FSA
Florida Stormwater Association

ANNUAL CONFERENCE

VISION AND ACTION: WORKING TOGETHER TO CREATE SAFE AND SUSTAINABLE WATERSHEDS

JUNE 15-17, 2022

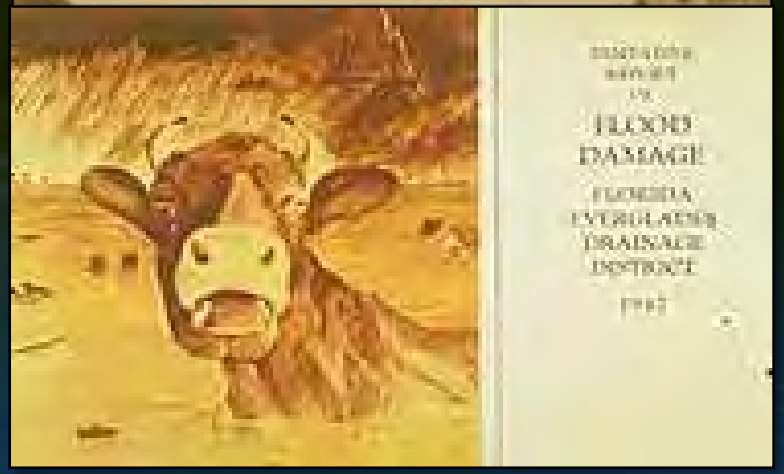
SANIBEL HARBOUR MARRIOTT, FT. MYERS, FLORIDA

Sea Level Rise and Flood Resiliency Plan

Carolina Maran, P.E., Ph.D., District Resiliency Officer

June 16, 2022

FLOOD CONTROL: Central & Southern Florida Project

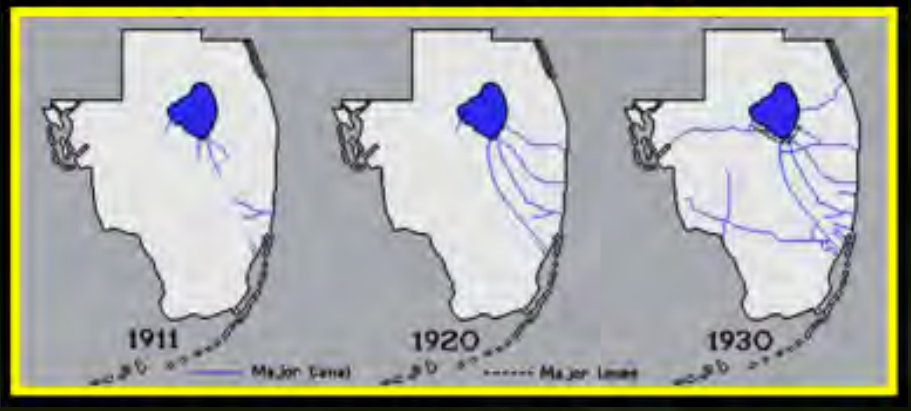


Joint Flood Protection Responsibility

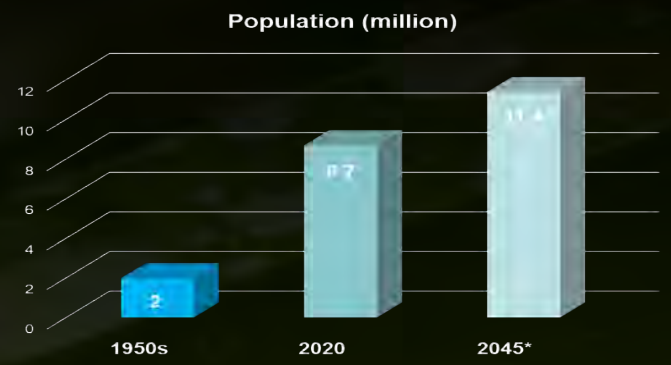
- Primary
  - USACE
  - SFWMD
- Secondary
  - Local Governments
  - Special Districts
- Tertiary
  - Homeowners Associations
  - Private Landowners

Recognizing Changed Conditions

Pre-1948 Drainage Projects

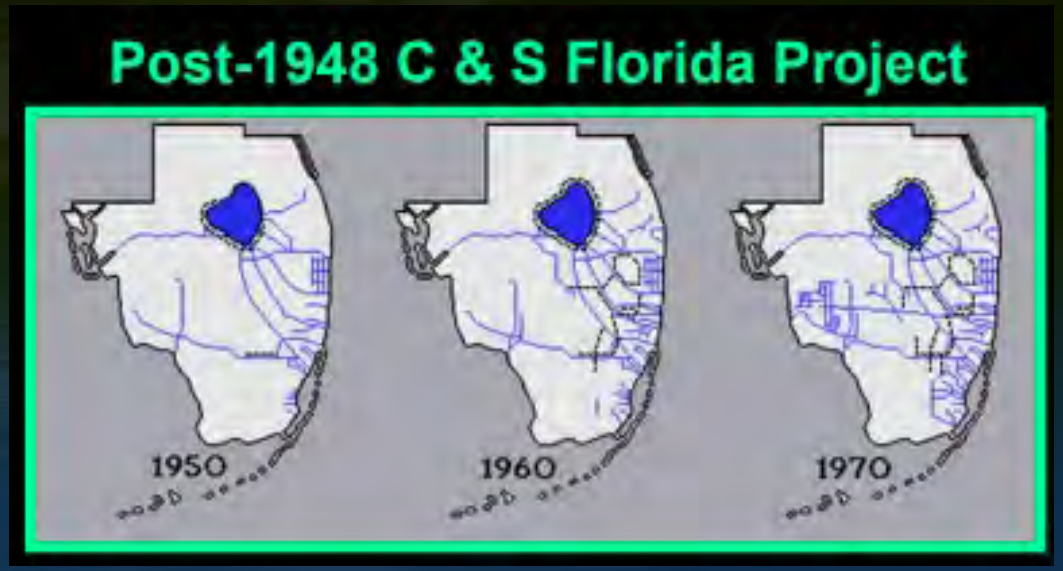


POPULATION GROWTH



* Estimate taken from BEBR 2017 publication (Median, SFWMD boundaries)

Post-1948 C & S Florida Project



Recognizing Changed Conditions: Emerging Trends in Regional Resiliency

Regional Rainfall

Changes in rainfall patterns will impact people and ecosystems by altering the amount of water in our region throughout t...

Elevations at Coastal Structures and Sea Level Rise

Tailwater and headwater elevations at coastal structures represent how sea level rise affects stormwater discharge capacity in South...

Saltwater Intrusion in Coastal Aquifers

The inland migration of saltwater poses a threat to water supply and critical freshwater habitats.

Salinity in the Everglades

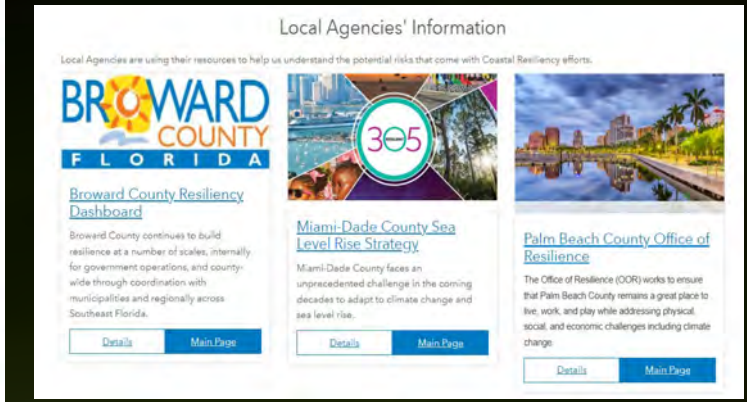
The salinization of previously freshwater systems poses threats to several factors.

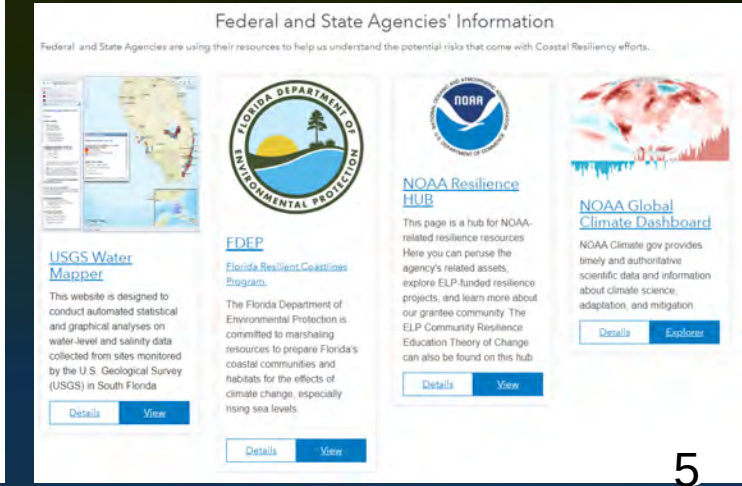
Estuarine and Mangrove Inland Migration

Trends in Estuarine Inland Migration provide insights to the impacts of sea level rise in coastal areas and the Everglades.

Soil Subsidence in South Florida

Maintaining soil elevations within coastal and intertidal habitats, as sea level changes, is an indicator of long-term stability of coastal.





https://sfwmd-district-resiliency-sfwmd.hub.arcgis.com/

Current Limitations in C&SF Operation

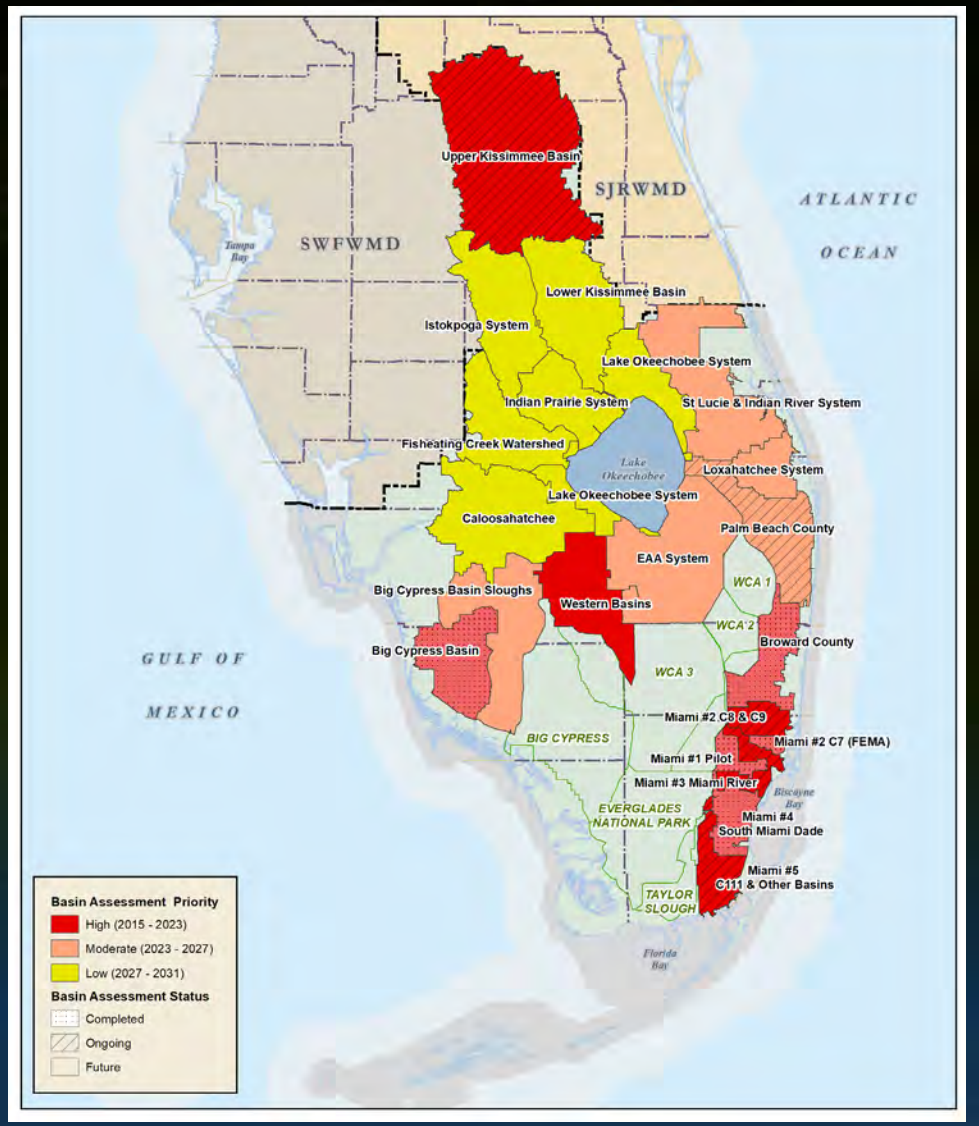
Reduction in Discharge Capacity

Flood Protection Level of Service Program

District's strategy for assessing and addressing the impacts of urban development and changing climate patterns on flood control

- Evaluate current and future flood risks to communities in South Florida
  - Based on 6 performance metrics including canal stages, discharge capacity, overland flood inundation and duration
  - Considers rainfall, groundwater levels, tides, storm surge and sea level

SFWMD.gov/FPLOS

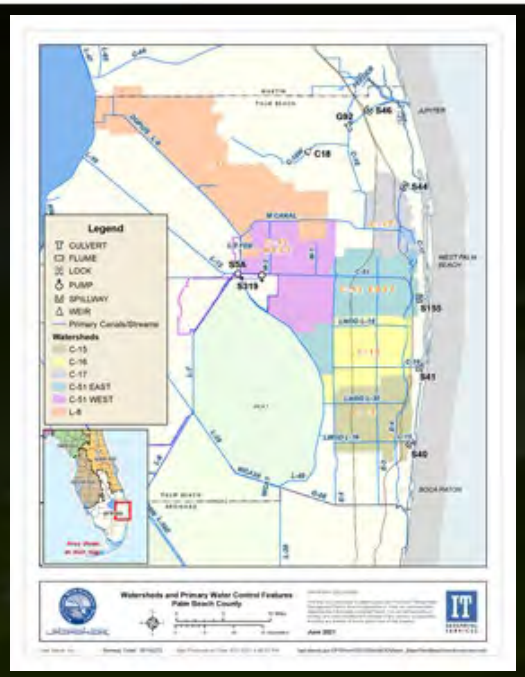


Presenter: Carolina Maran

Phase I: Ongoing FPLOS Projects

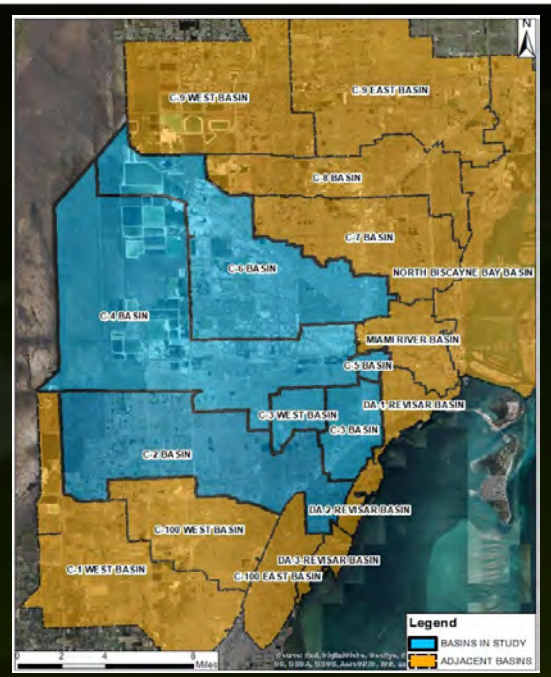
Upper Kissimmee Basin

Completion date: November 2023



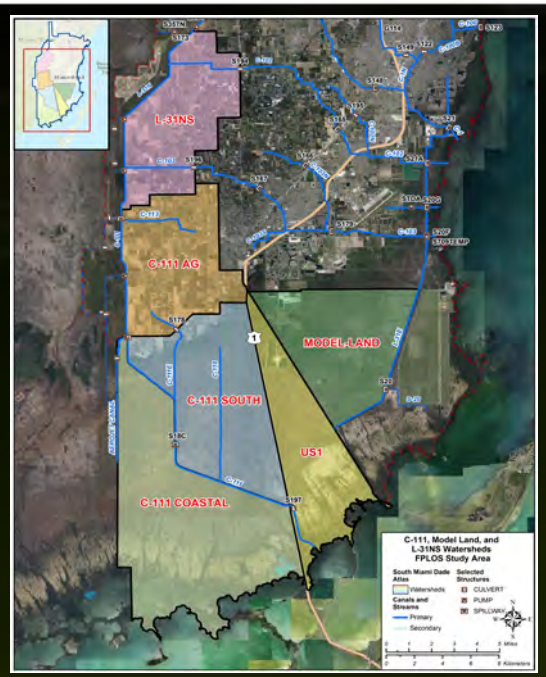
Palm Beach Basins

Completion date: February 2024



C2, C3W, C5 and C6 Watersheds

Completion date: December 2022



C-111, Model Land, and L-31NS Watersheds

Completion date: December 2022

<u>Completed Assessments</u>

- C4 Basin
- Big Cypress Basin
- C7 Basin
- C8/C9 Basins
- Broward Basins
- C-1, C-100, C102, and C-103 Basins

<u>Other Studies:</u>

- Low-Lying Tidal Structure Assessment
- Biscayne Bay Surge Model

<u>Future basins</u>: South Lee, Western Basins (C-139), St. Lucie & Indian River System

Future Extreme Rainfall Projections

ACKNOWLEDGMENTS

This technical memorandum was made possible by the guidance, support, and contributions of a dedicated team of individuals at the South Florida Water Management District, United States Geological Survey, and United States Army Corps of Engineers. We would like to especially acknowledge the technical feedback provided by the United States Geological Survey Caribbean–Florida Water Science Center and Florida International University Sea Level Solutions Center, and express our appreciation to the Future Extreme Rainfall Projections Technical Workgroup members who assisted with the preparation of this memorandum as follows:

PROJECT TEAM

South Florida Water Management District

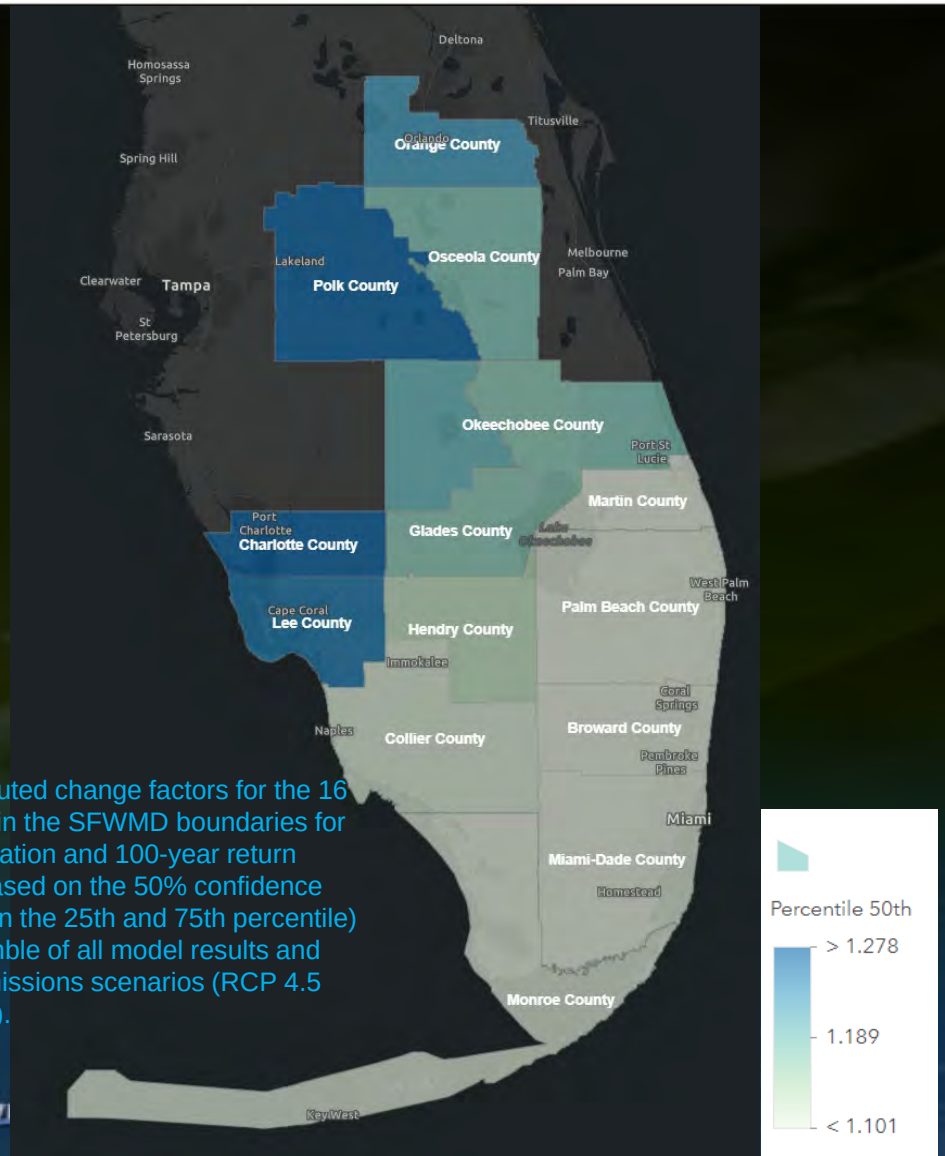
Carolina Maran	District Resiliency
Nicole Cortez	District Resiliency
Francisco Peña	District Resiliency
Walter Wilcox	Hydrology and Hydraulics Modeling
Jenifer Barnes	Hydrology and Hydraulics Modeling
Hongying Zhao	Hydrology and Hydraulics
Akin Owosina	Hydrology and Hydraulics
Karin Smith	Water Supply Planning
Kristopher Esterson	Water Supply Planning
Sean Sculley	Applied Sciences
Brian Turcotte	Applied Sciences
Todd Kimberlain	Meteorological Operations

United States Army Corps of Engineers

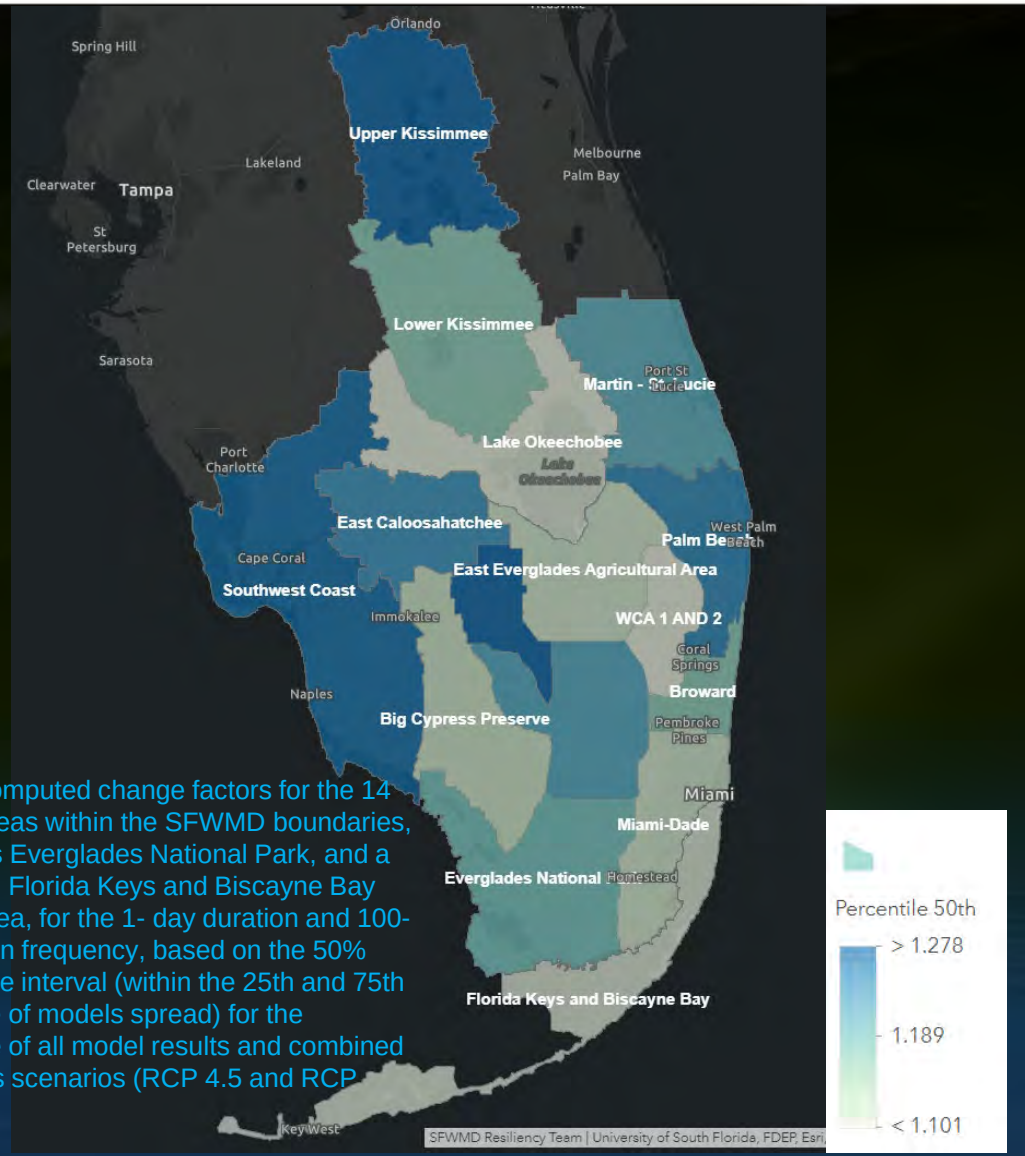
Ceyda Polatel	Jacksonville District
Drew Coman	Jacksonville District
Matt Fischer	Jacksonville District

https://apps.sfwmd.gov/sfwmd/gsdocs/TPubs/2022_SFWMD_TM_Adoption_of_Future_Extreme_Rainfall_Change_Facotrs_for_Resiliency_Planning_in_South_Florida.pdf

Future Extreme Rainfall Projections



Map of computed change factors for the 16 counties within the SFWMD boundaries for the 3-day duration and 100-year return frequency, based on the 50% confidence interval (within the 25th and 75th percentile) for the ensemble of all model results and combined emissions scenarios (RCP 4.5 and RCP 8.5).



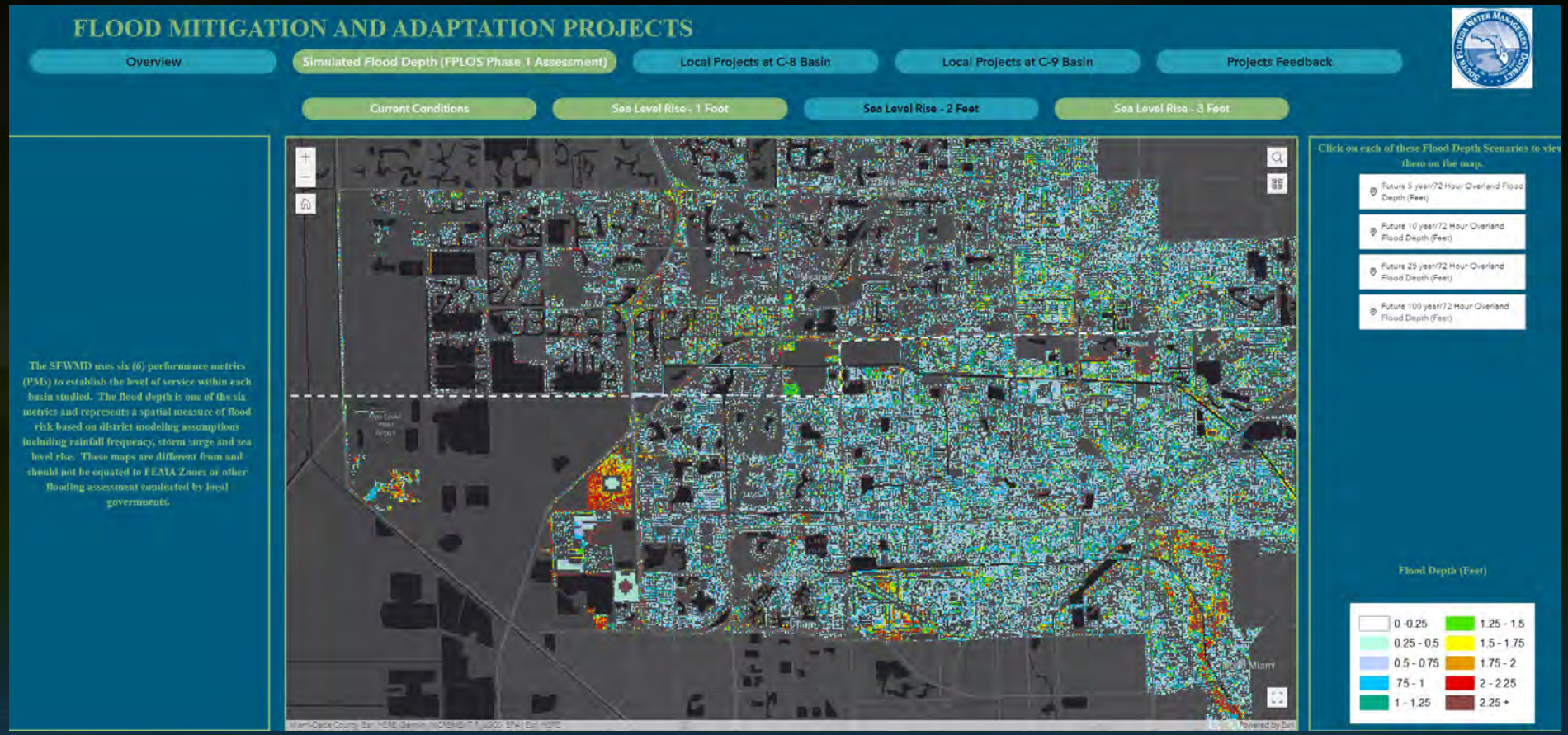
Map of computed change factors for the 14 rainfall areas within the SFWMD boundaries, as well as Everglades National Park, and a combined Florida Keys and Biscayne Bay rainfall area, for the 1- day duration and 100-year return frequency, based on the 50% confidence interval (within the 25th and 75th percentile of models spread) for the ensemble of all model results and combined emissions scenarios (RCP 4.5 and RCP 8.5).

Phase II Flood Adaptation & Mitigation Strategies

Basin-wide Coordinated Approach: understanding local and regional priority needs

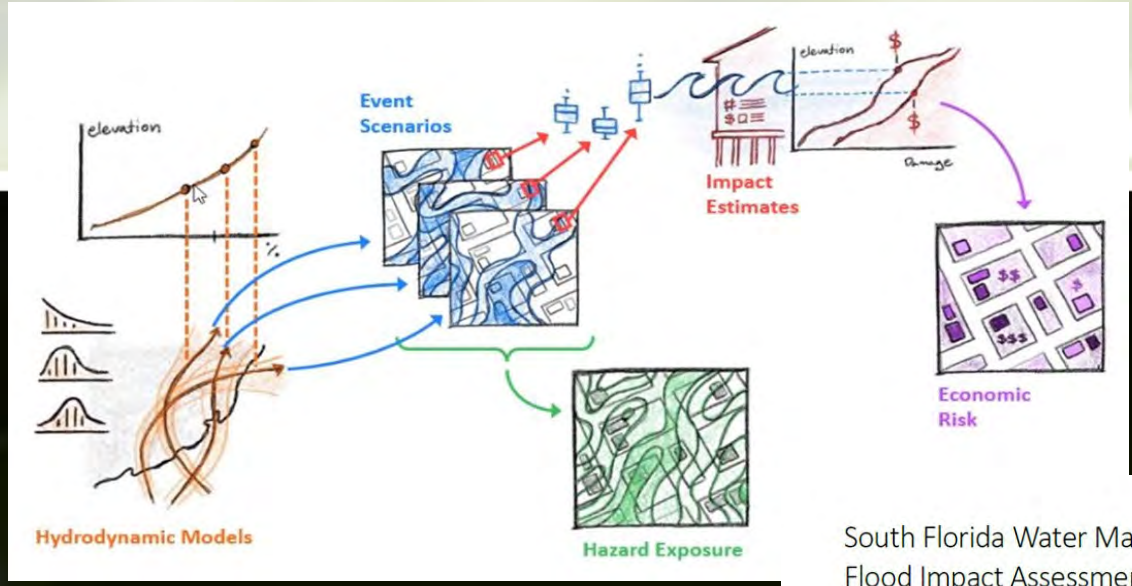
Working to identify local and regional solutions, and establish partnerships

C-8/C-9 Basins:
[C-8 C-9 Basins FPLOS (buildcommunityresilience.com)]

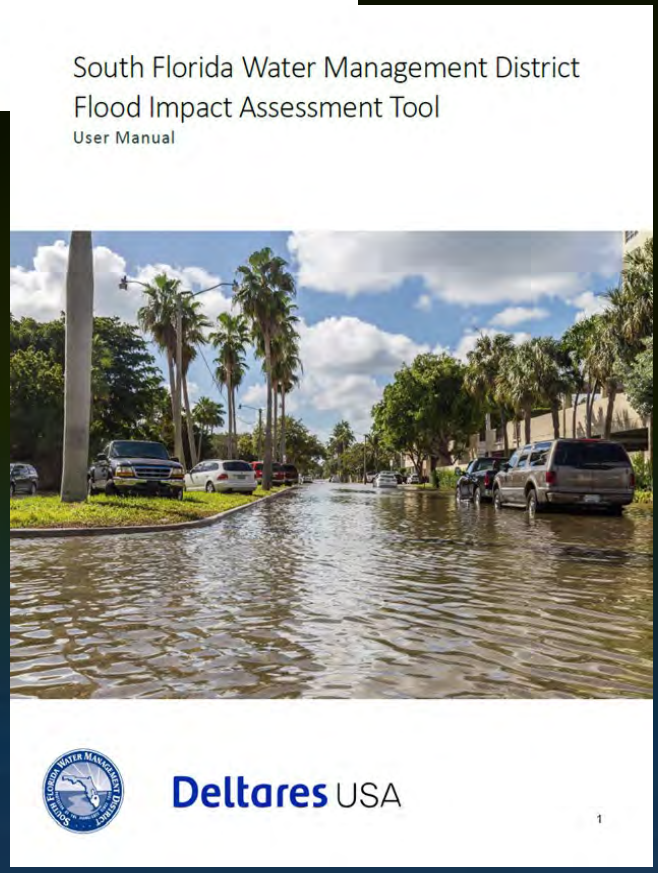


SFWMD – FIAT Tool

- Combines exposure data and flood maps with damage curves to calculate the flood damages and risk per object
- Developed to run quick, consistent, and well-founded flood damage risk calculations (cost estimates)
- Next steps: incorporating additional environmental and social benefits, as well as cascading impacts



Translating hydrodynamic model results into economic risk assessments.
Source: Taylor Engineering



Presenter: Carolina Maran

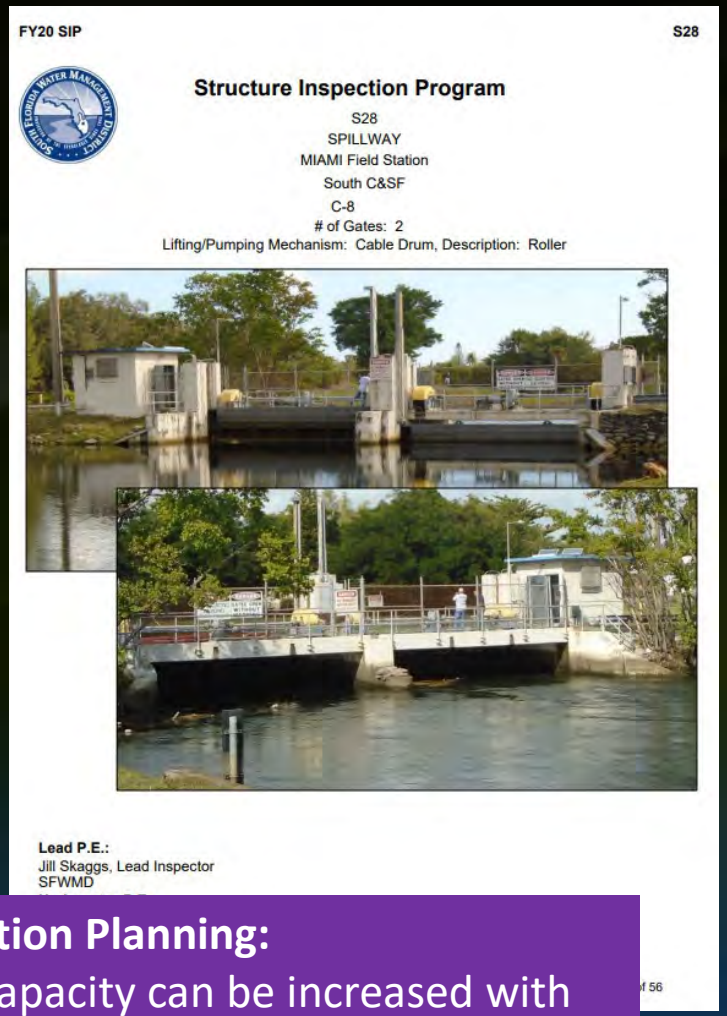
Planning for System Enhancements

Our Resiliency Vision

- Risk Reduction / Effectiveness
- Implementation Resources
- Anticipated Future Conditions
- Population and Critical Infrastructure Impacted
- Public Engagement and Leveraging Partnerships
- Ongoing Ecosystem Restoration Efforts
- Innovative Green/Nature-Based Solutions

Coastal Structures Resiliency – Projects Scope

- Non regret strategy: Structure Enhancements (replacement, as needed)
- Flood barriers (tying-in higher land)
- Restoring pump capacity for existing Infrastructure at critical locations
- Increasing operation flexibility in the system during major tropical storm/hurricane events
- Additional backup and redundancy for existing and new infrastructure
- Land and Real Estate needs for enhancements

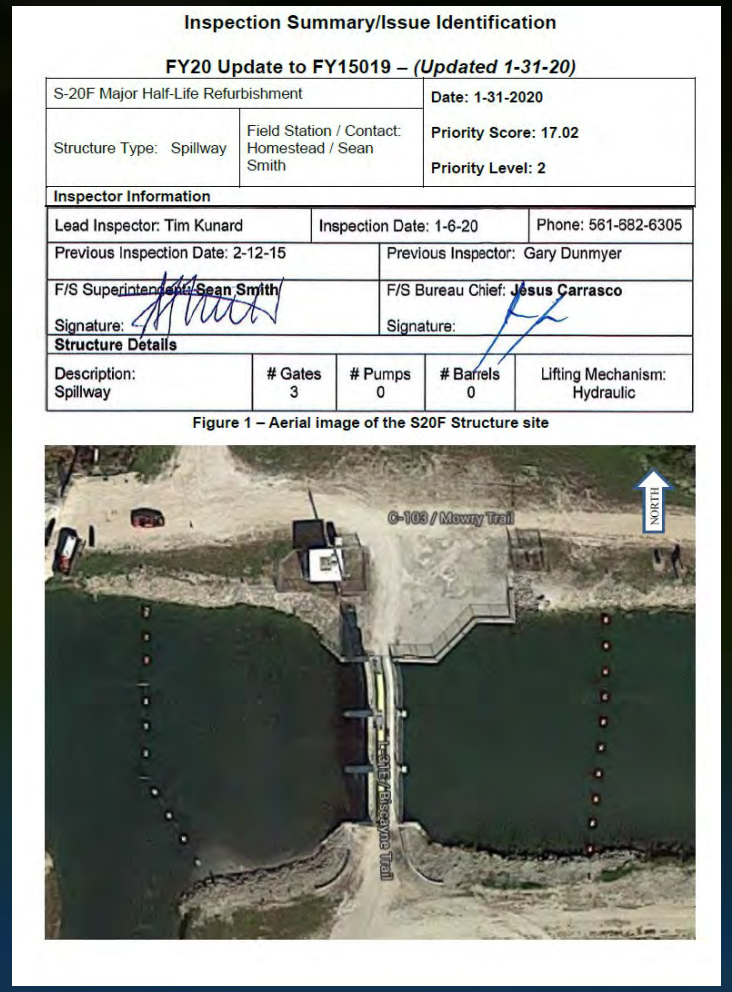


FY20 SIP S28

Structure Inspection Program

S28
SPILLWAY
MIAMI Field Station
South C&SF
C-8
# of Gates: 2
Lifting/Pumping Mechanism: Cable Drum, Description: Roller

