SOUTH FLORIDA WATER MANAGEMENT DISTRICT

SEA LEVEL RISE AND FLOOD RESILIENCY PLAN

Draft

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Executive Summary

The District is strongly committed to addressing the impacts of climate change on water resources, including rising sea-levels and changing rainfall and flood patterns. As a key part of its resiliency strategy, the District evaluates the status of its flood control infrastructure and advances adaptation strategies necessary to continue providing primary flood protection for South Florida under current and future climate conditions and sea level rise (SLR) scenarios. In coordination with the Florida Department of Environmental Protection, other State and Federal Agencies, and local governments, the District is making infrastructure adaptation investments that are needed to continue to successfully implement its mission.

The South Florida Water Management District Sea Level Rise and Flood Resiliency Plan, presented in this document, is the first District initiative to compile a comprehensive list of priority resiliency projects with the goal of increasing community resiliency to flooding and SLR impacts throughout South Florida. This goal will be achieved by updating and hardening water management infrastructure and implementing effective, resilient, basin-wide solutions. This initial list of projects was compiled based upon flood vulnerability assessments that have been ongoing for the past decade. These assessments utilize extensive data observations and robust technical hydrologic and hydraulic model simulations to characterize current and future conditions, and associated risks.

The District's Flood Protection Level of Service (FPLOS) Program has been advancing integrated modeling efforts in critical basins to aid in understanding system vulnerabilities and identifying cost-effective implementation strategies to assure that each basin can maintain its designated FPLOS under current and projected conditions. In addition, the District's Capital Improvement Plan (CIP) has been incorporating climate change and SLR considerations into the design of critical infrastructure projects. Both FPLOS and CIP Programs have been successful at identifying critical resiliency investments that are now being organized and expanded in this document.

This first list of priority resiliency projects focuses primarily on the investments needed to increase the resiliency of the District's coastal structures, including structure hardening needs and additional SLR adaptation needs. The projects included in this document represent urgent actions that need to be taken immediately to address the vulnerability of the existing flood protection infrastructure. Additional basin-wide flood adaptation strategies that are based upon future FPLOS recommendations will be included in the next update of this document.

The District seeks to implement projects that benefit the largest possible population by working closely with state, tribal, private and local communities and taking into consideration the needs of socially vulnerable communities. This document includes the multicriteria ranking approach that was developed to support the assessment of coastal basins in South Florida, including metrics that help to identify the most critical infrastructure, while also considering basin-wide resiliency needs. Cost estimates for each proposed project are also presented, as well as recommendations to incorporate sustainable and clean sources of energy whenever possible and utilize the most efficient designs available, using both traditional gray infrastructure improvements and nature-based solutions.

FLOOD AND SLR RESILIENCY ACTIONS BEING PROPOSED IN THIS DOCUMENT INCLUDE BUT ARE NOT LIMITED TO THE FOLLOWING ACTIONS

- HARDEN INFRASTRUCTURE AND RESTORE BASIN DISCHARGES
- ENHANCE DRAINAGE AND BASIN INTERCONNECTIVITY
- IMPROVE CANAL CONVEYANCE
- INCREASE LOCALLY DISTRIBUTED AND REGIONAL STORAGE AND INFILTRATION OPTIONS
- BUILD SITUATIONALLY APPROPRIATE INFRASTRUCTURE SUCH AS SEEPAGE WALLS AND FLOOD BARRIERS
- IMPLEMENT "SELF-PRESERVATION MODE" TO INCREASE OPERATIONAL CAPACITY AND FLEXIBILITY
- MAXIMIZE THE INTEGRATION OF GREEN INFRASTRUCTURE AND NATURE-BASED SOLUTIONS
- CONTINUE TO EXPAND PLANNING EFFORTS, INCLUDING H&H MODELING AND DATA ANALYSIS/MONITORING

Additional SLR and flood resiliency related projects are also presented in this document such as adding "self-preservation mode" function to water control structures, construction of the South Miami-Dade Curtain Wall, L31E Levee improvements, and the Corbett Levee project. Each of these projects help to increase the functionality and capacity of the District's flood control system. The Everglades Mangrove Mitigation Assessment Pilot Study is being presented to capture the adaptive foundational resilience of the coastal wetlands within the District, and to demonstrate the ability of coastal wetlands to adapt to rising sea levels via enhanced soil elevation change. Finally, critical planning projects are presented to continuously advance vulnerability assessments and scientific data and research to ensure the District's resiliency planning and projects are founded on the best available science.

Table of Contents

Introduction and Background

The South Florida Water Management District (District) is a regional governmental agency that manages the water resources in the southern half of the State, covering all or part 16 counties from Orlando to the Florida Keys, and serving a population of over 9 million residents. The District's mission is to safeguard and restore South Florida's water resources and ecosystems, protect our communities from flooding, and meet the region's water needs while connecting with the public and stakeholders.

Since its creation in 1949, the agency has been responsible for managing the Central and Southern Florida Project (C&SF Project), authorized by Congress in the Flood Control Act of 1948. The C&SF Project consists of 2,200 miles of canals; 2,100 miles of levees/berms, 84 pump stations, 778 water control structures and weirs, and 621 culverts. This regional water management system is the primary system of canals and natural waterways that connect to community drainage districts and hundreds of smaller neighborhood systems to effectively manage floodwaters caused by heavy rainfall events, through a coordinated effort among primary, secondary and tertiary system water managers. The C&SF Project is a multi-purpose system that provides flood control and water supply for municipal, industrial and agricultural uses. Additionally, the C&SF Project provides water for ecosystem restoration and protection of fish and wildlife resources as well as prevention of saltwater intrusion.

The C&SF Project is now over 70 years old and although it has been well maintained, it has not received major updates over that period. Extensive land development and population increase within the project footprint has exceeded the original design assumptions and significant changes in climate conditions and SLR have also impacted the project. Many communities in South Florida are exposed to coastal and inland flooding quite frequently. These risks and their potential impacts are multifaceted and involve flood hazards driven by storm surge, high tides and extreme rainfall.

The District is strongly committed to addressing the impacts of climate change, including rising sea-levels, and changing rainfall and flood patterns, and has created the District Resiliency Team to take on these challenges. As a key part of its resiliency strategy, the District evaluates the status of its flood control infrastructure and advances adaptation strategies necessary to continue providing primary flood protection for South Florida. The District's Flood Protection Level of Service (FPLOS) Program was established in 2015 to ensure that the regional flood control system provides the desired level of flood protection today and into the future, with consideration for land use changes, development and SLR. The FPLOS program has been advancing robust hydraulic and hydrologic modeling efforts in critical basins to aid in understanding system vulnerabilities, and to identify cost-effective implementation strategies to assure that each basin can maintain its designated FPLOS under current and projected conditions. FPLOS results are being advanced by the District, in tandem with regular operations and maintenance infrastructure investments.

The District's Capital Improvement Plan (CIP) is a major responsibility of the agency that requires continually making significant investments in the Operations and Maintenance (O&M) of the C&SF Project. The District integrates resiliency related investments into its $52 Million annual CIP by incorporating climate change and SLR considerations into the design of projects and critical infrastructure. The CIP process and projects are also considered when funding dedicated to resiliency efforts is secured. In coordination with the Florida Department of Environmental Protection (FDEP) and other State and

Federal Agencies, the District is making infrastructure adaptation investments that are needed to successfully implement its mission.

In May 2021, Governor Ron DeSantis signed Florida Senate Bill 1954 which created the Resilient Florida Program, providing significant funding to support flooding and SLR resiliency projects throughout the State. The District will be submitting a list of proposed projects to the Resilient Florida Program on an annual basis, beginning September 1, 2021 via this document.

The following recommended projects comprise the District's initial proposal to build innovative and cost-effective flood adaptation solutions. These solutions will be implemented in partnership with the FDEP and other local, State and Federal partners, in a manner that builds resiliency in the District's flood protection management system, now and in the future.

These projects were prioritized according to the District's Resiliency Vision, described in the first chapter of this document. The projects are founded on the principles of risk reduction, community wide benefits, cost effectiveness, well planned projects, full and dynamic integration of future conditions, consideration of associated water quality and ecosystem restoration objectives, leveraging partnerships with local, state and federal Agencies, and ensuring continuous stakeholder engagement.

Given the associated uncertainties related to climate change, and adoption of projection scenarios thereof, these solutions are being proposed as part of a dynamic adaptive pathways approach, in which the timing of their implementation is prompted by pre-established warning signals or triggers. This approach supports the development of a plan that can adapt to these future uncertainties.

The FPLOS Phase I Assessments and Phase II Adaptation Studies, as detailed in Chapter 2 of this document, provide the technical foundation for the development of the adaptation triggers that will determine the need for implementation of supplemental flood mitigation strategies. The projects included in this document represent urgent actions that need to be taken immediately to be prepared for the near future. Additional basin-wide flood adaptation strategies that are based upon FPLOS warning signals will be included in future plan documents, annually.

These critical projects were also evaluated in terms of their urgency and vulnerability to SLR, storm surge and extreme rainfall risks, and their impacts to critical lifelines and the communities living in these priority basins. Factors such as lower income populations and pre-identified local government adaptation action areas, and their alignment with other District CIP projects were also included in the evaluation. Chapter 3 describes the District's O&M and CIP programs and how they address resiliency. Chapter 4 includes a summary of the approach developed to identify and prioritize the projects. Finally, Chapter 5 presents a description of each individual project, their locations, completion schedule and respective cost estimates for implementing new resiliency features and modifying, and/or hardening the District's most vulnerable water control structures.

The need to continuously evolve our understanding of climate change, SLR and flood mitigation consequences is intrinsic to the District's Resiliency efforts. In the final portion of report in Chapters 6 and 7, a list of additional construction and priority planning projects is presented. These planning projects support the Resiliency Team's mission to coordinate scientific data and research needs to ensure the District's resiliency planning and projects are founded on the best available science.

1. Our Resiliency Vision

The District is committed to increasing community resiliency to flooding and SLR impacts throughout South Florida, by updating and hardening the C&SF Project infrastructure using both traditional gray infrastructure improvements and nature-based solutions. Our vision is driven by our desire to reduce risk by implementing effective, resilient solutions and anticipate future conditions, while engaging the public through various outreach activities. Our FPLOS and O&M CIP programs ensure that projects are designed, managed, and constructed using innovative techniques. District projects will incorporate sustainable and clean sources of energy whenever possible and utilize the most efficient designs available. The District seeks to implement projects that benefit the largest possible population by working closely with state, tribal, private and local communities and taking into consideration the needs of socially vulnerable communities. Below are descriptions of each of the criteria that when taken together, illustrate our resiliency vision and our unique role in addressing flood protection and water management infrastructure risks and vulnerabilities.

Risk Reduction/ Effectiveness

The District seeks to reduce risk while maximizing the effectiveness of our projects by advancing robust hydrologic and hydraulic integrated basin wide models through the FPLOS Program. This will allow us to look at maximum stages, bank exceedances and discharge capacity of our canals as well as the flood depths and durations of overland flood inundation. Additionally, coastal structure capacity and peak stages resulting from different storm surge and SLR scenarios can be examined.

Implementation Resources

Implementation measures describe how project costs and schedules will be managed, how the project will be implemented, and how innovative techniques will be incorporated. A well-planned resiliency project includes identification of technical and project management staff and other resources needed for successful implementation. Consideration is also given to potential technical, political, and financial challenges and how they can be overcome. Additionally, project costs and schedules and pre- and post-implementation monitoring plans should be well defined.

Anticipated Future Conditions

Future conditions within each project impact area (drainage basin) are important to consider when deciding if a project is viable. It is vital to know when and where the population within a basin is projected to increase, and if land use and development are predicted to shift. Understanding demographics and changes in economic status of the community is also important. Beyond the traditional planning tools, there is a need to address future climate conditions and their impacts, including SLR, increasing groundwater elevations, rainfall extremes and other related variables. The project should be responsive to any anticipated changes, and these changes should be integrated into the planning, design, and future operation of the project. Each potential project should be informed by and/or connected to planning efforts such as Hazard Mitigation Plans, Climate Adaptation Plans, Comprehensive Plans, and others.

Population and Critical Infrastructure Impacted

Effective resiliency projects have community-wide benefits and should identify the populations that will be impacted, both positively and negatively. Percentage of the population that will directly benefit from the project, including the extent of the project's direct and impacts on community lifelines (fundamental services that allow society to function), businesses, residents, public services and natural resources should be defined and vulnerable members of the community should be identified and taken into consideration. Positive impacts to vulnerable communities should be identified and maximized. The District strives to meet these criteria.

Public Engagement / Outreach

Outreach activities are an important way to gain public support for resiliency projects. The District is planning to engage the public through FPLOS workshops that will eventually span the entire district but are prioritized for basins with elevated flood risk where adaptation strategies and mitigation projects need to be collaboratively developed and implemented. FPLOS public workshops will give stakeholders with flood control responsibilities an opportunity to share provide input and help guide the selection of projects compatible with local efforts/initiatives. Information and feedback from the public can add value to the District's planning process by introducing a real-world perspective to modeling results. In addition, the District is planning more general Resiliency workshops that will include presentations from current SLR and climate change experts. The workshops will provide an opportunity for the public to interact with the District's Resiliency Team and share their ideas and concerns.

Leveraging Partners

The District continues to promote coordination with the public, educational institutions, stakeholders, and federal, state and local government agencies including the USACE, FDEP Office of Resilience and Coastal Protection, local governments, the Southeast Florida Regional Climate Change Compact, the Southwest Florida Regional Resiliency Compact, and the East Central Florida Regional Resilience Collaborative. The District is advancing integration and climate resilience strategies in the region with these partners.

Innovative Green/Nature-Based Solutions

The District is committed to seeking "green" or nature-based solutions (NBS) in addition to "gray" stormwater infrastructure improvements to increase resiliency. NBS include features such as living shorelines, wetlands, artificial reefs, other urban green infrastructure features and preservation and restoration of existing natural features. Both of gray and green features will be necessary to meet the challenges of climate change impacts, including SLR, along with basin-wide solutions to maximize the capacity of flood adaptation and achieve water quality benefits. District projects will also incorporate sustainable and clean sources of energy whenever possible and utilize the most efficient designs available.

2. Flood Protection Level of Service Program

Initiated in 2015, the District's Flood Protection Level of Service Program (FPLOS) allows the agency to evaluate the effectiveness of its flood control assets including canals, structures and pump stations to determine their ability to meet and continue to meet the flood protection needs of the region. The C&SF Project and other basins flood protection systems have many assets that are approaching end of design life, making it critical to implement this program to inform decisions on the flood control infrastructure needs of the region. The District is implementing the FPLOS program at a regional and local scale and has developed a methodology that helps to prioritize basins to study, and a suite of tools for evaluating structures and canals in selected watersheds, as well as a framework for establishing the level of service. The program incorporates input from meetings and workshops with local planning and stormwater management efforts, stakeholders, and resource managers. The FPLOS will be implemented in a phased approach in a 10-year cycle. Each basin will be evaluated, and actions taken as necessary, to ensure that the level of service is maintained. When remediation is needed, the lowest cost measures will be undertaken first, building to full replacement only when necessary. The cycle will provide opportunities to update land development and sea-level information and incorporate new technology and tools. This cyclic approach is the best use of funding and ensures that incremental, near-term measures will be incorporated into any long-term solution. The program is being executed in three stages.

Assessment Phase (Phase I)

This stage of the program involves a periodic exploratory investigation of the primary system and related work and studies necessary to identify choke points or deficiencies in the flood control infrastructure with a focus on the primary system. These studies continue in perpetuity and each basin is revisited once every 8 to 10 years unless significant changes in the flood control system necessitate a more frequent re-assessment.

Adaptation and Mitigation Planning Phase (Phase II)

When deficiencies are identified in the system (either current or projected based on factors such as SLR and future rainfall), an Adaptation and Mitigation Planning study is triggered which executes a search for a solution within the primary system as well as the secondary and tertiary systems. These public planning projects represent collaborative efforts with operators of the secondary and tertiary systems and identifies cost effective courses of action that will, when implemented, bring the flood control system back to design specifications or desired performance for the long term.

Implementation Phase (Phase III)

The final phase includes final project design, permitting, real estate acquisition, and construction activities necessary to implement the selected adaptation strategy and course of action.

The District has taken a comprehensive and high-level approach to addressing the flood protection needs of the region. It is rigorous in its analyses using high quality integrated modeling tools, and pragmatic in its implementation. At its core, this approach is a commitment to an ongoing assessment of the state of the system to ensure that problems are identified well before they occur, providing an opportunity to plan and implement adaptations and mitigations strategies.

With a goal to reassess every basin within the District at least once every 8 to 10 years, the program initiates two assessment studies every year, starting with the most at-risk basins. This is determined based on a SLR vulnerability assessment, observed flooding, and known system limitations. These studies answer the key question: are the flood protection assets working and will they continue to work for the next 50 years? Another strength of this method is the collaborative approach in search for the appropriate solution. The District engages partners and stakeholders with responsibility for the secondary and tertiary flood control systems to identify the best course of action to mitigate any identified deficiency.. The solutions are comprehensive and could range from a change in operations requiring no additional infrastructure, to major investments in infrastructure including using NNBS whenever possible. The cycle will provide opportunities to update land development and sea-level information and incorporate new technology and tools, to ensure that incremental, near-term measures will be incorporated into long-term solutions. Figure 1 below illustrates the latest status of the FPLOS assessments and the priority basins. Figures 2 and 3 summarize some initial results of the FPLOS assessments completed for Broward and Miami Dade Counties and for Big Cypress Basin (BCB).

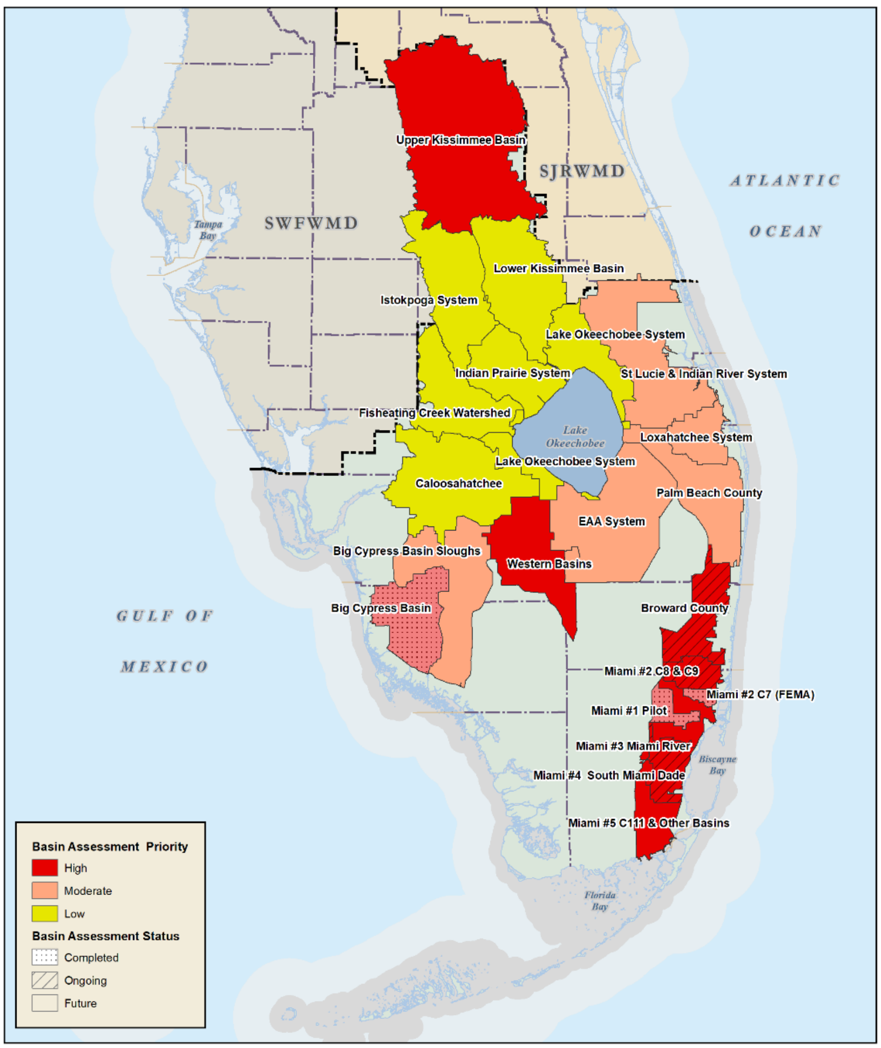


Figure 1. FPLOS Basin Assessment Priorities and Status of Implementation.

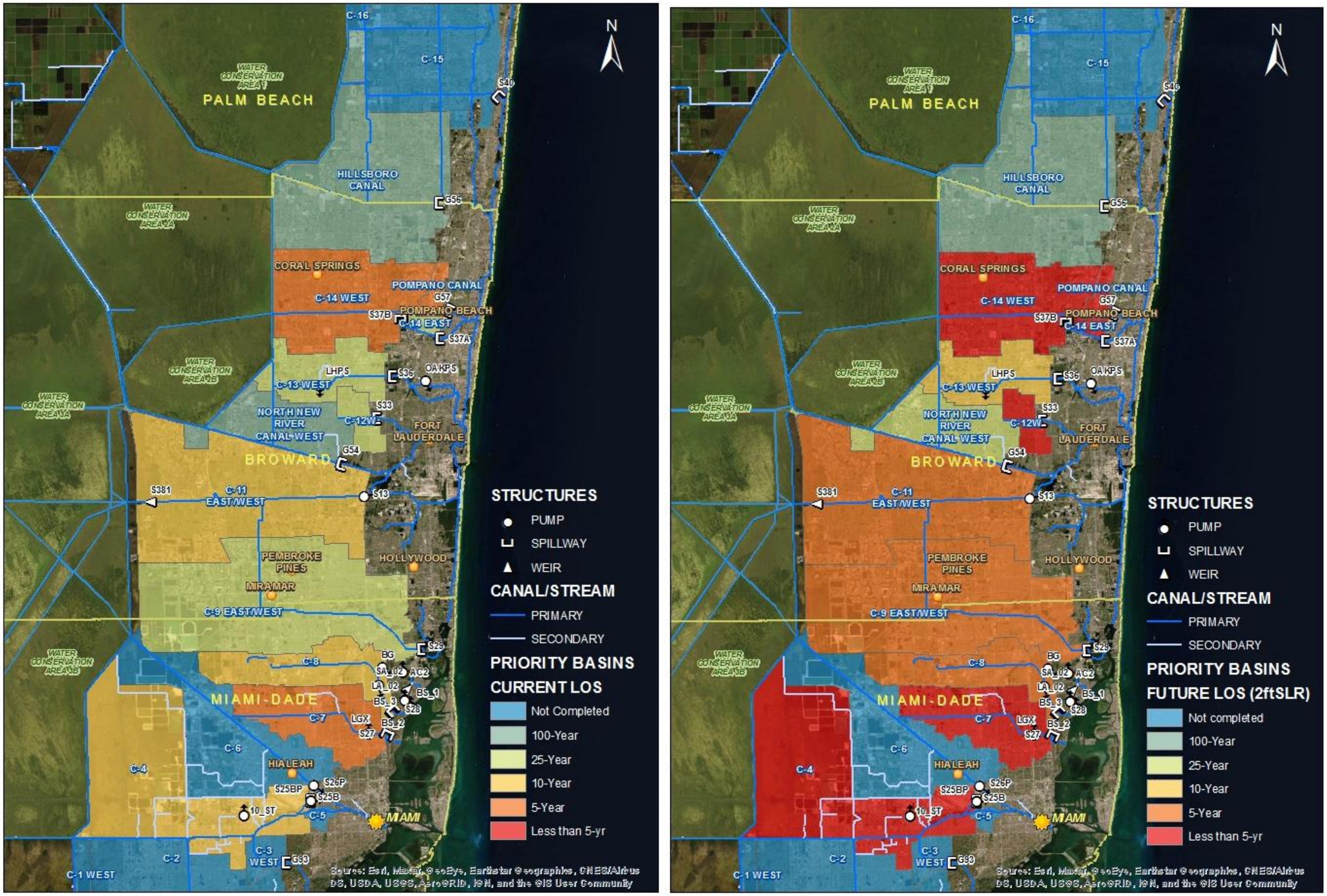
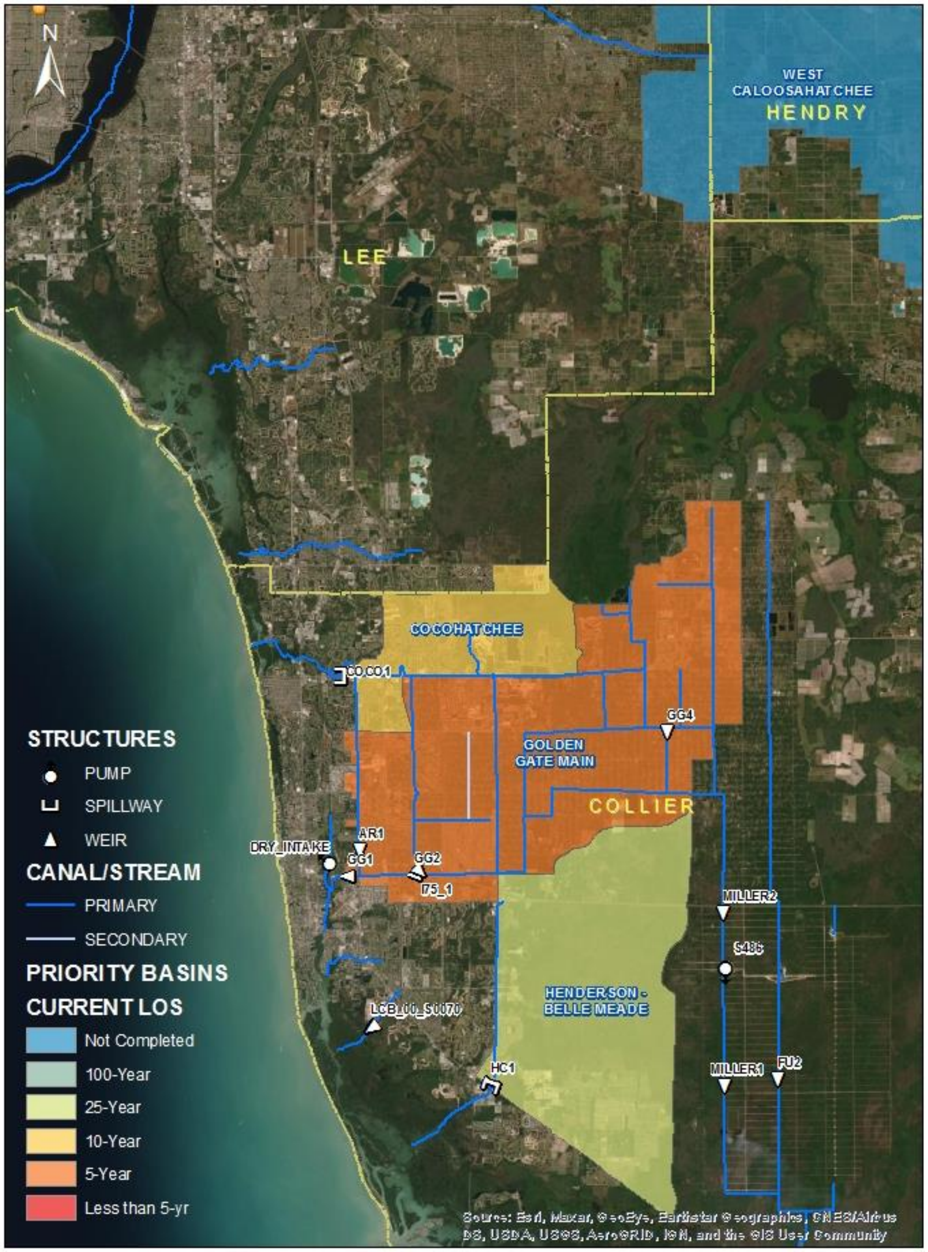


Figure 2. Current and Future Level of Service estimated as a result of completed FPLOS Assessments in critical basins within Broward and Miami-Dade Counties.



