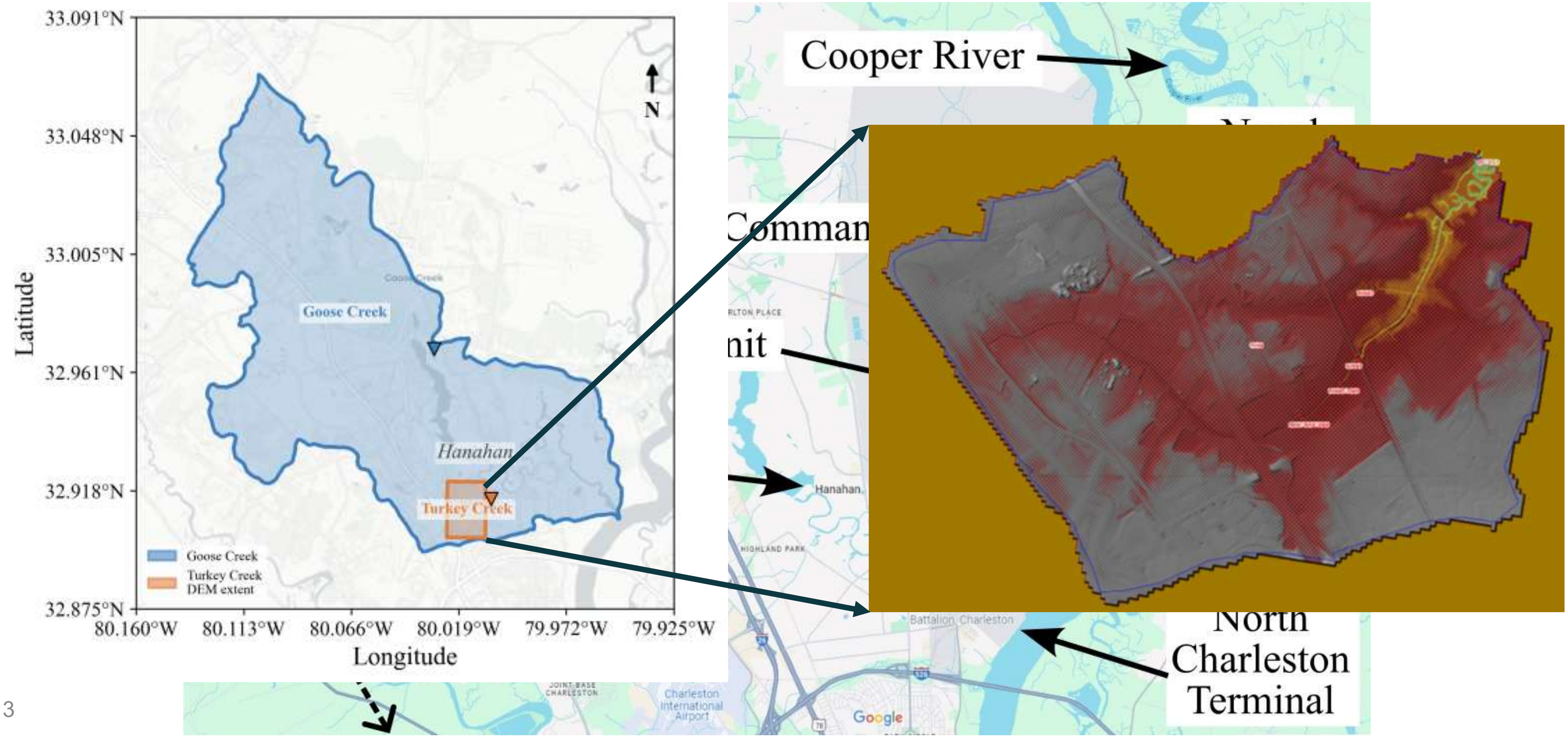
DATA-MODEL ASSIMILATION FOR URBAN COASTAL FLOOD RESILIENCE

City of Hanahan – September 8, 2026

Partners and Collaborators

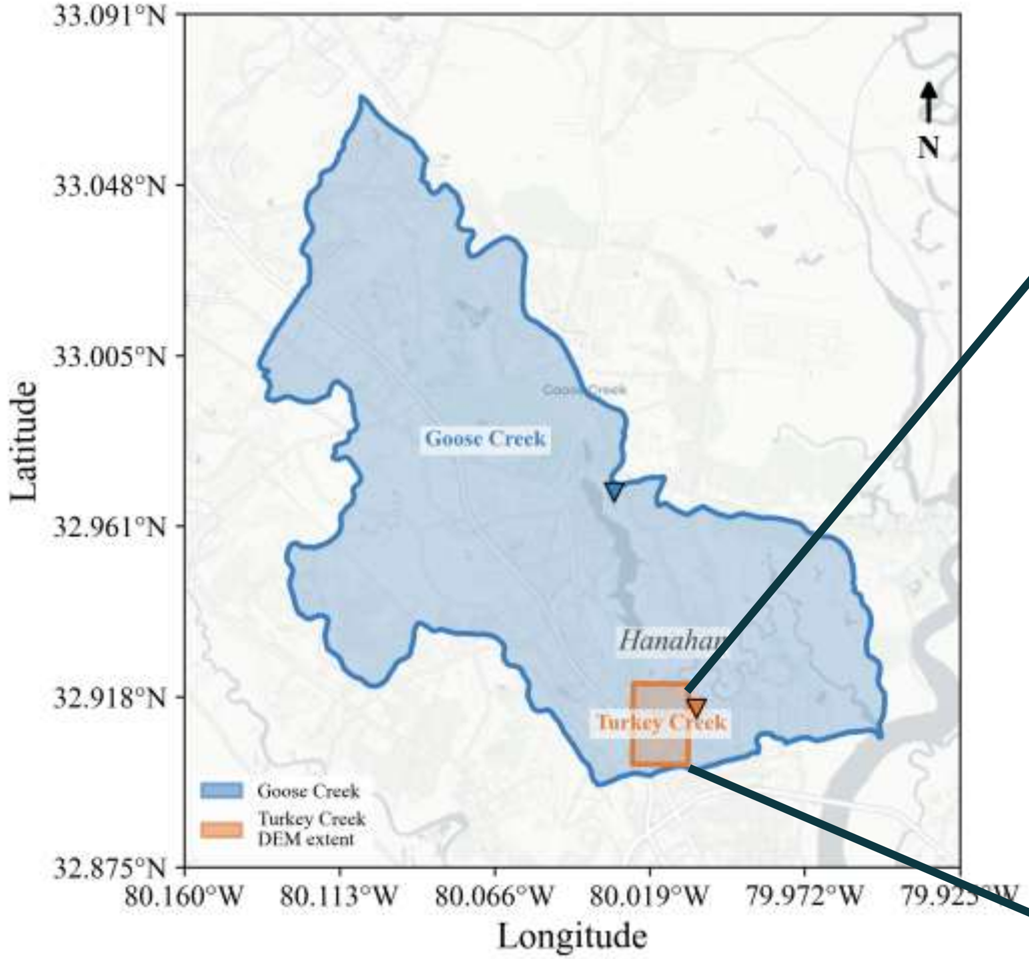
- *City of Hanahan*
- *Berkeley County*
- *Joint Base Charleston (Lindsey Graham)*
- *Community members*
- *Oak Ridge National Laboratory*
- *Lawrence Berkeley National Laboratory*

Testbed



33.091°N
33.048°N
33.005°N
32.961°N
32.918°N
32.875°N
Latitude
80.160°W
80.113°W
80.066°W
80.019°W
79.972°W
79.925°W
Longitude
N
Goose Creek
Hanahan
Turkey Creek
Goose Creek
Turkey Creek DEM extent
Cooper River
North Charleston Terminal
Hanahan
Battalion Charleston
Charleston International Airport
JOINT BASE CHARLESTON
HIGHLAND PARK
Google

Testbed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Longitude
N
Goose Creek
Hanahan
Turkey Creek
Goose Creek
Turkey Creek
DEM extent

Meet the Team


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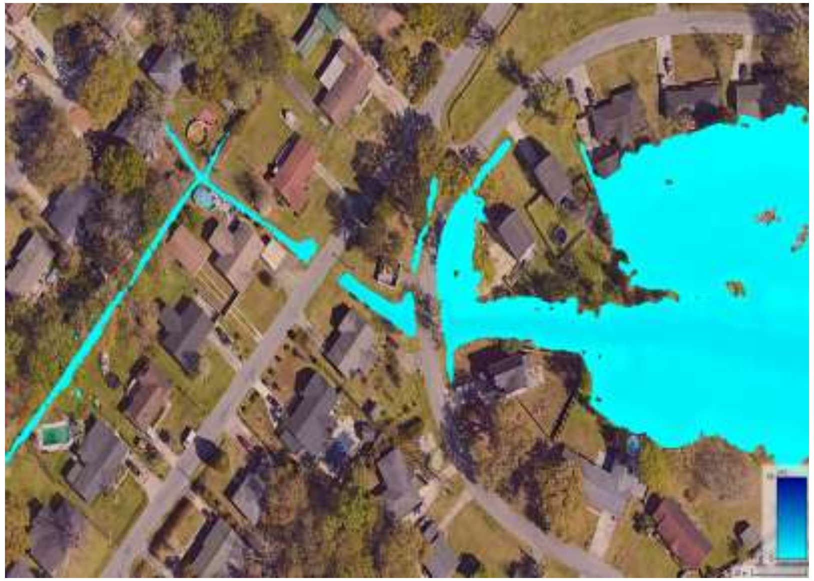
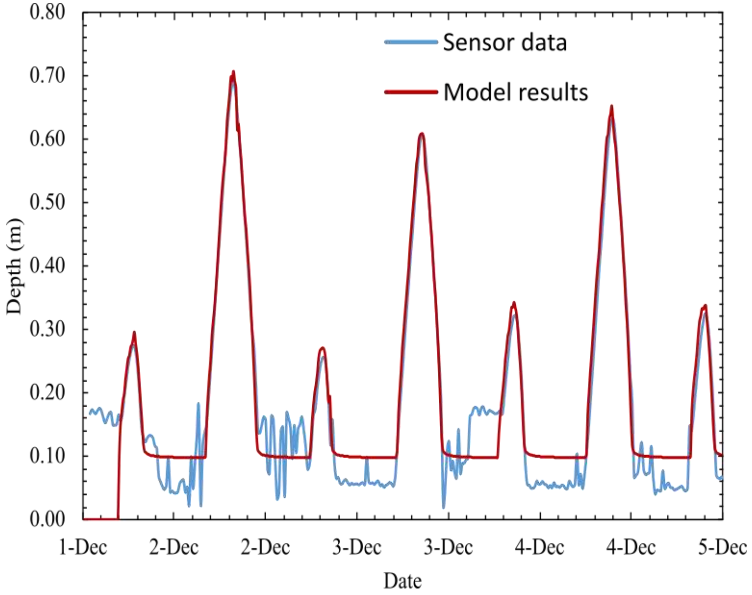
Md Ajwad Anwar

