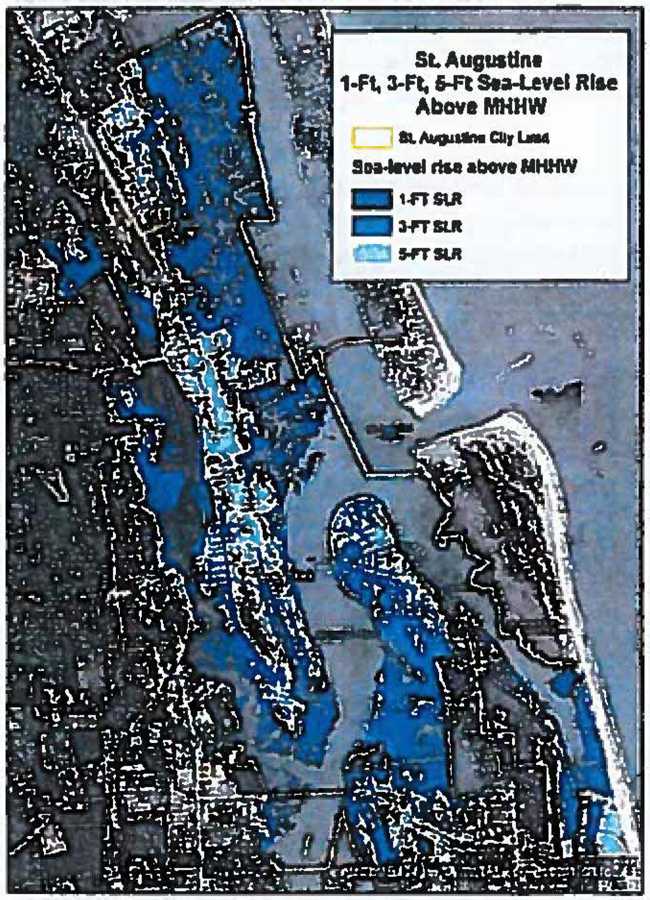
Adapting to Rising Tides

Coastal Resilience in St. Augustine: Baseline of Our Past, Beacon for Our Future

STUDY NARRATIVE

April 2016



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Executive Summary

Overview

For decades to come, St. Augustine, and coastal communities worldwide, will be increasingly affected by progressively rising seas. How the City prepares for the inevitability of sea level rise (SLR) is paramount to the success of the City's future resilience. This white paper, entitled Adapting to Rising Tides (ART), provides an *Introduction* to the SLR issue, an examination of *SLR Trends* from global to local, and a series of *SLR Projection* maps of the potential community *Impacts* given the City's geographic context. ART then summarizes the *Local Impacts*, discusses *Adaptation Strategies* currently being explored by other jurisdictions, and concludes with a list of *Next Steps* for the City to consider for the nearer- and longer-term future.

First Steps

The insights of ART provide a basis for City-wide policy discussions. ART suggests that the outcomes of these discussions may inform relevant amendments to the goals, objectives, policies, and strategies the City adopts in its statutorily-mandated Comprehensive Plan (Plan). For example, a new SLR Resiliency element may be added to the Plan. However, there is adequate capacity within the statutory framework for Plans in Florida to absorb and accommodate SLR goals, objectives, policies, and strategies throughout complementary existing elements.

Capital Improvements Element & Program. The University of Florida Resilient Communities Initiative (UFRCI) believes that productive City-wide discussions would engender implementation priorities that can be memorialized in the Capital Improvements Element (CIE) and Capital Improvements Program (CIP) of the City's Plan. The CIP is a good first step toward implementation of SLR adaptation activities, because the CIP helps to guide the City's budgetary investment priorities and is where policy starts becoming programmatic.

Intergovernmental Coordination, Cooperation, & Collaboration. The City need not face its SLR challenges alone. Like the multiscale driving factors and impacts of SLR, the City is part of a larger response web of local, regional, state, and federal scale actors and agencies. While the City-wide SLR adaptation discussion proceeds with jurisdictional concerns and considerations foremost, the City will probably be best-served by collaborating with these other entities at every level. This includes the City availing itself to the collaborative context of its ongoing partnership with UFRCI. Given the City's prominence as the Nation's Oldest City, it occupies a unique position to embrace the leading edge of the global conversations and actions to adapt to SLR.

Next Steps

The *Next Steps* and *Appendix* sections provide a suggested roadmap for further study on the development and implementation of City policies, procedures, and projects for SLR adaptation. As considered above, the ultimate strategies to adapt the City to the SLR challenge are policy decisions for City leaders to consider over the coming months, years, and decades. As rising tides force the governing bodies of coastal jurisdictions to make difficult decisions and allocate finite resources to adapt to the challenges that SLR portends, the policy and the planning efforts that support them are unlikely to be definitive or dispositive. The effort should be ongoing and reiterative as new information and greater knowledge is gained as to the ongoing effects of SLR, and as strategies are deployed and tested for their successes.

Table of Contents

1 Introduction and Purpose

Of the numerous challenges facing coastal communities in the foreseeable future, one of the most pernicious is that of ***relative sea level rise (SLR)***. Accepted projections for tidal and storm surge levels for the Northeast Florida coast over the next 15 to 85 years suggest SLR from 0.25 – 6.67 feet (0.08 – 2.03 meters). At these levels the infrastructure, neighborhoods, and historic properties in the City of St. Augustine's lower-lying areas will be adversely affected. Upgrading the form and function of public infrastructure may improve the community's resilience to the economic, environmental, and social disruptions that will likely accompany Northeast Florida SLR.

1.1 Coastal Florida: Economically Valuable, Ecologically Vulnerable

Because of Florida's low elevation and extensive coastal line (more than 1200 miles), the State is particularly vulnerable to the effects of SLR. An estimated 75% of Florida's 19.5 million population lives in coastal counties[i] and those counties "generate 79% of the state's total annual economy"[ii]. Florida's coasts also include productive ecosystems which support plant and animal life, provide food sources and invaluable ecosystem services. Florida ranks first nationally in coastal recreation participation at an estimated value between $5.36 billion to $23.75 billion annually.[iii]

Potential negative effects that could result from SLR, include but are not limited to:

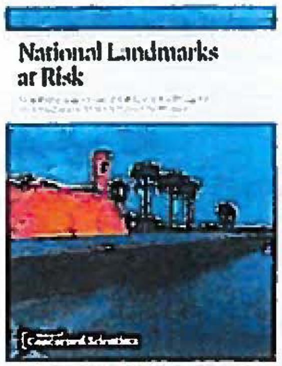
- Permanent inundation of low-lying coastal areas;
- Increased intermittent coastal flooding from storms and/or higher spring tides resulting in damage to physical public infrastructure (e.g., roads, bridges, lift stations), homes, businesses, civic and cultural resources, and related critical facilities;
- Reduction in capacity, or complete failure, of stormwater management systems;
- Beach and shoreline erosion and migration;
- Alteration, degradation, or collapse in coastal habitats, ecosystem services, and managed natural resources; and
- Impacts to groundwater via saltwater intrusion, further magnified by increased consumptive use and extraction with population growth.

1.2 St. Augustine: Baseline of Our Past, Beacon for Our Future

As the "oldest continuously occupied settlement of European and African American origin in the United States," St. Augustine is a national treasure. The City was founded in 1565, in part, because of its location on a natural harbor accessible to the Atlantic Ocean.

By design, the central part of the city and adjacent fortifications were originally constructed on lands assumed to remain dry from sea and storm given known coastal and inland floodplain trends at that time. Over several centuries, the City gradually expanded along the natural coastal ridge that spans the east coast of Florida. The lower-lying lands east of the ridge, toward the Intracoastal Waterway (ICW) and beyond to the Atlantic Ocean, are those areas mostly likely to be negatively affected by incremental SLR.

