Measured and Computed Compound Flooding along Two Heavily Urbanized Rivers, West-Central Florida, USA

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Outline

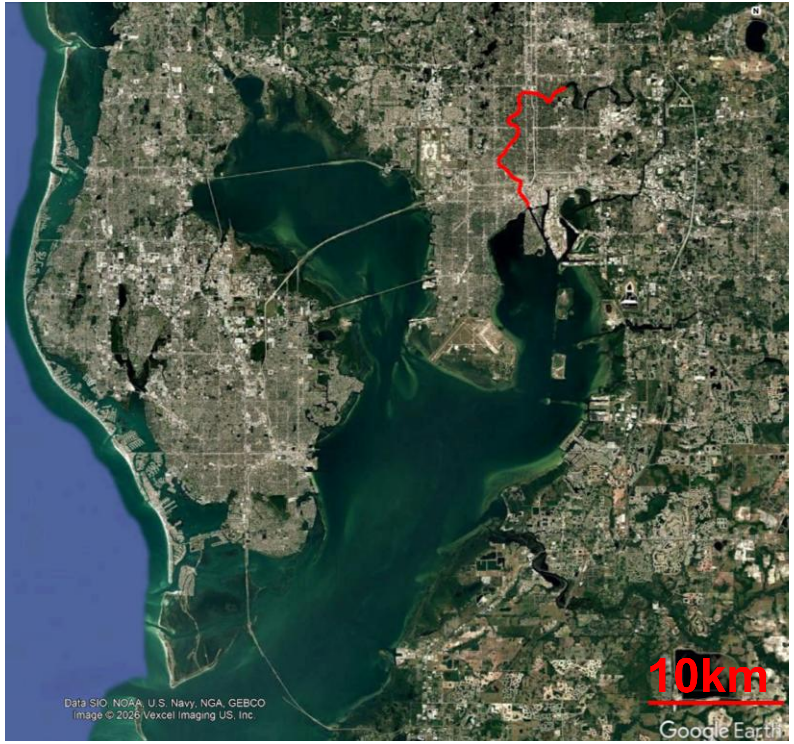
- Introduction
- Study area
  - Hillsborough River
  - Anclote River
- Field data collection
- Numerical Modeling
- Summary
- On-going work

Introduction

- Compound flooding: the combination of two (storm surge and rainfall) or more flood drivers leads to a more severe flooding event than a simple linear sum
- Hurricanes Helene and Milton in 2024 provide an opportunity to examine compound flooding: both measured and computed
  - Hurricane Helene generated record storm surge
  - Hurricane Milton produced record rainfall, but depressed water-level
  - An obvious worst-case scenario would be Hurricane Helene’s surge coupled with Hurricane Milton’s rainfall event, i.e., Compound Flooding
  - Numerical modeling provides a valuable tool to evaluate compound flooding
- Both Hillsborough River and Anclote River flow through densely populated urban areas
  - The land elevation characteristics in the drainage basin are quite different
  - There is a large dam on Hillsborough River, but not on Anclote River
- Water-level is one of the easier parameters to measure
  - Hillsborough River has several water-level gauges along the river
  - Anclote River has just one, in the tidally influenced section of the river
- Water-level is also one of the easier parameters to simulate using numerical modeling as compared to, e.g., velocity and salinity

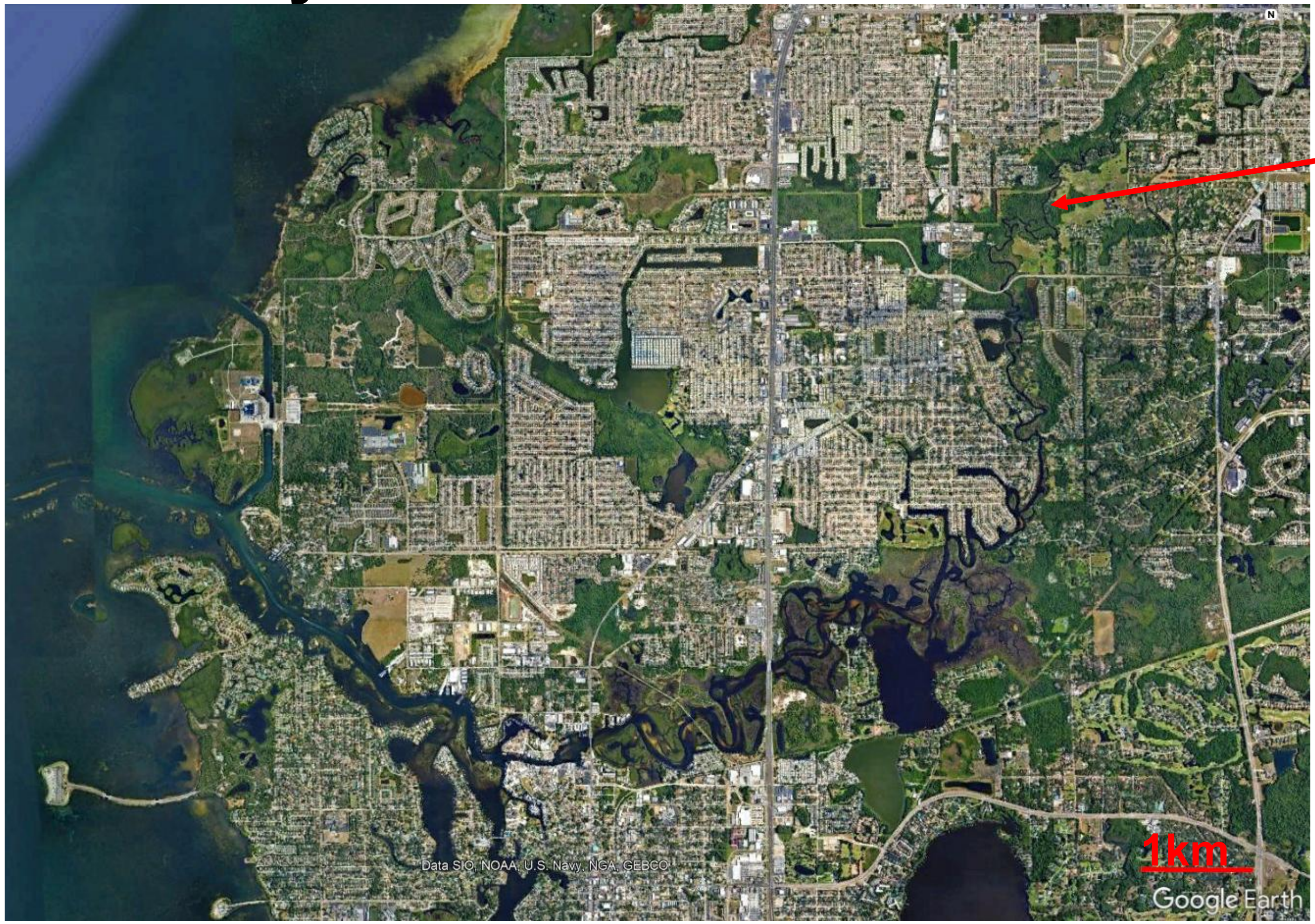
- Goal: Utilize numerical modeling to assess compound flooding under the two recent hurricanes

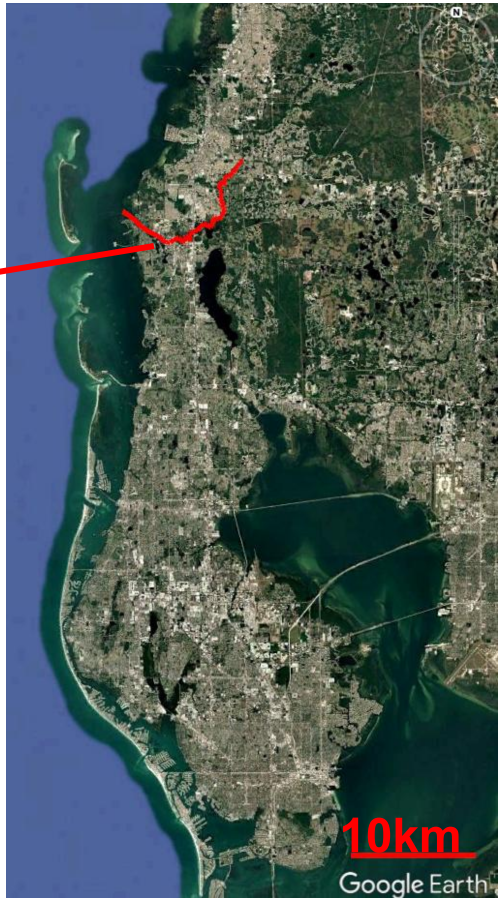
Study Area: Hillsborough River



- **Total length of the river is 60 mi (97 km) flowing through both Pasco and Hillsborough Counties**
- **A large dam was constructed in 1945**
- **This study focuses on the tidally influenced portion of the river south of the dam (~9.9 mi (16km))**
- **This portion runs roughly north-south and is highly developed**

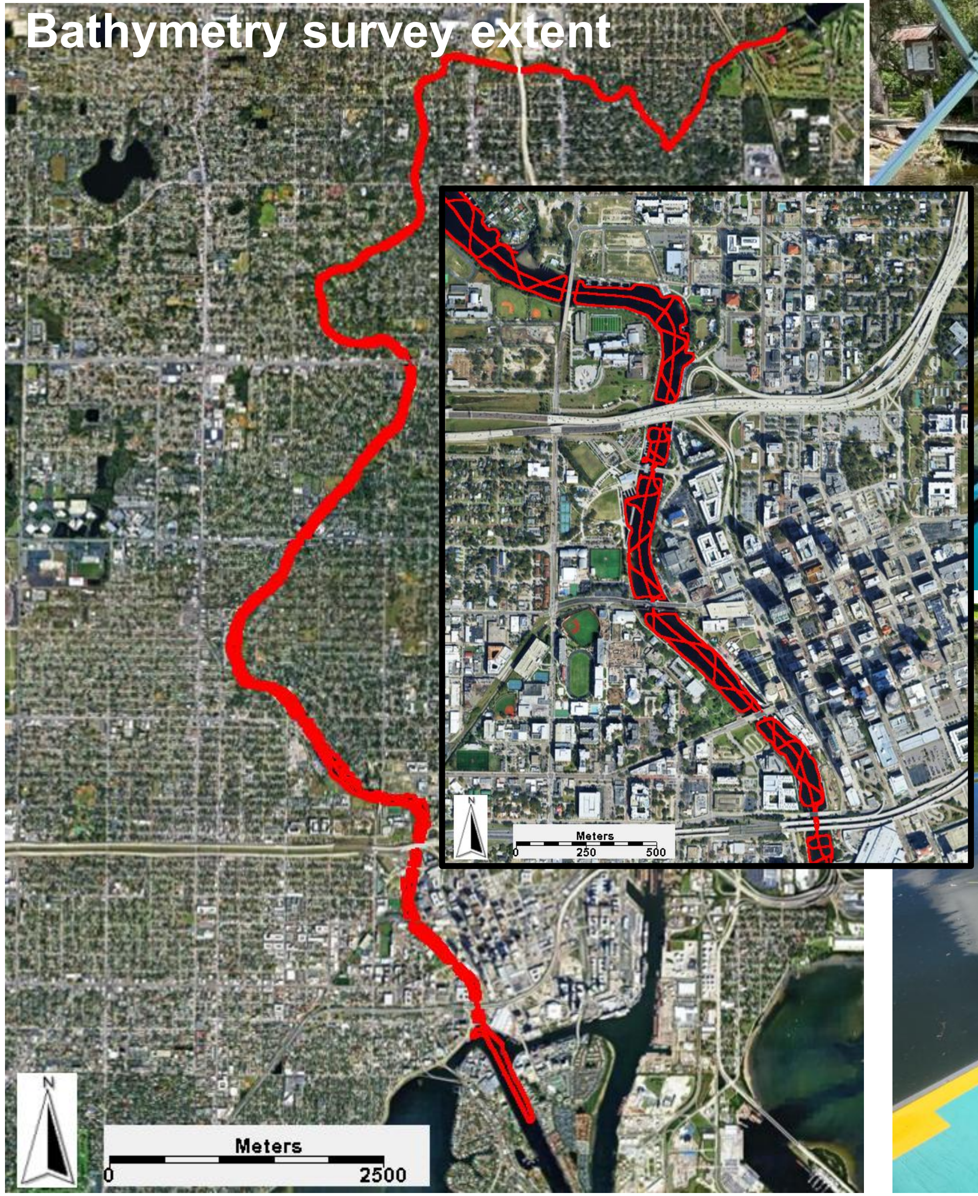
Study Area: Anclote River





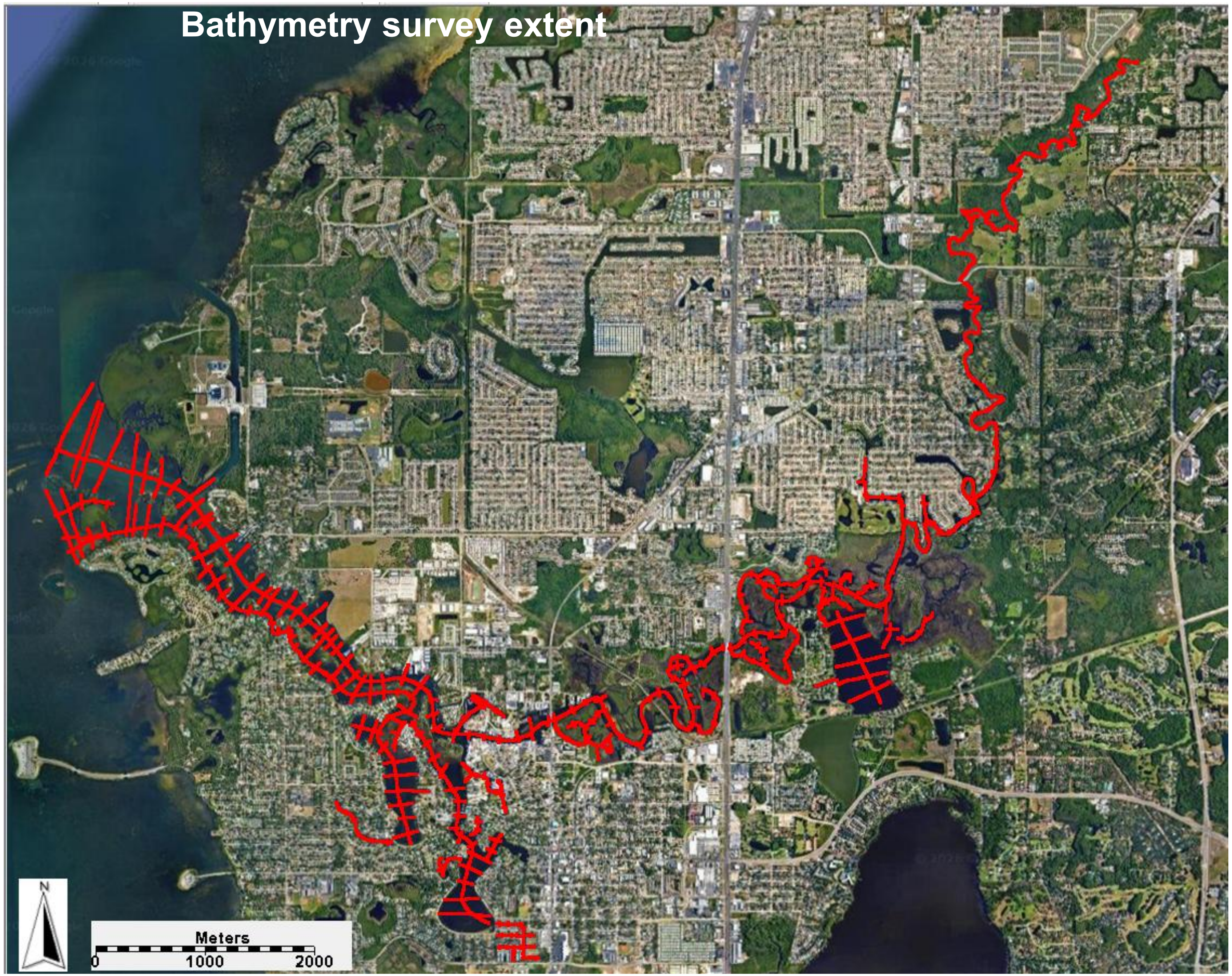
- Total length of the River is 29 mi (47 km)
- Model focuses on lower 20 km
- This portion runs both roughly north-south and east-west and is developed although to a lesser degree than Hillsborough River

Field data collection: Hillsborough River



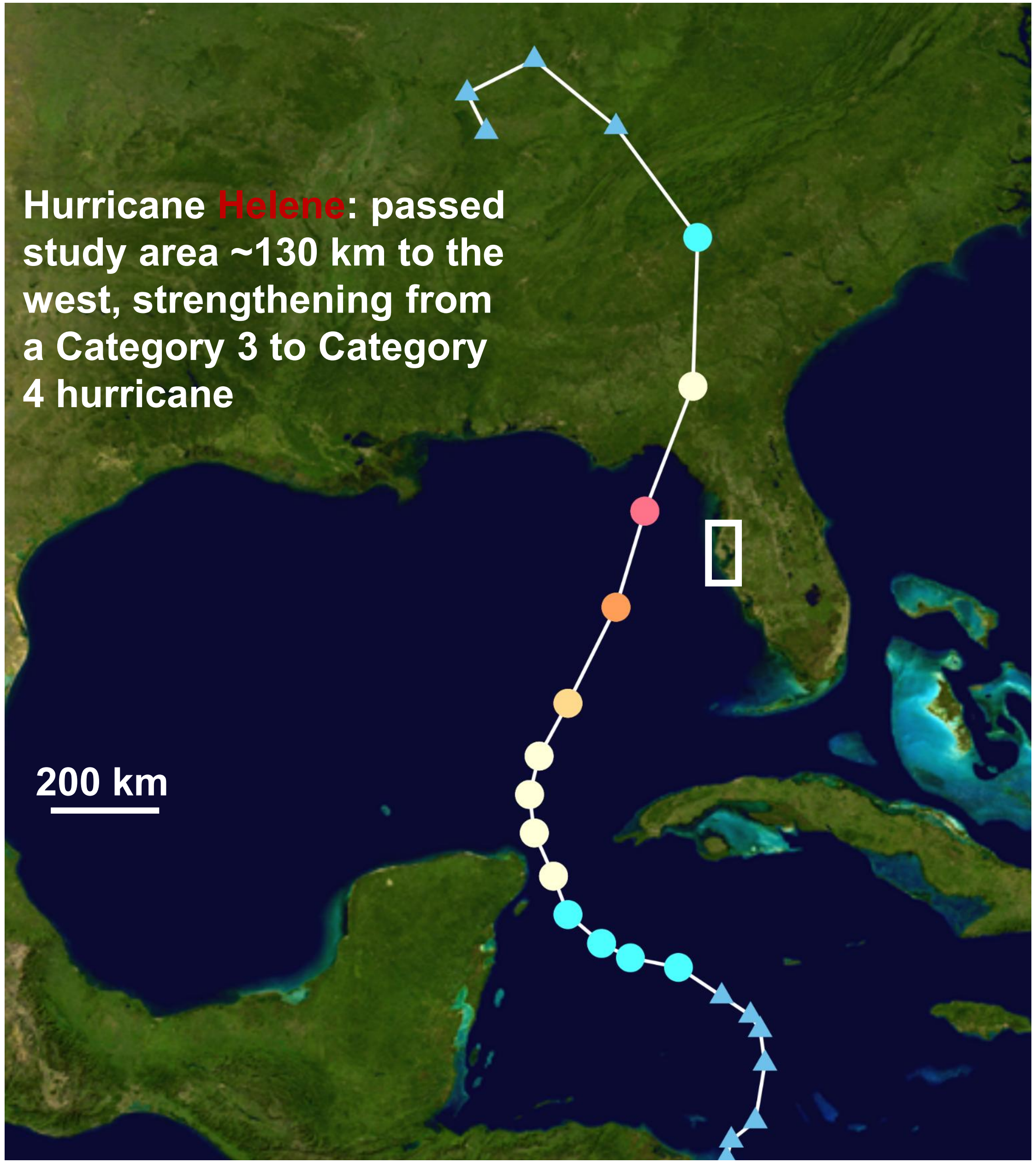
- Bathymetry survey (vessel mounted echosounder and RTK-GPS) from the dam to the seaward boundary (Tampa Bay)
- Deployed a SeaguardII ADCP for one month
- Used a Flow-tracker to measure flow velocity over one tidal cycle

