# Evaluating the applicability of UAV-based sonar for bridge substructure monitoring

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## Introduction

Currently, NCDOT manages approximately 13,700 bridges, with 8.4 percent of these bridges considered in poor condition. Despite systematic inspection protocols, traditional methods have limitations, such as insufficient monitoring of upstream scour features. UAV based sonar offers considerable benefits compared to traditional methods. The current inspection protocols involve taking soundings at specific points around bridge substructures and making additional measurements after high water events to track changes in the streambed profile. UAV sonar systems are able to capture thousands of points rapidly, yielding a much more detailed view of the streambed and bridge substructure. In this research the Appalachian State Drone team tested a UAV sonar system for bathymetric monitoring.

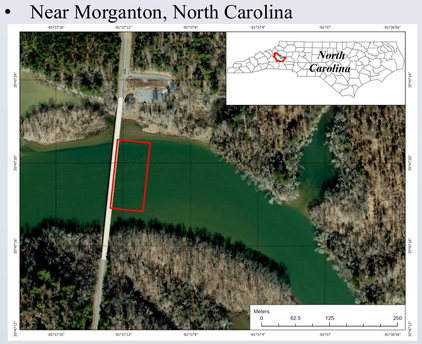
### Objectives:

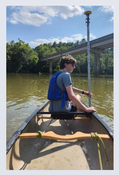
- **Assess the applicability of UAV-based sonar for bathymetric mapping.**
- **Evaluate the accuracy of UAV-observed soil erosion and river channel change by comparing with *in-situ* measurements.**
- **Demonstrate the value of high-quality bathymetric data for comparative analysis.**

## Study Area & Data Collection

### Study Area

- Huffman Bridge on Rhodhiss Lake, 35.789° N, -81.619° W
- Near Morganton, North Carolina



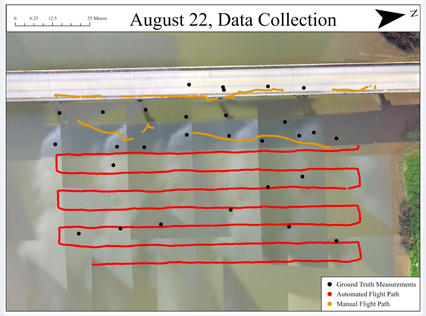



### Data Collection

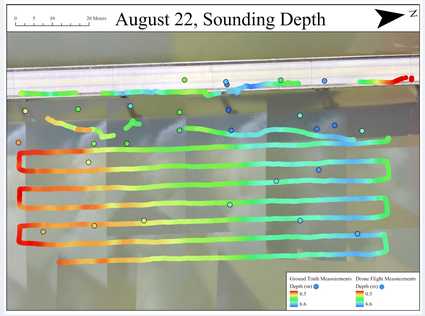
- UAV flight dates: 08/22/2024, 11/1/2024
- Ground data collection: 08/22/2024
- Instruments: DJI Matrice 600 Pro, ECT 400S Echosounder, Trimble DA2 DGPS