Lead P.E.:
Jill Skaggs, Lead Inspector
SFWMD



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

Figure 1 – Aerial image of the S20F Structure site

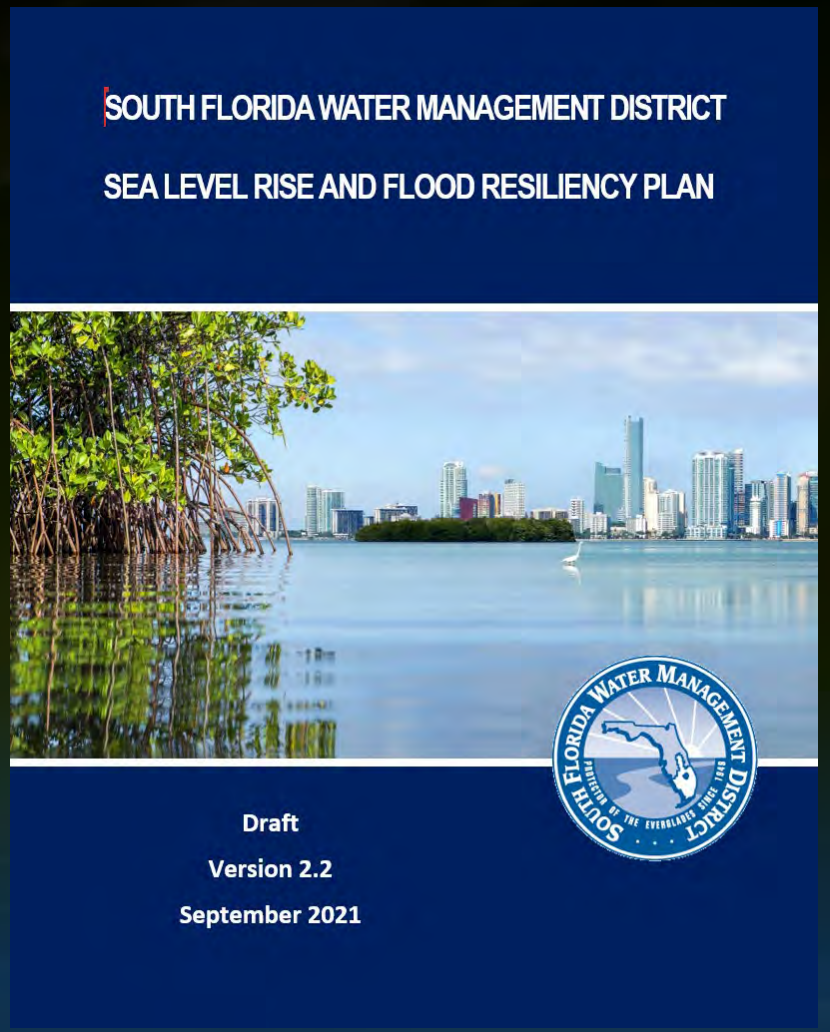
Adaptation Planning:
pump capacity can be increased with time, through a phasing approach

Additional Resiliency Projects

- Self Preservation Mode at Coastal Structures
- Corbett Levee
- South Dade Curtain Wall
- Everglades Mangrove Migration Assessment
- Water Supply Vulnerability (Planning)
- Statewide Regional Climate Projections (Planning)
- Ongoing FPLOS Assessments (Planning)
- Flooding Events Mapping and Database Tool (Planning)
- Other Data / Monitoring Needs

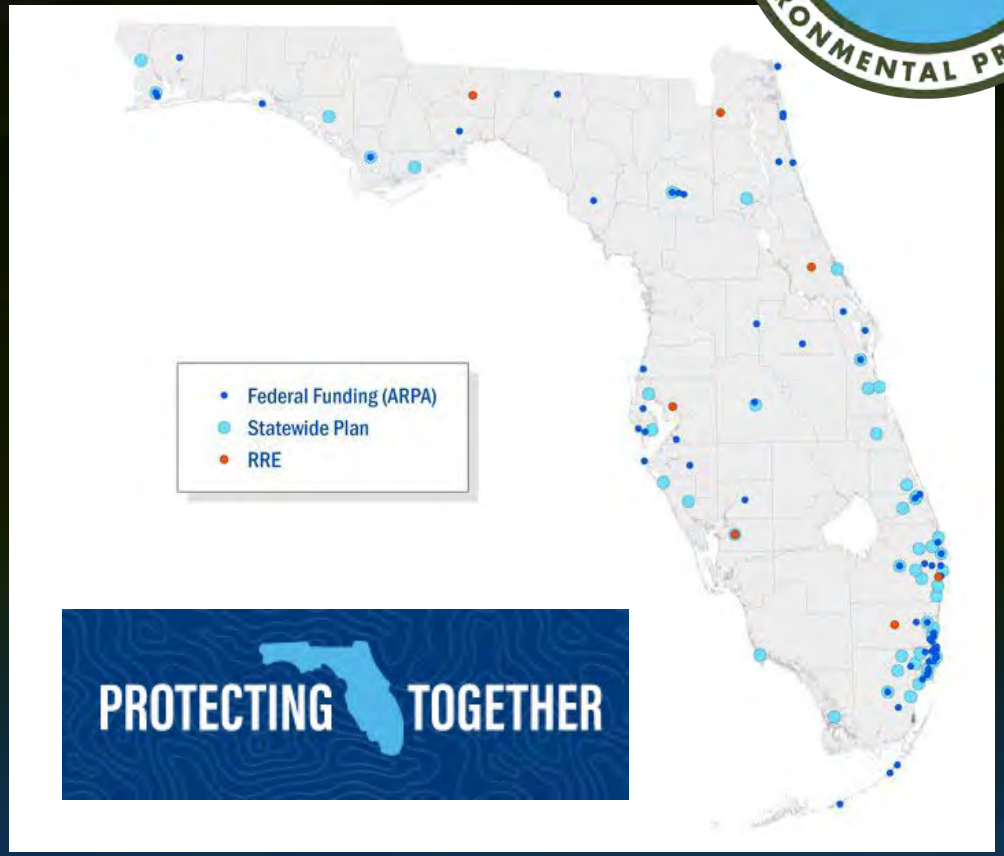
Project Plan Document & Next Steps

- Continuous formulation process (yearly by Sept 1st)
- Open for Public Comments
- Leverage additional funding opportunities
- HB 513 (2022): District to submit consolidated annual report regarding status of C&SF System to EDR, FDEP, Governor, & Legislature



Resilient Florida: Historic and Largest Flood Resiliency Initiative

- SB 1954 (2021) / HB 7053 (2022): Resilient Florida Program – Statewide Flooding and Sea Level Rise Resilience
- Over $697 million available to support efforts to ensure state and local communities are prepared to deal with the impacts of flooding from sea level rise, extreme rainfall and intensified storms
- $200M (TBC) available in FY2023



USACE/SFWMD: C&SF Flood Resiliency Plan

- To be conducted under Section 216 of the Flood Control Act of 1970
- Upcoming study to recommend adaptation strategies to build flood resilience in the communities served by the C&SF system
- Cost Share Agreement between USACE and SFWMD being finalized (3x3x3 Study)
- Study to be initiated later in Fall 2022

Integrating Local, Regional, Natural, Inland Drainage and Coastal Flood Resiliency Strategies

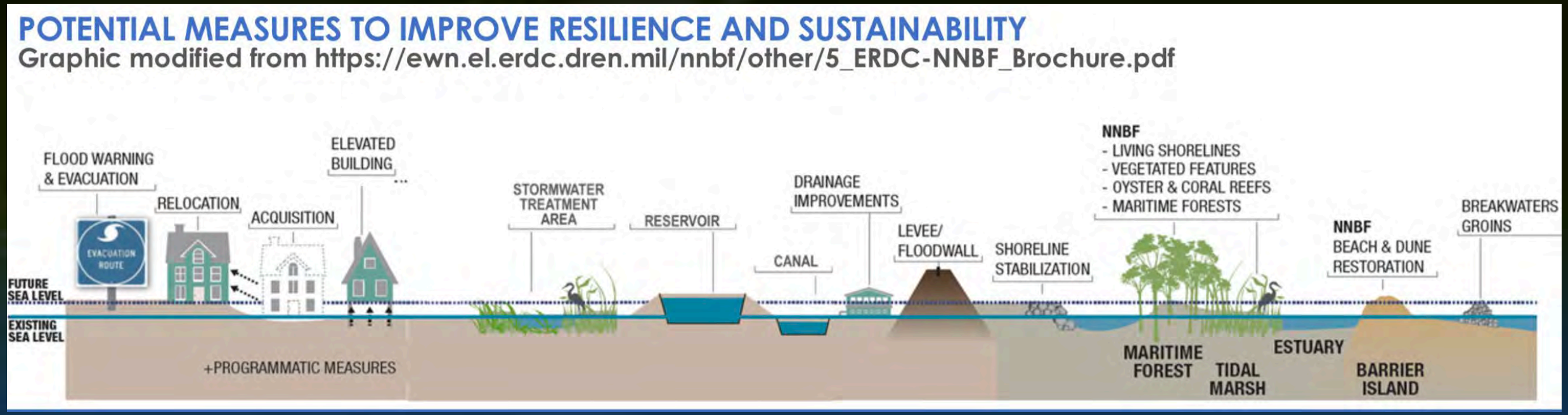
Counties' Projects

Local Municipalities' Projects

USACE Studies (SACS, C&SF) / Projects

Regional Climate Compacts' Initiatives

Others



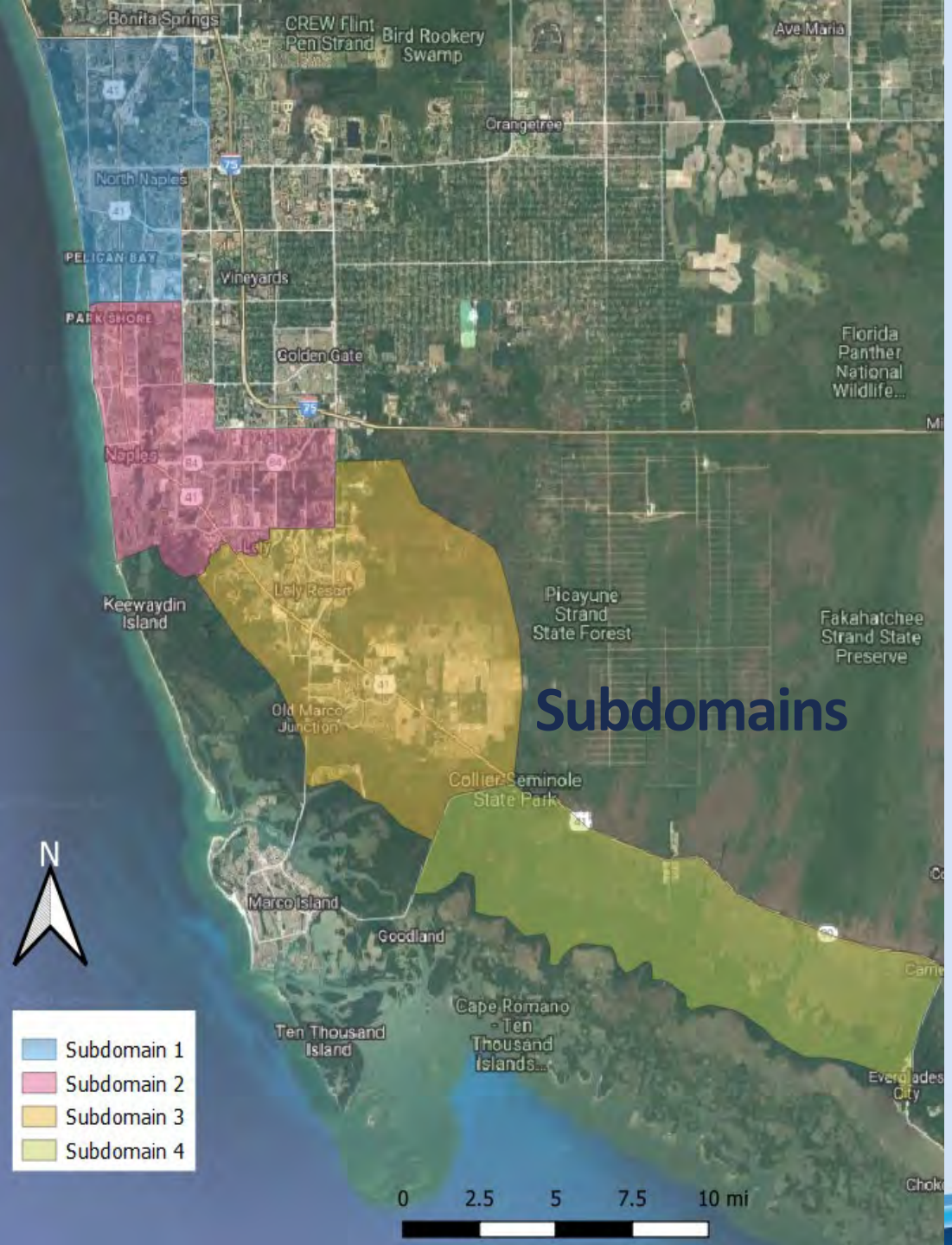
Source: USACE

Thanks!

Questions?

Carolina Maran, Ph.D., P.E.,
cmaran@sfwmd.gov
District Resiliency Officer

South Florida Water Management District
www.sfwmd.gov/resiliency



Predicted Hurricane Storm Surge and Rainfall Flooding in Highly Urbanized Collier County Coastal Areas

Florida Storm Water Association

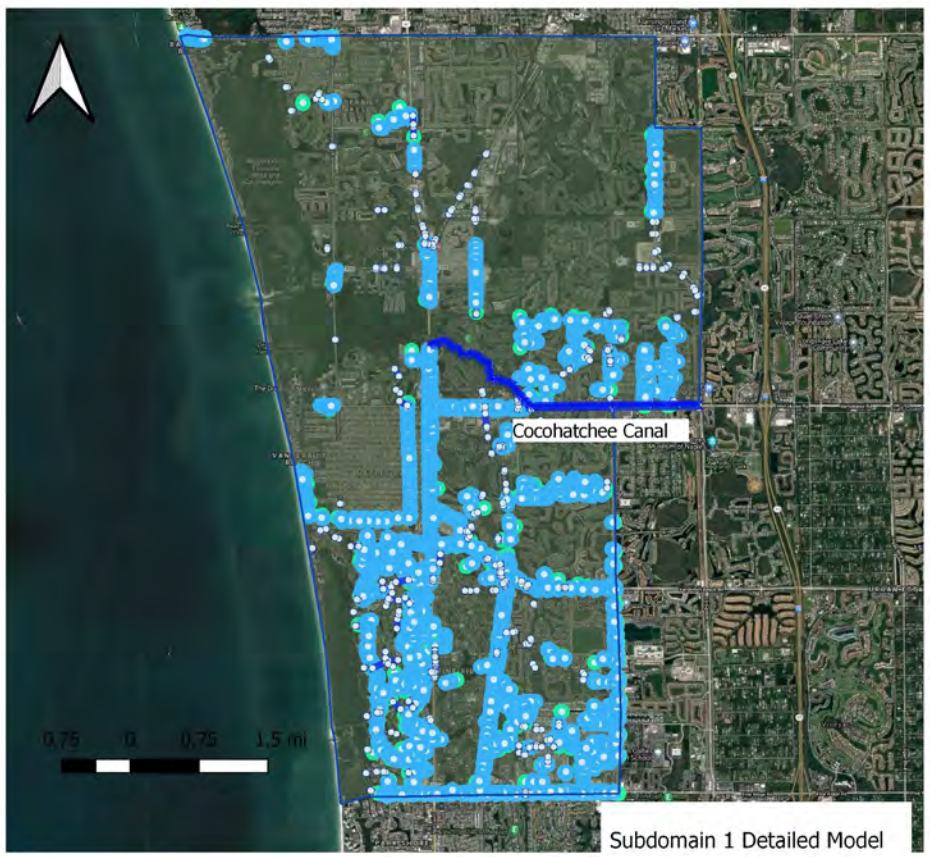
Annual Conference 2022

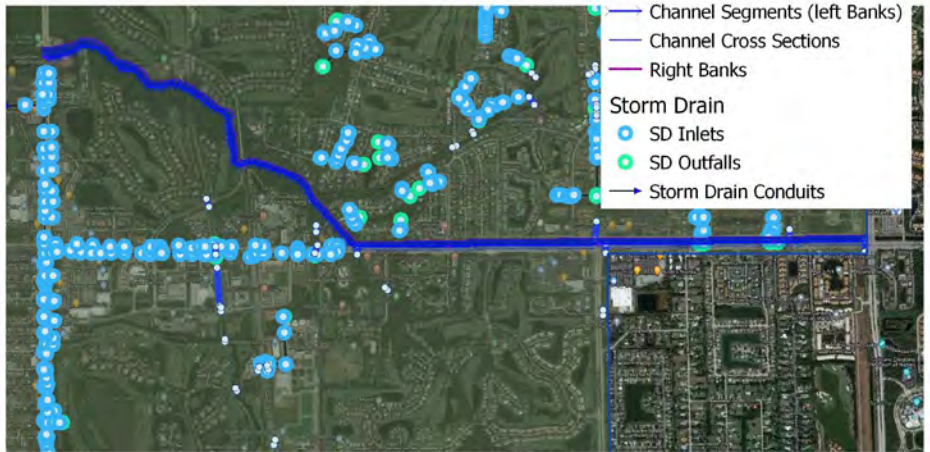
Presented by: Noemi Gonzalez Ramirez, Ph.D., P.E.

FLO-2D Software, Inc.