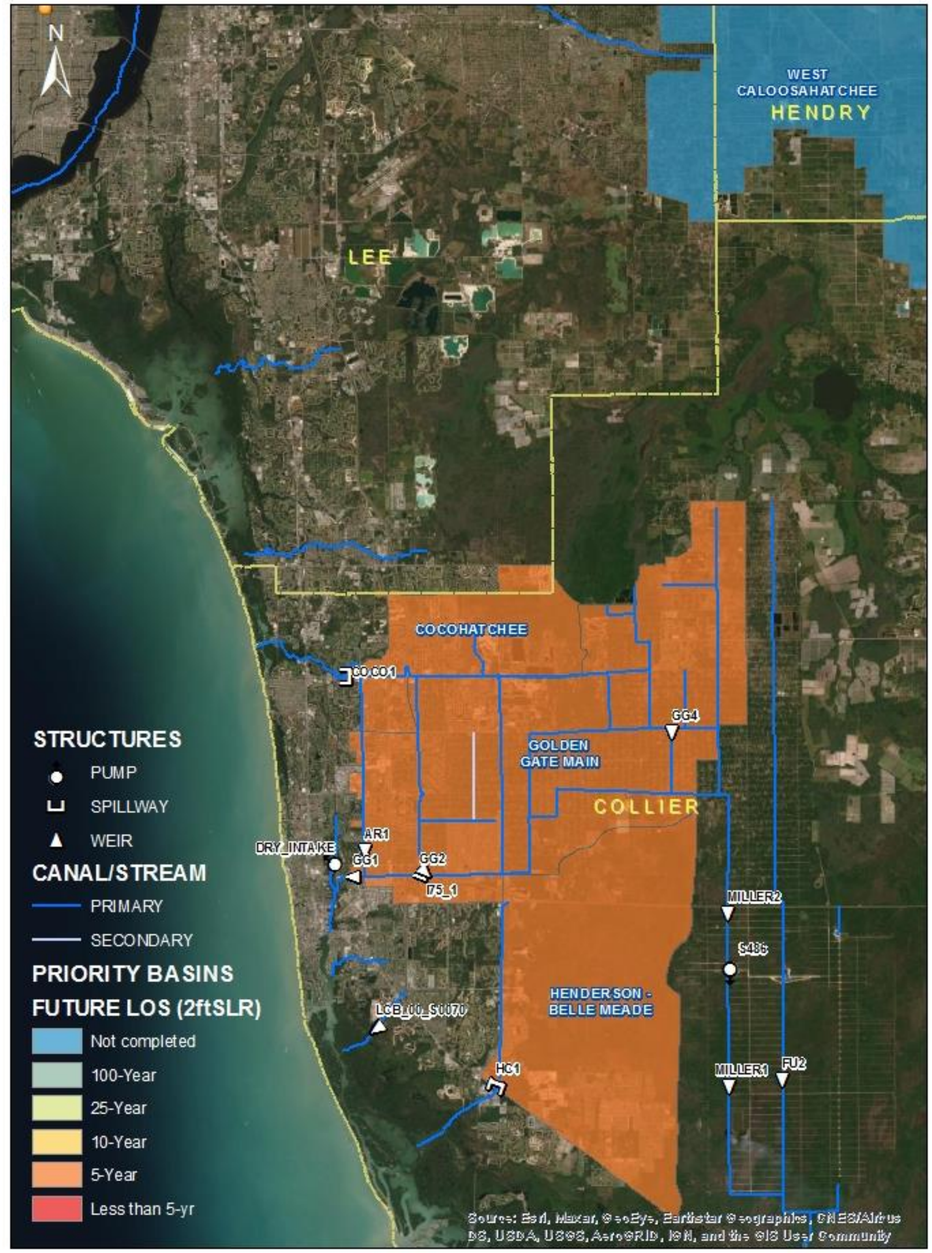


Figure 3. Current and Future Level of Service estimated as a result of completed FPLOS Assessments in critical basins within the BCB Basin.

3. Operations & Maintenance Program and Capital Improvements

The District has a multimillion-dollar Capital Improvement Plan already in place, with an average annual budget of $52M. All water control structures are inspected every five to seven years as part of the District's Structure Inspection Program (SIP), which is integrated into its O&M Program. Inspections cover civil, structural, mechanical, electrical, and underwater components of the structure and each component is rated based on the severity of deficiencies, and on the urgency of recommended corrective actions. The individual component ratings are evaluated together to formulate an overall rating that guides prioritization of corrective actions. Figure 4 illustrates examples of the structure inspection program reports and the risk matrix utilized to calculate the overall rating. The "likelihood of failure" scoring is calculated based on the inspection of physical condition, the ability to operate and maintain the structure/facility as intended and the frequency of operation. The "consequences of failure" scoring is based on the location and size of the structure/facility, accounting for public health, safety, security & service, its financial impact on surrounding land use and upstream/downstream impacts, and its back up operational options.

The inspection reports are also used to help guide the Resiliency Program. Structures that receive a critical rating for corrective actions are then analyzed by the Resiliency Team and modifications for SLR and climate change impacts are recommended. This process ensures that the Resiliency Program and the CIP are integrated and improvements at each structure are coordinated. The goal is to not have to go back to the same structure twice within a short period of time.

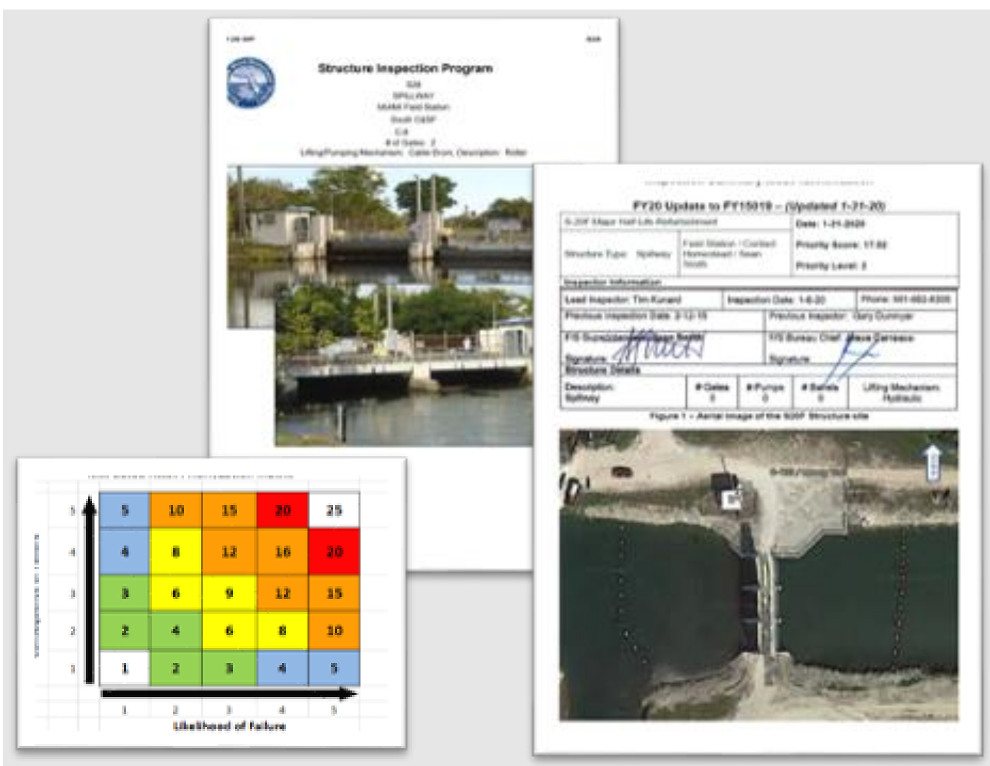


Figure 4. Examples of Structure Inspection Program Reports and the O&M Overall Rating Risk Matrix

4. Characterizing and Ranking Our Resiliency Projects

The District is initially focusing its infrastructure investment priorities looking at water control structure adaptation needs to SLR. During the initial stages of SLR impact, the District is continuing to operate structures through operational changes, by investing in extending the top of gates, and implementing structure hardening measures. As sea levels increase, additional measures are required to maintain headwater stages at structures and prevent saltwater intrusion and flooding impacts. Hardening existing facilities can substantially improve their functionality and performance by reducing the vulnerability of systems and equipment to flooding and maintaining their ability to protect against saltwater intrusion. Adaptation to SLR and storm surge involve large scale projects that integrate floodwalls, gates, and forward pumps to properly manage surface and groundwater within the area. In addition, long-term SLR may also involve seepage barriers to avoid saltwater intrusion and control the long-term rise in groundwater levels. Some of these efforts are beginning to be advanced in the region, to address storm surge and other coastal hazards.

Many of the District's coastal structures were constructed over 70 years ago and are no longer capable of conveying their design discharge due to changes within the watershed, SLR, and climate change. The District is proposing to restore the original design discharge at these structures by installing forward pump stations that can continue to discharge to tide when gravity discharge ceases (during storm surge or extreme high tide events) and to augment gravity discharge at critical times. Figure 5 below illustrates the relative percent of time that gate closures were needed during the High Tide Season in 2020 at four different locations. As observed in these charts, these gates were closed for about 3-5 hours on average, per day during high tide events, and with a significant increase up to 15 hours per day during the peak of the 2020 high tide season.

To determine pumping capacity needs at the coastal structures, pump sizes at the most immediate priority structures have been initially estimated using one half of the design discharge capacity of the structure. For instance, a structure with a design discharge capacity of 1,000 cubic feet per second (cfs) would need a 500 cfs pump station. Structures ranked as intermediate in terms of priority would use one quarter of the design discharge capacity for initial pump sizing. Structures ranked in the long-term need category would not have pump cost estimates until they move from long-term to intermediate need. Initial pump sizing is based on: a) existing C&SF forward pump implementation strategies; b) the assumption that other local flood mitigation strategies will be advanced in the basin in combination with the local forward pump solutions; c) the consideration of downstream capacity; and d) best professional judgement. Figures 6 and 7 below illustrate a comparison between the amount of time needed to remove the cumulative flows (or the total runoff to bring the stages back to normal operating ranges) for the scenarios with forward pumps sized at 25% and 50% of the spillway design capacity, relative to the no pump scenario. The design of forward pump stations will be adaptable and will include the ability to easily add additional pumps in the future as environmental conditions change. The precise nature of improvements at each structure, including consideration of replacement needs, additional flooding barriers, and forward pump sizing, will be determined during the feasibility and design phases for each structure, and as part of the more detailed and comprehensive FPLOS adaptation planning phase, which includes the assessment of larger regional forward pump strategies.

The effectiveness of using forward pumps to reduce flood risk and restore the original level of service can be demonstrated by the operational results of existing forward pumps at the S-25B and S-26 coastal structures. During Hurricane Isaias, between July 20 and August 2, 2020, the average daily landside water levels (headwater) were lowered consistently at structures with gravity flow and a forward pump. At the S-25B and S-26 coastal structures, landside water levels were reduced significantly with the combination of gravity flow and forward pumping. During the same storm event at S-27, S-28 and S-29, the average daily landside water levels increased with gravity flow alone. These observations demonstrate the existing limitations and associated challenges in maintaining or reducing landside water levels by relying solely upon gravity flow.

Another flood mitigation alternative is the utilization of emergency storage options. One example is the C-4 Emergency Detention Basin (C-4 EDB) in Miami-Dade County. When the C-4 Canal can't handle the water volume necessary to prevent flooding, the C-4 EDB is employed to receive and store the excess water. The forward pump station at the mouth of C-4 Canal is the first component of the C-4 EBD that is used, when needed, in addition to gravity flow. The S-26 Pump Station at the mouth of the Miami River Canal in the C-6 basin was built to ensure the higher tailwater as a result of the S-25B pumping does not impact C-6 upstream of S-26. These stations pump to the Miami River and are used first for flood control. The EDB is used for larger rain events when stages continue to rise, and additional flood mitigation is needed. The C-4 EDB provides improved flood protection for the City of Sweetwater, Miami-Dade County, City of Miami, and City of West Miami.

The District is also committed to seeking "green" or nature-based solutions in addition to "gray" infrastructure improvements to increase resiliency. NNBS include features such as living shorelines, wetlands, artificial reefs, other urban green infrastructure features and preservation and restoration of existing natural features. Both gray infrastructure examples previously described and green features will be necessary to meet the challenges of climate change impacts, including SLR, along with basin-wide solutions to maximize the capacity of flood adaptation. The restoration of design discharge capacities will need to be combined with additional upstream and downstream solutions, to be advanced as part of the FPLOS Phase II dynamic adaptive pathway approach. This approach and considerations were applied in the FPLOS Assessment for the C-7 Basin: Identification and Mitigation of Sea Level Rise Impacts (2015 FEMA PDM Study). The main objective of this study was to reduce the potential for loss of life and property by recommending alternative mitigation strategies to be updated in the Miami-Dade County Local Mitigation Strategy (LMS). The project had two elements: 1) a technical assessment of the FPLOS for the existing infrastructure under current and future SLR scenarios; and 2) a strategic assessment of alternative mitigation strategies intended for incorporation into the Miami-Dade LMS. The study evaluated a series of mitigation alternatives for the basin involving local hydraulic measures (M1), a regional forward pump (M2) and elevating buildings (M3) and associated benefits to be implemented by multiple agencies. The results show various pathways (sequences and combination of mitigation strategies) can be explored. If an individual flood mitigation alternative is not able to achieve the specified target of the performance criteria, additional or other mitigation strategies are needed. Adaptation pathways were assessed for the entire C-7 Basin, as summarized in Figure 7 below, showing how multiple strategies can be combined over time.

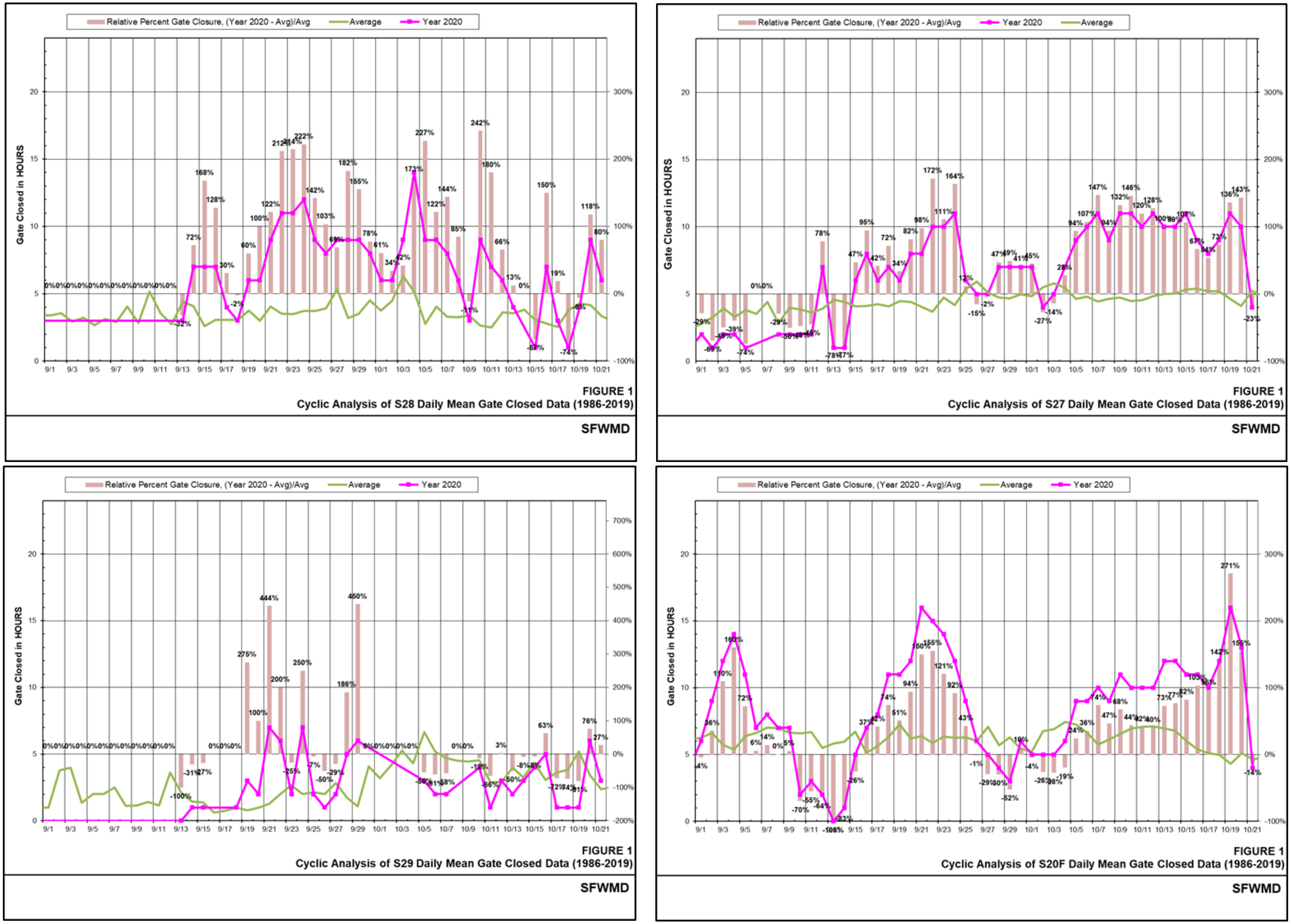


Figure 5. Relative Percent Gate Closure Times during the 2020 High Tide Season

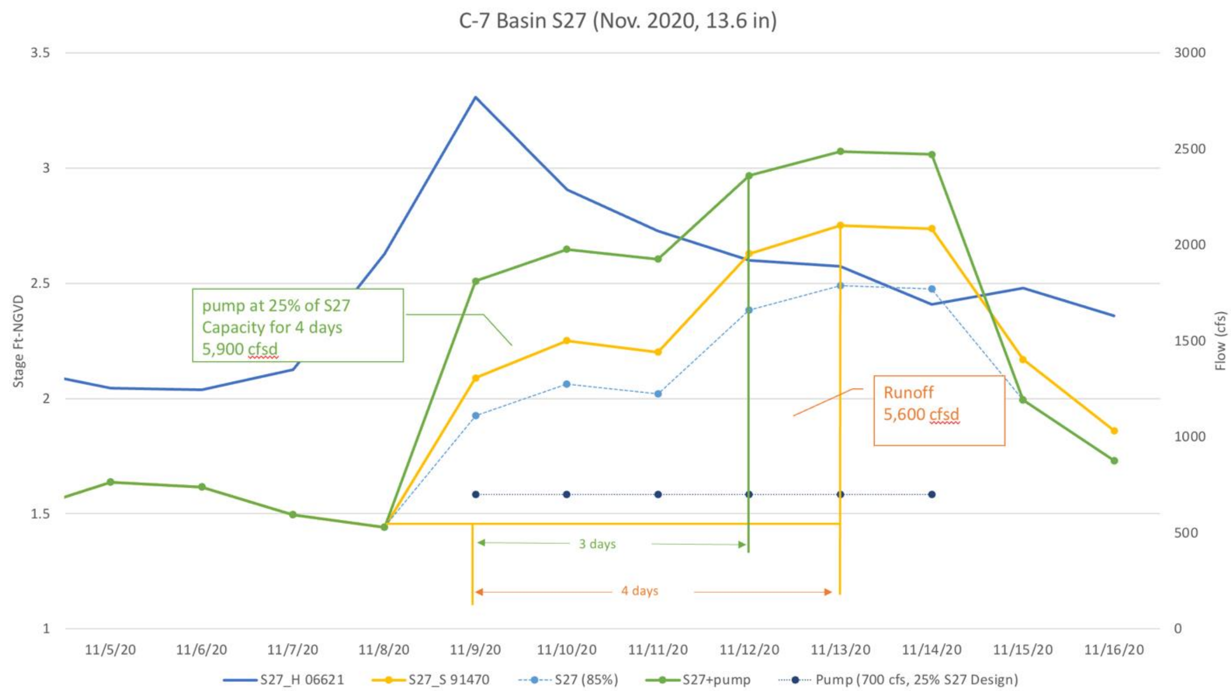


Figure 6. Potential amount of time needed to remove the cumulative flows at S-27 (5600 cfsd total runoff to bring the stages back to normal operating ranges during Tropical Storm Eta in November 2020) for the scenario with forward pumps sized at 25% of the spillway design capacity (3 days) relative to the no pump scenario (4 days)

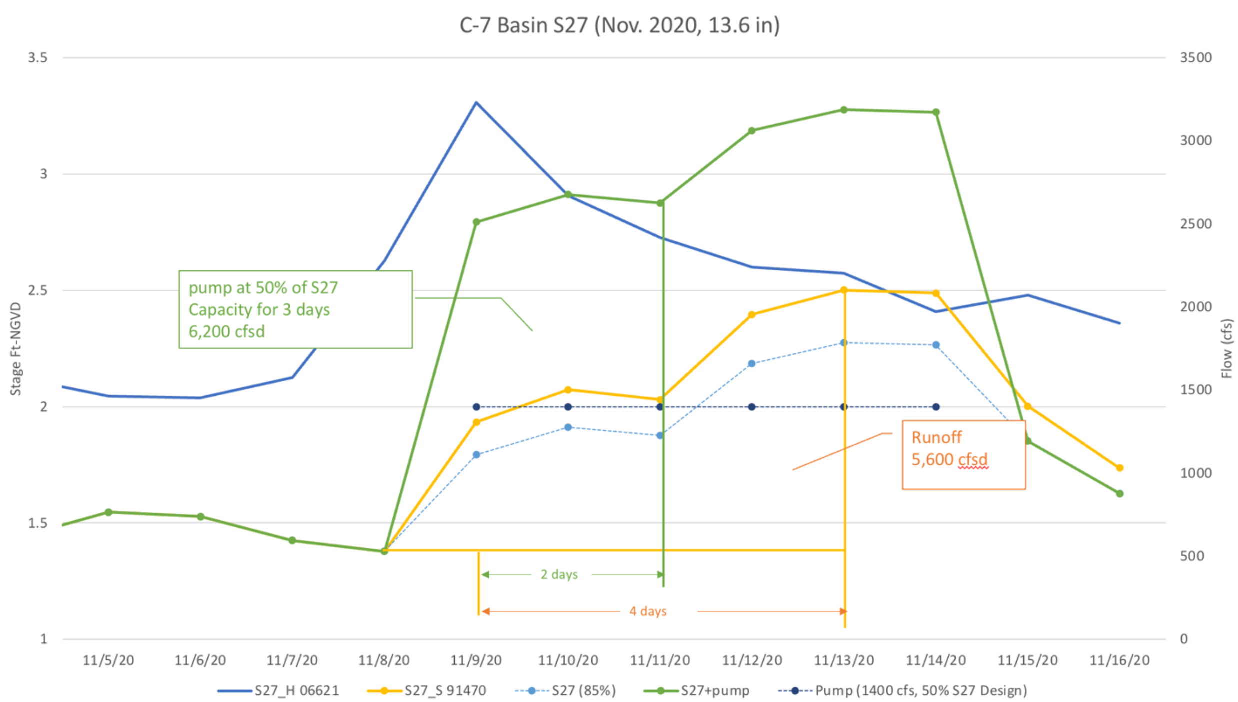


Figure 7. Potential amount of time needed to remove the cumulative flows at S-27 (5600 cfsd total runoff to bring the stages back to normal operating ranges during Tropical Storm Eta in November 2020) for the scenario with forward pumps sized at 50% of the spillway design capacity (2 days) relative to the no pump scenario (4 days)

