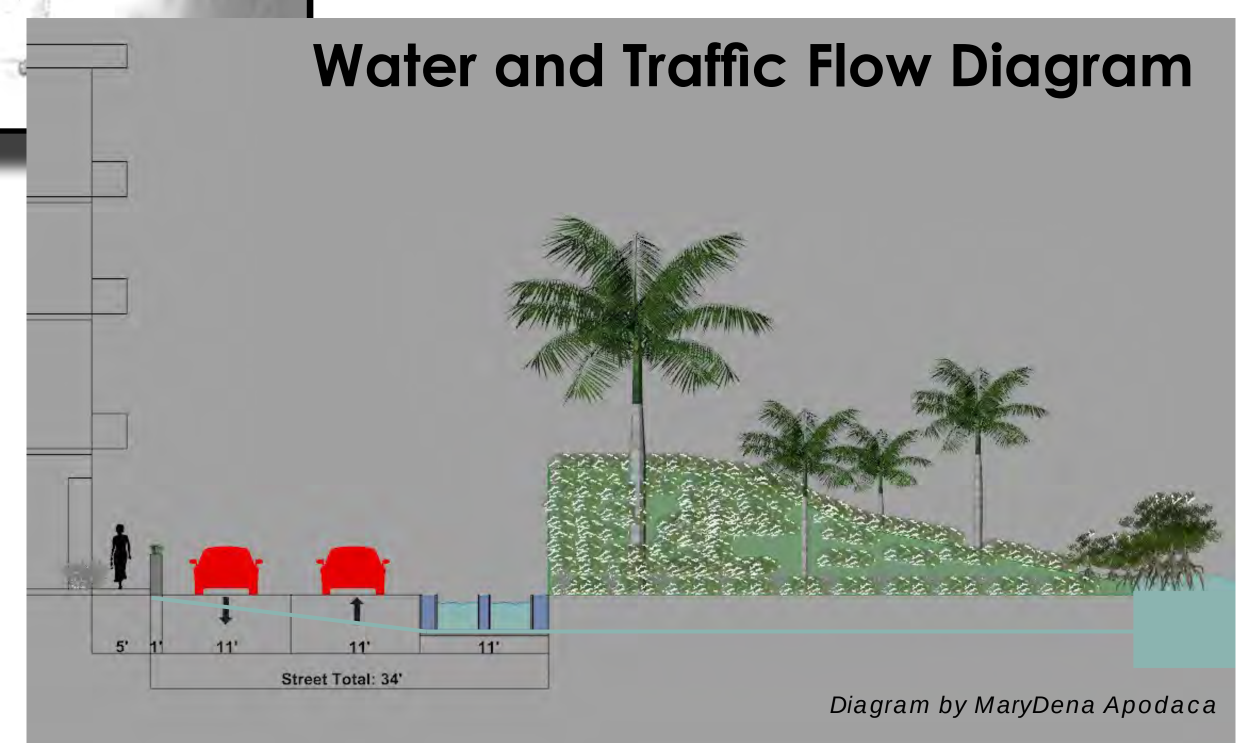
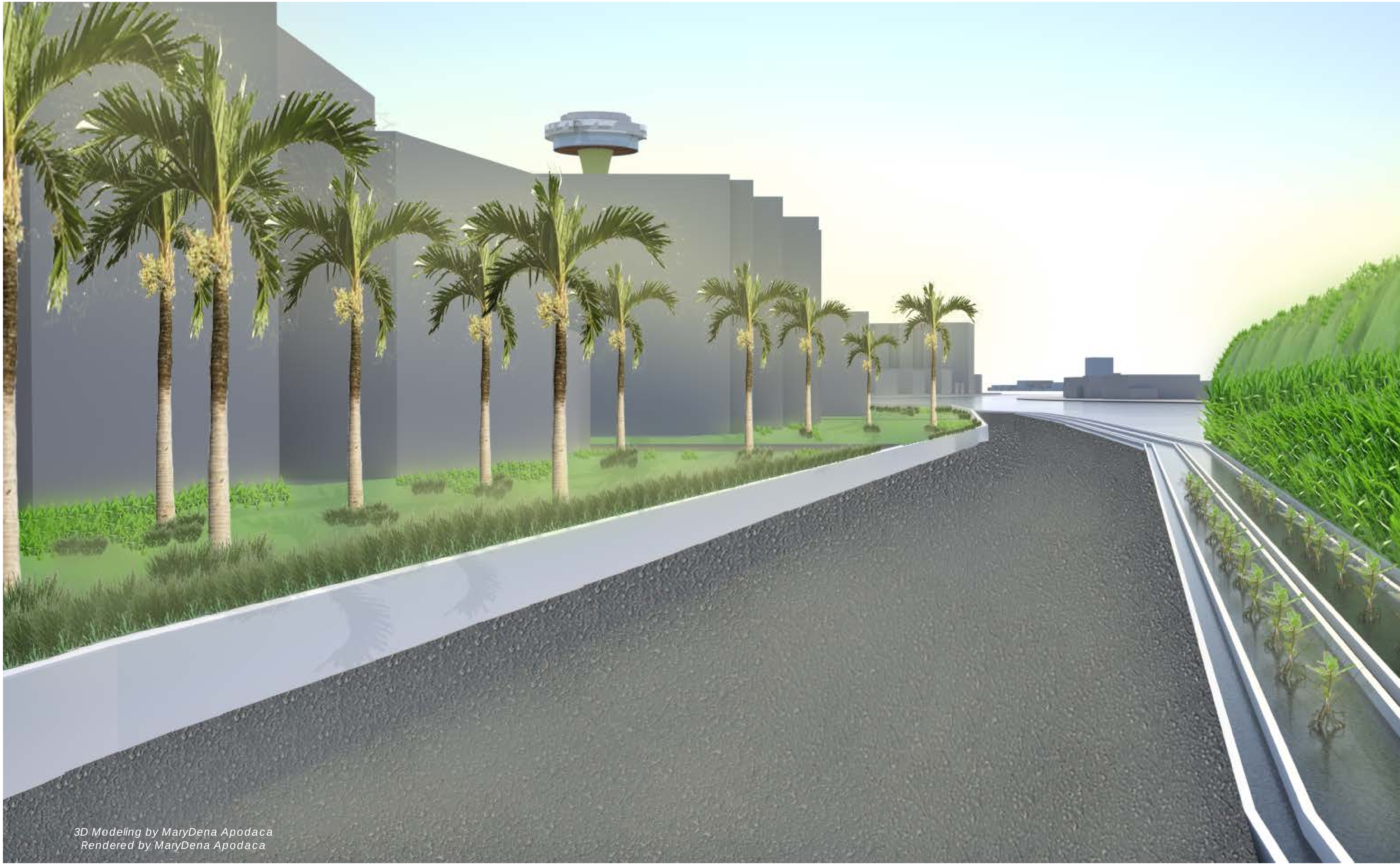


Diagram by MaryDena Apodaca


3D Modeling by MaryDena Apodaca
Rendered by MaryDena Apodaca

WATER MOAT

Sketch by Roman Titov

Design Precedent

Source: DrainageKits.com

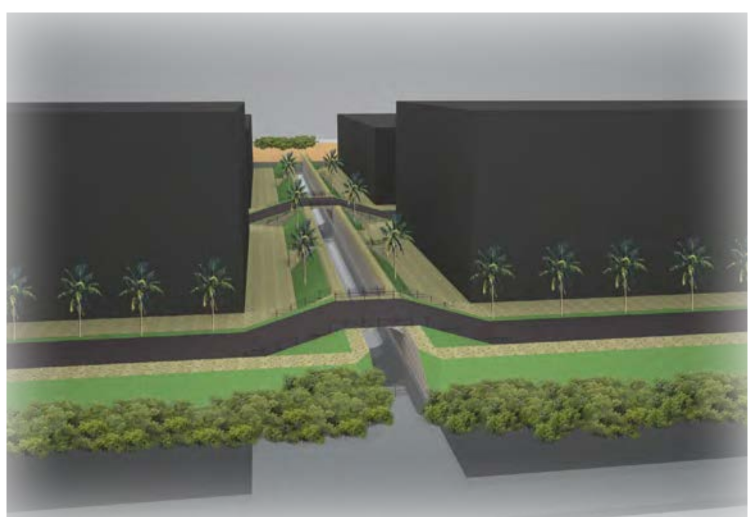
Design Description

The Water Moat concept is specifically designed for the corner of Alton Road and 6th Street in the Flamingo Lummus area. Precedents were established for a clear and comprehensive design that could be incorporated into the City's infrastructure. The final result is an actual moat that encompasses an entire block, covered by a decorative grate for minimal street changes. To the right, the rendering presents a grate which reads: Miami Beach. Ultimately, Water Moats can be installed throughout the City for efficient storm water storage which leaves the city environment untouched.

3D Modeling by Roman Titov
Rendered by Roman Titov

34TH STREET CANAL

Concept Model



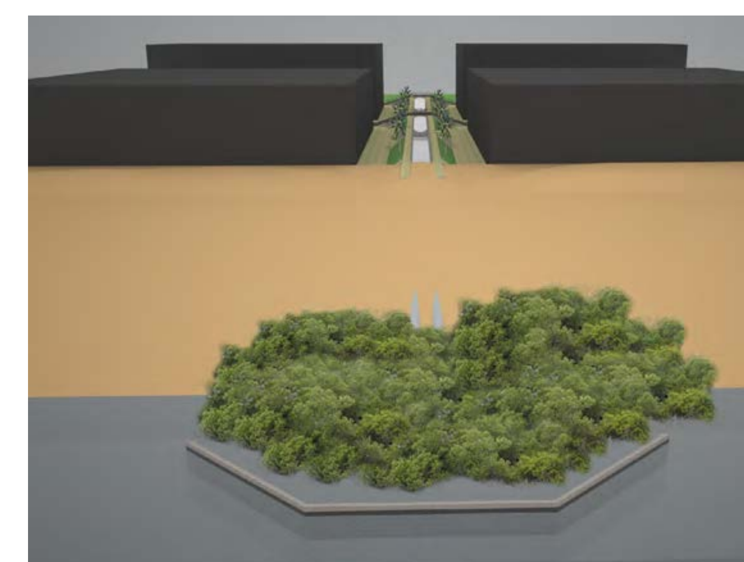
Model by Dan Cahalane

Design Description

In the area adjacent to Indian Creek from 27th street north to 40th street, elevations have frequently been identified as low as 2-ft contours. The level of extreme inundation here has resulted in the consideration of some radical ideas, specifically for the interface between Indian Creek itself and Indian Creek Road and 34th street from the creek to the ocean.

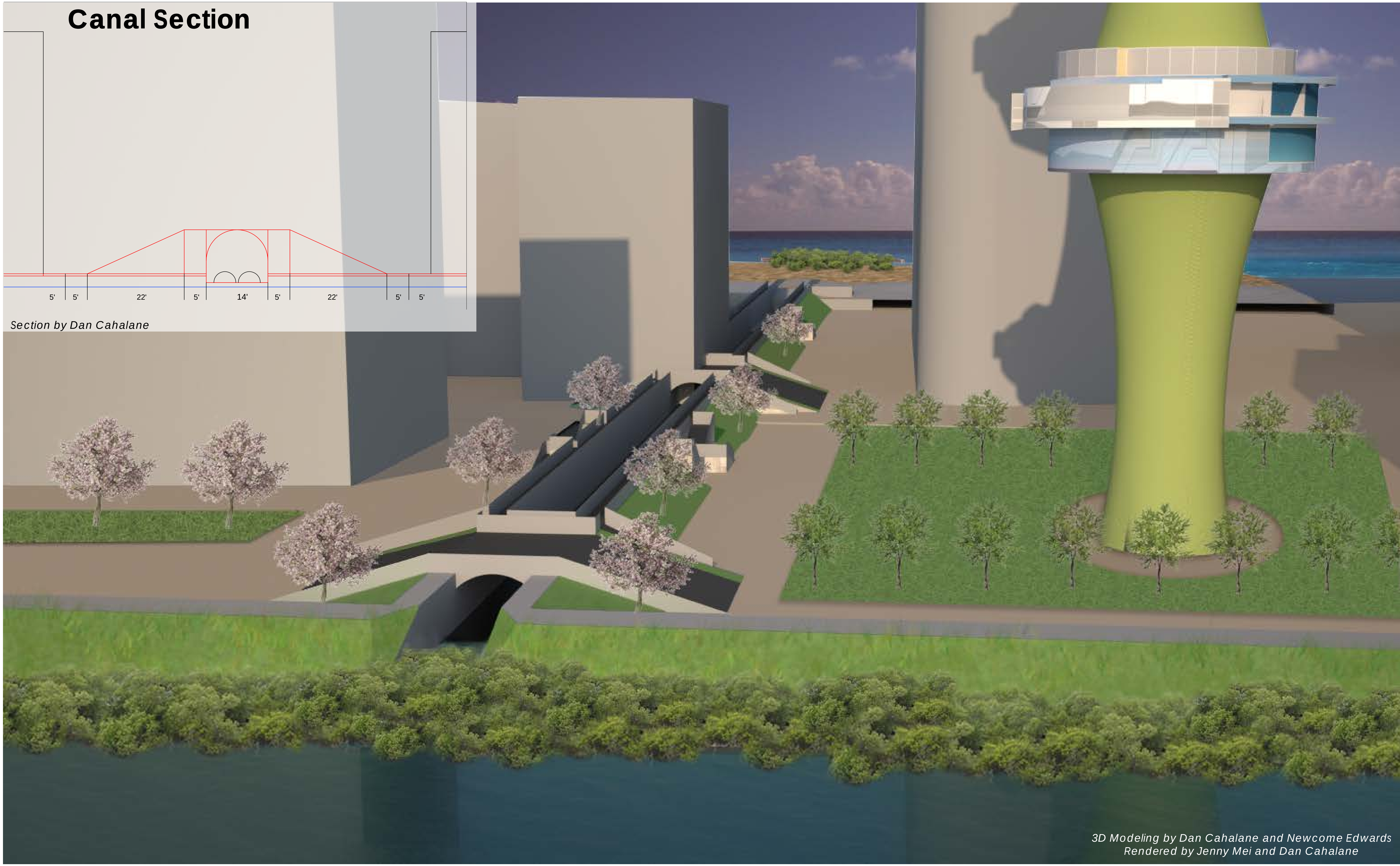
The Design Studio proposes a drainage canal on 34th Street. This will be an 800-ft canal spanning from Indian Creek to the beach and into the Atlantic. The Canal is to be 15-feet wide with walkways and amenities on either side. Ocean-side of the canal will be a series of two to three pipes that pour excess water into the ocean from the creek while maintaining the existing dune system. The pipes will contain one-way flanges to prevent ocean water from entering the canal. Additionally, the area on the ocean side will contain mangrove plantings to help transition the fresher water into the ocean and prevent an exorbitant pressure-build from the ocean side into the canal, and limit the effects of the erosion from the canal runoff.

Mangrove Beach Anchor



Model by Dan Cahalane

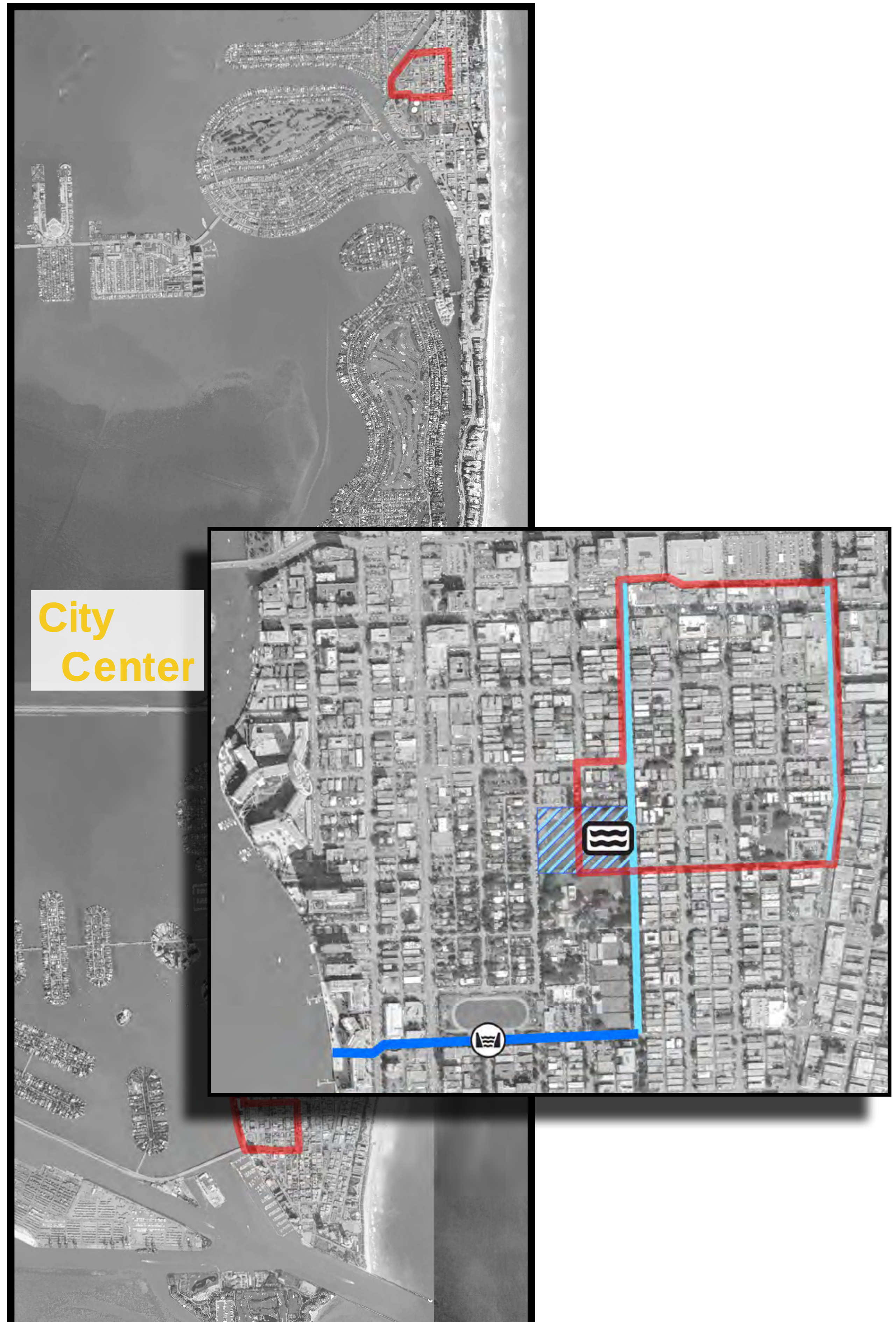
Canal Section



Section by Dan Cahalane

3D Modeling by Dan Cahalane and Newcome Edwards
Rendered by Jenny Mei and Dan Cahalane

