
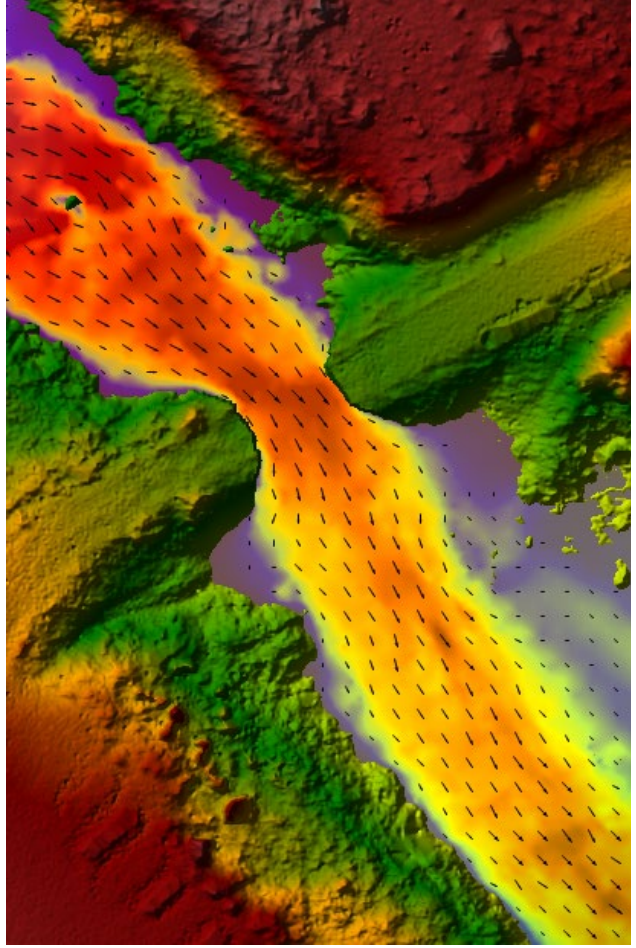
