Sea-Level Rise Technical Planning Assessment for the City of Satellite Beach

Technical Report · April 2019

DOI: 10.13140/RG.2.2.25376.23044

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Project conducted through funding support provided by the
Florida Sea Grant College Program and the City of Satellite Beach

APRIL 2019

Acknowledgments

This publication was supported by the National Sea Grant College Program of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), Grant No. NA 18OAR4170085, in partnership with the City of Satellite Beach, FL. The views expressed are those of the authors and do not necessarily reflect the view of these organizations. Additional copies are available by contacting Florida Sea Grant, University of Florida, PO Box 110409, Gainesville, FL, 32611-0409, (352) 392.2801, www.flseagrant.org.

The authors give a sincere thanks to the staff, elected officials, and citizens of Satellite Beach who provided large amounts of input, feedback, and ideas throughout the project. We give special thanks to the following people who graciously worked with the project team to develop project datasets and approaches: Courtney Barker, City Manager; Building Official and Floodplain Administrator; Allen Potter, Director of Public Works; Nick Sarzone, Environmental Program Coordinator; Dr. John Fergus, City of Satellite Beach Sustainability Board; Dr. Randall Parkinson, Florida International University; and Dr. Ken Lindeman, Florida Institute of Technology. The following undergraduate students at Stetson University also made invaluable contributions to the project: Emily Niederman, Savannah Hardisky, Emily Dolatowski, Charles Abbatantuono, and George Winsten.

Suggested citation: Evans, J.M., E. Mitchell, A. Carr, C. Goodison, P. Zwick, and T. McCue. 2019. Sea-Level Rise Technical Planning Assessment for the City of Satellite Beach. Gainesville: Florida Sea Grant.

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Chapter 1: Introduction

Many coastal cities in the United States have recently started to plan and implement adaptations for sea-level rise and other climate change-driven flood risks. Although climate change is a global phenomenon driven by global processes, it is increasingly recognized that the timing, degree, and severity of impacts that specific communities face are quite local and variable. Because the range of future climate change scenarios is dependent on a complex interaction of human behaviors and environmental responses that cannot be readily predicted, climate adaptation planning – even at the local level – is an inherently complicated, multi-faceted, and evolving field (Bierbaum et al. 2013; Kunreuther et al. 2013).

This report describes a three-year Florida Sea Grant-sponsored project to develop site-level infrastructure data and hazards models to support climate adaptation planning and municipal decisions within the City of Satellite Beach, Florida. Satellite Beach is a beachfront municipality within the Palm Bay-Melbourne-Titusville Metropolitan Area of Brevard County, Florida. Located approximately 20 miles south of Cape Canaveral on a long, narrow barrier island, Satellite Beach is bordered to the east by the Atlantic Ocean and to the west by the Banana River – a sub-estuary within the Indian River Lagoon complex. The 2010 population of Satellite Beach was 10,109 on a land area of approximately 3 square miles (U.S. Census Bureau 2018). The local economy is largely driven by a combination of beach recreation and a local aerospace industry associated with the nearby Patrick Air Force Base and Kennedy Space Center.

Satellite Beach is widely recognized throughout central Florida for its forward-looking efforts to promote natural resource stewardship and environmental sustainability at the local level. A few examples of these initiatives include municipal ownership and public management for approximately 40% of the City's Atlantic beach coastline, purchase of solar energy systems for several City-owned facilities, implementation of multiple stormwater water quality improvement projects, and a municipal Sustainability Board that meets on a monthly basis. In 2017, Satellite Beach worked with researchers at Florida Institute of Technology (FIT) to develop and adopt an initial Sustainability Action Plan, which serves as an evolving platform to inform local policies and guide infrastructure decisions that promote greater social, economic, and environmental sustainability in the City over time (Eichholz and Lindeman 2017).

The formal team for the current project includes academic investigators and planning professionals from Stetson University's Institute for Water and Environmental Resilience (IWER), the East Central Florida Regional Planning Council (ECFRPC), University of Florida's GeoPlan Center (GeoPlan), Florida Sea Grant's Coastal Planning Program, and Erin Deady, P.A. This project team worked in close coordination with Satellite Beach officials, staff, and stakeholders in crafting and implementing the scope of work, activities, and deliverables described in this report.

Coastal Hazards in Satellite Beach

As a guiding concept for planning purposes, sustainability is often defined as actions or developments that provide for present ne eds while not compromising the ability of future generations to provide for their needs (World Commission on Environment and Development 1987). While there are many individual metrics involved in measuring and tracking sustainability, one of the most crucial is the capacity of a community to anticipate, withstand, and recover from hazards and associated disaster events. This recovery capacity is often referred to as resilience (Ahern 2011). Accordingly, resilience planning is a process that is designed to help a community enhance its ability to anticipate and recover from a wide range of hazards and potential disasters to which it may be exposed in the future (Tobin 1999).

A fundamental objective of coastal resilience planning is to develop greater understanding of the many natural and human factors that affect hazard exposure and impact in the coastal area. Florida's Atlantic barrier islands are dynamic coastal environments regularly subject to processes such as sediment erosion, sediment accretion, and large water table fluctuations from both tides and precipitation. Satellite Beach's location on such a barrier island results in exposure of the community to hazards associated with these processes, as well as more irregular exposure to high winds, storm surge, intense rainfall, and coastal erosion events associated with coastal storms. Objective understanding of these processes is a necessary step for crafting, implementing, and adapting appropriate public policies – as well as encouraging private actions by private citizens and businesses – that may reduce potential community impacts from given hazards events over time.

It is well known that the most acute flooding and erosion hazards in Satellite Beach and much of Florida's coastal zone are associated with Atlantic tropical cyclones. In recent decades, Satellite Beach has experienced wind, rain, and erosion impacts from several named tropical storms and hurricanes, including Erin (1995) Frances (2004), Jeanne (2004), Fay (2009), Matthew (2016), and Irma (2017). However, it is notable that none of these storms produced a direct hit in the local area, and thus local damage, while extensive and disruptive, was not catastrophic. Moreover, no area of Brevard County – including Satellite Beach – has experienced a direct landfall from a Category 3 or greater hurricane over the course of the known historical weather record for the area, which begins in approximately 1850. Although this record suggests that the Brevard County coastline may have a lower probability of a major hurricane strike as compared to some other areas of coastal Florida, hazards planners and disaster management officials are careful to stress that Brevard County is by no means immune to the possibility of direct impacts from a major hurricane in the future (Brevard County 2009).

Satellite Beach also has exposure and vulnerability to more chronic flooding and erosion hazards that occur independently of tropical cyclones. For example, some of the most critical local beach erosion events are associated with winter cold fronts or nor'easters that bring elevated winds, waves, and precipitation that, while typically not as acute as tropical cyclones, can persist for days (Dolan and Davis 1994; USACE 2010). Convective thunderstorms that form during summer afternoons in central Florida regularly bring intense downpours in local areas, with the potential to cause large amounts of runoff and flooding in low-lying or poorly drained areas. Regular wave action not associated with major storms also is a cause of erosion on certain sections of the Atlantic beach (USACE 2010). While some areas of the shoreline are naturally erodible due to geomorphic factors (e.g., coastline shape and the geologic composition of underlying sediments and rocks), jetties and the dredged Port Canaveral channel to the north of Satellite Beach potentially have reduced southward sediment transport through the longshore drift current (USACE 2010).

Local Resilience Planning

Over the past decade, Satellite Beach has engaged in sustained public discussions about coastal resilience, with a specific focus on development of planning processes to better understand how climate change is changing the community's hazards profile. This process began in 2009 (Parkinson 2010), when Satellite Beach entered into a partnership with the East Central Florida Regional Planning Council (ECFRPC) and the Indian River Lagoon National Estuary Program (IRLNEP) on a Climate Ready Estuaries (CRE) project, as funded by the U.S. Environmental Protection Agency (EPA). Vulnerability assessments and public outreach conducted through the CRE project focused specifically on how beach erosion and coastal flooding would be exacerbated by a range of sea-level rise scenarios through the year 2100 (Parkinson and McCue 2011).

The assessments and outreach from the CRE project led directly to the formation of a local Sea

Level Rise Subcommittee on the City's Comprehensive Planning and Advisory Board (Parkinson and McCue 2011). Through the work of this Subcommittee, in 2013 Satellite Beach became the first city in Florida to amend their Comprehensive Plan to incorporate policy language for developing Adaptation Action Areas as a strategy for sea level rise planning at the local level. To begin adopting the Adaptation Action Area policy, Satellite Beach then entered into a follow-up project with ECFRPC, as funded through the Florida Department of Environmental Protection's (DEP) Coastal Partnership Initiative (CPI), to conduct sea-level rise vulnerability assessments of the City's critical facilities in the years 2040, 2070, and 2100 (ECFRPC 2015). The CPI project also used an on-line public survey tool—Metroquest—to gain information and perspectives about sea-level rise and flood hazards resilience from over 400 local residents and business owners in Satellite Beach.

A key technical and policy outcome from the CPI work was delineation of an "Inland Flooding Adaptation Action Area" (IFAAA), which was also incorporated directly into the City's Comprehensive Plan in 2015 (City of Satellite Beach 2016; visualization shown below as Figure 1). The Comprehensive Plan defines the IFAAA as areas "located within the Coastal High Hazard Area or FEMA 100 Year Flood Zone" or "areas which are expected to be inundated with water using the U.S. Army Corps of Engineers (USACE) high projections" for sea-level rise at the year 2070 (Section 5; Policy 1.14.3). Further language within the Comprehensive Plan defines the IFAAA "as a tool for assisting the City in prioritizing infrastructure funding and policy implementation for flood alleviation improvement and mitigation projects" (Section 5; Policy 1.14.3). The year 2018 is defined as the deadline for the City to "update city processes and city-wide plans to incorporate the IFAAA where appropriate" (Section 5: Policy 1.14.6).

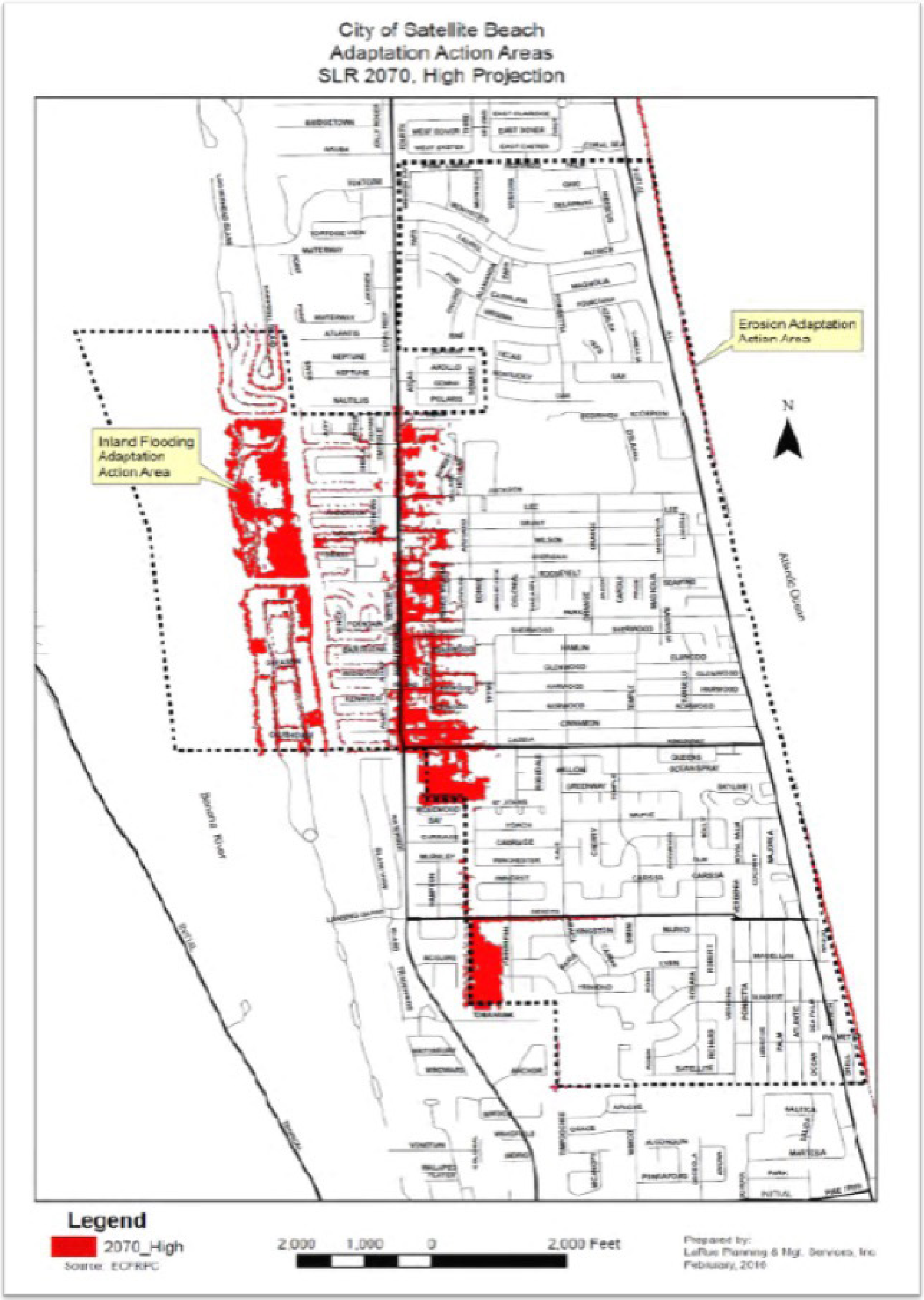
Florida Sea Grant Project

Satellite Beach's IFAAA, as well as the Erosion Adaptation Action Area (EAAA) located along much of the City's Atlantic beachfront (shown in Figure 1), specifically reflects the City's acknowledgement that climate change is expected to increase coastal hazard and flooding exposure in the local community in at least three ways:

- 1. Sea-level rise, as caused by thermal expansion of warmer ocean waters and an increased mass of ocean water associated with polar ice sheet melt, that will reduce stormwater drainage capacity, increase beachfront erosion potential, and progressively inundate low-lying land areas (Parris et al. 2012) .
- 2. Larger and stronger hurricanes, as fueled by warmer ocean waters, that will tend to produce higher storm surges and larger amounts of precipitation when they impact a local area (Knutson et al. 2010).
- 3. A higher frequency of extreme precipitation events, including from non-hurricane storms, due to the fact that a warmer atmosphere can hold greater amounts of water vapor, which can then be expressed as rainfall (Raghavendra et al. 2018).