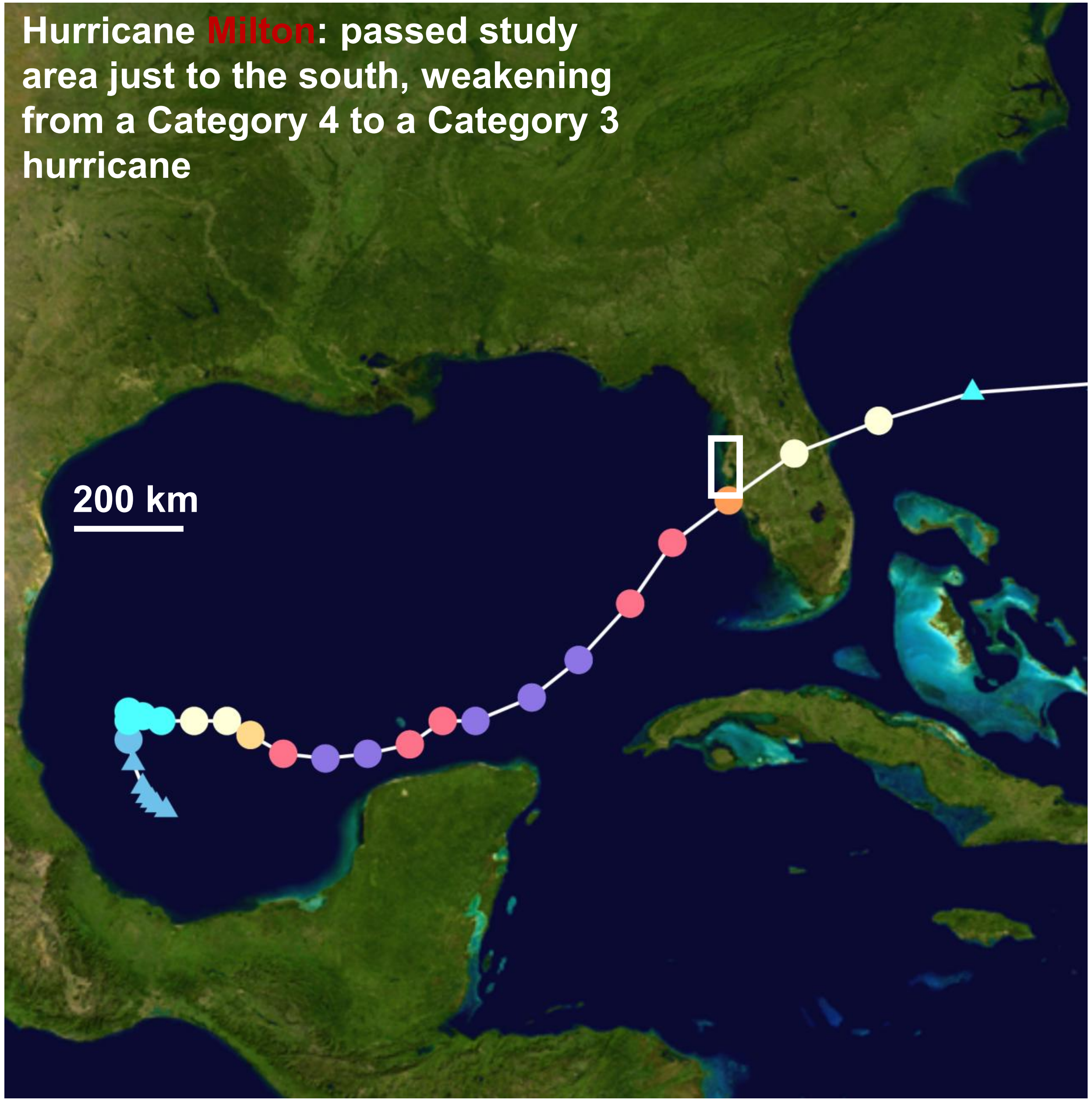
Field data collection: Anclote River



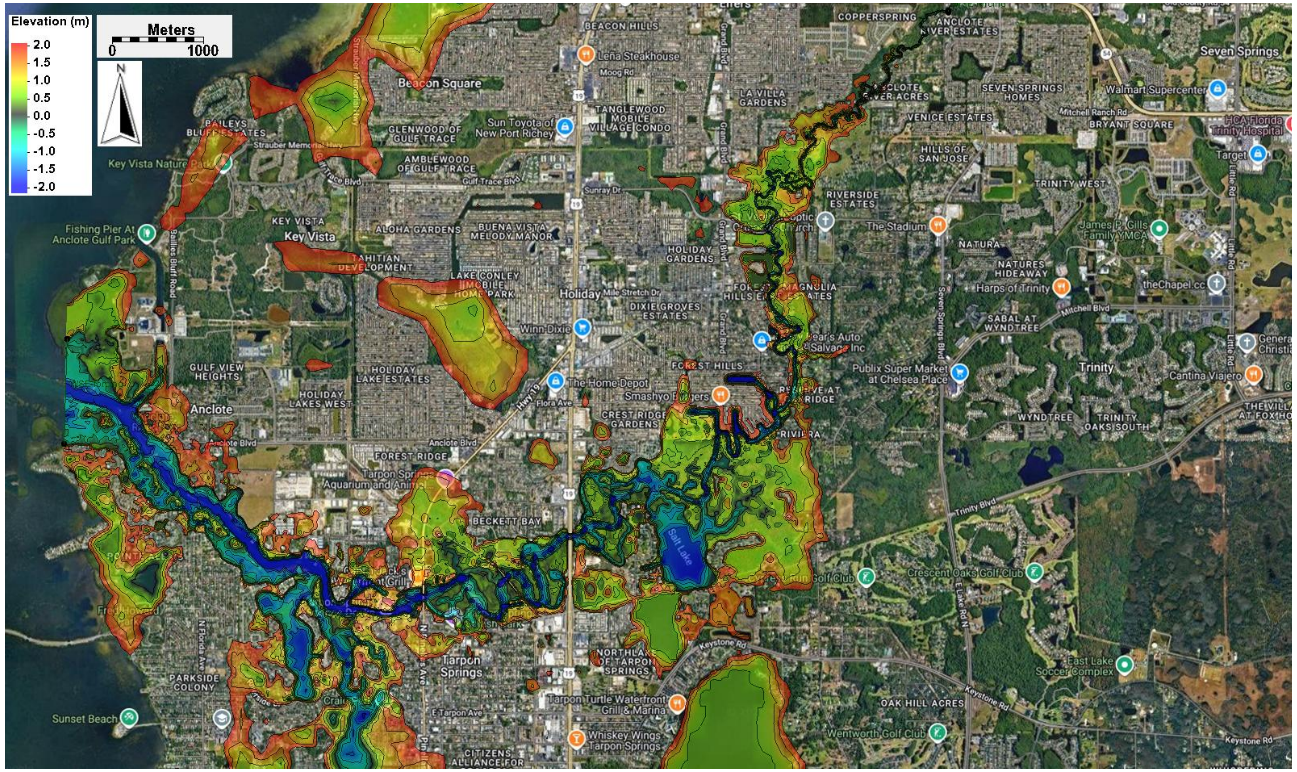
- Bathymetry survey (vessel mounted echosounder and RTK-GPS) from the landward extent of the project to the seaward boundary (Gulf)

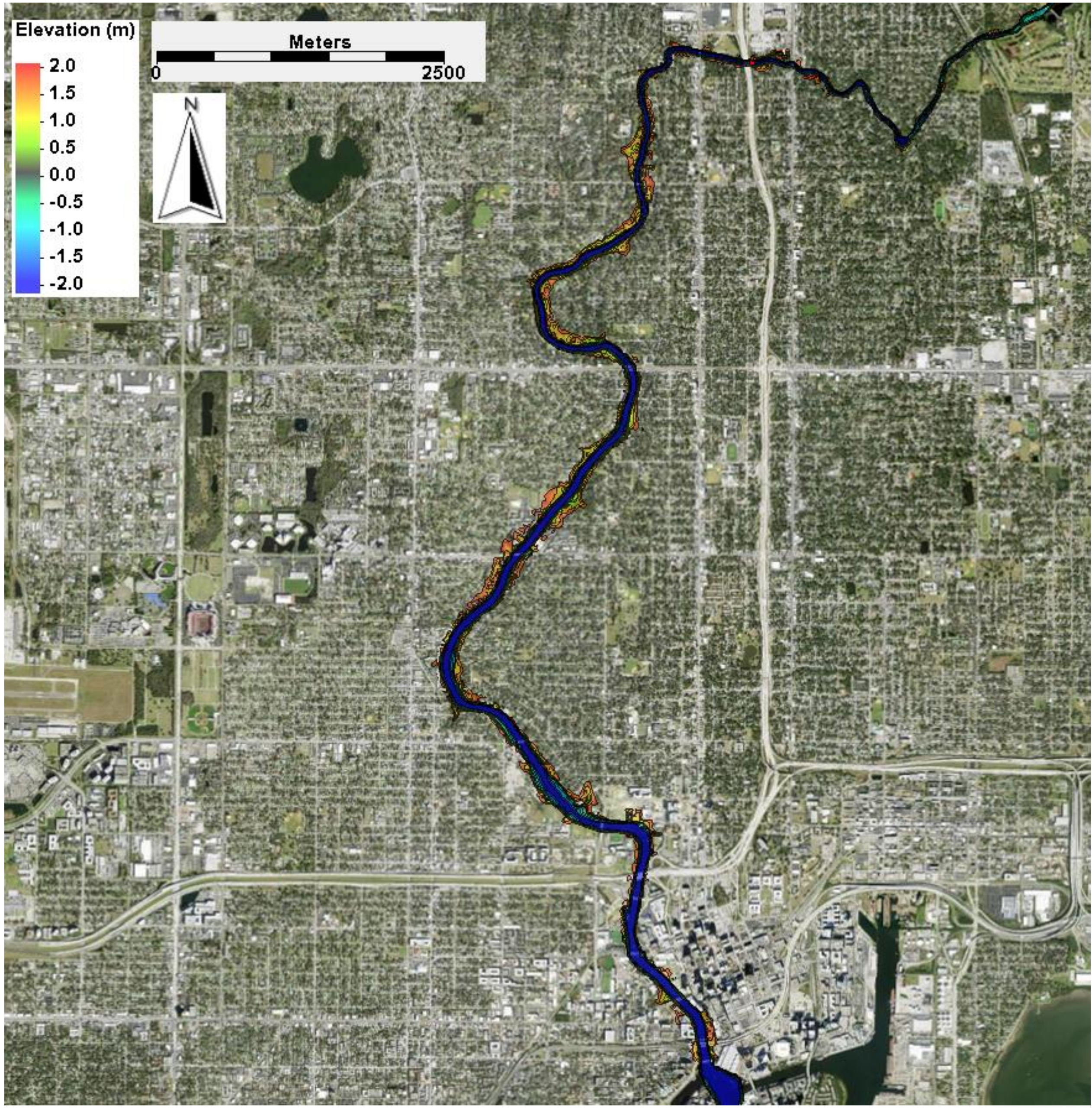
Why these two storms





Why these two rivers

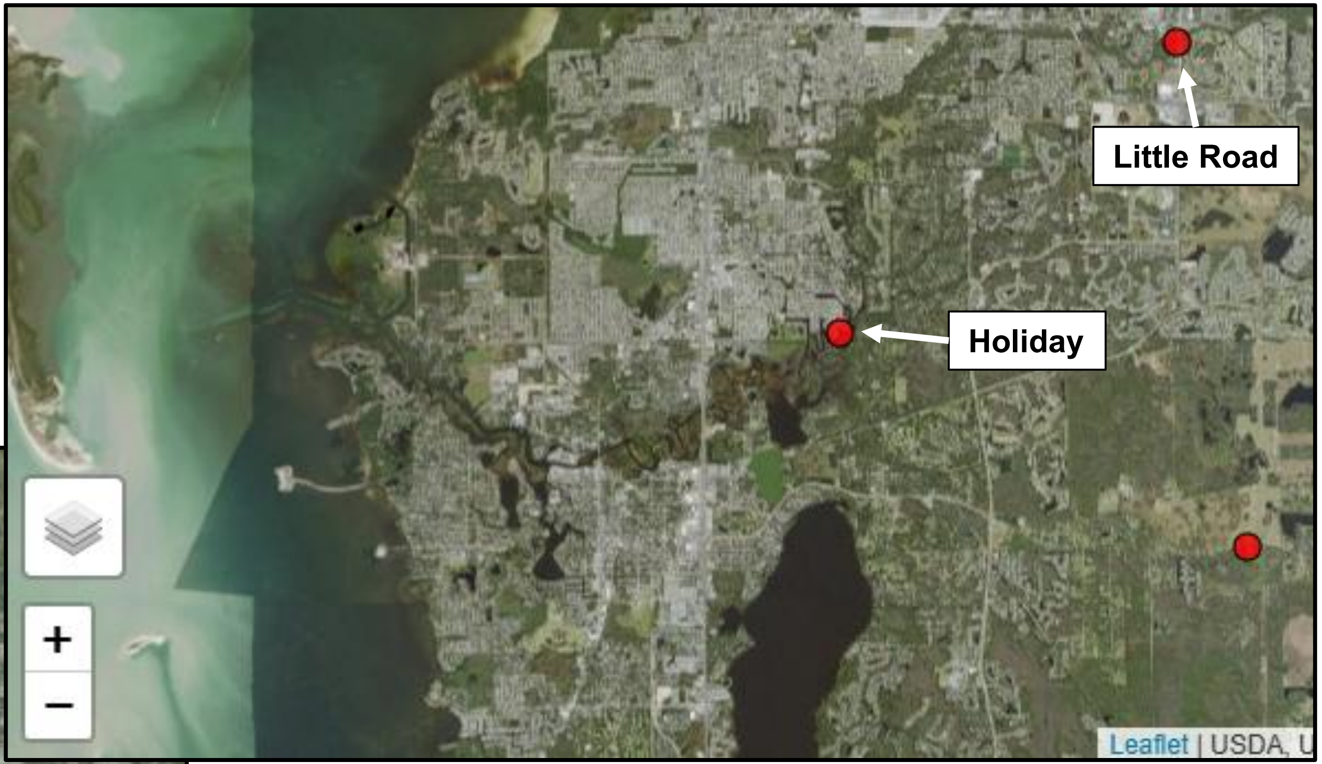




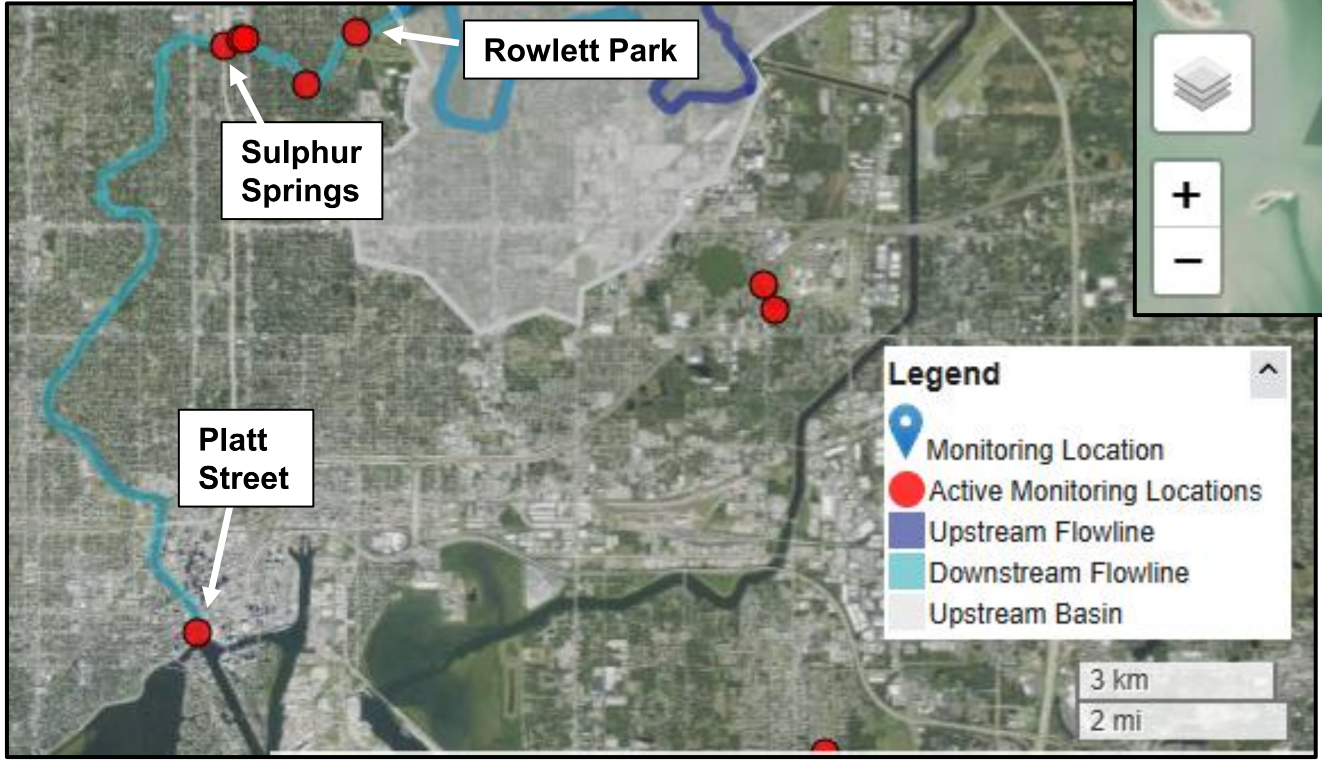
- Warmer colors are elevation between 0 and 2 m
- Cooler colors are elevation lower than 0 m
- The low elevation land along Anclote river includes both developed land and wetlands
- Hillsborough River is well confined with the high surrounding land

USGS gauges along the rivers

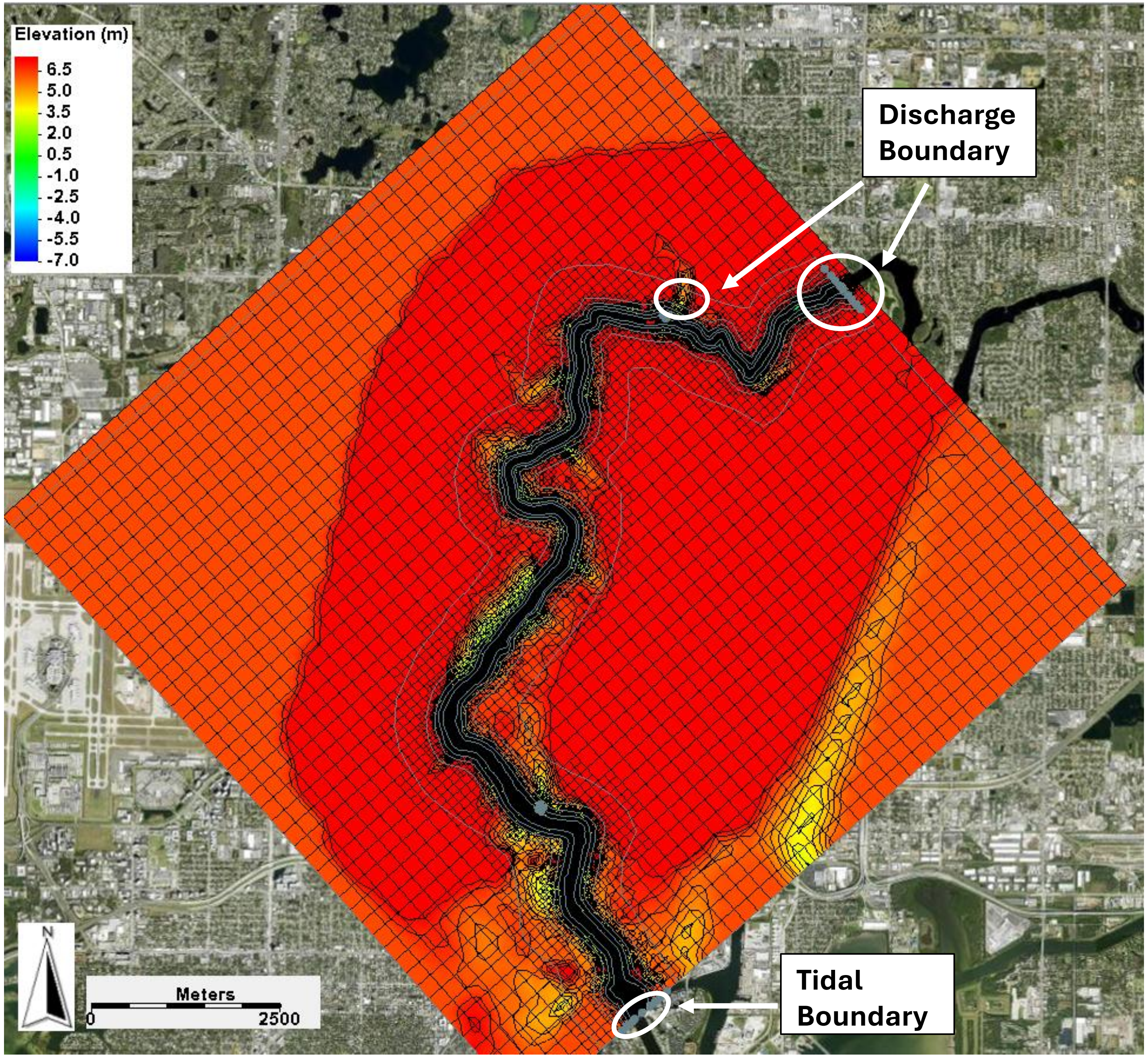
- Only two gauges along the river and the rest are far inland



