Anticipating Sea Level Rise: Looking To the Past and Future in Miami-Dade County, Florida

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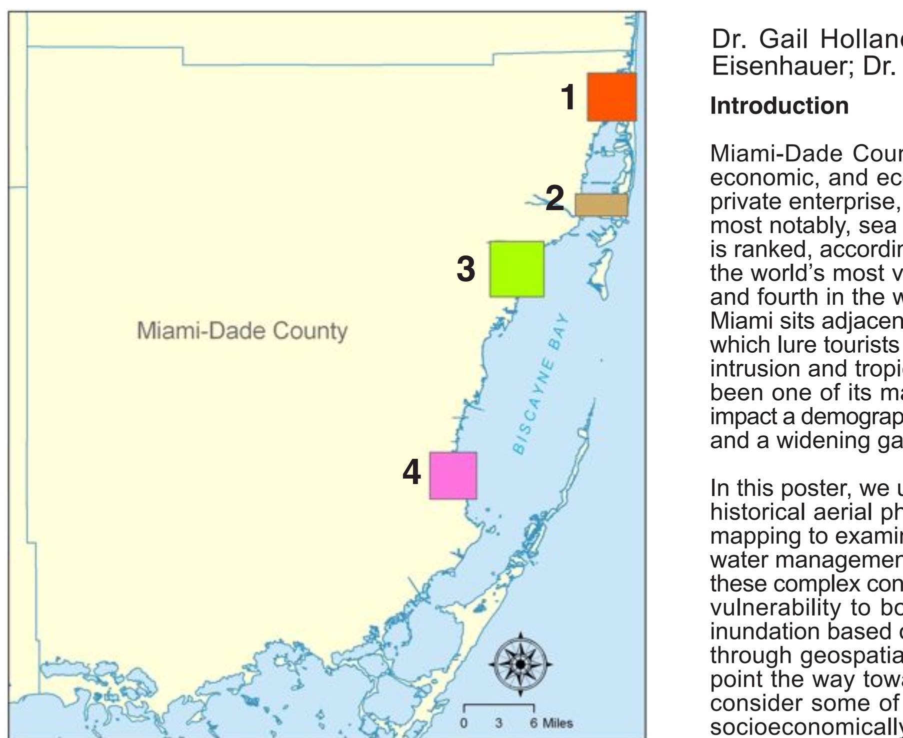

Location Map for Miami-Dade Co.

1. North Miami Beach area shown upper right.
2. Downtown-Miami Beach strip shown below.
3. South Miami area shown bottom left.
4. Turkey Point area shown bottom right.

Introduction

Miami-Dade County is a unique locus of multiple interacting socio-cultural, political, economic, and ecological forces. Miami's rapid urbanization process, largely driven by private enterprise, has engendered an increasing vulnerability to climate change events, most notably, sea level rise. With an average elevation of only six feet, the city of Miami is ranked, according to the Organization for Economic Cooperation and Development, as the world's most vulnerable urban region in terms of assets exposed to coastal flooding and fourth in the world in terms of population exposed. The built environment of greater Miami sits adjacent to two national parks, home to highly diverse ecological communities, which lure tourists from all over the world and yet, faces escalating threats from saltwater intrusion and tropical storms. Thus, while Miami's coastal, subtropical locale has always been one of its main attractions, it may soon be its curse. Moreover, sea level rise will impact a demographically diverse population in a city characterized by residential segregation and a widening gap between rich and poor.

In this poster, we use a combination of geospatial technologies, including georeferenced historical aerial photography, LiDAR imagery and geographic information system (GIS) mapping to examine change over time in the vegetation, land cover, settlement patterns, water management, and built environment of Miami-Dade. The poster highlights some of these complex conditions and visually illustrates, through GIS mapped projections, Miami's vulnerability to both tropical storm surge events and gradual saltwater intrusion and inundation based on different sea level rise scenarios. We show how looking to the past through geospatial imaging that illustrates the region's environmental history may help point the way toward a potentially more sustainable future for Miami-Dade. Finally, we consider some of the social justice implications posed by sea level rise in an already socioeconomically stratified city and ask how meaningful public engagement can be fostered, in part through existing community based organizations.