With the explicit acknowledgment of these hazards in the City's Comprehensive Plan came recognition that implementation of the IFAAA for municipal infrastructure would require comprehensive integration and development of data about key infrastructure at a site level. Previous vulnerability assessments, while crucial for identifying general flood risks and visualizing future sea-level rise scenarios, lacked a necessary level of data precision and granularity for informing site-level decisions about capital improvement projects moving forward. Development of more precise and comprehensive infrastructure datasets was therefore identified as a next step for identifying specific infrastructure adaptation project ideas and associated timetables for local implementation.

Figure 1: City of Satellite Beach (2016) Adaptation Action Areas



Beginning in mid-2015, several members of the current project team worked with the City of Satellite Beach to develop a summary scope of work for achieving a primary project goal, as consistent with the Comprehensive Plan, to identify specific adaptation projects for implementation within the IFAAA by 2018. Achievement of this overall project goal was broken down into three specific work objectives:

Objective 1: To integrate and comprehensively update the City's municipal infrastructure data within a geographic information systems (GIS) framework.

Objective 2: Utilize newly developed GIS datasets to implement enhanced flood vulnerability assessments at a resolution appropriate for informing site-level decisions.

Objective 3: Apply flood vulnerability assessments to support specific capital improvement project and policy development recommendations within the IFAAA.

The project team then worked with the City of Satellite Beach to further define and expand upon this summary scope of work in an application for funding support through the Florida Sea Grant Program's 2016 Omnibus Request for Proposals. In addition to the three objectives discussed above, two other project objectives consistent with the outreach and education mission of the National Sea Grant College Program were incorporated into the funding request:

Objective 4: To collaboratively engage in the resilience planning process with a broad range of local stakeholders through a series of public and technical workshops.

Objective 5: To provide undergraduate and graduate students with extensive training and applied experience in conducing technical analysis and public engagement processes.

Implementation of the full scope of work for achieving these project objectives and overall project goal was funded by Florida Sea Grant, with an official project start date of February 1, 2016. Matching funds and in-kind support for project implementation was also provided by the City of Satellite Beach, Stetson University, the Colleges Universities Disasters Assessment and Research Center (CUDARC), and University of Florida. The full suite of outcomes and deliverables from this implemented scope of work form the basis of the final project report presented here.

Chapter 2: Sea-Level Rise and Local Water Levels

Sea-level rise is widely recognized as the most apparent and chronic consequence of climate change in coastal areas. The effects of recent and ongoing sea-level rise, which is generally estimated as about five to eight inches globally over the course of the twentieth century (Dangendorf et al. 2017), are already clear in many coastal communities in Florida. For example, increased occurrence of "sunny day" flooding of roads, yards, and other human property during astronomical high tide events, often colloquially referred to as "king tides," has received substantial media attention in several southeast Florida communities over recent years (e.g., Lyons 2018). Other long-term consequences of sea-level rise that are receiving management attention include heightened community risk from coastal storm surges, reduced stormwater drainage potential, and beach erosion (Evans et al. 2016).

The exact amount and timing of future sea-level rise that will occur over the next several decades cannot be known with complete certainty. However, there is a high level of scientific agreement that sea-level rise is currently accelerating well beyond the rate observed in the twentieth century (Parris et al. 2012). But because the range of potential sea-level rise scenarios is quite divergent and there is no firm state or federal standard to follow, local communities typically must decide upon a specific set of sea-level rise scenarios to use within their own planning processes. Accordingly, a community's choice of sea-level rise scenarios generally involves discussion of sea-level rise and climate change science, community attitudes regarding risk tolerance, and the nature and life cycle of assets being assessed for current and future flood risk (Eastern Research Group, Inc. 2013).

The base sea-level rise rate curve that Satellite Beach has adopted for its Comprehensive Plan is the U.S. Army Corps of Engineers (USACE) "High" projection through the year 2070. This projection is based upon a climate change scenario that brings about continued warming of oceans and quickening polar ice sheet melt over the twenty-first century, resulting in substantially accelerated sea-level rise rates (National Research Council 1987). The community chose this projection due to the judgment that greater costs and higher degrees of societal disruption would occur if the City failed to make adequate preparations for its own roads, drainage infrastructure, and critical facilities. In Satellite Beach, the USACE High scenario would result in a 2070 sea-level rise of approximately 2.85 feet above 1992 mean sea level (MSL). This value is benchmarked to the NOAA tide gauge at Daytona Beach Shores, the nearest gauge to Satellite Beach at which NOAA publishes a local sea level change trend rate (Figure 2). A long-term summary of the USACE High sea-level rise projection for Daytona Beach Shores through 2070, as related to the 1992 equivalent MSL defined by the National Tidal Datum Epoch (NTDE), is provided as Table 1.

Atlantic Ocean Water Levels

Following a technical process similar to the one recommended by the Southeast Florida Regional Climate Change Compact (2012), we utilized the NOAA VDatum 3.4 tool (Yang et al. 2012) to develop estimates of 1992 NTDE equivalent tidal datum values, as relative to NAVD88, for the Atlantic Ocean at Satellite Beach (Table 2). We further note that these VDatum 3.4 values show close agreement with datum values calculated for the NOAA tide gauge at Trident Pier in Port Canaveral (Figure 3), which is the closest active NOAA tide gauge to Satellite Beach (~15 miles to the north of the City). Unless otherwise noted, the VDatum 3.4 estimates are used as the standard basis for Atlantic Ocean water levels throughout this report. Localized estimates of Atlantic Ocean MHHW, the tidal datum typically utilized for base sea-level rise scenarios for locations with semidiurnal tides, under the USACE High sea-level rise projection are provided as Table 3.

The Trident Pier gauge represents a relatively short-term and recent sea-level record, with the station being first installed and active since October 1994. Although NOAA does not currently publish an official long-term sea-level rise rate for this site, analysis of mean sea level data at the gauge (Figure 3) indicates a localized sea-level rise trend of approximately 0.23 in/yr (0.0193 ft/yr; 5.8 mm/yr). This sea-level rise trend is more than three times the twentieth century sea-level rise trend extrapolated from global tide gauge records, and well over the twice the local sea-level rise trend published for Daytona Beach Shores, which was discontinued as a permanent NOAA tide gauge site in 1984.

The Trident Pier record is, however, consistent with regional research showing a recent (beginning in approximately 2011) acceleration of the sea-level rise trend along Florida's Atlantic coast. There is currently a lack of scientific consensus as to whether this sea-level rise acceleration is a localized and potentially short-term anomaly (Valle-Levinson et al. 2017), or if it is instead indicative of a more long-term shift predicted by climate change models (Park and Sweet 2015). Nevertheless, it is notable that Trident Pier data since 2012 have shown water levels that generally track and occasionally exceed the USACE High sea-level rise projection. While additional analysis of Trident Pier gauge data should be conducted in future planning cycles, the most current information provides objective, empirical justification for continued use of the USACE High projection for planning purposes in Satellite Beach at this time.

Figure 2: Historic sea-level rise trend at NOAA tide gauge #8721120, Daytona Beach Shores, FL. The published trend is equivalent to 0.091 in/yr (0.0076 ft/yr), or approximately 9.1 inches over 100 years. (Image from https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=8721120, accessed July 11, 2018.)

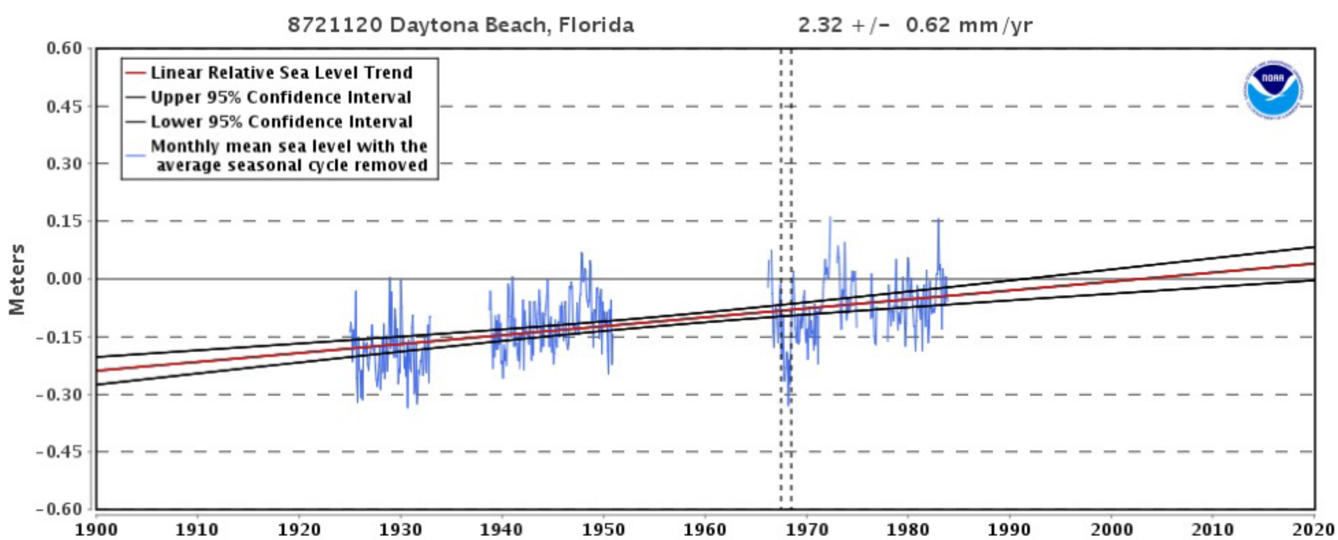


Table 1: Projected local mean sea level (MSL) at Daytona Beach Shores, FL, from 1992-2070, US Army Corps of Engineers High Scenario. Derived from the US Army Corps of Engineers Sea-Level Change Calculator (http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html, accessed July 6, 2018).

Year	Feet Relative to 1992 MSL
1992	**0.00**
2000	0.09
2010	0.26
2015	**0.37**
2020	0.50
2030	0.83
2040	**1.22**
2050	1.69
2060	2.23
2070	**2.85**

Table 2: Calculated 1992 tidal datum heights for the Atlantic Ocean at Satellite Beach, FL, as derived through NOAA VDatum 3.4

Tidal Datum	Feet Relative to NAVD88
Mean Lower Low Water (MLLW)	-2.90
Mean Sea Level (MSL)	-1.00
Mean Higher High Water (MHHW)	1.09

Table 3: Local mean higher high water (MHHW) estimates for the Atlantic Ocean at Satellite Beach, FL, under the USACE (2013) High sea-level rise scenario

Year	Feet Relative to NAVD88
1992	1.09
2015	1.46
2040	2.31
2070	3.94

Figure 3: Water level datums at NOAA tide gauge #8721604, Trident Pier, Port Canaveral, FL. (Image from https://tidesandcurrents.noaa.gov/datums.html?id=8721604, accessed July 10, 2018.)

