Airborne LiDAR System for Urban Stream Management

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Collaborators

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U.S. Army Corps of Engineers

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That’s me!

Significance

In the American West, **less than 5%** of native riparian habitat remains *(Krueper 1995).*

Manning's Equation

$$Q = \frac{1.49}{n} * A * R^{2/3} * S^{1/2}$$

Manning's coefficient

Look-up Table *(Chow 1959)*

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Problem

Traditional methods for estimating hydraulic resistance due to vegetation are **qualitative** and **inconsistent** *(Fischenich 1997).*

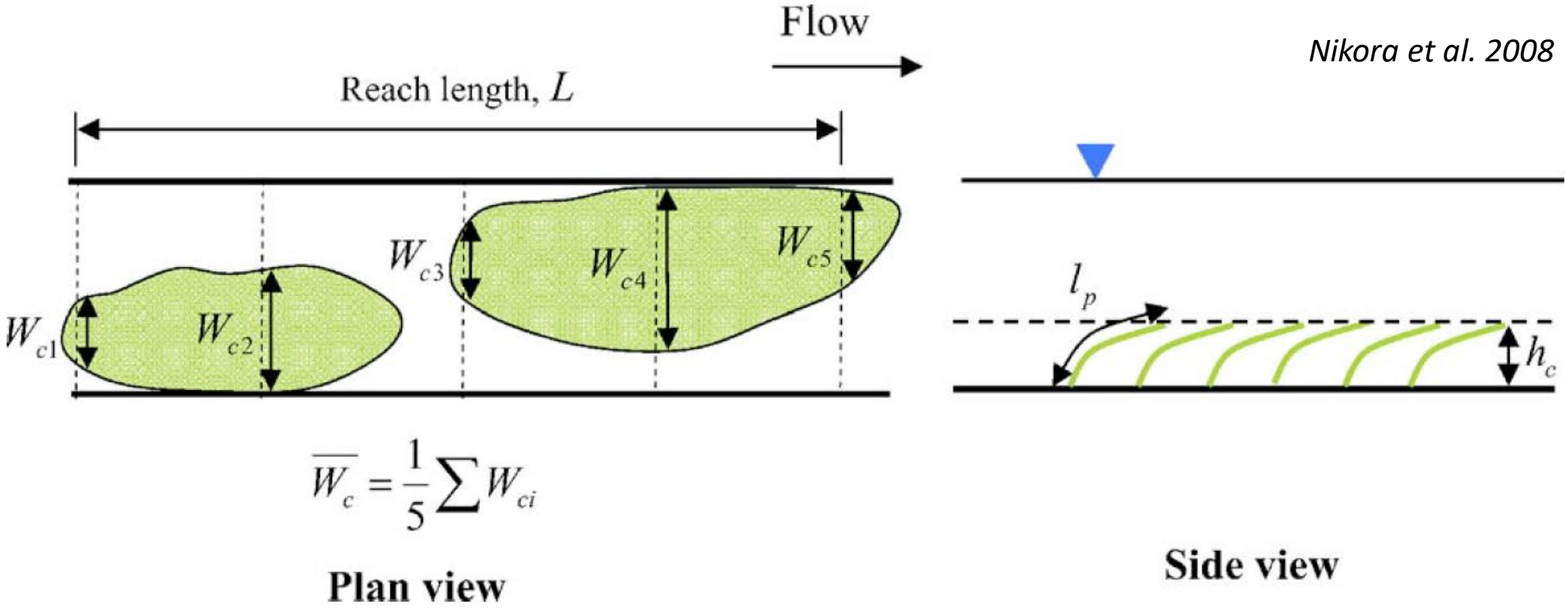
Research Question

How can we improve estimates of hydraulic resistance due to vegetation?