Email: noemi@flo-2d.com

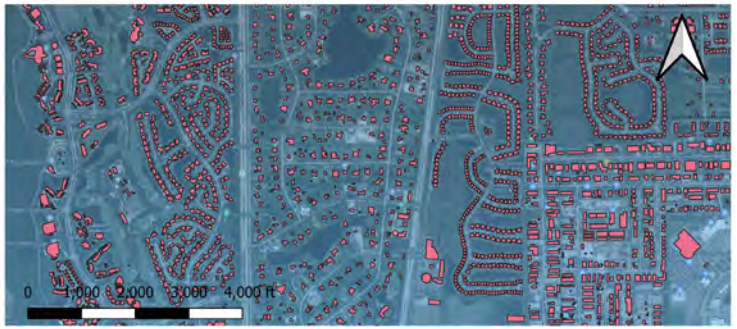
Urbanized Coastal FLO-2D Model Subdomains





Subdomain	Location	Area (mi^2)	Grid Size (ft)	No. of Elements
1	North Naples	33.61	25	1,510,494
2	Naples	40.84	25	1,913,550
3	Naples Manor	79.62	30	2,426,133
4	Everglades City	63.19	50	702,282

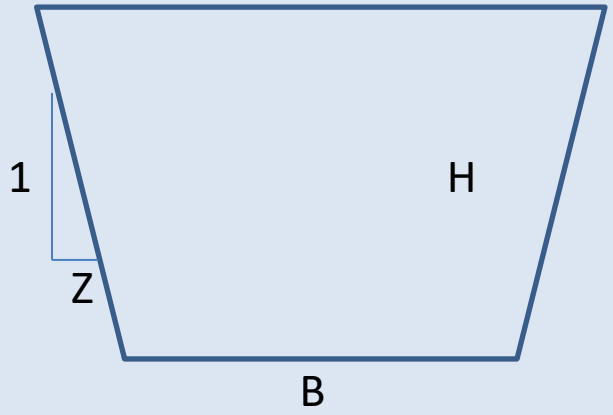
Detailed Urban Model:



- Rainfall (NEXRAD) and Infiltration
- Roughness based on land use
- Storm surge, tidal conditions, SLR
- Upstream basin inflows and boundary conditions
- 76,712 buildings
- Levees, detention basins and lakes
- 707 Hydraulic structures, culverts and bridges
- 503 Storm drain systems with more than 6500 inlets
- 5 major Canals: Cocohatchee, Golden Gate Main Canal, Gordon River Extension, Haldeman Creek and Henderson Creek

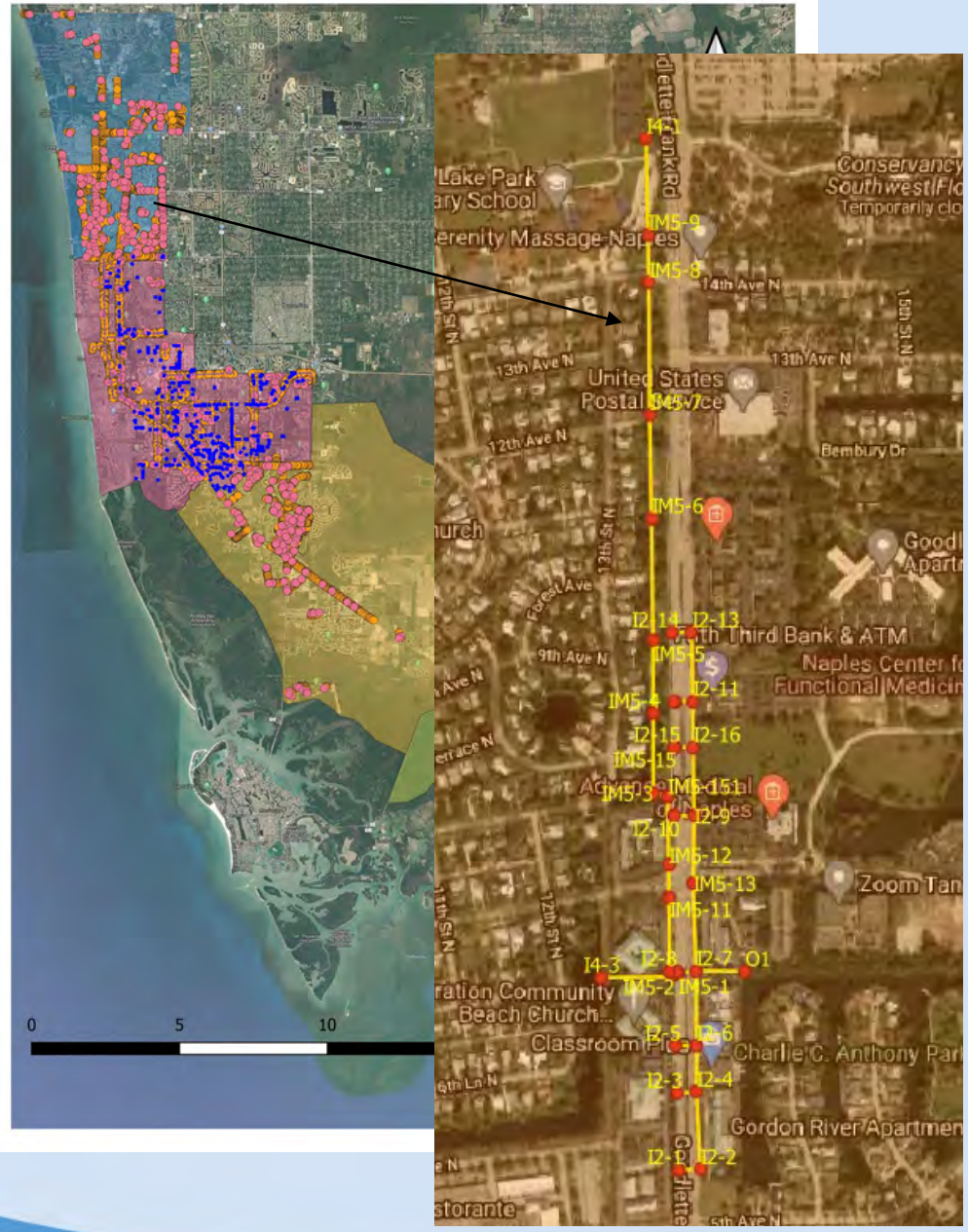
Typical Channel Cross Sections

CANAL	Depth	Bottom Width	Slope
Cocohatchee	7	70	0.2
Cocohatchee	8.4	70	0.2
Cocohatchee	9	100	2
Golden Gate Main Canal	13	98	1.8
Gordon River Ext	5.6	50	1.5
Haldeman Creek	6	95	1.5
Henderson Creek	7.2	40	2
Henderson Creek	8.75	40	2



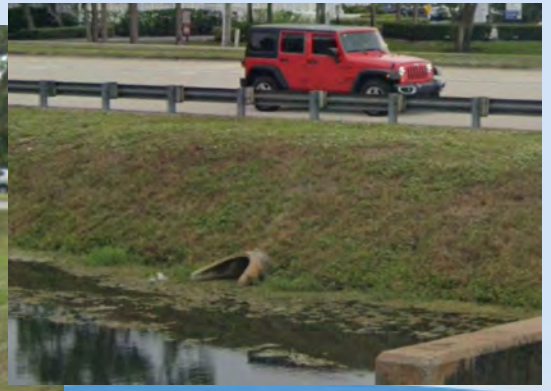
T: Top Width
B: Bottom Width
Z: slope
H: Depth

Storm Drain Features by Subdomain

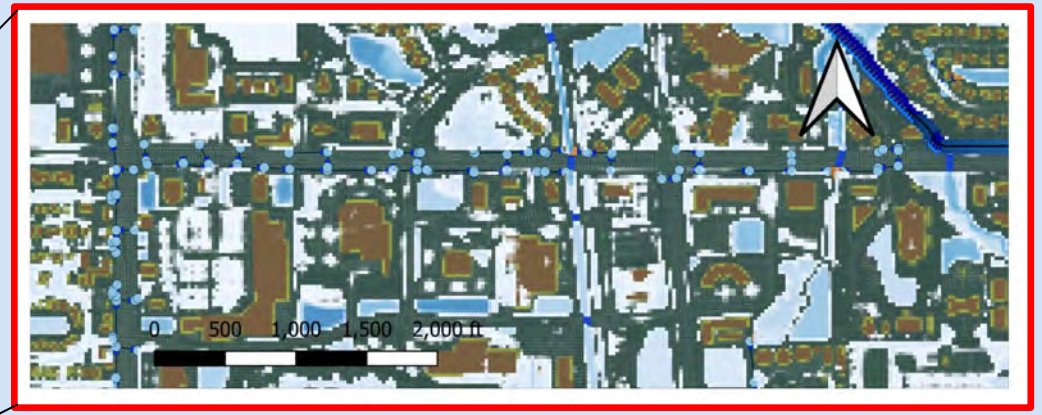


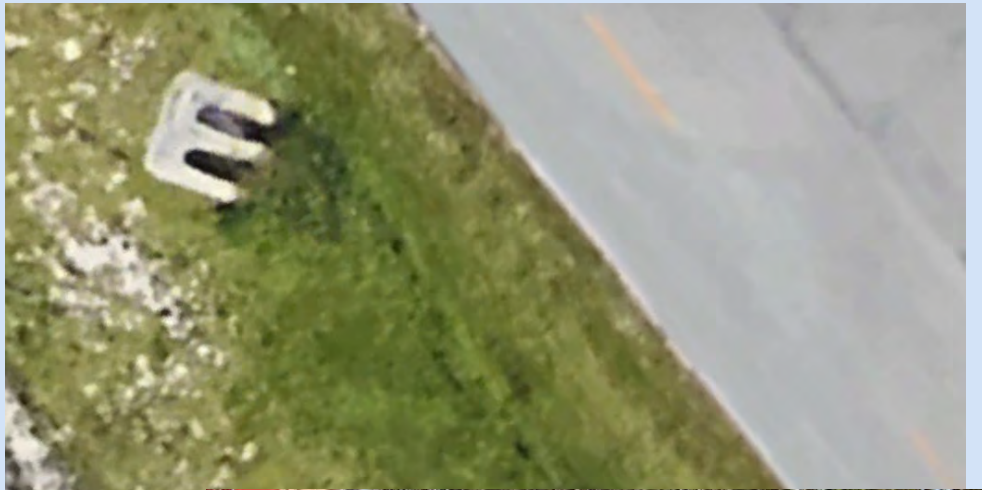
Subdomain	Networks	Inlets	Conduits	Manholes	Junctions	Outfalls
1	221	2281	2314	420	29	221
2	172	3245	3371	809	126	172
3	110	985	1008	152	22	110
4	0	0	0	0	0	0
Totals	503	6511	6693	1381	177	503

