

City of Punta Gorda Adaptation Plan Update

This report is an addendum to the 2009 City of Punta Gorda Adaptation Plan.

Adaptation Plan Addendum
City of Punta Gorda

Final Report

Prepared for

City of Punta Gorda

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ACRONYMS & ABBREVIATIONS

AAA	Adaptation Action Area
ADCIRC	Advanced Circulation Model
AR5	Fifth Assessment Report
BFE	Base Flood Elevation
BSI	Burnt Store Isles
CCS	Center for Climate Strategies
CFR	Code of Federal Regulations
CHHA	Coastal High Hazard Area
CHNEP	Coastal & Heartland National Estuary Partnership, est. 2019 (formerly Charlotte Harbor National Estuary Program)
CPA	Community Planning Act
CPI	Coastal Partnership Initiative
CRA	Community Redevelopment Agency
CWA	Clean Water Act
CZMS	Coastal Zone Management Subgroup
DDC	Depth Damage Curve
DEO	Department of Economic Opportunity
EPA	Environmental Protection Agency
ERP	Environmental Resource Permit
FAC	Florida Administrative Code
FAR	First Assessment Report
FCMP	Florida Coastal Management Program
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transportation
FEMA	Federal Emergency Management Agency
FFE	First Floor Elevations
FIRM	Flood Insurance Rate Map
FR	Federal Register
GIS	Geographic Information System
HMGP	Hurricane Mitigation Grant Program
IPCC	Intergovernmental Panel on Climate Change
LAG	Lowest Adjacent Grade Elevations
LDR	Land Development Regulations
LiDAR	Light Detection and Ranging
LRTP	Long Range Transportation Plan
MLLW	Mean Lower Low Water
MHHW	Mean Higher High Water
NAVD88	North American Vertical Datum of 1988
NCA	National Climate Assessment
NCA4	Fourth National Climate Assessment
NFIP	National Flood Insurance Program
NMFS	National Marine Fisheries Services

NOAA	National Oceanographic and Atmospheric Administration
NWP	Nationwide Permit
PGI	Punta Gorda Isles
RAE	Restore America's Estuaries
RCP	Representative Concentration Pathway
RESTORE	Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act
RGP	Regional General Permit
RSM	Regional Suitability Model
SAGE	Systems Approach to Geomorphic Engineering
SAMP	Special Area Management Plan
SB	Senate Bill
SFHA	Special Flood Hazard Area
SPGP	Statewide Programmatic General Permit
SSH	Sea Surface Height
SWEL	Storm Surge Stillwater Elevations
SWFRPC	Southwest Florida Regional Planning Council
SWFWMD	Southwest Florida Water Management District
TNC	The Nature Conservancy
USACE	US Army Corps of Engineers
UN	United Nations
USGCRP	US Global Change Research Program
WMO	World Meteorological Organization

1.0 EXECUTIVE SUMMARY

In 2018, the City applied for NOAA's 2018-2019 Florida Resilient Coastlines: Resiliency Planning grant, administered by FDEP. The City received the formal executed grant award in January 2018 and contracted with Taylor Engineering, Inc. in February 2019 to conduct a vulnerability analysis for city-owned critical infrastructure and prepare an addendum to the 2009 climate adaptation plan with a living shoreline element. This report is the product of this contract.

A vulnerability assessment was conducted to address public infrastructure within City limits, with an emphasis on coastal flooding impacts to critical facilities and historic properties. The purpose of a vulnerability assessment is to help a municipality or community identify and prioritize structural and social assets that are likely to be impacted by future coastal flooding and sea level rise. Vulnerability assessments are broken into three components: exposure analysis, sensitivity analysis, and focus area identification and mapping. This analysis also forms the basis for complying with the "Peril of Flood" statute requirements as found in Section 163.3178(2)(f)(1-6), Florida Statutes. For purposes of this analysis, properties were sorted into three categories: general publicly owned, critical public facilities, and historic properties.

To evaluate the degree of exposure, 12 flood scenarios were considered resulting from a combination of 3 sea level rise scenarios and 3 storm surge events. The sea level rise scenarios include: Mean Higher High Water (MHHW) to simulate a low inundation, 1.5 ft for medium inundation, and 3 ft for high inundation. The City of Punta Gorda chose these thresholds because the 1.5 ft rise will most likely occur within the time horizon of the City's 2040 Comprehensive Plan or a homeowner's 30-year mortgage, while the 3 ft sea level rise is more suitable for planning capital improvement projects with a 50-year design life. The three tropical storm surge types analyzed were 25-year (4% annual chance) flood, 100-year (1% annual chance) flood, and 500-year (0.2% annual chance). The results of the exposure analysis are presented in Appendix A.

Upon preliminary completion of the vulnerability exposure analysis, the City engaged stakeholders and citizens to provide input in the next steps. A public workshop was held on April 5, 2019 and is summarized in Appendix D. Prior to the workshop, Taylor Engineering developed an online survey to solicit feedback, gauge public perception on sea level rise and the City's efforts to improve resiliency. The stakeholder input received during the workshop helped to inform and prioritize vulnerable regions (focus areas) for the development of adaptation strategies.

The following criteria were also used to identify Adaptation Focus Areas: parcel inundation at 3 ft of sea level rise, ratio of flooded acreage to non-flooded acreage at 3 ft of sea level rise, number of publicly owned parcels inundated, number of critical facilities inundated, and number of historic properties inundated. These criteria yielded three distinct adaptation focus areas for further investigation and narrowing of adaptation strategies. These three regions are the Downtown Focus Area, the Fire Station Focus Area, and the US 41 Commercial Focus Area.

For each Adaptation Focus Area, a variety of strategies for helping the City become more resilient are recommended. A matrix of adaptation strategies is illustrated in Appendix B. The adaptation strategy of creating living shorelines to protect Punta Gorda from dynamic wave action is described in detail in Appendix C. Suggested changes to the City's comprehensive plan are in the final section. Grants to pursue for funding adaptation strategies appear in Appendix E.

2.0 BACKGROUND

2.1 Location and History

The City of Punta Gorda is located in southwest Florida in Charlotte County (Figure 2.1). It lies along the south bank of the Peace River at the northern end of Charlotte Harbor. The City was founded in 1884 with, on the instructions of Colonel Isaac Trabue, every waterfront block designated as a park. This legacy serves the City to this day with a string of public waterfront parks connected by the 2.5 mile long Trabue Harborwalk promenade. Incorporated on December 7, 1887 after the arrival of the railroad and the construction of the Hotel Punta Gorda, the City thrived on winter seasonal visitors, agricultural trade, and commercial fishing.

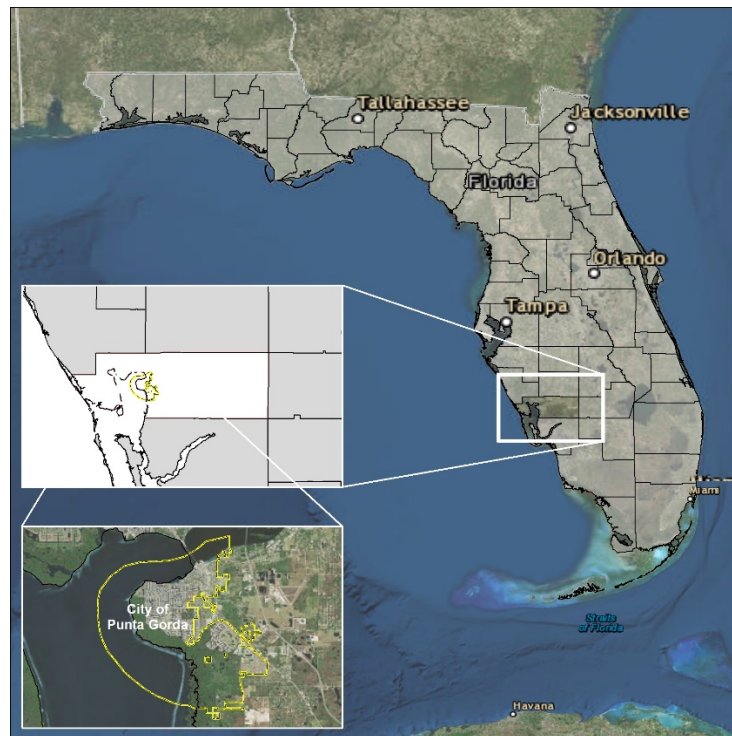


Figure 2.1 Location of Charlotte County and the City of Punta Gorda

Punta Gorda's fortunes ebbed and flowed along with the national economy and Florida's real estate cycle of boom and bust through World War II. The Punta Gorda Army Airfield, site of the current Punta Gorda Airport, opened in 1943 to train pilots, housing 1,200 soldiers during its peak operating capacity. In the late 1950's another housing boom began in the area with the development of Punta Gorda Isles, a residential subdivision designed with canals connected to Charlotte Harbor. With nearly 55 miles of canals, each 100 feet wide and ranging from 5 to 17 feet deep, this development used dredged material from the canals to raise the elevation of the canal-front land for residential construction. This new housing development drew retirees from the north attracted by warm winters, recreational fishing, and boating. With a small-town feel, waterfront parks, a system of pathways for walking and bicycling, and a collection of independent shops and restaurants, Punta Gorda continues to benefit from the preservation of its rich and unique history.

With much of the City constructed on dredged material fill, the land is very low-lying with significant areas of wetland and open lands (state-owned conservation lands) principally between the west side of Punta Gorda Isles and Charlotte Harbor and along Alligator Creek. The City consists of nearly 16 square miles of land, much of which is generally flat and ranging from sea level to approximately fifteen feet above sea level. Of the 16 square miles of land, nearly 47% is conservation land and 5% designated for recreation. Due to the City's low elevations and its proximity to the Gulf of Mexico, Punta Gorda is at risk of flooding during high tides and extreme rain and storm events. Using the Federal Emergency Management Agency (FEMA) database, a review of historical storm events was reviewed. A listing of Southwest Florida's historic floods caused by storm surge is shown in Table 2.1.

Table 2.1 Significant Storm Surge at the Fort Myers NOAA Gauge (FEMA 2014)

Event Name	Date	Surge at Fort Myers, FL unless otherwise noted (feet NAVD88)	Storm Intensity at Landfall
Tampa Bay Hurricane	10/25/1921	7 ft above normal high tide ¹	Category 3
Great Miami Hurricane	9/18/1926	12.0 ²	Category 4
Hurricane Donna	9/11/1960	11.8 ³	Category 4
Hurricane Alma	6/09/1966	4.1	Category 3
Tropical Storm Gabrielle	9/14/2001	3.3	Tropical Storm
Hurricane Charley	8/11/2004	8.2 ⁴	Category 5
Hurricane Frances	9/06/2004	3.0	Category 2
¹ Monthly Weather Review (October 1921) at Punta Gorda, FL			
² U.S. Weather Bureau report (1963), in Punta Rassa-Fort Myers area, referenced to MSL			
³ U.S. Weather Bureau report (1963) near Estero, FL, referenced to MSL			
⁴ FEMA high water mark report (2004) at Fort Myers Beach			

Notably, Hurricane Charley is the most recent major hurricane (Category 3 or higher) to impact Punta Gorda. As shown in Table 2.1, a maximum recorded storm surge height 8.2 feet above the measured mean high-water mark was measured in Fort Myers Beach. Since the City of Punta Gorda is located several miles inland, not on the open coast, use of this surge elevation is not practical since storm surge tends to dampen/decrease over land. In order to determine likely storm surge elevations within the City, the Fort Myers tide gauge located on the Caloosahatchee River was used, located approximately 19 miles inland of the reported high-water mark. As measured by the Fort Myers tide gauge, Hurricane Charley brought 140 mph winds and no significant storm surge (NOAA 2019).

Prior to Hurricane Charley, the region had not seen a major hurricane since 1960, when Hurricane Donna made landfall in Naples and tracked just east of Punta Gorda. After Hurricane Charley, the City's restoration efforts saw the rebuilding of many structures to new, more stringent building codes. These new building codes provide enhanced protection for structures against both flood and wind hazards. The historic downtown and the waterfront area revitalization after Hurricane Charley used more resilient and sustainable strategies than had been applied in the past. In 2009, the Southwest Florida Regional Planning Council (SWFRPC) and Charlotte Harbor National Estuary Program (CHNEP) produced Punta Gorda's first climate adaptation plan, funded by the Environmental Protection Agency (EPA).

2.2 2009 Climate Adaptation Plan Summary and Implementation Progress

In December 2008, the Punta Gorda City Council voted unanimously to participate in the EPA Climate Ready Estuary pilot program. This EPA program works with communities to assess climate change vulnerabilities, develop and implement adaptation strategies, and engage stakeholders. In 2009, the City, through partnerships with the SWFRPC, EPA, and the CHNEP, developed a climate adaptation plan. The City has been planning for impacts due to climate change and sea level rise since commissioning the 2009 climate adaptation plan. During that time, the City used public participation games, individual interviews, pre- and post-workshop surveys, and other tools to identify vulnerabilities. The 2009 plan identified 54 vulnerabilities, ranked by citizens during a series of public workshops. The citizens also reached a consensus on adaptation actions for the City to implement which corresponded to the listed vulnerabilities. These adaptation steps, not in ranked order, are summarized in Table 2.2, from the 2009 Climate Adaptation Plan (Beever, et al. 2009).

Table 2.2 Summary of 2009 Plan Adaptations with Quantifiable Metrics and City Goals

Adaptation	Proximal Monitoring Physical Measure	Secondary Measure	Responsible Entity Collecting Data	Primary Target Goal
Seagrass protection and restoration	Acres of seagrass in the Tidal Peace River segment	Quality of seagrass	SWFWMD/CHNEP	CHNEP seagrass target (951 acres) for Tidal Peace River segment
Xeriscaping and native plant landscaping.	Percent of City responsible landscape in xeriscape	Percent of citizen responsible landscape in xeriscape	City of Punta Gorda	25% by 2025
Explicitly indicating in the comprehensive plan which areas will retain natural shorelines. Constraining locations for certain high risk infrastructure.	% natural shoreline	% natural shoreline restored	City of Punta Gorda	50%
	Amount of TDR transferred Out of Environmental Sensitive Locations	amount of high risk infrastructure remaining in the Tropical Storm and Category 1 Storm Surge Zones	City of Punta Gorda	No high risk infrastructure remaining in the Tropical Storm and Category 1 Storm Surge Zones
Restrict fertilizer use.	Nitrogen concentrations and loads in River and Harbor	Reduction in nitrogen levels and loads in City canals	SWFWMD, Charlotte County, FMRI	Reduction in nitrogen in River and Harbor to achieve non-impairment per TMDL
Promote green building alternatives through education, taxing incentives, green lending.	Number of green buildings constructed	Estimated change in energy use in dollars and by energy audit methods	City of Punta Gorda	25% increase for building, 25% decrease for energy use by 2025
Drought preparedness planning.	Number of planning steps completed.	Number of use water restriction events	City of Punta Gorda	completed and implemented plan

The vulnerabilities listed by the citizens, categorized into eight major areas of climate change vulnerability, are listed below in order of priority:

1. Fish and Wildlife Habitat Degradation
2. Inadequate Water Supply
3. Flooding
4. Unchecked or Unmanaged Growth
5. Water Quality Degradation
6. Education and Economy and Lack of Funds
7. Fire
8. Availability of Insurance

Over the past decade since the initial adoption of the climate adaptation plan, the City has undertaken actions outlined in the report to increase resilience for the City and its infrastructure. These actions include participating in collaborative public private partnerships, policy changes, and maintenance and acquisition of greenspace. Several of the adaptations recommended in the 2009 plan have been achieved or shown significant progress over the last decade:

- Sea grass acreage has increased from 247 acres to 391 acres (a 58% increase) which is 41% of the goal of 951 acres (reported by City staff in February 2019).
- On June 6, 2012, the City of Punta Gorda adopted a fertilizer ordinance stricter than the state standard and has been implementing and enforcing it. A decrease in both nitrogen and phosphorus in the Punta Gorda canal system has been recorded since the introduction of the fertilizer ordinance.
- Buyout of properties with recurrent storm flood damage and conversion of those areas to public space
- Relocation of the City's public works facility to a less flood prone area located inland
- Construction of the new Emergency Management Center and improvements to the local building codes to require higher ground floor elevations.
- Reconstruction of roads and sidewalks using pervious pavement

Other progress specific to coastal resilience and closely related to the 2009 plan's adaptation strategies are noted in the City's 2018 grant application for the Florida Resilient Coastlines Program as follows:

- Collective partnership with Coastal & Heartland National Estuary Partnership (formerly known as the Charlotte Harbor National Estuary Program, CHNEP), The Nature Conservancy (TNC), and others for creation of a pilot living shoreline project to restore oyster reef along the eastern portion of Trabue Park, as a public private partnership
- Reducing tidal flooding with upgrades to the City's stormwater management system, installing tidal flex valves in historic downtown
- Providing support to TNC for the creation of a Coastal Resilience Decision Support Tool
- Helping with the University of Florida Conservation Clinic on Sea Grant Sea Level Rise Outreach Project

A summary of the City's progress implementing the adaptations from the 2009 climate adaptation plan is illustrated in Table 2.3.

Table 2.3 Summary of Implementation Progress - 2009 Climate Adaptation Plan

Vulnerabilities	Adaptations	February 2019 Status
1. Fish and Wildlife Habitat Degradation	1. Seagrass protection and restoration	In Progress
2. Inadequate Water Supply	2. Xeriscaping and native plant landscaping	In Progress
3. Flooding	3. Explicitly indicating in the comprehensive plan which areas will retain natural shorelines	In Progress
4. Unchecked or Unmanaged Growth	4. Constraining locations for certain high risk infrastructure	In Progress
5. Water Quality Degradation	5. Restrict fertilizer use	Completed
6. Education and Economy and Lack of Funds	6. Promote green building alternatives through education, taxing incentives, green lending	In Progress
7. Fire	7. Drought preparedness planning	Not yet underway
8. Availability of Insurance	8. Implementation of the other adaptations, particularly 3 and 4	In Progress

In 2018, the City applied for NOAA's 2018-2019 Florida Resilient Coastlines: Resiliency Planning grant, administered by FDEP. The City received the formal executed grant award in January 2019 and contracted with Taylor Engineering, Inc. in February 2019 to conduct a vulnerability analysis for city-owned critical infrastructure and prepare an addendum to the 2009 Climate Adaptation Plan with a living shoreline element. All work performed as part of the Climate Plan Update was completed prior to grant expiration on June 30, 2019.

2.3 Legislative Basis for Climate Adaptation Planning

Interest in, and concerns about, climate change have been discussed within the scientific community for several decades. The evolution of that concern into more formal public policy and eventually legislation arguably can be traced to the United Nations (UN) and World Meteorological Organization (WMO) establishing the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC consists of a group of government selected scientists from around the world who assess currently available information about climate change from a variety of published sources. The IPCC does not carry out research nor does it monitor climate related data. The IPCC published its First Assessment Report (FAR) in 1990 and has published updated reports every 5 to 7 years since. By the third IPCC report in 2001, the emphasis had moved from scientific assessment to potential impacts of climate change and the necessity for adaptation strategies.

During this time the United States began to address climate change primarily through participation in international treaties and accords, and with legislation addressing various underlying climate factors such as greenhouse gas emissions. There is still no single, unified U.S. national policy for responding to the impacts of climate change. Various federal agencies have prepared and published individual agency guidance on sea level change and climate adaptation. For example, the National Oceanic and Atmospheric Administration (NOAA) recommendations for local government are summarized in *Adapting to Climate Change: A Planning Guide for State Coastal Managers* (NOAA 2010). Existing national legislation such as the National Flood Insurance Act of 1968 and the Coastal Zone Management Act of 1972 have not been amended to specifically address adaptation to climate change although grant programs administered under those Acts are now funding such state and local planning efforts.

According to the Florida Department of Environmental Protection, Florida Resilient Coastlines Program's Florida Adaptation Planning Guidebook (FDEP 2018), Florida's first organized adaptation planning effort was the Southeast Florida Climate Leadership Summit in 2009. The Florida legislature passed the Community Planning Act (CPA) in 2011. Although not required, local governments could identify and develop an Adaptation Action Area (AAA) to address the impacts of sea level rise and in doing so, qualify for grant assistance. In 2013 the Florida Department of Economic Opportunity (DEO) began a 5-year effort titled Community Resiliency Initiative: Planning for Adaptation to Sea Level Rise to examine the statewide framework and best practices for integrating climate adaptation into existing local and state-wide planning processes.

Experience and results from the initial group of local planning grants under this DEO effort led to passage of SB 1094 in 2015, which is informally known as the "Peril of Flood" statute. This law requires consideration of future flood risk from storm surge and sea level rise in local government comprehensive plans. Specifically, Florida Statute Section 163.3178(2)(f)1 now includes sea level rise as one of the causes of flood risk that must be addressed in the "...redevelopment principles, strategies, and engineering solutions" to reduce flood risk (Florida Legislature 2015).

The City of Punta Gorda is responding to these requirements and to the general public welfare through updates to the Coastal Management Element of its 2040 Comprehensive Plan. The Coastal Management Element's contents drive other Plan elements including Future Land Use, Conservation, Recreation and Open Space, Infrastructure and Transportation. Implementing policies and requirements contained in the City's Land Development Regulations (LDR) include provisions for Soil Conservation; Transfer of Development Rights; and, Flood Hazard Areas.

2.4 Sea Level Rise Trend in Punta Gorda

The sea level rise projections used to establish the City's vulnerability thresholds originate from two credible source documents, the IPCC's most recently published report (known as the Fifth Assessment Report, AR5) and the US Global Change Research Program (USGCRP) Fourth National Climate Assessment Report (NCA4) released in November 2018. The AR5 was published in 2013 with the IPCC's Sixth Assessment Report expected to be publicly available in 2021. The sea level rise projections in the IPCC AR5 are based on future projections of greenhouse gas quantities in Earth's atmosphere. The first NCA was published in 2000, the second NCA in 2009 and the third was released in 2014. The USGCRP consists of 13 federal agencies, with NOAA serving as the lead agency for the NCA4 report. The report is based on an assessment of the peer-reviewed scientific literature, with ongoing participation of scientists and federal and non-federal stakeholders. The global sea level trend data used in this analysis originates from the 2018 NCA4 report.

Figure 2.2 compares the global sea level trends to the local sea level trends in Southwest Florida. The local sea level trends originate from data collected at a local NOAA tidal gauge. The closest NOAA tidal gauge to Punta Gorda is located in Fort Myers at the City's Yacht Basin, on the Caloosahatchee River 0.25 miles east of the US 41 bridge. This tidal gauge provides a close approximation for Punta Gorda's water level trends due to its riverine location within a similar proximity to the Gulf of Mexico as downtown Punta Gorda. The Fort Myers gauge (Station ID NO: 8725520) has measured monthly mean water levels since 1965 and hourly water levels since 1969 (NOAA 2019). Stations with datasets longer than 40 years are preferred for calculating sea level trends, as seasonal variability and multi-decadal variability is reduced with a longer duration dataset.

Figure 2.2 shows the monthly mean water level in meters, referenced to the North American Vertical Datum of 1988 (NAVD88). The trendlines shown on the graphic for the Fort Myers data illustrate the sea level rise rates. The year 1992 shows a "tipping point" in the dataset, where both local and global sea level rise accelerated. The difference between the global and local sea level rise is due to changes in Earth's gravitational field and rotation from melting of land ice in the Antarctic, land subsidence, and changing wind and ocean circulations. Although the post-1992 local sea level rise rate is approximately 40% more than the global rate during the same time period, the local rate includes regional sea surface height (SSH) changes caused by interannual climatic variability such as El Niño (NOAA 2017). Other variations in local sea level can be caused by vertical land movement (VLM), either subsidence or uplift.

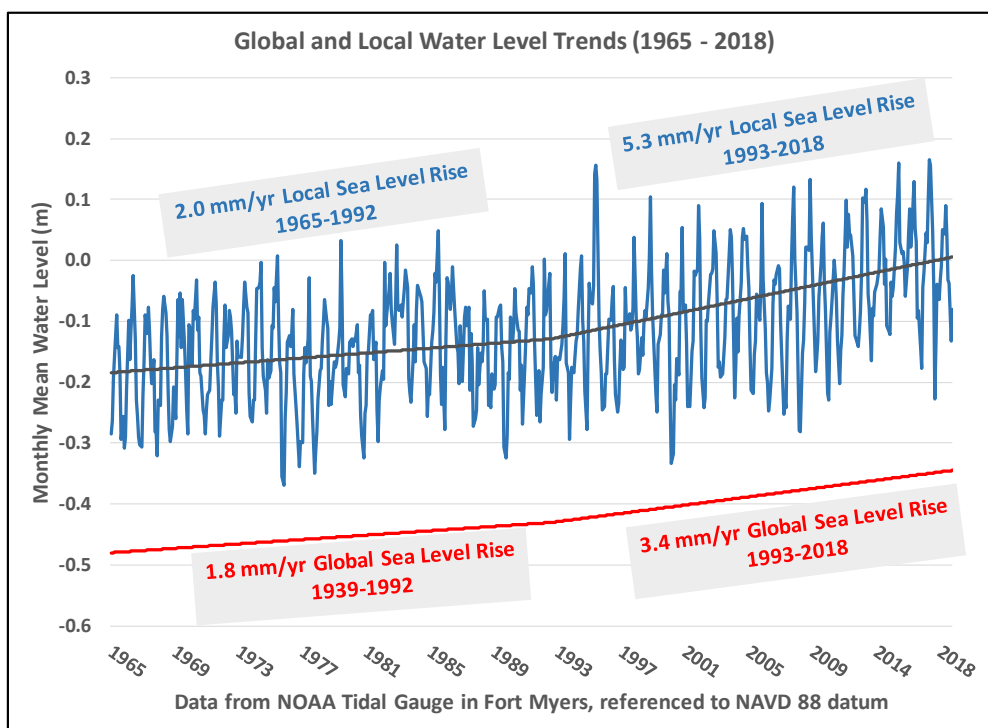


Figure 2.2 Global and Local Sea Level Trends in Southwest Florida

In Southwest Florida, VLM does not significantly affect local sea level rise as the subsidence trend is less than 1 inch per century (Houston 2019). The local sea level linear trend from 1965 to 2018 is 3.1 mm per year, which is equivalent to 1.02 ft over 100 years (NOAA 2019). The global sea level linear trend during this time period is also 3.1 mm per year (IPCC 2013). Due to the similarity in these trends, the IPCC and NCA4 projections are the best available future sea level projections to use for Punta Gorda.

The NCA4 report's sea level rise projections include six scenarios, created by NOAA: Low, Intermediate-Low, Intermediate, Intermediate-High, High, and Extreme. Figure 2.3 is a graphic from the 2018 USGCRP NCA4 showing the historic sea level trend, six sea level scenarios, and the IPCC AR5 sea level rise projections. Vertical bars on the right side of the graphic are from the 2013 IPCC AR5 report. These projections, called Representative Concentration Pathways (RCP), are future scenarios related to the concentration of carbon dioxide in the atmosphere. The AR5 report included four scenarios: RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5. The RCP numbers denote radiative forcing in units of Watt per m² of sunlight (IPCC 2013). Vertical lines above the RCP bars show a possible increase in Antarctic contribution due to new ice sheet data available in 2016 after the IPCC AR5 report was published (USGCRP 2018). The figure does not show RCP 6.0 because its sea level rise range is similar to RCP 4.5.

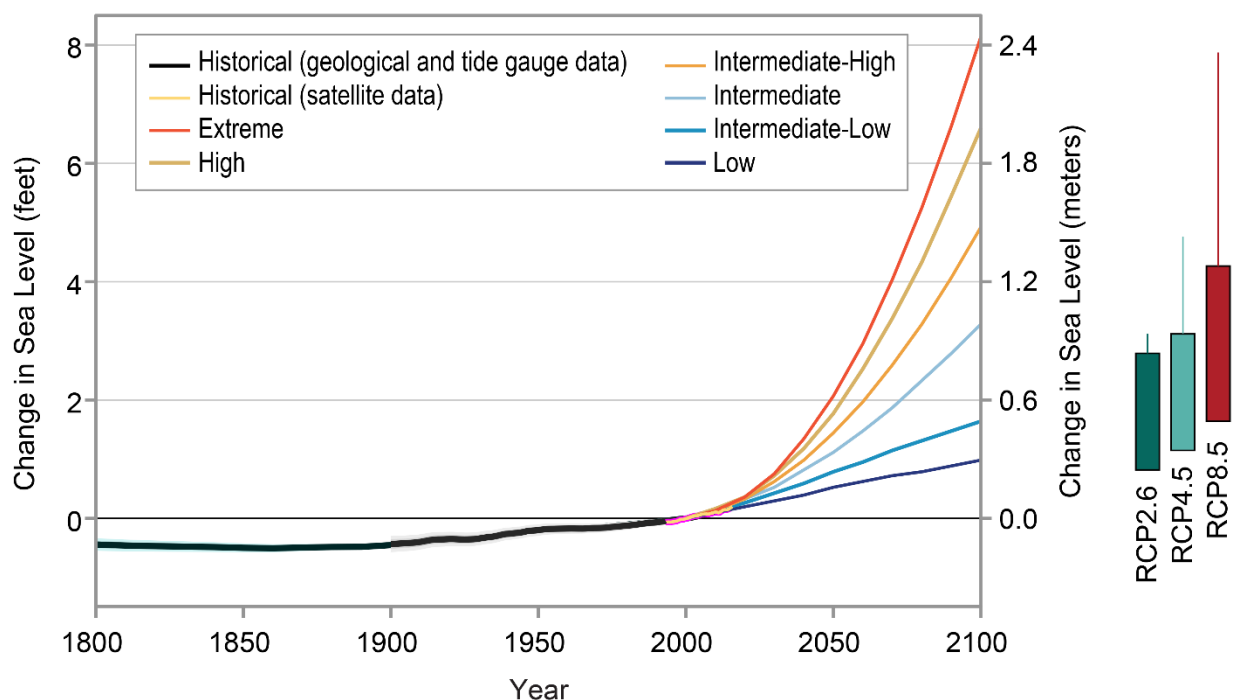


Figure 2.3 2013 IPCC and 2018 US National Climate Assessment Sea Level Projections and Historical Data (USGCRP 2018)

3.0 VULNERABILITY ASSESSMENT

In February 2019, the City contracted with Taylor Engineering to perform a vulnerability assessment of public infrastructure within City limits, with a focus on coastal flooding impacts to critical facilities and historic properties. The term ‘vulnerability’ is often interchangeable with ‘risk’ when measuring hazard impacts, however the NOAA definition of vulnerability is “The potential for loss of or harm/damage to exposed assets largely due to complex interactions among natural processes, land use decisions, and community resilience.” (FDEP 2018). The purpose of a vulnerability assessment is to help a municipality or community identify and prioritize which structural and social assets are likely to be impacted by future coastal flooding and sea level rise. Performance of a vulnerability assessment also forms the basis for complying with the “Peril of Flood” statute requirements as found in Section 163.3178(2)(f)(1-6), Florida Statutes. Using the best available sea level rise projections and flood inundation scenarios, Taylor Engineering evaluated the City’s vulnerability under 12 different flooding scenarios.

3.1 Methodology

This analysis uses a Geographic Information System (GIS)-based assessment of the City's public infrastructure with respect to sea level rise projections and tropical storm surge stillwater elevations (SWEL). The elevations of publicly owned buildings were compared to future sea level rise thresholds and storm surge inundation depths.

The City of Punta Gorda chose flooding thresholds for this vulnerability analysis of 1.5 ft and 3 ft sea level rise. These thresholds were chosen because the 1.5 ft rise will most likely occur within the time horizon of the City's 2040 Comprehensive Plan or a homeowner's 30-year mortgage, while the 3 ft sea level rise is more suitable for planning capital improvement projects with a 50-year design life. Figure 3.1 illustrates these thresholds relative to the global sea level rise scenarios discussed in Section 2.4. The zero ft horizontal line on the graphic coincides with the year 2000, which US federal agencies adopted as a benchmark for measuring sea level change (NOAA 2017). The Extreme scenario predicts 1.5 ft sea level rise by 2040 and 3 ft rise by 2060. The Intermediate-Low scenario predicts 1.5 ft of sea level rise by 2090 and 3 ft rise after 2100, beyond the range of this graphic (USGCRP 2018).

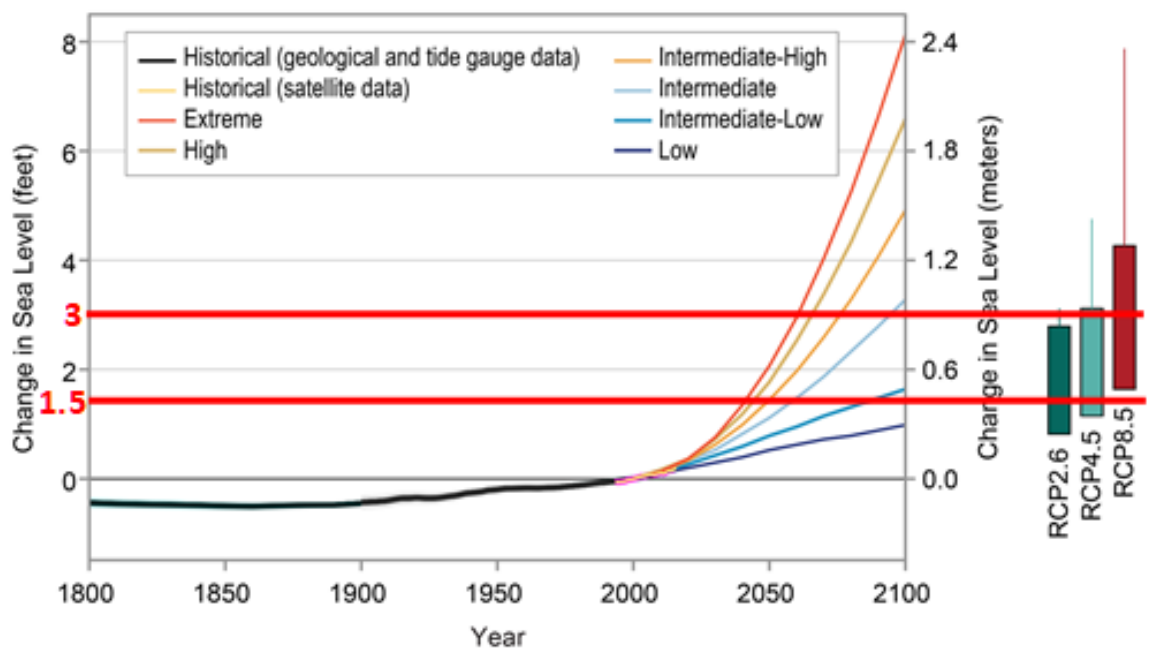


Figure 3.1 2013 IPCC and 2018 US National Climate Assessment Sea Level Projections and Historical Data

(Fourth National Climate Assessment, annotated to show Punta Gorda's thresholds of 1.5 ft and 3 ft)

For comparison of sea level scenarios, Table 3.1 summarizes the projections from the Charlotte County-Punta Gorda 2035 Long Range Transportation Plan, Punta Gorda's 2009 Climate Adaptation Plan, and the CHNEP Climate Change Vulnerability Assessment (2018). The Long-Range Transportation Plan also evaluated the 100 yr (1%) tropical storm surge inundation (Charlotte County-Punta Gorda Metropolitan Planning Organization 2010).

Table 3.1 Local Sea Level Rise Projections Comparison

Local Reference	SLR Scenarios in 2050	SLR Scenarios in 2100
	(inches)	(inches)
Charlotte County-Punta Gorda 2035 Long Range Transportation Plan	19.2	36
Punta Gorda's 2009 Climate Adaptation Plan	5 (90% probability)	10 (90% probability)
	9 (50% probability)	20 (50% probability)
	16 (5% probability)	36 (5% probability)
CHNEP 2018 Climate Change Vulnerability Assessment	9 (low)	15.72 (low)
	16.5 (intermediate)	45 (intermediate)
	35 (high)	99 (high)

All three plans look at sea level rise between 2000 and 2100. However, the 2009 Climate Adaptation Plan references statistical probabilities for each scenario (Beever, et al. 2009) whereas the CHNEP Climate Change Vulnerability Assessment report references low, intermediate, and high projection ranges. of 10 inches with 90% probability, 20 inches with a 50% probability, and 36 inches with 5% probability (Beever, et al. 2009). The 2009 plan also analyzed habitat and land use losses for seven different sea level rise scenarios. While there is some variability in the way the data is presented within each report, the range of sea level rise projections are aligned.

3.2 Datasets

To conduct a 'best practices' vulnerability assessment, the following data should be included: a) building location, b) first floor elevations (FFE), c) lowest adjacent grade elevations (LAG), d) replacement value, and e) year built. The year the structure was built helps to inform as to which building codes applied (e.g. pre- or post-Hurricane Charley). The replacement value is typically sourced from the County Property Appraiser's database; however, this information may not be accurate for all assets as some parcels are assigned a \$0 improved value, even though the parcel has buildings. One example of this was observed for the City's History Park.

To evaluate estimated damage and vulnerability, Taylor Engineering compared the projected elevation of various coastal flood scenarios to building's FFE to assess the risk exposure, sensitivity, and adaptive capacity of these assets. However, based on detailed review of the County Property Appraiser's and City-provided data, much of this information for publicly owned buildings was not available. The FFE and LAG was provided for twenty-two City-owned buildings; FFE data only for two other City properties was provided. The data from the elevation certificates provided by the City is summarized in Table A-1 in Appendix A. Approximate FFE's were collected for 13 additional buildings deemed critical for this assessment. The following datasets were available and provided information for our analysis:

- 2007 SWFWMD topographic LiDAR (3.8 ft horizontal & 0.6 ft vertical accuracy)
- ArcMap World Imagery basemap
- Google Earth Pro satellite imagery
- County Property Appraiser records
- County elevation certificates
- City elevation certificates
- City floodproofing certificates
- City flood location questionnaires
- City stormwater system locations
- National Register of Historic Places
- State Historic Preservation Office master site file of historic structures
- Taylor Engineering site measurements of building First Floor Elevations
- NOAA tide gauge, Fort Myers, water level observations, 1965-2018
- FEMA stillwater elevations from proposed Flood Insurance Rate Map Study

3.3 Assumptions

For many buildings in this study, the first-floor elevations were not available in the available data. Accurate first floor elevation for structures is a critical input to this vulnerability analysis. To fill in the data gaps, we performed a limited topographic assessment of the City- and County-owned buildings to obtain these first-floor elevations. This effort did not include Charlotte County school properties or Punta Gorda Housing Authority properties due to the large number of structures on each property. For these assets, we estimated first floor elevations based on the lowest adjacent grade. The building footprint outlines were compared with topographic data to determine the lowest adjacent grade that coincided with the building outline. With City staff approval, we assumed that first floor elevations were one foot above each building's lowest adjacent grade.

3.4 Asset Categories

This study sorted properties into three categories for analysis: general publicly owned, critical public facilities, and historic properties. The publicly owned properties were selected based on their ownership, as listed in the Charlotte County Property Appraiser's database. The properties in this category included the following ownership: City of Punta Gorda, CRA of City of Punta Gorda, Punta Gorda Housing Authority, Charlotte County, and Charlotte County School Board. The properties in the critical facilities category were listed in the 2015 Charlotte County Local Mitigation Strategy report as either County Essential Services or City Critical Facilities. The historic properties are those buildings either designated by the National Register of Historic Places or listed by the Florida State Historic Preservation Office as eligible for historic designation.

3.5 Workshop Input

To further refine the focus areas, a public workshop was held on April 5, 2019 to engage stakeholders and obtain feedback on perceived vulnerabilities and critical assets. During the workshop, participants were asked to review a list of ten vulnerable historic properties and ten publicly owned properties. These vulnerable assets were determined by comparing the first-floor elevation of each building with the associated parcel's flood inundation depth for each flood scenario. This preliminary list of vulnerable properties was prepared in advance of the workshop, then categorized into historic and publicly owned properties within City limits. The workshop attendees were asked to identify which properties on each list were most important to protect. They also added several "write-in candidates" of properties which were not listed, but that the participants felt were important to protect. The tallies of the participant's votes for the properties reviewed and added during the workshop are presented in Appendix D of this report. This feedback was used to refine the vulnerability analysis, develop focus areas, and subsequently identify appropriate adaptation strategies.

Following the public workshop, a separate charette was held with the CHNEP Technical Advisory Committee, providing the opportunity to collaborate with professionals within the Southwest Florida region.

3.6 Flood Scenarios Modeled

Once the critical infrastructure was identified, an exposure analysis was conducted. The exposure analysis considered 12 flood scenarios formed from combinations of three sea level rise scenarios and three storm surge flooding types. The flood scenarios are listed in Table 3.2 below.

Table 3.2 Flood Scenarios Used for City’s Vulnerability Analysis

#	Flood Scenario		
1	2019 water level (MHHW)		
2	1.5 ft sea level rise		
3	3 ft sea level rise		
4	2019 water level (NAVD88)	+	4% annual chance flood
5	2019 water level (NAVD88)	+	1% annual chance flood
6	2019 water level (NAVD88)	+	0.2% annual chance flood
7	1.5 ft sea level rise	+	4% annual chance flood
8	1.5 ft sea level rise	+	1% annual chance flood
9	1.5 ft sea level rise	+	0.2% annual chance flood
10	3 ft sea level rise	+	4% annual chance flood
11	3 ft sea level rise	+	1% annual chance flood
12	3 ft sea level rise	+	0.2% annual chance flood

The three sea level rise states were Mean Higher High Water (MHHW) to simulate a low inundation, 1.5 ft for medium inundation, and 3 ft for high inundation. The three tropical storm surge types analyzed were 25-year (4% annual chance) flood, 100-year (1% annual chance) flood, and 500-year (0.2% annual chance). Each sea level rise state was also analyzed with no storm surge flooding. The MHHW scenario, defined as “the average of the higher high water heights of each tidal day observed over the National Tidal Datum Epoch” represents today’s nuisance, chronic, or sunny day flooding, also called ‘king tides’ (NOAA 2019). The occurrence of nuisance flooding will continue to increase with sea level rise and can be further influenced by the tides and onshore winds.

3.7 Inundation Modeling

Inundation modeling was performed using a GIS-based vulnerability analysis, which compared the elevation of the various inundation scenarios using both a simple bathtub model and a modified bathtub model. A bathtub model simply identifies all areas under a target elevation as potentially flooded, regardless of hydrologic connectivity. The bathtub model was used for the 50-year (2% annual chance) flood shown for comparison of the four different SWEL flood boundaries (Figure A-19). The modified bathtub model, used for all other scenarios, applies a hydrologic connectivity filter to remove isolated inundated areas not connected to a major waterway. The City’s stormwater infrastructure GIS layer was used to inform these hydrologic connections in the model.

Several flood inundation scenarios were evaluated using SWEL data, created as part of a Flood Insurance Rate Map study. The SWEL represents the storm surge (not including waves or wave runup, defined as the maximum vertical extent of wave uprush above the still water level)

calculated using an ADvanced CIRCulation Model (ADCIRC computer model) analysis which runs hundreds of historic storms over a given topography and bathymetry. For this analysis, the 25-year (4% annual chance) flood, 100-year (1% annual chance) flood, and 500-year (0.2% annual chance) flood inundation scenarios were chosen and analyzed with and without sea level rise. The 1% and 0.2% annual chance floods were initially the only two SWEL datasets modeled and showed relatively little difference in the horizontal flood extent (Figures A-10 and A-13).

The 25-year (4% annual chance) scenario was added in order to achieve a more refined result for inclusion in the climate adaptation plan addendum (Figure A-7). Analysis of the water level data from the NOAA tidal gauge at Fort Myers showed no storm surge instances greater than a 23-year return period for the region (NOAA, 2019). A listing of the ten highest monthly water levels and associated return periods for the tide gauge is shown in Table 3.3. The storm surge caused by Hurricane Charley ranks sixth on the list, with an 11-year return period. Hurricane Donna does not appear on this list as the storm occurred in 1960, before the Fort Myers tide gauge began recording data in 1965.

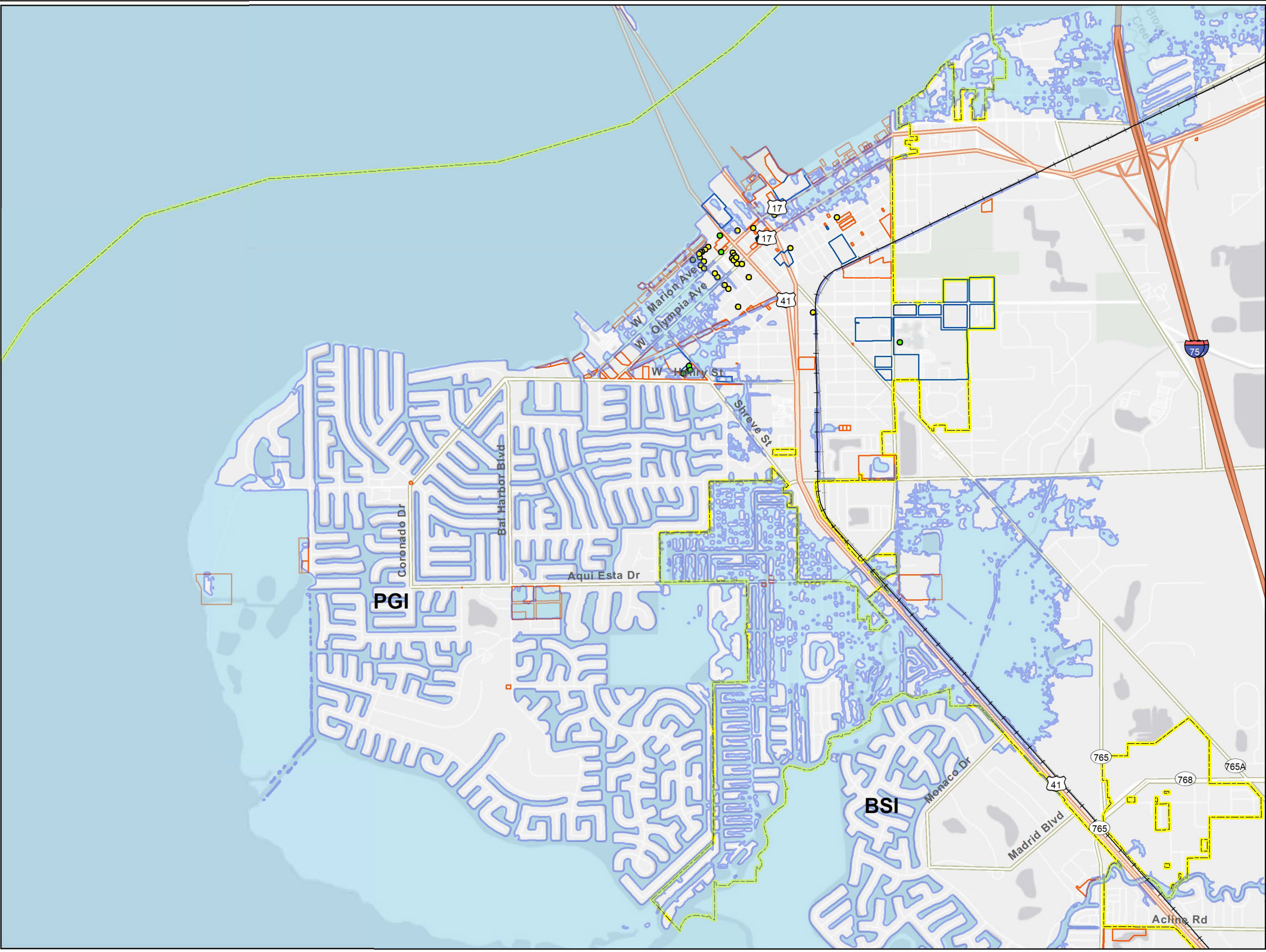
Table 3.3 Ten Highest Water Levels and Return Periods from Fort Myers Tide Gauge

Ran k	Year	Month	Water Level (ft NAVD)	Return Period (Yrs)
1	1988	11	3.68	23
2	2001	9	3.59	21
3	1982	6	3.58	21
4	1974	6	3.36	16
5	2017	9	3.32	16
6	2004	8	3.12	11
7	1985	8	3.05	10
8	1996	10	2.97	9
9	2004	9	2.96	9
10	2012	6	2.92	9

3.8 Results of Modeled Flood Scenarios

All twelve flood inundation scenarios can be viewed graphically as shown in the maps included in Appendix A. These maps illustrate the City's inundation during each flood scenario. Some scenarios, such as the 100 and 500-year SWEL, resulted in similar flooding extents and were therefore, not mapped. Notably, Figure 3.2 (an example of one of the maps shown in Appendix A) illustrates the extent of flood inundation within the city limits with 3 ft of sea level rise. Each of the flood scenarios shown in the Appendix is drawn in two versions, one similar to Figure 3.2 which shows the flooding within the city limits and one similar to Figure 3.3 which is zoomed in to the downtown area.

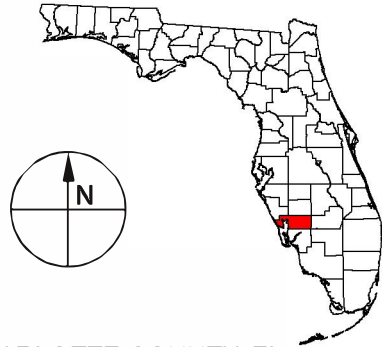
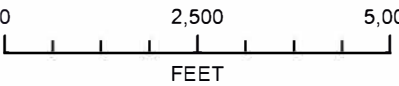
Disclaimer: This figure is not intended to show the exact location of flooding and does not account for all variables affecting future flooding, such as groundwater impacts, changing precipitation patterns, future construction, or erosion. As such, actual future flooding may differ from this graphic. This graphic should be used strictly as a planning reference tool and not for navigation, permitting, insurance rating, or other legal or regulatory purposes.



