CITY OF SARASOTA
Climate Adaptation Plan

Climate Adaptation Plan

FINAL REPORT

HDR

December 4, 2017


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Message from the City Manager

As a world class community, Sarasota has been blessed with enduring natural beauty, charm and diversity. As a coastal City, the application of climate change science to inform our administrative decisions, public policy, and infrastructure investments is critical. By using the most up to date models and information on what to expect, we are able to keep the short and long-term interests of our residents and businesses in mind. Doing nothing is not an option. We must both mitigate our contribution to the climate change challenge and adapt to changing circumstances if we are going to maintain the quality of life our residents and visitors enjoy.

Adapting to new circumstances can provide economic and social benefits, especially if we develop smart solutions that harness the energy and human capital of this great city. This report presents the City's first attempt at identifying the infrastructure that is vulnerable to officially forecasted sea level rise, storm surge, rain, and heat projections and presents options for adaptation. It's a foundation that will take much collaboration, commitment and partnerships from all sectors in our community as well as county, state, and federal government to move forward timely and effectively.

Local businesses, residents, academia, government institutions, and community foundations all have roles to play to contribute ideas and take ownership of a visionary future that moves climate adaptation projects and funding forward. By planning smart today, Sarasota will be better prepared for tomorrow. We hope you will join us on this journey towards resiliency by visiting SarasotaFL.gov for more information and becoming part of the solution.

Sincerely,

Thomas Barwin

City Manager
City of Sarasota

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Left | Sherri Swanson
Center | Sherri Swanson
Right | Michael Mccormick

SARASOTA CITY COMMISSION

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Vice Mayor Liz Alpert | District Two

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Key Terms

Adaptive Capacity: An asset's ability to accommodate a stressor caused by exposure to a climate impact(s). It considers the ability of the asset to return to normalcy after a disruption. It is closely related to resiliency.

Asset: An individual infrastructure component within a sector. They may be owned by the City of Sarasota, or they may be operated by a third party (e.g. Sarasota County, Florida Department of Transportation (FDOT) or other state or federal agencies).

Co-benefits: Additive synergies or benefits derived from taking an action to mitigate climate change.

Climate Impact: Climate-related changes occurring or projected to occur including sea level rise (SLR), storm surge, tropical storms, extreme precipitation/freshwater flooding, extreme heat and increased water temperature.

Critical Infrastructure: Public assets, systems, and networks vital to the City of Sarasota such that their disengagement or destruction would result in debilitating impacts to public health and safety, functionality of critical public utilities, safe evacuation, or the environment.

Consequence: A result or effect of a condition or impact, especially if the result is undesirable.

Digital Terrain Model: A 3D representation of the ground's surface.

Thermal Expansion: A general increase in the volume of [water] as its temperature increases.

Greenhouse Gas: An atmospheric gas that absorbs and emits solar radiation. The primary greenhouse gases in Earth's atmosphere include water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

Infrastructure: Made-made facilities and structures, as well as natural assets (e.g. mangroves) needed for the operation and overall resiliency of the City of Sarasota.

King Tide: Exceptionally high tide caused by a stronger than normal gravitational pull of the moon due to its proximity to the earth.

Likelihood: The probability that an asset will be damaged by a climate stressor based on the asset's spatial location with regard to future climate projections of SLR, storm surge, extreme heat and extreme precipitation.

Mean Higher High Water (MHHW): The average of the higher high water of each tidal day observed over the National Tidal Datum Epoch.

National Tidal Datum Epoch: The specific 19-year period over which tide observations are taken and reduced to obtain mean values for tidal datums.

Relative Sea Level Change: The level of rising or falling land (i.e. movement of earth's crust) in relation to the ocean surface. A local and regionally important phenomenon.

Resilience: The capacity for an infrastructure asset to absorb a climate stressor(s) (i.e. exposure) and return to a pre-disturbed state without any lasting functional change to the asset.

Risk: An understanding of how a climate impact could adversely impact infrastructure. It is a function of the likelihood that a particular asset would be impacted and the consequence(s) of damage or loss of the asset.

Sector: A cohesive system of public infrastructure with interacting components. For this study, we evaluated the following sectors: 1) Transportation, 2) Stormwater, 3) Water Supply, 4) Wastewater, 5) Public Lands, and 6) Critical Buildings.

Sensitivity: The degree to which an asset is directly or indirectly impacted by a stressor caused by exposure to a climate impact. Sensitivity considers the known or predicted effects of an impact on the asset.

Storm Surge: A rise in sea water generated by a passing storm, which can cause flooding in coastal areas. Surge water can combine with an astronomical tide to create a storm tide and cause even greater coastal flooding and damage.

Stressor: An external threat to an asset due to one or more climate impacts.

Photo | Sherri Swanson

Urban Heat Island Effect: An increase in temperature within an urban area caused by the removal of vegetation (e.g. trees) and an increase in pavement for roads and concrete for buildings, as well as other man-made components of civilization.

Vulnerability: The degree of exposure to physical harm an infrastructure asset could experience due to a future climate impact. It is a function of the sensitivity to a climate impact and the adaptive capacity of the asset in terms of replacement cost and resiliency.

Acronyms

- Atlantic Multi-decadal Oscillation (AMO)
- Capital Improvement Projects (CIP)
- Digital Elevation Model (DEM)
- Digital Terrain Model (DTM)
- Federal Emergency Management Agency (FEMA)
- Floodplain Management Plan (FMP)
- Florida Department of Transportation (FDOT)
- Geographic Information System (GIS)
- Global Positioning System (GPS)
- Green House Gas (GHG)
- Light Detection and Ranging (LiDAR)
- Low Impact Development (LID)
- Mean Higher High Water (MHHW)
- National Oceanic & Atmospheric Administration (NOAA)
- North American Vertical Datum 88 (NAVD88)
- National Weather Service (NWS)
- Parts Per Million (PPM)
- Period of Record (POR)
- Relative Sea Level Change (RSLC)
- Sea Level Rise (SLR)
- Urban Heat Island (UHI) Effect

Introduction

Understanding a community's vulnerabilities to climate change is essential for reducing exposure to risk and informing decisions to adapt. A community should develop effective adaptation strategies based on locally-informed perspectives in order to embrace opportunities and confront risks associated with climate change. The target goal is for a municipality to provide continuity of public service and safety during periods of infrastructure stress and system shock. A community that actively protects infrastructure to ensure continuity of public services will have a competitive advantage across economic, built, and natural environments as climate change makes a progressively greater impact on the region.

According to the National Climate Assessment's Southeastern U.S. Study, the Florida Gulf Coast is, and will continue to be, susceptible to sea level rise (SLR), storm surge, extreme heat, extreme precipitation, and periodic drought. Municipalities around Florida are experiencing the effects of climate change as subtle changes in these parameters are producing far reaching impacts and consequences in coastal communities. SLR is already causing changes to Florida's coastal biogeographic regions and is also presenting challenges with protecting public infrastructure and community assets around the state. Flooding problems experienced in many coastal cities during seasonally-high tides (i.e. King Tides) are a testament to this issue.

As a Gulf Coast community, the City of Sarasota recognizes the implications of climate change and is acutely aware of how SLR, storm surge, extreme precipitation, and extreme heat can impact public assets, including transportation networks, stormwater management, water supply, and wastewater systems, as well as public lands, coastal shorelines, the environment, and public well-being. How a community responds and adapts to climate change is critical as proactive preparations can help minimize loss of public services. Localized adaptions to climate change, particularly in coastal communities like the City of Sarasota, will be increasingly important during the 21st Century. The City of Sarasota has also made efforts to minimize its contributions to climate change including signing the U.S. Mayor's Climate Protection Agreement in 2007, conducting community-wide greenhouse gas (GHG) inventories, establishing GHG reduction targets, targeting a 100 percent renewable energy goal by 2045, and singing a resolution to adopt and uphold the goals of the Paris Agreement.

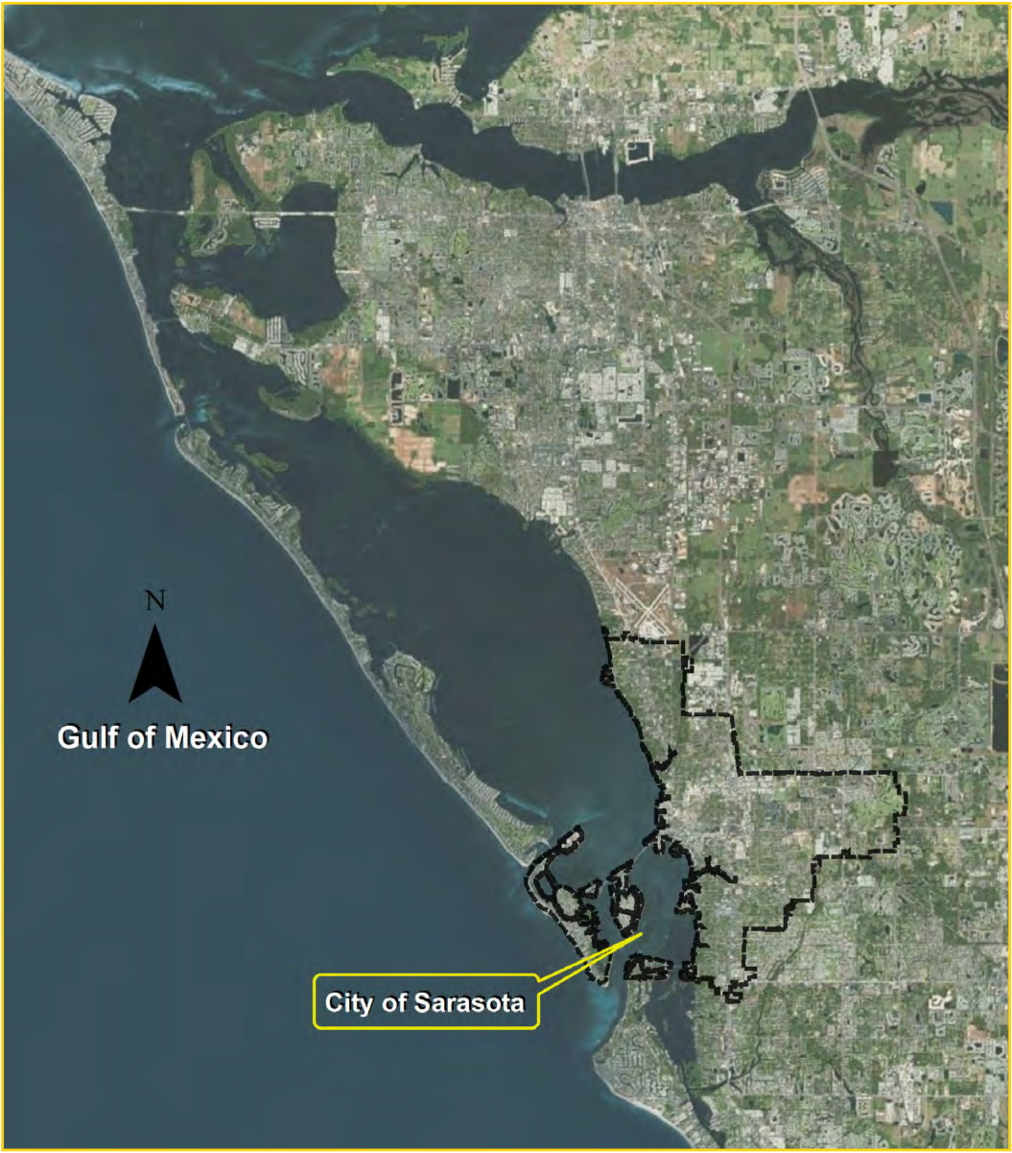
The purpose of this study was to evaluate climate threats to public infrastructure to understand how sea level rise (SLR), storm surge, extreme precipitation, and extreme heat might impact the City of Sarasota's transportation networks, stormwater management, water supply, wastewater systems, public lands, and critical buildings.

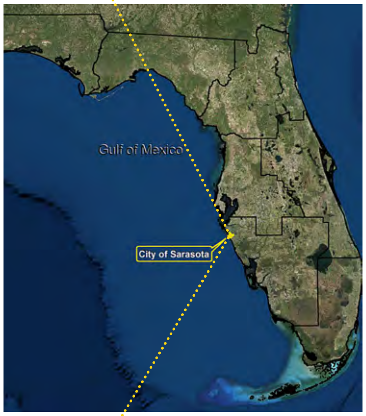
Regional Landscape

Florida is 500 miles long and 160 miles wide and is comprised predominantly of low lying plains with the exception of low hills around 200-300 feet above sea level in central and northern Florida. It is divided into four geographical landforms including the Atlantic Coastal Plain, the south Atlantic Coastal Plain, the East Gulf Coastal Plain, and the Florida Uplands. The City of Sarasota lies within the East Gulf Coastal Plain and is geographically defined by low elevations and flat rolling topography with tidal creeks and barrier islands.

Florida has over 1,200 miles of coastline of which 770 miles are along the Gulf of Mexico. Florida's intricate tidal shoreline, which includes inlets, bays, tidal creeks, and rivers, is significantly longer at 5,095 miles (NOAA Office for Coastal Management). Many of these shorelines are at risk due to climate-related change including ecosystems such as beaches, bays, estuaries, salt marshes, mangroves, bayous, shellfish bars, seagrasses, and reefs, all of which provide various ecological and economic benefits in terms fisheries, local resources, recreation, tourism, and aesthetics.

Most of Florida's approximately 20 million residents live within 60 miles of a coast and three-fourths of Florida's population reside in a coastal county supporting built environments and modern infrastructure services (Florida Oceans and Coastal Council, 2010). The City of Sarasota is a coastally-dependent city located along the Gulf of Mexico in Sarasota County. Typical temperatures range from an average of around 72° F during the winter months



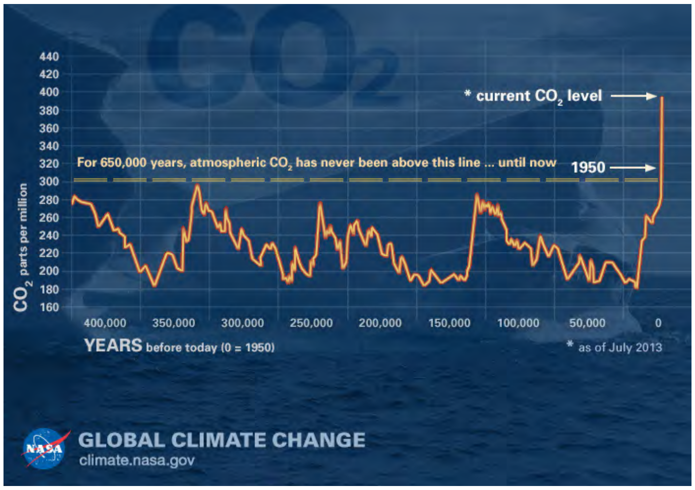


to about 90° F in the summer. An average of 53.6 inches of rain falls each year with the majority falling during the summer months. This west-central coastal city includes Sarasota Bay and the barrier islands of Lido Key and a portion of Siesta Key. The City mainland sits around 16 feet above sea level while the barrier islands average around 3 feet above sea level, making threats of storm surge and moderate SLR an important consideration. Increases in sea level, in combination with extreme storms, threaten the City's barrier islands with erosion and over wash deposition. The City encompasses nearly 24 square miles including approximately 10 square miles of water (City of Sarasota Floodplain Management Plan (FMP) 2015-2020). Approximately 40 miles of coastline surround the City, including 32 miles of man-made structures and eight miles of natural land (City of Sarasota FMP 2015-2020).

Past, Present, and Future Climate Change

The climate has changed throughout time, is changing now, and will continue to change into the future. Climate is defined as long-term averages and variations in weather measured over a period of decades (at least 30-years of period of record), and includes observations of land, atmosphere, ocean, and ice. The rate of change is influenced by both natural processes and human activities, such as an increase in atmospheric carbon dioxide (CO_2). Although natural processes have historically been the driving force behind climate change, data showing a dramatic increase in the global atmospheric CO_2 for the last 100 years of Earth's history is evidence of human's contribution. **Exhibit 1** illustrates this drastic increase in the distribution of global atmospheric CO_2 during the past century. Data prior to the 20th century were derived from Greenland ice cores.

Exhibit 1: Global Distribution of Atmospheric CO_2



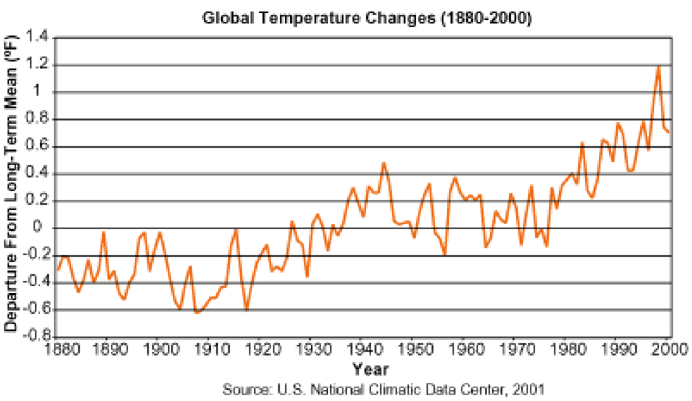
Increases in atmospheric CO_2 cause a blanket-like effect around Earth, which increases air temperatures. As temperatures rise, land-based glaciers and ice sheets melt and ocean water expands through the process of thermal expansion. Both processes contribute to SLR. Climate forecasts suggest SLR acceleration, which will further challenge coastal resiliency and management of public infrastructure, as well as stress coastal shorelines and Sarasota Bay. Storm surge associated with extreme storms and seasonally-high "King Tides" poses an immediate and credible threat to this community as tides surge increasingly higher and extend further inland. Modern infrastructure

(Top & Center): June 2012 King Tide at Bayou Louise, Siesta Key

(Bottom): 2017 King Tide as Hurricane Nate passed through the Gulf of Mexico – View under John Ringling Bridge

in coastal communities such as the City of Sarasota has not typically been designed to accommodate SLR or increased storm surge and now considerations regarding vulnerability, replacement, relocation, abandonment, or armament must be addressed. Extreme heat also threatens this region. Temperature changes on a global scale can be seen in **Exhibit 2**, which shows the changes in mean global temperatures since the late 1800s. Average annual air temperatures have increased in the Sarasota region over the past fifty years, which impacts and threatens human health. Additionally, extreme precipitation events, as well as prolonged and unpredictable periods of drought, exasperated by changing weather patterns, will challenge the management of stormwater, water supply, and sanitary sewer systems.

Exhibit 2: Global Temperature Changes (1880-2000)



Source: U.S. National Climatic Data Center, 2001

Tide Surge at Hart's Landing associated with Tropical Storm Colin (June 2016)

Infrastructure Vulnerability Study

For the City of Sarasota, community resilience to climate change begins with the inventory and assessment of public infrastructure vulnerabilities to natural and man-made hazards. As a modern coastal community with miles of tidally-influenced shorelines, the City has an essential responsibility to protect public health and safety by ensuring resiliency of municipal infrastructure.

Public services and critical infrastructure managed and maintained by the City of Sarasota are at increased risk due to climate-related changes such as rising sea levels, extreme storms and storm surge, flooding from extreme precipitation, and extreme heat. The City includes more than 500 miles of roads (many near the coast), water treatment and wastewater facilities less that 1-mile from the coast, stormwater management systems discharging to the bay, and public lands situated along tidal shorelines. Public infrastructure assets need to be adapted to accommodate forecasted climate changes.

A Six Step Systematic Process was used to evaluate system vulnerabilities and to develop climate adaption strategies for the City. These steps included:

1. ***Identify Climate Projections***
2. ***Infrastructure Inventory***
3. ***Vulnerability Assessment***
4. ***Prioritize Vulnerabilities***
5. ***Identify Adaption Strategies***
6. ***Adaption Plan***

This assessment involved an inventory of the City of Sarasota's infrastructure assets, spatial mapping of the assets using Global Information System (GIS), analysis of GIS metadata, utilization of climate projection tools to create spatially-relevant maps, and engagement with City staff through workshops intended to harness the expertise of those most knowledgeable of each sector's assets. The vulnerability assessment process also included public meetings and City Commission presentations.

This study evaluated man-made and natural, city-owned and managed infrastructure and considered the implications of impacts to those assets, including:

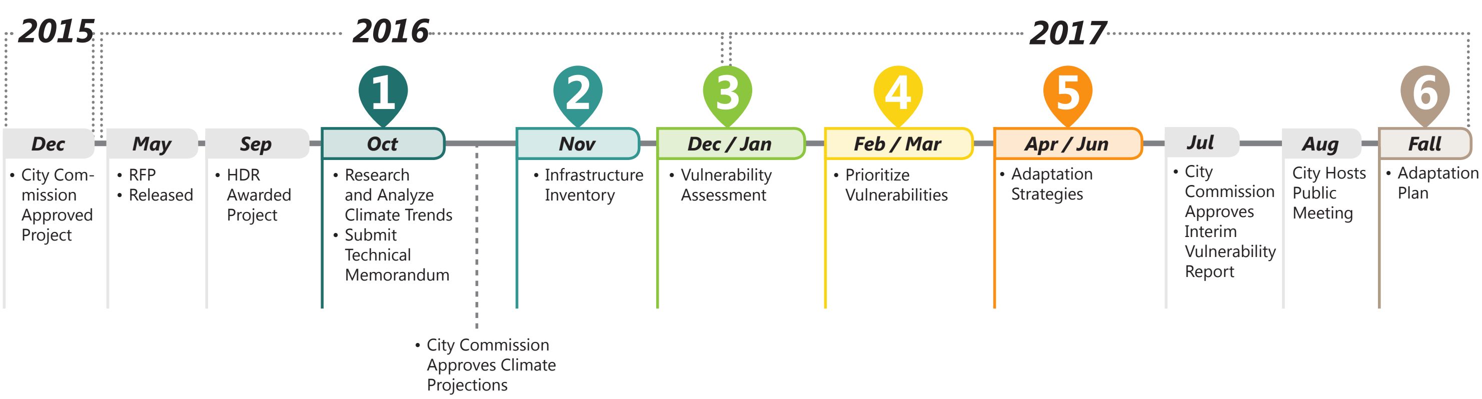
- Transportation Facilities
- Stormwater Management Facilities
- Water Supply Facilities
- Wastewater Facilities
- Public Lands (including parks and shorelines), and
- Critical Buildings

As part of this evaluation, impacts to non city-owned infrastructure were discussed including assets owned by the Florida Department of Transportation (FDOT) and Sarasota County, as well as the electrical grid. Although the City recognizes the critical nature of the electrical grid to the community, adaptation measures were not developed for this asset, which is owned and operated by others. However, the intent of this study was to initiate engagement and collaboration with entities such as Florida Power and Light Company (FPL) to develop greater overall resiliency within the City.

The concept for the City of Sarasota Climate Vulnerability Study was first presented to the City Commission in December 2015. The study was subsequently funded using local claims funds from the 2010 British Petroleum (BP) Deepwater Horizon Disaster.

As a first step in this study, a Climate Change Vulnerability Assessment and Adaptation Plan Technical Memorandum was prepared and presented to the City of Sarasota Commission November 21, 2016. This document established a baseline for the overall study by formally establishing climate projections relevant to this region to use throughout the vulnerability assessment. An Interim Vulnerability Report was provided to the City Commission in June 2017. This report outlined the methodology used to conduct the vulnerability assessment and identified vulnerable infrastructure to advance to the adaptation planning phase. This Final Climate Adaptation Plan incorporates information from the two previous reports and summarizes the final findings of the City of Sarasota's Infrastructure Vulnerability Assessment and Climate Adaptation Plan. An illustration depicting the timeline for this process is provided below in **Exhibit 3**.

Exhibit 3: Vulnerability Assessment and Climate Adaptation Plan Process



STEP 1 – **Identify Climate Projections**

1 Identify Climate Projections

The purpose of ***Step 1*** was to summarize scientific information and resources addressing climate change vulnerabilities specific to this region and to identify the latest climate science and industry models available for conducting this study. Step 1 set a foundation on which to build for modeling the City's infrastructure vulnerabilities to SLR, storm surge, extreme precipitation and extreme heat. The results of Step 1 were presented in the Climate Change Vulnerability Assessment and Adaptation Plan Technical Memorandum. A synopsis of potential changes to the Sarasota climate is provided in **Exhibit 4**.

Exhibit 4: Synopsis of Potential Changes in Climate Variables prepared for the City of Sarasota

Climate Variable	SARASOTA Trend	SARASOTA 2050 Projections
Sea Level Change by 2050	↑	6.4 inches to 2.4 ft.
HIGH air Temperature	↑	50 to 60 additional days ≥ 95°F per year
LOW air Temperature	↑	3.6 °F to 5.4 °F (increases with urbanization)
Water Temperature	↑	1.3 - 5°F
WATER: AVERAGE Precipitation	↑	Expected 5% increase, but with greater variablity
WATER: EXTREME Precipitation	↑	5% to 10%
WATER: EXTREME Drought	—	Same Potential
WATER: Hurricanes	↓↑	Not Known
WATER: Storm Surge	↑	Greater Potential
WATER: Coastal, Bay & Creek Flooding	↑	Greater Potential

Sources: SLR (NOAA, 2107) - range low to extreme; Storm Surge (National Climate Assessment); Temperature (NOAA NCDC / CICS); Precipitation (IPCC AR5 / National Climate Assessment); Flooding (IPCC AR5 / National Climate Assessment)

Climate Science

The term "climate change" is used to explain variations in global or regional climate over a defined period of time. Climate can be influenced by natural processes such as changes in solar activity or increased particulates in the atmosphere from forest fires or volcanoes, or human activities such as emission of GHG including carbon dioxide (CO_2), methane (CH^4), and nitrous oxides (NOX), which in turn influence climate changes. Growing evidence complied from scientists, researchers, and engineers around the world support the claim that the climate is changing and that the primary cause is linked to increasing levels of CO_2 in the atmosphere. According to reports by climate experts, 97 percent of publishing climate scientists believe this statement to be true (Cook, 2016). As shown in **Exhibit 1**, atmospheric CO_2 concentrations have increased steadily since the 19th Century (i.e. the Industrial Revolution) from around 280 parts per million (ppm) to over 400 ppm, which has been 100 times faster than the increase in CO_2 concentrations that occurred when the last ice age ended (NOAA, 2013). Increases in CO_2 concentrations have generally correlated to increases in air temperature, which in turn causes land ice to melt and the thermal expansion of ocean water.

Global climate change is a reality. Impacts from changes in global climate are occurring on local and regional levels to a degree that should warrant concern and proactive response. Although future climate projections using Global Climate Models are important tools for assessing future risk, observational data shows us that the climate has already changed within the period of record beyond the engineering criteria currently used to design much of our infrastructure.

Sea Level Rise

In order to provide a perspective to future vulnerabilities from climate-related SLR, it is necessary to understand that the sea level has undergone a steady rise during the available period of record (POR) and this rise should be used as a baseline for future change. Globally, sea level has increased approximately eight inches during the 20th century (www.globalchange.gov) although changes in sea levels vary around the world. Changes in global sea levels are driven by various factors including thermal expansion of ocean water caused by increasing water temperature, melting land ice, glacial rebound resulting in the rise of land mass, land subsidence, wind and currents, and aquifer withdrawals. Relative sea level change (RSLC) is used to capture these locally and regionally important phenomenon by incorporating changes caused by rising or falling land, as well as changes related to the ocean's water surface.

Researchers have been able to reconstruct sea level and global temperature changes for the past several thousand years using instrumental records and proxy data from climate archives to develop a better understanding of observed and future changes (Kemp *et al.,* 2011). This research suggests that the current climate warming is unprecedented in the past two millennia; however, the understanding of sea-level variability and climate deviations during this period is limited (Kemp *et al.*, 2011). SLR rise combines with other climate stressors - such as storm surge and extreme precipitation - to exacerbate flooding threats to coastal infrastructure.

Observational Sea Level Rise – Global

An understanding of global SLR begins with a historic perspective of how the oceans of the world came to be at their current levels. At the peak of the last glacial period (i.e. the ice-age) roughly 22,000 years ago, global sea levels were about 426 feet lower than they are today (Dietmar, 2008). Following the ice-age, the melting of glacial ice and glacial rebound contributed to the rise and fall in sea level that leveled off about 7000 years ago. Sea levels began rising again around the mid 19th Century to the early 20th Century and tide gauges have indicated that this rise has been accelerating over the past several decades (NASA, 2007). Recent studies analyzing sea level change over the past 3,000 years have shown that this acceleration is likely faster than during any of the 27 previous centuries (Kopp, 2016). While sea levels are known to rise at different rates regionally – meaning it may rise more quickly or slowly in certain places due to local conditions – sea levels are rising globally and experts link this to increasing CO_2 concentrations in the atmosphere, as shown in **Exhibit 1**. CO_2 concentrations are expected to continue to increase in the atmosphere into the foreseeable future, which will further increase global air temperatures perpetuating the melting of land ice and the expansion of ocean water. Most experts agree that sea levels will continue to rise and will increasingly threaten built environments and coastal infrastructure in the future.

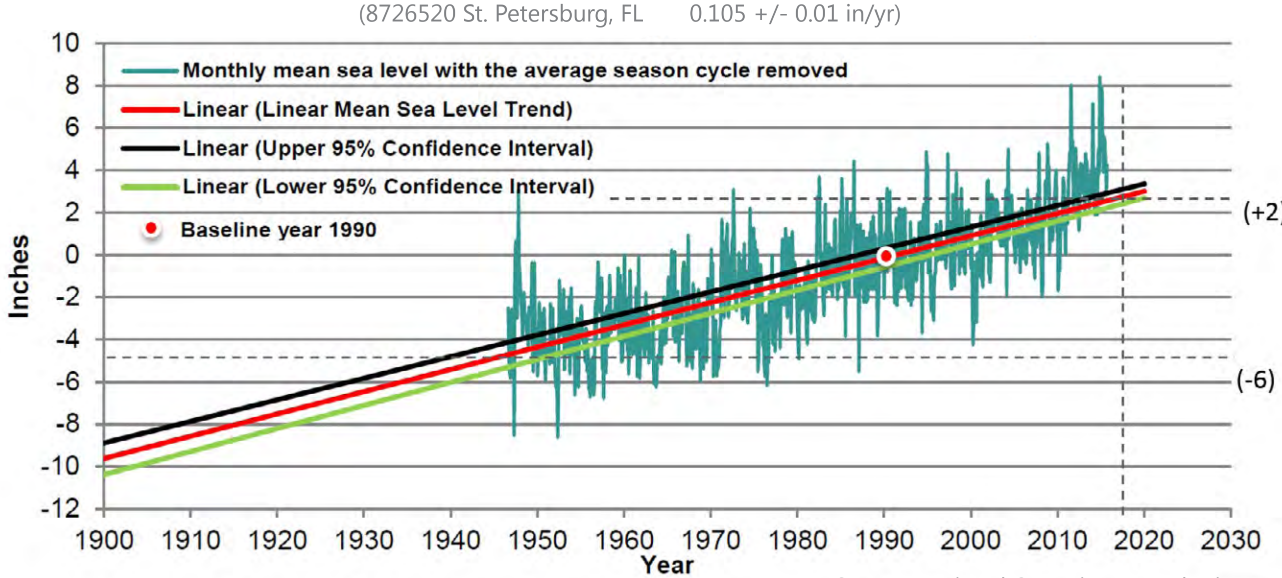
Observational Sea Level Rise – Local

The landscape setting that has caused Florida to be susceptible to SLR rise throughout the millennia is still in play today along the Gulf Coast. These factors are expected to be complicated and accentuated by climate change with the biggest change coming as the result of melting land ice and thermal ocean expansion. To better understand the implications of climate change in relation to observable trends, we consider the baseline, or historic reference, which is the state against which change is measured.

In **Exhibit 5**, we graph the sea level baseline, which represents observable, present-day conditions, in order to

Exhibit 5: Monthly Mean Sea Level Trend for St. Petersburg, FL Tide Gauge - 1900 to present

(8726520 St. Petersburg, FL 0.105 +/- 0.01 in/yr)



Source: National Oceanic Atmospheric Administration (NOAA) understand changes that are occurring without regard to any projected acceleration or deceleration in the trend. This exhibit shows historic fluctuations and average annual SLR at the National Oceanic and Atmospheric Administration (NOAA) St. Petersburg tide gauge (closest station to the City of Sarasota) beginning in 1947, the year sea level measurements began to be recorded at that gauge.