## Data Collection and Processing

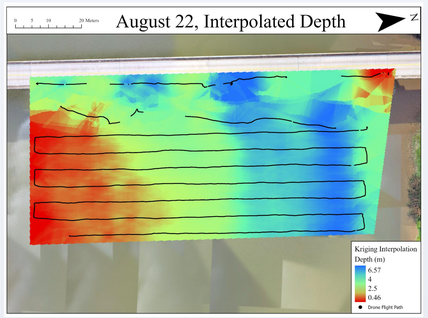
### Data Collection




### Recorded Depth



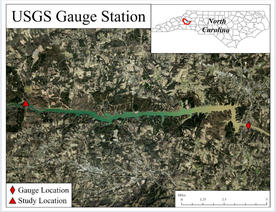

### Interpolated Bathymetric Map




**Universal Kriging** interpolation performed in ArcGIS Pro with UAV soundings to generate bathymetric map.

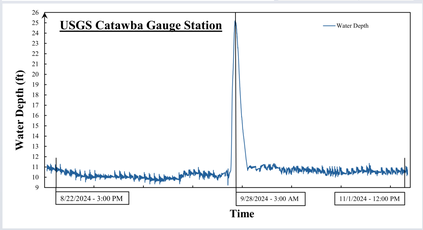
## Hurricane Helene

### Water Depth

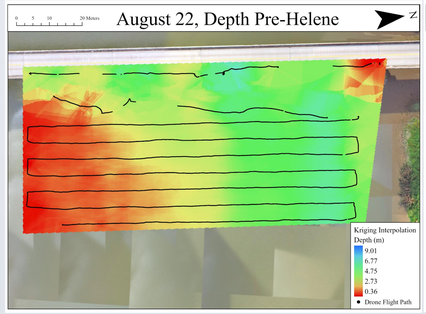



Study site located 22km (13.5mi) upstream from gauge station

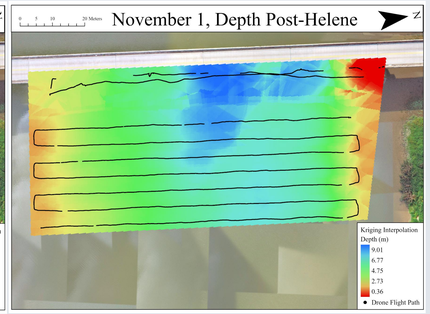
| Date | Depth |
|---|---|
| 8/22/2024 3:00 PM | 10.64 ft |
| 9/28/2024 3:00 AM | 25.25 ft |
| 11/1/2024 12:00 PM | 10.61 ft |




### Bathymetric Map, Pre-Helene



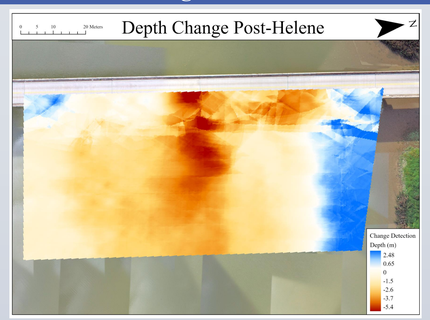

### Bathymetric Map, Post-Helene




- Following **Hurricane Helene**, another data collection was performed to observe the change that such a severe flood event had on the bathymetry.

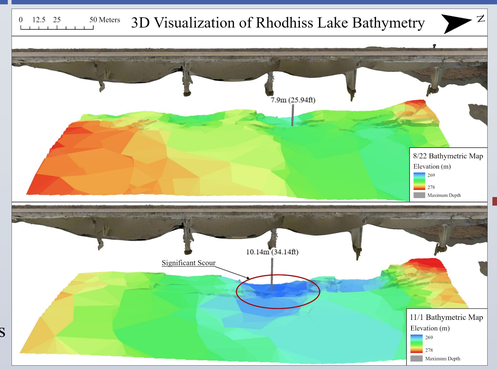
## Hurricane Helene's Effects

### Change Detection




To visualize the bathymetric change the "after" raster was subtracted from the "before" raster (before – after).

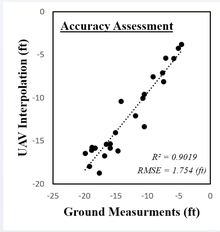
### 3D Products




Maximum depth increased **2.5m (8.2ft)**, with some areas eroding over **5 meters (16.4ft)**. The highest rate of erosion was just south of the deepest location at **5.4 meters** of erosion.

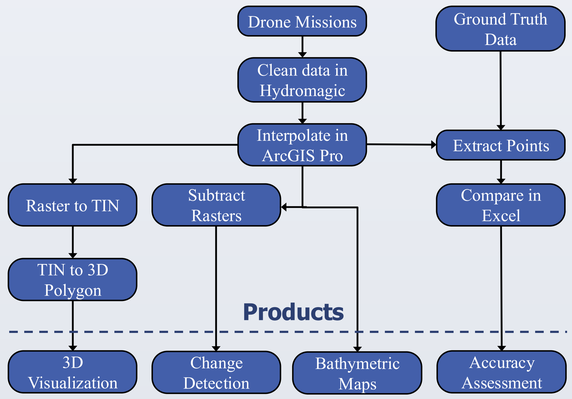
### Interactive Map

## Accuracy Assessment




The assessment was performed on August 22 and compares the ground measurements which were collected from a canoe with the extracted values from the UAV interpolation. The R-squared value and root mean square error (RMSE) both showed a strong correlation between these datasets.

## Methods




## Conclusions

- This study shows that, UAV-based sonar bathymetry has a significant correlation with in-situ measurements and can **provide accurate, high-resolution data**.
- UAV-based bathymetry can **significantly reduce the time and effort** required for traditional survey methods for monitoring bridges, while providing **greater detail** than traditional methods.
- The ability to **visualize the bathymetry** helps expand the understanding of fluvial responses to extreme floods.
- In these data collections the largest issue was the inability to go around the bridge footers. With the team's current equipment this is unfeasible, but high precision D-RTK and/or side scanning sonar would enable this collection and could offer incredible insight.
- A limitation of UAV-based sonar is the minimum depth that the sensor can read leaves information on shallow water and shorelines missing. This could be remedied by generating DEMs using the structure from motion (SfM) technique combined with sonar bathymetry. This method has potential to solve the shortcomings of both methods.

### Acknowledgements

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