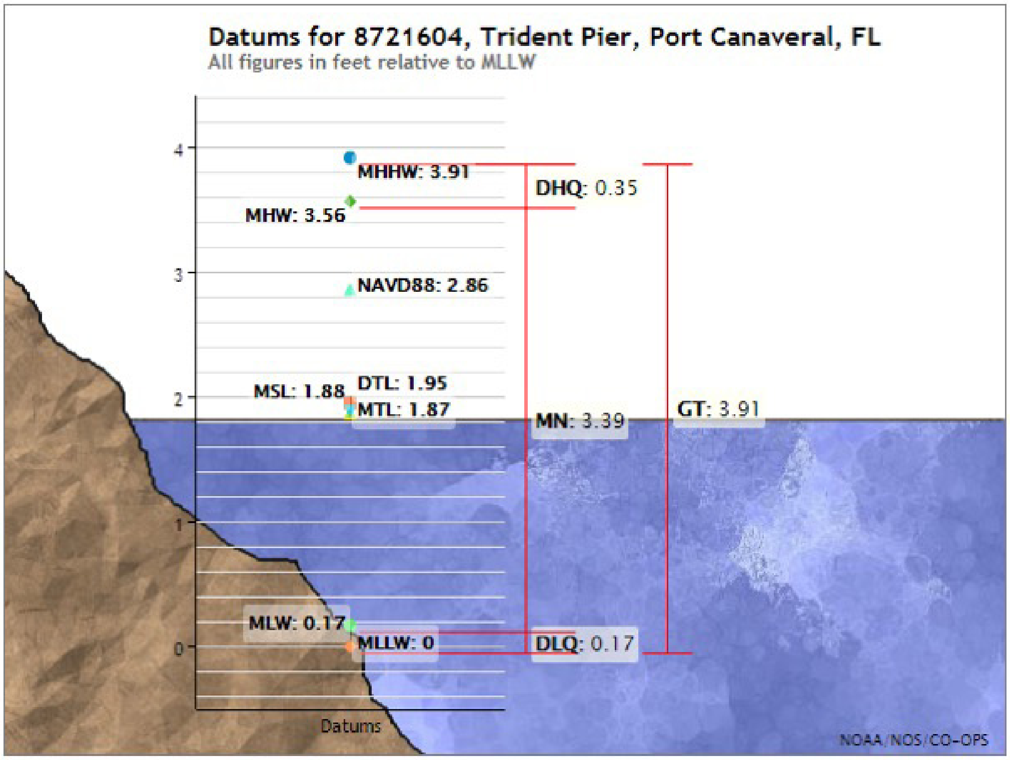
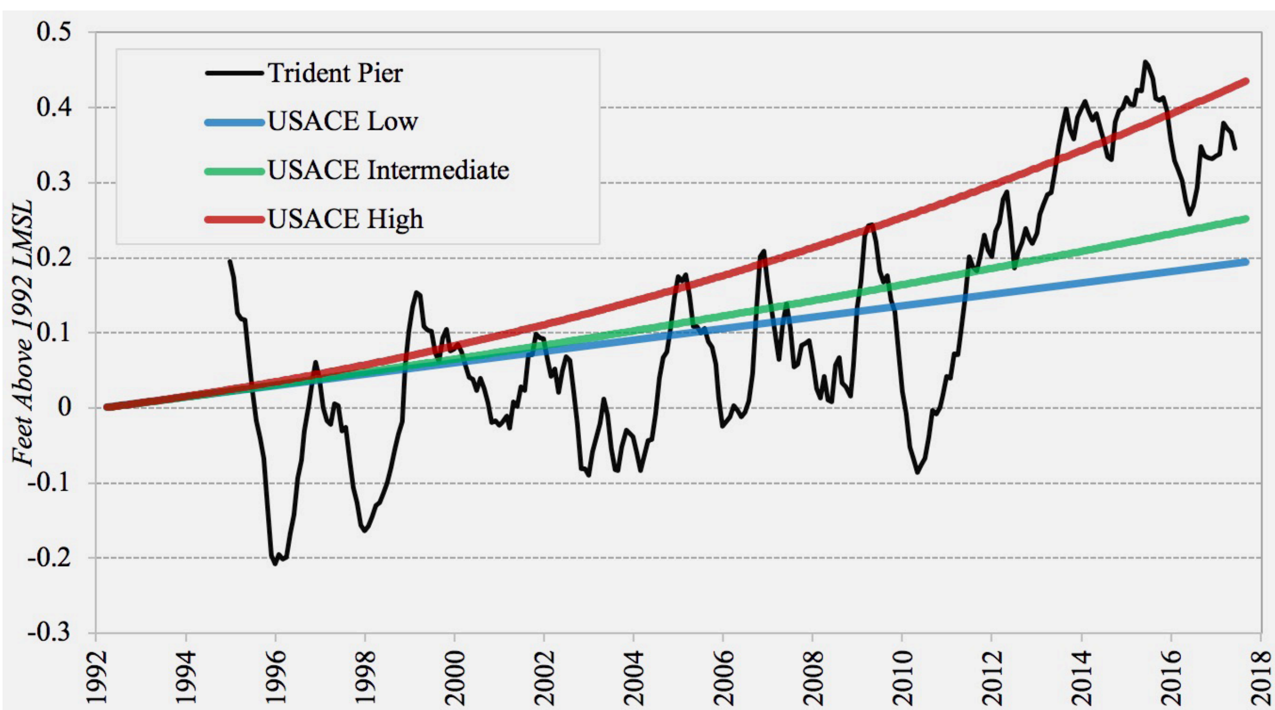


Figure 4: Running annualized average of local mean sea level (LMSL) for NOAA tide gauge #8721604 at Trident Pier, Port Canaveral, FL, in relation to USACE (2013) sea-level rise rate projection curves.



Banana River Water Levels

A relic beach dune that generally runs along State Highway A1A forms a north-south oriented topographic ridge across the City of Satellite Beach. This ridge causes most of the City of Satellite Beach, including almost all of the land area located westward of the A1A corridor, to drain westward into the Banana River system. For this reason, concerns about current and future flood risk in Satellite Beach are very intricately linked to the unique hydrologic behaviors observed in the Banana River.

Although the land mass separating the Atlantic Ocean and Banana River is quite narrow at Satellite Beach (~1 mile), water levels on the Banana River coastline behave quite differently than the levels observed on the Atlantic Ocean. This is largely because Sebastian Inlet, the nearest inlet into the Indian River Lagoon relative to Satellite Beach, is relatively narrow and thus permits limited volumetric exchange between the ocean and lagoon on each tidal cycle. Moreover, the distance between Sebastian Inlet and the Banana River at Satellite Beach (approximately 25 miles) exceeds the distance in which regular tidal energies can be transmitted through the inlet (Smith 1987). For these reasons, water level fluctuations on the Banana River do not follow the semi-diurnal tide cycles characteristic of the Atlantic coast. Instead, the Banana River water levels shift irregularly on a daily basis in response to local wind conditions, while also showing more seasonal responses to watershed-scale precipitation and regional changes in sea level equilibrium. In most years, this results in a seasonal high "rise" of the Banana River during the fall months (September to November) and a corresponding seasonal low "fall" of the Banana River during the late spring to early summer.

NOAA VDatum 3.4 provides a 1992 equivalent LMSL estimate of approximately -0.85 ft, relative to NAVD88, for the Banana River at Satellite Beach. However, the VDatum tool does not contain sufficient data to simulate the irregular annual changes in water level known to occur in the Banana River. A more complete baseline method for estimating Banana River water levels is provided by Parkinson (2010), who reports a St. Johns River Water Management District analysis of 1996 – 2000 water levels at the Carters Cut NOAA tide gauge (#8721789) within the Banana River. This tide gauge analysis provides a LMSL (reported as mean water level) value of -0.702 ft relative to NAVD88 for the period of record (datum year equivalent of 1998).

In May 2011, the Florida Department of Environmental Protection (DEP) installed an Indian River Lagoon water level station (#8721843; http://fldep-stevens. /station.php?site=8721843) at the west end of the U.S. 192 Bridge in Melbourne. We analyzed the raw six-minute data from this station over the period of 2011 – 2015 to provide a more recent source of local water level data. Analysis of this record provides an estimate for LMSL of -0.54 ft NAVD88, which we define here as datum year 2013. A summary of these historic data-based LMSL estimates for the Banana River at Satellite Beach is provided as Table 4.

Based on the Carters Cut record, Parkinson (2010) also reports a seasonal high water level (SHW), locally known as the "fall rise" due to the tendency for waters to rise seasonally in fall months, of 1 ft above LMSL as an additional water level datum for assessing future flood risk. Following Parkinson's (2010) approach, we also used the Melbourne record to calculate a SHW level, which we defined as the 98th percentile of water levels observed during the gauge period – or a water level value that would be exceeded approximately two weeks each year. This calculation resulted in a SHW value of 0.46 ft NAVD88, which is in very close agreement with Parkinson's (2010) estimate (i.e., 1 ft over LMSL) using the Carters Cut gauge.

In response to stakeholder observations of more extreme Banana River water levels anecdotally occurring approximately once a year, we developed a further analysis of "annual high water" (AHW) for the Melbourne record. We defined this annual high water as the 99.7th percentile water level, or the level that was exceeded for approximately 24 hours each year over the assessment period. Through this calculation, we calculated an AHW value of 0.88 NAVD88, or approximately 1.42 ft above LMSL, for the 2011 – 2015 Melbourne record. We note that the Melbourne station apparently experienced an extended malfunction beginning in early 2016, which is why we limit our analysis to the 2011 – 2015 time period. This time period of analysis therefore notably excludes the extreme high water events associated with Tropical Storm Fay, which pre-dated the gauge installation, as well as Hurricane Matthew (2016) and Hurricane Irma (2017) – which were not well-measured due to gauge malfunction.

For consistency with the sea-level rise projection method used on the Atlantic Ocean side, we benchmark our Banana River USACE High sea-level rise projections at 2015, 2040, and 2070 to the 1992 LMSL datum. Our 1992 equivalents for SHW (1 ft over LMSL) and AHW (1.42 over LMSL) are developed as relative equivalents with the values calculated with the 2011 – 2015 Melbourne DEP gauge data. The very close agreement between the 2015 USACE High projection of LMSL (i.e., -0.48 ft NAVD88) and the 2013-equivalent LMSL from the Melbourne gauge (i.e., -0.54 ft NAVD88) provides confidence that this is a reasonable datum estimation approach. However, we recommend that future flood assessment work in Satellite Beach and nearby communities revisit Banana River and/or Indian River water levels using the most recent, complete, and locally relevant data sources that may be available at the time of assessment.

Table 4: Calculations of historic local mean sea level (LMSL), as feet relative to NAVD88, for the Banana River, Satellite Beach, FL

Year	LMSL	Location	Data Source	Time Frame
1992	-0.85	Banana River at Satellite Beach	NOAA VDatum 3.4	1983 – 2001
1998	-0.70	Banana River at Carters Cut	NOAA Tide Gauge #8721789	1996 - 2000
2013	-0.54	Indian River at 192 Bridge, Melbourne	FL DEP Tide Gauge #8721843	2011 – 2015

Table 5: Projected Banana River water levels under the USACE High sea-level rise scenario, including local mean sea level (LMSL), seasonal high water (SHW), and annual high water (AHW), as feet relative to NAVD88

Year	LMSL	SHW	AHW
1992	-0.85	0.15	0.57
2015	-0.48	0.52	0.94
2040	0.37	1.37	1.79
2070	2.00	3.00	3.42

Chapter 3: Stormwater System

Built areas within the City of Satellite Beach are drained by a series of stormwater drainage systems that are owned and maintained by several different jurisdictional entities. Much of Satellite Beach is drained by stormwater infrastructure owned by the City and maintained by the City's Department of Public Works. Maintenance and improvements for this City-owned stormwater infrastructure system are funded through local stormwater fees levied by the City. Some portions of the City, particularly those that have been more recently developed or re-developed, are drained by stormwater systems owned and maintained by private interests. Most stormwater structures along the State Highway A1A and South Patrick Drive corridors within the City of Satellite Beach are owned and maintained by the Florida Department of Transportation. Although jurisdictionally distinct, there are complex hydrologic connections between all of these stormwater systems located within the City of Satellite Beach. Portions of the stormwater system in Satellite Beach also have hydrologic connections to stormwater systems in adjacent areas of unincorporated Brevard County (to the north) and the City of Indian Harbour Beach (to the south).

It is well-known that an inherent impact of sea-level rise is a reduction in the drainage rate potential of stormwater drainage systems that discharge into coastal water bodies. The straightforward cause of this phenomenon is that rising sea level will often cause the tailwater elevation of the receiving water body to exceed the water-level elevation of discharge points, including pipes or surface water discharge structures (e.g., weirs), that were designed to function with the lower sea level at the time of original construction. Over time, the water level elevation of receiving water bodies can cause stormwater systems to become partially or even completely inundated with tidewater inputs, often resulting in growth of saltwater adapted fouling organisms that can further restrict drainage. In some communities, surface infalls into stormwater systems at times become completely filled with tidewater and will back up entirely, causing saltwater to discharge out of infall structures and into streets, yards, and other built areas. Such tidewater back up events – often referred to as "sunny day" floods because they can occur on regular high tide events not associated with rainfall – typically indicate that the affected stormwater system will also have very low drainage functionality during large rainfall events, especially if these events correspond with a high tide.

Because most of the City of Satellite Beach was built prior to the passage of the 1972 Clean Water Act and the advent of more modern stormwater management systems, a large portion of the City's stormwater drainage infrastructure connects directly into the Banana River or other surface water features that discharge into the Banana River. Over recent years the City of Satellite Beach has undertaken a number of stormwater system upgrades designed to improve the quality and decrease the quantity of stormwater that is discharged into the Banana River, while also attempting to reduce the amount and extent of street flooding associated with large precipitation events. Examples of such stormwater upgrades developed in Satellite Beach over recent years include an innovative swale detention system along Cassia Boulevard, recreationally functional wet retention pond systems located at the City's Sports and Recreation Park and De Soto Park, and several pervious pavement projects located on low-lying streets and parking lots prone to stormwater ponding.

Nevertheless, it is very clear that rising sea levels are already impacting the drainage functionality of the Satellite Beach stormwater system, thereby making maintenance of the existing system increasingly difficult and expensive. Over time, sea-level rise can be expected to more regularly inundate existing pipe and outfall structures, inherently making the stormwater system less and less functional in draining rainwater from streets, yards, and structures. Because rising sea levels fundamentally change the conditions under which stormwater systems were originally designed and built, increasing flood impacts can be expected to occur even if the existing stormwater system is otherwise well-maintained (e.g., infrastructure is kept in good condition; solid obstructions are removed from drainage system; etc.) by the City of Satellite Beach and other authorities.

Database Development

As part of this project, we worked with the City of Satellite Beach Public Works Department to gather, develop, and integrate site-specific information about the City's stormwater infrastructure into a newly created geographic information systems (GIS) database. Sources of this information include Computer-Aided Design (CAD) files developed as part of the City's Stormwater Master Plan, archival print maps held by the Public Works Department, as-built drawings of recent stormwater improvements held by the Public Works Department, and field data collection data using global positioning system (GPS) equipment (Table 6).

The database contains an inventory of various stormwater features within the City, including stormwater detention and retention facilities, swales, underground pipe extents, infall locations, and outfall discharge points. All available information regarding the size, construction material, and invert (i.e., belowground) elevations of underground pipe infrastructure is included for mapped features. While all effort was made to ensure the accuracy of the dataset, it is known that the inventory is not complete for all areas of the City and generally does not include stormwater infrastructure owned and maintained by private entities. A generalized workflow of the stormwater GIS development process is shown as Figure 4, and a map visualization of the mapped infrastructure is shown as Figure 5. A final list of stormwater GIS files delivered to the City of Satellite Beach is provided as Appendix 1.