“Ecohydraulic” Parameters *(Nikora et al. 2008)*

1. Blockage Ratio
2. Relative Submergence

Vegetation Patch



Nikora et al. 2008

Blockage Ratio

$$2D\ Blockage\ ratio = \frac{A}{A_p} \quad / \quad 3D\ Blockage\ ratio = \frac{V}{V_p}$$

Where…

A = river cross-section area,

A_p = cross-sectional area of vegetation patch,

V = river reach volume, and

V_p = volume of vegetation patch in reach

Relative Submergence

$$Relative\ submergence\ of\ vegetation\ canopy = \frac{W \times H}{W_c \times h_c}$$

Where…

W = mean flow width,

H = mean flow depth,

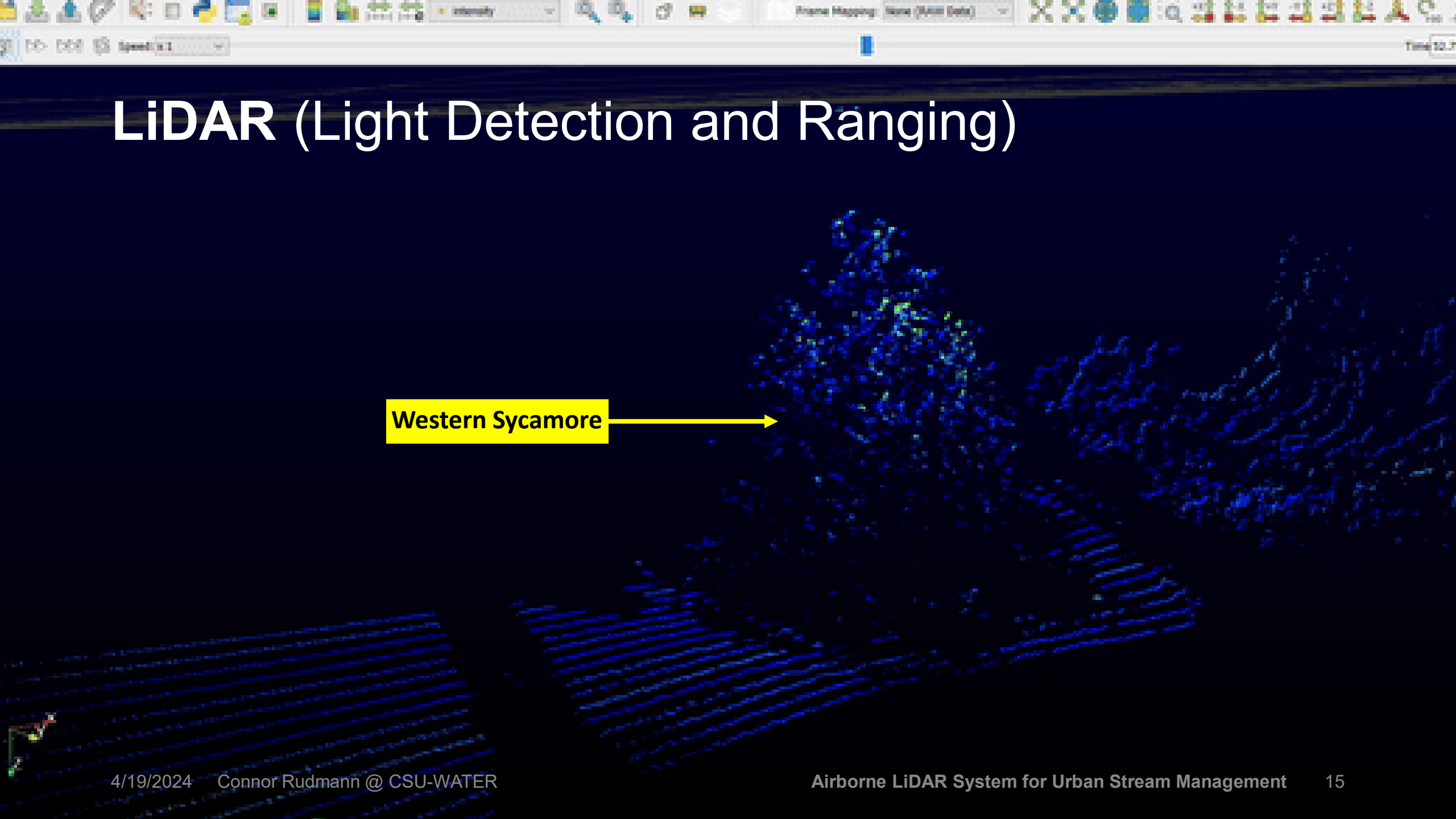
W_c = mean width of vegetation patches in a cross section, and

h_c = patch-averaged height of the vegetation canopy

Research Goal

Develop a **remote sensing tool** to measure ecohydraulic parameters.