Given the longevity and history of the City, the iterative planning for SLR scenarios through the year 2100 is reasonable and necessary, if not imperative. Like a lighthouse alerting sailors to the impending shift from sea to land, the City has a profound opportunity to serve as a national beacon highlighting the strategic resilience and adaptive capacity planning needed for all coastal cities in this new era of changing shorelines and floodplains.



A recent report from the Union of Concerned Scientists, *National Landmarks at Risk*, compiles a selection of case studies that highlight the urgency of SLR threats to the nation's most cherished monuments and historic sites, including the City. Castillo de San Marcos, North America's oldest masonry fort, is threatened by rising tides and is featured on the cover of that report. The "living seawall" completed by the National Park Service in 2011 adjacent to Castillo de San Marcos and other issues facing the historic district are referenced in the report. This is recognition at the highest levels that the well-being of the City is inherent to the well-being of the many historic assets to which the City is a steward and should encourage the City and its larger governance partners in their future collaboration endeavors.

1.3 Purpose of this Study

This study provides an overview of the potential SLR risks faced by the City and the opportunities for fostering resilience and adaptive capacity through local government action, leadership, and planning in collaboration with other arms of governance and forms of community involvement. This study narrative, and its associated appendices, provide the following decision support services to the City: (1) inform the community of current SLR trends and projections; (2) suggest potential land use and land cover SLR impacts; (3) provide theoretical time frames and "tipping points" during which critical City assets become inundated; and (4) summarize future action planning and outreach opportunities.

2 Sea Level Rise (SLR): Global vs. Relative Trends and Projections

2.1 Study Nomenclature

This section uses terms that may need clarification. "SLR" refers to sea level rise. "Global" SLR refers to a planetary average. "Relative" SLR refers to a local comparison between a single tide gauge and a single point on land. "Trend" refers to actual historical measurements. "Projection" refers to hypothetical future estimates. For the purposes of this study and unless preceded by the phrase "global average," all references to "SLR" make use of the "relative SLR" specific to the City.

2.2 Global Average SLR Trends

Global or "eustatic" sea level has risen about 8 inches over the last century and is projected to rise an additional 12 to 48 inches (0.31 to 1.22 meters) by 2100.[iv] While the average rate of global SLR over the last century was 0.67 inches (17.0 mm) per decade, however, the rate has increased to 1.26 inches (32.0 mm) per decade over the last twenty years.[v, vi] Two (2) primary factors contributing to global SLR: (1) thermal expansion from ocean warming and (2) net water volume increases from the melting of glaciers and ice sheets.[vii] See *the Appendices* for additional information.

2.3 Relative SLR Trends

We often hear the term, "global sea level rise," when considering coastal risk. However, sea levels are not rising uniformly across the globe. Some locations are experiencing greater rates of sea level rise than the global average, while others are experiencing lower. The differences are related to factors such as whether the land near the shore is sinking (subsidence) or rising (uplift), ocean currents, wind patterns, etc. When estimating the potential effects of sea level rise for a particular geographic area, it is critical to evaluate ***relative*** or local sea level rise.

Relative sea level rise (SLR) refers to how much sea levels are rising relative to a point on land. Relative SLR is estimated using local or relative sea level trends, which are calculated using historical measurements or observations of local sea level at individual tide stations. As such, relative SLR is more important for local decision support than global average SLR.

The National Oceanic and Atmospheric Administration (NOAA) operates a permanent network of tide stations across the United States to collect data on local water levels, tides, and currents. Tide gauges have been used in the U.S. since the late 1800s to reliably measure water levels.

2.4 Northeast Florida Relative SLR Trends

Generally, the east coast of the United States, including North Florida, has been gradually sinking since the last glacial peak approximately 20,000 years before present.[viii] Two (2) tide stations exist in proximity to St. Augustine: (1) Fernandina Beach and (2) Mayport. In operation since 1898, the Fernandina Beach tide gauge records show relative SLR of about 8 inches (203.2 mm) in the last 100 years, at a rate of 0.81 inches (20.6 mm) per decade.[ix] Similarly, the Mayport tide gauge records show relative SLR of about 8 inches (203.2 mm) since the tide gauge started collecting data in 1928, at a rate of 0.98 inches (24.9 mm) per decade.[x] While the Fernandina Beach rate of relative SLR is similar to the observed rate of global SLR over the past century, the Mayport rate of relative SLR is about 20% higher.

2.5 Northeast Florida Relative SLR Projections

Sea level trends, which are based on historical local sea level observations, are used with models of future scenarios of sea level to estimate what sea levels might be at a given point in the future. Given the longer historical data record, relative SLR trends from the Fernandina Beach tide station were used to estimate projected future sea levels within this study. Trends from this tide station were overlaid with two (2) sets of future sea level projections for evaluation and mapping: (1) the U.S. Army Corps of Engineers (USACE) and (2) the National Climate Assessment, commonly referred to as the NOAA projections. See ***the Appendices*** for a more complete explanation of this study's projection methodology, including alternative projections from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5) and the Southeast Florida Climate Compact.

Utilizing the USACE Sea-Level Change Curve Calculator, USACE and NOAA sea level rise projections were compiled by decade from the year 2030 through the year 2100 using relative SLR trends from the Fernandina Beach tide station (***Table 1*** and ***Figure 1***). The table below shows five projections (two projections are equivalent), with resulting amounts of relative SLR from 0.25 – 6.67 feet (0.08 – 2.03 meters).

Table 1. USACE and NOAA Relative Sea Level Rise (SLR) Projections, 2030 – 2100.

Year	Projected Amount of Relative Sea Level Rise (Feet)				
	NOAA Low & USACE Low	*NOAA Int Low & USACE Int*	*NOAA Int High*	*USACE High*	*NOAA High*
2030	0.25	0.38	0.66	0.79	0.99
2040	0.32	0.52	0.98	1.17	1.50
2050	0.38	0.68	1.35	1.63	2.10
2060	0.45	0.86	1.77	2.17	2.81
2070	0.52	1.06	2.26	2.77	3.63
2080	0.58	1.27	2.80	3.45	4.54
2090	0.65	1.50	3.39	4.21	5.56
2100	0.72	1.75	4.05	5.04	6.67