Figure 4. Workflow diagram of stormwater GIS development

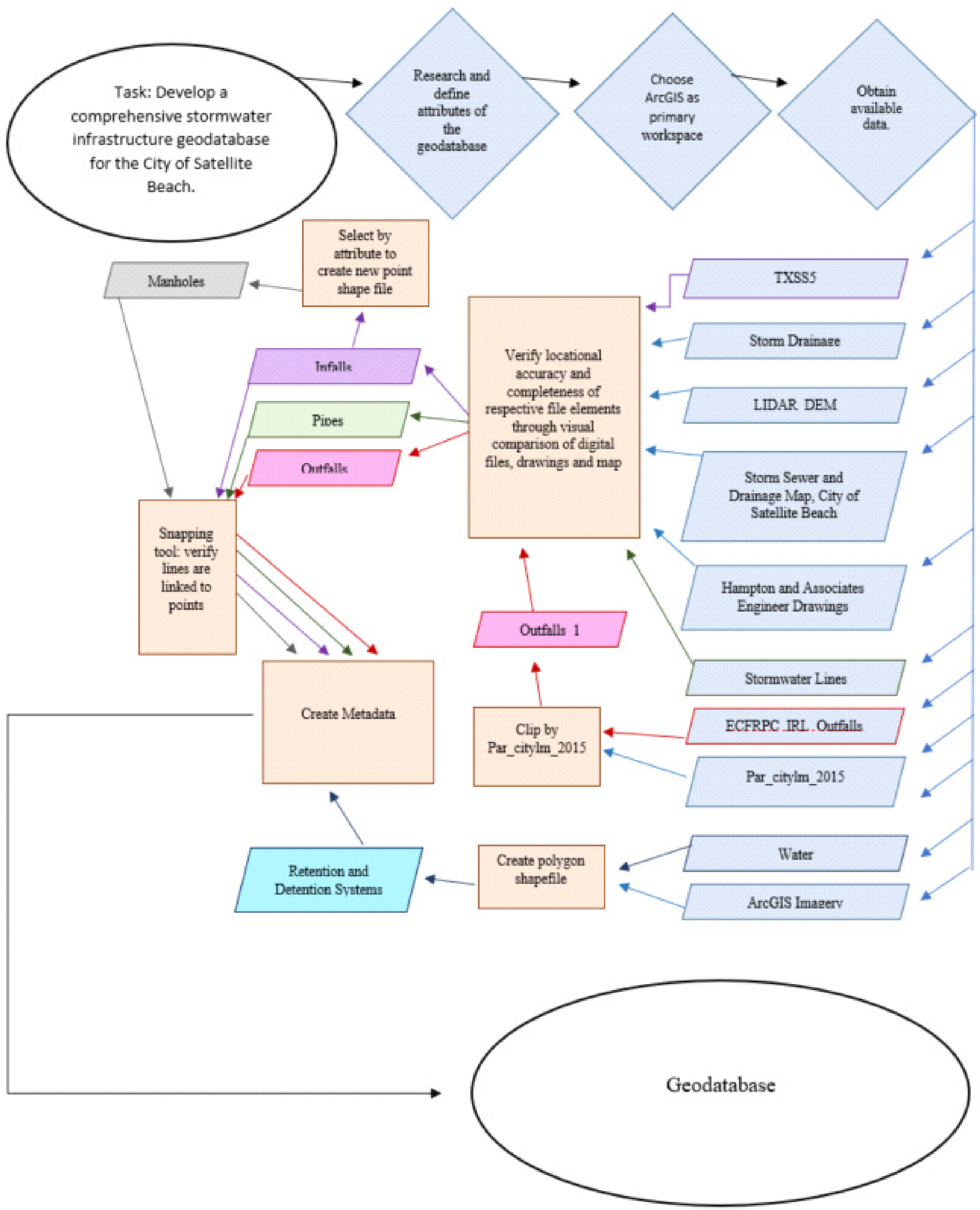


Table 6. Description of pre-existing stormwater data sources for the City of Satellite Beach

Maps, Datasets, and Inputs			
Type	**Title**	**Source**	**Notes**
Hardcopy Map	Storm Sewer and Drainage	City of Satellite Beach, Florida	Revision 1992
Engineer Drawing	Stormwater Master Plan Existing Stormwater 2000-2010	Quentin L. Hampton Associates, Inc. P.O. Drawer 29047 Port Orange, FL. 32129-02347	Engineer drawings for the City of Satellite Beach, Brevard County, Florida
	North City Limits Outfalls October 2010		
	Cassia Basin Stormwater Improvements Phase 1 February 2010 Plan and Profile – Temple Street		
	Cassia Basin Stormwater Improvements Phase 1 February 2010 Plan and Profile – Ocean Spray Avenue		
	Cassia Basin Stormwater Improvements Phase 1 February 2010 Plan and Profile – Greenway Avenue		
	Cassia Basin Stormwater Improvements Phase 2 September 2010 Plan and Profile – Kale Street		
	Cassia Basin Stormwater Improvements Phase 3June 2011 Plan and Profile – Cassia Boulevard		
	Shell Street Improvements (Beach Access Improvements Phase II) April 2015		
	Roosevelt Avenue Improvements December 2015		
Digital File (CAD)	TXSS50	2009 Hampton Associates Satellite Beach Stormwater Master Plan Quentin L. Hampton Associates Inc. P.O. Drawer 29047 Port Orange, FL. 32129-02347	Point shapefile of stormwater inlet data fields within the city limits. Projected Coordinate System: NAD 1983 HARN Stateplane Florida East Fips 0901, Linear Unit – Foot US; Geographic Coordinate System: GCS_North_American_1983.
	Storm_Drainage		Point shapefile of stormwater inlets and outlets within the city limits. Projected Coordinate System: NAD 1983 HARN Stateplane Florida East Fips 0901, Linear Unit – Foot US; Geographic Coordinate System: GCS_North_American_1983.
	Stormwater_Lines		Line shapefile of stormwater retention areas within the city limits. Projected Coordinate System: NAD 1983 HARN Stateplane Florida East Fips 0901, Linear Unit – Foot US; Geographic Coordinate System: GCS North American 1983 HARN.
	Water		Line shapefile of stormwater retention areas within the city limits. Projected Coordinate System: NAD 1983 HARN Stateplane Florida East Fips 0901, Linear Unit – Foot US; Geographic Coordinate System: GCS North American 1983 HARN.
	LIDAR_DEM		4 meter grainsize Digital Elevation Model (DEM). Raster values, denoted in feet, represent ground elevation above the North American 1983 HARN. (North American Vertical Datum 1988). Spatial Reference: NAD 1983 HARN Stateplane Florida East Fips 0901.
Digital File	ECFRPC_IRL_Outfalls	East Central Florida Regional Planning Council 455 N. Garland Ave Orlando FL 32801	Point File Geodatabase Feature Class containing data associated with outfalls discharging into the Indian River Lagoon. Projected Coordinate System: NAD_1983_HARN_StatePlane_Florida_East_FIPS_0901. Linear Unit: Feet. Earliest associated date: 2009 (metadata date).
Digital File (Download)	Par_citylm_2015	University of Florida GeoPlan Center https://www.geoplan.ufl.edu/	Polygon shapefile containing Florida city limit boundaries. Projected Coordinate System: Albers Conical Equal Area (Florida Geographic Data Library), Linear Unit - Meters; Geographic Coordinate System: GCS North American 1983 HARN.

Figure 5. City of Satellite Beach, Stormwater GIS Inventory

Tidal Backflow Analysis

Because tidewater backflow into underground stormwater pipe infrastructure is such a common source of drainage system failure, we used the projected Banana River water levels for 2015, 2040, and 2070 (Table 5) as the basis for developing an analysis assessing the spatial extent of tidewater backflow into stormwater infall points with recorded invert elevations (Figures 6-8)

Highlighted points in Figures 6-8 represent infalls with invert elevations that are below the lowest identified water level threshold. Infalls that show impacts at MHW would be expected to have tidewater backflow for at least one half of the year in the absence of future upgrades designed to prevent such backflow. Infalls showing impacts at SHW would be expected to have tidewater backflow for at least two weeks per year, while infalls with impacts at AHW would be expected to have tidewater backflow for at least one day per year.

The general pattern of expected backflow impacts is unsurprisingly concentrated along the South Patrick Drive corridor, with impacts steadily expected to move eastward with sea level rise. It is also notable that drainages along Jackson Avenue, Roosevelt Avenue, Cassia Boulevard, and Desoto Parkway all show high potential for tidewater backflow into the underground pipe system. All of these drainage systems have been substantially upgraded by the City of Satellite Beach over recent years for the express purpose of reducing street flooding impacts and water quality impacts into the Banana River. These upgrades include many features designed to redirect substantial stormwater volumes away from the pipe system and to retain stormwater in surface drainage features located at higher points in the landscape.

We do note that very few infalls located to the west of South Patrick Drive, most of which are associated with short stormwater pipe drainages that discharge directly into the Banana River canal system, currently have recorded invert elevations. Although no formal tidewater backflow assessments were developed for these infall systems that lack invert elevations, we have anecdotally observed that some of these small drainage systems are currently being impacted to some extent by tidewater backflow. Additionally, while some stormwater infrastructure located outside of the Satellite Beach City Limits was mapped as part of the inventory exercise, no tidewater backflow assessments were conducted for any infrastructure outside of Satellite Beach's municipal boundary.

Figure 6: City of Satellite Beach Stormwater Backflow Analysis, 2015 Water Level Projection

Figure 7: City of Satellite Beach Stormwater Backflow Analysis, 2040 Water Level Projection

Figure 8: City of Satellite Beach Stormwater Backflow Analysis, 2070 Water Level Projection

Chapter 4: Chronic Flooding Vulnerability Assessment for Municipal Facilities

Following and updating the inventory and vulnerability assessment developed by Parkinson (2010), we assembled a list of priority facilities within the City of Satellite Beach to assess for current and future flood risk (Figure 9; Tables 6 – 10). For all facilities, a baseline estimate of ground-level elevation was obtained by using ArcGIS 10.2.2 to extract values from a 4 feet horizontal resolution LIDAR-based DEM, as supplied to the project team by the City of Satellite Beach, with coverage within the City of Satellite Beach. The source of this LIDAR data is a 2007 – 2009 Florida Division of Emergency Management Coastal LIDAR Project, which has a published maximum root mean square error (RMSE) of 0.6 feet.

As a result of discussions with the City's Floodplain Manager, five facilities owned by the City of Satellite Beach were selected for more intensive site level investigations: 1) David R. Schechter Community Center; 2) Satellite Beach City Hall; 3) Satellite Beach Fire Station; 4) Satellite Beach Police Department; and 5) Satellite Beach Public Works. Point-based field elevation measures adjacent to these facilities were developed using an iGage X900S-OPUS GNSS static receiver and as processed through the NOAA National Geodetic Survey's Online Positioning User Service (OPUS). Point-based estimates of the building's first floor elevations were derived by measuring the linear distance of the floor above the ground level elevation obtained from the iGage static receiver. While we caution that the iGage elevation measurements do not meet survey quality standards, the measurement standard deviations received from OPUS reports ranged between 0.08 and 0.3 feet. In all cases, the reported standard deviation for OPUS measurements was less than the published RMSE associated with the LIDAR DEM (i.e., 0.6 feet). Moreover, the National Geodetic Survey reports that standard deviations obtained from OPUS processing reports will exceed the actual point measurement error over 95% of the time. Together, this suggests that the iGage-based field measurements can be considered as a much more accurate and precise method for informing site-level vulnerability assessments and planning decisions as compared to the ground-level estimates obtained from LIDAR data.

Based upon the elevation data and site investigation, we applied a narrative rubric for estimating the future flooding vulnerability at each facility under the USACE High sea-level rise scenario. We define these narrative future flood risk categories as follows:

1) "Potential" flood risk means that a facility or facility site area is likely to have at least 1% annual flood risk under a given future water level condition;

2) "Occasional" flood risk means that a facility or facility site area is likely to have at least 10% annual flood risk under a given future water level condition;

3) "Frequent" flood risk means that a facility or facility site area is likely to have at least 25% annual flood risk under a given future water level condition;

4) "Seasonal" flood risk means that a facility or facility site area can be expected to experience flooding for approximately 1-2 weeks per year under a given future water level condition; and

5) "Regular" flood risk means that a facility or facility site area can be expected to experience flooding for more than 2 weeks per year under a given future water level condition.

These categories reflect planning-level estimates of future flood risk from a combination of rainfall-driven stormwater (i.e., freshwater) flooding and tidewater (i.e., saltwater) inundation given the USACE High sea-level rise scenario. We caution that these flood risk categories are generalized estimates that assume no adaptation of the local infrastructure, and also that there is lower confidence in the flood vulnerability assessments of facilities with higher elevations. However, we also caution that there is potential for flood impacts to occur on facilities with low or indeterminate flood risk within this assessment, as it was not possible for the underlying analysis to account for all site-level factors that could result in flood impacts. As such, the given risk levels are intended for – and should only be used for – municipal planning and policy-development purposes, and do not imply a level of analytic precision required for site design or engineering assessments.