LiDAR (Light Detection and Ranging)



Approach

1. Develop airborne LiDAR system *(Del Savio et al. 2022)*
2. Scan 15m x 15m study plots *(Fehérváry et al. 2020)*
3. Extract ecohydraulic parameters *(Nikora et al. 2008)*
4. Generate Manning's roughness "heat map" *(Green 2005)*

(in-progress)

UAS (Unmanned Aerial System)

Drone (DJI Matrice 600 Pro)

MAX PAYLOAD: *6 kg*

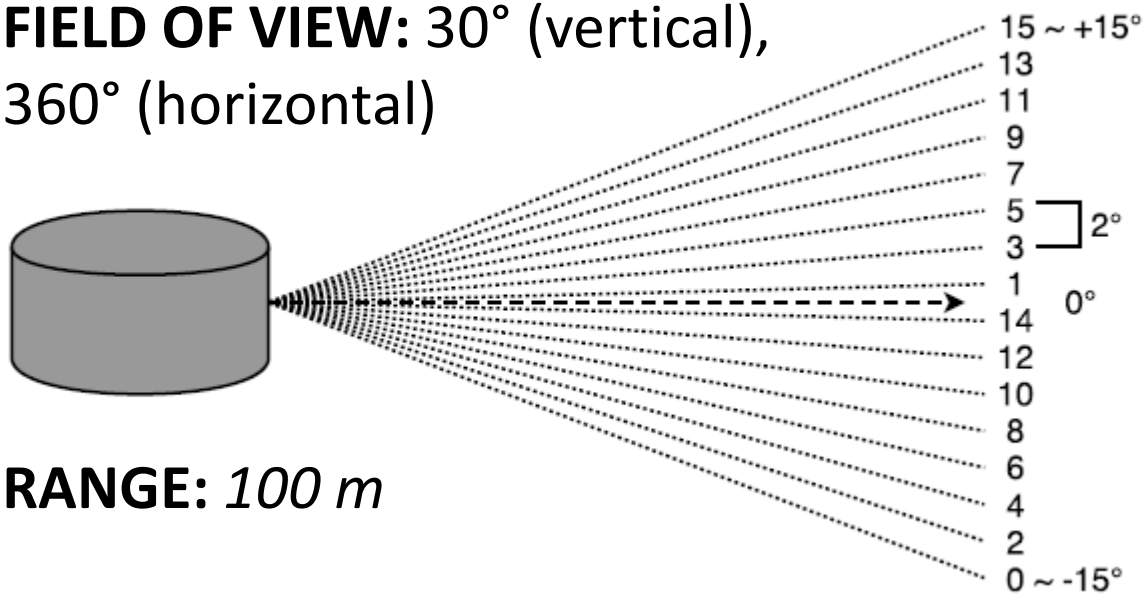
FLIGHT TIME: *30 minutes (hover)*

MAX SPEED: *8 m/s (no wind)*

GPS/IMU Precision:
±0.5 m (vertical), ±1.5 m (horizontal)

LiDAR Sensor (VLP-16)

FIELD OF VIEW: 30° (vertical), 360° (horizontal)