Taylor Engineering, Inc.
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Sarasota, FL 34236
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FIGURE 3.2
3 FT OF SEA LEVEL RISE IN
THE CITY OF PUNTA GORDA

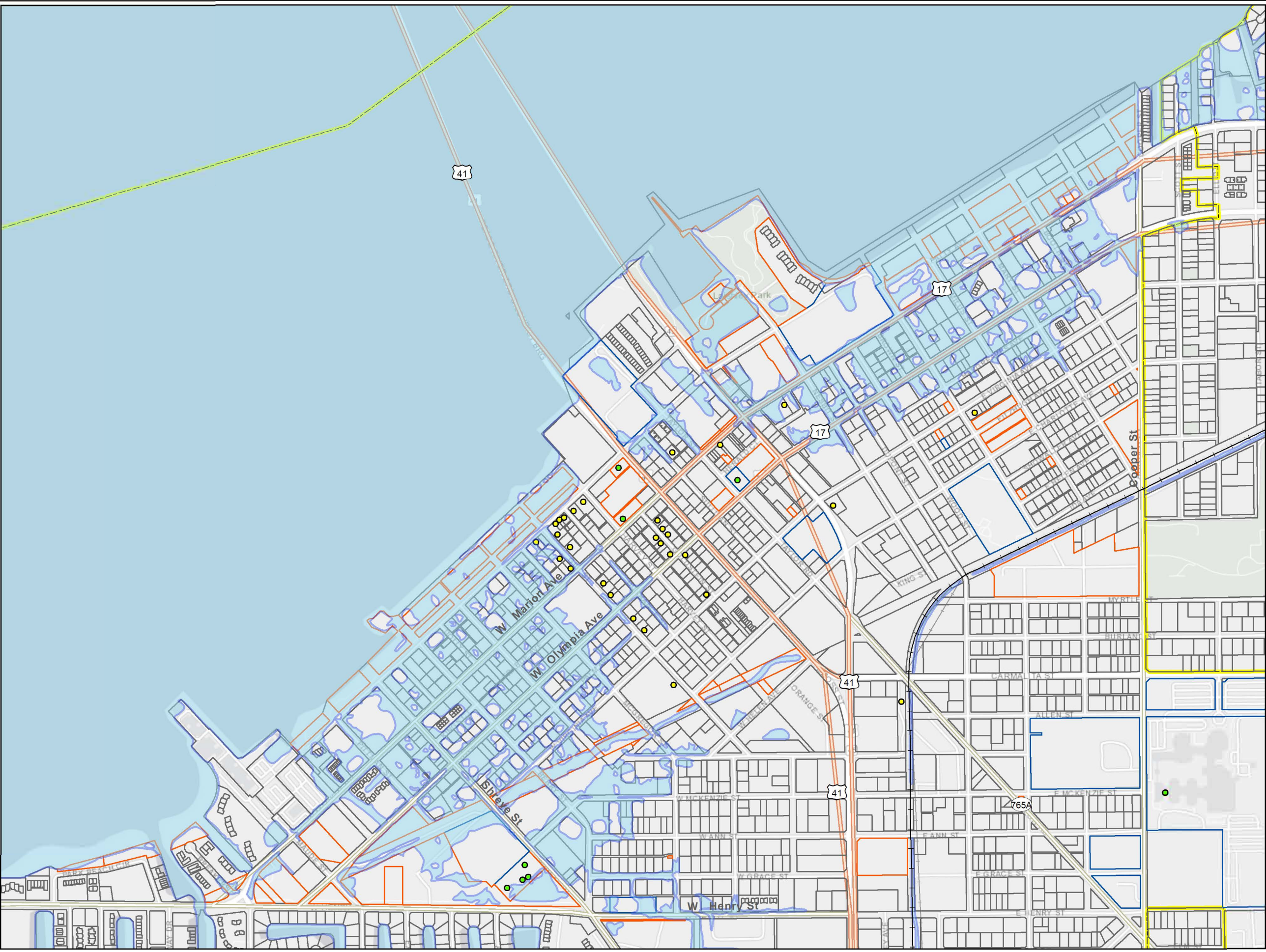
- 3 FT SLR
- Historic Buildings**
 - PRIVATE
 - PUBLIC
- Parcel Ownership**
 - Charlotte County
 - City of Punta Gorda
- Corporate Boundaries**
 - City of Punta Gorda

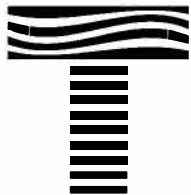


CHARLOTTE COUNTY, FL

Disclaimer: This figure is not intended to show the exact location of flooding and does not account for all variables affecting future flooding such as ground water impacts, changing precipitation patterns, future construction, or erosion. As such, actual future flooding may differ from this graphic. This graphic should be used strictly as a planning reference tool and not for navigation, permitting, insurance rating, or other legal or regulatory purposes.

Disclaimer: This figure is not intended to show the exact location of flooding and does not account for all variables affecting future flooding, such as groundwater impacts, changing precipitation patterns, future construction, or erosion. As such, actual future flooding may differ from this graphic. This graphic should be used strictly as a planning reference tool and not for navigation, permitting, insurance rating, or other legal or regulatory purposes.

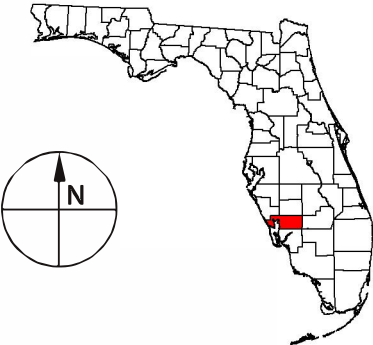
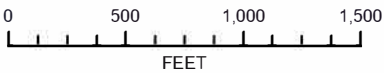




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FIGURE 3.3
3 FT OF SEA LEVEL RISE IN THE
CITY OF PUNTA GORDA

- 3 FT SEA LEVEL RISE
- Historic Buildings**PRIVATEPUBLIC
- Parcel Ownership**Charlotte CountyCity of Punta GordaNon Public
- Corporate Boundaries**City of Punta Gorda



CHARLOTTE COUNTY, FL

Disclaimer: This figure is not intended to show the exact location of flooding and does not account for all variables affecting future flooding such as ground water impacts, changing precipitation patterns, future construction, or erosion. As such, actual future flooding may differ from this graphic. This graphic should be used strictly as a planning reference tool and not for navigation, permitting, insurance rating, or other legal or regulatory purposes.

The 4% annual chance SWEL is the only SWEL scenario combined with the 1.5 ft and 3 ft sea level scenarios in Appendix A maps. The extent of flooding at the combined 4% annual chance SWEL with 1.5 ft of sea level rise shows 68% of publicly owned acreage flooded. Combining the 4% annual chance SWEL with 3 ft of sea level rise indicates 71% of these properties inundated. The maps for the remaining four scenarios in Appendix A include the combined SWEL and sea level rise scenarios, which are similar in magnitude and do not show much differentiation of flooding extent. A comparative plot illustrating the amount of flooding due to four different annual chance SWEL scenarios shows the slight variations in flood extent (Figure A-19).

Table 3.4 summarizes the percentage of publicly owned land which would potentially flood in each scenario. Public acreage for this analysis totals 860 acres, which includes publicly owned parcels in the city limits, as well as the Shell Creek Reservoir and the Punta Gorda Water Treatment Plant, both outside city limits. Total acreage in the City of Punta Gorda is approximately 65,000 acres.

Table 3.4 Percent of Public Property Flooded in the 12 Coastal Flooding Scenarios

Flood Scenario	Publicly Owned Acreage Flooded	% Of Publicly Owned Acreage Flooded
MHHW (Nuisance Flooding)	4.7 acres	1%
1.5' Sea Level Rise	151.3 acres	18%
3.0' Sea Level Rise	218.5 acres	25%
4% Annual Chance Flood	459.5 acres	53%
1.5 ft SLR + 4% Annual Chance	587.2 acres	68%
3 ft SLR + 4% Annual Chance	607.9 acres	71%
1% Annual Chance Flood	608.0 acres	71%
1.5 ft SLR + 1% Annual Chance	614.4 acres	71%
0.2% Annual Chance Flood	616.3 acres	72%
3 ft SLR + 1% Annual Chance	617.5 acres	72%
1.5 ft SLR + 0.2% Annual Chance	633.1 acres	74%
3 ft SLR + 0.2% Annual Chance	728.8 acres	85%

Tables A-2 and A-3 identify the critical facilities and historic properties flooded under each of the twelve scenarios in tabular format. Table A-4 shows the economic analysis of the City's critical facilities during the 1% annual chance flood, calculated by applying depth damage functions to known FFE's and building values. Figures A-1 through A-18 illustrate the inundation extent in graphical form.

4.0 ADAPTATION STRATEGIES

4.1 Range of Adaptation Strategies

Adaptation is defined by the IPCC as “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects” (IPCC 2013). Adaptation strategies can be classified by a variety of categories depending on the climate threat. A common classification for adaptation options for sea level rise, originated by the IPCC’s 1990 Coastal Zone Management Subgroup (CZMS), includes these three categories: (1) accommodate, (2) protect, and (3) (managed) retreat. This categorization of adaptation strategies is the worldwide standard still in use today (Haasnoot, et al. 2019). The 2009 City of Punta Gorda Adaptation Plan refers to these categories, but replaces “(managed) retreat” with “planned relocation” (Beever, et al. 2009). Further explanation of these adaptation classifications follows:

- 1) *Accommodate* – allows the land area to flood, reducing impacts to properties without impeding the environment’s natural systems. Examples are elevation of properties, wet floodproofing of structures, land-use planning, flood insurance, flood hazard mapping, and timely flood warnings to inform the public and encourage well-organized evacuations. An example of the accommodate strategy used by Punta Gorda is shown in Photograph 4.1.



Photograph 4.1 Wet Floodproofing (Accommodate Strategy) at Laishley Park

- 2) *Protect* – stops the land area from flooding up to a specified threshold, reducing impacts to properties while changing the environment’s natural systems. Examples are living shorelines, seawalls, beach and dune nourishment, and stormwater management.
- 3) *(Managed) Retreat / Planned Relocation* – permits the land area to flood, reducing impacts to citizens by removing them from the coastal flood zones. Examples are government buyouts of repetitive loss properties, rolling easements, removing critical

infrastructure from flood hazard zones, development controls, zoning changes, and land-use planning.



Photograph 4.2 Managed Retreat (Planned Relocation) of Historic Buildings

Communities can use a combination of these planned adaptation strategies to reduce the potential impacts caused by sea level rise. The three adaptation strategies listed above may be universal, however each adaptation method must be specifically tailored to the local focus area or individual property. There is no singular “one size fits all” method to adapt various communities or structures to sea level rise. The selection of an applicable and effective adaptation method requires assessment of multiple factors. These factors include time frame, scale of the response area, method of infrastructure, and type of adaptation.

There are two general time frames of response: (1) *proactive*, meaning to prepare, protect, and preserve prior to an event’s occurrence; and (2) *reactive*, which is restoring damage caused by an event. These time frames can be further categorized into long-term planning, intermediate-term planning, or short-term/immediate action. Often the availability of funding determines the time frame for adaptation. For example, post-disaster funding is available from the US government after a major disaster declaration via FEMA’s Hazard Mitigation Grant Program. This funding enables states and local governments to implement long-term hazard mitigation measures in the immediate aftermath of a disaster, which is not limited to flooding, but includes other natural hazards such as fires, tornadoes, and earthquakes. FEMA’s Pre-Disaster Mitigation Grant Program funds pre-planning prior to an event’s occurrence. These are two examples of funds available which may influence the time frame for adaptation planning.

The scale of the response area also determines the specific adaptation options considered. Adaptation methods range from *large-scale* (e.g., county or city) to *small-scale* (e.g., individual buildings or properties). Identification of a specific focus area is critical to narrowing the variety of adaptation strategies and choosing the most effective. For example, a large-scale flood protection option is the Thames Barrier in London, which can protect many properties from storm surge. A small-scale example is a flood barrier at the entrances of a building which can protect a single structure from flooding. Both examples employ “gray solutions,” which utilize hard engineered structures, typically built of concrete (hence the name “gray”).

The adaptation method chosen can range from *green* (e.g., natural or nature-based solutions which are built to mimic natural ecosystems) to *gray* (e.g., hard engineered structures) to *hybrid* (e.g., includes components from both green and gray methods). Examples of green infrastructure used to stabilize an eroding shoreline include beach and dune nourishment, artificial reef placement, seagrass restoration, and dune plantings. Gray infrastructure examples include seawalls, bulkheads, and stormwater drainage systems. Hybrid infrastructure examples for shoreline protection include seawalls paired with artificial reef materials at the base, living shorelines coupled with stone sills, and stormwater drains surrounded by mangrove plantings. Considerations for selection of hybrid shoreline protection include the amount of wave energy, desired environmental effects, ease of permitting, adjacent land use, and available funding. Photograph 4.3 shows the green protection strategy of a living shoreline.



Photograph 4.3 Living Shoreline in Punta Gorda

Another way to classify adaptation strategies is to group them into their specific applications: policies, emergency response, economic planning and assessment, infrastructure management, identification and monitoring, public awareness and education. Each category is outlined below with relevant examples derived from the Center for Climate Strategies Adaptation Guidebook (CCS 2011), FEMA’s Protecting Building Utility Systems From Flood Damage (FEMA 2017), US

Environmental Protection Agency (EPA) Climate Change Adaptation Plan (EPA 2014), and the Climate Adaptation App (Bosch Slabbers 2019).

1. **Policy** strategies include laws and regulations for efficient planning, as well as restrictions and permitting to account for climate change and its effects.

- a. *Planning*

- i. Implement a Special Area Management Plan (SAMP) to protect significant natural resources, life and property in coastal areas.
 - ii. Identify Adaptation Action Area (AAA) designations in local government's comprehensive plans within specific flood prone areas for the purpose of funding prioritization.
 - iii. Change the zoning for sensitive or hazard/flood prone areas.
 - iv. Limit current and future land use based on flood zones.
 - v. Establish site development setbacks or rolling easements.
 - vi. Provide guidelines for effective response to climate impacts.
 - vii. Require or enable metropolitan planning organizations to take climate change into account.
 - viii. Review transportation stability and durability regarding climate change.
 - ix. Implement coastal resource actions for adapting to more frequent severe storms and sea level rise.
 - x. Add climate change considerations to taxation and budget reform.

- b. *Restrictions*

- i. Prevent new construction in vulnerable zones.
 - ii. Enforce or institute building codes in flood and erosion prone areas.
 - iii. Prohibit hard structures along the shoreline.
 - iv. Minimize the extent of impervious surfaces.

- c. *Permitting*

- i. Refine permitting to include climate change effects.

2. **Emergency** strategies are intended for during or immediately after an event.

- a. *Public Awareness*

- i. Provide educational programs on appropriate behavior prior to and following extreme events.

- b. *Planning*

- i. Review the goals, strategies and plans of emergency preparedness, response and recovery under conditions induced by climate-related disruptions.
 - ii. Recommend or require standby power generators for the most critical infrastructure in case of extended public power outages. Verify that all hospitals and vital infrastructure are prepared.

c. Temporary Structures

- i. Use of sandbags to protect structures or system components.
- ii. Purchase flood barriers which can be assembled, moved into place, anchored, and filled with water, sand or gravel to provide self-supportive protection. An example of this type of protective flood barrier is shown in Photograph 4.4.



Photograph 4.4 Temporary Flood Barrier Protecting Building Entryway

- iii. Use plastic or other synthetic waterproof sheeting material to seal buildings and prevent water intrusion. This is known as a flood wrapping system.
- 3. Economic planning and assessment** strategies allow for understanding of the community's financial responses to impacts on water dependent industries and businesses.

a. Assessment & Planning

- i. Buyout properties in vulnerable areas to ensure no future development and risk is created.
- ii. Promote hazard insurance for homeowners and businesses.
- iii. Create economic incentives for individuals and businesses to reduce risk of losses through building design codes and support development in non-risk zones.
- iv. Add climate change considerations to taxation and budget reform.
- v. Seek federal funds for climate change costs.
- vi. Establish short-, mid-, and long-term budgets that include adaptation strategies and capital investments over time.

4. **Infrastructure** adaptation strategies include options to prepare, protect, and restore building structures, transportation, stormwater management systems and drainage, land development, and provide proper planning.

a. Structures

- i. Construct flood walls to protect individual buildings/facilities.
- ii. Build dikes, which are elongated artificially constructed embankments or levees protecting low-lying areas against higher water levels.
- iii. Create flood shelters in areas which experience severe flash flooding.
- iv. Use new and existing buildings in flood risk areas as flood defense barriers, if completely integrated in the flood defense system.

b. Transportation

- i. Raise curbs and create hollow roads in order to increase the storage and transport capacity of a road so that stormwater runoff does not flow into the surrounding buildings or neighborhoods.
- ii. Identify and reevaluate use of transportation routes in floodplains and coastal hazard zones.
- iii. Establish a Climate Change and Public Infrastructure Task Force.
- iv. Develop joint transportation strategies with adjacent communities, regions, and states to accommodate changing conditions and transportation system uses.
- v. Reduce impervious surfaces like roofs, roads, and parking lots so more water can infiltrate the soil and extra green space is created.
- vi. Construct/raise evacuation routes above the highest expected flood levels.

c. Land Development

- i. Create a bypass for a river or canal to reduce flood levels by providing extra discharge capacity.
- ii. Install additional ditches or swales to increase drainage in low-lying areas.
- iii. Improve the soil infiltration capacity by increasing the permeability of the soil.
- iv. Review land use plans in anticipation of changing development pressures and shifts in development patterns due to climate change.
- v. Reduce loss of wetlands due to hardening of estuarine shorelines.
- vi. Reduce or eliminate ocean, river, or bay outfalls.
- vii. Use beach nourishment to protect infrastructure in coastal areas.

d. Stormwater Management System/Drainage

- i. Add pumping stations to discharge water out of an area and increase pump capacities to better control the water table.
- ii. Incorporate storage and settling tanks to store excess runoff in urban drainage systems during wet periods, primarily if runoff exceeds the discharge capacity of the urban drainage system. The photograph to the

right illustrates an example of underground storage tanks used to store excess stormwater.



Photograph 4.5 Storage Tanks for Excess Runoff
(www.conteches.com)

- iii. If a combined sewer system, collecting rainwater and wastewater in one, is being used, reconstruction of separate systems can create additional capacity in storm events.
- iv. Capture runoff from a building's roof to increase local water storage. The runoff can be collected in a stormwater containment pit, small dams within small channels, or large areas can be designated as flood areas to store excess discharge.
- v. Utilize a rainwater tank (or rain barrel) to collect and store water runoff from roofs and rain gutters for irrigation of landscaping.

e. Infrastructure Planning

- i. Review construction standards for piers and seawalls for resilience to wave energy, storm surge (including negative surge), and future sea level rise.
- ii. Verify urban house stock, including multi-family homes and public housing units, are resilient to likely climate change effects.
- iii. Increase maintenance and cleaning of gutters, drainage ditches, and culverts, such as the example in Photograph 4.6.
- iv. Incorporate modifications to communications infrastructure to increase resiliency during routine maintenance and upgrades.
- v. Ensure communications infrastructure is accessible for repair and re-activation in the event of a climate related disaster.
- vi. Assess the vulnerability of special designation areas, areas of unique flora and fauna, and areas of essential ecosystem goods and services.

- Support healthy rivers, streams and vegetation to maintain water quality.
- vii. Increase environmental quality standards to enhance resilience of natural water systems.
- viii. Develop morphodynamic and ecological response models of primary coastal zones according to different climate scenarios.
- ix. Conduct coastal re-alignment planning conversion of land to salt marsh and grassland to provide sustainable sea defenses.



Photograph 4.6 Drainage Culvert along Punta Gorda's HarborWalk

5. Identification of key infrastructure and vulnerable areas provide the ability to manage the risks prior to failure. **Monitoring** of changes in sea level rise and storm surge allow for early warning systems and ensure adequate response/evacuation plans.

a. Mapping

- i. Identify and map key communications infrastructure (networks or points of production or distribution) that may be affected by climate change impacts.
- ii. Identify and map key energy infrastructure (networks, pipelines, power lines or points of production or distribution) that may be affected by climate change impacts.
- iii. Inventory and map the estuarine and ocean shoreline and its bathymetry, sediments, and vegetation.

b. *Public Awareness*

- i. Ensure accurate information reaches residents and tourists on behaviors and uses that ensure environmental quality and ecosystem resiliency.
- ii. Identify and engage representatives of key business areas potentially vulnerable to specific climate change effects.

c. *Monitoring*

- i. Initiate surveillance and monitoring of sea level rise related to storm surge early warning systems and ensure adequate response/evacuation plans.
- ii. Establish a series of permanent monitoring stations to continuously measure the absolute changes in sea level rise in coastal areas and characterize the dynamics of estuarine storm surges, astronomical tides and water flow.
- iii. Conduct a shoreline impact assessment to establish baseline data on the existing coastal resources and the projected impacts of sea level rise, including tides and weather.

d. *Planned Relocation*

- i. Survey vulnerable current inhabited areas. Develop relocation plans and contingency measures in the event of emergencies.
- ii. Develop strategies to address situations of changing ingress/egress routes to properties as support for access roads in areas vulnerable to sea level rise and associated hazards is withdrawn.
- iii. Investigate potential and limitations of eminent domain, vesting, grandfathering, and amortizing strategies to support relocation activities. The A.C. Freeman house is a local example of a historic structure which has been subject to Planned Relocation, with several moves in the building's history.
- iv. Create a rolling easement program, where practical.

Early identification, planning, and action increase a community's resilience to climate induced disasters. New construction and community planning can be designed with flood damage prevention in mind. A more comprehensive list of a variety of adaptation options is presented in Appendix B.

4.2 Focus Areas for Adaptation

As defined by the Florida Adaptation Guidebook, focus areas are the selected locations which “will receive a majority of the adaptation strategy attention” (FDEP 2018). The inputs from the April 2019 public workshop helped to inform this selection, by prioritizing which vulnerable facilities were important to the citizens who attended. Workshop participants ranked a pre-determined list of publicly owned facilities and historic buildings vulnerable to flood hazards. These citizens also contributed to the list of important critical facilities included in the focus areas. A summary of the public workshop and its results is in Appendix D.

The following criteria were used to identify focus areas within the City of Punta Gorda:

- Parcel inundation at 3 ft of sea level rise
- Ratio of flooded acreage to non-flooded acreage at 3 ft of sea level rise
- Number of publicly owned parcels (prioritized in public workshop) inundated
- Number of critical facilities (identified in public workshop) inundated
- Number of historic properties (prioritized in public workshop) inundated

These criteria were evaluated qualitatively, with analysis of the 3 ft sea level rise scenario (Figure 3.2) yielding three distinct Adaptation Focus Areas for further investigation and narrowing of adaptation strategies for the City of Punta Gorda. These three regions are the Downtown Focus Area, the Fire Station Focus Area, and the US 41 Commercial Focus Area (Figure 4.1). It is important to note that some critical facilities may not be included in focus areas but may be of importance in future City planning. One example is the Punta Gorda water treatment plant and the Shell Creek Reservoir.



Figure 4.1 Overview of Adaptation Focus Areas

The Downtown Focus Area, shown in Figure 4.2, borders the confluence of the Peace River with Charlotte Harbor and encompasses 423 total acres with approximately 226 acres (54%) being inundated by 3 feet of sea level rise. This focus area includes the downtown core of outdoor cafes, restaurants, art galleries, shops, and hotels, all of which are essential to the City's economy. Citizens and tourists are drawn to features like Fisherman's Village, the Harborwalk, Linear Park, Charlotte Harbor Event and Conference Center, and Laishley Park Municipal Marina.



Figure 4.2 Close-up of the Downtown Adaptation Focus Area

The eastern portion of the Downtown Focus Area proves vital to the citizens of Punta Gorda due to the concentration of medical services located here, anchored by the Bayfront Health Hospital. The hospital is the critical facility within City limits which was prioritized highest by the public workshop participants. This area also contains corridors for US Route 41 and US Route 17 that serve as major thoroughfares and emergency evacuation routes. Florida Department of Transportation (FDOT) maintains both roads.

In the western part of the Downtown Focus Area exists a high concentration of historically designated buildings both publicly and privately owned. A portion of this region is designated as a historic district by the National Register of Historic Places. In addition to the area's historic assets, this area contains a high concentration of publicly owned parcels and provides access to US 41.

The Fire Station Focus Area presented in Figure 4.3 is the second and smallest focus area. It is located in the center of the Punta Gorda Isles neighborhood, on Aquí Esta Drive. The district name is derived from Punta Gorda's Fire Department Station Number 3, which is the primary structure located within this area. A City-owned nature park and water tower comprise the remaining area, with a canal located along the eastern border. All of the property in this focus area is owned by the City. Vulnerability analysis shows that of the 26 acres within this focus area, 21 acres (nearly 81%) would be inundated at 3 feet of sea level rise.



Figure 4.3 Close-up of the Fire Station Adaptation Focus Area

The US 41 Commercial Focus Area presented in Figure 4.4 is the third and final focus area. It is located between US 41 and a section of canal neighborhoods along the City's border. This focus area totals 41 acres of private land with 35 acres (75%) inundated at 3 feet of sea level rise. There is no publicly owned property or critical facilities located within this area, however it borders a critical evacuation route and CSX-owned railroad line. This area was chosen as an adaptation focus area due to its high ratio of flooded to non-flooded property at 3 ft of sea level rise.

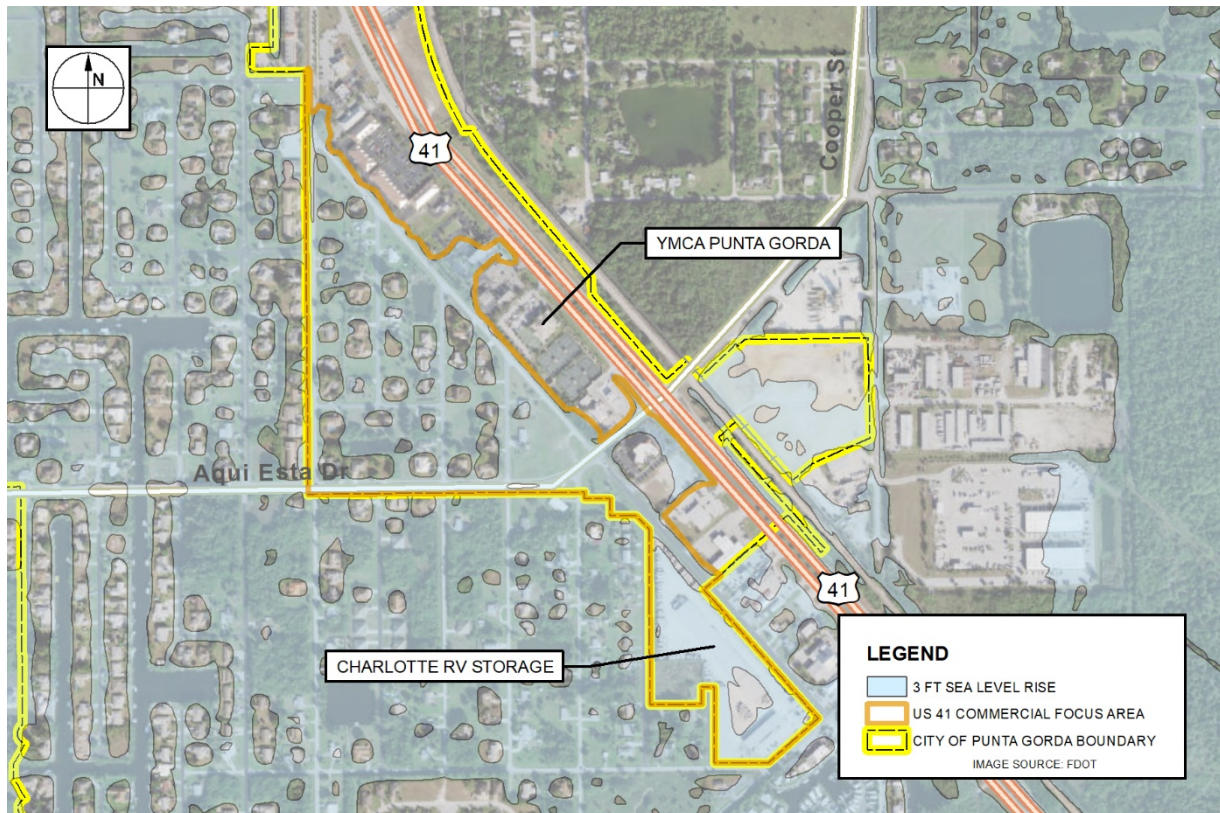


Figure 4.4 Close-up of US 41 Commercial Adaptation Focus Area

Table 4.1 presents a summary of the numbers of essential facilities and historic buildings within each of the Focus Areas. The highest concentration of critical infrastructure is located within the Downtown Focus Area, and most concentrated in the southern portion of this region. The table also highlights the total acreage in each area and the percent of acreage which is inundated at 3 feet of sea level rise. The high percentage of flooding in the Fire Station and US 41 Commercial Focus Areas shows the importance of selecting these regions as adaptation focus areas.

Table 4.1 Summary of Adaptation Focus Area Vulnerabilities at 3 ft of Sea Level Rise

Focus Area	Essential Infrastructure	Historic Buildings	Publicly Owned Parcels	Total Acres	Acres Inundated	Percent Flooded
Downtown	3	10	86	423	226	54%
Fire Station	1	0	6	26	21	81%
Commercial	0	0	0	47	35	75%

4.3 Current Adaptation Strategies Implemented

The City of Punta Gorda, due to its proximity to the Gulf of Mexico, Charlotte Harbor, and the Peace River, is exposed to potential flood hazards from storm induced surge, rain events, and extreme tides, all of which are exacerbated by sea level rise. Because the City has experienced these flood hazards before, many adaptation strategies are already in place and well-functioning. Keeping the City resilient to future climate change requires affirming these current strategies and expanding on them. In order to inspire the continuation and development of innovative strategies, the City's current adaptations are discussed below.

As outlined in the Center for Climate Strategies Adaptation Guidebook, mapping vulnerable areas and developing buyouts for these lands is a central adaptation strategy (CCS 2011). The City has embraced this concept, beginning with its founder, Colonel Isaac Trabue, who required that all waterfront blocks remain undeveloped for City parks. By designating much of the waterfront and low-lying flood prone areas as park lands, Colonel Trabue laid the groundwork for a resilient city. An example of this historic concept is the City's acquisition of the Punta Gorda Nature Park (Figure 4.5). This publicly owned space that is vulnerable to flooding has been allowed to stay primarily in its natural state instead of developed into residential properties, as originally planned in the mid-twentieth century. Ponce De Leon Park, Trabue Park, Laishley Park, Alice Park, Shreve Park, Pittman Park, and Gilchrist Park are other parks that act as a buffer for the City from the waters of the Peace River.

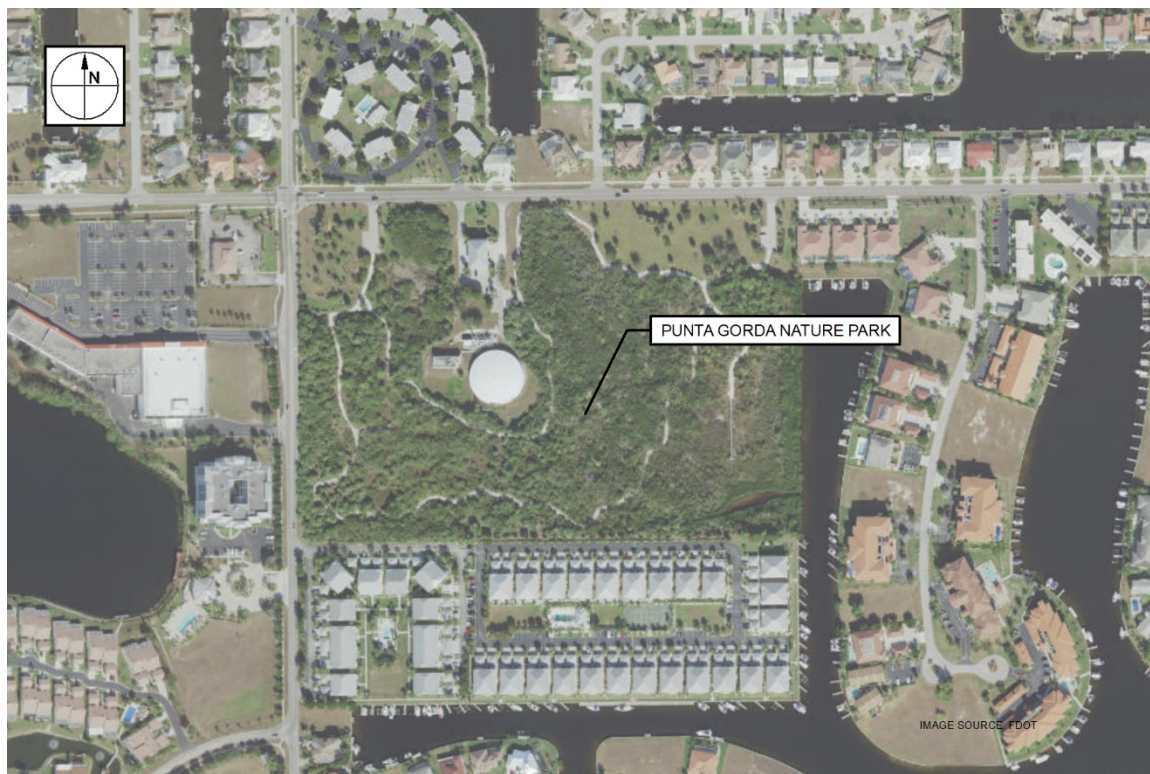


Figure 4.5 Punta Gorda Nature Park

In addition to City managed parks, Charlotte Harbor Preserve State Park (Figure 4.6) hugs the perimeter of the City of Punta Gorda's southwest border. This 45,387 acre Florida State Park protects more than 100 miles of shoreline along Charlotte Harbor in Charlotte and Lee Counties (FDEP 2019). This natural wetland barrier is the City's first defense against dynamic wave action, rising waters, and storm surge. Often referred to as "nature's kidneys," tidal marshes such as this park, filter large quantities of water, trapping sediments and pollutants. Natural shorelines are often augmented by manmade living shorelines to further protect against erosion.



Figure 4.6 Charlotte Harbor Preserve State Park

Living shoreline is a term used to define a variety of shoreline protection alternatives that allow for natural coastal processes with the strategic placement of plants, stone, fill, and other structural and organic materials. Living shorelines use native plants, sometimes supplemented with stone sills, offshore breakwaters, groins or biologs to reduce erosion, trap sediment, and filter runoff, while maintaining (or increasing) wetland habitat. Unlike traditional erosion control structures, such as bulkheads or seawalls that focus on deflecting wave energy away from a site and may increase erosion, living shorelines reduce energy and permit natural processes that maintain the health of the broader coastal system. Living shorelines act similar to natural shorelines, reducing wave energy, temporarily storing flood waters, increasing dissolved oxygen levels, and filtering pollutants and sediments which improves water quality. Appendix C provides technical guidance for living shorelines in Punta Gorda.

Currently, the City of Punta Gorda has numerous living shorelines. One example is juvenile “volunteer” mangroves transforming a ‘grey’ strategy into a green one along the Harborwalk (Photograph 4.7).



Photograph 4.7 “Volunteer” mangroves at Harborwalk

The mangroves are called “volunteers” because they grew on their own from seeds that were not planted by people. The City has also implemented living shorelines in the form of oyster beds offshore of Trabue Park and the Harborwalk. These bedded oysters provide protection for the shoreline and enhance water quality, while also creating habitat and recruiting other species (Photograph 4.8). These reefs were installed by volunteers led by the Coastal & Heartland National Estuary Partnership, formerly Charlotte Harbor National Estuary Program (CHNEP), as a community resilience initiative. A living shoreline project is planned to augment the hardened waterfront at the Four Points by Sheraton property, which is located between the northbound and southbound US 41 bridges. This project, the first of its kind in Punta Gorda, is the outcome of a public-private partnership formed in 2017 between the City and various entities.



Photograph 4.8 Artificial Oyster Reefs Implemented by CHNEP

“Sunny day” or “nuisance” flooding is caused when stormwater drains backflow from a combination of high tide, onshore winds, and sea level rise. A short-term solution to combat this type of flooding is to install check valves at the outfalls of stormwater pipes (Photograph 4.9).



Photograph 4.9 Stormwater Check Valve for Backflow Prevention

These check valves prevent backflow caused by tidal waters, allowing stormwater to flow out when enough line pressure exists in the discharge pipe. As of May 2019, the City of Punta Gorda has installed ten “duckbill-type” check valves at Chasteen Street South, Berry Street South, West Retta Esplanade, Berry Street North, Dolly Street, Chasteen Street North, McGregor Street, Nesbit Street, Milus Street, and M.L. King (Figure 4.7).

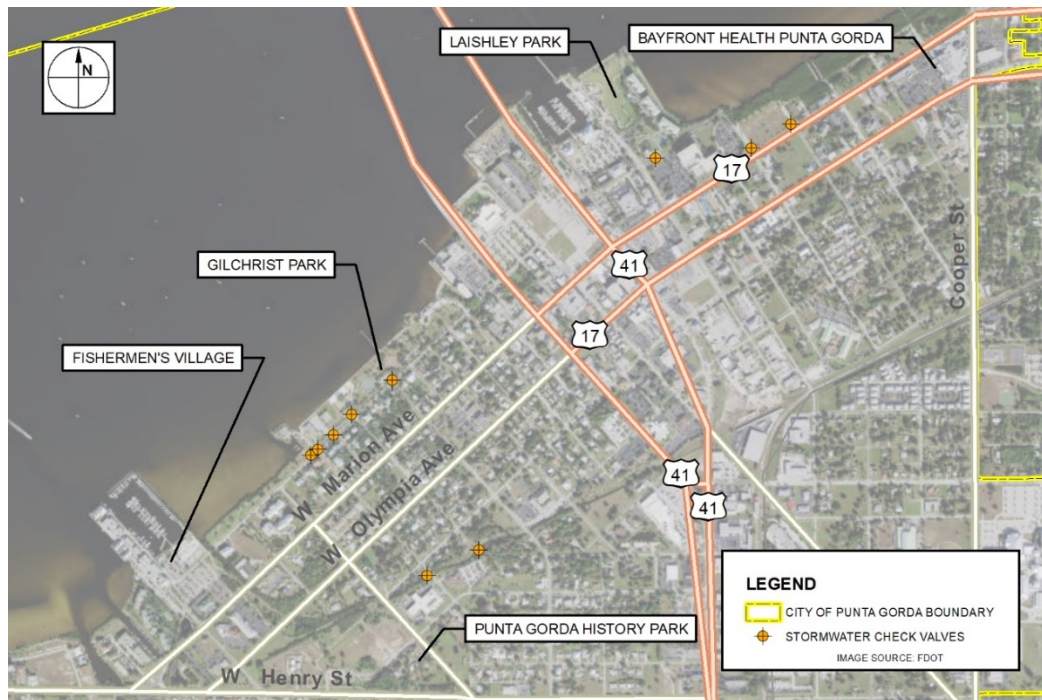


Figure 4.7 City of Punta Gorda Stormwater Check Valve Locations

Site and building specific adaptation strategies are already implemented at many publicly owned buildings within the City of Punta Gorda, as well as in the Historic District. Simply elevating critical electrical and mechanical elements of vulnerable buildings can be a cost-effective way to avoid damage caused by flooding as seen in Photograph 4.10. If possible, the entire structure can be elevated above the flood levels expected at future sea level rise scenarios. Many of the historic homes in the City use this adaptation strategy.



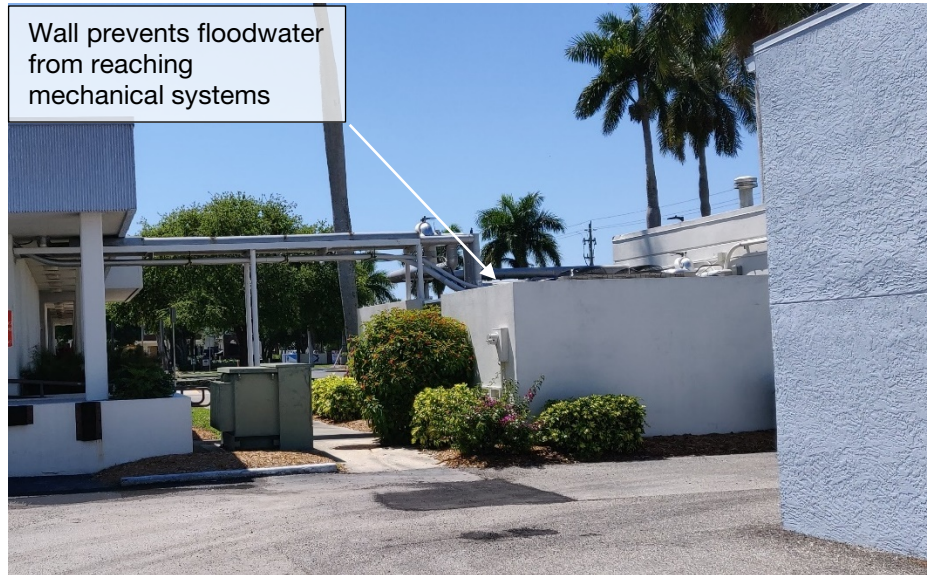
Photograph 4.10 Elevation of Backup Generator at Historic Charlotte County Courthouse

A relatively low-cost option to retrofit an existing structure to withstand flood damage is wet floodproofing. In this alternative, the crawlspace, basement, or attached garage of a building is adapted to allow water to flow into it, flooding the structure as the water rises. An advantage of this option is that the building does not sustain extensive structural damage since the hydrostatic pressure of the water pushing on the building's exterior walls is equalized by the water pressure inside the building. This method also prevents a house from becoming buoyant and floating off its foundation. Many of the low-lying public restrooms situated along the waterfront in the City of Punta Gorda were built with this adaptation measure (Photograph 4.11).



Photograph 4.11 Flood Vents for Wet Floodproofing at Gilchrist Park

Another relatively cost-effective measure to prevent flood damage is dry floodproofing where the building is sealed to prevent water from entering. The only type of construction that can be used in dry floodproofing is masonry. Dry floodproofing may only be used for retrofitting structures which are on a concrete slab or have a crawlspace. It is not recommended in a beachfront area which is subject to excessive wind and wave forces due to hurricanes. It is also not recommended in an area which is subject to flash flooding or moderate to fast velocity flooding. An example of dry floodproofing is shown in Photograph 4.12.



Photograph 4.12 Dry Floodproofed Mechanical Systems at County Tax Collector's Office

4.4 Recommended Strategies for Focus Areas

Specific recommended adaptation strategies are provided for each of the Adaptation Focus Areas defined in Section 4.2. The strategies discussed here refer to those listed in Appendix B and Section 4.1.

4.4.1 *Downtown Focus Area*

The Punta Gorda Downtown Focus Area is the largest of the three focus areas and contains the most critical facilities, most historically significant buildings, and largest number of publicly owned parcels compared to the other focus areas. In addition, this area contains both US 41 and US 17, which provide important emergency evacuation routes for the City.

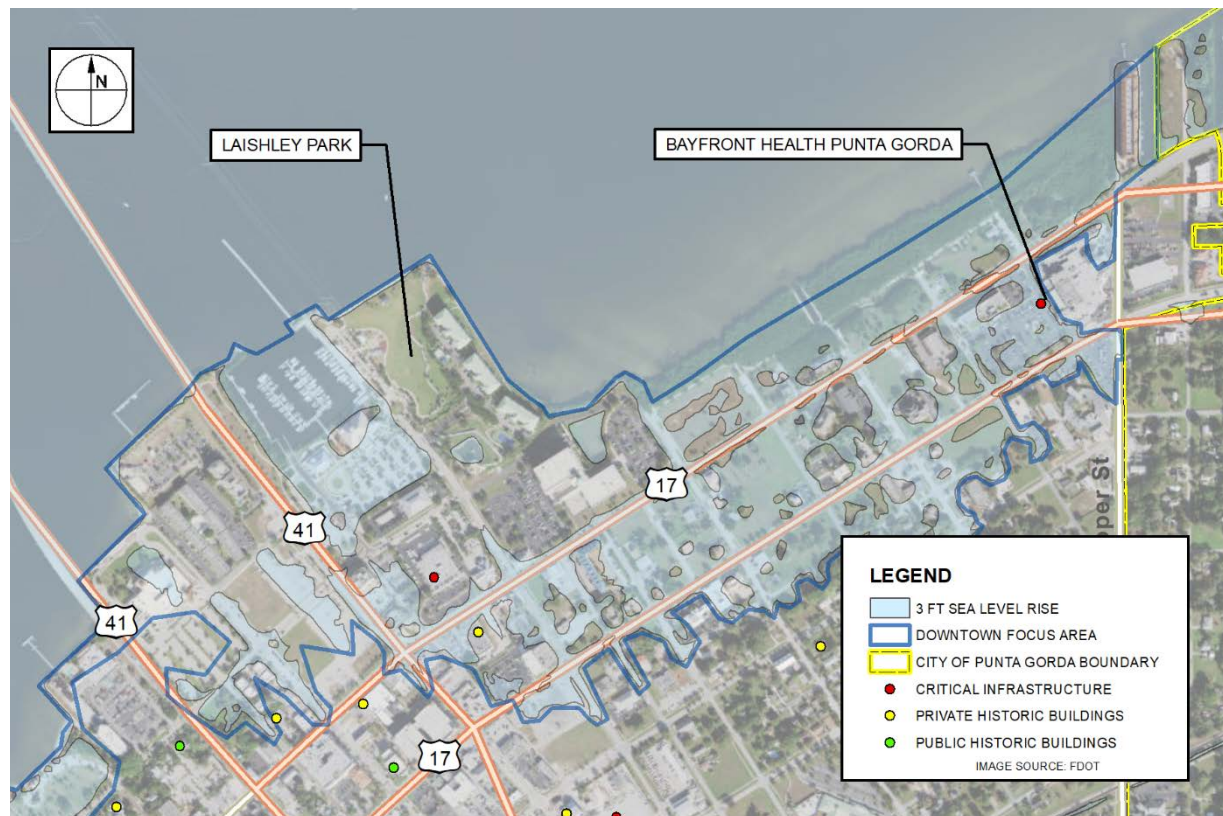


Figure 4.8 Downtown Focus Area, East of US 41

The critical infrastructure in this focus area which is affected by 3 feet of sea level rise include the privately-owned Bayfront Health Hospital, the United States Postal Service office, and a wastewater lift station on McGregor Street. None of these properties are fully inundated at 3 feet of sea level rise, however transportation to them would be impeded by roadways that are flooded.

It is important to note that other critical facilities or infrastructure may not be included in this focus area but may be of importance in future City planning. One example is the Punta Gorda wastewater station and tanks on Henry Street.

The flooding of the access roads and properties surrounding Bayfront Health Hospital are the most concerning of the issues in the eastern portion of the Downtown Focus Area (Figure 4.8). Without accurate FFE for the privately-owned hospital, it is unclear whether the building would be flooded at 3 ft of sea level rise, but transportation to and from the hospital would be hindered at this flood scenario. While the Planned Relocation strategy is the most prudent recommendation for this critical facility, it may not be economically feasible in the short-term but is the most practical long-term adaptation option. For the intermediate time frame, the 1.5 ft sea level rise scenario shows the inundation does not extend south of southbound US 17 (Marion Avenue). Therefore, the facilities south of Marion Avenue are not immediately threatened by sea level rise but are at risk of flooding due to storm surge and extreme rain events.



Photograph 4.13 Bayfront Health located within one block of the river
(<https://www.bayfrontcharlotte.com/punta-gorda>)

If the hospital, McGregor Street lift station, and United States Postal Service office remain in their current locations, long-term protection strategies should be further investigated. One protective action could be to raise a portion of Marion Avenue from Cooper Street westward to US 41 North to an elevation high enough to act as a physical barrier to water flowing in from the coast. Another recommended protection strategy involves using temporary emergency flood barriers at each low-lying entrance to the hospital, due to the hospital's proximity to the Peace River. However, where flood barriers are used, pumps are necessary to transfer rainwater that falls inside the flood barrier or water that seeps underneath the barrier.

Sandbags can be used as a temporary flood barrier but are not recommended as they have the disadvantage of potentially transforming the sand to hazardous material once saturated by floodwaters which contain a multitude of toxins. Another drawback of a temporary flood barrier is the inaccessibility to the building once deployed, which is not ideal for an essential hospital emergency room.

The “green boundary” which the City of Punta Gorda maintains on the eastern coast of the downtown focus area is beneficial not only for beautifying the City and enhancing shoreline habitats, but also for protecting inland properties from wave damage due to storms. Due to sea level rise, flooding caused by storm events starts from a higher baseline water level than in the past. For example, if a storm identical to Hurricane Donna were to occur in 2019, the storm surge would be over half a foot higher merely due to sea level rise. The harmful wind-driven waves which accompany a hurricane are proven to dissipate as they travel over vegetation. The same wind-driven waves build in size when traveling over open paved areas, such as roads and parking lots. Thus, a coast lined with vegetation such as mangroves and cordgrass reacts better at slowing dynamic wave action than one lined with vertical seawalls and roads.

The City of Punta Gorda’s waterfront parks are an adaptation strategy which works and can be expanded. We recommend that additional vegetation be added along the coastline offshore of the City’s waterfront parks to enhance the City’s resilience to flood events. Adding living shorelines offshore of existing seawalls helps to reduce waves impacting the coast and potentially damaging inland property. We also recommend encouraging mangrove growth by properly and minimally trimming mangroves, according to FDEP regulations. Allowing mangroves to grow taller and using windowing trimming techniques (Photograph 4.14) versus low hedging, provides for additional wind damage protection. Appendix C provides technical guidance specific to the City of Punta Gorda for the proper design, location, and construction of living shoreline measures.