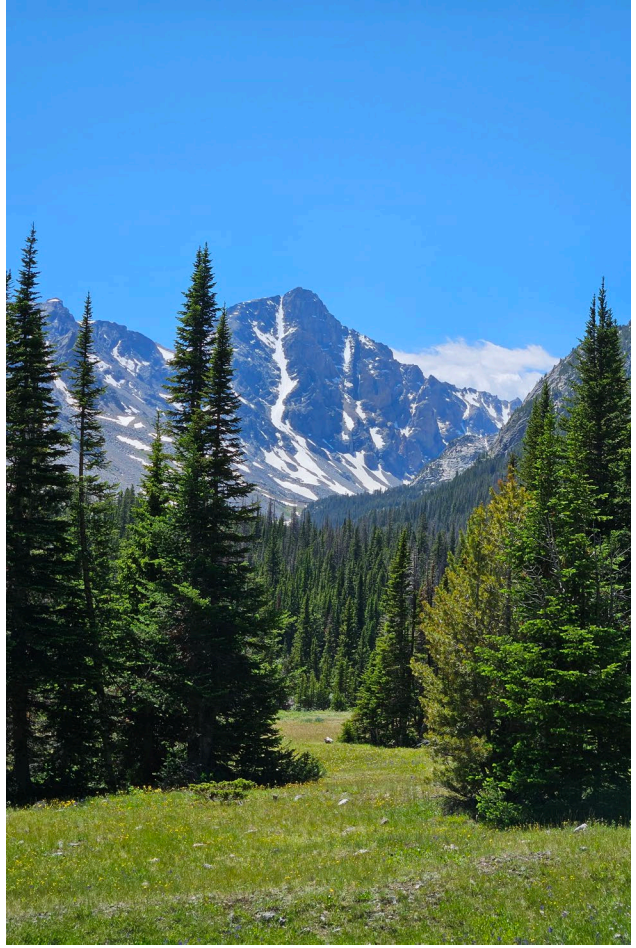
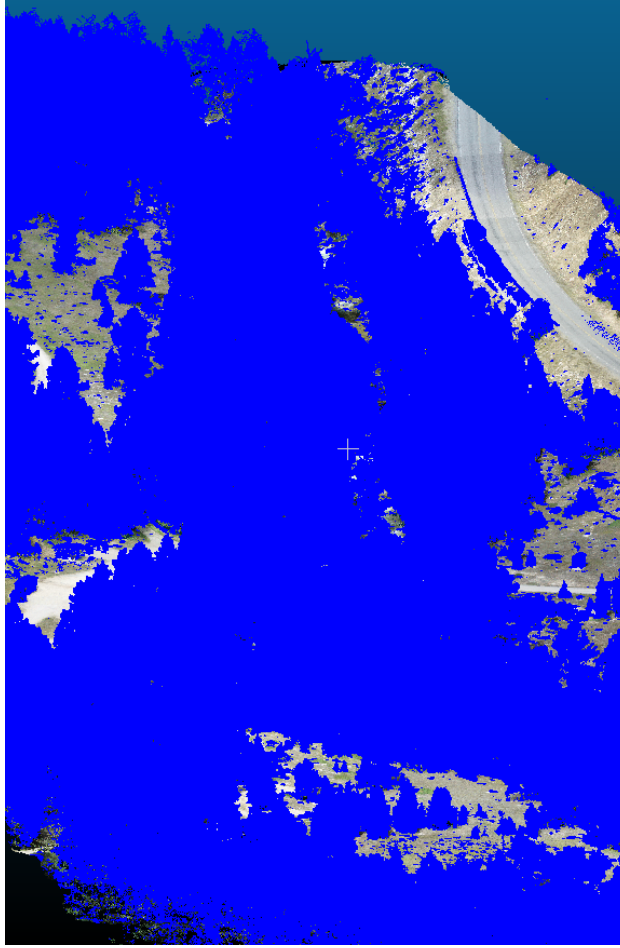