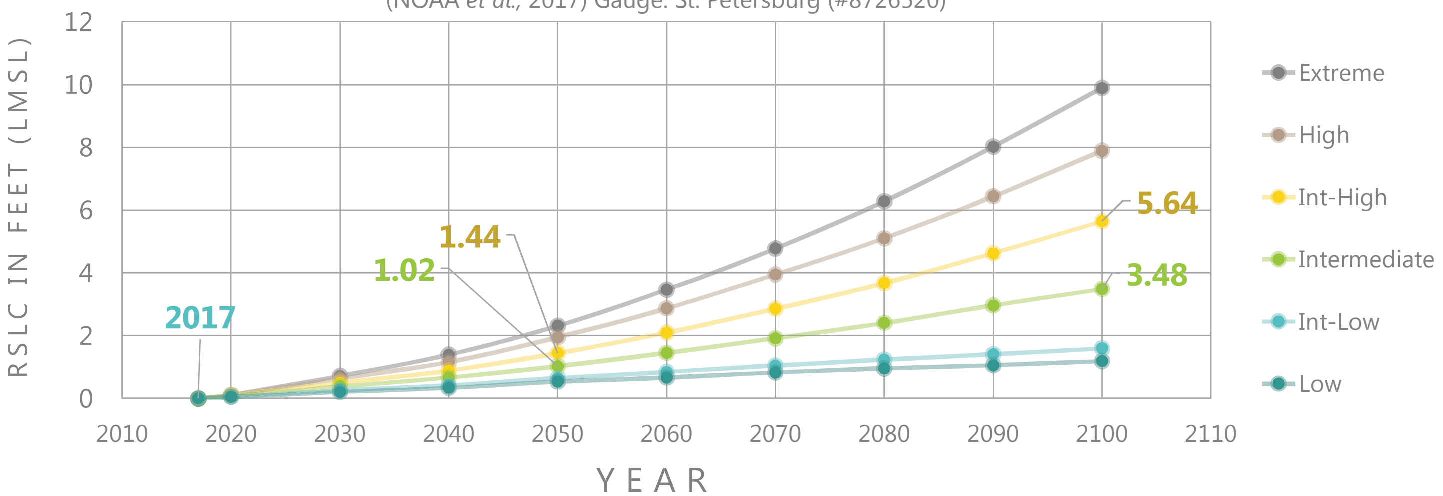
To create the baseline, scientists often use the year 1990 as the "baseline year" since it represents an important point of reference that industrialized nations measure against to evaluate reductions in GHG emissions (see U.N. Kyoto Protocol). The year 1990 was the year when the scientists began looking at data in terms of climate change and it serves as a dividing line between historic data and future data projections. Based on observed tidal data as shown in **Exhibit 5**, the City of Sarasota has experienced over seven inches of SLR since 1947 and around 2.55 inches between 1990 and 2015. Analysis of the data indicates that average annual rise in sea level is on the order of between 0.10 in/year and 0.11 in/year at the City of Sarasota.

During the course of this study, NOAA updated projections for future SLR scenarios to incorporate the most up-to-date science and methodologies and provide a more unified assessment of emission dependent probabilistic approaches and discrete scenario-based methods (NOAA, 2107). This study initially referenced the 2012 projections, but was updated to use the 2017 projections.

The International Panel on Climate Change (IPCC) developed a standard approach to modeling climate scenarios, which incorporates multiple factors to predict how future warming will contribute to climate change (IPCC, 2014). This standard set of scenarios, or Representative Concentration Pathways (RCP), helps ensure that research is complementary and comparable by defining consistent starting conditions, historical data, and projections to be used across the branches of climate science. The IPCC defines four RCPs (i.e. RCP8.5, RCP6, RCP4.5 and RCP2.6 - aka RCP3-PD) to describe possible rates and magnitudes of climate change depending on how much greenhouse gases are emitted.

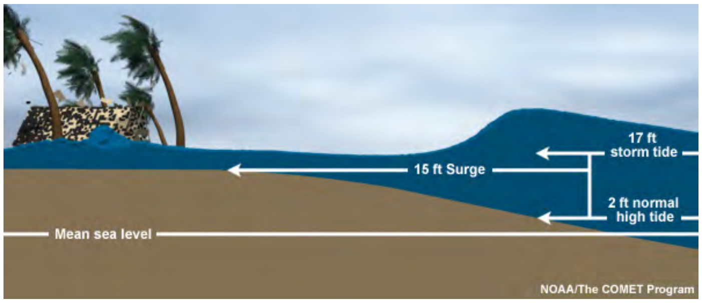
The 2017 projections, which utilize data from the 2014 IPCC, included the latest science about glaciers, which led to inclusion of a low probability but high consequence "extreme" SLR scenario to account for the loss of the Antarctica's glaciers. It also revised the lower bound of SLR using the latest tide gauge and altimeter-based estimates of rise that document that the rate of SLR has actually increased. Lastly, the new projections are probabilistic, factoring in the likelihood of the various scenarios being exceeded under the different future emission scenarios (i.e. RCPs). Based on the 2017 NOAA projections, **Exhibit 6** suggests that the Sarasota Region will experience about a 12 inch (intermediate) to 18 inch (intermediate high) rise in sea level by 2050 (above current conditions). These levels increase considerably through 2100.

Exhibit 6: Relative Sea Level Change Scenarios
(NOAA *et al.*, 2017) Gauge: St. Petersburg (#8726520)



Storm Surge and Extreme Storms

Storm surge is caused by an abnormal rise in water generated by a passing storm which can cause flooding in coastal areas. Surge water can combine with the astronomical tide and wind to create a storm tide. Storm tides can cause even greater coastal flooding and damage. Storm surge poses an immediate and credible threat to the City of Sarasota and surges are expected to worsen in terms of frequency and intensity as sea levels rise. Vulnerability to storm surge will increase in this region if surges associated with extreme storms (e.g. tropical storms and hurricanes), astronomical tides, higher winds, and waves become more frequent. Factors affecting storm surge include the direction of the storm approach (i.e. wind direction), the speed of the storm approach, the point of landfall, and the storm intensity (Weisberg, *et al.*, 2006).



Storm Surge Illustration
Source: NOAA

Some studies suggest that the Atlantic Multi-decadal Oscillation (AMO) drives natural cyclical variations in hurricane formation, while others suggest climate warming will cause an increase in hurricane formation (Knight, 2006), and intensity (US Global Change 2014; Kishtawal 2012). There is evidence that the intensity, frequency, and duration of North Atlantic hurricanes, as well as the frequency of the strongest hurricanes (i.e. Categories 4 and 5), have increased since the early 1980s (National Climate Assessment 2014). However, there remains debate among meteorologists about how much this has increased and current climate models leave uncertainty as to how much climate change could affect hurricane formation in the future.

According to the NOAA Hurricane Research Division (HRD), an increase in tropical cyclone peak wind-speed and rainfall is likely to occur as the climate continues to warm. A warmer atmosphere will lead to warmer ocean temperatures and tropical cyclones gain energy from waters above 80° F. Model studies and theory project a three (3) to five (5) percent increase in wind speed per 1.8° F increase of ocean surface temperatures (NOAA HRD 2007). By 2050 the Gulf of Mexico and Atlantic Ocean Sea Surface Temperatures (SST) are expected to be at least 1.3° F degrees warmer, and could be as much as 5° F warmer. More data analysis is warranted on this critical topic, as this topic has direct consequence for the City of Sarasota. Although the number of storms that have directly impacted within 30 miles of Sarasota have not increased since the 1980s, the National Climate Assessment is projecting an increase in intensity and frequency of storms that may impact this region in the future.

Wind

Another threat associated with extreme storms is wind. Wind pushes water towards land during storms to cause storm surge, but wind can also destabilize electrical networks and damage public infrastructure on land. Winds associated with Hurricane Irma, which passed Sarasota as a Category 1 hurricane, damaged electrical lines, knocking out power to the majority of the community, and uprooted trees causing water lines to break. Widespread power loss following the storm impacted sewer pump stations throughout the City.

Extreme Precipitation and Drought

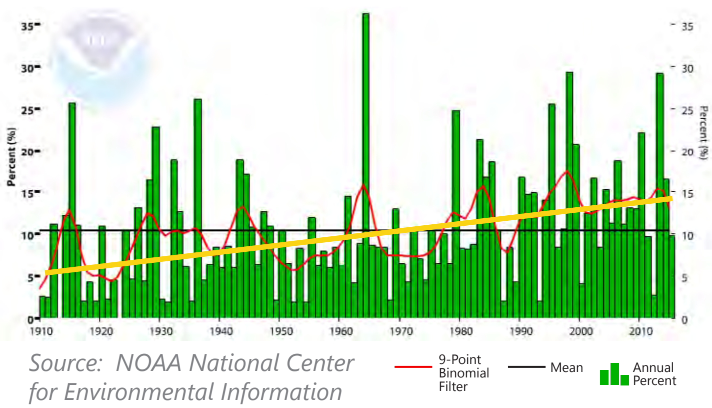
Global and local annual air temperatures have been rising over the past decades. While this rise in air temperatures is a concern for the City of Sarasota, an ancillary impact of the increase in air temperature is its effect on precipitation intensity. A common equation utilized in hydro-meteorology explains this phenomenon. The Clausius-Clapeyron equation and/or relation tells us that the equilibrium between water and water vapor depends upon the temperature of the system. If the temperature increases the saturation pressure of the water vapor increases. In other words, warmer air can hold more moisture than colder air. Thus, a warmer atmosphere can hold and release more moisture than a colder one. This relation explains why rainfall intensities will continue to increase as the atmosphere warms.

While global precipitation intensities have been variably changing, changes across the U.S have been profound during the last 100 years of period of record (POR). Data indicate that precipitation extremes have been increasing across the

U.S. (NOAA). **Exhibit 7** focuses on the southeastern U.S. and shows an increase in the yearly percentage of 24-hour precipitation extremes. The binomial trend line (red line) shows an upward, yet cyclical trend during the POR 1990 to 2015. This pattern of increasing precipitation intensity is expected to continue across the southeastern U.S. and throughout the Sarasota region.

Exhibit 7: Percentage of Extreme 1-day (24-hour) Rainfall Events Annually in the SE U.S.

Southeast Extremes in 1-Day Precipitation (Step 4) Annual (January-December) 1910-2015*



Source: NOAA National Center for Environmental Information
Linear trendline in yellow

Various factors influence precipitation patterns across Florida. Local, regional, and global climatic influences, such as sea breeze convection, El Niño / La Niña, and tropical systems, as well as human-derived factors (e.g. urban development) and microclimates (e.g. areas near water) affect weather systems throughout the state. The native Florida landscape is accustom to, but also sensitive to, impacts that result in changes in precipitation due to interannual variability in precipitation and notable periods of drought and extreme precipitation, which can linger for months or years. Atmospheric pressures from a changing climate could make weather extremes worse.

Typically, the Florida rainy season is characterized as roughly occurring May through October and the dry season November through April. A review of literature on rainfall suggests that precipitation patterns may be changing in Florida. In addition, as the atmosphere warms and holds more moisture, the frequency of heavy downpours is expected to increase. A recent study analyzing rainfall in Florida suggests a possible delay in the onset of wet season precipitation (i.e. drier May) leading to an overall decrease in wet season precipitation (Irizarry-Ortiz, *et al.*, 2013). At the same time, the study suggests a possible increase in the number of rainy days during the dry season (i.e. especially during November, December, and January). A delayed onset of the rainy season during the month of May could result in a greater incidence of localized drought episodes, which when combined with higher temperatures, could impact native habitats in parks and urban landscapes.

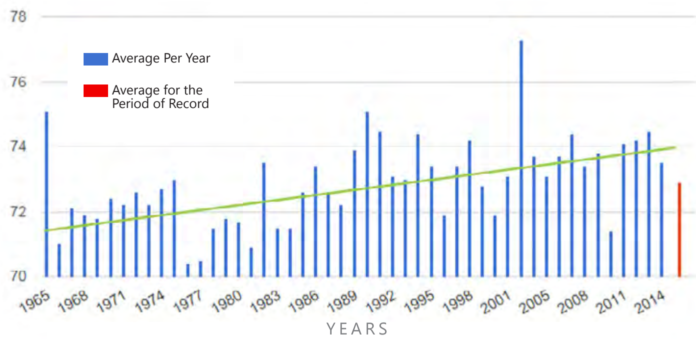
Extreme Heat

Air temperatures are expected to continue to rise across Florida. Air temperatures, particularly night air temperatures, are showing an upward trend in portions of the globe. As global average temperature's warm overall, heat waves are expected to increase in frequency and intensity and cold spells are forecast to become less frequent. Analysis of data from the second half of the 20th century shows a decrease in the daily temperature range (i.e. high versus low temperature) due mostly to an increase in the daily temperature minimum, which can be attributed to a combination of natural (climate warming) and human (Urban Heat Island Effect) factors (Irizarry-Ortiz, *et al.*, 2013).

Near term, global climate change is virtually certain to facilitate an increase in temperature thereby causing an increase in the number of unusually hot days and a decrease in unusually cold days for the region, as well as an increase in coastal water temperatures (e.g. bays, creeks). Average annual air temperatures have increased in the Sarasota region over the past 50 years by 2.2^0 F as observed at the meteorological reporting station located 5 miles ESE of Bradenton, FL. **Exhibit 8** provides a look at average annual temperature changes for the POR 1965-2014 for this meteorological reporting station as compiled by the Office of the Florida State Climatologist. The green trendline shows a temperature increase during the POR. Changes in air temperature over the last 50 years within the vicinity of the City of Sarasota are on par with the global temperature changes observed by NASA.

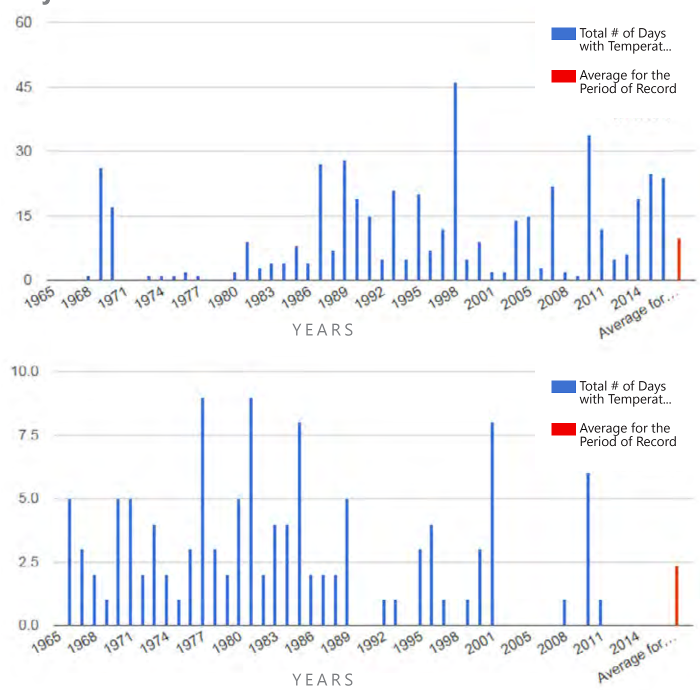
As shown in **Exhibit 9**, the number of days over 95° F for this region has increased since 1965 (Florida Climate Center, 2017). Similarly, the number of days below 32° F has decreased for the period of record. Estimates for increases in extreme heat were obtained from the National Climate Assessment for the Southeastern U.S. (2014). Currently, the City of Sarasota experiences approximately nine days each year that exceed 95° F. Projected temperatures indicate a rise in mean annual temperatures that could result in 50 to 60 additional days with high temperatures exceeding 95° F. This was determined by adding the projected increase in air temperatures to the average high temperatures for each month of the year based on the historic record.

Exhibit 8: Average Annual Temperature for POR 1965-2014 (station 5 miles ESE of Bradenton, FL)



Source: Florida Climate Center – Office of the State Climatologist
Trendline in green (↑2.2° F)

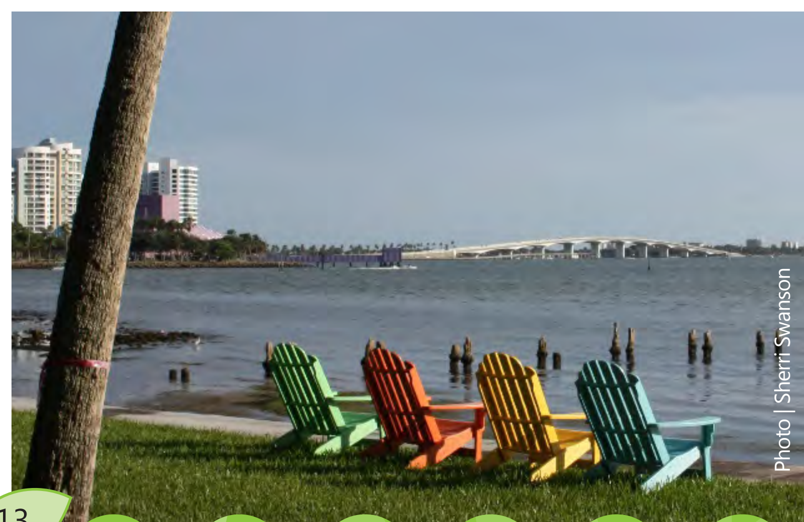
Exhibit 9: Florida Climate Center Temperature Projections



Source: Florida Climate Center – Office of the State Climatologist

Temperature data for Sarasota Bay (collected by Mote Marine Laboratory) were graphed to evaluate seasonal water temperature variations and grouped according to depth of sampling. Temperature sampling began in 1998 and data were collected through 2015. These data included temperature gauge stations north of Ringling Boulevard deemed to be representative of Sarasota Bay. This analysis suggested that overall, the water temperature in Sarasota Bay was virtually unchanged for the period of record; however, as air temperatures continue to rise in the region, heat transfer to shallow bay waters will be inevitable and changes to the local environment would be expected. It is unlikely that this brief snapshot in time shows the full picture of interactions occurring in Sarasota Bay. Additional data (e.g. longer period of record) and more analysis is needed to better understand temperature trends within Sarasota Bay as air temperatures rise in the region in order to protect this unique natural resource – and the economic value it offers the community in terms of fisheries, aesthetics, and tourism.

View toward John Ringling Bridge over Sarasota Bay



City of Sarasota Skyline

Urban Heat Islands

One consequence of urbanization, population growth, and the infrastructure that accompanies those parameters is an increase in impervious surfaces and non-vegetated areas, which can create a heat dome around developed areas. This increase in heat due to an expansion of pavement for roads and concrete for buildings and other man-made components of civilization is called the Urban Heat Island (UHI). UHIs happen when heat is trapped, created, discharged and/or reflected from hardened surfaces thereby increasing temperatures within a city compared with surrounding rural areas. This can lead to an inescapable heat loop where the heat island continues to warm. UHIs have been linked to increased energy consumption (to cool interior buildings), which in turn leads to increases in CO_2 emissions, an increase in air pollutants from GHG emissions such as ozone, and thermal pollution in water leading to greater evaporation - all of which can further exacerbate climate change.

While there were no available studies specific to the City of Sarasota, information on the UHI effect on the State of Florida can be obtained through analysis of geographic changes in the length of the hot season, which typically starts the beginning of May and ends the middle of November in Sarasota. Some cities in south Florida (i.e. Miami-Dade County north to Palm Beach County) have seen a tremendous increase in the length of the hot season, which is primarily attributable to the UHI effect; however, much smaller increases have occurred in areas like Sarasota that have not experienced similar urbanization expansions.

An illustration of an urban heat island

Climate Tools and Methodologies

The use of Global Climate Models (GCM) to project future climate variables continues to be perfected as new methodologies are applied to greater computing power. For this study, we used the latest climate projection models and assessment tools to analyze the four climate variables evaluated by this vulnerability analysis.

Sea Level Rise

For our analysis we used the NOAA Digital Coast Sea Level Rise Mapper tool to project SLR over the City of Sarasota to year 2050 and 2100. However, this infrastructure vulnerability analysis focused on NOAA 2050 projections, which suggest that the Sarasota Region will experience a 12 inch to 18 inch rise in sea levels by that time (i.e. NOAA intermediate versus NOAA intermediate high). GIS-based information was downloaded from the NOAA Digital Coast Sea Level Rise Mapper and layered onto the physical landscape of the City of Sarasota to visualize community-level impacts from SLR and coastal flooding. The SLR metadata tidal datum was feet above Mean Higher High Water (MHHW) in orthometric values of North American Vertical Datum 88 (NAVD88). The NOAA data were obtained from the closest tide gauge to the City of Sarasota, located at St. Petersburg. NOAA data from this gauge was converted to a point shapefile using latitude and longitude information. To incorporate tidal variability, a "modeled" surface (or raster) was created. This raster represented the same vertical datum as the elevation data (NAVD88) and was used as a surface upon which SLR was added.

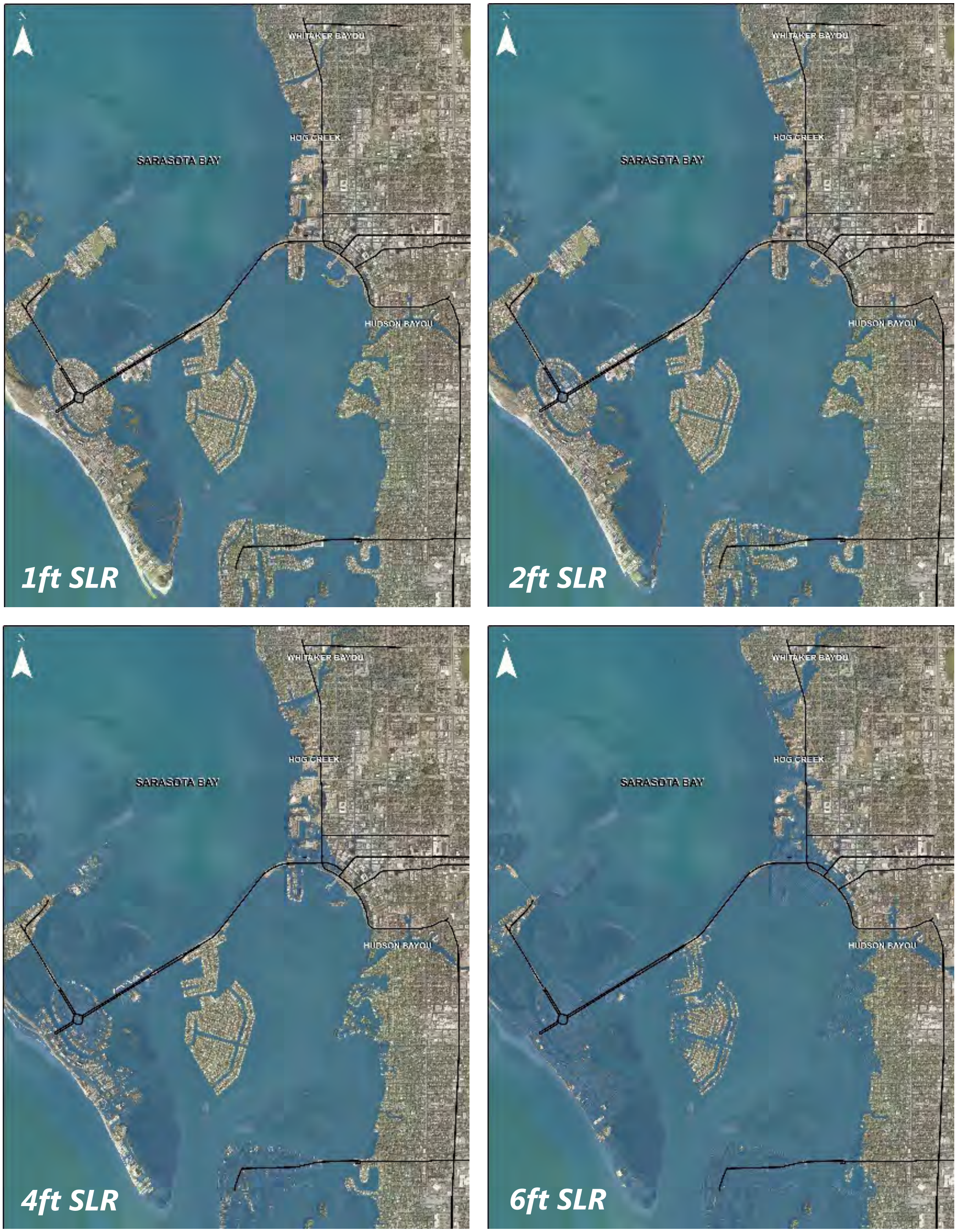
The NOAA Office for Coastal Management mapped SLR inundation using a "modified bathtub approach" that attempted to account for local and regional tidal variability and hydrological connectivity. The process incorporated the DEM of the area and the tidal surface model that represented spatial tidal variability. The tidal model was created using the NOAA National Geodetic Survey's VDATUM datum transformation software (http://vdatum.noaa.gov) in conjunction with spatial interpolation/ extrapolation methods and represented the MHHW tidal datum in orthometric values (NAVD88). The metadata records were available for the 1ft through 6ft SLR inundation layers. The maps shown in **Exhibit 10** use the NOAA data to display how SLR at various levels (i.e. 1ft, 2ft, 4ft, and 6ft) would affect the City irrespective on the year.

The data incorporated the best publically-available and accessible SLR and elevation data, mapped SLR on top of MHHW, incorporated local and regional tidal variation of MHHW, evaluated inundation for hydrological connectivity, and preserved hydrologically unconnected areas greater than one acre, but displayed these separately from hydrologically connected inundation. However, NOAA noted that these data were not intended for site-specific analysis and that data did not incorporate future changes in coastal geomorphology (i.e. assumed present conditions persist, which will not be the case). The analyses performed within this study were somewhat constrained by the amount of remote sensing data. As with all studies of this nature, an expansion of the remote sensing network would be useful in refining projection output by including additional tide gauge, rain gauge and flow monitor data at the local level and obtaining high resolution data from the recent launch of the GOES-16 environmental satellite.

Beach flooding along Siesta Key during October 2017 King Tide as Hurricane Nate passed by in the Gulf of Mexico

Photo | Lee Hayes Bryon

Exhibit 10: Sea Level Rise Projections



Storm Surge

Although future increases in the magnitude of storm surges are expected to be a consequence of increased storm intensity due to climate change, there are currently no publically available models that project and quantify these future storms. Thus, to evaluate storm surge vulnerabilities for the City of Sarasota, the study investigated possible storm surge scenarios using NOAA tools that account for historic storms, peak coincidence of storm surge, astronomical tides, wind and waves, and water elevations categorized through the measure of tropical cyclone strength called the Saffir-Simpson scale (www.nhc.noaa.gov/aboutsshws.php).

As of May 12, 2010, storm surge potential for each category on the Saffir-Simpson scale was removed by the NOAA/ National Hurricane Center (NHC) due to NHC's need to better convey information on a storm-by-storm basis. The storm surge values associated with that scale, which were derived from climatological values for storms in each of the categories, is still useful as a guide for storm surge vulnerability modeling. For this study, storms surges associated with Category 1, 2, 3, 4, and 5 tropical cyclones were used as input for geospatial referencing to better understand potential hazards to City infrastructure.

A vulnerability analysis that depicted a combination of future SLR plus storm surge was considered to determine the potential impacts to infrastructure from rising seas in conjunction with future storms. These GIS-based projections were used to estimate the possible combined affect of storm surge from a Category 1 hurricane plus SLR in 2050 and a Category 3 hurricane plus SLR in 2050. The data for this analysis included the NOAA SLR datum and the National Weather Service (NWS) Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model.

Sea, Lake, and Overland Surge from Hurricanes (SLOSH)

SLOSH is a computerized numerical model developed by the NWS to estimate storm surge elevations resulting from historical, hypothetical, or predicted hurricanes. This model incorporates various parameters such as atmospheric pressure, storm size, direction, and speed, and storm track to model the wind field which creates the storm surge (NOAA, 2016). The SLOSH model considers local conditions such as shorelines and bays, water depths, coastal infrastructure (e.g. bridges and roads) and other physical features, and is referenced to NAVD88. The SLOSH model details are available here: www.nhc.noaa.gov/surge/slosh.php

In order to estimate the additive impacts of SLR plus storm surge 2050, the variability of storm surge vertical and horizontal inundation at various hurricane intensities (i.e. CAT 1, 2, 3, etc.) needed to be considered so that the addition of SLR could be projected visually onto maps. Since SLOSH provided a range of vertical depths as output (i.e. 3-ft increments above 3-ft.) for each hurricane category, a decision was made to yield a spatial analysis that included the most appropriate portion of those ranges in order to convey a combination of SLR plus storm surge. The analysis produced a spatial inundation rendering that maintained the variability of storm surge by utilizing an approximation from the next level of hurricane category higher to simulate the addition of SLR. While these data provide an approximation of inundation, they are within the range of projection that would result from a strict addition of SLR plus storm surge, but maintain the vertical and horizontal extent of inundation associated with hurricane intensities.

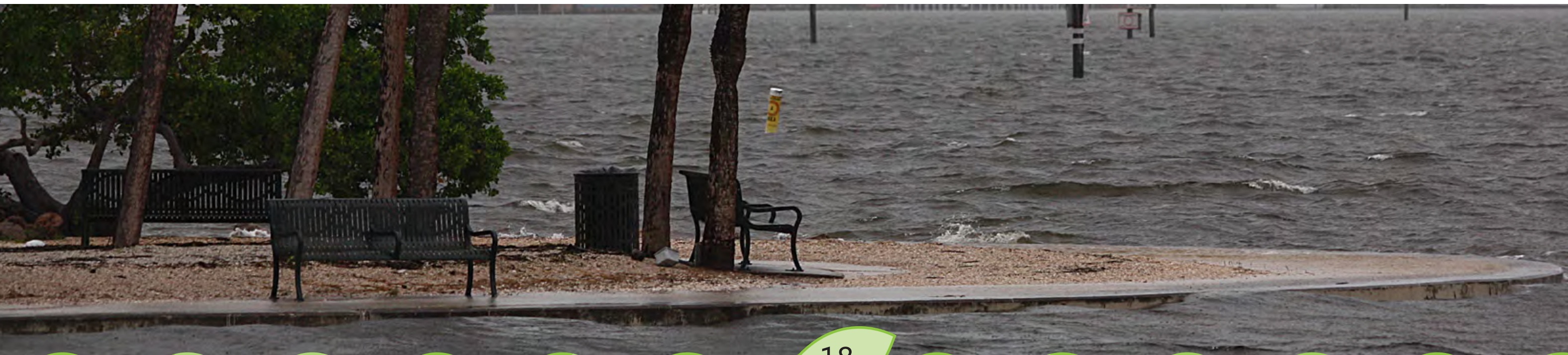


Photo | Sherri Swanson

Extreme Precipitation

According to NASA, average precipitation across the U.S. has increased by about five percent since 1900; however, regional variations due to complex climatic interactions. The southeast has experienced a mix of increases and decreases. Projections suggest continuation of the recent U.S. trend towards increased precipitation, including heavy extreme precipitation, but overall distribution of rain will be variable with some regions expected to decrease (NASA, 2016). This study uses the National Climate Assessment projection for the Southeastern U.S., which suggests a 5% to 10% increase in extreme precipitation events by 2050, although regional variabilities, localized rainfall and the distribution of storms across the state remains somewhat uncertain.

This Vulnerability Assessment incorporated the Sarasota County Stormwater Model to project flooding within the City of Sarasota associated with the 100 year storm event. The County had modeled a series of hydraulic computer simulations using the Streamline Technologies Interconnected Channel and Pond Routing (ICPR) version 3 software. This computer simulation was specifically developed to evaluate the relatively unique rainfall events in Florida. The model was developed for all of Sarasota County's baysheds. This study merged outputs from the three primary watershed models that encompass the City and the minor Coastal watershed model. The predominant watersheds included the Whitaker Bayou, Hudson Bayou and Phillippi Creek Watersheds, as well as the Sarasota Bay Coastal Watershed, as shown in **Exhibit 11**.