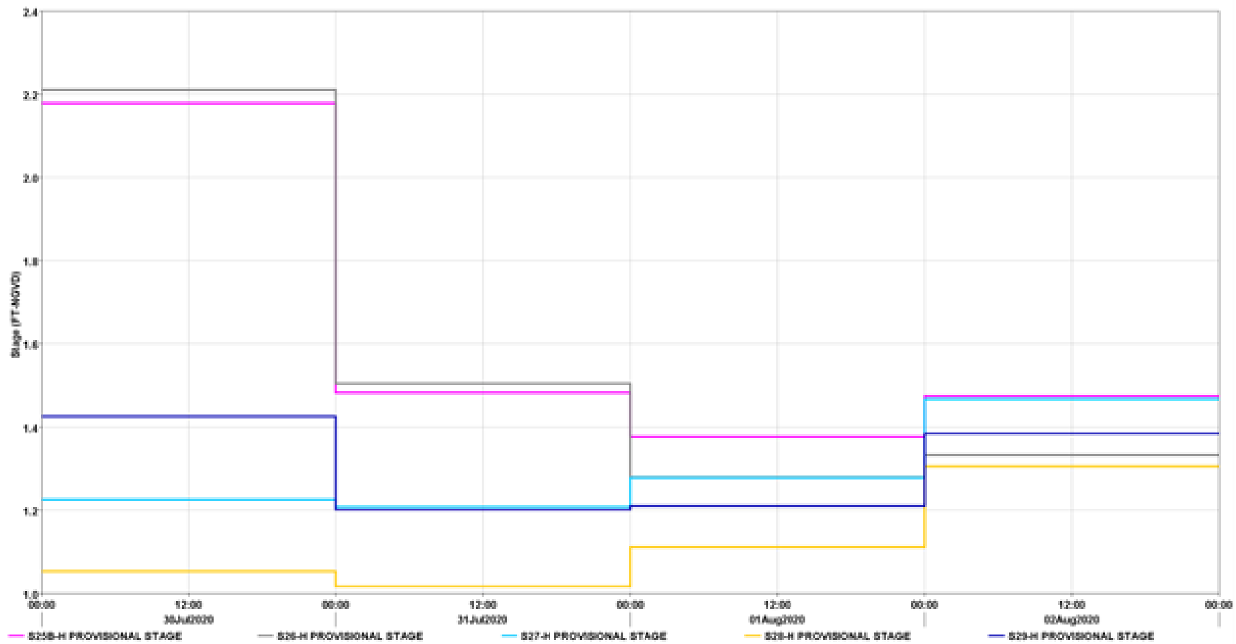


Figure 8. Observed Headwater Stages during Hurricane Isaias, in July/August, 2020, at Coastal Structures with forward pump (S-25B and S-26) vs. Coastal Structures with gravity discharge only (S-27, S-28, S-29)

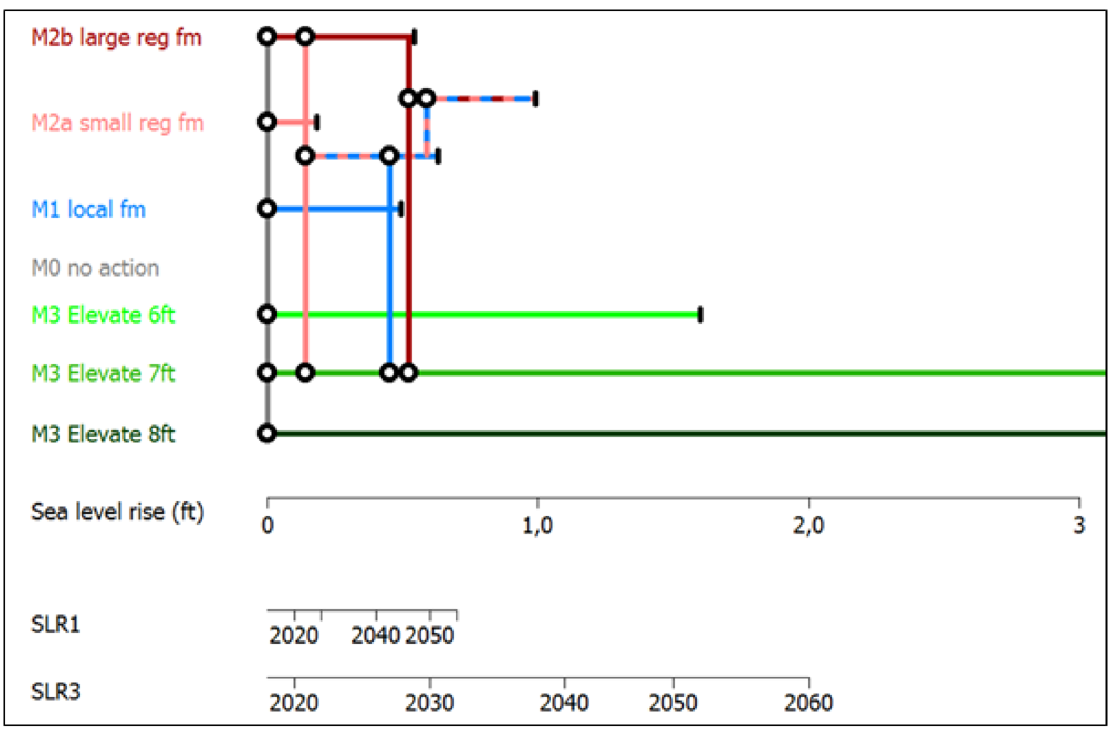


Figure 9. Adaptation Pathways map for the entire basin, based on the simulated expected annual damage for the current sea-level and the two possible future sea level rise scenarios.

Updated FEMA Coastal Zone A Maps and the USACE South Atlantic Coastal Study and Back Bay Feasibility Studies were recently released in response to coastal storm risks and flood protection needs. These studies were developed focusing on storm surge flood inundation risks. The District is working closely with these Federal Agencies to coordinate the implementation of coastal adaptation strategies such as beach and dune restoration, shoreline stabilization, flood walls and nature and natural base solutions, including living shorelines, oyster and coral reefs, marshes, etc. Figure 10 below summarizes how these combinations of solutions can be advanced, through cooperation among local, state, regional and Federal Agencies.

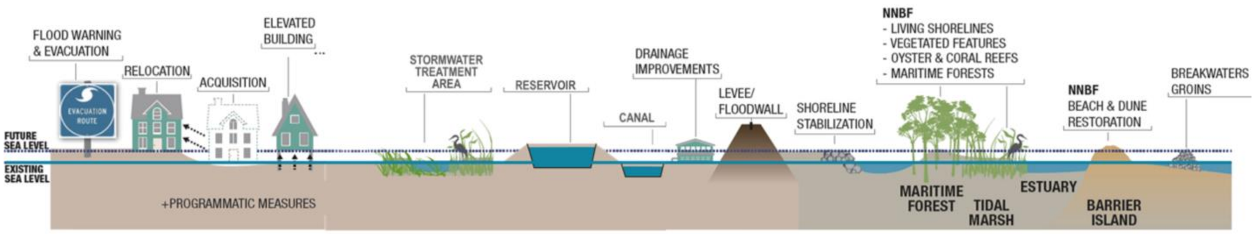


Figure 10. Potential Flood Mitigation Measures to improve resilience and sustainability (Source: USACE, modeled from https://ewn.el.ercd.dren.mil/nnbf/other/5-ERDC-NNBF_Brochure.pdf)

Applying the Resilient Florida Program Criteria to Determine Priority Basins

A multicriteria ranking approach was developed to support the assessment of coastal basins in South Florida, including metrics that help to identify the most critical infrastructure. The selection of criteria were based on the Resilient Florida Program initial formulation, as detailed below.

On May 12, 2021, Governor DeSantis signed into law SB1954, making over $640 million available in FY21/FY22 to support efforts to ensure our state and local communities are prepared to deal with the impacts of SLR, intense rainfall events and flooding. This program will be administered by the FDEP and it allows water management districts to submit a list of proposed projects that mitigate the risks of flooding or SLR on water supplies or water resources of the state by September 1, 2021 and each September 1 thereafter. Each project submitted to the program must contain a description of the project, project location, completion schedule, cost estimate, and the cost share percentage available with a minimum of 50%. The legislation requires FDEP to implement a scoring system for assessing each project. The scoring system will include the following tiers and criteria:

1. *Tier 1 must account for 40 percent of the total score and consist of all of the following criteria:*
   a. *The degree to which the project addresses the risks posed by flooding and sea level rise identified in the local government vulnerability assessments or the comprehensive statewide flood vulnerability and sea level rise assessment, as applicable.*
   b. *The degree to which the project addresses risks to regionally significant assets.*
   c. *The degree to which the project reduces risks to areas with an overall higher percentage of vulnerable critical assets.*
   d. *The degree to which the project contributes to existing flooding mitigation projects that reduce upland damage costs by incorporating new or enhanced structures or restoration and revegetation projects.*
2. *Tier 2 must account for 30 percent of the total score and consist of all of the following criteria:*

    a. *The degree to which flooding, and erosion currently affect the condition of the project area.*
    b. *The overall readiness of the project to proceed in a timely manner, considering the project's readiness for the construction phase of development, the status of required permits, the status of any needed easement acquisition, and the availability of local funding sources.*
    c. *The environmental habitat enhancement or inclusion of nature-based options for resilience, with priority given to state or federal critical habitat areas for threatened or endangered species.*
    d. *The cost-effectiveness of the project.*

3. *Tier 3 must account for 20 percent of the total score and consist of all of the following criteria:*
    a. *The availability of local, state, and federal matching funds, considering the status of the funding award, and federal authorization, if applicable.*
    b. *Previous state commitment and involvement in the project, considering previously funded phases, the total amount of previous state funding, and previous partial appropriations for the proposed project.*
    c. *The exceedance of the flood-resistant construction requirements of the Florida Building Code and applicable floodplain management regulations.*

4. *Tier 4 must account for 10 percent of the total score and consist of all the following criteria:*
    a. *The proposed innovative technologies designed to reduce project costs and provide regional collaboration.*
    b. *The extent to which the project assists financially disadvantaged communities.*

The criteria implemented to prioritize the most critical infrastructure include the following (Figure 11):

Likelihood of Failure (20% weight to each Category)

- Return period of overbank flow and flood control system deficiencies due to SLR
- Consideration of finish floor elevation (FFE) lower than the base flood elevation (BFE)
- Coastal Structure Operation Limitations Under Category 5 Storm Surge Event
- Canal bank exceedance and reduced conveyance capacities at inland canals due to SLR
- Basin-wide FPLOS Level of Service or Major Observed Flooding Events

Consequence of Failure (20% weight to each Category)

- Total Population
- Extension of the drainage area beyond design specifications of the flood control system
- The existence of lower income populations
- The existence of critical lifelines within/in the proximity of the project area
- The existence of public water supply wellfields within the proximity of the saltwater interface

All infrastructure projects receive a certain amount of points for each of the evaluated criteria. Projects with the highest combination of points become the highest priority projects. The selection of infrastructure projects that were included as part of this ranking effort was based on the identification of coastal structures that are vulnerable to SLR and storm surge impacts. Table 1 lists all the infrastructure projects and presents the total points obtained for each criterion listed on the column headings, as well as the sum of the total points by resiliency criteria solely and including the District's O&M Structure Inspection Program Ratings. The legend below the table explains how points were determined for each criterion, according to a predetermined range of conditions. Figure 11 illustrates some of these adopted criteria, and how values vary spatially. This ranking process will be updated continuously with the latest science and available data, as part of future updates.

Likelihood of Failure Scoring

Category	Basis	Weighting	1 (Low Probability)	2	3	4	5 (High Probability)	TOTAL BY CATEGORY	JUSTIFICATION
Return Period of Overbank Flooding	Coastal Structure Performance Under Higher Tailwater Elevations	20%	>25-yr		25-yr		5-yr or less		
Sea Level Resulting in Overbank Flooding			>2 ft	>1 ft to 2 ft	>0.5 to 1 ft		0.5 ft or less		
Category			Category V: bank-full elevation could be reached under a 25-yr surge event with >2 ft to 3ft of SLR; Category VI: >25-yr	Category IV: bank-full elevation could be reached under a 25-yr surge event with >1 ft to 2 ft of SLR	Category III: bank-full elevation could be reached under a 25-yr surge event with >0.5 to 1 ft of SLR	Category II: bank-full elevation could be reached under a 25-yr surge event with 0.5 ft or less of SLR	Category I: bank-full elevation could be reached under a 2-yr or 5-yr surge condition		
FFE<BFE + 3' (or 2' inland)	Coastal Structure Finish Floor Elevation versus Flood Elevation	20%					FFE < BFE + 3' or 2' (inland)		
Lockout required to protect equipment under Cat5 Storm Surge	Coastal Structure Operation Limitations Under Cat5 Storm Surge	20%					Yes		
Exceedance of Canal Normal Operating Range	Inland Canal Performance Under Higher Tailwater Elevations	20%		Less than or Equal to 1 ft	More than 1 ft	> 2.5 ft	> 3.5 ft		
FPLOS Phase I Deficiency (Current Conditions)	Basinwide Level of Service - Current and Future FPLOS Assessment Results	20%	25-yr		10-yr		5-yr		
FPLOS Phase I Deficiency (Future Conditions)			25-yr		10-yr	5-yr	Less than 5-yr		
Known chronic and nuisance flooding report	Major Observed Flooding (where FPLOS Assessment Results are not available)						Yes		
				TOTAL WEIGHTED AVERAGE LIKELIHOOD OF FAILURE				0	

Consequence of Failure Scoring

Category	Basis	Weighting	1 (No Impact)	2	3	4	5 (High Impact)	TOTAL BY CATEGORY	JUSTIFICATION
Total Population	Census Population at each Basin Drainage Area	20%	Up to 50,000 people	Up to 100,000 people	Up to 200,000 people	Up to 500,000 people	More than 500,000 people		
Counties Adaptation Action Areas	Priority Action Areas Boundaries, as identified by the Counties	20%	Does not Intersect Adaptation Action Area				Intersect Adaptation Action Area		
Financially Disadvantage Areas Density	Households with income below $15,000 per Basin Drainage Area	20%	Lower Density		Average		Higher Density		
Public Water Supply Wellfields	Public water supply wellfields within 20,000ft of the 2018/2019 Saltwater Interface	20%	Lower Number		Average		Higher Number		
Critical Assets / Critical Lifelines Density	Critical lifeline assets per draingage area (Airports, Hospitals, Hazardous Waste, Law Enforcement, Schools, Fire Station, etc.)	20%	Lower Density		Average		Higher Density		
				TOTAL WEIGHTED AVERAGE CONSEQUENCY OF FAILURE				0	

Overall Score	0

CIP/SIP Risk Matrix

Category	Basis	Plus	1	2	3	4	5	TOTAL BY CATEGORY	JUSTIFICATION
SIP Overall Rating	Structure Inpection Program Report Final Category	Up to +5 pts	Overall C-2		Overall C-3		Overall C-4		
CIP Status	Project already in Design or Pre-Design Stage as part of CIP						Design or Issue ID Status		
				RESILIENCY IMPACT RATING				0	

Overall Resiiliency Score Plus SIP/CIP Status	0

Figure 11: Criteria Categories and Scoring utilized for the ranking of resiliency projects

Table 1. Ranking of Infrastructure Projects, according to the likelihood of failure and consequence of failure criteria, and total summarized points.

Structures	Likelihood of Failure								Consequence of Failure										
	Return Period of Overbank Flooding	Sea Level Resulting in Overbank Flooding	FFE<BFE + 3' (or 2' inland)	Lock out needed (Cat5)	Exceedance of Canal Normal Operating Range	FPLOS Phase I Deficiency (Current Conditions)	FPLOS Phase I Deficiency (Future Conditions)	Known chronic and nuisance flooding report	Total Population	Counties Adaptation Action Areas	Financially Disadvantage Areas	Public Water Supply Wellfields	Critical Assets / Lifelines Density	Likelihood of Failure Scoring	Consequence of Failure Scoring	**Resiliency Total Points**	SIP Overall Rating	CIP Status	**Total Points (SIP + Resiliency)**
S27	5	5	5	5	4	5	5	0	4	5	5	3	5	4.80	4.40	**21.12**	3	5	**25.12**
S26/S26PS	3	5	5	5	4	0	0	5	4	1	5	5	3	4.60	3.60	**16.56**	5	5	**21.56**
S29	3	3	5	5	3	1	4	0	5	1	5	5	3	4.00	3.80	**15.20**	5	5	**20.20**
S28	5	5	5	5	4	3	4	0	4	5	5	1	5	4.60	4.00	**18.40**	3	0	**19.90**
G57	3	3	5	0	4	5	5	0	4	1	5	5	5	3.40	4.00	**13.60**	3	5	**17.60**
S22	3	2	5	5	5	0	0	5	4	1	1	3	5	4.50	2.80	**12.60**	3	5	**16.60**
S37A	3	5	5	0	3	1	5	0	4	1	5	5	5	3.40	4.00	**13.60**	3	0	**15.10**
G58	5	5	5	5	4	0	0	0	2	5	5	1	3	3.80	3.20	**12.16**	5	0	**14.66**
S123	3	5	5	5	5	0	0	0	4	1	5	1	3	3.80	2.80	**10.64**	3	5	**14.64**
S20F	3	2	5	5	5	0	0	0	1	1	1	5	3	3.50	2.20	**7.70**	5	5	**12.70**
S21	3	3	5	5	5	0	0	0	4	1	5	1	3	3.60	2.80	**10.08**	5	0	**12.58**
S21A	3	1	5	5	5	0	0	0	3	1	5	1	1	3.40	2.20	**7.48**	5	5	**12.48**
G93	3	3	0	0	5	0	0	5	2	1	5	1	5	2.60	2.80	**7.28**	3	5	**11.28**
S25B/S25BPS	5	5	5	0	3	3	5	5	4	1	1	1	1	3.60	1.60	**5.76**	5	5	**10.76**
G56	3	1	5	0	2	0	0	5	4	1	1	5	1	2.80	2.40	**6.72**	3	5	**10.72**
G54	3	5	0	0	2	0	1	5	4	1	1	5	3	2.20	2.80	**6.16**	3	5	**10.16**
S25	5	5	5	5	4	0	0	5	4	1	1	1	1	4.80	1.60	**7.68**	3	0	**9.18**
S33	3	3	0	0	3	1	5	0	3	1	5	3	5	2.20	3.40	**7.48**	3	0	**8.98**
S20G	3	1	5	5	5	0	0	0	1	1	1	1	3	3.40	1.40	**4.76**	5	0	**7.26**
S13/S13PS	1	1	5	0	2	3	4	5	4	1	1	3	3	2.60	2.40	**6.24**	0	0	**6.24**
S36	3	3	0	0	2	1	3	0	4	1	5	3	3	1.60	3.20	**5.12**	1	0	**5.62**
S197	3	1	5	5	2	0	0	5	1	1	1	1	1	3.80	1.00	**3.80**	3	0	**5.30**
S20	5	5	0	5	3	0	0	0	1	1	1	1	1	2.60	1.00	**2.60**	3	0	**4.10**

Resiliency Prioritization Matrix

Consequence of Failure					
5	**5**	**10**	**15**	**20**	**25**
4	**4**	**8**	**12**	**16**	**20**
3	**3**	**6**	**9**	**12**	**15**
2	**2**	**4**	**6**	**8**	**10**
1	**1**	**2**	**3**	**4**	**5**
	1	2	3	4	5
	Likelihood of Failure				

(+5 CIP/SIP Points)

>1	Low Impact
>4	Medium Low Impact
>6	Medium Impact
>9	Medium High Impact
>16	High Impact

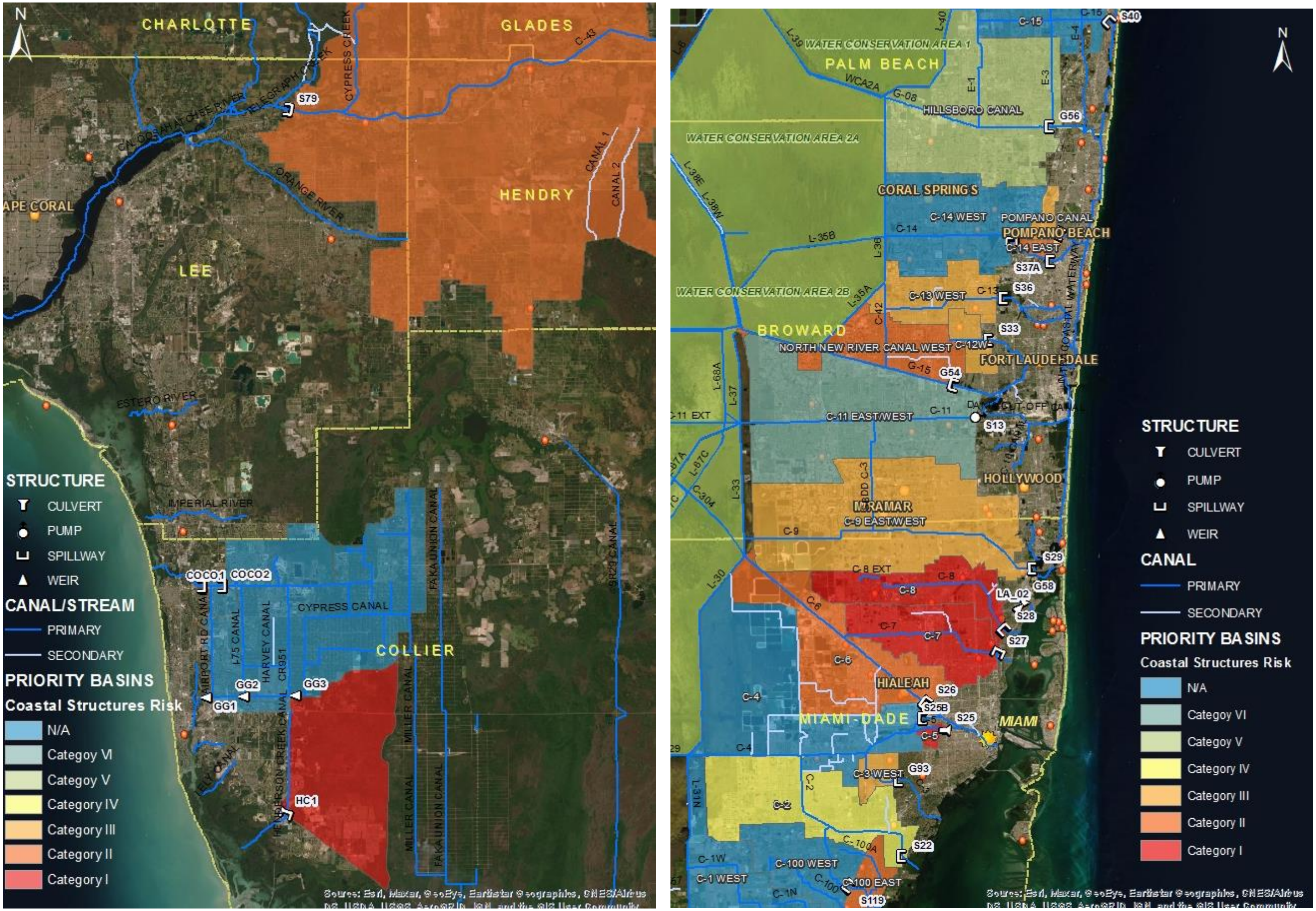


Figure 12. Costal Structure Performance Under Higher Tailwater Conditions in Miami Dade and Broward Counties and Big Cypress Basin.