EVERYTHING IS BETTER IN 2D:

USE OF A 2-DIMENSIONAL HYDRAULIC MODEL FOR INDIRECT DISCHARGE ESTIMATION AND OTHER APPLICATIONS IN STREAM GAGING

Todd Blythe

Co-authors: Jake Mohrmann, Troy Lechman, Matt Norberg, and John Lunzer

CONTENT

Indirect Discharge Overview

Conventional Methods

Using 2D Hydraulics Overview

Findings

Validation & Comparisons

What Next…

“INDIRECT DISCHARGE”

Sometimes it is not feasible, or physically possible, to measure discharge during a flood.

Indirect discharge calculation relies on estimating the discharge associated with water surface elevation indicators.

This can be particularly useful in a lot of applications…

USES OF INDIRECT DISCHARGE

Paleo-Hydrology

- Paleo-Flood Analysis
- Geomorphology
- Risk Assessment
- Flood Frequency Extension

Measurement of Stream Discharge

- Estimate discharge when gear won't cut it
  - Record Floods
  - Difficult Sites
- Rating-Curve Development

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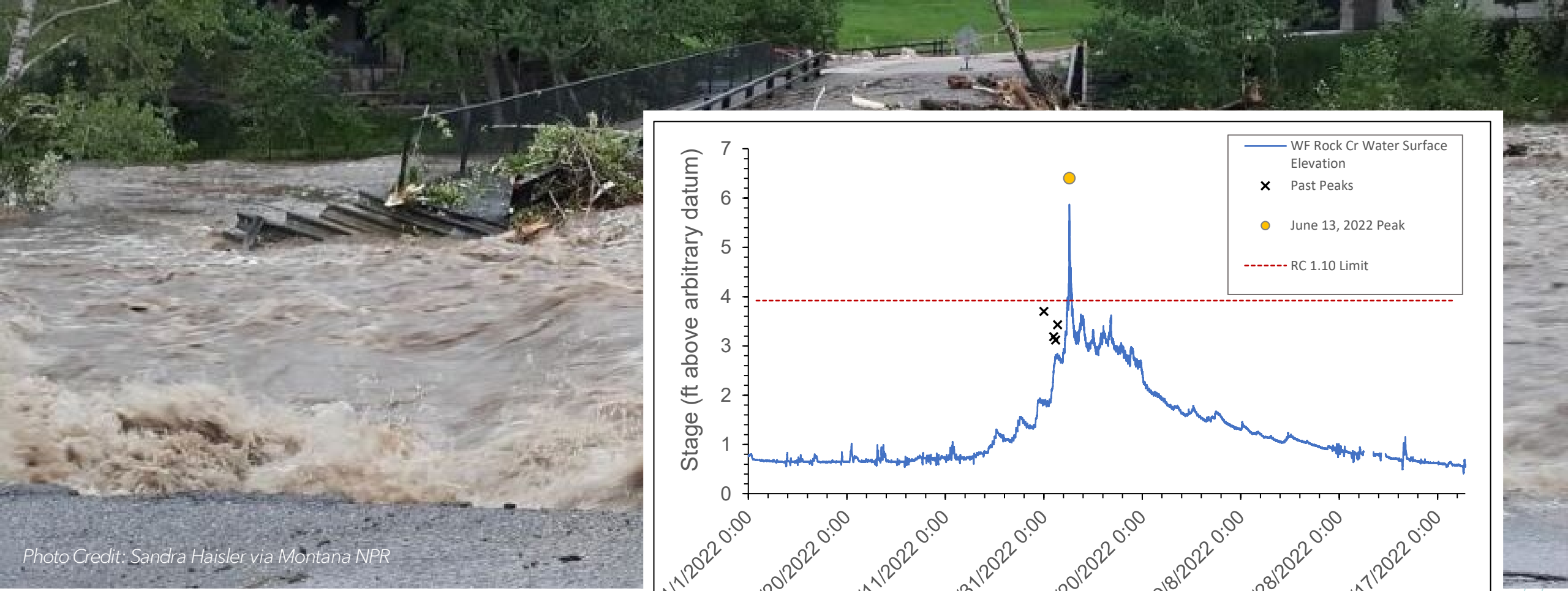
YELLOWSTONE BASIN FLOODING, JUNE 2022

DNRC gaging station – West Fork Rock Cr near Red Lodge, MT



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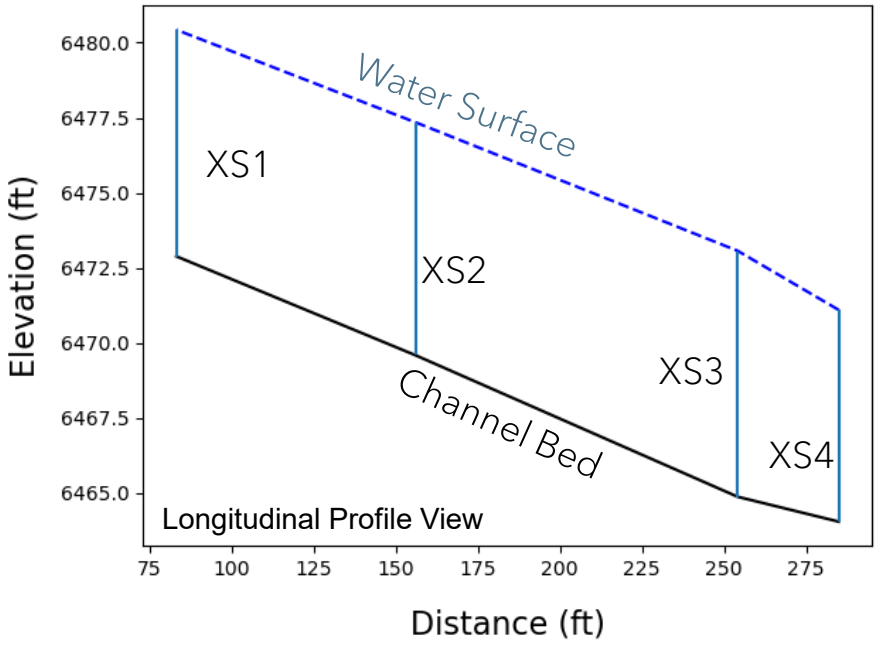
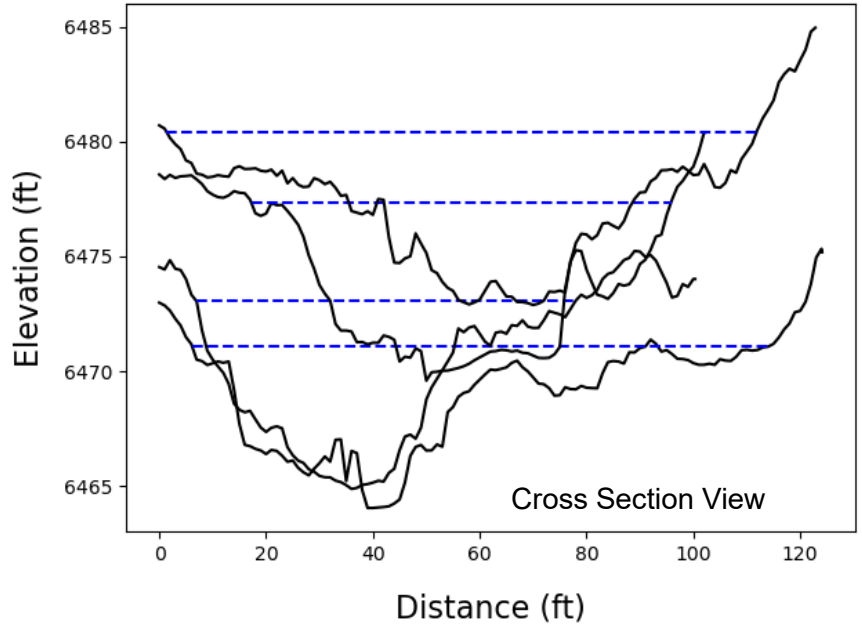