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Figure 1A: 1924 Aerial Photo (Underwood & Underwood)

Figure 1B: 2006 Aerial Photo (Fla. DOT)

North Miami/ North Miami Beach Area

This region has historically been marked by 'water' problems. In the early 1910s and 20s land owners argued north Biscayne Bay was "polluted" because of frequent fish kills caused by the natural extremes occurring where large freshwater flows, drastic cold snaps, and marine processes were common to the area. Successfully arguing for Baker's Haulover inlet through Miami Beach (lower right) to solve the assumed water pollution would lead to significant changes in land values for "waterfront" properties using dredge and fill to radically alter the coastal marshes for development. The rapid development of the early 1920s was stalled by the Great Hurricane of 1926 and during the 1930's and 1940's increased salt water intrusion into the freshwater supply became a persistent problem. Salt water intrusion and hurricanes are still major concerns today, and yet sea level rise threatens to further exacerbate both.

This 1924 aerial photograph shows a city still dominated by "green infrastructure" (dark colors). Green Infrastructure is a term used to describe practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality. The central northern area in Figure 1A had been recently cleared and stands out as a marker of the conversion to gray infrastructure (light colors), or the built environment, that would overcome the landscape in the following decades. Gray infrastructure refers to the built environment, represented by real estate, roads, concrete, and includes sewers and other water control structures, i.e. bridges, viaducts. According to the South Florida Water Management District (SFWMD), the salinity control in North Miami Beach (See S-29 in Fig 1B) is one of the most vulnerable in South Florida. While the SFWMD is designing new pumping systems to mitigate the effects of SLR on structures such as S-29, the EPA and other organizations promote the use of green infrastructure to mitigate overflows, reduce flood risks, and reduce pollution in the aquifers. The aerial photography from 1924 shows the potential that South Florida has for re-harnessing what is now termed 'green' infrastructure.

One of the primary effects of sea level rise in this region is represented by salt water intrusion into the freshwater aquifer that lies a few feet below the surface and is directly connected to the ocean. Saltwater intrusion has been a concern in South Florida since the 1930s. In 1945, saltwater advanced deep into the mainland due to increased freshwater extraction, uncontrolled drainage, and a lengthy drought. The situation has been temporarily remedied since then through the implementation of a more controlled drainage system and the construction of several salinity / flood control structures. (See Figure 1B) These structures, allow the increase of freshwater levels in the surficial aquifer on the west side of the structures (usually in the dry season) in order to prevent salt water intrusion from the east side. Since these structures have a double role, salinity control and flood control, water managers have to monitor and control the water levels so that these two functions are kept in balance. However, sea level rise significantly reduces the flood discharge capacity, as well as the ability to keep salt water from intruding inland.

With sea level rise projections of two to six inches per decade (South Florida Regional Compact 2011), a situation as the one showed in Fig 1C above is conceivable in the next few decades. Here nearly all of the mangroves of the intertidal zone are completely inundated.

In addition to being one of the most vulnerable cities in terms of sea level rise effects on freshwater resources and flooding, North Miami Beach is also one of the most socially vulnerable cities in Miami Dade County. North Miami Beach has one of the highest poverty rates among the county's municipalities, with almost 19% of residents living in poverty. For comparison, Miami Dade County averages 16.4%, while the national average is 13.3% (Census Bureau 2011).