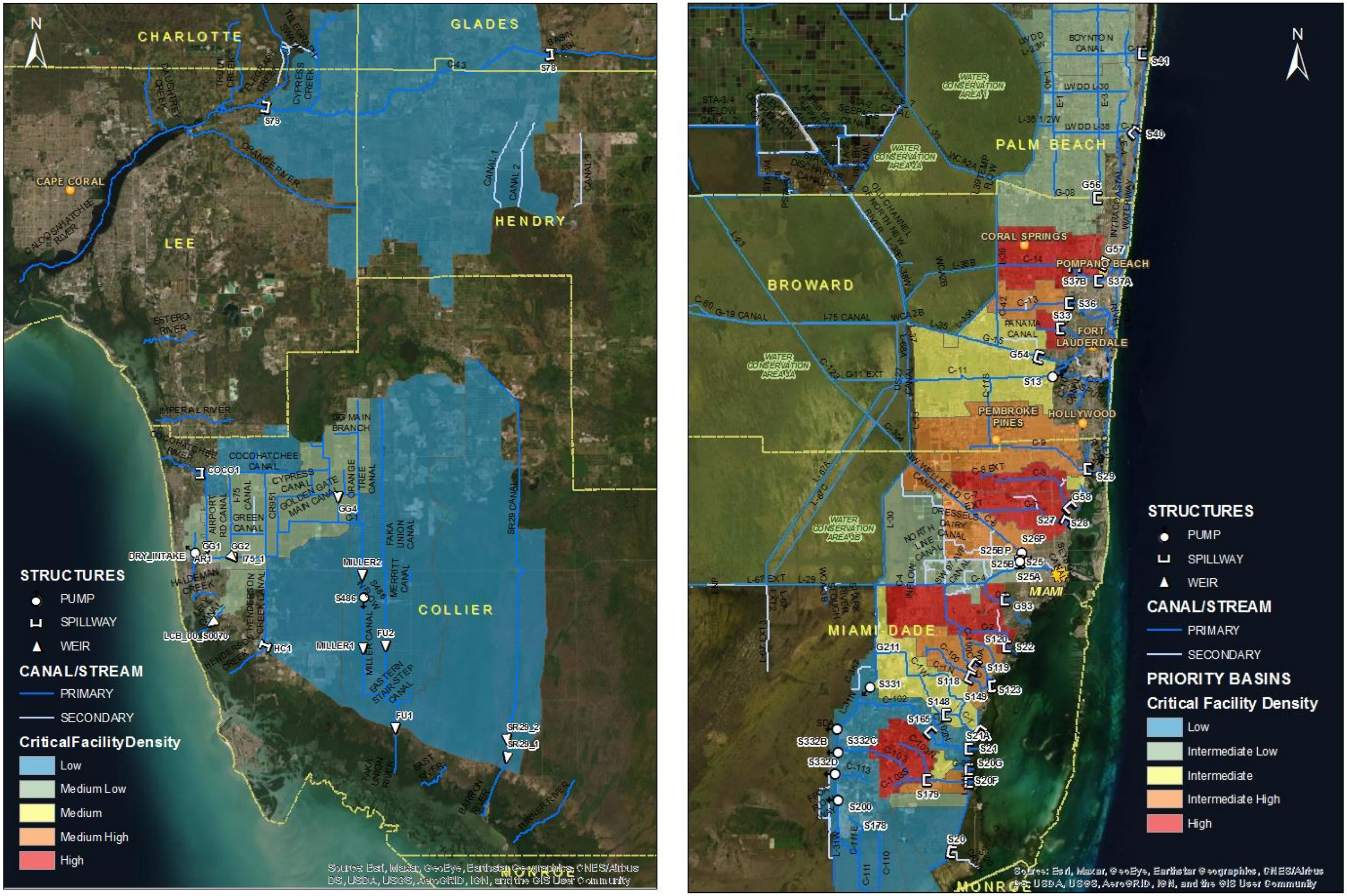


Figure 13. Critical Facility / Lifelines Density for project priority basins in Miami Dade and Broward Counties and Big Cypress Basin.

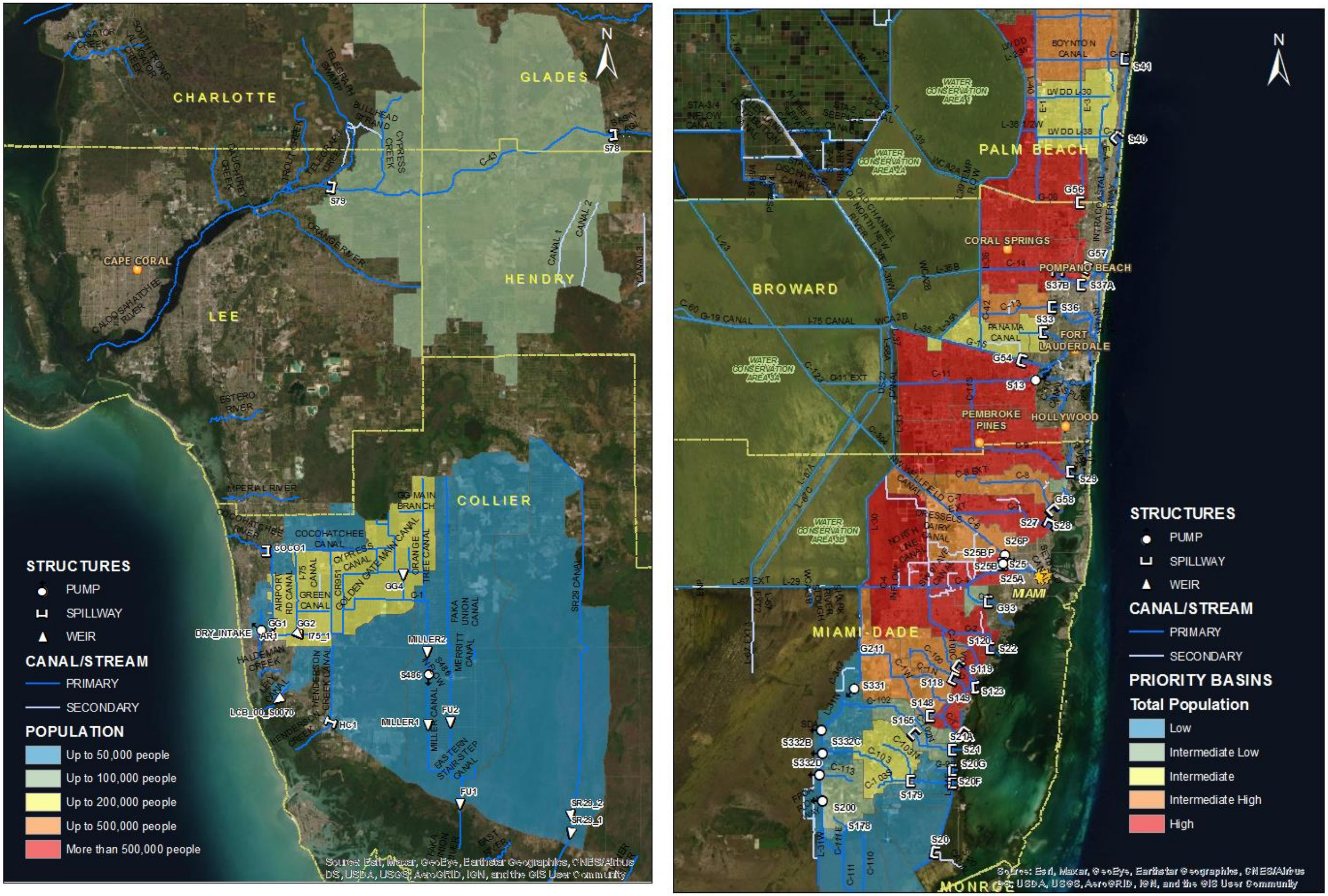


Figure 14. Total Population Ranking for project priority basins in Miami Dade and Broward Counties and Big Cypress Basin.

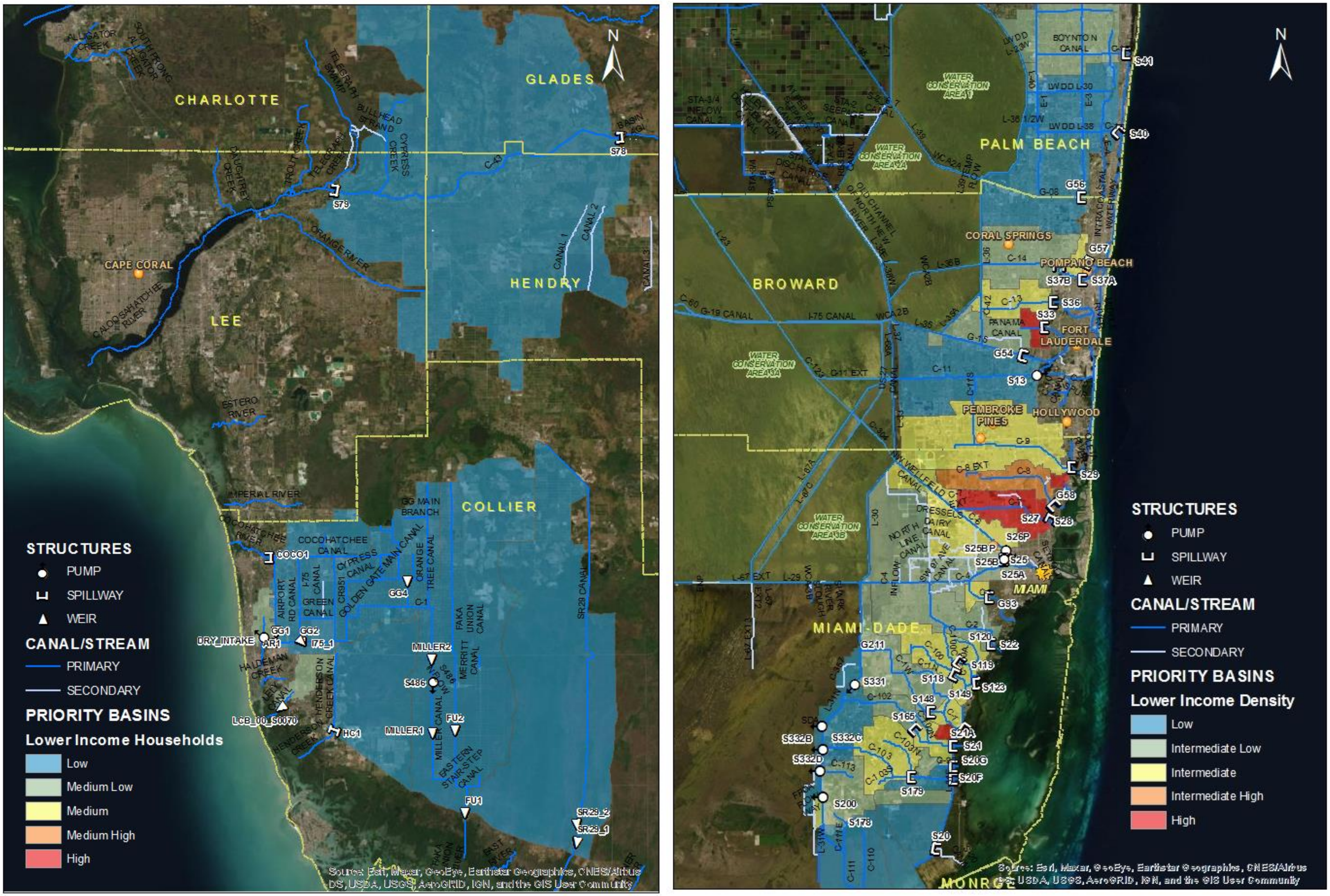


Figure 15. Lower Income Households for project priority basins in Miami Dade and Broward Counties and Big Cypress Basin.

5. Priority Structure Cost Estimates

The cost estimates for structure improvements were prepared using the District's current understanding of construction cost in the marketplace and historical costs from projects of similar scope. Additionally, the District followed cost estimating procedures like those employed by the U.S. Army Corps of Engineers. The initial sizing of each proposed pump station is based upon the recent FPLOS study results. Pump station discharge capacity was calculated using half of one quart of the design discharge capacity of the structure (see justification in Resiliency Approach section above). For instance, a structure with a discharge capacity of 1000 cfs would need a 250 cfs pump station. The pump station cost estimates were calculated by a Professional Engineer certified in the State of Florida. Estimates were based upon the District's record of pump station costs from 2006 to present and adjusted for coastal conditions in Miami-Dade County. The cost estimates for each forward pump station were calculated based upon the range of pumping capacity of the pump station (Table 2). For example, a 250 cfs pump station would cost $13,750,000 as the cost per unit of discharge for the "up to 250 cfs range" is $55,000. All estimated costs include backup generators, as appropriate, and the schedules for implementation of the Coastal Structure Refurbishment and Forward Pump Projects is estimated at an average of 1.5 years for design and 2.5 years for construction. Schedules will be adjusted based upon confirmation of project implementation. Real Estate costs were determined for the S-27 and S-29 Coastal Structures and range from $8M - $16M depending on the project footprint and the land use within the areas surrounding the project. An initial placeholder of $7M for real estate costs, as well as $2M for tying the structure back to higher elevation were included in all the structure cost estimates and will be refined during the pre-design stage. Cost estimates for forward pumps and respective backup generators (at 10% of pump total costs) are also included, but forward pumps may not be recommended for all the structures. Feasibility studies, conducted as part of FPLOS Phase II efforts, will confirm the need for forward pumps. Detailed cost estimates for each structure can be found in Appendix A.

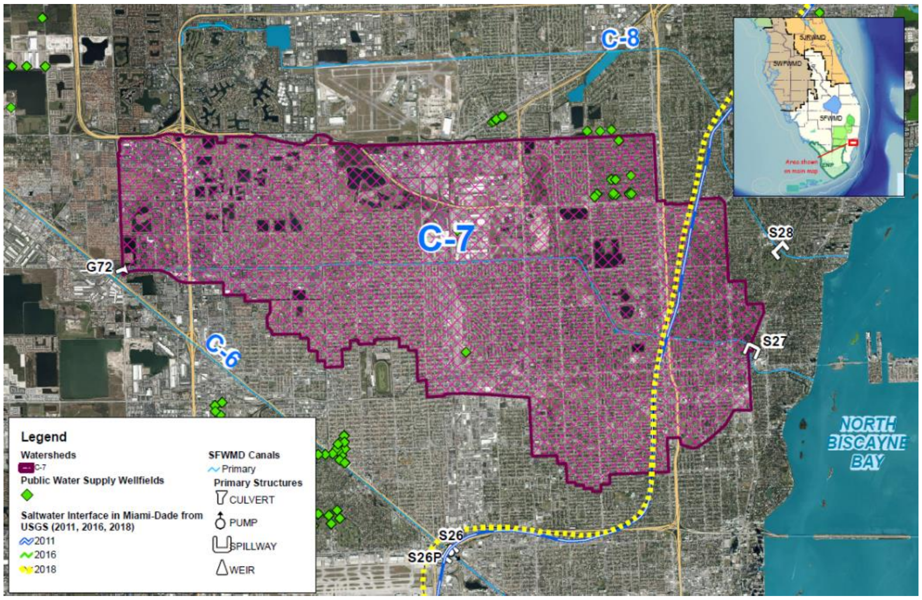
Table 2. Summary of Cost Assumptions

Pump Capacity % (from Design Discharge)	
Medium High and High Impact Structures	50%
Medium, Medium Low and Low Impact	25%

Forward Pump Cost Estimates			
Cubic Feet Per Second	**Threshold**	**Cost per Unit of Discharge**	
Up to 250	250	$	55,000.00
250-500	500	$	53,000.00
500-750	750	$	51,000.00
750-1000	1000	$	50,000.00
> 1000	other	$	48,000.00

Real Estate Costs - Placeholder Average Cos	$	7,000,000.00
Forward Pump Backup Generator	10% of forward pump costs	
Tie Back (flood barriers around Coastal Struc	$	2,000,000.00

S-27 Coastal Structure Resiliency



S-27 is a reinforced concrete, gated spillway, with discharge controlled by two vertical lift gates with a discharge capacity of 2,800 cfs. Operation of the gates is automatically controlled. The structure is in the City of Miami near the mouth of C-7 Canal about 700 feet from the shore of Biscayne Bay. The C-7 Basin has a population of about 275,000 people within 32 square miles, in the northeastern portion of Miami-Dade County. The area drained by the C-7 Canal is fully developed with primarily residential and commercial uses. The C-7 Canal is the central flood control feature that receives and conveys basin flood waters by gravity through the S-27 Coastal Structure to sea. This structure maintains optimum water control stages upstream in C-7 (Little River Canal); it passes the design flood (75 percent of $the Standard Project Flood) without exceeding upstream flood design stage, and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of high tides.

As evidenced during the recent Tropical Storm Eta in November 2020, SLR is limiting the ability of these central flood control features to convey flood waters (Figure 16). Serious flooding events occurred in the C-7 Basin, with near 100-year rainfall volumes, and higher sea levels impeding the S-27 Coastal Structure's ability to deliver those volumes to tide.

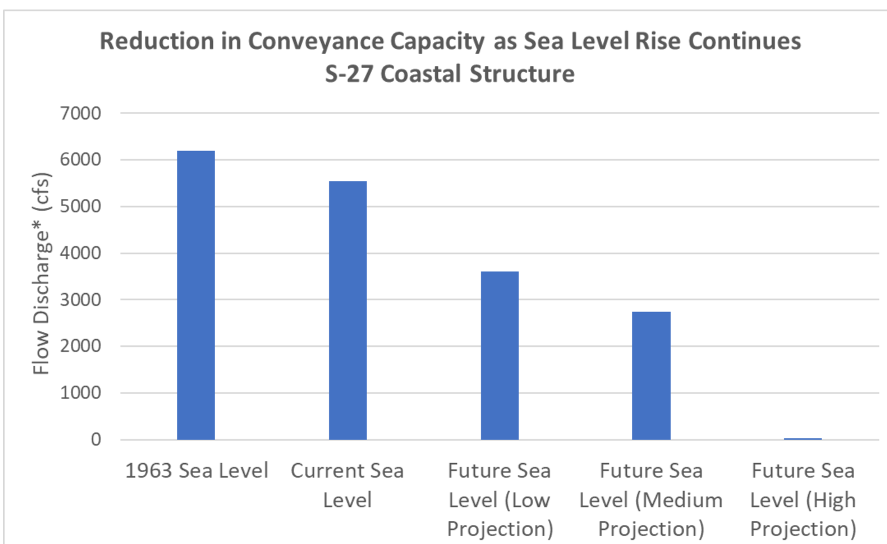


Figure 16. Reduction in conveyance capacity at S-27 as SLR continues.

The FPLOS Program is developing water management models to evaluate system operations under changed current and future conditions and recommend priority infrastructure investments in critical locations. Recent observations and FPLOS model results show the S-27 Structure is in urgent need of modifications.

In addition, SFWMD will partner with Miami Dade County to ensure that the proposed infrastructure projects adhere to the recommendations of the Biscayne Bay Task Force and prioritize Biscayne Bay health and resilience. The Task Force report also recommends accelerating green infrastructure solutions for flooding, resiliency and water quality that include a review of watershed habitat restoration opportunities in repetitive loss areas and future flood hazard areas; and evaluating and allocating cost savings of Community Rating Systems (CRS) benefits into the Biscayne Bay watershed water quality restoration plan. A request for innovation will be presented, as part of this project design, to advance a water quality pilot technology at Little River Basin, to be associated with the proposed project components.

A total cost estimate to harden the S-27 Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the C-7 Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Additional funds to purchase real estate for the project are included and negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-27 Cost Estimate	
Structure Hardening	$5,642,523
Forward Pump – 1400cfs	$67,200,000
Forward Pump Backup Generator Facility	$6,720,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$12,234,378
Water Quality Pilot Technology RFI	$500,000
Real Estate	$10,000,000
Total	**$104,296,902**

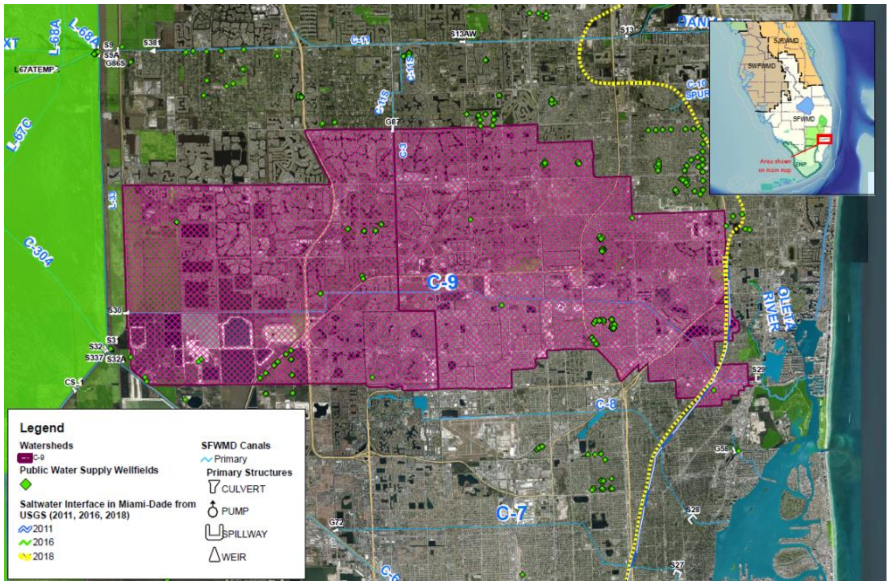
S-26 Coastal Structure Resiliency

S-26 is a two-bay, reinforced concrete gated spillway located in the City of Miami at the NW 36th Street crossing of the Miami (C-6) Canal, between NW North River Drive and NW South River Drive, northeast of the Miami International Airport. The structure consists of two 14.1 feet high by 26.0 feet wide gates with a discharge capacity of 3,470 cfs. The discharge from the structure is controlled by two hydraulically driven cable operated vertical lift gate mechanisms. The gates can either be remotely operated from the District Control Room or controlled on-site. To maintain flood protection for the C-6 basin, a 600 cfs pump station was added to the S-26 spillway as part of the Miami Dade County Flood Mitigation Program. The S-26 is the outlet to tide for the C-6 basin. The structure maintains optimum water control stages upstream in the C-6 Canal. It was designed to pass 100% of the Standard Project Flood (SPF) without exceeding upstream flood design stage and restricts downstream flood stages and discharge velocities to non-damaging levels, and it prevents saltwater intrusion during periods of extreme high tides. The structure is maintained by the Miami Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes 122

S-26 Cost Estimate	
Structure Hardening	$7,101,519
Forward Pump – 1735 cfs	$83,280,000
Forward Pump Backup Generator Facility	$8,328,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$15,106,428
Real Estate	$7,000,000
Total	**$122,815,946**

S-29 Coastal Structure Resiliency



The S-29 Coastal structure is a reinforced concrete, gated spillway, with discharge controlled by four cable operated, vertical lift gates with a discharge capacity of 4,780 cfs. Operation of the gates is automatically controlled so that the gates open or close in accordance with the seasonal operational criteria. The structure is in the City of North Miami Beach near the mouth of the C-9 (Snake Creek Canal) and about 500 feet from the shore of Lake Maule. The C-9 Basin is a region of about 450,000 people within100 square miles, in the southern portion of Broward County and northeastern portion of Miami-Dade County. The area drained by the C-9 Canal is fully developed with primarily residential and commercial uses. The C-9 Canal is the central flood control feature which receives and conveys basin flood waters by gravity through the S-29 Coastal Structure to sea. This structure maintains optimum water control stages upstream in C-9; it passes the design flood (100 percent of the Standard Project Flood) without exceeding upstream flood design stage, and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of extreme high tides.

As evidenced during the recent Tropical Storm Eta, SLR is limiting the ability of these central flood control features to convey flood water (Figure 17). Serious flooding events occurred in the C-9 Basin, with greater than 100-year rainfall volumes, and higher sea level impeding the S-29 Coastal Structure's ability to deliver those volumes to tide.

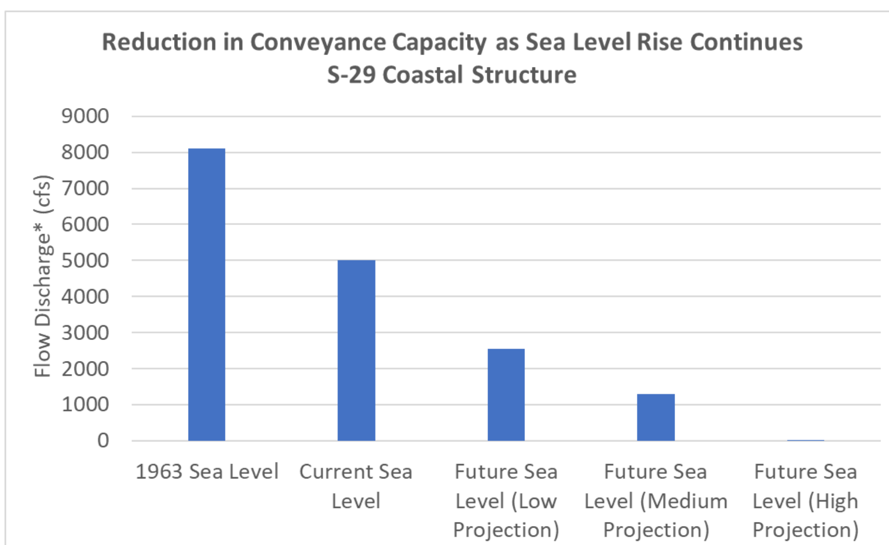


Figure 17. Reduction in conveyance capacity at S-29 as SLR continues

The FPLOS Program is developing water management models to evaluate system operations under changed current and future conditions and recommend priority infrastructure investments in critical locations. Recent observations and FPLOS model results show the S-29 Structure is in urgent need of modifications.