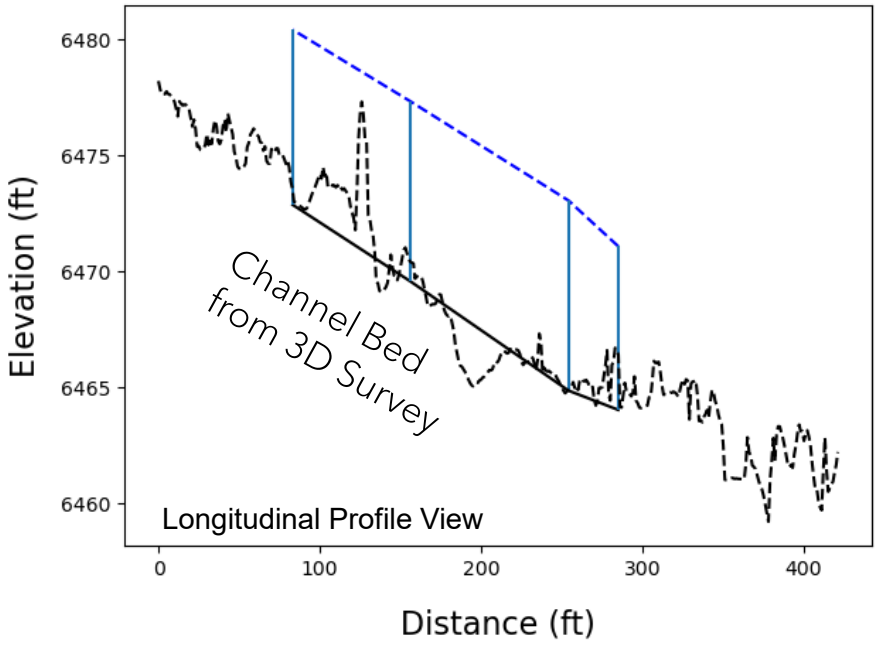
CONVENTIONAL INDIRECT METHOD SLOPE-AREA METHOD

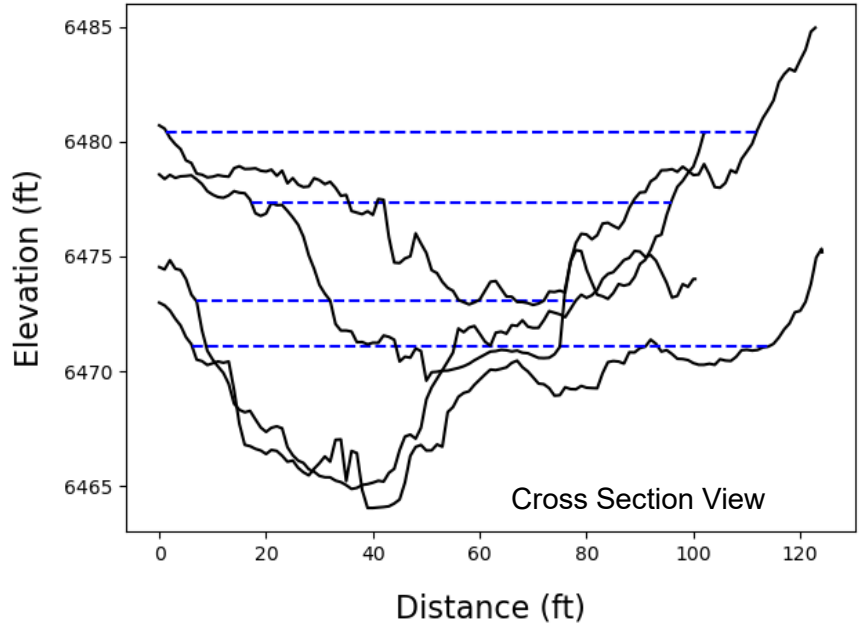
Based on Conservation of Energy Principles

$$V = \frac{k}{n} R_h^{2/3} S^{1/2}$$ Manning's Equation

Steps:

- Survey High Water Marks
- Survey Cross Sections
- Assign Manning's n
- Run Calculations





CONVENTIONAL INDIRECT METHOD SLOPE-AREA METHOD

Some Drawbacks:

- Careful site selection
- Selecting a Manning's n?
- Misses channel information
- Deterministic, not probabilistic

WHY CHANGE IT UP?

2D Hydraulic Models have a lot of uses

Continuous mapping of hydraulics

Potentially lower uncertainty

Less sensitivity to roughness coefficients

Error/Uncertainty Tracking

MODEL COMPARISONS

Robust analysis of 2D model indirect methods to adopt standard practices

Want to isolate uncertainty derived from field data collection methods

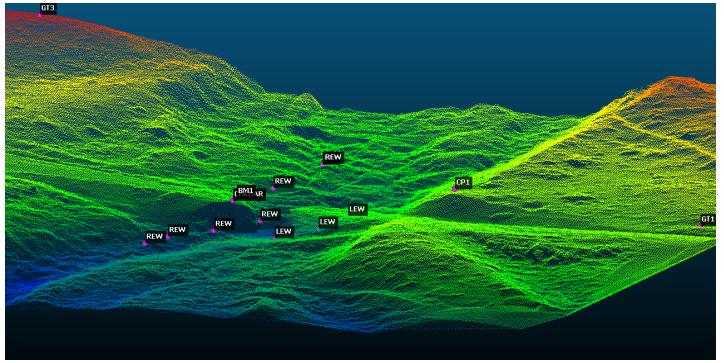
Photogrammetry derived (overlapping aerial photos) VS. LiDAR derived terrain

Is extra survey and processing effort worth it?