Figure 9: Municipal and Other Essential Facilities in the City of Satellite Beach

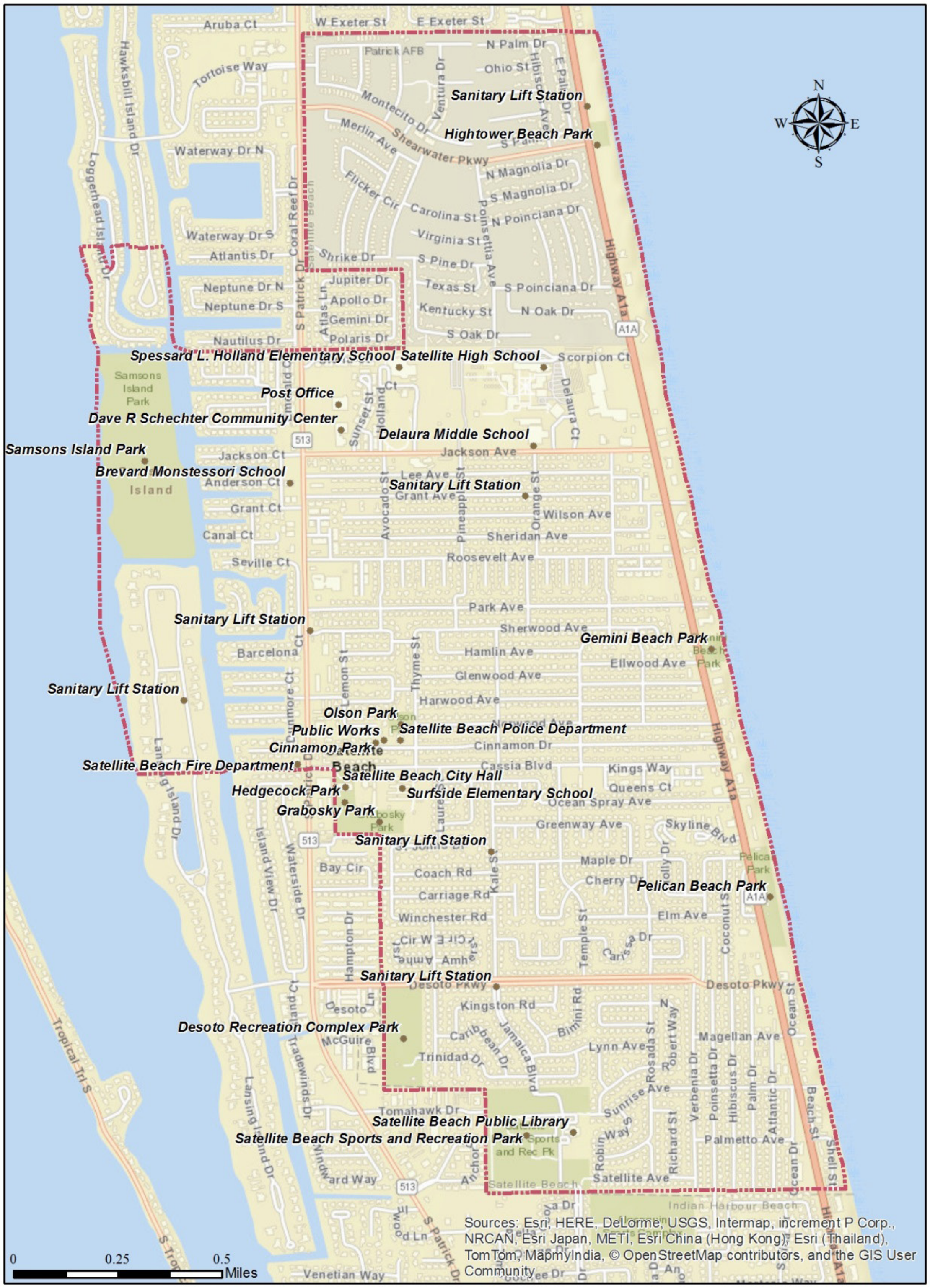


Table 7: Ground and floor elevation estimates (as feet relative to NAVD88) with associated chronic flood assessments under USACE High sea-level rise – Satellite Beach-owned priority facilities.

Facility	~ Ground Elevation (LIDAR DEM)	~ Floor Elevation (OPUS)	Chronic Flood Vulnerability (Timing Onset & Estimated Impact)
Dave R Schechter Community Center	4.2	4.1	**2040**: Occasional access limitations from stormwater flooding **2070**: Frequent access limitations and occasional stormwater flooding into facility
Satellite Beach City Hall	3.6	4.8	**2040**: Occasional access limitations from stormwater flooding **2070**: Frequent access limitations and potential for stormwater flooding into facility
Satellite Beach Fire Station	4.0	*Engine Bays*: 4.5 *Main Building*: 5.0	**2040**: Occasional access limitations from stormwater flooding **2070**: Frequent access limitations and potential for stormwater flooding into facility
Satellite Beach Police Department	5.0	6.1	**2040**: Occasional access limitations from stormwater flooding **2070**: Frequent access limitations from stormwater flooding
Satellite Beach Public Works	4.0	4.5	**2040**: Occasional access limitations from stormwater flooding **2070**: Frequent access limitations and occasional stormwater flooding into facility

Table 8: Ground elevation estimates for park facility structures owned by the City of Satellite Beach. All values as feet relative to NAVD88.

Facility	~ Site Ground Elevation (LIDAR DEM)	Chronic Flood Vulnerability (Timing Onset & Estimated Impact)
Cinnamon Park	2.4	**2040**: Frequent access limitations from stormwater flooding **2070**: Regular saltwater flooding of the site
Desoto Recreation Complex Park	2.9	**2040**: Frequent access limitations from stormwater flooding **2070**: Seasonal saltwater flooding of the site
Gemini Beach Park	13.4	**2040**: N/A (does not account for erosion risk) **2070**: N/A (does not account for erosion risk)
Grabosky Park	2.3	**2040**: Frequent access limitations from stormwater flooding **2070**: Regular saltwater flooding of the site
Hedgecock Park	2.9	**2040**: Frequent access limitations from stormwater flooding **2070**: Seasonal saltwater flooding of the site
Hightower Beach Park	12.9	**2040**: N/A (does not account for potential erosion risk) **2070**: N/A (does not account for potential erosion risk)
Olson Park	5.3	**2040**: Potential access limitations from stormwater flooding **2070**: Occasional access limitations from stormwater flooding
Pelican Beach Park	14.0	**2040**: N/A (does not account for potential erosion risk) **2070**: N/A (does not account for potential erosion risk)
Satellite Beach Sports and Recreation Park	5.6	**2040**: Potential access limitations from stormwater flooding **2070**: Occasional access limitations from stormwater flooding

Table 9: Ground elevation estimates for schools located within the City of Satellite Beach. All values as feet relative to NAVD88.

Facility	~ Site Ground Elevation (LIDAR DEM)	Chronic Flood Vulnerability (Timing Onset & Estimated Impact)
Brevard Montessori Private School	5.4	**2040**: Potential access limitations from stormwater flooding **2070**: Occasional access limitations from stormwater flooding
Delaura Middle School	7.2	**2040**: N/A **2070**: N/A
Satellite Senior High School	7.3	**2040**: N/A **2070**: N/A
Spessard L. Holland Elementary School	5.6	**2040**: Potential access limitations from stormwater flooding **2070**: Occasional access limitations from stormwater flooding
Surfside Elementary School	4.8	**2040**: Occasional access limitations from stormwater flooding **2070**: Frequent access limitations from stormwater flooding

Table 10: Ground elevation estimates for sanitary lift stations located within the City of Satellite Beach. All values as feet relative to NAVD88.

Location	~ Site Ground Elevation (LIDAR DEM)	Chronic Flood Vulnerability (Timing Onset & Estimated Impact)
Grant Ave	7.8	**2040**: N/A **2070**: N/A
Highway A1A	11.7	**2040**: N/A **2070**: N/A
Jamaica Blvd	3.9	**2040**: Occasional access limitations from stormwater flooding **2070**: Frequent access limitations from stormwater flooding
Kale Street	6.9	**2040**: N/A **2070**: N/A
Lansing Island Dr	3.1	**2040**: Frequent access limitations from stormwater flooding **2070**: Seasonal saltwater flooding of the site
Sherwood Ave	2.5	**2040**: Frequent access limitations from stormwater flooding **2070**: Regular saltwater flooding of the site

Table 11: Ground elevation estimates for other government service facilities located within the City of Satellite Beach. All values as feet relative to NAVD88.

Facility	~ Site Ground Elevation (LIDAR DEM)	Chronic Flood Vulnerability (Timing Onset & Estimated Impact)
Brevard County Library, Satellite Beach	7.4	**2040**: N/A **2070**: N/A
U.S. Post Office, Satellite Beach	4.7	**2040**: Occasional access limitations from stormwater flooding **2070**: Frequent access limitations from stormwater flooding

Chapter 5: Extreme Event Water Level Assessment

The Multi-Hazard Loss Estimation Methodology (or HAZUS-MH) is a standardized methodology created by the Federal Emergency Management Administration (FEMA) to estimate potential losses from earthquakes, hurricane winds, and floods. The HAZUS Flood Hazard Model is used to estimate riverine and coastal flood hazards and potential damage to buildings, infrastructure, and land use. The software models specific return intervals of flooding (such as the 100-year return interval, also known as the 100-year storm or 1% annual probability storm) and damages resulting from those events.

For this project we used Coastal Flood Hazard Model in the HAZUS-MH Version 3.1 (a freely downloadable add-on to ESRI's ArcGIS 10.2.2 software) to develop water level estimates for 100-year return interval flood events under both current and future (2040 and 2070) conditions in the City of Satellite Beach. The Coastal Flood Hazard Model incorporates computations from FEMA's erosion, Wave Height Analysis for Flood Insurance Studies (WHAFIS), and RUNUP models to develop estimates of flood height under a defined storm event for any given coastline study area. The output from the Coastal Flood Hazard Model is a flood depth grid that describes the projected depth and extent of flood waters in the study area under the modeled flood event. This depth grid can then be used to predict the impacts of the modeled flood event on essential facilities, property, and economic activity within the study area.

The HAZUS-MH Coastal Flood Hazard Model incorporates flood height information derived from FEMA's Flood Insurance Rate Maps (FIRMs), which are used by FEMA to delineate and regulate 100-year return interval floodplains for federally backed flood insurance purposes. However, it is important to note that the Coastal Flood Hazard Model uses a separate, and generally more risk-averse, process for delineating the100-year coastal flood event as compared to the process used by FEMA for delineating the 100-year regulatory floodplain and as defined by published FIRMs.

A fundamental difference between the HAZUS and FIRM methodologies stems from the divergent purposes between the two models. An express purpose of HAZUS modeling is to inform decisions about evacuation, maintenance of essential emergency services, and facilitation of efficient rescue and recovery processes in the event of a disaster event. Because such decisions inherently involve potential risks to human life, safety, and welfare, the HAZUS modeling process is set up to be risk-averse – in other words, the model results tend to err toward overestimation of potential flood risk. By contrast, the fundamental purpose of a FIRM is to set premium rates for the insurance of property against flood risk. Although there currently is substantial effort by FEMA to update FIRMs using high resolution elevation datasets and refined flood modeling techniques, financial difficulties within the National Flood Insurance Program (NFIP) over recent years suggest that FIRMs may tend toward the underestimation of flood risk at some locations. (Leatherman 2018; Pralle 2019)

The primary elevation input for our HAZUS modeling in Satellite Beach was a 5-meter horizontal resolution digital elevation model (DEM) compiled by the University of Florida GeoPlan Center (UF GeoPlan 2013). For several locations in Satellite Beach where the UF GeoPlan Center DEM contained null data, we appended elevation values derived from the lower resolution (9 meter horizontal resolution) National Elevation Dataset (USGS 2018). This population of numeric elevation data throughout the study area (i.e., removal of null values) was required to ensure that the HAZUS Coastal Flood Hazard Model would successfully complete the depth grid process.

Stillwater elevations (SWELs), which are the heights of the modeled flood event without the effect of waves, for the base 100-year return interval flood event in Satellite Beach were sourced from the 2014 Flood Insurance Study (FIS) for Brevard

County (FEMA 2014). In addition to the base 100-year return interval flood event, we also developed HAZUS Coastal Flood Hazard depth grids that simulate the effects of the USACE High sea-level rise scenario in both 2040 and 2070. These sea-level rise models were developed by adding relative increments of sea-level rise, as benchmarked to an assumed 1992 NTDE water level reference (i.e., 1.22 feet in 2040; 2.85 feet in 2070), to the base SWEL heights for the Satellite Beach coastline.

In Table 12, the projected flood depth above the first floor elevation for each of the five City-owned priority facilities, as based upon the HAZUS Coastal Flood Hazard Model flood depth grid. The projected aboveground flood depth results for all other inventoried facilities are listed in Table 13. We caution that these HAZUS results are appropriate for use in informing disaster planning and response, but may not be appropriate for making investment decisions designed for the sole purpose of protecting private property from present and future flood risk. This is because while the modeled flood event should be regarded as technically possible, the "true" probability of an event of this magnitude impacting the City of Satellite Beach may be somewhat lower than the 1% annual probability suggested by the HAZUS modeling approach that we employed.

A site-level assessment of extreme event flood risk for the current Satellite Beach Fire Station, as presented to the Satellite Beach City Council in August 2017, is provided as Appendix 2 of this report. Taking into account the current and future flood risks identified by this assessment, the Satellite Beach City Council has allocated funds for the relocation of the Satellite Beach Fire Station to an alternative site located on substantially higher ground.

Table 12: Estimated flood depth, as feet above first floor elevation, for a 1% annual probability coastal flood event, as calculated using HAZUS Coastal Flood Hazard Model. Depths for 2040 and 2070 are based upon the USACE High sea-level rise scenario.

Facility	Base	2040	2070
Schechter Community Center	4.4	5.6	7.3
Satellite Beach City Hall	3.8	5.0	6.7
Satellite Beach Fire Station	*Engine Bays*: 4.0 *Main Building*: 3.5	*Engine Bays*: 5.2 *Main Building*: 4.7	*Engine Bays*: 6.9 *Main Building*: 6.4
Satellite Beach Police Department	2.6	3.8	5.5
Satellite Beach Public Works	4.6	5.8	7.5

Table 13: Estimated flood depth, as feet above site ground elevation, for a 1% annual probability coastal flood event, as calculated using HAZUS Coastal Flood Hazard Model. Depths for 2040 and 2070 are based upon the USACE High sea-level rise scenario.

Facility	Base	2040	2070
Cinnamon Park	6.5	7.7	3.4
Desoto Recreation Complex Park	5.8	7.0	8.7
Gemini Beach Park	N/A	N/A	N/A
Grabosky Park	6.6	7.8	9.5
Hedgecock Park	5.8	7.0	8.7
Hightower Beach Park	N/A	N/A	N/A
Olson Park	3.6	4.8	6.5
Pelican Beach Park	N/A	N/A	N/A
Satellite Beach Sports and Recreation Park	4.3	5.5	8.2
Brevard Montessori Private School	3.4	4.6	6.3
Delaura Middle School	1.7	2.9	4.6
Satellite High School	1.4	2.6	4.3
Spessard L. Holland Elementary School	4.5	5.7	7.4
Surfside Elementary School	4.2	5.4	7.1
Grant Ave	1.2	2.4	4.1
Highway A1A	N/A	N/A	N/A
Jamaica Blvd	5.0	6.2	7.9
Kale Street	2.1	3.3	5.0
Lansing Island Dr	5.3	3.5	8.2
Sherwood Ave	6.2	7.4	9.1
Brevard County Library, Satellite Beach	1.1	2.3	4.0
U.S. Post Office, Satellite Beach	3.8	5.0	6.7

Chapter 6: Property Tax Impact Assessment

Ad-valorem (property) tax is the largest revenue source for the City of Satellite Beach, representing 58.2% of the general fund and 39% of all revenues for the city budget. Property values have steadily increased in the City over the past 5 years and that trend is expected to continue (City of Satellite Beach, 2017). As the City strives to maintain high levels of public service and functional infrastructure for its citizens, understanding the impacts of sea level rise and flooding on the property tax base can assist the city in the evaluating the cost-benefit of flood mitigation efforts.