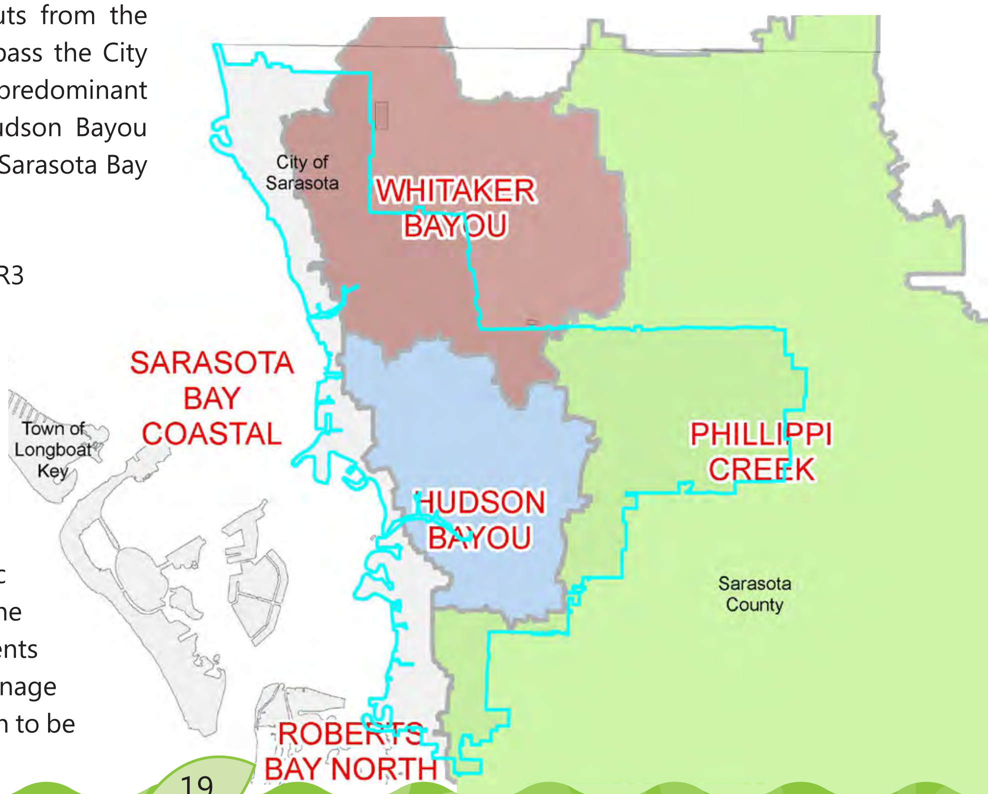
Existing infrastructure was mapped for the ICPR3 model and brought into the digital environment, including surveyed measurements for stormwater pipes, structures, weirs, culverts, ponds, channels, and other infrastructure designed to convey the stormwater. The model also included LiDAR (Light Detection and Ranging) data to identify the topography within each bayshed. While this hydraulic model is an approximation or simulation, the results have been verified by field measurements and provide an estimation for post-storm drainage conditions. The County ICPR3 model has proven to be the best available industry standard to predict flood stages within the City of Sarasota and was adopted by the Federal Emergency Management Agency (FEMA) to identify the insurance floodplain delineations.

Data from FEMA was incorporated into the Sarasota County Stormwater Model, which was obtained from the Standard Digital Flood Insurance Rate Map (DFIRM) Database. Two of the three major watersheds were updated with new DFIRM data (November 2016). At the time of the study, changes had not been finalized for the Phillippi Creek Watershed or the Coastal Watershed.

Extreme Heat

The likelihood of increases in air temperature for the City of Sarasota was not quantified on a site-by-site basis like other climate projections, but it was determined, based on Global Climate Model (GCM) output, to be likely in all areas of the City by 2050. Impacts from higher air temperatures on changing weather patterns, air quality, UHI effect, water temperatures, recreation and tourism, general comfort, and energy use will be very likely. Extreme heat can also stress

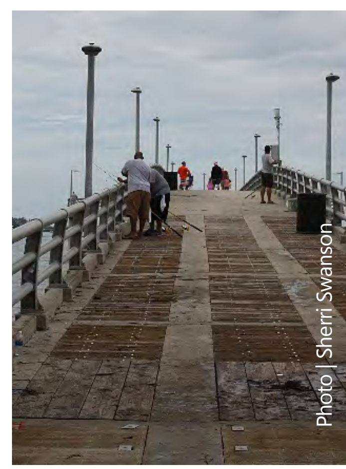
Exhibit 11: City of Sarasota Watersheds



city infrastructure and increase costs for operation, maintenance and replacement of assets. While the advent of more days of extreme heat is likely by the year 2050, consequences from these impacts are expected to be much greater on the populace and environment than on city infrastructure.

Excessive heat can lead to increases in extreme rainfall and atmospheric gases, such as water vapor, which can increase the atmosphere's ability to retain heat. Excessive heat and higher heat index values (i.e. "feels like temperature") can affect day-to-day life by increasing outdoor discomfort and increasing the demand for electricity to cool buildings, which can lead to power outages. Although not city-owned, the electrical grid is vulnerable to extreme heat. Conservation measures and alternative energy options need to continue to be part of the overall resiliency solution. Additionally, as observed during Hurricane Irma, the electrical grid is highly vulnerable to wind damage. Following the storm, parts of the City remained without power supply for up to twelve days, which not only caused public discomfort due to warm air temperatures, but also caused wastewater lift stations to fail due to lack of power. Increases in extreme heat will exacerbate public health concerns due to diminished air quality, intensify the UHI effect, and increase temperatures in coastal waters such as Sarasota Bay, tidal creeks, estuaries, and gulf waters.

Harmful algal blooms (HAB) that lead to red tide events are projected to benefit from a warmer climate. Researchers at NOAA are working to understand how warmer water temperatures may benefit algal species that cause HABs. HABs are fueled by nutrients in the water, and are distributed by currents. Some toxic algal species are believed to have a competitive advantage (e.g. higher proliferation) in warmer tidal waters. Studies suggest that warmer waters could increase bloom persistence and duration and expand the geographic range of some toxic algal species (O'Neil *et al.*, 2012). HABs can also lead to fish kills. One of the largest HAB that affected Sarasota beaches occurred in the Gulf of Mexico in 2014, when water temperatures were at record highs (IFAS, 2015). The photo to the right was taken during the summer of 2016 on Lido Beach. Red tide events can cause respiratory irritation in humans and extreme heat can be deadly to vulnerable human populations. A more detailed study on the influence of warmer waters on HABs and the effects of extreme heat on human heath and the environment is needed to identify heat-related risk within the City of Sarasota.



(Top): Lido Beach

(Bottom Left): Lido Beach Fish Kill

(Bottom Right): Tony Saprito Fishing Pier

Photo: Sherri Swanson

STEP 2 – **Infrastructure Inventory**

2 Infrastructure Inventory

The purpose of ***Step 2*** was to conduct a comprehensive infrastructure inventory for assets within the City of Sarasota. This included infrastructure owned and operated by the City, as well as infrastructure currently supporting city operations, but owned and/or operated by others.

Infrastructure Inventory

Infrastructure assets were organized by city sector. A total of 219 assets were inventoried, as shown in **Table 1**. The study considered both man-made and natural infrastructure throughout the City limits including:

- Transportation Facilities
- Stormwater Management Facilities
- Water Supply Facilities
- Wastewater Facilities
- Public Lands (including parks and shorelines), and
- Critical Buildings

Table 1: Infrastructure Inventory

City Asset (by Sector or Department)	Number Inventoried and Analyzed
• Transportation	34
• Stormwater Management	52
• Water Feature	11
• Water Supply	21
• Wastewater	34
• Public Lands and Shorelines	53
• Buildings	14
TOTAL	**219**

Assets within the City limits were geo-spatially mapped in GIS ArcMap 10.4. An Excel database was generated from these mapped data and used to organize, inventory, and evaluate details for each infrastructure asset (**Appendix A**). The GIS maps helped identify infrastructure in high-risk areas and provided a foundation upon which to model future flood hazards associated with three of the four climate variables including 1) SLR, 2) storm surge, and 3) extreme precipitation. Impacts due to future projections for extreme temperature were considered separately.

Data Collection

The spatially-implicit, infrastructure data originated from a variety of state and federal sources, as well as other data stewards, collectors, producers, and/or publishers including Sarasota County and the Florida Geographic Data Library (FGDL). Some asset data were not electronically available. In these instances, data were mapped from latitude and longitude coordinates provide by city staff or locations obtained from reports. Some infrastructure assets required field location using Global Positioning System (GPS) applications. City engineers and utility professionals helped fine-tune locations of infrastructure and identify gaps in GIS datasets.

Available Light Detection and Ranging (LiDAR) and digital elevation model (DEM) 3D representation of the ground surface data were reviewed. Sarasota County LiDAR (2007) was used in the Sarasota County Stormwater Model to estimate ground elevations. This raster data set was used in GIS to better understand localized conditions when analyzing specific infrastructure assets. Additionally, stormwater model output was used in the evaluation of freshwater flooding. The DEM available for this project was projected in a horizontal datum NAD83 – Florida HARN State Plane West Feet 0902 and vertical datum NAVD88 feet. The vertical accuracy of the mass points was determined to be 0.3-feet RMSE (root-mean-square error). The Digital Terrain Model (DTM) was intended to support 2-foot contours with the vertical accuracy of ground points in unobscured areas not to exceed 0.6-feet RMSE.

Photo | Sherri Swanson

STEP 3 – **Vulnerability Assessment**

3 Vulnerability Assessment

The purpose of the **Step 3** was to evaluate the 219 existing infrastructure assets inventoried during Step 2 in order to provide a comprehensive review of near- and long-term infrastructure vulnerabilities to future climate threats. Global climate modeling has shown that climatic changes have already occurred with regard to increased average air temperatures, SLR and storm surge, as well as increased storm and precipitation intensity, and that these changes will be exacerbated over time. These climate changes are expected to continue to threaten coastal infrastructure assets in this area.

Vulnerability was defined as the degree of exposure to physical harm that infrastructure could experience due to a future climate impact. Vulnerability was considered a function of the sensitivity to a climate impact and the adaptive capacity of the asset in terms of replacement cost and overall resiliency.

Vulnerability = Sensitivity x Adaptive Capacity

The study focused on the year 2050, based on consensus reached by the city staff working group about asset lifecycles and system replacement needs and considered SLR projections; storm surge associated with Gulf storms plus SLR 2050; inland flooding from extreme precipitation; and increased water and air temperatures due to extreme heat. Qualitative information was gathered about historical and/or current impacts to city infrastructure. City staff guided an evaluation to understand the City's most critical infrastructure assets.

Photo | Visit Sarasota

Critical Infrastructure Assets

Public assets, systems, and networks vital to the City of Sarasota such that their disengagement or destruction would result in debilitating impacts to public health and safety, functionality of critical public utilities, safe evacuation, and environmental protection.

Step 3: Climate Change Working Group

Sensitivity

Sensitivity was defined as the degree to which an asset could be directly or indirectly impacted by exposure to a climate threat. The sensitivity analysis considered known and projected climate impacts. City staff provided information related to current observable climate stressors, overall asset susceptibility to projected climate threats, and anticipated impacts based on asset management experiences and climate projections. City staff were asked to evaluate if climate change was currently stressing each asset and were then asked to review the climate projection maps created for SLR, storm surge and extreme heat to rate how susceptible each asset would be in 2050, based on their expertise. Each asset was evaluated for sensitivity on a scale of one (1) to five (5) for a maximum score of five (5). Infrastructure sensitivity was ranked according to the scale shown in **Table 2** below:

Table 2: Sensitivity Legend

1	LOW	Slightly Susceptible in 2050
2	MED-LOW	Somewhat Susceptible in 2050
3	MEDIUM	Moderately Susceptible in 2050
4	MED-HI	Very Susceptible in 2050
5	HIGH	Extremely Susceptible in 2050

Adaptive Capacity

Adaptive Capacity was defined as an asset's ability to accommodate impacts of a stressor caused by exposure to a climate impact. It considered whether the asset would be repaired, removed, or relocated and the associated cost and time needed for return to normalcy after a disruption. Staff considered that assets were impacted and evaluated if adaptation was realistic based on location, cost, and effort. Each asset was evaluated for adaptation on a scale of one (1) to five (5) for a maximum score of five (5). Adaptive capacity was ranked according to the parameters described in **Table 3** below.

Table 3: Adaptive Capacity Legend

1	($)	Infrastructure can adjust to climate threat with no modification or cost
2	($$)	Infrastructure can adjust to climate threat with slight modification and minimal cost
3	($$$)	Infrastructure can adjust to climate threat with some modification and cost
4	($$$$)	Infrastructure cannot adjust to climate threat without modification and cost
5	($$$$$)	Infrastructure cannot adjust to climate threat without substantial modification or cost

Photo | Sherri Swanson

STEP 4 – **Prioritize Vulnerabilities**

4 Prioritize Vulnerabilities

Step 4 was conducted to prioritize infrastructure vulnerabilities to understand which assets were most at risk to climate change. To prioritize vulnerabilities, a risk assessment was performed for each of the 219 infrastructure assets.

Risk was derived from the product of the likelihood of a particular climatic event impacting the asset and the consequences of that impact. We looked at gradients of threat to specific infrastructure through a likelihood of impact ranking using GIS spatial analysis to merge asset locations with climate projections to better understand the likelihood that climate would impact an asset. A subsequent consequence analysis was conducted to gauge whether the loss of a particular asset would adversely impact the City. The results were used to determine the overall risk associated with the loss of a particular asset.

Likelihood Analysis

Climate change will likely lead to localized SLR, higher storm surge, more frequent extreme precipitation episodes and drought, as well as higher average annual temperatures and periods of extreme higher temperatures (i.e. heat waves). The anticipated changes associated with SLR, storm surge, and extreme precipitation were projected on maps for the year 2050 and assessed according to the likelihood that they would impact the City of Sarasota's infrastructure. Impacts due to future projections for temperature were evaluated independent of this analysis, but were considered a vulnerability for this study. Each of the four climate projection parameters below were evaluated on a scale of one (1) to five (5) and averaged for a maximum score of five (5).

- SLR 2050
- Category 1 level storm surge plus SLR 2050
- Category 3 level storm surge plus SLR 2050
- Freshwater Flooding from Extreme Precipitation

GIS spatial analysis was used to develop a likelihood ranking. This analysis was used to evaluate the location of each asset with consideration of the surrounding conditions in conjunction with each of the aforementioned climate projections. Likelihood scores were assigned to each asset based on projection overlays and the likelihood of impact to each asset (e.g. if the SLR projection did not overlay the asset then SLR = 0). The likelihood ranking was as shown in **Table 4** below:

Table 4: Likelihood Legend

1	RARE	Asset highly unlikely to be impacted if climate event occurs *(event could happen, but probably not)*
2	LESS LIKELY	Asset not expected to experience impact if climate event occurs *(impact approximately once every 10-25 years)*
3	POSSIBLE	Asset impact may occur if climate event occurs *(impact approximately once every 10 years)*
4	LIKELY	Strong possibly that the asset will be impacted if climate event occurs *(impact approximately one time each year)*
5	VIRTUALLY CERTAIN	Asset highly likely to be impacted if climate event occurs *(could happen several times per year; greater than 50% probability)*

Sea Level Rise (SLR) 2050

The likelihood of SLR continuing to affect the City of Sarasota is virtually certain. This study considered SLR projections using NOAA intermediate and intermediate high projections for 2050, as determined by the NOAA Global Climate Modeling (GCM). Estimates suggest that our area will experience a 12 inch (intermediate) to 18 inch (intermediate high) rise in sea levels by 2050. We used NOAA data from the St. Petersburg tide gauge. The likelihood of the projected SLR under the 2050 scenario was evaluated against anticipated inundation impacts to specific infrastructure located throughout the City based on GIS renderings that incorporated geospatial data to produce visual maps.

The likelihood of SLR 2050 impacting city infrastructure was correlated to the NOAA models and rated on a scale of 0 (no anticipated impact) to 5 (highest likelihood of impact) within the risk analysis spreadsheet (**Appendix A**). While locations immediate to the coast were more likely to show increased vulnerability, low-lying inland regions up tidal creeks were also identified as having increased threat of inundation due to SLR.

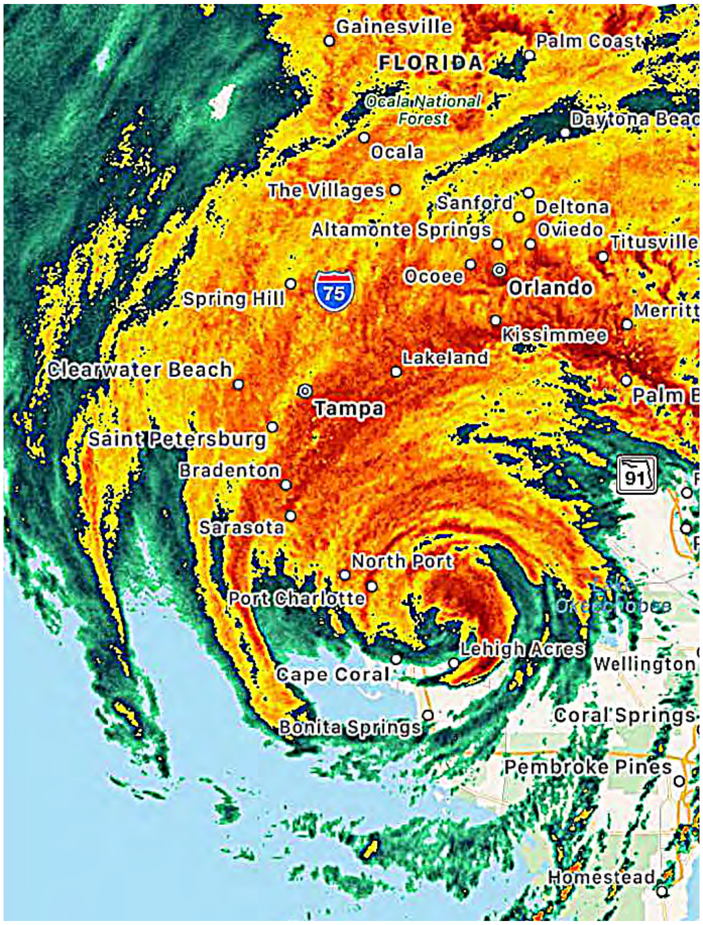
Storm Surge Plus SLR (2050)

Regional storm surge projections were derived using the SLOSH model to identify at risk city infrastructure due to storm phenomenon in the Gulf of Mexico. During the course of this study, our region felt the effects of several named storms including Tropical Storms Collin (June 2016), Hermine (Sept 2016), and Emily (July 2017) and Hurricanes Matthew (Oct. 2016), Irma (Sept. 2017), and Nate (Oct. 2017). Several factors need to be evaluated when considering storm surge and the associated damage caused by coastal flooding including storm intensity, direction of the storm approach, speed of the storm approach, point of landfall, tide levels, and high wind. In addition to coastal flooding caused by extreme storms, mitigation of wind damage must also be considered.

GIS projections were used to estimate the possible combined affect of storm surge from a Category 1 hurricane plus SLR in 2050. The same exercise was performed using a Category 3 hurricane plus SLR in 2050. The likelihood of storm surge plus SLR impacting infrastructure in the City in 2050 was scored on a scale of 0 (no impact) to 5 (highest likelihood of impact). Generally, the likelihood of impact associated with these projections was straightforward (i.e. inside or outside the area of inundation). However, institutional and local knowledge, as well as professional judgment were also applied to non-explicit GIS projection values.

Extreme Precipitation

Short duration, intense rainfall data from the last 30 years combined with Global Climate Model projections as reported in the IPCC Assessment Report 5 for the Southeastern U.S. indicate a 5% to 10% increase in extreme precipitation events by 2050. City staff were provided maps depicting



Hurricane Irma's approach to Sarasota (Sept. 2017)

100-year flood event areas throughout the City. These maps were created by merging outputs from the Sarasota County Stormwater Model and were based on the FEMA DFIRM flood zone maps, which identified geographic areas that FEMA defined according to varying levels of flood risk and type of flooding. The likelihood of freshwater flooding in 2050 was scored on a scale of 0 (no anticipated impact) to 5 (highest likelihood of impact). For this likelihood measure, we referenced available information related to historic and recent flooding events, which relied on institutional and local knowledge, as well as professional judgment.

Extreme Heat

An extreme heat questionnaire was provided to city staff to develop an understanding of the diverse range of impacts associated with extreme heat events on city infrastructure. While it was determined that city infrastructure will be at greater risk due to extreme heat, human health and environmental quality were more immediate concerns. Consensus was reached that a detailed assessment of the effects of extreme heat on human heath and the environmental would help identify heat-related risk within the City of Sarasota. A Heat Vulnerability Index might be an important future measure to understand where people could be most vulnerable to heat-related stress from increased air temperature and humidity and where areas might experience the greatest environmental change.

Consequence Analysis

The consequence analysis was the second factor used to determine risk. A qualitative assessment was conducted to understand the consequences of a climate impact to each asset. The degree of loss in terms of the following five key consequences was evaluated. The consequences of infrastructure loss was ranked according to the scale shown in **Table 5**.

Table 5: Consequence Legend

1	NEGLIGIBLE IMPACT(S): Resilient
2	MINOR IMPACT(S): Temporary or inconvenient delay, loss or setback
3	MODERATE IMPACT(S): Wide spread delay, loss or setback
4	MAJOR IMPACT(S): Significant and long lasting delay, loss or setback
5	CATASTROPHIC: Extensive loss; likely irreversible/not cost feasible to restore

1. ***Public Health (H)*** | Observable and projected impacts to the well-being of city residents, work force, and tourists with regard to heat stress (outdoor recreation), discomfort (energy demand), water quality (red tide), air quality (UHI), and disease (tropical or water-borne illness).
2. ***Public Safety (S)*** | Observable and projected impacts to the well-being of city residents, the work force, and tourists with regard to safe evacuation or physical threats from storms (e.g. hurricanes, tornados) or flooding events.
3. ***Economic Loss (ECO)*** | Observable and projected consequences to government infrastructure or public services including damage to city-owned assets or financial burdens associated with asset repair or increased maintenance. This takes into account city-wide economic consequences to local business and tourism, as they relate to loss of public services.
4. ***Environmental Damage (ENV)*** | Observable and projected impacts that alter natural resources, damage native habitats and green space, contaminate water, and harm fisheries or native wildlife.
5. ***Cultural and Historic Significance (C&H)*** | Observable and projected impacts to historic communities or cultural assets (e.g. government buildings, bridges, water features, parks, golf courses, natural areas, or cultural assets that define the City's identity.

We harnessed the technical expertise of staff and used the scale below to rank the consequence(s) of damage or loss associated with each asset. For this analysis we assumed an asset was impacted by either freshwater or saltwater flooding. Each of the five consequences was evaluated on a scale of one (1) to five (5). The results of each were additive for a maximum score of twenty-five (25).

The results of the likelihood and consequence analysis were incorporated into the equation below to determine the overall risk associated with the loss of a particular asset.

Likelihood x Consequence = Risk

Risk Scale

Results

The City's transportation, stormwater management, water supply, and wastewater infrastructure, as well as public lands and critical buildings were assigned scores in collaboration with city staff, as discussed above. This engagement process, combined with the GIS-focused likelihood analysis, was used to create vulnerability outputs for the 219 inventoried assets. This initial inventory included thirty-four (34) transportation assets, fifty-two (52) stormwater assets, eleven (11) water features, twenty one (21) water supply assets, thirty-four (34) wastewater assets, forty seven (47) public lands, six (6) public shorelines, and fourteen (14) buildings.

The vulnerability and risk analysis were combined to rank the overall vulnerably of each infrastructure asset. This process was used to prioritize the City of Sarasota's infrastructure assets with the greatest vulnerabilities to the four climate threats evaluated by the study, as shown in the example for Whitaker Bayou shown below in **Table 6**.

The results of the vulnerability assessment (i.e. vulnerability versus risk) were graphed to prioritize the most vulnerable assets (see **Exhibit 12**). Assets were prioritized using a two step approach. First, a review of the graphic output was conducted. ***Those assets that score highly vulnerable and at high risk were considered a priority for improving resiliency within the City of Sarasota.*** Second, meetings were held with each sector lead (i.e. city staff) to discuss the graphed results and to identify assets of particular concern or importance that may not have ranked as highly vulnerable or at high risk. These assets were identified based on alignment with future City plans and programs and local knowledge and expertise. The full list of assets evaluated by this vulnerability assessment is in **Appendix A**.

The vulnerability and risk assessments prioritized fifty-six (56) infrastructure assets (out of 219 evaluated) that were considered most critical to bolstering the City's resiliency to climate change. Twenty four (24) additional infrastructure assets that were not initially rated as high risk and vulnerability were prioritized due to site-specific conditions and local knowledge.

Exhibit 12: Vulnerability Assessment Graph

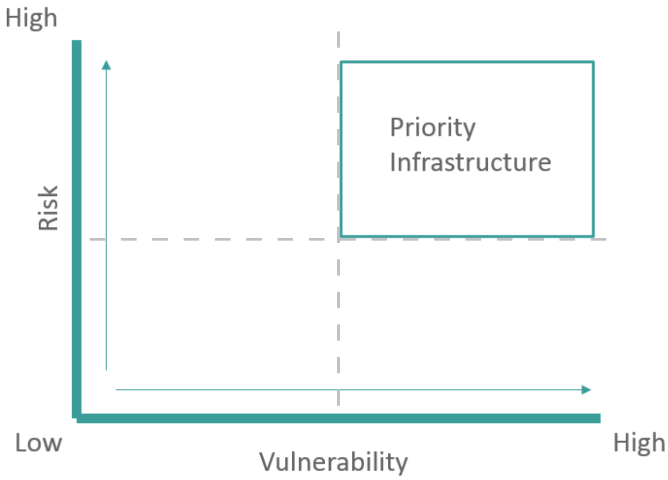


Table 6: Scoring Process for Vulnerability and Risk Assessment

Asset ID (Sector)	Local Name	Vulnerability (Sensitivity x Adaptive Capacity)			Likelihood of Impact (2050)					Consequence (n=25)						Risk (n=125)
		Sensitivity (n=5)	Adaptive Capacity (n=5)	Overall Vulnerability (n=25)	SLR	CAT1 + SLR	CAT3 + SLR	ExP	AVG (n=5)	H	S	ECO	ENV	C&H	SUM	
WF-1	Whitaker Bayou	4	4	**16**	5	5	5	5	**5.0**	5.0	5.0	4.0	5.0	4.0	**23.0**	**115.0**

Prioritized Vulnerabilities: *Transportation*

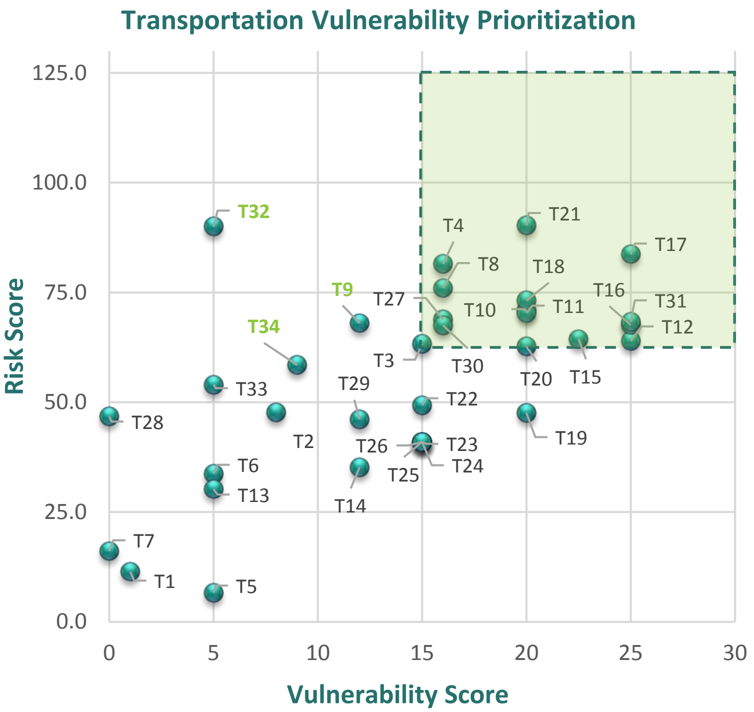
The goal of the City of Sarasota is to develop and maintain a safe, convenient, and efficient multi-modal transportation system. The City includes more than 500 miles of roads within 5-miles from the coast including major arterials and interstate connectors under State or County jurisdiction. These roads provide a critical link for the public during evacuations and need to be protected from flooding and damage to ensure long-term viability. The City also provides bike lanes, pedestrian pathways, and a public boat ramp. A transportation infrastructure assessment must consider obstacles to public access, emergency evacuation, road and bridge integrity, motorist safety, and alternative transportation such as pedestrian and bicyclist routes and water transportation opportunities.

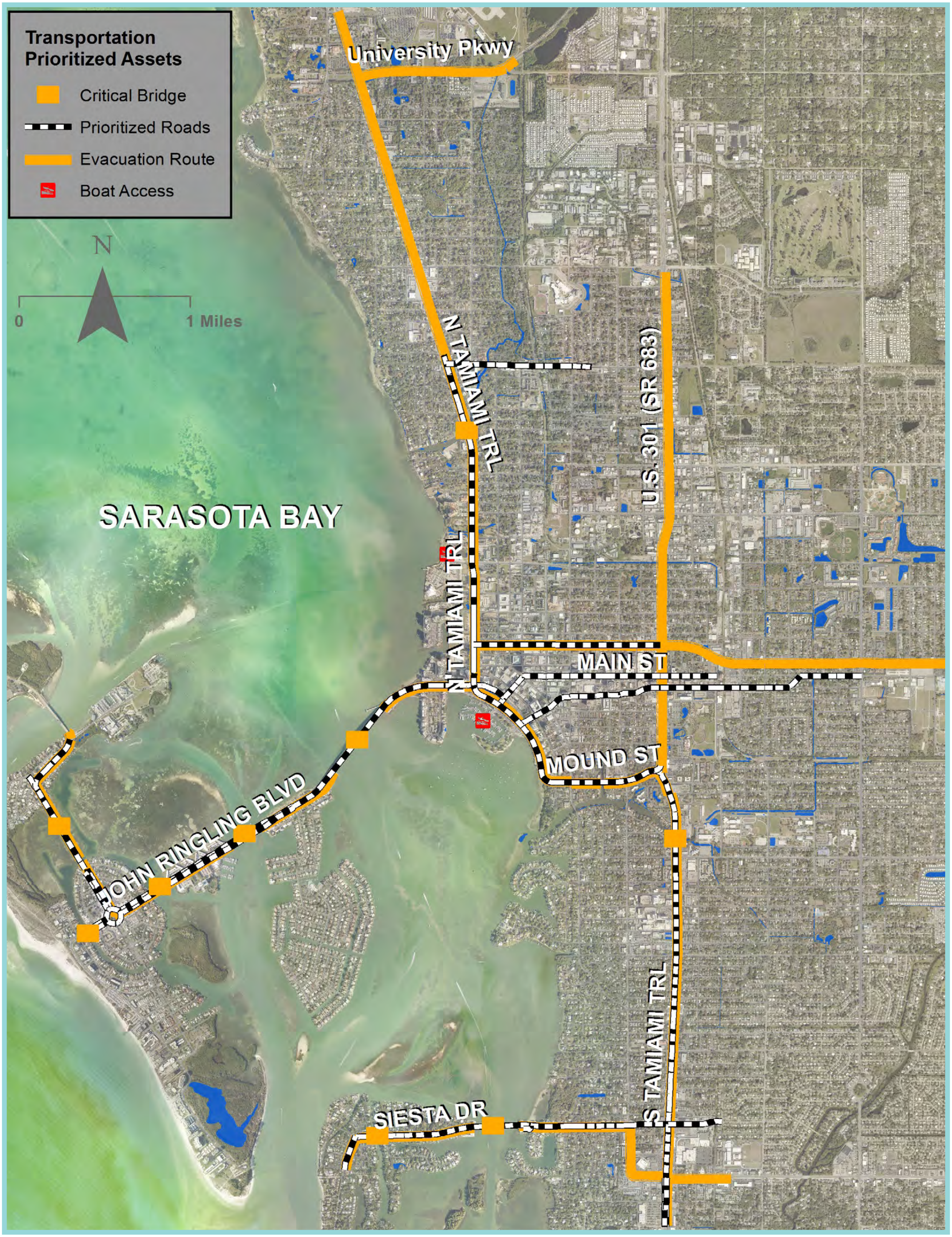
Thirty-four (34) transportation assets were evaluated of which fifteen (15) were deemed most vulnerable, as listed in **Exhibit 13**. These included road segments along the coast; major bridges along evacuation routes; city streets with cultural and/or economic significance; and boater mooring and access points. As would be expected, many city and State-owned bridges over tidal waters were prioritized as vulnerable. In addition to the 15 prioritized assets, three additional road segments (green text) were advanced for further review due to known flooding concerns and importance of the asset.

