# SURFACE AND SUBSURFACE HYDROLOGY AND FLOOD MITIGATION IN ESTERO RIVER HEADWATERS, SOUTHWEST FLORIDA

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## Introduction and Motivation

Five years of research have studied pond, wetland, and groundwater hydrology on the Florida Gulf Coast (FGCU) campus, a 400-acre system with some 200 acres of preserved wetlands; 100 to 150 acres of impervious surface; and 13 stormwater detention ponds. Florida regulations specify detention ponds for pollutant removal – they are not intended, and not effective, for mitigating flood runoff (Rodriguez, 2018; Krueger, 2019), even though they are widely perceived that way by residents (Wilkey et al. 2018). Previous research documents FGCU wetlands' importance in detaining runoff (Mullen et al 2020), mitigating flooding downstream in the highly-populated Estero River watershed. Typically, little or no runoff discharges from the FGCU campus headwaters into the river, even after extreme events like the September 2017 Hurricane Irma when downstream areas experienced flooding.

## Objective

Improve understanding of mechanisms where stormwater ponds, open-space wetlands, and groundwater interact to detain runoff and avoid flooding in a high-rainfall, low-relief, highly-developed watershed, especially their relative influence during high-precipitation events under a variety of antecedent conditions.

## Methods

- FGCU campus is instrumented with a network of gauges.
- Surface elevation data collected since 2017 by AWRA-FGCU Student Chapter volunteers at 12 manual gauges at 24-hour intervals through wet season, 7-day intervals during dry season.
- Water table elevation data collected since 2019 by Dr. Thomas and Dr. Rotz from 24 piezometers at 7-day intervals year-round since 2019.
- Automated sensors (5 surface, 7 groundwater) have recorded at 10-minute or 60-minute intervals since 2020.
- Paired sets of proximate sensors and piezometers document surface water-groundwater relationship for two locations.


Figure 1: The FGCU campus. Buildings and paved surfaces show clearly against undeveloped areas, nearly all seasonal wetlands. Darkest features (open water) are stormwater ponds. Squares highlight two surface water sensors and two groundwater sensors that are used in this research. Stars show all other 17 surface water gauges and sensors.

## Results

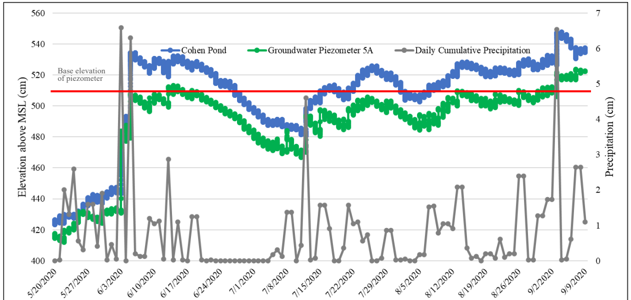


Figure 2: Surface water (Cohen Pond) and groundwater (Piezometer 5A) elevation, one wet season, June – September 2020, with 24-hour precipitation. Surface water and groundwater both rose rapidly with intense precipitation in dry conditions, June 3rd; declined during dry period June 20 – July 4; remained high through wet season, fluctuating with varying precipitation.

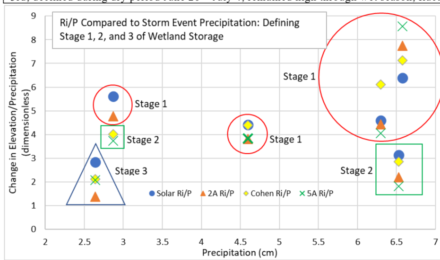


Figure 3: Surface water (Cohen and Solar Ponds) and groundwater (Piezometer 5A and 2A) elevation change per precipitation (Ri/P) of storm events in wet season 2020. Stage 1 storms have high Ri/P per precipitation and Stage 2 has low Ri/P per precipitation. Stage 3 Ri/P values are similar to those in Stage 2, yet with less precipitation; compares wetland storage before and after hydrated soils and standing water are present.

→ Surface water and surficial groundwater are closely coupled: elevations moved in tandem through 2020 wet season at both locations monitored. Elevation differences are explained by topography and water table gradient.

→ Surficial groundwater elevation is highly responsive to storm events: groundwater Ri/P greater, and attained more rapidly, than expected – typically asymptotic after 24 hours, vs 48-72 hours for surface water.

→ Wetland storage is activated when pond elevation is higher than lowest elevation of adjacent wetlands (Stage 2 per Mullen et al. 2020), i.e. base elevation of piezometer in adjacent wetlands, different for each pond. That may occur from high single-event precipitation or high (wet-season) water table.

- When pre-storm pond elevation is much less than wetland elevation (Stage 1), elevation change per unit precipitation (Ri/P) is much greater. Ponds are effective at capturing runoff, avoiding flooding. Groundwater also rises rapidly, but during dry season when water table is low, it does not affect ponds.
- When pre-storm pond elevation is high enough to spill into pond-adjacent wetlands (Stage 2), Ri/P is much lower. Ponds capture much less runoff and wetlands much more: common in wet-season events.
- Storm events when wetlands are hydrated due to high surficial water table (Stage 3) show higher Ri/P per magnitude of storm, confirming expected heightened propensity to flood during wet / saturated conditions.

## Discussion

1. *Future research* should verify findings with additional data: wet/dry seasons; high/low water table; Stage 1 vs Stages 2 and 3 at time of storm event; antecedent period rainfall; others.
   - Response of ponds and water table to a given storm event affected by many variables, and major storm events – crucial to understand for flood mitigation – occur so infrequently that long term observations are necessary.
2. *Implications for land-use decisions* suggest Southwest Florida communities should supplement existing flood mitigation (volume-based stormwater detention ponds), shown to be unsatisfactory in detaining runoff from high-precipitation events, with extensive open space. During wet season, when FGCU ponds overflow in high Ri/P events, wetlands accommodate runoff which would cause flooding in developments that lack comparable open space.

## Conclusions

- Relative importance of various mechanisms differs according to antecedent conditions, all driven to varying degrees by short term and long term precipitation.
- Groundwater and surface water are closely coupled, with groundwater rising rapidly in response to high-precipitation events.
- Response of groundwater to high-precipitation events mimics previously identified response of surface water during different antecedent conditions, i.e. greater Ri/P during Stage 1 conditions.
- Both groundwater and surface water persist at high elevation late in wet season; so high-precipitation are more likely to produce flooding than in dry season, even with substantially lower Ri/P during Stage 2. Capacious FGCU campus wetland storage avoids flooding even in those conditions.

## Acknowledgements

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