RANGE: *100 m*

DATA DENSITY: *~300,000 points/s*

Accuracy: : +/- 3 cm

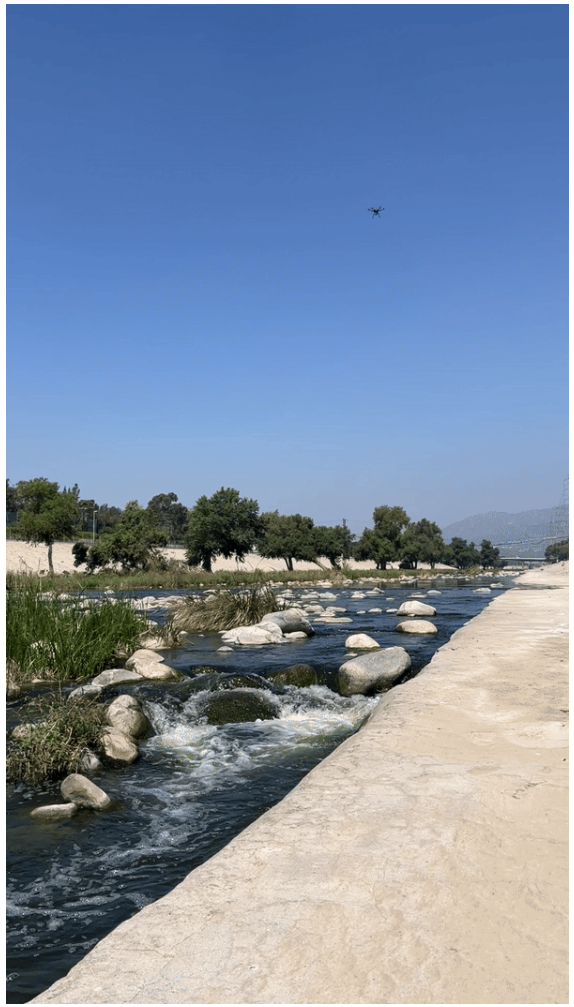
Microcomputer / Data Logger (“FlyPi”)