Usman Khan

Today's Talk

- Digital twin framework overview
- UAV deployable stage height sensor
- Field deployment in Hanahan, SC
- Flood modeling with HEC-RAS and TRITON
- Flood-Aware Intelligent Antifragile Traffic Signal Control



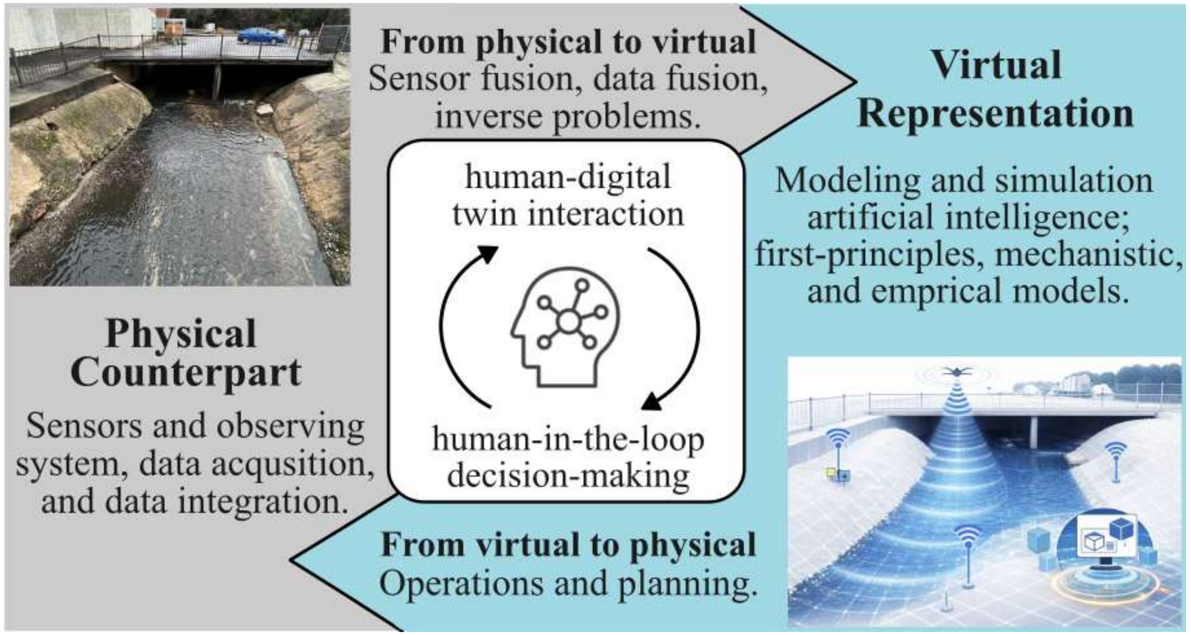


Flooding Digital Twin Framework

by: Prof. Austin Downey

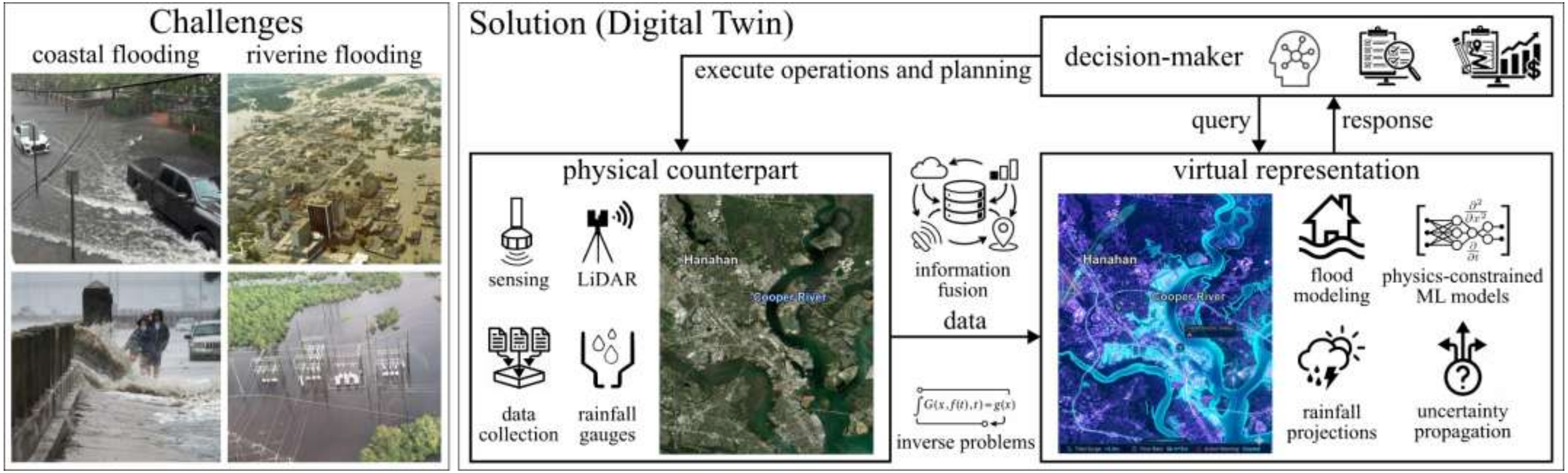
Elements of the Digital Twin Ecosystem

- Information flows bidirectionally between the virtual representation and physical counterpart.
- These information flows may be through automated processes, human-driven processes, or a combination of the two.



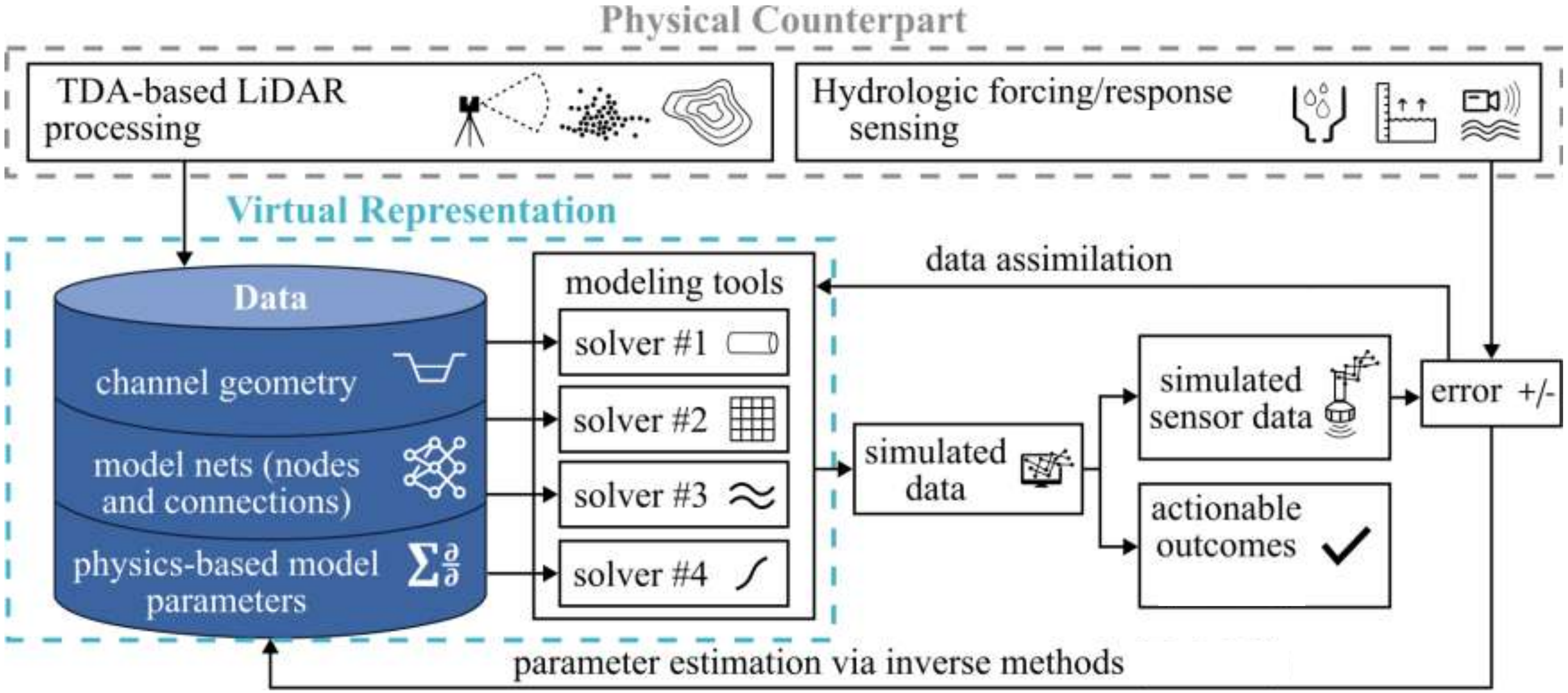
Decision-Maker Layer in the DT

- **Decision Maker:** Uses DT insights to issue controls
    - Actions are directed towards the physical counterpart
    - Queries are directed towards the virtual representation
- **Query/Response Loop:** The virtual representation answers targeted questions and provides predictions for informed decisions