- Hillsborough River is better measured

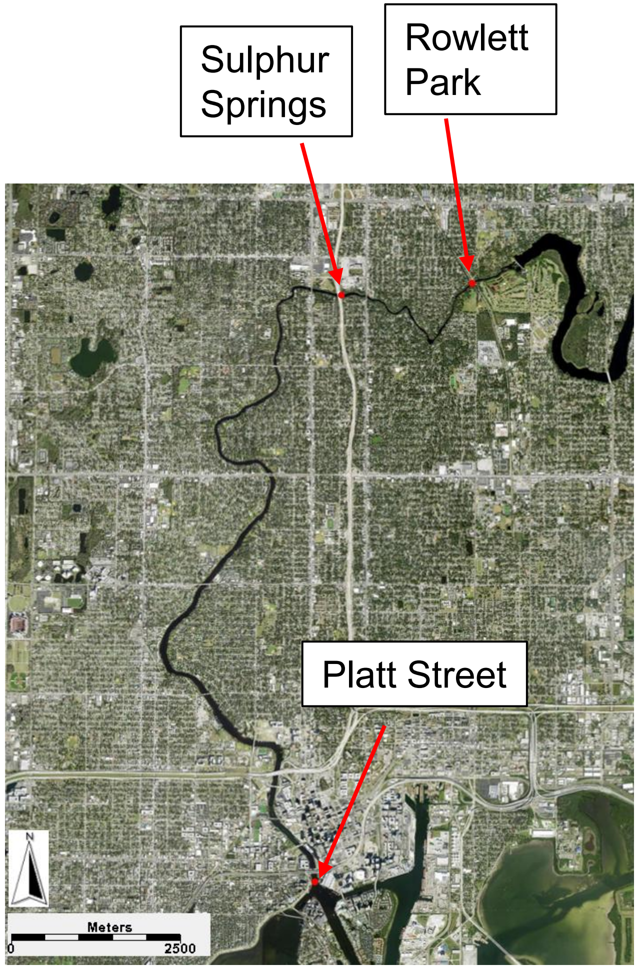


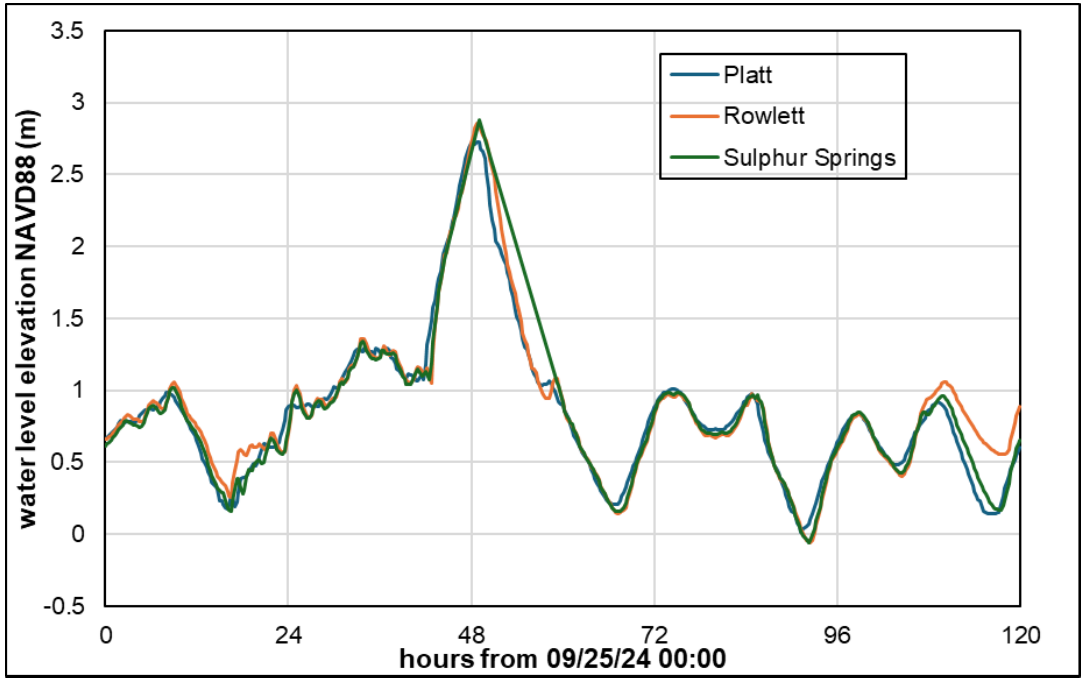
Model Construction for Hillsborough River

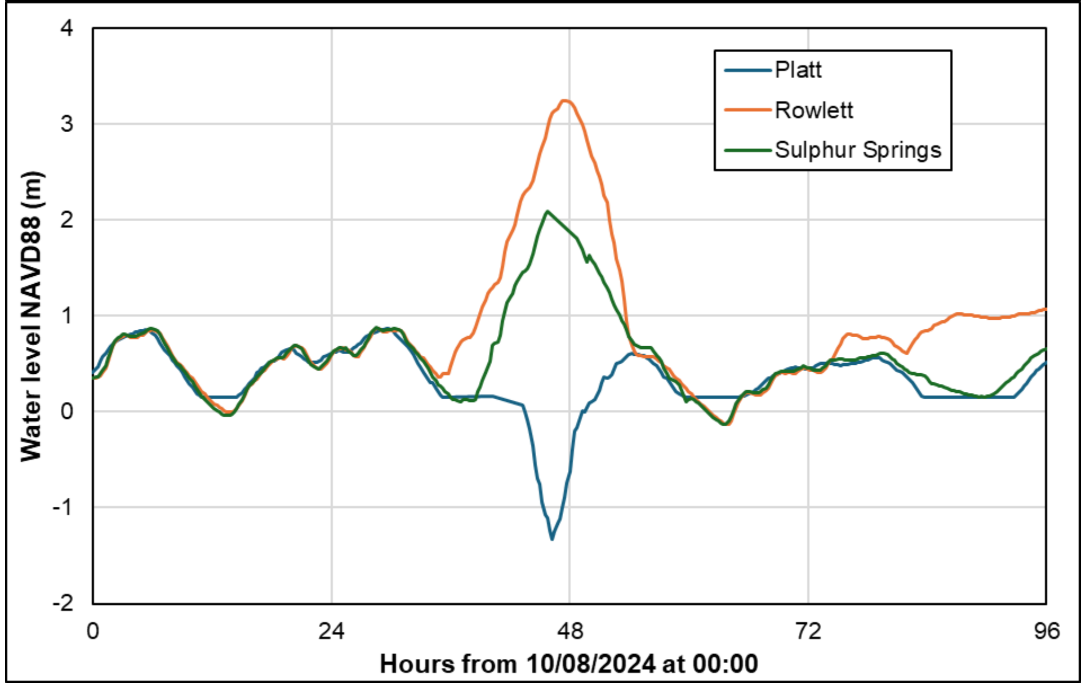


- Telescoping grid to increase efficiency (river and shoreline 7m x 7m, ~30 m from shoreline14m x 14m, ~70m from shoreline 28m x28 m, 140 m from shoreline 56m x 56m, 550m from shoreline 112m x112m, margins of the domain were 224m x 224m
- Boundary Conditions
  - Discharge boundary at dam
  - Discharge boundary at Sulphur Springs
  - Tidal boundary (WSE) at opening to Tampa Bay (Platt Street Bridge)
- Bathymetry collected by USF was combined with LiDAR data from NOAA to develop an accurate and complete DEM

Hurricanes Helene and Milton's impact on the Hillsborough River



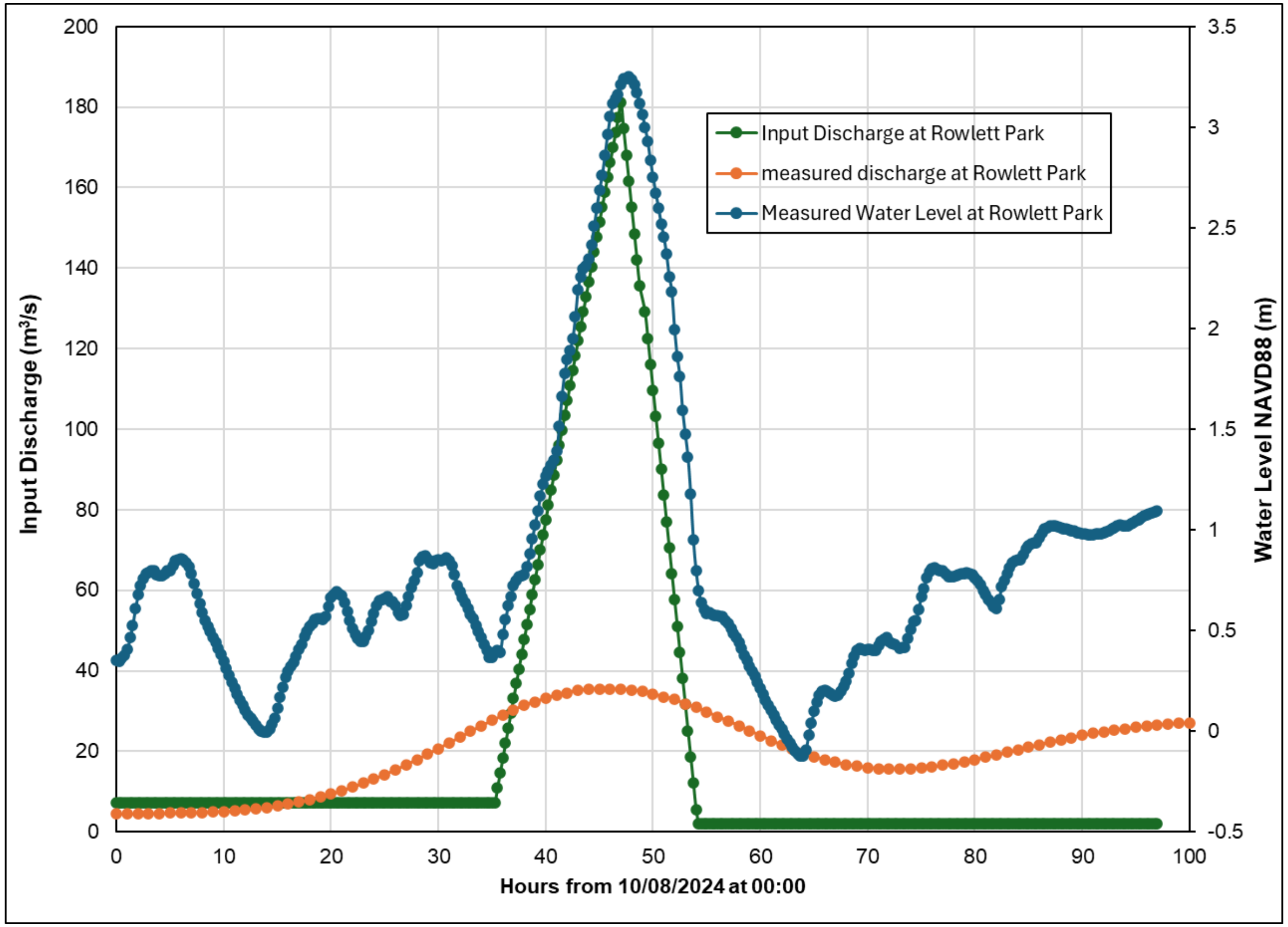




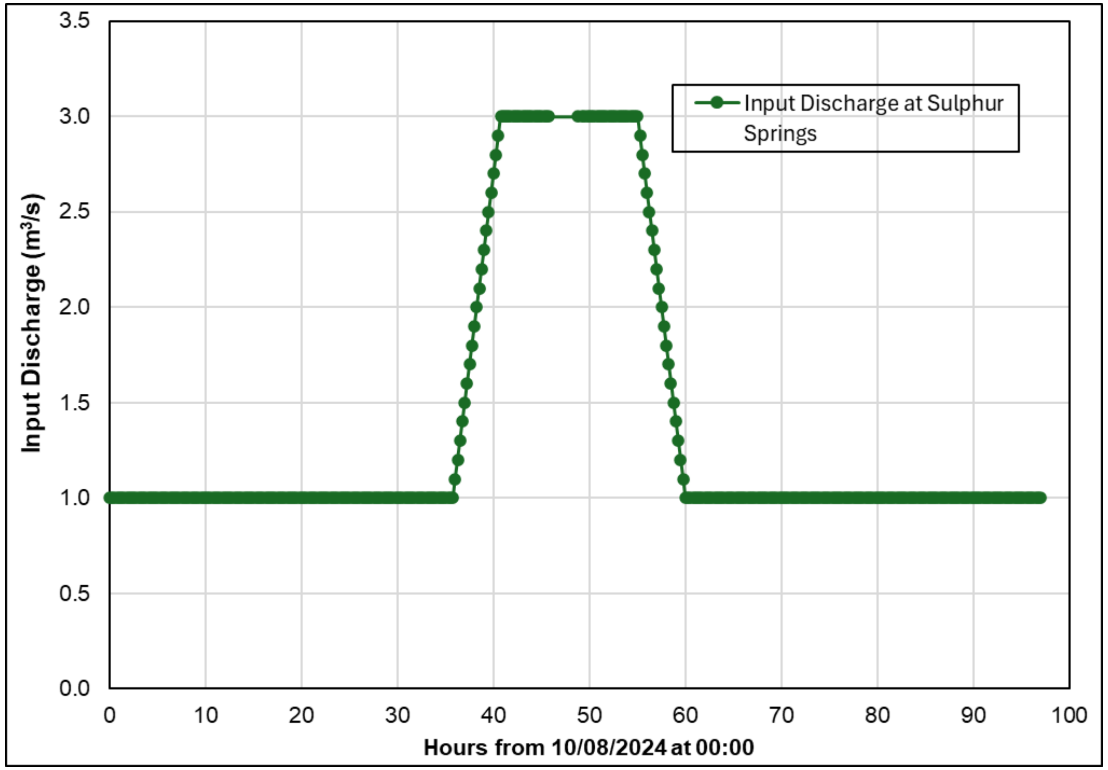
- Helene's surge propagated up the entire river
- During Hurricane Milton there was a large water level gradient (~4.5m) within the river
- The depressed water level associated with the negative storm surge was measured at the Platt water level gauge at the mouth of the river
- The elevated water level measured at the Rowlett and Sulphur Springs gauge was driven by the heavy rainfall

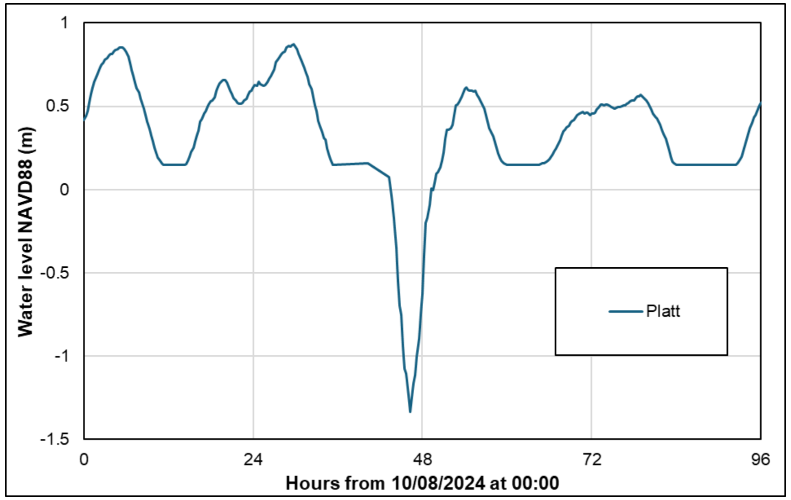
Model input values for Hurricane Milton at discharge boundaries

- The input discharge values (in green) and measured discharge values (in orange) at the Rowlett discharge boundary (primary axis)
- Milton's measured water level (in blue) at Rowlett Park (secondary axis)