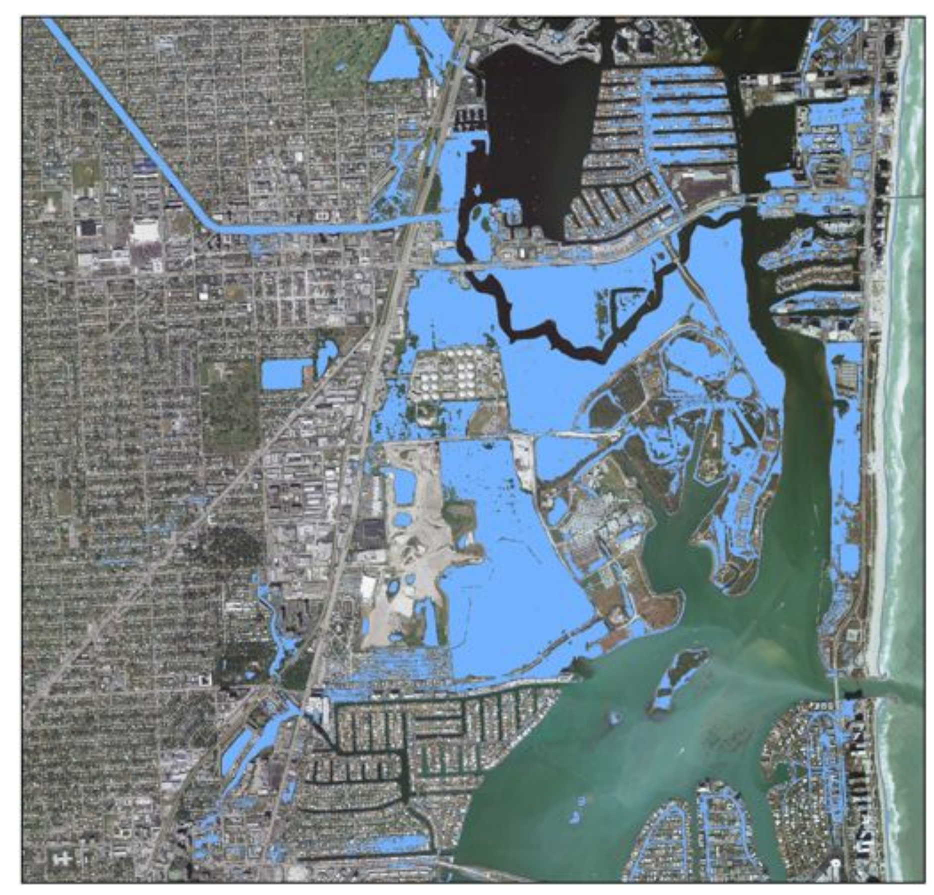


Figure 1C: 3 foot sea level rise inundation (Extrapolated from FDEM LiDAR)

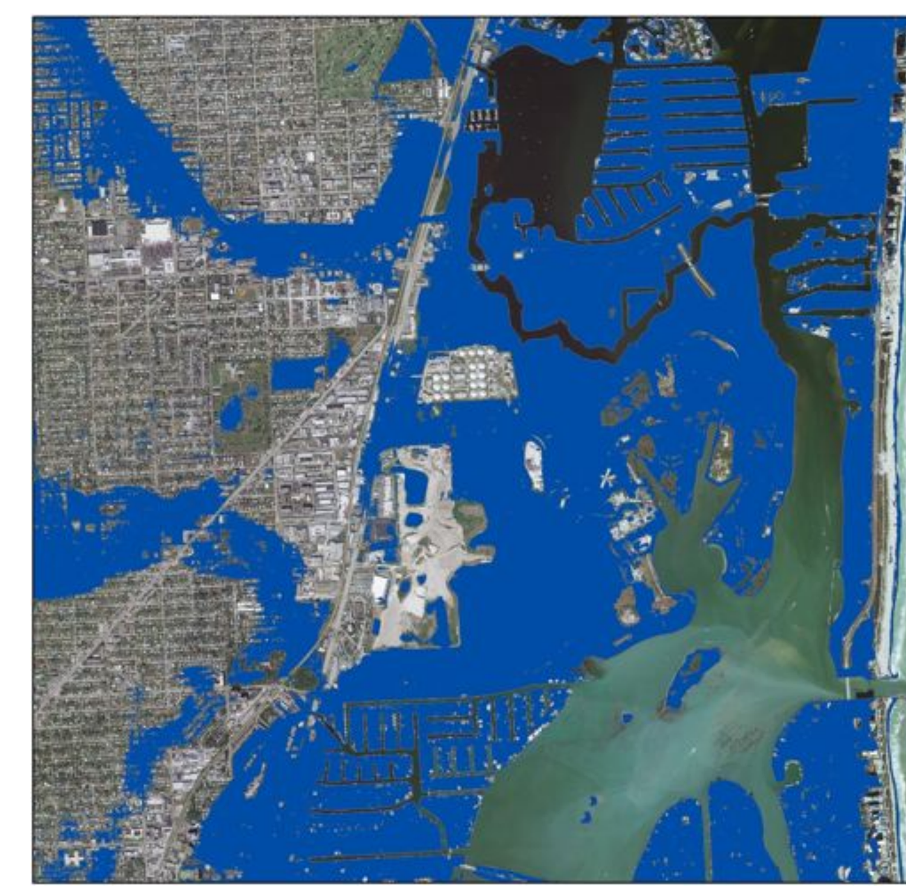


Figure 1D: 6 foot sea level rise inundation (Extrapolated from FDEM LiDAR)