PARK RESERVOIR CANAL

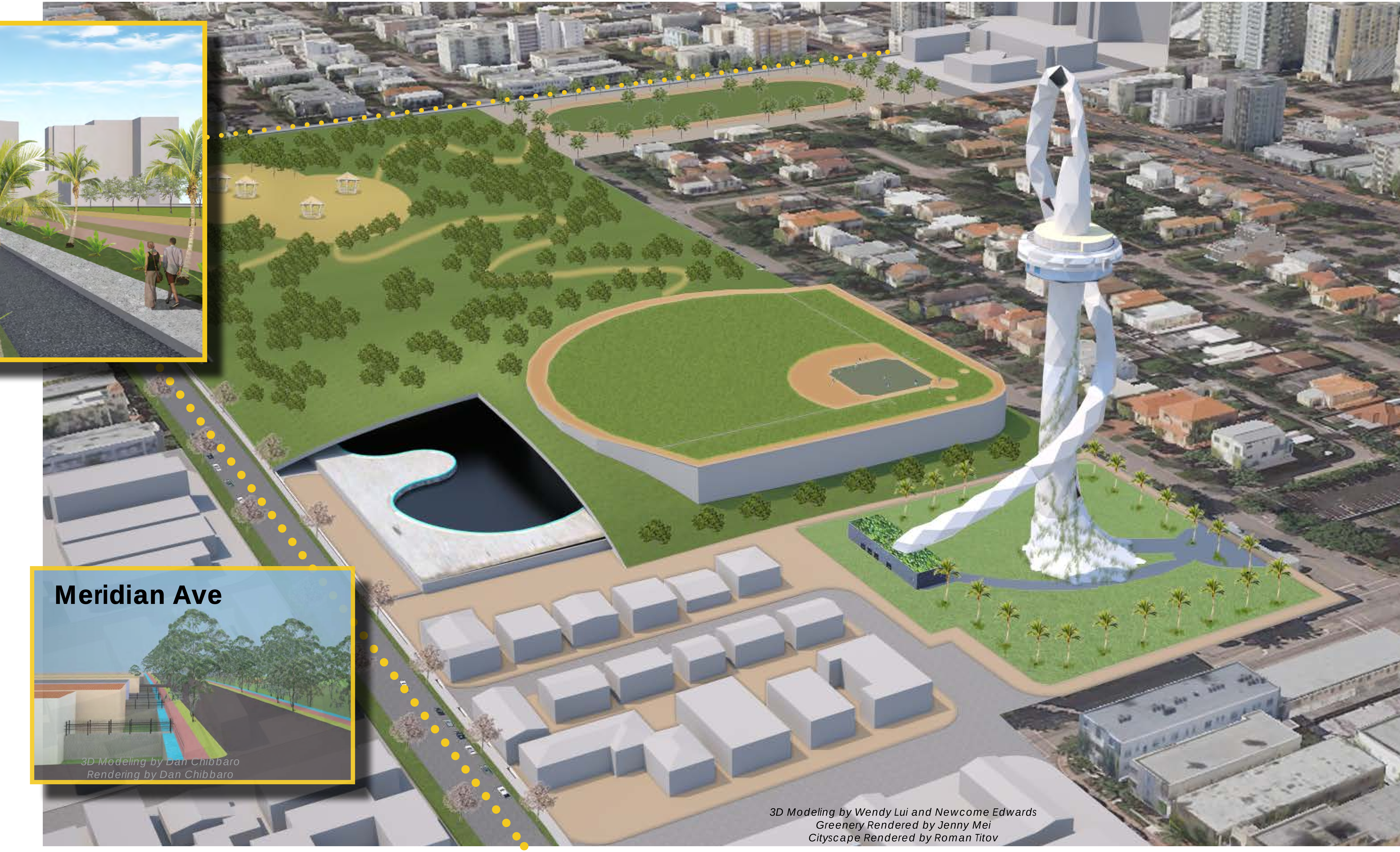


Key Design Features

Dimensions: *575’*625’*12’*
Location Target Areas: *Flamingo Park*
Location Specific: *Under the baseball field in Flamingo Park*

Design Description

The design studio proposes installing a water storage reservoir beneath the flood prone Flamingo Park by elevating the park 12 feet. This area will provide temporary and semi-permanent storage capacity for storm-water, and King Tides by providing over-flow storage capacity for the current and planned water pumps. The reservoir system will drain out via the proposed elevated street on Meridian Avenue and an open air street level canal on 11th Street. The design calls for the stored water to pass through a gravel contact oxidation treatment before en-tering the canal systems to ensure the water qual-ity entering Biscayne Bay. Moreover, this reservoir system will maintain Flamingo Park’s cultural and recreational amenities for the entire Miami Beach community.

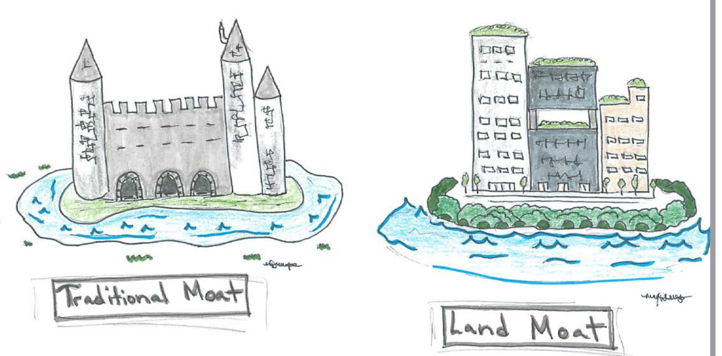

Meridian Ave
3D Modeling by Dan Chibbaro
Rendering by Dan Chibbaro
3D Modeling by Wendy Lui and Newcome Edwards
Greenery Rendered by Jenny Mei
Cityscape Rendered by Roman Titov

MANGROVE PIERS & LAND MOATS

Design Description

The Mangrove Piers and Land Moats design is proposed for North Beach along Tatum Waterway and Tatum Waterway Drive between 79th and 75th Streets. This design is mainly about enhancing the natural barrier capacity of the mangrove. Mangrove Piers, located at the forefront in the water, are piers specifically for the purpose of planting mangrove. These Piers are hollowed out at the bottom so the mangroves obtain their required access to water and can, over time, spread their seedlings out into adjacent areas of the water. This initial and long-run cultivation and liniing of mangroves would pose as a natural barrier against rising sea levels. To further the barrier capacity of the mangroves, we lined the water edge of Tatum Waterway with land moats to protect the homes directly off of Tatum and also lined and interior set of blocks along Tatum Waterway Drive and the school with land moats, which would add yet another line of defense against flooding should barrier capacity be overwhelmed along the waterfront. Aside from providing natural resiliency, we designed the Mangrove Piers and land moats to create beautiful landscaping, waterfront views, recreational space, and to revitalize the front setbacks of residential properties.

Concept Sketch

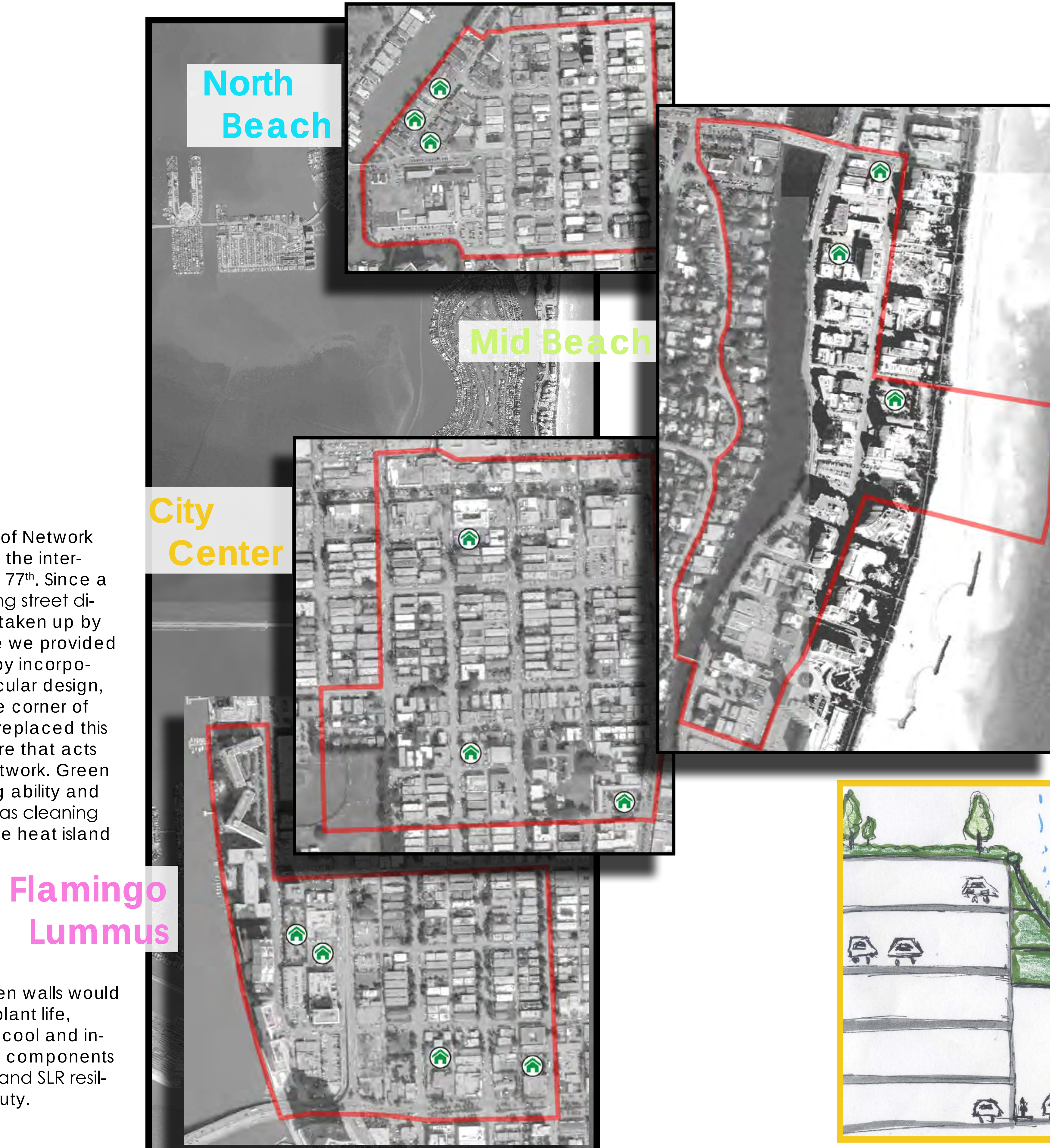


Sketch by MaryDena Apodaca

The concept of the land moat derived from the traditional moat as a part of medieval fortifications preventing an attack on the foundations of a castle. Instead of a channel in the land that contained water, we reversed the concept so that the land acts as a barrier against encroaching water. Land Moats differ from traditional embankments in two ways. First, they are not a community level sea aramament, but a block level armament — designed to keep water from entering a building if a primary embankment fails. Second, they are specifically designed as a to mimic natural topography to allow for native vegetation to keep the design in place.

3D Modeling by MaryDena Apodaca and Mouli Luo
Rendering by MaryDena Apodaca

PARKING STRUCTURES/ GREEN ROOFS



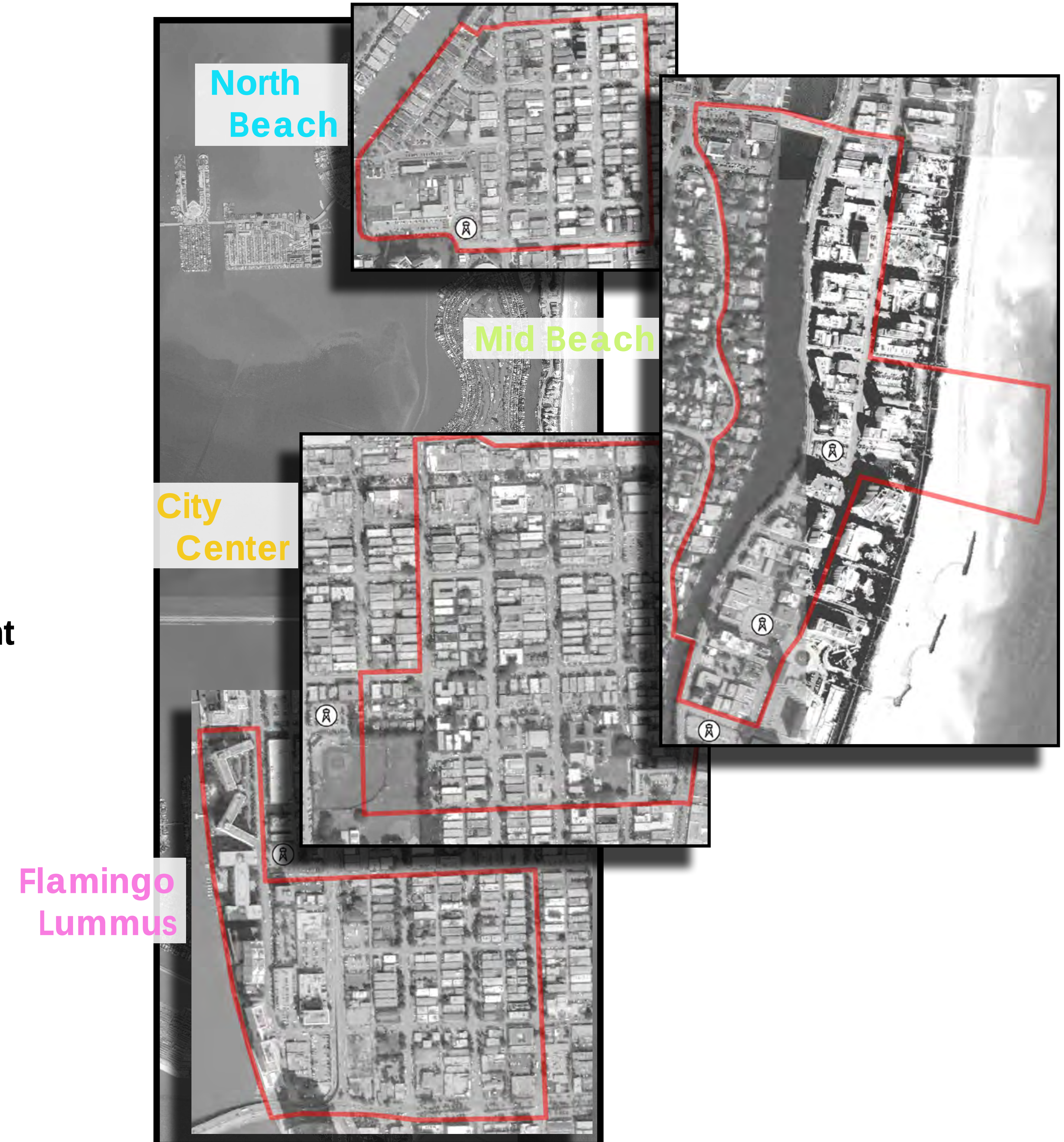
Design Description

The Parking Structure with a Green Roof Network design is proposed for North Beach at the intersection of Tatum Waterway Drive and 77th. Since a number of our designs modified existing street dimensions or required space currently taken up by surface parking, we wanted to ensure we provided compensation for this loss of parking by incorporating parking structures. For this particular design, there was once surface parking at the corner of Tatum Waterway Drive and 77th – we replaced this area of parking with a parking structure that acts as the cornerstone to a green roof network. Green roofs have strong rain water capturing ability and also have great health benefits, such as cleaning air of carbon dioxide and reducing the heat island effect. The various green roofs placed atop existing buildings and the parking structure would be connected by a lovely green overpass and green walls.
In addition to this design's main water-capturing function, the green roofs, green overpass, and green walls would create a lush vertical topography of plant life, enhance views, keep residential units cool and increase fresh air. Overall, these natural components will enhance Miami Beach's flooding and SLR resiliency while adding to its outdoor beauty.