A total cost estimate to harden the S-29 Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the C-9 Basin is presented below. The estimate includes modifications to the existing structure and control building, addition of a forward pump and construction of flood barriers. The additional pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Additional funds to purchase real estate for the project are included and negotiations with Miami Dade County for land purchase will initiate upon funding confirmation. The project is located within an existing Miami-Dade County park and negotiations might result in reduced real estate costs. The current location of major equipment in the deck of the structure might trigger a need for replacement instead of hardening, which will be confirmed during Design.

S-29 Cost Estimate	
Structure Hardening	$10,452,319
Forward Pump – 2000cfs	$97,915,774
Forward Pump Backup Generator Facility	$10,448,077
Structure Tie Back (Flood Barrier)	$2,769,122
Design, Implementation & Construction Management	$18,237,794
Real Estate	$16,000,000
Total	**$155,823,087***

*May need to be replaced rather than refurbished, costs may be higher.

S-28 Coastal Structure Resiliency

S-28 is a reinforced concrete, gated spillway, with discharge controlled by two cable operated, vertical lift gates that are 17.5 feet high by 27.8 feet wide. The structure has a discharge capacity of 3,220 cfs. S-28 is in the City of Miami near the mouth of C-8 about a mile from the shore of Biscayne Bay. Operation of the gates is automatically controlled so that the gate hydraulic operating system opens or closes the gates in accordance with the operational criteria. This structure maintains optimum water control stages upstream in C-8; it passes the design flood (100 percent of the Standard Project Flood) without exceeding upstream flood design stage, and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of extreme high flood tides. S-28 is maintained by the Miami Field Station.

A total cost estimate to harden the S-28 Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the C-8 Basin is presented below and it includes modifications to the existing structure and control building, addition of a forward pump and construction of flood barriers. The additional pumping capacity will extend the conveyance performance for additional years as sea level rises, delay out of bank flooding, and reduce canal peak stages. Additional potential funds to purchase real estate for the project are included and negotiations with landowner will initiate upon funding confirmation.

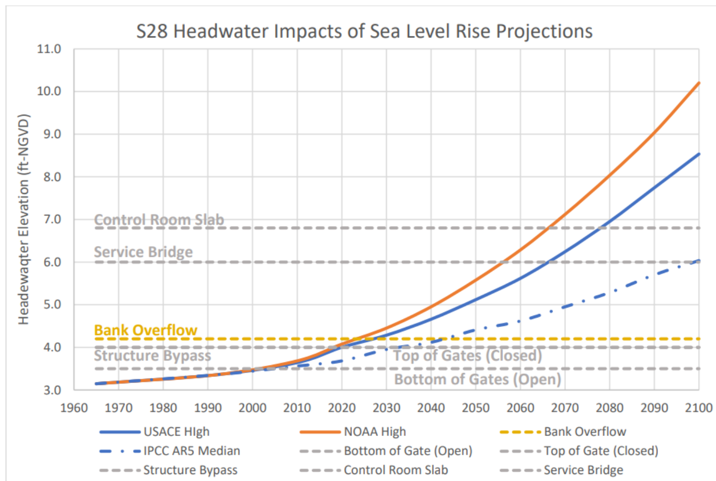


Figure 18. S-28 Headwater Impacts of Sea Level Rise Projections

S-28 Cost Estimate	
Structure Replacement	$13,510,594
Forward Pump – 1500cfs	$79,639,466
Forward Pump Backup Generator Facility	$8,750,314
Structure Tie Back (Flood Barrier)	$2,987,463
Design, Implementation & Construction Management	$15,733,176
Real Estate	$7,000,000
Total	**$127,621,014**

G-57 Coastal Structure Resiliency

G-57 is a reinforced concrete, gated spillway with discharge controlled by two stem-operated, vertical lift gates measuring 6 ft. high by 14 ft. wide. Discharge capacity at G-57 is 375 cfs. Operation of the gates is automatically controlled so that the gate operating system opens or closes the gates in accordance with the operational criteria. The structure is located on the Old Pompano Canal just east of Cypress Road. This structure maintains upstream water control stages in Old Pompano Canal. It passes the design flood without exceeding the upstream flood design stage and restricts downstream flood stages and channel velocities to non-damaging levels; and it prevents saline intrusion. G-57 is serviced by the Fort Lauderdale Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

G-57 Cost Estimate	
Structure Hardening	$5,316,285
Forward Pump – 200cfs	$10,312,500
Forward Pump Backup Generator Facility	$1,031,250
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$2,799,005
Real Estate	$7,000,000
Total	**$28,459,040**

S-22 Coastal Structure Resiliency

S-22 is a two-bay, reinforced concrete gated spillway located in C-2 (Snapper Creek) Canal, about 7,000 feet from the mouth of Biscayne Bay and about ten miles southwest of downtown Miami. The C-2 Canal has as an open channel connection with the C-4 Canal, west of intersection of Turnpike and Miami SW 8th Street. The structure has two (2) 15.0 feet high by 17.7 feet wide gates and a discharge capacity of 1905 cfs. The gates are operated by an electric driven cable drum. The gates can either be remotely operated from the District Control Room or controlled on-site. The purpose of S-22 is to permit release of flood runoff from the tributary basin, prevent over-drainage, and prevent saltwater intrusion during periods of extreme high tides. The structure maintains optimum stages upstream in the C-2 Canal. The structure is maintained by the Miami Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-22 Cost Estimate	
Structure Hardening	$5,997,785
Forward Pump – 1000cfs	$47,625,000
Forward Pump Backup Generator Facility	$4,762,500
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$9,057,792
Real Estate	$7,000,000
Total	**$76,443,078***

*May need to be replaced rather than refurbished, costs may be higher.

S-37A Coastal Structure Resiliency

This structure is a reinforced concrete, gated spillway with discharge controlled by two stem-operated, vertical lift gates. The structure has a discharge capacity of 3,890 cfs. Operation of the gates is automatically controlled so that the gate operating system opens or closes the gates in accordance with the operational criteria. The structure is located on C-14, 150 feet east of Dixie Highway and just east of the F.E.C. Railroad. This structure maintains optimum upstream water control stages in C-14; it passes the design flood (40% and 60% of the Standard Project Flood from the western and eastern portions of the drainage basin, respectively) without exceeding the upstream flood design stage, and restricts downstream flood stages and channel velocities to non-damaging levels; and it prevents saltwater intrusion during periods of extreme high tides. S-37A is maintained by the Fort Lauderdale Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-37A Cost Estimate	
Structure Hardening	$6,240,444
Forward Pump	$48,625,000
Forward Pump Backup Generator Facility	$4,862,500
Structure Tie Back (Flood Barrier)	$2,000,00
Design, Implementation & Construction Management	$9,259,191
Real Estate	$7,000,000
Total	**$77,987,136**

G-58 Coastal Structure Resiliency

G-58 is a four-barrel corrugated metal pipe culvert located on Arch Creek immediately downstream from the Florida East Coast Railroad bridge. Features include one 60-inch culvert and three 72-inch culverts. The discharge capacity of this structure is 300 cfs. This structure maintains optimum upstream water control stages in Arch Creek; it passes the design flood (60% of the Standard Project Flood) without exceeding upstream flood design stage; and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of extreme high tides. G-58 is serviced by the Miami Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

G-58 Cost Estimate	
Structure Hardening	$6,136,884
Forward Pump	$4,125,000
Forward Pump Backup Generator Facility	$412,500
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$1,901,157
Real Estate	$7,000,000
Total	**$21,575,542**

S-123 Coastal Structure Resiliency

S-123 is a fixed crest, reinforced concrete, gated spillway, with discharge controlled by two cable operated, vertical lift gates measuring 12.7 ft. high by 25.0 ft. wide. Discharge capacity at this structure is 2,300 cfs. Operation of the gates is automatically controlled so that the gate hydraulic operating system opens or closes the gates in accordance with the operational criteria. The structure is located near the mouth of C-100 below the junction of C-100, C100A and C-100B and about 600 feet from the shore of Biscayne Bay. This structure maintains optimum water control stages upstream in Canals C-100, C-100A, and C-100B; it passes the design flood (40 percent of the Standard Project Flood) without exceeding upstream flood design stage, and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of extreme high tides. The structure is maintained by Miami Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-123 Cost Estimate	
Structure Hardening	$6,533,070
Forward Pump	$55,200,000
Forward Pump Backup Generator Facility	$5,520,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$10,387,960
Real Estate	$7,000,000
Total	**$86,641,031**

S-20F Coastal Structure Resiliency

Inspection Summary/Issue Identification

FY20 Update to FY15019 – *(Updated 1-31-20)*

S-20F Major Half-Life Refurbishment		**Date: 1-31-2020**
Structure Type: Spillway	Field Station / Contact: Homestead / Sean Smith	**Priority Score: 17.02** **Priority Level: 2**
Inspector Information		
Lead Inspector: Tim Kunard	Inspection Date: 1-6-20	Phone: 561-682-6305
Previous Inspection Date: 2-12-15	Previous Inspector: Gary Dunmyer	
F/S Superintendent: **Sean Smith** Signature:	F/S Bureau Chief: **Jesus Carrasco** Signature:	
Structure Details		

Description:	# Gates	# Pumps	# Barrels	Lifting Mechanism:
Spillway	3	0	0	Hydraulic

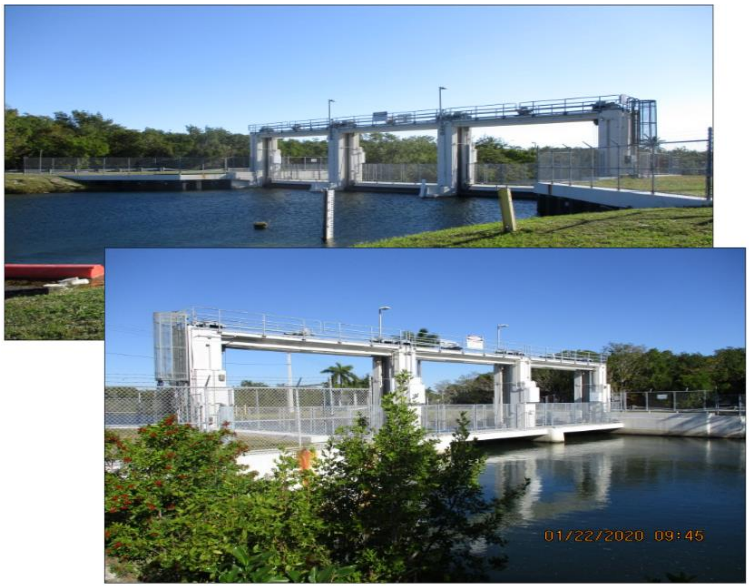
Figure 1 – Aerial image of the S20F Structure site

S-20F is a three-bay, reinforced concrete gated spillway, located on the L-31E Levee at its junction with C-103 (Mowry) Canal, about 2,000 feet from the shore of Biscayne Bay and 190 feet east of SW 320th Street, approximately 8.7 miles southeast of the City of Princeton in eastern Miami-Dade County. The structure consists of three 13.0 feet high by 25.0 feet wide gates and has a discharge capacity of 2,900 cfs. Discharge from the structure is controlled by three hydraulically driven cable operated vertical lift gates. The gates can either be remotely operated from the District Control Room or controlled on-site. The S-20F Structure maintains optimum stages upstream along the C-103 Canal. The structure restricts downstream flood stages and discharge velocities to non-damaging levels and prevents saltwater intrusion during periods of extreme high tides. The structure is maintained by the Homestead Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-20F Cost Estimate	
Structure Hardening	$7,312,238
Forward Pump	$36,975,000
Forward Pump Backup Generator Facility	$3,697,500
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$7,497,710
Real Estate	$7,000,000
Total	**$64,482,449**

S-21 Coastal Structure Resiliency



S-21 is a reinforced concrete gated spillway with three cable operated vertical lift gates, located near the mouth of C1 at its junction with L31E and about 3,500 feet from the shore of Biscayne Bay. Each gate measures 10.7 feet high by 27.8 feet wide. The discharge capacity of S-21 is 2,560 cfs. Operation of the gates is automatically controlled so that the hydraulic operating system opens or closes the gates in accordance with the operational criteria. This structure maintains optimum water control stages upstream in C1 and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of extreme high tides. The gates can be remotely controlled by either the on-site controls or from the SFWMD Control Room. Operation of the gate is automatically controlled so that the gate opens or closes in accordance with the operational criteria.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-21 Cost Estimate	
Structure Hardening	$7,328,487
Forward Pump	$32,640,000
Forward Pump Backup Generator Facility	$3,264,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$6,784,873
Real Estate	$7,000,000
Total	**$59,017,360**

S-21A Coastal Structure Resiliency

S-21A is a reinforced concrete, two-bay, gated spillway located near the mouth of C-102 canal (Princeton) at its junction with the L-31E Levee, about a mile from the shore of Biscayne Bay and immediately east of SW 97th Avenue. The structure consists of two 11.8 feet high by 20.8 feet wide gates and has a discharge capacity of 1300 cfs. The discharge from the structure is controlled by two hydraulically driven cable operated vertical lift gates. The gates can be remotely controlled by either the on-site controls or from the SFWMD Control Room. Operation of the gate is automatically controlled so that the gate opens or closes in accordance with the operational criteria. Upstream of S-21A, the C-102 canal has an open junction with the L-31E canal on its north bank. The southern junction is controlled by a gated project culvert. A new pump station (S-705) is scheduled to be constructed in this junction as part of the Biscayne Bay Coastal Wetlands Project. The structure is maintained by Homestead Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-21A Cost Estimate	
Structure Hardening	$6,288,289
Forward Pump	$33,150,000
Forward Pump Backup Generator Facility	$3,315,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$6,712,993
Real Estate	$7,000,000
Total	**$58,466,282**

G-93 Coastal Structure Resiliency

G-93 is a two-bay, reinforced concrete gated spillway with two single stem vertical lift gates measuring 5.0 feet high by 10.0 feet wide on the C-3 (Coral Gables) Canal, west of Southwest 57^{th} Ave (Red Road or SR959) in the City of Coral Gables. This structure has a discharge capacity of 640 cfs. The C-3 Canal has an open connection to the C-4 Canal just east of the Palmetto Expressway and continues about 4.1 miles downstream of G-93 through highly urbanized South Miami areas before discharging to Biscayne Bay at Sunrise Harbor. The original structure, G-97, was replaced in January 1990 by G-93. The structure maintains optimum upstream water control stages; it was designed to pass 40% of the Standard Project Flood (SPF) plus a small discharge from the C-4 basin without exceeding upstream flood design stage and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of high tides. The structure is maintained by Miami Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

G-93 Cost Estimate	
Structure Hardening	$4,231,301
Forward Pump	$16,960,000
Forward Pump Backup Generator Facility	$1,696,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$3,733,095
Real Estate	$7,000,000
Total	**$35,620,397**

S-25B Coastal Structure Resiliency

S-25B is a two-bay, reinforced concrete gated spillway located in the City of Miami immediately east of the Northwest 42nd Avenue (Le Jeune Road) crossing of the C-4 (Tamiami) Canal, east of Miami International Airport. The structure consists of two 11.9 feet high by 22.8 feet wide gates with a discharge capacity of 2000 cfs. The gates are controlled by two hydraulically driven cable operated vertical lift gate mechanisms. The gates can either be remotely operated from the District Control Room or controlled on-site. Structure S-25B controls flow from the C-4 canal to the Miami Canal downstream of S-26. The structure maintains optimum stages upstream in the C-4 Canal. It was designed to pass 100% of the Standard Project Flood (SPF) for the eastern portion of the C-4 basin without exceeding upstream flood design stage and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion from the Miami Canal during periods of extreme high tides. This structure also includes a forward pump station. The S-25B Forward Pump station is a reinforced concrete, electric pump station, with discharge controlled by three 200 cfs pumps. These pumps were added to the gravity structure S-25B in 2002 to maintain discharges from the land side to the seaside of the structure when gravity capacity is limited, or the gates need to be closed due to the threat of saltwater intrusion. The pumped water flows into the 120-foot box culvert that runs under and along the edge of a golf course south of the S-25B spillway and discharges downstream (east) of S-25B into the C-4 Canal. The culvert is 10 feet high by 8 feet wide and consists of segmental sections with bell and spigot type connections. The pumps can either be remotely operated from the District Control Room or controlled on-site. This structure is operated in coordination with the adjacent S-25B spillway. The structure is maintained by Miami Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-25B Cost Estimate	
Structure Hardening	$6,465,811
Forward Pump	$48,000,000
Forward Pump Backup Generator Facility	$4,800,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$9,189,872
Real Estate	$7,000,000
Total	**$77,455,683**

G56 Coastal Structure Resiliency

G-56 is a reinforced concrete gated spillway, with discharge controlled by three cable operated, vertical lift gates. This structure has a discharge capacity of 3,760 cfs. The gates are operated on-site or remotely from the District Control Room. The new structure was completed in 1991 to replace the old Deerfield Lock Structure. The structure is located near the mouth of the Hillsboro Canal, about two miles west of Deerfield Beach. This structure maintains optimum water control stages in the Hillsboro Canal. It passes flood flows while limiting the upstream stage, downstream stage and channel velocity. G56 is serviced by the Fort Lauderdale Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

G-56	
Structure Hardening	$8,859,342
Forward Pump	$90,240,000
Forward Pump Backup Generator Facility	$9,024,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$16,518,501
Real Estate	$7,000,000
Total	**$133,641,844**

G-54 Coastal Structure Resiliency

G-54 is a reinforced concrete gated spillway, located on the North New River Canal about 0.9 mile west of the intersection of I-595 and Florida's Turnpike, west of Ft. Lauderdale. The structure consists of three 9.5 feet high by 16 feet wide gates with a discharge capacity of 1,600 cfs. The discharge from this structure is controlled by hydraulically driven cable operated vertical lift gates. The gates can either be remotely operated from the District Control Room or controlled on-site. Construction of G-54 was completed in 1992 to replace the old Sewell Lock Structure. This structure maintains optimum water control stages in the North New River canal. It passes watershed flows or regulatory releases from Water Conservation Area (WCA)-2 while limiting the upstream stage, and channel velocity. G-54 is serviced by the Fort Lauderdale Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

G-54 Cost Estimate	
Structure Hardening	$8,023,036
Forward Pump	$40,000,000
Forward Pump Backup Generator Facility	$4,000,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$8,103,455
Real Estate	$7,000,000
Total	**$69,126,491**

S-25 Coastal Structure Resiliency

S-25 is a single barrel, corrugated metal pipe culvert with a reinforced-concrete headwall and operating platform on the upstream (west) side. The structure is in the C-5 (Comfort) Canal, at the exit ramp from the East-West Dolphin Expressway (SR 836) and the crossing of Northwest 27th Avenue in the City of Miami. The structure consists of one 9.1 feet high by 8.3 feet wide gate with a discharge capacity of 320 cfs. S-25 can either be remotely operated from the District Control Room or controlled on-site. S-25 maintains an optimum upstream stage in C-5 Canal; it was designed to pass 1-in-10 flood without exceeding upstream flood design stage and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of extreme high tides. The structure is maintained by Miami Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-25 Cost Estimate	
Structure Hardening	$3,695,351
Forward Pump	$8,800,000
Forward Pump Backup Generator Facility	$880,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$2,306,302
Real Estate	$7,000,000
Total	**$24,681,654**

S-33 Coastal Structure Resiliency

S-33 is a reinforced concrete, gated spillway with discharge controlled by a cable operated, vertical lift gate that is 9.0 feet high by 20.0 feet wide. The structure has a discharge capacity of 920 cfs. The gates can be remotely controlled by either the on-site controls or from the SFWMD Control Room. Operation of the gate is automatically controlled so that the gate opens or closes in accordance with the operational criteria. The structure is located on C-12 about 1/2 mile east of State Road 7. This structure maintains optimum upstream water control stages in C-12; it passes the design flood (50% of the Standard Project Flood) without exceeding the upstream flood design stage, and restricts downstream flood stages and channel velocities to non-damaging levels, and it prevents saltwater intrusion into the area west of the structure. S-33 is maintained by the Fort Lauderdale Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-33 Cost Estimate	
Structure Hardening	$4,237,616
Forward Pump	$12,650,000
Forward Pump Backup Generator Facility	$1,265,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$3,022,892
Real Estate	$7,000,000
Total	**$30,175,508**

S-20G Coastal Structure Resiliency

S-20G is a reinforced concrete gated spillway located near the mouth of the Military Canal at its junction with the L-31E Levee, about 2,300 feet from the shore of Biscayne Bay. The structure is located immediately north of SW 301 Street, approximately 8 miles east of the City of Homestead in eastern Miami-Dade County. The structure consists of one 12.3 feet high by 25.8 feet wide gate. The discharge capacity of S-20G is 900 cfs. The structure is controlled by a hydraulically driven cable operated vertical lift gate. The gate can either be remotely operated from the District Control Room or controlled on-site. Operation of the gate is automatically controlled so that the hydraulic operating system opens or closes the gate in accordance with the operational criteria. Upstream of S-20G, the Military Canal does not have open junctions with the L-31E levee and both junctions are controlled by gated (flashboard riser) project culverts (L-31E PC-17&18). The northern junction is controlled by Project Culvert L-31E PC-17, which controls flow between the C-102 (S-21A) basin and the Military Canal (S-20G) basin. The southern junction is controlled by Project Culvert L-31E PC-18, which controls flow between the C-103 (S-20F) basin and the Military Canal (S-20G) basin. The structure maintains optimum stages upstream in the Military Canal and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of extreme high tides. S-20G is maintained by Homestead Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-20G Cost Estimate	
Structure Hardening	$4,084,409
Forward Pump	$12,375,000
Forward Pump Backup Generator Facility	$1,237,500
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$2,954,536
Real Estate	$7,000,000
Total	**$29,651,446***

*May need to be replaced rather than refurbished, costs may be higher.

S-13 Coastal Structure Resiliency

S-13 is a pump station with a gated spillway that can control flow that bypasses the pumps. The structure is in C-11 (South New River Canal) about 300 feet west of U.S. Highway 441 and 5.5 miles southwest of Fort Lauderdale. It is a reinforced concrete structure with a concrete block superstructure. The pump station has a capacity of 540cfs at a 4-foot static head and is powered by a diesel engine. The gated spillway features a 16-foot wide by 11-foot high vertical lift gate which is raised or lowered by means of stem hoists. Operation of the gate is normally controlled automatically but may be controlled manually during emergencies or for servicing. Other equipment includes a 5-ton manually operated overhead bridge crane for general maintenance. The purpose of the structure is to release flood runoff from, prevent over drainage of, and saltwater intrusion into the agricultural area served by C-11 (South New River Canal) west of the structure. The purpose of the pump station is to pump surplus water through C-11 from the agricultural area west of the structure at a rate of 3/4 inch per day to keep water levels in the canal west of the structure at an optimum water control stages upstream in C-11 East. This structure is maintained by the Fort Lauderdale Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building. Additional funds to purchase real estate for the project are included and negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-13 Cost Estimate	
Structure Hardening	$32,269,673
Forward Pump	$ -
Forward Pump Backup Generator Facility	$ -
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$5,140,451
Real Estate	$ -
Total	**$39,410,124**

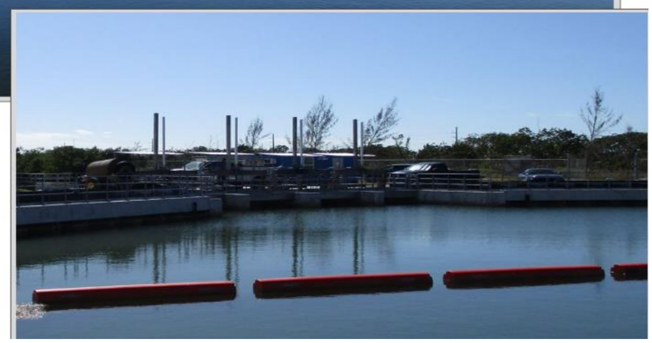
S-36 Coastal Structure Resiliency

S-36 is a reinforced concrete, gated spillway with discharge controlled by a cable operated, vertical lift gate that is 14.0 ft. high by 25.0 ft. wide. The structure has a discharge capacity of 1,090 cfs. Operation of the gate is automatically controlled so that the gate electric motor opens or closes the gate in accordance with the seasonal operational criteria. The structure is located on C-13 west of Oakland Park. This structure maintains optimum water control stages upstream in C-13; it passes the design flood (50 percent of the Standard Project Flood) without exceeding upstream flood design stage, and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saltwater intrusion during periods of extreme high tides. S-36 is maintained by the Fort Lauderdale Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-36 Cost Estimate	
Structure Hardening	$4,619,722
Forward Pump	$14,442,500
Forward Pump Backup Generator Facility	$1,444,250
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$3,375,970
Real Estate	$7,000,000
Total	**$32,882,442**

S-197 Coastal Structure Resiliency



S-197 is a four-barrel cast-in-place concrete box culvert with four vertical slide gates measuring 10.0 ft x 10.0 ft. The structure has a discharge capacity of 2,400 cfs. S-197 is located upstream of the mouth of the C-111 about three miles from the shore of Manatee Bay and 750 ft east of U.S. Highway 1. The gates are manually operated by the field station. Real time stage data are available through telemetry. The S-197 maintains optimum water control stages upstream in the C-111 Canal, prevents saltwater intrusion during high tides and blocks reverse flow during storm surges. This structure usually remains closed to divert discharges from S-18C overland to the panhandle of the Everglades National Park. S-197 is opened for flood control when the overland flow capacity, with S-197 closed, is insufficient. This structure is maintained by the Miami Field Station.