Downtown Development

The Genting Group, a Malaysian conglomerate and leading multinational corporation in the leisure, hospitality, gaming, and entertainment industry, recently purchased 13.9 acres of bayfront property for $236 million as part of a plan to develop the $3 billion Resorts World Miami. With the exception of Walt Disney World in Orlando, this is the largest private property development in Florida's history, and the largest property development (in terms of dollar value) to be announced in North America since 2004. Resorts World Miami is planned to comprise four hotels, restaurants, residences, retail shops, and a convention center. Furthermore, the corporation is in negotiations with all 160 state legislators to gain permission to operate one of the world's largest casinos. The site's planners, Arquitectonica recently unveiled computer generated images of the proposed project.

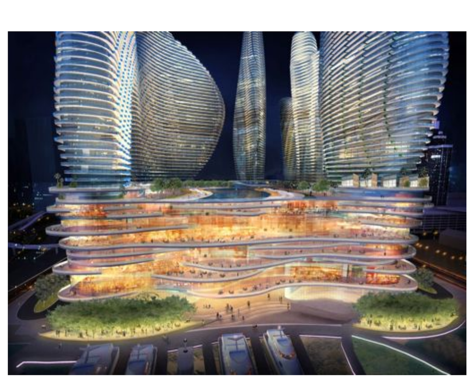


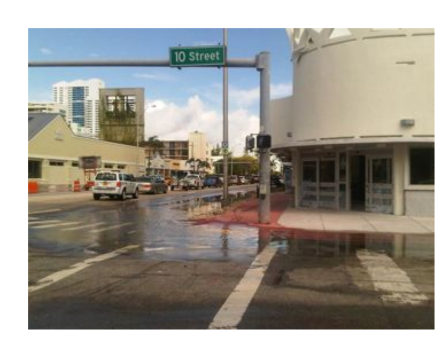
Figure 2 shows how much of the land surrounding what would be Resorts World Miami (on the west shore of Biscayne Bay) will be inundated at 3 feet of sea level rise.

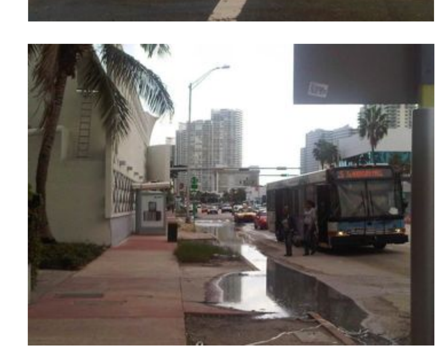
While Miami is seen as one of the topmost cities vulnerable to climate change, it is still viewed globally as a prime locale for capital investment and large scale development projects. How does this example demonstrate the willingness of capitalist investors to gamble on Miami's future?

Arquitectonica image

Figure 2: Downtown Miami to South Miami Beach

Pale blue = 1 foot sea level rise
Medium blue = 2 foot sea level rise
Dark blue = 3 foot sea level rise





Early Signs of Sea Level Rise on Miami Beach

LiDAR data is increasingly being used to produce inundation maps at various stages of sea level rise for small scale areas. But the complex topography, hydrology, and built features of coastal urban areas means that maps alone tell us relatively little about the early impacts of sea level rise on urban life. On Miami Beach, the effects of rising sea level are already beginning to be visible with water accumulating in low-lying areas of the city during extremely high tides. Because the city's storm drainage system dumps directly into Biscayne Bay, when tides are high water can flow in a reverse direction out of storm drains and onto streets that sit at a particularly low elevation (see photos at left). Much of this flooding often goes unnoticed as its appearance is limited and patchy throughout the city. According to LiDAR elevation data, the corner depicted in the first photo is less than 1.22' in elevation meaning that with a 1 foot rise in sea level, flooding (see Figure 2, pale blue) will occur regularly in this area during the highest tide of the day. These early observations raise many important questions: what is the extent and the nature of flooding that will begin to change urban life, and how will residents, visitors, and the government begin to adapt? At what point will it enter widespread consciousness that this problem is worsening due to climate change, and will this have an impact on carbon consuming behavior? What will be the impact on the area's economy and population growth? How will the city's diverse socio-economic groups be impacted by the changes, and what tools and information will be available to help residents adapt?