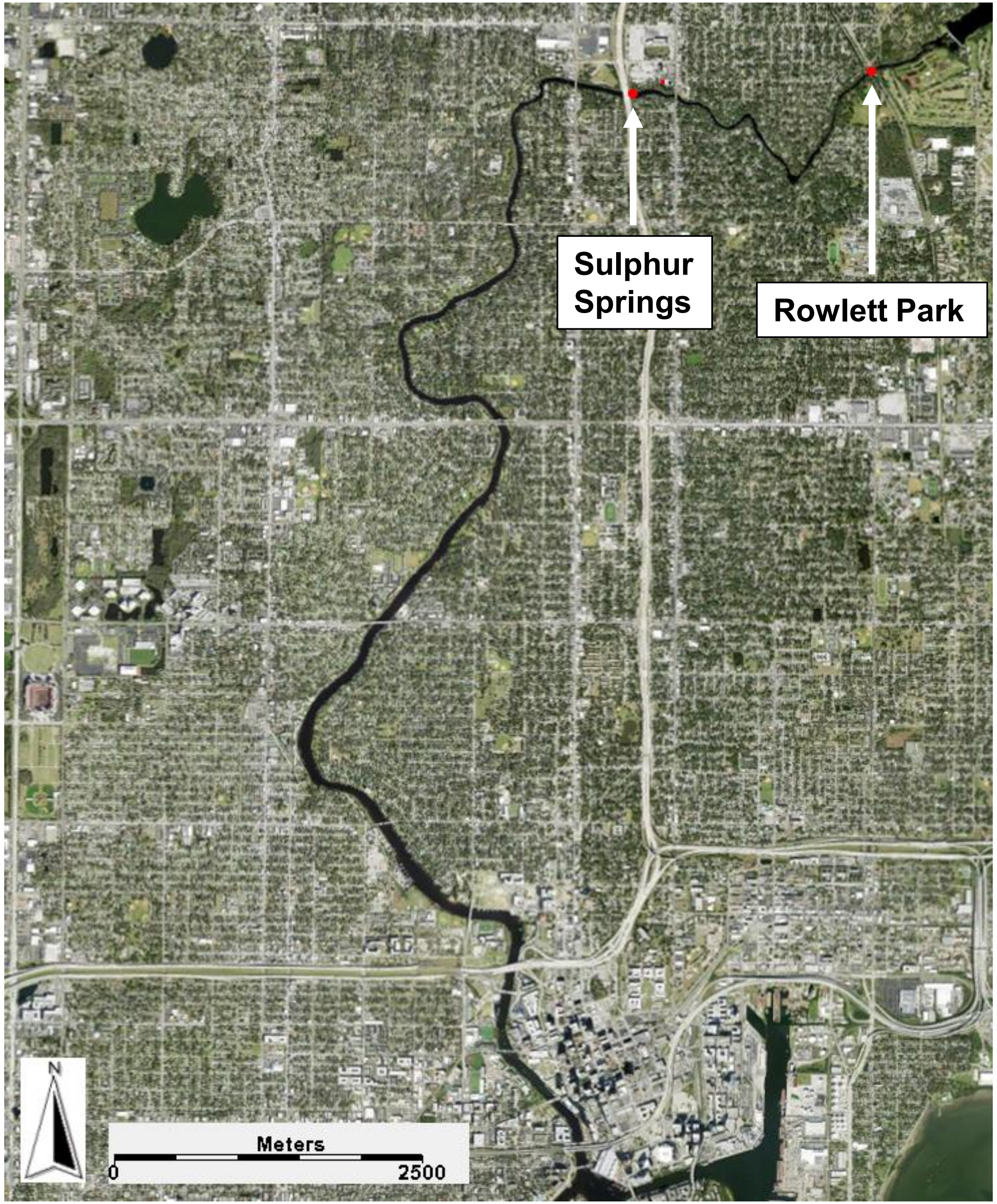


The input discharge values at Sulphur Springs



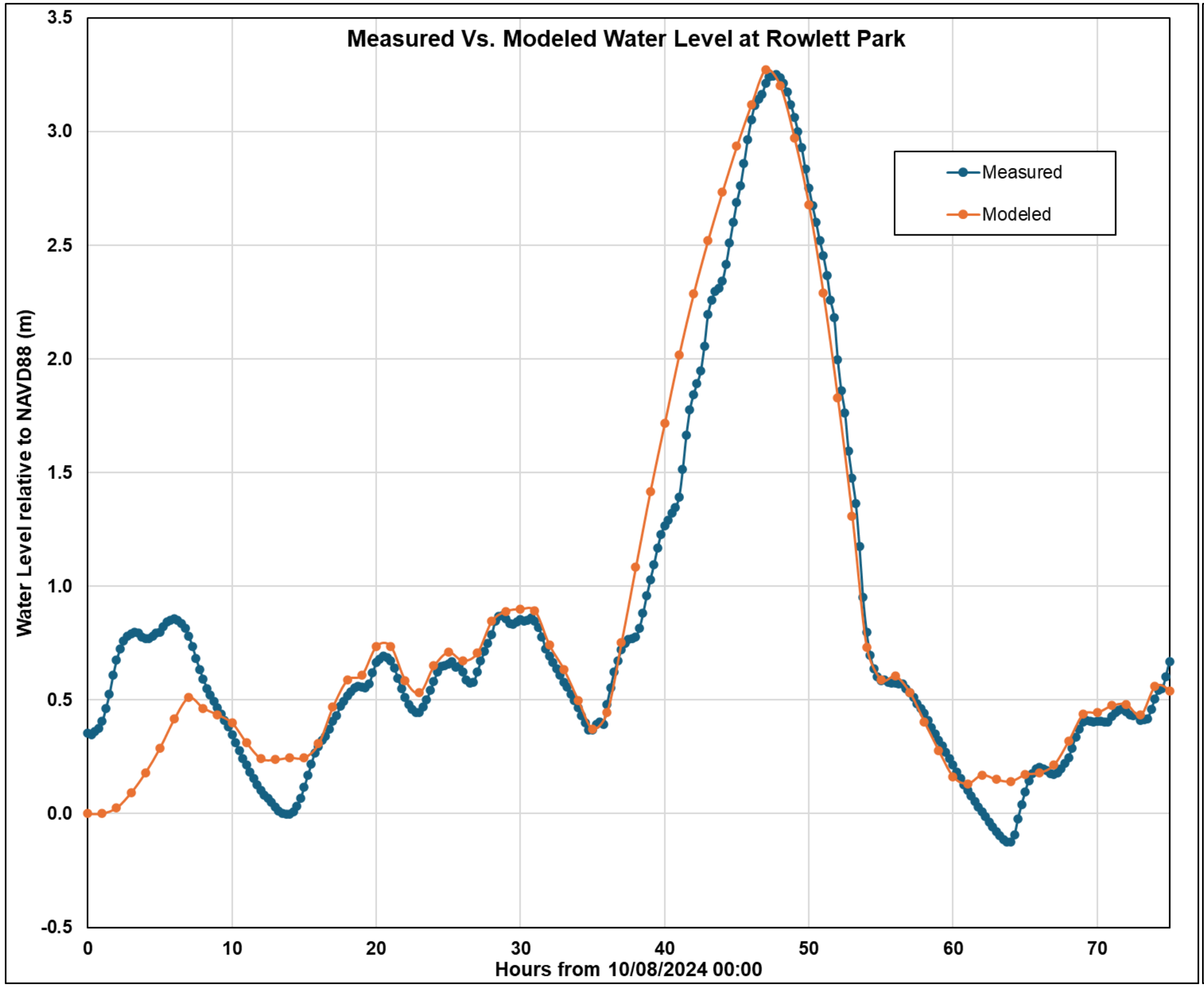


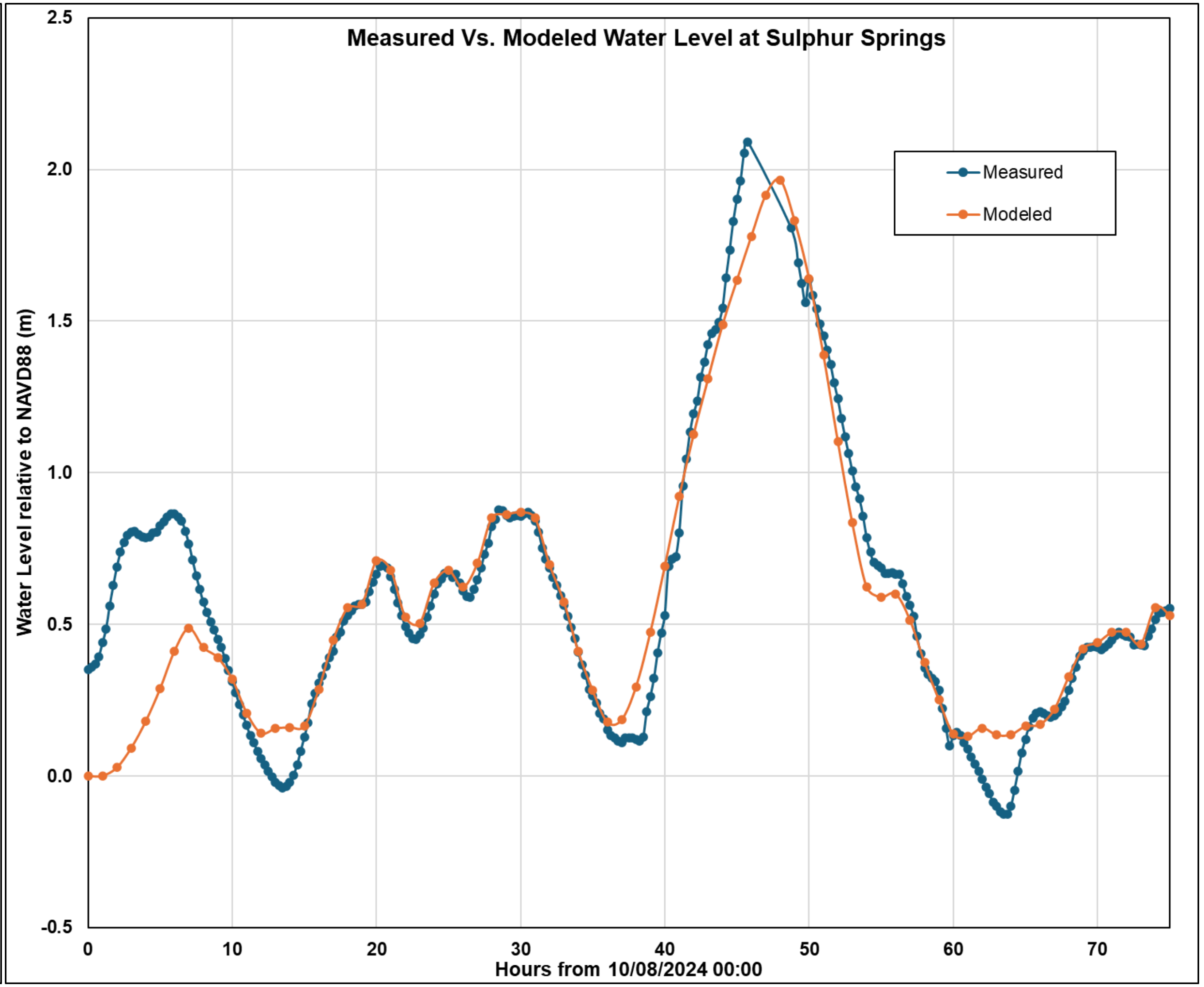
Measured water level values extracted from the Platt Street Bridge used to drive the water surface elevation boundary at the seaward boundary of the domain



- Water level extracted at both Rowlett Park and Sulphur Springs Park USGS gauge locations
- This data is used to verify the model in terms of predicting water level under the conditions during Hurricane Milton

Modeled vs. Measured Water Level at Rowlett and Sulphur Springs

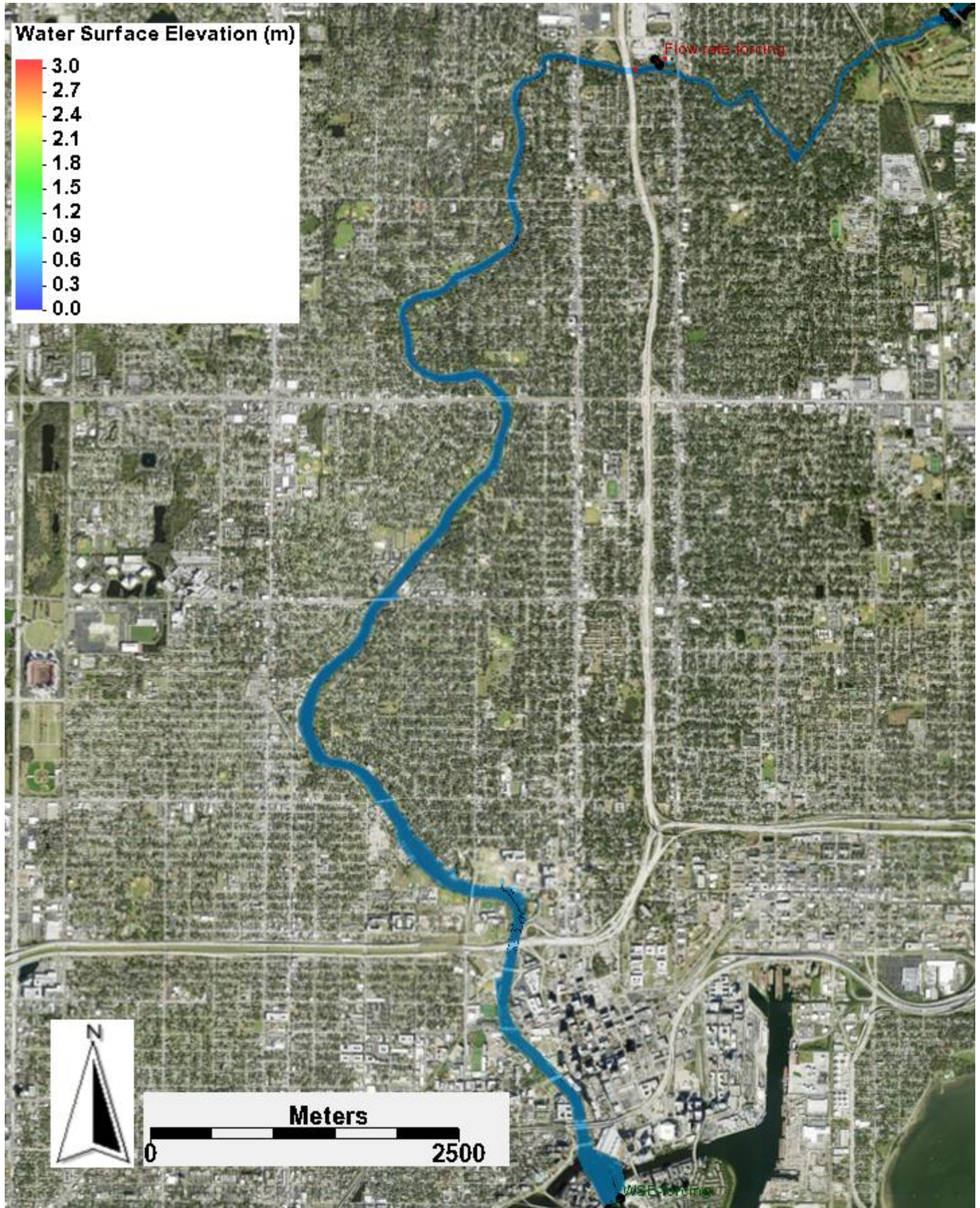




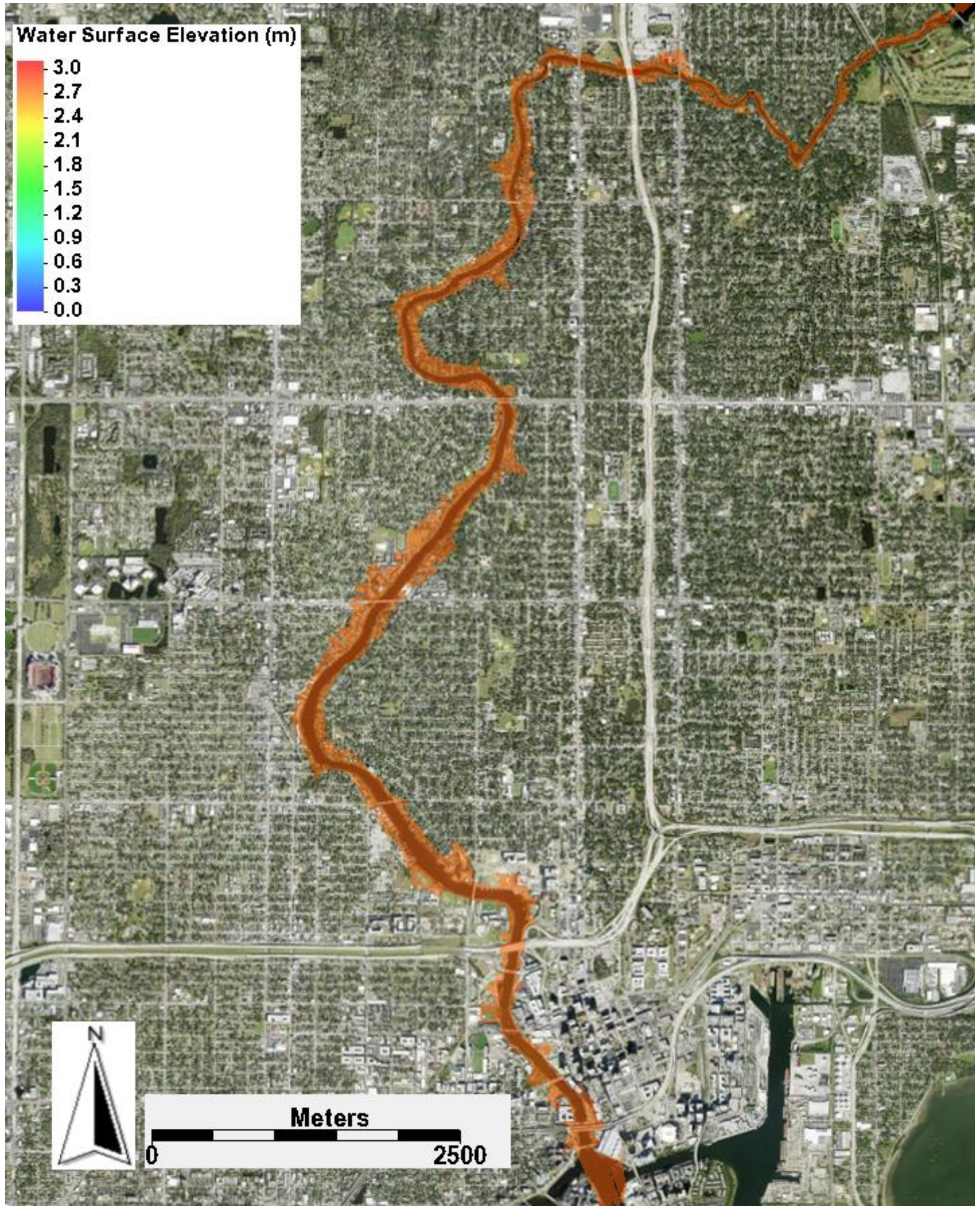
- Rowlett Park predicted well
- Sulphur Springs slightly under predicted the peak water level by ~13 cm and slightly over predicted the time of the peak by about 30 minutes
- Note: the measured discharge values are too low, “modified” discharge was used.