Total length of SD pipes: 161 miles



FLO-2D Urban Model – Detailed Results

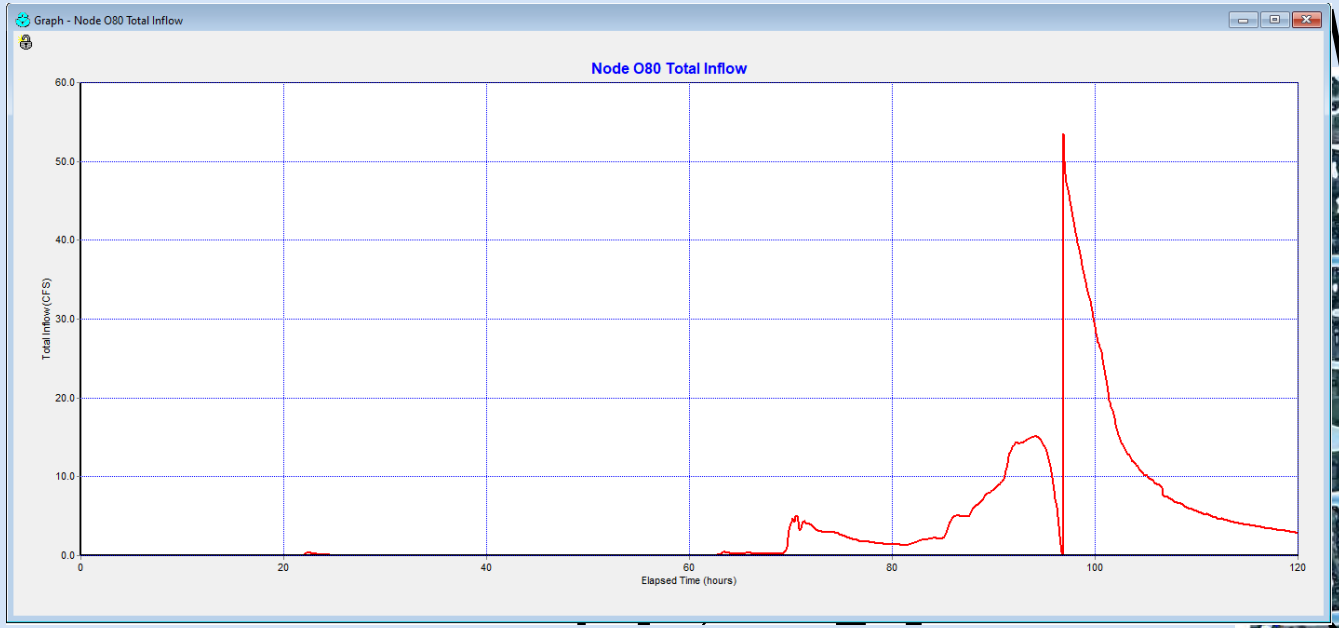


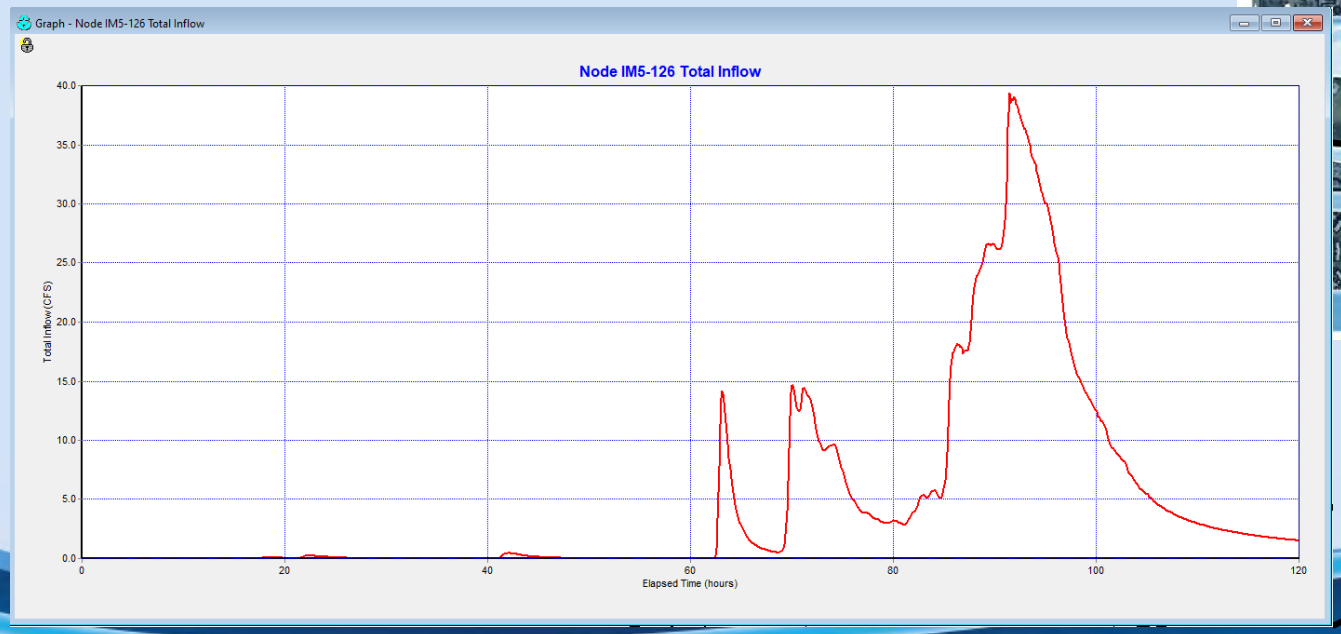


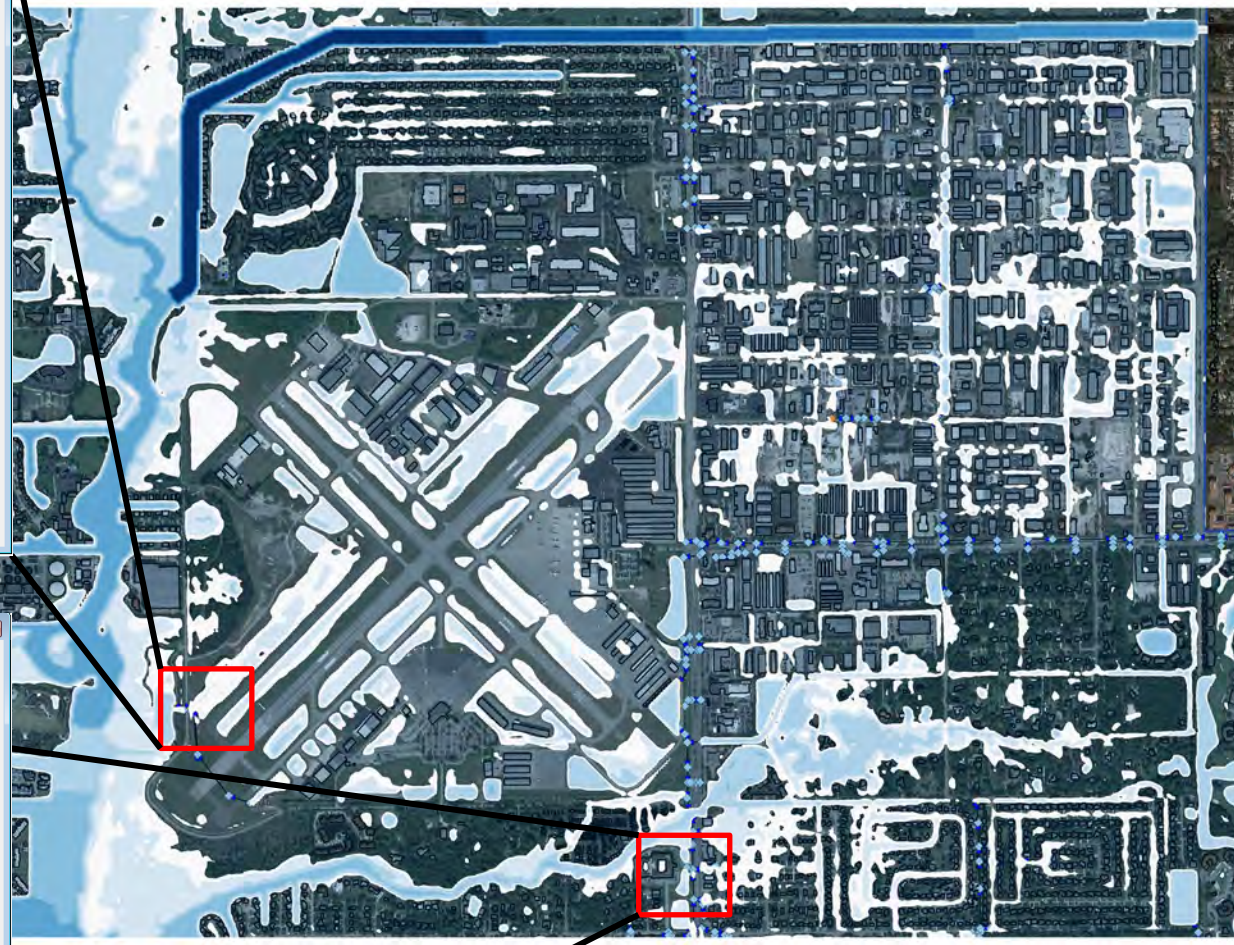
FLO-2D Predicted Urban Flooding

FLO-2D

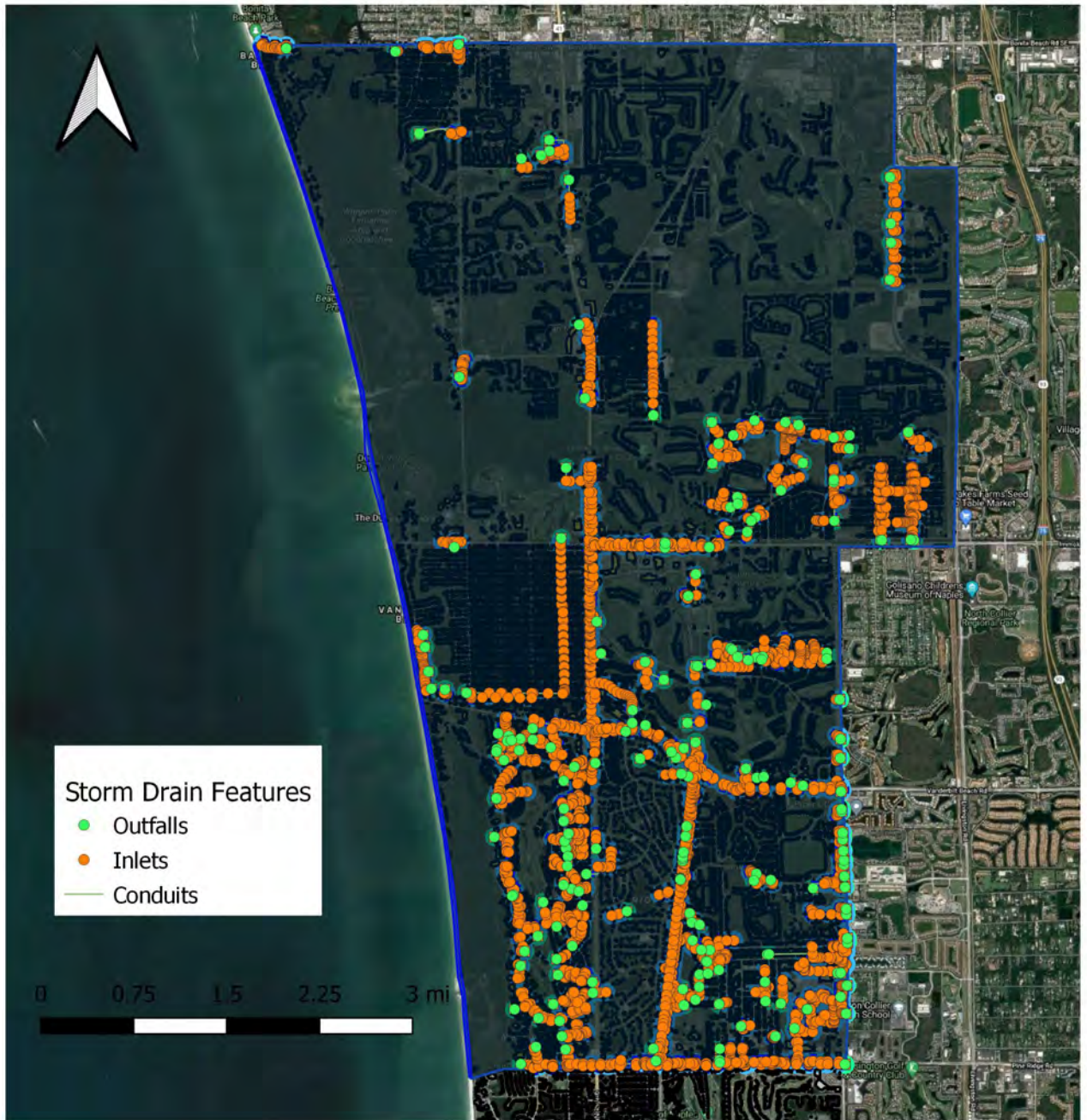
FLO-2D Urban Model – Detailed Results

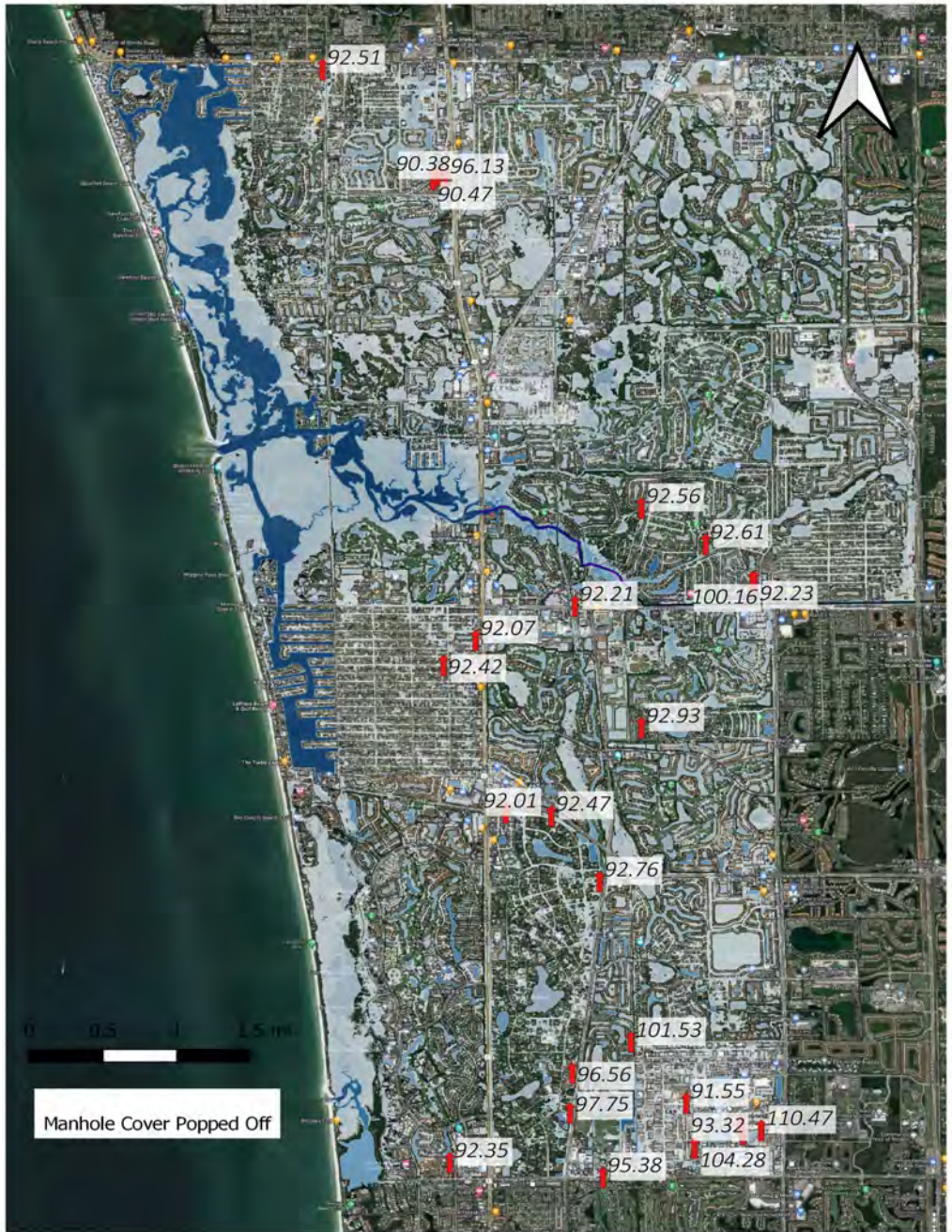




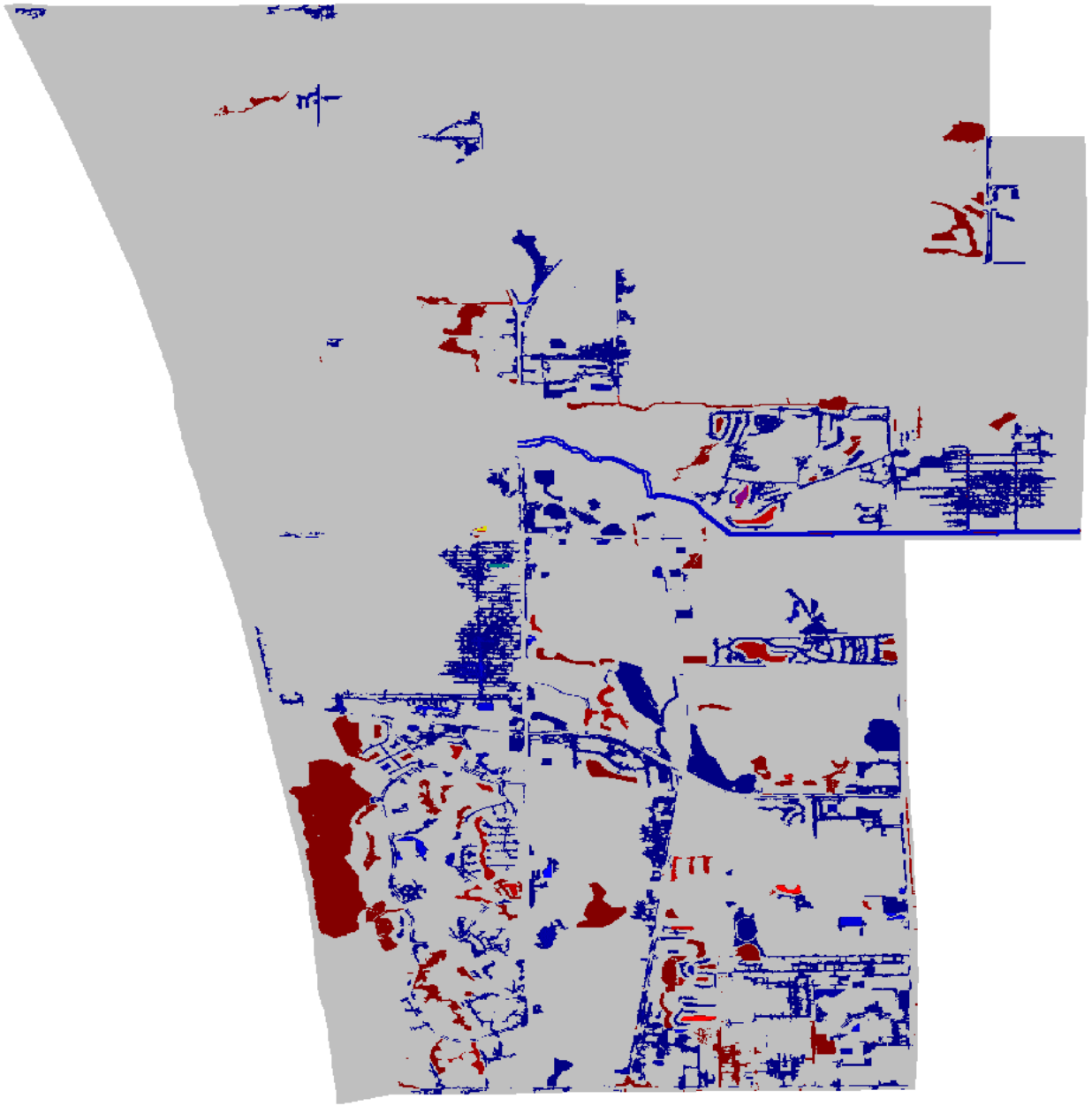


FLO-2D Urban Model – Detailed Results





Storm Drain Impact on Hurricane Irma Flooding with/without SD



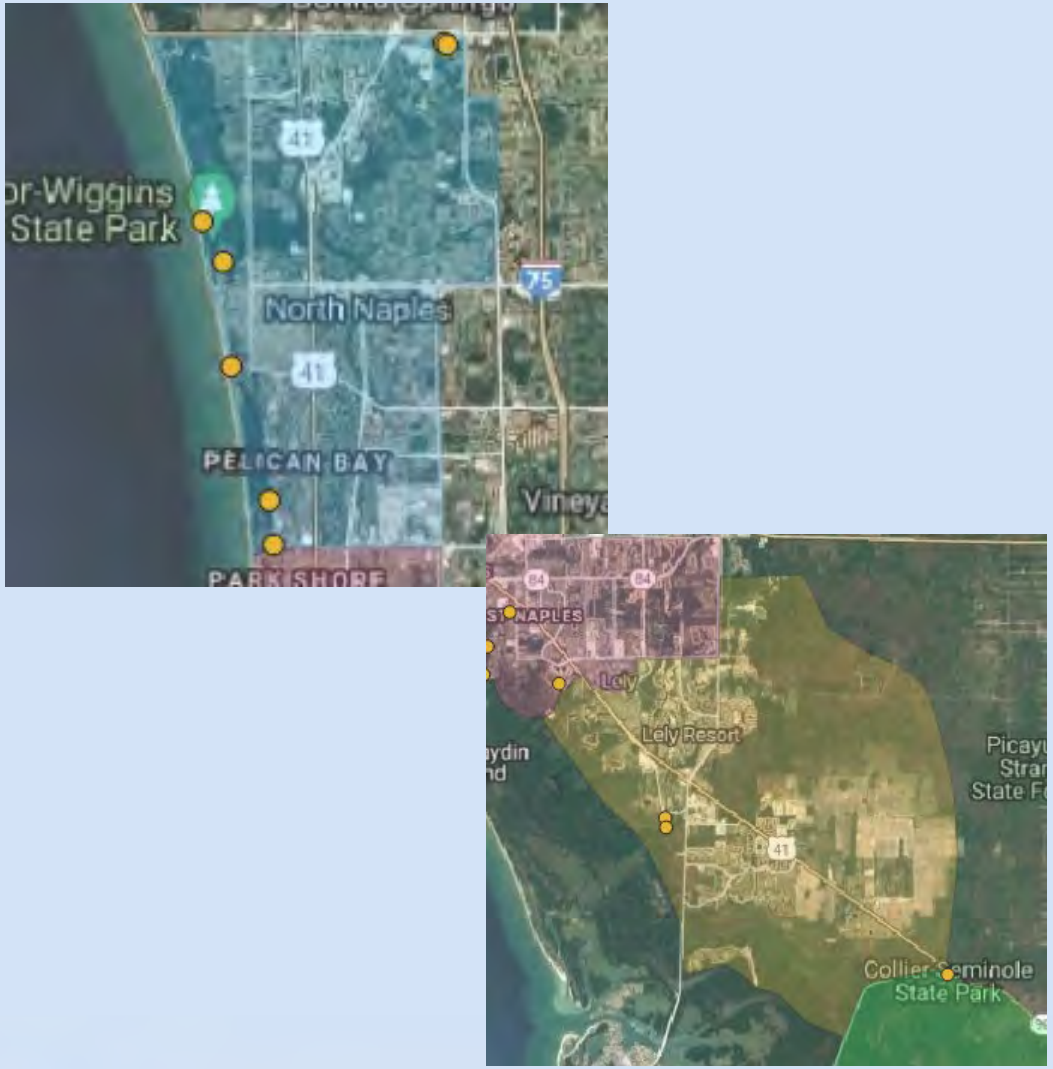
With SD minus without SD

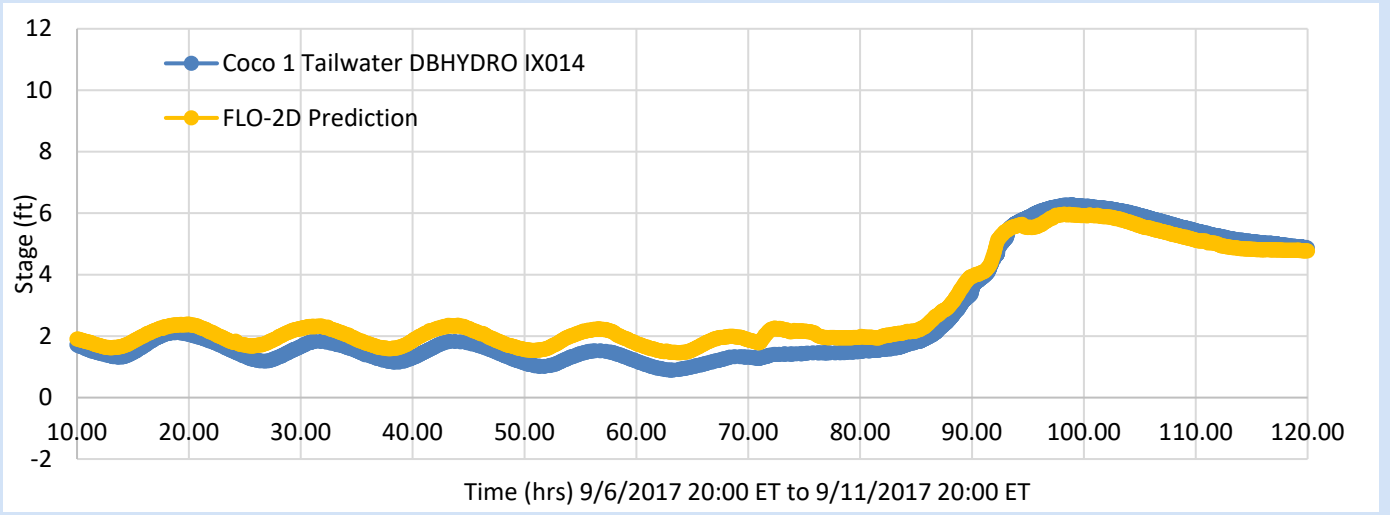
Difference (ft or fps

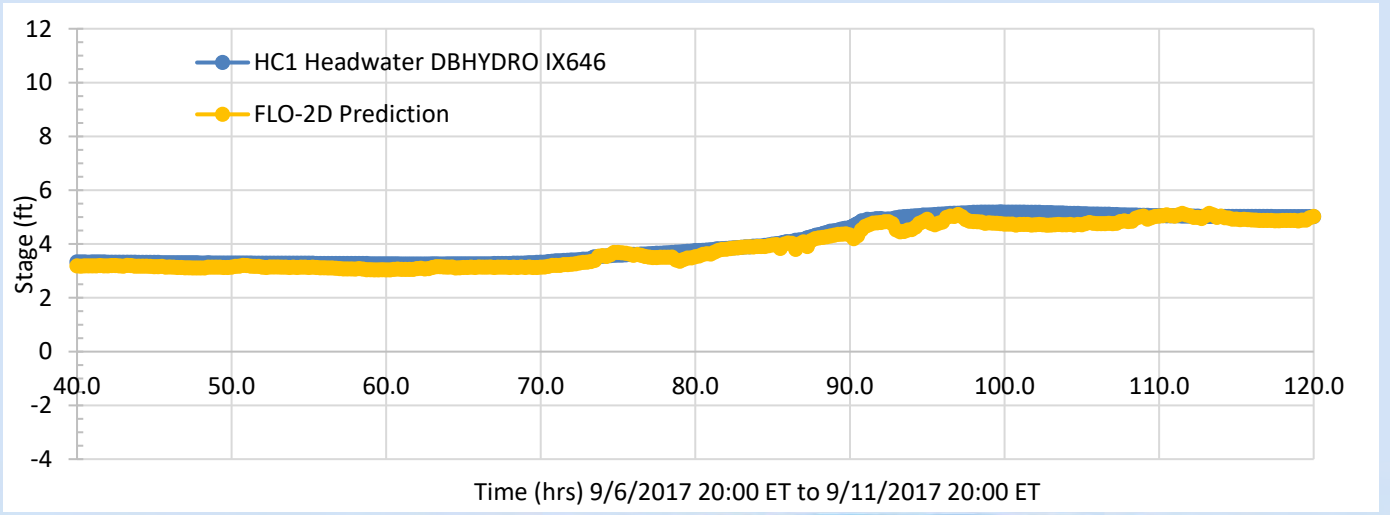
Diff Legend

	7.0 < DIFF <	8.0	
	6.0 < DIFF <	7.0	
	5.0 < DIFF <	6.0	
	4.0 < DIFF <	5.0	
	3.0 < DIFF <	4.0	
Red	2.0 < DIFF <	3.0	
	1.0 < DIFF <	2.0	
	0.1 < DIFF <	1.0	
	-0.1 < DIFF <	0.1	
	-1.0 < DIFF <	-0.1	
	-2.0 < DIFF <	-1.0	
Blue	-3.0 < DIFF <	-2.0	
	-4.0 < DIFF <	-3.0	
	-5.0 < DIFF <	-4.0	