A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-197 Cost Estimate	
Structure Hardening	$6,358,509
Forward Pump	$30,600,000
Forward Pump Backup Generator Facility	$3,060,000
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$6,302,776
Real Estate	$7,000,000
Total	**$55,321,286**

S-20 Coastal Structure Resiliency

S-20 is a reinforced concrete, gated spillway located on L-31E about three miles from the shore of Biscayne Bay. The structure has a discharge capacity of 450 cfs, with discharge controlled by a cable operated, vertical lift gate that is 11.4 feet high by 16.8 feet long. Operation of the gate is automatically controlled so that the gate's hydraulic operating system opens or closes the gate in accordance with the seasonal operational criteria. This structure maintains optimum water stages in the upstream agricultural area. The structure passes the design flood (40 percent of the Standard Project Flood) without exceeding upstream flood design stage and restricts downstream flood stages and discharge velocities to non-damaging levels. S-20 also prevents saltwater intrusion during periods of extreme high tides. The structure is maintained by the Homestead Field Station.

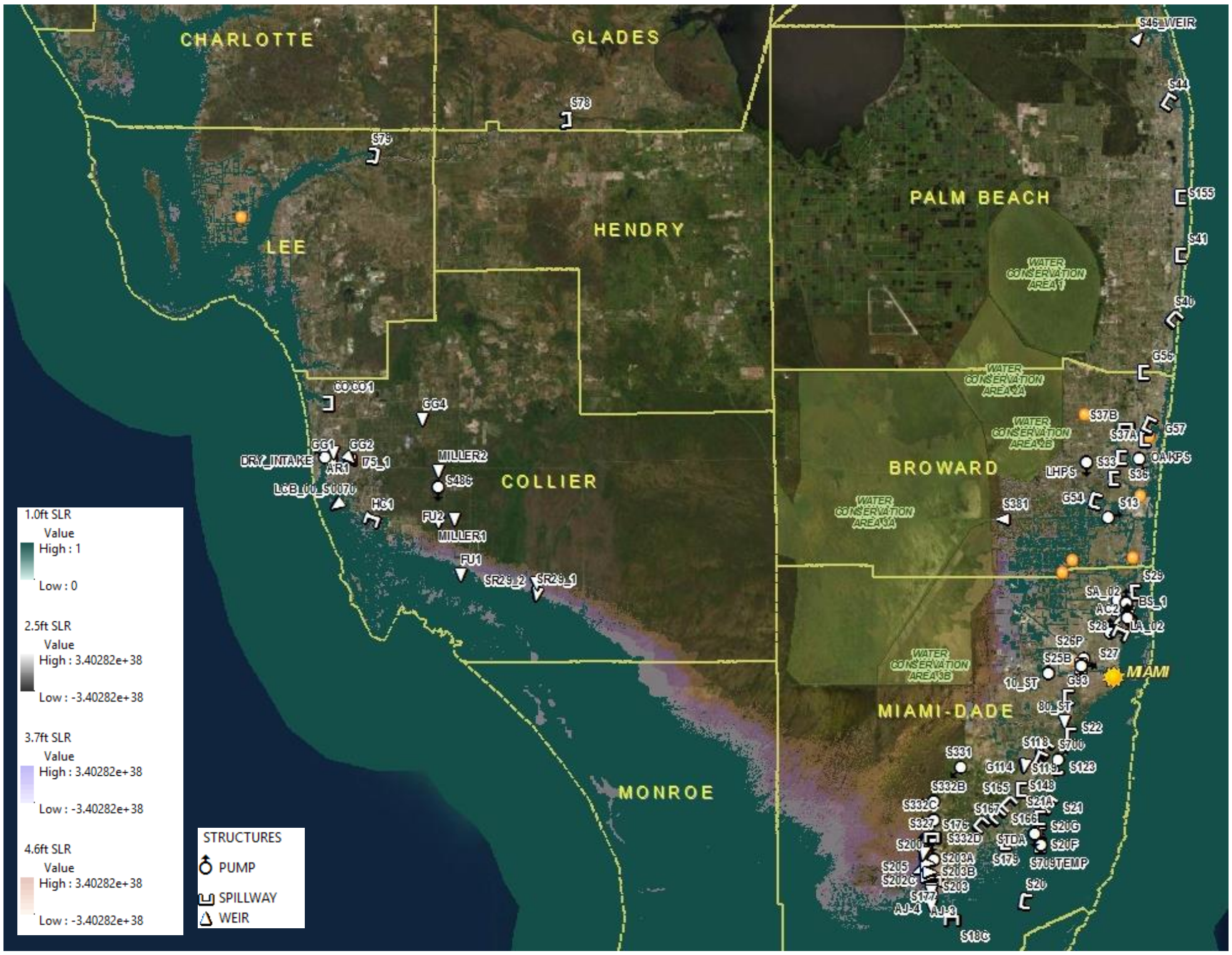
A total cost estimate to harden this Coastal Structure, to address flooding, SLR and other related risks to vulnerable communities in the Basin is presented below. The estimate includes modifications to the existing structure and control building, as well as an additional forward pump. The supplementary pumping capacity will extend the conveyance performance for additional years as sea levels rise, delay out of bank flooding, and reduce canal peak stages. Placeholder funds to tie the structure to higher land elevations and to purchase real estate for the project are included. Negotiations with private property owners for land purchase will initiate upon funding confirmation.

S-20 Cost Estimate	
Structure Hardening	$4,198,152
Forward Pump	$6,187,500
Forward Pump Backup Generator Facility	$618,750
Structure Tie Back (Flood Barrier)	$2,000,000
Design, Implementation & Construction Management	$1,950,660
Real Estate	$7,000,000
Total	**$21,955,062***

*May need to be replaced rather than refurbished, costs may be higher.

Remaining Coastal Structures Resiliency

Additional structures will become vulnerable to SRL, as the estimated projections occur in the future. Therefore, there will be the need to harden remaining Coastal Structures to increase their resiliency, along with the installation of forward pumps to maintain basin discharge levels while sea levels rise, and local flood mitigation strategies.



An initial placeholder cost is being proposed for structures identified to be within the 3.7SLR inundation scenario, and it will be refined during pre-design stages. Funding will be used harden the Coastal Structures identified below to address flooding and other related risks to vulnerable communities at the respective basin due to changed climate conditions, including sea-level rise. The pumping capacity will extend the conveyance performance for additional years as seas rise, delay out of bank flooding, and reduce canal peak stages. The restoration of discharge capacities will need to be combined with additional upstream and downstream solutions to be characterized as part of FPLOS Phase II Adaptation Strategies, and advanced as part of the Design phase.

Coastal Structures	Basin Name	Area (Acres)	Hardening Overall Estimated Costs (Placeholder)
G211	8.5 SQ. MILE AREA	4764.33	$ 27,500,000.00
S119	C-100 WEST	16660.17	$ 27,500,000.00
S148	C-1 WEST	32624.60	$ 27,500,000.00
S155	C-51 EAST	47012.34	$ 27,500,000.00
S165	C-102 WEST	8405.92	$ 27,500,000.00
S178	C-111 AG	17563.47	$ 27,500,000.00
S179	BD-C103 CENTRAL/WEST	22685.71	$ 27,500,000.00
S200	FROG POND DETENTION AREA	1727.37	$ 27,500,000.00
S331	L-31NS	16838.66	$ 27,500,000.00
S332B	NDA	2788.98	$ 27,500,000.00
S332C	SDA	2473.26	$ 27,500,000.00
S332D	S332D DETENTION AREA	3155.06	$ 27,500,000.00
S37B	C-14 WEST	32246.98	$ 27,500,000.00
S40	C-15	39423.02	$ 27,500,000.00
S41	C-16	39812.66	$ 27,500,000.00
S44	C-17	22357.07	$ 27,500,000.00
S46	C-18/CORBETT	65735.53	$ 27,500,000.00
S79	WEST CALOOSAHATCHEE	350114.60	$ 27,500,000.00
		TOTAL	**$ 495,000,000.00**

6. Additional Resiliency Related Projects

Self-Preservation Mode at Critical Structures, Coastal Structures Hardening and Storm Surge Protection

Implementation of self-preservation mode at water control structures means building or retrofitting structures with systems that make the structure more resilient. A self-preservation mode system includes a backup generator to power the structure when conventional power is lost and computer systems that can be programed to operate the structure appropriately and independently, without the direct control of water managers. Adding self-preservation mode capabilities to critical water control structures will allow water managers to manage the system for flood control, water supply, environmental restoration and saltwater intrusion prevention even when communication with the structure is lost due to weather or other circumstances.

Currently, in advance of storm onslaught, storm surge modeling predictions are compared to the finished floor elevations of the coastal structures to determine which finished floor elevations are below the predicted surge elevation. District staff then disable the power and back-up generator with the structure gates fully open to avoid permanent damage to the electrical system which could occur if the structure were energized during the predicted storm surge event. This so-called “structure lockout” is performed with the gates open to reduce the risk of damage to the structure and so that storm generated runoff can pass through the structure even if the gates are no longer operational. However, this procedure also allows smaller storm surge events to pass through the structure and propagate upstream when it could have potentially been blocked by closing the gates.

Manually operated structures require that decisions to release water be made long before storm impacts affect a given area. Water releases from non-automated structures must be done while it is safe for staff to visit the site to implement pre-storm operations. Automated structures allow water managers to delay water releases until they are actually warranted, which can help to avoid over-draining the area upstream, particularly when storm conditions do not occur as originally predicted. Structures with self-preservation mode capabilities can mitigate the consequences of a change in a storm’s path because they allow more flexible operational strategies. Structures with self-preservation mode capabilities can preserve environmentally sensitive lands and prevent damage to stormwater treatment areas, caused by over-draining the area unnecessarily. Structures with self-preservation mode capabilities can also help avoid prolonged drought conditions that can occur when water is released late in the wet season in anticipation of a storm that does not materialize.

Once self-preservation features are added to critical structures, gates will continue to be operable during the initial onslaught of the storm, well after it is no longer safe for personnel to travel to the site to manually disable the power and backup generator. Additionally, adding an independent system override to the gate controls and/or a pre-hurricane initiated program to the local Remote Terminal Unit (RTU) and/or Backup Controller (BUC) so that the structure will operate as desired even if communications are lost. For example, if tailwater stage reaches a specific pre-determined high elevation, the structure will shut itself off by going into a lockdown mode that first opens all gates and then shuts off commercial power and disables the generator.

The coastal structures were originally intended to provide a barrier to reduce saltwater intrusion without

SELF-PRESERVATION MODE FOR COMBATTING STORM SURGE DAMAGES AND SALTWATER INTRUSION AT COASTAL WATER CONTROL STRUCTURES

- MAXIMIZING THE OPERATIONAL CAPACITY AT CRITICAL WATER CONTROL STRUCTURES
- DETERMINATION OF ELEVATION TO EXTEND GATES TO PREVENT REVERSE FLOW DURING A NON-STORM RELATED EXTREME HIGH TIDE OR MINOR STORM
- OPTIMIZING THE TIME TO OPEN AND CLOSE GATES BEFORE STORM SURGE INUNDATES CRITICAL EQUIPMENT AND/OR CAUSES THE STRUCTURE TO FAIL
- AVOIDING UNNECESSARY LOCKOUTS

increasing flood risk from rainfall in the basin. They were not designed to provide robust storm surge protection, however some surge protection can be achieved during less significant events. Therefore, the ability to operate structure gates for an extended period into a storm event is desirable. In many cases, the tops of structure gates can be extended to maximize the ability to protect against storm surge. The elevation for self-preservation mode to begin the lockdown procedure should be higher than a non-storm related extreme high tide which may already result in reverse flow over the closed gates, but low enough to allow time for all gates to open fully before the storm surge inundates critical equipment that could fail due to pressure on closed gates. The infrastructure to accomplish this must be hardened such that it is not susceptible to damage from windblown debris and/or storm surge. The lockdown would be lifted manually by District staff sent to the site to evaluate any damage to the mechanical and electrical systems after the all-clear has been issued after a storm event. Like the current pre-storm lockdown, after the storm has passed, if damage has occurred the gates would remain open or be operated by alternate means (portable generator, crane, other temporary measures) until repairs have been completed.

The District will prioritize the implementation of a self-preservation mode system that will enhance electrical components and sensors in critical coastal structures to maximize our operational capacity and minimize the time gates need to be locked in the open position, given anticipated storm surge scenarios. Considering recently observed and projected increases in frequent storm surge/ high tailwater conditions, maximizing operational flexibility of coastal structures is necessary for optimal flood control and prevention of saltwater intrusion. Implementing self-preservation mode infrastructure is a relatively inexpensive investment that can pay dividends. The majority of District controlled structures already have backup generators (the most expensive component) and therefore they only need automation components such as hardened sensors, communication equipment and computer systems added.

Other strategies that the District considers to be related to the self-preservation concept include maximizing the operation of secondary flood control system, increasing the ability to transfer water between basins and also optimizing the operation of stormwater treatment areas (STAs) by adding backup generators and enhancing automation so that drawdowns can be avoided when not necessary.

STAs depend on certain hydrologic conditions (water levels) to optimize nutrient removal, because aquatic plants require a certain water level range to grow and thrive. When the water level in an STA is kept within the optimal range, the STA can operate most efficiently. Drastic changes in water level can severely impact the efficiency of an STA and can even cause aquatic vegetation to die, thus turning an STA into a nutrient source instead of a nutrient sink. Adding backup generators, remote control and automation to the pump stations that control water levels in STAs helps to ensure that water levels are kept at their optimal range even when a power failure occurs at the pump station and avoid unnecessary drawdown operations when storm prediction is highly uncertain.

Maximizing the operation of secondary flood control system is another way to increase the resiliency of the C&SF System. For instance, the primary system (C&SF Project) may be operating at maximum efficiency, but if a secondary water control structure is clogged with debris or has suffered a power outage, flooding upstream of the secondary structure can occur. The District is committed to partnering with the entities that operate secondary water control systems to make modifications to the secondary systems that increase resiliency of the entire flood control system.

Another strategy that is promising for making the C&SF Project more resilient is increasing connectivity between basins. Having the ability to move water from a flooded basin to an adjacent basin that can handle additional water could be a very effective tool that does not require discharging to tide. With increased connectivity between basins, water managers could have powerful additional tools for operating the system to optimize flood control efforts.

Table 3 summarizes the self-preservation actions needed, at each prioritized C&SF structure, and initial estimated costs to implement additional programming costs, and backup controller instrument and platform; install backup controller and other automation features; modify gates for added high tide protection against reverse flow, according to the number of gates in each selected coastal structure; modify structure by adding seals, which would replace the need for raining equipment; and add backup generators and additional automation needs.

Table 3. Modifications and costs needed to harden coastal structures

Coastal Structure (number of gates)	Additional Programing; storm resilient Back Up Controller instrument and platform	Install Backup Controller and other automation features	Modify gates for added high tide protection against reverse flow	Modify Structure by adding seals (*this would replace the need for raising the heights)	Add Backup generator and other automation needs
S-123 (2)	$ 150,000.00		$ 100,000.00	$ 50,000.00	
S-22 (2)	$ 150,000.00		$ 100,000.00		
S-27 (2)	$ 150,000.00		$ 100,000.00		
S-28 (2)	$ 150,000.00		$ 100,000.00		
S-21 (3)	$ 150,000.00		$ 150,000.00	$ 75,000.00	
S-25 (1)	$ 150,000.00		$ 50,000.00		
S-20 (1)	$ 150,000.00		$ 50,000.00		
S-20F (3)	$ 150,000.00		$ 150,000.00		
S-20G (1)	$ 150,000.00		$ 50,000.00		
S-21A (2)	$ 150,000.00		$ 100,000.00		
S-25B (2)	$ 150,000.00		$ 100,000.00		
S-26 (2)	$ 150,000.00		$ 100,000.00		
S-29 (2)	$ 150,000.00		$ 100,000.00		
S-197 (4)	$ 25,000.00				
COCO1		$ 175,000.00			
GG-1		$ 175,000.00			
HC1		$ 175,000.00			
COCO2		$ 175,000.00			
GG2		$ 175,000.00			
COCO3		$ 175,000.00			
GG3		$ 175,000.00			
STA 1W Expansion					$ 1,615,000.00
STA 1E Expansion					$ 600,000.00
Automation Upgrades: S319, S362, G310, G335, G370, G372 (a)					$ 875,913.00
MW Backbone Radio Upgrade (b)					$ 2,450,000.00
S-285/290 SCADA Retrofit (c)					$ 1,383,157.89
Manatee Gate Control Panel Replacements at G-150, G-151 (d)					$ 3,430,000.00
Other Generator/Automation Needs (e)					$ 3,000,000.00
TOTAL	1975000	1225000	1250000	125000	$ 13,354,070.89

OBS: Cost estimates are assuming in-house Design. **TOTAL $ 17,929,070.89**

(a) Automation Upgrades - Additional costs in FY23 and FY24 of about $2.1M are included as part of the $3M annual recurring funds.

(b) Radio Upgrade - Additional costs in FY23 of about $650K are included as part of the $3M annual recurring funds

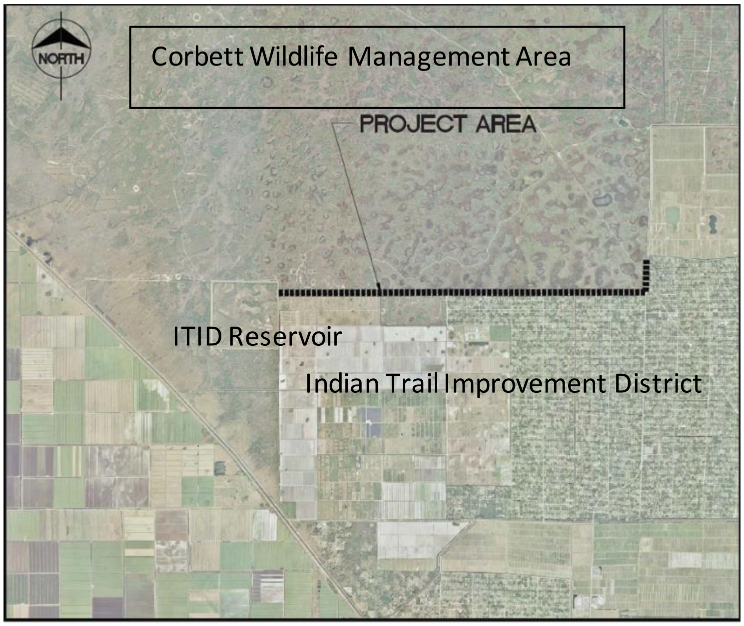
(c) SCADA Retrofit - Additional costs in FY23 of about $820K are included as part of the $3M annual recurring funds

(d) Panel Replacement: Additional costs in FY23 and FY24 of about $1,5M are included as part of the $3M annual recurring funds

(e) Recurring funding needs for backup generators / automation in other inland structures, inter-basin transfer/connections and secondary system integration.

Corbett Levee

In August of 2012, Tropical Storm Isaac brought unprecedented rainfall to areas of central Palm Beach County resulting in widespread flooding in the area. As part of the State's response to the Storm, the Indian Trail Improvement District (ITID) Corbett Levee was identified as an area of critical concern for berm failure due to localized slope failures, excessive seepage, and the formation of boils (seepage pathways). In September 2012, the SFWMD was directed by the Governor's Office to immediately convene a multi-agency working group to develop a plan for strengthening the Corbett Levee to meet current USACE and South Florida Water Management District standards and to increase the level of flood protection in the area for over 40,000 residents.



The project was designed and constructed by the District following the latest engineering and construction technologies. The first phase of the project included building 2.6 miles of levee to the east of the ITID Reservoir. However, the eastern section of levee remains unfinished due to lack of funding. Therefore, the project is currently not meeting its full flood protection potential.

Completion of this project is needed to address excess flooding due to the impacts of climate change such as an increase in the number and intensity of tropical cyclones. For instance, rainfall impacts from Tropical Storm Isaac were well beyond the design capacity of the berm that existed prior to the construction of the Corbett Levee. Finishing this project would increase the District's operational flexibility and therefore improve the system's resiliency to flooding. Additionally, Corbett Wildlife Management Area has been held at artificially low water levels for several years resulting in habitat loss. Finishing the levee project would allow water managers to safely restore more natural hydroperiods to Corbett Wildlife Management Area. The proposed final section of levee is approximately three miles long and would cost $9.3M.

Amount	Description of Annual Activity
$9,300,000	Construction

L31E Levee Improvements

The proposed strategy consists of hardening the L31E Levee and addressing other resiliency issues as the District advances its O&M investments. The estimated project total of $13M will be submitted for FDEP consideration through the Statewide Flooding/SLR Resiliency Plan in September 2021 (to be confirmed upon SB1954 implementation). Addressing coastal structures vulnerability to SLR and storm surge is a high priority in South Florida. Funding will be used harden L31E Levee, a component of the 72-year old Central and Southern Florida Project, to address storm surge risks and SLR vulnerability. The L31E Levee is one of the priority projects on our CIP list.

Funds are needed to advance resiliency strategies to reduce vulnerability of communities upstream of the L31E Levee. This project is being included as a placeholder to exemplify infrastructure investments needed for different components of the C&SF Project. Future modeling efforts will determine additional resiliency needs at other levee structures, based on the determination of what cross sectional change that a vulnerable levee would need to provide more protection from storm surge and SLR

Amount	Description of Annual Activity
$3,000,000	Design and Permitting
$10,000,000	Construction: Refurbishment

G-6A Pump Station Resiliency

The G-6A Pump Station will have the same capacity as one of the pumps at the existing S-6 Pump Station which was constructed in 1957. South Florida now experiences increased rainfall intensity and flooding due to climate change. The existing S-6 Pump Station now pumps at full capacity and has no back up in case of failure. The G-6A Pump Station is needed to continue to provide flood protection and to reduce the impacts of increased rainfall and flooding and by serving as a redundant feature in case one of the pumps fail. This new feature will make the flood control system more resilient. A second pump station in this location will create a redundant flood control feature that can be used in the event of system failure as well as allow for taking one pump offline for maintenance without the risk of reducing the overall required pumping capacity.

Amount	Description of Annual Activity
$58,336,000	Design and Construction

Everglades Mangrove Migration Assessment (EMMA) Pilot Study: Directing Coastal Resilience

Directing Coastal Resilience: The Everglades Mangrove Migration Assessment (EMMA) Pilot Study

EMMA is designed to capture the adaptive foundational resilience of the coastal wetlands within the SFWMD, with an emphasis on nutrient depleted mangroves. By adaptive we mean that this resiliency project will demonstrate the ability of coastal wetlands to adapt to rising sea levels via enhanced soil elevation change. This pilot study will evaluate and implement the ability of coastal communities to shift to foundational plant communities that are more resilient to higher water depths and salinities, which in turn, are able to accrete more peat, capture more sediments, sequester more carbon and keep up with SLR. This is a foundational project because it is focused on the plant communities such as mangrove swamps and sawgrass plains, that are endemic to the historic and extant ecology of Florida. Resilience is the ability of the foundational communities to shift rates of productivity, community structure and spatial extent, in the face of SLR, to minimize wetland conversion to open water habitats and maximize shoreline retention. EMMA is focused upon the hydrologic attributes needed to enhance, restore and preserve wetland function and extent, and as such, has direct relevance to water management, hydrological models, planning and decision making.

EMMA is a large-scale, landscape field manipulation of sediment and dredge material, with the potential to be incorporated into the USACE Beneficial Use Program (The Role of the Federal Standard in the Beneficial Use of Dredged Material from U.S. Army Corps of Engineers New and Maintenance Navigation Projects (PDF)), in the scrub mangrove ecosystem of the Model Lands, which is owned by Miami Dade County, and is not subject to the WQ or soil nutrient constraints associated with the Everglades Forever Act. Results of EMMA will have implications for and application to all coastal wetlands of Florida that are vulnerable to SLR.

EMMA would take advantage of the new Thin Layer Placement (TLP) technology associated with distributing dredge spoil across an existing wetland to add elevation and, when needed, additional soil phosphorus (Berkowitz et al. 2019, VanZomeren et al. 2018). Beneficial uses of dredged material such as TLP will build landscape resiliency by improving soil aeration in the root zone, thereby increasing redox potentials (Eh), plant productivity, soil accretion, and by supplying a medium for greater carbon sequestration, which allows coastal wetlands to keep pace with SLR (DeLaune et al 1990, Baustian et al 2015).