Hurricane Helene

Regular high tide

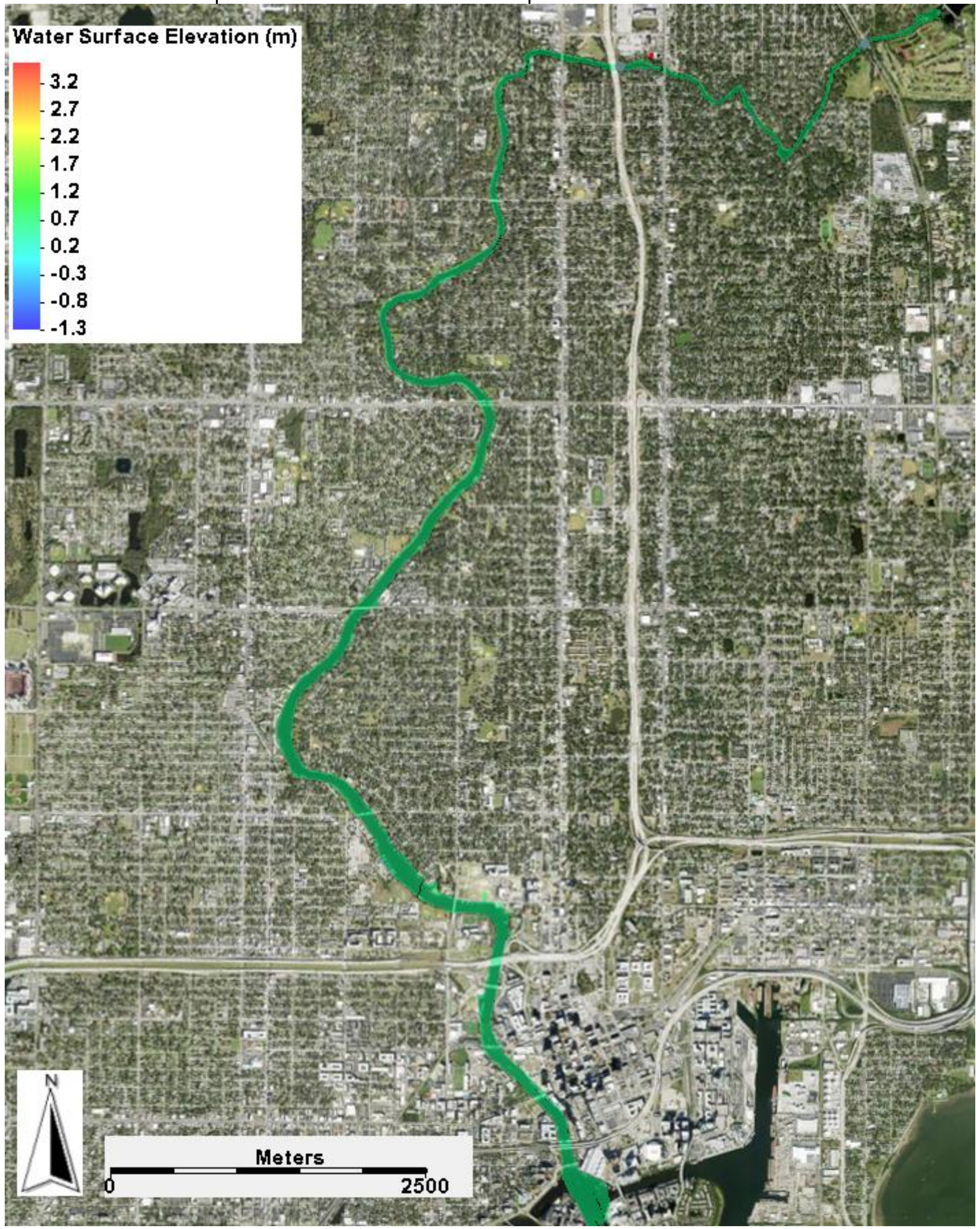


Peak Storm Surge

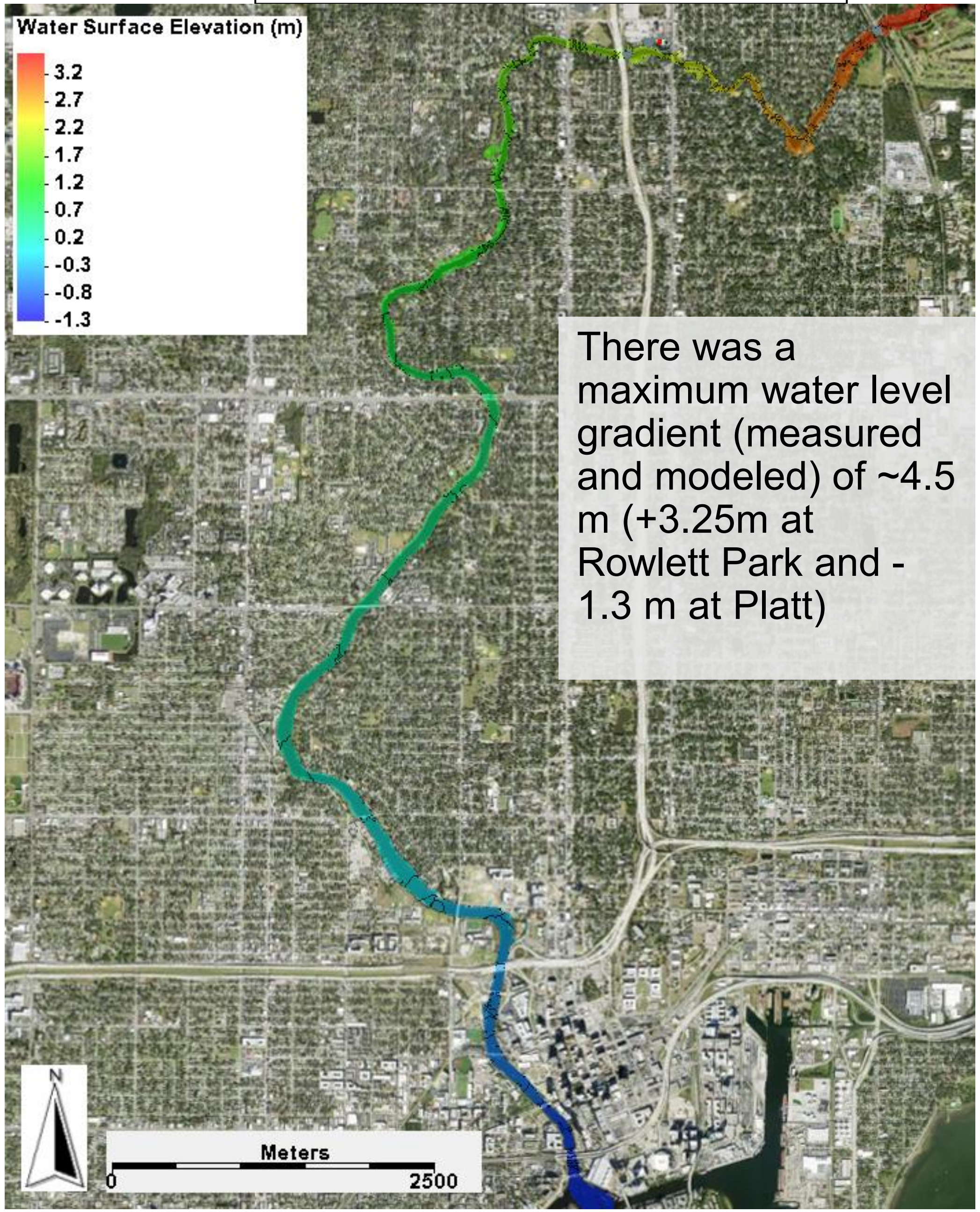


Hurricane Milton

Regular high tide

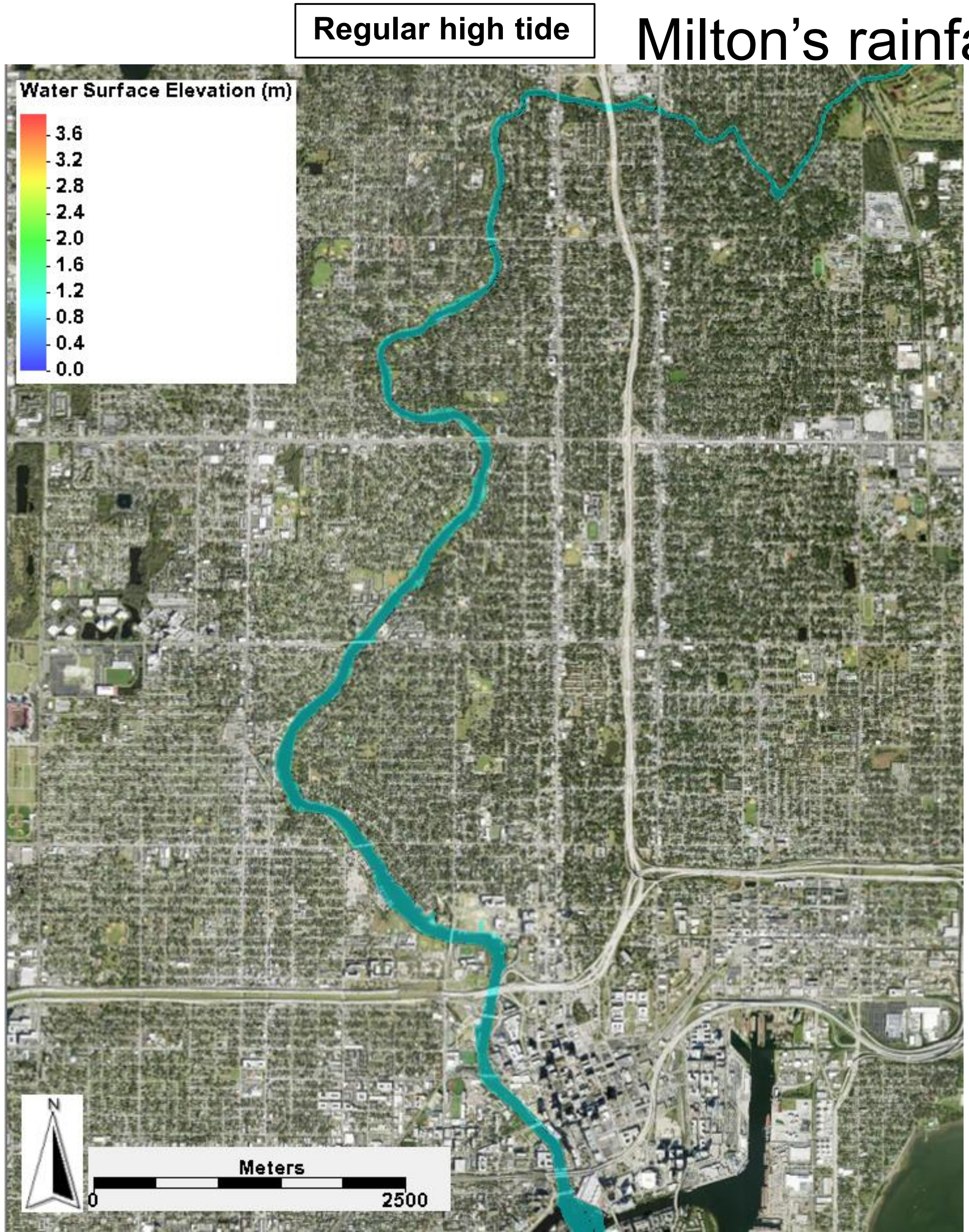


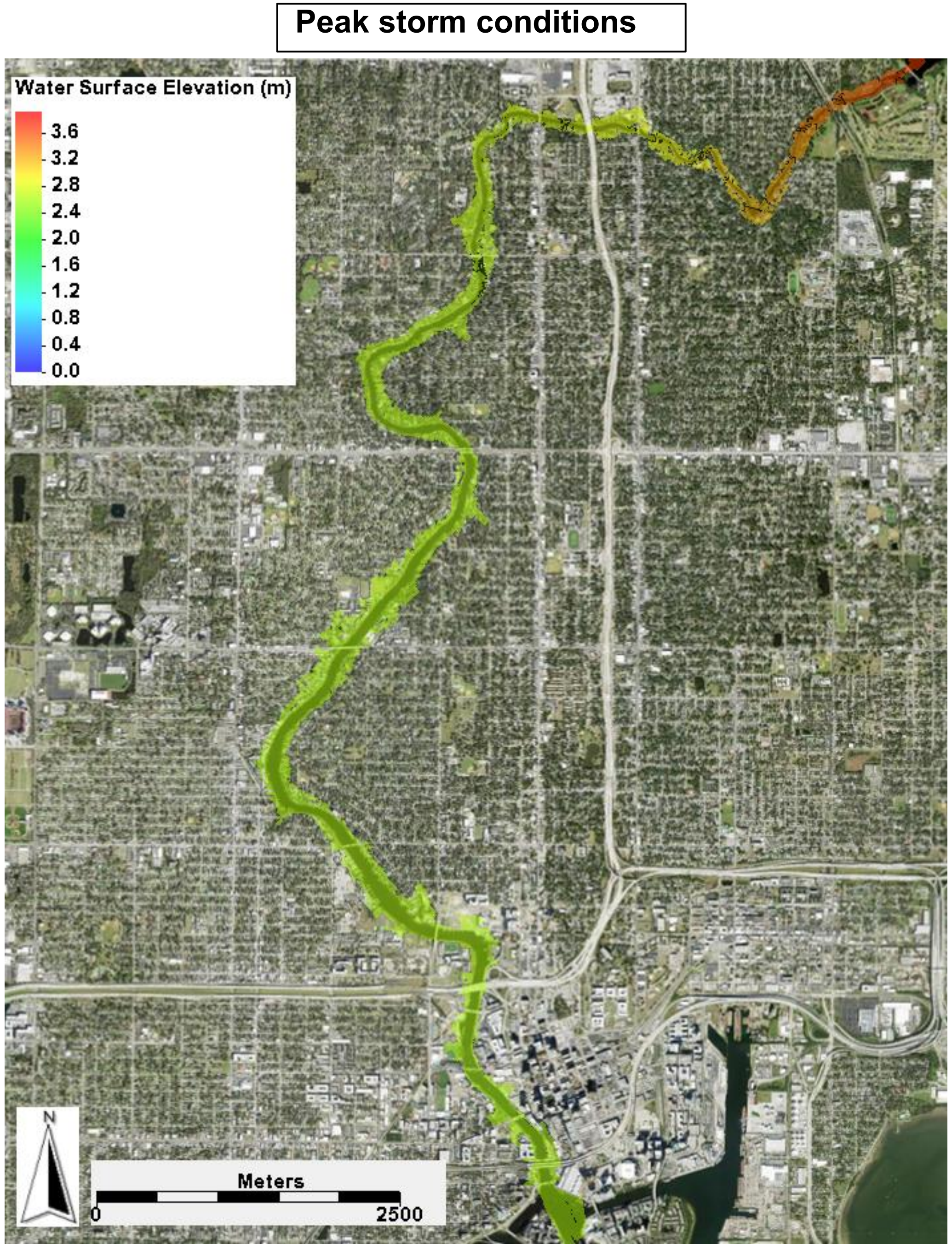
Peak water-level gradient generated



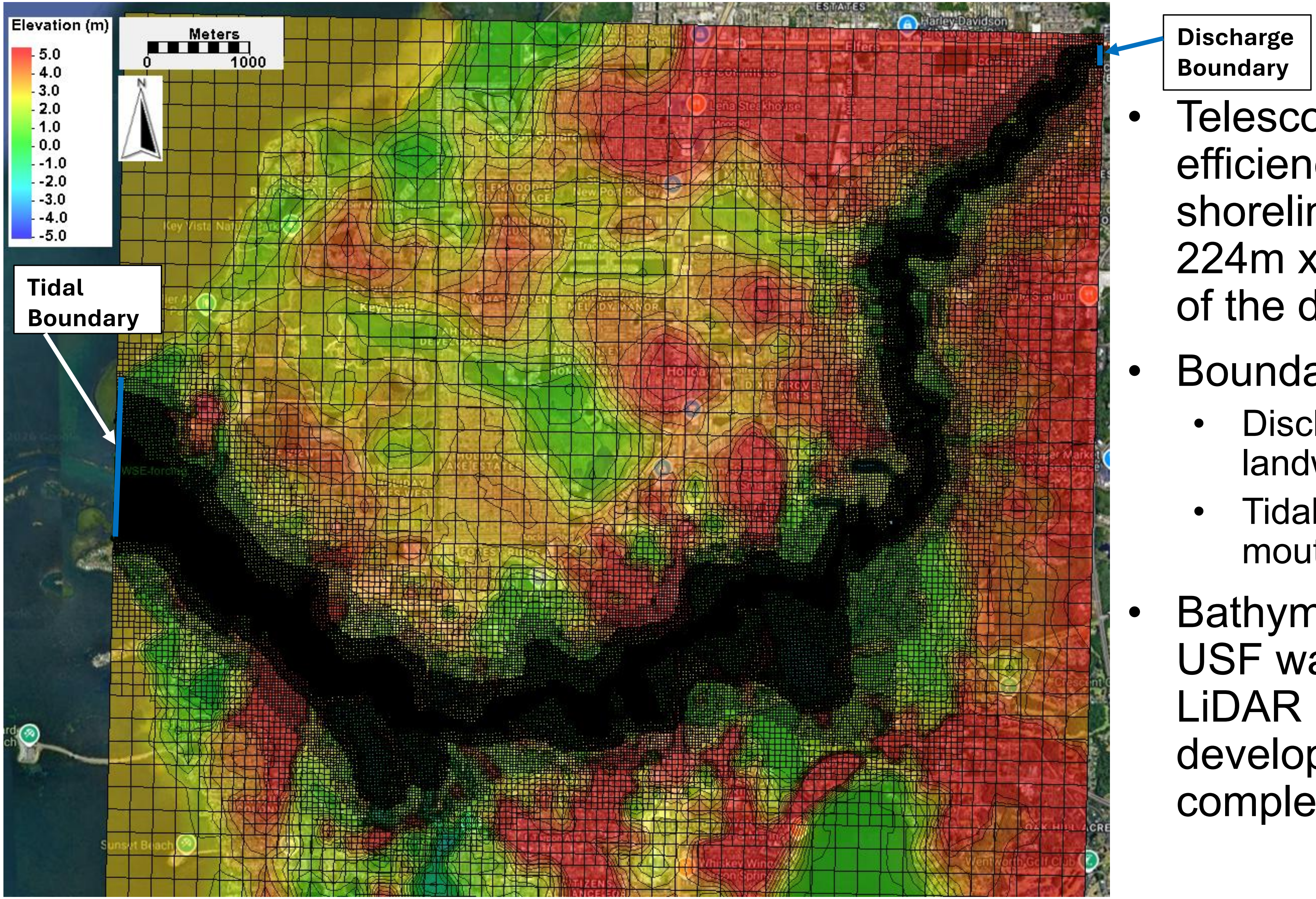
There was a maximum water level gradient (measured and modeled) of ~4.5 m (+3.25m at Rowlett Park and -1.3 m at Platt)

Worst Case: Helene’s storm surge and Milton’s rainfall event



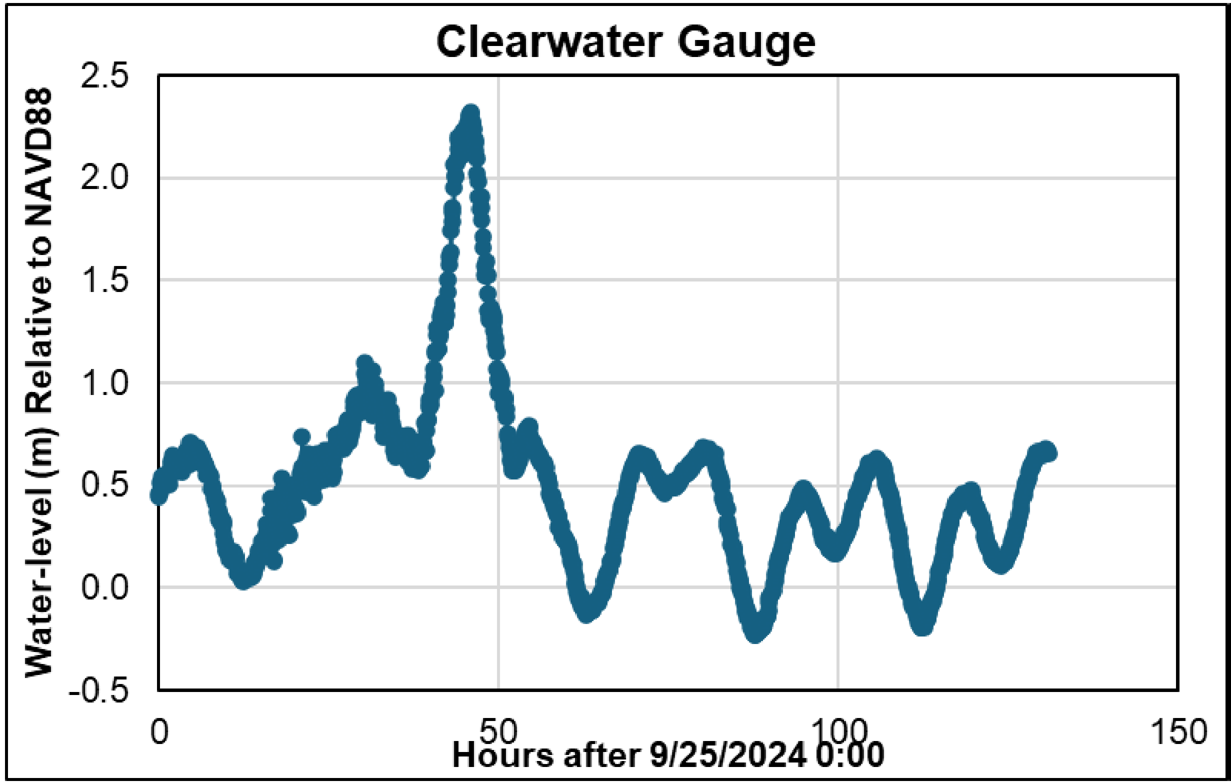


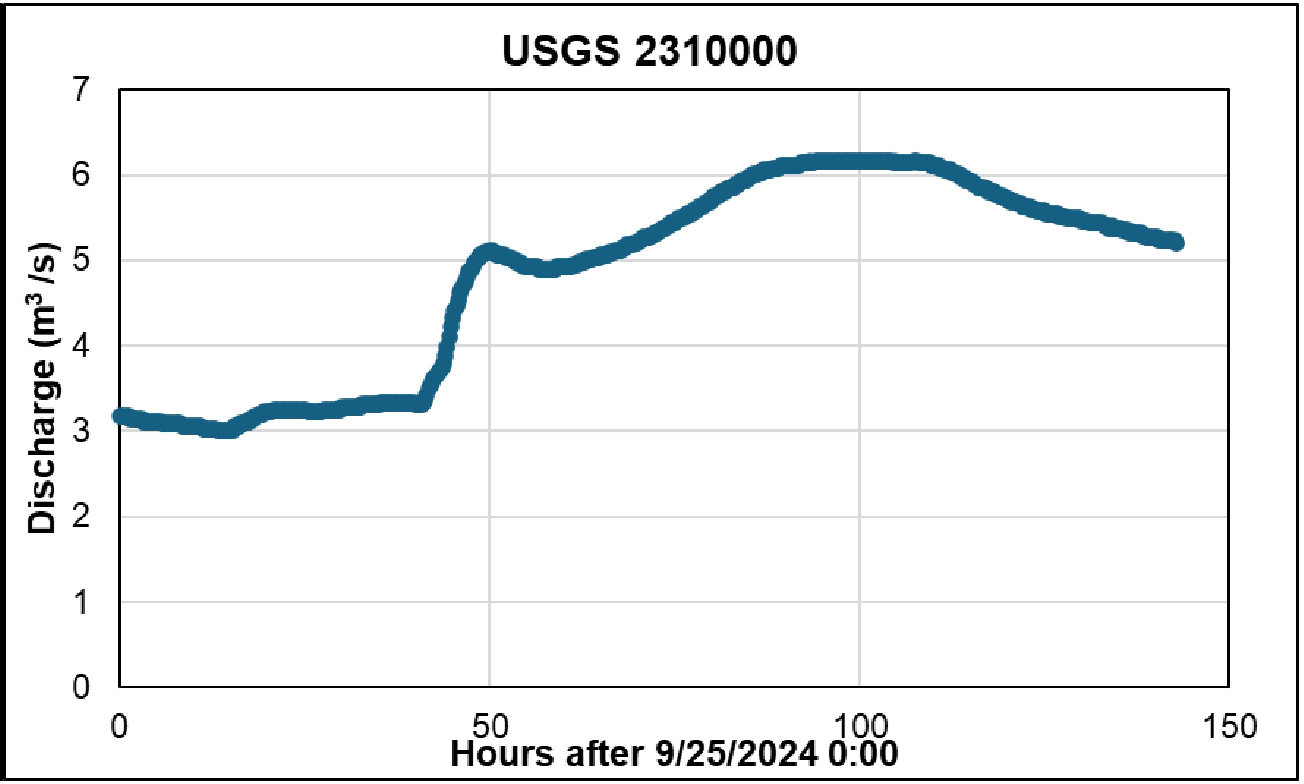
Model Construction for Anclote River



- Telescoping grid to increase efficiency: river and shoreline 7m x 7m, up to 224m x 224m at the margins of the domain
- Boundary Conditions
  - Discharge boundary at landward boundary of the grid
  - Tidal boundary (WSE) at the mouth of the river
- Bathymetry collected by USF was combined with LiDAR data from NOAA to develop an accurate and complete DEM