Hurricane Irma Calibration Results
23 USGS HWMs and Tidal Structures Stages



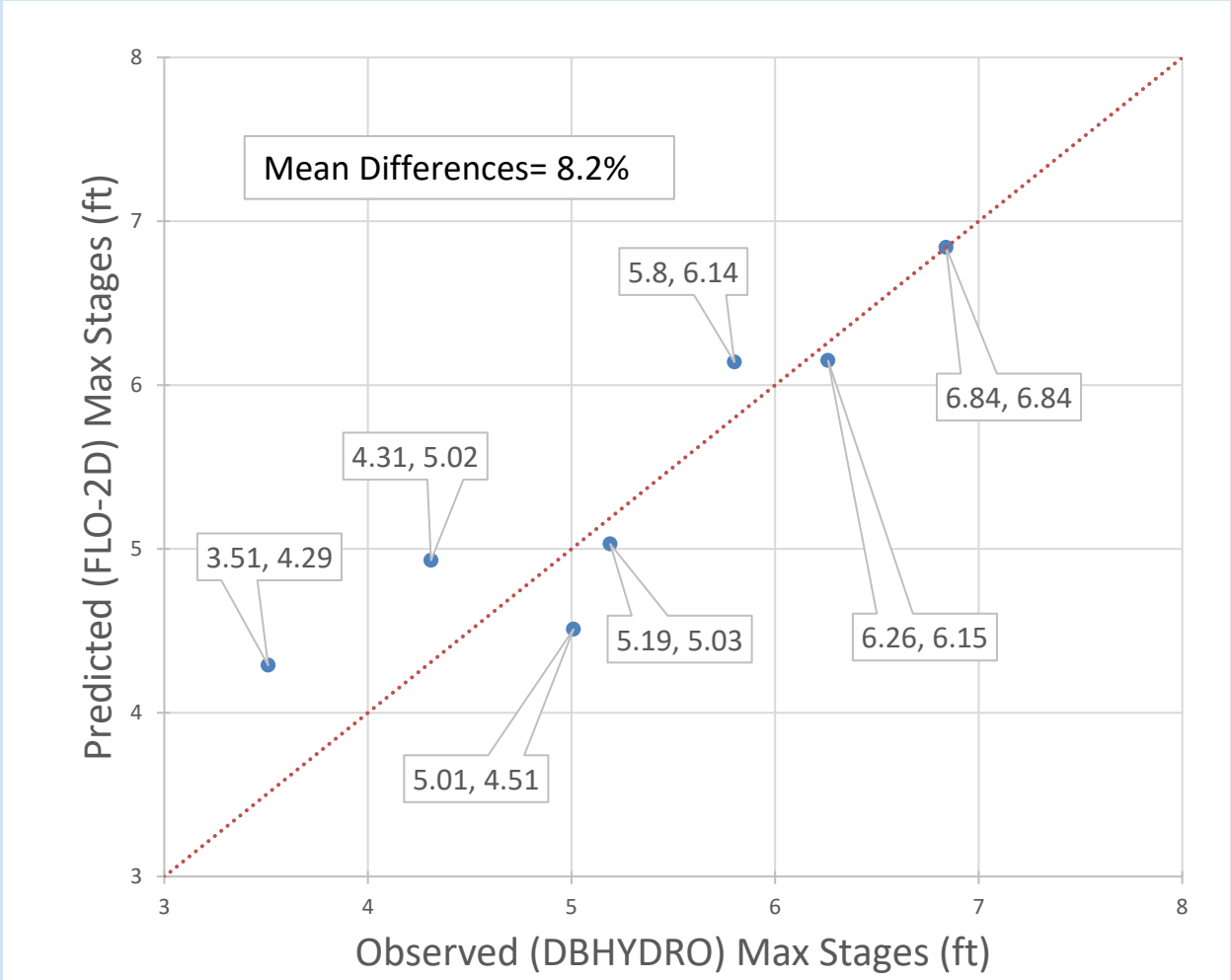




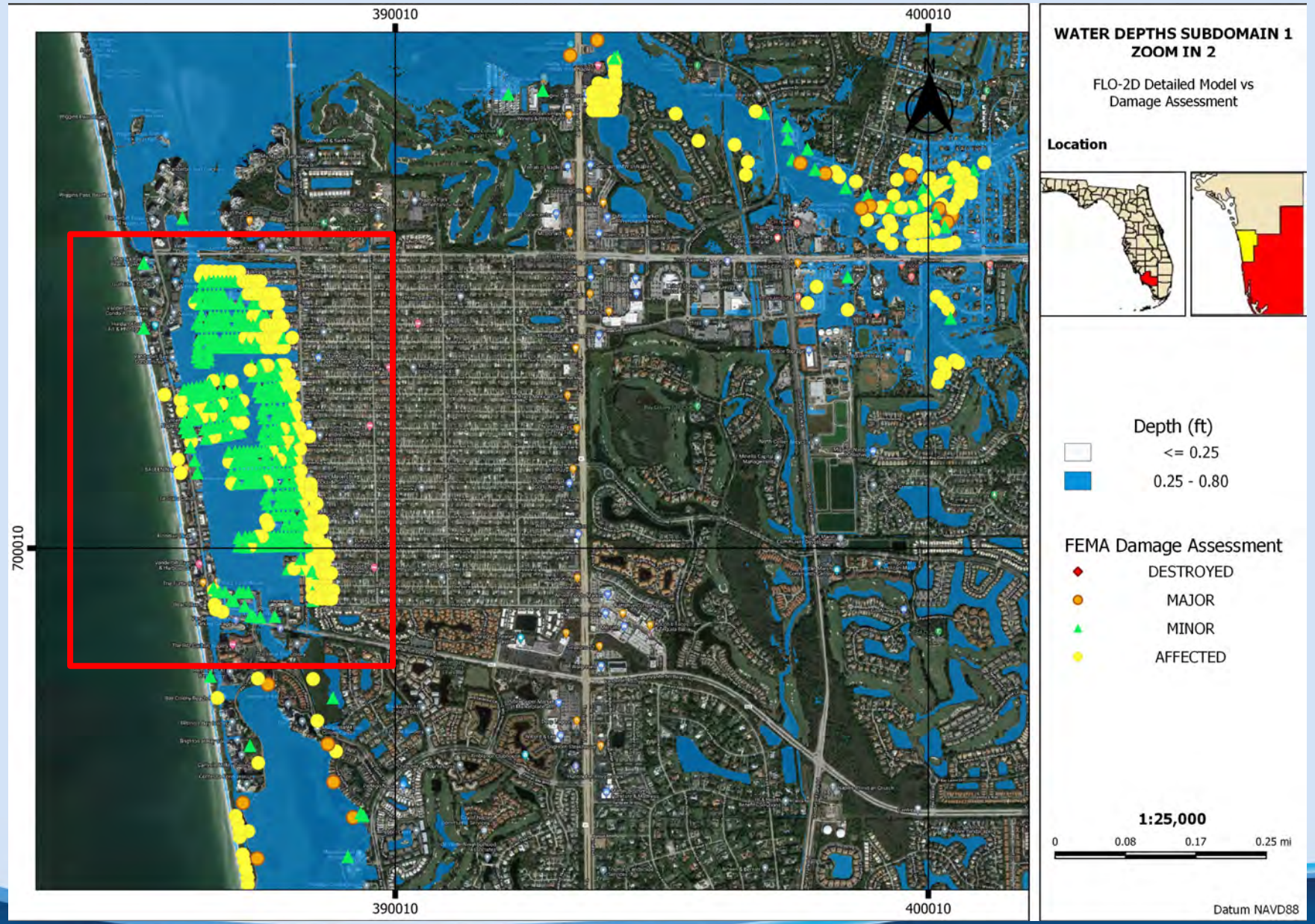
Observed (DBHYDRO) versus Predicted (FLO-2D) Maximum Stages

		Max Stages (NAVD 88)		
		Observed DBHYDRO	FLO-2D	Difference (%)
Sub1	COCO_1_H	6.84	6.84	0.0
	COCO_1_T	6.26	6.15	-1.8
Sub 2	GG1_H	5.8	6.14	5.9
	GG1_T	4.31	5.02	16.4
Sub3	HC1_H	5.19	5.03	-3.1
	HC1_T	3.51	4.29	22.2
Sub4	FU1_T	5.01	4.51	-10.0

The 3 worst gage matches were tailwater stage.
For the 2 worst correlations FLO-2D overpredicted the tailwater stage. This could be storm surge overprediction or rainfall runoff volume and timing.



Hurricane Irma Calibration Results Using FEMA Damage Assessment



WATER DEPTHS SUBDOMAIN 1
ZOOM IN 2

FLO-2D Detailed Model vs
Damage Assessment

Location

Depth (ft)
<= 0.25
0.25 - 0.80

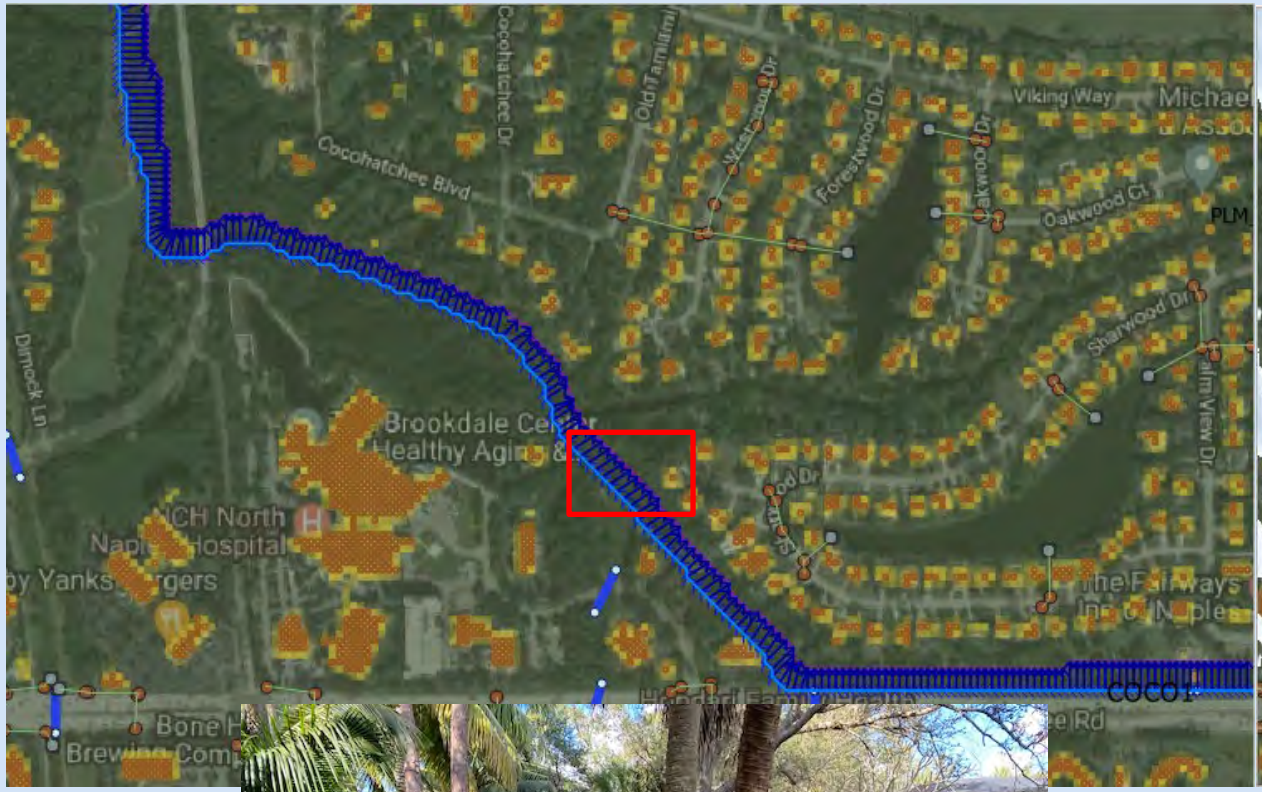
FEMA Damage Assessment
DESTROYED
MAJOR
MINOR
AFFECTED

1:25,000

0 0.08 0.17 0.25 mi

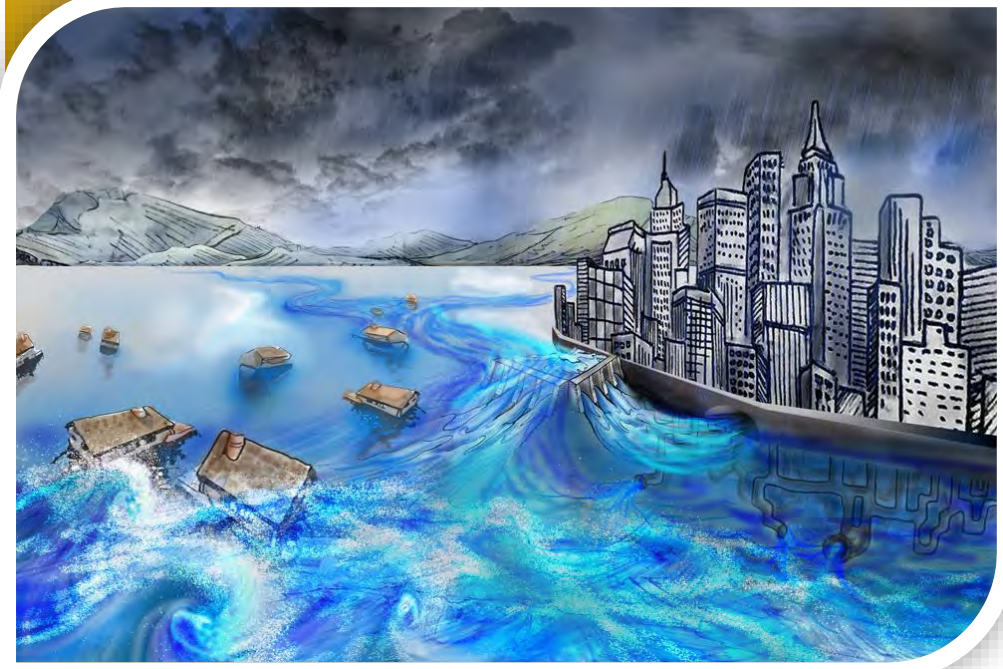
Datum NAVD88

Subdomain 1 - Field Visit 12-4-2021



Field Visit 12-4-2021

Compounding effects of Storm Surge, Sea Level Rise, Extreme Rainfall and Water Table on Urban Flooding in South Florida

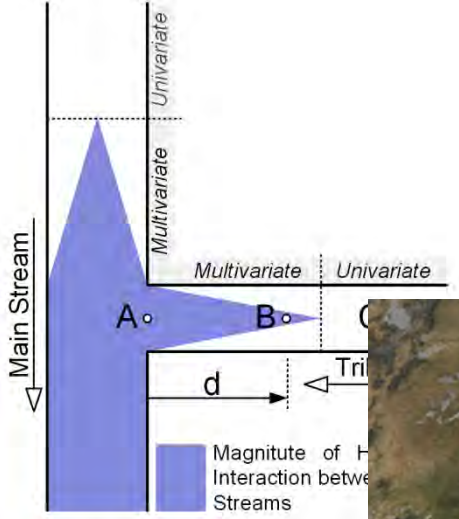


Robert Jane[1], Luis Cadavid[2], Thomas Wahl[1]

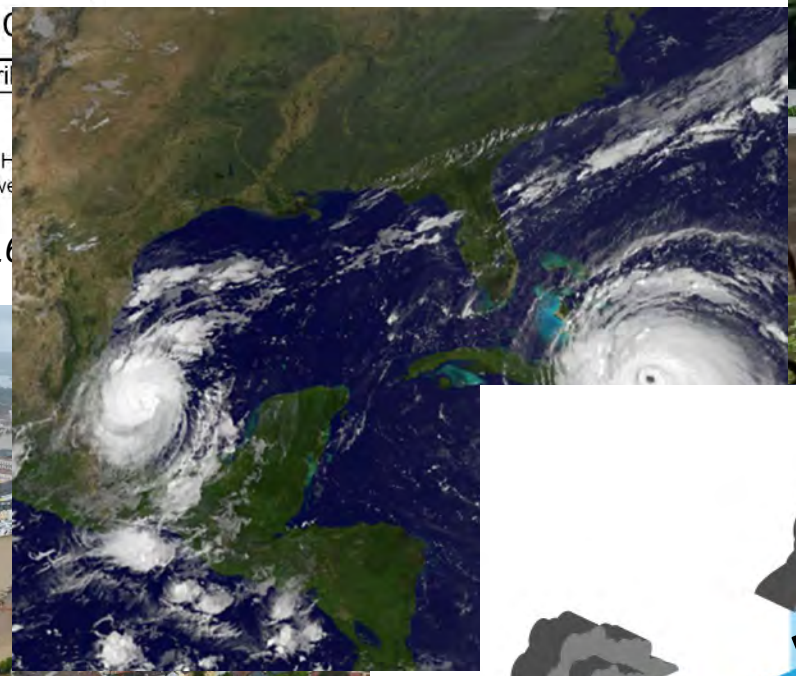
[1]Civil, Environmental and Construction Engineering Department & National Center for Integrated Coastal Research, University of Central Florida

[2]Operational Hydraulics Unit – Applied Hydraulics Section, South Florida Water Management District

Compound flooding

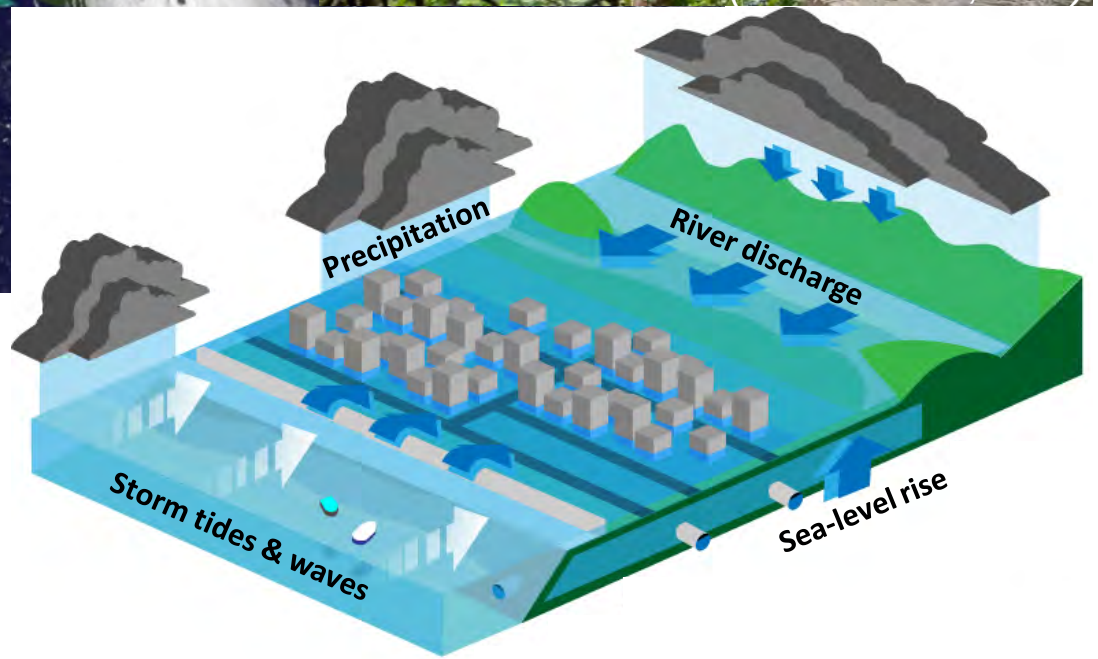


(Bender et al., 201



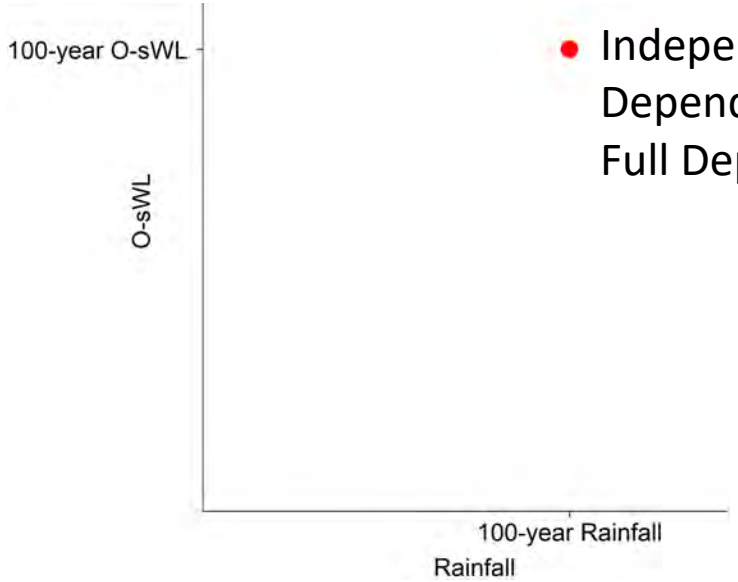
(The Guardian, 2020)

(Washington post, 2013)



Problem

- Rainfall and surge are driven by common meteorological forcings and often exhibit statistically significant correlation.
- Assuming independence between the flooding drivers may lead to underestimation of flood risk and under-design.
- South Florida Water Management District (SFWMD) undertakes Flood protection level of service (FPLOS) assessments.
- FPLOS currently assumes full dependence between rainfall and sea level (O-sWL), i.e. that the 100 year event comprises the 100-year rainfall event and the 100 year O-sWL.