Goals and Objectives: Changes in water management in concert with SLR, has caused coastal wetlands to subside, tidal creeks to fill in (Meeder et al 2018)), peat to collapse (Wilson et al 2019), and plant communities to shift to slow growing, transgressive, open water habitats (Meeder et al, 2018)). Peat collapse causes rapid declines in soil surface elevation (Chambers et al. 2019), converting wetlands in a vegetated state to an open water state (Cahoon et al. 2003; McKee et al. 2011; Baustian et al. 2012; Voss et al. 2013; Wilson 2018). In South Florida, peat collapse has been observed in sawgrass (*Cladium jamaicense*) peat marshes and coastal mangroves, which are highly organic (>85%), and depend on inputs of organic material to maintain and raise soil elevation, as they receive little inorganic sediment input (Rejmankova and Macek 2008, Chambers et al 2019). Since changes in soil surface elevation in mangrove and sawgrass peat marshes is largely a function of primary productivity, there is growing concern that saltwater intrusion will increase coastal marsh degradation.

Without intervention, the current trajectory of SLR will result in significant land loss and loss of stormwater protection. Intervention that promotes accretion rates that act to maintain or outpace SLR in key coastal communities (e.g. those adjacent to historic tidal creeks) will result in a myriad of ecosystem and socio-economic benefits. The goal of this Pilot is to advance our understanding of biological vs. physical controls on the capacity of coastal wetlands to persist under increased SLR. Our objectives are to:

1. Develop demonstration scale evidence that supports managed wetland transgression to include sediment augmentation via a TLP strategy.
2. Evaluate the adaptive resilience of coastal mangroves to phosphorus enrichment in combination with enhanced soil elevations.

Study Design: Peat accumulation and mangrove plant growth will be measured along 1000m transects that have been elevated by TLP in comparison to mangroves that have been locally spiked with elevated phosphorus (Figure 1). The multifactorial design (Figure 2) will divide each transect into control transects and TLP treatment transects to document costs and benefits of TLP and help establish the protocols for effective beneficial use of dredge materials in coastal habitats.

Permanent Benchmarks and Soil Elevation Surveys

Permanent benchmarks will need to be installed in and around the study area to preserve relevance to SL and SLR. Six Class "B" (Stainless Steel rod driven to refusal) NGS stability standard monuments will be established. The work will include, but not limited to, processing the data, Quality Assurance, describing, typing, and reconnaissance. If no published NGVD 29 elevations were available at the site, NGVD 29 elevations will be derived from the NAVD 88 elevations by means of applying a site-wide, uniform datum shift, or offset value, of -0.456 meter (-1.496 feet). The sense of the algebraic sign of this value is NAVD 88 elevation minus NGVD 29 elevation. This value will be obtained from the NGS VERTCON model and was computed by both the NGS VERTCON Online web site (*http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html*, accessed May 2007, version 2.0) and by means of the software CORPSCON version 6.0.1 (which itself uses the NGS-developed VERTCON software).

Figure 1. Each transect would be L=1000 ft; W=500 ft; Depth= 4 inches and require some 8000 cubic yards of TLP

No TLP Transect					
Control P, 0 TLP, 0 RM	Control P, 0 TLP, 0 RM	Control P, 0 TLP, 0 RM	+ P, 0 TLP, 0 RM	+ P, 0 TLP, 0 RM	+ P, 0 TLP, 0 RM
Walkway					
Control P, 0 TLP, RM	Control P, 0 TLP, RM	Control P, 0 TLP, RM	+ P, 0 TLP, RM	+ P, 0 TLP, RM	+ P, 0 TLP, RM
TLP Transect					
Control P, + TLP, 0 RM	Control P, + TLP, 0 RM	Control P, + TLP, 0 RM	+ P, + TLP, 0 RM	+ P, + TLP, 0 RM	+ P, + TLP, 0 RM
Walkway					
Control P, + TLP, RM	Control P, + TLP, RM	Control P, + TLP, RM	+ P, + TLP, RM	+ P, + TLP, RM	+ P, + TLP, RM

Figure 2. Study multifactorial design includes P enrichment, TLP sediment additions and red mangrove (RM) plantings.

The horizontal datum for this survey will be the North American Datum of 1983 (NAD 83). Soil Elevation surveys will be conducted using real-time kinematics referenced to the 1988 North American Vertical Datum (NAVD88) with Trimble R8 global navigation satellite system receiver equipment (Trimble Inc., Sunnyvale, CA, USA) with a horizontal accuracy of ± 1 cm and a vertical accuracy of ± 2 cm. Soil elevations will be set out with respect to the North American Vertical Datum of 1988 (NAVD 88) and the National Geodetic Vertical Datum of 1929 (NGVD 29). NAVD 88 elevations will be determined by differential leveling from benchmarks.

Sediment Elevation Table (SET)

The SET is an extremely accurate and precise leveling device (Figure 2) designed to sit on a permanent benchmark pipe or rod and measure changes in elevations in inter-tidal and sub-tidal wetlands (Boumans and Day 1993, Cahoon 1995). Once installed on the benchmark, the SET establishes a constant reference plane with respect to the benchmark, allowing for repeated measurements of the sediment surface (Cahoon et al. 2002). Changes in the elevation of the soil surface over time will be measured using the surface elevation table–marker horizon (SET–MH) methodology, which has been widely used and recommended for monitoring intertidal surface-elevation trajectories in coastal wetlands (Cahoon 1995).

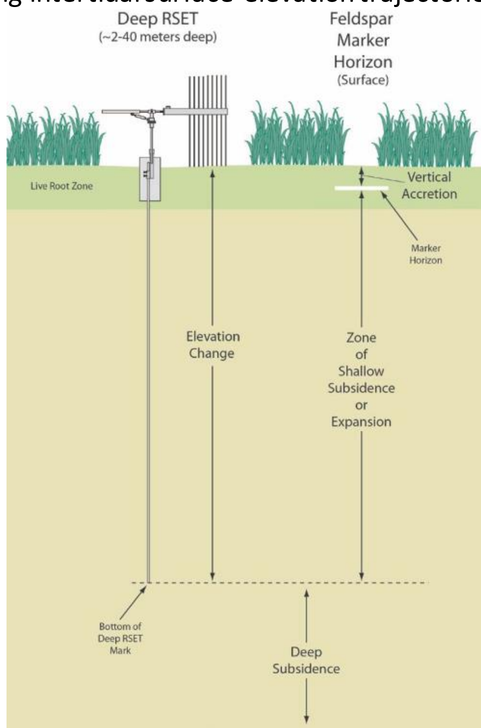


Figure 2. Sediment Elevation Table (SET) and marker horizon (MH) methodology

Biotic Monitoring: Above and belowground biomass. Mangroves are considered 'bottom heavy plants' as they invest much of their biomass into their root system (Komiyama et al., 2008, 2000). Mangroves have two kinds of root systems adapted to the anoxic and saline conditions of mangrove habitats: aerial roots that grow above the soil surface, and belowground roots. Belowground root biomass in mangroves generally contributes up to 60% of the total tree biomass (Khan et al., 2009; Komiyama et al., 1987; Tamooh et al., 2008). It is critical that we understand the belowground processes in this pilot study. At each plot, duplicate root cores (that is, sampling units; 0–45 cm depth; shallow root zone) will be randomly collected using a PVC coring device (10.2 cm diameter 9 45 cm length. Roots will be sorted into diameter size classes of less than 2 mm, 2–5 mm, and greater than 5 mm (fine, small, and coarse roots, respectively). Each root sample will be oven-dried at 60 °C to a constant mass and weighed.

Composition, tree density, and basal area in tall and scrub mangroves will be quantified through measurements of the species and diameter at 1.3 m height (DBH) of all trees rooted within a designated study plot, which will be 154 m2 (radius of 7 m). Similarly, due to the lower density of the scrub mangroves, tree density and biomass will be measured in six 2 m radius plots. The diameter of trees of *R. mangle* will be measured at the main branch, above the highest prop root. In scrub mangroves, the diameter of the main branch of the tree will be measured at 30 cm from the ground (D30).

Soil carbon and nutrients. At each plot, soil samples for bulk density and nutrient concentration will be collected using a peat auger consisting of a semi-cylindrical chamber of 6.4 cm radius attached to a cross handle. Soil cores will be systematically divided into depth intervals of 0–15 cm, 15–30 cm, 30–50 cm, 50–100 cm. Root and soil samples will be analyzed for Total Carbon, Total Nitrogen and Total Phosphorus.

Interstitial chemistry. Porewater salinity and chemistry of the soil may change during this study and may impact belowground processes and accretion rates, Interstitial chemistry will be analyzed by extracting water from the ground at 30 cm using a syringe and an acrylic tube. The syringe is rinsed twice before obtaining a clear water sample from which salinity was measured using an YSI-30 multiprobe sensor.

Schedule and Costs: Total costs, shown in Table 1, do not reflect the current efforts to integrate this pilot study with (1) funding from the USACE Regional Sediment Management (RSM) Division to locate and distribute TLP spoil materials or (2) funding from the National Science Foundation, given to FIU for its Long-Term Ecological Research (LTER) to address the dynamics of ecosystem change in South Florida due to climate change. The exact amounts of the USACE and the FIU LTER combined contributions to EMMA and the creation of an adaptive foundational resilience protocol is not yet known and will need to be negotiated.

	FY 2022				FY 2023				FY 2024				FY 2025				
Activities	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Cost
Permits & Plan Formulation		X	X														$50,000
Install Benchmarks			X	X													$50,000
Elevation Surveys				X	X												$50,000
Locate and Analyze Dredge Spoil		X	X	X													$60,000
Harvest and Grow Mangrove propagules			X	X	X		X	X	X								$100,000
Distribute Spoil as TLP				X	X	X			X								$450,000
Install TLP SET's and Walkways				X	X			X	X								$90,000
Plant Mangroves					X	X			X	X							$65,000
WQ, Soil, Plant Analysis and Monitoring				X		X		X		X		X		X			$175,000
Soil and Elevation Monitoring				X		X		X		X		X		X			$135,000
Annual Reports					X				X				X				$30,000
Final Report and Recommendations																X	$50,000
TOTAL																	$1,305,000

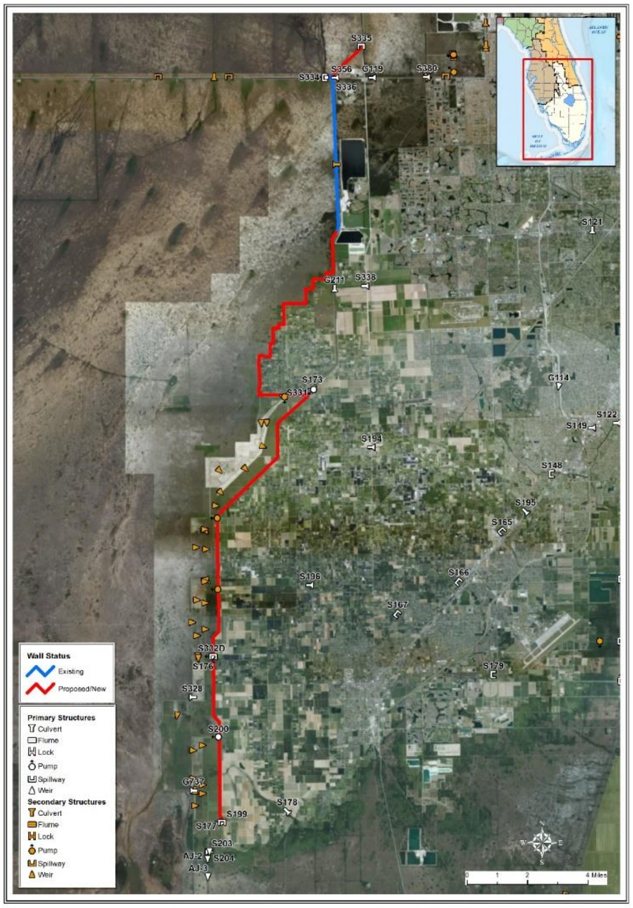
Table 1. Schedule and costs associated with the EMMA Pilot Study. TLP =Thin Layer Placement.

Summary

To plan for a sustainable South Florida ecosystem, it is important to identify ecological vulnerabilities to sea-level rise (SLR) and ask how we might direct water management to minimize saltwater intrusion, peat collapse (Sklar et al, 2019) and land loss. SLR projections for the next 50 years will threaten the structure and function of coastal wetlands in South Florida and there is agreement among coastal scientists that sea level is rising at rates that will inundate most lowlands distributed along the coasts (Ross et al 2000; Sweet et al, 2017, Sklar et al, 2019; Sklar et al, 2021).

This demonstration-scale pilot study is a nature-based management measure to increase coastal mangrove elevation and enhance net belowground storage of carbon. It will document the efficiency and effectiveness of TLP to increase the adaptive capacity of Florida's coastal wetlands and keep up with SLR. Results are applicable to areas throughout the Gulf and Atlantic Coasts of Florida, where direct preservation, enhancement, and restoration of mangrove and other vegetative communities, will build coastal resiliency, reduce storm surge damage, and create habitat for a large variety of fish and wildlife species.

South Miami Dade Curtain Wall



The South Miami Dade Curtain Wall Project is being implemented by the District in the southern part of its water management system, adjacent to southwest Miami-Dade County developed areas and Everglades National Park. Curtain Walls are in-ground groundwater and seepage barriers that help to limit water flow in South Florida's porous aquifer. The South Miami-Dade Curtain Wall Project will increase the District's ability to manage water levels in Water Conservation Area 3A in Everglades National Park. Benefits associated with these established engineering features include flood protection, water supply maintenance, saltwater intrusion prevention, and ecosystem restoration, by improving water flow to Florida Bay and other estuaries. More specifically, this project will help prevent seepage of water from Everglades National Park while keeping the water in the park to support restoration goals and promote flow south toward Florida Bay, instead of seeping eastwards towards developed areas of South Dade where such seepage contributes to a reduction in flood protection level of service.

Extensive hydrologic and hydraulic modeling efforts allowed the District to evaluate the most effective alternatives in terms of the alignment, depth and extension of these proposed barriers, and associated impacts. Feasibility Assessments developed since this project was first conceptualized, describe project alternatives in combination with the current and future condition operations of the C&SF water management features and CERP projects in the region. This project has been positively received in many of the public meetings that have been held and is of interest to private, public, local, state and federal stakeholders in the region.

The recent modelling effort completed by the District in 2018 demonstrated the benefit of the curtain wall for both restoration and flood control. Several curtain wall configurations were examined. Figure 19 illustrates three different scenarios; a 27-mile South a 19-mile scenario, from Structure S-331 to Structure S-177, including a portion of the 8.5 Square Mile Area (Las Palmas Community) in unincorporated Miami Dade County; a 19-mile North scenario, from Structure S-335 including all of the 8.5 Square Mile area; and a 31-mile Full Extent scenario from Structure S-335 to Structure S-177. The 27-mile South scenario, with gaps in the curtain wall, was recommended for more detailed study and implementation because it provided the best outcome for restoration and flood control while mitigating impacts to Biscayne Bay, Taylor Slough and water supply.

The results of the H&H modeling, illustrated in Figure 20 below, demonstrate the flood control and restoration improvements resulting from the 27-mile South scenario. Wetter conditions were observed in Everglades National Park and drier conditions were observed in the eastern developed areas and in the South Dade agricultural areas demonstrating improved restoration and flood protection conditions, respectively.

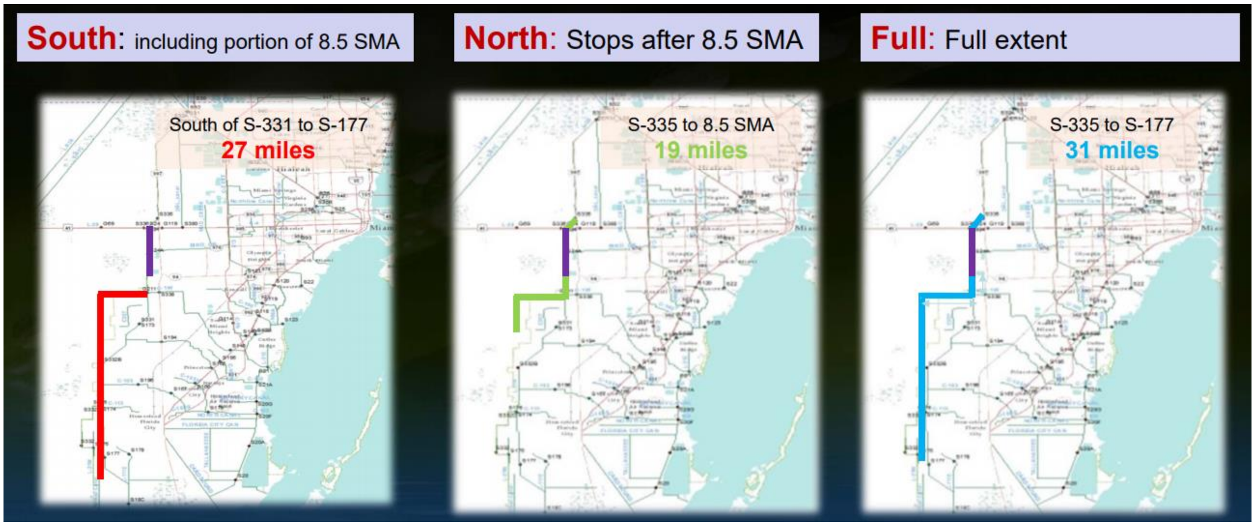


Figure 19: Location and extension of three curtain wall configuration scenarios examined in 2018

Results of all three scenarios also show increased average annual overland flows to Shark River Slough, during wet and dry seasons, compared to the No Wall scenario, as illustrated in Figure 21 below. Flows to Taylor Slough also improved with the Full and South wall scenarios. Successfully intercepting and redirecting flows back into Everglades National Park reduces the availability of regional water to Biscayne Bay, therefore, ongoing studies and future opportunities to ensure flows to Biscayne Bay are maintained or enhanced are being advanced as part of parallel efforts. The Biscayne Bay Southeastern Everglades Ecosystem Restoration Project (BBSEER) is being advanced in collaboration with the USACE with the goals of making progress towards restoration of depth and duration of freshwater at Biscayne Bay, as well as ecosystem structure and function with improved native plant and animal abundances and diversity. The study recommended additional data collection and more rigorous modeling which was authorized and funded by the Governing Board in 2020. The project, public planning process that engages stakeholders and partner agencies is ongoing.

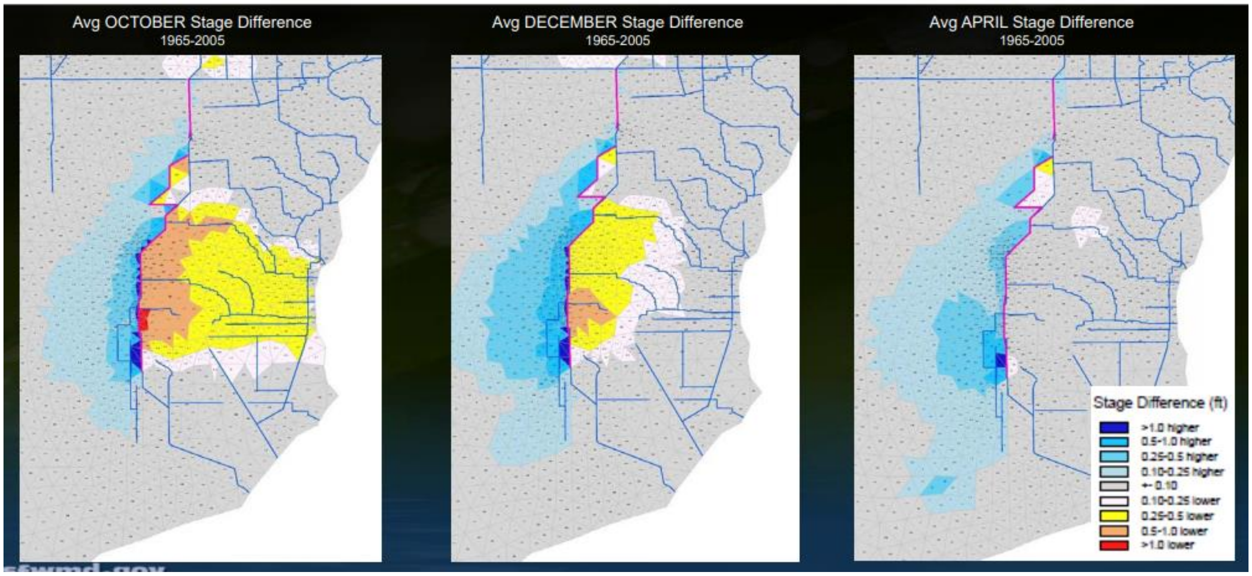


Figure 20: H&H modeling results illustrating the average water stage difference with and without the full extent curtain wall scenario.

	No Wall	South Wall	North Wall	Full Wall
Shark River Slough	833	890	873	884
Wet Season (Jun-Oct)	466	501	486	491
Dry Season (Nov-May)	367	389	387	393
Taylor Slough	85	109	82	99
Wet Season (Jun-Oct)	61	74	59	69
Dry Season (Nov-May)	24	35	23	30
Biscayne Bay	927	874	897	889
North Bay	561	534	571	570
Central Bay	120	114	121	121
South Bay	246	226	205	198

Figure 21. Average Annual Overland Flows to Shark River Slough during wet and dry seasons for three curtain wall scenarios compared to the no wall scenario.

In March 2021, the SFWMD Governing Board approved the construction of the initial phase of the South Miami Dade Curtain Wall Project, which consists of a 2.3-mile-long, 26-inch wide curtain wall along the 8.5 Square Mile Area (Las Palmas Community) in unincorporated Miami Dade County. The 8.5 Square Mile Area Curtain Wall is underway and scheduled to be completed within the next 12 to 16 months. The total costs for the initial 2.3 miles - $15M is fully funded with State Funds in a multiyear project. The project was bid on a per unit length basis to allow continuation of the wall subject to additional funding.

Additional new funding will facilitate construction of incremental curtain wall sections, increasing the ability of water managers to address high water events in Water Conservation Areas and the Central Everglades, promote flows to Florida Bay, and better utilize assets built for achieving restoration goals and providing flood mitigation.

This current funding request is to incrementally build the curtain wall assuming five to ten miles every three to five years at an average cost of $8M per mile escalated for inflation for the out years. The final design of the full wall will be established at the end of the public planning process and may exceed the total miles recommended in the initial study. Additional project refinement and confirmation of the final extension of the South Miami-Dade Curtain Wall will be defined based on further model analyses and monitoring efforts throughout the construction of the 2.3-mile segment.

Implementation Timing	Amount*	Incremental Strategy
Immediate Needs (FY22-FY25)	$60,000,000	Construction of 5-10 Miles
Near Term (FY25-FY28)	$60,000,000	Construction of 5-10 Miles
Intermediate Term (FY28-FY31)	$60,000,000	Construction of 5-10 Miles
Long Term (FY31-FY34)	$60,000,000	Construction of 5-10 Miles

*Cost in 2020 dollars will be adjusted for future years, assuming 7.5 Miles

7. Planning Projects

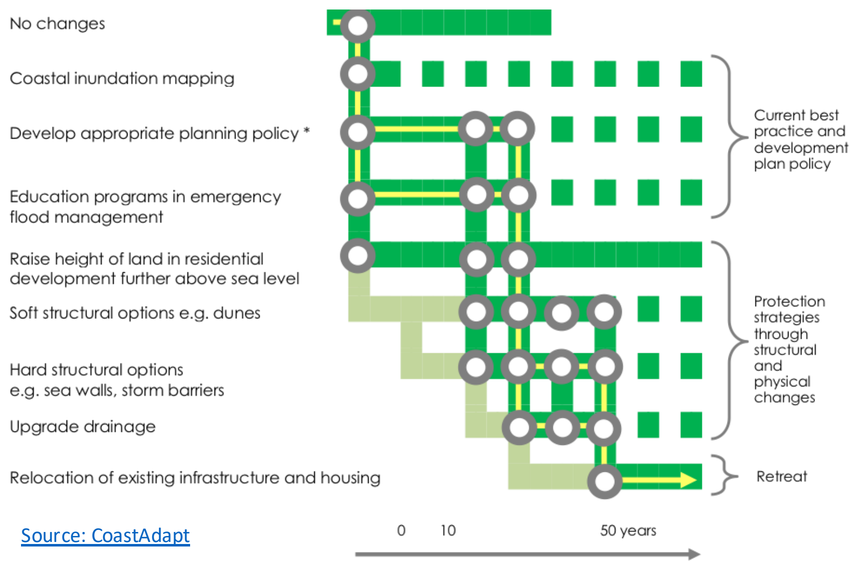
Various planning projects and efforts are being prioritized as part of the District's Resiliency Program. These studies are an integral part of providing South Florida with a robust and resilient flood infrastructure, now and in the future. Planning projects help support the District's Resiliency mission, by coordinating scientific data and research needs to ensure the projects are founded on the best available science.

Hydro-meteorological monitoring has played an important role in managing the water control system in South Florida. Through its DBHYDRO tool, the District stores and makes hydrologic, water quality, and hydrogeologic data available to the public and partner agencies. Continuing efforts to enhance monitoring become are important to combat a changing climate and increasing sea levels. Science and data are required to build a resilient water management system and infrastructure that addresses current and future impacts. Hydro-meteorological data such as seawater level, air temperature, incoming solar radiation, rainfall, and evapotranspiration rate can provide trends that can help with prediction of climate change. Due to the slow process of climate change, monitoring stations must be high quality and stable to minimize environmental disturbances to the station. In this context, the District is implementing a set of water and climate resilience metrics with the goal of tracking and documenting shifts and trends in District-managed water and climate data. These efforts support the assessment of current and future climate conditions scenarios and District resiliency investment priorities. As part of the District's communication and public engagement priorities, the effort will provide information to stakeholders, and public and partner agencies, while supporting local resiliency strategies. Five key planning projects are detailed below, to support the continued monitoring and metrics development efforts, including: a web tool implementation to support real time trend analysis of the Water and Climate Resilience Metrics, enhancement of the District's saltwater interface mapping and monitoring, hydrometeorological data monitoring, flooding events database tool and the development of regional climate rainfall projections.