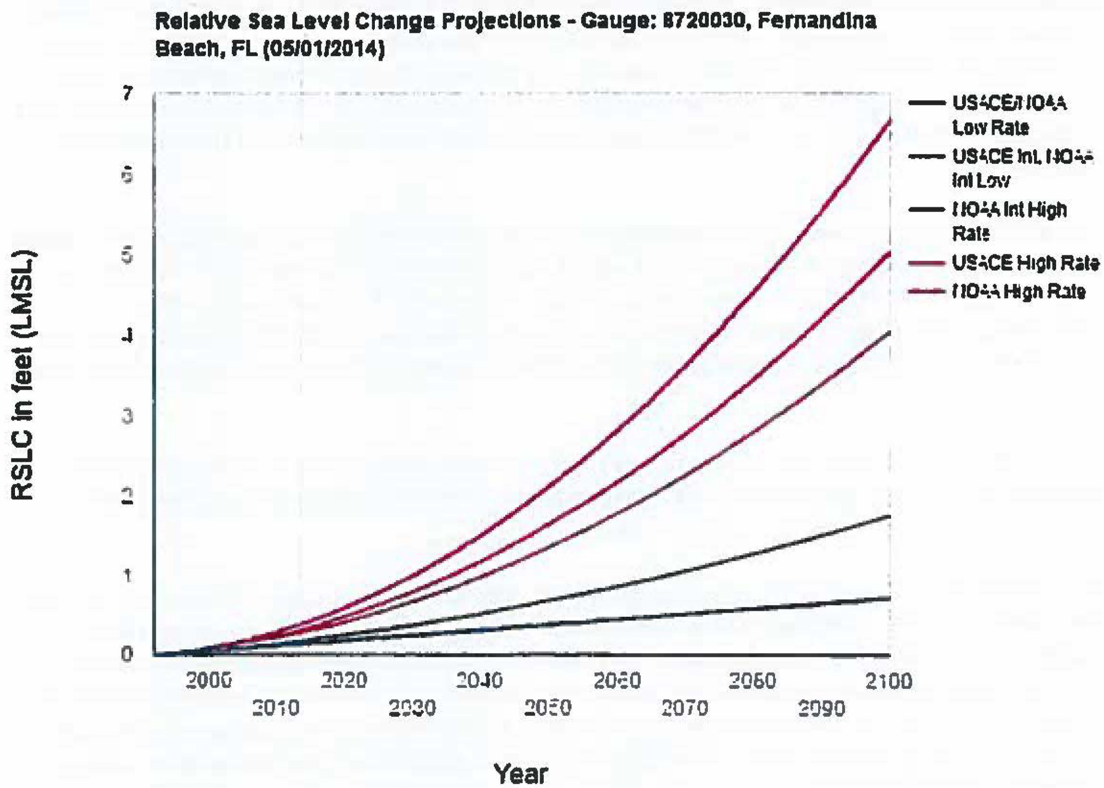


Figure 1. USACE and NOAA relative sea level change projections (in feet), Fernandina Beach, Florida.

3 Relative Sea Level Rise (SLR): Potential St. Augustine Local Impacts

3.1 Relative SLR Inundation Mapping Methodology

This paper utilized a "bathtub" model for mapping SLR on top of high tide (Mean Higher High Water – MHHW – tidal datum). A Digital Elevation Model (DEM), sourced from Lidar data, was used to identify low-lying areas. Six (6) relative SLR scenarios (6-inches, 1-foot, 2-foot, 3-foot, 4-foot, and 5-foot) were initially mapped to get an overview of the amounts of estimated relative SLR over the next century and to decide with which scenarios to conduct map overlays. Under only six (6) inches of relative SLR, approximately 23% of the City's land area is affected, the majority of which is salt marsh. By three (3) feet of relative SLR, the potentially affected land area of the City rises to 42% and impacts extend into the built infrastructure.

Because of the limited scope of this report, the following three (3) scenarios were used to evaluate potential impacts to the City: ***1-foot, 3-foot, and 5-foot of relative SLR on top of MHHW.*** These scenarios represent reasonable planning thresholds, both in the amount of land area impacted and the projected time period for impacts. A scenario of one-foot of SLR would affect approximately 25% of the City's area and is projected to occur as early as 2030, or as late as 2070. While the one-foot scenario only affects 2% more area than the 6 inch scenario, the results of impact analyses using a one-foot scenario will yield a higher level of confidence because of the margin of error within the elevation data. Furthermore, one-foot and three-foot SLR scenarios were used in the regional SLR analysis *Planning Matanzas.*

A three-foot SLR scenario would affect approximately 42% of the City and is projected to occur as early as 2070, or as late as 2100. As detailed in this report, the three-foot SLR scenario could significantly impact the City's assets and built environment. Finally, a five-foot SLR scenario would affect approximately 68% of the City and is projected to occur no earlier than 2085. While the impacts to the City under this scenario are the greatest, the time frame for potential impacts is towards the end of this century.

Using the three relative SLR scenarios, simple GIS overlays were conducted to evaluate the potential impacts to the City of St. Augustine's built and natural environments. Additional details on these methods can be found in the Study Appendices.

While SLAMM (Sea Level Affecting Marshes Model) has been used for other regional analyses, this study used a bathtub model. Both the bathtub model and SLAMM identify low-lying areas vulnerable to flooding from sea level rise. SLAMM results go further to identify land use changes that could occur if developed areas transition to wetland and open water. Because of the limited scope of this report and because much of the City is already urbanized, this study did not assume that developed areas would transition to wetland or open water. This land use transition adaptation strategy should be subject of continuing community dialog.

3.2 Potential St. Augustine Relative SLR Impacts

The following categories were analyzed for potential impacts: (a) Low-lying land areas; (b) Land use types; (c) Land cover types; (d) Critical infrastructure and asset types; and (e) Historical and cultural resources.

3.2.1 Low-Lying Areas Affected

The first analyses included calculation of the land area, land use types, and land cover types potentially impacted at three (3) increasing intervals of relative SLR. *Table 2* summarizes these three (3) scenarios of projected relative SLR (one-foot, three-foot, and five-foot) and the corresponding time frames when that amount of relative SLR is projected to occur. The acres, square miles, and percent of the City inundated under each level of relative SLR (*Table 2* and *Figure 2*) are based on the USACE and NOAA projections (*Table 1*). It should be noted that the time frame in *Table 2* does not include historic sea level trend (USACE Low and NOAA Low rates), which only projects 8 inches of relative SLR by 2100 and does not account for ocean warming or glacial melt.

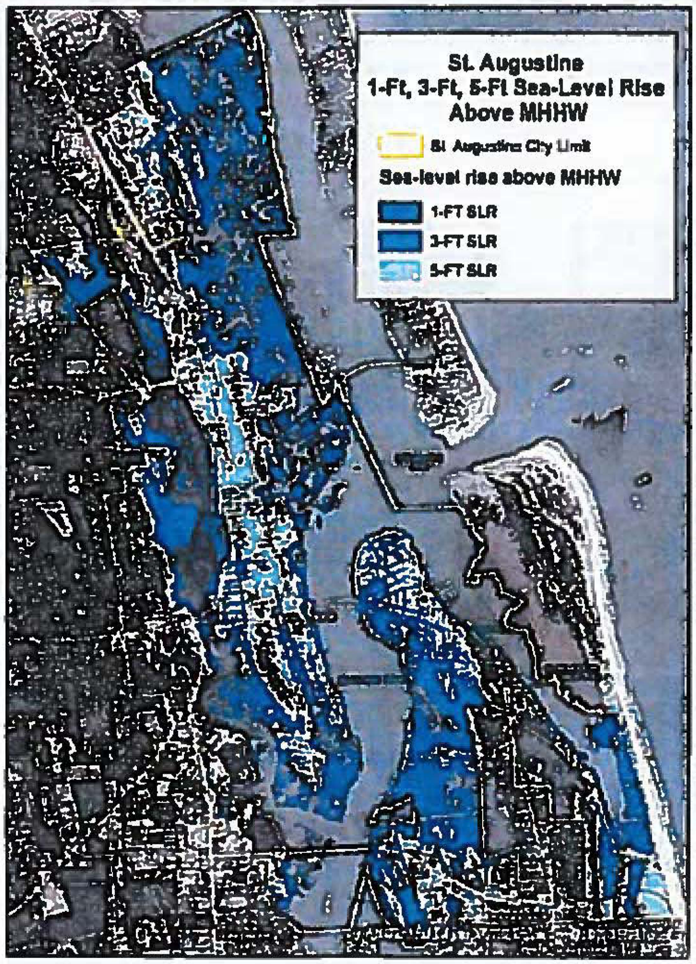


Figure 2. One-foot, three-foot, and five-foot scenarios of relative SLR over MHHW in the City of St. Augustine. Full size images are available within the Appendices.