This analysis looked at the potential impacts to the City of Satellite Beach's property tax base under the USACE (2013) High sea-level rise scenarios at the years 2040 and 2070. To estimate potential property value losses, flood maps were first generated to indicate the extent and depth of flooding at local mean sea level (LMSL), seasonal high water (SHW), and annual high water (AHW) under each SLR scenario. Next, the flood maps were overlaid with property parcel data to calculate the amount of flooding on each parcel. Finally, property value impacts were summarized by SLR scenario. As a companion to the stormwater system analysis, this analysis highlights areas of the City that will likely flood under SLR scenarios, in the absence of flood mitigation measures.

Water Level and Elevation Data

This analysis used the USACE (2013) High SLR projections for 2040 (1.22 ft) and 2070 (2.85 ft), as consistent with the City of Satellite Beach Comprehensive Plan. Water level datums for the IRL, as described above in Tables 4 & 5, were used as the basis for the analysis. Local mean water sea level (LMSL) represents the approximate average daily IRL water levels; seasonal high water (SHW) represents the water levels experienced annually during the fall season and lasting approximately two weeks; and annual high water level (AHW) represents an extreme water level reached approximately once per year. For our analyses of future water levels under SLR conditions, we considered LMSL to be permanent flooding and SHW and AHW to be periodic flooding. Elevation data for the analysis were derived from the UF GeoPlan (2013) statewide Digital Elevation Model, which utilizes the 2007-2008 Florida Division of Emergency Management Coastal LIDAR data at a 5-m horizontal cell-size resolution in Satellite Beach.

Property Parcel Data

Property parcel data for 2017 was downloaded in GIS format from the Brevard County Property appraiser. The parcel dataset was clipped to the limits of the City of Satellite Beach. The "*Taxable Value Non-School*" value was used for impact calculations. This value represents the total combined value that the property can be taxed for; includes every tax district for which the property is in and accounts for all tax deductions.

SLR Mapping Methods

Flooded areas in each SLR scenario were identified by evaluating the future water levels (referenced to NAVD88) against the DEM (also referenced to NAVD88). Land elevations below that of the future water levels were extracted from the DEM. The depth of flooding was calculated by subtracting the future water level from the land elevation. For these maps, hydro-connectivity of the land was not considered, and hence isolated, low-lying areas not geographically connected to a water body were included in the resulting maps. Because the soils in Satellite Beach are highly porous and rain events can commonly co-occur with flooding or high-water events, these low-lying areas were included due to their likelihood of flooding and/or receiving runoff.

Estimating Impact on Property Values

The purpose of this analysis was to estimate the potential loss in taxable property value due to SLR flooding under three future scenarios. The method for calculating property value impacts from SLR follows the Hazus-MH methodology that relates the depth of flooding to the severity of the economic impact (FEMA 2018). Hazus-MH uses depth-damage curves (or functions) to estimate damages, where the deeper the flood level, the greater the resulting economic impact. These assumptions were modified slightly, to match the type and duration of flood event under future SLR scenarios. Hazus-MH depth-damage curves assume a flood event, from which the waters will recede. In the case of SLR flooding, some water will not recede, leaving properties partially or completely submerged all year long. Other properties will incur periodic flooding (nuisance or high tide flooding) with increasing frequencies that precludes cost-effective flood mitigation measures.

The depth, location, and frequency of flooding will determine whether a property owner is willing to invest in adaptation measures to protect their homes, buildings, or private property. To estimate economic impact due to these permanent and periodic flooding events, a few assumptions were made regarding loss. The first assumption (stated above) is the depth-damage relationship, where the higher the flood level, the greater the economic impact. The second assumption is that property value impact is also related to the proportion of the total property flooded. All properties that incur some flooding will not be assumed to be a total loss. However, if a parcel was over 50% flooded and the mean flood depth was greater than 0.5 foot, then the impact to the property was considered a total loss (meaning the full value of the property would be impacted).

Previous studies estimating property impacts from SLR have used the parcel centroid (or center point of the parcel) to overlay with flood maps and determine impact (i.e. if the parcel centroid is flooded, then the entire parcel is considered a loss) (Fu and Song 2017). Because Satellite Beach is a small municipality, we also had the opportunity to examine other methods which would evaluate the proportional loss of the parcel based on the percentage of the parcel flooded (Zhang et al. 2011).

For each parcel, flood statistics were calculated as minimum, maximum and mean flood depths per parcel, square feet of parcel flooded, and percentage of parcel flooded. Full value loss was assumed for parcels with greater than 50% flooded area and a mean flood depth of greater than 0.5-ft. For parcels with less than 50% flooded area, impact was calculated as: Impacted value = (Percentage of the flooded area) x (property value) x (Hazus-MH depth-damage factor for the mean flood depth on the parcel).

Results & Discussion

Visualizations of flood impacts under the USACE High SLR projection for 2040 and 2070 are respectively given as Figure 10 and Figure 11. Under the 2040 SLR scenario for all water levels (MWL, SHW, and AHW), the impacts to taxable property value are under 1% of the total taxable property base (Table 14).

Under the USACE High Projection for 2070, the percentage of the total taxable property value impacted under this SLR scenario is less than 1% at LMSL, approximately 2% at SHW and 2.5% at AHW (Table 14). Those percentages represent approximately \$5 million, \$16.5 million, and \$21.1 million, respectively of the total taxable property value. The values for AHW

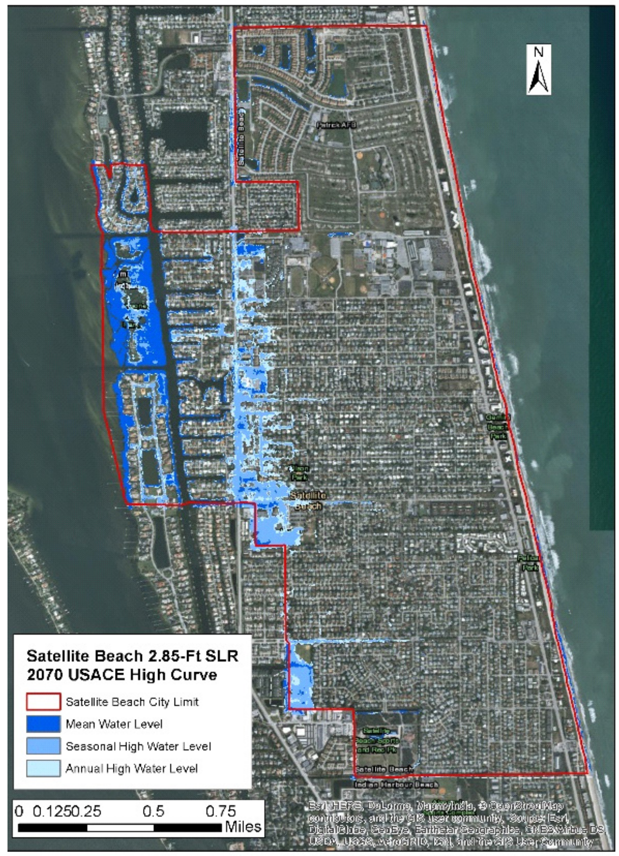
Results of this assessment show relatively small direct impacts to property from tidewater flooding in 2040 and 2070. This is due to the types of property and areas impacted under these scenarios, many of which are publicly owned and not contributing to the tax base. This analysis also focused on direct impacts of flooding, meaning that only properties with flooding occurring on-site are included in the impact estimates. Other areas with predicted flooding include major roadways, which are not accounted for in the impact calculations.

Table 14. Estimated Impacts to City of Satellite Beach Property Tax Base (2017 Dollars)

Water Level	2040 Impact	2040 Taxable %	2070 Impact	2070 Taxable %
MWL	$324,476	0.04%	$4,910,045	0.58%
SHW	$1,902,221	0.22%	$16,491,974	1.95%
AHW	$3,697,020	0.44%	$21,153,853	2.50%

Figure 10: Visualization of estimated tidal flooding at 2040 USACE High sea-level rise projection

Figure 11: Visualization of estimated tidal flooding at 2070 USACE High sea-level rise projection



Several publicly owned properties are highly vulnerable at the 2070 SLR scenario (2.85 ft), where permanent flooding is projected to be more widespread. At high water levels (seasonal and annual), the projected flooding extent is pushed further inland. Of particular concern is the southeast corner of South Patrick Drive and Cassia Blvd, which includes City Hall, the FPL electric substation, ballfields, and an elementary school. South Patrick Drive and Cassia Blvd, major arterials in the City, are estimated to be heavily impacted under most SLR scenarios. Without flood mitigation interventions, standing water and repeated saltwater exposure could cause damage to roadbeds, underground utilities, and vehicle undercarriages. Sampson's Island is one of the first public facilities to be impacted at 2040. Other recreation facilities are predicted to be highly vulnerable at the 2070 SLR scenario. Quality of life and in particular, recreation opportunities, have historically been important to residents of Satellite Beach. Protecting these public amenities, which provide a high quality of life, will be important for the City to consider.

While individual properties may not be flooded, access to property may be restricted, which could result in property value decline for non-flooded parcels lacking access. As properties become regularly or permanently flooded, it is assumed that the value of those properties will decrease. However, there is also evidence that the value of properties *adjacent* to flooded properties may also decrease. It is reasonable to expect that a tipping point or threshold will exist for neighborhoods; as a certain percentage (threshold) of properties in a neighborhood become flooded, then it is likely the entire neighborhood's property value would decrease, even if some individual properties do not sustain flooding. Central to the City's adaptation planning considerations will be balancing the cost of maintaining public services and infrastructure to ensure quality of life, while implementing adaptation strategies and flood mitigation measures in a cost-effective manner that maintains levels of taxes, assessments, and fees at a level that residents and businesses can afford.

Appendix 1

Listing of final stormwater GIS files delivered to the City of Satellite Beach, and description of their respective attributes

City of Satellite Beach Stormwater Infrastructure Geodatabase		
Title	**Description**	**Attributes**
Infalls	Point Feature Class NAD 1983 HARN StatePlane Florida East FIPS 0901. Linear Unit: Feet.	OBJECTID: Data attribute inherent to the ESRI shapefile format, which defines a unique feature number. Shape: Data attribute inherent to the ESRI shapefile format, which defines the data as a point, polyline, or polygon. N_Invert: defines the north invert depth of infall pipe in feet S_Invert: defines the south invert depth of infall pipe in feet E_Invert: defines the east invert depth of infall pipe in feet W_Invert: defines the west invert depth of infall pipe in feet NE_Invert: defines the northeast invert depth of infall pipe in feet NW_Invert: defines the northwest invert depth of infall pipe in feet SE_Invert: defines the southeast invert depth of infall pipe in feet SW_Invert: defines the southwest invert depth of infall pipe in feet Structure: Describes infall type Top_Elev: describes the top elevation of the infall (in feet) in relation to NAVD88. Source: indicates the original source data for a specific point Field_Vrfy: indicates whether field verification of point attributes is recommnded. Notes: this attribute contains information supporting recommended field verifications or other information deemed pertinent Rastervalu: Digital Elevation Model top elevation values associated with a point. Min_Invert: value of the lowest invert elevation (in feet) associated with the point
Manholes	Point Feature Class NAD 1983 HARN StatePlane Florida East FIPS 0901. Linear Unit: Feet.	OBJECTID: Data attribute inherent to the ESRI shapefile format, which defines a unique feature number. Shape: Data attribute inherent to the ESRI shapefile format, which defines the data as a point, polyline, or polygon. N_Invert: defines the north invert depth of infall pipe in feet S_Invert: defines the south invert depth of infall pipe in feet E_Invert: defines the east invert depth of infall pipe in feet W_Invert: defines the west invert depth of infall pipe in feet NE_Invert: defines the northeast invert depth of infall pipe in feet NW_Invert: defines the northwest invert depth of infall pipe in feet SE_Invert: defines the southeast invert depth of infall pipe in feet SW_Invert: defines the southwest invert depth of infall pipe in feet Structure: Describes Manhole type Top_Elev: describes the top elevation of the manhole (in feet) in relation to NAVD88. Source: indicates the original source data for a specific point Field_Vrfy: indicates whether field verification of point attributes is recommnded. Notes: This attribute contains information supporting recommended field verifications or other information deemed pertinent Rastervalu: Digital Elevation Model top elevation values associated with a point. Min_Invert: value of the lowest invert elevation (in feet) associated with the point