Photograph 4.14 Windowing Trim Technique of Mangroves

The western portion of the Downtown Focus Area (Figure 4.9) includes the Historic District and contains the highest concentration of historic properties in the City. This area is low-lying and especially prone to flooding. Many houses in this area have been elevated over time, most likely due to FEMA's National Flood Insurance Program (NFIP) for repetitive loss properties and the Hurricane Mitigation Grant Program (HMGP) (FEMA 2019). Elevating structures at heights above the Base Flood Elevation (BFE) is an appropriate adaptation strategy for historic assets. Elevating a house is an acceptable adaptation option in the *Accommodate* category, although its cost and the potential for changing the character of a historic neighborhood sometimes make this a less than ideal option. Floodproofing, a *Protect* strategy, is a suitable option for non-residential historic structures. For non-historic structures with substantial damage or repetitive loss, it is often more appropriate to apply a *Managed Relocation* strategy, which includes both the buyout and demolition of structures in FEMA Special Flood Hazard Areas (SFHA). Local governments can apply for FEMA grants to assist with the buyout of neighborhoods with a significant number of flood damaged properties.

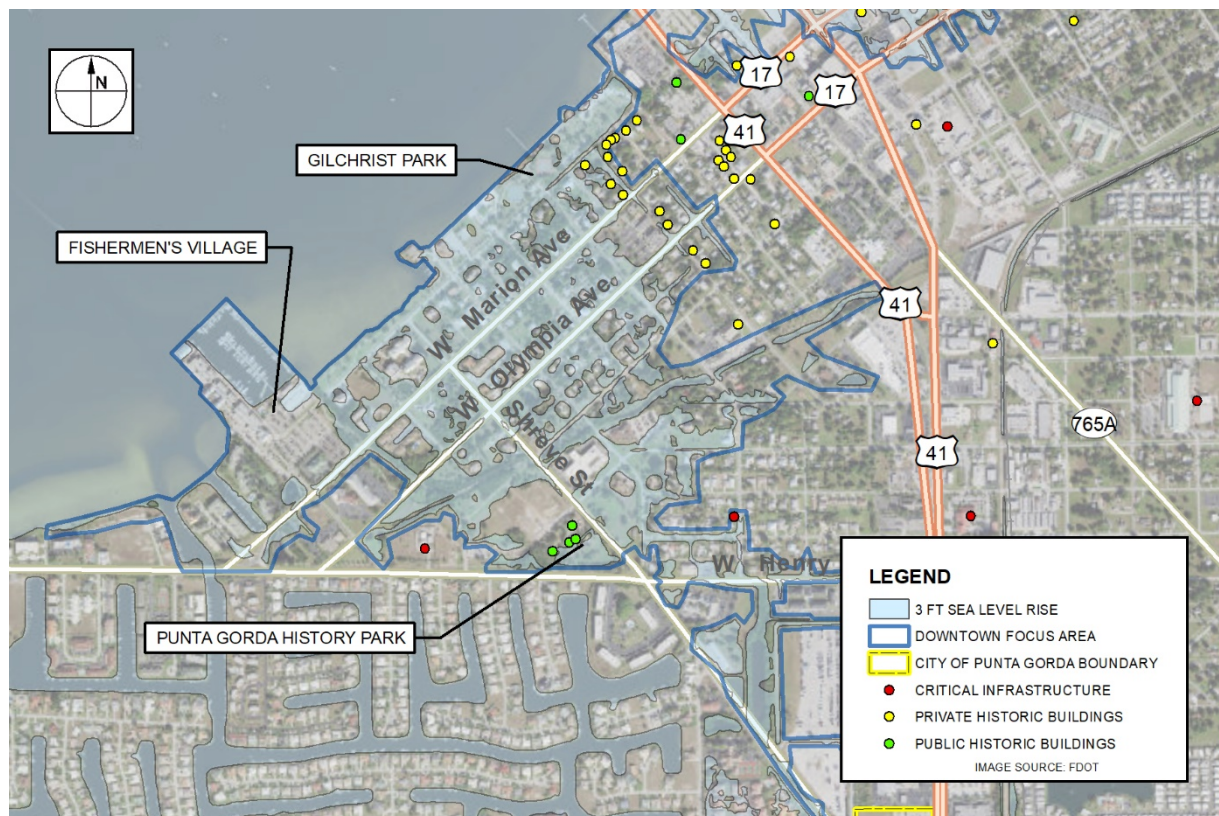


Figure 4.9 Downtown Focus Area, West of US 41

An alternative adaptation strategy for substantially damaged or repetitive loss properties is for the municipality to buy the property, demolish it, convert it into a park or other public space, and change the zoning to prohibit others from building on it. Another policy-driven strategy is the identification of Adaptation Action Areas (AAA) which allow a local government to prioritize funding and potentially apply for specialized grants for those areas at high flood risk due to sea level rise. AAAs are different from the Coastal High Hazard Area (CHHA), but some cities in Florida have combined the two designations, creating AAAs from CHHAs. CHHAs are defined by FEMA as SFHAs along the coasts that have additional hazards due to wind and wave action. These areas are identified on Flood Insurance Rate Maps (FIRMs) as zones V or VE (FEMA 2019).

We recommend the two policy changes discussed in the previous paragraph for consideration for the Downtown Focus Area, especially the western portion where many historic buildings exist. The preservation of the integrity of this unique district classified by the National Register of Historic Properties should advance prioritization of this area for future policy amendments, either in the City's Comprehensive Plan, or other planning documents.

The southwest corner of the Downtown Focus Area, when modeled with 3 feet of sea level rise, shows potential vulnerability to flooding and requires adaptive measures. The canal located between Shreve Street and Magdalena Street at the center of Figure 4.10 is tidally influenced and allows water to backflow into the adjacent properties. A possible short-term strategy to prevent flooding in this area is the installation of one-way stormwater h only allow the flow of water in one direction. These check valves, discussed in Section 4.3, allow stormwater to flow out, but prevent backflow from the canal due to high tides, storm surge, or sea level rise.

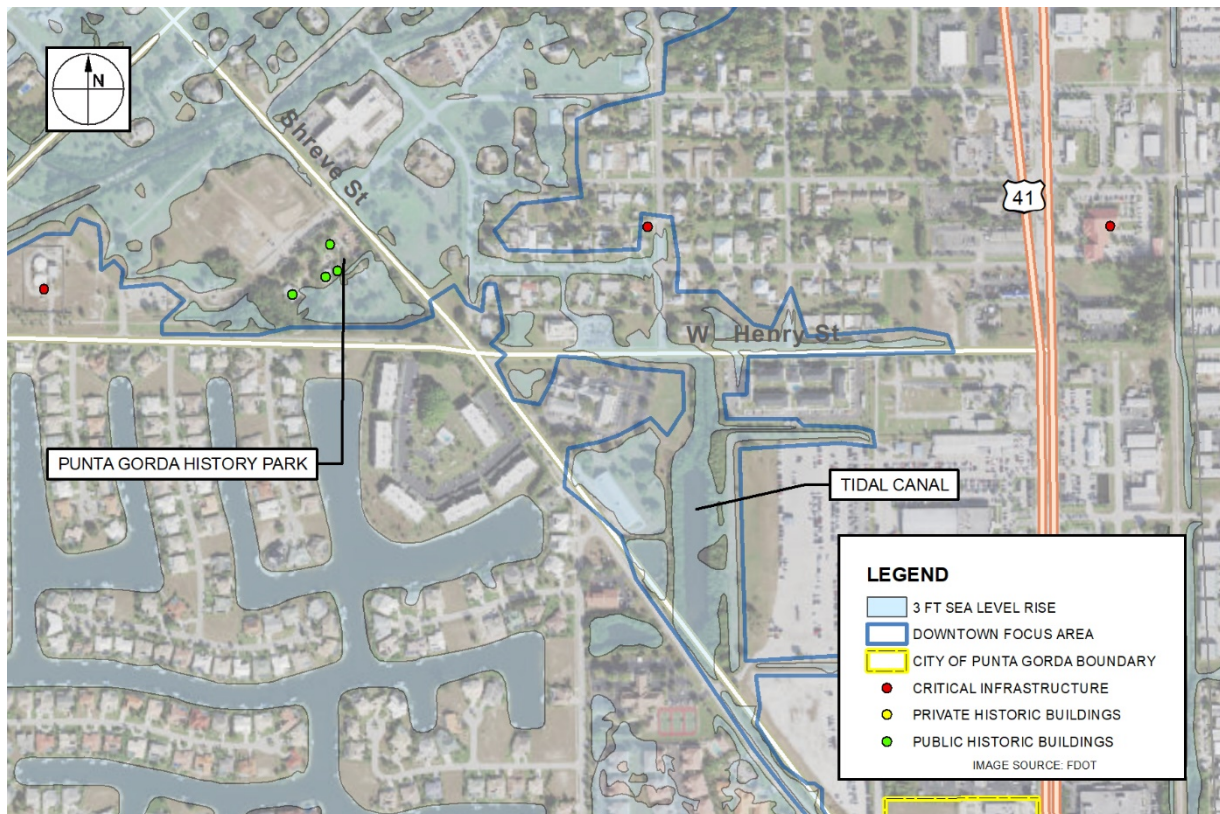


Figure 4.10 Downtown Focus Area, Southwest Near the Punta Gorda Library

A possible long-term solution to combat flooding in this area is the installation of wet wells in conjunction with pumps (Figure 4.11). While underground cisterns for stormwater are not normally considered in Florida due to the high water table, this adaptation option should be considered. Underground water tanks store excess stormwater runoff in urban drainage systems during wet periods, primarily when runoff exceeds the discharge capacity of the urban drainage system. The benefits of a stormwater storage system are two-fold. It not only provides excess capacity to prevent roads and properties from flooding, but it also stores water which can be used later for irrigation. If the tank incorporates filters or a settling system, it can also remove sediments, pollutants, and excess nutrients from the stormwater.

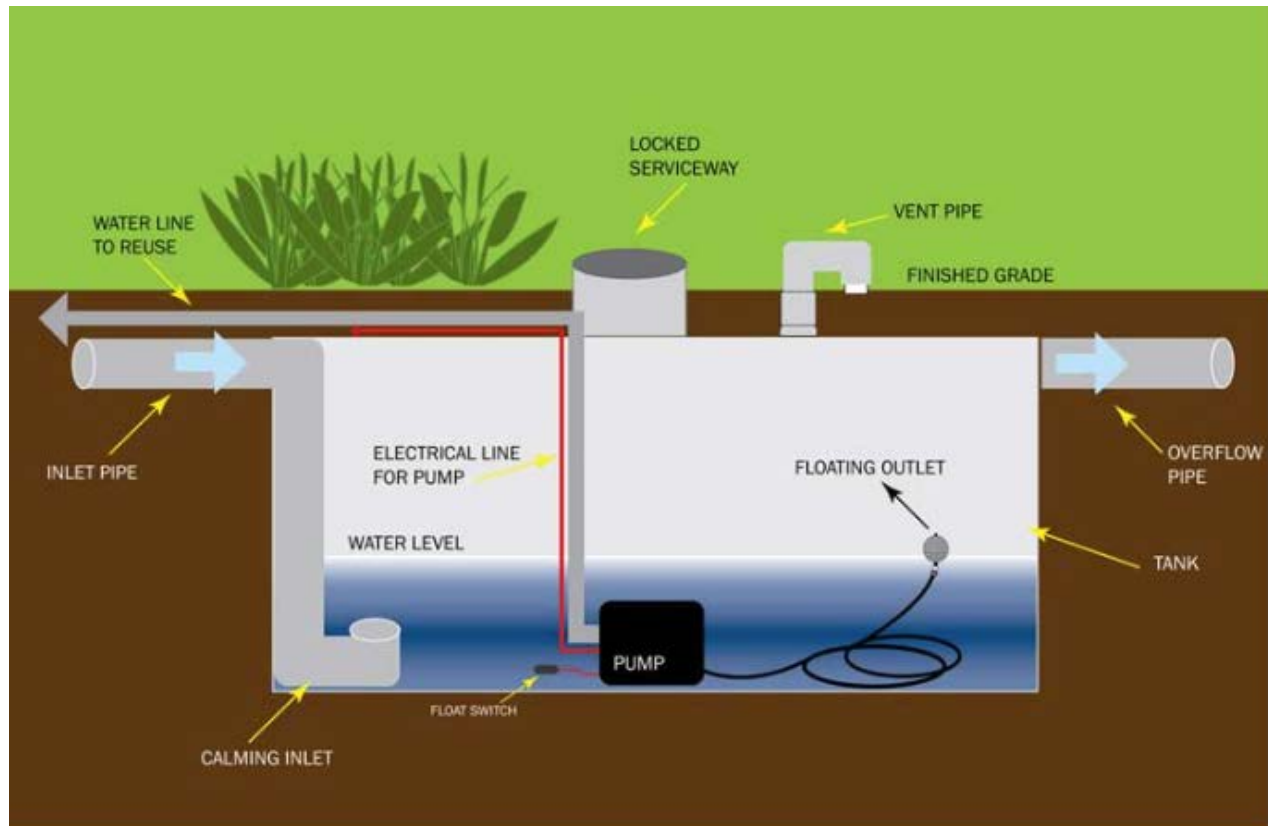


Figure 4.11 Typical Components of an Underground Rainwater Cistern
(Source: www.conteches.com)

For this specific canal area, the City has an easement along the south side of Henry St adjacent to the Good Shepherd Preschool and across the street from the Punta Gorda Library. The easement appears to be a swale for stormwater runoff with an adjacent berm. This swale, a linear depression running parallel to the road, is likely to overflow due to high tide or storm surge, since it's tidally connected to the canal. For a long-term adaptation solution, we suggest replacing this swale with a buried high-capacity stormwater pipe with a check valve, or investigate using a system of linear cisterns.

These stormwater improvements suggested above could possibly provide protection against future flooding within this focus area but would require further study of the watershed which feeds these stormwater components. Specifically, the elevation of all stormwater outfalls should be assessed as part of a stormwater master plan review and these elevations compared to future

sea level rise scenarios. The addition of numerous check valves where the stormwater system interfaces with a tidally influenced water body may provide for a short-term solution. Long-term solutions, although expensive, include removing swales to prevent overflow of floodwater to adjacent properties and creating wet wells with pumps for temporary storage of stormwater. Cisterns for storing excess stormwater runoff could be incorporated under City-owned parking lots or open park space.

The complexity of factors that contribute to coastal flooding should be analyzed in order to fully address the City's specific vulnerabilities. As the sea level rises, storm water infrastructure that relies on gravity to move water through the pipes can be compromised as the outfalls are partially or completely submerged (Figure 4.12). A high-water event combined with sea level rise can prolong storm induced flooding. This prolonged exposure to saltwater can cause damage to the City's stormwater infrastructure.

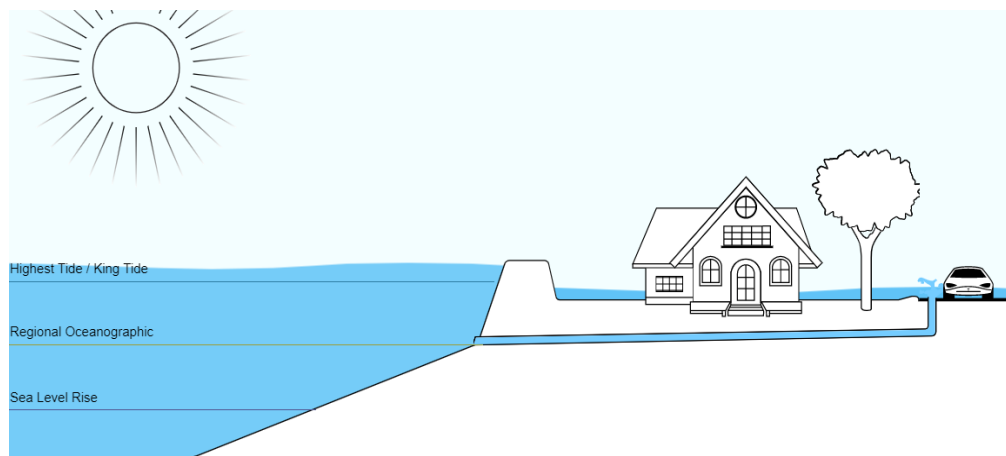


Figure 4.12 Coastal Flooding due to Stormwater Drainage Inundation
(<https://coast.noaa.gov/stormwater-floods/understand/>)

Currently, the City of Punta Gorda infrequently experiences nuisance flooding during king tides. Due to the City's extensive tidally influenced canals and the proximity to Charlotte Harbor, the frequency of this flooding will increase over time as sea level rises. Therefore, the City should address and implement stormwater management improvements throughout this focus area.

4.4.2 US 41 Commercial Focus Area

The US 41 Commercial Focus Area poses a unique challenge for applying adaptation strategies due to its location on the edge of the City limits. The City of Punta Gorda's boundary causes this focus area to be a peninsula surrounded by Charlotte County property. Since US 41 runs northwest through this focus area, it provides a significant degree of linear protection against flooding originating from the northwest. Due to FDOT roadway construction elevation standards that range between 5 and 6 ft NAVD, the primary flood exposure to this area is from the southwest. The main source of flood water in this focus area is from water overtopping low lying areas that are hydrologically connected to Alligator Creek and its associated man-made canal systems.

The most significant vulnerability in this focus area originates from a low-lying area just south of the Charlotte RV Storage adjacent to the City boundary (Figure 4.13). At 3 ft of sea level rise, a tidal canal within the Punta Gorda RV Resort allows water to overtop Rio Villa Drive and move into the City of Punta Gorda boundaries. Currently, there are two shallow swales on either side of Rio Villa Drive that provide drainage for the area.

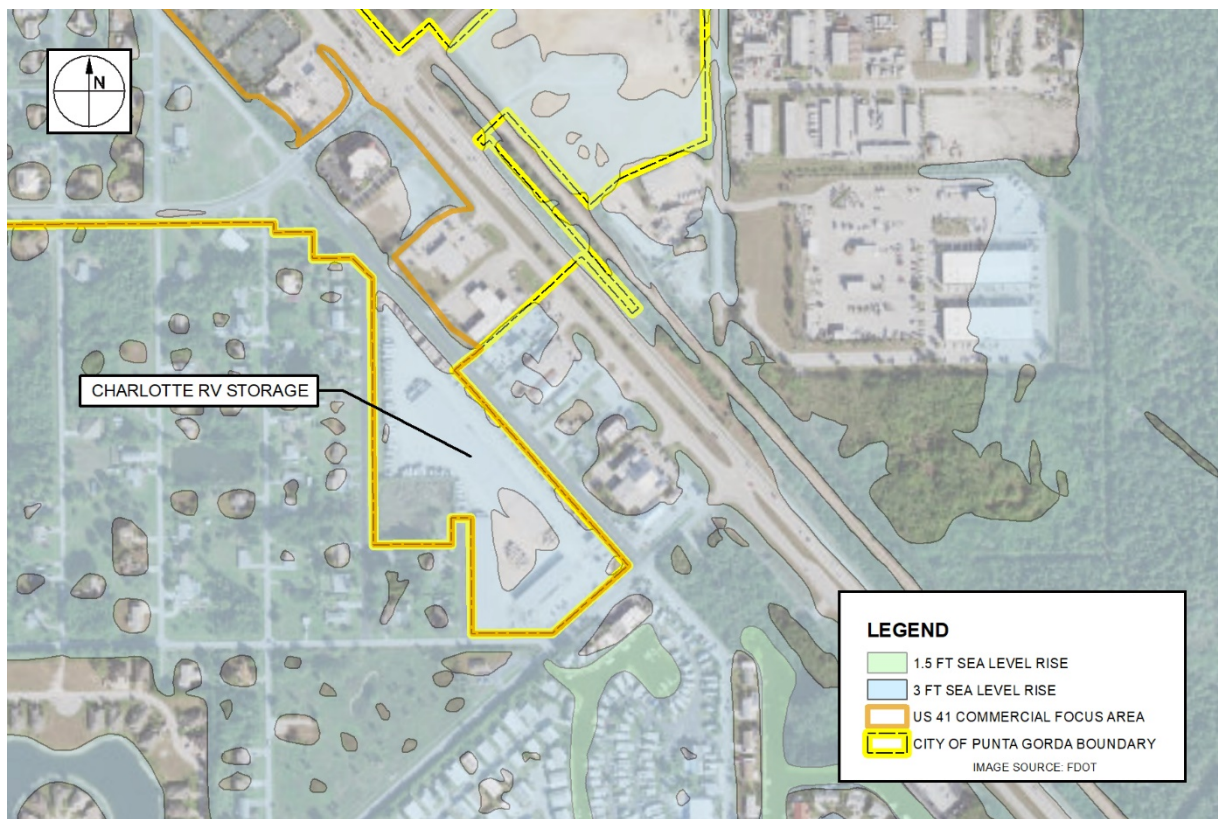


Figure 4.13 US 41 Commercial Focus Area, South

Future adaptation strategies for this issue will require coordination with Charlotte County and could include a variety of measures. An available short-term solution for this problematic area would be to deepen the two swales that already exist giving the storm water and rising water due to sea level rise a path to follow. Unfortunately, this is only a short term or “band aid” solution. The City could also implement large catch basins and pumps to collect and disperse water from these areas or use these two strategies in concert. Finally, the City could recommend

that Charlotte County raise the seawalls in the canal systems in the area as a short-term solution to prevent water from overtopping this system.

The second identified vulnerable area is located at the southwest border of the US 41 Commercial Focus Area (Figure 4.14). As the sea level rises to 3 ft, the water appears to overtop many of the neighborhood canal systems and hydrologically move to areas of low land elevation. In order to prevent this flooding, it will again require coordination with Charlotte County since most of the flood water appears to originate from outside the Punta Gorda City limits. Possible adaptation strategies include the short-term solution of raising the sea walls within the canal systems, an intermediate-term solution of installing robust catch basins and pumping stations, or a long-term solution of buying out and rededicating this vulnerable area to natural open space.

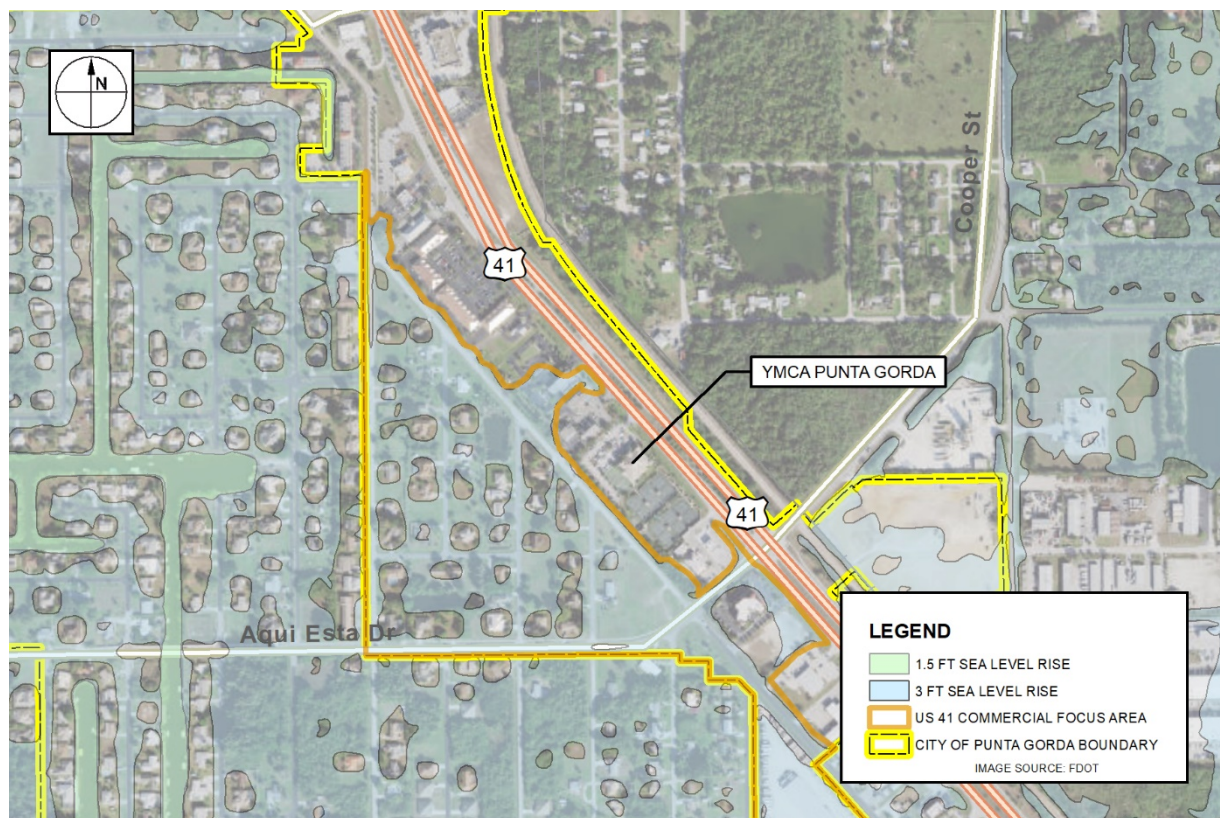


Figure 4.14 US 41 Commercial Focus Area, North

Both vulnerable zones in this focus area could benefit from long-term monitoring of water levels within the canal system as well as monitoring and data collection of conditions during events that could stress the current system. Creating a robust system to monitor points of vulnerability during extreme tides, storm induced surge, and rain could be beneficial for better understanding how the current systems perform under these conditions and aid in future long-term planning.

4.4.3 Fire Station Focus Area

The Fire Station Focus Area (Figure 4.15) offers the City of Punta Gorda a unique opportunity to continue the preservation of City owned land as natural parks. Punta Gorda Nature Park currently occupies most of this focus area and provides a buffer for the centrally located buildings and water tank. As an adaptive strategy, we recommend that the City retains this vulnerable area as predominantly nature park land.

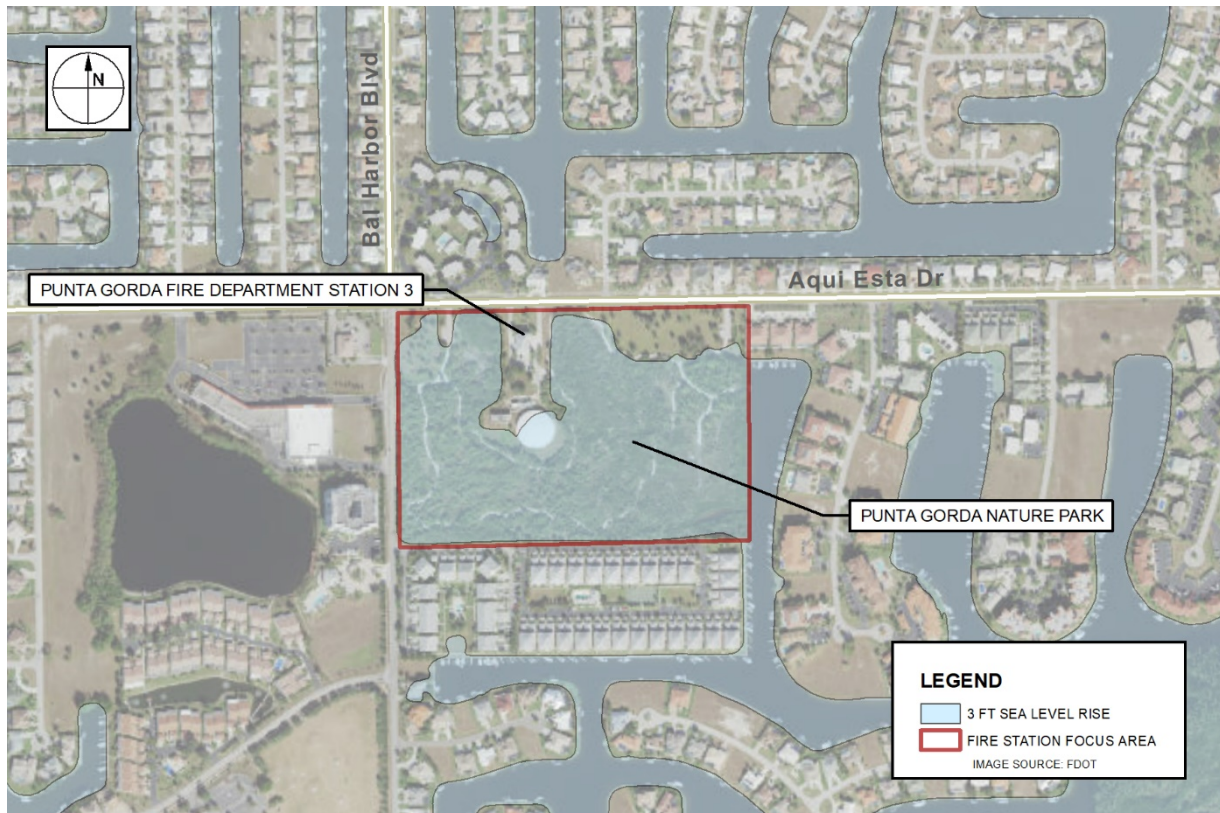


Figure 4.15 Fire Station III Focus Area

Since Fire Department Station III is already located on this portion on land and its central location in the Punta Gorda Isles neighborhood is vital to the efficient emergency response for its citizens, the City of Punta Gorda must protect the station from future higher water levels. At 3 ft of sea level rise, Fire Station III will not be susceptible to flooding due to its 5.9 ft FFE and 5.84 LAG (all elevations in NAVD88). The two cross streets which provide access to the Fire Station, Aqui Esta Drive and Bal Harbor Boulevard also remain above water in the 3 feet sea level rise scenario.

In addition to retaining the designation to park land, the City could also raise the borders of the canal system that acts as a barrier to the tidally influenced waters contained within and that eventually connect to the Gulf of Mexico. Again, monitoring water levels at these vulnerable areas would be helpful to understand storm effects. Enhancing and monitoring the mangrove living shoreline on the east side of the focus area is recommended.

5.0 RECOMMENDATIONS

5.1 Suggested Changes to Comprehensive Plan

This section contains specific language to be added to the City's Comprehensive Plan, written in the format of Punta Gorda's current plan.

GOAL 2B.7: Coastal Resilience: To increase the City's resilience to the impacts of climate change and sea level rise by developing and implementing adaptation strategies and measures in order to protect human life, natural systems, economic resources, property, and infrastructure.

Objective 2B.7.1: Punta Gorda will develop and implement adaptation strategies for areas vulnerable to coastal flooding, tidal events, storm surge, flash floods, stormwater runoff, salt water intrusion and other impacts related to climate change or exacerbated by sea level rise, with the intent to increase the City's comprehensive adaptability and resiliency capacities.

Policy 2B.7.1.1: Identify public investments and infrastructure at risk to sea level rise and other climate related impacts.

Measurement: List public investments and infrastructure at risk from rising sea levels and develop adaptation strategies for vulnerable areas and assets by the year 2021, to be re-evaluated every 5 years after.

Policy 2B.7.1.2: Adaptation strategies may include, but not be limited to:

- a. Accommodation
- b. Protection
- c. Planned relocation
- d. Other strategies

Policy 2B.7.1.3: The City's Climate Adaptation Plan should be maintained and updated periodically in order to incorporate the best available scientific data and technological advances. Evaluate Adaptation Focus Areas and designate new Focus Areas for development of further adaptation priorities.

Measurement: The City's Climate Adaptation Plan will be updated at least once every 10 years. Adaptation Focus Areas to be re-evaluated and new ones designated, as necessary.

Policy 2B.7.1.4: The elevation of the City's stormwater outfalls should be assessed as part of a stormwater master plan review, with these elevations compared to future sea level rise scenarios, and appropriate adaptations implemented to prevent backflow "nuisance flooding."

Measurement: Review the stormwater master plan and elevations of stormwater outfalls, comparing these to future sea level rise scenarios after each Climate Adaptation Plan update. Implement adaptations to prevent backflow "nuisance flooding."

Policy 2B.7.1.5: The City shall establish a living shoreline pilot project at a City-owned park in order to encourage citizens to incorporate living shorelines on their properties.

Measurement: One or more new living shoreline project designed and constructed on City-owned property by 2022.

Policy 2B.7.1.6: The City will pursue grants, alternative funding, and partnerships in order to implement adaptation and resilience projects outlined in the Climate Adaptation Plan.

Measurement: Alternative funding awarded for City adaptation and resilience projects.

Objective 2B.7.2: The City will consider identifying and designating Adaptation Action Areas (AAAs), as provided by Section 163.3164(1), Florida Statutes. The City will develop specific adaptation strategies for properties located in AAAs.

Policy 2B.7.2.1: Considerations for AAA designation may include, but not be limited to:

- a. Areas which experience tidal flooding, or flooding due to extensive rainfall
- b. Areas which have a hydrological connection to coastal waters
- c. Locations which are within areas designated as evacuation zones for storm surge
- d. Other areas impacted by stormwater/flood control issues

Measurement: Identify and designate areas within the City which are at risk from coastal flooding and prioritize funding for infrastructure and adaptation planning for these AAAs.

Policy 2B.7.2.2: As a basis for the designation of AAAs, the City will utilize the best available data and resources in order to identify and understand the risks, vulnerabilities and opportunities to formulate timely and effective adaptation strategies.

Measurement: After each Climate Adaptation Plan update, re-evaluate City's areas at risk from coastal flooding and assess their possible inclusion as AAAs.

5.2 Future Work Needed

We recommend that the City of Punta Gorda acquire updated LiDAR data and more complete FFE data for publicly-owned buildings. The lack of elevation data for Charlotte County schools and Punta Gorda Housing Authority properties hindered a more complete vulnerability study. Similar data for federal and state-owned property within the City limits, which are not included in this study, would result in a more comprehensive analysis. Additionally, the elevations of critical roadways, particularly evacuation routes, should be added for further adaptation planning.

The Climate Adaptation Plan should be maintained and updated periodically as a 'living document' that continually evolves. Updates to the IPCC, National Climate Assessment, and sea level rise projections are published every 5 to 7 years; with the next update of the IPCC anticipated in 2021. As those updates become available, the City should re-evaluate flood thresholds used in this vulnerability analysis. The three storm surge scenarios of 4%, 1%, and 0.2% annual chance showed fairly similar inundation areas. We recommend using a higher frequency flood, such as the 10% annual chance flood, for future work.

Given the amount of water frontage and available City owned park space, we recommend that the City develop a living shoreline pilot study at Laishley Park, using the technical guidance document found in Appendix C. We also recommend that any previously initiated and ongoing living shoreline studies be evaluated and modified to align with the criteria developed in the living shoreline guidance document.

We prepared a summary matrix (Appendix E) of funding alternatives, consisting of 21 potential grant options that fit the City's needs. We identified the top three grants that best align with the City's goals, objectives, and identified adaptation strategies. We recommend that the City pursue the grants listed below to update the Climate Adaptation plan with additional data outlined above, develop an implementation plan, and pursue development of a living shoreline pilot study.

5.2.1 *Recommended Grants*

Florida Department of Environmental Protection (FDEP)

Coastal Partnership Initiative (CPI) Grant Program

<https://floridadep.gov/rcp/fcmp/content/grants>

Funding limits: No more than \$30,000 and no less than \$10,000, for planning, design and coordination activities; and No more than \$60,000 and no less than \$10,000 for construction projects, habitat restoration, invasive exotic plant removal or land acquisition.

The Coastal Partnership Initiative grant program was developed to promote the protection and effective management of Florida's coastal resources at the local level. The Florida Coastal Management Program (FCMP) makes NOAA funds available, on a competitive basis, to eligible local governments. Eligible local governments are defined as Florida's 35 coastal counties and all municipalities within their boundaries that are required to include a coastal element in their local comprehensive plan. Florida's public colleges and universities, regional planning councils, national estuary programs and nonprofit groups also may apply if an eligible local government agrees to participate as a partner.

Each year, the FCMP publishes a CPI Brochure and a "Notice of Availability of Funds" in the Florida Administrative Register to solicit CPI applications from eligible entities. CPI grants provide support for innovative, local, coastal management projects in four program areas:

- Resilient Communities
- Public Access
- Working Waterfronts
- Coastal Stewardship

Eligible entities may apply for grants for community projects such as habitat restoration, park planning and improvements, waterfront revitalization, and improving communities' resiliency to coastal hazards.

US Department of the Treasury

The Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act of 2012 (RESTORE Act)

<https://www.treasury.gov/services/restore-act/Pages/Direct%20Component/Direct-Component.aspx>

The RESTORE Act established a new Trust Fund in the Treasury of the United States, known as the Gulf Coast Restoration Trust Fund. Eighty percent of the civil penalties paid after July 6, 2012, under the Federal Water Pollution Control Act in connection with the Deepwater Horizon oil spill will be deposited into the Trust Fund and invested.

The Department of the Treasury-administered Direct Component makes 35 percent of the civil penalties deposited into the Trust Fund available to four Gulf Coast states, 23 Florida counties, and 20 Louisiana parishes. The Direct Component is governed by the RESTORE Act final rule at 31 CFR Part 34, effective on February 12, 2016 after publication on December 14, 2015. Further, grant recipients under the RESTORE Act must comply with the guidance issued by the Office of Management and Budget entitled, "Part 200 – Uniform Administrative

Requirements, Cost Principles, and Audit Requirements for Federal Awards" at 79 CFR 75880 (December 19, 2014.)

As provided in the RESTORE Act and final rule, activities, programs, and projects that are eligible for grants awarded under the Direct Component (eligible activities) include:

- Restoration and protection of the natural resources, ecosystems, fisheries, marine and wildlife habitats, beaches and coastal wetlands of the Gulf Coast Region;
- Mitigation of damage to fish, wildlife and natural resources;
- Implementation of a Federally approved marine, coastal, or comprehensive conservation management plan, including fisheries monitoring;
- Workforce development and job creation;
- Improvements to or on state parks located in coastal areas affected by the Deepwater Horizon oil spill;
- Infrastructure projects benefitting the economy or ecological resources, including port infrastructure;
- Coastal flood protection and related infrastructure;
- Planning assistance;
- Promotion of tourism in the Gulf Coast Region, including promotion of recreational fishing;
- Promotion of the consumption of seafood harvested from the Gulf Coast Region; and
- Administrative costs.

The RESTORE Act specifies who may apply to receive funds under the Direct Component, administered by Treasury. Treasury's regulations list the Direct Component eligible states, counties, and parishes who may apply:

- In Alabama, the Alabama Gulf Coast Recovery Council or such administrative agent as it may designate;
- In Florida, the Florida counties of Bay, Charlotte, Citrus, Collier, Dixie, Escambia, Franklin, Gulf, Hernando, Hillsborough, Jefferson, Lee, Levy, Manatee, Monroe, Okaloosa, Santa Rosa, Pasco, Pinellas, Sarasota, Taylor, Wakulla, and Walton;
- In Louisiana, the Coastal Protection and Restoration Authority Board of Louisiana through the Coastal Protection and Restoration Authority of Louisiana;
- In Louisiana, the Louisiana parishes of Ascension, Assumption, Calcasieu, Cameron, Iberia, Jefferson, Lafourche, Livingston, Orleans, Plaquemines, St. Bernard, St. Charles, St. James, St. John the Baptist, St. Martin, St. Mary, St. Tammany, Tangipahoa, Terrebonne, and Vermilion;
- In Mississippi, the Mississippi Department of Environmental Quality; and
- In Texas, the Office of the Governor or an appointee of the Office of the Governor.

The RESTORE Act and the Treasury final rule direct the state, county, and parish applicants to prepare multiyear implementation plans that prioritize eligible activities for Direct Component funds and to obtain broad-based participation from individuals, businesses, Indian tribes, and non-profit organizations as part of preparing their multiyear plans. The state, county, or parish applicants may periodically update their plans by following the same steps, including obtaining public input, prior to submitting their revised plans to Treasury. A private individual may choose to seek consideration of its proposal by contacting the state, county, or parish applicant, based on the proposed project's geographic location. The Direct Component FAQs provide details about this process.

Under the RESTORE Act, Gulf Coast region means:

- In the Gulf Coast States, the coastal zones defined under section 304 of the Coastal Zone Management Act of 1972 that border the Gulf of Mexico;
- Land within the coastal zones described in paragraph (1) of this definition that is held in trust by, or the use of which is by law subject solely to the discretion of, the Federal Government or officers or agents of the Federal Government;
- Any adjacent land, water, and watersheds, that are within 25 miles of the coastal zone described in paragraphs (1) and (2) of this definition; and
- All Federal waters in the Gulf of Mexico.

The Treasury rule explains further that Direct Component activities are carried out in the Gulf Coast Region when, in the reasonable judgment of the eligible entity applying to Treasury for a grant, each severable part of the activity is primarily designed to restore or protect that geographic area. The state, county, or parish must demonstrate that the activity will be carried out in the Gulf Coast Region when they apply for a grant.

Under the RESTORE Act, activities designed to protect or restore natural resources must be based on best available science. Best available science means science that maximizes the quality, objectivity, and integrity of information, including statistical information; uses peer-reviewed and publicly available data; and clearly documents and communicates risks and uncertainties in the scientific basis for such projects.

A state, county, or parish applicant must look at the nature of the activity, rather than the title of the eligible activity, when deciding whether this requirement applies. They must explain in their application how the activity is based on the "best available science" and cite peer-reviewed, objective, methodologically sound literature sources that support the conclusion that the proposed scope of work is an effective way to achieve the stated objectives that are set out in the RESTORE Act.

Florida Department of Economic Opportunity (FDEO)

Community Planning Technical Assistance Grant

<http://www.floridajobs.org/community-planning-and-development/programs/community-planning-table-of-contents/technical-assistance/community-planning-technical-assistance-grant>

The Florida Department of Economic Opportunity (DEO) anticipates that the Florida Legislature will appropriate funding for Community Planning Technical Assistance Grants. The grants provide communities the opportunity to develop innovative planning and development strategies to promote a diverse economy, vibrant rural and suburban areas and meet the requirements of the Community Planning Act, while protecting environmentally sensitive areas. The grants can also be used for disaster recovery or resiliency planning and economic development by communities impacted by Hurricanes Irma and Michael.

Community Planning Technical Assistance Grants are available to:

- Counties and municipalities; and
- Regional planning councils that propose projects on behalf of or for the benefit of counties, municipalities or the region and that have support, in writing, from the counties or municipalities affected by the proposed grant project.

Grant awards typically range from \$25,000 to \$40,000, but award amounts may vary. Funding is contingent upon an appropriation from the Legislature.

Projects are developed by the county, municipality or regional planning council and generally relate to community planning and economic development strategies that implement the requirements in the Community Planning Act. Communities impacted by Hurricanes Irma and Michael are encouraged to apply for projects related to disaster recovery or resiliency. Applicants are encouraged to seek funding for innovative, creative or unique approaches to planning and development.

Past Grant Projects

Examples of projects funded in prior years include the following:

- Priority Action Plan for the Avon Park Air Force Range Sentinel Landscape Program;
- Strategic plan for agricultural sustainability and food production;
- Strategic plan and sites inventory for designation of a freight logistics zone;
- Rail preservation plan for long-term multi-modal transportation uses;
- Sea level rise impacts to stormwater outfalls in the Indian River Lagoon;
- Visual imaging for public projects;
- Community redevelopment area plans and finding of necessity reports;
- Transportation corridor plans, complete streets plans and bicycle/pedestrian plans;
- Master plans for recreation, neighborhoods, infrastructure, urban design, etc.; and
- Amendments to comprehensive plans and land development regulations.

6.0 REFERENCES

- Beever, J, W Gray, D Trescott, D Cobb, J Utley, D Hutchinson, J Gibbons, et al. 2009. *City of Punta Gorda Climate Adaptation Plan*. Technical Report 09-04, Southwest Florida Regional Planning Council and Charlotte Harbor National Estuary Program.
- Bosch Slabbers, Deltares, Sweco, KNMI, Witteveen+Bos. 2019. *Climate APP*. <http://www.climateapp.nl/>.
- CCS. 2011. *Comprehensive Climate Action Planning: The Center for Climate Strategies Adaptation Guidebook*. Center for Climate Strategies.
- Charlotte County-Punta Gorda Metropolitan Planning Organization. 2010. *"2035 Long Range Transportation Plan"*. Punta Gorda: Charlotte County-Punta Gorda Metropolitan Planning Organization.
- Charlotte County-Punta Gorda Metropolitan Planning Organization. 2015. *"2040 Long Range Transportation Plan"*. Charlotte County & The City of Punta Gorda: Charlotte County-Punta Gorda Metropolitan Planning Organization.
- City of Punta Gorda. 2017. *"City of Punta Gorda Comprehensive Plan 2040"*. City of Punta Gorda: City of Punta Gorda.
- . 2019. *"Punta Gorda: Florida's Harborside Town: Public Records"*. Accessed June 2019. <http://www.ci.punta-gorda.fl.us/government/city-clerk/public-records>.
- . 2019. *Punta Gorda: Florida's Harborside Hometown: City Facilities*. Accessed 2019. <http://www.ci.punta-gorda.fl.us/Home/Components/FacilityDirectory/FacilityDirectory/16/59>.
- Contech Engineered Solutions. 2019. *Cistern Design Considerations for Large Rainwater Harvesting Systems*. Accessed 2019. <https://www.conteches.com/knowledge-center/pdh-article-series/cistern-design-considerations-for-large-rainwater-harvesting-systems>.
- ECONcrete. 2019. *ECONcrete: Products*. Accessed 2019. <https://econcretetech.com/products/#ECOSeawall>.
- EPA. 2014. "US Environmental Protection Agency Climate Change Adaptation Plan."
- FDEP. 2018. *Florida Adaptation Planning Guidebook*. Florida Department of Environmental Protection.
- . 2019. *Florida State Parks: Charlotte Harbor Preserve State Park*. Accessed 2019. <https://www.floridastateparks.org/parks-and-trails/charlotte-harbor-preserve-state-park>.
- FEMA. 2019. *FEMA Definitions*. Accessed 2019. <https://www.fema.gov/national-flood-insurance-program/definitions>.
- FEMA. 2017. *Protecting Building Utility Systems from Flood Damages: Principals and Practices for the Design and Construction of Flood Resistant Building Utility Systems*. FEMA P-348, Edition 2.
- FEMA. 2014. *Technical Outreach Southwest Florida*. RiskMAP Presentation, Port Charlotte, Florida: FEMA.
- Florida Legislature. 2015. *2018 Florida Statutes*. Accessed 2019. http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=0100-0199/0163/Sections/0163.3178.html.
- Florida Living Shorelines. 2019. *Florida Living Shorelines: Mangrove Planter*. Accessed 2019. <http://floralivingshorelines.com/project/flagler-mangrove-planter/>.
- Haasnoot, M, S Brown, P Scussolini, J Jimenez, A T Vafeidis, and R Nicholls. 2019. "Generic adaptation pathways for coastal archetypes under uncertain sea-level rise." *Environmental Research Communications*, in press.
- Houston, James, interview by Angela Schedel. 2019. *In-person conversation* (February).

- 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*. Cambridge, UK.: Cambridge University Press.
- IPCC. 1990. *Strategies for Adaptation to Sea Level Rise*. Report of the IPCC Coastal Zone Management Subgroup: Intergovernmental Panel on Climate Change., Geneva: IPCC.
- National Park Service. 2019. *"National Register of Historic Places"*. Accessed 2019. <https://www.nps.gov/subjects/nationalregister/data-downloads.htm>.
- National Research Council. 2007. *Mitigating Shore Erosion Along Sheltered Coasts*. Washington, DC: The National Academies Press.
- NOAA. 2010. *"Adapting to Climate Change: A Planning Guide for State Coastal Managers"*. Silver Springs: NOAA Office of Ocean and Coastal Resource Management.
- NOAA. 2017. *Global and Regional Sea Level Rise Scenarios for the United States*. NOAA Technical Report NOS CO-OPS 083, Silver Spring, MD: National Oceanic and Atmospheric Administration.
- . 2019. *NOAA Tides and Currents: Fort Myers, Caloosahatchee River, FL - Station ID: 8725520*. Accessed 2019. <https://tidesandcurrents.noaa.gov/stationhome.html?id=8725520>.
- Ruppert, T. and Stewart, A. 2015. *Summary and Commentary on Sea-Level Rise Adaptation Language in Florida Local Government Comprehensive Plans and Ordinances*. Houston Endowment.
- Southwest Florida Water Management District". 2018. *"GIS, Maps & Survey"*. <https://www.swfwmd.state.fl.us/resources/data-maps/gis-maps-survey>.
- SWFWMD. 2010. *"Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek"*. Brooksville: Southwest Florida Water Management District.
- Sydney Metropolitan Catchment Management Authority and Department of Environment and Climate Change NSW. 2009. *Environmentally Friendly Seawalls: A Guide to Improving the Environmental Value of*. Sydney: Department of Environment and Climate Change NSW.
- USGCRP. 2018. *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. Washington, DC: U.S. Global Change Research Program.