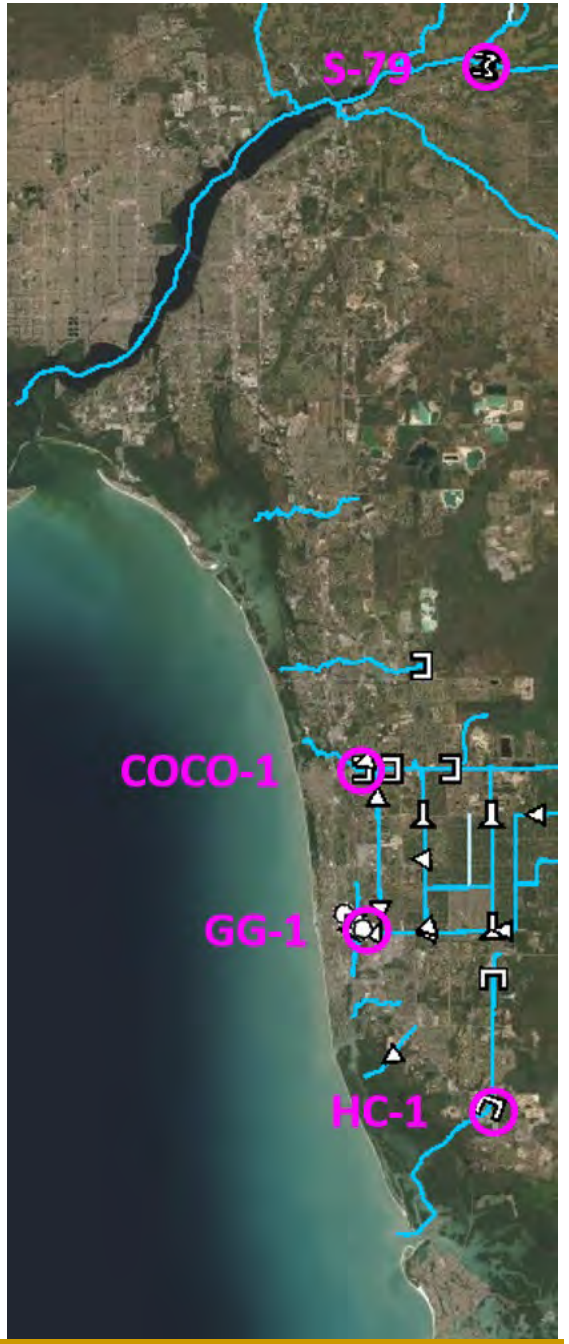


- Independence: 10,000 years
  Dependence: ?
  Full Dependence: 100 years

Objective

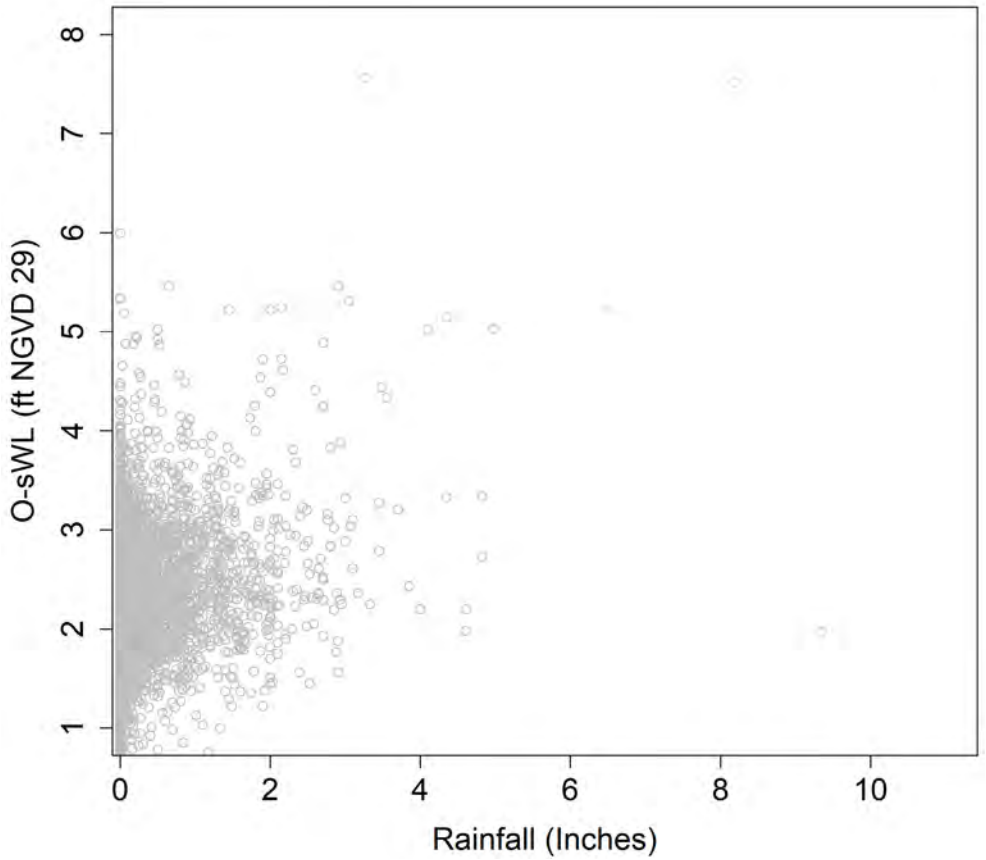
Devise a procedure to robustly estimate the joint probabilities of extreme rainfall and ocean-side water levels for future FPLOS investigations.

Case study site



Methodology

- Two way conditional sampling is used to identify events where at least one of the drivers is above a high threshold.



○ Sample conditioned on rainfall
× Sample conditioned on O-sWL

Methodology

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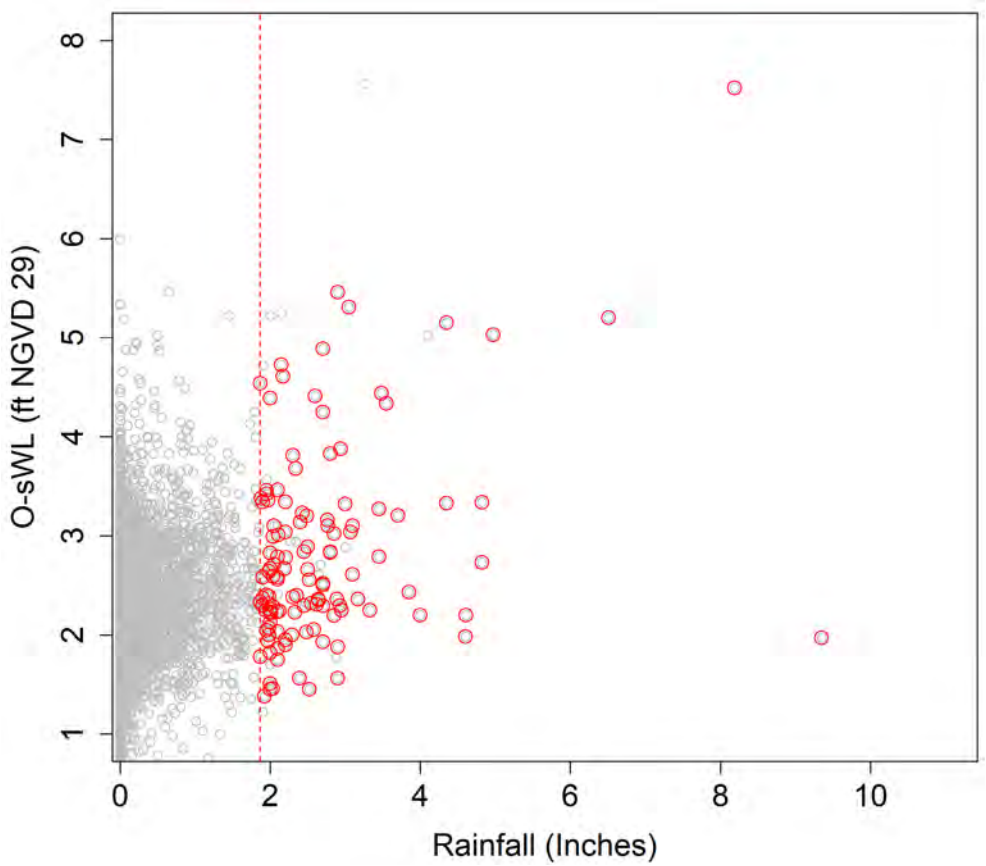

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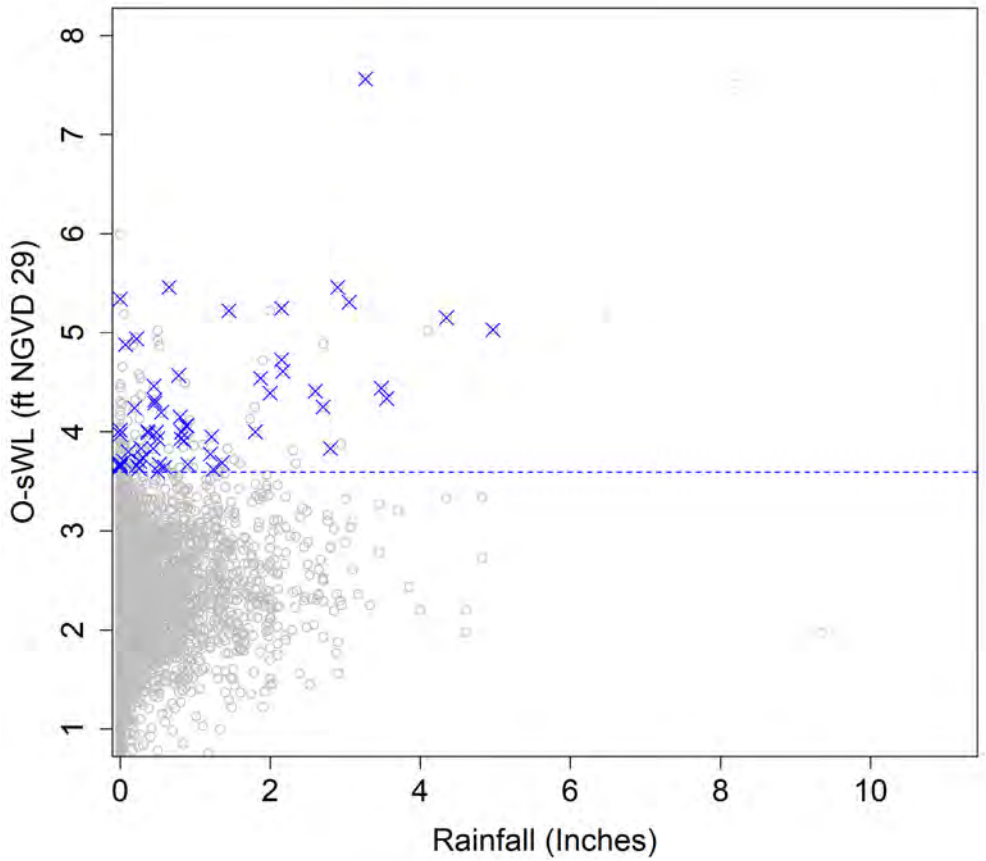

- Sample conditioned on rainfall
- Sample conditioned on O-sWL

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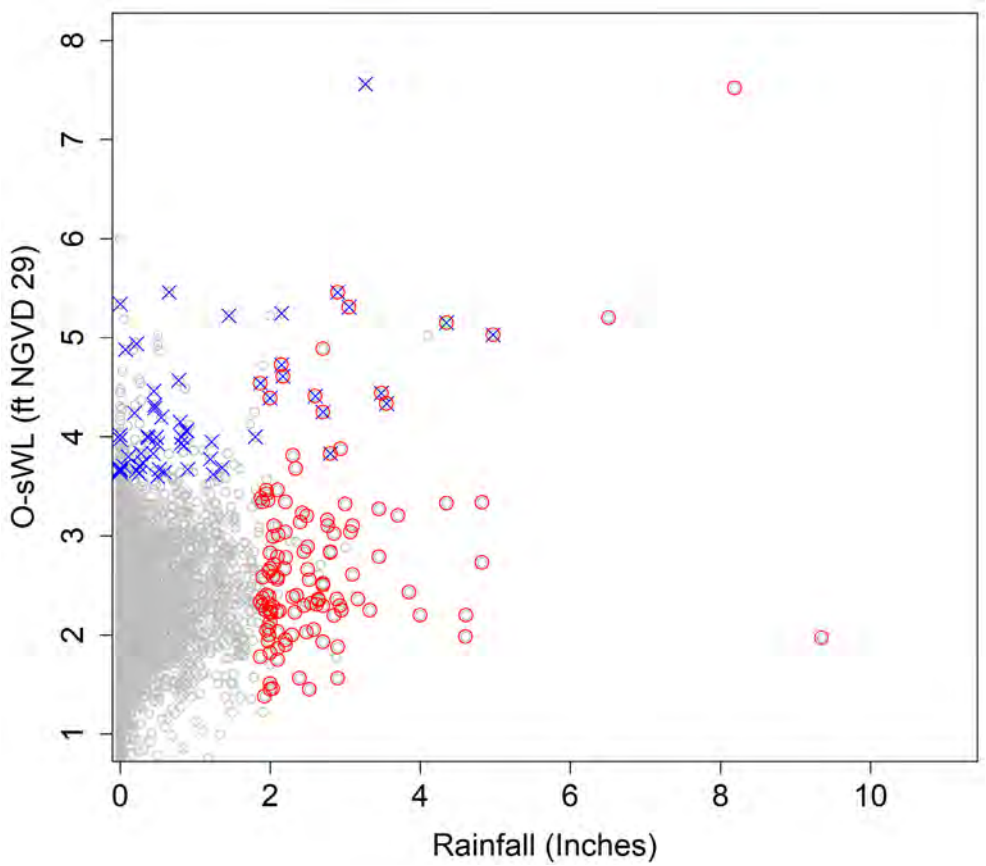

○ Sample conditioned on rainfall
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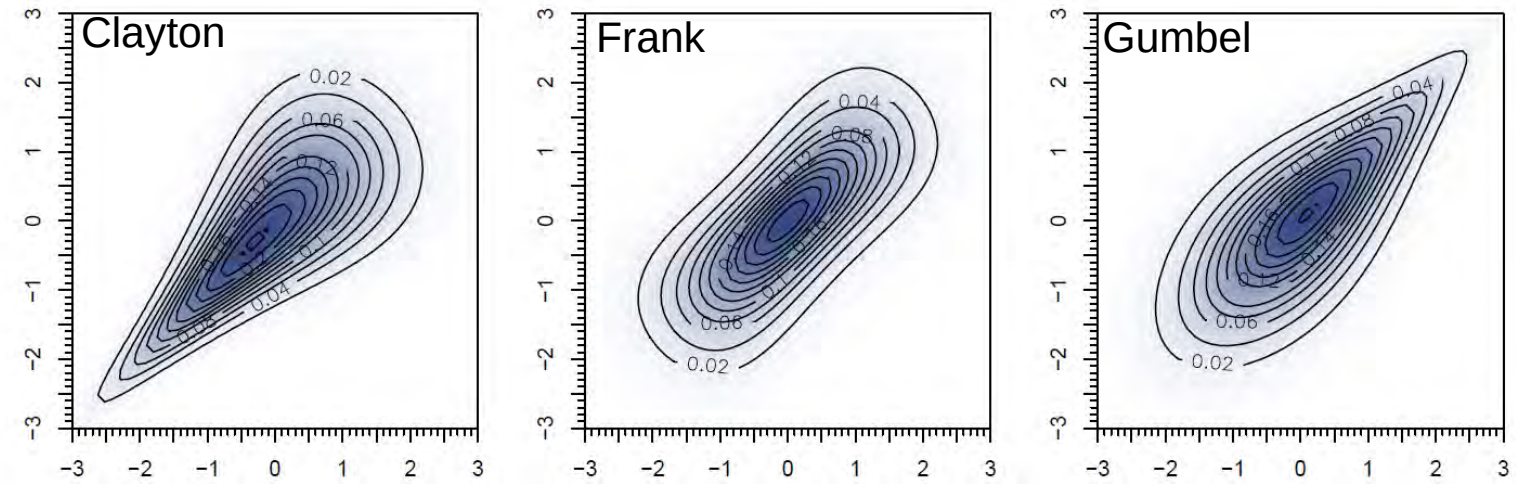
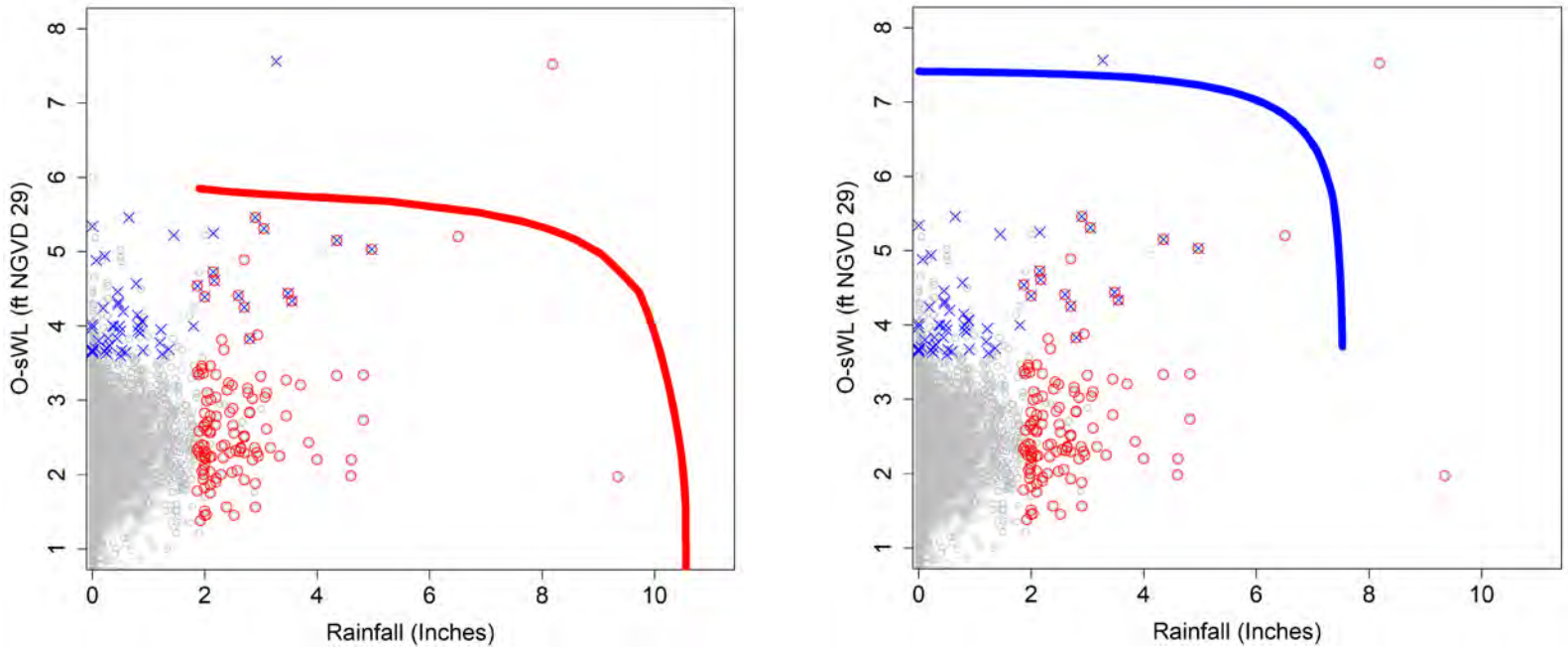
Methodology



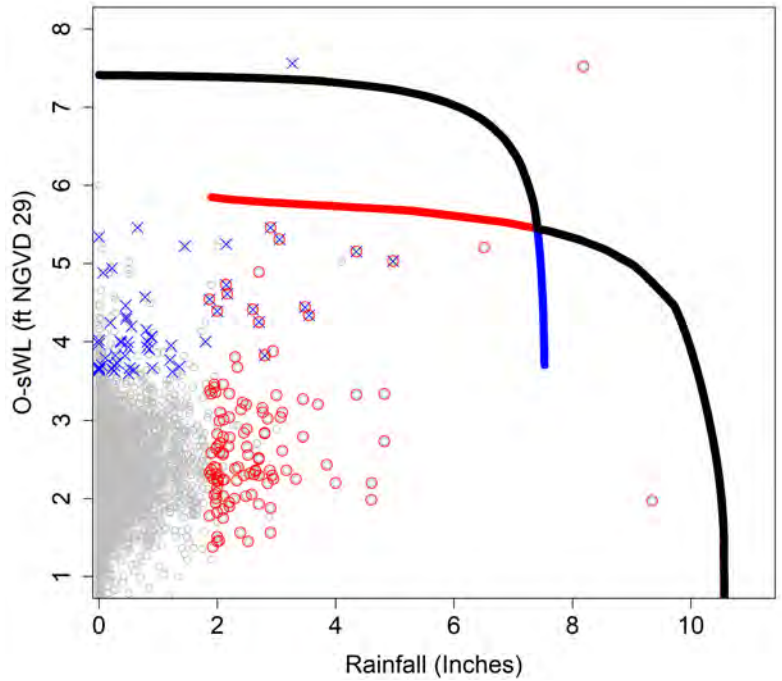
- A bivariate copula is a two-dimensional probability distribution function able to capture the dependence between a pair of variables.
- Copulas allow more flexibility in the choice of marginal distributions than traditional bivariate models.
- For each conditional sample we select the best fitting among 40 copula families.