5V Battery Pack

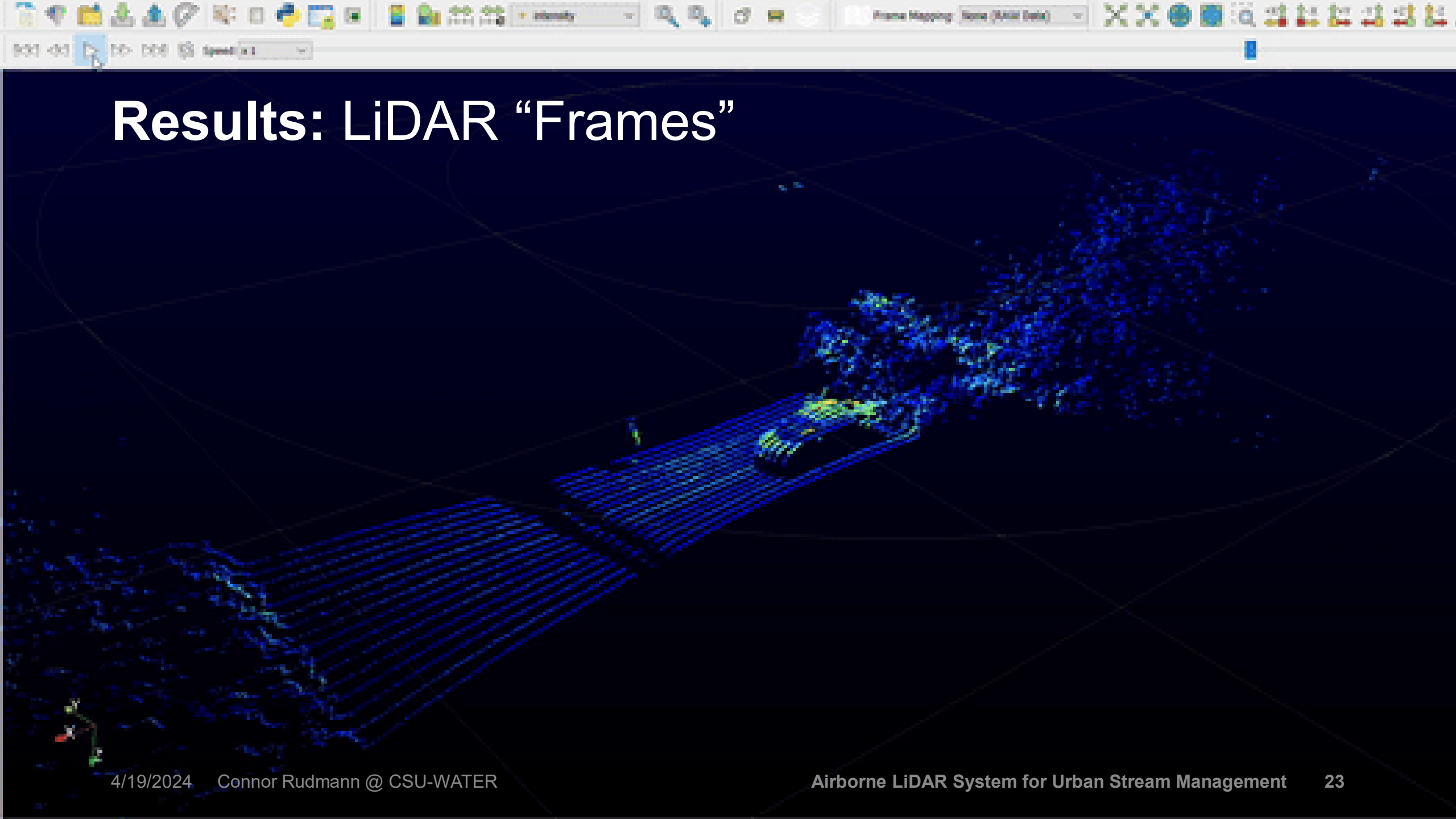
Raspberry Pi 4

Field Computer (“PortaPi”)