Sketch by MaryDena Apodaca

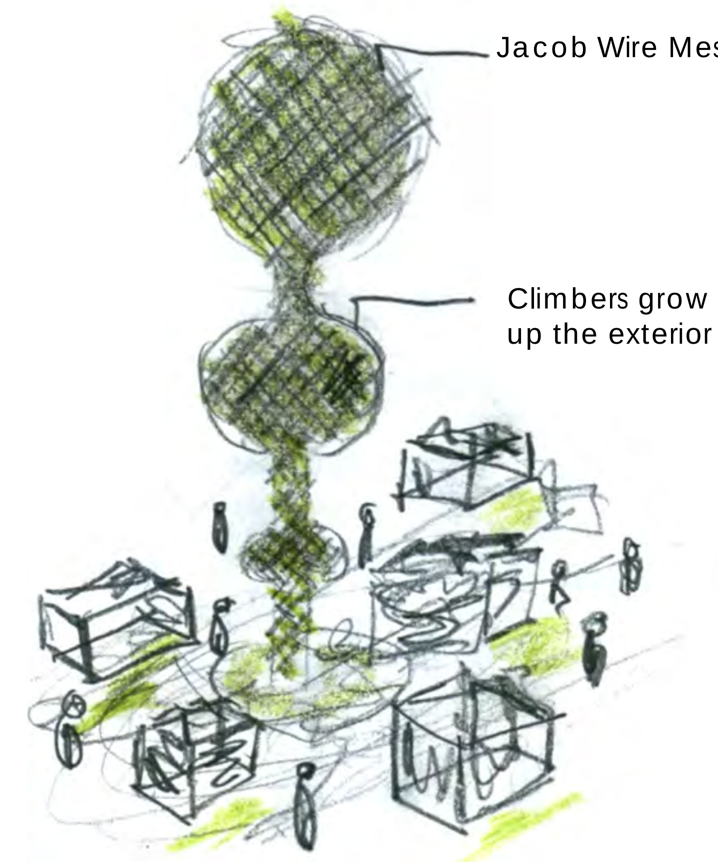

3D Modeling by MaryDena Apodaca and Mouli Luo
Rendering by MaryDena Apodaca
3D Modeling by MaryDena Apodaca and Mouli Luo
Rendering by MaryDena Apodaca

WATER TOWER



Design Precedent

Conceptual Sketch



Sketch by Newcome Edwards

Design Description

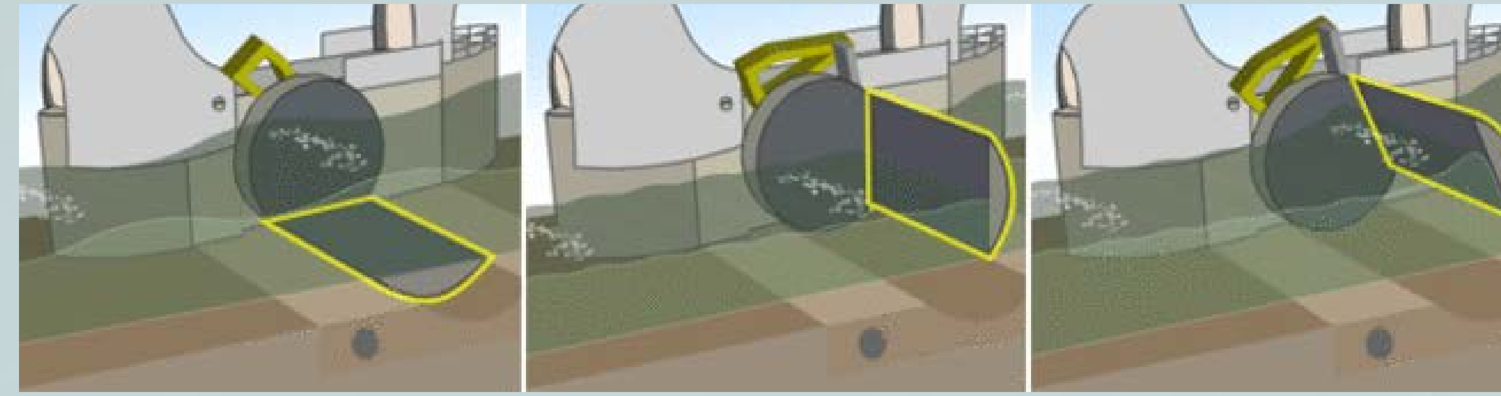
The Water Tower concept has the potential to be designed by various artists, particularly those who have had experience with environmental designs. Climbers are intended to grow up the tower's wire mesh façade, as illustrated in the above sketch. It can function as an alternative storage of rainwater which would eventually be released through evapotranspiration. It also has the potential to incorporate commercial space in the top, including such things as a rotating restaurants that could offer views of Miami and Miami Beach. Ultimately, Water Towers can help combat Sea Level Rise while acting as an artistic landmark.

3D Modeling by MaryDena Apodaca, Mouli Luo, and Newcome Edwards
Greenery Rendered by MaryDena Apodaca
Cityscape Rendered by Roman Titov

FLOOD WALL

Design Precedent:
Thames River Barrier

How it works



"How does the Thames Barrier Stop London From Flooding?" BBC, 2014

Secondary Interior Barrier

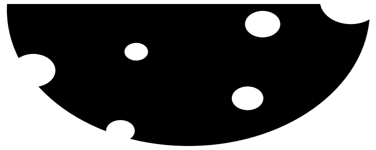
Rendering by Newcome Edwards

Design Description

Our Design Studio used the Thames River Barrier as a main precedent for the Flood Wall design. This particular concept would be implemented west of the Flamingo Lummus area in South Beach. It functions as a barrier to prevent high tides and storms surges from reaching exposed communities in Miami Beach area. The rotating gates in the pictures above demonstrate how the Flood Wall works. Underspill that results from major storm events is allowed to flow under the barrier in a controlled fashion.

Rendering by Newcome Edwards

Rendering by Newcome Edwards



LIMESTONE SOLUTIONS

Design Description

Miami Beach rests on pourous limestone bedrock. These conditions allow for displaced freshwater or even sea water to flood the City from below regardless of any adaptation or protection strategies adopted. Therefore the Design Studio proposes two solutions to limit the effects of SLR from below.

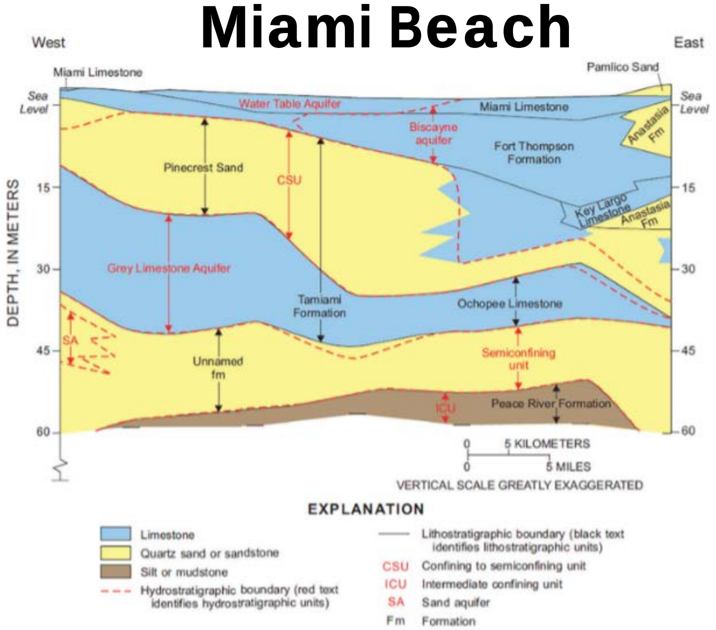
Vertical Solution

The vertical solution is derived from a report by Re.invest 2015. They proposed digging down into the bedrock 200 feet along the edges of the city and pumping an impermeable solution to reduce the amount of water coming in from the ocean.[1] This would stabilize the water table. Then the city could pump the water table lower, increasing the ground's water storage capacity.

Betonite Waterproofing

Photo by DRI-LOK Corporation

Water Table, Miami Beach



Re.invest Miami Beach City Report pp 5

Netherlands Soil Map

Article · March 2015 · Acta Agriculturae Scandinavica, Section B - Soil & Plant Science
Henk Ritzema, accessed via Research Gate

Horizontal Solution

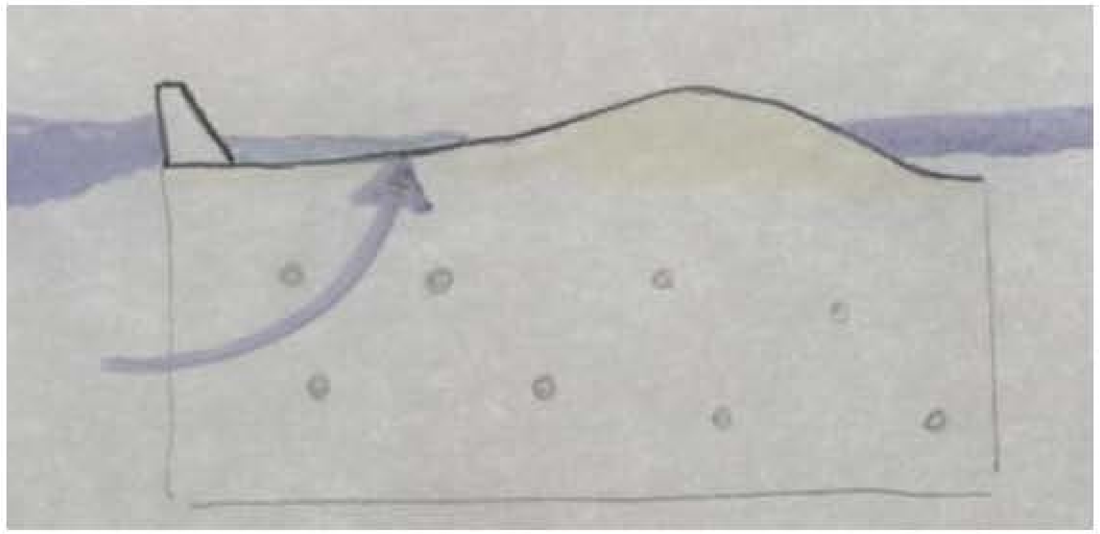
The Design Studio also took an outsider's approach to solving the problem. Based on our case study analysis, we found that the areas where levees and dikes were effective, such as along the Mississippi River or the Netherlands, all had a layer of impermeable clay as a major component of their soil. Clay is an incredible material - cheap, abundant, and highly impermeable, making it an effective water barrier. Therefore, we propose putting a layer of clay down beneath the soil to create an impermeable cap, preventing flooding from below.
We recommend using a betonite clay waterproofing. It's effective -- absorbs water and swells making it a self sealing low permeability layer. It is proven -- used as the impermeable barrier to prevent ground water contamination in landfills and superfund sites.[2]

Endnotes:

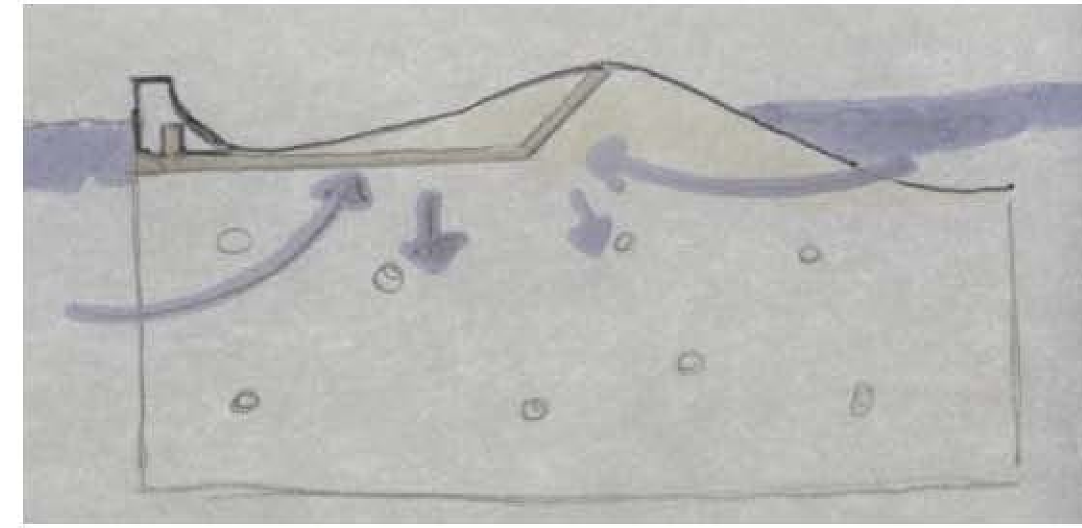
1.) Re.invest Miami Beach City Report pp 5

2.) Karnland, O., Olsson, S. and Nilsson, U. 2006. Mineralogy and sealing properties of various bentonites and smectite-rich clay materials. SKB Technical Report TR-06-30. Stockholm, Sweden.

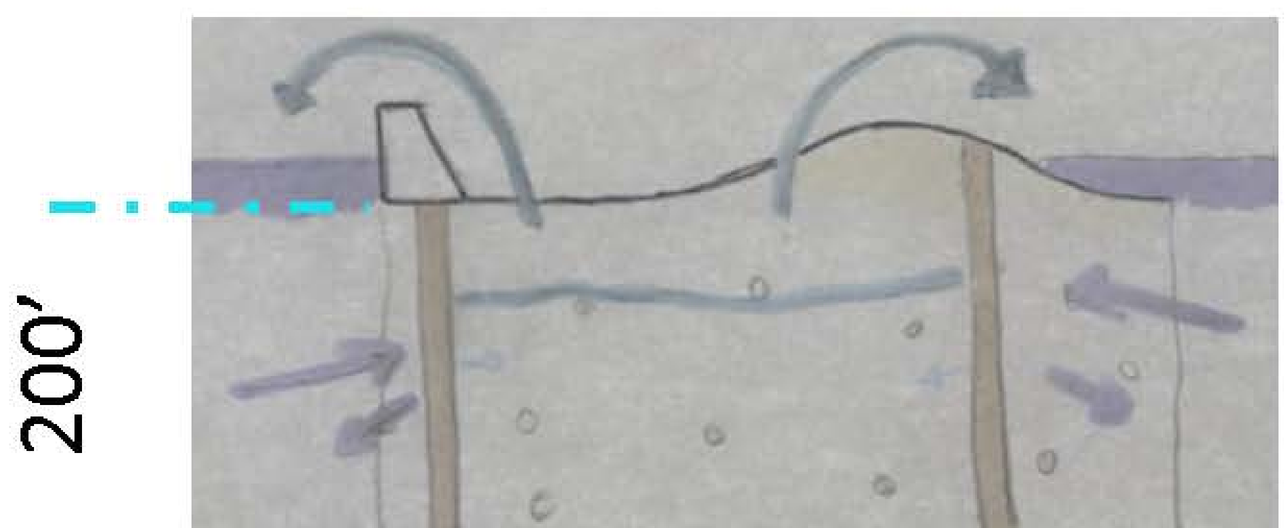
Normal Conditions



Horizontal Solution



Veritcal Solution



Sketches and Diagram by Dan Cahalane

ZONING ANALYSIS

The design strategies presented in this section are recommended place-based solutions for Miami Beach's select neighborhoods in addressing SLR. In this section, zoning recommendations are presented in order to provide Miami Beach with regulatory solutions for addressing SLR issues. These recommendations are both neighborhood-specific and can be applied to the City as a whole.

The City currently implements various Land Development Regulations that address flooding issues. For instance, the City's code of ordinances has an entire Chapter dedicated to Floods (Chapter 54) and has various zones and overlay zones that address the protection of marine life and the upland (Chapter 142, Article II, Division 16: Waterway District WD-1 and Chapter 142, Article III, Division 2: Dune Preservation Overlay). Chapter 110 Utilities, Article III: Stormwater Utility discusses comprehensive plan standards and the stormwater management system. Single family residences also have bulk requirements (setbacks, height, etc.) that discuss minimum flood elevation (Division II, Sec. 142-105). More recently in 2013, the City adopted a Chapter on Sustainability (Chapter 100), which includes a Green Building Ordinance and an Energy Economic Development Zone Pilot Program.

Although the City has incorporated many interesting and useful ordinances that address flooding and AECOM has made recommendations for updating that code, this studio makes additional recommendations for the City of Miami Beach. The Land Development Regulation amendments presented in this section cover zoning themes including:

1. Adaptation Action Areas (AAAs)
2. Parking Structures
3. Raised Streets
4. Energy Efficiency
5. Urban Tree Canopy
6. Restoration Areas vs. Growth Areas
7. Pre-Event Model Recovery Ordinance

Each Theme is discussed by first presenting the issue, outlining the recommendations which have been presented as goals or policies in local planning documents, and listing, where possible, applicable case studies. In addition, each recommendation is categorized. Miami Beach does not have many opportunities to implement Retreat SLR strategies, which require retreating inland. Therefore, the Land Development Regulation recommendations presented here will likely be categorized as an Accommodation strategy, in which the aim is to reduce the risk of inundation and flooding, not to eliminate it.

Adaptation Action Areas (AAAs)

The City of Miami Beach suffers from disruptive flooding including SLR, sunny-day flooding, the drainage concerns that result and most importantly, the relationships between these risks and the City's vulnerabilities. In order to address these issues effectively, Miami Beach must come up with a strategy for dealing with the effects of these risks on the City physically, environmentally and socially.

Recommendation 1: Define and Codify

In this section, the Studio recommends that the City define and codify "Adaptation Action Areas" (herein referred to as "AAA") as a way to differentiate and prioritize areas where risks are high and vulnerabilities exposed. The following definition, at the recommendation of AECOM and the Regional Climate Action Plan (110 Recommendations), should be incorporated into the existing Land Development Regulations:

"Adaptation Action Area" or "Adaptation Area" means a designation in the coastal management element of a local government's comprehensive plan which identifies one or more areas that experience coastal flooding due to extreme high tides and storm surge, and that are vulnerable to the related impacts of rising sea levels for the purpose of prioritizing funding for infrastructure needs and adaptation planning.

Recommendation 2: Methodology and AAAs

The Studio recommends that the City of Miami Beach utilize the methodology developed by this Studio for identifying Adaptation Action Areas since the resulting map spatially defines vulnerabilities in relationship to risks. These vulnerabilities include vulnerable populations (elderly, poor), buildings (businesses and residential), infrastructure (roads, schools, hospitals, public works), natural resources, historical resources, and economic resources.

Parking Structures

Based on inundation maps created for Miami Beach, it is evident that the Lincoln Road -- South Beach area reaches flooding up to five feet during long rain periods and storms. The largest districts within Lincoln Road are the Residential Multi-family Zone (RM-1) district, Government Use Zone (GU) district, Commercial Medium Density Zone (CD-2) district, and Commercial High Intensity Zone (CD-3) district. Considering that majority of AAA is zoned as these districts, zoning changes should focus specifically on these locations. The Townhome Residential Zone (TH) district and Residential Office Zone (RO) district would have a lower priority level.

Recommendation 1: Lower Floor Solution

The City of Miami Beach should consult the Studio's methodology for parking structure development that fully meets the criteria. Off-street parking facilities for different land buildings or uses may be provided and used collectively or jointly in any zoning district in which the separate uses would be permitted. Zoning language should be developed that allows the lower level of parking structures to be flooded during storm events. These particular facilities would have a separate designation from those that are not allowed to flood. With these in place, more drainage basins will be created to catch runoff from severe weather occurrences.

Recommendation 2: Designated Zones

With proper ordinance revisions, the City should establish more sites throughout Miami Beach specifically for parking structures. The lack of supply currently has visitors and tourists parking on-street, which directly affects residents who rely on these spaces. At least three facilities should be developed around commercial zones that are also accessible to residents. This way, on-street parking will be eased by the construction of structures throughout the City. For each new facility, a large amount of street spaces will be opened up for the people who really need them.