Gulfstream Drive (SR789) Storm Surge Debris following Hurricane Hermine

Exhibit 13: Transportation Vulnerability Prioritization

ID	Asset Name	Risk Score
T3	Bayfront Marina	63.3
T4	10th Street Boat Ramp	81.5
T8	Main Street	76.0
T9	Fruitville (SR758)	68.0
T10	Ringling Blvd.	71.0
T11	Siesta Drive (SR758)	70.4
T12	US41 (SR45)	64.0
T15	Little Ringling Bridge at Coon Key	64.4
T16	John Ringling Bridge (SR789)	67.6
T17	John Ringling Causeway	83.7
T18	J. Ringling Culvert @ St. Armand's	73.2
T20	SR789 over Pansy Bayou	62.7
T21	SR789 Causeway @ Pansy Bayou	90.3
T27	US41 Bridge-Whitaker Bayou	68.9
T30	US41 Bridge-Hudson Bayou	67.5
T31	Siesta Key Draw Bridge	68.3
T32	Siesta Bridge at Hanson Bayou	90.0
T34	Dr. Martin Luther King Jr. Way	58.5




Transportation Prioritized Assets
Critical Bridge
Prioritized Roads
Evacuation Route
Boat Access
N
0
1 Miles
University Pkwy
N TAMIAMI TRL
U.S. 301 (SR 683)
SARASOTA BAY
N TAMIAMI TRL
MAIN ST
MOUND ST
JOHN RINGLING BLVD
S TAMIAMI TRL
SIESTA DR

Prioritized Vulnerabilities:
Stormwater

The City of Sarasota partnered with Sarasota County in 1998 through an interlocal utility agreement to administer, plan, operate, manage, and maintain the City's stormwater program. In addition, stormwater outfalls along state roads in the City are managed by the FDOT. The City of Sarasota's stormwater facilities include a system of natural and manmade conveyance and retention systems, as well as storm sewers, ditches, and pipe outfalls (i.e. culverts) that discharge to natural water features (i.e. Whitaker and Hudson Bayous, and Phillippi Creek) and ultimately Sarasota Bay. Stormwater runoff can provide a non-point source of pollution by carrying pesticides, fertilizers, and petroleum to surface waters and natural waterways, which creates a critical water quality issue in the region.

Fifty-two (52) stormwater assets were evaluated within the City limits of which twenty-nine (29) were deemed vulnerable, as listed in **Exhibit 14**. These included stormwater pipes and channel outfalls along major roads near the coast and stormwater pump stations that help alleviate flooding during storm events, as well as a recognition that many minor drainage outfalls also discharge to tidal waters and are expected to experience impacts from SLR, storm surge and extreme precipitation. Public lands and green space were recognized as providing value to address increased volumes of stormwater and improve water quality. These public land assets are variously linked to stormwater benefits and are prioritized below as part of the public lands evaluation.

Stormwater Vulnerability Prioritization

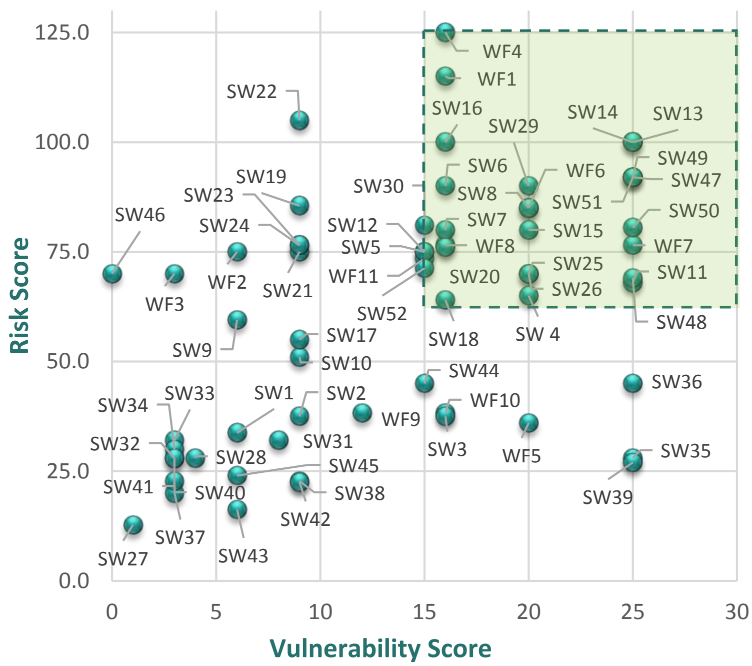
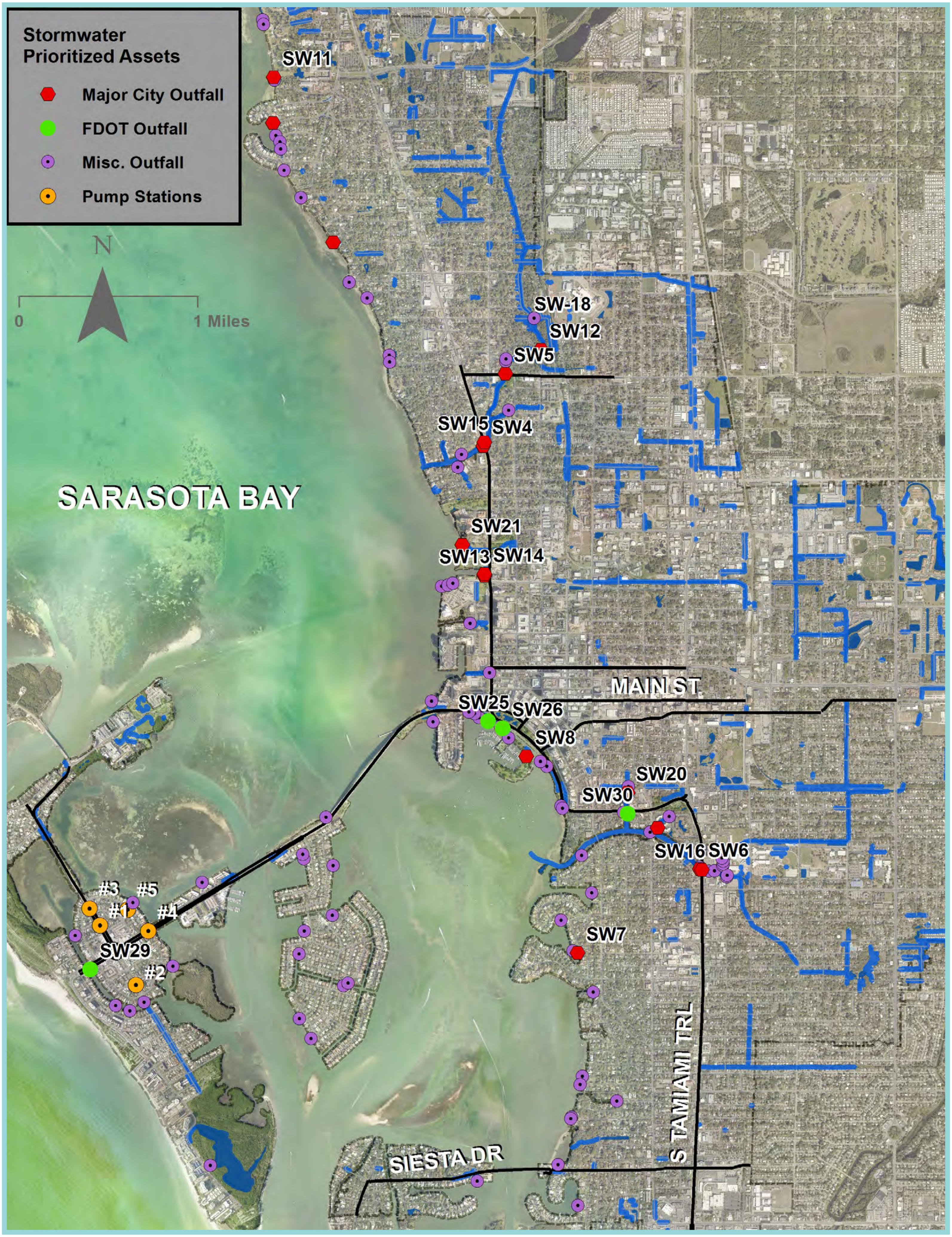


Exhibit 14: Stormwater Vulnerability Prioritization

ID	Asset Name	Risk Score
SW4	FDOT Outfall US41/Whitaker Bayou	65.0
SW5	City Outfall MLK/Whitaker Bayou	75.0
SW6	FDOT Outfall Hudson Bayou/US41	90.0
SW7	City Outfall Harbor Drive	80.0
SW8	City Outfall Marina Jacks/Ringling	85.0
SW11	City Outfall Ringling Museum	68.0
SW12	City Outfall Whitaker Bayou/Lemon	75.0
SW13	City Outfall 10th Street/US41	100.0
SW14	City Outfall 10th Street/US41	100.0
SW15	FDOT Outfall US41/Whitaker Bayou	80.0
SW16	City Outfall Hudson Bayou/Osprey	100.0
SW20	City Outfall Hudson Bayou	76.0
SW25	FDOT Outfall Golden Gate	70.0
SW26	FDOT Outfall Marina Jacks	70.0
SW29	FDOT Outfall St. Armand's	90.0
SW30	FDOT Hudson Bayou/US41	81.0
SW47	Pump Station: Madison/Blvd of Pres.	92.0
SW48	Pump Station: Jackson/Blvd of Pres.	69.0
SW49	Pump Station: Washington/Blvd Pres.	92.0
SW50	Pump Station: John Ringling Blvd	80.5
SW51	Pump Station: Madison/Washington	92.0
SW52	Drainage Outfalls to Tidal Waters	71.3
WF1	Whitaker Bayou	115.0
WF4	Hudson Bayou	125.0
WF6	St. Armand's Canals	85.0
WF7	Pansy Bayou	76.5
WF8	Brushy Bayou	76.5
WF11	Phillippi Creek (Main B)	73.5



Stormwater Prioritized Assets
Major City Outfall
FDOT Outfall
Misc. Outfall
Pump Stations
N
0
1 Miles
SARASOTA BAY
SW11
SW-18
SW12
SW5
SW15
SW4
SW21
SW13
SW14
MAIN ST
SW25
SW26
SW8
SW20
SW30
SW16
SW6
#3
#5
#1
#4
SW29
#2
SW7
S TAMIAMI TRL
SIESTA DR

Utilities

Three independent utility systems are owned, operated, and maintained by the City of Sarasota Utilities Department including potable water, sanitary sewer or wastewater collection, and reclaimed water. This study evaluated the water supply (i.e. potable water) and wastewater collection systems. In comparison to the other sector assets, the utility system (i.e. water supply and wastewater) scores did not identify highly vulnerable infrastructure. Due to the critical nature of utility systems, these systems have been engineered for redundancy and resiliency to withstand a certain level of catastrophic events. However, these systems are not indestructible nor without susceptibility to potential failures. System vulnerabilities related to utilities are highlighted on the following pages.

(Top Left): Saltwater Intake Structure
(Top Right): City Well #4 - Panama Drive
(Bottom): City of Sarasota Wastewater Treatment Plant

Prioritized Vulnerabilities: *Water Supply*

The mission of the City of Sarasota Utilities Department is to enhance the quality of life of all residents by providing a safe and reliable water supply. The City operates one water treatment plant, which was originally built in 1982 but has undergone retrofits and improvements to comply with increasing regulatory requirements. The design service life for the internal processes is approximately 20 years.

The City uses two wellfields to source drinking water: the Verna wellfield and the downtown brackish water wellfield, which includes ten (10) city wells. The downtown wellfield, west of the water treatment plant, pulls brackish water from the aquifer while the Verna wellfield, approximately 20 miles east of the City, draws freshwater from a shallow aquifer. A two step process is used to produce drinking water. Brackish water from the downtown wellfield is treated with reverse osmosis (RO). The Verna groundwater is treated by an ion exchange process to soften the water. The ion exchange process requires salt – similar to home softening units. The seawater intake structure, located along Sarasota Bay pulls salty water from the bay for this process. The two products are blended to produce drinking water.

The City uses a tiered rate structure to encourage water conservation and year-round water use restrictions reduce water use. These conservation measures, as well as the built in redundancy, ensure a reliable drinking water supply to the City during both drought conditions and hurricane season and are projected to withstand future pressures even considering population increases in 2050. Although the water supply was not deemed highly vulnerable, the water supply distribution system was determined to be vulnerable to damage during storms due to saturated soils and wind overtopping trees with roots near pipes.

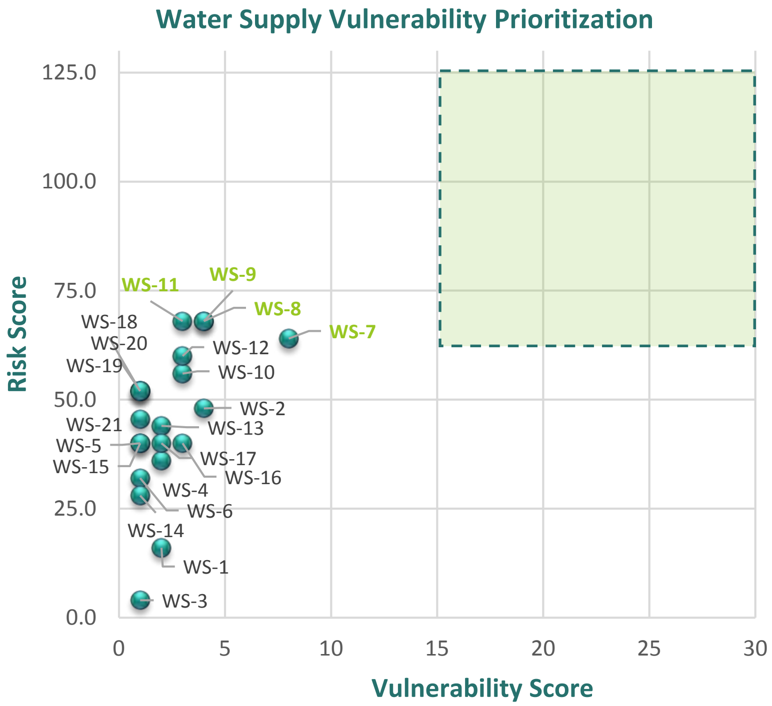
Twenty-one (21) water supply assets were evaluated; four (4) were deemed most vulnerable, as listed in **Exhibit 15**. In addition to distribution pipes, these four infrastructure included the saltwater intake structure along Sarasota Bay and three brackish production wells on the mainland located near the bay.

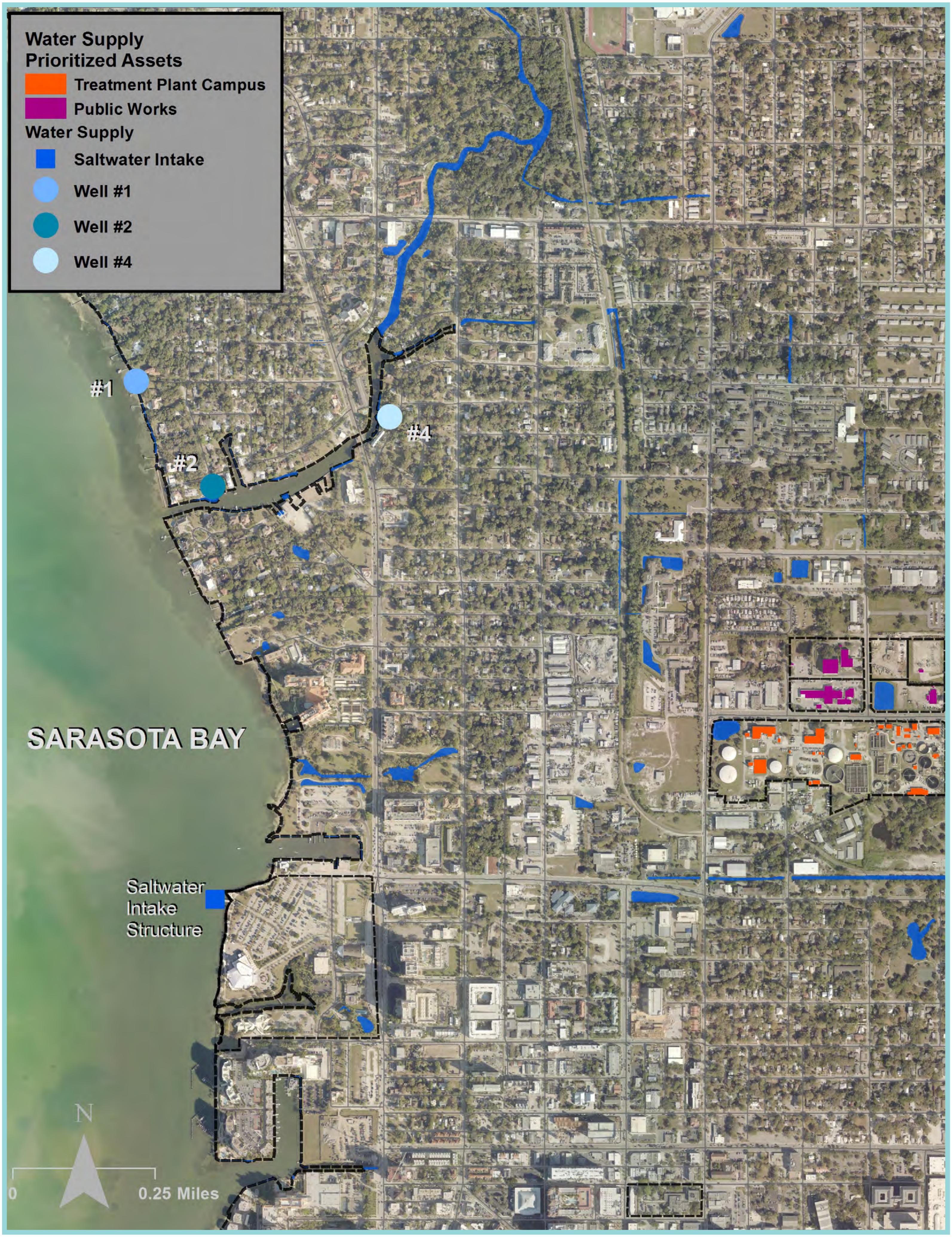
Photo | City of Sarasota Utilities Department

City Well #1 - 22nd Street along Sarasota Bay

Exhibit 15: Water Supply Vulnerability Prioritization

ID	Asset Name	Risk Score
W-7	Saltwater Intake Structure	64
W-8	Well #1 @ 22nd Street	68
W-9	Well #2 @ Alameda Avenue	68
W-11	Well #4 @ Panama Drive	68




Water Supply
Prioritized Assets
Treatment Plant Campus
Public Works
Water Supply
Saltwater Intake
Well #1
Well #2
Well #4
#1
#4
#2
SARASOTA BAY
Saltwater
Intake
Structure
N
0
0.25 Miles

Prioritized Vulnerabilities:
Wastewater

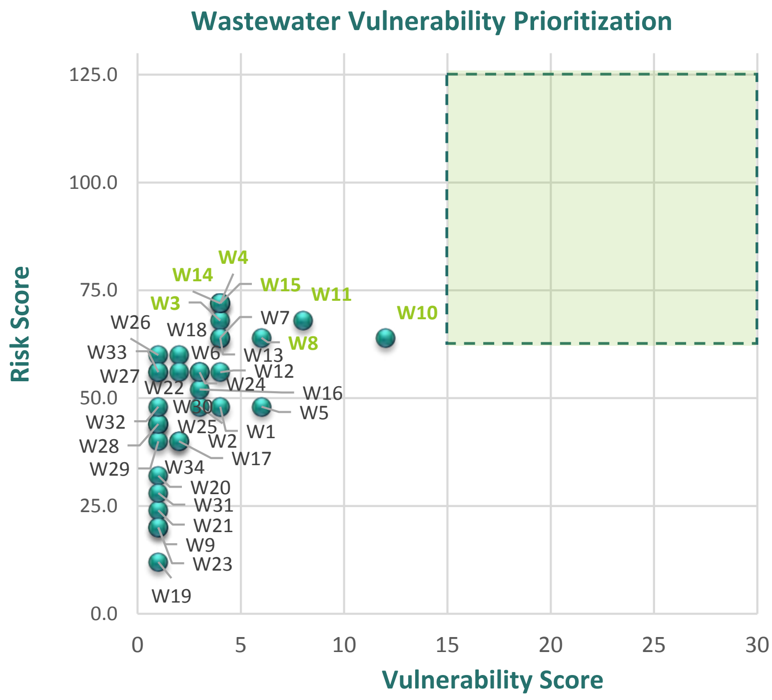
The mission of the City of Sarasota Utilities Department is to enhance the quality of life of all residents by providing safe, reliable, and effective sewer services. The City owns, operates, and maintains one wastewater treatment plant. The wastewater treatment plant was built in 1951, but has undergone multiple expansions. The majority of its components have a service life projected to be more than 20 years.

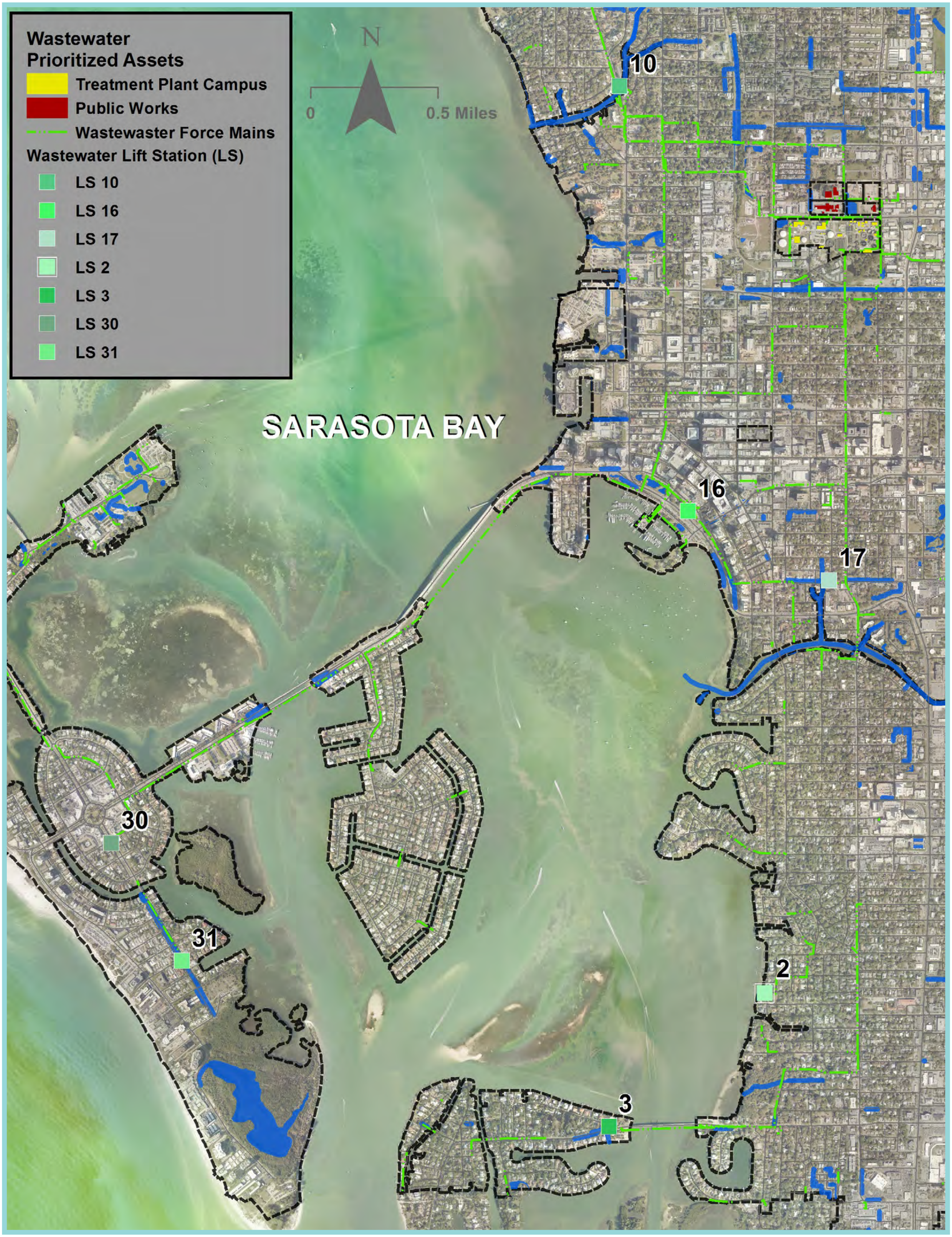
The wastewater collection system uses gravity and pressurized pipes to collect wastewater from all over the City's service area. It uses gravity collection pipes to transport sewer water to "lift" or pump stations, which are then pumped through force mains to the wastewater treatment plant located on 12th Street. The City uses an Advanced Wastewater Treatment (AWT), which incorporates biological and chemical treatments to remove nutrients. The City hauls away the residual sludge to create fertilizer pellets (i.e. soil additive) and the treated effluent is reclaimed for reuse water for irrigation. Excess reuse water during the wet season is injected into the deep injection well located off 12th Street. When there is too much reclaimed water, the City will, as a last resort, discharge the highly treated water into Whitaker Bayou. Due to the downstream water quality concerns in Whitaker Bayou and Sarasota Bay from disposal of treated effluent, the City constructed the deep injection well. This deep injection well is supported by the Sarasota Bay National Estuary Program and regulated by the Florida Department and Environmental Protection.

Thirty-four (34) wastewater assets, were evaluated of which seven (7) were deemed most vulnerable, as listed in **Exhibit 16**. These included high volume lift stations near Sarasota Bay and on St. Armand's Circle and potentially vulnerable lift stations along the mainland coast. Power loss due to storms, including power surges and lack of generator power, where identified as system vulnerabilities. Vulnerabilities along sewer force mains related to sewer system overflows (SSO) during wet weather episodes were also evaluated.

Exhibit 16: Wastewater Vulnerability Prioritization

ID	Asset Name	Risk Score
W-3	Lift Station #2	68.0
W-4	Lift Station #3	72.0
W-8	Lift Station #10	64.0
W-10	Lift Station #16	64.0
W-11	Lift Station #17	68.0
W-14	Lift Station #30	72.0





Wastewater Prioritized Assets
Treatment Plant Campus
Public Works
Wastewaster Force Mains
Wastewater Lift Station (LS)
LS 10
LS 16
LS 17
LS 2
LS 3
LS 30
LS 31
N
0
0.5 Miles
SARASOTA BAY
10
16
17
30
31
2
3

Prioritized Vulnerabilities: *Public Lands*

The goal of the City of Sarasota is to provide and maintain a high-quality and environmentally-compatible system of open spaces and recreation facilities (City Plan 2008).

An infrastructure inventory must consider coastal protection opportunities, which requires an understanding of the resiliency of hardened shorelines, beaches, natural shorelines (e.g. mangroves), and ecosystem services (e.g. recreational fisheries). As sea levels increase in the Gulf of Mexico, barrier islands and bays will change, which will alter the dynamics between Gulf beaches and tidal inlets. Shoreline infrastructure such as seawalls are expected to become increasingly susceptible to flood damage, storm surge, and wave impacts as these conditions compound due to rising seas.

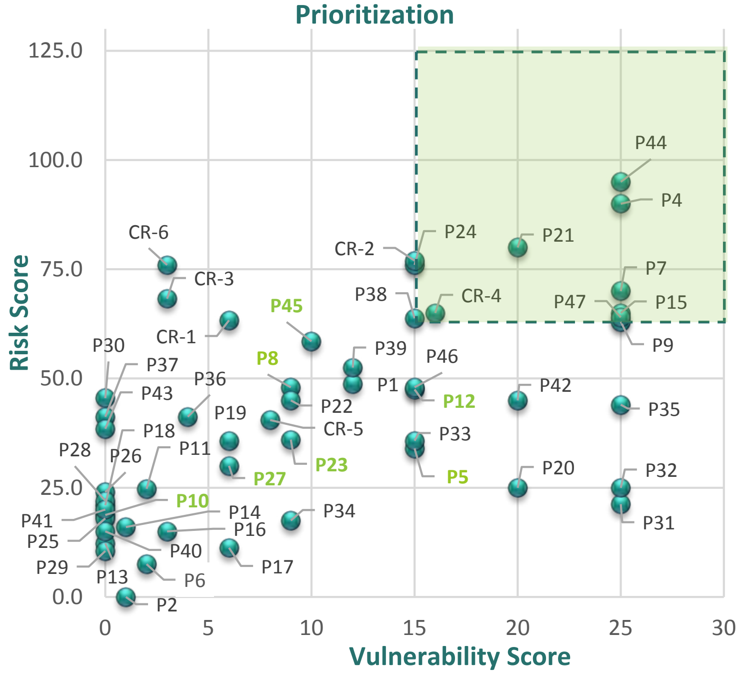
Exhibit 17: Public Lands and Shorelines Vulnerability Prioritization

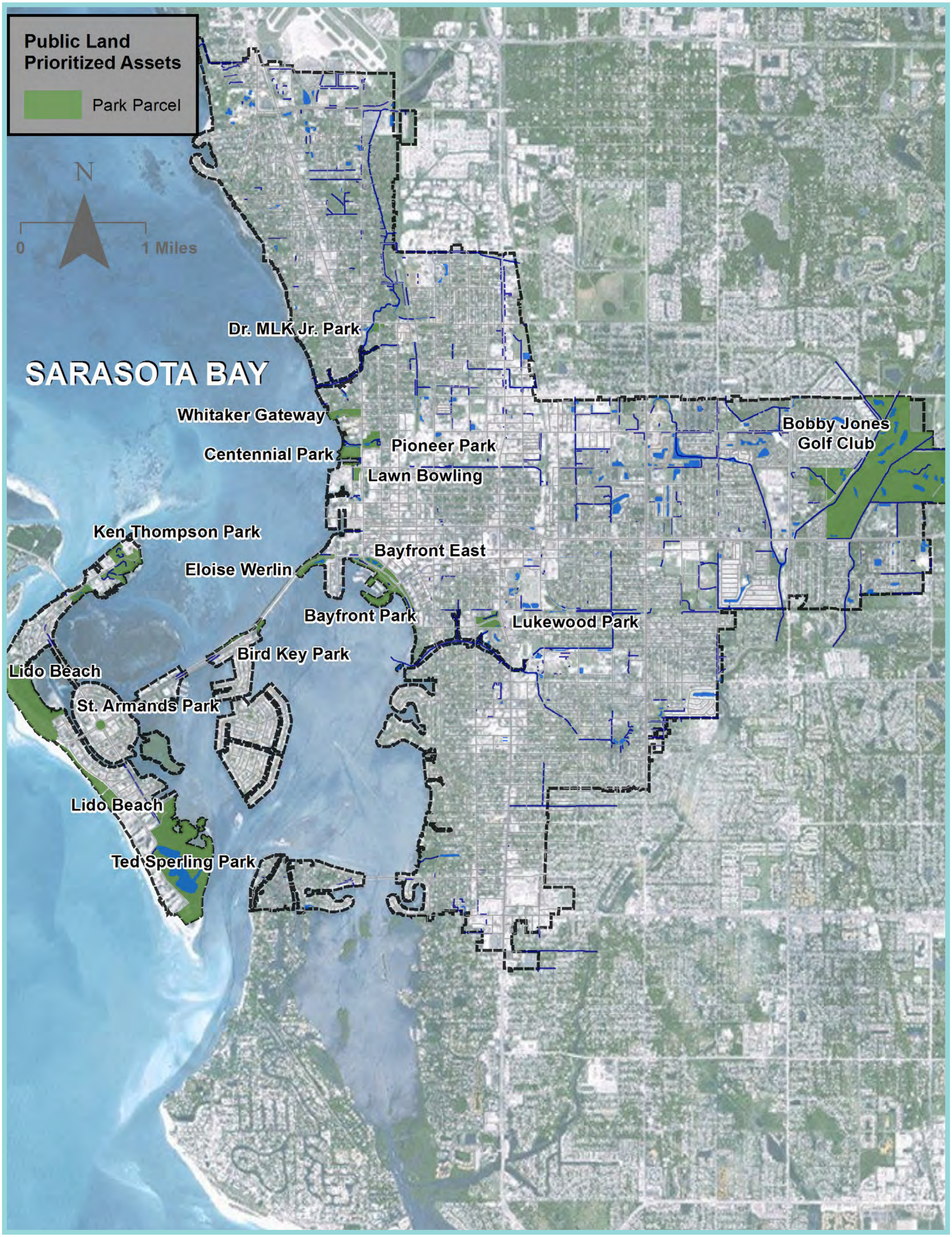
ID	Asset Name	Risk Score
P4	Bayfront Marina Park	90.0
P5	Bayfront Park East 41	34.0
P7	Bird Key Park	70.0
P8	Bobby Jones Golf Club	48.0
P9	Centennial Park	63.0
P10	Charles Ringling Park	18.8
P12	Dr. MLK Jr. Park	47.5
P15	Eloise Werlin Park	65.0
P21	Ken Thompson Park	80.0
P23	Lawn Bowling	36.0
P24	Lido Beach	76.5
P27	Lukewood Park	30.0
P38	Pioneer Park	63.8
P44	Ted Sperling Park	95.0
P45	St. Armand's Circle Park	58.5
P47	Whitaker Gateway Park	64.0
CR2	Sarasota Bay Estuary	77.0
CR4	Seawalls (Public Lands)	65.0

Public lands were evaluated for vulnerabilities, but were also recognized as critical assets to bolster community resilience. As expected, many coastal public lands will experience increased vulnerabilities by 2050, but the direct consequences of loosing or abandoning certain public lands varied. Considerations included cultural and/or economic significance, recreational use and water access, community cohesion, and environmental value such as mature trees, green space, and benefits to reducing the UHI effect.