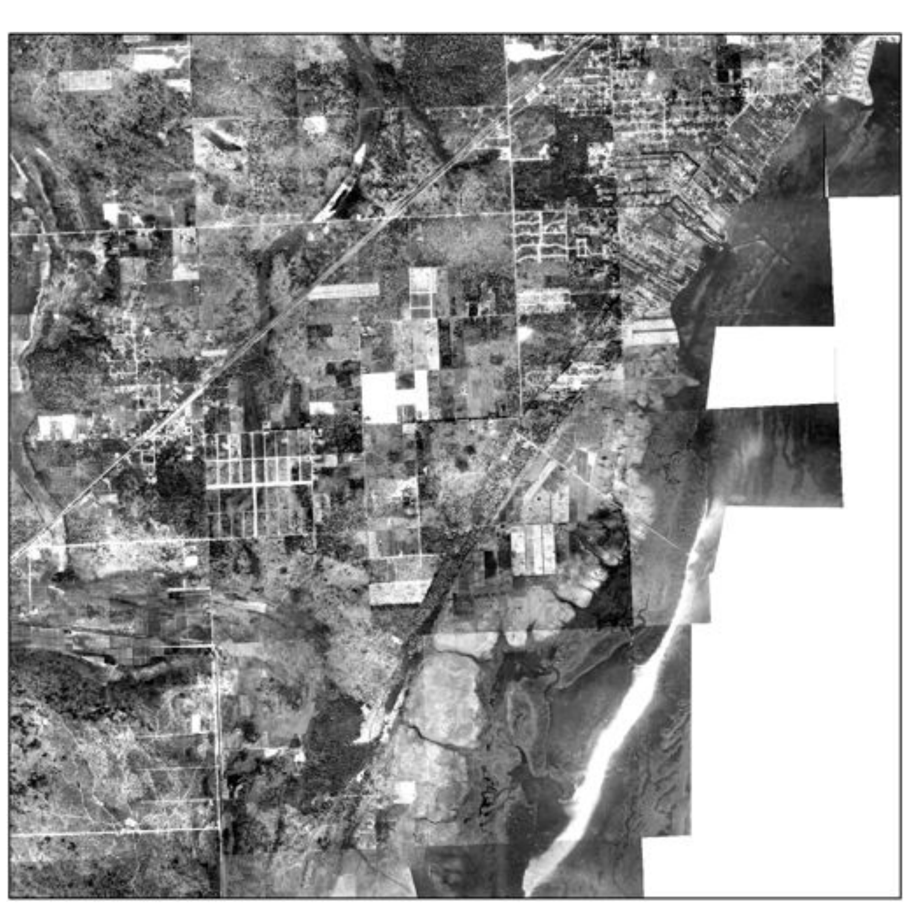


Figure 3A: 1924 Aerial Photo (Underwood & Underwood)