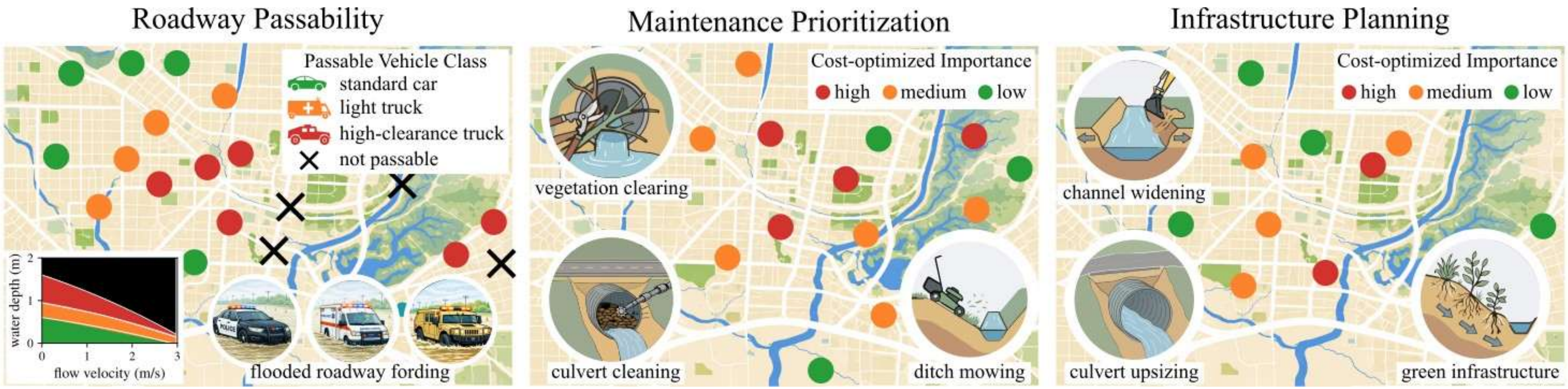
How We Build a Digital Twin

- We combine real-world data with physics-based models, update it continuously, and use it to answer practical questions.



From Data to Action: What the Digital Twin Delivers

- This isn't just a model—it will produce things cities can use immediately: safer routing, better maintenance decisions, and smarter investments.



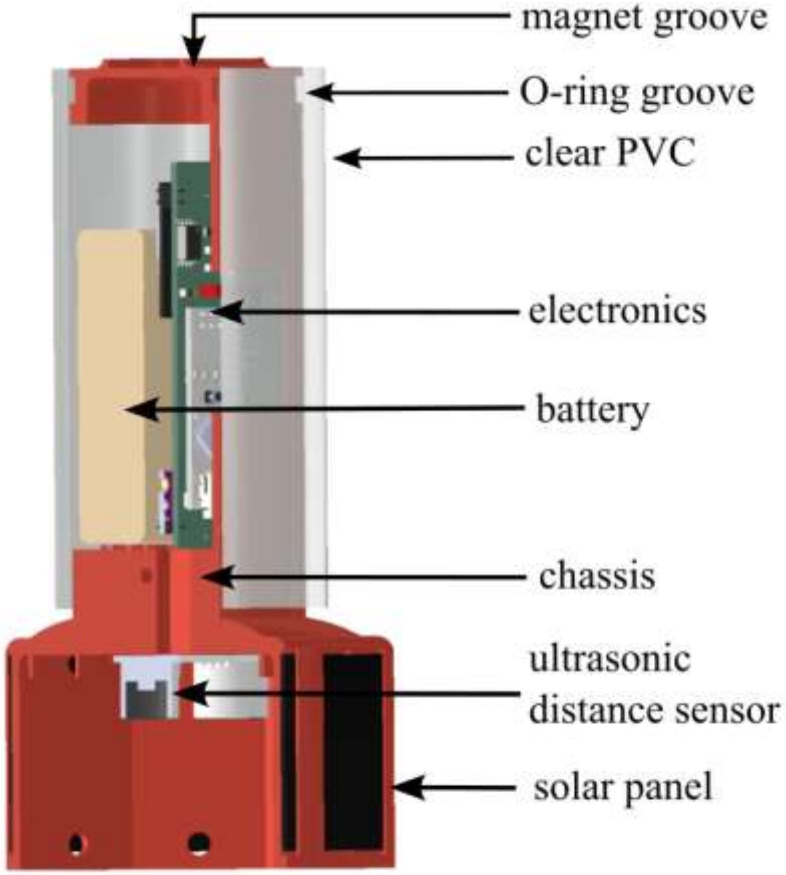
UAV deployable stage height sensor

Contributors: Md Asifuzzaman Khan, Tracy Tran, Ajani Davis, Carlisa Wright

Sensor design

- Based on open-source hardware and software
- 3D printed parts
- Size, Weight and Power constrained package
- All contained in one package
- Easy to deploy
- Focused towards citizen science

Full body view



Cross section view

SWaP-Constrained UAV-deployable Water-Level Sensor (SCUWLS)

The UAV deployable version

- An electro-permanent magnet (EPM) combines a permanent magnet with an electrically switchable magnetic field.

OpenGrab
EPM V3

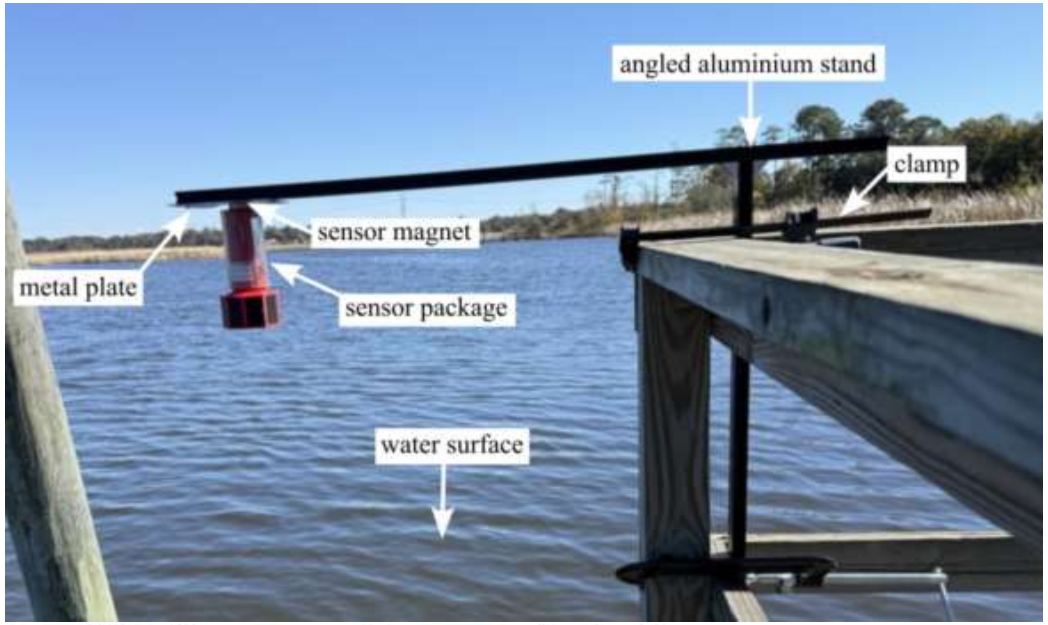
Field deployment

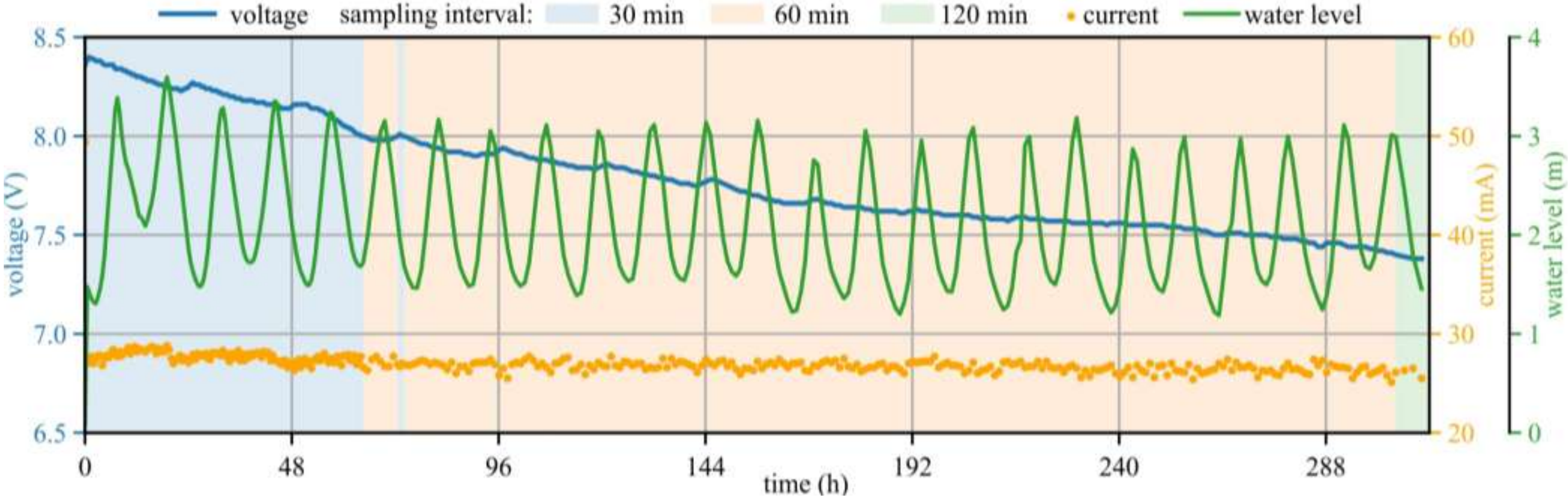
CITY OF HANAHAN
EST. 1973
SOUTH CAROLINA