City of Satellite Beach
Stormwater Infrastructure Geodatabase

Title	Description	Attributes
Outfalls	Point Feature Class NAD 1983 HARN StatePlane Florida East FIPS 0901. Linear Unit: Feet.	OBJECTID: Data attribute inherent to the ESRI shapefile format, which defines a unique feature number.
		Shape: Data attribute inherent to the ESRI shapefile format, which defines the data as a point, polyline, or polygon.
		Location_Name: Outfall identified by or related to nearest street. Multiple outfalls along the same street are numbered consecutively (1, 2, 3 . . .) from North to South and West to East (Example: S Patrick Dr. 1) Where multiple outfalls occur on opposite sides of a street, outfalls are defined by cardinal direction (example Anderson Ct 2N – second outlet from west to east, located on the north side of the street). Where multiple outfalls exist side by side, outfalls are defined alphabetically from North to South, and West to East (Example: Cassia Blvd 2a – second outfall occurring along Cassia Blvd, first multiple outfall in that location.)
		Width_In: width dimiension of associated pipe denoted in inches
		Height_In: height dimiension of associated pipe denoted in inches
		Type: indicates the shape of the associated pipe, generally "circular" or "Box".
		Material: Indicates the composition type of the associated pipe (concrete, metal, etc.)
		Source: indicates the original source data for a specific point
		Field_Vrfy: indicates whether field verification of point attributes is recommnded.
		Notes: This attribute contains information supporting recommended field verifications or other information deemed pertinent
		Invert_ft: indicates the value of the lowest invert elevation (in feet) associated with the point
Pipes	Line Feature Class NAD 1983 HARN StatePlane Florida East FIPS 0901. Linear Unit: Feet.	OBJECTID: Data attribute inherent to the ESRI shapefile format, which defines a unique feature number.
		Shape: Data attribute inherent to the ESRI shapefile format, which defines the data as a point, polyline, or polygon.
		Shape_Length: Data attribute inherent to the ESRI shapefile format, which defines the length of the line in feet
		Length_ft: indicates the length of the pipe as defined in the as-built (original source).
		Type: indicates the shape of the pipe, generally "circular" or "Box".
		Material: Indicates the composition type of the pipe (concrete, metal, etc.)
		Width_In: width dimiension of associated pipe denoted in inches
		Height_In: height dimiension of associated pipe denoted in inches
		N_Invert: defines the north invert of the pipe in feet
		S_Invert: defines the south invert of the pipe in feet
		E_Invert: defines the easth invert of the pipe in feet
		W_Invert: defines the west invert of the pipe in feet
		Top_Elev: describes the top elevation of the pipe (in feet) in relation to NAVD88.
		Source: indicates the original source data for a specific pipe
		Field_Vrfy: indicates whether field verification of pipe attributes is recommnded.
		Notes: This attribute contains information supporting recommended field verifications or other information deemed pertinent

City of Satellite Beach
Stormwater Infrastructure Geodatabase

Title	Description	Attributes
Retention and Detention Systems	Polygon Feature Class NAD 1983 HARN StatePlane Florida East FIPS 0901. Linear Unit: Feet.	OBJECTID: Data attribute inherent to the ESRI shapefile format, which defines a unique feature number.
		Shape: Data attribute inherent to the ESRI shapefile format, which defines the data as a point, polyline, or polygon.
		Shape_Length: Data attribute inherent to the ESRI shapefile format, which defines the perimeter of the polygon in feet
		Shape_Area: Data attribute inherent to the ESRI shapefile format, which defines the area of the polygon in feet
		Depth_Inches: indicates the depth of the structure (denoted in inches) as defined in the as-built (original source).
		Source: indicates the original source data for a specific structure
		Field_Vrfy: indicates whether field verification of structure attributes is recommnded.
		Notes: This attribute contains information supporting recommended field verifications or other information deemed pertinent

Appendix 2

Site Flood Vulnerability Assessment for the Satellite Beach Fire Department

(1390 South Patrick Drive, Satellite Beach, FL)

Report for the City of Satellite Beach

August 28, 2017

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Adam Carr, Crystal Goodison, and Dr. Paul Zwick

GeoPlan Center, University of Florida

Assessment conducted through funding and project support provided by the Florida Sea Grant College Program

Background

Stetson University and the University of Florida GeoPlan Center are currently collaborating with the City of Satellite Beach on a 2-year study intended to assist the City with local efforts to increase its resilience to current and future flood hazards. Research and technical assistance activities under this project include updates and modernization of local stormwater drainage maps into a geographic information system (GIS) context, development of highly detailed flood hazard assessments using the Federal Emergency Management Agency's HAZUS-MH software platform, and outreach assistance to communicate results of these processes to local citizens and elected officials.

Officials with the City of Satellite Beach recently approached the project team for assistance in characterizing the site-level flood hazard at the City's Fire Department facility, located at 1390 South Patrick Drive. While there are no reports that the Fire Department building itself has ever experienced direct flooding above its finished floor elevation, officials and citizens report that shallow flooding has at times in the recent past impacted the driveway leading from the fire truck bay into South Patrick Drive. In addition, South Patrick Drive itself is known to sometimes experience shallow flooding in the vicinity of the Fire Department facility during heavy rainfall events. Such observations of recent flooding, combined with the City's longstanding concerns about reduced future drainage conditions associated with ongoing sea-level rise (Parkinson and McCue 2011), have raised some concern about the appropriateness of the current Fire Department site.

This investigation provides a rapid characterization of the flood risk hazard at the current Fire Department facility using a suite of site-specific data and flood modeling tools. While it is cautioned that the timing of future flood events cannot be forecast with absolutely precise detail, it can be stated unequivocally that rising sea-levels and higher frequency of intense rainfall events are already impacting the East Central Florida region, including Satellite Beach (Williams 2013; Walsh et al. 2014).

Because the City's Fire Department personnel would be expected to provide critical first responder services, including conduct of emergency operations as the flood event unfolded, this investigation takes a decidedly risk-averse approach toward assessment of the site-level flood hazard. Any direct flooding impact to the Fire Department facility itself during the course of a major flooding event clearly would be expected to impede the response capabilities of first responders, thus posing significant additional risks to the public safety and welfare of the community during the flood disaster event. Moreover, substantial flood damage to a critical facility, such as a Fire Department, would also major logistical challenges during any post-disaster recovery period. For all these reasons, most newly constructed fire stations within flood-prone areas are built to highly risk-averse standards similar to the approach taken within this investigation.

Characterization of Site and Vicinity

Dr. Jason Evans collaborated with the City of Satellite Beach's Building Official, John Stone, and Fire Chief Don Hughes to record two high precision elevation measurements at the current Fire Department site through the use of a CHC X90-OPUS Static GPS Receiver. One measurement, taken at an apparent low point in the driveway from the fire truck bay to South Patrick Drive, indicated an elevation of 2.46 feet above the North American Vertical Datum of 1988 (NAVD88). A second measurement, taken at grade on the north-facing outside wall of the Fire Department complex, indicated an elevation of 4.82 feet above NAVD88. Reported technical confidence (95%) in the accuracy of GPS elevation data points is +/- 2 inches or less. These two measurements, along with several other elevation data points within the vicinity as previously recorded through site survey work by Quentin L. Hampton and Associates, are displayed in Figure A1.

More general elevation data in the form of a Digital Elevation Model (DEM) constructed from Light Detection and Radar (LIDAR) point data, as originally collected in 2007-2008 by the Florida Division of Emergency Management, was supplied to Dr. Evans by a local citizen, Dr. John Fergus. The DEM for Satellite Beach is at a 4 feet by 4 feet horizontal cell resolution, with an estimated vertical accuracy of +/- 6 inches at the 95% confidence level. A visualization of elevations from the LIDAR DEM, along with higher resolution point elevation data, in the vicinity of the Fire Department site is displayed in Figure A2. Notably, the LIDAR and point elevation data show much of South Patrick Drive near the Fire Department as lying at elevations that are less than 3 feet NAVD88.

Building Official Stone provided Dr. Evans with an as-built drawing (Figure A3) for the Fire Department site that included Finished Floor Elevation data for the fire engine bay room (listed as 5.84 feet) and the main Administration building (6.33 feet). In addition, archival site drawings of the Fire Department site and vicinity with survey point elevations were also supplied by Mr. Stone (Figure A4). Cross-reference of the archival elevation data listed in the Fire Station as-built (Figure A3) and broader site characterization (Figure A4) with the point and LIDAR elevations in Figures A1-A2 indicate consistent discrepancies that show the more recent elevation data as approximately 1.25 – 1.5 feet lower than the archival data. This discrepancy is strongly suggestive of the older data being referenced to the National Geodetic Vertical Datum of 1929 (NGVD29). In the vicinity of Satellite Beach, a point elevation referenced to NGVD29 will be approximately 1.41 feet higher than the same point elevation as referenced to NAVD88 (NOAA 2017).

Based on this suite of data, the Finished Floor Elevation of the Fire Department's engine bay room is generally estimated at 4.4 to 4.5 feet above NAVD88, while the administration building is estimated at 4.9 to 5.0 feet above NAVD88. It is cautioned that these estimates are given for general planning and flood risk characterization purposes only and that design-quality elevation data for the Fire Department site would require additional site characterization by a licensed surveyor.

HAZUS Flood Hazard Assessment for the Fire Department Facility

The HAZUS-MH modeling approach is frequently used by local governments for evacuation and hazard mitigation planning purposes, including the identification of essential facilities such as schools, police stations, hospitals, and fire stations that are potentially at-risk from floods and other natural hazards (FEMA 2007; Volusia County 2015). In collaboration with the City of Satellite Beach and other project partners, faculty and staff at the University of Florida's GeoPlan Center have utilized the HAZUS-MH software package to conduct 100-year coastal flood hazard models for the City of Satellite Beach.

The coastal flooding package defines the 100-year flood risk for a given facility as the depth of water that has a 1% probability of occurring in that facility due to a storm surge event for any given year. These depth grids for Satellite Beach were derived through use of 100-year storm surge height estimates on the Atlantic coastline, which the HAZUS model then dispersed through transected profiles and hydrologically connected flow paths into the lagoon or estuary side of the barrier island.

The "current condition" 100-year flood depth grid, as derived from HAZUS, for the Fire Department site and vicinity is shown in Figure A5. This "current condition" represents the 100-year flood depth risk under current sea-level heights, meaning that anticipated future rises in sea-level are not factored into the flood risk assessment. As annotated within Figure A5, the modeled 100-year flood in HAZUS indicates a flood depth of approximately 6 feet in the Fire Department driveway and adjacent areas of South Patrick Drive, with approximately 4 feet of water depth within the building itself.

Clearly, such an extreme flood event as depicted in the HAZUS scenario would be an unprecedented and catastrophic event for the City of Satellite Beach and adjacent communities. While the coastal flood module within HAZUS does not explicitly define the storm scenario that would produce such flooding, direct Atlantic landfall and stalling of a major hurricane in a position that sustained multiple days of very strong winds and heavy rainfall would be the most likely scenario for such an extreme event.

HAZUS Flood Assessment as Compared to the Flood Insurance Rate Map (FIRM) Process

The project team presents these results with the careful caveat that the HAZUS 100-year flood assessment for Satellite Beach quite substantially differs from the 100-year floodplain delineation provided by FEMA's Brevard County Flood Insurance Rate Maps (FIRMs). In fact, the current FIRM does not include the Fire Department site within the 100-year regulatory floodplain (also known as the Special Flood Hazard Area), and the listed 100-year flood height within the currently in force FIRM for the Banana River coastline in Satellite Beach is approximately 1.7 feet above NAVD88. While new preliminary FIRMs in Brevard County are scheduled to have formal public review from September 19-21, there is currently no indication that the preliminary FIRMs will result in the Satellite Beach Fire Department site being incorporated into the revised 100-year regulatory floodplain.

Dr. Evans, Mr. Stone, and other members of the project team recently had a phone conversation with members of the technical mapping team tasked with developing the new preliminary FIRMs for Brevard County to discuss the apparent discrepancies between the HAZUS results and the FIRMs. One primary difference is that HAZUS results are used to inform evacuation and emergency responses, both of which are extremely risk-averse processes due to the implied risks to human life if mistakes are made or a seemingly improbable event occurs.

By contrast, the fundamental purpose of FIRMs is to develop a basis for setting annualized flood insurance rates through the National Flood Insurance Program. While the FIRM process involves development of highly rigorous technical models and a thorough public review period, research indicates that a substantial proportion of flood losses occur outside of designated 100-year floodplains (Highfield et al. 2012). For this reason, sole reliance on 100-year regulatory floodplain boundaries is increasingly seen as inadvisable for local planning purposes (Li and van de Lindt 2012), particularly when there is substantial local knowledge of stormwater drainage conditions and site hydrology factors that may not be captured through the FIRM process (Highfield et al. 2014). Such caution is particularly warranted for a critical facility located in a low-lying area that has been observed to have flooding issues.

Given the past observations of semi-frequent nuisance flooding in the Satellite Beach Fire Department driveway and adjacent areas South Patrick Drive, the results from HAZUS – while seemingly extreme and alarming – are nevertheless consistent with the view that the current Fire Department site may be at an unacceptably high risk of current and future flooding. While such concerns can be derived solely from past experience and assessment of current water level conditions, it is very clear that the depth, duration, and overall risk of future flooding at the current Satellite Beach Fire Department site will be further exacerbated by ongoing sea-level rise.

Alternative Site Characterization

A potential site for relocating the Fire Department has been identified on the north side Jackson Ave. just west of the intersection with Magnolia Avenue. As shown in Figure A6, current grade elevations for the upland portions of the site range from 7 to 8.5 feet above NAVD88, with adjacent roadways generally showing a similar elevation profile. Additional elevation of the site through design and construction grading activities would further lessen the extreme event flood risk profile of any facility constructed on the alternative site.