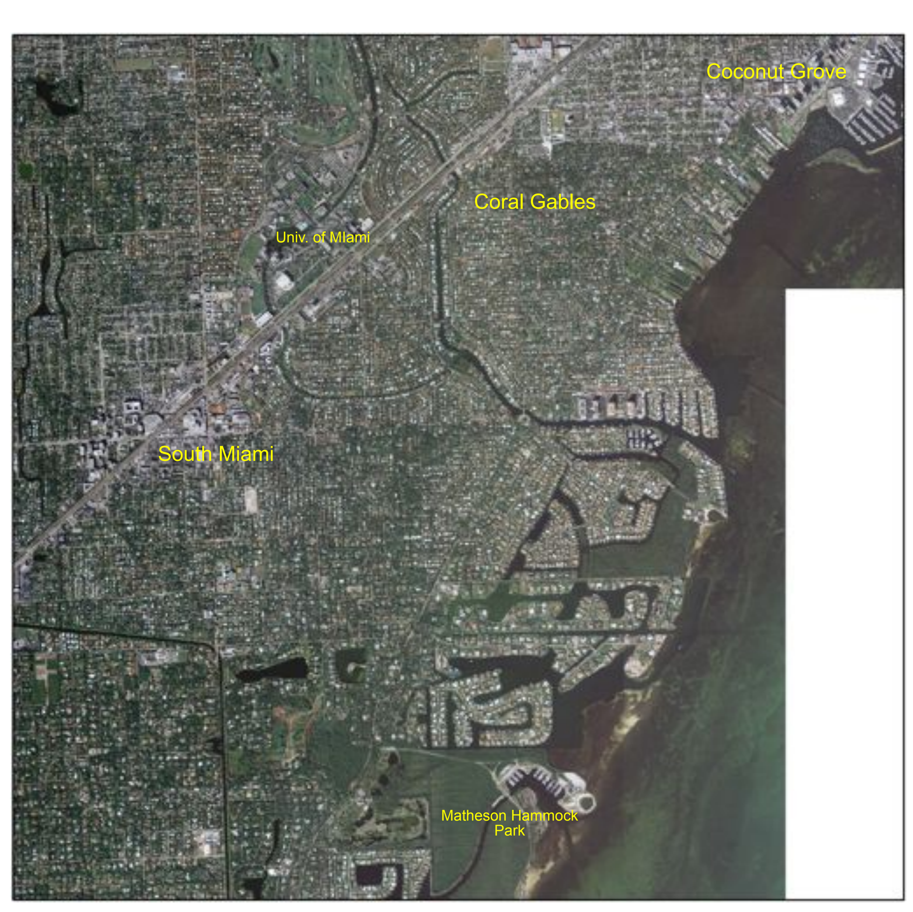


Figure 3B: 2006 Aerial Photo (Fla. DOT)

Figure 3C: 1 foot sea level rise inundation (Extrapolated from FDEM LiDAR)

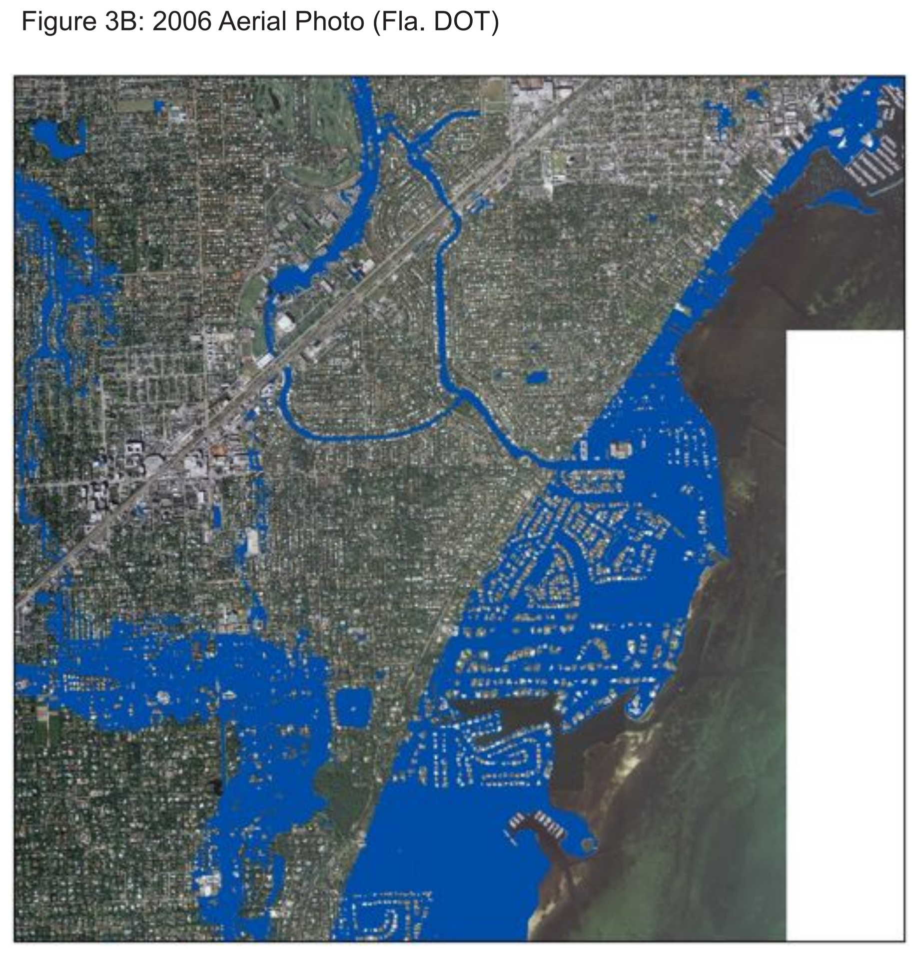
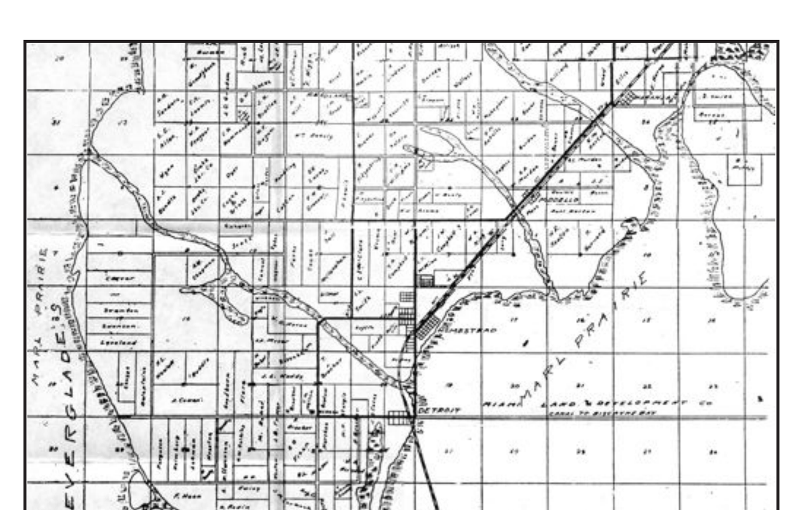