HANAHAN
South Carolina

https://www.cityofhanahan.com/

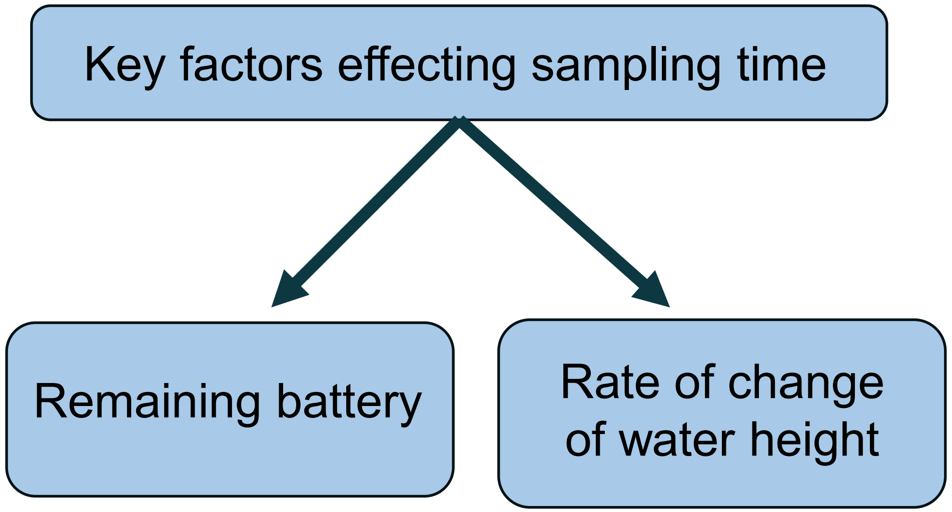
Deployed sensor at a dock at the intersection of Turkey Creek and Goose Creek

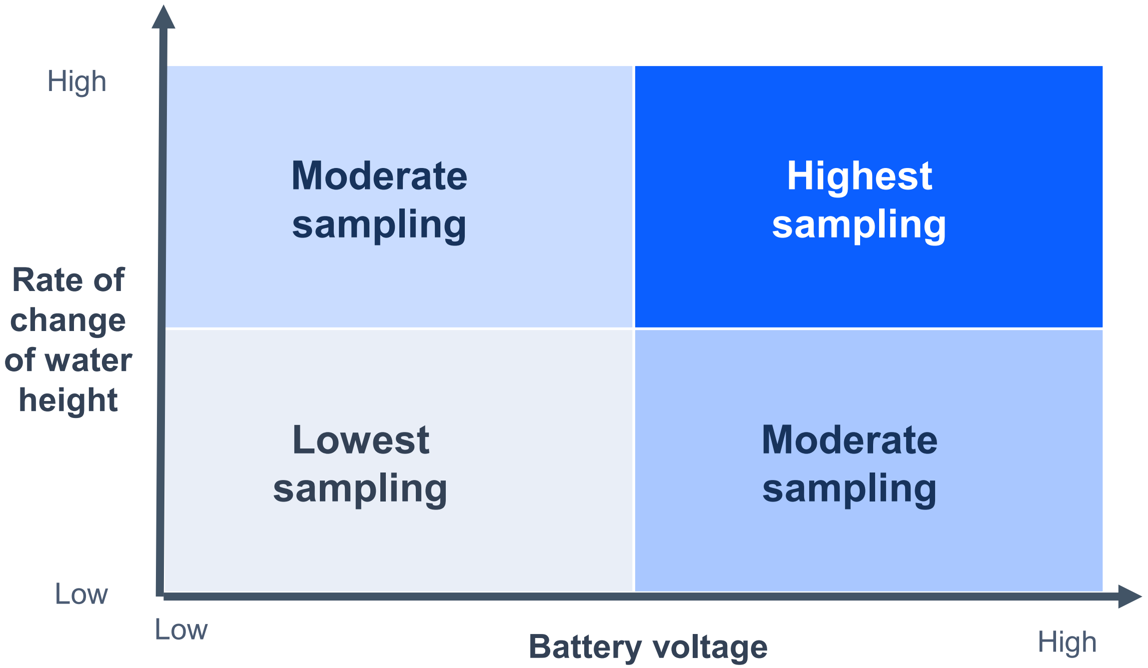




Firmware update

- Goal is to create a controller that dynamically sets the sampling interval for optimal power usage





Fast change + strong battery -> short interval
Stable water level + weak battery -> long interval

Field Deployment and Flood Modeling in Hanahan, SC

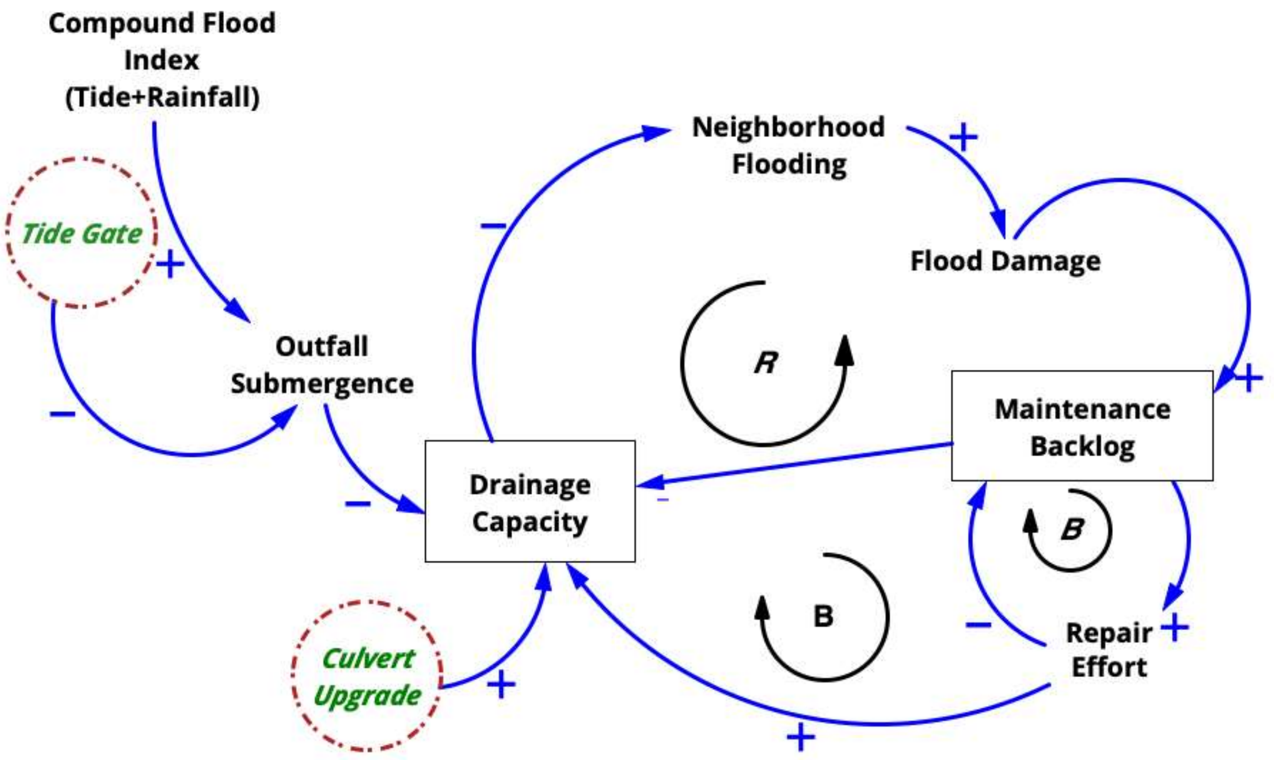
Contributors: Ayman Mokhtar Nemnem, Ajwad Anwar, Md Asifuzzaman Khan, Usman Khan, Shiva Balachandran, Ege Kurter

Understanding how flooding works in Hanahan

Not one cause — a system of connected causes

What we are mapping

- Tide and rain together (compound flooding)
- Drainage capacity
- What can be changed
- Cost to benefit