Recommendation 3: Inundation Zoning

Miami Beach should consider adopting an off-street parking Overlay Zone to be incorporated throughout the City. This overlay zone should not be based on the Studio's Vulnerability and Risk Relational Map; rather on an inundation map to determine where the most vulnerable locations are. They should also be developed on sites near residential neighborhoods to accommodate the number of

Image of raised street in Miami Beach.
https://www.bergeronlanddev.com/land-development-projects/

homeowners who have no other parking alternatives, particularly in RM-1 and TH districts.

Raised Streets
In an effort to reduce sunny-day flooding instances throughout the City, Miami Beach has opted to elevate street grades, eliminating the possibility for streets being inundated with water. However, the City should design the elevated streets in such a way that allow for an "eyes on the street" environment and permit accessibility. If sidewalks remain unelevated, streets are less likely to be "watched" by individuals, suggesting that streets, or in this case sidewalks, may become unsafe alleyway environments. In addition, new streets that are severely elevated will limit individuals with mobility issues.

Recommendation 1: "Eyes on the Street"
By elevating the street and not elevating the sidewalk or storefront, it is harder for passersby and people in buildings to have a good view of the street. Take the already elevated xxxx street for example. Those eating at the cafe at the original street grade will be staring at the feet of passersby. They will be unable to view the activity happening at the elevated street level where "natural proprietors" of the street would normally monitor activity. Not only is the elevation of streets and not sidewalks a risk for potential crime, it is as Jane Jacobs suggests also very boring.

Recommendation 2: Accessibility
Those with mobility issues might have a hard time accessing the various grades. When sidewalks and streets are simultaneously elevated, it becomes nearly impossible to access. Curb and transition ramps are two designs that should be incorporated into zoning language when looking at elevations. Parts of the road system that transition from the roadway to the public sidewalk level would be a part of this language. Wherever a sidewalk intersects with a street transition, a curb ramp or flush landing should be provided. Any corner would have a curb ramp as well.

Energy Efficiency
A global solution in reducing SLR is to confront the warming of the Earth. Ocean waters are rising because of heat-trapping gases in the atmosphere. Miami Beach is one of the major zones that needs to address this problem. Through electricity demand and air conditioning, the risk of warming increases. In a dense city like Miami Beach, energy should be a major discussion topic when thinking about ways to combat SLR.

Recommendation 1: LEED Design
Zoning language for LEED design should be incorporated into existing zoning under Chapter 100: Sustainability, Article I: Green Building Ordinance. Any missing elements from this type of design should be integrated within the ordinance. LEED is a form of building design and construction that creates a healthy environment, and is cost-effective and resource-efficient. It can be developed for multiple purposes, such as retail, education, healthcare, data centers, warehouses, and multifamily residential buildings. Currently, 92% of LEED-certified construction projects are improving energy performance by at least 10.5%(1). The City of Miami Beach should expand on its existing Green Building Ordinance to include LEED-ND (Neighborhood Development).

Urban Tree Canopy
Urban forests are a vital environmental, economic, and social asset to the City. Trees reduce energy consumption and thus save money by stabilizing temperature, creating shade, acting as a wind and sound barrier. and reducing stormwater surface runoff. An urban tree canopy is defined as the layers of leaves, branches, and stems of trees that cover the ground when viewed from above. The goal of Miami Beach is to increase the City's urban tree canopy by about 30% of the existing canopy by the year 2020. The current tree canopy of Miami Beach being 15.4%+/-1.14%.

Recommendation 1: Street Trees
Street Trees are an effective component of Green Streets only if they thrive. The critical root zone, the area around a tree required for the it's survival, must be protected. This zone is determined by tree size, species and surrounding soils. Often, streets trees fail when they are planted in highly disturbed soils with poor drainage, aeration, structure, and little organic matter. Within the critical root zone, adequate soil volume and mixture should be provided that are not compacted and have access to both air and water. Recommended street tree planting methods include: group plantings, structural soils and cells, deep tree pits, and connected tree pits.

Recommednation 2: Maintenance
Any plantings located in the right-of-way including but not limited to trees, shrubs, ground cover, and sod shall be maintained by the abutting property owner and approved by the planning, design and historic preservation division. Miami beach should adopt construction protection rules for all public trees including fencing, no storage of hazardous materials, no cutting into root zones. Any public trees removed or damaged during construction associated with private development will be required to be replaced on- or off-site with an equivalent amount of tree caliper, meaning that the removal a 24-inch diameter tree would require a replacement with 6 four-inch diameter trees.

Recommendation 3: Placement Requirements
Ceremonial streets, commercial streets, major thoroughfares, and other streets important to the City pattern should use formal, consistent planting palettes chosen for their distinct design qualities to provide a strong aesthetic character and facilitate place recognition. Neighborhood residential or smaller streets may use a more diverse, less formal planting palette to indicate neighborhood preference and create a rich planting variety. One canopy tree or grouping of three palms shall be provided for every 25 linear feet of frontage in a required yard abutting a public right-of-way. Where a driveway crosses a landscaped easement and a curb cut is provided, the driveway shall be paved with a hard surface material such as concrete, asphalt, or decorative unit pavers and shall have a clearly defined edge between paving and landscaped easement.

CASE STUDY 1: Cumberland, Maryland

Urban forests have been a major environmental characteristic of Cumberland's environmental, economic, and social integrity. There is a high tree canopy coverage within the Maryland city and many of them are being cut down due to age. This results in significant tree canopy loss.

The city lays out a variety of benefits that come from having an Urban Tree Canopy. Water quality is improved with the presence of street trees; leaves and branches intercept falling rain which ultimately blocks pollutants from reaching stormwater. Air quality benefits through the reduction of carbon dioxide that trees provide while also releasing oxygen as they photosynthesize. The physical and mental health of a community is better off when trees are present in an urban environment. People are encouraged to participate in outdoor activities when an urban tree environment is present.

http://www.ci.cumberland.md.us/DocumentCenter/View/217

ZONING ANALYSIS

Restoration Areas vs. Growth Areas
There is potential in Miami Beach to designate certain sections as Restoration and Growth Areas. "Restoration" describes a location that is vulnerable to environmental hazards, and needs additional fortification developments. "Growth" areas describe where growth is encouraged and adaptation planning has been implemented.

Recommendation 1: Land Acquisition
Local governments and appropriate regional planning authorities should prioritize land acquisition in these areas. These areas could also be established or acquired through mitigation or transfer-of-development rights initiatives. Local governments should place priority on the acquisition of land in these areas for restoration, agriculture, or recreational open space.

Recommendation 2: Growth Spots
Growth should be encouraged in zones outside of the AAA which have higher topographic elevations and the presence of existing transportation infrastructure. These Growth Areas would be incorporated with urban design guidelines that address character of urban place and provide a high quality pedestrian experience through landscape, and the creation of public space. The City could determine locations best for growth and restoration areas. In addition to Adaptation Action Areas (AAAs), they should be developed near major commercial areas, specifically in South Miami Beach (CD-3), where growth has more potential.

Pre-Event Model Recovery Ordinance
The Model Recovery Ordinance for Miami Beach outlines the foundation on which the City can efficiently manage short- and long-term recovery, preferably in advance of a declared disaster, and after. This section focuses on the necessary actions to facilitate recovery, and provides a structured format for capturing essential recovery requirements.

Miami Beach prepares in advance for potential hurricane or other natural hazards. Their Comprehensive Plan suggests that the City government should "provide public improvements and restrict development activities that would damage or destroy coastal resources, protect human life and limit public expenditures in areas subject to destruction by natural disasters in a manner maintaining or improving the marine and terrestrial animal habitats, vegetation, land, air, water, and the visual, aesthetic quality of Miami Beach for present and projected, future populations."

Recommendation 1: Recovery Management Organization
Miami Beach has a Hurricane Guide that was prepared in 2015, which establishes short and long term recovery plans, and urges the citizens and business to develop a disaster preparedness plan before emergency strikes. The Atlantic hurricane season officially goes from June 1 to November 30. Although 97% of tropical activity occurs in these six months, hurricanes have been known to strike throughout the year. According to NOAA, the most common month for hurricanes is September. We propose a recovery management organization that has the authority and is equipped to assist in recovery, is established.

Recommendation 2: Recovery Plan
The Recovery Management Organization shall prepare a Recovery Plan addressing pre-event and post-disaster recovery policies, strategies, and actions; if possible, the Recovery Plan shall be adopted by the City Council before a disaster, and amended afterwards, as needed. The Plan should have the following subheads- Plan content, coordination with other organizations, consultation with citizens, adoption, amendments, implementation, training and exercise, and coordination with related plans.

Recommendation 3: Hazard Mitigation Program
Prior to a major disaster, the Recovery Management Organization, with City Council concurrence, shall establish a hazard mitigation program by which natural hazards, risks, and vulnerability are addressed for prioritized short- and long-term mitigation actions leading to reduced disaster losses. The hazard mitigation program shall include preparation and adoption of a Local Hazard Mitigation Plan, an amendment of the Comprehensive Plan to include a Natural Hazard/Safety Element [or equivalent]. This will be done while keeping in mind emergency actions that deal with immediate hazards abatement, including hazardous materials management.

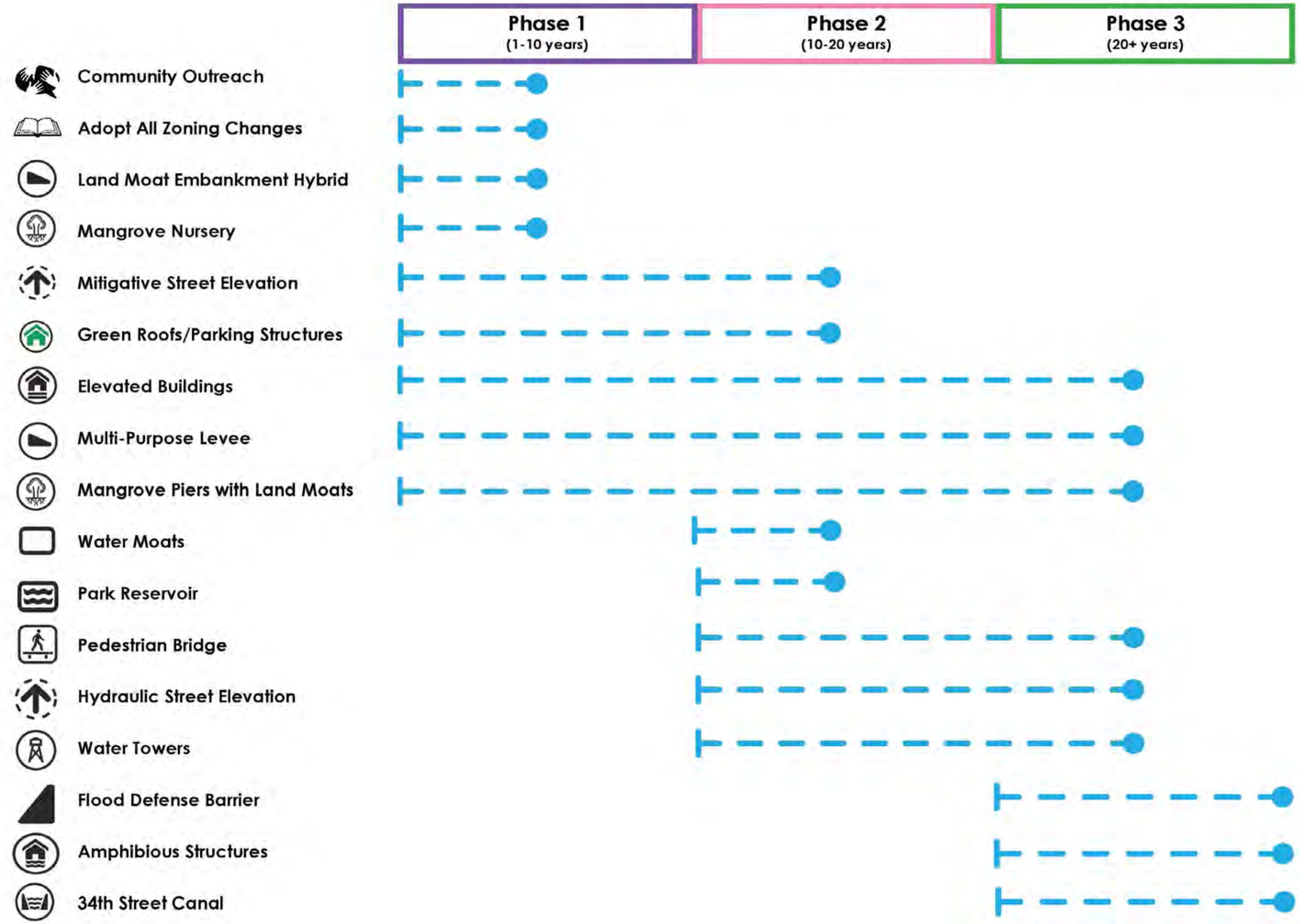
CASE STUDY 2: Chicago, Illinois

The streets on most of the South Side and parts of the North and West Sides in the 1950's were raised by an average of between four and five feet. Some other places were elevated by as much as eight feet. For the purposes of facilitating drainage and accommodating the city's sewerage system, this entire process was done in two stages throughout the decade. The most interesting part of this effort, and the one that drew commentary from tourists, was the raising of existing buildings to the higher grades.

Property owners were left to individually raise buildings while the streets were taken care of through public funding. Frame structures were easier to raise, though many were not raised, but the raising of large brick hotels, banks, and other business buildings was a technological feat in the 1850s. George M. Pullman, of sleeping car fame, made his initial reputation in Chicago raising buildings.

http://www.encyclopedia.chicagohistory.org/pages/1202.html

PHASING / FINANCING



Graphic made by Andrew Pagano, Dan Chibbaro, and Virginie Nadimi

The Miami Beach Design Studio proposes a phasing schedule that is split into three groups: Phase 1 (0-10 years), Phase 2 (10-20 years), Phase 3 (20+ years), as shown in Figure X. The design typologies included in each phasing group were selected to be consistent with the results of the studio's Miami Beach site and risk prioritization analysis. Estimated financial cost of each typology were considered in the development of the phasing schedule. However, the potential of each design typology to protect Miami Beach's most vulnerable areas from rising sea levels was the most influential factor when considering which design typologies should be prioritized.

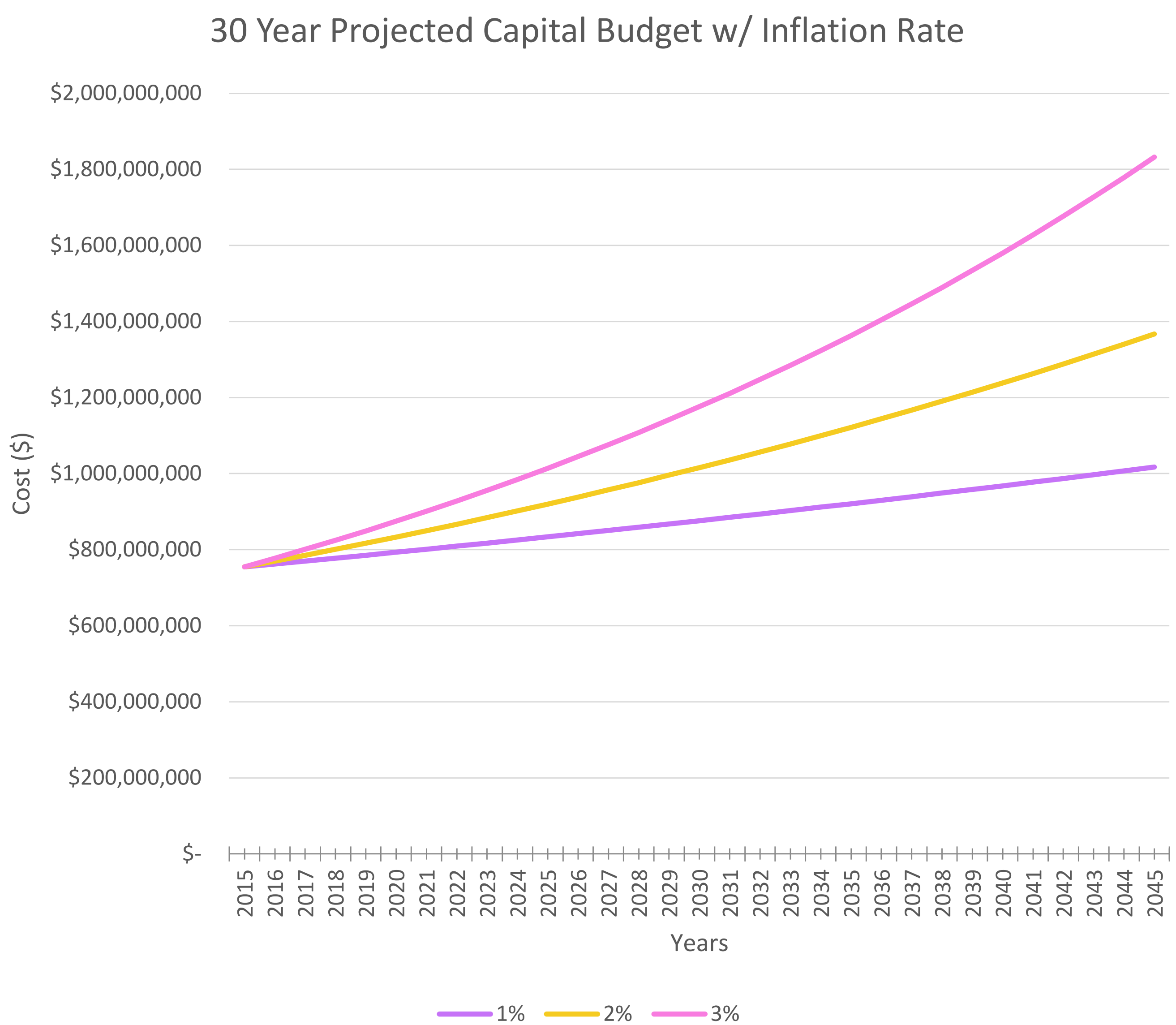
The design typologies included in Phase 1 represent the projects that the studio believes should be started immediately as these projects have the potential to be the most impactful solutions for Miami Beach's long term resiliency. This includes the planning and design processes for the bayside multi-purpose levee and the Mid Beach embankment that were developed to mitigate some of the worst contemporary flooding observed during site analysis. Phase 1 also includes conducting a robust community outreach process and enacting the necessary zoning changes to facilitate implementation, both of which serve as the foundation for all necessary changes to Miami Beach's built environment. All Phase I initiatives and projects are recommended to be completed by a year 10 benchmark.