Figure 3D: 6 foot sea level rise inundation (Extrapolated from FDEM LiDAR)

South Miami

The early topography of what is now the municipality of South Miami was characterized by pine rockland forest bisected by low transverse glades that allowed water to move from the Everglades to Biscayne Bay. This four panel vignette highlights the transition to a landscape dominated by gray infrastructure, obscuring the historic 'green infrastructure' of Miami-Dade. Because Miami's elevation ranges from sea level to a maximum natural elevation of 26 feet, even minor amounts of sea level rise challenge the present-day gray infrastructure of the city. Looking to the past, as we can see from the 1924 aerial photo (Fig 3A), human settlement at that time was concentrated in the higher pine rocklands, while land adjacent to the lower and wetter transverse glades was used primarily for vegetable and pineapple farming. Looking to the future, in our 1 foot of sea level rise scenario (Fig 3C), saltwater inundation is flooding the coastal marsh which has been radically altered by dredge and fill for residential developments and marine facilities. At the 6 foot sea level rise scenario (Fig 3D), projected to occur shortly after 2100, we see considerable inundation within the low lying areas, mimicking many of the water features of the 1924 photo (Fig 3A) except that the freshwater in the transverse glades has been replaced with saltwater. How might a better understanding of the topography underlying the ubiquitous gray infrastructure of our urban built environment help us to better plan for and adapt to sea level rise in the future?



Examining this hand-drawn 1912 property owners' map of Homestead and Redlands District reveals the early settlers' reluctance to own portions of the transverse glades. This reluctance indicates full knowledge of the hydrological conditions of the transverse glades, which were shallowly flooded prairies for much of the year. In later years, after drainage succeeded in lowering Everglades water levels, it became possible to first farm the glades and then develop them by replacing natural features with gray infrastructure. This type of historical sleuthing is one example of the archival methods we employ in the ULTRA project to develop a diagnostic ecohistory of the Miami-Dade region. Looking back at the region over time allows us to see how people reacted and adapted to the local hydrology. It also has predictive value as we look to a future in which sea level rise plays a central role in shaping possibilities for urban landscape transformations.
(P. W. Harlem collection)