Hurricane Helene

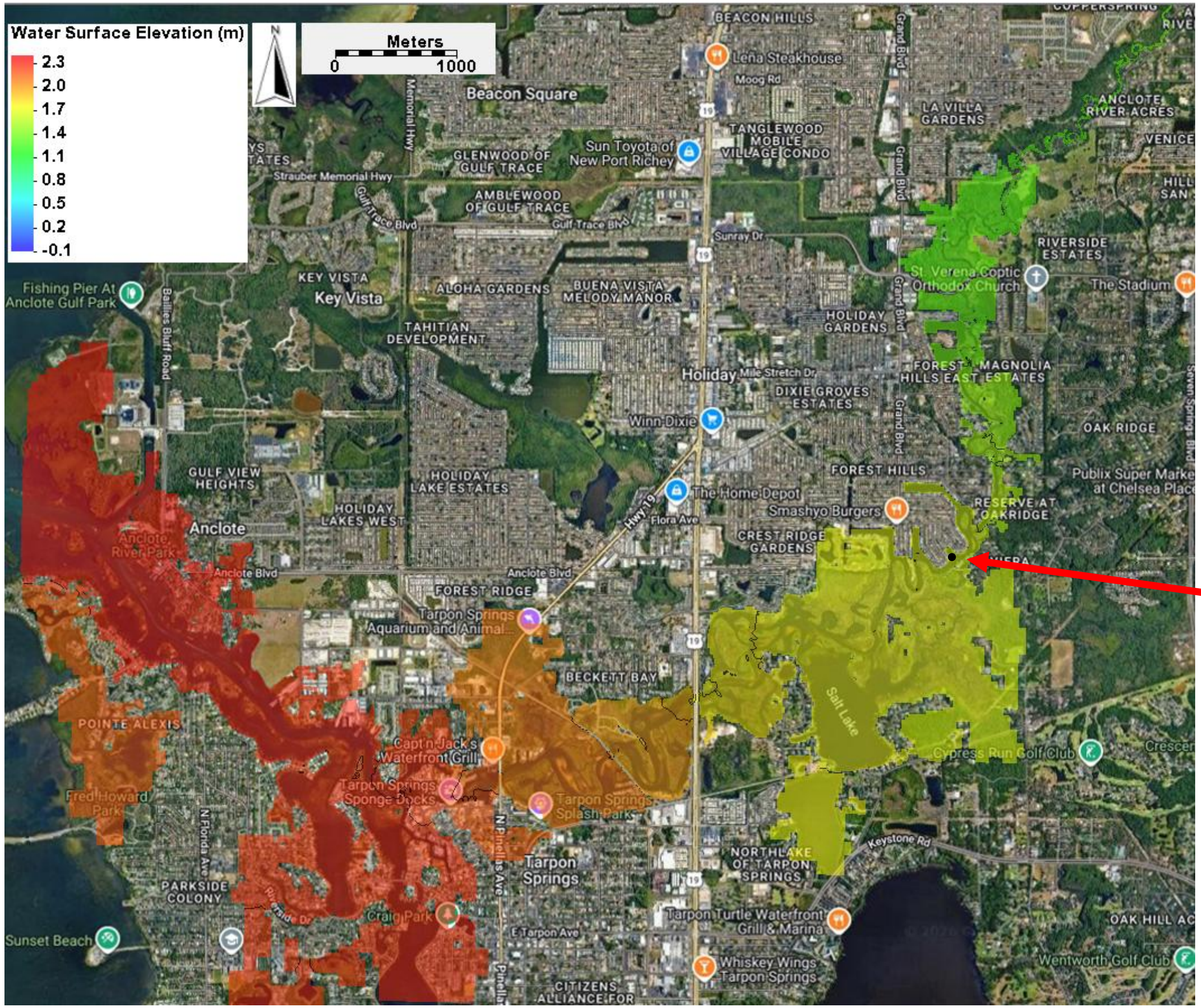


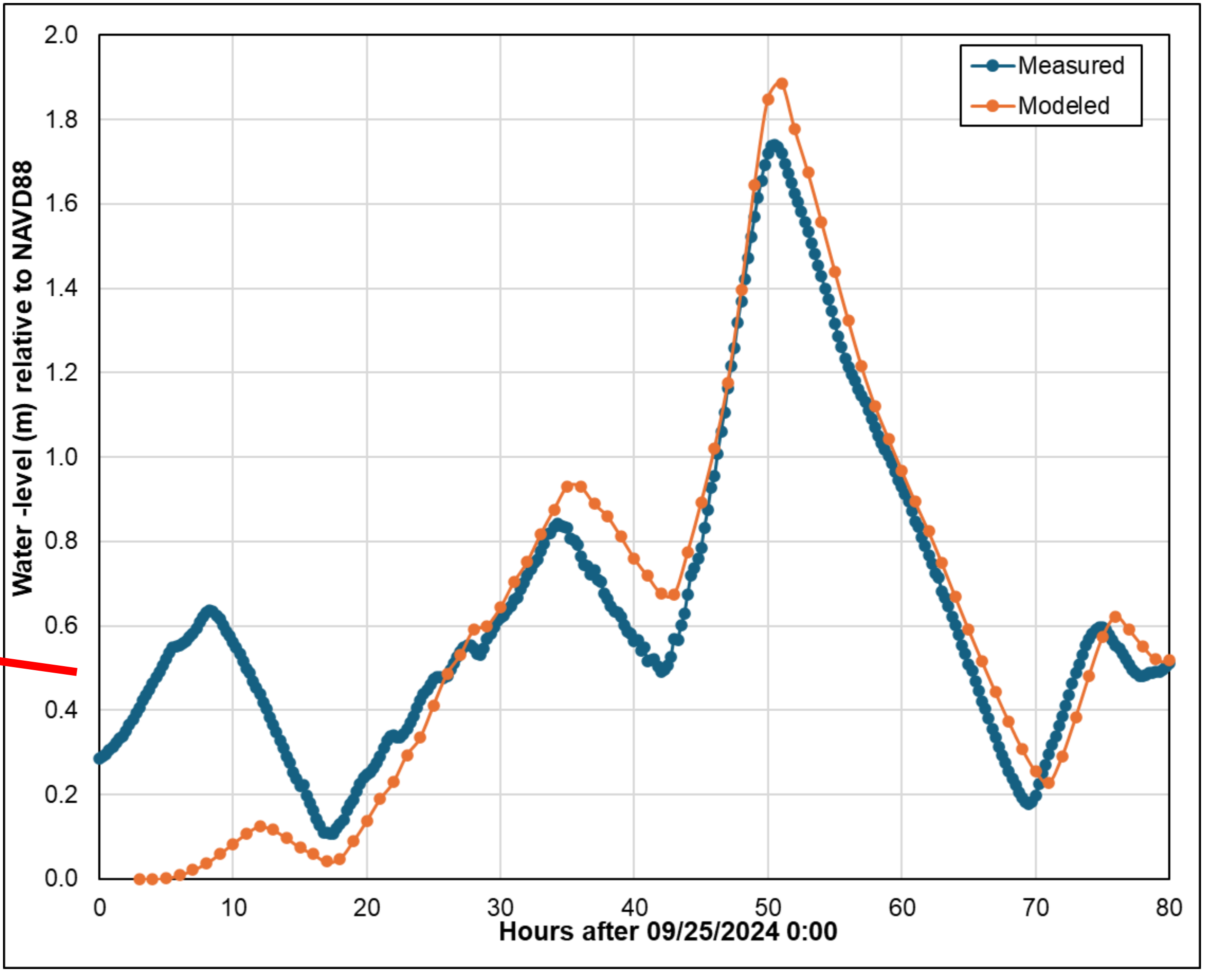


- **Peak water-level at about +2.3 m measured at the Clearwater gauge about 23 km south of the river mouth**
- **Peak discharge was about 6.2 m^3/s measured at USGS gauge 2310000 at the landward boundary of the model domain**
- **Mainly a storm surge event**

Hurricane Helene

Peak surge with measured river discharge

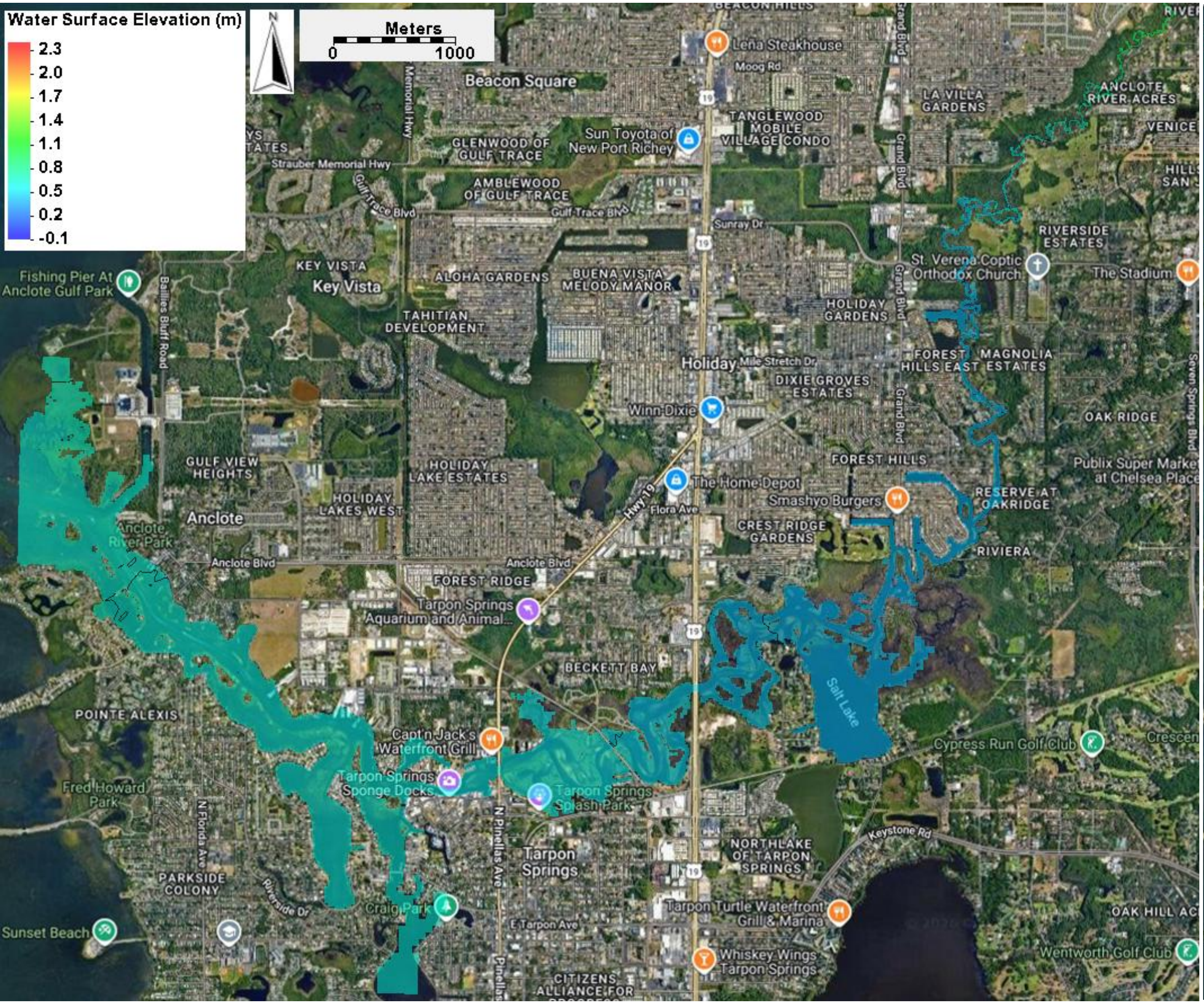




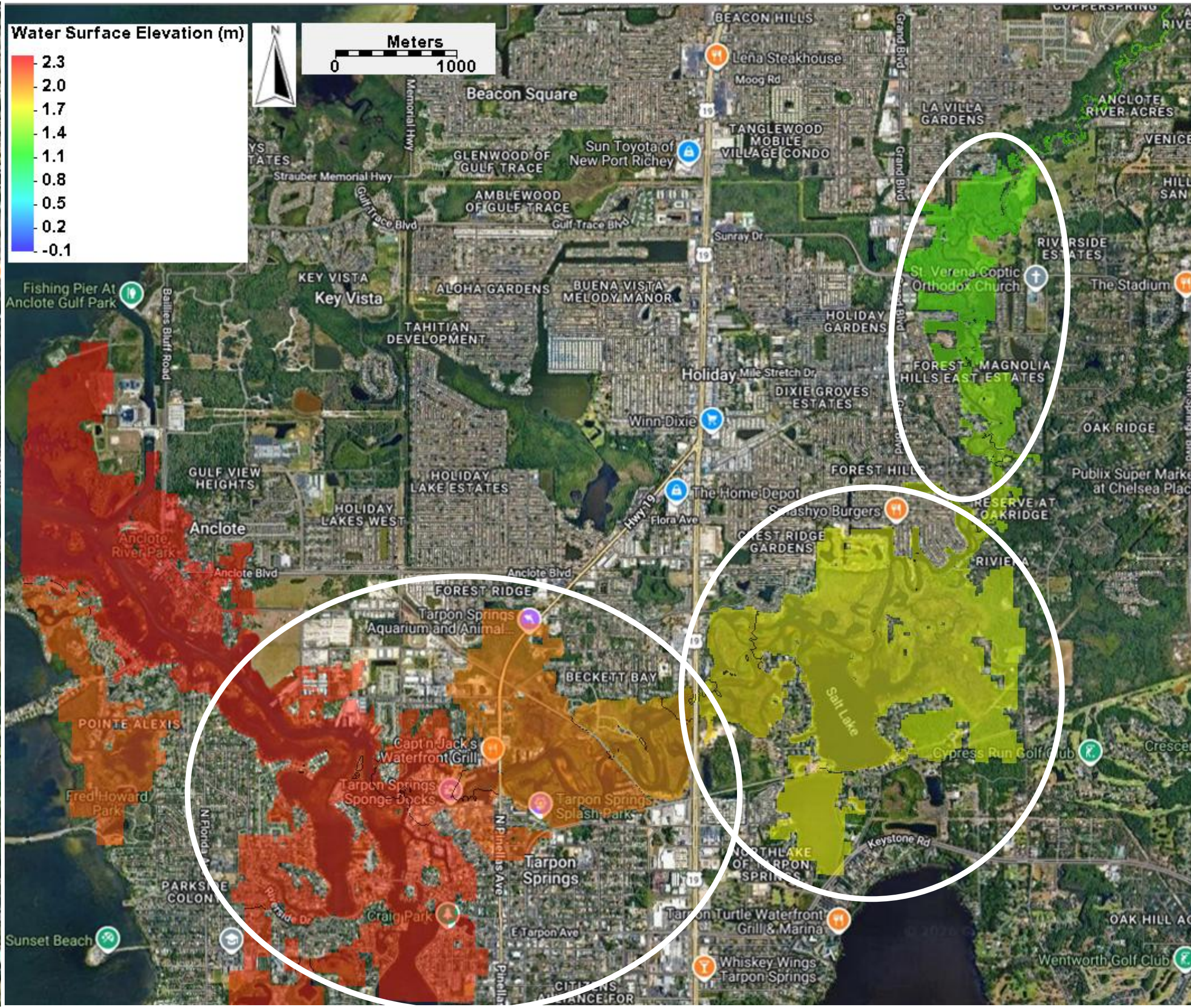
- Extracted water-level at USGS gauge 02310075 (Anclote river near Holiday Fl) compared to the modeled water-level.
- Model over-predicted the peak surge by about ~15cm and by 30 minutes, likely because NOAA’s Clearwater tide station is 23 km south.

Hurricane Helene

Regular high tide

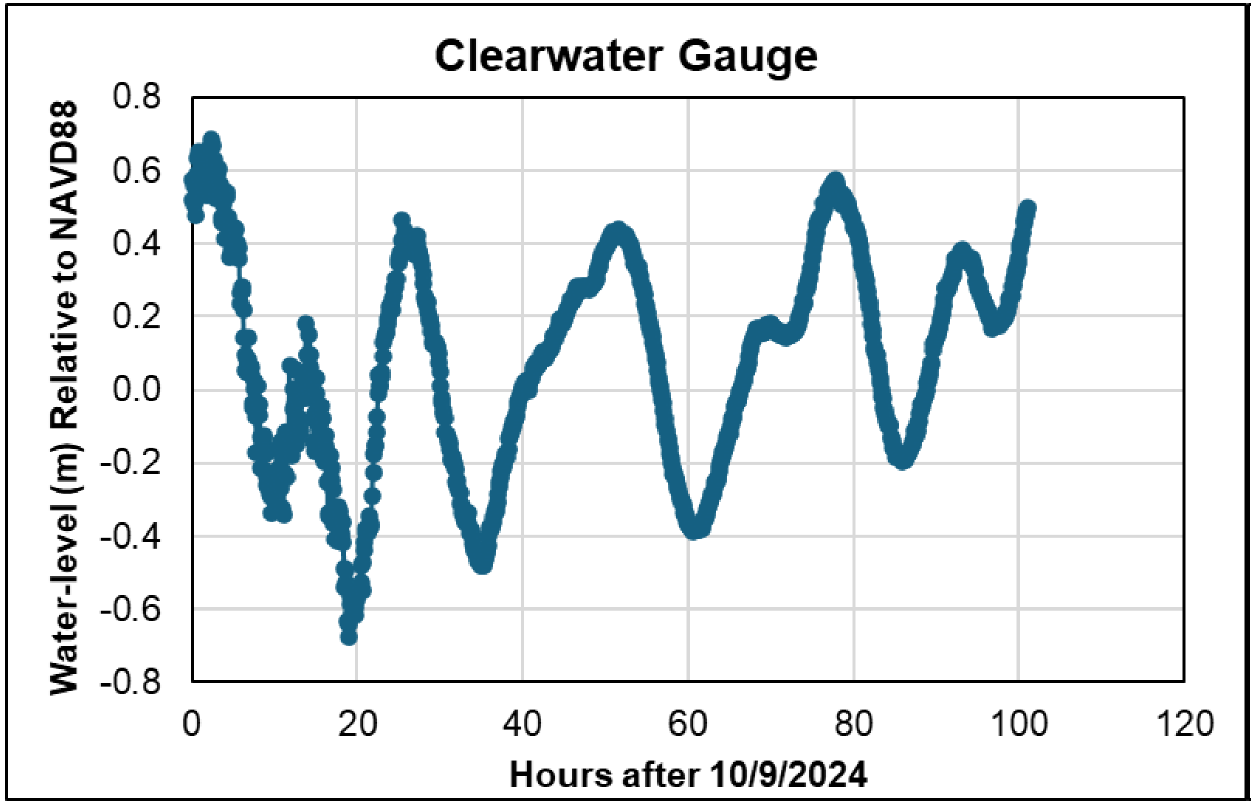


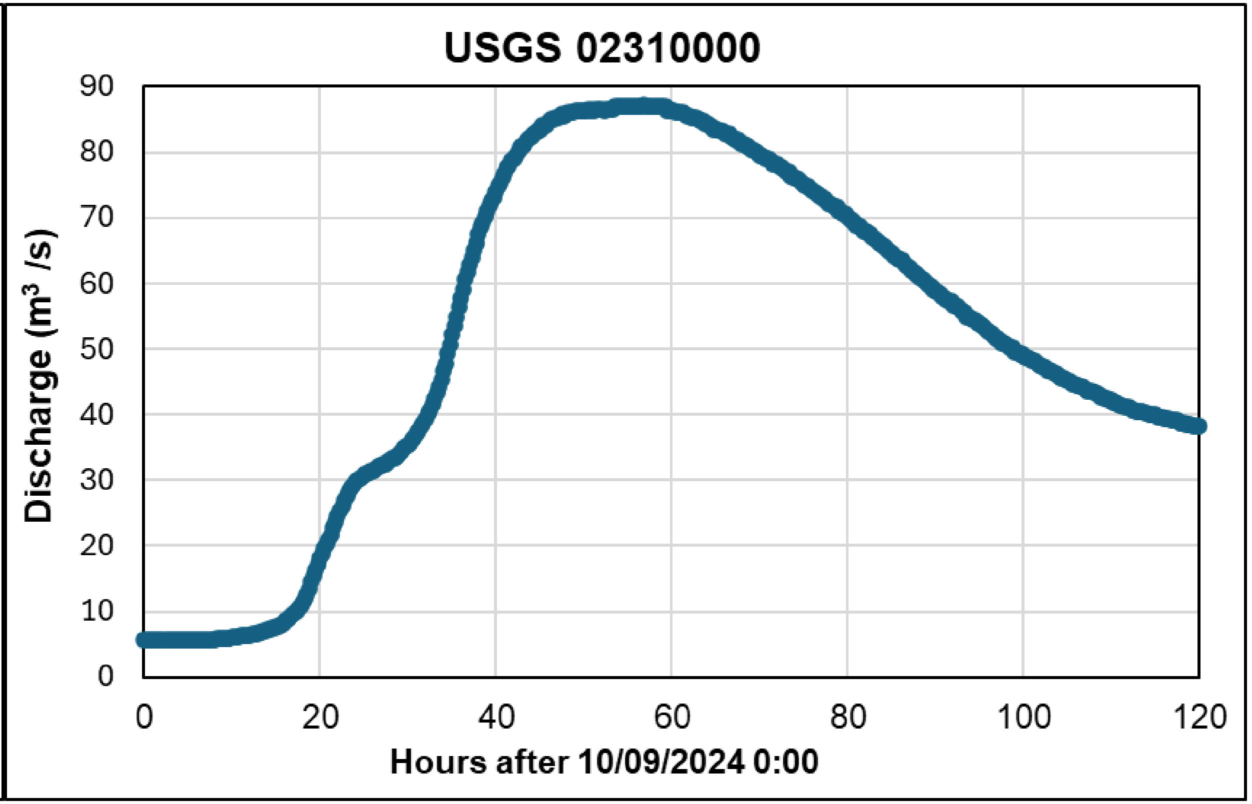
Peak surge with measured river discharge