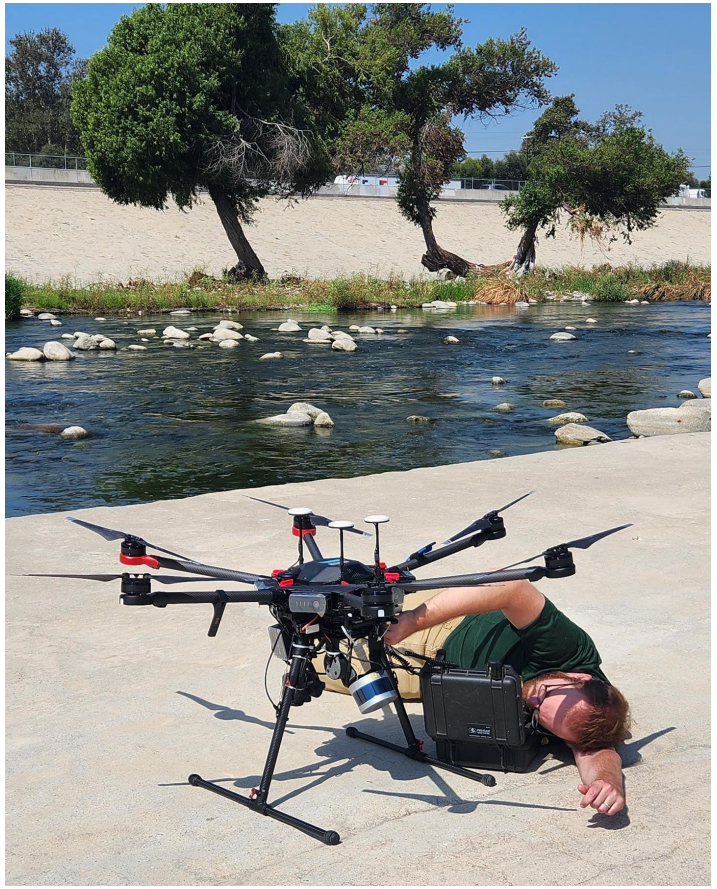
Test Flights



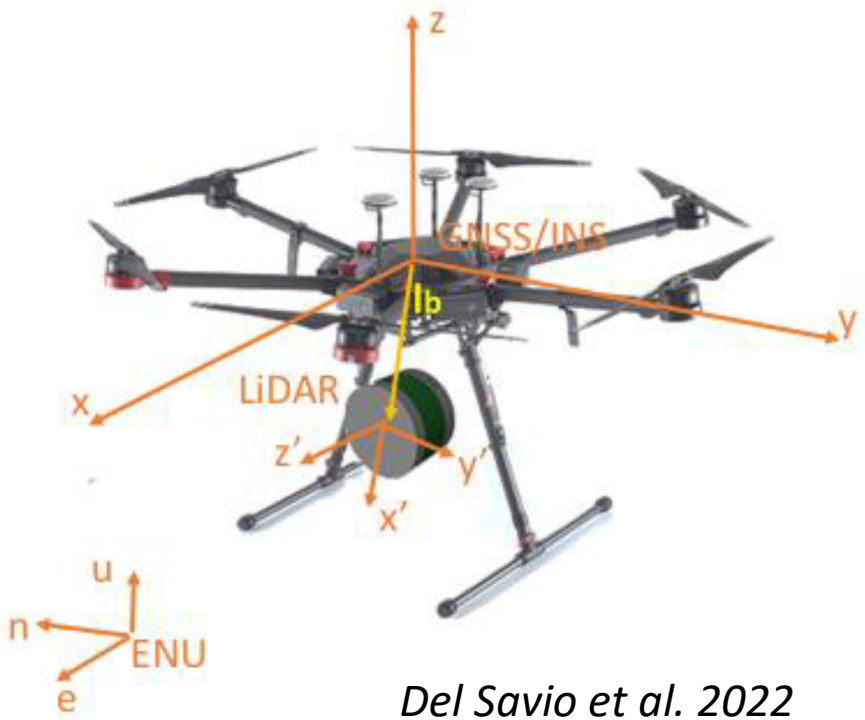
Results: LiDAR “Frames”



Challenges: Debugging



Challenges: Georeferencing



Del Savio et al. 2022

Next Steps (short-term)

- Scan additional study plots at the L.A. River
- Work with LiDAR manufacturer to integrate drone GPS/IMU data