Methodology



- Derive the desired JPC for each conditional sample.
- Obtain the full JPC by overlaying the two JPCs from the samples.
- Simulate from the fitted model to find the relative probability of events on the JPC.
- Select the “most-likely” design event.

Methodology



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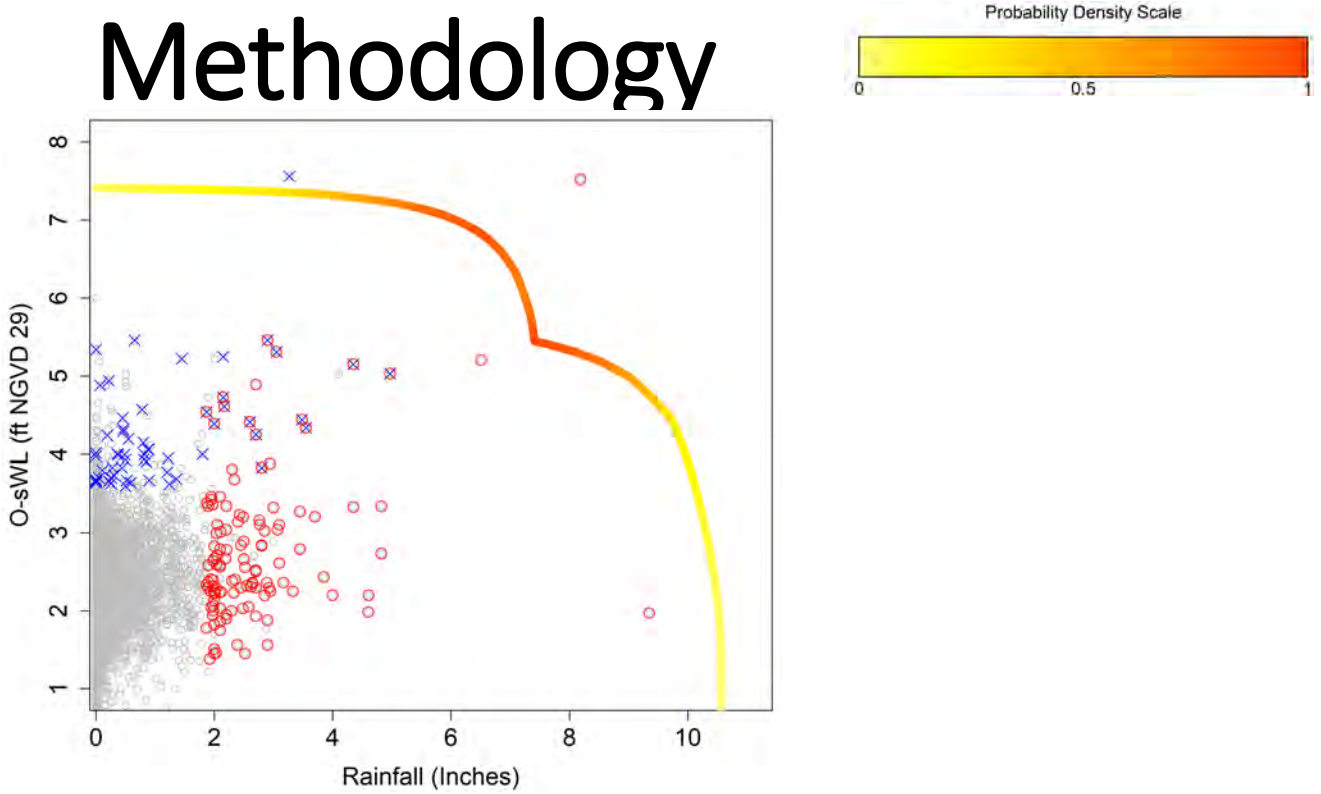

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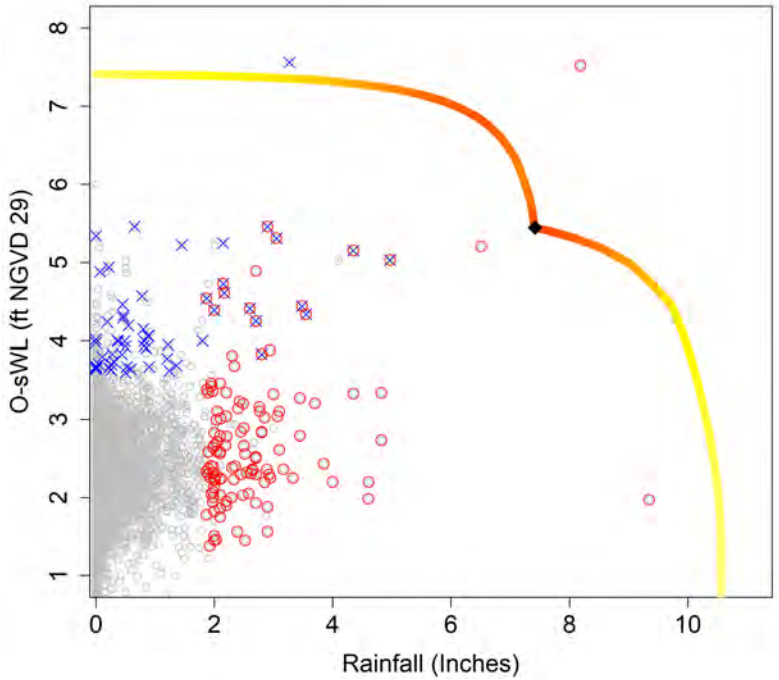

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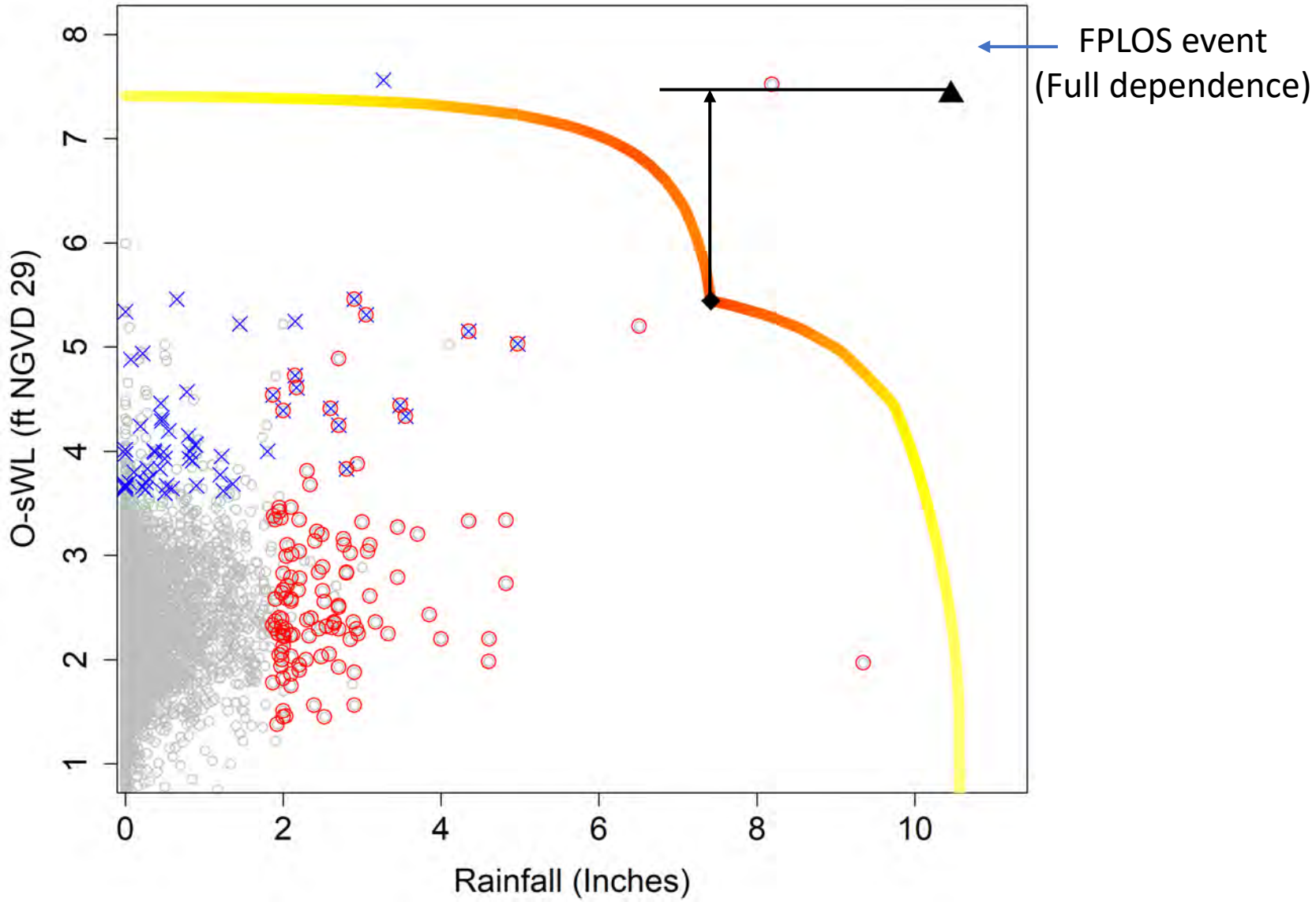
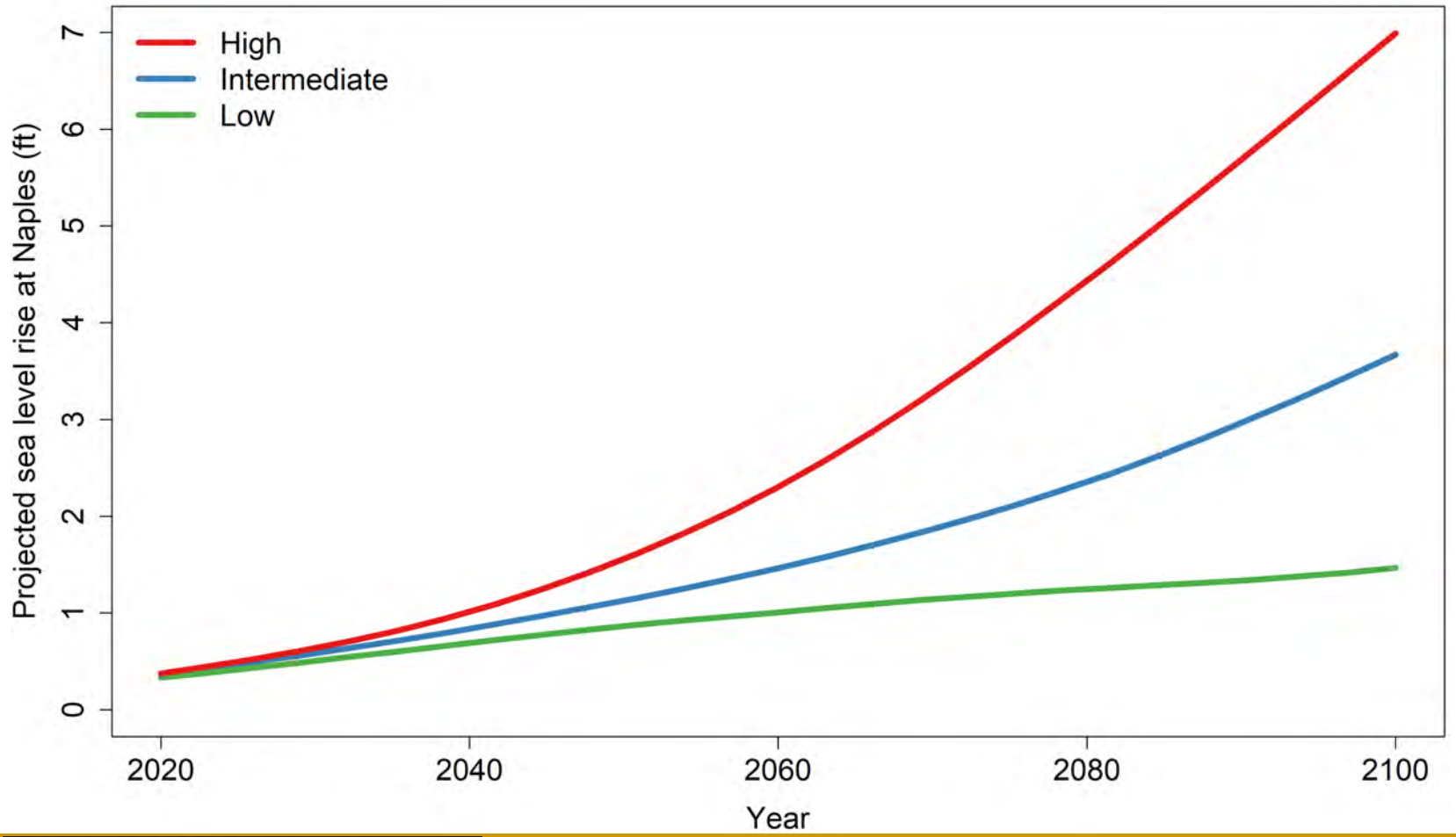
FPLOS factor of safety

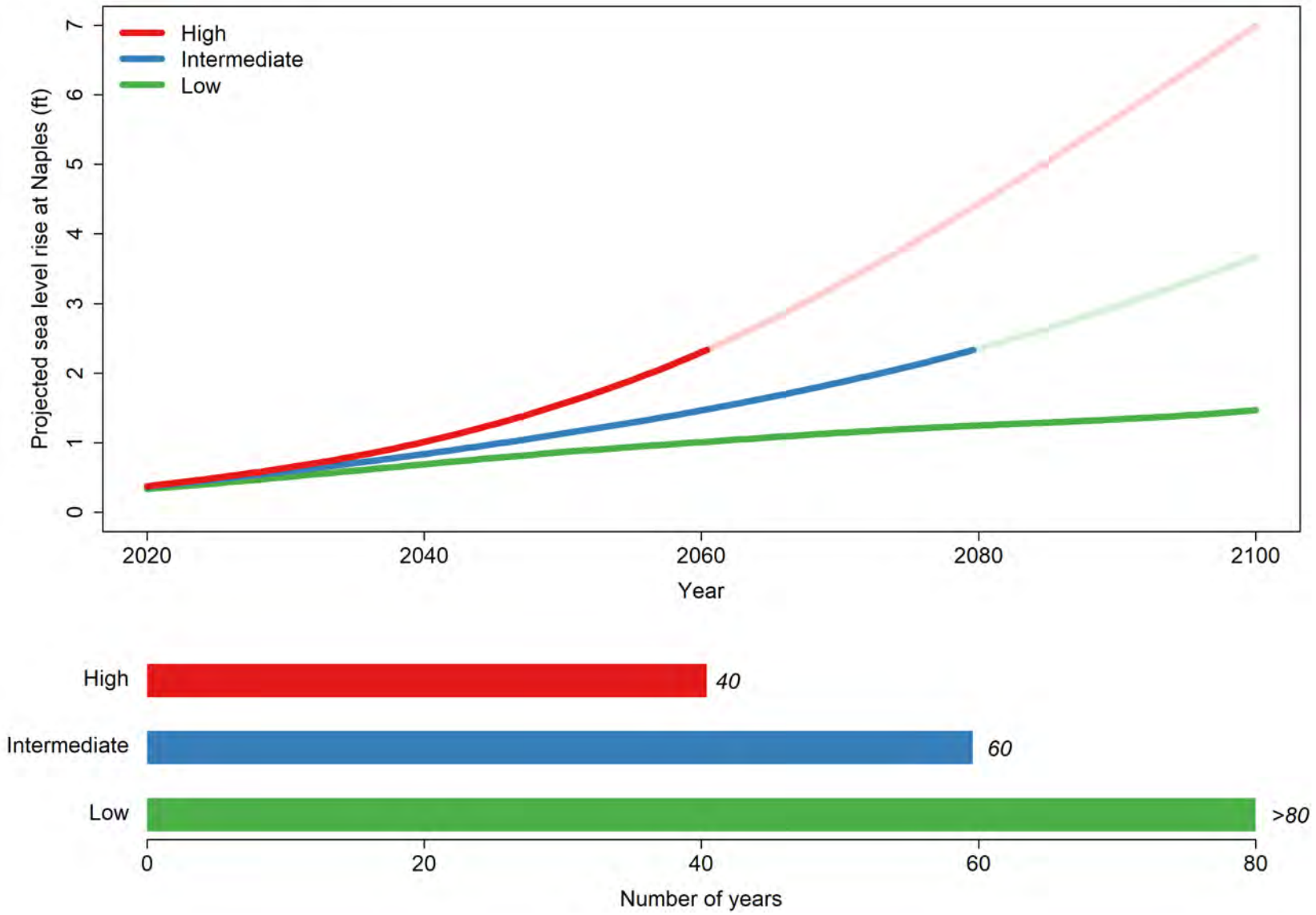


Sea level rise

- Local sea level rise scenarios for Naples from the Interagency Sea Level Rise Scenario Tool (2022).



Sea level rise



Conclusions

- Several types of compound flooding exist (three main categories).
- FPLOS assessments currently undertaken by the SFWMD tend to be conservative.
- Sea level rise may erode the safety factor over the coming decades.

Next steps

- Extended the modeling to include the coincident groundwater level.
- Tested the sensitivity of the joint rainfall – O-sWL probabilities to rainfall event duration.
- Model the time lags between rainfall and O-sWL peaks as well as the event duration (hydrographs) to provide boundary conditions for H&H modeling.