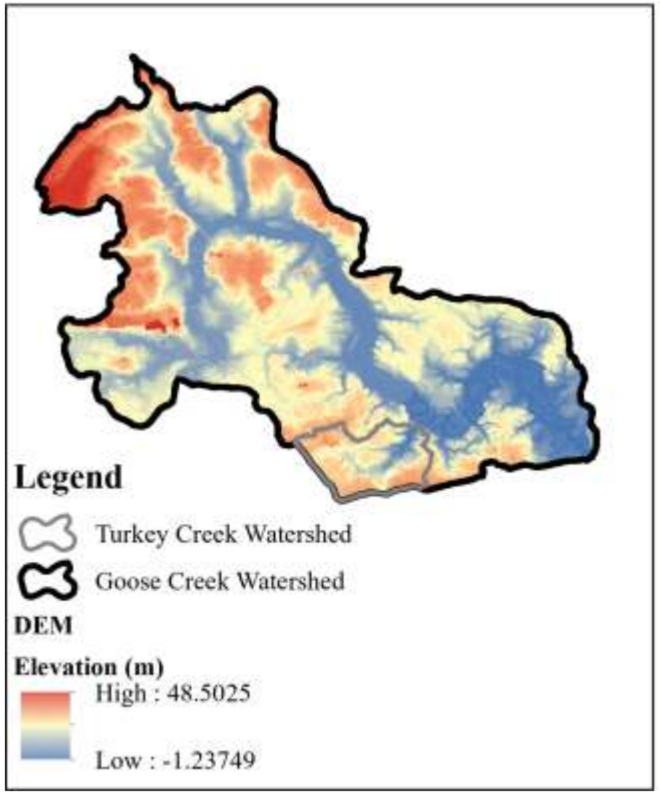


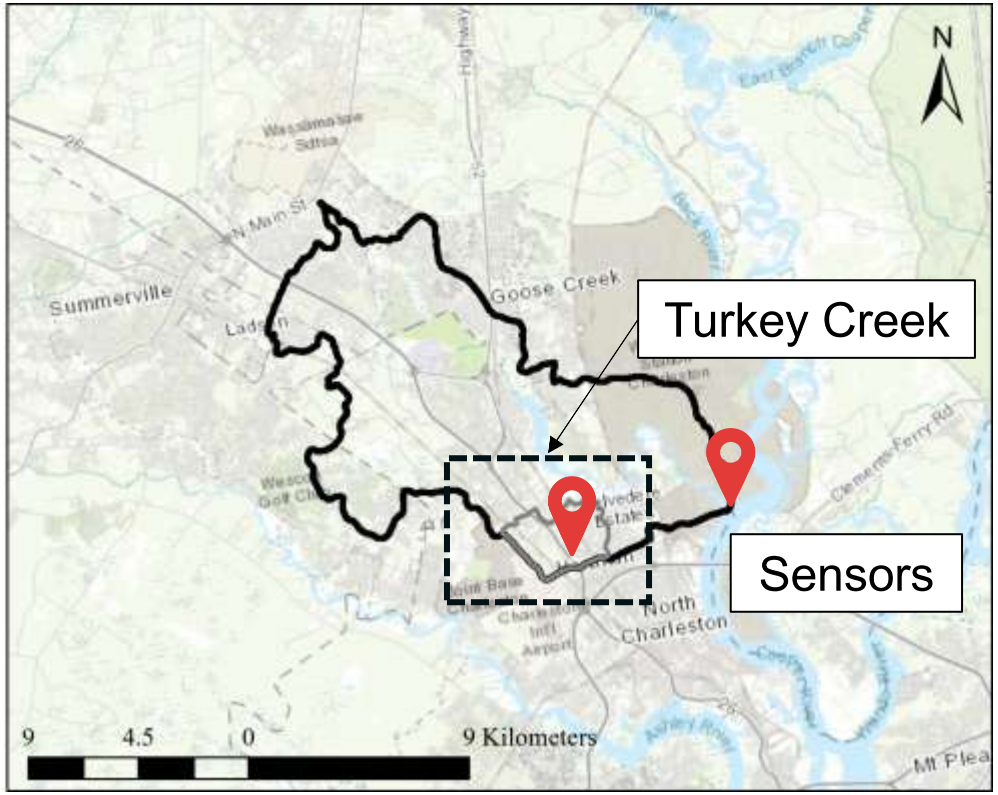
(+) one goes up, the other goes up
(–) one goes up, the other goes down

Causal loop diagram to understand the system dynamics

Turkey Creek Watershed

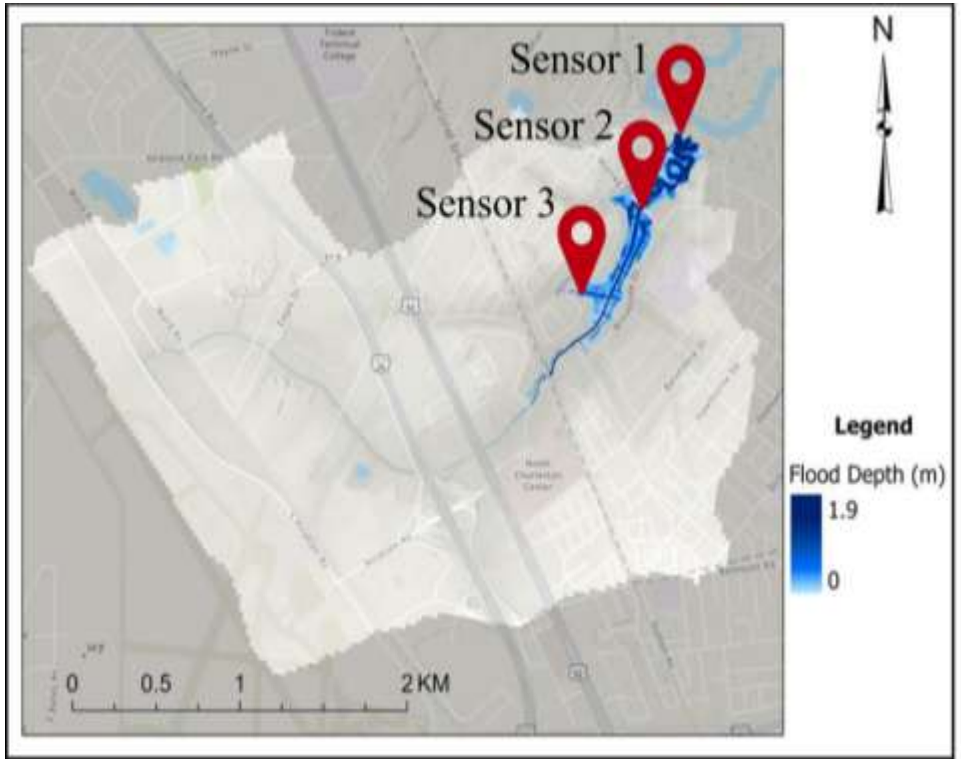
- Goose Creek watershed Area =143 km^2
- USGS Digital Elevation Model(DEM) 10 M resolution.
- Focus on the Turkey Creek watershed = 9 km^2
- Lidar 2 ft resolution
- Total of 4 sensors deployed