Table 2. Area of City Impacted for Three Relative SLR Scenarios Over MHHW.

RSLR Above MHHW	Time Frame	City Area	Area Inundated		
(Feet)	*(Year)*	*(Acres)**	*(Acres)*	*(Sq. Miles)*	*(% of City)*
1.0	2030 – 2070	5,362	1,353	2.11	25.22%
3.0	2070 – 2100+	5,362	2,260	3.53	42.15%
5.0	2085 – 2100+	5,362	3,672	5.74	68.48%

*Total City Acres of 5,362 or 8.38 square miles was used for the analyses in this report. This number is based on the dry land area identified in the Digital Elevation Model within the City Boundaries.

3.2.2 Land Cover Types Affected

Table 3 details the land cover types potentially affected under the three relative SLR scenarios (***Figure 3***). The percentages listed for each scenario in ***Table 3*** represent the proportion of each impacted land cover type to the total area for that type. These percentages are meant to indicate the major land cover types affected under each SLR scenario. Not surprisingly, the land cover type most affected under these three scenarios of relative SLR is Salt Marsh. These salt marshes provide critical ecosystem services for the area. Inundation of these salt marshes may diminish the protective storm surge buffering function they currently serve.

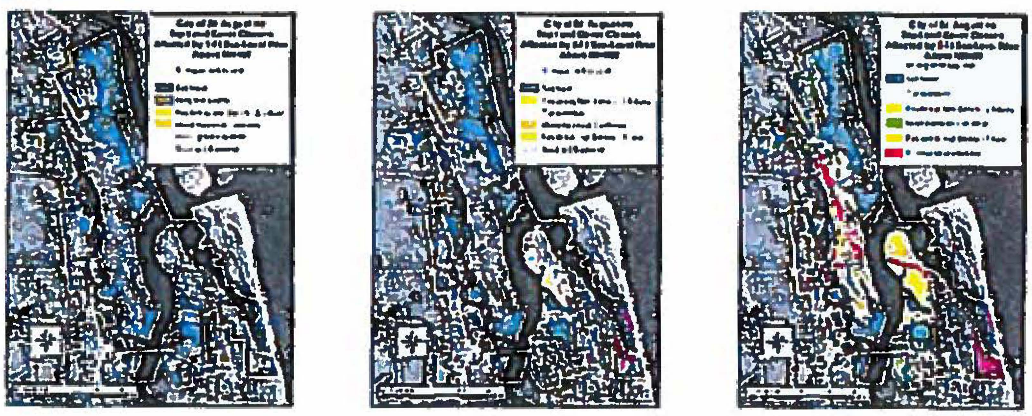


Figure 3. Visual area of potentially impacted land cover types for three relative SLR scenarios over MHHW. Full size images are available within the Appendices.

Table 3. Acreage of Potentially Impacted Land Cover Types for Three Relative SLR Scenarios MHHW.

City Land Cover		1-Foot SLR Impacts		3-Foot SLR Impacts		5-Foot SLR Impacts	
(Type)	*(Acres)*	*(Acres)*	*(%)*	*(Acres)*	*(%)*	*(Acres)*	*(%)*
Salt Marsh	2022.6	1207.9	59.7	1265.9	62.6	1269.3	62.8
Transportation	838.4	4.7	0.6	173.5	20.7	465.5	55.5
Residential, Med. Density (2-5 DU/AC)	749.3	12.0	1.6	178.0	23.8	424.5	56.7
Mixed Hardwood-Coniferous	291.4	11.9	4.1	110.6	38.0	220.7	75.7
Residential, High Density (> 5 DU/AC)	310.1	3.0	1.0	50.5	16.3	199.9	64.5
Commercial and Services	373.8	2.5	0.7	36.7	9.8	173.3	46.4
Shrub and Brushland	236.4	8.0	3.4	66.9	28.3	159.8	67.6
Maritime Hammock	321.6	1.2	0.4	52.8	16.4	154.1	47.9
Institutional	247.8	2.8	1.1	27.7	11.2	144.1	58.2
Parks and Zoos	80.7	1.8	2.2	20.9	25.9	49.7	61.6
Cultural - Terrestrial	92.6	2.2	2.4	24.8	26.8	48.2	52.1
Mangrove Swamp	42.9	38.6	90.0	41.1	95.8	41.6	97.0
Beach Dune	60.2	4.2	7.0	20.4	33.9	34.6	57.5
Community rec. facilities	34.0	0.7	2.1	8.5	25.0	29.9	87.9
Rural Open	35.9	1.1	3.1	15.4	42.9	28.5	79.4
Mesic Flatwoods	26.8	1.5	5.6	25.2	94.0	26.6	99.3
Mixed Scrub-Shrub Wetland	27.1	7.1	26.2	18.6	68.6	24.3	89.7
Marshes	22.4	5.6	25.0	16.3	72.8	21.3	95.1
Wet Prairie	20.3	2.0	9.9	19.6	96.6	19.8	97.5
Urban Open Land	127.9	0.1	0.1	1.7	1.3	15.1	11.8
Coastal Uplands	13.7	4.2	30.7	12.9	94.2	13.7	100.0
Hydric Pine Flatwoods	17.1	0.0	0.0	5.8	33.9	13.7	80.1
Coastal Grassland	11.5	1.9	16.5	9.6	83.5	11.2	97.4
Mixed Wetland Hardwoods	27.9	0.0	0.0	6.8	24.4	11.1	39.8
Non-vegetated Wetland	9.8	8.3	84.7	8.6	87.8	8.6	87.8
Estuarine	1791.2	7.2	0.4	7.8	0.4	8.0	0.4
Other Wetland Forested Mixed	16.1	0.0	0.0	5.5	34.2	7.9	49.1
Sand Beach (Dry)	30.7	6.6	21.5	7.4	24.1	7.5	24.4
Residential, Low Density (< 2 DU/AC)	12.0	0.3	2.5	2.4	20.0	6.1	50.8
Sewage Treatment Pond	12.9	0.2	1.6	1.0	7.8	4.8	37.2
Industrial	15.0	0.1	0.7	1.3	8.7	4.5	30.0
Utilities	7.7	0.1	1.3	3.0	39.0	3.6	46.8
Stormwater Treatment Areas	4.7	0.1	2.1	1.1	23.4	2.8	59.6
Wet Flatwoods	2.7	0.0	0.0	2.0	74.1	2.3	85.2
Artificial Impoundment / Reservoir	88.6	0.2	0.2	1.2	1.4	2.3	2.6
Floating / Emergent Aquatic Vegetation	1.7	0.0	0.0	1.4	82.4	1.7	100.0
Tidal Flat	47.5	1.3	2.7	1.4	2.9	1.4	2.9
Riverine	71.7	1.0	1.4	1.4	2.0	1.4	2.0
Cultural - Lacustrine	1.3	0.0	0.0	1.3	100.0	1.3	100.0
Cypress	1.8	0.0	0.0	0.0	0.0	1.2	66.7
Urban Open Forested	0.9	0.0	0.0	0.1	11.1	0.9	100.0
Field Crops	0.5	0.2	40.0	0.5	100.0	0.5	100.0
Extractive	2.1	0.0	0.0	0.0	0.0	0.3	14.3
Total Impact (All Types)	8151.3	1351.0	16.6	2258.0	27.7	3668.0	45.0

3.2.3 Land Use Types Affected

Next, land use types were overlaid with the relative SLR scenarios to give context to the types of affected land area. *Table 4* details the land uses of the potentially affected areas under three critical relative SLR scenarios. The percentages listed for each scenario in *Table 4* represent the proportion of each impacted land use type to the total area for that type. These percentages are meant to indicate the major land use types affected under each SLR scenario. The land uses most affected are Public/Semi-Public, Acreage Not Zoned for Agriculture, Residential, Vacant Residential, and Recreation. *Figure 4* visually represents the impacted land use types detailed in *Table 4*.