In addition to observed and projected data analysis and monitoring processes, hydraulic and hydrologic modeling efforts are fundamental in evaluating the effectiveness of the District's flood control assets which include canals, structures and pump stations. Modeling efforts help to determine if the flood control system meets and will continue to meet flood protection needs. The FPLOS Program is being implemented at a regional and local scale using a suite of tools and performance indicators for evaluating structures and canals in selected watersheds, as well as a framework for establishing the level of service at each basin. The program incorporates input from meetings and workshops with local planning and stormwater management efforts, stakeholders, and resource managers. The results provide support for local flood vulnerability assessments, based on the latest modeling tools and most advanced dynamic H&H models, simulating existing drainage infrastructure to determine flood inundation scenarios, the necessary integration between surface and groundwater systems, and tidal/storm surge and rainfall scenarios for current and future conditions. Modeling efforts also include future conditions groundwater modeling to evaluate SLR, the saltwater intrusion monitoring network, and climate change impacts that may influence future water use vulnerability.

Recurring funding needs to continue to advance Phase I - Assessments and Phase II Adaptation Studies in priority basins, annually, as well as groundwater modeling efforts, are detailed below.

FPLOS Adaptation and Mitigation Planning (Phase II Studies)



Source: CoastAdapt

FPLOS Phase II studies will advance previously developed FPLOS Phase I water management (H&H) models to identify feasible flood adaptation and mitigation solutions in critical basins. Results of these studies will help develop recommendations for regional and local integrated strategies and priority infrastructure investments and operational changes that may be required to ensure continued long-term performance of the at-risk parts of the system. When the FPLOS assessment (Phase I Studies) identifies a deficiency in the flood control system, a detailed public planning study is initiated to identify appropriate resilient adaptation strategies. This public planning approach ensures the agency, in collaboration with partners and stakeholders, determines the best local and regional solutions that are not limited to the primary system. The comprehensively evaluated and coordinated course of action, based on robust technical assessments, will ensure that the District's flood protection systems maintain their level of service, in response to population growth, land development, SLR and climate change.

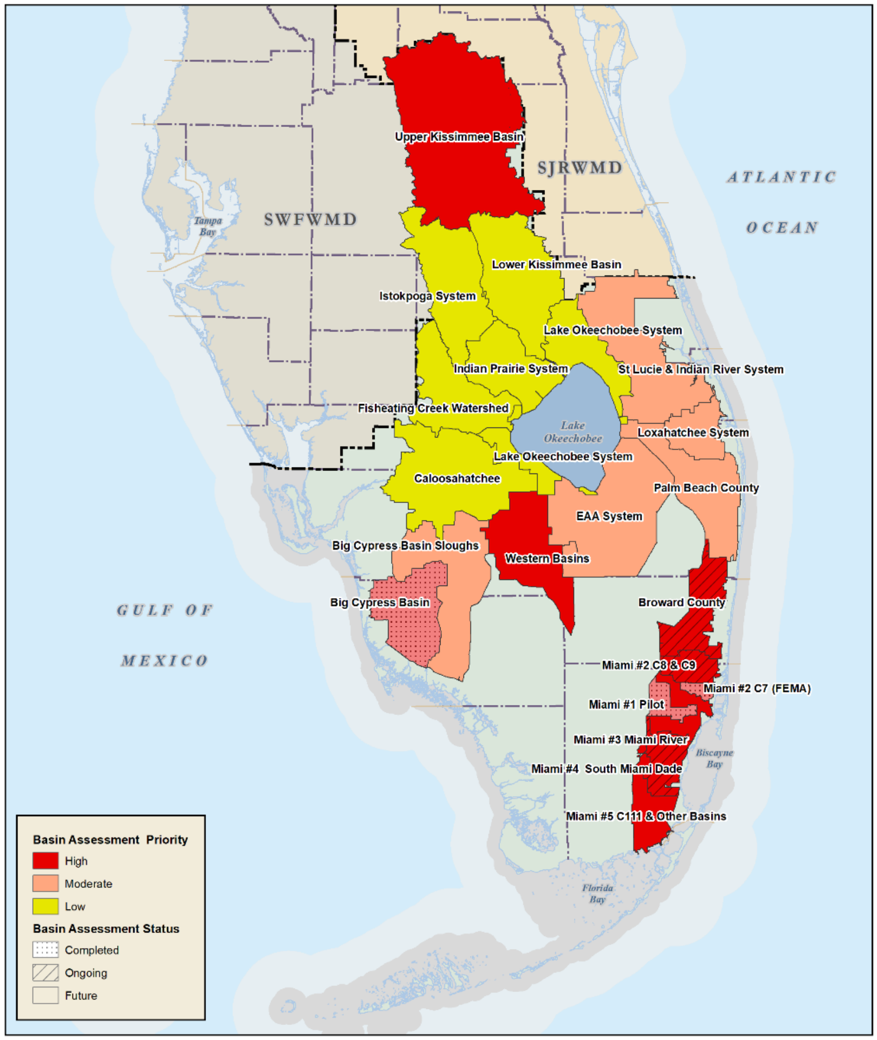
It is crucial that this phase of the FPLOS program be properly and well-funded, preferably with recurring funds, because it identifies projects that are ready to design and build, both for the District and for local stakeholders that are responsible for secondary and tertiary flood control assets. Results from this phase may (on a project by project basis) provide recommendations for cost-share opportunities with federal, state or local partners. A constant stream of properly, regionally evaluated project features across the three tiers of the flood control system will position the region well to compete for state and federal funds for flood control and flood resilience infrastructure.

An adaptation pathway approach is incorporated into the Phase II studies to support the definition of an implementation strategy for the recommended projects (sequences and combinations of flood adaptation and mitigation strategies). If an individual flood mitigation alternative is not able to achieve the specified target of a pre-determined performance criteria, additional mitigation strategies are triggered, setting up a plan on how multiple strategies can be implemented over time.

In FY21, Phase II Studies were kicked off in the C-9 and C-8 Basins in Broward and Miami-Dade Counties. Completion of the C-7 Pilot Phase II Study is expected to be initiated in FY22. The Program annual budget is $2M with at least one new start every year. Design costs are not included as part of this phase and will be completed upon funding confirmation for each individual recommended flood adaptation project.

Total Amount of Funding Request	Duration
$8,000,000	Recurring

FPLOS Assessment (Phase I Studies)

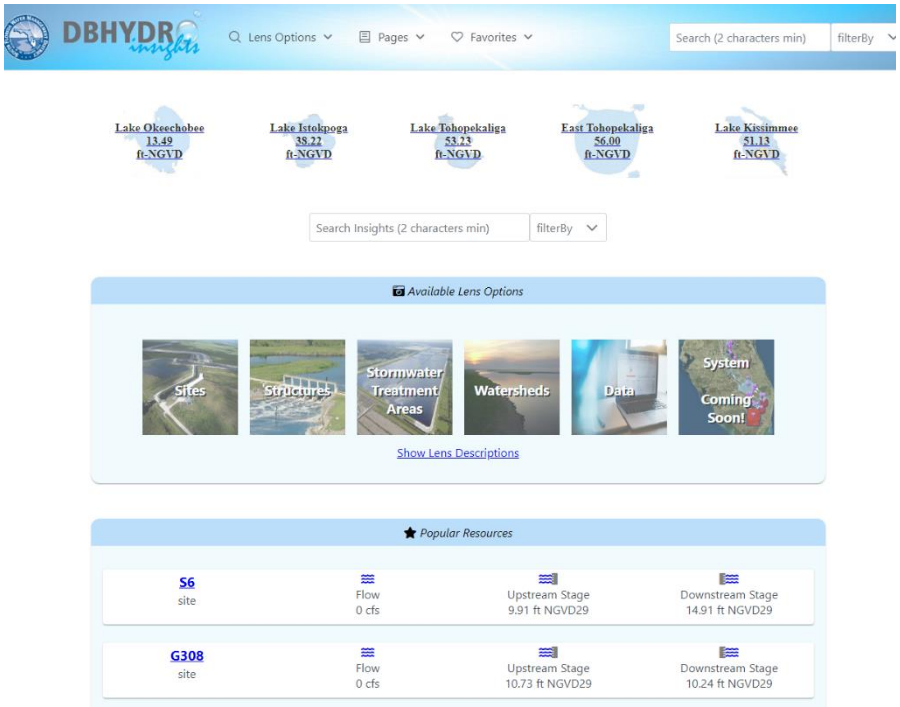


FPLOS Phase I Studies have been ongoing for the past 6 years. These studies identify and prioritize long-term infrastructure improvement needs, in response to population growth, land development, SLR and climate change. Requested funding will be used to advance the development of water management (H&H) models to evaluate the flood protection system operations under changed current and future conditions. This phase identifies issues in the flood control system in 8 to 10-year cycles through a comprehensive, regional approach to addressing flood risks, intensified by sea-level rise. Phase I studies also properly characterize flood vulnerability, risks to critical assets, and potential co-benefits of integrated solutions. This effort is integrated into the District's Capital Improvement Program to ensure its structures, pumps, and canals are functioning as designed, and will remain operational under future climate conditions.

This request is for full funding, which will allow the FPLOS program to meet its planed schedule of two new assessments each year, to meet the goal of cycling through all District basins every 8 to 10 years. All FPLOS H&H models, input data and output results developed as part of assessment and adaptation planning efforts are being and will continue to be stored in the statewide model management system (https://apps.sfwmd.gov/smmsviewer/).

Total Amount of Funding Request	Duration
$4,000,000	Four years

Water and Climate Resiliency Metrics - Web Tool Implementation



As part of a series of resiliency initiatives to address changing conditions, the District is laying out a plan to establish a set of water and climate resilience metrics districtwide. These science-based metrics are being developed with the goal of tracking and documenting shifts and trends in District-managed water and climate data. The metrics support the assessment of current and future climate condition scenarios and related operational decisions that inform District resiliency investment priorities. As part of the District's communication and public engagement priorities, this effort informs stakeholders, the public, and partner agencies about the District's resilience efforts, while supporting local resiliency strategies.

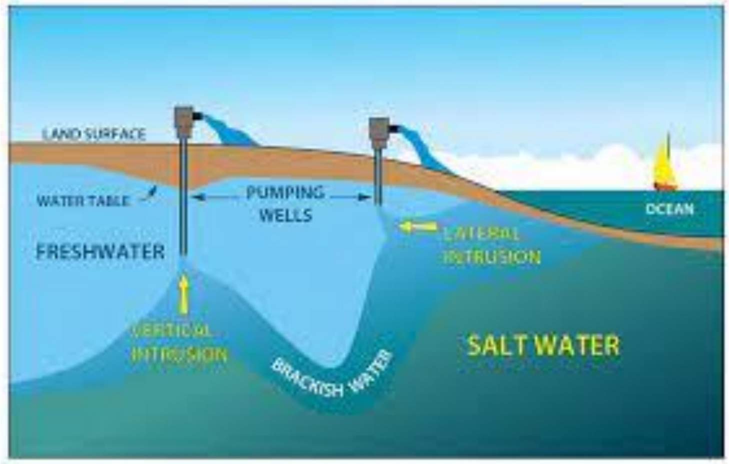
The Water and Climate Resiliency Metrics are an important step towards planning for the future with consideration of long-term observed trends and their impacts on the District mission. The initial set of selected water and climate resiliency metrics are currently being automated for publication through an interactive web portal, providing navigation to different locations districtwide and access to real time data. The portal will generate alternative mapping, chart, and graph options to display and communicate trend results, supported by a story map.

This webtool will provide real time updates to observed data and automated trend analysis, for the fifteen prioritized Water and Climate Resiliency Metrics. Real time automation will minimize rework and reprocessing of trend analysis for the selected key metrics, based on best available data and will be integrated into our existing database tools.

This recurring funding request is for the development of the webtool in year 1, through consulting / IT development support. In future years, funding will be utilized to incorporate new metrics, as recommended by the extensive stakeholder review process. In addition, funding will support integration between DBHydro and the webtool/story map, and to initiate technical support for the development of the Water and Climate Resiliency Metrics Phase II – Development of Future Projections.

Total Amount of Funding Request	Duration
$1,200,000	Four Years

Future Conditions Groundwater Modeling & Saltwater Interface Mapping



Future conditions groundwater modeling will evaluate SLR and other climate change impacts on future water use vulnerability as well as reevaluate the saltwater intrusion monitoring network. The modeling results will inform the installation of new or replacement monitoring wells on an as-needed basis and will be integrated into ongoing maintenance of other District groundwater monitoring networks. These efforts will be advanced in close coordination (and potential partnerships) with local and regional stakeholders and partner agencies.

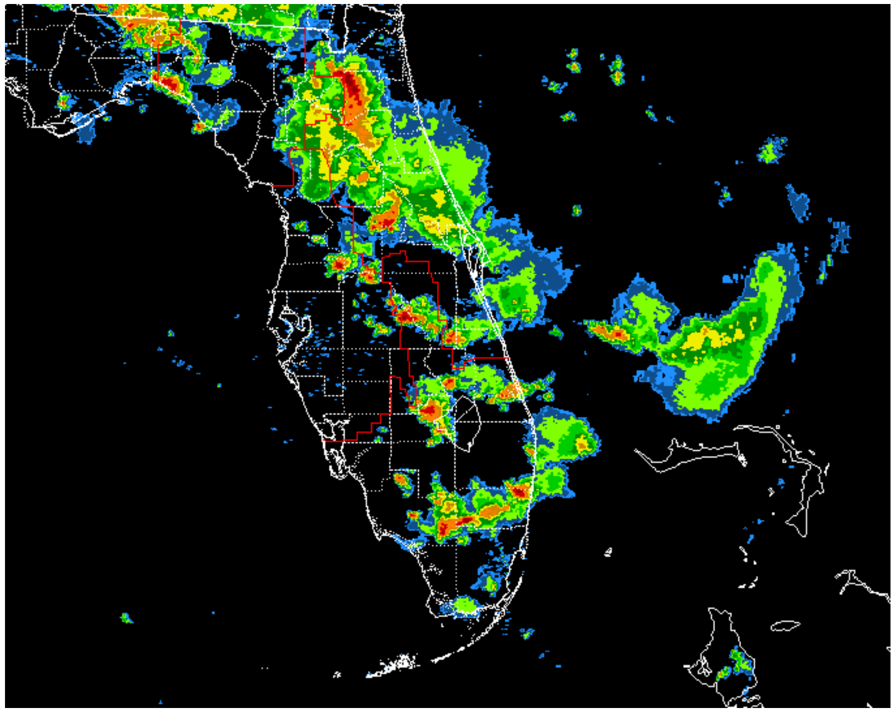
Changes in operational strategies and infrastructure investments are being planned by SFWMD as alternative adaptation/mitigation strategies to address climate change impacts. Assessments of future conditions groundwater elevations and aquifer recharge and pumping rates will be used as input for water supply planning efforts, determination of the potential for saltwater intrusion and flood protection level of service modeling efforts. These assessments will also be a valuable consideration as part of environmental resource permitting (accounting for soil storage).

Requested funds are needed to assess future water use vulnerability, utilizing the modeling tools currently under development, i.e. the East Coast Surficial Model. The District's saltwater intrusion monitoring network is essential to determine the position of the saltwater interface in coastal aquifers. This network was established ad-hoc using existing wells at varying locations and depths. The data from this monitoring network is used to monitor the movement of saltwater in our coastal freshwater aquifers, development of saltwater interface maps at 5-year intervals, and in the District's water use permitting process. Re-evaluating and maintaining the saltwater intrusion monitoring network is essential to monitor the potential intrusion of saltwater into fresh coastal aquifers and the sustainability of these water sources. The existing network has multiple locations with significant spatial data gaps and improperly constructed wells. The existing network is providing insufficient information on the multiple sources of saltwater intrusion used for mapping the distribution of saltwater in the aquifer. Other wells have been destroyed or damaged without being repair or replaced and are clustered around wellfields but sparse near the saltwater front and between wellfields.

This recurring funding request is for the advancement of consulting / IT development support to support groundwater model development and scenario runs, as well as to support the identification and construction of new saltwater intrusion monitoring wells, in coordination with local Utilities.

Total Amount of Funding Request	Duration
$1,200,000	Four Years

Hydrometeorological Data Monitoring



This recurring funding request for Hydrometeorological monitoring will be used for establishing key baseline monitoring stations, and evapotranspiration monitoring for Lake Okeechobee and the rainfall monitoring network, focusing on specific resiliency needs. Future additional data needs will be identified and validated through the Water and Climate Resiliency Metrics Project.

Hydrometeorological monitoring has played an important role in managing water control systems in South Florida. Stage, flow and rainfall data are used daily in SFWMD's Operations and Control Center. District weather stations, Florida Agricultural Weather Network's stations, and National Oceanic and Atmospheric Administration stations, have been used to calibrate/verify the Geostationary Operational Environmental Satellite estimate of incoming solar radiation. Incoming solar radiation is the most important factor that drives evapotranspiration, and therefore is vital for generation of reference evapotranspiration and potential evapotranspiration estimates for all of Florida at the resolution of 2-km by 2-km grids.

With proper support from the Resiliency program, rainfall analyses, such as temporal and spatial distribution, and trend analysis, can be strengthened and conducted at a more frequent interval. Rain gauge stations can be added to the network to address the coverage disparity identified by the Rain Gauge Network Optimization study. A properly distributed rain gauge network will benefit radar rainfall estimates, and climate change trend analysis. Additionally, the National Hurricane Center in Miami has been using the meteorological data from the District's weather stations for hurricane prediction. More accurate data would benefit these efforts as well.

Building resilient water management systems and infrastructure requires science and data. Time series hydro-meteorological data such as seawater level, air temperature, incoming solar radiation, rainfall, and evapotranspiration rate can provide input for trend analyses used for the prediction of climate change.

Total Amount of Funding Request	Duration
$300,000	Recurring

Statewide Regional Climate Projections (FDEP Project Lead, in coordination with Water Management Districts)

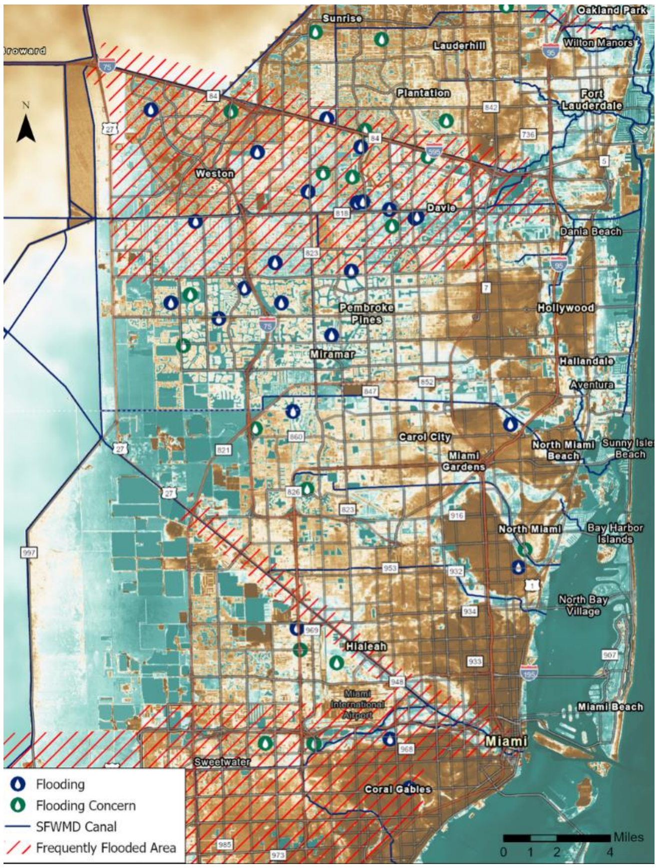
Statewide Regional Climate Projections will be developed in coordination with academia and partner agencies to capture conditions/mechanisms of rainfall, and other related climate variables. This funding request will be advanced in coordination with FDEP and other water management districts. Determination of future extreme rainfall conditions (both wet and dry conditions) is key for evaluating potential impacts from climate change to operation of District infrastructure and mission implementation. There is specific interest in determination of future rainfall scenarios as part of FPLOS Phase I Assessments.

The District, the U.S. Geological Survey, Florida International University (FIU) and local governments have been working over the past five plus years at evaluating global and regional climate models to estimate future extreme rainfall conditions. In May 2019, the District and FIU organized a Workshop to define a strategy for the development of uniform rainfall scenarios in Florida. As part of the short-term workshop recommendations, the District is assessing best available downscaled climate datasets and identifying a subset of best performing model datasets that are relevant to inform the extreme rainfall scenarios. A separate long-term effort should be conducted as recommended in the 2019 Workshop, because the use of available climate datasets for estimating future rainfall in Florida is challenging, and biases in extreme rainfall are still relatively large when comparing past observation with climate model's historic data. A Florida Regional Climate Projections modeling effort would be better suited to capture conditions/mechanisms of rainfall occurrences in our State, including contributions from tropical storms and sea breeze, as well as Florida shelf and ocean dynamics, and other important climatic processes. Advancing a statewide regional climate projections model would certainly reduce future rainfall uncertainty estimates in Florida.

Total Amount of Funding Request	Duration
$2,000,000	Four Years – One Time

Flooding Events Mapping and Database Tool

The Flooding Events (Statewide) Mapping and Database Tool, upon funding approval, will expand District's capacity to collect flood event observations and build a more robust database, in coordination with FDEP and the State Geographic Information Officer and other WMDs. This would serve to better inform the FPLOS Program assessment and model calibrations, as well as infrastructure hardening priorities and additional planning efforts. Flooding Events Mapping is also one of the key priority Water and Climate Resiliency Metrics, and the collection of new data will expand District's capacity to evaluate future trends.



A crowdsourcing tool was initially proposed to streamline the collection of flood reports, standardize the reported information, provide a means to submit digital images, and centralize information in a repository for long-term maintenance and evaluation. The intent of this data collection is to obtain pictures and information about local flooding that can be used to supplement quantitative data and validate model results.

Although the gauge network in South Florida is vast, it does not provide flooding measurements for all critical areas. Where quantitative measurements are available, water surfaces can be interpolated and used in combination with high resolution elevation data to estimate flood extent and depth. Where quantitative data do not exist, crowd sourced depth estimates can be used to do the same. If captured during an event, pattern analysis of estimates can be used to deploy reconnaissance teams to collect more precise measurements. The District is planning to start the tool implementation in coordination with the 298 Districts and local governments. Outreach and communication would be decided by each 298 District or local government to reach out to the public. In parallel, the District initiated consultation with the State Geographic Information Officer to learn details and legal considerations about the Survey 1-2-3 Public Data Acquisition Web Application that FDEP and other State Agencies have been successfully implementing (Beach Access Issues, Post Hurricane Debris Reports, Blue Green Algae, and others). FDEP may have interest in potentially hosting this crowd sourcing application, based on pre-existing models, and coordinating with other WMDs.

Total Amount of Funding Request	Duration
$1,000,000	Four Years – One Time

Green Infrastructure Flood Mitigation Strategies - Associating Water Quality Benefits in the Little River Watershed

In partnership with Miami-Dade County and Florida International University, this project proposed the integration of scientific research and coastal water management challenges to develop actionable information for resilience of coastal environments in the face of climate change, SLR, and land-use development. The overall goal is to identify nature-based features that can be evaluated for flood protection and water quality benefits in consultation with stakeholders to improve watershed restoration planning.

To enhance regional adaptive capacity for addressing the increasing challenges of flood and water quality protection, a more comprehensive approach to watershed management is needed. In this project, we propose to address the overarching question: What are the flood mitigation and water quality benefits of cumulative “green elements” of the Community Rating System (CRS) program and other nature-based features with and without gray flood mitigation approaches? By planning for restoration and enhancement of natural functions that can improve flood protection and water quality benefits within the watershed in a coordinated effort across agencies, supported by expertise of local academic and NGO collaborators, we strive to enhance socio-ecological resilience in the face of SLR and land-use change.

Quantifying flood mitigation and water quality benefits through comprehensive watershed restoration planning is a key outcome of the project. Comparing FPLOS performance metrics, water quality benefits (specifically, TP, TN, and TSS load reductions), and averted economic damage (Bouwer et al. 2017) across the diverse set of watershed restoration scenarios will support flood protection planning with quantifiable environmental, societal, and economic benefits assessed by this project. It is expected that future funding opportunities will result in construction of immediately feasible CRS/Low Impact Development features and zoning/code changes to enable more transformational CRS/Low Impact Development features to be constructed across the C-7 and other basins in South Florida.

Total Amount of Funding Request	Duration
$450,000	Three Years – One Time

Appendix A. Cost Estimates

See excel spreadsheet.