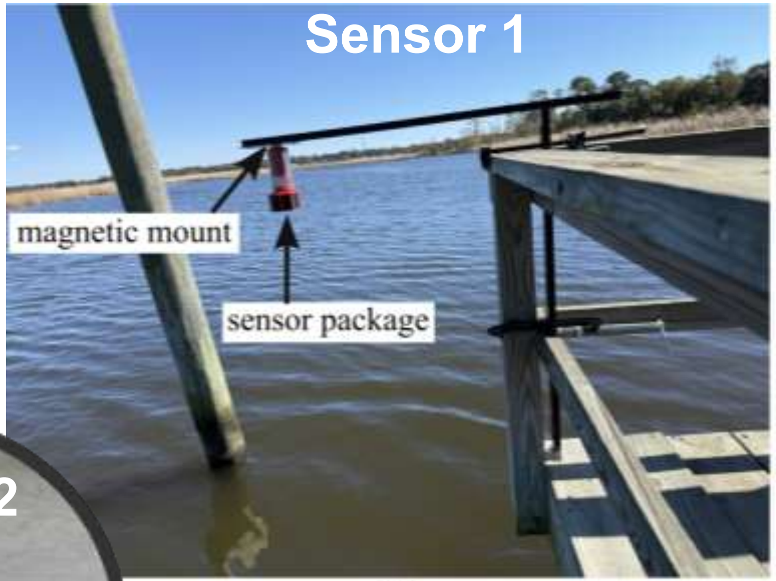




Field deployment

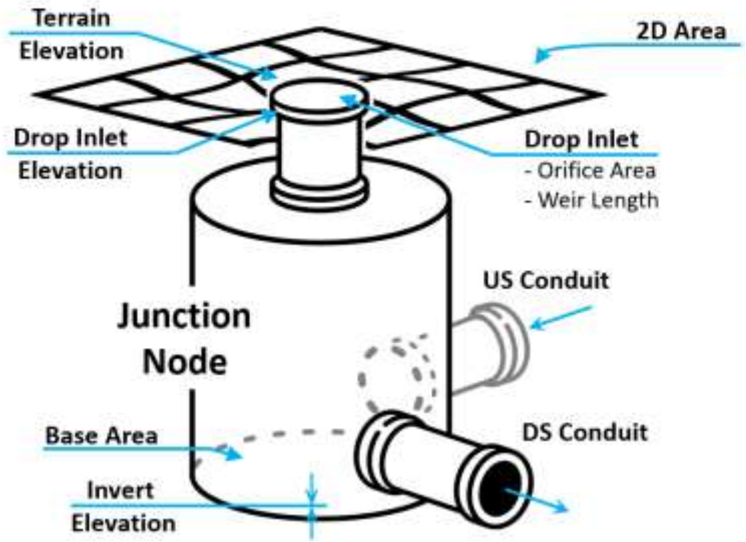
Turkey Creek, SC

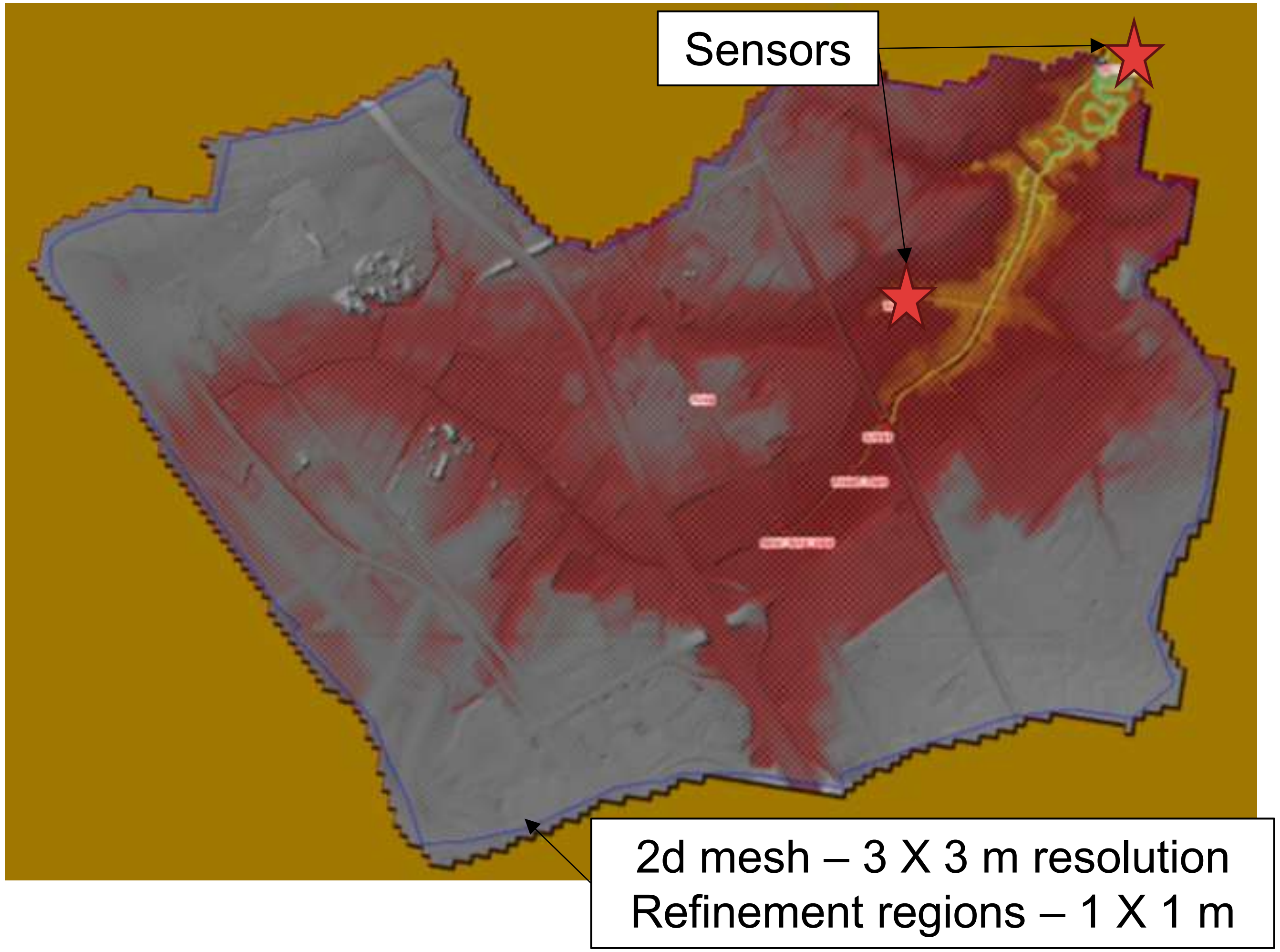




HEC-RAS Model Domain

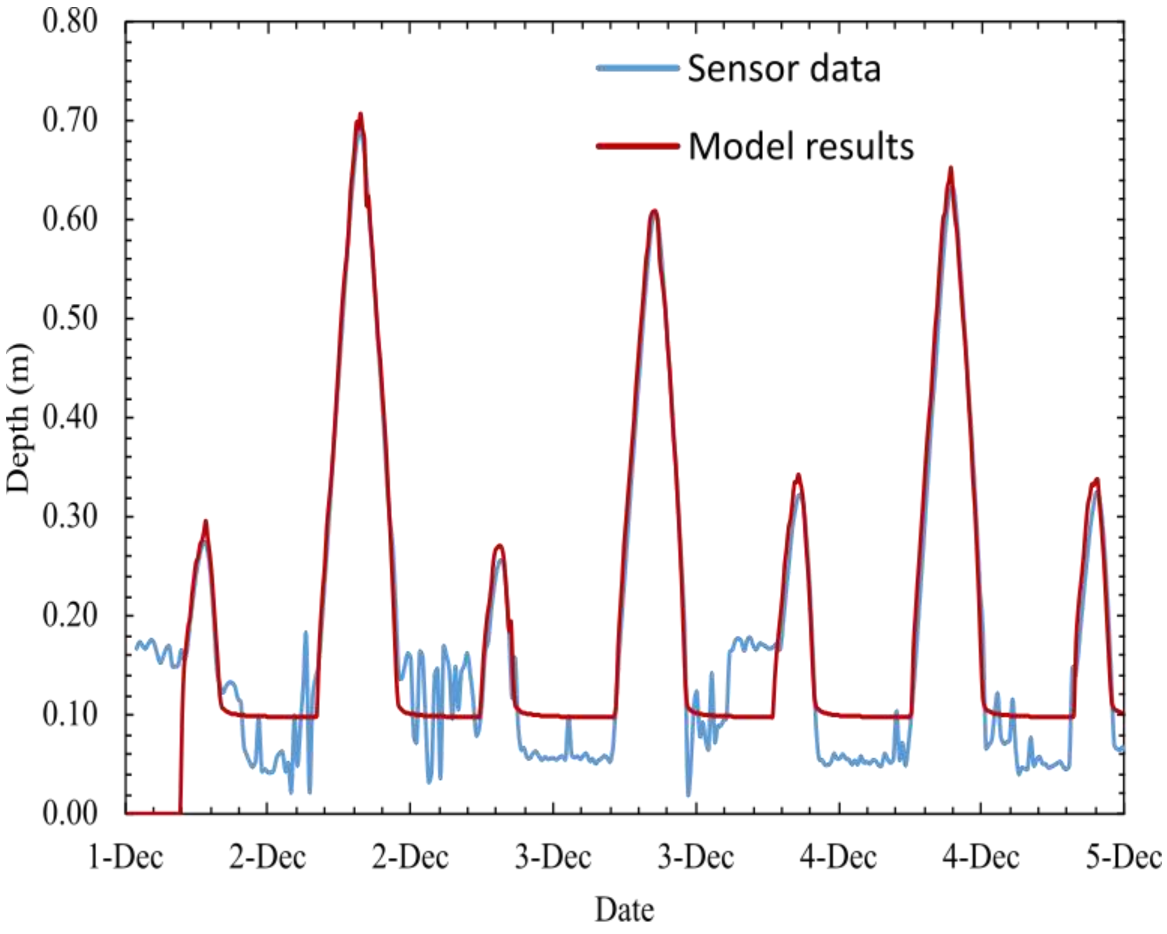
- USACE - HECRAS 2D model.
- Covers Turkey Creek watershed.
- No. of cells is 900k.
- Lidar 2ft DEM.
- Tidal boundary + excess rainfall over grid
- Next steps: incorporate storm networks