Forty-seven (47) public lands and six (6) public shorelines were evaluated of which nine (9) public lands and two (2) public shorelines were deemed vulnerable, as listed in **Exhibit 17**. These included, coastal park land along Sarasota Bay, beaches and dunes on Lido Key, public lands along bridges and causeways, seawalls, and Sarasota Bay. Seven (7) additional public lands were advanced to the adaptation stage due to benefits related to stormwater including opportunities to address flooding and water quality concerns for the region. For example, Bobby Jones Golf Club and Dr. MLK Jr. Park offer multi-benefit opportunities to improve water quality and relieve inland flooding.

Public Lands and Shorelines Vulnerability Prioritization




Public Land Prioritized Assets
Park Parcel
N
0
1 Miles
SARASOTA BAY
Dr. MLK Jr. Park
Whitaker Gateway
Centennial Park
Pioneer Park
Lawn Bowling
Bobby Jones Golf Club
Ken Thompson Park
Eloise Werlin
Bayfront East
Bayfront Park
Lukewood Park
Bird Key Park
Lido Beach
St. Armands Park
Lido Beach
Ted Sperling Park

Living Shorelines (LSL) and Living Seawalls

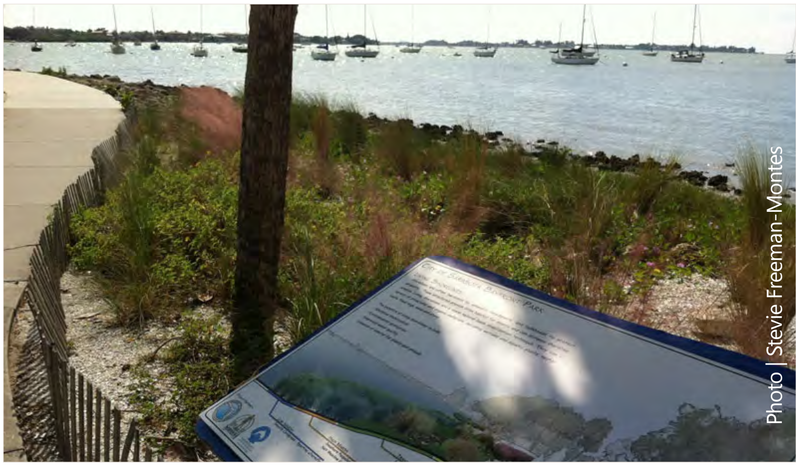
Living Seawalls are a hybrid design between a traditional seawall and a LSL. These seawalls are one option on a spectrum of shoreline stabilization choices, where naturally vegetated grass or mangrove shorelines may not be feasible. The City of Sarasota is installing a Living Seawall pilot project at Bayfront Park in downtown Sarasota. Mote Marine Laboratory will study the project to assess wave reflection and biodiversity and help the City understand the function and value of the project. The project was partially funded through a Gulf Coast Innovation Challenge Grant from the Gulf Coast Community Foundation and from the Deepwater Horizon local claim funds. Living Seawalls not only improve aesthetic value but the first LSW installed by the City had the dual purpose of supporting local businesses contracted to design, manufacture and install the system.

Living Shorelines are a natural alternative to bulkheads and seawalls and provide benefits for climate resiliency, including: creating habitat, preventing pollution, reducing wave energy, stabilizing sediment, minimizing erosion, and mitigating storm and flood damage. The Sarasota Bay Estuary Program (SBEP), in partnership with the City of Sarasota, created a living shoreline along Bayfront Park. The project featured native plants across three intertidal zones. The project was designed to showcase the benefits of Living Shorelines.

As sea levels rise and extreme precipitation increases in frequency and intensity, natural shorelines will serve as a critical defense to climate change. Understanding options available to retrofit seawalls and create resilient Living Shorelines will be an important part of the City of Sarasota's climate change resiliency strategy.

The image to the right shows a Living Wall Seawall Project in Palmetto, FL.

View of Sarasota Bay from Ken Thompson Park



Bayfront Park Living Shoreline

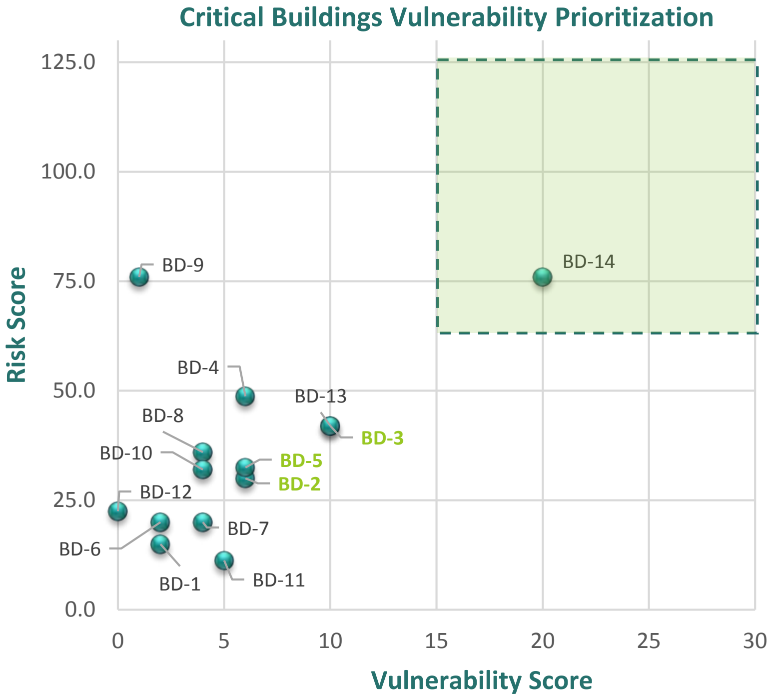
Prioritized Vulnerabilities:
Critical Buildings

Select critical buildings were evaluated as part of the vulnerability assessment. Most evaluated buildings were not deemed highly vulnerable, as the locations of many emergency services and operation centers have been sited with resiliency in mind. However, infrastructure assets supporting these critical buildings, such as access roads leading buildings, pipes supporting water supply and sanitary sewer, and stormwater management systems needed to protect the sites from flooding were in some instances considered vulnerable.

One area of the City, although not technically classified as critical infrastructure within this planning criteria, was considered in the vulnerability assessment. The acreage along the Bayfront on city-owned land is the focus of a future development plan called Bayfront 20:20. This land contains the G. Wiz and Van Wezel buildings, as shown in **Exhibit 18**. Although the future of these buildings is unknown, the site was prioritized as vulnerable to climate impacts that will need to be considered during future revitalization and development. In addition, three additional buildings were considered with regard to opportunities to mitigate the UHI effect and sustainable building upgrades. These included the Public Works and Utility Operation buildings and City Hall.

Exhibit 18: Critical Buildings Vulnerability Prioritization

ID	Asset Name	Risk Score
BD-2	Public Works Buildings	30.0
BD-3	Utility Operation Buildings	42.0
BD-5	City Hall	32.5
BD-14	G. WIZ & Van Wezel	76.0



Van Wezel Performing Arts Hall

City of Sarasota Public Works Buildings

Photo | Sherri Swanson

STEP 5 – **Adaptation Strategies**

5 Adaption Strategies

Step 5 involved development of adaptation measures to address the vulnerabilities identified for the fifty-six (56) prioritized assets considered most critical to bolstering the City's resiliency to climate change. Adaptation measures were also developed for twenty-four (24) additional assets that were advanced to the adaptation stage due to local knowledge and location.

A menu of climate adaptation strategies was compiled for the vulnerable assets identified by this study to help find opportunities to make the City's infrastructure more resilient to SLR, storm surge, extreme precipitation, and extreme heat. The goal was to review potential adaption measures for the eighty (80) assets deemed most vulnerable or critical to the operation of the City of Sarasota. The following tables summarize the adaption measures considered during this study through planning reviews and scientific analysis, working group sessions with city staff, and engagement with the public. These measures have been condensed for inclusion in the body of this report.

Although grouped by sector, these adaption measures should not be looked at individually. Given the large number of assets reviewed and the interconnected nature of public infrastructure, we identified considerable overlap between adaptation measures. This suggests a need for ongoing close coordination with regional and local partners to ensure synergy, improve effectiveness of project designs, and expand funding opportunities. One opportunity identified by this study was to enhance dialogue between internal departments, the City, County, and the FDOT regarding infrastructure within Sarasota City limits. Greater communication will expand the understanding of how climate change could impact City infrastructure in the future and will encourage greater collaboration between departments and agencies to solve the important issues facing this coastal community.

Interactive Public Meeting Exercise

Many adaptation measures identified for one sector complemented opportunities in other sectors. For example, the city-owned parcel along Sarasota Bay near 10th Street (i.e. Centennial Park) provides public amenities, boater access, stormwater management for US41, and green space to buffer Sarasota Bay. The site is also considered important to the master planning of the Bayfront 20:20 design. This park can serve to reduce impacts from the downtown UHI effect and provide multi-benefit opportunities such as treatment of stormwater, flood alleviation, and expansion of an urban forest corridor. Naturally vegetated shorelines, such as mangrove shorelines and green stormwater infrastructure can enhance the park aesthetics for the public, provide shade zones, and increase carbon sequestration to reduce GHG accumulations in the atmosphere. Other co-benefits included opportunities to alleviate flooding along roads using public lands (or public-private partnerships) to create stormwater catchment areas such as urban green space corridors and water plazas (i.e. open space - typically dry - but designed to capture water during rain events).

This study was interactive. Workshops were conducted with city staff and the public to explore infrastructure vulnerabilities and help develop the menu of adaptation measures. Five (5) workshops were held with city staff between Oct. 2016 and June 2017 and an interactive public meeting was held August 29, 2017. The public meeting was attended by nearly 100 community members and included interactive "live polling" and breakout sessions to engage the public in active discussion about sector specific vulnerabilities and adaptation measures.

Adaptation Strategies: *Transportation*

A list of transportation vulnerabilities was developed to further the conversation about climate change adaptation and evaluate the resiliency of the City's transportation network. Many of the vulnerabilities were the result of multiple climate change impacts. For example, King tides, SLR, storm surge and extreme precipitation were linked to an increase in coastal road flooding.

Transportation infrastructure will experience unique vulnerabilities to climate change given the long operational expectations of these hardened systems and the requirements to maintain safe motorist and pedestrian conditions along these multimodal networks. Transportation assets in the City are expected to be impacted by all four climate change variables evaluated by this study.

A number of vulnerabilities were discussed with regard to the City's transportation network with particular focus on tidal flooding, inland flooding, emergency evacuation, boater access, bridges and causeways, public safety, resilient landscaping, and alternative transportation, as well as the contribution of roads to the City's UHI effect. A list of transportation vulnerabilities is provided to the right. Key adaption measures discussed to address climate change focused on the need to reduce road flooding, stabilize causeways to withstand higher tides, improve bridge designs to withstand storms, expand alternative transportation options, and install heat and drought tolerant landscaping along road corridors. **Table 7** provides a summary of the Transportation Adaptation Measures developed during this study. One unique concept included designing floodwater vaults under some roads and parking areas to not only protect water quality and reduce flooding, but to increase land elevations above SLR projections. Another measure included protecting shorelines along causeways using hybrid options such as LSL and Living Seawalls to reduce damage from wave energy. To achieve the goal of flood protection, the City might also consider land use strategies that reduce impervious surfaces throughout the City. Some permeable pavement strategies might include an expansion of pervious parking areas, innovative design standards for urban developments, enhancement of pervious areas in public spaces to capture additional water, and replacement of impervious asphalt with pervious surfaces in alleys, along bike lanes, and in other low traffic areas.

Co-Benefits: *improved road safety • greater transportation resiliency • reduced carbon emissions • beautification of streetscapes • shaded sidewalks for the public • habitat for fisheries • recreational fishing • minimization of the UHI effect.*

Transportation Vulnerabilities

1. King Tides and sunny day flooding will continue to inundate roads
2. Wave energy from storms and inundation from high tides will stress seawalls along roads
3. Road flooding will occur during high tide, surge and rain events as tidal waters block culverts and slow drainage
4. Emergency evacuation routes will be blocked due to flooded roads
5. Flooded bridge approaches will reduce safe access to bridges
6. Storm surge will increase wave energy on coastal bridges that undermines bridge abutments and seawalls
7. Strong winds from tropical storms will add pressure (lateral and uplift forces) to bridges
8. Strong storms will cause storm surge in boat basins and dislodge boats
9. Higher tides and surge events will increase salt corrosion inland
10. Landscape mortality will increase from prolonged heat and drought (also salt exposure)
11. UHI effect will increase (more asphalt; more heat) causing higher day temperatures (and less cooling at night)
12. Only one City/public boat launch available for emergency vehicles
13. Pedestrians and cyclists will use outdoor space less due to extreme heat
14. A beach wash over at North Lido Beach could expose Pansy Bayou and expose SR789 to wave damage

Table 7: Transportation Adaptation Measures

ID	Asset	Description	General Adaptation Measures (Solutions)	Site Specific Measures
T3	BAYFRONT MARINA @ BAYFRONT PARK	Boats and Marinas	1. Upgrade stormwater outfalls discharging to boat basin to improve road drainage (many culverts submerged at high tide and during storm surge) 2. Add catchment basins or vaults to capture stormwater from US41 3. Install elevated pumps with generators to pump water off roads 4. Initiate seawall revitalization/removal program to protect critical roads 5. Install LSL or living seawalls along ROW to attenuate waves and accrete sand 6. Elevate shoreline above 2050 SLR projections (earthen terracing, living levees) creating multi-purpose, vegetated pedestrian zones for road and flood protection 7. Buffer sidewalks and parking lots with infiltration strips, grid pavements, and vegetation to reduce flooding as SLR reduces basin drainage 8. Shift work for city staff during extreme heat (spring/summer) 9. Modify landscape pallet to include heat/drought tolerant species 10. Install pedestrian cooling zones (shade trees, hydration stations) 11. Develop a storm surge protection warning system 12. Develop maintenance guidelines to clean boat basin during red tide 13. Develop evacuation/recovery plan for dislodged boats (e.g. storms) 14. Fund a floodgate study	• Replace concrete docks and pilings with floating docks and buildings
T4	DON ROEHR BOAT RAMP @ 10TH STREET (i.e. Centennial Park)			• Add boat ramp redundancy for emergency response (e.g. joint-use with marina or college along US41)
T8	MAIN STREET (US41 to Lime Ave.)	Business District - Downtown	1. Develop Climate Resiliency Road Design Guidelines (reference in RFPs) 2. Identify public properties or public-private land partnerships for resiliency improvements along roads (i.e. infiltration or flood storage) 3. Raise elevation of intersection at US41 4. Evaluate stormwater improvements near US41 to alleviate flooding from extreme precipitation as SLR reduces basin drainage 5. Consider salt resistant equipment for signals/signage 6. Consider salt water corrosion during design modifications 7. Reduce carbon emissions using complete streets designs (e.g. modal shifts from driving to walking, cycling, and transit) 8. Create cooler pavement (open grid along alleys, parking lots, and sidewalks) 9. Install pedestrian cooling zones along roads (shade trees, hydration stations) 10. Modify landscape pallet to include heat/drought tolerant species 11. Store water in or under parks for irrigation in dry season 12. Establish a city fund to support land acquisition to mitigate flooding along roads 13. Review repetitive loss areas to understand flood prone roads and damage zones 14. Review Zoning Code and conduct a Cost Benefit Study to understand opportunities to incorporate more pervious surfaces	• Install flood catchment vaults under parking lots (City Hall) and parking garages • Identify Low Impact Development (LID), infiltration or vault opportunities at downtown parks, in alleys, and along open lots and green space
T10	RINGLING BLVD. (Gulfstream to Tuttle)			• Identify LID, infiltration or vault opportunities at Charles Ringling Park • Install flood catchment vaults under parking lots (County Building and parking lots)

Table 7: Transportation Adaptation Measures (continued)

ID	Asset	Description	General Adaptation Measures (Solutions)	Site Specific Measures
T12	US41 (SR45)	See map for vulnerable low elevation segments along routes	1. Consider alternate transportation options 2. Collaborate with FDOT and County to minimize stormwater flooding from extreme precipitation along with high tides, SLR and storm surge 3. Install pumps with generators to pump flood waters off roads 4. Consider salt resistant equipment for signals/signage 5. Consider salt water corrosion during design modifications 6. Backflow devices to stop salt water surges inland 7. Create flood catchment basins along these route in parks and along alleys 8. Create cooler pavement (pervious alleys, parking lots, park walkways, sidewalks) 9. Install pedestrian cooling zones along routes (shade trees, hydration stations) 10. Add an urban tree network to reduce UHI effect 11. Modify landscape pallet to include heat/drought tolerant species 12. Store water in or under parks for irrigation in dry season 13. Shift work for city staff during extreme heat (spring/summer) 14. Establish a city fund to acquire public lands to capture water and mitigate flooding 15. Identify public properties or public/private land partnerships for resiliency improvements (i.e. infiltration or flood storage) 16. Map repetitive loss areas to understand flood damage zones 17. Reduce carbon emissions using complete streets designs (e.g. modal shifts from driving to walking, cycling, and transit) 18. Review Zoning Code and Conduct a Cost Benefit Study to understand opportunities to incorporate more pervious surfaces throughout the City 19. Prioritize protection and reinforcement of this evacuation route for the foreseeable future	• Utilize Gulfstream/US41 roundabout to address Gulfstream drainage • Use US41 as buffer to protect downtown • Raise US41 road profile to create a coastal buffer (dike) to protect downtown • Add earthen levees along the bayfront to raise land and serve as joint-use pedestrian zones • Collaborate with FDOT to address climate impacts during road redesign
T9	FRUITVILLE RD. INTERSECTION WITH US41			• Raise intersection at US41 • Improve drainage ditch capacity leading to boat basin to accept additional volume of stormwater
T34	DR. MLK JR. WAY			• Raise intersection at US41 and at Whitaker Bayou • Purchase/buy lands and implement recommended LID (green infrastructure) treatments along Whitaker Bayou (reference: Whitaker Bayou Greenway Park and Stormwater LID Retrofit Pilot - 2012)

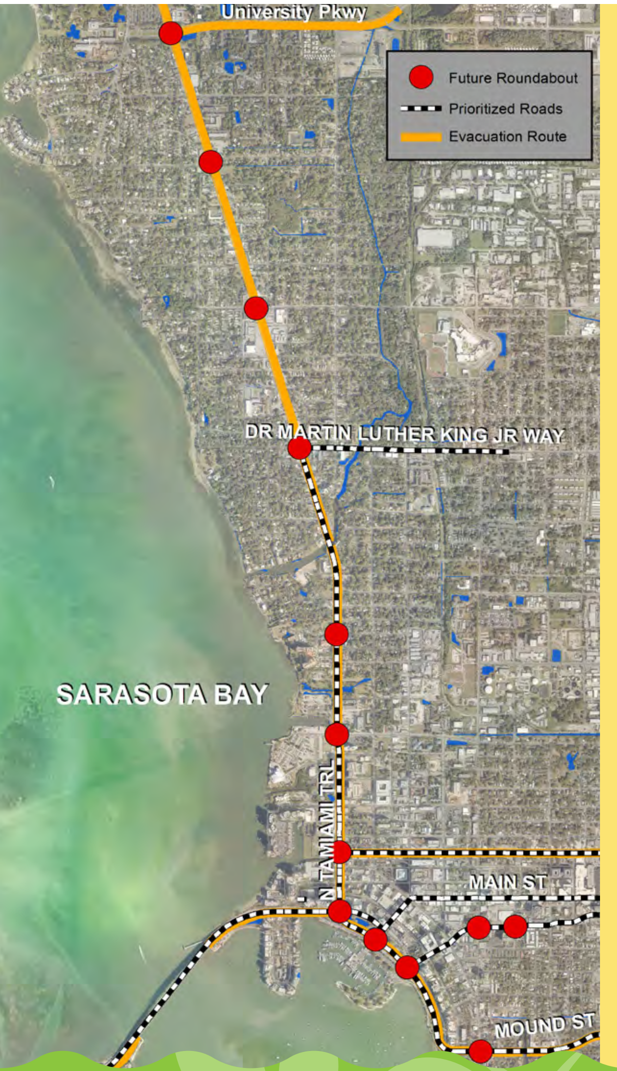
Table 7: Transportation Adaptation Measures (continued)

<table>
<tr><th>ID</th><th>Asset</th><th>Description</th><th>General Adaptation Measures (Solutions)</th><th>Site Specific Measures</th></tr>
<tr><td>T15</td><td>LITTLE RINGLING BRIDGE @ COON KEY</td><td rowspan="3">Bridges and Causeway Over Sarasota Bay</td><td rowspan="5">1. Develop climate change design/maintenance guide for rehabilitation/replacement of bridges (RPF/RFQ standards)
2. Collaborate with Longboat Key to ensure consistency in adaptation/evacuation plans
3. Utilize sustainable design standards: Greenroads, LEED, and Envision
4. Adaptation needed along entire route to protect road/bridge access
5. Establish a collaboration group with FDOT for bridge redesigns within city limits
6. Consider bridge access wrt SLR and surge during redesign, retrofit, replacement
7. Establish a water evacuation route/protocol if road or bridges become impassible
8. Redesign elevations of bridges above highest storm surge predictions to reduce lateral and uplift forces
9. Raise causeways and stabilize/buffer road slopes to prevent wash outs (seawalls, bulkheads, mangrove vegetation, more reef balls)
10. Living/hybrid shoreline protection techniques to promote accretion
11. Develop measures to ensure road access to bridge during flood events
12. Install pumps with generators to pump flood waters off roads
13. Develop a storm surge protection warning system</td><td rowspan="3">• Expand green design opportunities at Bird Key Park and Eloise Werlin Park to protect road and bridge infrastructure – mangroves, planter balls, etc.</td></tr>
<tr><td>T16</td><td>SR789 BRIDGE (JOHN RINGLING)</td></tr>
<tr><td>T17</td><td>JOHN RINGLING CAUSEWAY</td></tr>
<tr><td>T20</td><td rowspan="2">SR789</td><td>Bridge to LBK over Pansy Bayou</td><td>• Enhance dunes at Lido Beach to improve resiliency of Pansy Bayou</td></tr>
<tr><td>T21</td><td>Causeway to LBK over Pansy Bayou</td><td>• Raise elevation of causeway
• Install LSL treatments to accrete soils along shoreline</td></tr>
<tr><td>T18</td><td>JOHN RINGLING BLVD - LIDO KEY - ST. ARMAND'S CIRCLE</td><td>Culverts</td><td colspan="2">1. Coordinate with county stormwater engineers to manage drainage
2. Design storm surge protection measures
3. Improve weirs/control structures
4. Upgrade pump system with salt resistant equipment and backup generators
5. Develop retention canal design with water quality treatments
6. Create water plazas along Blvd Presidents/Ringling promenades to capture flood water
7. Identify areas for bioswales and infiltration areas to hold stormwater
8. Install underground stormwater storage tanks to reduce flooding</td></tr>
</table>

Table 7: Transportation Adaptation Measures (continued)

ID	Asset	Description	General Adaptation Measures (Solutions)
T27	US41 (SR45) WHITAKER BAYOU	Bridges over Tidal Creeks	1. Redesign elevations of bridges above highest storm surge predictions to reduce lateral and uplift forces 2. Develop climate design/maintenance guide for rehabilitation/replacement of bridges (set RPF/RFQ standards) 3. Utilize sustainable design standards: Greenroads, LEED, and Envision. 4. Develop a climate collaboration group for bridges within city limits 5. Design storm surge protection measures and develop a storm surge protection warning system 6. Fund a floodgate study
T30	US41 (SR45) HUDSON BAYOU		

Main Street Roundabout



US41 (Tamiami Trail) and Gulfstream Roundabout

The FDOT is designing several roundabouts along US41 in downtown Sarasota, including a central roundabout at the intersection of US41 and Gulfstream Avenue. This high-volume, critical intersection supports an important evacuation route for the City of Sarasota for barrier island residents (i.e. Lido Key and Longboat Key) and provides access to St. Armand's Circle and Lido Beach, two important economic drivers and tourism destinations for the community.

This intersection has been identified as vulnerable, as it currently experiences visible flooding during King Tides, storm events, and extreme rainfall events. This roundabout is currently under design by the FDOT.

The FDOT, the City of Sarasota, and Sarasota County have initiated dialogue to discuss effective adaptation measures to address this centrally-located and highly-critical City intersection. Measures to consider include a subterranean vault, flood pumps, pond and water feature expansions, higher road elevations, and coastal terracing or living levees along the Bayfront to raise shoreline elevations. Sarasota County will evaluate opportunities to improve stormwater infrastructure along the Bayfront, adjacent to the City's downtown core, which will greatly inform the adaptation strategies chosen. Continued collaboration will be needed for this and all future roundabouts along US41 to integrate adaptation measures within each project design that build resiliency (and protect the City) along this critical roadway corridor.

(Top): Road flooding along US41 (N. Tamiami Trail) from heavy rain event August 27, 2017

(Bottom): Little Ringling Bridge at Coon Key

Adaptation Strategies:
Stormwater

A list of stormwater vulnerabilities was developed to further the conversation about climate adaptation and to evaluate the resiliency of the City's stormwater network. Many of the vulnerabilities identified were the result of multiple climate impacts, and several adaption measures for improving stormwater management provided co-benefits across infrastructure sectors. Of the sectors evaluated, stormwater infrastructure was found to have the greatest vulnerabilities. Stormwater assets are expected to be impacted by all four climate change variables evaluated by this study.

A number of vulnerabilities were discussed with regard to the City's stormwater network with particular focus on gaining a better understanding of the implications of reduced drainage to tidal basins resulting from increased SLR, storm surge, and inland precipitation; future tide levels with regard to current pipe outfalls; and stormwater storage limitations and opportunities.

A variety of potential adaptation measures were developed with the understanding that these measures would not be one-size-fits all solutions and that many measures would require cross-sector and stakeholder collaboration. **Table 8** provides a summary of the stormwater adaptation measures developed during this study. Adaption measures included the installation of pumps to remove tide and rain water during storm events and establishment of a storm surge warning system. The study identified the need to establish of a city fund to support the identification and acquisition of public lands available to provide stormwater catchment and flood relief. These lands might be obtained through direct purchase, city easements, or public-private partnerships and could consider repetitive loss properties that experience extreme flooding, as well as interconnected corridors to create a green network throughout the City. Some unique concepts included floodwater vaults under open land to reduce flooding and elevate land above the SLR projections and opportunities to link stormwater management (e.g. reclaimed fields and canals) with neighborhood improvements and expansion of a green urban corridor. Another measure included the creation of water plazas to capture rain water throughout the City or the use of parking garages to hold flood water during extreme rain events. Similar to ponds and vaults, alternative flood catchment areas could serve a dual purpose of providing public space, recreational areas, and parking when dry, but hold water during flood events. The City's role in protecting public assets like Sarasota Bay and tidal creeks was also discussed. The City considered opportunities to implement LID projects along public waterways – as well as the value of LID projects on private lands in cooperation with landowners – as a way to reduce flooding and protect natural resources vital to our community. The City will actively engage with

Co-Benefits: *flood alleviation on roads • flood protection for buildings and businesses • expansion of open space • water quality improvements in Bay and creeks • CO_2 Sequestration • fishing • tourism*

Stormwater Vulnerabilities

1. Manhole covers may loosen or dislodge during storm or flood events.
2. King Tides and sunny day flooding will continue to slow drainage to the Bay during extreme precipitation
3. Greater street flooding and stormwater overflows due to increased SLR, storm surge and extreme precipitation
4. Systems may become undersized and impacted as sea levels rise
5. Electrical outages, power surges and/or damaged generators reduce effectiveness of pump systems
6. SLR will reduce drainage during extreme precipitation (capacity)
7. Salinity concentrations will increase landward (tidal creeks)
8. Water quality will be impacted by extreme precipitation
9. Water quality will be impacted by extreme heat
10. Saltwater corrosion moves upstream

Centennial Park – Multi-Use Stormwater Facility

The study identified opportunities to provide innovative streetscapes that capture flood waters from King Tides, SLR, storm surge, and extreme precipitation. Many stormwater adaptation measures complement opportunities in other sectors. One uniquely positioned area of interest was Centennial Park, a city-owned parcel along Sarasota Bay. This site sits between Hog Creek and the 10th Street boat ramp basin. This site provides public amenities, boater access, stormwater management for US41, and green space to buffer Sarasota Bay.

Innovative and carefully-designed measures to manage tidal water and freshwater flooding at this site could benefit the City's park system, fisheries tourism, water quality in Sarasota Bay, alternative transportation, and flood alleviation on roads. The park could also serve to reduce impacts associated with the downtown UHI effect through expansion of an urban forest corridor, installation of green infrastructure and the creation of water plazas to create blue-green corridors. Subterranean vaults could also be installed under existing parking areas to alleviate flooding along US41 and improve water quality. Vaults could be used to raise the elevation of the land to withstand near term SLR projections. A deployable storm surge barrier and warning system could be installed along Hog Creek. Multi-partner collaboration and a strong commitment to protecting this area as sea levels rise are essential factors to ensuring the continued use of this public space in the near future.

Innovation is not without cost and climate adaption measures require a decision to invest in the City's future. The City identified the need for funding to update drainage model and upgrade stormwater infrastructure, as well as a funding mechanism to secure additional public land opportunities and public-partnerships.

City – County Interlocal Agreement

"Since 1998, the City of Sarasota and Sarasota County have operated under an interlocal agreement for stormwater management within the municipal limits of the City and the unincorporated area of the County. The interlocal agreement puts Sarasota County in charge of basin master planning, non-routine capital projects, the operation and maintenance of the Stormwater system, and the National Pollutant Discharge Elimination System permit compliance through the Florida Department of Environmental Protection. The City is responsible for ensuring development projects within the City limits are in compliance with applicable City stormwater control and management regulations, appointing two city residents as members of the County's Stormwater Environmental Advisory Committee, and providing comments regarding Stormwater Environmental Utility projects or services specified in any drainage basin located wholly or partially within the municipal limits of City."

community partners to support LID projects, such as the Whitaker Bayou Greenway Park LID concepts developed by the SBEP in 2012.

The project team met with Sarasota County during the course of this study to discuss revisions to the Sarasota County drainage model that covers the watershed basins within the City. Through interlocal agreement, the City and County will seek funding to revise the model to update data inputs and merge SLR and precipitation into the output to inform decisions on level of service flood issues and water quality improvements. The model updates will consider the 2100 NOAA intermediate scenario as a baseline.