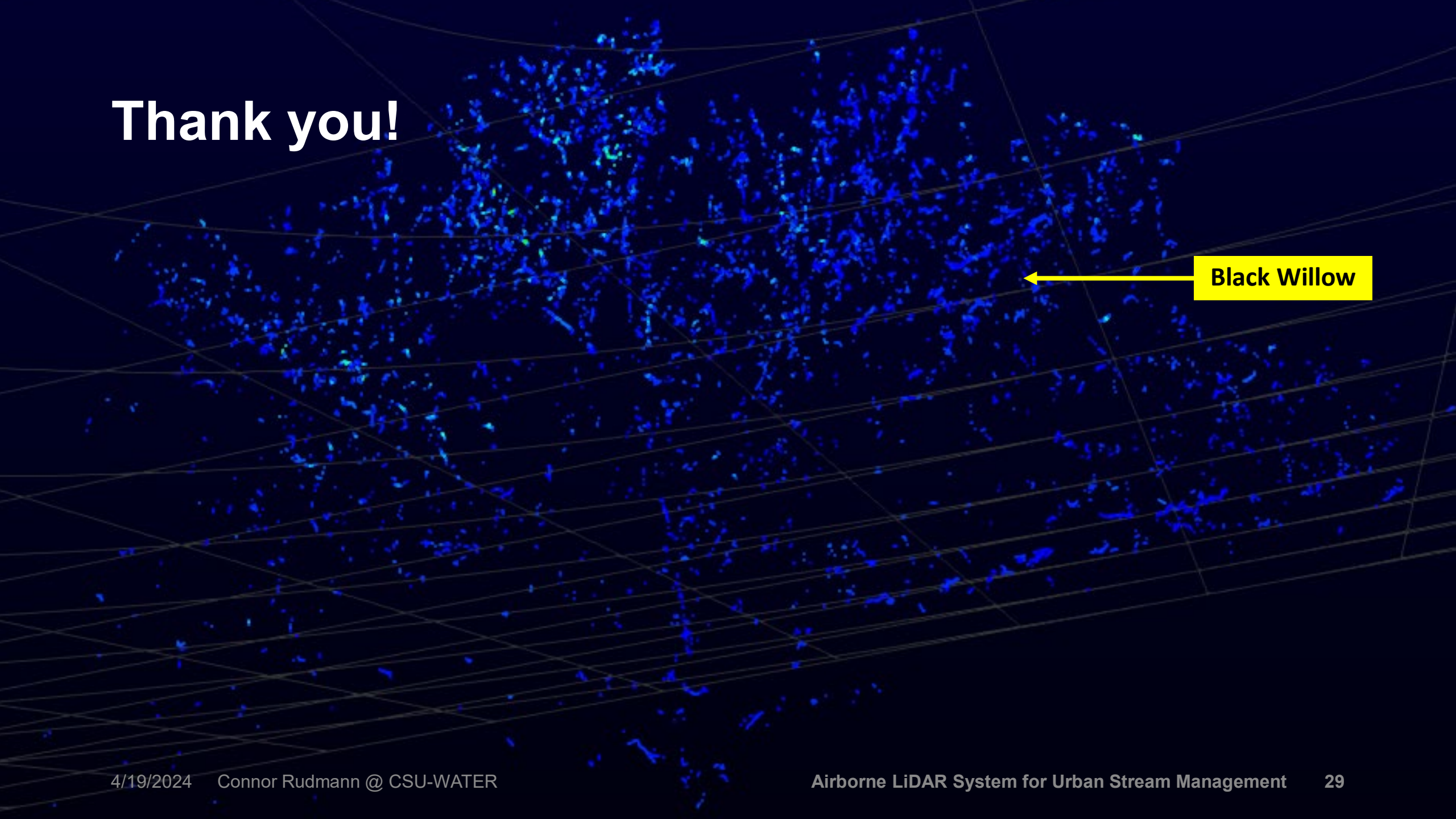
Next Steps (long-term)

- Scan additional study plots at the L.A. River
- Work with LiDAR manufacturer to integrate GPS/IMU data
- Generate composite point clouds of study plots
- Develop ecohydraulic parameter extraction workflow

Research Goal

Develop better **tools** for river restoration and management.

Thank you!



References

1. Chow, V.T. 1959. Open Channel Hydraulics. McGraw-Hill, New York.
2. Del Savio A. A., Luna Torres A., Chicchón Apaza M. A., Vergara Olivera M. A., Llimpe Rojas S. R., Urday Ibarra G. T., Reyes Ñique J. L., Macedo Arevalo R. I. 2022. “Integrating a LiDAR Sensor in a UAV Platform to Obtain a Georeferenced Point Cloud.” Applied Sciences. 2022; 12(24):12838. https://doi.org/10.3390/app122412838
3. Fehérváry, István, and Tímea Kiss. 2020. “Identification of Riparian Vegetation Types With Machine Learning Based on LiDAR Point-Cloud Made Along the Lower Tisza’s Floodplain”. Journal of Environmental Geography 13(1-2):53-61. https://doi.org/10.2478/jengeo-2020-0006.
4. Fischenich, J.C. 1997. “Hydraulic impacts of riparian vegetation; Summary of the literature.” Technical Report EL-97-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
5. Frueder, D. J. 1995. “Effects of livestock management on Southwestern riparian ecosystems.” General Technical Report RM-GTR-272. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. p. 281-301.
6. Green, J.C. 2005. “Comparison of blockage factors in modelling the resistance of channels containing submerged macrophytes.” River Restoration and Applications 21(6):671-686. http://dx.doi.org/10.1002/rra.854
7. Nikora, V., Lamed, S., Nikora, N., Debnath, K., & Reid, M. 2008. “Hydraulic resistance due to aquatic vegetation in small streams: Field study.” Journal of Hydraulic Engineering, 134(9): 1326-1332. http://dx.doi.org/10.1061/(ASCE)0733-9429(2008)134:9(1326)