APPENDIX A

**INUNDATION
SCENARIOS**

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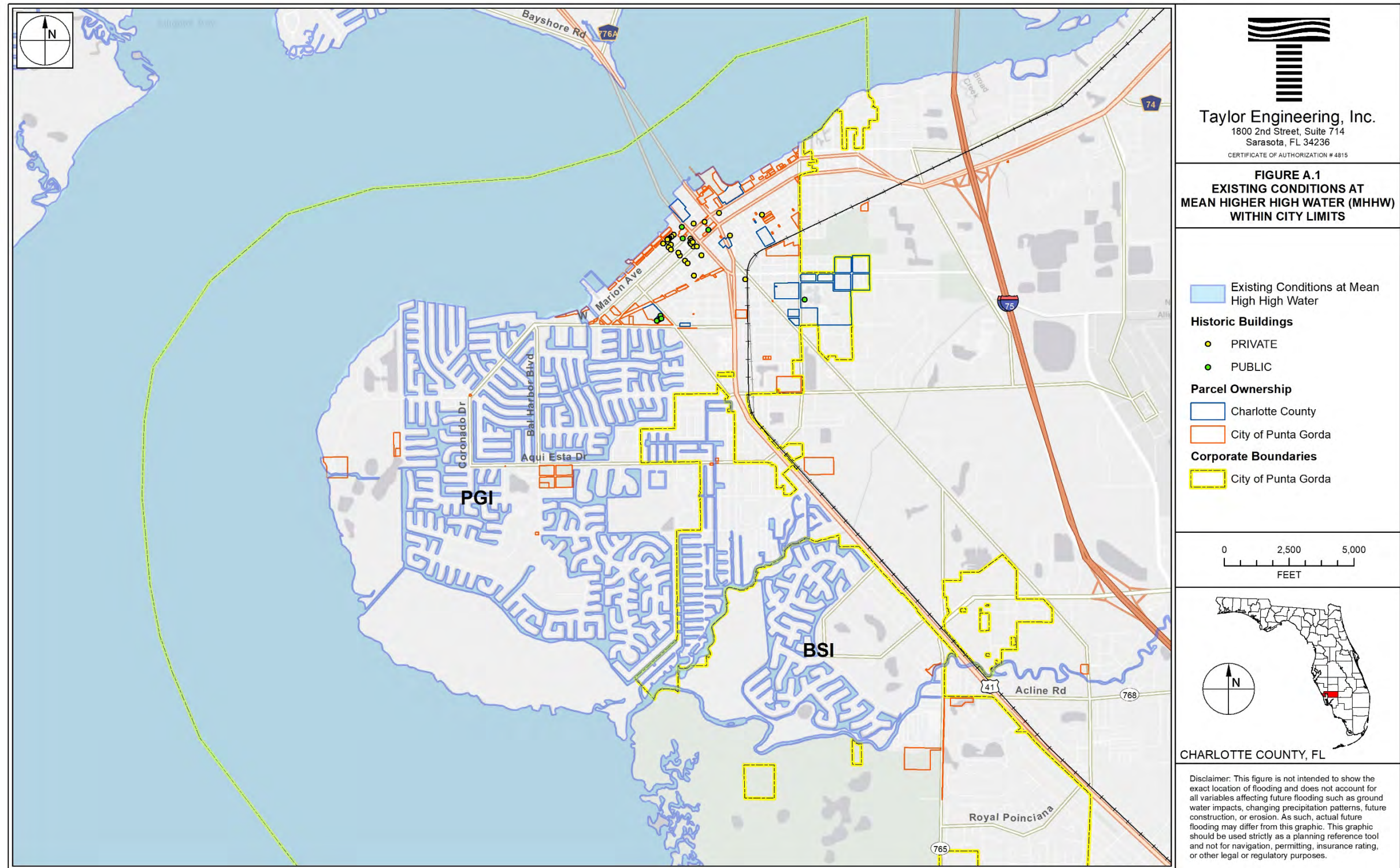