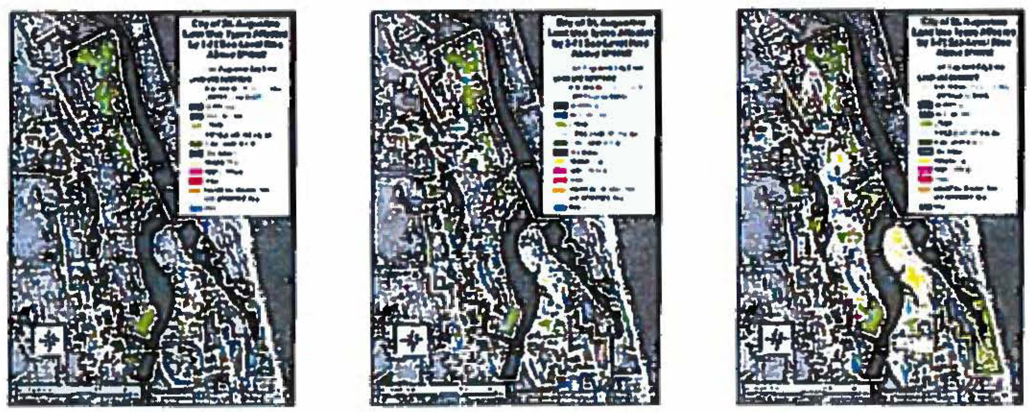


Figure 4. Visual area of potentially impacted land use types for three relative SLR scenarios over MHHW. Full size images are available within the Appendices.

Table 4. Acreage of Potentially Impacted Land Use Types for Three Relative SLR Scenarios MHHW.

City Land Use		1-Foot SLR Impacts		3-Foot SLR Impacts		5-Foot SLR Impacts	
(Type)	*(Acres)*	*(Acres)*	*(%)*	*(Acres)*	*(%)*	*(Acres)*	*(%)*
Public / Semi-Public	1778.3	592.5	33.3	704.9	39.6	826.5	46.5
Residential	1000.6	35.4	3.5	220.7	22.1	605.7	60.5
Parcels / No Value (Water, Roads)	2362.3	63.0	2.7	251.2	10.6	516.0	21.8
Other (Mostly open land)	639.7	377.5	59.0	404.7	63.3	412.7	64.5
Acreage Not Zoned for Agriculture	435.8	72.1	16.5	175.6	40.3	306.0	70.2
Retail / Office	565.5	30.4	5.4	85.5	15.1	237.3	42.0
Recreation	333.7	35.0	10.5	107.2	32.1	214.0	64.1
Vacant Residential	322.6	38.9	12.1	131.9	40.9	212.8	66.0
Institutional	218.2	15.9	7.3	35.9	16.5	131.8	60.4
Vacant Non-Residential	241.3	46.0	19.1	70.9	29.4	111.0	46.0
Water	62.9	30.8	49.0	40.9	65.0	44.8	71.2
Centrally Assessed	66.4	8.2	12.3	19.0	28.6	29.6	44.6
Industrial	41.4	0.3	0.7	2.3	5.6	11.0	26.6
ROW	21.6	4.9	22.7	7.3	33.8	10.5	48.6
Total Impact (All Types)	8090.3	1351.0	16.7	2258.0	27.9	3668.0	45.3

3.2.5 Critical Infrastructure and Asset Types

To assess the impact of relative SLR on the City's critical infrastructure and public assets, the following five (5) categories were analyzed: (1) Social Services/ Government Buildings (including but not limited to fire and police stations, City Hall, post offices, and libraries); (2) Key cultural attractions on the National Register of Historic Places (including the Castillo de San Marcos and the Cathedral Basilica of St. Augustine, which were selected for their national and local prominence and high visibility in the city); (3) Schools and Universities (primarily public schools); (4) Parks and Recreational Facilities; and (5) Public Works Facilities (including lift stations, manholes, and the location of the Wastewater Treatment Plant on Riberia Street). The asset categories were each overlaid with the three (3) relative SLR scenarios to assess if, and when, an asset might be impacted. ***Table 5*** summarizes the potentially affected stormwater facilities (mapped in ***Figure 5*** and ***Figure 6***). ***Table 6*** lists the potentially affected City government building assets (mapped in ***Figure 7***). ***Table 7*** lists the potentially affected parks and recreational facilities (mapped in ***Figure 8***).

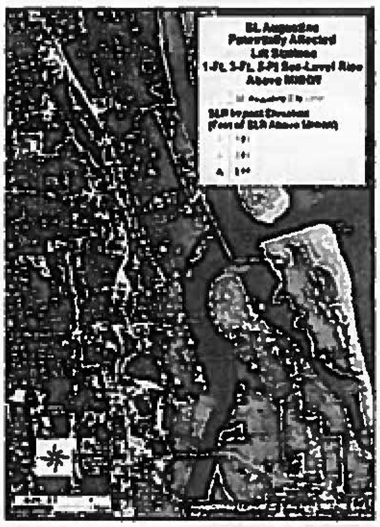


Figure 5. Potentially affected lift stations for three relative SLR scenarios over MHHW. Full size images are available within the Appendices.

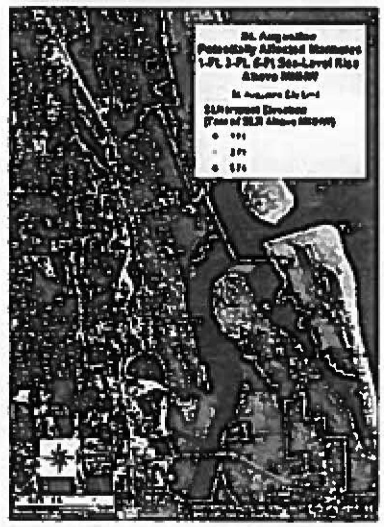


Figure 6. Potentially affected sewer manholes for three relative SLR scenarios over MHHW. Full size images are available within the Appendices.

Table 5. Summary of Potentially Affected Public Works Facilities for Three Relative SLR Scenarios Over MHHW.

City Public Works Assets		1-Foot SLR Impacts		3-Foot SLR Impacts		5-Foot SLR Impacts	
(Type)	*(Total #)*	*(#)*	*(%)*	*(#)*	*(%)*	*(#)*	*(%)*
Lift Stations	45	2	4	18	40	32	71
Manholes	1578	6	0	437	28	1097	70
Waste Water Treatment Plant *(1 plant,*	1	1	100	1	100	1	100
Total Impact (All Types)	1624	1351	83	2258	139	3668	226

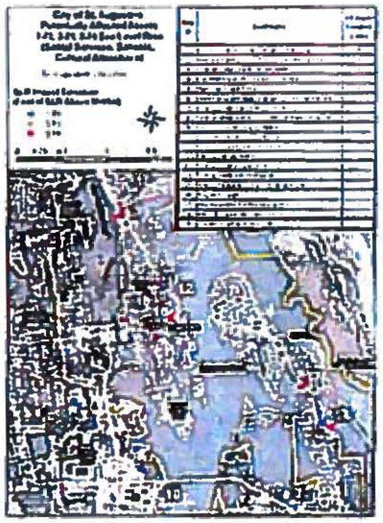


Figure 7. Potentially affected city building assets for three relative SLR scenarios over MHHW. Full size images are available within the Appendices.