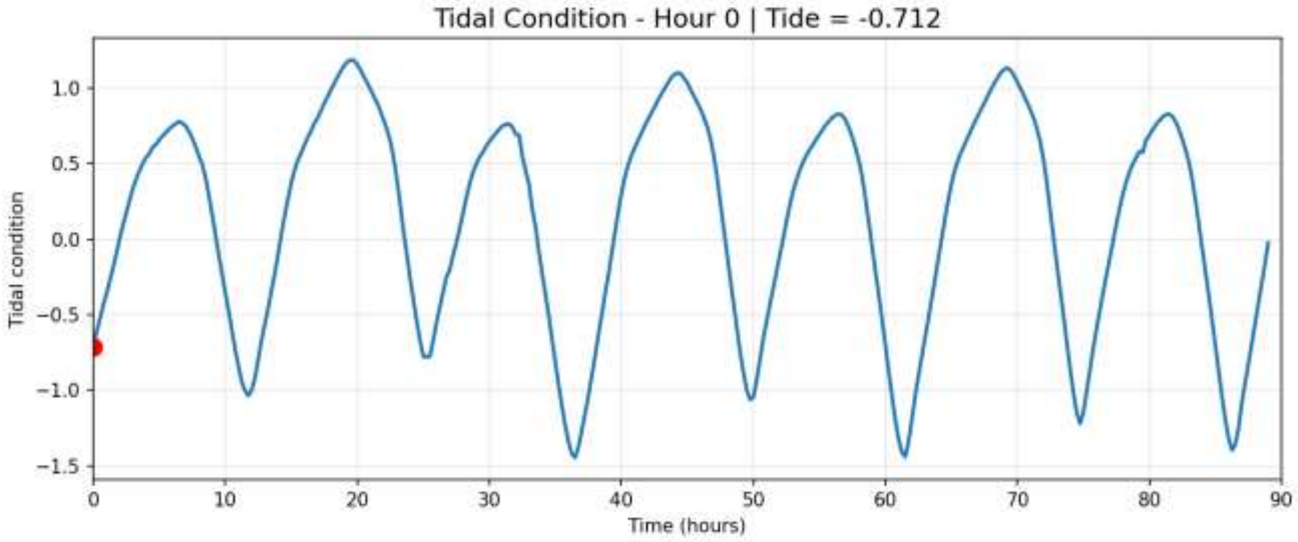


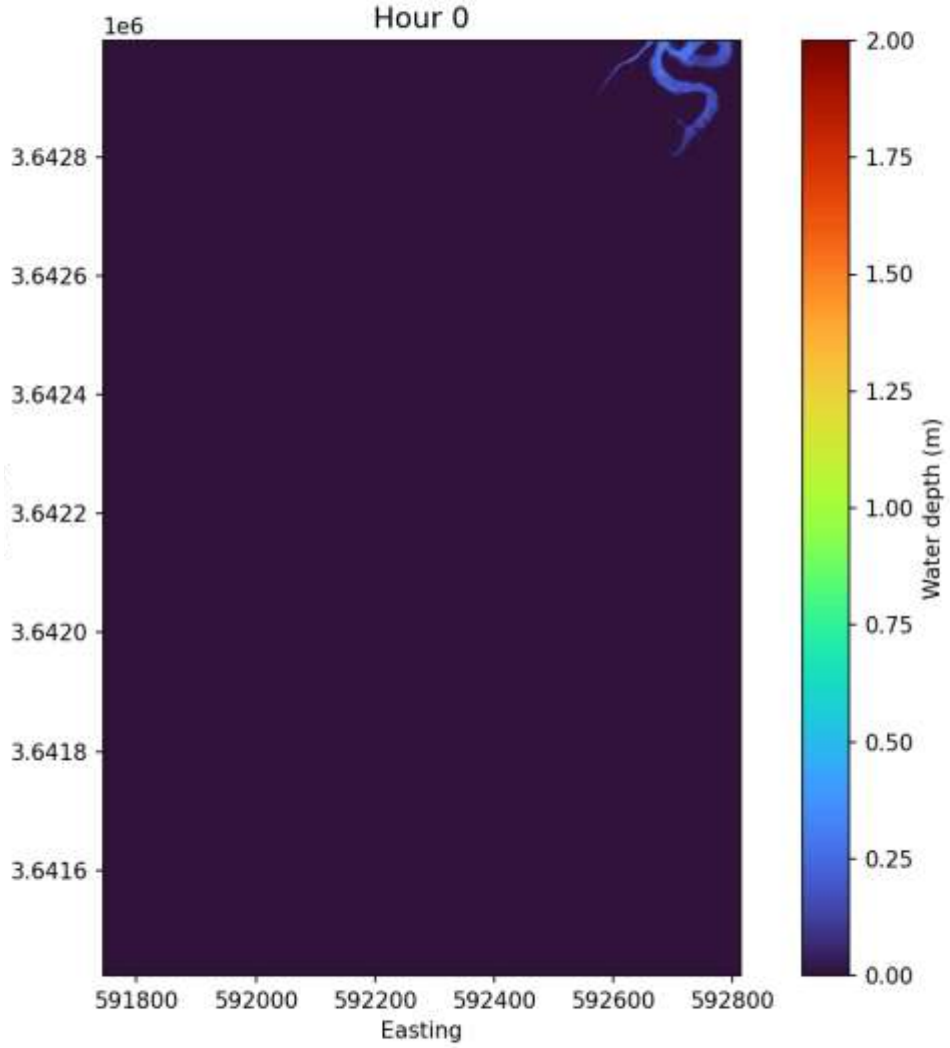
Results


Sensor 1
Sensor 2
Sensor 3
N
Date/Time
Depth (m)


Sensor data
Model results
Depth (m)
Date
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1-Dec
2-Dec
2-Dec
3-Dec
3-Dec
4-Dec
4-Dec
5-Dec

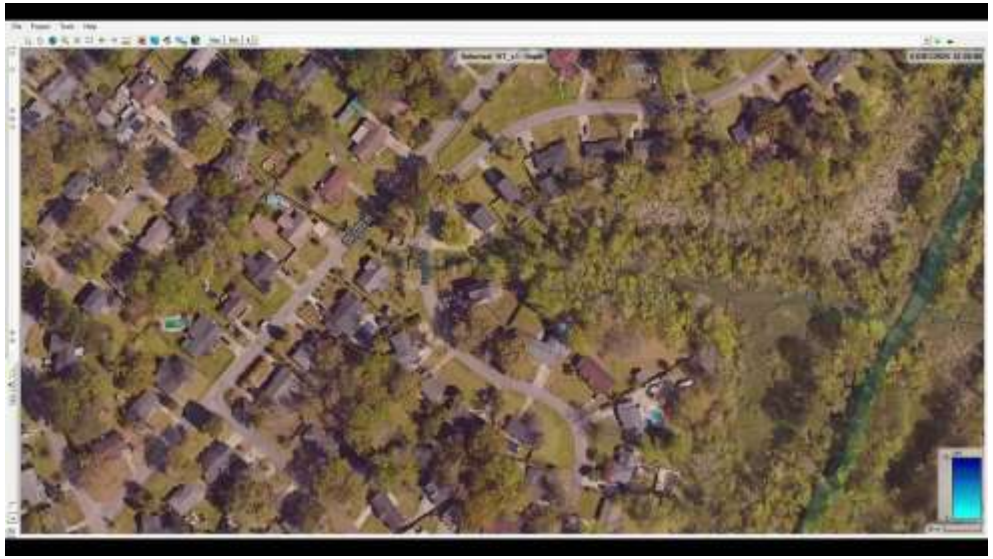
TRITON OPEN SOURCE MODEL (FAST SIMULATION)





Checking Different Scenarios

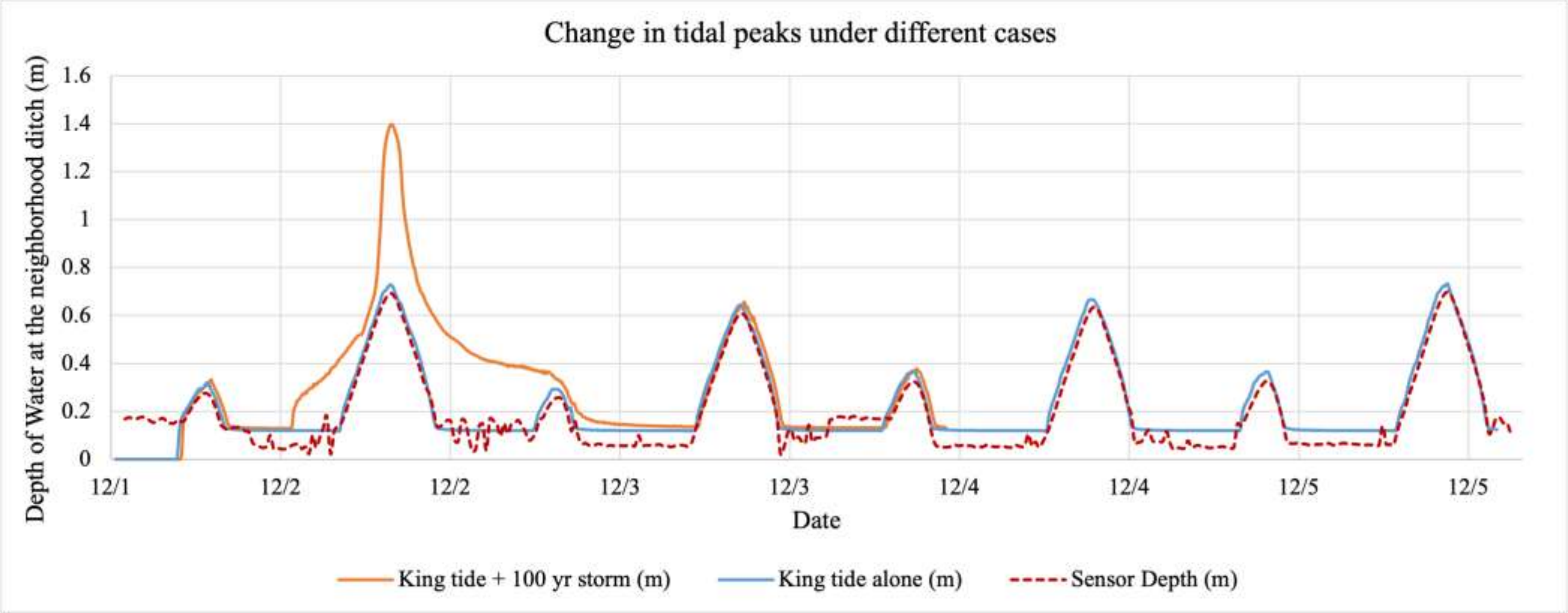
December King Tide Event with 100yr rainfall



December King Tide Event without rainfall

- Same king tide in all three cases
- **Without rain:** No ditch flooding
- **With a 100-year storm:** Redeemer and Hillside Drive floods
- The tide alone is manageable — it's the combination that causes flooding

Redeemer Drive Ditch Water Depth



- King tide + 100 yr Storm: Peak is almost double

Ongoing Work

An operational Digital Twin supported by real data, physics-based and system dynamics models

