Assessment of Hybrid Infrastructure Systems under Multi-Flood Hazards in Coastal Georgia

Félix Santiago-Collazo[1], Matthew Chambers[1], Daniel Buhr[1], Haley Selsor[1], and Brian Bledsoe[1]

[1]University of Georgia

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Abstract

Tropical coastal communities accommodate critical infrastructure, densely-populated urban regions, tourism-driven economies, and industrial facilities. These communities are prone to multiple flood hazards such as nuisance flooding, tropical cyclones, extreme rainfall events, and sea-level rise (SLR). Thus, governments and stakeholders Are pursuing a range of measures to enhance flood resiliency. These alternatives can be classified into structural (i.e., conventional infrastructure), non-structural, natural and nature-based features (NNBF), and hybrid systems. While there is a large body of published work on coastal risk reduction via conventional infrastructure and NNBF, there is a paucity of information on Hybrid Infrastructure Systems (HIS) in the literature, especially under multi-flood hazard scenarios. This research aims to assess various HIS under multiple flood hazards for flood reduction and wildlife and habitat benefits in the coastal community of Tybee Island (Georgia, US). This community is the most densely populated barrier island in Georgia and receives over 1 million visitors each year. The Interconnected Channel and Pond Routing (ICPR) hydrodynamic model was selected to simulate hydrologic (e.g., rainfall and infiltration) and coastal (e.g., tides, storm surge, and SLR) processes, and various combinations of HIS including several conventional infrastructures (e.g., stormwater drainage system, culverts, pump systems), inland (e.g., bioswales and pocket parks) and coastal (e.g., horizontal levees and retention ponds with smart tidal gates) NNBF. Results show that NNBF can prolong the service life of conventional infrastructure in a HIS by reducing flooding stress on these structures while promoting wildlife habitats and marsh conservation by increasing the hydraulic connectivity in the tidal river system. HIS alternatives were ranked using multi-criteria decision analysis. The local government, residents, and stakeholders will select their preferred alternative for detailed design. Local studies and modeling of multi-hazard flood processes can provide insight into the performance of HIS, thus providing the opportunity to policy-makers and government agencies to improve design standards and permitting procedures for HIS at a regional scale.

Assessment of Hybrid Infrastructure Systems under Multi-Flood Hazards in Coastal Georgia

University of Georgia Institute for Resilient Infrastructure Systems | Network for Engineering with Nature

Félix L. Santiago-Collazo, Matt Chambers, Daniel Buhr, Haley Selsor, and Brian P. Bledsoe

School of Environmental, Civil, Agricultural and Mechanical Engineering
University of Georgia, Athens, GA, USA
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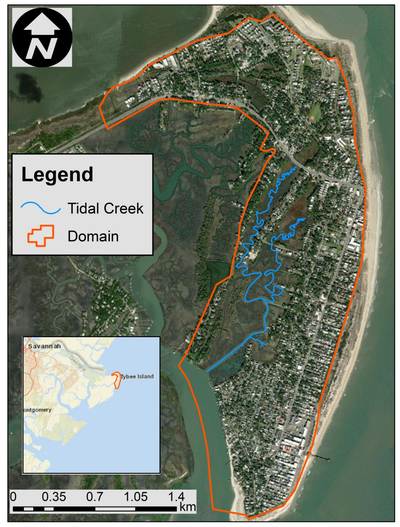
Introduction

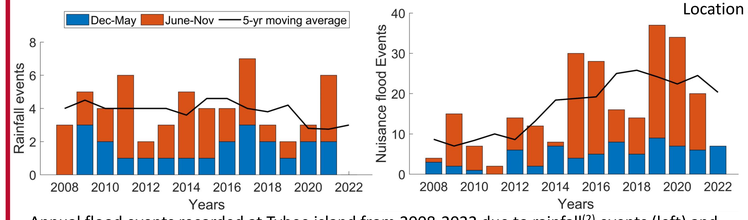
- Coastal communities faces multiple flood hazards:
  - nuisance flooding
  - extreme rainfall events
  - tropical cyclones
  - sea-level rise
- Climate change increase frequency and intensity
- Practical solutions should move towards Hybrid Infrastructure Systems (HIS)
  HIS= structural + non-structural + natural and nature-based features (NNBF)

Tybee Island (Georgia, USA)

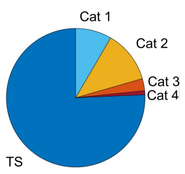
- 3,000 residents & 1 million visitors / year
- Current stormwater sewer system
  - Promotes saltwater flooding
  - Fails under a 10-yr rainfall event (190 mm in 24 hr)
- Current relative sea level trend[1]: 3.44 ± 0.26 mm/yr



Location of Tybee Island within the east coast of US

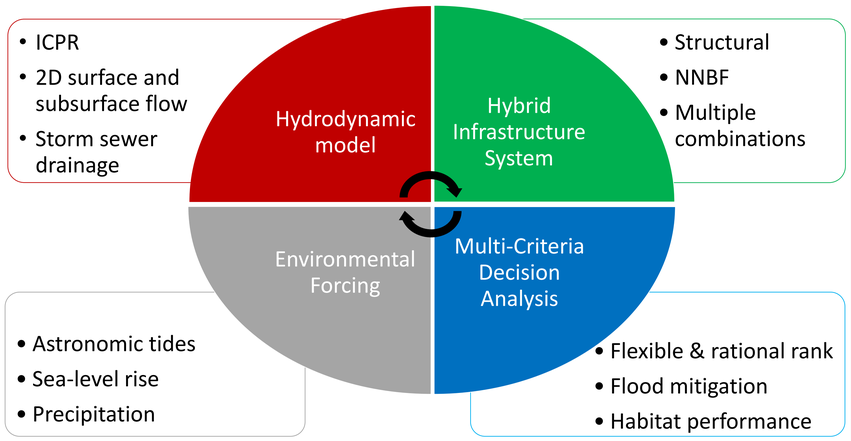


Annual flood events recorded at Tybee island from 2008-2022 due to rainfall[2] events (left) and nuisance flood[1] events (right)