- **Large areas including both wetlands and low-lying developed areas were flooded.**

Hurricane Milton

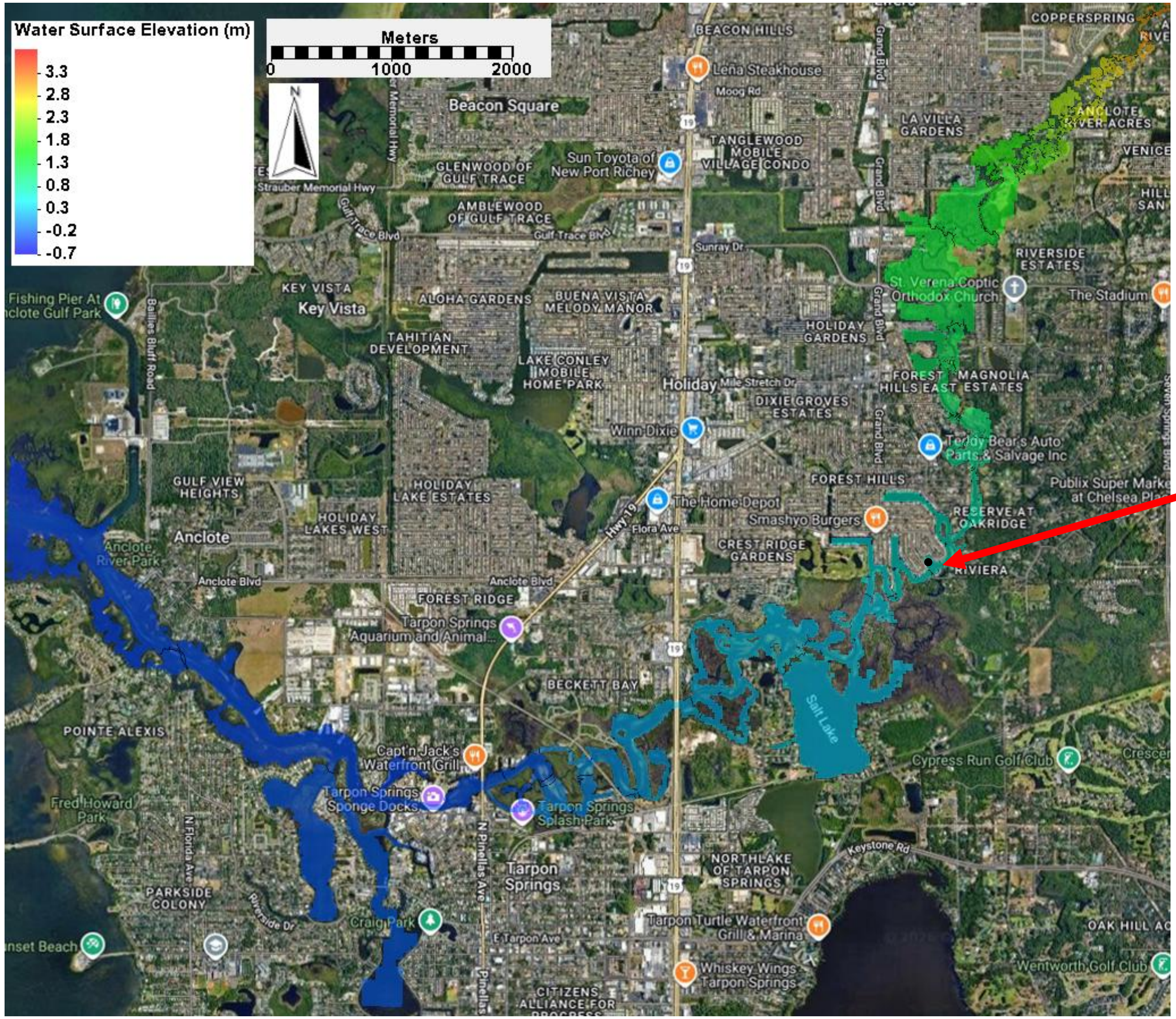


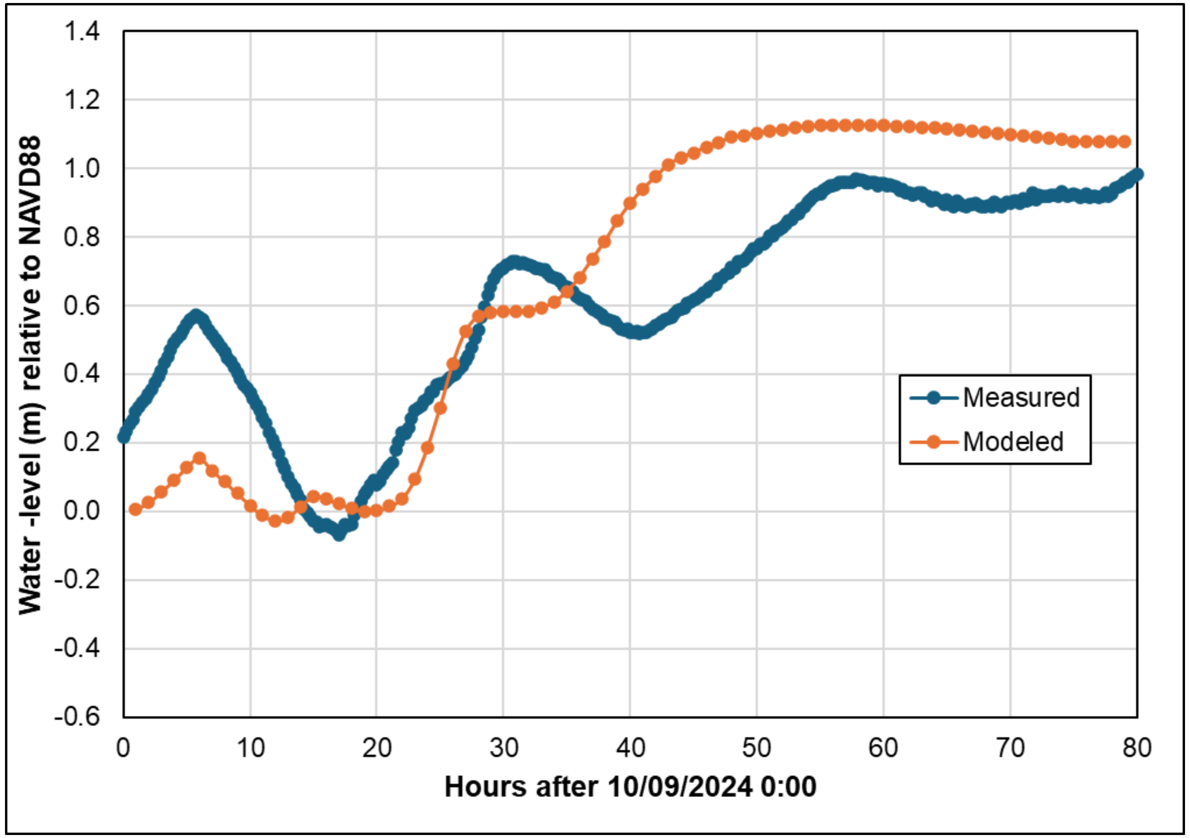


- **Milton made landfall south the study area resulting in a measured negative storm surge of about -0.7 m**
- **Milton was a heavy participation event with the peak discharge lasting over 24 hours**
- **The peak discharge rate was about 85 m^3/s and occurred after the negative surge event**

Hurricane Milton

Low tide with high measured river discharge

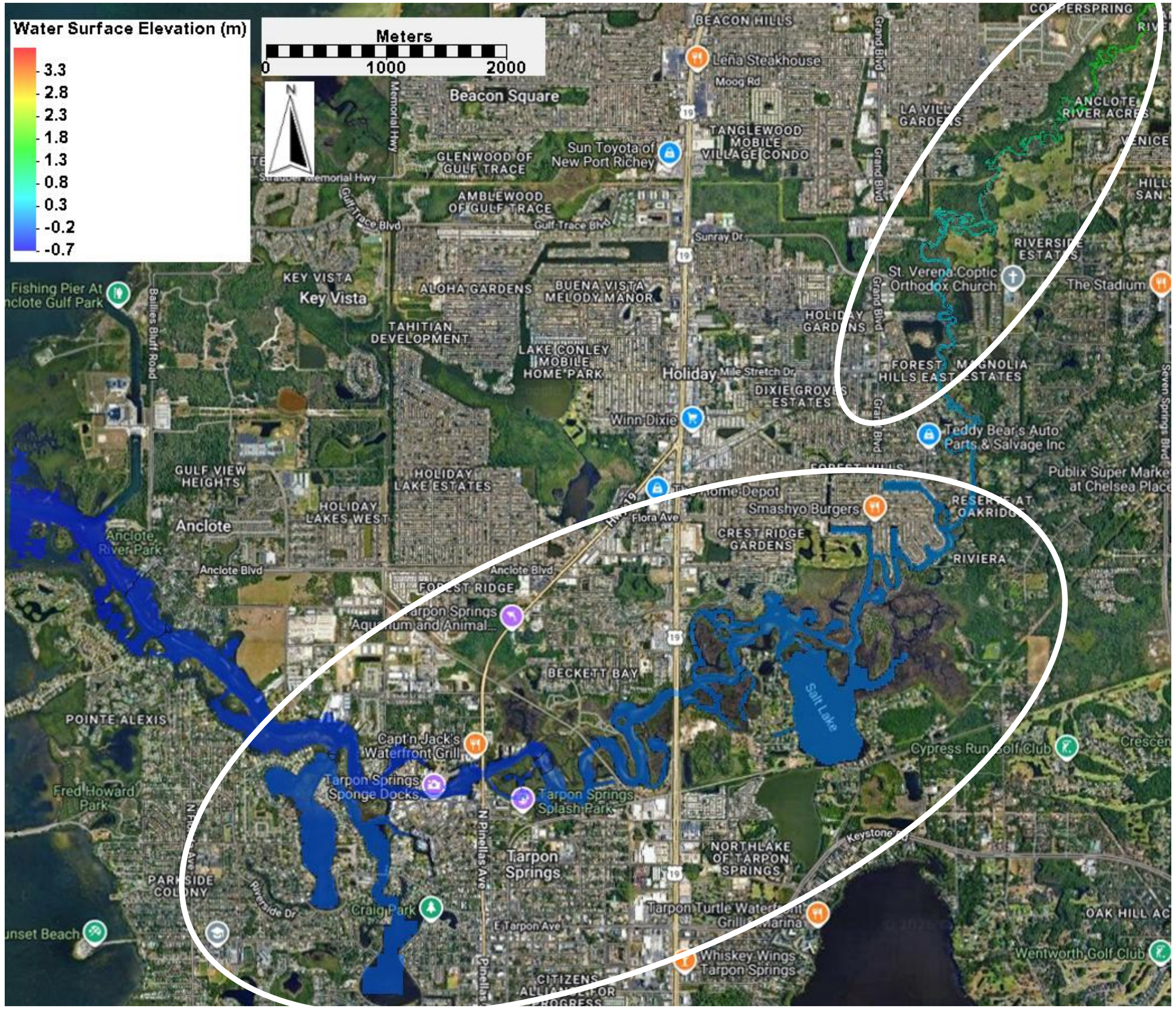




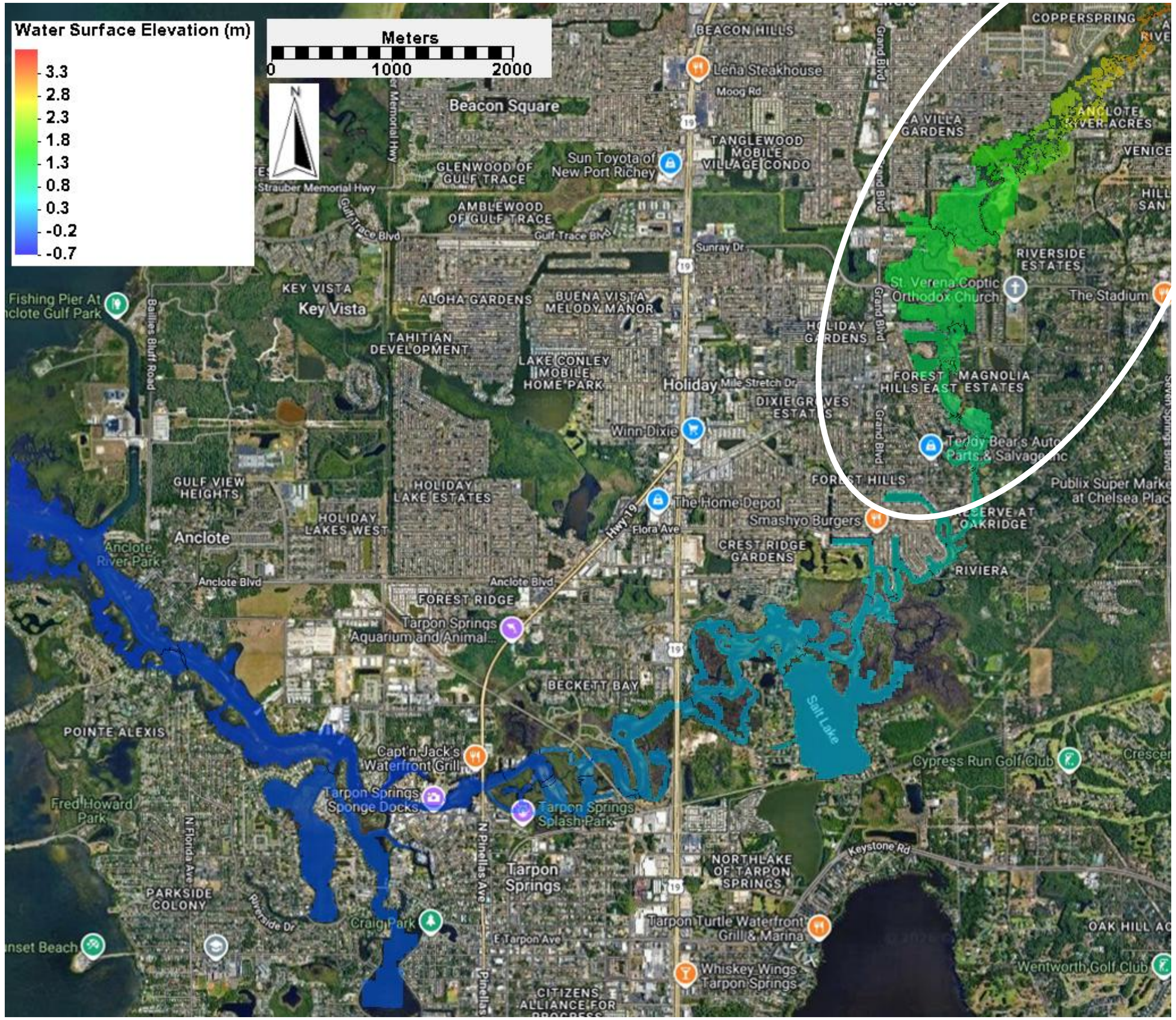
- **Extracted water-level at USGS gauge 02310075 (Anclote river near Holiday Fl) compared to the modeled water-level.**
- **Modeled and measured water levels do not match too well.**

Hurricane Milton

Negative surge before the peak discharge

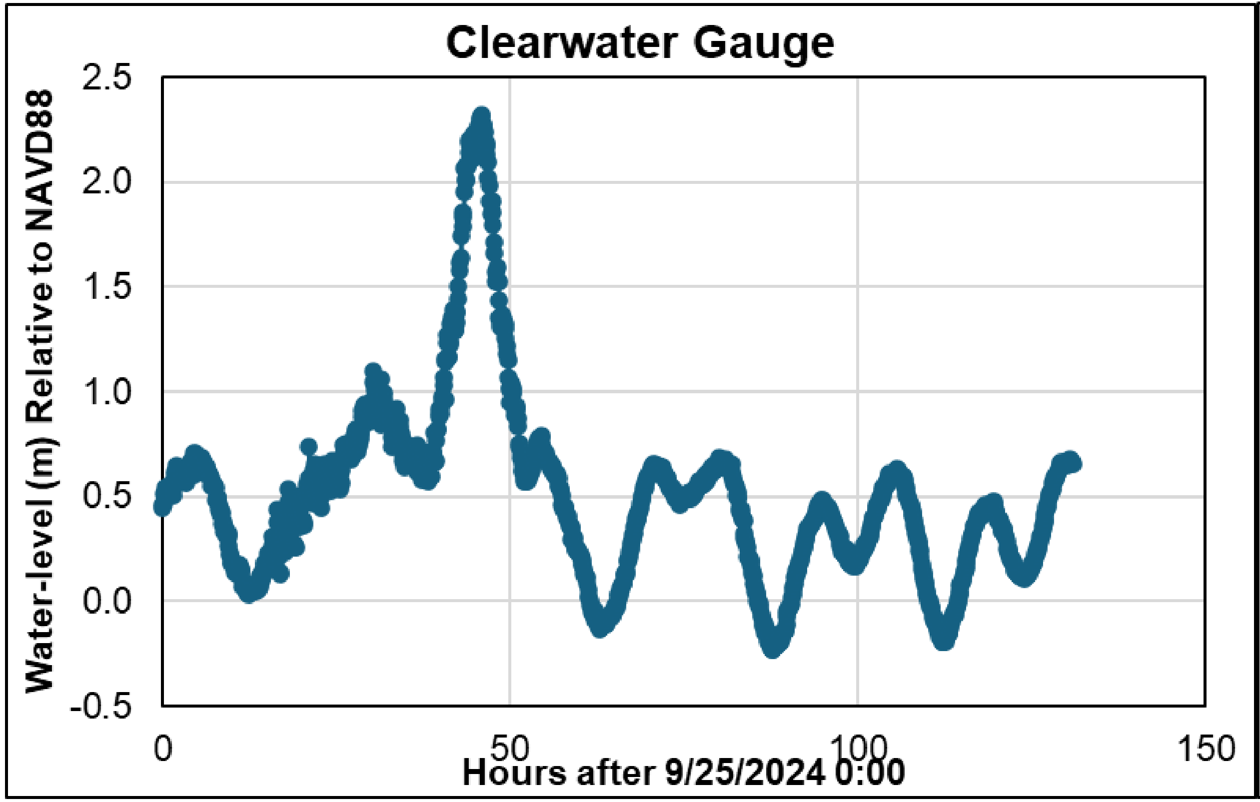


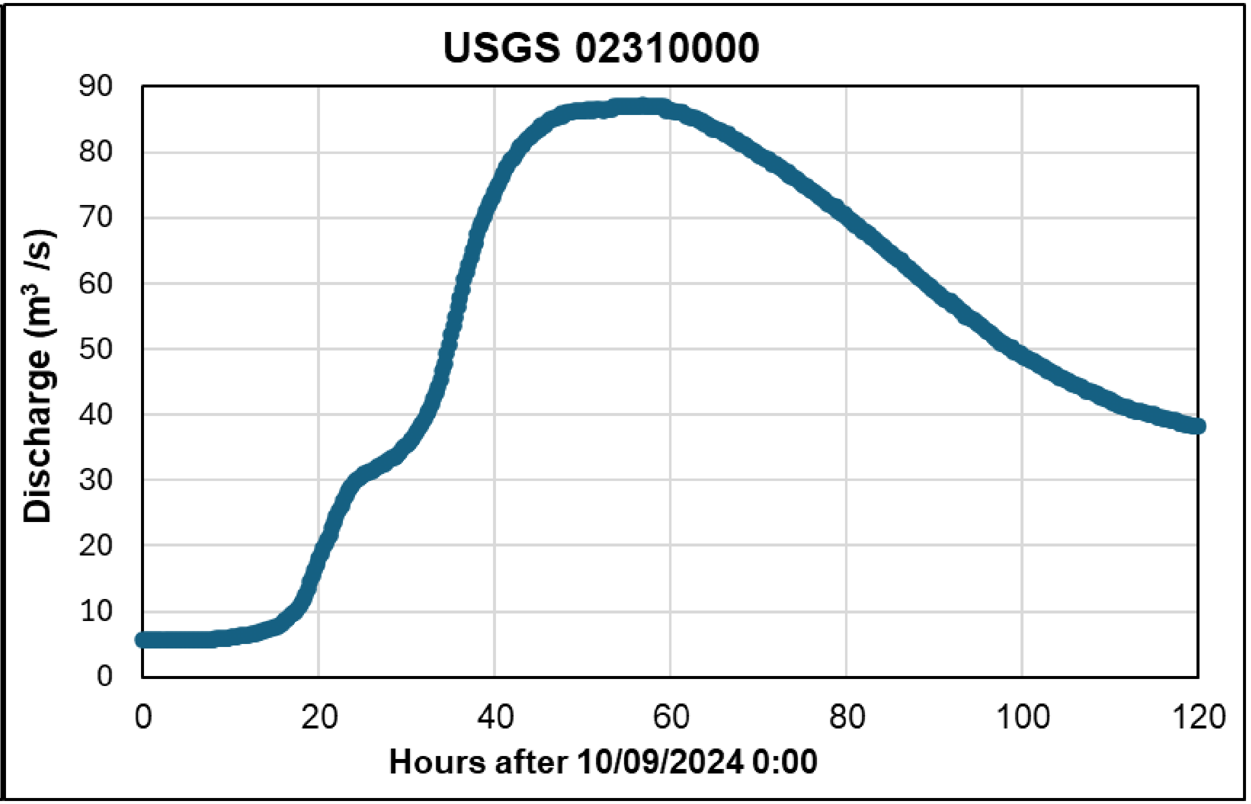
Low tide with high discharge (largest gradient)