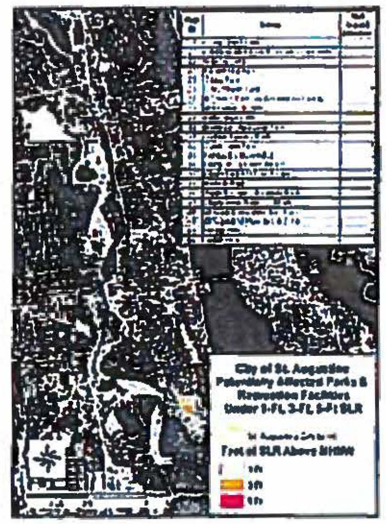


Figure 8. Potentially affected city parks and recreational facilities for three relative SLR scenarios over MHHW. Full size images are available within the Appendices.

Table 6. Potentially Affected City Building Assets (Social Services/ Government Buildings, Cultural Attractions, and Schools) for Three Relative SLR Scenarios Over MHHW.

Asset Category	Map ID	Asset Name	SLR Impact Elevation (Feet)
Social Services/ Government Buildings	1	City of St. Augustine Fire Dept. Main Station	5
	2	Replacement Station 7 (Proposed Replacement)	3
	3	St Augustine Police Department	3
	4	Lightner Museum City Hall Complex	3
	5	National Guard Armory	5
	6	National Guard Headquarters of Florida (Barracks)	3
	7	St Augustine Branch Post Office	5
	8	St Augustine Historic Downtown Parking Facility	5
	9	St Johns County Main Library	5
	10	St Johns County School Board	3
	11	St Johns County Visitors Center	5
Cultural Attractions	12	Castillo de San Marcos	1
	13	St Augustine Alligator Farm	5
	14	St Augustine Amphitheatre	5
	15	The Cathedral Basilica of St. Augustine	5
Schools and Universities	16	Flagler College	3
	17	Florida School for the Deaf and Blind	3
	18	Ketterlinus Elementary School	3
	19	University of St. Augustine	3

Table 7. Potentially Affected Parks and Recreation Facilities for Three Relative SLR Scenarios Over MHHW.

Asset Category	Map ID	Name	SLR Impact Elevation (Feet)
Parks and Recreation Facilities	21	Doug Crane Park	3
	22	Eddie Vickers Park And Gallmore Center	3
	23	Francis Field	3
	24	Fullerwood Park	3
	25	Gibbs Park	3
	26	Government Yard	5
	27	J Edward Red Cox Recreation Facility	3
	28	Joe Pomar Jr Park	1
	29	Ketterlinus Gym	3
	30	Maria Sanchez Lake Park	3
	31	Nelmar Terrace Park	1
	32	Oglethorpe Park	5
	33	Parque De Menendez	3
	34	Plaza De La Constitucion	3
	35	Ponce De Leon Circle Park	3
	36	Railway Park	5
	37	Santo Domingo Redoubt Park	5
	38	Shore Drive Waterfront Park	1
	39	St Augustine Carpet Golf Park	3
	40	St Augustine Municipal Marina	3
	41	Swing Park	5
	42	Twine Park	3

3.2.6 Historical and Cultural Resources

To assess the potential impacts of relative SLR on the City's historical and cultural resources, GIS data from the Florida Master Site File was utilized. The Florida Master Site File, which is maintained by the Florida Division of Historical Resources, is an inventory of historic resources including cemeteries, districts, and structures. These historic resources in the Florida Master Site File may or may not be listed in the National Register of Historic Places (NRHP), which is an official federal designation of historical significance. Historic sites listed on the NRHP, as well as historic cemeteries and historic structures were overlaid with the three (3) scenarios of relative SLR and impacts are summarized below in ***Table 8*** and ***Table 9***, as well as visualized in ***Figure 9, Figure 10***, and ***Figure 11***.

The Florida Master Site File lists 12 historic cemeteries within the City, none of which would be affected under a one-foot relative SLR scenario. Five (5) historic cemeteries would be potentially affected under a three-foot relative SLR scenario, and 11 historic cemeteries would be potentially affected under a five-foot relative SLR scenario (***Table 8*** and ***Figure 9***).

The Florida Master Site File lists approximately 3,288 structures recorded on its inventory within the City of St. Augustine. These structures are primarily private residences. At the one-foot relative SLR scenario, only four (4) structures (all private residences) are potentially affected. At the three-foot and five-foot relative SLR scenarios, approximately 922 and 2,291 structures, respectively, are potentially affected (***Table 8*** and ***Figure 10***).

Furthermore, 31 sites are individually listed on the National Register of Historic Places within the City. Under a one-foot relative SLR scenario, four (4) of these sites would be potentially affected, including the Castillo de San Marcos National Monument. Under a three-foot relative SLR scenario, another 11 sites would be potentially affected, and under a five-foot relative SLR scenario, another nine (9) sites would be potentially affected. See *Table 9* and *Figure 11* below for the list of specific sites potentially affected under the three (3) relative SLR scenarios.

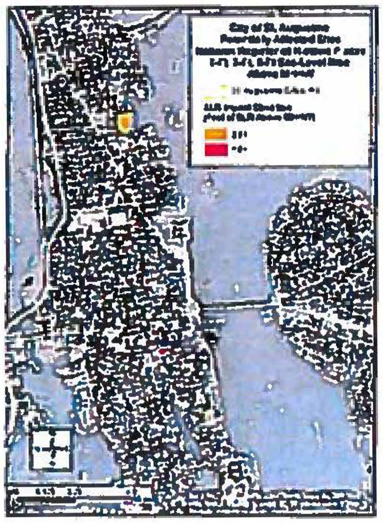


Figure 9. Potentially affected historic cemeteries for three relative SLR scenarios over MHHW. Full size images are available within the Appendices.

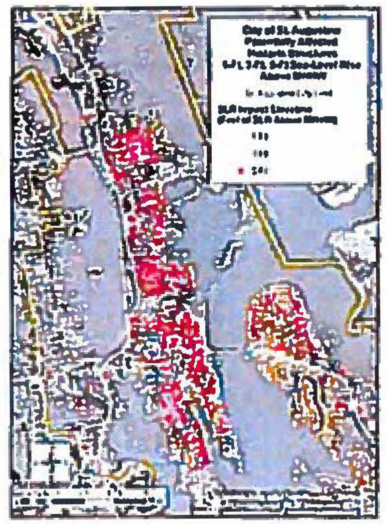


Figure 10. Potentially affected historic structures for three relative SLR scenarios over MHHW. Full size images are available within the Appendices.

Table 8. Summary of Florida Master Site File Affected Historic Structures and Cemeteries for Three Relative SLR Scenarios Over MHHW.

Florida Master Site File - Historic Resources		1-Foot SLR Impacts		3-Foot SLR Impacts		5-Foot SLR Impacts	
(Type)	*(Total #)*	*(#)*	*(% Private)*	*(#)*	*(% Private)*	*(#)*	*(% Private)*
Florida Master Site File - Historic Structures	3,288	4	100	922	79	2291	81
Florida Master Site File - Historic Cemeteries	12	0	N/A	5	N/A	11	N/A

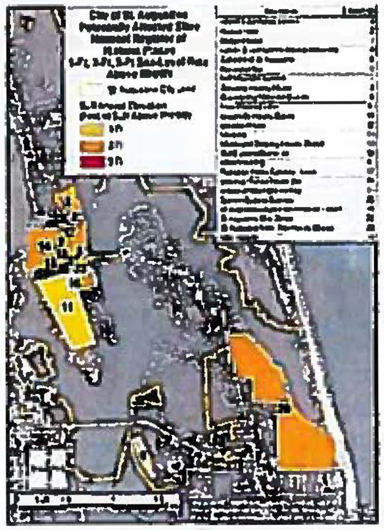


Figure 11. Potentially affected National Register of Historic Places for three Relative SLR scenarios ver MHHW. Full size images are available within the Appendices.