Figure A.1 Existing Condition Mean Higher High Water Line Within City Limits

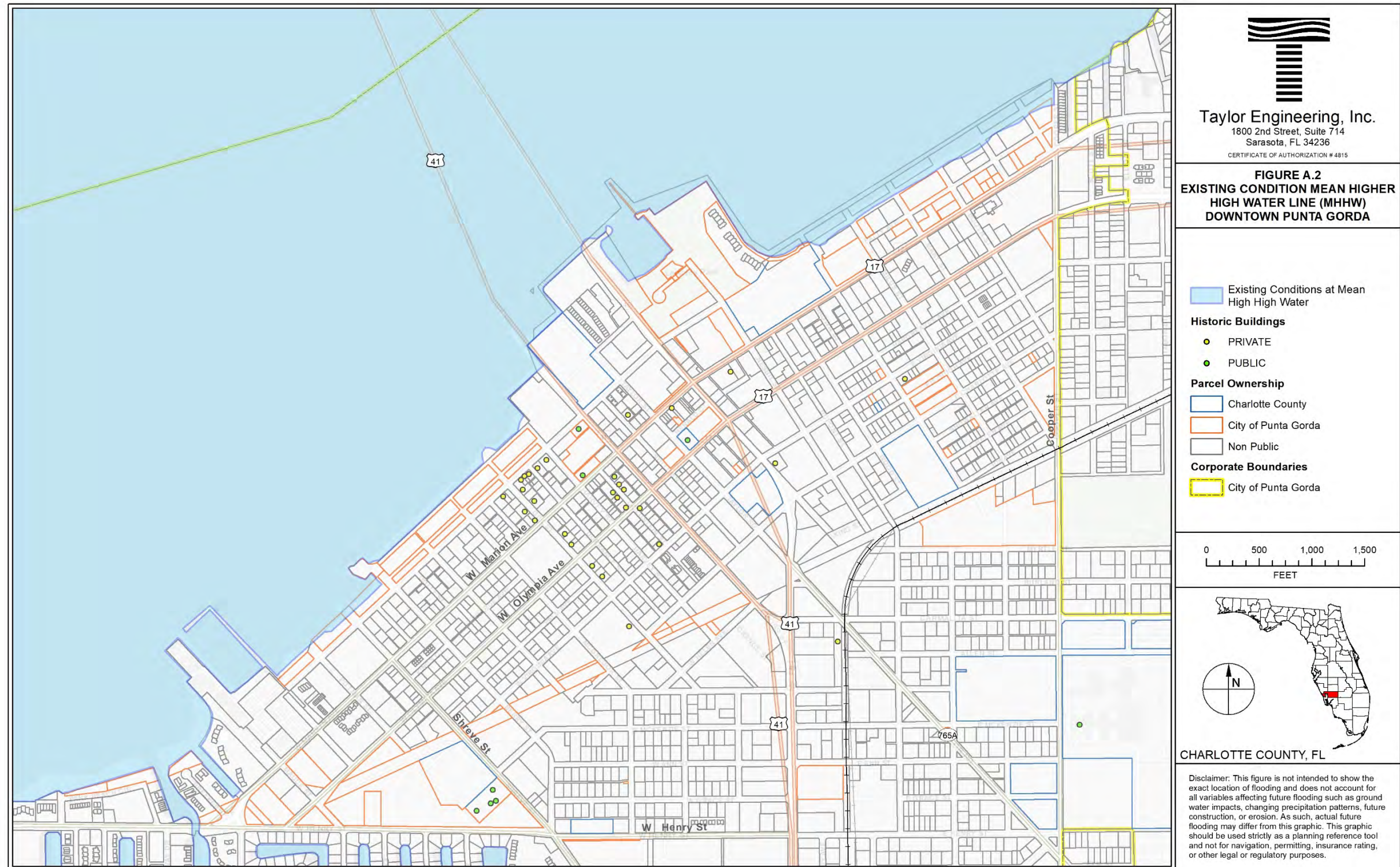


Figure A.2 Existing Condition Mean Higher High Water Line, Downtown Punta Gorda

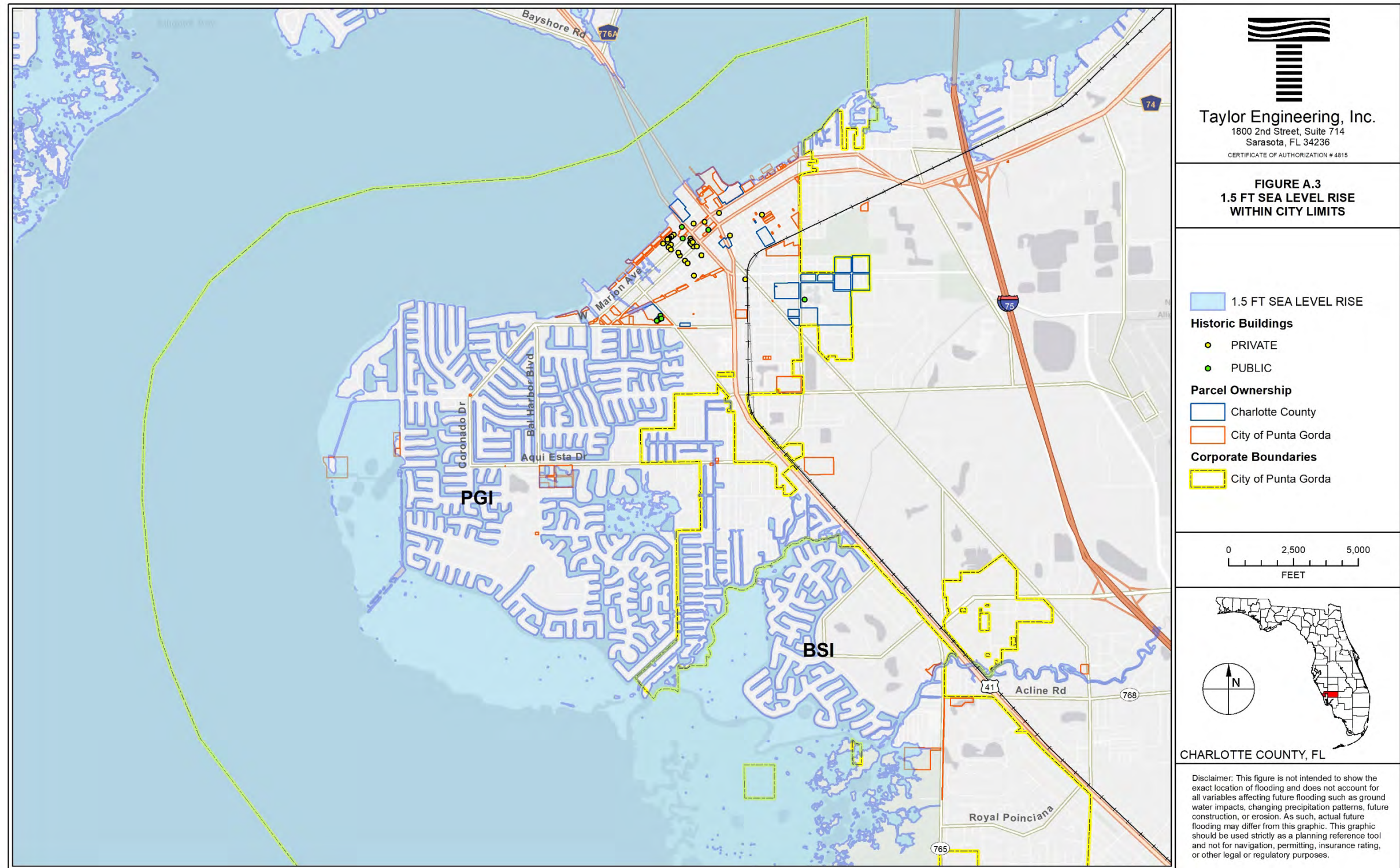


Figure A.3 1.5-Ft Sea Level Rise Within City Limits

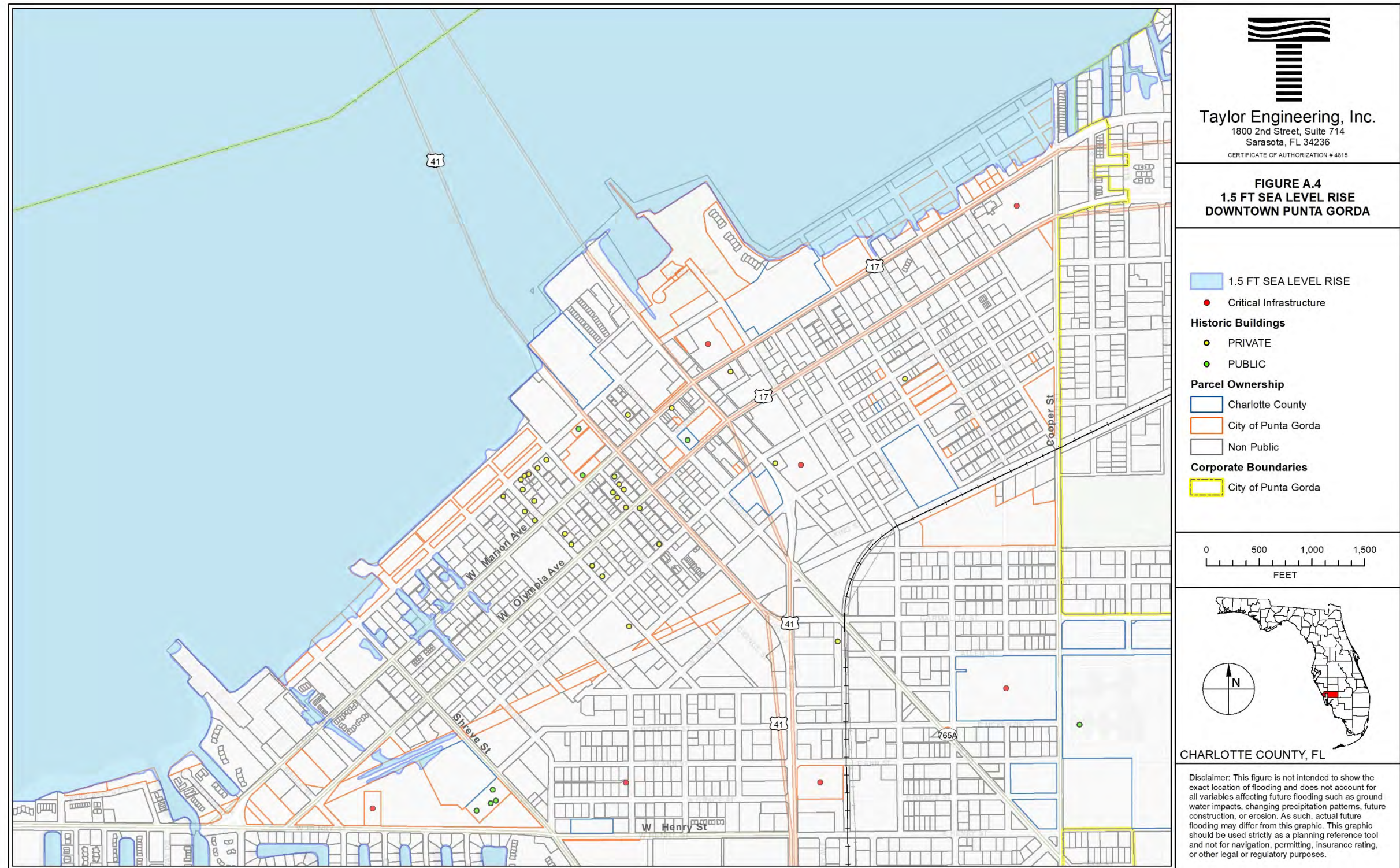


Figure A.4 1.5-Ft Sea Level Rise, Downtown Punta Gorda

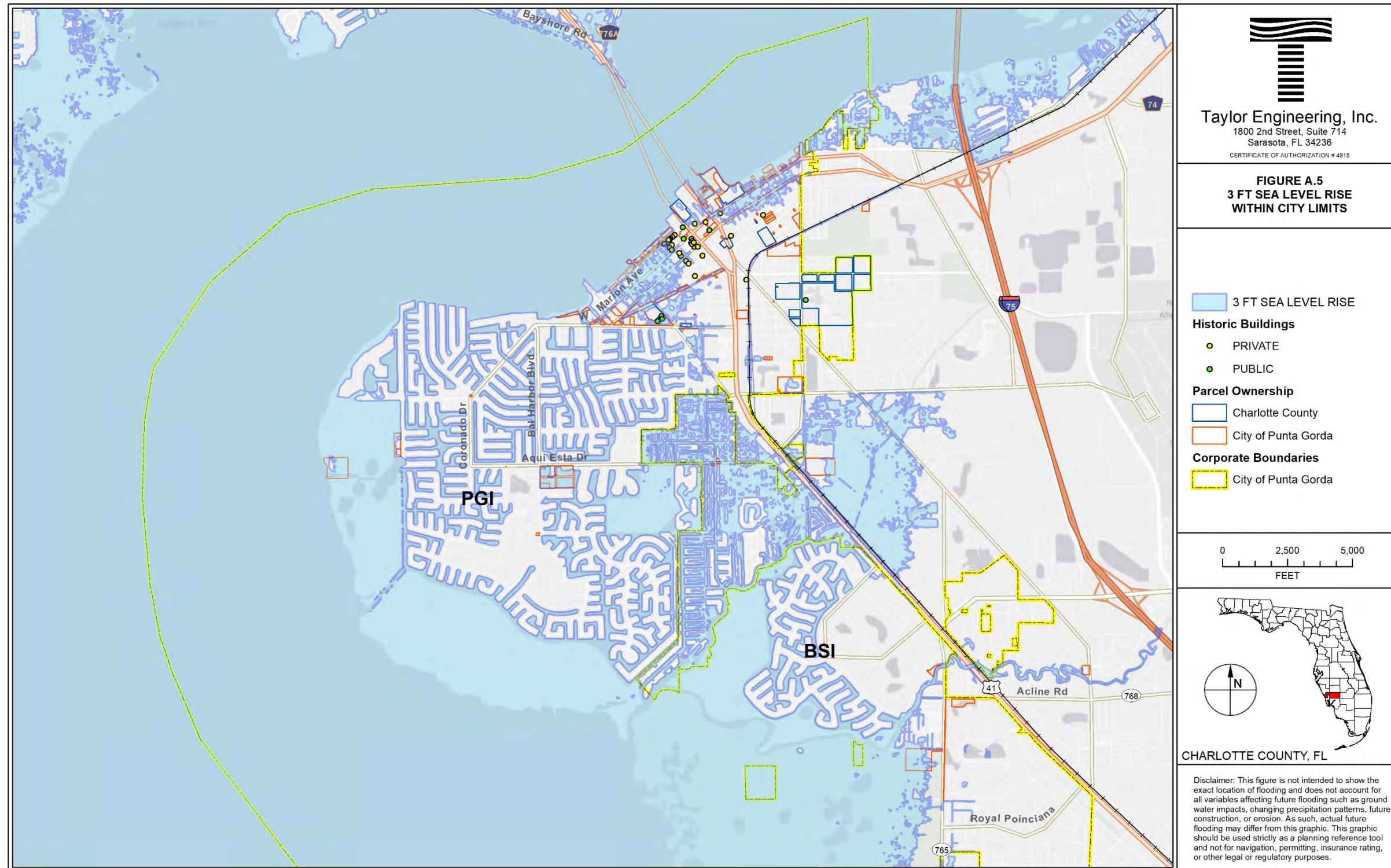


Figure A.5 3.0-Ft Sea Level Rise Within City Limits

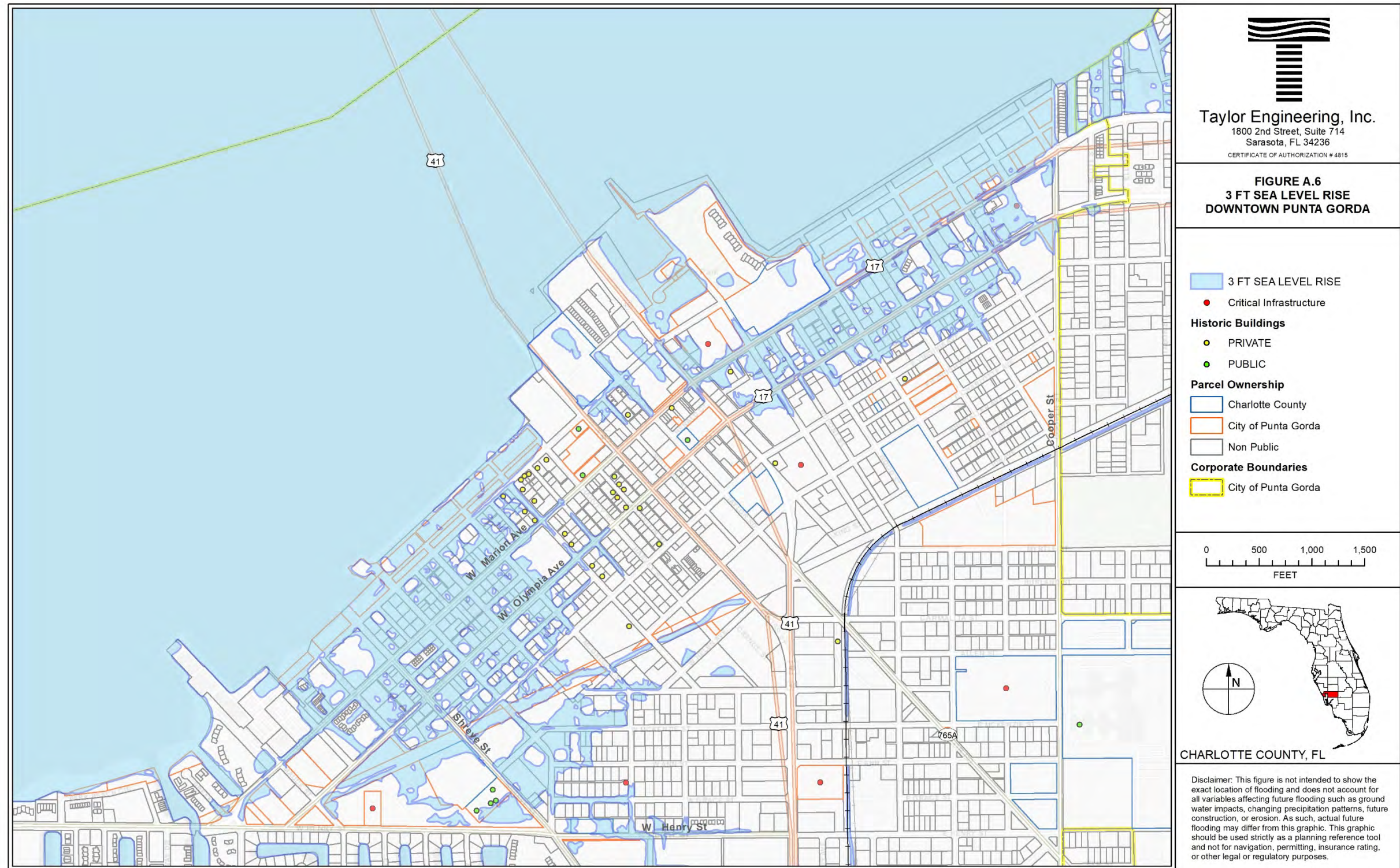


Figure A.6 3.0-Ft Sea Level Rise, Downtown Punta Gorda

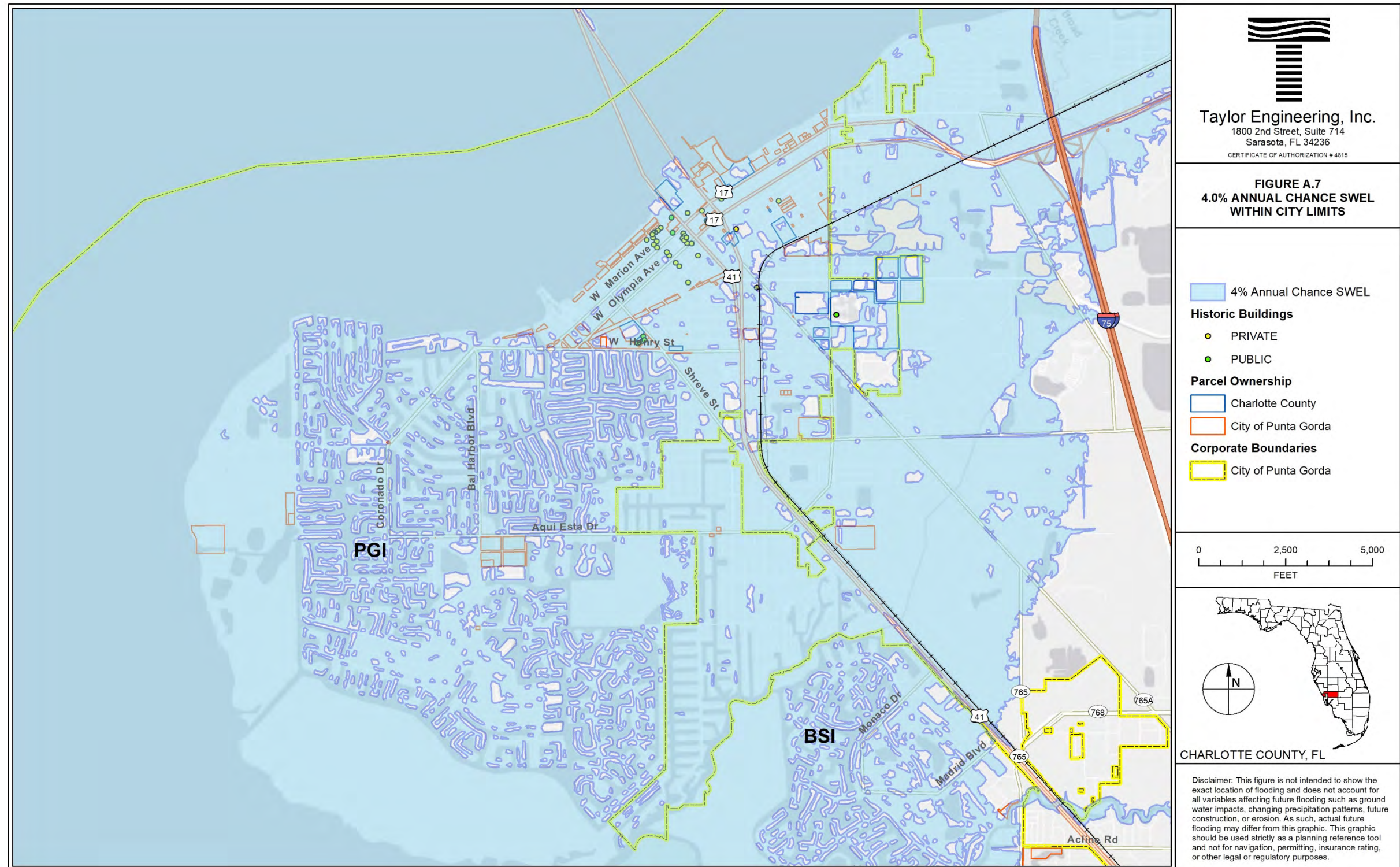


Figure A.7 4% Annual Chance SWEL Within City Limits

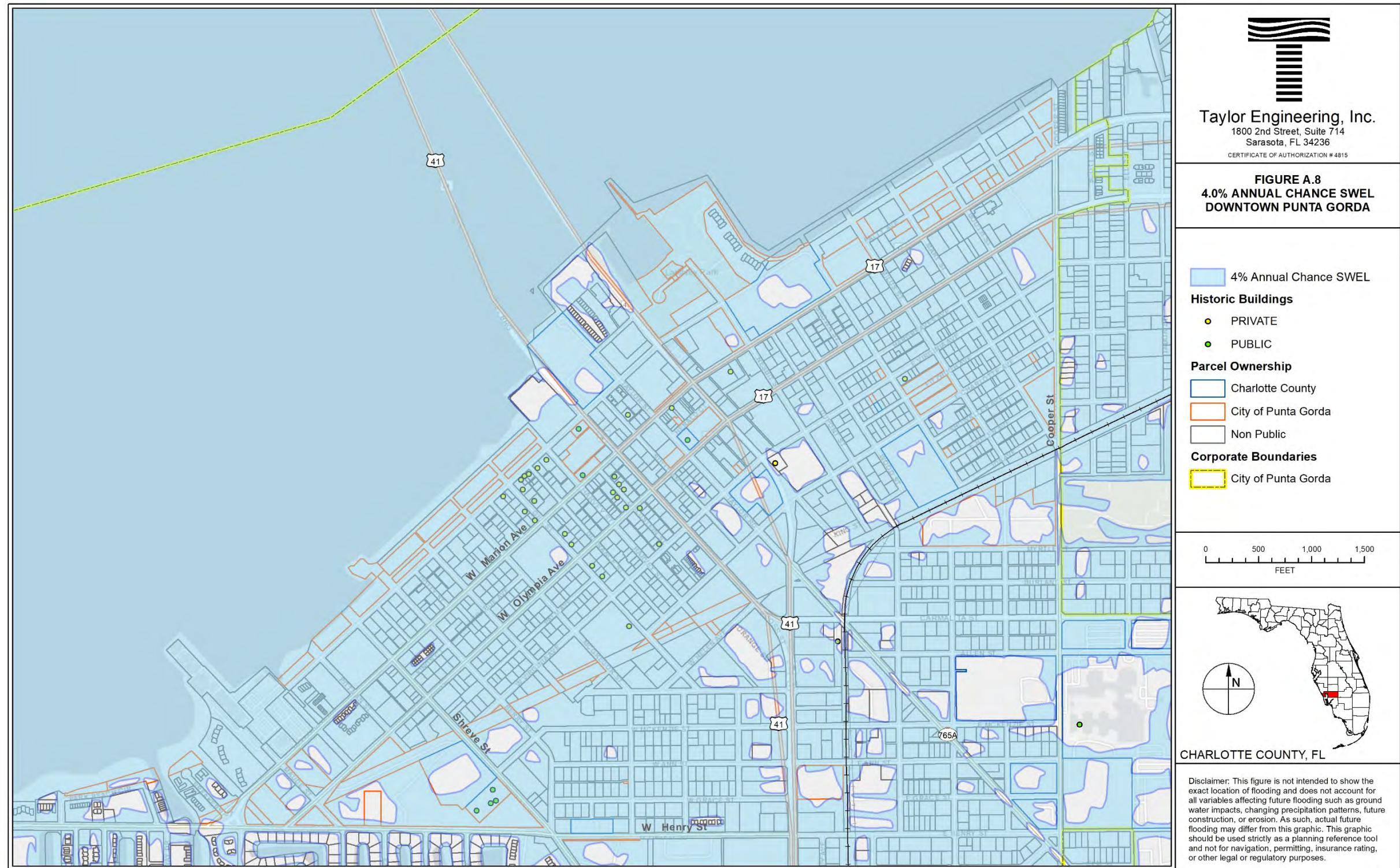


Figure A.8 4% Annual Chance SWEL, Downtown Punta Gorda

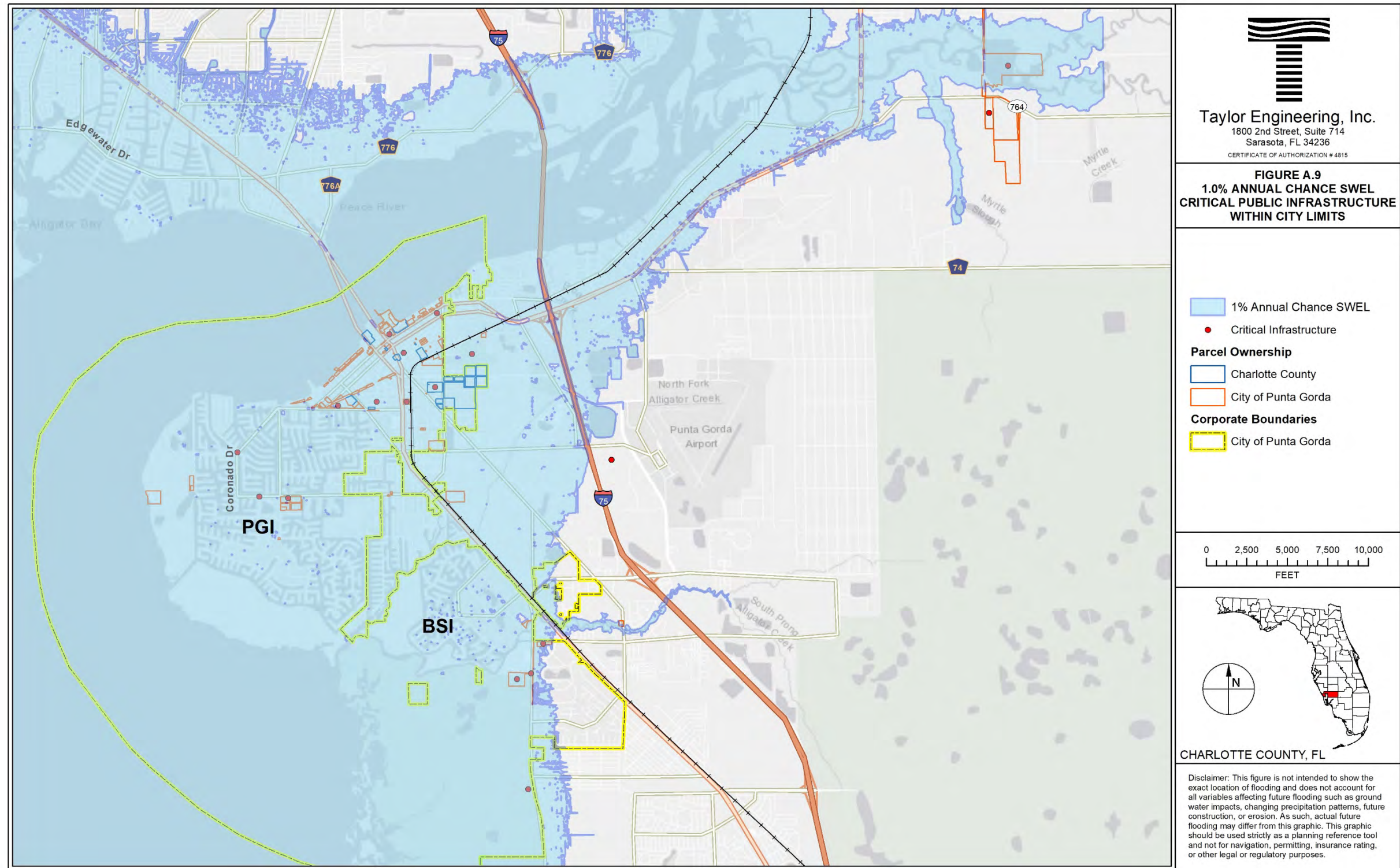


Figure A.9 1% Annual Chance SWEL, Critical Public Infrastructure

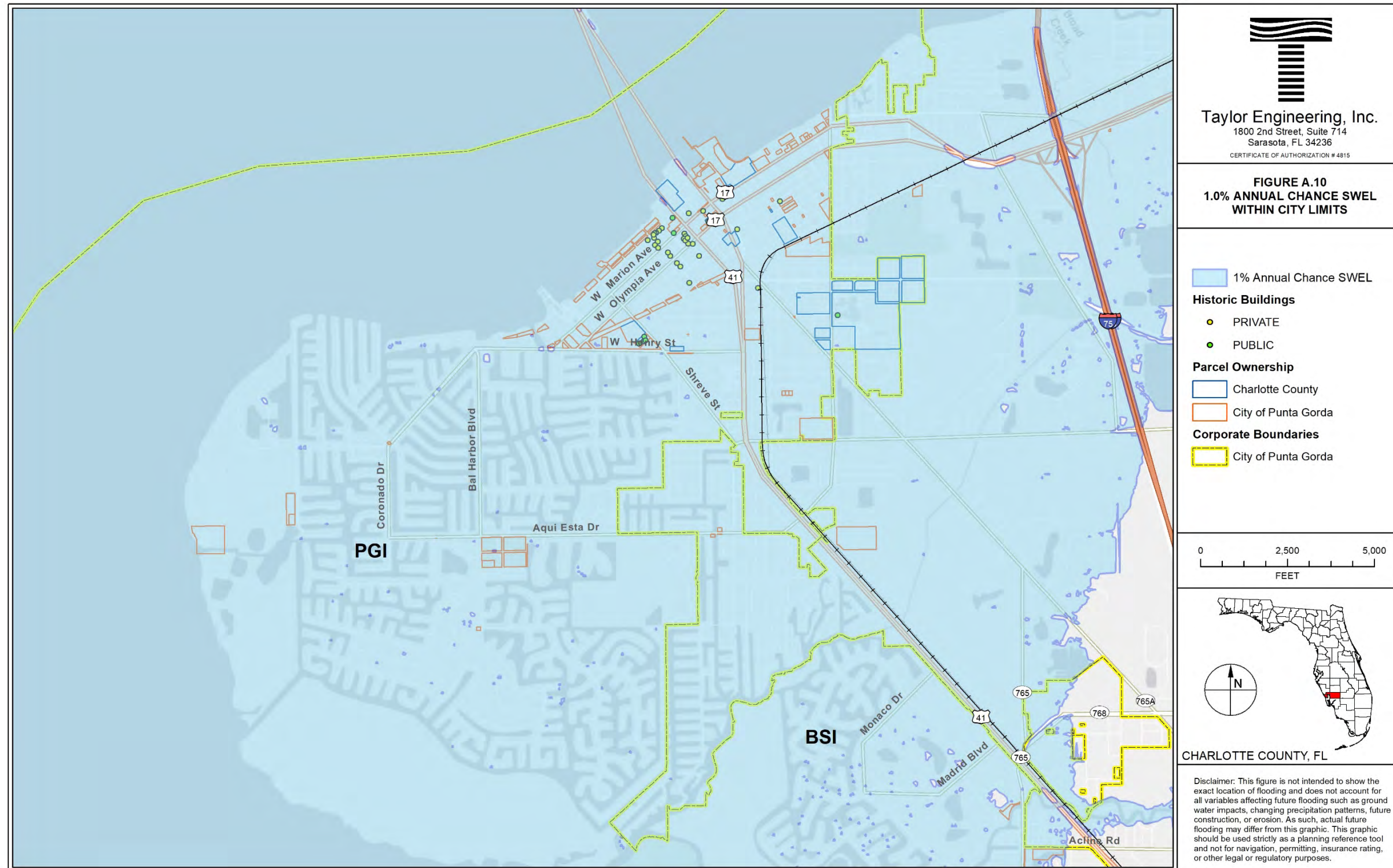


Figure A.10 1% Annual Chance SWEL Within City Limits

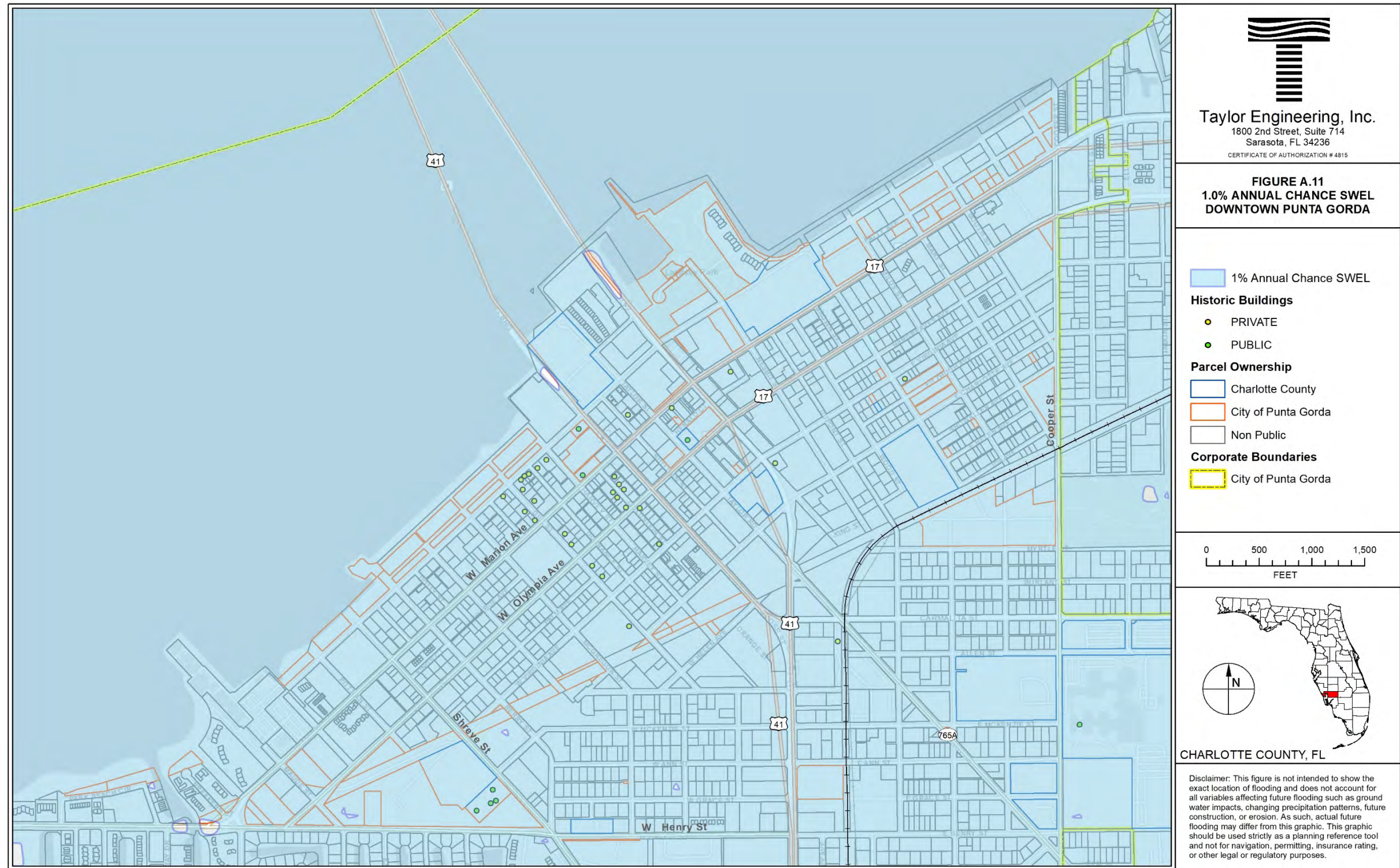


Figure A.11 1% Annual Chance SWEL, Downtown Punta Gorda

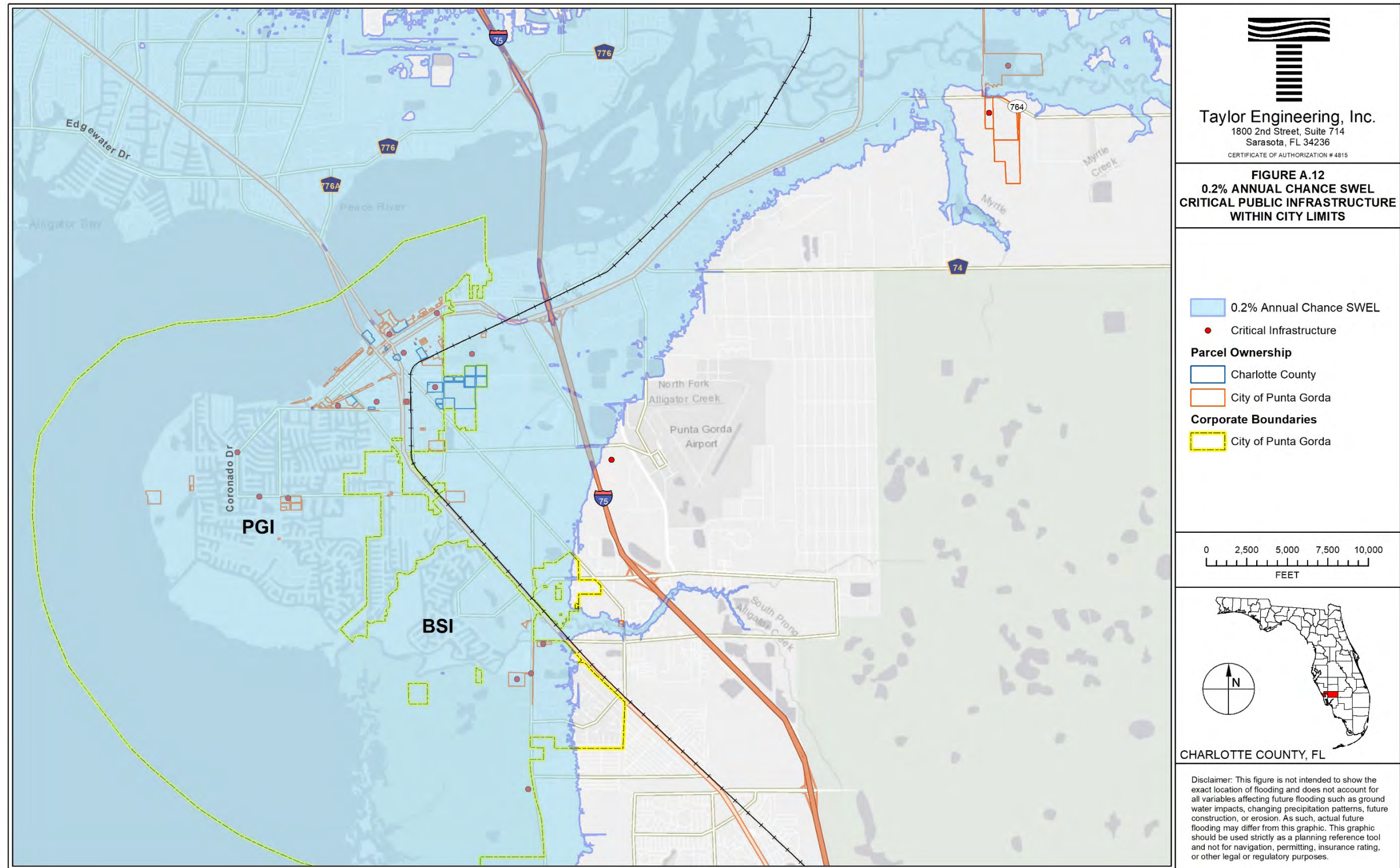


Figure A.12 0.2% Annual Chance SWEL, Critical Public Infrastructure

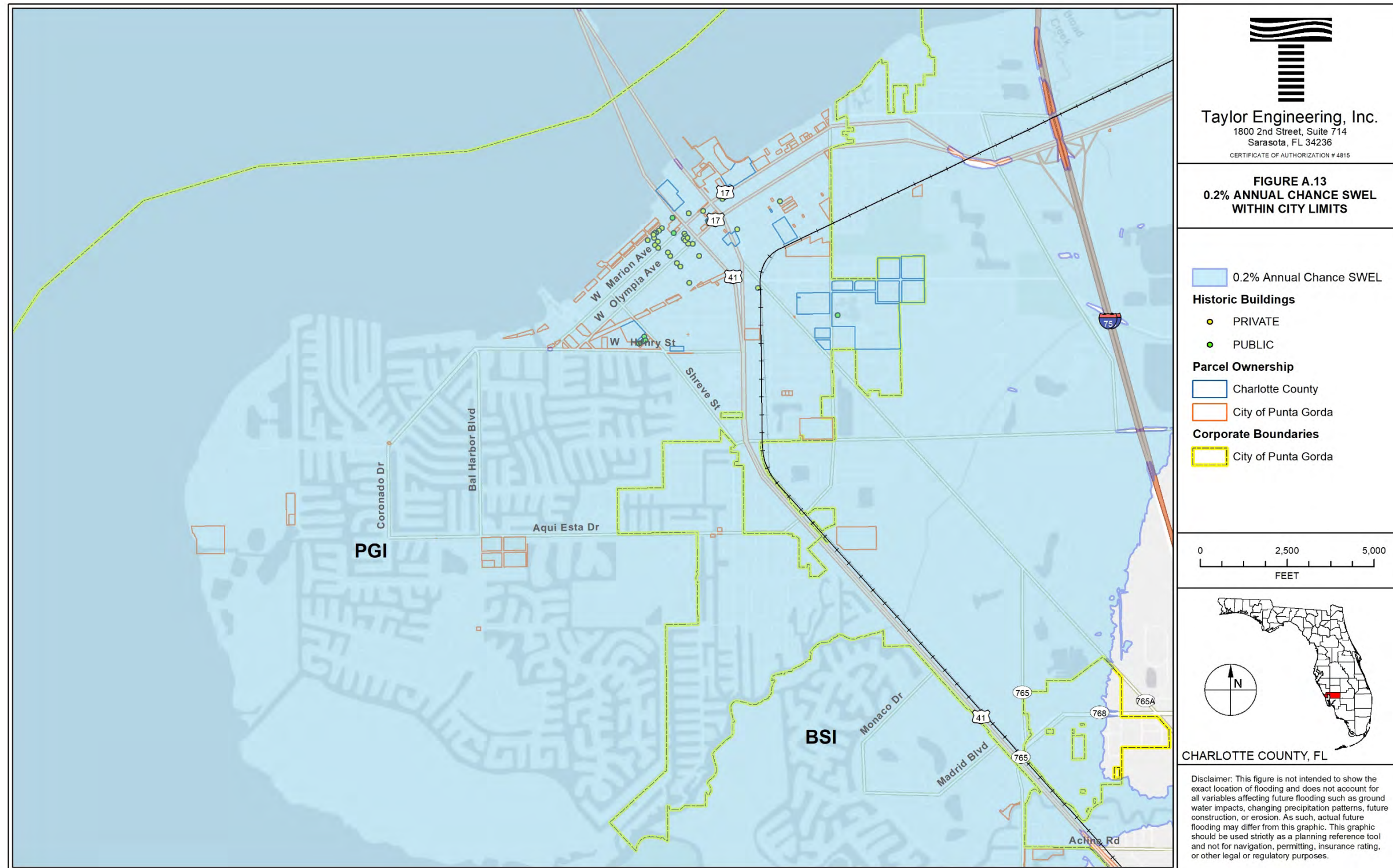


Figure A.13 0.2% Annual Chance SWEL Within City Limits

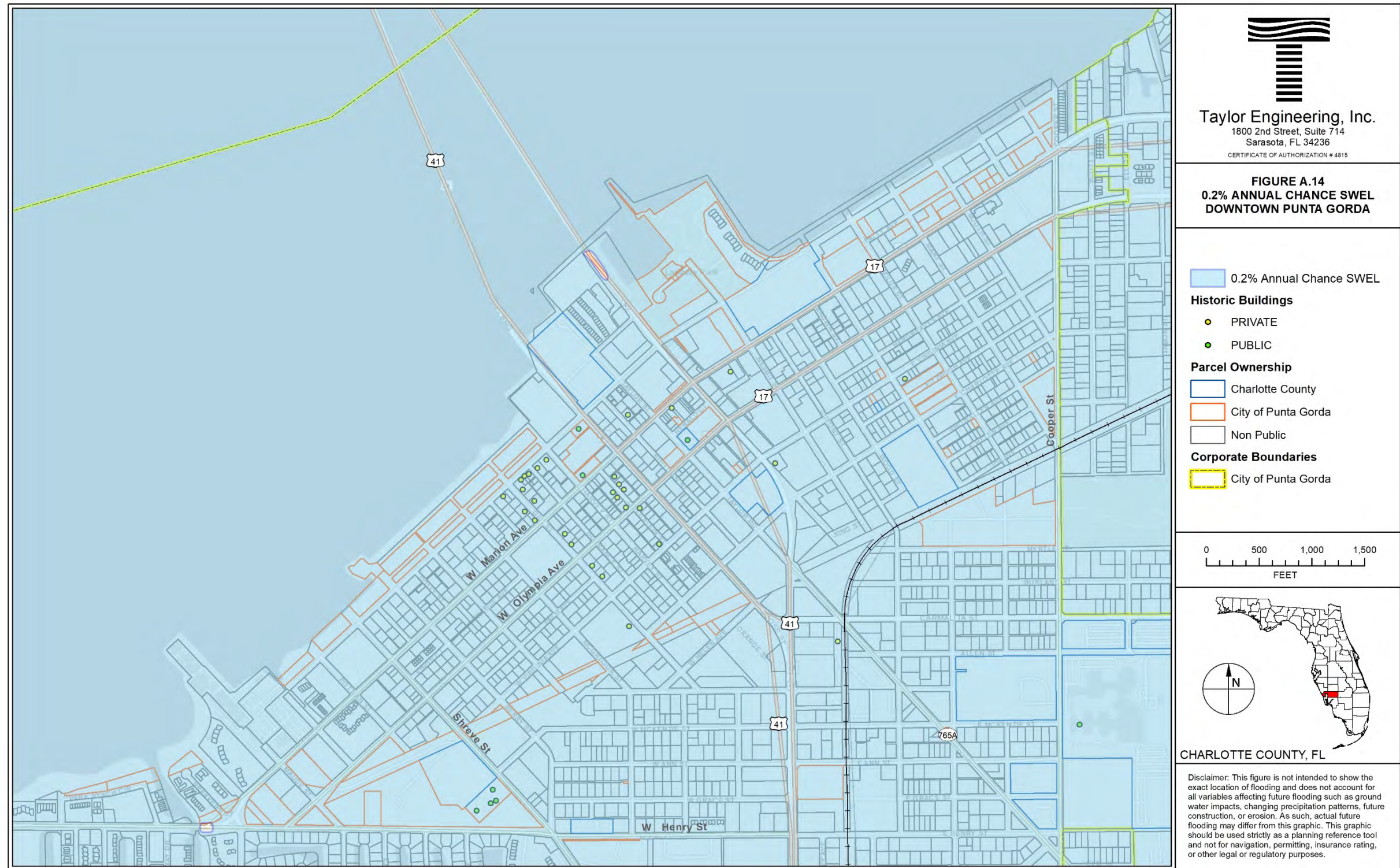


Figure A.14 0.2% Annual Chance SWEL, Downtown Punta Gorda

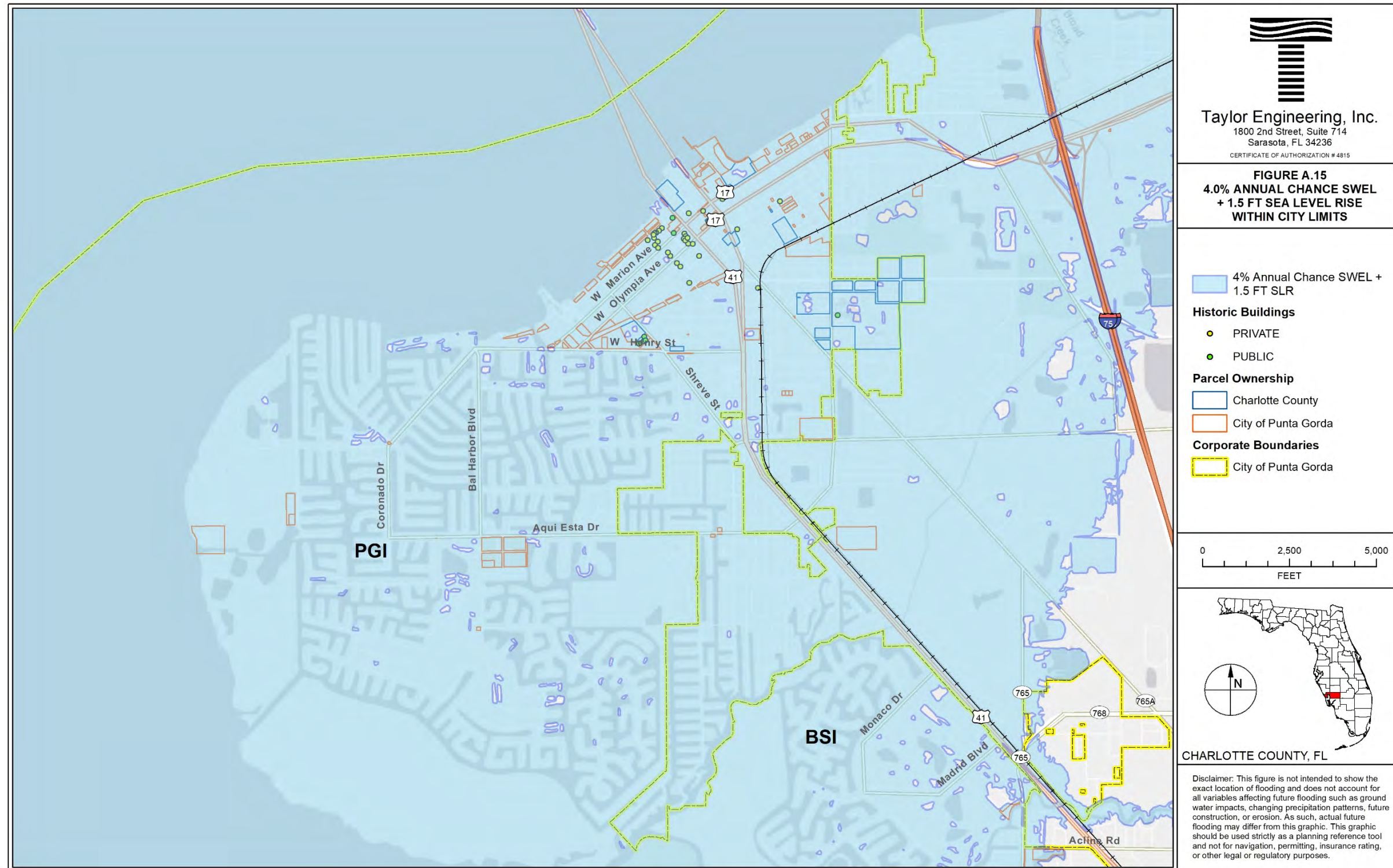


Figure A.15 4% Annual Chance SWEL + 1.5-Ft Sea Level Rise Within City Limits

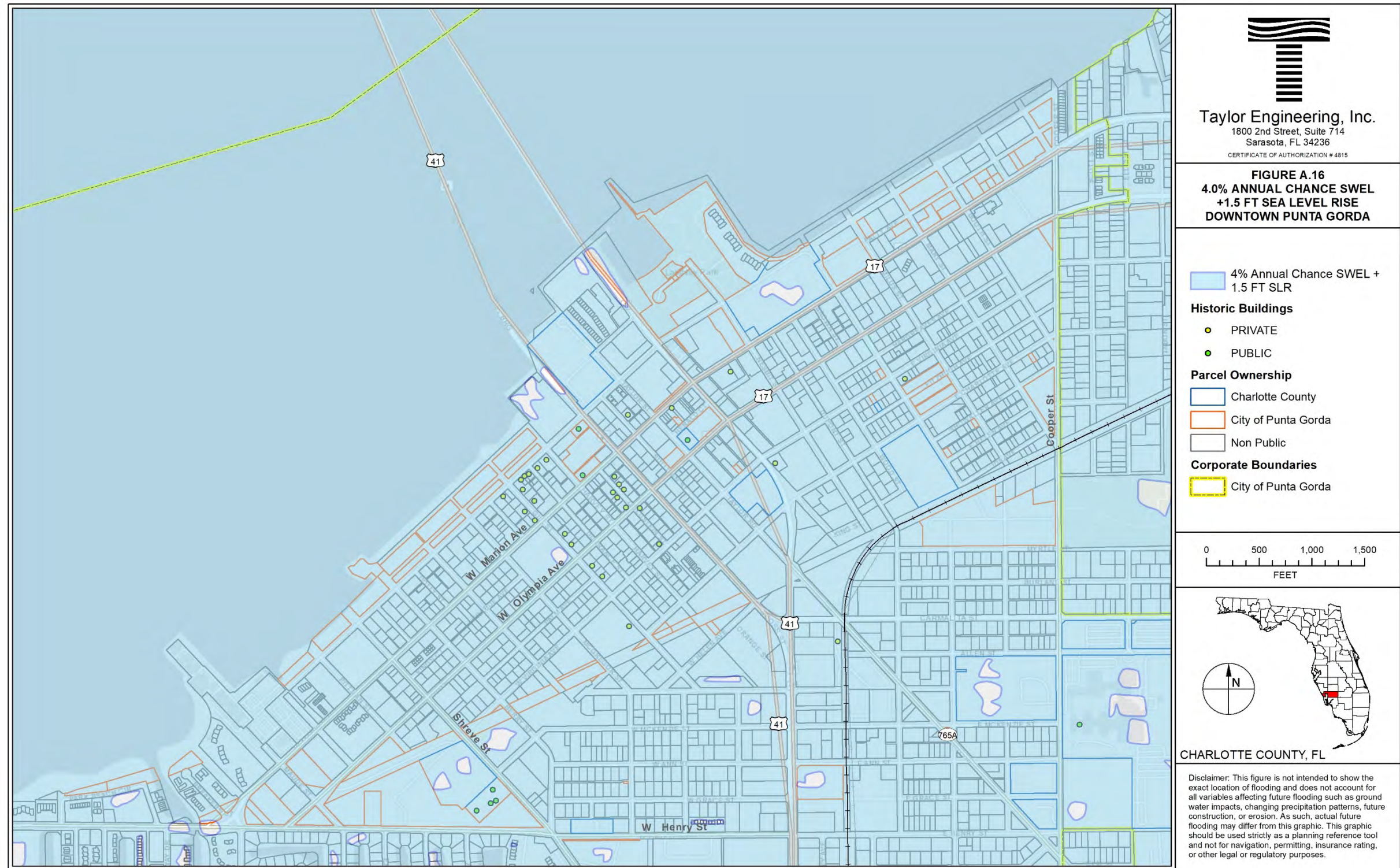


Figure A.16 4% Annual Chance SWEL + 1.5-Ft Sea Level Rise, Downtown Punta Gorda

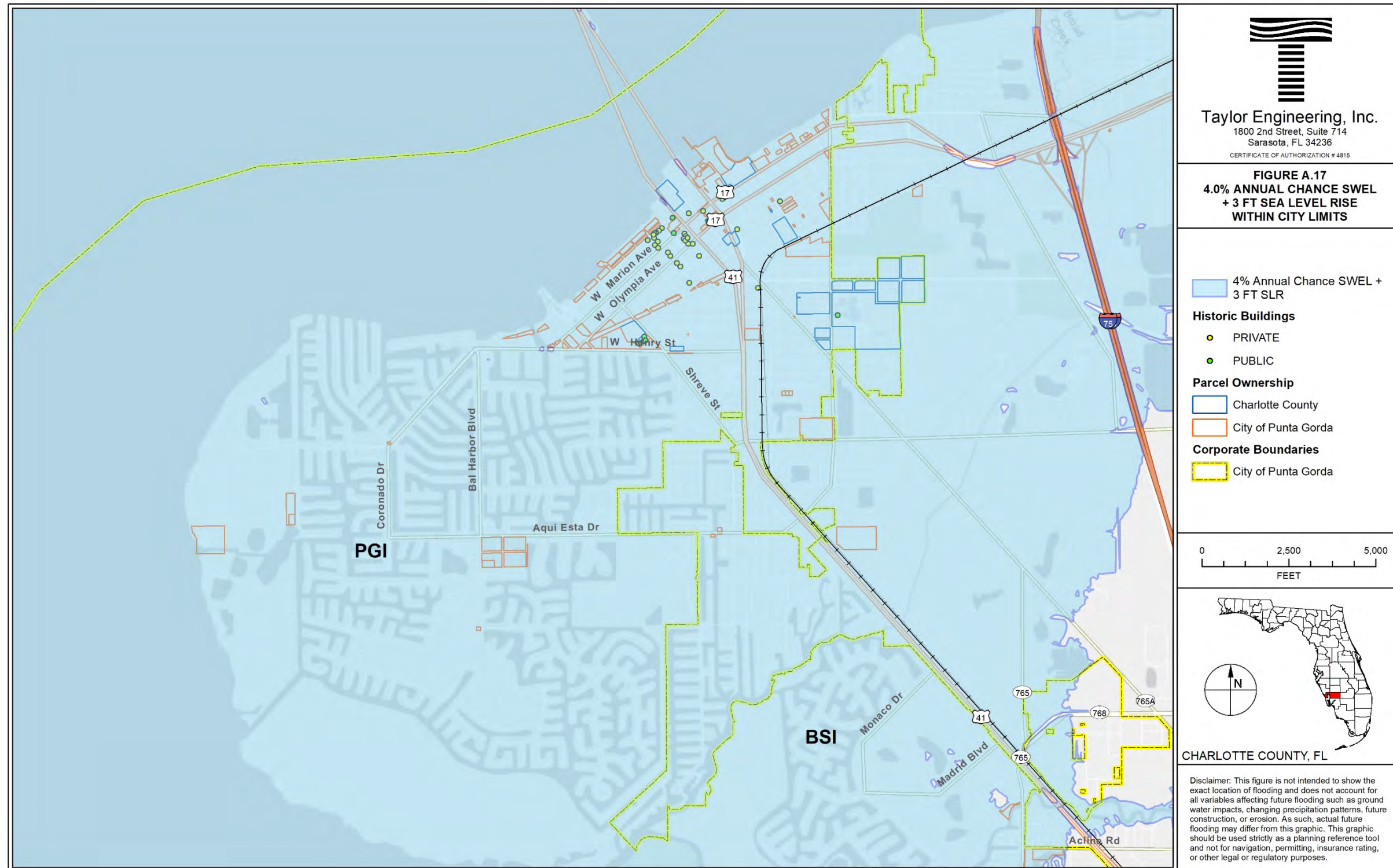


Figure A.17 4% Annual Chance SWEL + 3.0-Ft Sea Level Rise Within City Limits

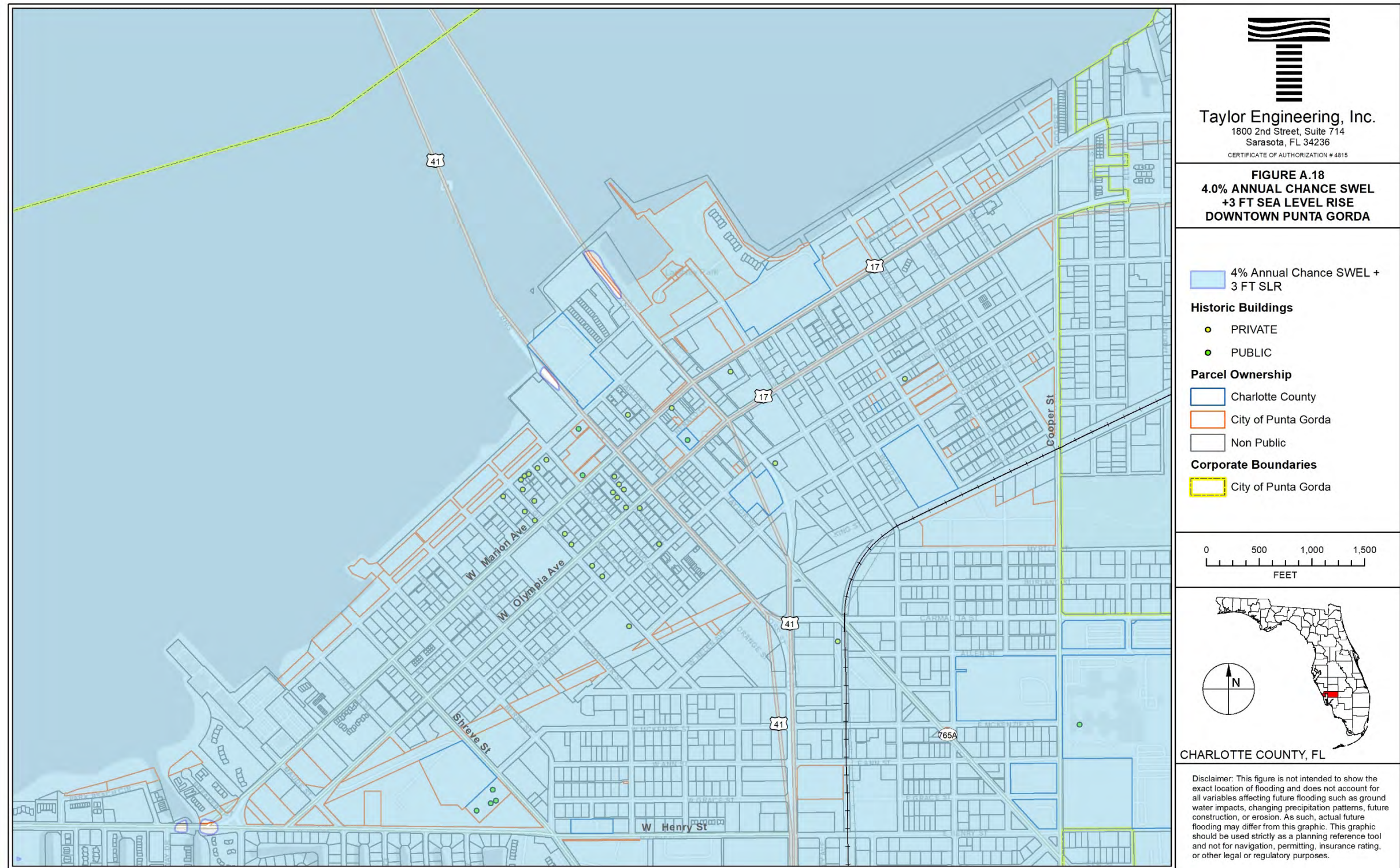


Figure A.18 4% Annual Chance SWEL + 3.0-Ft Sea Level Rise, Downtown Punta Gorda

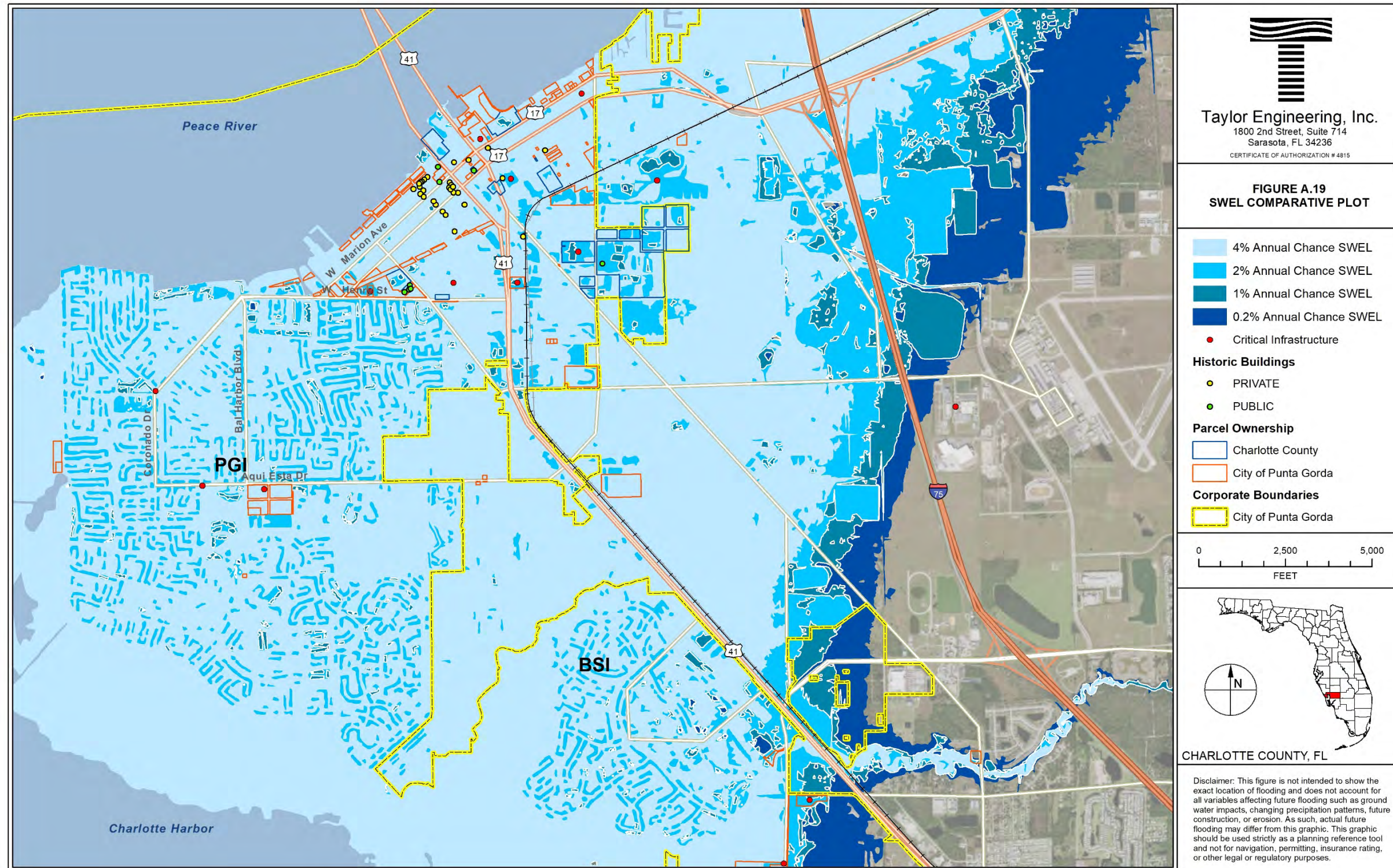


Figure A.19 SWEL Comparative Plot

Table A.1 Elevation Certificates Provided by The City

Address #	Street Name	Building Descriptor	FFE	LAG	Date Built or Surveyed
2601	Acline Rd	Seminole Lakes, Tract 1, Phase 1	11.71	10.4	2008
1623	Aqui Esta Drive	Booster Station	7	6.6	2000
1625	Aqui Esta Drive	PGC	13	N/A	N/A
4300	Bailey Ave	Booster Station	19.9	16.2	1984
30999	Bermont Rd	Wastewater Treatment Plant (Generator/Maintenance Bldg)	27.9	27.4	1984
10051	Burnt Store Rd	Fire Station 2	9.2	6.8	1983
3130	Cooper St	Cooper St Commerce Center (Utilities Administration)	8.8	8.4	2009
3132	Cooper St	Public Works Administration (NAVD88 Conversion=-1.18')	8.4	8	2009
100	E Retta Esplanade	Bldg #111, Harbormaster Bldg	10.5	10.3	2007
100	E Retta Esplanade	Bldg #2, Laishley Crabhouse Ctr (Aka 150 Laishley Ct)	10.6	4.4	2009
126	Harvey St	City Hall Annex	16.6	5.9	1992
117	Herald Court	Herald Court Garage	5.6	5.5	2009
650	Mary St	Cooper St Rec Center	7.2	6.8	1985
650	Mary St	Cooper St Rec Center Trabue Addition	9.3	6.4	2009
802	Retta Esplanade	Punta Gorda Boat Club-Shreve Park	5.6	5.4	1965
1410	S Tamiami Trail	Public Safety Bldg	9.3	6.3	2002
900	W Henry St	Public Works Customer Service (Master Pump Station)	8.5	8.2	1972
326	W Marion Ave	City Hall	7.9	6.1	1927
260	W Retta Esplanade	Museum Society	5.3	3.9	1958
400	W Retta Esplanade	Gilchrist Park Restroom (Required EI Of 13.3', Has A Flood Variance)	5.39	N/A	2006
750	W Retta Esplanade	Bayfront Center-Berry Park	5	4.6	1963
975	W Virginia Ave	Central Warehouse	9.1	8.6	1989
1007	W Virginia Ave	Canal Maintenance Office	5.1	4.6	1955
38100	Washington Loop Rd	Water Treatment Plant	17	16.5	1971

Table A.2 Historic Properties with Inundation in the 12 Coastal Flooding Scenarios

"X" Indicates This Parcel Shows Some Degree of Flood Inundation at The Corresponding Flood Scenario.

Name	Address	Account	Publicly Owned	MHHW	1.5 Ft SLR	3.0 Ft SLR	4% Annual Chance Flood	1% Annual Chance Flood	0.2% Annual Chance Flood	1.5 Ft SLR + 4% Annual Chance	1.5 Ft SLR + 1% Annual Chance	1.5 Ft SLR + 0.2% Annual Chance	3.0 Ft SLR + 4% Annual Chance	3.0 Ft SLR + 1% Annual Chance	3.0 Ft SLR + 0.2% Annual Chance
HISTORIC RESIDENCE	108 GILL ST	412201480001				X	X	X	X	X	X	X	X	X	X
WOMENS CLUB OF PUNTA GORDA	118 SULLIVAN ST	412306355001				X	X	X	X	X	X	X	X	X	X
SMITH ARCADE BUILDING	121 E MARION AVE -UNIT 125	412306331005				X	X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	123 GILL ST	412201479008				X	X	X	X	X	X	X	X	X	X
HISTORY PARK	501 SHREVE ST	412212280002	Y			X	X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	509 W RETTA ESPLANADE	412201479002				X	X	X	X	X	X	X	X	X	X
CHARLOTTE HS/MS	1001 EDUCATION AVE	412308151001	Y					X	X	X	X	X	X	X	X
PUNTA GORDA RAILROAD DEPOT	1009 TAYLOR RD	412307202005					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	122 GILL ST	412306351001					X	X	X	X	X	X	X	X	X
CITY HALL ANNEX	126 HARVEY ST	412306353004	Y				X	X	X	X	X	X	X	X	X
AC FREEMAN HOUSE	126 HARVEY ST	412306353004	Y				X	X	X	X	X	X	X	X	X
FIRST NATIONAL BANK BUILDING	128 HERALD CT	412306376005					X	X	X	X	X	X	X	X	X
DUPLEX/RESIDENTIAL	212 GILL ST -UNIT B	412306356004					X	X	X	X	X	X	X	X	X
OLD SCHOOL HOUSE APTS	215 GOLDSTEIN ST	412306358012					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	219 GOLDSTEIN ST	412306358013					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	224 GILL ST	412306356006					X	X	X	X	X	X	X	X	X
OLD COURTHOUSE	226 TAYLOR ST	412306378001	Y				X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	231 GOLDSTEIN ST	412306358015					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	302 GOLDSTEIN ST	412306364001					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	310 GILL ST	412307106002					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	331 GOLDSTEIN ST	412306363010					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	350 GILL ST	412307106004					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	401 W RETTA ESPLANADE	412306352002					X	X	X	X	X	X	X	X	X
FIRST BAPTIST CHURCH	403 GILL ST	412307111008					X	X	X	X	X	X	X	X	X
BLANCHARD HOUSE	406 DR MARTIN LUTHER KING JR BLVD	412306415001					X	X	X	X	X	X	X	X	X
ICEHOUSE	408 TAMIAMI TRL	412306388001					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	413 W RETTA ESPLANADE	412306352001					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	451 W RETTA ESPLANADE	412201480005					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	455 W RETTA ESPLANADE	412201480004					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	459 W RETTA ESPLANADE	412201480003					X	X	X	X	X	X	X	X	X
HISTORIC RESIDENCE	502 W MARION AVE	412201479010					X	X	X	X	X	X	X	X	X



Table A.3 Critical Facilities with Inundation in the 12 Coastal Flooding Scenarios.

"X" Indicates This Parcel Shows Some Degree of Flood Inundation at The Corresponding Flood Scenario.

Name	Address	Account	Publicly Owned	Within City Limits	MHHW	1.5 Ft SLR	3.0 Ft SLR	4% Annual Chance Flood	1% Annual Chance Flood	0.2% Annual Chance Flood	1.5 Ft SLR + 4% Annual Chance	1.5 Ft SLR + 1% Annual Chance	1.5 Ft SLR + 0.2% Annual Chance	3.0 Ft SLR + 4% Annual Chance	3.0 Ft SLR + 1% Annual Chance	3.0 Ft SLR + 0.2% Annual Chance
FIRE STATION III	1623 AQUI ESTA DR	412213301001	Y	Y		X	X	X	X	X	X	X	X	X	X	X
SHELL CREEK RESERVOIR	38171 WASHINGTON LOOP RD	402420400001	Y			X	X	X	X	X	X	X	X	X	X	X
PG WATER TANK	10401 BURNT STORE RD	412329434001	Y	Y		X	X		X	X	X	X	X	X	X	X
US POST OFFICE PG	130 E MARION AVE	412306328008	Y	Y			X	X	X	X	X	X	X	X	X	X
BAYFRONT HEALTH PUNTA GORDA	809 E MARION AVE	412306284002		Y			X	X	X	X	X	X	X	X	X	X
LIFT STATION	1421 MCGREGOR ST	412307156018	Y	Y				X	X	X	X	X	X	X	X	X
LIFT STATION	AQUI ESTA DR	412214426001	Y	Y				X	X	X	X	X	X	X	X	X
ELECTRIC TRANSFORMERS	W MARION AVE	412211455001	Y	Y				X	X	X	X	X	X	X	X	X
POLICE & FIRE DEPARTMENT	111 E ANN ST	412307258001	Y	Y					X	X	X	X	X	X	X	X
FPL MAINTENANCE AREA	122 E CHARLOTTE AVE	412306452001		Y					X	X	X	X	X	X	X	X
SALLIE JONES ELEM SCHOOL	1230 NARRANJA ST	412307277001	Y	Y					X	X	X	X	X	X	X	X
FIRE STATION II	2601 ACLINE RD	412328151002	Y	Y					X	X	X	X	X	X	X	X
SOUTH COUNTY REGIONAL PARK	670 COOPER ST	412305376001	Y						X	X	X	X	X	X	X	X
PG WASTEWATER STATION	W HENRY ST	412212280003	Y	Y					X	X	X	X	X	X	X	X
FPL SUB STATION	11521 BURNT STORE RD	412332476001		Y					X	X		X	X	X	X	X
COUNTY JAIL/EMERGENCY OPERATIONS	26571 AIRPORT RD	412316200006	Y							X		X	X		X	X
WATER TREATMENT FACILITY	38100 WASHINGTON LOOP RD	402429100009	Y									X	X		X	X

Table A.4 Estimated Economic Impacts on Critical Infrastructure at the 1% Annual Chance Flood

NAME	ADDRESS	ACCOUNT	2019 BUILDING VALUE	YEAR BUILT	EST. FLOOD DAMAGE AT 1% ANNUAL CHANCE FLOOD
FIRE STATION III	1623 AQUI ESTA DR	412213301001	\$711,061	1996	\$158,567
SHELL CREEK RESERVOIR	38171 WASHINGTON LOOP RD	402420400001	unavailable	unavailable	no bldg value
PG WATER TANK	10401 BURNT STORE RD	412329434001	unavailable	unavailable	no bldg value
US POST OFFICE PG	130 E MARION AVE	412306328008	\$1,784,831	1974	no FFE
BAYFRONT HEALTH PUNTA GORDA	809 E MARION AVE	412306284002	\$9,726,372	1956	no FFE
LIFT STATION	1421 MCGREGOR ST	412307156018	\$655	1966	no FFE
LIFT STATION	AQUI ESTA DR	412214426001	unavailable	unavailable	no bldg value
ELECTRIC TRANSFORMERS	W MARION AVE	412211455001	unavailable	unavailable	no bldg value
POLICE & FIRE DEPARTMENT	111 E ANN ST	412307258001	\$2,484,054	2002	\$553,944
FPL MAINTENANCE AREA	122 E CHARLOTTE AVE	412306452001	\$569,317	1960	no FFE
SALLIE JONES ELEM SCHOOL	1230 NARRANJA ST	412307277001	\$15,177,240	2003	no FFE
FIRE STATION II	2601 ACLINE RD	412328151002	\$1,210,368	2008	no flooding
SOUTH COUNTY REGIONAL PARK	670 COOPER ST	412305376001	\$354,824	2005	no FFE
PG WASTEWATER STATION	W HENRY ST	412212280003	\$105,693	1984	\$24,626
FPL SUB STATION	11521 BURNT STORE RD	412332476001	\$5,676	1992	no FFE
COUNTY JAIL/EMERGENCY OPERATIONS	26571 AIRPORT RD	412316200006	\$56,546,018	2000	no FFE
WATER TREATMENT FACILITY	38100 WASHINGTON LOOP RD	402429100009	\$1,200,821	1971	no flooding



APPENDIX B

ADAPTATION STRATEGIES MATRIX

Table B.1 Adaptation Strategies Matrix

ADAPTATION TYPE	ADAPTATION TITLE	DESCRIPTION	SHORT, INTERMEDIATE, OR LONG TERM	MICRO / MACRO	GRAY, GREEN, OR HYBRID	DEGREE OF PROTECTION (LOW, MED, HIGH)	COST (\$,\$\$,,\$\$)
Economic Assessment and Planning	Taxation and Budgets	Add climate change considerations to taxation and budget reform	LONG TERM	MACRO	GREEN	MEDIUM	\$
Economic Assessment and Planning	Building Code Incentives	Create incentives for individuals and businesses to reduce risk of losses due to climate through building design codes	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$
Economic Assessment and Planning	Funding Support for Relocation	Identify financial and economic support mechanisms in response to relocation	INTERMEDIATE	MACRO	GREEN	LOW	\$
Economic Assessment and Planning	Financial Impact Assessment	Assess financial impact of property value changes	SHORT	MACRO	GRAY	LOW	\$
Economic Assessment and Planning	Funding for Adaptation Strategies	Provide funding for local communities to develop and implement location appropriate adaptation strategies	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$
Economic Assessment and Planning	Social Impacts Vulnerable Communities	Assess potential social impacts of climate change on incomes, and other measures of well-being in vulnerable communities	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Economic Assessment and Planning	Insurance Costs	Address increased insurance costs, especially in disaster sensitive, remote and/or economically challenged areas	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Economic Assessment and Planning	Economic Incentives	Provide economic incentives for building in non-risk zones	LONG TERM	MACRO	GREEN	MEDIUM	\$\$
Economic Assessment and Planning	Encourage Climate Impact Investments	Encourage private insurers, as investors, and the state pension funds to consider climate impact prevention in the prudent investment of portfolios. Create incentives for private investment in creating 'climate safe' development	LONG TERM	MICRO	HYBRID	MEDIUM	\$
Economic Assessment and Planning	Federal Funding	Seek federal funds for climate costs	SHORT	MICRO	HYBRID	MEDIUM	\$
Economic Assessment and Planning	Short, Mid, and Long Term Budgets	Establish short-, mid- and long-term budgets that include adaptation strategies and capital investments over time	LONG TERM	MACRO	HYBRID	MEDIUM	\$
Emergency Strategies	Sandbags	Temporary barriers constructed of sandbags can be used to protect structures or system components from flooding or provide additional height to existing flood barriers before flooding reaches critical levels	SHORT	MICRO	GRAY	MEDIUM	\$
Emergency Strategies	Temporary Flood Barriers	Temporary, self-supporting flood barriers that can be assembled, moved into place, anchored, and filled with water, sand or gravel and then removed after flood threats have passed.	SHORT	MICRO	GRAY	MEDIUM	\$\$
Emergency Strategies	Flood Wrapping Systems	Flood wrapping systems are temporary emergency measures in which plastic or other synthetic waterproof sheeting material is used to seal buildings and prevent water intrusion into the building and associated systems.	SHORT	MICRO	GRAY	MEDIUM	\$
Emergency Strategies	Flood Shelters	Flood shelters are created in areas which experience severe flash flooding. Elevated flood shelters should be constructed above the highest expected flood levels. They should be easily accessible and should be able to accommodate all people in the vicinity.	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Emergency Strategies	Protection of Life Support Facilities / Dangerous Goods	Life support facilities and dangerous goods like nuclear plants should be well defended against climate extremes. This vital infrastructure should be up and running even during extreme conditions.	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Emergency Strategies	Emergency Evacuation	Coordinate emergency evacuation and supply transportation routes with emergency preparedness systems to ensure capacity and resilience of escape routes compromised by natural disasters related to climate change	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Identification and Monitoring	Online Mapping	Include online mapping capability in planning information for multiple audiences including local governments	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$
Identification and Monitoring	Sea Level Rise Visualization	Create visualization tool for sea level rise and associated hazards	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$
Identification and Monitoring	Assessment of Trends	Conduct assessment of trends in change in land use and stability of natural landscapes	INTERMEDIATE	MACRO	GREEN	LOW	\$
Identification and Monitoring	Data Collection	Support ongoing collection and analysis of sea level rise, storm surge, and tidal data by existing institutions	LONG TERM	MACRO	GREEN	MEDIUM	\$
Identification and Monitoring	Transportation Routes Effectuated	Identify and reevaluate use of transportation routes in floodplains and coastal hazard zones	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$
Identification and Monitoring	Vulnerability Assessment	Conduct a vulnerability assessment for cultural resources such as museums and historical sites	INTERMEDIATE	MACRO	GRAY	LOW	\$
Identification and Monitoring	Evaluate Water Supply	Evaluate the vulnerability of the water supply systems and networks to climate change related impacts. Develop strategies to add resilience to these systems.	LONG TERM	MACRO	HYBRID	MEDIUM	\$
Identification and Monitoring	Identify Vulnerable Species	Map vulnerability of full spectrum of biodiversity (terrestrial, aquatic and marine)	INTERMEDIATE	MACRO	GREEN	LOW	\$



ADAPTATION TYPE	ADAPTATION TITLE	DESCRIPTION	SHORT, INTERMEDIATE, OR LONG TERM	MICRO / MACRO	GRAY, GREEN, OR HYBRID	DEGREE OF PROTECTION (LOW, MED, HIGH)	COST (\$,\$\$,,\$\$)
Identification and Monitoring	Map Land Changes	Map vulnerability of areas subject to salinification and erosion under different climate scenarios	SHORT	MACRO	GREEN	LOW	\$
Identification and Monitoring	Consolidate Ecological Monitoring	Consolidate and cross-reference ecological monitoring networks	SHORT	MACRO	GREEN	LOW	\$
Identification and Monitoring	Develop Biological Indicators	Develop a system of biological indicators for impact assessment	INTERMEDIATE	MACRO	GREEN	LOW	\$
Identification and Monitoring	Vulnerability of Flora and Fauna	Assess the vulnerability of special designation areas, areas of unique flora and fauna and areas of essential ecosystem goods and services	SHORT	MACRO	GREEN	LOW	\$
Identification and Monitoring	Mapping of Impacts on Watersheds	Improve mapping and characterization of likely storm and precipitation impacts to watersheds and riverine flood zones.	SHORT	MACRO	GREEN	LOW	\$
Identification and Monitoring	Coastal Models	Develop morphodynamic and ecological response models of primary coastal zones according to different climate scenarios	INTERMEDIATE	MACRO	HYBRID	LOW	\$\$
Identification and Monitoring	Coastal Vulnerability	Inventory and map the estuarine and ocean shoreline and its bathymetry, sediments, and vegetation. Assess vulnerability.	INTERMEDIATE	MACRO	HYBRID	LOW	\$\$
Identification and Monitoring	Shoreline Assessment	Conduct a shoreline impact assessment to establish baseline of data on the existing coastal resources and the projected impacts of sea level rise, include tides, weather	SHORT	MACRO	GREEN	LOW	\$
Identification and Monitoring	Vulnerable Populations	Identify health-related vulnerabilities of people, region, infrastructure and the economy	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Identification and Monitoring	Identify Vulnerable Cultural Resources	Complete a vulnerability assessment to identify specific cultural resources that may be most sensitive to climate change.	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Identification and Monitoring	Assess Disruptions	Assess potential disruption to states major economic sectors due to climate change	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Identification and Monitoring	Assess Value of Beach Services	Assess full value of beach services including habitat, tourism, storm buffer, etc.	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Identification and Monitoring	Tourism Climate Change Assessment	Conduct a climate change impact assessment by tourist region and resources, with a focus on most vulnerable sectors and locations and develop tourism policies integrating economic and resource conservation issues in the face of potential and observed consequences of climate change	SHORT	MICRO	GRAY	LOW	\$
Information and Education	Trades and Vocational Training	Establish structured training and vocational support for trades and others involved in implementation of new design standards	INTERMEDIATE	MICRO	HYBRID	LOW	\$
Information and Education	Integration into Higher Education	Integrate climate change and adaptation issues into advanced training in university, community college, and technical training programs	INTERMEDIATE	MICRO	HYBRID	LOW	\$
Information and Education	Healthy Waterways	Support healthy rivers, streams and riparian vegetation to maintain water quality	LONG TERM	MACRO	GREEN	MEDIUM	\$
Information and Education	Public Education	Provide outreach to the public and others to plan and prepare for climate change	INTERMEDIATE	MACRO	GREEN	LOW	\$
Information and Education	Educate Tourists	Ensure accurate information reaches current and potential tourists on behaviors and uses that ensure environmental quality and ecosystem resiliency at popular travel destinations	INTERMEDIATE	MICRO	HYBRID	LOW	\$
Infrastructure Management	Promote Wetland Accretion by Introducing Sediment	Maintains sediment transport to wetlands, which protects coastal land from storms	LONG TERM	MACRO	GREEN	HIGH	\$\$
Infrastructure Management	Utility Elevation	Installing or locating utility systems and components at or above the flood protection level required by local flood plain management regulations or building codes.	LONG TERM	MICRO	GRAY	HIGH	\$
Infrastructure Management	Utility Relocation	Moving existing utility systems and components previously installed below the base flood elevation to less vulnerable locations, preferably above the flood protection level required for new construction.	Intermediate	MICRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Component Protection	Protection of a system, equipment component, or group of components for exposure when located below the required flood protection level. Can include dry floodproofing for non-residential.	Intermediate	MICRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Flood Barriers (Passive or Active)	Barriers around a building system utility components to protect from flooding.	Intermediate	MICRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Protection of Exposed Risers, Conduits, and Cables	Installation on the most sheltered side of building. Protect by enclosing in insulated, rigid, and watertight conduits.	Intermediate	MICRO	GRAY	MEDIUM	\$
Infrastructure Management	Flood Damage-Resistant Materials	The utilization of materials that provide partial protection to elements exposed to flood.	Intermediate	MICRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Fast Replacement of Components	If elements cannot be elevated, relocated, or protected; installing components that allow for quick isolation and replacement is a viable option.	SHORT	MICRO	GRAY	MEDIUM	\$



ADAPTATION TYPE	ADAPTATION TITLE	DESCRIPTION	SHORT, INTERMEDIATE, OR LONG TERM	MICRO / MACRO	GRAY, GREEN, OR HYBRID	DEGREE OF PROTECTION (LOW, MED, HIGH)	COST (\$,\$\$,\$\$\$)
Infrastructure Management	Building on Partially Elevated Areas	Building on partially elevated areas reduces the flood risk locally. A farm located in a flood plain can for instance be constructed on an elevated area. The surrounding area is allowed to be flooded while the farm and its accompanying buildings remain dry.	LONG TERM	MICRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Construction on Piles	Constructions on piles are raised constructions built on piles. The piles can be used to create solid foundation and to make it possible for water to flow underneath the building. The ground flood level should be built above the design water level.	LONG TERM	MICRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Dams (To Redirect Water)	An artificially raised dam at a strategic location in a river or stream can redirect a part of the water flow into another direction. Most dams have a section called a spillway or weir over which, or through which, water flows, either sometimes or always. Dams generally serve the primary purpose of retaining water.	LONG TERM	MACRO	GRAY	HIGH	\$\$\$
Infrastructure Management	Elevated Flood Wall / Flood Gate	A flood wall can be constructed to protect individual vital buildings/facilities against flooding. They can be either permanent or dismountable. Sometimes gates are built in a flood wall to create space for roads. These gates are only closed during flood events.	LONG TERM	MACRO	GRAY	HIGH	\$\$\$
Infrastructure Management	By-Pass Creation	Creating a bypass for a river or canal can reduce flood levels in a specific location. A bypass provides extra discharge capacity for the river or canal. Thereby known bottlenecks can be solved.	LONG TERM	MACRO	GRAY	MEDIUM	\$\$\$
Infrastructure Management	Amphibious (Floatable) Constructions / Buildings	Amphibious buildings rest on the ground level and only start to float during a flood period. The structure is built on a float. Like in floating buildings, these floats are guided by vertical posts to avoid drift of the amphibious building.	LONG TERM	MACRO	HYBRID	MEDIUM	\$\$\$
Infrastructure Management	Artificial Islands	An artificial island is a man-made island is an island, which can be integrated with flood protection. The island can be created by land reclamation, expanding existing islets, construction on existing reefs, or merging several natural islets into a bigger island. Artificial islands may vary in scale from small islets for a single structure, to islands that support entire communities and cities.	LONG TERM	MACRO	HYBRID	HIGH	\$\$\$
Infrastructure Management	Check Valve / Non-Return Valves	A check valve or non-return valve is installed in pipes which are vulnerable for backflow in flood conditions. Backflow is known to take place in toilets and sewer systems. The valve will block flow if water flows in the wrong direction.	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$\$
Infrastructure Management	Compartments in Dike Rings	A compartment in a dike ring is a smaller area enclosed by secondary flood protection within a main dike ring. The main reason for dividing a dike ring in smaller compartments is to reduce damage in case of a dike failure / breach. Compartments in dike rings will also slow down a flood in case of a major dike breach to create more time for evacuation protocols.	LONG TERM	MACRO	HYBRID	HIGH	\$\$\$
Infrastructure Management	Compartments in Inflowing Large Waters	The compartments will divide large water surfaces into smaller and better controllable segments. These segments are connected with each other through a system of interacting locks or dams. A smaller amount of water can cause damage to low level terrain in case of a dike breach.	LONG TERM	MACRO	HYBRID	HIGH	\$\$\$
Infrastructure Management	Dikes	A dike is an elongated artificially constructed embankment or levee, which protects low-lying areas against higher water levels. It is usually made of clay and sand. Rock or concrete are used to protect the water facing outer slope against waves. Most dikes are constructed parallel to the course of a river in its floodplain or along low-lying coastlines.	LONG TERM	MACRO	HYBRID	HIGH	\$\$\$
Infrastructure Management	Dismountable and Temporary Buildings	Dismountable and temporary buildings can be an option for flood prone locations. For instance, temporary beach pavilions can be built along beaches to be used during summertime. During the stormy winter season, the buildings are dismantled.	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$\$
Infrastructure Management	Evacuation Routes at Elevated Level	Evacuation routes at an elevated level are necessary to as a route for safe evacuation in flood events. They should be constructed above the highest expected flood level. People affected by the floods can use the routes to reach safe (higher) ground.	LONG TERM	MACRO	GRAY	HIGH	\$\$\$
Infrastructure Management	Floodable Dike	A floodable dike is designed to protect a floodplain against frequent high-water levels. The dikes crest level is designed relatively low, so it is flooded in extreme high-water levels. This way the flood plain can be used for instance agriculture in normal conditions and for water storage in extremely wet conditions. A secondary dike further inland is frequently used to protect the vulnerable hinterland against extreme high-water levels.	LONG TERM	MACRO	HYBRID	HIGH	\$\$\$
Infrastructure Management	Floodplain Evacuation or Enlargement	The floodplain can be enlarged by lowering the level or increasing the width of the floodplain. Enlarging the floodplain will create more room for the river thereby increasing the discharge capacity and provide upstream retention. The risk of flooding is decreased as the capacity of the river to convey water is increased.	LONG TERM	MACRO	HYBRID	HIGH	\$\$\$
Infrastructure Management	Overtopping Proof Dike	An overtopping-proof dike is designed to withstand one of the most common failure mechanisms: overtopping of a dikes by waves. Prolonged overtopping could cause collapse of the landward slope. For better resistance against overtopping the dikes crest must be raised and the landward slope should contain a gentle slope.	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$\$
Infrastructure Management	Polder	A polder is a low-lying area enclosed by dikes or levees and forms an artificial hydrological entity. There is no connection with surface water outside the polder other than through manually operated pumps or inlets. There are three types of polders: Land reclaimed from a body of water, flood plains separated from the sea or river by a dike, marshes separated from the surrounding water by a dike and subsequently drained. A polder usually has an excess of water as its ground level is often lower than surrounding water levels. Pumping or opening sluices at low tide is necessary.	LONG TERM	MACRO	HYBRID	HIGH	\$\$\$