In Phase 2, the studio included the typologies that are recommended to be completed by the year 20 benchmark, including the water moats and park reservoir. Projects included in Phase 2 can be more easily invested in once the foundational progress of Phase 1 is completed. Even though these projects demand less urgency than those in Phase 1, they still have the potential to be effective at flood mitigation in Miami Beach's most vulnerable areas.

Finally, Phase 3 includes the typologies that should be pursued beyond the 20 year benchmark. This includes projects that do not necessarily target the most vulnerable areas of Miami Beach, such as the 34th street canal and flood defense barriers. However, these projects are still considered to have great potential at enhancing Miami Beach's resiliency, particularly once Miami Beach has a greater understanding of the impact of sea level rise in the 2030s and anticipated resiliency challenges in the second half of the century.

Financing

In order to assess the feasibility of the proposed projects, their costs were predicted as the aggregate of capital investment and maintenance. Since these projects are quite innovative and prob-



ably first of their kind, the costing is estimation to the closest reference available. It is suggested that the City of Miami Beach prepare a detailed implementation plan and schedule for each of the projects to compute the nearest actual expenditure.

To estimate the cumulative costs of the capital project, along with the annual maintenance and operation expenses, upfront cost and operating costs were analyzed and estimated. The investment required is represented on a scale of least to most expensive, least being less than a hundred thousand dollars and the most expensive being over a billion dollars. The ranges are given in the Legend to the right.

The project costs are obtained in correlation to the phasing. Represented in the table below, the project's upfront and operating costs for all the proposed projects are listed. As discussed in the phasing section, the most immediately required projects are included in Phase I and except for Multi-purpose levee, all the projects are anticipated to be under $100 million each. The most expensive project, Flood Defense Barrier has included in Phase III.

Before predicting the costs of the projects, an extensive research was conducted to find detailed project reports of capital projects with similar features in either the same geographic location or in cities with similar characteristics. The purpose of perusing through comparable projects was to enable us to undertake realistic assumptions on unit cost of each of the projects, which would form the basis to calculate the overall project cost. The unit costs were multiplied with the project's total units to compute the investment required and thus, to put them in the cost range. For instance, for "Elevated Buildings" in Phase I, FEMA guidelines were used to find out the cost of elevating a building on piles, posts or columns. According to the Elevation guideline, this value is $36/sq. foot. This value is adjusted to $50/sq. feet to incorporate cost escalation and underlying operational costs. Along the Tatum Waterway in North Beach, there are about 40 buildings that need to be elevated, with an average building area of 5,160 Sq. feet each. This puts the cost close to $10 million. The recommendations propose elevation of buildings at 4 locations throughout Miami Beach. If we assume that all the 4 locations will cost either $10 million or above, the project of Elevated Buildings will cost about $50 million, thus qualifying to be in the range of "$$".

Depending on the phase that the project will be implemented in, various factors of location, present cost and inflation were also considered while coming up with the rough estimates of the capital projects. In case of projects like, Structural Water Towers that is very innovative in its concept, the unit value for the construction of a usual water tower escalated by 50% was used. The unique design of each project was integral in determining what deviation from the standard unit cost was rational, to come up with a fair estimate. In cases where detailed project reports were not available, additional resources like papers, guidelines were used for estimation. Like in the case of Mangrove plantation, a research paper that discussed the costs of ecological restoration was referenced.

	Projects	Upfront	Operating
Phase I	Land Moat Embankment Hybrid	$$$	$$
	Mangrove/Tree Nursery with Permeable Planter	$$$	$$
	Parking structures/garage	$$$	$
	Street Elevation Type 1	$$$$	$
	Adopt All Zoning Changes	$	
	Green Roofs with Parking Structure System	$$	$
	Elevated Buildings	$$$$	$
	Multi-purpose Levee	$$$$$	$$$
	Mangrove Piers with Land Moats	$$$$	$
	Elevated Building/ Neighborhood	$$$	$
Phase 2	34th Street Canal	$$$$	$$
	Water Moat/block	$$$$	$
	Park Reservoir	$$$$$	$$
	Pedestrian Bridge/Neighborhood	$$$	$
	Street Elevation Type 2	$$$$	$$
	Structural Water Towers	$$$$	$$$
Phase 3	Flood Defense Barrier	$$$$$$	$$
	Amphibious Structures/per neighborhood	$$$$	$

LEGEND
$ = $10,000s
$$ = $100,000s
$$$ = $1,000,000s
$$$$ = $10,000,000s
$$$$$ = $100,000,000s
$$$$$$ = $1,000,000,000s

FUNDERS

FEMA – Hazard Mitigation Assistance

Hazard Mitigation Grant Program (HMGP) - HMGP assists in implementing long-term hazard mitigation measures following Presidential disaster declarations.

Pre-Disaster Mitigation Grants (PDM) - PDM provides funds on an annual basis for hazard mitigation planning and the implementation of mitigation projects prior to a disaster.

Flood Mitigation Assistance Grant Program (FMA) - FMA provides funds on an annual basis so that measures can be taken to reduce or eliminate risk of flood damage to buildings insured under the National Flood Insurance Program (NFIP).

Repetitive Flood Claims (RFC) - RFC provides funds on an annual basis to reduce the risk of flood damage to individual properties insured under the NFIP that have had one or more claim payments for flood damages.

Severe Repetitive Loss (SRL) - SRL provides funds on an annual basis to reduce the risk of flood damage to residential structures insured under the NFIP that are qualified as severe repetitive loss structures.

National Flood Insurance Program - Provides federally backed flood insurance to homeowners, renters and business owners in more than 22,000 communities across the nation.

Public Assistance (PA) Program - Section 406 Mitigation - The Public Assistance (PA) program provides supplemental Federal disaster grant assistance for debris removal, emergency protective measures, and the repair, replacement, or restoration of disaster-damaged, publicly owned facilities of certain Private Non-Profit (PNP) organizations.

Envrionmental Protection Agency

Clean Water Act Section 319 Grants - Grants for water source management programs including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and regulation.

Clean Water State Revolving Funds - State grants to capitalize loan funds. States make loans to communities, individuals, and others for high-priority water-quality activities.

Wetland Program Development Grants - Funds for projects that promote research, investigations, experiments, training, demonstrations, surveys, and studies relating to the causes, effects, extent, prevention, reduction, and elimination of water pollution.

National Oceanic and Atmospheric Administration (NOAA)

Coastal Services Center Cooperative Agreements - Funds for coastal wetlands management and protection, natural hazards management, public access improvement, reduction of marine debris, special area management planning, and ocean resource planning.

Coastal Services Center Grant Opportunities - Formula and program enhancement grants for implementing and enhancing Coastal Zone Management programs that have been approved by the Secretary of Commerce.

Coastal Zone Management Program - The Office of Ocean and Coastal Resource Management (OCRM) provides federal funding and technical assistance to better manage our coastal resources.

Marine and Coastal Habitat Restoration - Funding for habitat restoration, including wetland restoration and dam removal.

Floodplain, Wetland and Watershed Protection Programs

USACE Planning Assistance to States (PAS) - Fund plans for the development and conservation of water resources, dam safety, flood damage reduction and floodplain management.

USACE - Flood Damage Reduction - This program provides authority to plan, design and construct certain small flood-control projects in accordance with current policies and procedures, and that have not already been specifically authorized by Congress. Both structural (levees, channels or pumps, for instance) and non-structural (flood-proofing or relocation of structures, for example) solutions to reduce damages caused by over-bank flooding are considered.

USACE - Clearing and Snagging for Flood Control - Authority for this action is provided under Section 208 of the Flood Control Act of 1954, as amended. Program authority provides for minimal measures to reduce nuisance flood damages caused by debris and minor shoaling of rivers. Work under this authority is limited to instream clearing and snagging, or channel excavation and improvement with limited embankment construction by use of materials from the channel excavation.

USACE Flood Plain Management Services (FPMS) - Technical support for effective floodplain management

USACE Environmental Laboratory - Guidance for implementing environmental programs such as ecosystem restoration and reuse of dredged materials.

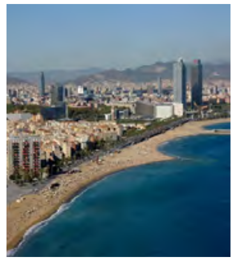
U.S. Fish & Wildlife Service Coastal Wetlands Conservation Grant Program - Matching grants to states for acquisition, restoration, management or enhancement of coastal wetlands.

U.S. Fish & Wildlife Service Partners for Fish and Wild life Program - Program that provides financial and technical assistance to private landowners interested in restoring degraded wildlife habitat.

Housing and Urban Development
Community Development Block Grants (CDBG) - Grants to develop viable communities, principally for low and moderate income persons. CDBG funds available through Disaster Recovery Initiative.
Disaster Recovery Assistance - Disaster relief and recovery assistance in the form of special mortgage financing for rehabilitation of impacted homes.
Neighborhood Stabilization Program - Funding for the purchase and rehabilitation of foreclosed and vacant property in order to renew neighborhoods devastated by the economic crisis.

APPENDIX A
CASE STUDIES

CASE STUDY 1: Barcelona, Carelonia



The city of Barcelona is a center for tourism, entertainment, sports, and other industries. High unemployment has increased the number of people unable to find homes, make mortgage payments, or afford utilities. There have been major impacts on social structures, main transportation lines, and power. The past decade has also put a strain on infrastructure there.

In response to these circumstances, officials have assembled teams to increase resiliency by analyzing shocks and coordinating efforts. The city has begun addressing pollution issues by creating projects that promote renewable energy, reduce reliance on fossil fuels, and adopting electric vehicles. A design concept which the city has recently implemented gives enough breathing room to the streets to ensure a comfortable environment.

KEY POINTS

Resilience challenges include flooding (coastal and rainfall), heat waves, high unemployment, lack of affordable housing, and social inequity.

In 2009, Barcelona launched an integrative disaster risk management and failure prevention-focused program in response to different hazard-related episodes.

That same year, city created the Infrastructure Urban Resilience Board for transversal projects to reduce urban vulnerability and guarantee stable quality of life.

Resilience model used to identify the weak points/risks in networks of infrastructures and services in the city and its metropolitan area.

Key to Barcelona's resilience model success was having established a robust partnership with the stakeholders who could contribute towards building a more resilient city.

CASE STUDY 2: Chennai, India

Chennai is the capital city of the Indian state of Tamil Nadu and the largest industrial and commercial center in South India. With a population of about 4.6 million people, Chennai is the fourth largest city in India and 36 th largest urban area in the world.

This case study is important not because the city has implemented innovative solutions, but instead to understand what should be avoided while planning for resiliency. Chennai was named one of the "hottest cities of 2015" by the BBC and one of the "52 places to go in 2014" by The New York Times. Parts of Chennai were hit by Tsunami of 2004. In Dec 2015, after 17 days straight of rain, the flood in Chennai killed at least 300 people, and affected the lives of hundreds of thousands.

Chennai floods are a direct result of change in climate, coupled with poor urban planning. More than 10 years after the city was hit by Tsunami, Chennai has been unsuccessful in implementing resilient strategies to mitigate the effects of climate change. Economic loses from the flooding is expected to be about $3 sbillion.

KEY POINTS

While planning for resiliency, density should be checked and restricted. Very high density results in frequent flooding resulting in considerable damage.

Adequate permeable surfaces should be maintained to increase the absorption of water to the ground, which doesn't get achieved in case of high density development.

When proposing innovative solutions, especially for resiliency, it should be strategized in consensus with the community and involve them at every possible step.

http://www.thehindu.com/news/cities/chennai/a-new- resilience-map- in-the-making/article8181053.ece

CASE STUDY 3: Hafen City, Hamburg

Germany's coast extends over 3700 km on both the North (1600 km) and Baltic Seas (2100 km). In political and administrative terms, five states (out of 16 states making up the Federal Republic of Germany) border these coasts: Lower Saxony, Bremen, and Hamburg belong to the North Sea region; Mecklenburg-Vorpommern belongs to the Baltic Sea region; and Schleswig-Holstein shares coasts with both seas.

Hamburg is a more robust area that deals with flood proofing and is located on the waterside of the main dike line. It is also within the flooding area of the Elbe estuary. Existing elevations of the HafenCity are between 4.4 m and 7.2 m above sea level and not adequately protected against flood. Almost every public road and bridge and all buildings will be elevated to the minimum height of 7.5 m above sea level. The buildings' foundations will serve as ground floor garages, which can be flooded in sever cases. Roads and paths are constructed above the flood line to ensure unrestricted access for the fire and emergency services in the event of an extreme storm tide. Total costs are estimated to reach about 600 million euro's

KEY POINTS

If the sea level on the North Sea were to rise significantly, efforts and cost requirements for the protection of the terrestrial drainage would be higher.

Most floodgates currently allow the natural drainage of inland waters at low tide cycles. This would have to be changed to pumping drainage stations (as used widely in the Netherlands) in order to pump the water out continuously.

http://inhabitat.com/hafencitys-flood- proof-design- in-germany- can-cheat- rising-sea- levels/

http://cleantechnica.com/2015/12/09/hafencity-designed-flood-proof/

CASE STUDY 4: Honolulu, Hawaii

Hawaii is a top tourist destination as popular as Miami Beach, and they are both suffering from severe flood issue recently. In addition to flooding, another problem for Government of Hawaii to solve is the vulnerable coast where erosions are exacerbating by the rising sea-level. Moreover, it has been observed that heavy rains and high tides are becoming more frequent as sea level rises. In Waikiki, downtown Honolulu – the famous resort haven, extreme high tides presently cause drainage problems in developed areas where intensifying storm runoff and rising ocean waters intersect.

According to Center for Island Climate Adaptation and Policy (ICAP), three basic approaches to sea-level rise adaptation have been identified:

Accommodation - Adjustment of an existing system to changing natural conditions.

Protection - Hardening of a system in its existing location to withstand impacts from changing conditions.

Retreat - Relocating existing structures to avoid impacts.

<u>KEY POINTS</u>
Shoreline construction setback: generally 40 ft. inland from the certified shoreline.

Raising building elevation requirement: 1-ft by 2050 and 3-ft by 2100 as sea-level rise benchmark.

Hard armoring and Non-structural armoring: sea walls, shoreline hardening, beach renourishment, and dune creation.

http://www.redorbit.com/news/science/1112936725/sea-level- rise-threatens- hawaiian-shorelines- 083113/

CASE STUDY 5: Galveston, Texas

Galveston, Texas shares many of the same natural hazards as Miami Beach. The city was destroyed in 1900 by a hurricane and rebuilt after elevating the city behind a 17 ft high 10 mile long sea wall. The city has issues with stormwater flooding from its bay side after 2008's Hurricane Ike despite its seawall.

Galveston is trying to rebuild and prepare for future flooding in the wake of Hurricane Ike. The city has created a Resiliency Index that includes a broad range of preparedness issues while looking at implementing environmental solutions to limit the impacts of flooding. The city is also implementing new code enforcement programs while keeping historic character.

<u>KEY POINTS</u>
Resiliency Index based on governance, society/economy, coastal restoration/protections, land use and structural design, risk knowledge, warning/evacuation, disaster recovery/emergency response, and public awareness.

Creating green streets to reduce stormwater run-off and flooding while improving property values

Sustainable Neighborhoods Code Compliance Strategy - outlines how the city of Galveston will inform, train, inspect, and operate a code enforcement program to limit storm and flood impacts

Raising standards - develop mitigation guidelines to reduce wind and flood damage to historic buildings.

http://www.academicjournals.org/article/article1379761464_Islam%20et%20al.pdf

http://www.cityofgalveston.org/DocumentCenter/View/192

https://coast.noaa.gov/slr/

CASE STUDY 6: New Orleans, Lousiana

With its Gentilly Resiliency District, New Orleans will create its first comprehensive resilience district in the Gentilly neighborhood. The project will change the landscape of the Gentilly neighborhood to filter and retain stormwater, rather than banish stormwater. Built on a former swamp, the Gentilly neighborhood is surrounded by water on three sides, with Lake Pontchartrain to the north, the Industrial Canal to the East, and the Orleans Avenue Canal to the West.

Today, a system of pumps exists to keep stormwater from filling up in low-lying areas of New Orleans, such as the Gentilly neighborhood. However, years of pumping has dewatered the soil, causing the land to sink relative to the surrounding water, thus making the process of staying dry even more complicated. With a $141 million grant from HUD, the City of New Orleans will implement a comprehensive stormwater management program in the Gentilly neighborhood that will complement traditional drainage systems of pipes and pumps with green infrastructure that will retain water, rather than banish it. Construction would end in 2022.

<u>KEY POINTS</u>
New Orleans is finding innovative ways to store water rather than continually buying larger pumps and building bigger canals.

Storing excess water in the landscape relieves pressure from the pumps. Moreover, it will also help mitigate subsidence, which occurs when groundwater is pumped out of the ground, causing it to dry out and collapse, making the city sink further below sea level.

http://livingwithwater.com/blog/urban_water_plan/solutions/

http://www.theatlantic.com/technology/archive/2015/09/why-doesnt-new-orleans-look-like-amsterdam/402322/

CASE STUDY 7: Norfolk, Virginia

The City of Norfolk is a 100ResilientCity (since Oct. 2015) that faces challenges including "sea level rise and recurrent flooding; a shifting economy; and a need to build strong, healthy neighborhood." It has 250,000 residents and has over 144 miles of coastline. The guiding document for the city's resilience sets up three goals in its framework:

Goal 1: Design the Coastal Community of the Future.

Goal 2: Create Economic Opportunity by Advancing Efforts to Grow Existing Industries and New Sectors.

Goal 3: Advance Initiatives to Connect Communities, Deconcentrate Poverty, and Strengthen Neighborhoods.

<u>KEY POINTS</u>
"Urban resilience is the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience."

Long-Term Recovery Plan Update - "how to respond to and bounce-forward from a major disaster"

Rapid housing recovery model - funded by a HUD grant

http://odu.edu/content/dam/odu/offices/research/docs/Pilot%20Project%20Presentation%2012-2%20update.pdf

http://nfkresilientcity.org/wp-content/uploads/2015/10/Norfolk_Resilient_Strategy_October_2015.pdf

http://www.defenseone.com/ideas/2015/08/norfolk-rising-water-naval-base/119903/

APPENDIX A
CASE STUDIES

CASE STUDY 8: Philadelphia, Pennsylvania

Philadelphia re-classified its streets from the typical Functional Classification of roadways to a new street typology based on the functional roadway classification, land-use characteristics, development density, and pedestrian activity level of streets.