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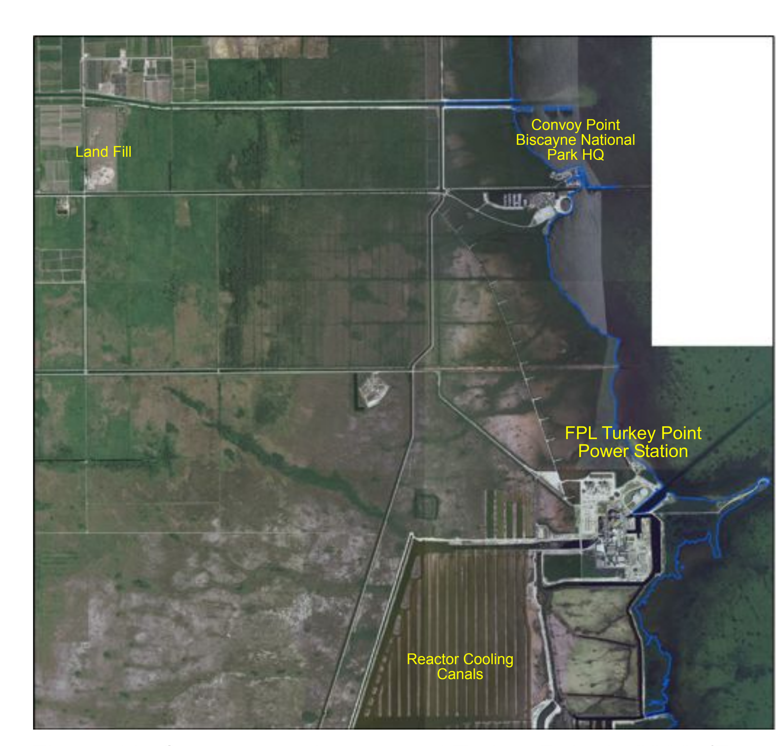

Figure 4A: Coastal marshes around Turkey Point in 2006. (Fla. DOT)

Turkey Point

Using LiDAR elevation data, we illustrate how a minimal sea level rise of 1 foot will inundate large areas of coastal marsh and farm land (Fig 4B). The coastal wetlands are highly important to the viability of the food chain of Miami's greater bioregion. Additionally, the bottom right corner of these figures show the problematic siting of the Turkey Point nuclear power station. With just one foot of sea level rise the existing facility becomes isolated, with unknown impacts on operation, maintenance, and evacuation in the event of disaster. In 2012, Florida Power and Light will begin constructing two more reactors on this site, with estimates of a total project cost between $12.1 and $17.8 billion. The additional reactors will make significant demands on an already challenged hydrological system.

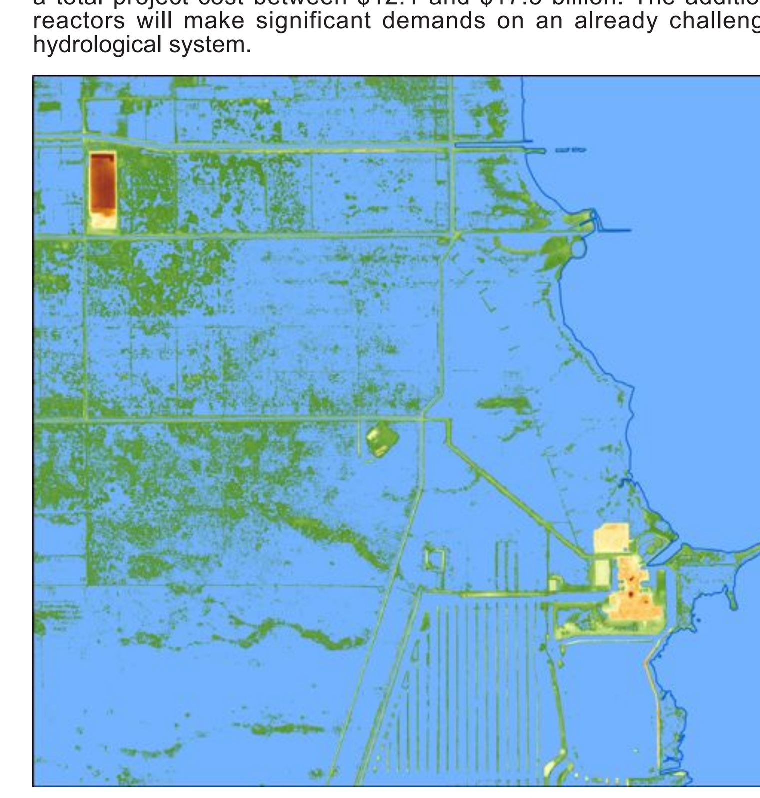

Figure 4B: Turkey Point area with 1 foot of sea level rise extrapolated from FDEM LiDAR and adjusted for tidal prism.