Distribution of tropical cyclones [3] within 50km of GA coastline (1853-2022) based on the Saffir-Simpson Hurricane scale

Modeling Framework & Hybrid Infrastructure System



NNBF Options

- Horizontal Levee
- Rain Harvesting
- Permeable Pavers
- Pocket Park
- Curb Cut Rain Garden
- Swale
- "Pocket" Parks
- Urban Tree Canopy

Structural Options

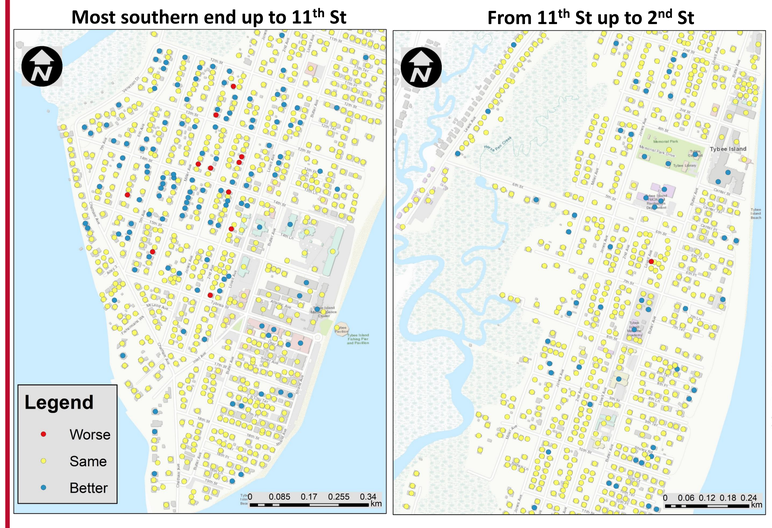
- Tidal Culvert Enlargement
- 2.28 km of additional pipes
- 50% of the existing system will have an increased diameter Backflow prevention outfalls

HIS Alternatives

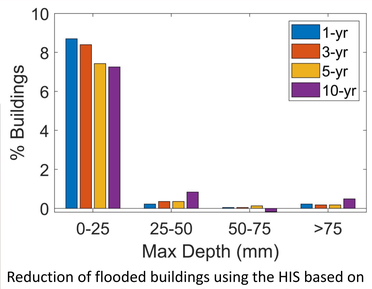
1. Public
2. Public + Commercial
3. Public + Residential
4. Public + Residential + Commercial

Location of the proposed NNBF at the south region of the island

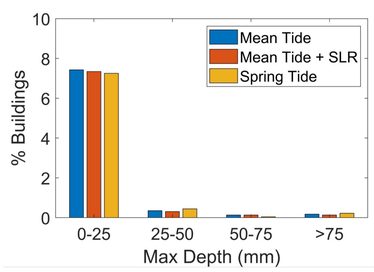
Results



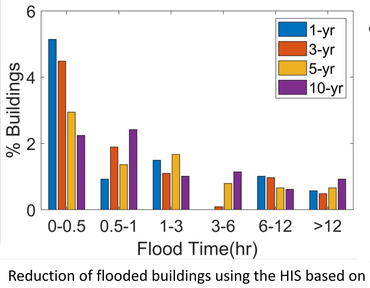
Comparison of buildings flooded (Base – HIS) for a 1-yr rainfall event using an average tide conditions
Worse = building flooded for HIS and not for Base
Better = building flooded for base and not for HIS



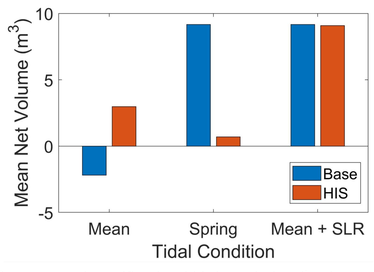
Reduction of flooded buildings using the HIS based on the maximum flood depth for each rainfall return period using an average tide conditions



Reduction of flooded buildings using the HIS based on the maximum flood depth for each coastal condition using a 5-yr rainfall event



Reduction of flooded buildings using the HIS based on the flood time (flood depth ≤ 25 mm) for each rainfall return period using an average tide conditions



Net volume (flood – ebb) through the 6th culvert averaged in time for each coastal condition using a 5-yr rainfall event

Future Work & Preliminary Conclusions

Future Work

- Simulated the different HIS alternatives under the various environmental forcings
- Execute the Multi-Criteria Decision Analysis and select the "best" HIS alternative
- Draft the 50% design of each component of the selected HIS

Preliminary Conclusions

- HIS can prolong the service life of structural features while providing many co-benefits, such as wildlife habitats enhancement, recreational opportunities, and improving urban esthetics
- HIS need to be assessed under multi-flood hazard events, especially for coastal communities

Acknowledgement & References

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1) National Oceanic and Atmospheric Administration (2022), "Fort Pulaski, GA Station (8670870)". Tides & Current dataset, [https://tidesandcurrents.noaa.gov/stationhome.html?id=8670870].
2) Community Collaborative Rain, Hail, and Snow Network (2022), "Tybee Island Station (GA-CT-37)", [https://www.cocorahs.org/].
3) National Oceanic and Atmospheric Administration (2022), "Historical Hurricane Tracks". [https://coast.noaa.gov/hurricanes/#map=4/32/-80].