The City then incorporated green stormwater infrastructure (GSI) as a way to implement stormwater management practices (SMPs) into its street network. The Design Manual "provides users with design standards, guidance on siting, information on elemental flexibility within SMPs, and an implementation process to guide users through the various steps of planning, design and construction of a green street."

KEY POINTS
Example of SMPs used for Philadelphia: Stormwater bump-outs, stormwater trees, stormwater tree trenches, stormwater planters, permeable pavement.

"Zones" of rights-of-ways: Vehicle cartway, curbside/buffer, furnishing, pedestrian

http://www.phillywatersheds.org/what_were_doing/gsdm

CASE STUDY 8: Fort Lauderdale, Florida

The City of Fort Lauderdale has endorsed and is acting on implementing the following "innovative pilot projects" all of which would be applicable and adaptable to our Miami Beach-specific planning and design strategies:

Adaptation Action Areas (AAA): An optional comprehensive plan designation for areas that experience coastal flooding and are thus vulnerable to related impacts of SLR. The objective of AAAs would be to prioritize funding for infrastructure and adaptation planning in those areas and support resiliency policies and protocols. The aforementioned Compact was instrumental in providing the support necessary to get the adaptation action area language adopted into the CPA. Fort Lauderdale is the pilot city for AAAs but hasn't highlighted a particular designated area as one from what I can tell; the policy was adopted locally in January 2015.

Pavedrain Systems: The Pave Drain System is designed to mitigate the danger and effects of major stormwater flow over paved surfaces, despite looking like typical pavement. Administered by Fort Lauderdale Transportation and Mobility Department. The city evaluated a pilot installment at City Hall's Orchid Parking Lot in November, 2013 by simulating a major stormwater event, with a firetruck loaded with 700 gallons of water that was then released onto the PaveDrain surface.

http://www.florida-stormwater.org/assets/MemberServices/Conference/2012-Annual-Conference/14%20-%20river%20oaks%20preserve%20sw%20park.pdf

http://gyr.fortlauderdale.gov/greener-government/climate-resiliency

CASE STUDY 9: Rotterdam, Netherlands

The Dutch city of Rotterdam is at the forefront of the battle with climate change and sea level rise. Located in South Holland, in a delta of the Rhine and Meuse Rivers, Rotterdam is the second most populated urban area in the Netherlands, with over 600,000 residents, and the largest port city in Europe in terms of tonnage. It has an extensive distribution system of rails, roads, and waterways, which earned it the name, "Gateway to the World," in Europe.

Rotterdam, Netherlands

Like other cities in the Netherlands, this "City on a River" has had a long history with water. With more than 80% of the city below sea level, Rotterdam has accumulated much experience in the area of resiliency over centuries of dealing with flooding and other water issues. Throughout its history, Rotterdam has carried out innovative water management projects ranging from windmills to dykes as measures to control the surrounding waters for the city's needs. The disastrous storm surge and flood of 1953, which caused almost 2,000 casualties and widespread property damage, prompted Rotterdam to develop a delta plan to bolster its flood protection system. Technological advances allowed Rotterdam to build higher sea barriers, including the Maeslantkering (Maeslant Storm Surge Barrier), which opened in 1997 and is one of the largest moving structures in the world.

http://www.100resilientcities.org/cities/entry/rotterdams-resilience- challenge#/-_Yz5jJmg%2FMSd1PWI%3D/

http://inhabitat.com/rotterdams-floating- pavilion-is- an-experimental- climate-proof- development/

http://www.greenplanetarchitects.com/en/project/commercial/museumpark

CASE STUDY 10: Shanghai, China

The municipality of Shanghai is located in the east of China. Shanghai is the largest city by population in Mainland China with over 23 million people. Much of the population resides along the coastal area of the city. As an important global financial center and the busiest container port in the world, Shanghai is China's most important economic center.

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Geomorphic characteristics:
1. Located on the estuary of the Yangtze River in East China, and is built on an alluvial plain with a very flat topography.

2. The city's subsidence has been expanding at an alarming rate.

Climate influence:
1. Subtropics monsoon climate with adequate rainfall, especially in summer.

2. Threaten of Typhoon.

3. Climate change and sea level rising.

http://www.georgetownclimate.org/sites/www.georgetownclimate.org/files/GCC-Shanghai_Flooding-August2015.pdf

http://www.asfpmfoundation.org/ace-files/pdf_ppt/StudentPaper2013_FloodResistancetoFloodResilience_FitzRandolph.pdf?pagename=pdf_ppt/StudentPaper2013_FloodResistancetoFloodResilience_FitzRandolph.pdf

CASE STUDY 11: Tokyo, Japan

The "Next Tokyo" initiative is quite useful/relevant to our Miami Beach challenge because it illustrates the innovation and intricacy we can apply (especially design-wise) to our final plan. What I found particularly pertinent is the harmonious relationship created between Tokyo as a city (existing and future development i.e. the built environment) and nature (sea level rise and flooding) via the way "Next Tokyo" was shaped, laid out, and built. I think viewing Miami Beach and its sea level rise/flooding challenges as antagonistic will limit our ability to produce an effective and sustainable solution. Accommodating the inevitable effects of sea level rise while finding creative and durable ways for Miami Beach to carry on a certain level of development is an aim we should keep at the forefront of our work.

KEY POINTS

Megacity density/scale as the new foundation to Miami Beach's development

Natural disaster preparation led by design/infrastructure/natural elements

Experiment with shape and material in design (e.g. the hexagons)

Accommodate the realities of population and development demand and sea level rise/flooding in both policy and design

Maximize use of water storage/distribution systems

https://www.architecturaldigest.com/story/tokyo-will-look-like-2045-including-mile-high-skyscraper?mbid=nl_020816_Weekly&CNDID=40305497&spMailingID=8520589&spUserID=MTIwOTQ0MzM0MDM0S0&spJobID=860836950&spReportId=ODYwODM2OTUwS0

http://global.ctbuh.org/resources/papers/download/2335-next-tokyo-2045-a-mile-high-tower-rooted-in-intersecting-ecologies.pdf

APPENDIX B
GIS METADATA

GIS Overlay Analysis

We conducted the weighted overlay analysis with ArcGIS 10.3. The tool is nested under "Spatial Analyst Toolset/ Overlay". It contains a group of methodologies applied in optimal site selection or suitability modeling. Since the overlay analysis requires inputs as raster, we converted all our factors into raster first, and then multiply by the weights we assigned as Table 1.

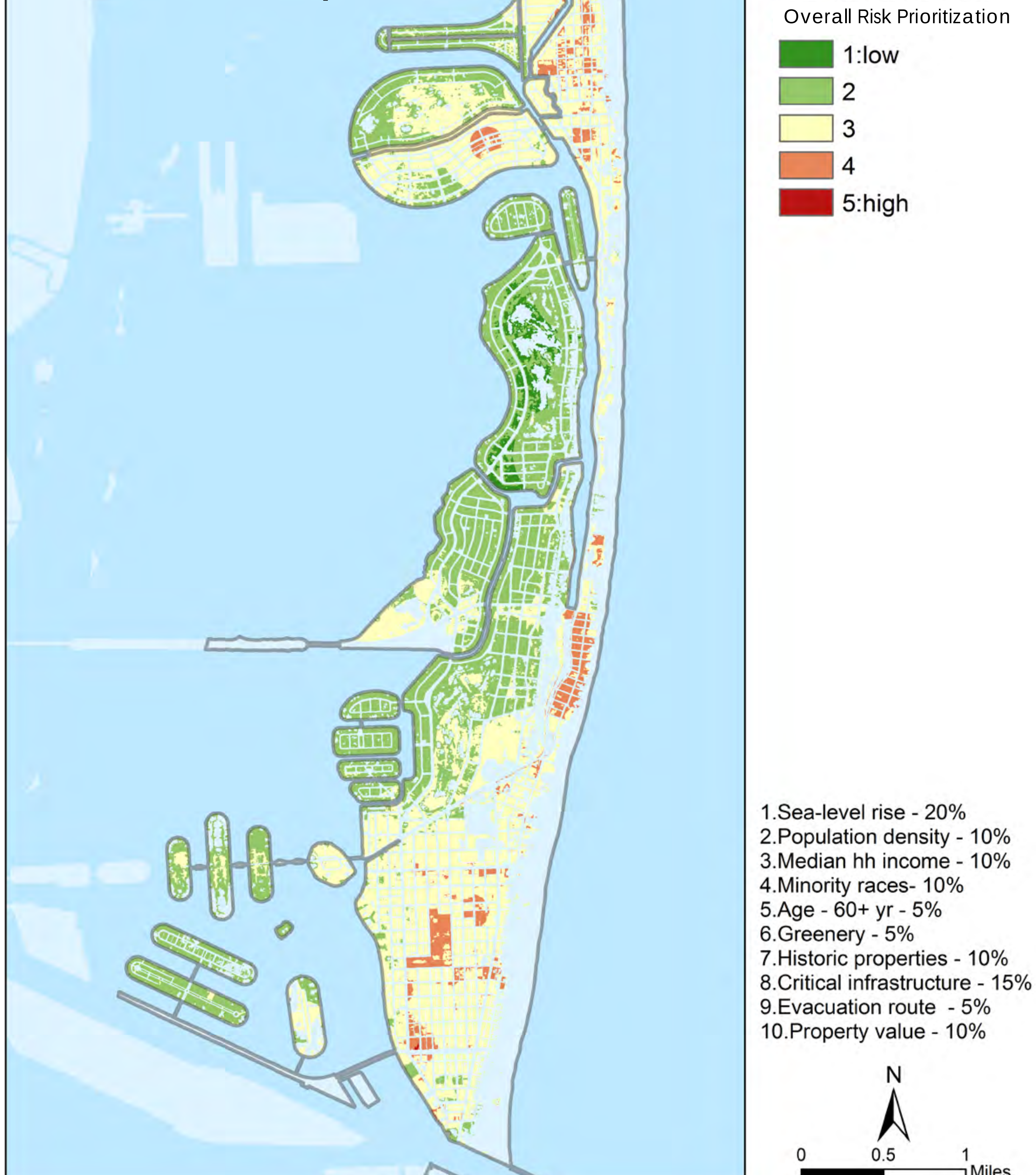
The steps we took for different inputs are illustrated as follows.

1. DEM layer - The factor of sea-level rise is made from a digital elevation model (DEM), which is originally in the form of raster. We just reclassified elevation less than 1-foot to be "1", 1- to 3-foot to be "3", 3- to 5-foot to be "5", and set the rest to "No Data".
2. Polygon layers - Factors such as population density, median income, racial groups, senior citizens, and property values are vector layers. We converted them by the tool "Conversion toolset/ to Raster/Polygon to Raster", and reclassified each into integer scales from 1 to 5.
3. Distance layers – Factors such as distance- to-greenery, critical infrastructures, and evacuation routes. We first applied the tool "Distance/ Euclidean Distance" under Spatial Analyst Toolset and got the outputs as raster files. Then, we reclassified each into integer scales from 1, 3, and 5.
4. Multiple sources layers - Since we have two sources for historic properties, one is a point data recording where the individual properties are located, and the other one is a polygon layer containing boundaries of designated historic districts. First, we joined the point data into parcel polygon, and converted the joined parcel layer and historic district layer into Raster files. Then, we combined the two raster layers with the tool "Raster Calculator", and specified the intersections to be "5", areas contain either one to be "3", and areas not included in both two as "1".
5. Lastly, when all factors were accounted for, we used the weighted overlay tool, and set the weights span from 1 to 5. The result is showed as Figure 1, Inundation Map

Table 1: Risk Priority Methodology

Criteria	Scale	Risk Score	Priority Level	Weight
Sea Level Rise	1 ft	5	High	20.00%
	3 ft	3		
	5 ft	1		
	Other	0		
Population Density	<20% Quintile	1	Medium	10.00%
	21-40% Quintile	2		
	41-60% Quintile	3		
	61-80% Quintile	4		
	>80% Quintile	5		
Median Household Income	<20% Quintile	5	Medium	10.00%
	21-40% Quintile	4		
	41-60% Quintile	3		
	61-80% Quintile	2		
	>80% Quintile	1		
Racial Minorities	<20% of population	1	Medium	10.00%
	21-40% of population	2		
	41-60% of population	3		
	61-80% of population	4		
	>80% of population	5		
Age - 60+ years	<20% of population	1	Low	5.00%
	21-40% of population	2		
	41-60% of population	3		
	61-80% of population	4		
	>80% of population	5		
Greenery	1-500 ft	1	Low	5.00%
	500-1000 ft	3		
	>1000 ft	5		
Historic Properties	Historic Building/District	5	Low	10.00%
	Non Historic Building/District	1		
Critical Infrastructure	<500 ft	5	High	15.00%
	500-1000 ft	3		
	> 1000 ft	1		
Evacuation Route	<500 ft	5	low	5.00%
	500-1000 ft	3		
	> 1000 ft	1		
Assessed Property Value	<20% Quintile	1	Medium	10.00%
	21-40% Quintile	2		
	41-60% Quintile	3		
	61-80% Quintile	4		
	>80% Quintile	5		

Figure 1: Miami Beach Sea Level Inundation Map



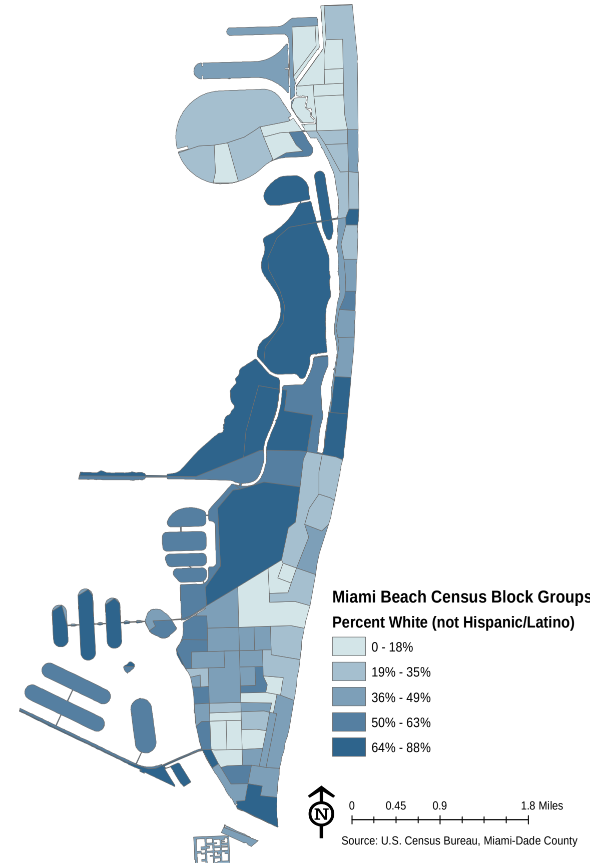
GIS Mapping by Wendy Liu

Table 2: GIS File Documentation and Sources

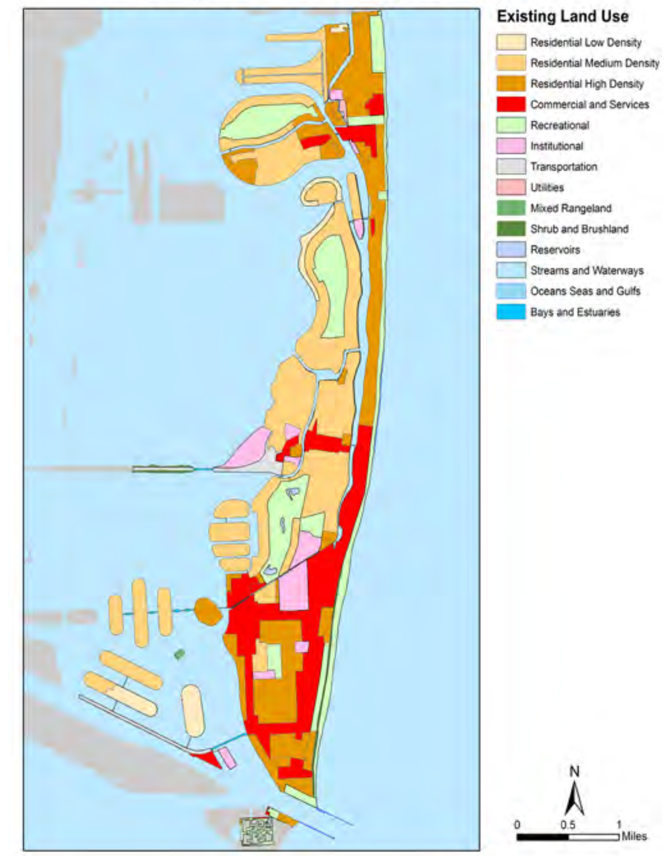
Content	Description	Source
Maimi.gdb - dade_bnd	County boundary	http://www.swfwmd.state.fl.us/data/gis/layer_library/category/cartographic
miami_bc_bgroup	Census block group	Tiger 2014
miami_bc_bnd	Municipality boundary up to coastline	http://gisweb.miamidade.gov/GISSelfServices/GeographicData/MDGeographicData.html
miami_bc_water	Municipality boundary out to water	http://gisweb.miamidade.gov/GISSelfServices/GeographicData/MDGeographicData.html
DEM	Digital Elevation Model (DEM) Mosaic - 5-Meter Cell Size - Elevation Units Inches (2013)	http://www.fgdl.org/metadataexplorer/explorer.jsp
Aerial Photos - q1501nw, q1501sw, q1502se, q1502ne	2004 RGB State Plane Units:FT JPEG 2000	http://www.labins.org/mapping_data/aerials/aerials.cfm
	2013 Building_footprint	http://gis.mdc.opendata.arcgis.com/datasets/1e87b925717747c7b59979caa7779039_1
gc_hospitals_feb13	Florida Hospitals	http://www.fgdl.org/
Hurricane Shelters	Hurricane Shelter Locations	http://gisweb.miamidade.gov/GISSelfServices/Data/HTML/HurricaneShelter.htm
Primary Evacuation Routes	Evacuation Routes	http://gisweb.miamidade.gov/GISSelfServices/Data/HTML/PrimaryEvacuationRoute.htm
Fire Station	Miami Dade County Fire Stations	http://gisweb.miamidade.gov/GISSelfServices/Data/HTML/FireStation.htm
Municipal Police Stations	Miami Dade County Municipal Police Stations	http://gisweb.miamidade.gov/GISSelfServices/Data/HTML/MunicipalPoliceStation.htm
County Police Stations	Miami Dade County Police Stations	http://gisweb.miamidade.gov/GISSelfServices/Data/HTML/PoliceStation.htm
Sewerage	County Sewer Pump Stations	No metadata link -- http://gisweb.miamidade.gov/GISSelfServices/GeographicData/MDGeographicData.html
FLORIDA PARCEL DATA STATEWIDE - 2012	Parcel data including tax valuation and last sale price	http://www.fgdl.org/metadataexplorer/explorer.jsp
Population	2010-2014 American Community Survey 5-Year Estimates, U.S. Census	http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
Median Income	2010-2014 American Community Survey 5-Year Estimates, U.S. Census	http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
Race	2010-2014 American Community Survey 5-Year Estimates, U.S. Census	http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
Age	2010-2014 American Community Survey 5-Year Estimates, U.S. Census	http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
Land use	Statewide Land Use Land Cover 2015	http://www.fgdl.org/metadataexplorer/explorer.jsp
Historic properties	Historical Structure Locations in Florida - January 2016	Historical Structure Locations in Florida - January 2016