ADAPTATION TYPE	ADAPTATION TITLE	DESCRIPTION	SHORT, INTERMEDIATE, OR LONG TERM	MICRO / MACRO	GRAY, GREEN, OR HYBRID	DEGREE OF PROTECTION (LOW, MED, HIGH)	COST (\$,\$\$,,\$\$,\$\$,\$\$)
Infrastructure Management	Quay / Wharf	A Quay or wharf is a structure on the shore of a harbor or on the bank of a river or canal. I can be a good flood protection in locations where available space is limited. Quays are mostly reinforced concrete structures.	LONG TERM	MACRO	GRAY	MEDIUM	\$\$\$
Infrastructure Management	Raising Land	Raising land is often used to increase the difference between water levels and construction levels. Usually sand is used to raise new roads above the existing ground level. This measure reduces the flood risk. Ground water and surface water levels can rise	LONG TERM	MACRO	HYBRID	MEDIUM	\$\$\$
Infrastructure Management	Relocation of Buildings, Utility, Facilities, and Infrastructure	Some public utilities or vital infrastructure could be located in vulnerable flood prone locations. Relocation to higher ground is an option to minimize flood risk.	LONG TERM	MACRO	GREEN	HIGH	\$\$\$
Infrastructure Management	Seepage Barrier	The main purpose of a seepage barrier is to reduce the rate of seepage: for instance, to reduce the loss of water from a reservoir or to reduce the water pressure on the structure. The seepage barrier can also be used as a vertical levee enforcement.	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Super Dike	A super dike is much higher and wider than a traditional dike. It is designed to be unbreakable and to reserve space for urban developments on top of the dike.	LONG TERM	MACRO	GRAY	HIGH	\$\$\$
Infrastructure Management	Unbreakable Dikes	An unbreakable dike is an over-dimensioned dike which will protect low lying land for a longer time span than a traditional dike. Most likely the dike is higher and wider than required by design standards. An unbreakable dike requires less maintenance during its lifetime.	LONG TERM	MACRO	HYBRID	HIGH	\$\$\$
Infrastructure Management	Use of Buildings as Flood Defense	New and existing buildings in flood risk areas can be used as flood defense. The buildings should be completely integrated in the flood defense to create a reliable flood defense.	INTERMEDIATE	MACRO	GRAY	LOW	\$\$\$
Infrastructure Management	Deepen Water Bodies	To mitigate droughts, it is necessary that sufficient water can be stored during the wet period, so it becomes available during a drier period. To maximize storage capacity the volume of water bodies can be increased. One way to increase the storage volume is by increasing the depth of rivers, canals and ponds. The amount of water which can be stored in this way can become available when water is scarce. The water bodies are refilled when water is abundant during wet periods. Increased helps reducing flood risk as rivers are able to transport a larger amount of water and ponds and lakes have a larger retention capacity.	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$\$
Infrastructure Management	Increase Height Difference Between Street Level and Ground Floor Level	Rainwater is usually collected in streets. To reduce probability for flood water to enter buildings the difference between street level and ground floor level can be increased. This way more water can be stored in the street profile without flooding the buildings	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Increased Pump Capacity	By increasing the pump capacity water tables can be controlled better. Responding to heavy rains becomes easier, and the chance of flooding is reduced. The need for buffer capacity, translated into low water tables in rivers and channels, is also reduced as the managers have more pumping capacity. Water levels can remain at higher levels which increases the retention capacity of the system in case of droughts.	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Increased Storage or Discharge Capacity of Surface Water	Increasing the size of a channel or pond, the discharge and storage capacity of surface water can be improved. The discharge of a river can be improved by, removing obstacles and lowering groins. Excavating floodplains, increasing the area of the water body or depoldering large areas along the river, improves the storage capacity of the water bodies. Both measures have the ability to reduce flood risk and improve the ability to manage the water.	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$\$
Infrastructure Management	Pumping Stations	A pumping station is used to discharge water out of an area. It can be used to transport sewer water in pressure mains. Another option is use in polder systems to pump water from a low-lying area into a main water body like a river or a lake. It is always applied when no natural flow of water is possible.	SHORT	MICRO	GRAY	LOW	\$\$
Infrastructure Management	Raised Curbs / Hollow Roads	Raised curbs and hollow roads are used to increase the storage and transport capacity of a road. In extreme rainfall events excess water is stored in between the curbs instead of flowing into buildings directly.	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Storage / Settling Tank and Storage Basins	Storage/settling tanks are designed to store excess runoff in urban drainage systems during wet periods, primarily if runoff exceeds the discharge capacity of the urban drainage system some. The settling tank is designed to prevent polluted runoff to be discharge in surface water.	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Increased Capacity of Sewer System	Increasing the capacity of the sewer system increases the ability of the system to drain excess surface water during heavy rains and prevent flooding.	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Reconstruct Combined Sewer Systems to Separate Sewer Systems	Old sewer systems were often constructed as combined sewers systems, collecting rainwater and wastewater in one system. A separate sewer system is designed to collect sanitary and storm water runoff separately. Rainwater can be stored and/or treated, therewith creating an additional water resource. The sanitary water is in a separate sewer system is more concentrated and wastewater runoff is more steady.	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Smart-Drain (Ground Water)	A smart drain is used to control groundwater levels. The drain operation is based on the actual groundwater levels. If the groundwater level is too high, more water is drained. If the groundwater level is too low, drainage is limited.	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$



ADAPTATION TYPE	ADAPTATION TITLE	DESCRIPTION	SHORT, INTERMEDIATE, OR LONG TERM	MICRO / MACRO	GRAY, GREEN, OR HYBRID	DEGREE OF PROTECTION (LOW, MED, HIGH)	COST (\$,\$\$,,\$\$,\$\$)
Infrastructure Management	Infiltration and Transport Sewer	An infiltration and transport-sewer (IT) can function as a underground storage and infiltration mechanism, or a storm water drain. The IT sewer is a permeable pipeline which buffers the water until it is able to infiltrates back into the soil. During heavy rain, when soils are fully saturated and water can no longer infiltrate, the IT sewer functions as a storm water drain. excess water is diverted to the ends of the pipeline where it is discharged into another water body. With this buffering capacity the IT sewer is able to reduce flooding and improve water availability during periods of droughts.	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Ditches	A ditch is usually defined as a small to moderate depression created to channel water. A ditch can be used for drainage, to drain water from low-lying areas, alongside roadways or fields, or to channel water from a more distant source for plant irrigation. A trench is a long narrow ditch. Ditches are commonly seen around farmland especially in areas that have required drainage such as low land areas.	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Use of Groundcover and Shrubbery	Using groundcover and shrubbery has a few benefits compared to unplanted surfaces. By reducing the velocity of the water on the surface, trees and shrubs improve the infiltration of the water. In addition, plants improve the infiltration rate of the soil. In short, planted surfaces improve the infiltration capacity of the surface and thereby reduce the chance of flooding. Planted surfaces also cool the environment through evapotranspiration and by providing shade. Planted surfaces thereby have the ability to reduce the heat island effect and reduce peak summer temperatures by 1 to 5 degrees Celsius. As it provides shade reduce surface runoff as their features reduce the velocity of the water on the surface. This ability is especially interesting in urban areas where heat reduces the livability of the city.	LONG TERM	MACRO	GREEN	LOW	\$
Infrastructure Management	Porous Pavements	Permeable paving is a range of sustainable materials and techniques for permeable pavements with a base and subbase that allow the movement of water through the surface. In addition to reducing runoff, this effectively traps suspended solids and filters pollutants in the soil. Besides pavements examples include roads, lawns and lots that are subject to light vehicular traffic, such as parking lots.	LONG TERM	MACRO	HYBRID	MEDIUM	\$
Infrastructure Management	Improve Soil Infiltration Capacity	Improving the soil infiltration capacity means improving the permeability of the soil. If the infiltration capacity of the soil is increased, more water will percolate into the soil and less water will runoff directly. This will reduce peak runoff and promoted groundwater recharge.	LONG TERM	MACRO	GREEN	LOW	\$
Infrastructure Management	Infiltration Fields and Strips with Above-Ground Storage	Infiltration fields and strips with above-ground storage combine infiltration and water storage. This way peak runoff is reduced.	INTERMEDIATE	MACRO	HYBRID	LOW	\$\$
Infrastructure Management	Rainwater Retention Ponds With or Without Infiltration Possibilities	Increasing the storage can be applied on different scales. Capturing runoff from the roof of the house is seen as the smallest scale. This is followed by the retention of runoff of an agricultural field by creating small dams within small channels or depressions in the field. And ultimately large areas can be designated as a flood area to temporarily store excess discharges of the river.	INTERMEDIATE	MACRO	HYBRID	LOW	\$\$
Infrastructure Management	Wadi (Bioswales / Infiltrating Filter Swales)	A wadi is a naturally designed buffer and infiltration filter. A wadi can be a shallow ditch or depression in the field. The wadi detaches rainwater runoff from streets and rooftops from the traditional sewer system. For the larger part of the year, the wadi remains dry. Only during heavier rain events will the wadi be filled with water. This way clean water is infiltrated into the soil it can be used during drier periods.	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Shallow Infiltration Measures	Shallow infiltration measures are focused on increasing infiltration in the shallow unsaturated zone. By increasing infiltration run off peaks are lowered, reducing pluvial flood risk. Also, groundwater is recharged, reducing the impact of droughts. Examples of shallow infiltration measures are infiltration crates and soakaways.	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$\$
Infrastructure Management	Flexible Water Level Management	By using flexible natural fluctuations in the water level can improve rainfall runoff characteristics. In wet periods water levels are allowed to rise, in dry periods water levels are allowed to lower. This reduces the use of pumping stations or water inlet systems.	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$
Infrastructure Management	Water Squares	This type of square can combine water storage with the improvement of the quality of urban public space. The water square can be understood as a twofold strategy. It makes money invested in water storage facilities visible and enjoyable. It also generates opportunities to create environmental quality and identity to central spaces in neighborhoods. Most of the time the square can be used as a recreational space. When heavy rains occur, rainwater that is collected from the neighborhood will flow into the water square for a short times pan. After it has been in use as buffering space, the filtered water is returned to the water system.	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Artificial Urban Wetlands	Natural wetlands function as water retention basins, sediment traps and wastewater treatment areas by filtration and the immobilizing harmful microorganisms. The wetlands can be implemented with or without additions which improve the treatment capacity. Would extra treatment capacity is needed due to regular overtopping of the sewage system, mining or heavy industry, additional techniques can be implemented. Aeration, alteration soil composition or the introduction of a particular plant species in the area can all improve the treatment capacity.	LONG TERM	MACRO	GREEN	MEDIUM	\$\$



ADAPTATION TYPE	ADAPTATION TITLE	DESCRIPTION	SHORT, INTERMEDIATE, OR LONG TERM	MICRO / MACRO	GRAY, GREEN, OR HYBRID	DEGREE OF PROTECTION (LOW, MED, HIGH)	COST (\$,\$\$,\$\$\$)
Infrastructure Management	Rainwater Tanks	A rainwater tank (sometimes called a rain barrel in North America, or a water butt in the UK) is a water tank used to collect and store rainwater runoff, typically from rooftops via rain gutters. Stored water may be used for watering gardens, agriculture, flushing toilets, in washing machines or washing cars during dry periods	SHORT	MICRO	GREEN	LOW	\$
Infrastructure Management	Reduced Paved Surfaces	Paved surfaces like roofs, roads and parking lots, reduce the infiltration capacity of the soil and increase the surface water runoff. As a consequence, flood risk and the need for additional water retention capacity is increased. By decreasing the total area of paved surfaces, more water is can infiltrate the soil and extra green space is created. The increase in green space also has a positive effect on the heating of a city. Green areas help cooling the area by providing shade and the possibility of evapotranspiration.	LONG TERM	MACRO	GREEN	MEDIUM	\$\$
Infrastructure Management	Gutter	A gutter is a non-permeable open drain to collect transport rainwater. Usually a gutter runs along a road. It is connected to either a manhole or a surface water body.	LONG TERM	MACRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Public Infrastructure Design	Build to last: build resiliency into public infrastructure	LONG TERM	MACRO	HYBRID	MEDIUM	\$
Infrastructure Management	Increased Design Standards for Industrial Systems	Design industrial systems to reduce vulnerability to future sea level rise and associated hazards	LONG TERM	MICRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Sewage and Solid Waste Management	Improve sewage and solid-waste management infrastructure to reduce vulnerabilities to climate change (i.e. storm surge, flooding, inundation)	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Evaluate Stormwater Infrastructure	Evaluate and improve capacity of storm water infrastructure for high intensity rainfall events	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$\$
Infrastructure Management	Beach Nourishment	Use beach nourishment to protect infrastructure in coastal areas	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$\$\$
Infrastructure Management	Management of Possible Submerged Structures	Develop retreat strategies for the management of existing structures or conditions that may become submerged hazards to navigation or public health (e.g. effluent outfalls, water intakes, septic fields, rock walls, docks and piers)	INTERMEDIATE	MACRO	GREEN	LOW	\$
Infrastructure Management	Industrial Systems	Site industrial systems away from areas vulnerable to extreme changes in weather conditions	LONG TERM	MACRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Relocation of Structures	Consider relocation of threatened structures	LONG TERM	MACRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Strengthen Building Codes	Strengthen building codes and increase building inspection frequency	LONG TERM	MACRO	GRAY	MEDIUM	\$\$
Infrastructure Management	Research Potential Gray Structures	Investigate consequences of installation of hard structural options (such as dikes, levees, floodwalls, and saltwater intrusion barriers) and soft structural options (such as dune restoration and creation wetland restoration, periodic beach nourishment temporary barriers) to ensure comprehensive and effective response	SHORT	MACRO	GRAY	LOW	\$
Infrastructure Management	Construction Standard Review	Review construction standards for piers and wharves for wave strength resistance	SHORT	MICRO	GRAY	LOW	\$
Infrastructure Management	Public Housing Resilience	Make sure urban housing stock, including multi-family homes and public housing units are resilient to likely climate change effects	INTERMEDIATE	MICRO	HYBRID	LOW	\$\$
Infrastructure Management	Storm Water Capacity	Evaluate and improve capacity of storm water infrastructure for high intensity rainfall events	LONG TERM	MACRO	GRAY	MEDIUM	\$\$\$
Infrastructure Management	Storm Water Capacity	Evaluate and improve capacity of storm water infrastructure for high intensity rainfall events.	LONG TERM	MACRO	HYBRID	HIGH	\$\$\$
Infrastructure Management	Maintenance of Drainage	Increase maintenance and cleaning of gutters, drainages ditches and culverts	SHORT	MICRO	HYBRID	LOW	\$
Infrastructure Management	Modify Communication Infrastructure	Incorporate modifications to communications infrastructure to increase resiliency during routine maintenance and upgrades	INTERMEDIATE	MACRO	GRAY	LOW	\$\$
Infrastructure Management	Identify Energy Infrastructure	Identify key energy infrastructure (networks, pipelines, power lines or points of production or distribution) that may be affected by climate change impacts	SHORT	MICRO	GRAY	LOW	\$
Infrastructure Management	Modify Energy Infrastructure	Incorporate modifications to energy infrastructure to increase resiliency during routine maintenance and upgrades	INTERMEDIATE	MACRO	GRAY	LOW	\$\$
Infrastructure Management	Hydrology Models	Develop complete climate-hydrology models to create reliable scenarios of all aspects of the hydrological cycle, including extreme events	SHORT	MACRO	GRAY	LOW	\$
Infrastructure Management	Modify Topography	Modify land topography to reduce runoff, improve water uptake, reduce erosion and sedimentation in streams	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$
Infrastructure Management	Living Shoreline	Reduce loss of wetlands due to hardening of estuarine shoreline	LONG TERM	MACRO	GREEN	MEDIUM	\$\$



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Infrastructure Management	Ocean Outfalls	Reduce or eliminate ocean outfalls	LONG TERM	MICRO	GREEN	LOW	\$
Infrastructure Management	Green Spaces	Increase urban vegetation- plant trees, roof gardens through planned growth and local ordinances protecting vegetation and open space.	LONG TERM	MICRO	GREEN	MEDIUM	\$\$
Infrastructure Management	Pedestrian Friendly Planning	Adapt the built environment to make communities more walkable and pedestrian friendly, and ensure consideration of climate change planning	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	Special Area Management Plan (SAMP)	Plans which provide for increased specificity in protecting significant natural resources, reasonable coastal dependent economic growth, improved protection of life and property in hazardous areas, including those areas likely to be affected by land subsidence, sea level rise, or fluctuating water levels of the Great Lakes, and improved predictability in governmental decision making”	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$\$
Policies & Strategic Planning	Allow Coastal Wetlands to Migrate Inland	Through the use of setbacks, density restrictions, or land purchases a city can mitigate the effects of sea level rise. This adaptation preserves habitat for venerable species and preserves coastal land from developments.	LONG TERM	MACRO	GREEN	HIGH	\$\$
Policies & Strategic Planning	Prohibit Hard Shore Protection	Create policies that restrict the implementation of hard structures along coastal properties	LONG TERM	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Develop Planning Laws	Review planning laws, maps, plans, and development guidelines for Effective Response to Climate Impacts such as sea level rise, saltwater intrusion, drought, more frequent and intense storms, storm surges and flooding, erosion, heat waves.	INTERMEDIATE	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Review Land Use Plans	Review land use plans in anticipation of change development pressures and shifts in development patterns due to climate change	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$
Policies & Strategic Planning	Adaptations in Land Use Planning	Support/Conduct Comprehensive Land Use Planning that incorporates adaptation strategies	LONG TERM	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Regional Planning with Climate Change	Engage in regional planning processes in relationship to climate change	LONG TERM	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Adaptative Land Use Planning	Develop a series of models for adaptive land use planning for decision-makers at all jurisdiction levels	LONG TERM	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Climate Change Projection in Urban Planning	Require consideration of climate change projections in urban planning	LONG TERM	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Critical Area Planning	Integrate critical area planning requirements with comprehensive planning laws, including emergency planning and infrastructure planning requirements	LONG TERM	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Require Comprehensive Planning	Require that counties act on comprehensive planning requirements	INTERMEDIATE	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Critical Area Planning	Strengthen existing critical area planning and implement requirements to address sea level rise and associated coastal hazards	INTERMEDIATE	MACRO	HYBRID	MEDIUM	\$
Policies & Strategic Planning	Deter Development in Vulnerable Areas	Guide future development out of areas vulnerable to sea level rise and associated hazards	LONG TERM	MACRO	GREEN	HIGH	\$\$
Policies & Strategic Planning	End Permitting in Vulnerable Areas	End permitting of new home construction in areas vulnerable to sea level rise and associated hazards	LONG TERM	MACRO	GREEN	HIGH	\$\$
Policies & Strategic Planning	Update Floodplain Maps	Develop a strategy to regularly update floodplain maps	LONG TERM	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Identify High Hazard Areas	Identify high hazard areas (at risk for flooding, sea water inundation, etc.)	SHORT	MACRO	HYBRID	LOW	\$
Policies & Strategic Planning	Sheltered Coastlines	Increase erosion and hazard planning focused on sheltered coastlines	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$
Policies & Strategic Planning	Transportation and Land Use	Integrate transportation and land use planning	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$
Policies & Strategic Planning	State Transportation Plan	Ensure climate change is considered in reviews of state transportation plan	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$
Policies & Strategic Planning	Metropolitan Planning	Require/enable metropolitan planning organizations to take climate change into account	LONG TERM	MACRO	GREEN	MEDIUM	\$
Policies & Strategic Planning	Existing Programs in Transportation	Review existing coastal programs for coverage of sea level rise & other climate impacts on transportation	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$
Policies & Strategic Planning	Transportation Planning	Develop joint transportation strategies with adjacent communities, regions and states to accommodate changing conditions and transportation system use	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$
Policies & Strategic Planning	Task Force	Establish Climate Change and Public Infrastructure Task Force	LONG TERM	MACRO	GREEN	MEDIUM	\$



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Policies & Strategic Planning	Local and State Coordination	Establish a coordinating mechanism to assure that local governments act in concert with the state to reduce future impacts from climate change SLR and associated hazards	LONG TERM	MACRO	GREEN	MEDIUM	\$
Policies & Strategic Planning	State Building Codes	Review State Building and Design Codes to promote resiliency of communities, to mitigate storm and flood damage.	LONG TERM	MACRO	HYBRID	MEDIUM	\$
Policies & Strategic Planning	Evaluation of Mechanical and Electrical	Establish a mechanism to evaluate and recommend new design standards for structures (and placement of mechanical and electrical equipment) that may be vulnerable to SLR and associated hazards	LONG TERM	MACRO	HYBRID	MEDIUM	\$
Policies & Strategic Planning	Limit Infrastructure	Limit infrastructure investments in hazard-affected coastal areas	LONG TERM	MACRO	GREEN	HIGH	\$\$
Policies & Strategic Planning	Institute Design Standards	Institute new hazard-resistant building codes and design standards to reduce vulnerability of structures to future sea level rise and associated hazards	LONG TERM	MACRO	GRAY	MEDIUM	\$\$
Policies & Strategic Planning	Increased Design Standards	Increase infrastructure design standards to address lower probability events	LONG TERM	MACRO	GREEN	MEDIUM	\$\$
Policies & Strategic Planning	Building Regulations to Include Climate Change	Require consideration of climate change projections in building guidelines	LONG TERM	MACRO	HYBRID	MEDIUM	\$\$
Policies & Strategic Planning	Building Regulations to Include Adaptation	Support/Conduct Comprehensive Building Regulation that incorporates adaptation strategies and requirements	LONG TERM	MACRO	HYBRID	MEDIUM	\$\$
Policies & Strategic Planning	Review Building Codes	Review existing building and plumbing codes that are likely to be affected by climate change	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Policies & Strategic Planning	Update Building Codes	Update building codes, design standards to include setback zones and phased-out or no development in exposed areas	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Policies & Strategic Planning	Limit Construction in Flood Plains	Limit construction in 100-year floodplain	LONG TERM	MACRO	GREEN	HIGH	\$\$
Policies & Strategic Planning	Address Ingress and Egress	Develop strategies to address situations of changing ingress/egress to structures as support for access roads in areas vulnerable to sea level rise and associated hazards is withdrawn	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	Limitations of Existing Policies	Investigate potential and limitations of eminent domain, vesting, grandfathering, and amortizing strategies to support relocation activities	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	Analysis of Migration Strategies	Analyze incentivized / forced, subsidized migration	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	High Hazard Buyouts	Buyout unused properties in areas vulnerable to sea level rise and associated hazards	LONG TERM	MACRO	GREEN	HIGH	\$\$\$
Policies & Strategic Planning	Relocate from Vulnerable Areas	Relocate from highest risk barrier islands and low-lying lands, removing infrastructure that may exacerbate flooding and natural processes	LONG TERM	MACRO	GREEN	HIGH	\$\$\$
Policies & Strategic Planning	Rolling Easements	Enact law that authorizes the state to secure a rolling property easement as sea level rises	LONG TERM	MACRO	GREEN	HIGH	\$\$
Policies & Strategic Planning	Strategic Plans	Require that local government coastal land use plans include a strategic plan for responding to sea level rise, and other climate risks.	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	Climate Safe Communities	Develop new criteria for ‘climate safe’ communities and developments	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	Real Estate Disclosures	Update real estate transaction disclosure requirements for hazards related to climate change	INTERMEDIATE	MACRO	GRAY	LOW	\$
Policies & Strategic Planning	Require Disclosure of Hazards	Enact legislation to require sellers of coastal properties to disclose potential hazards to buyers. Coastal hazards disclosure should accompany all real estate transfers of properties in coastal counties	INTERMEDIATE	MACRO	GRAY	LOW	\$
Policies & Strategic Planning	Environmental Standards	Increase environmental quality standards to enhance resilience of natural water systems	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	Flood Plain Mapping	Improve flood plain mapping given increasing frequency of major flood events	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Policies & Strategic Planning	Coastal Zone Management Plan	Create integrated coastal zone management (ICZM) plans and support Coastal Zone Management program	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Policies & Strategic Planning	Implement Living Shorelines	Conduct coastal re-alignment planning including conversion of land to salt marsh and grassland to provide sustainable sea defenses (IPCC)	LONG TERM	MACRO	GREEN	HIGH	\$\$
Policies & Strategic Planning	Coastal Resource Action Policies	Develop coastal resource action policies for adapting to more frequent severe storms, sea level rise, drought, erosion, and acute flooding events	INTERMEDIATE	MACRO	GREEN	MEDIUM	\$
Policies & Strategic Planning	Coastal Adaptation Program	Create a Coastal Adaptation Program	INTERMEDIATE	MACRO	GREEN	LOW	\$



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Policies & Strategic Planning	Beach Nourishment	Create or update State Beach Nourishment Program	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	Beach Management Plan	Create or update Strategic Beach Management Plan with climate impacts	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	Climate Driven Immigration	Anticipate and prepare for potential climate-driven immigration from neighboring countries, especially along border states	LONG TERM	MACRO	HYBRID	LOW	\$
Policies & Strategic Planning	Assistance Programs	Design assistance programs to respond to potential economic impacts, housing needs, dislocation and chronic deficiencies impacting health and quality of life in communities	INTERMEDIATE	MACRO	HYBRID	LOW	\$
Policies & Strategic Planning	Adaption Action Area (AAA) Zoning	Enact planning laws that prevent new construction in vulnerable zones, Coastal High Hazard Area (CHHA) / Adaptation Action Areas(AAA)	LONG TERM	MACRO	GREEN	HIGH	\$\$
Policies & Strategic Planning	Establish Leadership	Establish leadership in climate adaptation technology and career fields: engineering and design services, climate-sensitive infrastructure systems, ecosystem and beach management, economic security and services related to human health and safety.	INTERMEDIATE	MACRO	GREEN	LOW	\$
Policies & Strategic Planning	Adapt Industries	Adapting state industries to more frequent severe weather events and disruption of once predictable patterns	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$\$
Policies & Strategic Planning	Engage Business Representatives	Identify and engage representatives of key business areas potentially vulnerable to specific climate change effects	INTERMEDIATE	MICRO	GRAY	LOW	\$
Policies & Strategic Planning	Conservation in Tourism	Implement aggressive water conservation, energy conservation and efficiency and recycling/waste management at popular travel destinations	INTERMEDIATE	MICRO	GREEN	LOW	\$
Policies & Strategic Planning	Restructure Permitting	Refining permitting programs to account for climate change	INTERMEDIATE	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Restructure Zoning	Zoning Development away from sensitive and hazard prone areas	LONG TERM	MACRO	GREEN	HIGH	\$\$
Policies & Strategic Planning	Setbacks and Easements	Creating setback or rolling easements	LONG TERM	MACRO	GREEN	HIGH	\$
Policies & Strategic Planning	Restrict Hard Structures	Restricting the use of shore protection structures	LONG TERM	MACRO	GREEN	MEDIUM	\$
Policies & Strategic Planning	Impervious Surfaces	Minimizing extent of impervious surfaces	LONG TERM	MACRO	HYBRID	MEDIUM	\$
Policies & Strategic Planning	Buffers	Establishing buffers around natural features	LONG TERM	MACRO	GREEN	MEDIUM	\$\$
Policies & Strategic Planning	Restructure Building Codes	Instituting or strengthening building codes in flood- and erosion-prone areas	INTERMEDIATE	MACRO	GRAY	MEDIUM	\$

APPENDIX C

Living Shoreline

Technical Guidance Document



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1.0 INTRODUCTION

Anticipating both environmental and economic impacts from climate change and sea level rise, proactive shoreline management is critical to protect property interests and estuarine ecosystems. Over the past century, extensive development in the coastal zone has resulted in the proliferation of traditional ‘hard’ shoreline stabilization measures such as bulkheads, seawalls and revetments. When designed and constructed properly, these structural measures have proven successful at stabilizing shorelines. However, they have also resulted in a number of negative impacts on adjacent shorelines and critical intertidal and nearshore habitats when not properly designed or maintained. Contrary to the traditional approach, shoreline stabilization does not need to create a hard barrier between land and water to be effective (NOAA, 2015).

In recent years, a variety of softer, more nature-based shoreline stabilization approaches have been developed to reduce erosion by creating natural features (Figure C1.1-Figure C1.2). These approaches are known under a variety of names such as “living shorelines”, “green shores”, “nature-based features”, and “ecologically enhanced shorelines”. In contrast to the traditional shoreline stabilization options, living shorelines protect ecosystem services and (when properly designed and installed) perform better over time in controlling erosion and preventing catastrophic flood and storm damage (Miller et al., 2015). Over time, as sea level rises, a living shoreline may maintain its elevation relative to local sea level. (NOAA, 2015). According to Morris et al (2015), wetlands may increase in elevation by nearly 12 mm/year, surpassing the global rate of sea level rise. Oyster reefs may increase in elevation at a rate of nearly 60 mm/year (Ridge et al 2017, Rodriguez et al 2014).

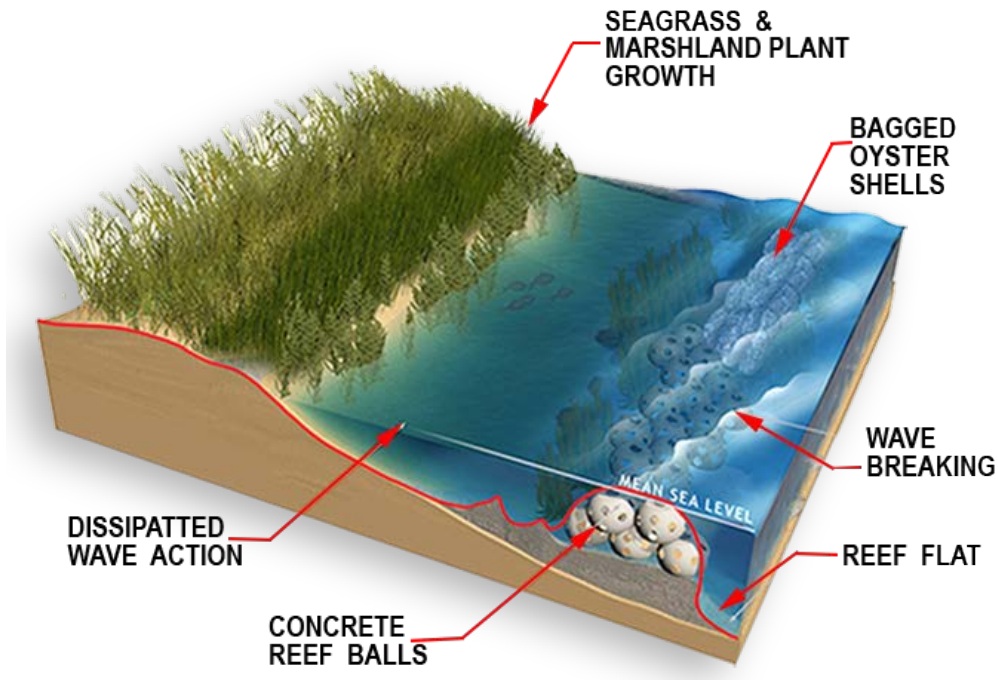


Figure C1.1 Combined Structural and Nonstructural Living Shoreline Installation, Pre-Storm Condition
(graphic by EWN/ERDC)

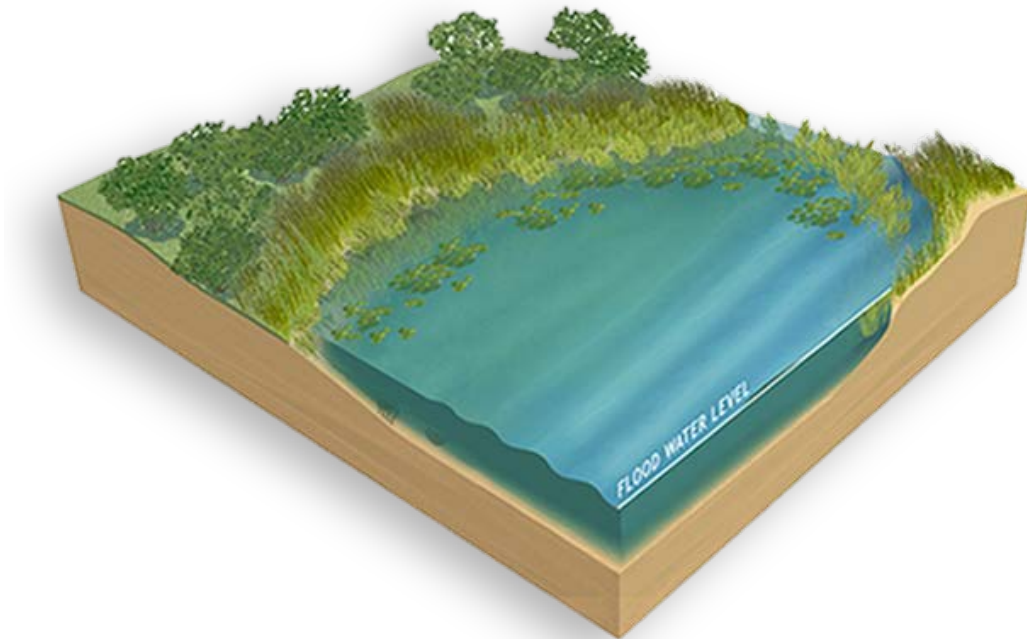


Figure C1.2 Combined Structural and Nonstructural Living Shoreline Installation – Inundated Storm Condition
(graphic by EWN/ERDC brochure)



Originally developed in the Chesapeake Bay nearly two decades ago, the living shorelines approach has gradually gained momentum. The National Research Council (2007) report “Mitigating Shore Erosion along Sheltered Coasts” advocated the development of a new management framework within which decision makers would be encouraged to consider the full spectrum of options. More recently, a U.S. Army Corps of Engineers (USACE) (2013) report on coastal risk reduction and resilience advocated an integrated approach to risk reduction that draws from a full array of available measures. Both documents encourage greater consideration of projects such as living shorelines which offer multiple benefits of providing shoreline stabilization, habitat creation, adaptive capacity, nutrient sequestration, and water quality improvements. The NOAA graphic (Figure C1.3) summarizes the ways in which various nature-based approaches can be used independently or in combination to achieve those benefits.

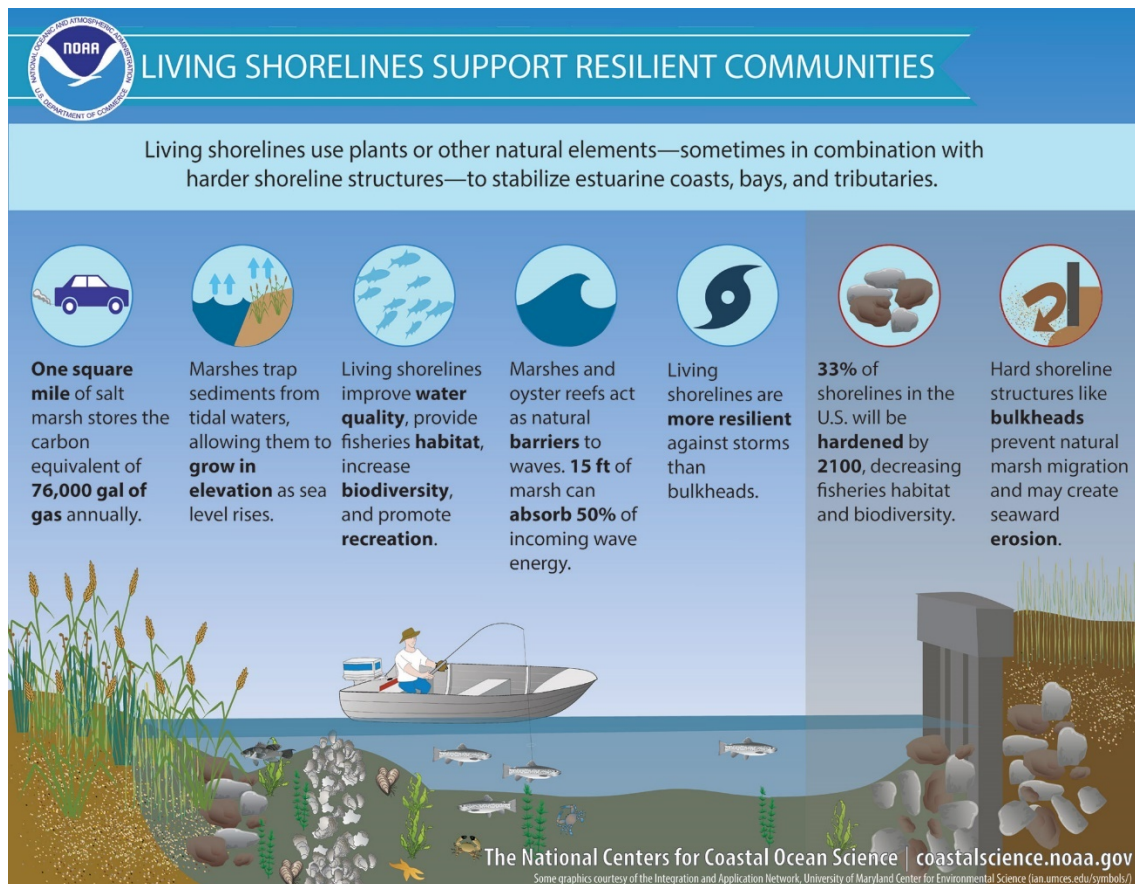


Figure C1.3 Living Shorelines Infographic (NOAA)

Erosion control, protection from storm and flood damage, and coastal climate change adaptation strategies are addressed differently on a regional basis due to regional differences in biogeophysical conditions (RAE, 2015). The use of living shorelines is one approach that can be implemented successfully under various conditions to address erosion, threats from flooding and inundation, ecosystem protection, and adaptation to ecosystem shifts brought about by climate change and sea level rise.



This document provides technical guidance to the City of Punta Gorda on engineering, planning, regulatory authorizations, and monitoring required for successful design and implementation of living shoreline projects.

2.0 BACKGROUND

In February 2019, the City of Punta Gorda contracted Taylor Engineering, Inc. to conduct a vulnerability analysis of the city's publicly owned infrastructure, prepare an addendum to the 2009 Climate Adaptation Plan, and develop a living shorelines technical guidance document. The City received a NOAA Resiliency grant in January 2019 to fund the work, with the grant expiring June 30, 2019.

The City's 2009 Climate Adaptation Plan identified a series of adaptation strategies developed by a working group with community input through public outreach and workshops. The 2009 plan identified eight categorized vulnerabilities: 1) fish and wildlife habitat degradation, 2) inadequate water supply, 3) flooding, 4) unchecked or unmanaged growth, 5) water quality degradation, 6) education and economy and lack of funds, 7) fire, 8) availability of insurance. From this, the working group identified 104 acceptable change adaptations. The consensus top adaptations, applicable to each vulnerability, were:

- Seagrass protection and restoration
- Xeriscaping and native plant landscaping
- Explicitly indicating in the comprehensive plan which areas will retain natural shorelines
- Constraining locations for certain high-risk infrastructure
- Restrict fertilizer use
- Promote green building alternatives through education, taxing incentives, green lending
- Drought preparedness planning

Notably, the first three items (listed above) identify adaptation strategies related to implementation of living shorelines. Since the City's inception, preservation of greenspace has been a cornerstone for land use management, beginning with Colonel Isaac Trabue in 1884 who designated all waterfront blocks as City parks. This legacy serves the City to this day with a string of public waterfront parks connected by the 2.5-mile-long Trabue Harborwalk promenade. The City has taken a proactive approach to acquiring and preserving greenspace for the creation of parks and natural recreational areas.

Currently, the City of Punta Gorda has a few living shorelines in place. Naturally occurring mangrove forests thrive in many places on the water's edge. In some locations, juvenile mangroves are transforming a 'gray' shore protection strategy into a 'green' one that will eventually adapt to changes in the sea level (Photograph C2.1 & Photograph C2.2). The City has also implemented oyster restoration projects in partnership with the Nature Conservancy (TNC) and the Coastal & Heartland National Estuary Partnership (CHNEP, formerly known as Charlotte Harbor National Estuary Program) using volunteer engagement. Part of a community resilience initiative, the oyster reefs were installed to protect the shoreline while also creating habitat and recruiting estuarine wildlife to the reefs and surrounding waters.



Photograph C2.1 Mangrove Living Shoreline, February 2019



Photograph C2.2 "Volunteer" Mangrove Living Shoreline, February 2019



In 2018, the City also completed a conceptual level living shoreline pilot project study, Tiki Point at Harborwalk fronting the Four Points Sheraton Hotel in the downtown area. The Harborwalk is a waterfront promenade that connects Trabue Park, Laishley Park, the Charlotte Harbor Events Center, Gilchrist Park, and Fishermen's Village. A public-private partnership was formed between the City, CHNEP, TNC, the Florida Department of Environmental Protection (FDEP) Aquatic Preserves, Four Points Sheraton, and Jacobs Engineering. The hotel expressed interest in improving the natural aesthetics and habitat value along the hotel's seawall (Figure C2.1), within a public easement that exists along the City's Harborwalk.



Figure C2.1 Tiki Point at Four Points by Sheraton Living Shoreline Pilot Project Location
(from Jacobs Engineering Technical Memo dated August 2018)

As part of the 2019 Climate Adaptation Plan addendum, the City seeks to further define living shorelines as one adaptation strategy for improving the City's resilience to the effects of climate change and sea level rise. Rather than a traditional 'managed retreat / planned relocation' approach, the City's goal is to take advantage of the publicly owned greenspace and focus on advancing living shoreline stabilization features into the water for increased upland flood protection. According to the 2009 Climate Adaptation Plan, the concept of "rolling easements" was addressed to manage areas where shorelines are hardened to allow for continued lateral



public access to the shoreline even as the intertidal zone (deemed as state-owned public lands) translates landward with rising water levels. However, such easements are not applicable in all areas.

3.0 LIVING SHORELINES DEFINED

There are many definitions for living shorelines. Restore America's Estuaries (RAE 2015) defines a living shoreline as "any shoreline management system that is designed to protect or restore natural shoreline ecosystems through the use of natural elements and, if appropriate, manmade elements. Any elements used must not interrupt the natural water/land continuum to the detriment of the natural shoreline ecosystems." NOAA¹ defines living shorelines as "a shoreline management practice that provides erosion control benefits; protects, restores, or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural organic materials (e.g. biologs, oyster reefs, etc.)". When protecting coastal properties, a living shoreline approach represents a 'softer and greener' alternative to 'gray' approaches such as traditional armoring (e.g., seawalls, bulkheads). A living shoreline uses natural materials such as wetland plants, oyster shell, coir fiber logs, sand, wood, and native rock to stabilize the shoreline and maintain valuable fish and wildlife habitat. Every living shoreline design should result from careful consideration of the project site and strategic placement of natural components along the shoreline profile.

¹<https://shoreline.noaa.gov/glossary.html#partj>, accessed June 12, 2019.



Figure C3.1 depicts a range of shoreline stabilization techniques from ‘green’, nature-based materials to a hybrid (combination) approach to ‘gray’ traditional hardened structures. NOAA encourages the use of these softer techniques for shoreline stabilization, however, after consultation with a variety of research institutes, non-governmental organizations, USACE, and FEMA, the “Systems Approach to Geomorphic Engineering (SAGE) continuum” was developed. This continuum provides a wider range of living shoreline strategies, which are outlined in the SAGE Natural and Structural Measures for Shoreline Stabilization brochure (http://sagecoast.org/docs/SAGE_LivingShorelineBrochure_Print.pdf). The stabilization techniques on the left side of the figure represent more green methods while those on the right side represent more traditional, hard stabilization techniques.

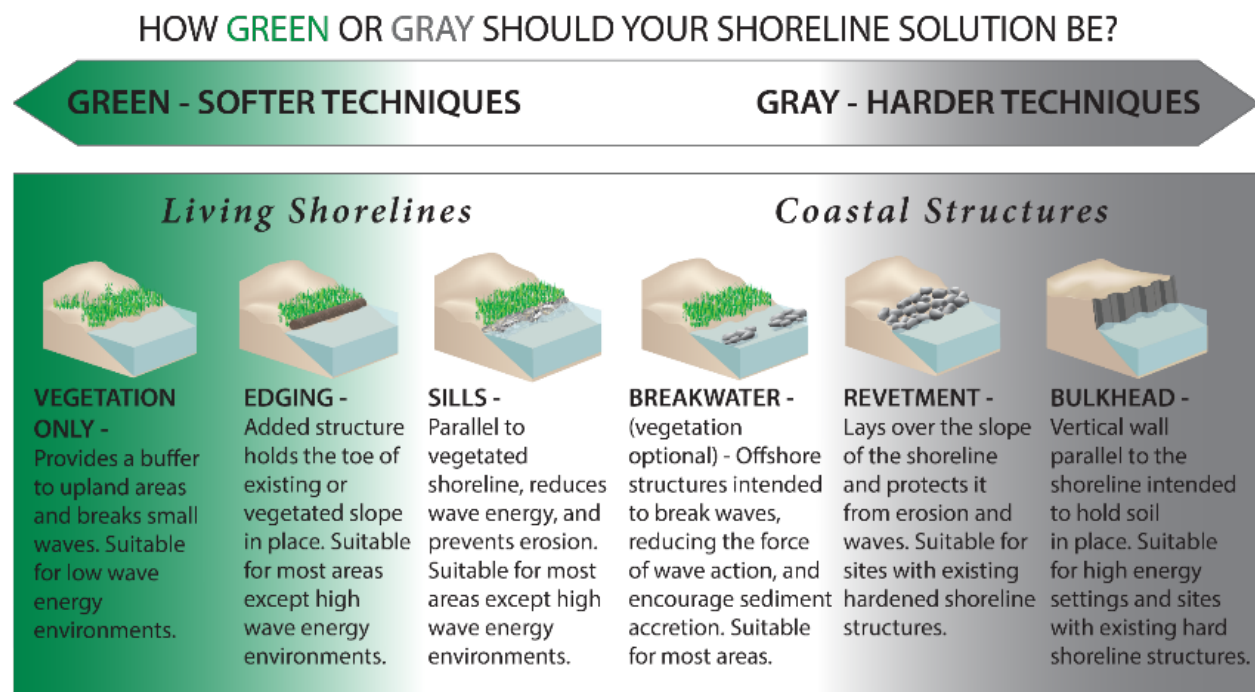


Figure C3.1 Range of Green to Gray Alternatives based on Wave Energy
(NOAA Guidance for Considering the Use of Living Shorelines, 2015 adapted from SAGE, 2015)

The key differentiator in selecting among the spectrum of green to gray solutions depends on the existing project site conditions and, specifically, the degree of exposure to wave energy. When engineered and constructed correctly, a living shoreline not only provides erosion control, but also maintains coastal processes. Similar in behavior to naturally vegetated coastlines, living shorelines reduce wave energy and storm impacts, reduce erosion and property loss, trap sediments, improve water clarity, filter pollutants, preserve coastal resiliency, provide recreational opportunities, and provide important fish and wildlife habitat.



4.0 SITE EVALUATION

The first step in developing a successful living shoreline project is to perform a siting analysis in order to determine the most appropriate management system. For each potential site evaluated, the following considerations must be identified: shoreline type, degree of energy (waves, currents), potential sediment transport characteristics, types and location of ecological resources present, and the nature of adjacent land uses. Selection of a shoreline management system is largely dependent on the type of shoreline. A mix of hardened and natural vegetated shorelines exist within City limits, consisting of vertical bulkheads, natural mangrove fringe and pocket beaches. According to the Estuaries Report Card, the nearshore zone along the Peace River and Charlotte Harbor includes intertidal and shallow flats with oysters, mangroves, and aquatic vegetation in some areas. The nearshore zone consists of primarily fine-grained silty sand with fractions of shell along the east and west sides of the harbor (Estuaries Report Card, 2005 and 2017).



5.0 DESIGN CRITERIA

Once the shoreline type is identified for the selected project site, a coastal conditions analysis should be performed to determine the appropriate design. Several site-specific parameters are used to characterize site conditions and determine the optimum solution. To design long-term shoreline stabilization, the designer must analyze the coastal conditions affecting the site. The following parameters used to develop such analysis are identified and defined below.

- Reach – a longshore segment of shoreline where influences and impacts, such as wind direction, wave energy, littoral transport, etc. mutually interact. Understanding the limits for which these influences are bounded beyond the selected project site allows the designer to understand the degree of exposure and shoreline orientation.
- Fetch – a cross-shore distance along open water, over which wind blows to generate waves. For any given shore, fetch distances vary depending on wind direction.
- Topographic conditions – the slope and elevation of the foreshore within a defined project area. The nearshore slope impacts the behavior of waves and currents immediately offshore of the project site. Steeper slopes tend to reflect energy while milder slopes generally absorb and dissipate energy.
- Tidal range – the vertical difference between high and low tide. Understanding the water level changes and potential water depths at all stages of the tide help to inform the range of applicable solutions.
- Storm surge – the temporary rise in sea level due to the action of wind stress on the water surface and low atmospheric pressure created during storms. Surge is the difference between the highest water level caused by a storm and the predicted astronomical tide level.
- Wave energy – the force exerted on a shoreline by waves. Different areas have lower or higher wave energy depending on the wave height, degree of exposure, shoreline orientation, proximity to navigation channels, wind, and bathymetry.
- Currents – the movement of water from one location to another. Currents are driven by wind, tides, and density differences due to water temperature and salinity variations.
- Water quality and salinity - chemical, physical, and biological characteristics of water. Water quality can affect the ability of aquatic plants and animals to thrive.
- Sediment transport – the movement of sediment, usually caused by water or wind. Sediment transport can occur over vast segments of shoreline or in localized areas. An example of localized sediment transport is scour adjacent to a vertical bulkhead and alongshore transport of the scoured material.

Waves generated by local winds tend to be one of the dominant forces impacting shorelines and are considered in nearly all engineered shoreline improvements. As the wind blows over the surface of a water body, its energy is transferred to the water (Miller et al, 2015). The wind speed, duration, and open water distance (fetch) over which it acts will determine size of the waves. For sites located inland, wave growth is limited by the available fetch, resulting in wave heights and periods that are generally much smaller than those observed on open coastlines. In a study conducted by (Shafer et al, 2003), an evaluation of wave climate statistics in relation to wetland establishment was performed for several sites in Texas and Alabama. The study found that the percent exceedance of wave height (percent of time wave heights are above any one value) varied between sites (Shafer et al, 2003). The patterns observed in this study suggest that the 20th percentile wave height statistics are indicators of long-term shoreline stability and vegetation



characteristics, representing a critical threshold for marsh establishment and long-term survival (Shafer et al, 2003). However, for most sheltered water bodies, minimal wave observations within vegetated shorelines exist. For inland or more sheltered water bodies, wave energy generated by boat wakes are often a critical design parameter. Evaluation of this parameter is further described below.

Miller et al. (2015) documented the industry standard for engineering design of shoreline stabilization techniques, specifically for living shorelines. The Miller et al (2015) paper classified typical living shoreline design parameter values (for projects in New Jersey) into low, medium, and high ranges of magnitude (Table C5.1) and then identified living shoreline techniques potentially suitable for each of the parameter ranges (Table C5.2). Though these criteria were developed for projects in New Jersey, (with the exception of 'ice') these parameter ranges are applicable for all project areas including Punta Gorda.