Table 8: Stormwater Adaptation Measures

ID	Asset	Description	Location	General Adaptation Measures (Solutions)	Site Specific Measures
SW1	Stormwater Manholes		Tidal and Evacuation Routes	1. Fasten covers for safety in low elevation areas prone to flooding and tidal areas with surge 2. Fasten covers along evacuation routes 3. Research innovative (resistant) seals for tidal areas	
SW4	WHITAKER BAYOU	Drainage Outfall Pipes (Culverts)	US41 Bridge @ Whitaker Bayou	1. Secure funding; update drainage model 2. Consider inland rainfall, SLR, and storm surge in future model analyses 3. Establish a city fund to support acquisition of public lands to mitigate flooding (e.g. easements, public-private partnerships, repetitive loss properties) 4. Coordination: roads and bridges 5. Secure funding/ develop mechanisms and protocol for redesign, retrofit, armoring, or relocation of assets 6. Identify areas to install natural infrastructure for flood management 7. Install/upgrade pump systems in flood areas 8. Install tide backflow devices to protect inland from extreme tide events 9. Stabilize slopes/outfalls (rip-rap, vegetation, seawall) 10. Identify land near outfalls for stormwater/flood retention/ catchment 11. Identify upstream flood relief areas for catchment areas (dry/wet), stormwater vaults, bioswales, and water gardens 12. Add infiltration elements in parking areas to absorb stormwater 13. Develop protocol to collaborate with FDOT and Sarasota County 14. Develop a maintenance plan to maintain/enhance drainage 15. Design for storm surge protection to protect inland zones from tides 16. Install a storm surge warning system 17. Fund a floodgate study	• Maintenance plan to clean oysters or other natural growth from pipe outfalls and culverts
SW15					
SW5			MLK Bridge		
SW12			West of Lemon		
SW52			Smaller outfalls		
SW18		Open Channel Outfall	32nd Street Bridge to N. Riverside Dr.		• Install canal aeration system • Develop plan to maintain/enhance drainage (R&R) • Explore federal funding to improve capacity near bridges • Coordinate with Sarasota Bay Estuary Program and County to acquire land for proposed Whitaker Bayou LID improvements
SW13	CENTENNIAL PARK	Drainage Outfall Pipes (Culverts)	10th Street @ US41		• Maintenance plan to clean oysters or other natural growth from pipe outfalls and culverts
SW14					
SW1		Open Channel Outfall Hog Creek	Discharges to Bay @ Centennial Park		• Install device in system for water aeration • Expand Hog Creek restoration site to capture flood water • Consider water catchment areas, infiltration areas, vaults, and bioswales at Centennial Park, Pioneer Park and Lawn Bowling • Reference the 20:20 Plan
SW6	HUDSON BAYOU	Drainage Outfall Pipes (Culverts)	US41 Bridge		• Maintenance plan to clean oysters or other natural growth from pipe outfalls and culverts
SW30					
SW52			Smaller outfalls		
SW16		Open Channel Outfall / Catchment	Osprey to US41		• Maintenance plan for slope stabilization (R&R) • Install canal aeration system • Increasing volume capacity: dredging/sediment removal • Redesign canal slopes and channels at outfalls - levees, rip-rap, vegetation • Install storm surge protection barriers • Upstream relief opportunities: • Vaults under parking lots and ball fields • Utilize Lukewood Park for water plazas • Collaborate with Sarasota High School
SW20			Hudson Bayou - Alderman Street to Pine Tree Lane		
SW7	SARASOTA BAY	Drainage Outfall Pipes (Culverts)	Harbor Acres		• Verify and or secure easements • Coordinate with Sarasota County to update Harbor Acres drainage model
SW8	MARINA JACK / GOLDEN GATE BASIN		Marina Jack		• Elevate land along the coast/implement flood protection measures to address climate impacts (2050) • Maintenance plan to clean oysters or other natural growth from pipe outfalls and culverts
SW25			Golden Gate		
SW26			Marina Jack		
SW52			Small outfalls		
SW11	SARASOTA BAY		Ringling Museum		• Consider partnership opportunities to capture stormwater

Table 8: Stormwater Adaptation Measures (continued)

ID	Asset	Description	Location	General Adaptation Measures (Solutions)
SW29	ISLAND DRAINAGE OUTFALLS	St. Armand's Drainage Outfall (Culverts)	SR 789 - St. Armand's	1. Improve weirs/control structures 2. Install tide backflow devices to protect inland during extreme tide events 3. Develop funding mechanisms and replacement protocol for retrofits or redesign of assets 4. Consider back up generators, as well as renewable solar and wind energy (with battery storage) 5. Develop a retention canal design with pumps and WQ skimmer system 6. Increase canal capacity 7. Add open grid pavement and/or infiltration elements to absorb stormwater 8. Install water plazas/bioswales along promenades leading to infiltration areas/vaults in circle 9. Involves coordination with public works, businesses, parks, FDOT and County
SW39		Siesta Key Weir	Concrete weir and wooden skimmer at Norasota Way	1. Establish a city fund to support acquisition of public lands to mitigate flooding 2. Consider city easements, public-private partnerships, multi-use areas, and repetitive loss properties 3. Joint collaboration needed with County and FDOT to protect his area 4. Weir and stormwater pond at Norasota Way 5. Pump systems may be needed during extreme events 6. Design backflow devices to protect island during extreme tide events
SW47	ST. ARMAND'S PUMP STATIONS	Central Madison; Blvd of Pres.		1. Add power source, backup generator or off grid power (e.g. solar, wind) for emergencies 2. Design pump capacity for peak discharge 3. Could require abandonment or retrofit of assets 4. Develop climate maintenance and operation protocol 5. Install backwater devices - consider efficiency and resistance to salt and oysters (O&M) 6. Involves coordination with public works, merchants, parks sectors, and Sarasota County 7. Replace with corrosion resistant equipment
SW48		Jackson Drive; S Blvd of Pres.		
SW49		N Washington; N Blvd of Pres.		
SW50		John Ringling Blvd; Washington		
SW51		E Madison Dr; N Washington		
WF 1	WHITAKER BAYOU	Tidal Water Feature	Tidal Creek	1. Design storm surge protection measures to protect inland from tidal flooding 2. Initiate a remote alert system (tide gauge) for storm surge events 3. Conduct a floodgate study 4. Install backflow devices to protect inland during extreme tide events 5. Install pumps to protect roads from flooding during king tides or surge events 6. Consider mangroves buffer creeks, stabilize slopes and reduce velocities 7. Create flood relief zones (catchment areas/vaults) up creeks in parks or along "greenway parks" 8. Retrofit/maintain major outfalls to account for changes in SLR (update drainage model) 9. Coordinate with Sarasota County and Sarasota Bay Estuary Program 10. Reference existing studies 11. Develop dredging and bank stabilization protocol 12. Evaluate infrastructure vulnerabilities along Bayous and Creeks (e.g. box culverts, bridges, weirs)
WF 3	HOG CREEK			
WF 4	HUDSON BAYOU AND CANALS			
WF 11	PHILLIPPI CREEK		Main B	
WF 6	ST. ARMAND'S CANALS			1. Develop a retention canal design with upgraded pump system 2. Add more pump systems (corrosion resistant) with elevated generators (and backup generators) 3. Install retention swales, infiltration areas, or vaults along promenades leading to circle 4. Design water plazas along promenades to manage flood waters during high tides 5. Elevate land above 2050 projections creating multi-purpose pedestrian zones for flood protection
WF 7	PANSY BAYOU			1. Dune restoration along North Lido Beach to improve shoreline resiliency 2. Develop ecological restoration concepts to enhance environmental quality in bayou 3. Recognize tidal flushing could improve WQ
WF 8	BRUSHY BAYOU			1. Identify natural solutions to protect Ben Franklin Drive 2. Develop protection measures in collaboration with Sarasota County 3. Develop ecological restoration techniques to protect park and road

Adaptation Strategies: *Water Supply*

A list of water supply vulnerabilities was developed to further the conversation about climate change adaptation and to evaluate the resiliency of the City's water distribution network. Vulnerabilities were considered with regard to the City's water supply with particular focus on protecting utility equipment and pipe distribution networks.

The City's water supply network is expected to be vulnerable to climate change, but to a lesser degree than other systems. A list of water supply vulnerabilities is provided to the right. **Table 9** provides a summary of adaptation measures developed for the City's most vulnerable water supply assets. While extreme drought is a concern for future water supply, the current system is expected to be adequate to supply the City of Sarasota through the foreseeable future. The 2017 hurricane season did highlight some vulnerabilities. Hurricane Irma provided a real-world example of how high winds can damage underground water distribution pipelines. During the hurricane, several pipelines were damaged by falling trees. To address this vulnerably, the City will collaborate internally to develop utility landscape standards to ensure a healthy urban tree network to reduce the UHI effect while helping to minimize pipe damage from overturned trees and roots.

Water Vulnerabilities

1. Possible overheating and failure of electrical components during heat waves
2. Equipment impacts due to uptake of poor water quality caused by extreme precipitation or heat
3. Pipe damage will occur due to saturated soils and tree roots during extreme precipitation events
4. Heat stress for workers will increase during extreme heat events
5. The electrical grid will continue to be vulnerable to wind from tropical storms.
6. Increased chloride levels in brackish water well field due to saltwater intrusion to aquifer

Utility Friendly Landscaping

Hurricane Irma highlighted vulnerabilities with regard to the City's water supply network due to wind. Twenty-one (21) water main breaks occurred during the storm; ten (10) were the result of fallen tree roots pulling up underground water infrastructure. In some cases, trees were either planted too close to waterlines or the type of tree was not appropriate for an area. Both scenarios have the potential to result in damage to pipelines when trees overturn due to high winds. This vulnerability prompted a closer look at ways to encourage the "right tree, right place" approach to plantings throughout the city in both private and public locations.

The City is revising its zoning code to a Form Based Code. Form Based Codes use the character of place as the organizing principle. These Codes establish an organization that ranges from urban to rural transect zones. For each zone (i.e. an "urban core") the code will recommend trees that developers or residents should consider in their landscape plans given the location's density and context. These recommendations will assist the city in regulating a "right tree, right place" approach, while helping prevent future root and underground utility conflicts. Additionally, the city is beginning an Urban Forestry Master Plan, which includes mapping public trees to identify utility conflicts in rights-of-way and parks. By identifying and mitigating conflicts, this City will promote community-wide resilience in our water distribution system, while recognizing the value of maintaining a healthy urban tree network throughout the City.


Photo | City of Sarasota Utilities


Photo | City of Sarasota Utilities

Table 9: Water Supply Adaptation Measures

<table>
<tr><th>ID</th><th>Asset</th><th>Location</th><th>General Adaptation Measures (Solutions)</th></tr>
<tr><td>WS 2</td><td>WATER TREATMENT PLANT</td><td>Along 12th Street East of N Orange Avenue</td><td>1. Develop climate-specific engineering controls/guidelines to protect equipment from inundation
2. Relocate potentially affected equipment/components to higher ground
3. Move HVAC equipment to safe zones
4. Improve existing facility redundancies
5. Ensure energy backup - powerlines + generators provide redundant feeds for electric
6. Purchase more mobile generators
7. Maintain agreements with FPL and fuel companies, but consider adding backup options for a more holistic on-site "micro-grid" approach
8. Add alternative energy options into the energy plan (e.g. solar and wind power with battery backup)
9. Upgrade facility with heat resistant equipment
10. Upgrade pipes near coast with salt resistant materials
11. Add open grid pavement and/or infiltration elements in parking areas to absorb stormwater
12. Blue roofs to capture and store rainwater (reduce flooding)
13. Install "cool roofs" for greater solar reflectance
14. Shift work for city staff during extreme heat (spring/summer)</td></tr>
<tr><td>WS 7</td><td>SEAWATER INTAKE STRUCTURE @ SARASOTA BAY</td><td>South of 10th Street</td><td>1. Develop engineering control guidelines to protect equipment
2. Install higher quality water filters or initiate replacement protocol during red tide events
3. Develop water quality protocol during red tide events
4. Consider relocation of asset as SLR and surge increases</td></tr>
<tr><td>WS 8</td><td>CITY WELL #1</td><td>22nd Street</td><td rowspan="3">1. Use wells in the interim, but consider longer term relocation of assets as chloride levels increase from saltwater intrusion
2. Consider hybrid reverse osmosis / desalination treatments as chloride levels increase from saltwater intrusion
3. Replace wells, as needed, with stainless steel casings and move away from coast
4. Replace filters as needed to maintain water quality
5. Protect control panels from saltwater</td></tr>
<tr><td>WS 9</td><td>CITY WELL #2</td><td>Alameda Drive</td></tr>
<tr><td>WS 11</td><td>CITY WELL #4</td><td>Panama Drive</td></tr>
</table>

Adaptation Strategies:
Wastewater

A list of wastewater vulnerabilities was developed to begin the conversation about adaptation opportunities to better protect the City's utilities and to minimize discharges to tidal water features. Vulnerabilities were considered with regard to the management of wastewater with particular focus on protecting facility equipment and pipe distribution networks and reducing system failures due to excess water inputs.

The wastewater system is expected to be impacted by climate change, but to a lesser degree than other systems. Several vulnerabilities were discussed with regard to the City's wastewater network with particular focus on extreme precipitation, extreme heat, saltwater corrosion and power supply. **Table 10** provides a summary of adaptation measures developed for the City's most vulnerable wastewater assets.

Extreme precipitation and loss of power supply will continue to be primary concerns for the wastewater system. Hurricane Irma highlighted vulnerabilities with regard to the City's electrical grid and illustrated how even short-term power loss can adversely impact operation of the utility system. Several lift stations (LS) were identified as vulnerable. While the high-volume lift stations (LS#10 and LS#16) have backup generators and pipe redundancy, smaller lift stations, as well as lift stations along the coast share mobile generators.

Some key adaption measures discussed to address climate change focused on the need to continue to fund the City's Inflow and Infiltration (I&I) Program to identify and repair pipes to reduce sanitary sewer overflows (SSO) to streets, tidal creeks and Sarasota Bay. Another adaptation measure will be to enhance the resilience of the City's power supply available to the WWTP and sanitary sewer lift stations, particularly the smaller stations throughout the City.

Wind damage crippled the City's electrical grid following Hurricane Irma causing sanitary sewer lift stations across the City to temporarily fail. Power supply resiliency concepts discussed to address future electrical failures included creating a micro-grid power source at the WWTP and at lift stations that incorporates alternative energy with battery storage to reduce dependence on the power grid and fossil fuels. The City also discussed purchasing additional mobile generators to provide more resources during wide-spread power outages.

Wastewater Vulnerabilities

1. Possible overheating and failure of electrical components during heat waves
2. Excess water inputs to system (I&I) during extreme rain or tidal surge events from damaged pipes and manholes will cause sanitary sewer overflows if volume exceeds capacity and power supply is lost.
3. Corrosion of equipment due to saltwater intrusion inland
4. Heat stress for workers will increase during extreme heat events
5. The electrical grid will continue to be vulnerable to wind from tropical storms.

Sanitary Sewer Overflow (SSO)

Inflow and Infiltration (I&I)

Inflow and infiltration (I&I) describe groundwater and stormwater that enters pipes dedicated for wastewater or sanitary sewer that are designed strictly to transport wastewater from sanitary fixtures such as toilets, sinks, bathtubs, and showers.

Inflow is stormwater that enters the sanitary sewer system. Various sources contribute to inflow including footing/foundation drains and drains from roofs, downspouts, window wells, driveways, and sump pumps. These sources are often improperly or illegally connected to sanitary sewer systems.

Infiltration is groundwater that enters sanitary sewer systems through cracks in sewer pipes or manholes. Cracks may be caused by age-related deterioration, loose joints, poor design, installation or maintenance errors, damage, or root infiltration. During Hurricane Irma, excess rainwater entered pipes and caused system overflows around the city. Compounding this problem was widespread loss of power due to toppled power lines. This power loss prevented smaller lift stations from pulling sewer to the treatment plant.

Sewer pipes are designed to last an average of 20-50 years, but many go much longer without inspection or repair and are likely to be cracked or damaged. Sanitary manholes that have lost their structural integrity are another source of infiltration.

The City is addressing this vulnerability through a 5-year project to inspect all sewer mainlines within the City limits with a target completion in September 2019. Future climate adaptation planning will continue to address pipeline inspections and repairs to reduce I&I and help reduce impacts associated with extreme precipitation. Planning will also explore new opportunities to ensure uninterrupted power supply at the WWTP and lift stations, such as installation of micro-grid power sources, including off-grid alternative energy stations with battery storage, and the purchase of additional mobile generators – all of which can help prevent power loss that can lead to sanitary sewer overflows.

Photo | City of Sarasota Utilities

(Top): Sanitary Sewer Overflow August 27, 2017 Extreme Precipitation Event

(Center): Mobile Generator

(Bottom): Wastewater Treatment Plant

Table 10: Wastewater Adaptation Measures

<table>
<tr><th>ID</th><th>Asset</th><th>Location</th><th>General Adaptation Measures (Solutions)</th></tr>
<tr><td>WS 1</td><td>WASTEWATER TREATMENT PLANT</td><td>1850 12th Street</td><td>1. Continue to fund the City's I&I program to fix leaky pipes and improve the capacity of the WWTP
2. Develop climate-specific engineering controls/guidelines to protect facility equipment from inundation
3. Ensure energy backup plans - powerlines plus generator provide redundant feeds for electric; maintain agreements with FPL and fuel companies
4. Maintain agreements with FPL and fuel companies for primary power, but consider adding resiliency by incorporating a more holistic micro-grid approach on site
5. Relocate potentially affected equipment/components to higher ground
6. Relocate equipment into HVAC zone
7. Continue with Capital Improvement upgrades when possible to improve facility reliability and redundancy
8. Upgrade facility with heat resistant equipment
9. Upgrade sewer pipes near coast with salt resistant materials
10. Shift work for city staff during extreme heat (spring/summer)</td></tr>
<tr><td>WW8</td><td>LIFT STATION #10</td><td>US41 at Whitaker Bayou</td><td rowspan="7">1. Continue to fund the City's I&I program to fix leaky pipes and improve the capacity of the WWTP
2. Develop engineering controls/guidelines to protect equipment (saltwater protection)
3. Reinforce protection for generators (protective structures)
4. Relocate generators and potentially affected equipment/components to higher ground (second floor)
5. Invest in backup generators to provide more resources during wide-spread power outages
6. Consider trailer mounted generators for areas prone to storm surge to avoid damage
7. Protect generators from cool water hits hot generators – damage
8. Develop engineering controls/guidelines to protect water quality
9. Add redundancy by adding generators for emergency conditions to prevent sewage overflow to bay
10. Add redundant pipes for flow during surge or extreme precipitation to capture additional volume</td></tr>
<tr><td>WW10</td><td>LIFT STATION #16</td><td>Gulfstream Boulevard</td></tr>
<tr><td>WW3</td><td>LIFT STATION #2</td><td>Harmony Lane</td></tr>
<tr><td>WW4</td><td>LIFT STATION #3</td><td>Siesta Drive</td></tr>
<tr><td>WW11</td><td>LIFT STATION #17</td><td>Ohio Place</td></tr>
<tr><td>WW14</td><td>LIFT STATION #30</td><td>Monroe Drive</td></tr>
<tr><td>WW15</td><td>LIFT STATION #31</td><td>Cleveland</td></tr>
</table>

Adaptation Strategies:
Public Lands

A list of public land vulnerabilities was developed to further the conversation about climate change adaptation and to evaluate the resiliency of the City's public land holdings. Many vulnerabilities identified were the result of multiple climate change impacts. Specifically, SLR, storm surge and extreme precipitation events were linked to increases in coastal flooding on a number of public land sites.

Public lands are expected to be impacted by all four climate change variables evaluated by the study. Vulnerabilities were discussed with regard to the City's public lands network with focus on tidal and inland flooding; outdoor tourism; recreational use during extreme heat events; heat, salt and drought tolerant landscaping; stormwater opportunities for flood control and water quality; and opportunities to expand a network of public green space. A list of public lands vulnerabilities is provided to the right. **Table 11** provides a summary of adaptation measures developed for the City's most vulnerable public lands.

Public lands will experience unique challenges due to climate change given the location of many of these lands along the coast and due to the role they serve in providing recreational value and a "sense of place" in the community. This study evaluated the critical role these lands will play in city-wide adaptation. The study identified possible ways that improvements to public lands could better protect the City and ways some improvements would be compatible with stormwater management, as well as other infrastructure sectors. As adaption measures are selected and implemented, it will be important to stay true to the "nature" of the public lands, the importance these lands play in the community, and the roles they serve in attracting tourism to our region. Cross-sector support and collaboration will be critical.

An expansion of the City's public land holdings would be prudent given the various ways public lands will absorb climate change impacts. Expansion of these holdings could be pursued through establishment of a city fund to support the identification and acquisition of lands through direct purchase, easements, and innovative partnerships with

Co-Benefits: *beautification of cityscape • habitat for fisheries • recreational fishing • minimization of the UHI effect • recreational corridors • community cohesion • public heath • carbon sequestration • rolling easements*

Public Lands Vulnerabilities

1. Pressure from development within the parks leading to removal of trees and greenspace
2. Man-made protection enhancements could conflict with natural assets
3. Loss of uplands will continue to gradually occur as SLR floods shorelines
4. King tides and storm surge will inundate coastal parks
5. Higher tides and SLR reduce discharge rates and prolong inland flooding
6. Shoreline erosion will accelerate with stronger storms and higher tide events
7. Shorelines with low seawalls will see inundation
8. Water quality will be impacted by extreme precipitation
9. Water quality will be impacted by extreme heat
10. Fisheries populations may shift with warming waters
11. HAB likely more common with warming waters
12. Stagnant stormwater ponds will occur during periodic droughts
13. Reduced use by public during extreme heat
14. Recreational value diminishes with loss of uplands and extreme heat
15. Heat stress for city maintenance staff
16. Landscape plant mortality due to prolonged heat/drought events
17. Wind damage to buildings, power grid, and trees

(Top): City Bioswale

(Bottom): Lido Beach

a focus on creating coastal buffers and interconnected corridors throughout the City. As discussed, the City will look for opportunities to protect public shorelines using various techniques including hybrid options such as LSL and living seawalls to attenuate wave energy and buffer lands.

The City will identify adaptation measures that incorporate "blue" and "green" infrastructure designs versus traditional "grey" infrastructure, particularly within parks. Unique adaptation measures for public lands include subterranean vaults under parks to reduce flooding and raise land elevations above SLR projections and opportunities to partner to promote stormwater management designs that improve neighborhoods and the community. The study considered water plazas and bioswales to move water around the City in a controlled manner during heavy rainfall or storm surge events. Similar to ponds and vaults, alternative water features could serve the dual purpose of providing public space, recreation areas, and parking during dry periods, but would hold water during flood events.

As the City continues to grow and develop, it must continue to recognize the benefit of green space in reducing the UHI effect. City's that protect urban trees or "leafy infrastructure" receive multiple benefits such as a reduction in air pollution and cooling costs and an expansion of urban corridors and CO_2 sequestration. As temperatures increase and droughts become more sever, the City will also need to consider climate-ready landscape plantings for parks. This will also include replacement of wind susceptible, non-native trees such as Australian pines with more tolerant native species.

Lastly, an increase in air temperature will impact public health. This will be apparent in outdoor spaces such as parks, along multi-modal transportation routes, and in business districts. The study identified a need to install public cooling stations throughout the City to provide water and shade for pedestrians, as well as the need to develop protocols to ensure the wellbeing of city workers during extreme heat events. To better understand the threats of heat to city staff and to the community, the City might develop a Heat Vulnerability Index for city parks to understand where

Bayfront Park

Public lands can inspire communities and instill a sense of stewardship and pride. Climate change has the potential to affect public lands through increased tidal flooding and erosion along coastal parks, natural and man-made shorelines, and Gulf beaches due to higher tides, stronger storms, and extreme rainfall. Protection of these lands will require planners and designers to find ways to soften the urban hardscape with more flexible nature-based designs better able to withstand future climate challenges and pressures.

Public lands along the City's shorelines are irreplaceable, but more, they are essential and beneficial. Public places support the well-being of the community – providing green space, promoting social well-being, encouraging recreation, providing biodiversity, attracting visitors, buffering downtown development, and protecting water quality in Sarasota Bay. Protection of these lands will need to be considered holistically – green, blue and grey development – as they will serve as a first line of defense against rising tides and storm surge and will provide unique opportunities to manage flood waters and expand green space. While hardened infrastructure may be one piece of the puzzle, innovative and flexible green and blue designs, as well as an expansion of native habitats, should be prioritized to better prepare these public lands to adapt to water.

Bayfront Park is one such public space lying along the frontline and buffering downtown City of Sarasota and Tamiami Trail (US41) from high tide events, sea level rise, and storm surges. This diverse public space showcases community art, supports boat moorings, and provides recreational space, entertainment and dining services. The area supports native mangrove shorelines and shorebirds, as well as recreational fishing opportunities, all of which attract residents and tourists to the area. Prioritizing the protection and enhancement this space from climate impacts – including innovative grey, green and blue designs – will help the City of Sarasota mitigate the impacts of climate change for years to come.

(Top Right): Mangrove Shoreline along Selby Gardens

(Bottom Left): Marina Jack Charter Fleet Catch

(Bottom Right): Whitaker Gateway Park

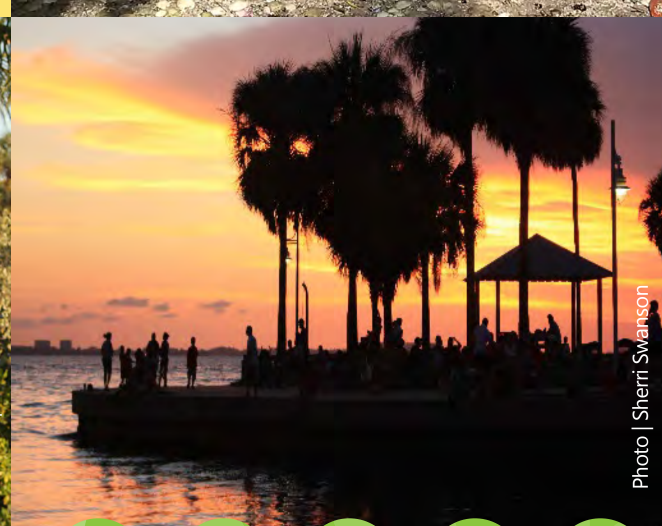


Table 11: Public Lands Adaptation Measures

ID	Asset	Location	General Adaptation Measures (Solutions)
P4	BAYFRONT PARK	Downtown Bayfront Parks	1. Establish a city resiliency fund to support acquisition of public lands to expand greenspace for climate mitigation 2. Identify public land or public/private land partnerships for resiliency improvements 3. Map repetitive loss areas to understand flood damage zones and benefits for climate mitigation 4. Elevate land above SLR to create multi-purpose vegetated zones for inland flood protection 5. Add boat launch for emergency boat access for rescue or to ferry supplies to islands 6. Replace concrete docks with floating docks 7. Develop a boat evacuation and recovery plan for dislodged boats 8. Develop maintenance guidelines to clean boat basin during red tide or following storms (debris) 9. Initiate seawall revitalization/removal program (e.g. wall drains, LSL) 10. Install living shoreline/seawalls to attenuate wave and accrete sand 11. Expand infiltration areas along sidewalks and parking lots to absorb stormwater 12. Modify landscape pallet to include heat/drought tolerant species 13. Store water in or under parks for irrigation in dry season 14. Add trees and expand green space to mitigate UHI 15. Shift work for city staff during extreme heat (spring/summer) 16. Install pedestrian cooling zones (shade trees, hydration stations) 17. Identify opportunities for shaded sidewalks 18. Develop a Heat Vulnerability Index study for city parks 19. Identify opportunities to expand greenspace as opposed to hardened amenities
P5	BAYFRONT PARK EAST SIDE OF US41		1. Expand ponds to buffers downtown Sarasota from SLR, SS and ExP 2. Consider opportunities to enhance stormwater capacity 3. Create water plazas to manage flood water 4. Install underground stormwater vaults 5. Install or upgrade pump systems 6. Install backflow devices to protect inland during extreme tide events 7. Modify landscape pallet to include heat/drought tolerant species 8. Expand urban tree network and green space to mitigate UHI effect 9. Install pedestrian cooling zones (shade trees, hydration stations) 10. Shift work for city staff during extreme heat (spring/summer) 11. Develop a Heat Vulnerability Index study for city parks
P7	BIRD KEY PARK	Ringling Causeway Parks	1. Enhance area to serve as a short-term, built up barrier to protect causeway and bridge from SLR 2. Develop armament or coastal protection/enhancement measures to protect and elevate land 3. Living shorelines (mangroves) or living seawalls as surge buffer to attenuate waves (short term) 4. Add additional reef balls to protect land and accrete sands 5. Modify landscape pallet to include heat/drought tolerant species 6. Install pedestrian cooling zones (shade trees, hydration stations) 7. Shift work for city staff during extreme heat (spring/summer)
P15	ELOISE WERLIN PARK		

Table 11: Public Lands Adaptation Measures (continued)

ID	Asset	Location	General Adaptation Measures (Solutions)	Site Specific Measures
P9	CENTENNIAL PARK	Bayfront Parks along US41	1. Coordinate with Bayfront 20:20 to consider SLR in future development 2. Expand greenspace as opposed to hardened amenities 3. Identify public properties or public/private land partnerships for resiliency improvements (e.g. infiltration area, green space, flood storage) 4. Establish a city resiliency fund to acquire public lands for climate mitigation and expansion of urban green space 5. Map repetitive loss areas to understand flood zones for climate mitigation 6. Present a plan for rolling easements to address land loss to SLR 7. Secure funding to update the drainage model w/inland rainfall, SLR, storm surge 8. Enhance area to serve as a built up barrier to protect/buffer City 9. Elevate barriers along shorelines (i.e. earthen terracing; living levees) – multi-purpose vegetated pedestrian zones to serve dual purpose of flood protection 10. Develop funding mechanisms for retrofits to update park stormwater assets 11. Utilize uplands for more stormwater capacity and flood alleviation during ExP 12. Replace asphalt with pervious surfaces (bioswales, infiltration strips) 13. Pump systems may be needed during extreme events 14. Add trees and green space to mitigate UHI effect 15. Modify landscape pallet to include heat/drought tolerant species 16. Foster a healthy urban forest that is more wind-resistant through proper tree pruning, as well as replacement of wind-susceptible, non-native trees (e.g. Australian pines) with wind-tolerant, native Florida trees (e.g. sand live oak) 17. Install pedestrian cooling zones (shade trees, hydration stations) 18. Develop maintenance guidelines to clean shoreline during red tide events 19. Develop a heat vulnerability index for city parks to understand where pedestrians are most vulnerable to heat-related stress 20. Add LSL (mangroves) or living seawalls to buffer waves and create habitat 21. Shift work for city staff during extreme heat (spring/summer) 22. Install emergency tide/surge gates to control upstream flooding 23. Install a remote storm surge alert system	• Prioritize protection of boat ramp for emergency services and public access to Bay and Gulf • Add boat ramp redundancy • Plant mangroves near US41 to provide shoreline protection
P47	WHITAKER GATEWAY PARK			• Consider adding Living Seawalls along Sarasota Bay
P23	LAWN BOWLING			• Large green space in downtown Sarasota that could mitigate UHI
P38	PIONEER PARK			• Protect historical property and grand trees • Site could accept additional water • Utilize ROW north of Hog Creek (uphill) for more capacity
P27	LUKEWOOD PARK			

Table 11: Public Lands Adaptation Measures (continued)