Testing what helps

- Different culvert size
- Ditch cleaning
- A tide gate to reduce the tidal amplitude in the creek
- Combinations

Two models, side by side

- Physics-based models — hours per run
- Fast system dynamics model — runs in minutes
- Checked against each other, and against a real sensor in the ditch

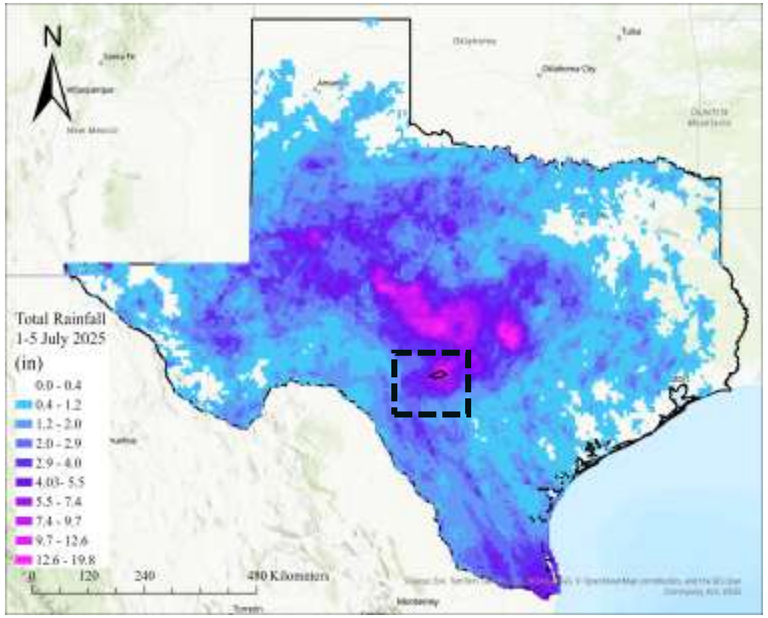
The goal: ask a question, get an answer promptly

Analyze various combinations of forcing and interventions to find the best possible flood management approaches.

Texas Camp Mystic flash flood

July 2025

- **>200 mm** rainfall in 12 hours
- **130 fatalities** (27 at Camp Mystic)
- **no upstream monitoring**

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STRATEGIC RIVER SENSORS COULD HAVE FOREWARNED OF TEXAS CAMP FLOOD DISASTER

WATER LEVELS UPSTREAM ROSE HOURS BEFORE CAMP MYSTIC'S DEADLY FLOOD

18 December 2025


EurekAlert!

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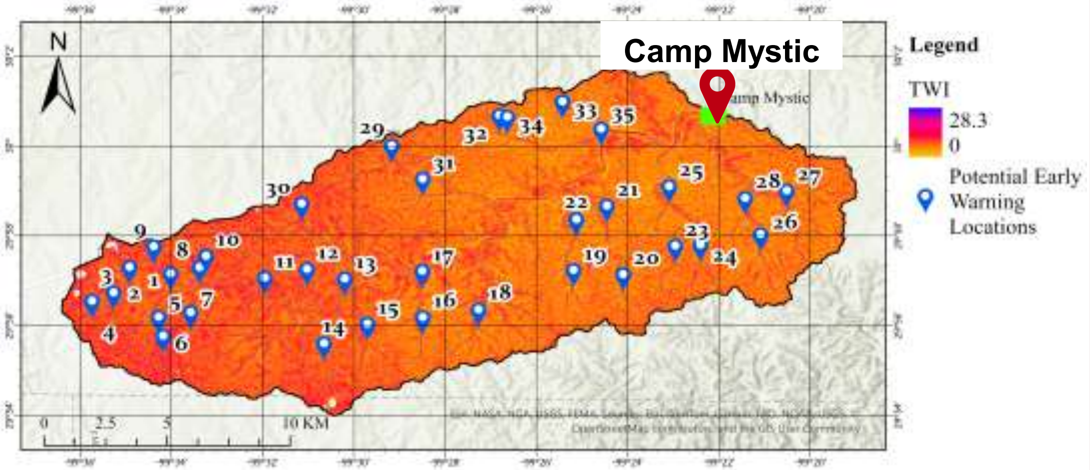
NEWS RELEASE 18-DEC-2025

Strategic river sensors could have forewarned of Texas Camp flood disaster

Water levels upstream rose hours before Camp Mystic's deadly flood

(Mokhtar et al., 2026)
Read the paper here



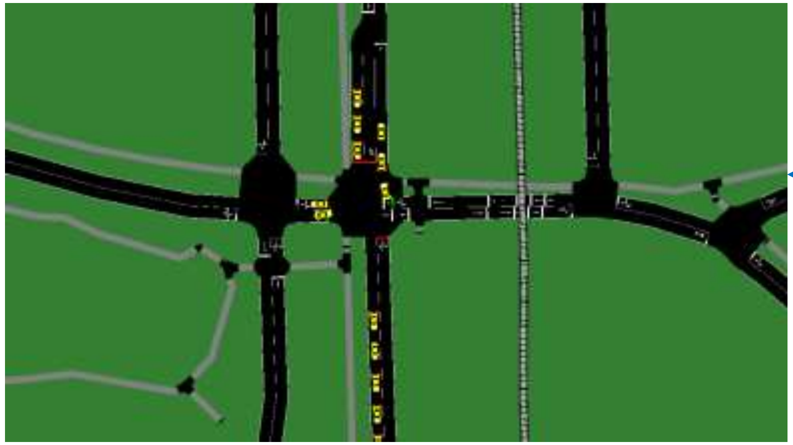
STUDY AREA and Traffic Simulation

Study area (Buist/Spruill, North Charleston, SC)

Satellite Image

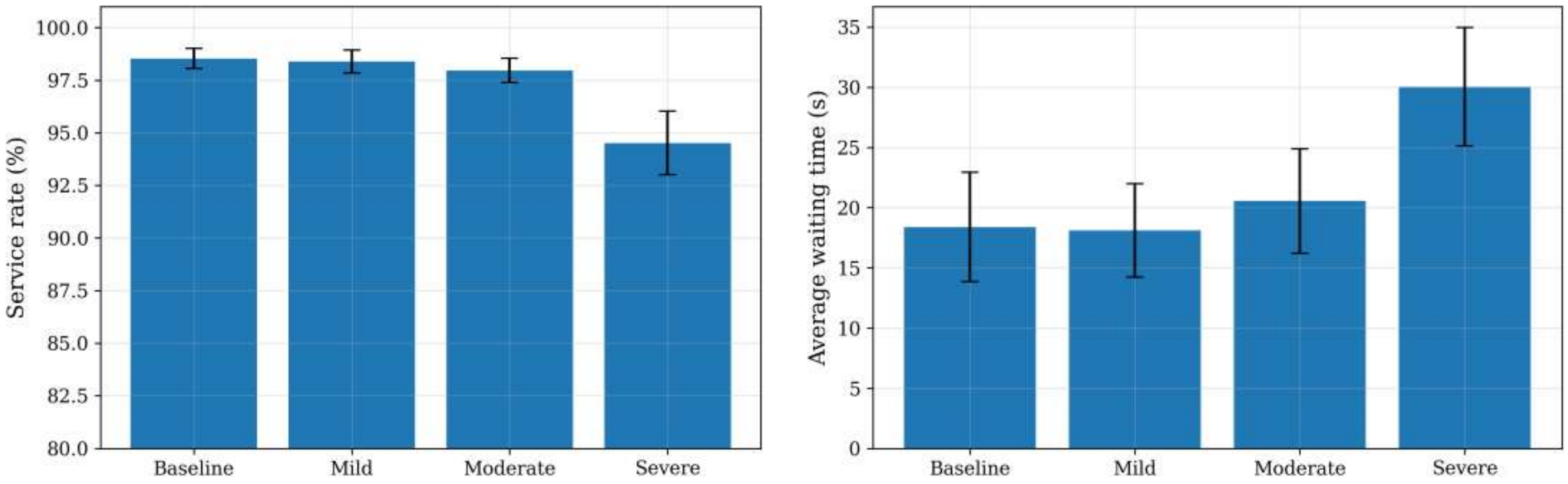
OSM Web Wizard for SUMO

SUMO network



SUMO network (Buist/Spruill Intersection)

Operational Performance Under Increasing Flood Severity



- Service rate remains above 97% through Moderate flooding, indicating that most travel demand is still completed
- Severe flooding produces the clearest degradation, reducing service rate to about 94.5% and increasing mean waiting time to about 30 s.

Summary

Data-Model Assimilation for Urban Coastal Flood Resilience

ONR-funded digital twin project (USC, NC A&T, Benedict College, ORNL, LBNL) for compound tidal + rainfall flooding in the Turkey Creek watershed, Hanahan, SC — combining field sensors, physics-based hydraulic models (HEC-RAS, TRITON), and system dynamics modeling.

Custom UAV-Deployable Sensor Hardware

Low-cost, solar-powered, magnetically mounted water-level sensor (SCUWLS), deployable without site access. Four units currently in Turkey Creek; firmware update in progress for adaptive sampling based on battery and rate of change.

Key Finding: Flooding Is Compound, Not Single-Cause

Tide alone maybe manageable, but tide plus heavy rainfall drives flooding on streets like Redeemer and Hillside Drive. A fast system dynamics model tracks both the slower physics-based models and real sensor data closely enough for rapid what-if testing.

Operational Relevance and Next Steps

Testing concrete interventions (culvert upsizing, ditch cleaning, tide gates, and combinations) for cost-effective mitigation.

Thank You for Your Time

Questions and Discussion