Table C5.1 Design Criteria Classification Ranges (Miller, et al, 2015)

Parameter	Criterion		
	Low/Mild	Moderate	High/Steep
System Parameters			
Erosion History	<2 ft/yr	2 ft/yr to 4 ft/yr	>4 ft/yr
Sea Level Rise	<0.2 in/yr	0.2 in/yr to 0.4 in/yr	>0.4 in/yr
Tidal Range	< 1.5 ft	1.5 ft to 4 ft	> 4 ft
Hydrodynamic Parameters			
Waves	< 1 ft	1 ft to 3 ft	> 3 ft
Wakes	< 1 ft	1 ft to 3 ft	> 3 ft
Currents	< 1.25 kts	1.25 kts to 4.75 kts	>4.75 kts
Ice	< 2 in	2 in to 6 in	> 6 in
Storm Surge	<1 ft	1 ft to 3 ft	>3 ft
Terrestrial Parameters			
Upland Slope	<1 on 30	1 on 30 to 1 on 10	>1 on 10
Shoreline Slope	<1 on 15	1 on 15 to 1 on 5	> 1 on 5
Width	<30 ft	30 ft to 60 ft	>60 ft
Nearshore Slope	<1 on 30	1 on 30 to 1 on 10	>1 on 10

Note: with the exception of 'ice', all parameters outlined above are applicable to shorelines within the City of Punta Gorda.



Table C5.2 Appropriate Conditions for Various Living Shoreline Approaches (Miller, et al, 2015)

	Marsh Sill	Breakwater	Revetment	Living Reef	Reef Balls
System Parameters					
Erosion History	Low-Med	Med-High	Med-High	Low-Med	Low-Med
Relative Sea Level	Low-Mod	Low-High	Low-High	Low-Mod	Low-Mod
Tidal Range	Low-Mod	Low-High	Low-High	Low-Mod	Low-Mod
Hydrodynamic Parameters					
Wind Waves	Low-Mod	High	Mod-High	Low-Mod	Low-Mod
Wakes	Low-Mod	High	Mod-High	Low-Mod	Low-Mod
Currents	Low-Mod	Low-Mod	Low-High	Low-Mod	Low-Mod
Ice	Low	Low-Mod	Low-High	Low	Low-Mod
Storm Surge	Low-High	Low-High	Low-High	Low-High	Low-High
Terrestrial Parameters					
Upland Slope	Mild-Steep	Mild-Steep	Mild-Steep	Mild-Steep	Mild-Steep
Shoreline Slope	Mild-Mod	Mild-Steep	Mild-Steep	Mild-Mod	Mild-Steep
Width	Mod-High	Mod-High	Low-High	Mod-High	Mod-High
Nearshore Slope	Mild-Mod	Mild-Mod	Mild-Steep	Mild-Mod	Mild-Mod
Offshore Depth	Shallow-Mod	Mod-Deep	Shallow-Deep	Shallow-Mod	Shallow-Mod
Soil Bearing	Mod-High	High	Mod-High	Mod-High	Mod-High
Ecological Parameters					
Water Quality	Poor-Good	Poor-Good	Poor-Good	Good	Poor-Good
Soil Type	Any	Any	Any	Any	Any
Sunlight Exposure	Mod-High	Low-High	Low-High	Mod-High	Low-High

Note: with the exception of 'ice', all parameters outlined above are applicable to shorelines within the City of Punta Gorda.



Comparatively, the parameter limitations identified by Miller et al are considered more conservative than those outlined by the USACE Systems Approach to Geomorphic Engineering (SAGE) brochure entitled “Natural and Structural Measures for Shoreline Stabilization” (2015). Table C5.3 summarizes wave energy by classifying wave heights into low, medium, and high energy categories, as defined by SAGE (2015). Notably the wave heights cataloged within each low, medium and high category is nearly double that of the wave height thresholds identified for similar exposure categories.

Table C5.3 Summary of Wave Energy

Wave Heights	Description	Typical Range
Low	Limited fetch in sheltered, shallow or small water body (such as estuary, river, bay)	< 2 foot
Medium	A range that combines elements of low and high energy (e.g. shallow water with a large fetch or partially sheltered)	2 to 5 feet
High	Large fetch, deep water, open ocean	> 5 feet

With much of the waterfront in Punta Gorda located along the Charlotte Harbor, the City is exposed to a relatively large fetch up to nearly 6 miles to the west. The waterfront is also located in close proximity to a navigation channel where boat traffic is prevalent. Vessel-generated waves (boat wakes) are a significant source of wave energy within sheltered water bodies. As vessels pass, waves are generated by the bow and stern as it moves through the water. Once wake waves are generated, they propagate through the water and are modified by the local site conditions. In the Punta Gorda area, multiple marinas and an abundance of private docks support extensive boat traffic as people traverse Charlotte Harbor and the Peace River. The waves caused by wind and boat wakes, in combination with the presence of existing vertical bulkheads and hardened shorelines, leads to a complex design challenge for shoreline protection. Taylor Engineering recommends applying more conservative wave height thresholds as identified in Tables C5.1 and C5.2 in future living shoreline design projects.

Given the location and physical orientation of the City’s urban downtown waterfront to the harbor, the site conditions are similar across the City’s various shoreline reaches. Average daily tidal datums are estimated by NOAA using observed water level data at long-term tide stations. In review of living shoreline design reports developed for the City by others, the tidal range utilized for those analyses references a historic tide station in Punta Gorda (Station ID No: 8725744) located near Fishermen’s Village. This is a subordinate station that actively recorded water levels for eight months from 1977-1978 and was removed in 1981, reporting only monthly tidal data for a 9-month period. This outdated tidal information does not account for water level changes over the past 40 years such as sea level rise, making this data obsolete and inconsistent with the recommendations outlined in the Climate Adaptation Plan addendum to consider future planning horizons.

Alternatively, Taylor Engineering recommends the NOAA tidal gauge located in Fort Myers at the City’s Yacht Basin, along the Caloosahatchee River, 0.25 miles east of the US 41 bridge. This tidal gauge is a close approximation for Punta Gorda’s water level trends due to its riverine location within a similar proximity to the Gulf of Mexico as downtown Punta Gorda. The Fort Myers gauge (Station ID NO: 8725520) has measured monthly mean water levels since 1965 and hourly water levels since 1969. Stations with datasets longer than 40 years are preferred for



calculating sea level trends, as seasonal variability and multi-decadal variability is reduced with a longer duration dataset. While the latter tidal gauge provides more comprehensive data, it is recommended that both stations be evaluated when selecting living shoreline designs within the tidal zone.

In addition to tidal range, consideration of potential storm surge water elevations is necessary in order to achieve specific design goals. For traditional engineered structures, determination of storm surge is critical; however, for living shorelines, this parameter is less significant as most of these approaches are low lying and likely to be overtopped during extreme conditions. The key when considering storm surge is to design living shorelines to withstand and maintain stability when exposed to storm related receding waters. Upon review of storm surge data from FEMA, Table C5.4 summarizes the storm surge elevations for 10, 25, 50, 100, and 500-year storms within Charlotte County. Storm surge events can better be described as the potential frequency of occurrence within any given year.

Table C5.4 FEMA Storm Surge Range for Charlotte County

Surge Event (yr)	Annual Chance of Occurrence (%)	Min (ft)	Max (ft)
10	10%	2.2	4.9
25	4%	4.6	6.9
50	2%	5.6	8.5
100	1%	5.3	10.2
500	0.2%	8.9	14.3

Though Punta Gorda is a peninsular point, the City-owned shoreline is located primarily along the interior portion of the Charlotte Harbor. The southwestern shoreline surrounding Punta Gorda is a state-owned conservation land buffer, called Charlotte Harbor Preserve State Park. The City's shoreline is oriented facing primarily northeast to southwest and spans approximately 18,000 linear feet along the waterfront.

According to windspeed data recorded at the Punta Gorda Airport on WindHistory.com, the dominant winds are from the northeast (11.6%) with an average windspeed of 7 knots. However, the greatest prevailing windspeeds are from the west-southwest and south-southwest at 10 knots. As Florida's second largest open water estuary (Estuaries Report Card, 2005), the fetch distances must be carefully considered for successful project performance. Maximum fetch distances were estimated using Google Earth from both the northeastern-most and southwestern-most locations within the City. In both cases, the maximum fetch distance measured approximately 5 to 6 miles from the west-southwest. According to NOAA Navigational Chart number 11426, the water depths along that azimuth range between 6 to 15 feet MLLW, with the deeper areas extending to the far west in the open water portion of the bay. All these factors have an impact on both regional and local sediment transport trends.

A review of previous documentation indicates that sediments along the downtown waterfront consist of primarily poorly consolidated fine sand with varying degrees of organic content (Jacobs, 2018). In some shoreline segments, black organic muck pockets with small factions of fine sand and shell fragments were found, including the presence of oyster shells.



6.0 LIVING SHORELINE ALTERNATIVES

Coastal systems typically include both natural and manmade elements. The interactions among these features determine coastal vulnerability, reliability, risk, and resiliency (USACE SAGE, 2015). An array of shoreline management strategies exists for coastal and estuarine systems which have been succinctly described in the SAGE brochure and outlined below. These strategies, which may be used independently or in combination are listed below (USACE SAGE, 2015).

- Natural features, created through the action of physical, biological, geologic, and chemical processes operating in nature, and include mangroves, dunes and oyster reefs. Such features are designed, engineered, and constructed to mimic a natural system.
- Structural features, created to reduce coastal risk by decreasing shoreline erosion, wave damage, and flooding. These features include seawalls, bulkheads, groins and breakwaters – each requiring engineered design and construction.
- Non-structural features, such as modifications in public policy, management practices, and regulatory policies. These measures could be implemented through established land use regulations, emergency response planning, flood preparedness planning, and structural acquisition/relocation).

As recognized by the USACE and NOAA, an integrated ‘hybrid’ approach to risk reduction through the incorporation of natural, nature-based features in addition to non-structural and structural measures is the key to improving social, economic, and ecosystem resilience. The table below, from USACE SAGE (2015) summarizes a range of acceptable green, gray and hybrid approaches to resilient shoreline management.

To summarize the overall benefits as outlined in the table, such green to gray living shoreline measures each provide erosion control and shoreline stabilization. However, incorporation of green to hybrid type approaches improve biological, social and economic elements. Restoration and enhancement of habitats provide support for fish and wildlife populations, result in increased property values, and improved recreational use/public access. Other physical benefits include increased resilience and absorption of wave energy, storm surge and floodwaters, improved water quality from settling and trapping of suspended sediment, and carbon sequestration (USACE SAGE, 2015).

Typical challenges in development and design of living shoreline projects, specifically in urban environments, include limited land space, high velocity waters, lack of performance monitoring, lengthy permitting processes, land ownership constraints, and available funding. Though funding availability is often an issue, materials selection greatly influences the overall project cost. As outlined in Table C6.1, green shoreline approaches are often cheaper than traditional gray shoreline stabilization techniques, however, careful consideration must be given to the operation and maintenance of such installations over the project lifecycle. Note that the estimated costs identified for initial construction, operations and maintenance (Table C6.1) represent average order of magnitude costs for similar projects implemented in recent years based on data available at the time of the publication. Project costs may vary based on site conditions, accessibility, material selection, and design.

Table C6.1 Green to Gray Living Shoreline Management Alternatives

	Option	Description	Suitable Site Characteristics	Material Options	Benefits	Disadvantages	Estimated Cost	Comment
	Vegetation Only	Roots hold soil in place to reduce erosion. Provides a buffer to upland areas and breaks small waves.	Low wave energy environments.	• Native plants	• Dissipates wave energy • Slows inland water transfer • Increases natural storm water infiltration • Provides habitat and ecosystem services • Minimal impact to natural community and ecosystem processes • Maintains aquatic/terrestrial interface and connectivity • Flood water storage	• No storm surge reduction ability • No high water protection • Appropriate in limited situations • Uncertainty of successful vegetation growth and competition with invasive	Initial Construction: Up to \$1,000/linear foot Operations & Maintenance: Up to \$100/linear foot	Native plants and materials must be appropriate for current salinity and site conditions.
	Edging	Structure to hold the toe of existing or vegetated slope in place. Protects against shoreline erosion	Most areas except high wave energy environments.	Vegetation base with the following options: • “Snow” fencing • Erosion control blankets • Geotextile tubes • Living reef (oyster/mussel) • Rock gabion baskets	• Dissipates wave energy • Slows inland water transfer • Provides habitat and ecosystem services • Increases natural storm water infiltration • Toe protection helps prevent wetland edge loss	• No high water protection • Uncertainty of successful vegetation growth and competition with invasive	Initial Construction: \$1,000 up to \$2,000/linear foot Operations & Maintenance: Up to \$100/linear foot	Native plants and materials must be appropriate for current salinity and site conditions.
	Sills	Parallel to existing or vegetated shoreline, reduces wave energy and prevents erosion. A gapped approach would allow habitat connectivity, greater tidal exchange, and better waterfront access.	Most areas except high wave energy environments.	Vegetation base with the following options: • Stone • Sand breakwaters • Living reef (oyster/mussel) • Rock gabion baskets	• Provides habitat and ecosystem services • Dissipates wave energy • Slows inland water transfer • Provides habitat and ecosystem services • Increases natural storm water infiltration • Toe protection helps prevent wetland edge loss	• Require more land area • No high water protection • Uncertainty of successful vegetation growth and competition with invasive	Initial Construction: \$1,000 up to \$2,000/linear foot Operations & Maintenance: Up to \$100/linear foot	Native plants and materials must be appropriate for current salinity and site conditions.
	Beach Nourishment Only	Large volume of sand added from outside source to an eroding beach. Widens the beach and moves the shoreline seaward.	Low-lying oceanfront areas with existing sources of sand and sediment.	• Sand	• Expands usable beach area • Lower environmental impact than hard structures • Flexible strategy • Redesigned with relative ease • Provides habitat and ecosystem services	• Requires continual sand resources for renourishment • No high water protection • Appropriate in limited situations • Possible impacts to regional sediment transport	Initial Construction: \$2,000 up to \$5,000/linear foot Operations & Maintenance: \$100 up to \$500/linear foot	Sediment size and characteristics must match.
	Beach Nourishment & Vegetation on Dune	Helps anchor sand and provide a buffer to protect inland area from waves, flooding and erosion.	Low-lying oceanfront areas with existing sources of sand and sediment.	Sand with vegetation can also strengthen dunes with: • Geotextile tubes • Rocky core	• Expands usable beach area • Lower environmental impact • Flexible strategy • Redesigned with relative ease • Vegetation strengthens dunes and increases their resilience to storm events • Provides habitat and ecosystem services	• Requires continual sand resources for renourishment • No high water protection • Appropriate in limited situations • Possible impacts to regional sediment transport	Initial Construction: \$2,000 up to \$5,000/linear foot Operations & Maintenance: \$100 up to \$500/linear foot	Sediment size and characteristics must match. Native plants and materials must be appropriate for current salinity and site conditions.
	Breakwater	Offshore structures intended to break waves, reducing the force of wave action and encourages sediment accretion. Can be floating or fixed to the ocean floor, attached to shore or not, and continuous or segmented. A gapped approach would allow habitat connectivity, greater tidal exchange, and better waterfront access.	Most areas except high wave energy environments often in conjunction with marinas.	• Grout-filled fabric bags • Armorstone • Pre-cast concrete blocks • Living reef (oyster/mussel) if low wave environment • Wood • Rock	• Reduces wave force and height • Stabilizes wetland • Can function like reef • Economical in shallow areas • Limited storm surge flood level reduction	• Expensive in deep water • Can reduce water circulation (minimized if floating breakwater is applied) • Can create navigational hazard • Require more land area • Uncertainty of successful vegetation growth and competition with invasive • No high water protection • Can reduce water circulation • Can create navigation hazard	Initial Construction: \$5,000 up to \$10,000/linear foot Operations & Maintenance: Over \$500/linear foot	Rock/stone needs to be appropriately sized for site specific wave energy. Could be green by using oysters to colonize rocks or alternative forms and materials.
	Groin	Perpendicular, projecting from shoreline. Intercept water flow and sand moving parallel to the shoreline to prevent beach erosion and break waves. Retain sand placed on beach.	Coordination with beach nourishment.	• Concrete/stone rubble • Timber • Metal sheet piles	• Protection from wave forces • Methods and materials are adaptable • Can be combined with beach nourishment projects to extend their life	• Erosion of adjacent sites • Can be detrimental to shoreline ecosystem (e.g. replaces native substrate with rock and reduces natural habitat availability) • No high water protection	Initial Construction: \$2,000 up to \$5,000/linear foot Operations & Maintenance: \$100 up to \$500/linear foot	Rock/stone needs to be appropriately sized for site specific wave energy. Could be green by using oysters to colonize rocks or alternative forms and materials.

	Revetment	Lays over the slope of a shoreline. Protects slope from erosion and waves.	Sites with pre-existing hardened shoreline structures.	• Stone rubble • Concrete blocks • Cast concrete slabs • Sand/concrete filled bags • Rock-filled gabion basket	• Mitigates wave action • Little maintenance • Indefinite lifespan • Minimizes adjacent site impact	• No major flood protection • Require more land area • Loss of intertidal habitat • Erosion of adjacent unreinforced sites • Require more land area • No high water protection • Prevents upland from being a sediment source to the system	Initial Construction: \$5,000 up to \$10,000/linear foot Operations & Maintenance: \$100 up to \$500/linear foot	Rock/stone needs to be appropriately sized for site specific wave energy. Could be green by using oysters to colonize rocks, using vegetation or alternative forms and materials.
	Bulkhead	Parallel to the shoreline, vertical retaining wall. Intended to hold soil in place and allow for a stable shoreline.	High energy settings and sites with pre-existing hardened shoreline structures. Accommodates working water fronts (eg: docking for ships and ferries).	• Steel sheet piles • Timber • Concrete • Composite carbon fibers • Gabions	• Moderates wave action • Manages tide level fluctuation • Long lifespan • Simple repair	• No major flood protection • Erosion of seaward seabed • Erosion of adjacent unreinforced sites • Loss of intertidal habitat • May be damaged from overtopping oceanfront storm waves • Prevents upland from being a sediment source to the system • Induces wave reflection	Initial Construction: \$2,000 up to \$5,000/linear foot Operations & Maintenance: \$100 up to \$500/linear foot	Could be green by using green wall or biowall or alternative forms and materials.
	Seawall	Parallel to shoreline, vertical or sloped wall. Soil on one side of wall is the same elevation as water on the other. Absorbs and limits impacts of large waves and directs flow away from land.	Areas highly vulnerable to storm surge and wave forces.	• Stone • Rock • Concrete • Steel/vinyl sheets • Steel sheet piles	• Prevents storm surge flooding • Resists strong wave forces • Shoreline stabilization behind structure • Low maintenance costs • Less space intensive horizontally than other techniques (e.g. vegetation only)	• Erosion of seaward seabed • Disrupt sediment transport leading to beach erosion • Higher up-front costs • Visually obstructive • Loss of intertidal zone • Prevents upland from being a sediment source to the system • May be damaged from overtopping oceanfront storm waves	Initial Construction: \$5,000 up to \$10,000/linear foot Operations & Maintenance: Over \$500/linear foot	Could be green by using green wall or biowall or alternative forms and materials.





Green, softer approaches require site conditions that include low wave energy, small fetch, gentle slopes, and a sheltered coastal orientation, as shown in Photograph C6.1. Harder, gray shoreline stabilization approaches are suitable in areas with high wave energy, lengthy fetch, steep slopes, and exposure to open coast conditions. Photograph C6.1 demonstrates an edging approach to shoreline stabilization (as outlined in Table C6.1), using native vegetation supported by oyster reefs to hold the toe of the slope in place. Other edging approach examples successfully used in southwest Florida include the use of planter boxes, geosynthetic cellular systems such as “Geoweb” or other similar products.



Photograph C6.1 Oyster Breakwater, Cat Point in the Florida Panhandle



6.1 Shoreline Vegetation Options for Southwest Florida

When properly designed for site conditions, living shorelines generally become more stable over time as plants grow. Naturally vegetated shorelines absorb wave energy (Anderson and Smith, 2014) while maintaining the ability to bounce back to their pre-stressed condition. Mangroves and marsh vegetation trap sediment and may increase in elevation to keep pace with sea level rise. According to Morris, et al (2002), wetlands can increase upward nearly 12mm per year. Similarly, mangroves can migrate landward faster than sea level rise (Das and Vincent, 2009, Gilman et al, 2007). Selection of proper vegetation depends on whether the site is located in low, mid, or high marsh tidal zones. Florida Living Shorelines² provides the following information on salt tolerant plants suitable for tidal zones in southwest Florida (Photograph C6.2).

The low tidal zone generally extends from the seaward edge of wetland vegetation shoreward to about the mean high water line. This zone floods daily and is generally exposed at low tide. Plants suitable for this zone include:

- Red mangrove (*Rhizophora mangle*) – generally the dominant species
- Black mangrove (*Avicennia germinans*)
- White mangrove (*Laguncularia racemosa*)



Photograph C6.2 Marsh Restoration in St. Johns County, FL

² <http://floridalivingshorelines.com/marshplants/#South>, accessed June 13, 2019.



Mid-tidal zone vegetation generally occurs near the mean high water line and experiences regular to occasional flooding. Plants suitable for this zone include:

- Red mangrove (*Rhizophora mangle*)
- Black mangrove (*Avicennia germinans*)
- White mangrove (*Laguncularia racemosa*)
- Saltwort (*Batis maritima*)
- Glasswort (*Sarcocornia ambigua*)

High-tidal zone vegetation experiences flooding under extreme high tides and storm surge. Plants suitable for the high-tidal zone include:

- Black mangrove (*Avicennia germinans*)
- White mangrove (*Laguncularia racemosa*)
- Saltmeadow cordgrass (*Spartina patens*)
- Saltgrass (*Distichlis spicata*)
- Sea purslane (*Sesuvium portulacastrum* or *S. maritimum*)
- Seashore dropseed (*Sporobolous virginicus*)
- Seashore paspalum (*Paspalum vaginatum*)
- Black needlerush (*Juncus roemerianus*)
- Sand cordgrass (*Spartina bakeri*)
- Marsh elder (*Iva frutescens*)
- Sea ox-eye daisy (*Borrchia frutescens*)



6.2 Oyster Restoration

Oyster reefs are a key habitat in southwest Florida estuaries, providing numerous species of fish and invertebrate with territory for foraging, refuge, nursery, and other critical life cycle functions. However, the oyster reefs in Charlotte Harbor and elsewhere in the region have been largely lost; destroyed by dredging, oyster shell mining, and watershed urbanization effects such as sedimentation, water quality changes, and greatly increased human activity. This has resulted in an estimated 90% loss of historic oyster habitat in Charlotte harbor and the other estuaries within the CHNEP region. TNC Florida Chapter identified Charlotte Harbor as a Florida marine priority area in TNC's larger strategy to restore the Gulf of Mexico (TNC, 2017).

While oyster reef installations have been occurring in Charlotte Harbor (e.g. Photograph C6.3), for many years the efforts did not take place within a well-defined restoration plan. In 2012, CHNEP and its partners developed the CHNEP Oyster Habitat Restoration Plan (Plan; Boswell et al 2012). The Southwest Florida Oyster Working Group (SWF OWG) guided plan development, which was produced through a CHNEP Nature Conservancy (TNC) partnership. The Plan uses the TNC four-step "conservation by design" approach to define oyster restoration needs and strategies. The Restoration Suitability Model (RSM), developed as part of the Plan, identifies over 40,000 acres highly suitable for oyster restoration within the Charlotte Harbor System (Figure C6.1 Charlotte Harbor Habitation Restoration Suitability Model Results).



Photograph C6.3 Oyster Reef Installation in Charlotte Harbor near downtown Punta Gorda, 2015 (Mosaic 2019)

The Plan has a long-term goal of restoring 1,000 - 6,000 acres of oyster reef. That long-term goal is supported by a series of short term objectives:

- Map oyster habitats by type within the CHNEP by 2020.



- Design, implement and monitor the success of pilot oyster restoration projects in a variety of habitats in 50% of the CHNEP estuary segments by 2020 (Photograph C6.4).
- Increase public awareness of the ecosystem value of native oyster habitats by including
- Integrate community stewardship components in each oyster restoration project.
- Assist partners in seeking state, federal and organizational funding opportunities to support oyster habitat restoration projects.



Photograph C6.4 Artificial Oyster Reefs Implemented by CHNEP, February 2019

As part of the efforts to meet those objectives, Punta Gorda recently partnered with CHNEP, TNC, FDEP, and community volunteers to test three types of materials often used in oyster restoration projects to see which method produces the best larval oyster recruitment. Bagged shells were most attractive, with over twice the recruitment of loose shell (about 600 larvae/square meter) which was twice as attractive as shell mats, which recruited over 300 larvae/square meter). However, the shell mats produced larger individuals. This project also supports the development of community stewardship and public awareness critical for the long-term program to succeed.

In addition to the critical ecosystem functions oyster reefs provide, they can also survive and help combat consequences of sea level rise. Oyster reefs stabilize sediments, shorelines, and adjacent habitats, buffering wave energy and aiding water quality. Sediment deposition and stabilization within and around oyster reefs can result in net sediment elevation in oyster reef areas (Bahr and Lanier 1981). Oyster reefs can grow vertically up to 60 mm/year (Ridge et al, 2017 and Rodriguez et al, 2014). Based on the City's 2019 vulnerability analysis, the local rate of sea level rise is 3.1 mm/year. Predicted oyster growth rates are capable of outpacing local



sea level rise at this time. Oyster reef creation has been identified as a means of reducing shoreline erosion and loss of saltmarsh habitat due to sea level rise in Charlotte Harbor (Geselbracht et al. forthcoming; from Boswell et al 2012).

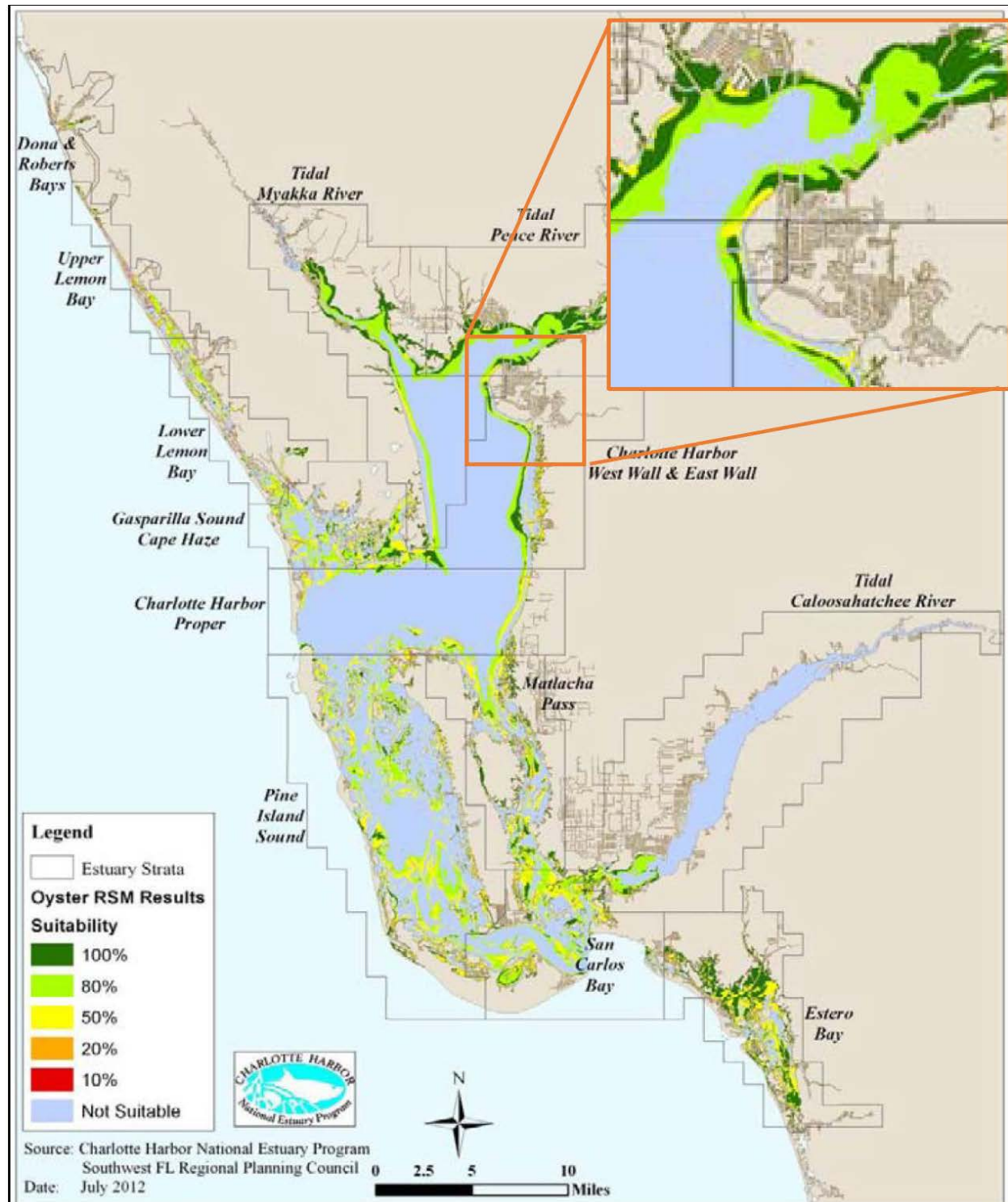


Figure C6.1 Charlotte Harbor Habitation Restoration Suitability Model Results
(Boswell, 2012)



6.3 Hybrid Approaches

For site conditions where wave energy exceeds 1 foot or more, a hybrid living shoreline approach is most viable. The City's waterfront is located within relatively shallow water. Due to the open 6-mile fetch to the west, greatest prevailing winds from the west southwest, and moderate to heavy vessel traffic (boat wakes) within the vicinity, a hybrid approach is recommended for most shoreline segments. As outlined in Table C6.1, a range of solutions such as a rock planted sills, planter boxes, limestone riprap, concrete oyster domes, marine mattresses or breakwater type solution can be used. The City, in partnership with other entities, has developed conceptual level alternatives analysis for an 800 linear foot segment of shoreline fronting the Sheraton Four Points Hotel along the downtown waterfront (Photograph C6.5).



Photograph C6.5 Existing Shoreline Conditions along the Four Points Sheraton Waterfront
(*Jacobs Engineering Technical Memo, 2018*)



One example of this approach can be found in plan view (Figure C6.2). The project is located in Okaloosa County, exposed to a 10-mile fetch along the Choctawhatchee Bay. Though specific vegetation types may vary by region, the technical design approach remains the same. The design accounted for wind-driven waves, boat wakes from the adjacent navigation channel, sediment transport and existing ecological concerns; similar to conditions within the City of Punta Gorda. Notably, the green, red, and yellow zones represent low, medium, and high shoreline zone species as well as open areas to allow for natural recruitment.

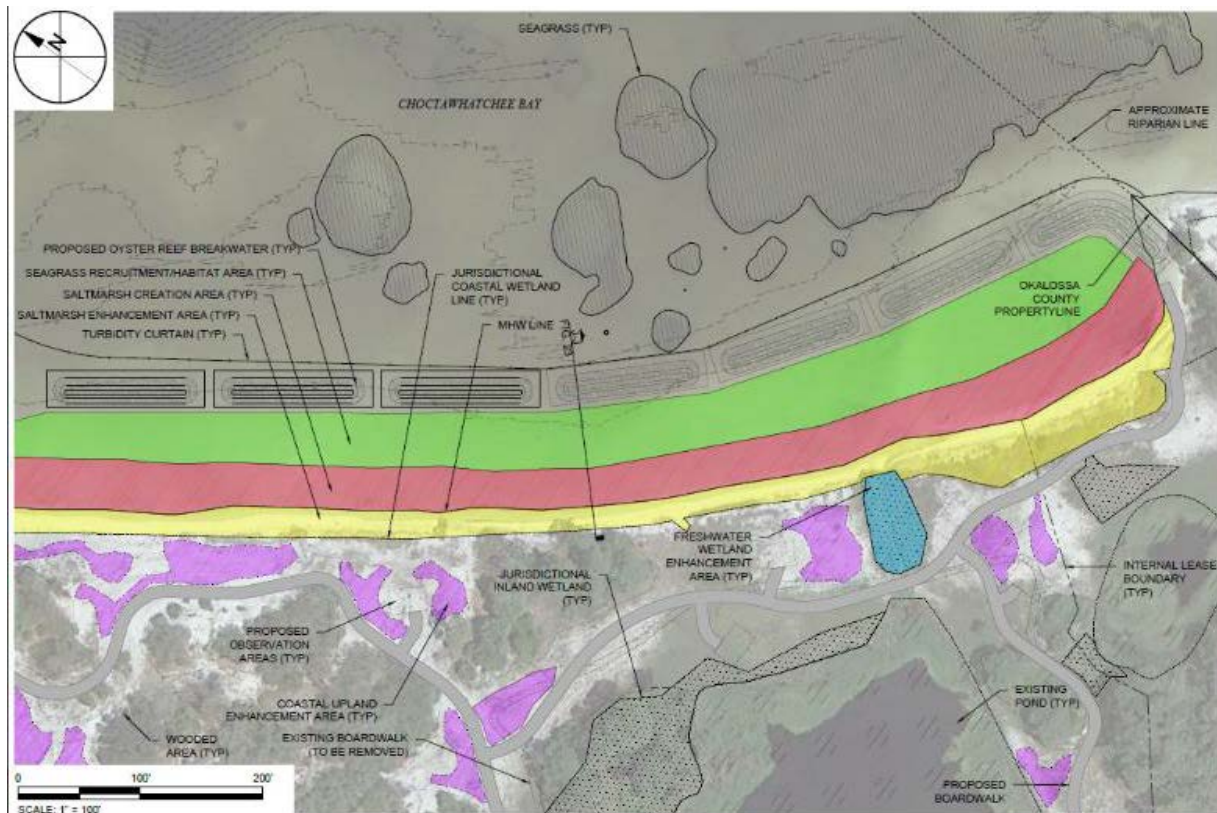


Figure C6.2 Okaloosa Baywalk Living Shoreline Design Plan View (*Taylor Engineering*)



The material elements consist of oyster reef breakwaters composed of limestone to allow for oyster recruitment. In this case, rock is required to accomplish the required stability necessary to withstand the moderate wave climate. Figure C6.3 depicts a representative cross-section of this design.

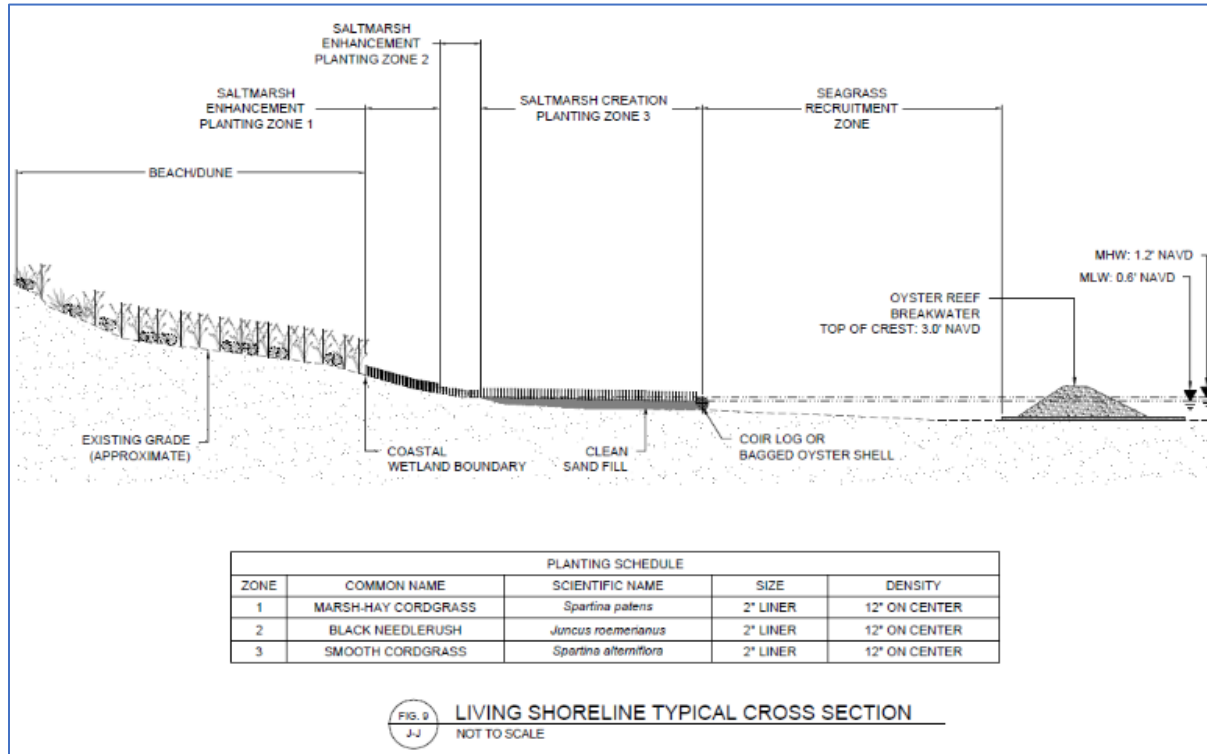


Figure C6.3 Okaloosa Baywalk Living Shoreline Design Cross-section View (*Taylor Engineering*)

Another hybrid living shoreline example is shown in Figure C6.4 and Figure C6.5. Located at Cat Point in Franklin County, Florida; this project site adjoins the Apalachicola National Estuarine Research Reserve. The design consists of an oyster reef breakwater constructed of suitable substrate for marine mattress filling, such as limestone, oyster cultch, or a composite of the two. The marine mattresses, a cellular geogrid basket, provide ease in constructability, acting as a semi-emergent, low-crested natural segmented breakwater for wave attenuation.

Along the shoreline, suitable plantings are specified within each intertidal zone with clean open sandy bottom to accommodate natural vegetation recruitment. For such designs, a planting schedule with site specific vegetation types, spacings, and sizes are paramount for implantation of successful projects. Incorporation of a natural/native-material wave attenuation structure waterward of the planting area allows vegetation to take root and stabilize.



Much of the City's downtown waterfront is already hardened with vertical walls. Therefore, mid and high intertidal planting zones may be limited in some areas. Due to the presence of vertical walls, localized scour along the toe is typical when exposed to moderate wave energy. Under the influence of tides, waves and currents, sediments suspended in the water column resulting from toe scour can be transported to other reaches or segments of shoreline. This phenomenon is important when planning for installation of living shorelines as nearshore living shorelines may require periodic maintenance to maintain adequate fill necessary to stabilize living shoreline elements.

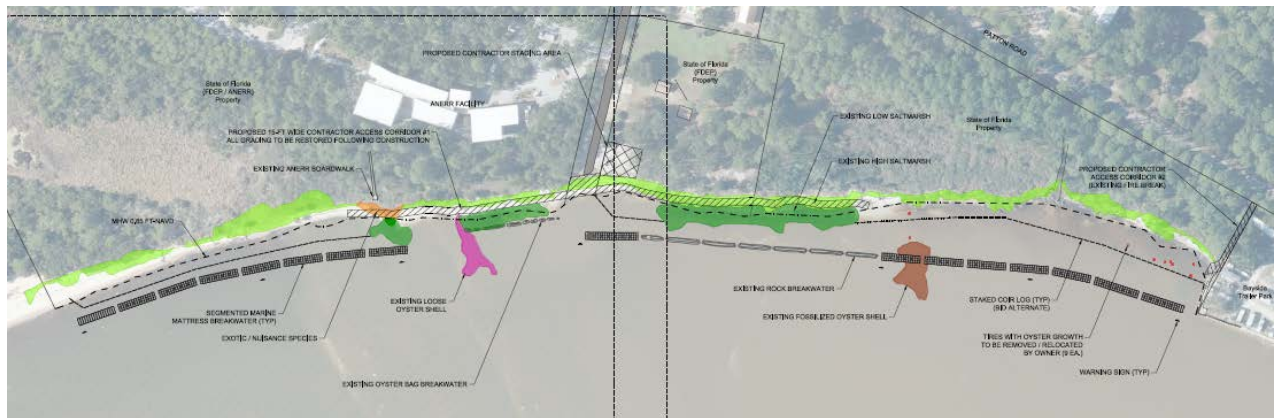


Figure C6.4 Cat Point Living Shoreline Plan View (*Taylor Engineering*)

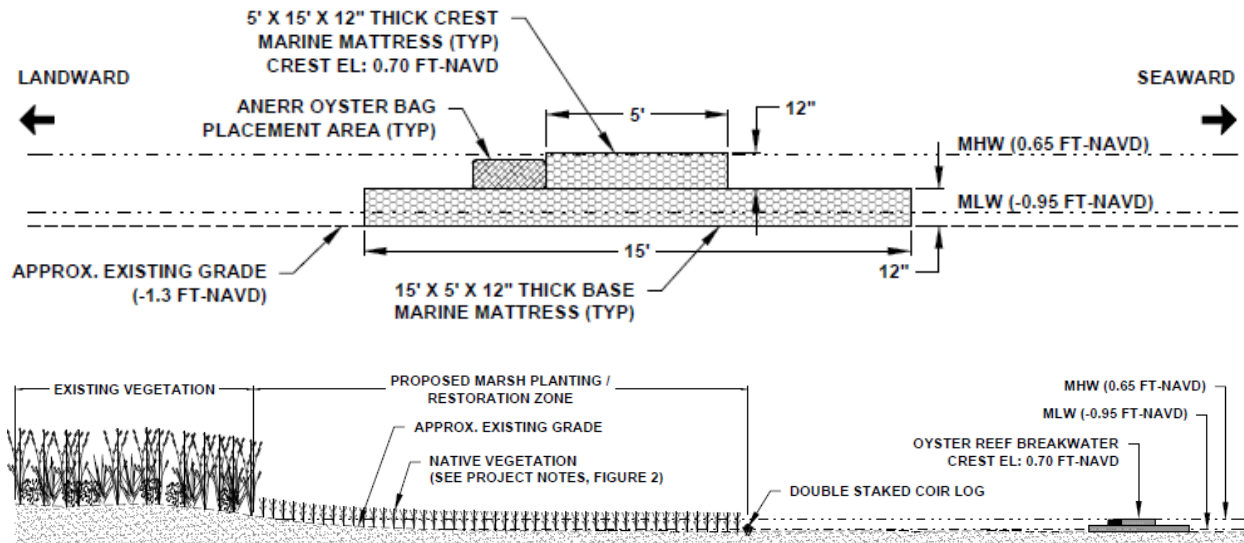


Figure C6.5 Cat Point Living Shoreline Cross-section (*Taylor Engineering*)

It is important to evaluate the level of risk for continued erosion with the level of protection that is acceptable at a particular site. Decision-makers should keep in mind that no shoreline stabilization technique (hardened or living shoreline) is guaranteed to prevent the loss of infrastructure during the most severe storms (NOAA, 2015). However, living shorelines can be more resilient than hardened vertical structures in storms with high storm surge. Storm surge can roll over the living shoreline and inundate the land, leaving the shoreline minimally impacted. In contrast, wave energy from the waterward side and retreating water can undermine bulkheads and seawalls that are not high enough to prevent overtopping and inundation of the land behind the structures.



7.0 MAINTENANCE AND MONITORING

Maintenance is critical for continued growth and minimizing storm damage sustained by living shoreline sites. Maintenance includes replanting vegetation as needed, maintaining fill, periodic debris removal, and removal of interfering invasive species. Traditional hard stabilization structures also require maintenance and repair to deal with deterioration and damage.

Living shoreline projects are planned and designed to meet specific goals and design criteria, but it is important to monitor installed projects to gauge their performance and perform adaptive management. Although many studies have demonstrated the benefits of natural, nature-based living shorelines, data gaps exist (Yepsen et al., 2016). For example, while salt mangroves and salt marshes provide coastal resilience benefits to communities during storms, little is known about how those benefits vary with storm size, speed, and duration (Sutton-Grier et al., 2015). Monitoring the effectiveness of living shorelines in preventing erosion and sustaining information to evaluate whether living shorelines should be considered for other similar environments. In most, if not all cases, regulatory or grant funding agencies require monitoring of projects. Ideally, monitoring should be initiated before project installation in order to gauge project performance through a series of monitoring stages: a) baseline monitoring, b) as-built survey, and c) performance monitoring.

Baseline monitoring includes data collection (e.g., topography, sediment characteristics, vegetation) prior to design and installation of a project to document the condition against which future monitoring will be compared. As-built surveys are monitoring surveys conducted immediately after project construction to demonstrate that the project meets the engineering specifications and regulatory requirements. Performance monitoring following installation allows for comparison of the baseline site condition and as-built conditions. This process provides documentation on progress and project performance compared to the project goals. Performance monitoring can inform the need for potential adaptive management or maintenance if a project is not performing as intended (Yepsen et al., 2016).

Kreeger and Moody (2014) and Yepsen et al. (2016) discuss the framework of monitoring plan development and provide tables to guide the user in selecting monitoring metrics and methods based on project design type, goals, and other considerations (Figure C7.1).



Figure C7.1 Stepwise Progression for Monitoring Plan Development (*Yepsen et al, 2016*)



Generally, the project objective will help to define the core set of metrics used to evaluate project success. Recent studies indicate that living shoreline projects typically don't begin to thrive until several years post-construction. Ongoing annual monitoring for a period of six years or more may be necessary to fully document project development and performance.

8.0 REGULATORY CONSIDERATIONS

As with all construction projects in Florida that involve surface waters or wetlands, living shoreline projects must consider regulatory requirements and obtain authorizations from state and federal governments. In addition, Punta Gorda's waterfront is within the Gasparilla Sound – Charlotte Harbor Aquatic Preserve. This designation by the State of Florida provides for additional protection and management by the state to preserve these areas in their natural or existing conditions. Chapter 18-20 Florida Administrative Code (FAC) sets management policies and criteria for activities within aquatic preserves. Activities within Aquatic Preserves must have a positive public benefit; dredging and filling activities are typically prohibited, with few exceptions. In order to receive authorization, a restoration project proposed within an aquatic preserve must demonstrate that the project will have an overall benefit to the aquatic preserve and demonstrate consistency with existing aquatic preserve management plans.

The waters within City limits are also within the National Marine Fisheries Service (NMFS) designated smalltooth sawfish critical habitat boundary (as of September 2009 per 50 CFR Part 226). The designation area contains nursery areas featuring "red mangroves and shallow euryhaline habitats characterized by water depths between the Mean High Water line and 3 ft (0.9 m) measured at Mean Lower Low Water (MLLW).

8.1 State and Federal Permitting:

State permits are issued by either the FDEP or the Southwest Florida Water Management District (SWFWMD). Federal permits for restoration of projects within waters of the United States (e.g., within wetlands or submerged areas) are issued by the USACE. Instructions and additional information for state applications can be found at on the FDEP (2019a) regulatory website. Information on the USACE permitting process, forms and guidance for the Jacksonville District may be found within the USACE Jacksonville District Source Book (USACE 2019).

Engineers and practitioners planning to implement submerged habitat restoration projects are encouraged to seek pre-application meetings with federal and state regulatory staff prior to permit application submittal. Specific permitting guidance can be obtained from such meetings on an individual project basis.

In relatively recent regulatory developments, state and federal agencies now provide expedited permitting for living shorelines and other similar projects to encourage landowners, municipalities, and planners to consider softer design solutions for shoreline stabilization.



8.2 State Permitting:

Projects affecting wetlands generally require a state environmental resource permit (ERP) issued by the FDEP or SWFWMD. Most submerged lands on which Punta Gorda living shoreline projects would be located are state owned and would, therefore, also require a state submerged lands use authorization. The ERP process follows Chapter 62-330, Florida Statutes, and the rules thereunder. Chapter 18-21 FAC governs sovereignty submerged lands management and uses, providing a guide for permitting decisions. The rule defines several types of authorization for various activities. FDEP's Submerged Lands and Environmental Resources Coordination program (FDEP 2019b) reviews applications for proposed works in wetlands and other surface waters as well as works in uplands that can affect water quality and quantity, to ensure compliance with the Florida Administrative Code and Florida Statutes

The FDEP may exempt a project from permitting or require one of several possible authorizations for living shoreline projects. The least complicated processes include review for a Verification of Exemption from Permitting or a General Permit, combined with a Statewide Programmatic General Permit (SPGP). The exemption and general permit authorizations, for projects with minimal or no impacts, include expedited review. The SPGP, which also requires only a short review period usually concurrent with the rest of the review process, allows the state to conclude that the impacts of a proposed project are so minimal that no federal review is required. An agreement between the State of Florida and the USACE Jacksonville District defines the conditions under which an SPGP can be issued. The process greatly expedites the review time if a proposed living shoreline project meets the State's design limitations. Those limitations, similar to the USACE requirements, include a project length less than 500 feet extending no more than 35 feet offshore.

8.3 Federal Permitting:

Most proposed construction that occurs in the waters of the US require a permit from USACE. That agency is responsible for issuing permits pursuant to the Rivers and Harbors Act of 1899 Section 10 and the Federal Water Pollution Control Act of 1972 (Clean Water Act or CWA) Section 404. Although the USACE and the US Environmental Protection Agency (EPA) share certain administrative responsibilities under the CWA, the USACE is the lead permitting entity for activities taking place in wetlands (Section 404 permits) while the EPA oversees water quality permitting under other provisions of the CWA (RAE, 2015). Water quality permitting authority in Florida has been delegated by the EPA to the FDEP. The USACE accepts the state permit for a project as the required water quality certification EPA would otherwise issue. The EPA does hold veto authority over USACE issued Section 404 permits but this authority is rarely used.