Figure A1: Point Elevation Data, Satellite Beach Fire Department and Vicinity

Figure A2: Point and LIDAR Elevation Data, Satellite Beach Fire Department and Vicinity

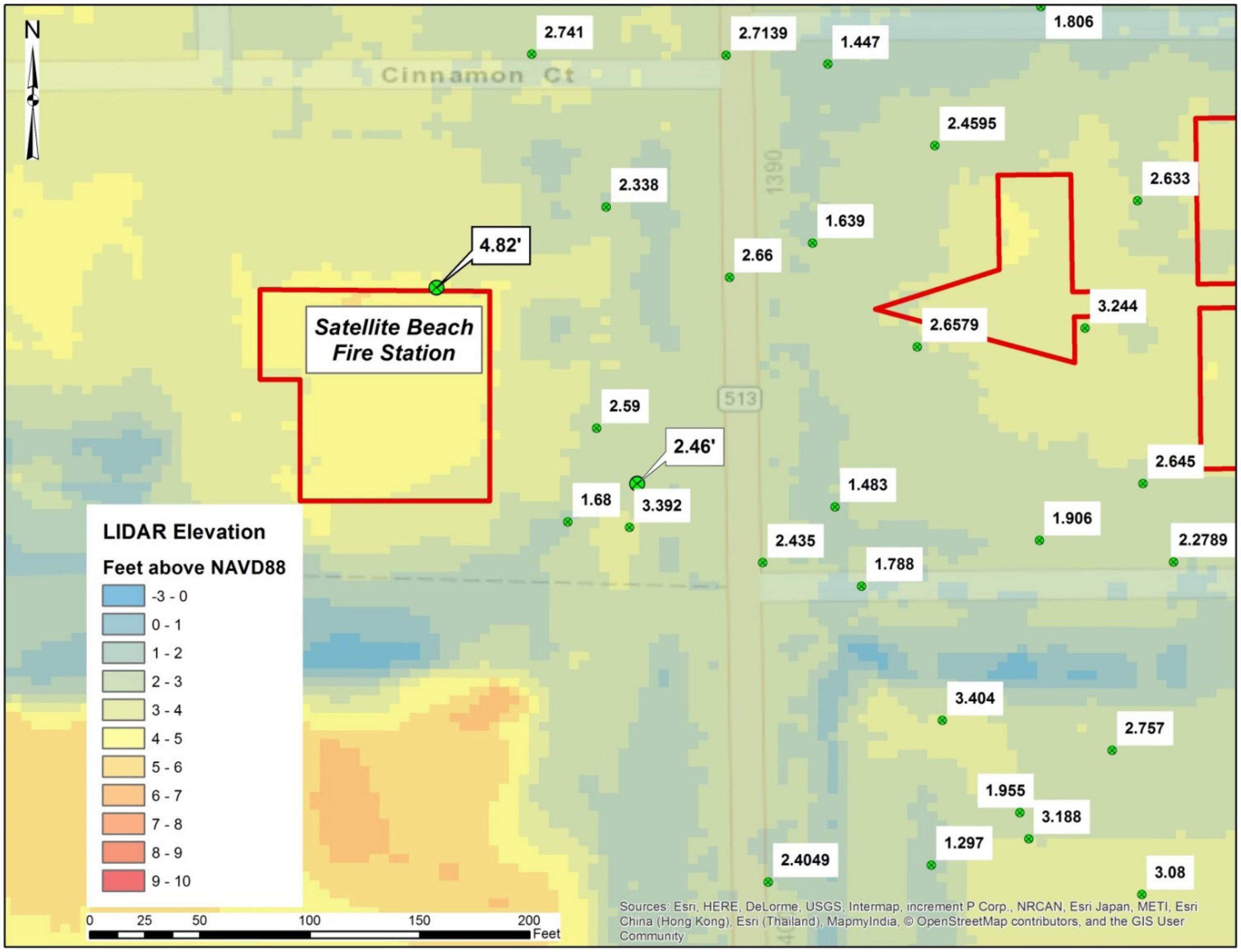

Figure A3: As-Built Drawing with Finished Floor Elevations, Satellite Beach Fire Department

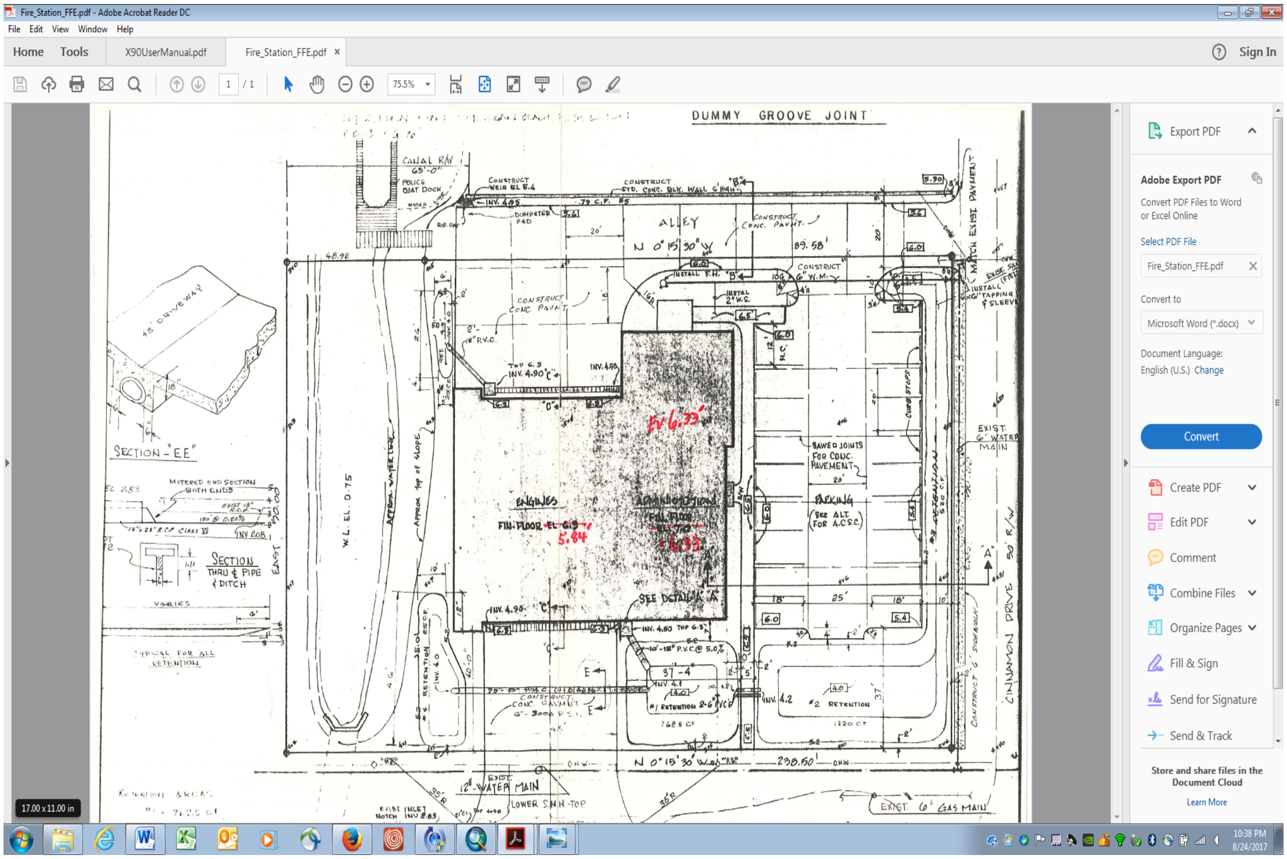

Figure A4: Building Department Site Drawing and Point Elevations, Satellite Beach Fire Department and Vicinity

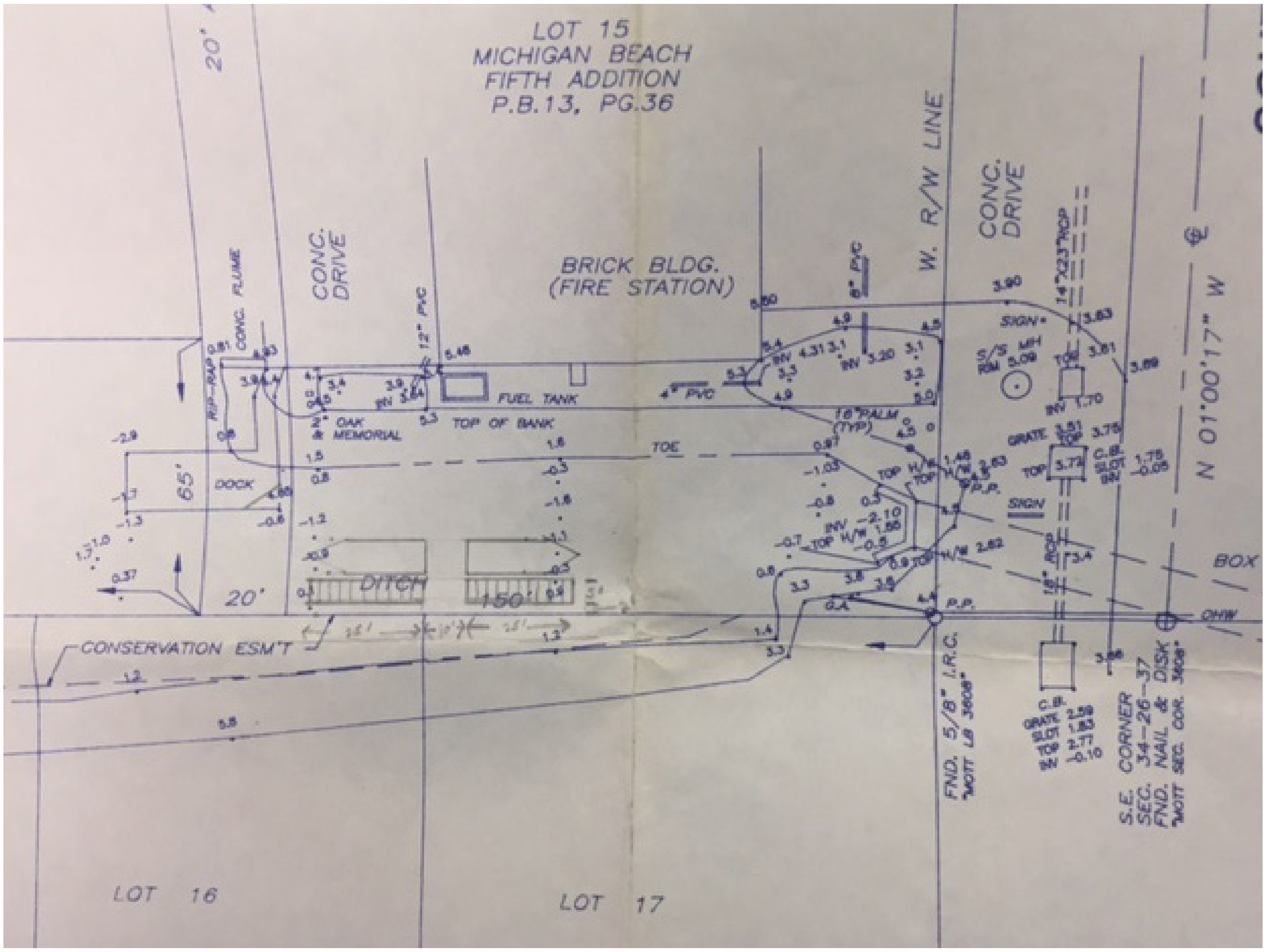

Figure A5: HAZUS-MH Flood Depth Grid, Satellite Beach Fire Department and Vicinity

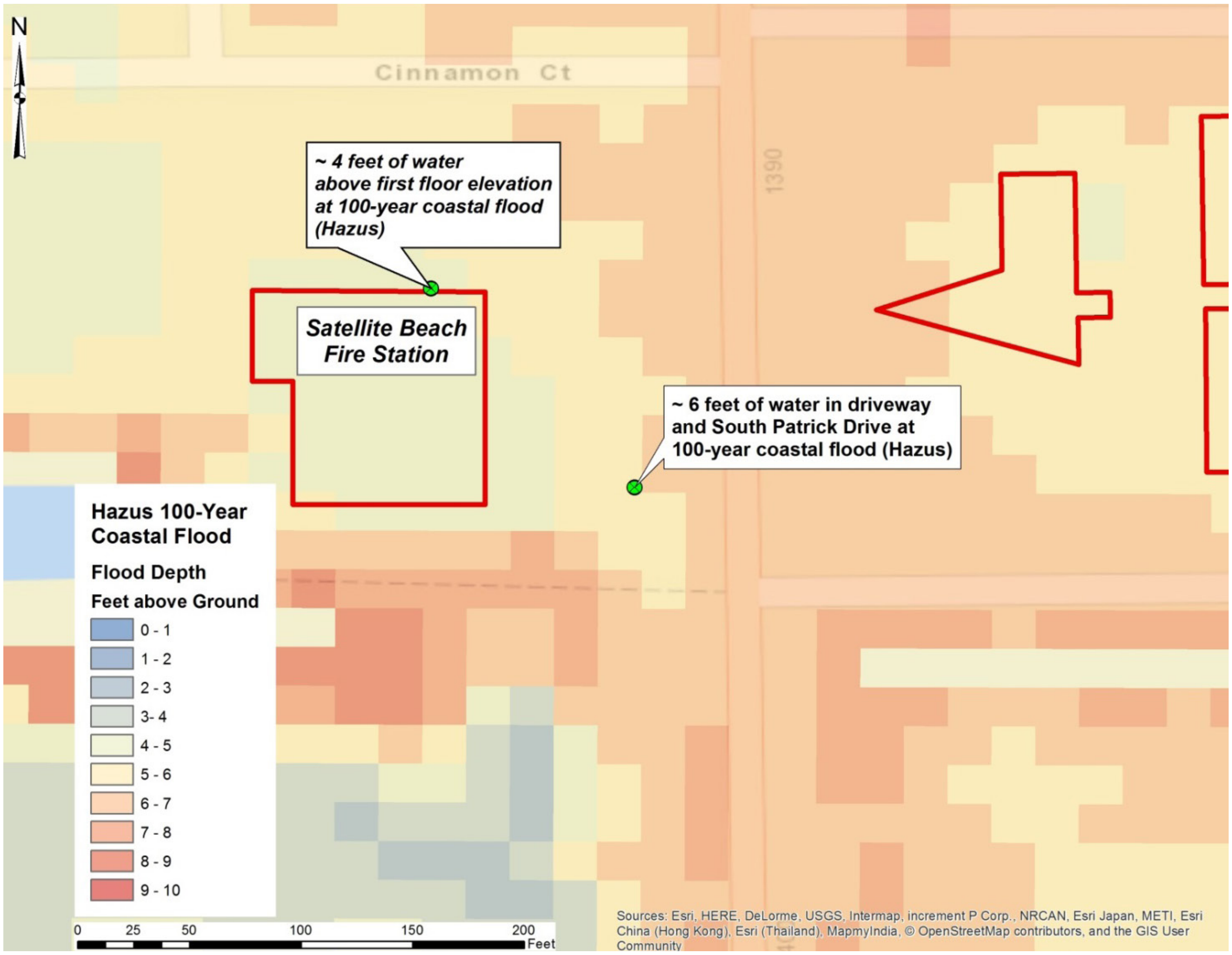

Figure A6: Point Elevations for Jackson Avenue Site

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