Table 9. Summary of Potentially Affected Sites on the National Register of Historic Places for Three Relative SLR Scenarios Over MHHW.

Site Name	SLR Impact (Feet above MHHW)	Site Name	SLR Impact (Feet above MHHW)
Castillo de San Marcos National Monument	1	Solla–Carcaba Cigar Factory	3
Fort Mose Site, Second	1	Bridge of Lions	3
Fish Island Site	1	St. Augustine Alligator Farm Historic District	3
Lincolnville Historic District	1	Gonzalez-Alvarez House	5
St. Augustine Town Plan Historic District	3	Cathedral of St. Augustine	5
Spanish Coquina Quarries	3	Rodriguez-Avero-Sanchez House	5
Abbott Tract Historic District	3	Sanchez Powder House Site	5
Model Land Company Historic District	3	Llamblas House	5
Alcazar Hotel	3	Markland	5
Hotel Ponce De Leon	3	St. Augustine Civic Center	5
Grace United Methodist Church	3	Villa Zorayda	5
Record Building	3	Old St. Johns County Jail	5

3.3 Summary of Potential St. Augustine Local Impacts

Under the scenarios of one-foot, three-foot, and five-foot relative SLR, 25%, 42%, and 69% of the City's land area would be permanently inundated or submerged. The following sub-sections describe in more detail the major potential impacts for each of the three scenarios, based on GIS analyses conducted for this study.

3.3.1 One-Foot Relative SLR Over MHHW Scenario

Approximately 1,353 acres or 25% of the City's land area would be inundated with one (1) foot of relative SLR, which is ***projected to occur as early as 2030, or as late as 2070.***

The majority of this impacted area is Salt Marsh (approximately 89%) and Mangrove Swamp (approximately 3%). In relation to relative sea levels, these tidal ecosystems are typically among the lowest elevation, and the most heavily impacted, land cover types under all relative SLR scenarios. The effects of rising tides on salt water marsh habitats is well documented in Florida, and scientists suggest it is imperative to implement conservation and adaptation measures of these tidal ecosystems as quickly as possible.[xi]

Analysis shows potential inundation to the Castillo de San Marcos National Monument, but that could be protected by the current seawall. Analysis also shows limited inundation on the perimeter of the Wastewater Treatment Plant property, in close proximity to the plant's northern most treatment structures.

Large areas of impacted salt marsh include the areas along the Tolomato River in the northeastern part of the City, along the San Sebastian River in the western part of the City, along the Matanzas River in the southern part of the City, and along Salt Run on the western side of Anastasia Island and Anastasia State Park. Land uses potentially affected include Public/ Semi-Public (approximately 44% or 592 acres), Open Land (approximately 28% or 378 acres), Acreage not zoned for agriculture (approximately 5% or 72 acres), and Vacant Non-Residential (approximately 3% or 46 acres).

3.3.2 Three-Foot Relative SLR Over MHHW Scenario

Approximately 2,260 acres or 42% of the City's land area would be inundated with three (3) feet of relative SLR, which is ***projected to occur as early as 2070, or as late as 2100.***

Salt marsh comprises a majority (approximately 56%) of the affected area, but within this scenario impacts also begin to extend into urbanized land uses. Land cover classes affected include Residential Medium Density two to five (2-5) dwelling units per acre (approximately 178 acres or 8%), Transportation (approximately 174 acres or 8%), Mixed Hardwood-Coniferous (approximately 111 acres or 5%), and Shrub and Brushland (approximately 67 acres or 3%).

Land uses potentially affected include Public/ Semi-Public (approximately 705 acres or 31%), Open Land (approximately 405 or 18%), Acreage not zoned for agriculture (approximately 176 acres or 8%), Residential (approximately 221 acres or 10%), Vacant Residential (approximately 132 acres or 6%) and Recreation (approximately 107 acres or 5%).

Residential areas on the western and northern parts of Anastasia Island are significantly impacted. Impacts to the City's public works facilities can also be seen under a three-foot relative SLR scenario, including 18 lift stations and 437 manholes potentially submerged and continued inundation on the property of the Wastewater Treatment Facility. Notable assets potentially impacted at the three-foot relative SLR scenario include City Hall, the Police Department, National Guard Headquarters of Florida, Flagler College, the Florida School for the Deaf and Blind, and the St. John's School Board. Additionally, more significant inundation occurs around the Castillo de San Marcos National Monument. Parks and recreational facilities are also impacted, with 14 of the 23 facilities located in the City affected at the three-foot relative SLR scenario.

3.3.3 Five-Foot Relative SLR Over MHHW Scenario

Approximately 3,672 acres or almost 69% of the City's land area would be inundated with five (5) feet of relative SLR, which is ***projected to occur no earlier than 2085.***

In earlier relative SLR scenarios, many properties and assets are only partially submerged due to relative SLR. However, under a five-foot relative SLR scenario, many properties and assets become completely submerged. Land cover classes affected include Salt Marsh (approximately 1,269 or 35% of impacted area), Transportation (approximately 466 acres or 13%), Residential Medium Density two to five (2-5) dwelling units per acre (approximately 425 acres or 12%), Mixed Hardwood-Coniferous (approximately 221 acres or 6%), Residential High Density greater than five (5) dwelling units per acre (approximately 200 acres or 5%) and Commercial and Services (approximately 173 acres or 5%).

Land uses most affected include Public/ Semi-Public (approximately 764 acres or 26% of impacted area), Open Land (approximately 410 acres or 14%), acreage not zoned for agriculture (approximately 241 acres or 8%), Residential (approximately 440 acres or 15%), Vacant Residential (approximately 174 acres or 6%) and Recreation (approximately 172 acres or 6%).

Major impacts would be seen in residential areas, social service facilities, government buildings, historic districts, stormwater facilities, parks and recreational facilities, and more. Notable assets impacted include the Cathedral Basilica of St. Augustine, Fire Department Main Station, St. Augustine Civic Center, St. Augustine Amphitheater, and St. John's County Main Library. While these impacts can appear troubling, given the earliest estimated time frame for those relative SLR amounts, the City has several decades to design and develop adaptive strategies.

4 Next Steps: Community Adaptation Strategies and Tools

Given existing knowledge, guidance, and preliminary local government implementation, the City may choose to consider five major categories of adaptation strategies and five major categories of adaptation tools worthy of the City of St. Augustine's future consideration.

4.1 Planning for Relative SLR in the City

To date, the most comprehensive resource in Northeast Florida to address relative SLR is the recently completed *Planning for Sea Level Rise in the Matanzas Basin* project, led by the University of Florida and the Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR). The three-year project, funded by the NERR System Science Collaborative, engaged local stakeholders within a population area of 150,000 residents, across 264,000 acres within St. Johns and Flagler Counties, and "investigated the Matanzas area's vulnerability to sea level rise and identified [locally relevant, spatially explicit] potential adaptation strategies."