In general, the USACE regulates "dredge and fill" activities (excavation or placement of material) in navigable waters of the United States under 33 CFR Part 329 by requiring a permit. There are several types of permits, but those most germane to the discussion of living shorelines include General Permits and Individual permits. General Permits, primarily Nationwide Permits (NWP) and Regional General Permits (RGPs), allow a project which meets specific design criteria and operate under specific permit conditions to proceed without an individualized (more detailed) assessment of the project. In an effort to streamline the permitting process for living shoreline projects, the USACE authorized Nationwide Permit 54 (NWP 54) in March 2017 for "Living Shoreline" projects. In order to qualify for this permit, the following design criteria must be met:



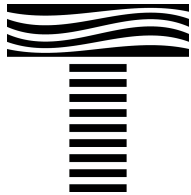
- The living shoreline must have a substantial biological component that maintains the natural continuity of the land-water interface and retain or enhance shoreline ecological processes,
- The structure and/or fill area cannot extend more than 30 feet from mean low water in tidal waters,
- The activity must be no more than 500 feet in length along a bank/shoreline,
- Structural materials (coir logs, oyster shell, etc.) must be anchored or be sufficiently weighted to prevent relocation from wave action or water flow,
- Native vegetation should be utilized,
- The discharges of dredged or fill material must be the minimum necessary for the establishment and maintenance of the living shoreline,
- The activity must be designed, constructed, and maintained so that it has no more than minimal adverse effects on water movement between the waterbody and the shore. The activity must also have minimal adverse effects on the movement of aquatic organisms,
- The living shoreline must be properly maintained.

In 2017 the USACE also reauthorized the Nationwide Permit 27 (NWP 27) for “Aquatic Habitat Restoration, Establishment, and Enhancement Activities” and Nationwide Permit 13 (NWP 13) for “Bank Stabilization” with a clarification that this includes authorization of a variety of erosion control techniques using native plants for bioengineering or vegetative stabilization.

Typically (although not always) compensatory mitigation is not required under this type of permit – but the NWP permits severely limit the amount of allowable impact. Further, federal regulations state that the NWP program will not authorize projects that are likely to jeopardize the continued existence of a threatened or endangered species as listed or proposed for listing under the Federal Endangered Species Act, or to destroy or adversely modify the critical habitat of such species. As Punta Gorda shoreline wetlands include smalltooth sawfish critical habitat and may include other listed species habitats, the USACE may determine that a proposed action could impact this or another listed species. Under requirements of the National Environmental Policy Act and Endangered Species Act they may decide to consult with the National Marine Fisheries Service (NMFS) or another federal agency to determine the potential for adverse impacts. Upon completion of consultations, they may authorize the activity under the NWP by adding activity-specific conditions or assert discretionary authority and require an individual permit.

9.0 CITY LIVING SHORELINE SITES

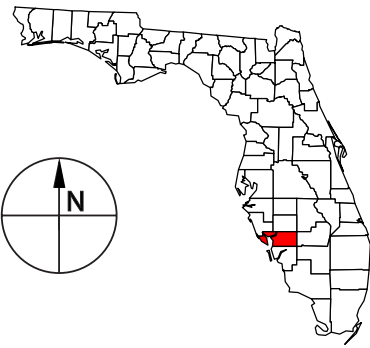
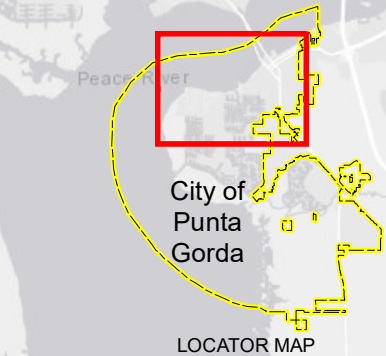
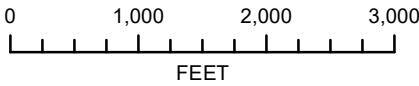
As outlined in the Center for Climate Strategies Adaptation Guidebook, mapping vulnerable areas and developing buyouts for these lands is a crucial adaptation strategy. The City of Punta Gorda, in essence, followed this strategy at its founding when Colonel Isaac Trabue designated much of the coastline and many low-lying, flood prone areas as natural park lands. The Punta Gorda Nature Park is a great example of publicly own space that is vulnerable to flooding but allowed to stay primarily in its natural state. Ponce De Leon Park, Trabue Park, Laishley Park, Alice Park, Shreve Park, and Gilchrist Park are other parks that act as a buffer for the city from the waters of the Peace River (Figure C9.1).



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Sarasota, FL 34236
CERTIFICATE OF AUTHORIZATION # 4815

**FIGURE 9.1:
MAP OF
PUNTA GORDA PARKS**

- Parks**
- HARBORWALK
 - LINEAR PARK
 - SHREVE STREET
 - OTHER CITY PARKS
- Corporate Boundaries**
- CITY OF PUNTA GORDA



CHARLOTTE COUNTY, FL



During development of this report, Taylor Engineering staff visited several sites with City staff to observe potential living shoreline locations identified below:

- Gilchrist Park
- Breakers Park (south of Fisherman's Village)
- Ponce de Leon Park
- Old fire station in Burnt Store Isles subdivision, near Alligator Creek
- Harborwalk Boardwalk
- Linear Park, 1 mile of tidal creek

Based on feedback received during this site visit, one of the City's adaptation goals include the concept of 'retreat by advancing' into the water to reduce vulnerability, applying living shoreline elements as part of adaptation strategy. The 6 small parks (Figure C9.2) located along the southwest region of the City adjacent to Punta Gorda Isles - identified as Shreve, Pittman, Alice, Breakers, Elizabeth, and Wilson Parks – consist primarily of a limestone rock revetment with mangroves along the shoreline.



Figure C9.2 Park Directory Sign, Harborwalk Park Punta Gorda



Much of the shoreline fronting Trabue Park remains relatively natural, vegetated with lush mangroves and oyster reefs within the shallow nearshore zone. The shoreline along Gilchrist Park appears to be largely hardened with a vertical concrete bulkhead. The park spans between two points for a length of approximately 2000 linear feet, with the Punta Gorda Waterfront Hotel & Suites to the east and the Punta Gorda Boat Club to the west. A small pocket beach is located adjacent to the hotel, suggesting sediment transport is occurring within the area. A thorough site analysis should be performed to determine the viability of each site for a range of living shoreline techniques.

10.0 RECOMMENDATIONS

There are a multitude of opportunities for developing successful living shoreline projects with the City. In order to advance the City's initiative to implement living shoreline techniques to reduce vulnerability to upland flooding, the following recommendations and next steps are outlined below for City consideration:

- Evaluate all projects currently in the planning and design phase to verify proper site conditions, identify and evaluate design criteria used, and refine the design and selected living shoreline techniques as necessary.
- Obtain bathymetric data within the nearshore zone for all potentially considered living shoreline project areas to identify water depths for consideration when conducting siting analyses.
- Develop living shoreline projects in concert with the goals and objectives outlined in the City's Comprehensive Plan.
- Maintain consistent data collection protocol, including the use of published, publicly available data such as tides. For example, consider the use of the Ft. Myers tide station for the best available tidal data.
- Develop a monitoring and maintenance plan for all projects currently installed and for future planned installations to evaluate performance. Performance monitoring should be implemented in all existing and future projects annually over a minimum 5 year period.
- In preparation for future subsequent design efforts, consider deployment of an acoustic doppler current profiler (ADCP) to measure water current velocities and wave heights, representative of multiple potential sites. This instrumentation can be deployed on a piling or mounted to the bottom in order to capture real-time, site-specific data. A pre-design monitoring period of 1 to 2 months is sufficient for use in developing appropriate site-specific living shoreline design.
- Continue to carefully plan for and implement sound engineered, shoreline stabilization projects – both for replacement of existing shoreline treatments and new projects.



11.0 REFERENCES

Anderson, M.E. and Smith, J.M., 2014. *Wave attenuation by flexible, idealized salt marsh vegetation*. Coastal Engineering, 83, pp.82-92.

Augustin, L.N., Irish, J.L. and Lynett, P., 2009. *Laboratory and numerical studies of wave damping by emergent and near-emergent wetland vegetation*. Coastal Engineering, 56(3), pp.332-340.

Baggett, L.P., S.P. Powers, R. Brumbaugh, L.D. Coen, B. DeAngelis, J. Greene, B. Hancock, and S. Morlock, 2014. *Oyster habitat restoration monitoring and assessment handbook*. The Nature Conservancy, Arlington, VA, USA., pp.96

Bahr, L.M. and W.P. Lanier. 1981. The ecology of intertidal oyster reefs of the South Atlantic coast: a community profile. U.S. Fish and Wildlife Service, Office of Biological Services, Washington DC. FWS/OBS-81/15. 105 pp.

Beever, J, W Gray, D Trescott, D Cobb, J Utle, D Hutchinson, J Gibbons, et al. 2009. *City of Punta Gorda Climate Adaptation Plan*. Technical Report 09-04, Southwest Florida Regional Planning Council and Charlotte Harbor National Estuary Program.

Boswell, J.G., Ott, J.A., Birch, A., Cobb, D. 2012. *Charlotte Harbor National Estuary Program Oyster Habitat Restoration Plan*. Charlotte Harbor National Estuary Program Technical Report. Ft. Myers, FL.

Das, S. and Vincent, J.R., 2009. *Mangroves protected villages and reduced death toll during Indian super cyclone*. Proceedings of the National Academy of Sciences, 106(18), pp.7357-7360.

FDEP 2019a. *Forms of the Environmental Resource Permitting and Submerged Lands Programs*. Available at: <https://floridadep.gov/water/submerged-lands-environmental-resources-coordination/content/forms-environmental-resource>. Accessed June 2019.

FDEP 2019b. *Sovereign Submerged Lands (SSL) - Proprietary Authority versus Regulatory Authority* in Chapter 18-21, F.A.C. Available at: <https://floridadep.gov/water/submerged-lands-environmental-resources-coordination/content/sovereign-submerged-lands-ssl>. Accessed June 2019.

Florida Living Shorelines. (2019) *Marsh Plants*. Retrieved from <http://floridalivingshorelines.com/marshplants/#South>

Gilman, E.L., Ellison, J. and Coleman, R., 2007. *Assessment of mangrove response to projected relative sea-level rise and recent historical reconstruction of shoreline position*. Environmental Monitoring and Assessment, 124, pp.105-130.

Hardaway, Jr., C.S. and R.J. Byrne, 1999. *Shoreline Management in Chesapeake Bay*. Special Report in Applied Marine Science and Ocean Engineering Number 356. Virginia Institute of



Marine Science, College of William & Mary, Gloucester Point, Virginia.
<http://web.vims.edu/physical/research/shoreline/docs/ShorelineErosionInCBay.pdf>

Hardaway, C.S. and J.R. Gunn, 2000. Shoreline Protection: Design Guidelines for Pocket Beaches in Chesapeake Bay, USA. Proceedings, Carbonate Beach 2000. ASCE, December 5-8, 2002, Key Largo, FL. p. 126-139.

Hardaway, C.S., Jr., W. G. Reay, J. Shen S. B. Lerberg, D. A. Milligan, C. A. Wilcox, and K. P. O'Brien. 2007. *Performance of Sills: St. Mary's City, St. Mary's River, Maryland*. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Jacobs Engineering Technical Memo (2018). Tiki Point at Harborwalk Living Shoreline Pilot Project.

Kreeger, D., Moody, J., Buckner, J., Whalen, L., Rothrock, S., Ross, D., Cole, P. and Padeletti, A., 2014. Development of a conceptual plan for a living shoreline near Harrison Avenue in North Camden, New Jersey.

Miller, J., Rella, A., Williams, A., and Sproule, E. 2015. *Living Shorelines Engineering Guidelines*. Stevens Institute of Technology. New Jersey.

Morris, J.T., Sundareshwar, P.V., Nietch, C.T., Kjerfve, B. and Cahoon, D.R., 2002. *Responses of coastal wetlands to rising sea level*. Ecology, 83(10), pp.2869-2877.

Mosaic 2019. Charlotte Harbor Oyster Reef Restoration Partnership. Accessed at: http://www.mosaicco.com/Who_We_Are/3770.htm, June 2019.

National Research Council. 2007. *Mitigating Shore Erosion Along Sheltered Coasts*. The National Academies Press.

National Oceanic and Environmental Administration (NOAA). 2015. *Guidance for Considering the Use of Living Shorelines*. 2015.

Needelman, B.A., S. Crooks, C.A. Shumway, J.G. Titus, R.Takacs, and J.E. Hawkes. 2012 *Restore-Adapt-Mitigate: Responding to Climate Change Through Coastal Habitat Restoration*. B.A. Needelman, J. Benoit, S. Bosak, and C. Lyons (eds.). Restore America's Estuaries, Washington D.C., pp. 1-63.

Punta Gorda Airport. (n.d) *Wind History*. Retrieved from <http://windhistory.com/map.html#4.00/36.00/-95.00>

Restore America's Estuaries (RAE). 2015. *Living Shorelines: From Barriers to Opportunities*. Arlington, VA.

Ridge, J.T., Rodriguez, A.B., Fodrie, 2017. *Evidence of exceptional oyster-reef resilience to fluctuations in sea level*. Ecology and Evolution, 7, pp.10409-10420.



Rodriguez, A.B., Fodrie, F.J., Ridge, J.T., Lindquist, N.L., Theuerkauf, E.J., Coleman, S.E., Grabowski, J.H., Brodeur, M.C., Gittman, R.K., Keller, D.A. and Kenworthy, M.D., 2014. *Oyster reefs can outpace sea-level rise*. *Nature climate change*, 4(6), p.493.

Schuster, E. and Doerr, P. 2015. *A Guide for Incorporating Ecosystem Service Valuation into Coastal Restoration Projects*. The Nature Conservancy. Delmont, NJ.

Shafer, D., Roland, R. & Douglass, S., 2003. *Preliminary Evaluation of Critical Wave Energy Thresholds at Natural and Created Coastal Wetlands*, Vicksburg, MS: US Army Corps of Engineers, Engineering Research and Development Center.

Sovereign Submerged Lands (SSL) - Proprietary Authority versus Regulatory Authority in Chapter 18-21, F.A.C. (n.d.). Retrieved from <https://floridadep.gov/water/submerged-lands-environmental-resources-coordination/content/sovereign-submerged-lands-ssl>

Sutton-Grier, A.E., Wowk, K., and Bamford, H. 2015. *Future of our Coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies, and ecosystems*. *Environmental Science and Policy* 51:137-148.

Systems Approach to Geomorphic Engineering (SAGE). 2015. *Natural and Structural Measures for Shoreline Stabilization*. Accessed at http://sagecoast.org/docs/SAGE_LivingShorelineBrochure_Print.pdf, June 13, 2019.

U.S. Army Corps of Engineers (ASCE). 2013. *Coastal Risk Reduction and Resilience*. CWTS 2013-3. Washington, D.C: Directorate of Civil Works, U.S. Army Corps of Engineers

U.S. Army Corps of Engineers, Regulatory Program of the Corps of Engineers, Federal Register, 42(138): 37121 – 37164, (1977). Available at <http://media.swf.usace.army.mil/pubdata/enviro/Regulatory/permitting/nwp/1977/1977nwp.pdf>.

U.S. Army Corps of Engineers, Decision Document: Nationwide Permit 13, (2012). Available at http://www.usace.army.mil/Portals/2/docs/civilworks/nwp/2012/NWP_13_2012.pdf.

U.S. Army Corps of Engineers (USACE). 2019. Jacksonville Regulatory Division – Source Book. Available at: <https://www.saj.usace.army.mil/Missions/Regulatory/Source-Book/>

Yepsen, M., Moody, J., Schuster, E. 2016. *A Framework for developing monitoring plans for Coastal Wetland Restoration and Living Shoreline Projects in New Jersey*. A report prepared by the New Jersey Measures and Monitoring Workgroup of the NJ Resilient Coastlines Initiative, with support from the NOAA Coastal Resilience (CRest) Grant Program.



APPENDIX D

Public Workshop Summary

Punta Gorda Climate Adaptation Plan Update

April 5, 2019

PUBLIC WORKSHOP SUMMARY

Workshop Purpose: Inform the public of the City’s previous Climate Adaptation Plan and the status of the current project to update the plan, source public input to help prioritize vulnerable historic and publicly owned properties, share information about adaptation options, specifically living shorelines

Attendees: Mitchell Austin, Joan LeBeau – City of Punta Gorda; Jennifer Hecker – CHNEP; Angela Schedel, Jenna Phillips – Taylor Engineering; Dianne Rosensweig – ESA; Videojournalist from WINK; approximately 20 citizens in attendance (see attached sign-in sheet and photos)

Materials: sign-in sheets, 6 Easels, 6 City map posters, packing tape (to stabilize easels), 18 smaller maps (11x17) for each table, 2 Easel pads, 6 markers, 4 packs of colored sticky flags, 12 packs of medium post-it notes, 25 pens, 2 laptops, HDMI cord, laser pointer, backup projector, 2 outdoor signs

Snacks: napkins, small plates, fruit, pastries, serving spoons, cups, stirrers, sugar, creamer (with ice pack), coffee, filter and coffee pot

Timeline: 8:00-9:30 – Set-up of the room: round tables, chairs, computer, projector, easels, rectangular tables for snacks and sign-in sheets; Snack table set-up: start the coffee brewing early; Place on tables: two of each type of map, post-it note pads, pens

9:30-10:05 – Greeting attendees, filling in sign-in sheets, socializing, snacks, filling out survey via laptop

10:05-10:25 – (Joan) Introduction of workshop and key people; (Jenna) Explain purpose of today’s workshop, goals of the project, overview of Taylor Engineering’s expertise, review results of online survey (30 respondents as of 11PM on April 4, 2019)

10:25-10:45 – (Angela) Discuss sea level rise trends and forecast, present overview of methodology and data from preliminary vulnerability assessment, explain how public input will be gathered

10:45-11:05 – Public input and stretch/bio break. 3 “stations” for public inputs

1. Laptop (manned by Dianne) on back table for filling out survey
2. Easels with maps showing publicly owned properties with 1.5’ and 3’ sea level rise, easel with “Top 10 List” of these vulnerable properties. Use sticky flags for public to select their top 2 out of

the list of 10 (or use post-its to write in ones they think we missed). Use sticky flags to indicate areas of flooding concern on the map.

3. Easels with maps showing all historic properties (both public and private) with 1.5' and 3' sea level rise, easel with "Top 10 List" of these vulnerable properties. Sticky flags for public to select their top 2 out of the list of 10 (or use post-its to write in ones they think we missed). Use sticky flags to indicate areas of flooding concern on the map.

11:05-11:25 – (Angela) Wrap up of public input on easels, reflections of concerns heard during discussion with attendees, introduce resilience, adaptation options

11:25-11:45 – (Jenna) Present living shoreline definition and show examples, Conclusion, Thank you's

11:45-12:00 – Formal presentation complete, questions and one-on-one conversations with attendees

Public Input: Attendees voted using sticky flags to indicate which of the properties listed were their top 2 priorities to protect from sea level rise and coastal flooding. The "Top 10 List" of vulnerable properties was selected based on a preliminary vulnerability analysis which compared each building's Finished Floor Elevation to the 1.5 foot and 3 foot sea level rise scenarios. The City planners helped the consultant to whittle the list down to the most vulnerable, given their unique knowledge of the City and its properties.

The tally of votes, including one write-in candidate, is summarized in the tables below:

Historic Properties		Publicly-Owned Properties	
Property	Votes	Property	Votes
Old City Hall	6	Wastewater Station - Henry St.	11
Railroad Depot	4	County Grace St Annex	5
Charlotte High School	3	Cooper St Recreation Center	3
History Park	2	Fire Station III - Aqui Esta	3
County Courthouse	2	County Visual Arts Center	2
PG Women's Club	2	Oak Tree Village - Public Housing	1
Blanchard House Museum (added by attendees)	2	Charlotte High School	1
A.C. Freeman House	1	PG Boat Club	0
Ice House	1	Bayfront Center YMCA	0
Smith Arcade	0	County Tax Collector's Office	0
First National Bank	0		

Public Input (cont.): During discussions around the easels, several attendees noted that Critical Infrastructure was missing from the “Top 10 Lists” and used post-it notes to add assets which were important to them. Once the formal public input time concluded, the consultant explained the rationale for leaving out the Critical Infrastructure. The reasoning for the planned omission of the list of Critical Infrastructure points back to the purpose of the workshop. To best value the public’s time, the consultant chose to list only the Top 10 most vulnerable publicly-owned and historic properties, as these are unique to the City of Punta Gorda. Critical Infrastructure assets are similar between municipalities and are already identified on maps on the city and county websites. The elevation and location of these assets are known, as well as the City’s prioritization of these assets. The list of Critical Infrastructure which the workshop attendees were concerned about protecting from sea level rise is summarized in the table below:

CRITICAL INFRASTRUCTURE	
Property	Votes
Fresh Water Supply (ie. Shell Creek Reservoir)	6
Hospital	4
Post Office	2
Punta Gorda Police Station	2
Electrical Power	1
Charlotte County Jail	1

Final Notes: Comments from the attendees were positive. The attendees wanted more information about how to protect their residences. They were less concerned about the City and County’s vulnerable properties and wanted to know what actions the City was planning which might help to protect their houses. Several were concerned about their seawalls being overtopped or scoured behind due to sea level rise and coastal flood events.

After the workshop, the City received positive media attention from WINK in the form of an online article and video which aired on the evening news.

April 5, 2019 Public Workshop Photos











Results of Online Survey



Build Community Resilience | Punta Gorda, FL

[Home](#)

[Take our Survey](#)

Flood Risk Survey | Punta Gorda, FL

How are you affiliated with Punta Gorda?

Full-time resident ▼

How would you characterize the [flood hazard](#) risk for your community?

No Risk ▼

How would you characterize the [sea level rise](#) risk for your community?

No Risk ▼

Do you think your [home](#) is at risk from [flooding](#)?

No ▼

Do you know what [adaptation planning](#) is?

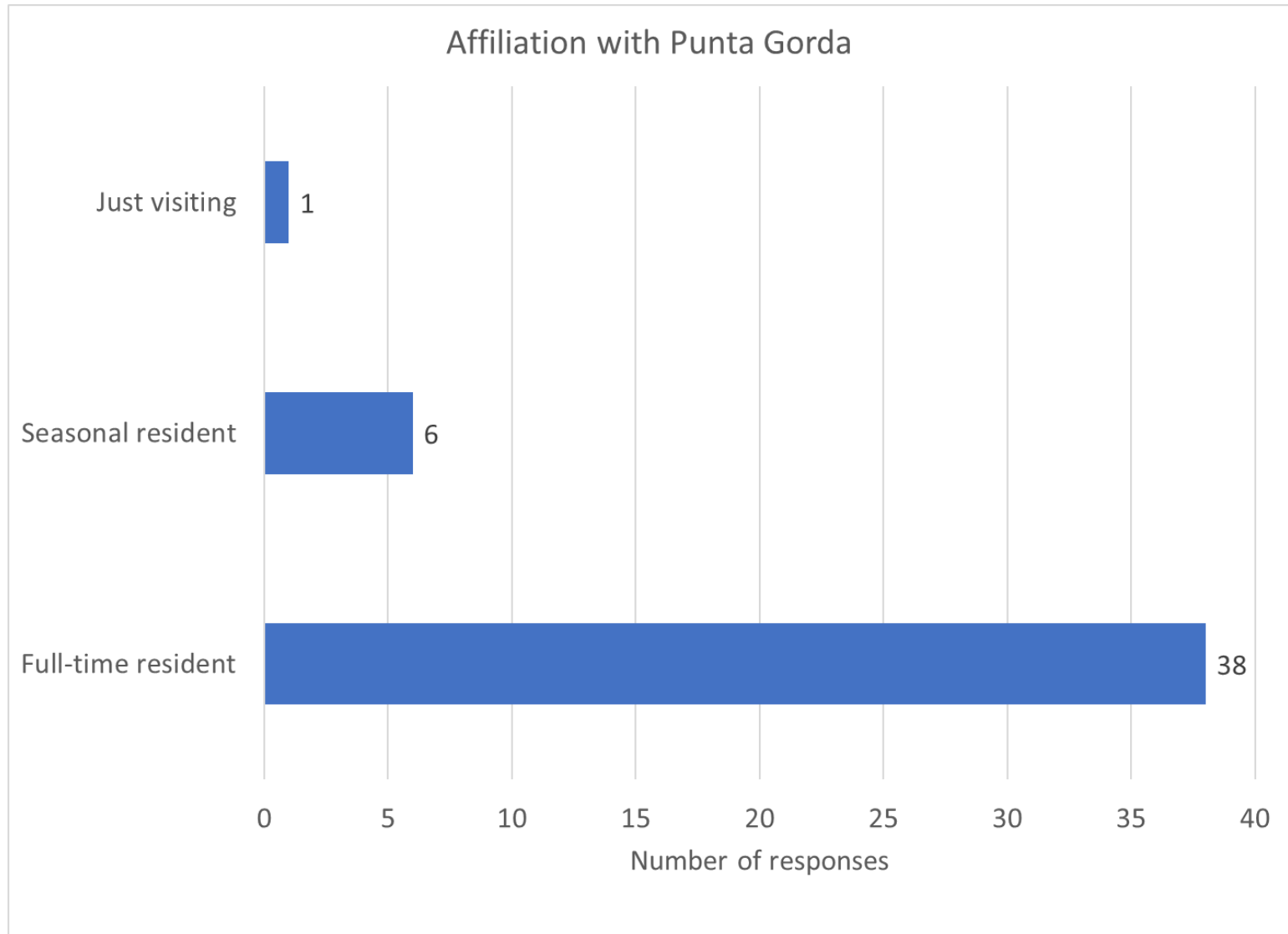
No ▼

Does your city have an [adaptation plan](#)?

No ▼

Survey was active March 26 through May 30, 2019 and received 45 responses

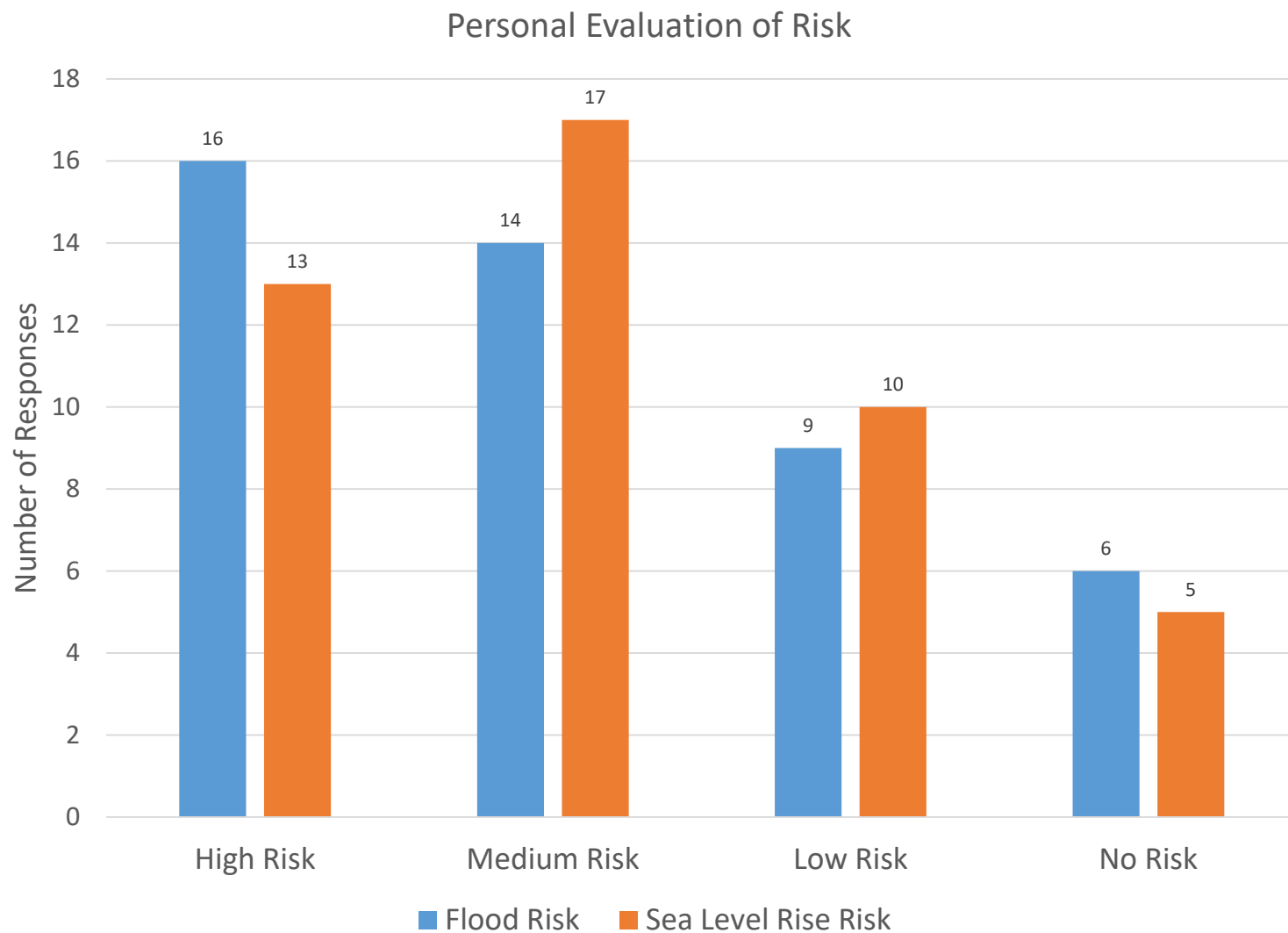
Preliminary Survey Results



Preliminary Survey Results

- How would you characterize the flood hazard risk for your community?
- How would you characterize the sea level rise risk for your community?

Preliminary Survey Results



Preliminary Survey Results

- Do you think your home is at risk of flooding?
Yes = 58% , No = 42%
- Do you know what adaptation planning is?
Yes = 40% , No = 60%
- Do you know what a living shoreline is?
Yes = 49% , No = 51%

Preliminary Survey Results

- Does your city have an adaptation plan?
Yes = 27% , No = 73%
- Is the city doing enough to plan for sea level rise?
Yes = 20% , No = 80%

City of Punta Gorda Adaptation Plan



**Southwest Florida Regional Planning Council
Charlotte Harbor National Estuary Program
Technical Report 09-4**

8/14/2009

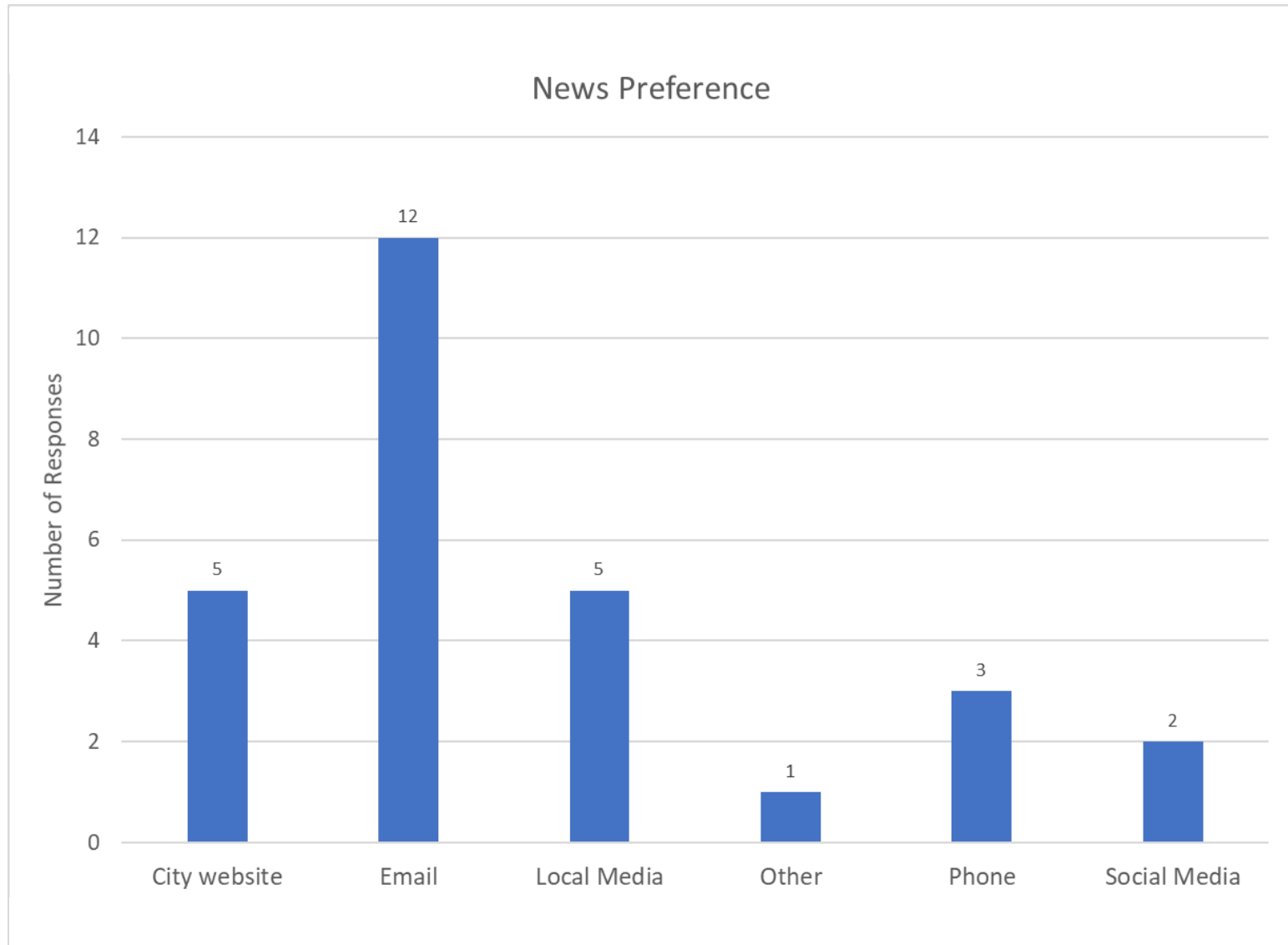
James W. Beever III, Whitney Gray, Daniel Trescott, Dan Cobb, Jason Utley, David Hutchinson,
John Gibbons, Tim Walker, Moji Abimbola: SWFRPC
And Lisa B. Beever, Maran Hilgendorf, Judy Ott: CHNEP



1926 Victoria Avenue
Fort Myers FL 33901
(239) 338-2550

www.SWFRPC.org and www.CHNEP.org

Preliminary Survey Results





APPENDIX E

SUMMARY OF FUNDING ALTERNATIVES



Punta Gorda Climate Adaptation Plan Addendum

Summary of Funding Alternatives

Summary: External funding support is an important component of the City's updated Plan in order to comprehensively develop and implement strategic adaptations to improve resiliency. Taylor Engineering has researched and compiled a comprehensive list of available funding sources and/or grant opportunities to assist the City in future implementation of the strategies outlined in the Plan. The list outlines funding sources and summarizes the type of funding, source, projected potential value, cost share details, application deadlines, and potential application requirements.

These funding opportunities are compiled, sorted and ranked in order of applicability to best fit the City's needs surrounding priority vulnerable focus areas and corresponding adaptation strategies. The list, consisting of 21 potential funding opportunities, reflects the most current data compiled at the time of delivery. Due to the ever-changing nature of grants and these type of funding opportunities, the client should investigate thoroughly any source they plan to pursue.

Grant Source	Grant Title	Website / Contact	Details	Funding Type	Potential Value	Cost Share Requirements	Deadlines	Application Requirements / Additional Details
FEMA	Hazard Mitigation Grant Program (HMGP)	https://www.fema.gov/hazard-mitigation-grant-program-guide-state/local-governments	A Presidential Major Disaster Declaration provides for the availability of HMGP funds at the request of a state's Governor in eligible communities within a state, tribe, or territory.	Disaster Relief and Hazard Mitigation	\$35.333 billion	15% \$2 billion of estimated aggregate amounts of disaster assistance, 10% for between \$2 and \$10 billion, and up to 7.5% of \$10 and \$35.3 billion. For states with Enhanced Mitigation Plan up to 20% (not to exceed \$35.3 billion).	Must provide a Letter of Intent within 30 days after a disaster declaration	Must provide a Letter of Intent within 30 days after a disaster declaration
NOAA	Broad Announcement	https://coast.noaa.gov/funding/pdf/NOAA-NFA-NFAPO-2018-2005418-NOAA-BAA-posted-09.30.2017.pdf	FY2018 – FY2020 NOAA Broad Agency Announcement. The notice requests proposals for special projects and programs associated with NOAA's strategic plan and mission goals. This broad agency announcement is a mechanism to encourage research, education and outreach, innovative projects, or sponsorships that are not addressed through NOAA competitive discretionary programs. It is not a mechanism for awarding congressionally directed funds. Funding for potential projects in this notice is contingent upon the availability of Fiscal Year 2019 and Fiscal Year 2020 appropriations.	Climate Adaptation and Mitigation	Determined on Project Basis	Determined on Project Basis	15-May-19	https://coast.noaa.gov/funding/pdf/NOAA-NFA-NFAPO-2018-2005418-NOAA-BAA-posted-09.30.2017.pdf

Grant Source	Grant Title	Website / Contact	Details	Funding Type	Potential Value	Cost Share Requirements	Deadlines	Application Requirements / Additional Details
NFWF	National Coastal Resilience Fund for 2019	https://www.nfwf.org/coastalresilience/Pages/2019rfa.aspx	The National Fish and Wildlife Foundation (NFWF) is pleased to announce the National Coastal Resilience Fund for 2019. NFWF will make investments to restore and strengthen natural systems so they can protect coastal communities from the impacts of storms, floods, and other natural hazards and enable them to recover more quickly, while also enhancing habitats for important fish and wildlife populations.	Coastal Resilience Projects	\$29 million to be awarded, with project awards ranging from \$125,000 to \$3 million	A minimum 1:1 non-federal match in cash or in-kind services is expected and strongly encouraged.	Ongoing	Go to easygrants.nfwf.org to register in NFWF's Easygrants online system.
NFWF	Resilient Communities Program	https://www.nfwf.org/resilientcommunities/Pages/home.aspx	Wells Fargo and NFWF launched the Resilient Communities Program, designed to prepare for future environmental challenges by enhancing community capacity to plan and implement resiliency projects and improve the protections afforded by natural ecosystems by investing in green infrastructure and other measures.	Resilient Communities	Up to \$500,000	Projects that meet or exceed a 1:1 match ratio will be more competitive.	Ongoing, FY19 Pre-Proposal Due Date February 19, 2019	https://www.nfwf.org/resilientcommunities/Pages/2019rfa.aspx
SF	Hydrologic Sciences	https://nsf.gov/funding/pgm_summ.jsp?piid=13684&org=NSF	The Hydrologic Sciences Program focuses on the fluxes of water in the environment that constitute the water cycle as well as the mass and energy transport function of the water cycle. The Program supports the study of processes from rainfall to runoff to infiltration and streamflow; evaporation and transpiration; the flow of water in soils and aquifers; and the transport of suspended, dissolved, and colloidal components.	Hydrological Sciences	Determined on Project Basis	Determined on Project Basis	Ongoing	Additional Contacts: Holly Barnard (hbarnard@nsf.gov) and Ingrid Padilla (ipadilla@nsf.gov)

Grant Source	Grant Title	Website / Contact	Details	Funding Type	Potential Value	Cost Share Requirements	Deadlines	Application Requirements / Additional Details
NSF	Environmental Sustainability	https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505549	The goal of the Environmental Sustainability program is to promote sustainable engineered systems that support human well-being and that are also compatible with sustaining natural (environmental) systems.	Environmental Engineering and Sustainability	Determined on Project Basis	Determined on Project Basis	Ongoing	Addition Contacts: Bruce Hamilton (bhamilton@nsf.gov) and Brandi L. Schottel (bschotte@nsf.gov)
NSF	Marine Geology and Geophysics	https://www.grants.gov/web/grants/view_opportunity.html?oppld=295449	The Program supports science that includes: Structure, composition, tectonics, and evolution of the oceanic lithosphere; Paleooceanography, paleoclimate, and sea level change; Submarine volcanology, petrology and geochemistry of the oceanic crust and upper mantle; Marine hydrogeology, seeps and gas hydrates, water-rock interaction, and hydrothermal vent and fluid formation and geochemistry; Geochemical indicators of life operating below the seafloor; Marine sedimentology and coastal processes, stratigraphy, sediment transport, and diagenesis; Mid-ocean ridge spreading, back-arc rifting, transform processes, and ocean island/seamount formation and evolution; Submarine components of subduction zone systems and passive margins; and Marine geohazards.	Geology and Geophysics of the Present Ocean Basins and Margins	Determined on Project Basis	Determined on Project Basis	Ongoing	NSF grants.gov support (grantsgovsupport@nsf.gov)

Grant Source	Grant Title	Website / Contact	Details	Funding Type	Potential Value	Cost Share Requirements	Deadlines	Application Requirements / Additional Details
NSF	Humans, Disasters, and The Built Environment	https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13353	The Humans, Disasters and the Built Environment (HDBE) program supports fundamental, multidisciplinary research on the interactions between humans and the built environment within and among communities exposed to natural, technological and other types of hazards and disasters.	Interactions Between Humans and the Built Environment	Determined on Project Basis	Determined on Project Basis	Ongoing	Additional Contact: Robin Dillon-Merrill (rdillonm@nsf.gov)
FDEP	Resilience Planning Grants FY 19-20	https://florida.dep.gov/fco/florida-resilient-coastlines-program/content/funding-opportunities	The Florida Department of Environmental Protection, through the Florida Resilient Coastlines Program, will provide financial assistance aimed at preparing coastal Florida communities for current and future effects of rising sea levels, including coastal flooding, erosion and ecosystem changes.	Vulnerability Assessments, Adaptation Plans, Resiliency Plans	Up to \$75,000	N/A	Ongoing	Applications due to FRCP at Resilience@FloridaDEP.gov
FDEP	Adaptation Action Initiative Grants FY 19-20	https://florida.dep.gov/fco/florida-resilient-coastlines-program/content/funding-opportunities	The Florida Department of Environmental Protection, in partnership with the Florida Department of Economic Opportunity and other agencies, will provide assistance to local governments to take action related to adaptation to current and future risks related to sea level rise, including coastal flooding, erosion and ecosystem changes.	Vulnerability Assessment, Adaptation Planning	Up to \$75,000	N/A	Ongoing	Applications due to FRCP at Resilience@FloridaDEP.gov
FDEP	Coastal Partnership Initiative (CPI) Grant Program	https://florida.dep.gov/rcp/fcmp/content/grants	The Coastal Partnership Initiative grant program was developed to promote the protection and effective management of Florida's coastal resources at the local level.	Resilient Communities, Public Access, Working Waterfronts, Coastal Stewardship	Up to \$60,000	Grant recipients are required to provide 100% (1 to 1) matching funds, which may be cash or in-kind	Opens Fall 2019	For more information contact Toni Clanton (Toni.R.Clanton@FloridaDEP.gov)

Grant Source	Grant Title	Website / Contact	Details	Funding Type	Potential Value	Cost Share Requirements	Deadlines	Application Requirements / Additional Details
FDEP	Florida Department of State Historic Structures Grant Program	https://dos.myflorida.com/historical/grants/	The Historic Preservation Grants Program allocates state funds appropriated by the Legislature and federal funds apportioned to the state by the U.S. Department of the Interior, National Park Service, for the preservation and protection of the state's historic and archaeological sites and properties.	Science and Technology and other Research and Development	Up to \$50,000	Match requirement: 1:1, unless waived, with a minimum cash match contribution of 25%	Opens April 1 and closes June 1, 2019	Applications will be accepted online at dosgrants.com and primary contact (DHRgrants@dos.myflorida.com)
FDEP	Governor's Grants	Whitney.Gray@FloridaDEP.gov	FDEP has been allotted \$6 million in a governor's grant that is allocated to be spent on environmental projects (coral, adaptation planning, and implementation).	Development of resilient Florida Communities	Determined on Project Basis	Determined on Project Basis	Ongoing as of 4/2019	Contact Whitney Gray at FDEP for more information on specific requirements

Grant Source	Grant Title	Website / Contact	Details	Funding Type	Potential Value	Cost Share Requirements	Deadlines	Application Requirements / Additional Details
U.S. Dept. of the Treasury	Restore Act-Direct Component	https://www.treasury.gov/services/restoration/act/Pages/DirectComponent.aspx	The Direct Component sets aside 35 percent of the penalties paid into the Trust Fund for eligible activities proposed by the States of Alabama, Mississippi, Texas, Louisiana and 20 Louisiana parishes, and 23 Florida counties. These activities include: Restoration and protection of the natural resources, ecosystems, fisheries, marine and wildlife habitats, beaches and coastal wetlands of the Gulf Coast Region; Mitigation of damage to fish, wildlife and natural resources; Implementation of a Federally approved marine, coastal, or comprehensive conservation management plan, including fisheries monitoring; Workforce development and job creation; Improvements to or on state parks located in coastal areas affected by the Deepwater Horizon oil spill; Infrastructure projects benefitting the economy or ecological resources, including port infrastructure; Coastal flood protection and related infrastructure; Planning assistance; Promotion of tourism in the Gulf Coast Region, including promotion of recreational fishing; Promotion of the consumption of seafood harvested from the Gulf Coast Region; and Administrative costs.	Gulf Coast Region	Dependent on the Trust Fund balance	No cost sharing or matching is required. Please note that federal grant requirements apply to the entire grant award, including both the federal and nonfederal funds.	Applications will be accepted on a rolling basis as long as funds are available in an Applicant's allocation. This funding opportunity announcement will close on August 30, 2019.	https://www.treasury.gov/services/restoration/act/Documents/FOAs/RESTORE%20Act%20Direct%20Component%20-%20Non-Construction%20Activities-9.pdf

Grant Source	Grant Title	Website / Contact	Details	Funding Type	Potential Value	Cost Share Requirements	Deadlines	Application Requirements / Additional Details
U.S. Dept of the Treasury	Centers of Excellence Research Grants Program	https://www.treasury.gov/services/restoration/Pages/COE/Centers-of-Excellence.aspx	Coastal and delta sustainability, restoration, and protection, including solutions and technology that allow citizens to live in a safe and sustainable manner in a coastal delta in the Gulf Coast Region; Coastal fisheries and wildlife ecosystem research and monitoring in the Gulf Coast Region; Funded projects to include: Offshore energy development, including research and technology to improve the sustainable and safe development of energy resources in the Gulf of Mexico; Sustainable and resilient growth, economic and commercial development in the Gulf Coast Region; and Comprehensive observation, monitoring, and mapping of the Gulf of Mexico.	Gulf Coast Region	Dependent on the Trust Fund balance	No cost sharing or matching is required. Please note that federal grant requirements apply to the entire grant award, including both the federal and nonfederal funds.	Applications will be accepted on a rolling basis as long as funds are available in an Applicant's allocation. This funding opportunity announcement will close on August 30, 2019.	https://www.treasury.gov/services/restoration/Documents/FOAs/Rnd%2010%20-%20COE%20FOA%20GR-RCE-19-001%20-%20FINAL.pdf
VKRF	V. Kann Rasmussen Foundation Environmental Grants	http://www.vkrf.org/home	VKRF favors projects that: take stock of the scale of the environmental problems, use a systems approach to achieve change, link policy, advocacy, and practical solution, have international significance and perspective – even if US based are based on original thinking and creative ideas.	Environment	Determined on Project Basis	N/A	Ongoing	Program inquiries can be sent to Executive Director Irene Krarup (ikrarup@vkrf.org)

Grant Source	Grant Title	Website / Contact	Details	Funding Type	Potential Value	Cost Share Requirements	Deadlines	Application Requirements / Additional Details
FWS	Conserving Southeastern Coastal Communities	https://www.fws.gov/southeast/our-services/coastal-conservation/#types-of-projects-section	The Southeast Region Coastal Program supports voluntary, proactive and cooperative projects in these areas, focusing efforts to restore and protect habitat for federal trust species. We provide technical expertise and financial assistance to: Private landowners and citizens; Native American tribes; Non-profit organizations; Municipal and local governments; Business and industry.	Coastal Conservation	Determined on Project Basis	Determined on Project Basis	Ongoing	https://www.fws.gov/southeast/our-services/coastal-conservation/#types-of-projects-section
TKF	The Kresge Foundation	https://kresge.org/programs/environment	TKF invests through three focus areas: Building capacity and commitment, strengthening the evidence base and developing tools, and transforming key urban systems.	Environment	Determined on Project Basis	Determined on Project Basis	Ongoing	https://kresge.org/opportunities
EPA	National Estuary Program Coastal Watersheds	https://www.epa.gov/nep/national-estuary-program-coastal-watersheds-request-applications-rfa	The U.S. Environmental Protection Agency (EPA) is soliciting applications from eligible applicants for the National Estuary Program (NEP) Coastal Watersheds Grant to support projects that address urgent and challenging issues that threaten the ecological and economic well-being of coastal and estuarine areas	Coastal Watershed	Up to \$4 million	EPA requires the applicant to provide a minimum 25% match of the total federal request	Currently closed, look for new request for proposal	https://www.epa.gov/sites/production/files/2018-11/documents/nep_coastal_watersheds_rfa.pdf
NRL	Naval Research Laboratory Broad Agency Announcement	https://www.nrl.navy.mil/doing-business/contracting-division/baa/current	The Naval Research Laboratory (NRL) is the Navy's corporate laboratory. NRL conducts basic and applied research for the Navy in a variety of scientific and technical disciplines. The basic research program is driven by perceptions about future requirements of the Navy.	Science and Technology and other Research and Development	Determined on Project Basis	Determined on Project Basis	Ongoing	https://www.nrl.navy.mil/doing-business/contracting-division/baa/current



Grant Source	Grant Title	Website / Contact	Details	Funding Type	Potential Value	Cost Share Requirements	Deadlines	Application Requirements / Additional Details
EDA	Economic Development Administration Disaster Supplemental	https://www.grants.gov/web/grants/view-opportunity.html?oppid=302953	The Economic Development Administration (EDA) has published the Disaster Supplemental Notice of Funding Opportunity (NOFO) making \$587 million available to eligible grantees in communities impacted by natural disasters.	Disaster Relief and Hazard Mitigation	Determined on Project Basis	Determined on Project Basis	Ongoing	https://www.eda.gov/funding-opportunities/