ID	Asset	Location	General Adaptation Measures (Solutions)
P21	KEN THOMPSON PARK	Lido Key Parks	1. Prioritize protection and enhancement of Ken Thompson boat ramp for emergency services to evacuate island 2. Elevate shorelines (e.g. earthen terracing; living levees) – to function as multi-purpose vegetated pedestrian zones to serve dual purpose of flood protection 3. Install living shorelines (mangroves) as a surge buffer and to attenuate waves and accrete shoreline 4. Develop seawall protection measures along New Pass 5. Replace impervious asphalt with pervious surfaces 6. Develop landscape pallet tolerant to wind/extreme heat/drought/salinity 7. Install and maintain pedestrian cooling zones (shade trees, hydration stations) 8. Shift work for city staff during extreme heat 9. Develop maintenance guidelines for cleanup during red tide events 10. Initiate a working group to develop a comprehensive resiliency plan for all interests (i.e. City leases) on the island (e.g. Save Our Seabirds, Marine Max, Mote Marine, SSS) 11. Install elevated pumps with generators to pump water off roads and better manage flooding 12. Consider a micro-grid power source to support lessees on this City Island including alternative energy options that reduce dependence on the power grid during extreme storm events
P24	LIDO BEACH		1. Decide on the level of acceptable land loss 2. Present a plan for rolling easements to understand options in areas most vulnerable to SLR 3. Short-term (2050) – initiate beach improvement/renourishment projects 4. Long-term solutions (2100) – beach may prove difficult to save 5. Man-made "engineered" protection could conflict with natural enhancement 6. Study pros/cons of man-made, engineered solutions 7. Develop restoration techniques to naturally accrete sands 8. Expand dune restoration along Lido Beach to improve shoreline resiliency 9. Add shade and hydration cooling zones for pedestrians 10. Shift work for city staff during extreme heat 11. Develop a heat vulnerability index for city parks to understand areas where pedestrians are most vulnerable to heat related stress 12. Initiate maintenance guidelines to clean beach during red tide 13. Develop long-term solutions to maintain public space and tourism along beaches as coastlines succumb to SLR and storm surge. Consider raised boardwalks and platforms for pedestrian use, as well as opportunities for underwater recreation
P44	TED SPERLING PARK		County-owned Ted Sperling Park may benefit from similar adaptation measures as North Lido

Table 11: Public Lands Adaptation Measures (continued)

<table>
<tr><th>ID</th><th>Asset</th><th>Location</th><th>General Adaptation Measures (Solutions)</th><th>Site Specific Measures</th></tr>
<tr><td>P8</td><td colspan="2">BOBBY JONES GOLF CLUB</td><td rowspan="2">1. Secure funding to update drainage model
2. Consider inland rainfall, SLR, and storm surge (ExP + SLR + SLOSH) in future model analyses
3. Establish a city fund to support acquisition of public lands to mitigate flooding (e.g. city easements, public-private partnerships, multi-use areas, repetitive loss properties)
4. Present a plan for rolling easements to understand options to acquire public lands to buffer bayou
5. Develop a heat vulnerability index for city parks to understand the level pedestrians are vulnerable to heat related stress at facility
6. Use park to mitigate downstream flooding and water quality
7. Identify opportunities for stormwater retrofits
8. Partner with SBEP to develop habitat and fisheries enhancement programs
9. Partner with local, state and federal organizations proposing restoration efforts focused on water quality enhancements in Sarasota Bay
10. Consider temporary open water catchment features, underground storage vaults, bioswales, and/or water garden to capture stormwater.
11. Modify landscape pallet to include heat/drought tolerant species
12. Store water in or under parks for irrigation in dry season
13. Install pedestrian cooling zones (shade trees, hydration stations)
14. Shift work for city staff during extreme heat (spring/summer)</td><td>• Adjacent to Phillippi Creek Main B. Could serve to mitigate flooding from storm surge and Ex P
• Incorporate "blue roofs" to capture and store rainwater (reduce freshwater flooding in paved areas)
• Paint roofs white to reflect heat
• Use water storage basins for landscape irrigation</td></tr>
<tr><td>P12</td><td colspan="2">DR. MARTIN LUTHER KING JR. PARK</td><td>• Adjacent to Whitaker Bayou. Could serve to mitigate flooding from storm surge and extreme precipitation
• Create a green urban network along the Bayou
• Consider LID opportunities studied by Sarasota Bay Estuary Program - Whitaker Bayou Greenway Park and Stormwater LID Retrofit Pilot (2012)
• Foster a healthy urban forest that is more wind-resistant through proper pruning, as well as replacement of wind-susceptible, non-native trees with wind-tolerant, native Florida trees</td></tr>
<tr><td>CR2</td><td colspan="2">SARASOTA BAY NATIONAL ESTUARY</td><td colspan="2">1. Collaborate with Sarasota Bay National Estuary Program (staff, TAC, CAC)
2. Refer to SBEP's Vulnerability Assessment as expert documentation on bay vulnerability
3. Collaborate with local experts & organizations on red tide research, responses, and solutions
4. Establish a city fund for acquisition of public lands along bay for climate mitigation and land migration
5. Map city properties/easements available for resiliency improvements along bay
6. Map repetitive loss properties to understand coastal damage zones
7. Restore and enhance mangrove shorelines to protect (buffer) uplands and coastal infrastructure
8. Plant mangroves to moderate water temperatures (shade for fish)
9. Collaborate with the SBEP to support projects (such as LID and LSL) that protect Sarasota Bay</td></tr>
</table>

Table 11: Public Lands Adaptation Measures (continued)

ID	Asset	Location	General Adaptation Measures (Solutions)
CR4	SEAWALLS		1. Initiate a seawall revitalization monitoring/replacement/enhancement program - retrofit to relieve drainage pressure 2. Add infiltration areas to absorb stormwater 3. Consider curved seawalls 4. Add riprap or mangrove balls in front of seawalls 5. Replace seawalls with earthen dikes – create joint-use recreation areas 6. Install living seawalls to buffer tides and surge 7. Study potential hardened shoreline locations for replacement with a living shorelines (LSL) to attenuate wave energy, accrete sands, improve water quality (LSL adapt to better protect shorelines from SLR and storm surge) 8. Plant mangroves to provide refuge for fisheries, which benefits tourism 9. Establish a city fund to support acquisition of public lands along bay for land migration 10. Identify city properties/easements available for resiliency improvements 11. Map repetitive loss properties to better understand sea wall damage zones 12. Restore and enhance mangrove shorelines to protect (buffer) uplands 13. Identify mangrove migration opportunities to protect coastal infrastructure
P10	CHARLES RINGLING PARK		Consider opportunities for green design to reduce flooding and UHI such as vaults, bioswales and water plazas
P45	ST. ARMAND'S CIRCLE PARK		

Sarasota Sailing Squadron (SSS)

The Sarasota Sailing Squadron (SSS), is a private, not for profit, sailing club on city-leased land at the northeastern corner of Ken Thompson Park. The SSS has initiated measures to reduce vulnerabilities to climate threats that are expected to increasingly impact the facility. This includes the creation of a Hurricane Preparedness Plan for the club, as well as measures to make the facility more resilient and safer for members. The SSS recently conducted a wind and storm surge study to understand threats from flooding and wave damage. The SSS plans to install a wave attenuation system to buffer the SSS boat basin from storm surge approaching from Sarasota Bay. The system will be designed to protect the SSS from damage associated with at least a Category 2 storm surge event. The SSS will pay for this capital upgrade with matching funds supplied by the West Coast Inland Navigation District (WCIND). In addition to protecting the boat basin from flood events and waves, the club is installing tie-down anchors for boats stored on the property. The SSS is also assessing insurance policies related to the vulnerability of the clubhouse to wind, extreme tides, and storm surge. They are evaluating electrical upgrades and developing innovative concepts to manage tide waters that could periodically flow through the building during extreme events. They will also consider hurricane straps and wind mesh to protect the structure. The SSS currently generates most of its power via onsite solar panels and is inventorying the system for efficiencies and vulnerabilities. Lastly, the SSS plans to replace hazardous, non-native Australian pine trees that are susceptible to toppling during high winds with native species that are wind and salt resistant.

Adaptation Strategies:
Critical Buildings

A cursory review of critical buildings was conducted to begin the conversation about adaptation. A full scale analysis of buildings was beyond the scope of the project; however, buildings essential to utility operations, city business, and future redevelopment along Sarasota Bay where deemed important for this review.

A number of vulnerabilities were considered with regard to public buildings with particular focus on stormwater management and flooding; pressures on the power grid during extreme heat events (e.g. excessive energy use); damage to power lines due to high winds; and climate-ready landscaping. This review identified the need for coordination to ensure climate change vulnerabilities are considered during the planning of The Bay (Bayfront 20:20) and identified multi-use opportunities on city lands such as opportunities to reduce the UHI effect.

Critical Buildings Vulnerabilities

1. Increased chance of structure inundation due to storm surge and extreme precipitation events
2. HVAC system stress (energy) in buildings during extreme heat episodes.
3. Loss of power due to extreme heat taxing the power grid or wind from strong storms
4. Additional operation expenses during heat events
5. Reduce building design life (building materials and equipment)
6. Increase wave energy & water logging behind sea walls along property limits
7. Landscaping may be stressed by extreme heat or drought. More salt tolerant plants may be needed.
8. UHI effect may increase as development continues (more concrete) and air temperature increases

Bayfront 20:20

Bayfront 20:20 is a 42-acre, city-owned parcel along Sarasota Bay. The public land was evaluated by this study due to future redevelopment plans. The parcel directly abuts the Bayfront and is bordered by Centennial Park to the north, US41 to the east, and Boulevard of the Arts to the south. Several existing buildings are located on the site, including the Van Wezel Performing Arts Hall, G. WIZ, the Sarasota Orchestra, the Sarasota Municipal Auditorium, and the Art Center.

The Sarasota Bayfront Planning Organization, Inc. (SBPO) is a privately-funded, not-for-profit board charged with developing a Master Plan to guide the sustainable redevelopment of the parcel in accordance with the shared vision of numerous community groups to "support the creation of a long-term master plan for the Sarasota Bayfront that will establish a cultural and economic legacy for the region while ensuring open, public access to the Bayfront." Additionally, the planning partners identified a desire for the development to be financially feasible, operationally viable, and environmentally sustainable and to enhance natural assets and community connectivity. The vision and principles were ratified by the City Commission in 2015. The City of Sarasota is an active partner of the SBPO and has representation on the board.

The Climate Adaptation plan identified this public land as vulnerable to future climate change. The City of Sarasota and its partners have a unique opportunity to redevelop this site with purpose and to ensure lasting impacts for future generations. Given this, it is important for development plans to integrate adaptation components that take into account the latest projections for SLR, storm surge, and future flooding, as well as opportunities for renewable energy designs and the protection of natural shorelines.

Table 12: Critical Buildings Adaptation Measures

<table>
<tr><th>ID</th><th>Asset</th><th>Location</th><th>General Adaptation Measures (Solutions)</th><th>Site Specific Measures</th></tr>
<tr><td>BD-2</td><td>PUBLIC WORKS BUILDINGS</td><td rowspan="2">12th Street</td><td rowspan="3">1. Develop Climate Resiliency Design Guidelines for city buildings and rehabilitations (reference Envision/LEED standards into RFPs)
2. Consider extreme heat during design, retrofits, and upgrades to expand life of asset
3. Flood proof buildings
4. Consider water catchment features, vaults, bioswales, and/or water gardens to capture and store rainwater (reduce flooding)
5. Expand green infrastructure/infiltration elements in parking lots
6. Buffer sidewalks and parking lots with green infiltration areas and infiltration islands
7. Add greenspace and trees to mitigate UHI effect
8. Consider green designs to manage extreme heat and improve building efficiency
9. Blue roofs to capture and store rainwater (reduce flooding)
10. Install "cool roofs" for greater solar reflectance
11. Consider solar installations to minimize pull off electrical grid
12. Improve energy efficiency
13. Modify landscape pallet to include heat/drought tolerant species
14. Plant to reduce maintenance and irrigation costs
15. Install pedestrian cooling zones (shade trees, hydration stations)
16. Fund/prepare a heat vulnerability index study to identify areas of risk within the City
17. Shift work to avoid worker heat stress during hotter weather</td><td>• Public works has the ability to relocate the facility under extreme future conditions. Abandon site, if deemed appropriate</td></tr>
<tr><td>BD-3</td><td>UTILITY OPERATION BUILDINGS</td><td>• Relocate facility, as needed under future conditions</td></tr>
<tr><td>BD-5</td><td>CITY HALL</td><td>1st Street</td><td>• Consider opportunities to manage stormwater (vaults beneath parking lot, pervious allies, bioswales)
• Secure funding to update drainage model to understand capacity for capture of stormwater in underground vaults</td></tr>
<tr><td>BD-14</td><td>G. WIZ AND VAN WEZEL</td><td>US41</td><td colspan="2">1. Upgrade buildings (or new building designs) should consider 2100 SLR and storm surge projections
2. Area will require elevated coastal protection/enhancement to protect parcel near term (2050-2100); SLR barriers
3. Shoreline terracing (earthen dikes; living levees) to protect land near term
4. Longer term likely to require retreat, abandonment or more extreme protection measures
5. Install upgrades to stormwater outfalls
6. Install pump systems to remove flood water from extreme precipitation
7. Backflow devices may be needed during extreme storm surge events
8. Install living shorelines or living seawalls (mangroves) as surge buffer to attenuate waves and accrete soils
9. Add mangroves (showcase windowing to encourage shoreline plantings
10. Initiate seawall revitalization/removal program (e.g. weep holes to drain, living seawalls, or LSL)
11. Replace impervious asphalt with pervious surfaces (i.e. parking lot asphalt with open grid pavement, infiltra-tion islands)
12. Consider temporary water catchment features, storage vaults, bioswales, and/or water gardens to capture stormwater
13. Consider solar power for buildings
14. Install green roofs and green walls segments to manage extreme Heat and improve building energy
15. Incorporate blue roofs to improve stormwater efficiency
16. Install cool roofs with great solar reflec tance
17. Develop a heat/drought resistant landscape pallet to reduce maintenance needs and irrigation costs.
18. Install pedestrian cooling zones (shade trees, hydration stations)
19. Establish a city fund to support acquisition of public lands to capture water and mitigate flooding
20. Present a plan for rolling easements to understand options to acquire lands in areas most vulnerable to SLR
21. Design storm surge protection measures and warning systems
22. Fund a floodgate study</td></tr>
</table>

Photo | Sherri Swanson

STEP 6 – **Adaption Plan**

6 Adaption Plan

The City of Sarasota is committed to working to adapt to the challenges of climate change and is aware that SLR, storm surge, extreme precipitation and extreme heat will impact public assets, including transportation networks, stormwater management, water supply, wastewater systems, public lands, and critical buildings. ***This Adaptation Plan was intended as a foundation upon which the City of Sarasota could build urban resilience***.

Community-wide resilience will require the City to work closely across the community while engaging citizens, businesses, and local organizations, as well as collaborating with government entities and public partners that jointly manage infrastructure resources. This initiative will require a multi-year commitment of resources and active participation and engagement across city departments. Implementation will require committed individuals to identify opportunities, prioritize actions, and provide expertise and inspiration to turn adaptation measures into infrastructure improvements.

The adaption measures outlined by this study will require funding. As with many projects in today's fiscally sensitive climate, funding for climate adaptation typically draws from a variety of financial resources. It is common for entities to look toward public-private partnerships, government programs, hazard preparedness and disaster relief assistance, grants, bonds, loans, and tax incentives. The intent is for this plan to better position the City to identify and target funding resources, leverage investment opportunities, and establish public-private partnerships to drive innovation and investment.

This Adaptation Plan provides a resource to promote sustainable development within the City. It provides guidelines to incorporate into existing and future projects and policies and it promotes cohesion to strengthen partnerships in order to implement measures to protect public assets from future climate threats.

A Closer Look at Drainage

The City met with Sarasota County during the course of this study to discuss revisions to the Sarasota County drainage model that covers the watershed basins within the City of Sarasota. Through an interlocal agreement, the City and County have plans to seek funding for revisions to the drainage model during 2018 and 2019. Revisions will incorporate on the 2100 NOAA intermediate high (6ft) projections as a baseline.

The City might consider a future modeling analyses specific to the City of Sarasota by incorporating higher resolution DEM and LiDAR data with refined infrastructure survey data. Additionally, future analyses might consider modeling inland rainfall associated with SLR, hurricanes and storm surge (i.e. SLOSH + SLR + inland precipitation) to get a full perspective of infrastructure threats as extreme rainfall events become more common.

Photo | Sherri Swanson

Some of the overarching measures recommended for implementation by this Adaptation Plan include:

RECOMMENDATION 1 Integration of the recommendations within this Adaptation Plan and future iterations of this plan into City policy and planning based on direction from the Sarasota City Commission to "utilize scientific climate data to better predict future impacts to Sarasota" in order to inform long-range land use planning, zoning, and administrative decisions.

RECOMMENDATION 2 Integration of climate projections into Capital Improvement Projects (CIP) and relevant requests for proposals and requests for qualifications (i.e. RFP, RFQ) to encourage a focus on climate resiliency early in project planning.

RECOMMENDATION 3 Support Sarasota County's city-wide drainage model revisions that will incorporate SLR and encourage additional model inputs to address future storm surge and extreme (inland) precipitation.

RECOMMENDATION 4 Identification and annual tracking of funding sources, including, but not limited to, public-private partnerships, tax-exempt and "pay for success" bonds (e.g. green bonds; environmental impact bonds), grant opportunities (e.g. government; not-for-profit), and federal programs (e.g. FEMA), as well as participation in teaming partnerships (e.g. Sarasota County, SBEP) to improve climate resiliency and facilitate the hazard mitigation measures addressed herein.

RECOMMENDATION 5 Establishment of a city resiliency fund to acquire public lands for habitat protection, stormwater management, innovative green/blue infrastructure projects, and an expansion of "leafy" corridors and public space.

RECOMMENDATION 6 Evaluation of opportunities to implement public assessments to fund climate resiliency projects that protect public infrastructure assets and public lands.

RECOMMENDATION 7 Development of a Heat Vulnerability Index to understand where people could be most vulnerable to heat-related stress from increased air temperature and humidity, and to understand the influence of warmer waters on HABs as relates to human and environmental health.

RECOMMENDATION 8 Development of a Regional Climate Council that promotes a diverse and collaborative organization with intergovernmental coordination and the private sector to encourage public-private partnerships that work together to solve climate challenges. Harnessing insights from government and the private sector will be critical to addressing the climate challenges faced by this region.

RECOMMENDATION 9 Expand upon this climate change study to identify opportunities for greater resiliency across business districts, neighborhoods, and industrial areas, which directly benefit the local economy, cultural heritage, and disaster avoidance, respectively.

RECOMMENDATION 10 Utilize the City of Sarasota Sustainability Department to identify funding, facilitate implementation of adaptation measures, and provide annual reporting to the City Commission on the recommendations set forth by this plan.

The City of Sarasota funded preparation of this Vulnerability Assessment and Climate Adaptation Plan as a first step toward greater climate preparedness. Over the next year, the goal will be to create a more detailed action plan with responsibilities assigned for each of the ten recommendations listed above. The hope is that this plan will encourage greater community involvement and strengthen partnerships to make this community stronger and more resilient. The City understands that a community that responds to protect infrastructure assets to ensure resiliency of public services will have a competitive advantage as climate change makes progressively greater impacts on the region. The City of Sarasota is fully committed to prioritizing these recommendations with the intent of achieving climate resiliency and striving to make this City an economically, socially and environmentally appealing place to live, work and visit for generations to come.

– The City of Sarasota

Where Urban Amenities meet Small-town Living.

Photo | Michael Mccormick

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Assessment Tools

Esri Geographic Information System (GIS) version 10.4.1

NOAA Digital Coast Sea Level Rise Mapper (www.coast.noaa.gov/digitalcoast/tools/slr)

NOAA's Coastal Flood Exposure Mapper (www.coast.noaa.gov/digitalcoast/tools/flood-exposure)

NOAA National Climatic Data Center/Cooperative Institute for Climate and Satellites (www.ncdc.noaa.gov)

NOAA Atlas 14 Point Precipitation Frequency Estimator (http://hdsc.nws.noaa.gov/hdsc/pfds/index.html)

NOAA Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model (www.nhc.noaa.gov/surge/slosh.php)

HDR

Graphic Design & Layout | *Michele Myers*

CITY OF SARASOTA
Climate Adaptation Plan

Appendix A

INFRASTRUCTURE INVENTORY

HDR

City of Sarasota Infrastructure Vulnerability Assessment - Asset Summary Table

Asset ID (Sector)	Local Name	Unique ID / Location	Vulnerability (Sensitivity x Adaptive Capacity)			Likelihood of Impact (2050)					Consequence (n=25)						Risk (n=125)
			Sensitivity (n=5)	Adaptive Capacity (n=5)	Overall Vulnerability (n=25)	SLR	CAT1 + SLR	CAT3 + SLR	ExP	AVG (n=5)	H	S	ECO	ENV	C&H	SUM	
WATER FEATURES																	
WF-1	Whitaker Bayou		4	4	**16**	5	5	5	5	**5.0**	5.0	5.0	4.0	5.0	4.0	**23.0**	**115.0**
WF-2	Payne Terminal	10th St.	3	2	**6**	5	5	5	5	**5.0**	3.0	3.0	3.0	3.0	3.0	**15.0**	**75.0**
WF-3	Hog Creek	Centennial Park; Mangrove Restoration	3	1	**3**	5	5	5	5	**5.0**	3.0	2.0	2.0	4.0	3.0	**14.0**	**70.0**
WF-4	Hudson Bayou	Connects to interior Canals	4	4	**16**	5	5	5	5	**5.0**	5.0	5.0	5.0	5.0	5.0	**25.0**	**125.0**
WF-5	Bird Key Canals	Bird Key	4	5	**20**	5	5	5	1	**4.0**	3.0	3.0	1.0	1.0	1.0	**9.0**	**36.0**
WF-6	St. Armand's Canals	St. Armand's	4	5	**20**	5	5	5	5	**5.0**	3.0	3.0	5.0	1.0	5.0	**17.0**	**85.0**
WF-7	Pansy Bayou	North Lido Park; National Estuary; Manatee Refuge	5	5	**25**	5	5	5	3	**4.5**	4.0	3.0	2.0	5.0	3.0	**17.0**	**76.5**
WF-8	Brushy Bayou	South Lido Park	4	4	**16**	5	5	5	3	**4.5**	4.0	1.0	4.0	5.0	3.0	**17.0**	**76.5**
WF-9	Hanson Bayou	Siesta Key Residential Canal @ Siesta Dr.	3	4	**12**	5	5	5	2	**4.3**	3.0	2.0	1.0	2.0	1.0	**9.0**	**38.3**
WF-10	Bayou Louise	Siesta Key Residential Canal	4	4	**16**	5	5	5	2	**4.3**	3.0	2.0	1.0	2.0	1.0	**9.0**	**38.3**
WF-11	Philippe Creek (Main B)	Considers segment within the City Limits	3	5	**15**	1	3	5	5	**3.5**	4.0	4.0	3.0	5.0	5.0	**21.0**	**73.5**
PUBLIC SHORELINES																	
CR-1	Gulf of Mexico		3	2	**6**	2	3	3	3	**2.8**	5.0	5.0	5.0	5.0	3.0	**23.0**	**63.3**
CR-2	Sarasota Bay Estuary	National Estuary	5	3	**15**	2	3	4	5	**3.5**	4.0	3.0	5.0	5.0	5.0	**22.0**	**77.0**
CR-3	Mangrove Shorelines		3	1	**3**	3	4	5	1	**3.3**	3.0	5.0	5.0	5.0	3.0	**21.0**	**68.3**
CR-4	Seawalls		4	4	**16**	5	5	5	5	**5.0**	1.0	5.0	4.0	2.0	1.0	**13.0**	**65.0**
CR-5	Rip Rap (or hardened)		4	2	**8**	5	5	5	3	**4.5**	0.0	5.0	3.0	1.0	0.0	**9.0**	**40.5**
CR-6	Living Shorelines	Several Projects	3	1	**3**	4	5	5	2	**4.0**	1.0	5.0	5.0	5.0	3.0	**19.0**	**76.0**
TRANSPORTATION																	
T-1	Seminole Gulf Railroad		1	1	**1**	0	1	4	3	**2.0**	1.0	1.0	1.7	1.0	1.0	**5.7**	**11.4**
T-2	Sarasota-Bradenton International Airport		2	4	**8**	0	3	5	4	**3.0**	3.3	4.0	4.6	2.0	2.0	**15.9**	**47.7**
T-3	Bayfront Marina	Private Marina @ Bayfront Park	5	3	**15**	5	5	5	2	**4.3**	2.3	2.3	3.6	2.7	4.0	**14.9**	**63.3**
T-4	10th Street Boat Ramp	Centennial Park	4	4	**16**	5	5	5	5	**5.0**	2.3	4.5	4.0	2.5	3.0	**16.3**	**81.5**
T-5	Bee Ridge Road (SR 758)		1	5	**5**	0	0	1	1	**0.5**	3.0	4.0	3.3	2.0	1.0	**13.3**	**6.7**
T-6	Waldemere St.	Sarasota Memorial Hospital Access Only	1	5	**5**	0	1	5	3	**2.3**	4.3	4.0	3.0	1.7	2.0	**15.0**	**33.8**
T-7	Beneva Road	Segment within City	1	0	**0**	0	0	2	3	**1.3**	2.3	3.3	3.0	2.3	2.0	**12.9**	**16.1**
T-8	Main Street		4	4	**16**	3	5	5	3	**4.0**	3.5	3.0	4.5	3.0	5.0	**19.0**	**76.0**
T-9	Fruitville (SR 780)	Segment near US41 (Tamiami Trail) to US301	4	3	**12**	2	5	5	4	**4.0**	3.7	4.3	4.3	2.7	2.0	**17.0**	**68.0**
T-10	Ringling Blvd.		5	4	**20**	3	5	5	4	**4.3**	3.3	3.7	3.7	2.7	3.3	**16.7**	**71.0**
T-11	Siesta Drive (SR 758)		5	4	**20**	3	5	5	3	**4.0**	2.7	4.3	4.3	3.3	3.0	**17.6**	**70.4**
T-12	U.S.41 (SR 45)	Round-abouts 14th, 10th, Fruitville, Gulfstream	5	5	**25**	2	5	5	4	**4.0**	3.0	4.5	4.2	2.3	2.0	**16.0**	**64.0**
T-13	U.S. 301 (SR 683)		1	5	**5**	1	2	3	2	**2.0**	3.7	3.7	3.7	2.0	2.0	**15.1**	**30.2**
T-14	University Pkwy		3	4	**12**	0	0	5	3	**2.0**	3.7	4.3	4.0	3.3	2.3	**17.6**	**35.2**
T-15	Little Ringling Bridge at Coon Key (N/S)	170022/170951	5	4.5	**22.5**	2	5	5	1	**3.3**	4.3	5.0	5.0	3.5	2.0	**19.8**	**64.4**
T-16	John Ringling Bridge (SR789) (N/S)	170120/170141	5	5	**25**	2	4	5	2	**3.3**	4.3	5.0	4.5	3.7	3.3	**20.8**	**67.6**

City of Sarasota Infrastructure Vulnerability Assessment - Asset Summary Table

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			Sensitivity (n=5)	Adaptive Capacity (n=5)	Overall Vulnerability (n=25)	SLR	CAT1 + SLR	CAT3 + SLR	ExP	AVG (n=5)	H	S	ECO	ENV	C&H	SUM	
T-17	John Ringling Causeway	170176	5	5	**25**	4	5	5	4	**4.5**	4.3	5.0	4.3	3.7	1.3	**18.6**	**83.7**
T-18	J. Ringling Culverts at St. Armand's		5	4	**20**	4	5	5	5	**4.8**	3.7	4.3	3.7	2.7	1.0	**15.4**	**73.2**
T-19	SR789 Over Newpass	170158	5	4	**20**	1	4	5	1	**2.8**	4.3	5.0	4.3	2.0	1.7	**17.3**	**47.6**
T-20	SR 789 over Pansy Bayou		5	4	**20**	1	4	5	3	**3.3**	4.3	5.0	4.0	3.7	2.3	**19.3**	**62.7**
T-21	SR789 Causeway over Pansy Bayou		5	4	**20**	5	5	5	4	**4.8**	4.3	5.0	4.0	3.7	2.0	**19.0**	**90.3**
T-22	S. Blvd Presidents Bridge	175600	5	3	**15**	3	5	5	4	**4.3**	3.0	3.3	2.0	2.0	1.3	**11.6**	**49.3**
T-23	Bird Key Dr. Bridge 1	175575	5	3	**15**	3	5	5	1	**3.5**	3.3	3.7	2.0	1.7	1.0	**11.7**	**41.0**
T-24	Bird Key Dr. Bridge 2	175620	5	3	**15**	3	5	5	1	**3.5**	3.3	3.7	2.0	1.7	1.0	**11.7**	**41.0**
T-25	Wild Turkey Ln. Bridge	175550	5	3	**15**	3	5	5	1	**3.5**	3.3	3.7	2.0	1.7	1.0	**11.7**	**41.0**
T-26	Pheasant Dr. Bridge	175615	5	3	**15**	3	5	5	1	**3.5**	3.3	3.7	2.0	1.7	1.0	**11.7**	**41.0**
T-27	US41 (SR45) Bridge over Whitaker Bayou	170920	4	4	**16**	3	5	5	5	**4.5**	4.0	4.0	3.7	2.3	1.3	**15.3**	**68.9**
T-28	Orange Ave. Bridge over Hudson Bayou	175624	2	4	**8**	3	5	5	3	**4.0**	3.0	2.7	2.0	2.3	1.7	**11.7**	**46.8**
T-29	Osprey Ave. Bridge over Hudson Bayou	175950	4	3	**12**	2	5	5	3	**3.8**	3.0	3.7	2.3	2.0	1.3	**12.3**	**46.1**
T-30	US41 (SR45) Bridge over Hudson Bayou	170019	4	4	**16**	2	5	5	3	**3.8**	4.0	4.7	4.3	2.7	2.3	**18.0**	**67.5**
T-31	Siesta Key Draw Bridge	170061	5	5	**25**	2	4	5	2	**3.3**	4.3	5.0	4.3	3.7	3.7	**21.0**	**68.3**
T-32	SR-758 (Siesta Drive) Bridge at Hanson Bayou	170060	5	1	**5**	5	5	5	5	**5.0**	4.0	4.7	4.3	2.7	2.3	**18.0**	**90.0**
T-33	Siesta Drive Bridge over Bayou Louse	175505	5	1	**5**	5	5	5	3	**4.5**	3.0	3.0	3.0	2.0	1.0	**12.0**	**54.0**
T-34	Dr. Martin Luther King Jr. Way		3	3	**9**	0	4	5	4	**3.3**	5.0	3.0	3.0	2.0	5.0	**18.0**	**58.5**
CRITICAL BUILDINGS																	
BD-1	Emergency Operations Center	2099 Adams Lane	1	2	**2**	0	1	1	3	**1.3**	1.0	5.0	3.0	2.0	1.0	**12.0**	**15.0**
BD-2	Public Works Buildings	1761 12th Street	2	3	**6**	0	1	4	3	**2.0**	4.0	3.0	3.0	4.0	1.0	**15.0**	**30.0**
BD-3	Utilities Operation Buildings	1750 12th Street	2	5	**10**	0	1	4	3	**2.0**	5.0	5.0	5.0	5.0	1.0	**21.0**	**42.0**
BD-4	Federal Building	111 South Orange	2	3	**6**	0	5	5	5	**3.8**	1.0	1.0	4.0	2.0	5.0	**13.0**	**48.8**
BD-5	City Hall	1565 1st Street	2	3	**6**	0	1	5	4	**2.5**	1.0	2.0	4.0	2.0	4.0	**13.0**	**32.5**
BD-6	Sarasota County Sheriff's Office	2071 Ringling Blvd	1	2	**2**	0	1	1	3	**1.3**	3.0	5.0	5.0	2.0	1.0	**16.0**	**20.0**
BD-7	Sarasota County Fire Dept. Station 1	1445 4th Street	2	2	**4**	0	0	4	1	**1.3**	5.0	5.0	3.0	2.0	1.0	**16.0**	**20.0**
BD-8	Sarasota County Fire Dept. Station 2	2070 Waldemere Street	2	2	**4**	0	1	4	4	**2.3**	5.0	5.0	3.0	2.0	1.0	**16.0**	**36.0**
BD-9	Sarasota County Fire Dept. Station 3	47 N Adams Dr. (St. Armand's Circle)	1	1	**1**	4	5	5	5	**4.8**	5.0	5.0	3.0	2.0	1.0	**16.0**	**76.0**
BD-10	Sarasota County Fire Dept. Station 4	3530 Old Bradenton Road	2	2	**4**	0	0	5	3	**2.0**	5.0	5.0	3.0	2.0	1.0	**16.0**	**32.0**
BD-11	Sarasota County Fire Dept. Station 5	400 N Beneva Road	1	5	**5**	0	0	1	2	**0.8**	5.0	5.0	2.0	2.0	1.0	**15.0**	**11.3**
BD-12	City Sarasota Facilities Buildings	890 Central Ave	0	0	**0**	0	5	5	5	**3.8**	1.0	2.0	1.0	1.0	1.0	**6.0**	**22.5**
BD-13	Sarasota Memorial Hospital	1700 S Tamiami Trail	2	5	**10**	0	1	4	3	**2.0**	5.0	5.0	5.0	4.0	2.0	**21.0**	**42.0**
BD-14	City-owned Parcel (G. Wiz & Van Wezel)	1001 Blvd of the Arts	5	4	**20**	3	5	5	3	**4.0**	3.0	3.0	5.0	3.0	5.0	**19.0**	**76.0**
WATER SUPPLY																	
WS-1	Verna Well Fields	6300 West Verna Road	1	2	**2**	0	0	0	4	**1.0**	4.0	4.0	4.0	2.0	2.0	**16.0**	**16.0**
WS-2	Water Treatment Plant	1642 12th Street	2	2	**4**	0	2	5	5	**3.0**	4.0	4.0	4.0	2.0	2.0	**16.0**	**48.0**