Planning for Sea Level Rise in the Matanzas Basin
Project Homepage: http://planningmatanzas.org/
Document and Data Library: http://planningmatanzas.org/documents/

4.2 Adaptation Strategies

Current consensus, though still evolving, relative SLR adaptation strategies to develop and deploy include the following: (1) protection; (2) accommodation; (3) managed retreat or relocation; (4) avoidance; and (5) procedural. The basic purposes and applicability of these five (5) strategies are described below. Several existing resources (referenced in the Appendices) offer additional implementation and/or case study details. It is important to note that not all of these strategies may be suitable to the City and more thorough future evaluation will be necessary. *Protection strategies* (e.g., hard or soft armoring) may be applicable to valued assets with significant location-dependence, yet are unsuitable for infrastructure alteration or relocation. *Accommodation strategies* (e.g., redesigning, reengineering) may be applicable to valued assets which are suitable to alteration to reach sufficient elevation thresholds to avoid scenario-based inundation risks. *Managed retreat or strategic relocation strategies* (e.g., voluntary setbacks, transfer of development rights, easements) may be applicable to expendable assets with higher vulnerability to SLR and coastal hazards. *Avoidance strategies* (e.g., guiding urban development away from high risk areas) may be applicable to governmental policies, processes, and practices which define future land use planning. *Procedural strategies* (e.g., vulnerability assessments, community outreach and education) may be applicable to governmental policies, processes, and practices which deal with data collection and storage, geospatial and visual analytics, and related information technologies.

4.3 Adaptation Tools

Common relative SLR adaptation tools for the City to investigate for implementation include the following: (1) coordination, cooperation, collaboration, and decision support; (2) planning; (3) regulatory; (4) financial: government spending; and (5) financial: taxes, trusts, and market-based.

4.3.1 Learning from the Lessons of Other Institutions and Agencies

At the regional and local levels in Florida it is important to build upon the work done by others and to thoroughly examine the specific impacts of relative SLR in each locale. The State of Florida does not currently have a comprehensive statewide relative SLR adaptation strategy. However, much work has been done at the federal level, and in other states, regions, and cities, that can be applied to Northeast Florida. In addition, organizations such as the Florida Department of Economic Opportunity (DEO), the St. Johns River Water Management District (SJRWMD), and the Army Corps of Engineers (ACE) have adopted or implemented guidelines that assist in creating local strategies. *The materials referenced in the Appendices to this study summarize and point to these resources.*

4.3.2 Intergovernmental Coordination, Cooperation, and Collaboration

Policies, procedures, and jurisdictional boundaries vary. Regardless, no governmental entity is an island unto itself. The City is inextricably part of a larger web of local, regional, state, federal and global actors and agencies. We cannot overemphasize the fact that tools to address complex national and natural security challenges like SLR require continuous and mindful intergovernmental coordination, cooperation, and collaboration.

The State of Florida comprehensive plan regulations provided in Section 163.3177(6)(h), F.S. 2015 require an Intergovernmental Coordination Element to clearly identify interacting governmental units and coordinating mechanisms to address any potential inter-jurisdictional impacts from urban development. The scope and scale of the relative SLR threat and successful adaptation suggest that the City voluntarily revise the existing comprehensive plan elements, as appropriate, or alternatively, implement a stand-alone element with specific goals, objectives, policies, and strategies to establish a clear and comprehensive community-wide approach to relative SLR. A good opportunity to engage the community and local stakeholders would be the next Evaluation and Appraisal Review (EAR) of the City's Comprehensive Plan, which is due in December 2018. Once adopted, this element or provisions in appropriate elements will provide the basis and rationale for prioritized implementation through the City's Capital Improvement Plan and land development regulations. ***Table 10*** provides a useful matrix identifying important intergovernmental roles and agents. In conclusion, we note that the Adaptation Tools section of the Appendices references several especially useful resources for providing local government decision support.

Table 10. Possible coordination roles and collaborative agents working toward SLR and coastal hazard mitigation and adaptation within Florida local governments.[xii]

	Emergency Management				Growth Management, Planning & Building				Public Works		Environmental [illegible]		Administrative & Elective		
SLR / Hazard Mitigation & Adaptation Role	*SLR & coastal hazard data analyst(s)*	*Recovery operations expert(s)*	*Mitigation operations expert(s)*	*Evacuation & shelter expert(s)*	*Planning & zoning official(s)*	*Growth management planner(s)*	*Community development planner(s)*	*Building code official(s)*	*Electric & gas utility official(s)*	*Public works official(s)*	*Natural resource manager(s)*	*Hazardous waste manager(s)*	*City/County manager*	*City/County attorney*	*Budget & finance chief*
Prepare, review, & update LMS hazards identification & vulnerability assessment	✔			✔					✔		✔	✔			
Prepare, review, & update CEMP hazards analysis	✔			✔							✔	✔			
Assess natural hazard constraints in FLUE land suitability analysis	✔				✔	✔			✔	✔	✔	✔			
Analyze proposed dev/redevelopment in hazard areas for FLUE review & update any proposed FLUM amendments	✔			✔	✔	✔	✔				✔	✔			
Re-evaluate community exposure & vulnerability after disasters	✔			✔	✔			✔	✔	✔					
Review & update SLR / hazard mitigation policies in LMS, PDRP, AAA, & Comprehensive Plan	✔		✔	✔	✔	✔	✔	✔			✔	✔			
Review & update SLR / hazard mitigation structural projects in LMS, AAA, & CIE	✔		✔	✔	✔				✔	✔	✔	✔			
Review & update hazard redevelopment policies in LMS, PDRP, AAA, & Comprehensive Plan	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔			
Review & update PDRP operations policies and procedures		✔			✔		✔	✔	✔	✔			✔	✔	✔
Participate as member of Recovery Task Force	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔			✔	✔	✔

5 Endnotes

[i] Wilson, Steven G. and Thomas R. Fischetti. (May 2010). *Coastline Population Trends in the United States: 1960 to 2008*. Current Population Reports. U.S. Census Bureau. p. 4. https://www.census.gov/prod/2010pubs/p25-1139.pdf

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[iv] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds. *2014: Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2. http://www.globalchange.gov/nca3-downloads-materials

[v] IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.- K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324. http://www.ipcc.ch/report/ar5/wg1/

[vi] Mitchum, Gary. T. (August, 2011). *Sea Level Changes in the Southeastern United States. Past, Present, and Future*. University of South Florida. Florida Climate Institute and Southeast Climate Consortium. http://www.floridawca.org/node/271

[vii] The Earth's oceans absorb approximately 90% of the heat trapped by excess greenhouse gases in the atmosphere. About 40% of the historically observed sea level rise (SLR) can be attributed to thermal expansion from ocean warming, while 60% can be attributed to glacial and ice sheet melt. Source: Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds. *2014: Climate Change Impacts in the United States: The Third National Climate Assessment*. U S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2. http://www.globalchange.gov/nca3-downloads-materials

[viii] Gillis, Justin. January 13, 2014. *The Flood Next Time*. The New York Times: Environment Section. http://www.nytimes.com/2014/01/14/science/earth/grappling-with-sea-level-rise-sooner-not-later.html?smid=tw-share&_r=0

[ix] Mean Sea Level Trend. Tide Gauge 8720030: Fernandina Beach, FL. (NOAA). http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8720030

[x] Mean Sea Level Trend. Tide Gauge 8720218: Mayport, FL. (NOAA). http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8720218

[xi] Noss, Reed F., Joshua S. Reece, Thomas Hoctor, Michael Volk, and Jon Oetting. *Adaptation to Sea-Level Rise in Florida: Biological Conservation Priorities*. Grant Report. Kresge Foundation, August 27, 2014. http://dx.doi.org/10 13140/2.1.4068.2881.

[xii] Excerpted and adapted from *Protecting Florida's Communities: Land Use Planning Strategies and Best Development Practices for Minimizing Vulnerability to Flooding and Coastal Storms*. Florida Department of Community Affairs. 2005. p 48. http://research.fit.edu/sealevelriselibrary/documents/doc_mgr/449/Florida_Community_Protection_-_DCA_2005.pdf