APPENDIX C
GIS MAPPING

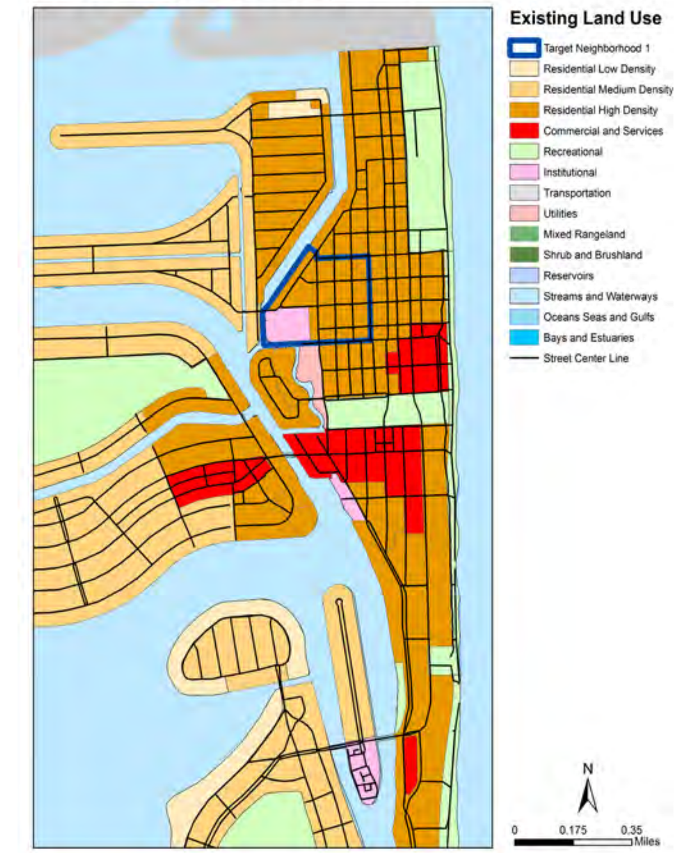
Miami Beach Percent White (not Hispanic/Latino)
2010-2014 American Community Survey 5-Year Estimates



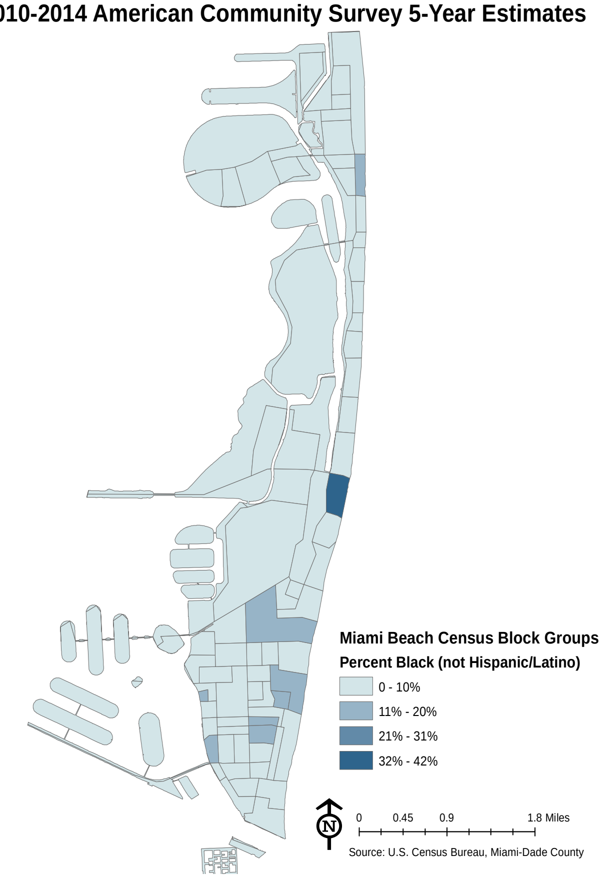
Existing Land Use Map, Miami Beach



Target Neighborhood #1, North Beach, Miami Beach

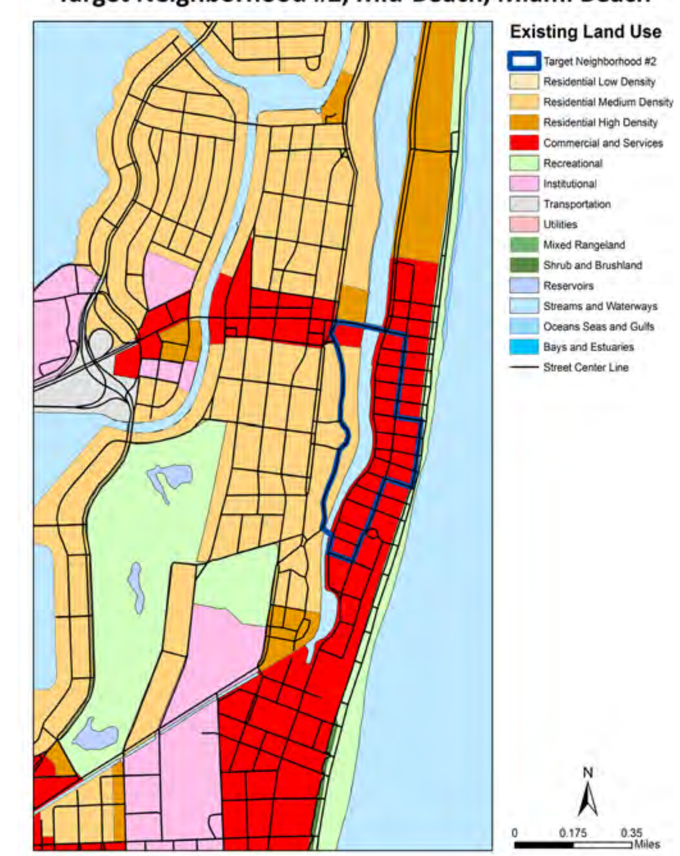


Miami Beach Percent Black (not Hispanic/Latino)
2010-2014 American Community Survey 5-Year Estimates

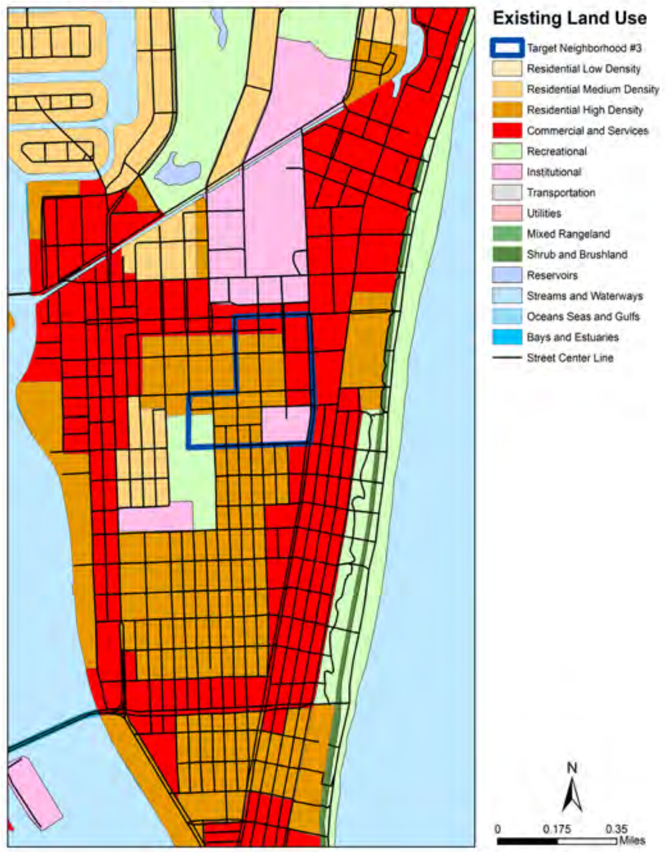


Future Land Use Map, Miami Beach

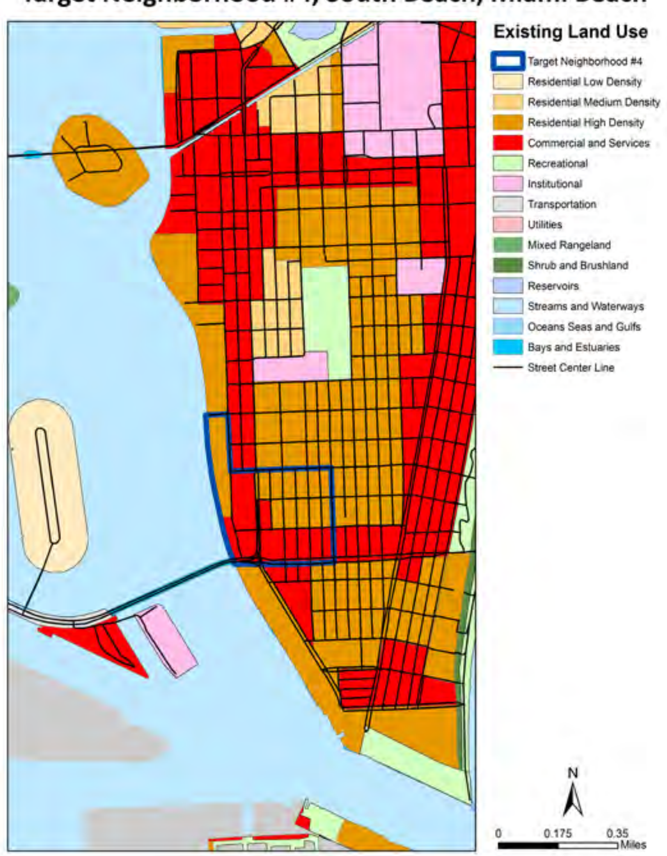
Target Neighborhood #2, Mid-Beach, Miami Beach



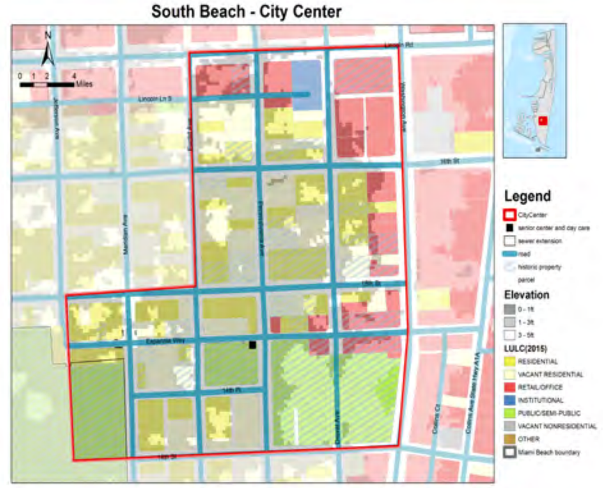
Target Neighborhood #3, South Beach, Miami Beach



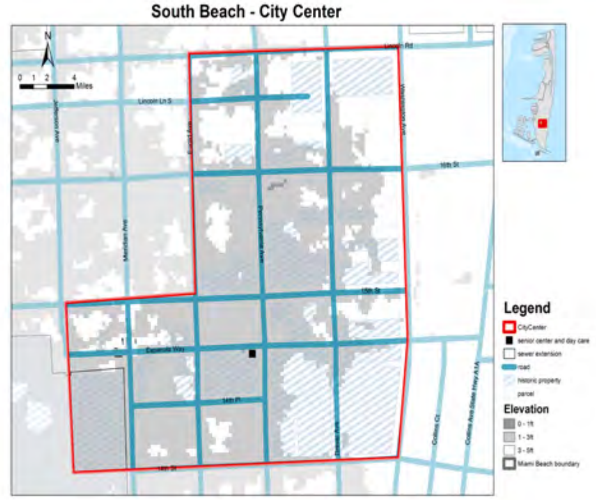
Target Neighborhood #4, South Beach, Miami Beach