City of Sarasota Infrastructure Vulnerability Assessment - Asset Summary Table

Asset ID (Sector)	Local Name	Unique ID / Location	Vulnerability (Sensitivity x Adaptive Capacity)			Likelihood of Impact (2050)					Consequence (n=25)						Risk (n=125)
			Sensitivity (n=5)	Adaptive Capacity (n=5)	Overall Vulnerability (n=25)	SLR	CAT1 + SLR	CAT3 + SLR	ExP	AVG (n=5)	H	S	ECO	ENV	C&H	SUM	
WS-3	South Water Tower Park	Elevated tank	1	1	**1**	0	0	0	1	**0.3**	4.0	4.0	4.0	2.0	2.0	**16.0**	**4.0**
WS-4	North Water Tower Park	Elevated tank	2	1	**2**	0	0	5	4	**2.3**	4.0	4.0	4.0	2.0	2.0	**16.0**	**36.0**
WS-5	Circus Ground Storage Tank/Pump Station		1	1	**1**	0	0	5	5	**2.5**	4.0	4.0	4.0	2.0	2.0	**16.0**	**40.0**
WS-6	Deep Injection Well		1	1	**1**	0	1	4	3	**2.0**	4.0	4.0	4.0	2.0	2.0	**16.0**	**32.0**
WS-7	Sea Water Intake Structure		4	2	**8**	5	5	5	1	**4.0**	4.0	4.0	4.0	2.0	2.0	**16.0**	**64.0**
WS-8	City Well Withdrawal Point	Well #1 @ 22nd Street	4	1	**4**	5	5	5	2	**4.3**	4.0	4.0	4.0	2.0	2.0	**16.0**	**68.0**
WS-9	City Well Withdrawal Point	Well #2 @ Alameda Ave.	4	1	**4**	5	5	5	2	**4.3**	4.0	4.0	4.0	2.0	2.0	**16.0**	**68.0**
WS-10	City Well Withdrawal Point	Well #3 @ Hickory Ave.	3	1	**3**	3	5	5	1	**3.5**	4.0	4.0	4.0	2.0	2.0	**16.0**	**56.0**
WS-11	City Well Withdrawal Point	Well #4 @ Panama Drive	3	1	**3**	5	5	5	2	**4.3**	4.0	4.0	4.0	2.0	2.0	**16.0**	**68.0**
WS-12	City Well Withdrawal Point	Well #5 @ 23rd Street	3	1	**3**	3	5	5	2	**3.8**	4.0	4.0	4.0	2.0	2.0	**16.0**	**60.0**
WS-13	City Well Withdrawal Point	Well #6 @ 21st Street	2	1	**2**	0	5	5	1	**2.8**	4.0	4.0	4.0	2.0	2.0	**16.0**	**44.0**
WS-14	City Well Withdrawal Point	Well #7 @ Goodrich Ave.	1	1	**1**	0	0	5	2	**1.8**	4.0	4.0	4.0	2.0	2.0	**16.0**	**28.0**
WS-15	City Well Withdrawal Point	Well #8 @ 18th Street	1	1	**1**	0	0	5	5	**2.5**	4.0	4.0	4.0	2.0	2.0	**16.0**	**40.0**
WS-16	City Well Withdrawal Point	Well #9 @ 11th Street	3	1	**3**	0	0	5	5	**2.5**	4.0	4.0	4.0	2.0	2.0	**16.0**	**40.0**
WS-17	City Well Withdrawal Point	Well #10 @ RR Track	2	1	**2**	0	0	5	5	**2.5**	4.0	4.0	4.0	2.0	2.0	**16.0**	**40.0**
WS-18	Pipes		1	1	**1**	0	3	5	5	**3.3**	4.0	4.0	4.0	2.0	2.0	**16.0**	**52.0**
WS-19	Raw 30inch lines		1	1	**1**	0	3	5	5	**3.3**	4.0	4.0	4.0	2.0	2.0	**16.0**	**52.0**
WS-20	Potable Water Gate Valves		1	1	**1**	0	3	5	5	**3.3**	4.0	4.0	4.0	2.0	2.0	**16.0**	**52.0**
WS-21	Potable Water Mains		1	1	**1**	0	3	5	5	**3.3**	4.0	2.0	4.0	2.0	2.0	**14.0**	**45.5**
WASTEWATER																	
WW-1	Waste Water Treatment Plant	1850 12th Street	1	4	**4**	0	2	5	5	**3.0**	4.0	2.0	4.0	4.0	2.0	**16.0**	**48.0**
WW-2	Waste Water Lift Station #1	Flores Avenue	3	1	**3**	0	5	5	2	**3.0**	4.0	2.0	4.0	4.0	2.0	**16.0**	**48.0**
WW-3	Waste Water Lift Station #2	Harmony Lane	4	1	**4**	3	5	5	4	**4.3**	4.0	2.0	4.0	4.0	2.0	**16.0**	**68.0**
WW-4	Waste Water Lift Station #3	Siesta Drive	4	1	**4**	3	5	5	5	**4.5**	4.0	**2.0**	4.0	4.0	2.0	**16.0**	**72.0**
WW-5	Waste Water Lift Station #7	Pomelo Avenue (to be replaced by LS87)	2	3	**6**	1	5	5	1	**3.0**	4.0	2.0	4.0	4.0	2.0	**16.0**	**48.0**
WW-6	Waste Water Lift Station #8	10th St. & Cocoanut Ave.	3	1	**3**	1	5	5	3	**3.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**56.0**
WW-7	Waste Water Lift Station #9	Bayshore Circle	4	1	**4**	1	5	5	5	**4.0**	4.0	2.0	4.0	4.0	2.0	**16.0**	**64.0**
WW-8	Waste Water Lift Station #10	US 41 at Whitaker Bayou	3	2	**6**	3	5	5	3	**4.0**	4.0	**2.0**	4.0	4.0	2.0	**16.0**	**64.0**
WW-9	Waste Water Lift Station #13	Calliandra Dr.	1	1	**1**	0	0	0	5	**1.3**	4.0	2.0	4.0	4.0	2.0	**16.0**	**20.0**
WW-10	Waste Water Lift Station #16	Gulfstream Avenue	4	3	**12**	2	5	5	4	**4.0**	4.0	2.0	4.0	4.0	2.0	**16.0**	**64.0**
WW-11	Waste Water Lift Station #17	Ohio Place	4	2	**8**	2	5	5	5	**4.3**	4.0	2.0	4.0	4.0	2.0	**16.0**	**68.0**
WW-12	Waste Water Lift Station #21	Bayshore Road	4	1	**4**	1	5	5	3	**3.5**	4.0	**2.0**	4.0	4.0	2.0	**16.0**	**56.0**
WW-13	Waste Water Lift Station #27	Bahia Vista at Phillippi Creek	2	2	**4**	3	5	5	3	**4.0**	4.0	2.0	4.0	4.0	2.0	**16.0**	**64.0**
WW-14	Waste Water Lift Station #30	Blvd. of Pres. & Monroe Dr.	4	1	**4**	3	5	5	5	**4.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**72.0**
WW-15	Waste Water Lift Station #31	Blvd. of Pres. & Cleveland	4	1	**4**	3	5	5	5	**4.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**72.0**

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			Sensitivity (n=5)	Adaptive Capacity (n=5)	Overall Vulnerability (n=25)	SLR	CAT1 + SLR	CAT3 + SLR	ExP	AVG (n=5)	H	S	ECO	ENV	C&H	SUM	
WW-16	Waste Water Lift Station #33	Bird Key Drive	3	1	**3**	2	5	5	1	**3.3**	4.0	2.0	4.0	4.0	2.0	**16.0**	**52.0**
WW-17	Waste Water Lift Station #38	Rilma Avenue	2	1	**2**	0	0	5	5	**2.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**40.0**
WW-18	Waste Water Lift Station #39	Hillview Street	2	1	**2**	0	5	5	5	**3.8**	4.0	2.0	4.0	4.0	2.0	**16.0**	**60.0**
WW-19	Waste Water Lift Station #40	8th St. & Shade Ave	1	1	**1**	0	0	0	3	**0.8**	4.0	2.0	4.0	4.0	2.0	**16.0**	**12.0**
WW-20	Waste Water Lift Station #52	Fruitville Rd	1	1	**1**	0	0	5	3	**2.0**	4.0	2.0	4.0	4.0	2.0	**16.0**	**32.0**
WW-21	Waste Water Lift Station #61	Oakwood Manor	1	1	**1**	0	0	5	1	**1.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**24.0**
WW-22	Waste Water Lift Station #86	11th Street	2	1	**2**	1	5	5	3	**3.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**56.0**
WW-23	Waste Water Lift Station #88	21st Street	1	1	**1**	0	0	0	5	**1.3**	4.0	2.0	4.0	4.0	2.0	**16.0**	**20.0**
WW-24	Waste Water Lift Station #89	Van Wezel Parcel	3	1	**3**	2	5	5	2	**3.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**56.0**
WW-25	Waste Water Lift Station #87	Future Asset	1	1	**1**	0	5	5	1	**2.8**	4.0	2.0	4.0	4.0	2.0	**16.0**	**44.0**
WW-26	Waste Water Gate Valve (GV) #72	17-072	1	1	**1**	**2**	**5**	**5**	**3**	**3.8**	4.0	2.0	4.0	4.0	2.0	**16.0**	**60.0**
WW-27	Waste Water Gate Valve (GV) #71	17-071	1	1	**1**	**1**	**5**	**5**	**3**	**3.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**56.0**
WW-28	Waste Water Gate Valve (GV) #99	18-099	1	1	**1**	**1**	**2**	**5**	**3**	**2.8**	4.0	2.0	4.0	4.0	2.0	**16.0**	**44.0**
WW-29	Waste Water Gate Valve (GV) #75	18-075	1	1	**1**	**1**	**1**	**5**	**3**	**2.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**40.0**
WW-30	Waste Water Gate Valve (GV) #15	29-015	1	1	**1**	**1**	**1**	**4**	**5**	**2.8**	4.0	2.0	4.0	4.0	2.0	**16.0**	**44.0**
WW-31	Waste Water Gate Valve (GV) #64	23-064	1	1	**1**	**1**	**1**	**4**	**1**	**1.8**	4.0	2.0	4.0	4.0	2.0	**16.0**	**28.0**
WW-32	Waste Water Gate Valve (GV) #6	17-006	1	1	**1**	**1**	**5**	**5**	**1**	**3.0**	4.0	2.0	4.0	4.0	2.0	**16.0**	**48.0**
WW-33	Waste Water Gate Valve (GV) #12	17-012	1	1	**1**	**1**	**5**	**5**	**3**	**3.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**56.0**
WW-34	Waste Water Force Mains		2	1	**2**	1	3	3	3	**2.5**	4.0	2.0	4.0	4.0	2.0	**16.0**	**40.0**
STORMWATER																	
SW-1	Stormwater Manholes	Throughout City	3	2	**6**	0	5	5	5	**3.8**	1.0	3.0	3.0	1.0	1.0	**9.0**	**33.8**
SW-2	Stormwater Baffle Boxes	Throughout City	3	3	**9**	0	5	5	5	**3.8**	2.0	1.0	3.0	3.0	1.0	**10.0**	**37.5**
SW-3	Stormwater Drop Structure(s)	Throughout City	4	4	**16**	0	5	5	5	**3.8**	2.0	2.0	3.0	2.0	1.0	**10.0**	**37.5**
SW-4	FDOT Outfall	US41/Whitaker Bayou Bridge (SW corner)	4	5	**20**	5	5	5	5	**5.0**	2.0	4.0	3.0	3.0	1.0	**13.0**	**65.0**
SW-5	City Outfall	MLK bridge @ Whitaker Bayou (NW corner)	4	4	**16**	5	5	5	5	**5.0**	2.0	4.0	3.0	3.0	3.0	**15.0**	**75.0**
SW-6	FDOT Outfall	Hudson Bayou @ US41 (SW corner)	4	4	**16**	5	5	5	5	**5.0**	3.0	4.0	5.0	3.0	3.0	**18.0**	**90.0**
SW-7	City Outfall	Harbor Drive	4	4	**16**	5	5	5	5	**5.0**	3.0	4.0	4.0	3.0	2.0	**16.0**	**80.0**
SW-8	City Outfall	Marina Jack @ Ringling Blvd.	5	4	**20**	5	5	5	5	**5.0**	3.0	4.0	4.0	3.0	3.0	**17.0**	**85.0**
SW-9	City Outfall	40th St. @ Bayshore Rd.	3	2	**6**	5	5	5	2	**4.3**	3.0	3.0	3.0	3.0	2.0	**14.0**	**59.5**
SW-10	City Outfall	Sun Cir. @ Sapphire Dr.	3	3	**9**	5	5	5	2	**4.3**	2.0	3.0	3.0	2.0	2.0	**12.0**	**51.0**
SW-11	City Outfall	Ringling Museum Property west of Capels Dr.	5	5	**25**	5	5	5	2	**4.3**	3.0	3.0	3.0	3.0	4.0	**16.0**	**68.0**
SW-12	City Outfall	Whitaker Bayou west of Lemon Ave. near RR	5	3	**15**	5	5	5	5	**5.0**	3.0	3.0	3.0	3.0	3.0	**15.0**	**75.0**
SW-13	City Outfall	10th Street @ US41	5	5	**25**	5	5	5	5	**5.0**	4.0	5.0	5.0	3.0	3.0	**20.0**	**100.0**
SW-14	City Outfall	10th Street @ US41	5	5	**25**	5	5	5	5	**5.0**	4.0	5.0	5.0	3.0	3.0	**20.0**	**100.0**
SW-15	FDOT Outfall	US41/Whitaker Bayou Bridge @ NE corner (SW-4)	4	5	**20**	5	5	5	5	**5.0**	2.0	5.0	3.0	3.0	3.0	**16.0**	**80.0**
SW-16	City Outfall - Open Channel / Catchment	Hudson Bayou - Osprey Bridge to E of US41 bridge	4	4	**16**	5	5	5	5	**5.0**	5.0	4.0	4.0	5.0	2.0	**20.0**	**100.0**
SW-17	City Outfall - Open Channel / Catchment	Hudson Bayou @ Central Park Condo	3	3	**9**	5	5	5	5	**5.0**	4.0	1.0	1.0	4.0	1.0	**11.0**	**55.0**
SW-18	City Outfall - Open Channel	Whitaker Bayou - 32nd St. Bridge to N. Riverside Dr.	4	4	**16**	1	5	5	5	**4.0**	4.0	3.0	3.0	4.0	2.0	**16.0**	**64.0**

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			Sensitivity (n=5)	Adaptive Capacity (n=5)	Overall Vulnerability (n=25)	SLR	CAT1 + SLR	CAT3 + SLR	ExP	AVG (n=5)	H	S	ECO	ENV	C&H	SUM	
SW-19	City Outfall - Open Channel	Whitaker Bayou @ Cocoaunt Bridge	3	3	**9**	3	5	5	5	**4.5**	5.0	4.0	3.0	5.0	2.0	**19.0**	**85.5**
SW-20	City Outfall - Open Channel	Hudson Bayou - Alderman St. to Pine St. Lane	4	4	**16**	3	5	5	3	**4.0**	5.0	4.0	3.0	5.0	2.0	**19.0**	**76.0**
SW-21	City Outfall - Open Channel	Connects @ Bay/Centennial Park	3	3	**9**	5	5	5	5	**5.0**	4.0	3.0	2.0	4.0	2.0	**15.0**	**75.0**
SW-22	Other Open Channel (tidal influence)	Throughout City	3	3	**9**	5	5	5	5	**5.0**	5.0	4.0	4.0	5.0	3.0	**21.0**	**105.0**
SW-23	NPDES Outfall	North of Bahia Vista along Phillippi Creek	3	3	**9**	2	5	5	5	**4.3**	5.0	5.0	4.0	2.0	2.0	**18.0**	**76.5**
SW-24	NPDES Outfall	North of Bahia Vista along Phillippi Creek	3	3	**9**	2	5	5	5	**4.3**	5.0	5.0	4.0	2.0	2.0	**18.0**	**76.5**
SW-25	FDOT Outfall	SR45 @ Golden Gate Tidal Basin	5	4	**20**	5	5	5	5	**5.0**	2.0	5.0	4.0	2.0	1.0	**14.0**	**70.0**
SW-26	FDOT Outfall	SR45 @ Marina Jack Boat Basin	5	4	**20**	5	5	5	5	**5.0**	2.0	5.0	4.0	2.0	1.0	**14.0**	**70.0**
SW-27	FDOT Outfall	SR780; North of Fruitville @ RR (west of Lime)	1	1	**1**	0	0	0	3	**0.8**	4.0	5.0	3.0	3.0	2.0	**17.0**	**12.8**
SW-28	FDOT Outfall	SR 780 (Fruitville Road)	2	2	**4**	1	1	1	5	**2.0**	2.0	5.0	3.0	2.0	2.0	**14.0**	**28.0**
SW-29	FDOT Outfall	SR 789 - St. Armand's	0	4	**0**	5	5	5	5	**5.0**	3.0	5.0	5.0	2.0	3.0	**18.0**	**90.0**
SW-30	FDOT Outfall	Hudson Bayou @ US41	4	4	**16**	3	5	5	5	**4.5**	3.0	5.0	5.0	2.0	3.0	**18.0**	**81.0**
SW-31	WR_08312002_0119	Canal behind 1379 MLK Pond Strux	4	2	**8**	1	5	5	5	**4.0**	2.0	1.0	2.0	2.0	1.0	**8.0**	**32.0**
SW-32	WR_03032009_101326	E of Old Bradenton Rd E of Whitaker Canal 3-1	1	3	**3**	1	5	5	3	**3.5**	2.0	2.0	1.0	2.0	1.0	**8.0**	**28.0**
SW-33	WR_02172009_113026	E of Old Bradenton Rd E of Whitaker Canal 3-1	1	3	**3**	1	5	5	5	**4.0**	2.0	2.0	1.0	2.0	1.0	**8.0**	**32.0**
SW-34	WR_03032009_100317	E of Old Bradenton Rd E of Whitaker Canal 3-1	1	3	**3**	1	5	5	4	**3.8**	2.0	2.0	1.0	2.0	1.0	**8.0**	**30.0**
SW-35	WR_03242009_152816	St. Armand's Key @ Blvd. of the Arts	5	5	**25**	2	5	5	3	**3.8**	2.0	2.0	1.0	2.0	1.0	**8.0**	**30.0**
SW-36	WR_03242009_130832	St. Armand's Key @ Blvd. of the Arts @ S. Lido	5	5	**25**	3	5	5	5	**4.5**	2.0	2.0	3.0	2.0	1.0	**10.0**	**45.0**
SW-37	WR_05272008_154820	Arlington Park Pond CL56-4	1	3	**3**	1	5	5	5	**4.0**	1.0	1.0	1.0	1.0	1.0	**5.0**	**20.0**
SW-38	WR_05132008_131723	Hatten and Shade - Canal 4-51 Hudson Canal	3	3	**9**	1	2	5	5	**3.3**	2.0	1.0	2.0	1.0	1.0	**7.0**	**22.8**
SW-39	WR_09092009_115600	Norasota Way	5	5	**25**	1	5	5	1	**3.0**	1.0	3.0	3.0	1.0	1.0	**9.0**	**27.0**
SW-40	WR_10222008_151243	Lake Ridge near Lockwood and 12th (Lateral BB)	1	3	**3**	1	2	5	5	**3.3**	1.0	2.0	2.0	1.0	1.0	**7.0**	**22.8**
SW-41	WR_05272008_164244	Jefferson Ave Canal Behind 2504 Arlington St.	1	3	**3**	1	5	5	5	**4.0**	1.0	2.0	2.0	1.0	1.0	**7.0**	**28.0**
SW-42	WR_07172008_094849	Sarasota HS Mote/ East of US41 (Hudson Canal 4-51)	3	3	**9**	5	5	5	3	**4.5**	1.0	1.0	1.0	1.0	1.0	**5.0**	**22.5**
SW-43	WR_10302010_4739	Fruitville Rd south of Bobby Jone (Canal C4-36)	2	3	**6**	1	2	5	5	**3.3**	1.0	1.0	1.0	1.0	1.0	**5.0**	**16.3**
SW-44	WR_12122014_111308	East of Osprey; South of Mound; West of US41	5	3	**15**	5	5	5	3	**4.5**	3.0	2.0	2.0	2.0	1.0	**10.0**	**45.0**
SW-45	WR_05152015_005826	Main B-1; SW of Beneva and Fruitville (Phillippi Creek Main B)	2	3	**6**	1	5	5	5	**4.0**	2.0	1.0	1.0	1.0	1.0	**6.0**	**24.0**
SW-46	NS_08222008_082723	Pump Station: Lockwood Ridge@ Greer Dr	2	1	**2**	1	5	5	3	**3.5**	5.0	5.0	5.0	3.0	2.0	**20.0**	**70.0**
SW-47	NS_03252009_094010	Pump Station: Madison Dr./ Blvd of Presidents	5	5	**25**	1	5	5	5	**4.0**	5.0	5.0	5.0	3.0	5.0	**23.0**	**92.0**
SW-48	NS_03262009_085415	Pump Station: Jackson Dr. /S Blvd of Presidents	5	5	**25**	1	5	5	1	**3.0**	5.0	5.0	5.0	3.0	5.0	**23.0**	**69.0**
SW-49	NS_03252009_090438	Pump Station: Washington Dr. /N Blvd of Presidents	5	5	**25**	1	5	5	5	**4.0**	5.0	5.0	5.0	3.0	5.0	**23.0**	**92.0**
SW-50	NS_03252009_124306	Pump Station: John Ringling Blvd/ Washington	5	5	**25**	1	5	5	3	**3.5**	5.0	5.0	5.0	3.0	5.0	**23.0**	**80.5**
SW-51	NS_03252009_082203	Pump Station: E. Madison Dr./ N. Washington Dr	5	5	**25**	1	5	5	5	**4.0**	5.0	5.0	5.0	3.0	5.0	**23.0**	**92.0**
SW-52	Drainage Outfalls (Pipes)	Throughout City; variable size; tidal discharge	5	3	**15**	4	5	5	5	**4.8**	3.0	3.0	4.0	2.0	3.0	**15.0**	**71.3**
PUBLIC LANDS																	
P-1	Arlington Park		3	4	**12**	0	5	5	5	**3.8**	4.0	1.0	4.0	1.0	3.0	**13.0**	**48.8**
P-2	Avion Park		1	1	**1**	0	0	0	0	**0.0**	2.0	1.0	1.0	1.0	1.0	**6.0**	**0.0**

City of Sarasota Infrastructure Vulnerability Assessment - Asset Summary Table

Asset ID (Sector)	Local Name	Unique ID / Location	Vulnerability (Sensitivity x Adaptive Capacity)			Likelihood of Impact (2050)					Consequence (n=25)						Risk (n=125)
			Sensitivity (n=5)	Adaptive Capacity (n=5)	Overall Vulnerability (n=25)	SLR	CAT1 + SLR	CAT3 + SLR	ExP	AVG (n=5)	H	S	ECO	ENV	C&H	SUM	
P-3	Babe Ruth Park		0	0	**0**	0	0	3	3	**1.5**	0.0	0.0	0.0	0.0	0.0	**0.0**	**0.0**
P-4	Bayfront Marina Park		5	5	**25**	5	5	5	5	**5.0**	4.0	2.0	4.0	4.0	4.0	**18.0**	**90.0**
P-5	Bayfront Park East 41		5	3	**15**	2	5	5	5	**4.3**	1.0	1.0	1.0	1.0	4.0	**8.0**	**34.0**
P-6	Beneva / Fruitville Park		1	2	**2**	0	0	4	2	**1.5**	1.0	1.0	1.0	1.0	1.0	**5.0**	**7.5**
P-7	Bird Key Park		5	5	**25**	5	5	5	5	**5.0**	2.0	1.0	3.0	5.0	3.0	**14.0**	**70.0**
P-8	Bobby Jones Golf Course		3	3	**9**	0	2	5	5	**3.0**	4.0	1.0	4.0	3.0	4.0	**16.0**	**48.0**
P-9	Centennial Park	10th St. boat ramp	5	5	**25**	3	5	5	5	**4.5**	4.0	1.0	3.0	3.0	3.0	**14.0**	**63.0**
P-10	Charles Ringling Park	Ringling Blvd.	0	0	**0**	0	5	5	5	**3.8**	1.0	1.0	1.0	1.0	1.0	**5.0**	**18.8**
P-11	Circus Hammock		2	1	**2**	0	1	5	5	**2.8**	1.0	1.0	1.0	4.0	2.0	**9.0**	**24.8**
P-12	Dr. Martin Luther King Jr. Park		5	3	**15**	4	5	5	5	**4.8**	3.0	1.0	2.0	1.0	3.0	**10.0**	**47.5**
P-13	Eastwood Park		0	0	**0**	0	0	5	2	**1.8**	2.0	1.0	2.0	1.0	1.0	**7.0**	**12.3**
P-14	Ed Smith Complex		1	1	**1**	0	1	0	3	**1.0**	4.0	1.0	5.0	1.0	5.0	**16.0**	**16.0**
P-15	Eloise Werlin Park	Ringling Causeway	5	5	**25**	5	5	5	5	**5.0**	3.0	1.0	3.0	2.0	4.0	**13.0**	**65.0**
P-16	Firehouse Park		1	3	**3**	0	2	5	3	**2.5**	2.0	1.0	1.0	1.0	1.0	**6.0**	**15.0**
P-17	Fredd Atkins Park		2	3	**6**	0	0	0	5	**1.3**	2.0	1.0	2.0	1.0	3.0	**9.0**	**11.3**
P-18	Galvin Park		0	0	**0**	1	5	5	1	**3.0**	2.0	1.0	2.0	1.0	1.0	**7.0**	**21.0**
P-19	Gillespie Park		2	3	**6**	0	1	5	5	**2.8**	4.0	1.0	3.0	1.0	4.0	**13.0**	**35.8**
P-20	Indian Beach Park		5	4	**20**	5	5	5	5	**5.0**	1.0	1.0	1.0	1.0	1.0	**5.0**	**25.0**
P-21	Ken Thompson Park	City Island and Sarasota Sailing Squadron	5	4	**20**	5	5	5	5	**5.0**	4.0	1.0	4.0	3.0	4.0	**16.0**	**80.0**
P-22	Laurel Park Sarasota		3	3	**9**	0	5	5	5	**3.8**	4.0	1.0	3.0	1.0	3.0	**12.0**	**45.0**
P-23	Lawn Bowling		3	3	**9**	1	5	5	5	**4.0**	2.0	1.0	1.0	1.0	4.0	**9.0**	**36.0**
P-24	Lido Beach		3	5	**15**	5	5	5	3	**4.5**	3.0	2.0	3.0	5.0	4.0	**17.0**	**76.5**
P-25	Links Plaza Park		0	0	**0**	0	1	5	3	**2.3**	1.0	1.0	2.0	1.0	3.0	**8.0**	**18.0**
P-26	Little Five Points Park		0	0	**0**	0	5	5	2	**3.0**	1.0	1.0	2.0	1.0	3.0	**8.0**	**24.0**
P-27	Lukewood Park	Near US301	2	3	**6**	0	5	5	5	**3.8**	1.0	1.0	2.0	1.0	3.0	**8.0**	**30.0**
P-28	Mary Dean Park		0	0	**0**	0	1	5	5	**2.8**	2.0	1.0	2.0	1.0	2.0	**8.0**	**22.0**
P-29	McClellan Parkway Park		0	0	**0**	0	1	5	1	**1.8**	1.0	1.0	1.0	1.0	2.0	**6.0**	**10.5**
P-30	Municipal Auditorium		0	0	**0**	1	5	5	3	**3.5**	3.0	1.0	4.0	1.0	4.0	**13.0**	**45.5**
P-31	Nora Patterson Island Park		5	5	**25**	5	5	5	2	**4.3**	1.0	1.0	1.0	1.0	1.0	**5.0**	**21.3**
P-32	Norasota Way		5	5	**25**	5	5	5	5	**5.0**	1.0	1.0	1.0	1.0	1.0	**5.0**	**25.0**
P-33	North Water Tower Park	4700 Rilma Ave	5	3	**15**	0	1	5	5	**2.8**	3.0	1.0	3.0	3.0	3.0	**13.0**	**35.8**
P-34	Orange Avenue Park		3	3	**9**	0	0	5	5	**2.5**	2.0	1.0	2.0	1.0	1.0	**7.0**	**17.5**
P-35	Otter Key		5	5	**25**	5	5	5	1	**4.0**	0.0	2.0	3.0	5.0	1.0	**11.0**	**44.0**
p-36	Payne Park	2050 Adams Lane	2	2	**4**	1	1	4	5	**2.8**	4.0	1.0	4.0	1.0	5.0	**15.0**	**41.3**
P-37	Pineapple Park		0	0	**0**	0	5	5	5	**3.8**	2.0	1.0	3.0	1.0	4.0	**11.0**	**41.3**

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			Sensitivity (n=5)	Adaptive Capacity (n=5)	Overall Vulnerability (n=25)	SLR	CAT1 + SLR	CAT3 + SLR	ExP	AVG (n=5)	H	S	ECO	ENV	C&H	SUM	
P-38	Pioneer Park	Hog Creek	5	3	**15**	2	5	5	5	**4.3**	3.0	2.0	2.0	4.0	4.0	**15.0**	**63.8**
P-39	Robert L Taylor Community Complex		3	4	**12**	0	0	5	5	**2.5**	5.0	5.0	5.0	1.0	5.0	**21.0**	**52.5**
P-40	Roberts Memorial		0	0	**0**	0	0	5	5	**2.5**	1.0	1.0	1.0	1.0	2.0	**6.0**	**15.0**
P-41	San Remo Park		0	4	**0**	1	5	5	5	**4.0**	1.0	1.0	1.0	1.0	1.0	**5.0**	**20.0**
P-42	Sapphire Shores Park		5	4	**20**	5	5	5	5	**5.0**	2.0	1.0	2.0	2.0	2.0	**9.0**	**45.0**
P-43	Selby Five Points Park		0	0	**0**	0	5	5	1	**2.8**	3.0	1.0	4.0	1.0	5.0	**14.0**	**38.5**
P-44	Ted Sperling Park	South Lido	5	5	**25**	5	5	5	5	**5.0**	3.0	4.0	5.0	5.0	2.0	**19.0**	**95.0**
P-45	St Armand's Circle Park		5	2	**10**	3	5	5	5	**4.5**	5.0	1.0	2.0	1.0	4.0	**13.0**	**58.5**
P-46	Tony Saprito Pier		5	3	**15**	5	5	5	1	**4.0**	3.0	1.0	4.0	1.0	3.0	**12.0**	**48.0**
P-47	Whitaker Gateway Park		5	5	**25**	3	5	5	3	**4.0**	5.0	2.0	2.0	3.0	4.0	**16.0**	**64.0**

CITY OF SARASOTA
Climate Adaptation Plan

City of Sarasota

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