- **The negative surge event occurred before the large discharge event**
- **Large water-level gradient of 3.75 m during low-tide post Milton (+3.25 m at the landward boundary and -0.5 m at the seaward boundary)**

Worst case- Helenes's surge and Milton's rainfall: Compound Flooding

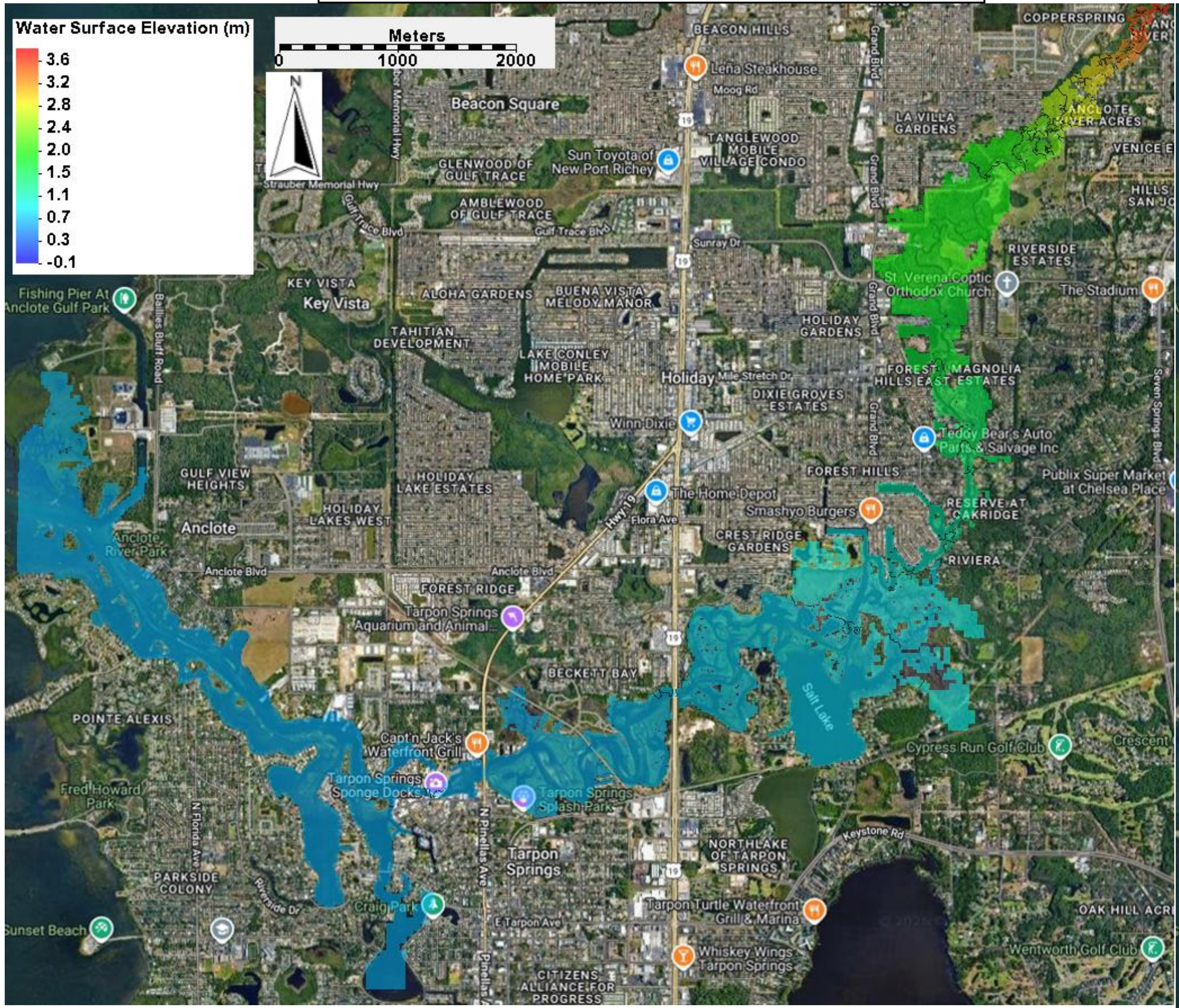




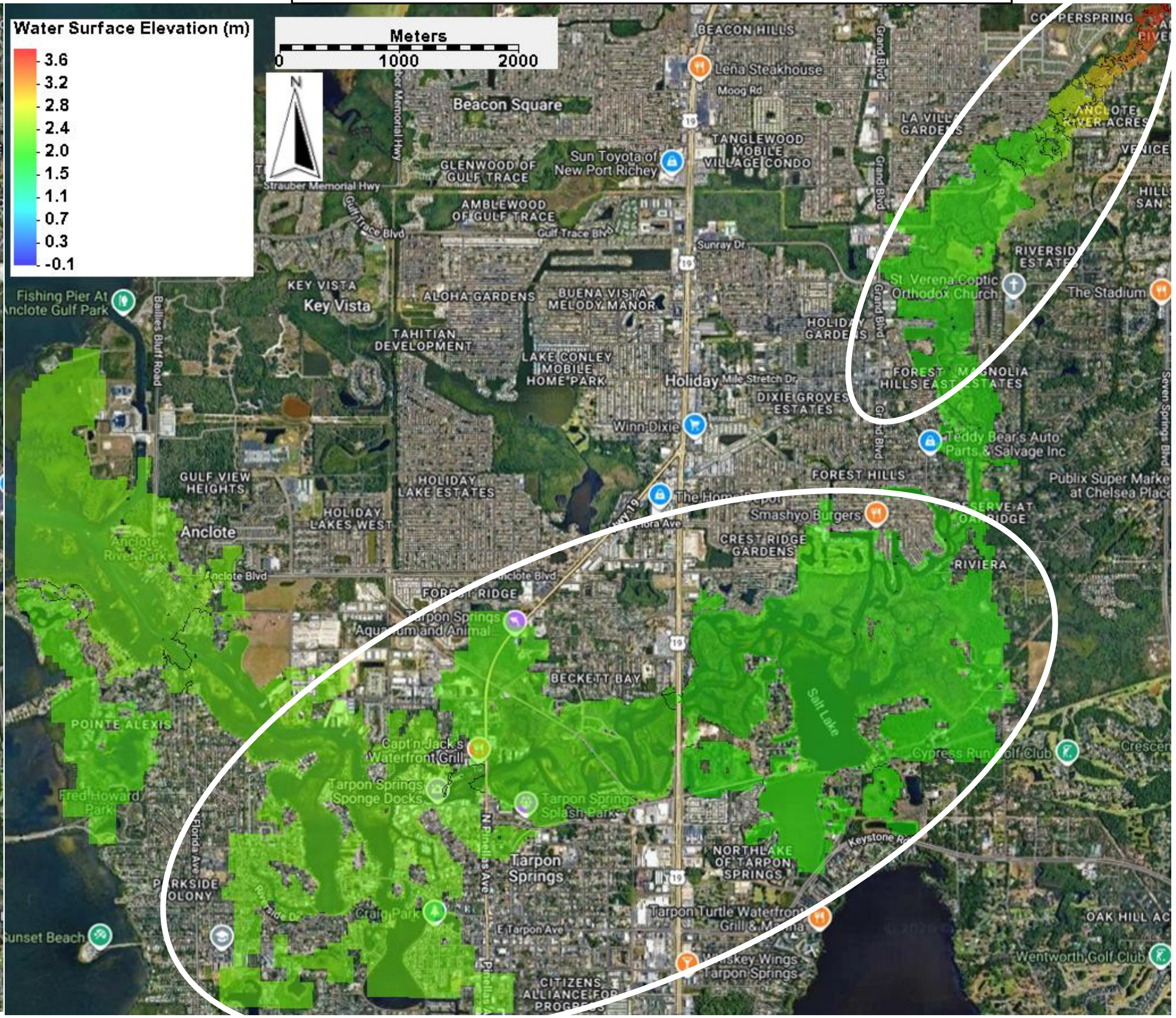
- **Helene's +2.3 m positive surge in tandem with the high discharge values associated with Milton**
- **These two events occurring simultaneously would result in a large compound flooding event**

Worst Case Scenario
Helene’s positive surge and Milton’s rainstorm event

Regular high tide with high discharge

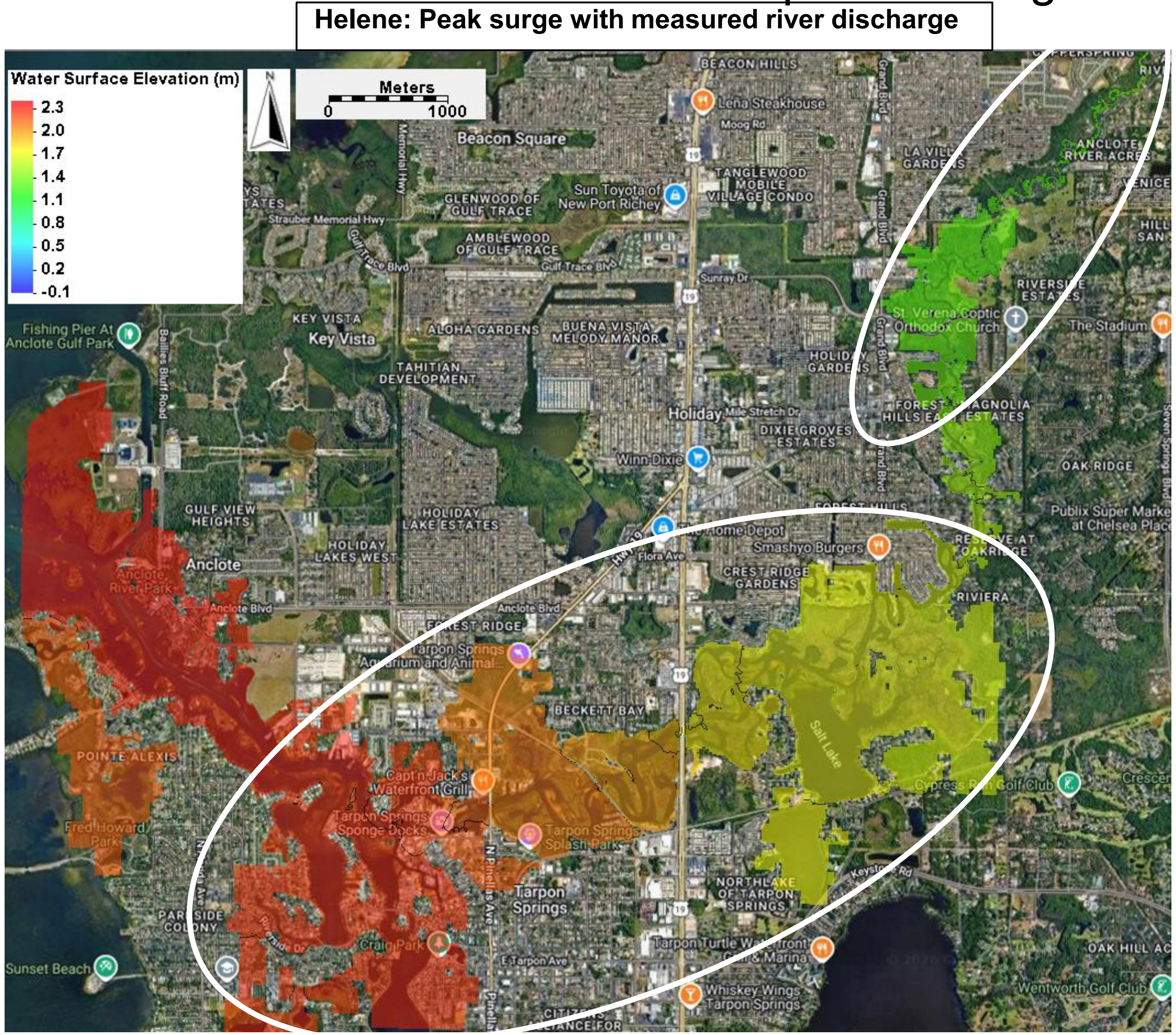


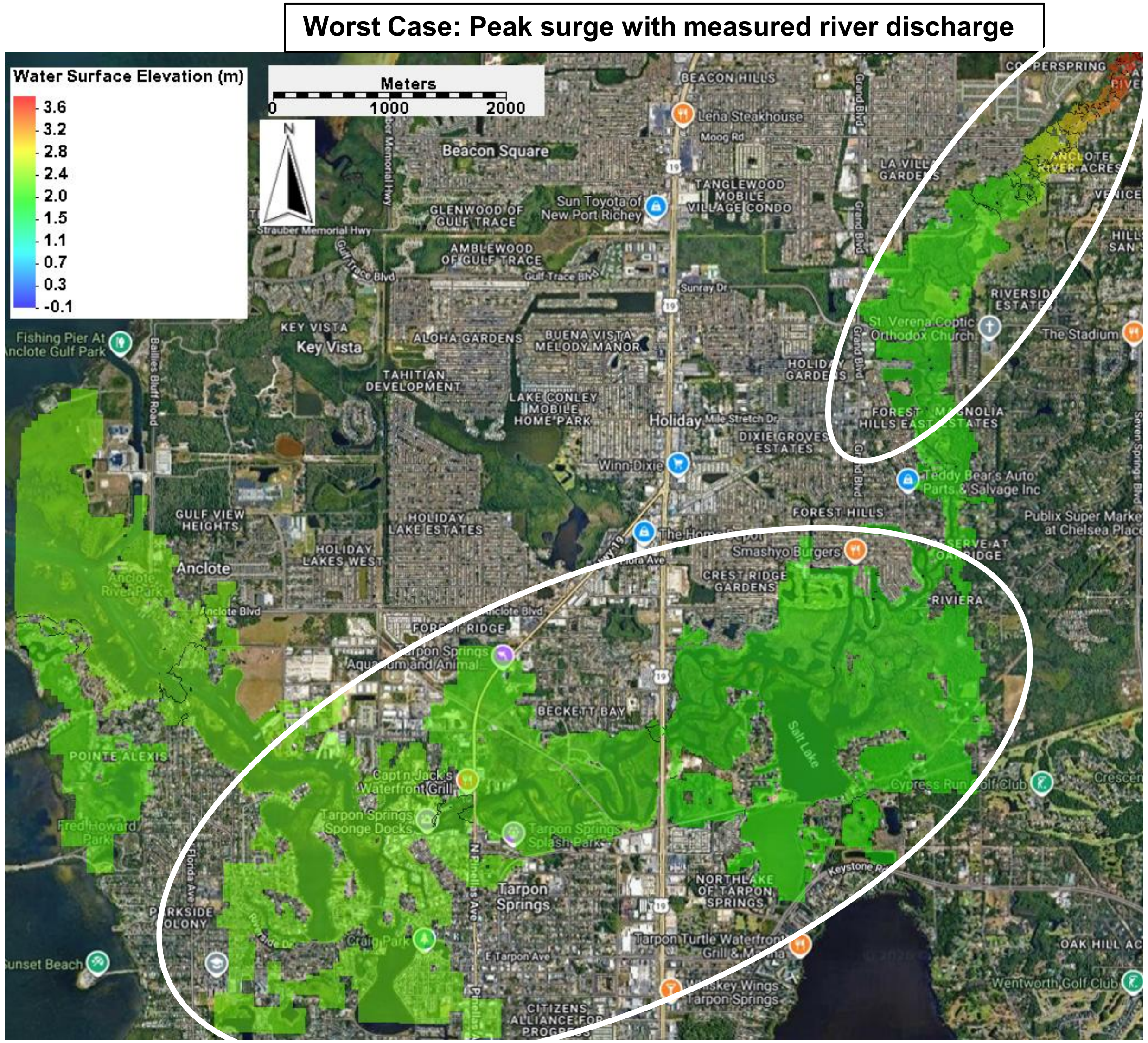
Peak surge with measured river discharge



- **Large areas were flooded.**

Worst Case Scenario
Helene's positive surge and Milton's rainstorm event

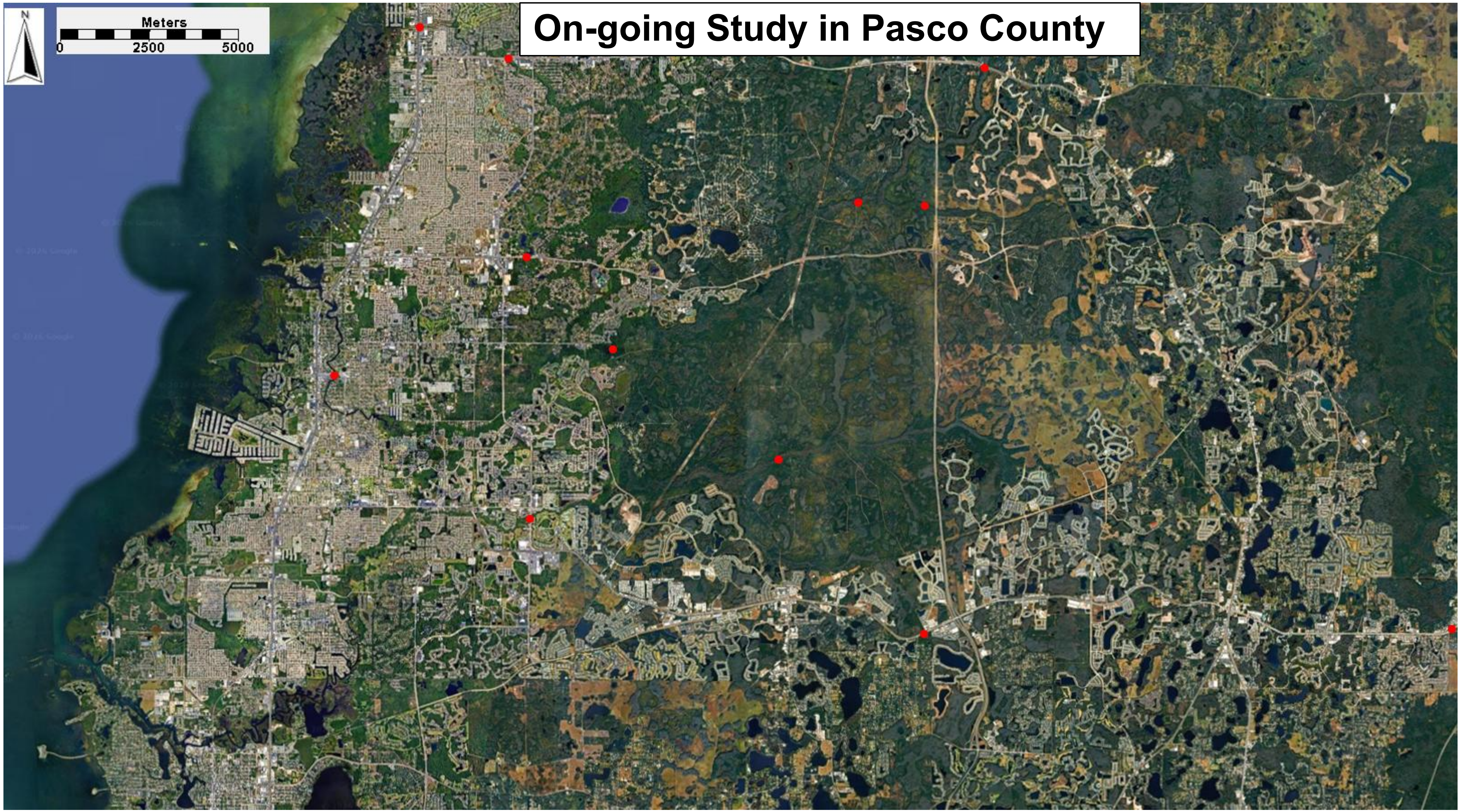




- **Large areas were flooded.**

- Summary
  - The banks of the Hillsborough River are high and the river is well confined. It is not as susceptible to compound flooding because of this.
  - Anclote is a much more vulnerable to flooding due to the low surrounding area and less confined river system.
  - Water level, bathymetry, and land elevation are fairly easy to measure. With these data, flooding by storm surge, rainfall events, and compound surge-rainfall can be computed accurately along complex coastal river systems using numerical models
  - Water-level measurements are essential to quantifying coastal flooding

On-going Study in Pasco County



- Existing gauges in the Pasco county area (that are currently operating)
- No data in low but populated areas prone to compound flooding (coastal or inland)
- Most gauges are in low wetland areas