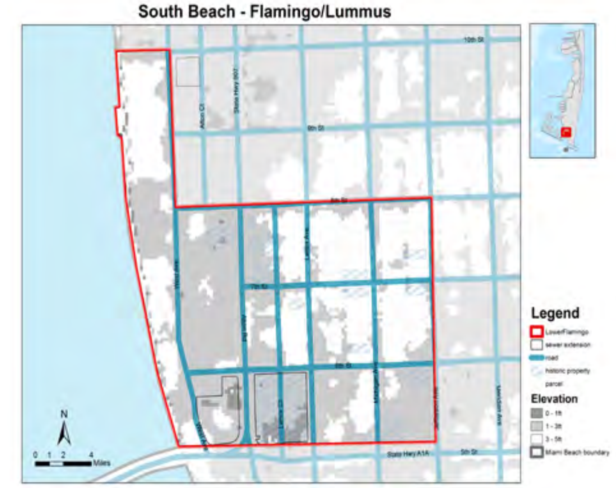
South Beach - City Center



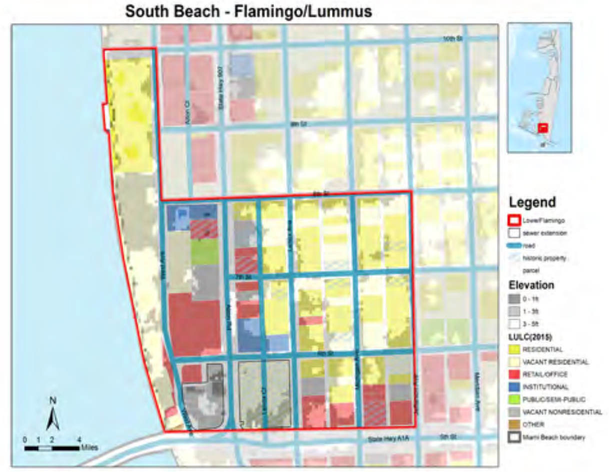
South Beach - City Center



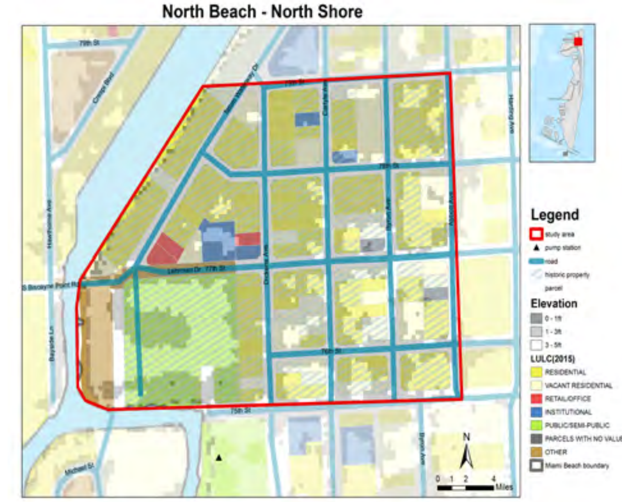
South Beach - Flamingo/Lummus



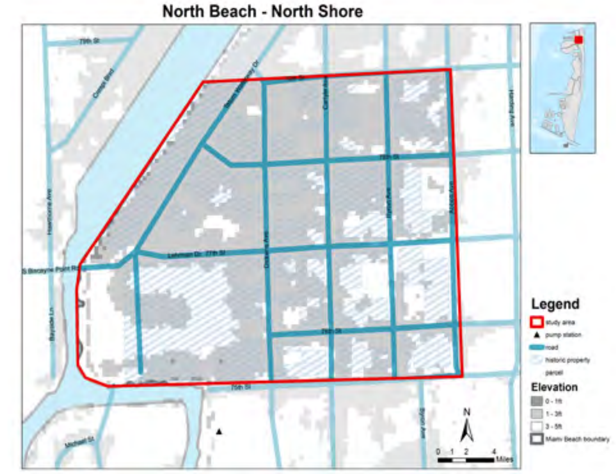
South Beach - Flamingo/Lummus



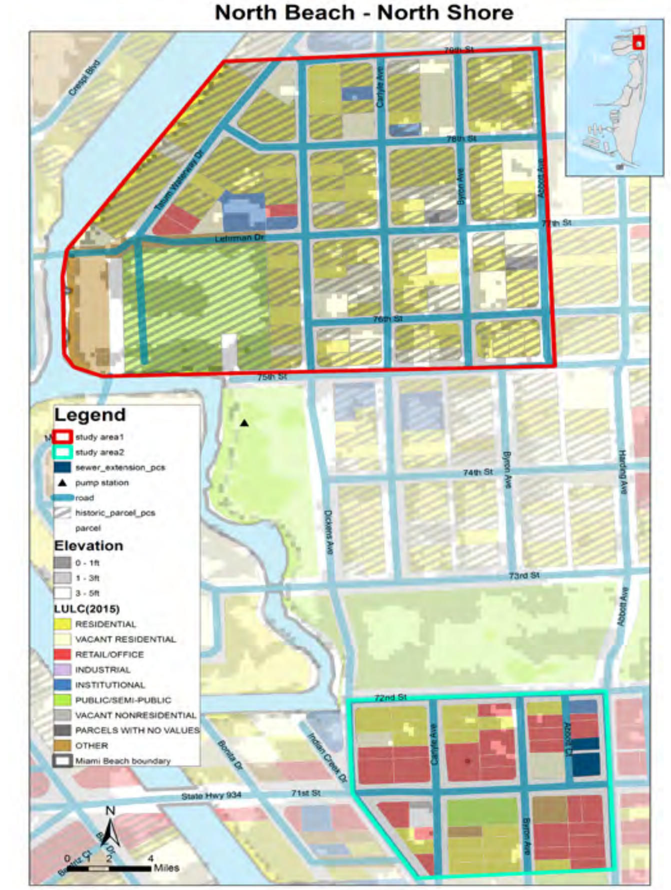
North Beach - North Shore



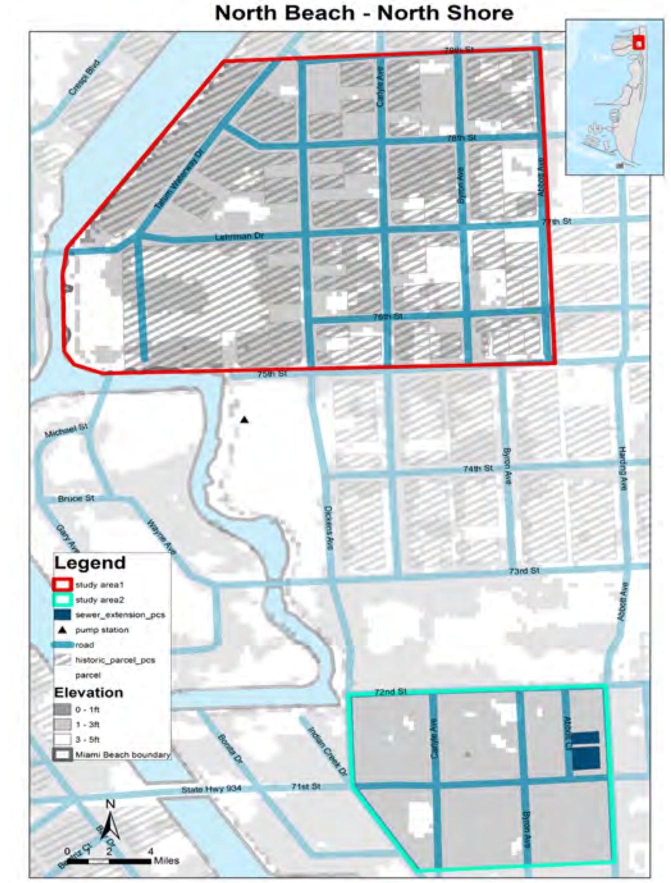
North Beach - North Shore



North Beach - North Shore

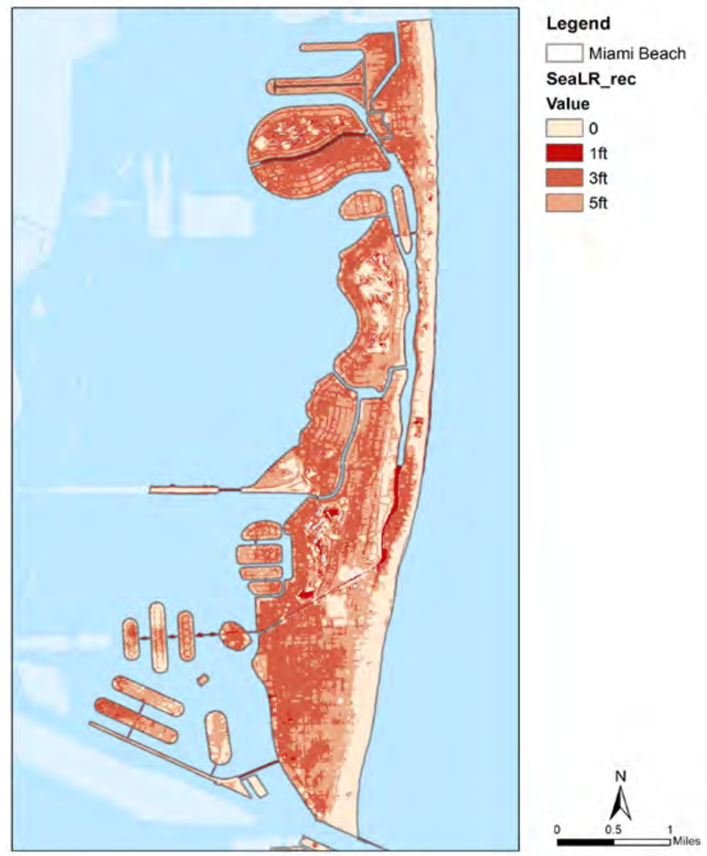


North Beach - North Shore

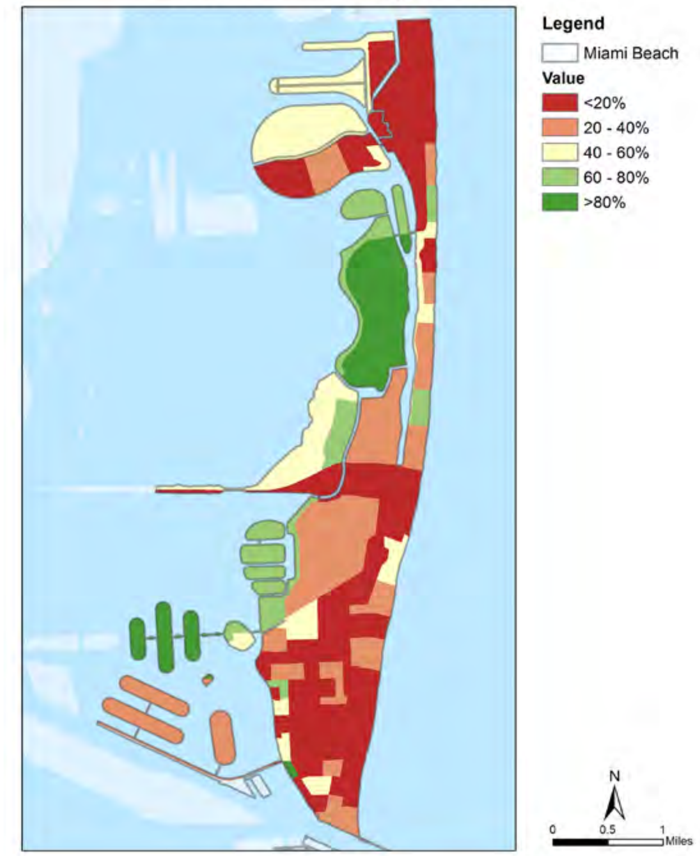


APPENDIX C
GIS MAPPING

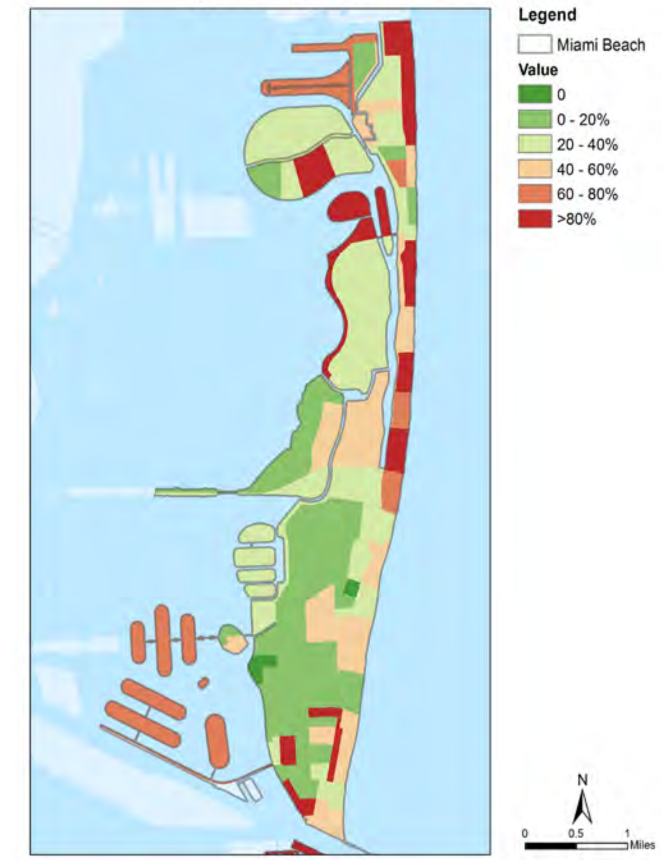
Sea-Level Rise Projection, Miami Beach



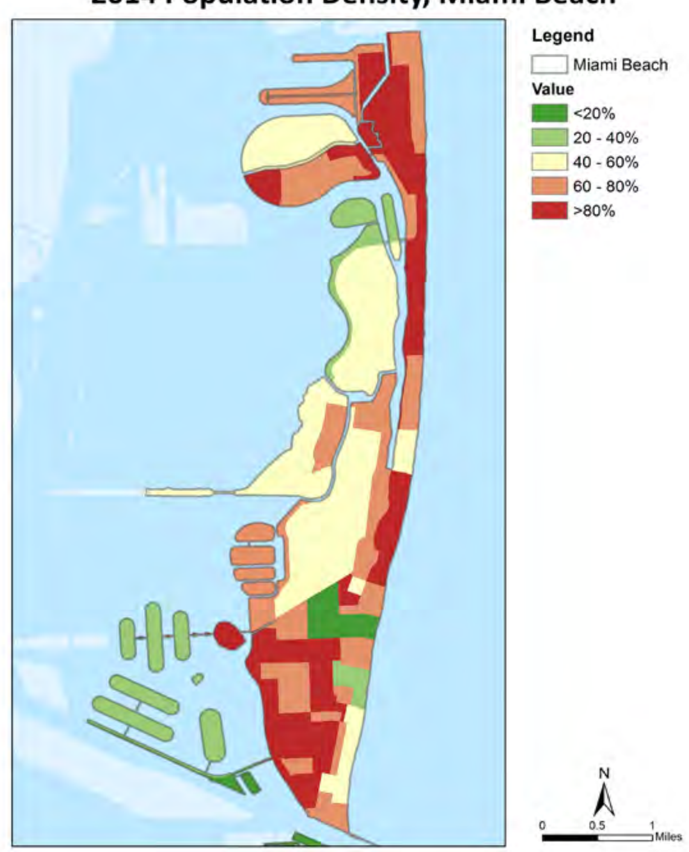
Median HH Income, Miami Beach



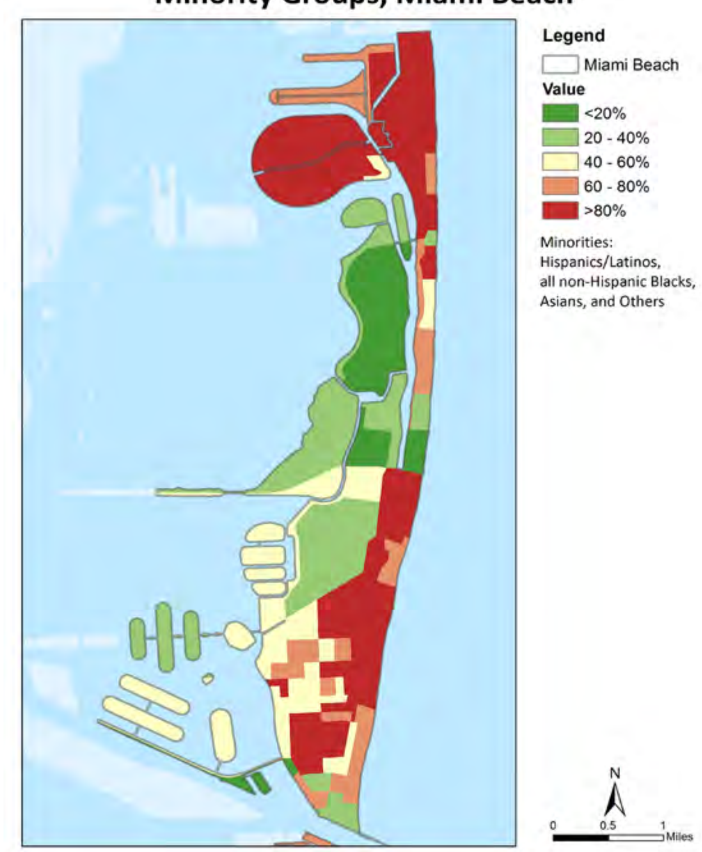
Age 60+ year, Miami Beach



2014 Population Density, Miami Beach



Minority Groups, Miami Beach

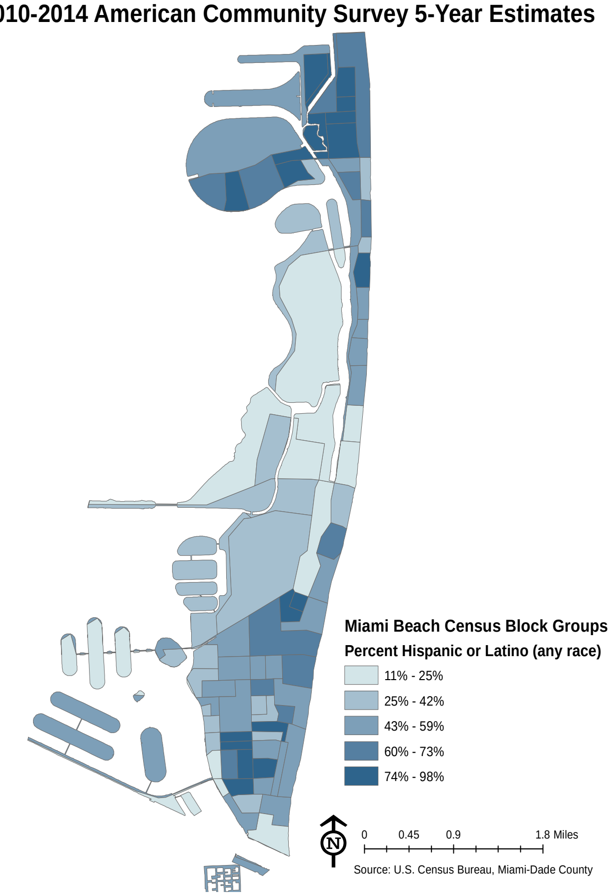


Distance to Greenery, Miami Beach

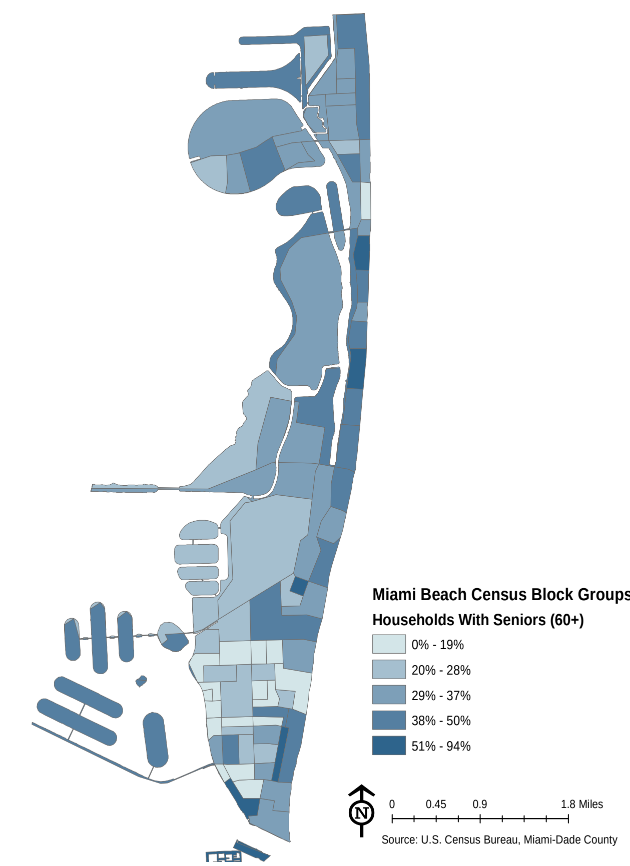
Historic Properties, Miami Beach

Distance to Evacuation Route, Miami Beach

Miami Beach Percent Hispanic or Latino (any race)
2010-2014 American Community Survey 5-Year Estimates



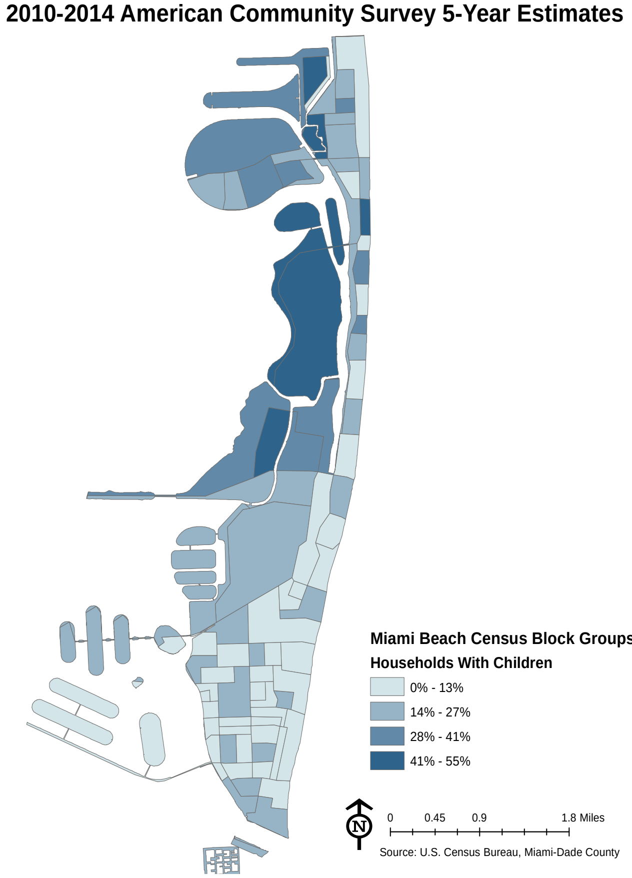
Miami Beach Households With Seniors (60+)
2010-2014 American Community Survey 5-Year Estimates



Distance to Key Infrastructure, Miami Beach

Land Value, Miami Beach

Miami Beach Households With Kids
2010-2014 American Community Survey 5-Year Estimates



Miami Beach Median Household Income
2010-2014 American Community Survey 5-Year Estimates