STEPS FOR USING A 2D HYDRAULIC MODEL

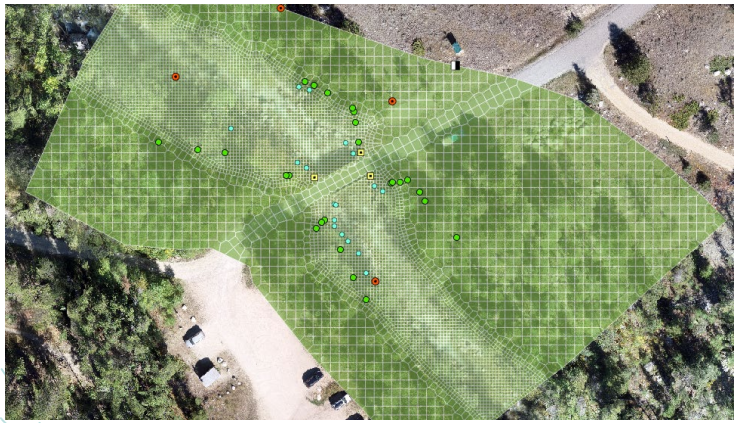
3D Channel Survey

Aerial Topography and Bathymetry



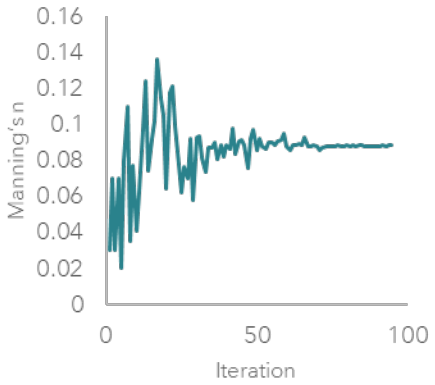
Process Terrain Data for use in Model

Point Cloud to DEM



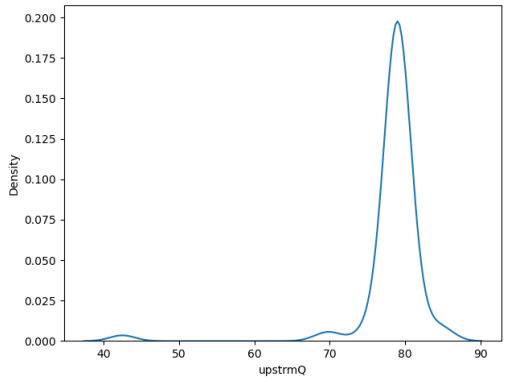
Build a 2D Model

Used HEC-RAS 6.4.1



Calibration of Channel Roughness

Using water surface elevation of a known discharge



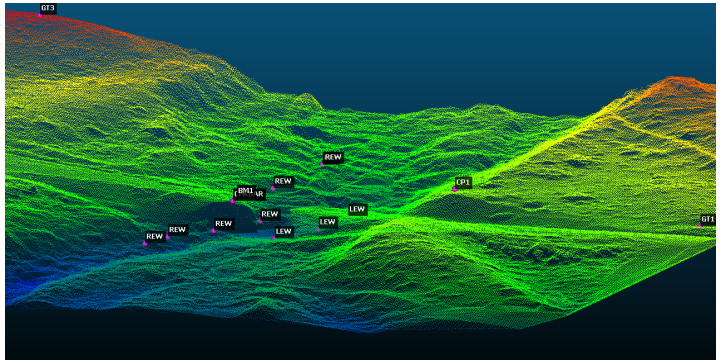
Optimization treating discharge as an unknown

Same process as calibration

WE'RE COMPARING 2 DIFFERENT SURVEY METHODS…

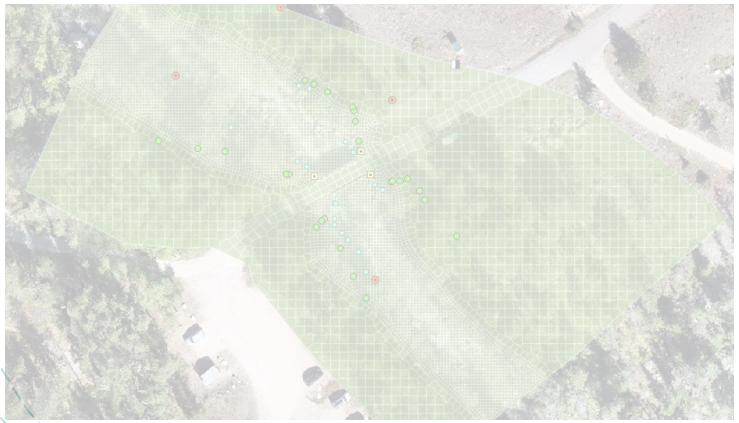
3D Channel Survey

Photogrammetry vs. LiDAR



Process Terrain Data for use in Model

Different Process for each



Build a 2D Model

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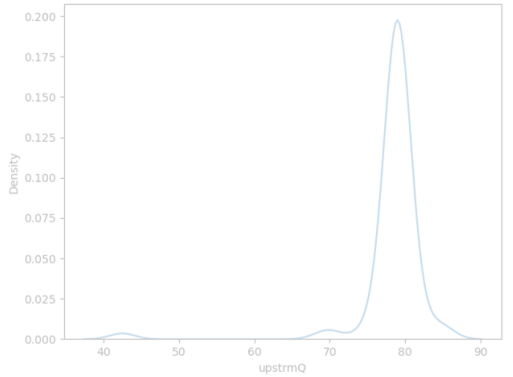


Optimization treating discharge as an unknown

Same process as calibration

MODEL CALIBRATION

1 VARIABLE

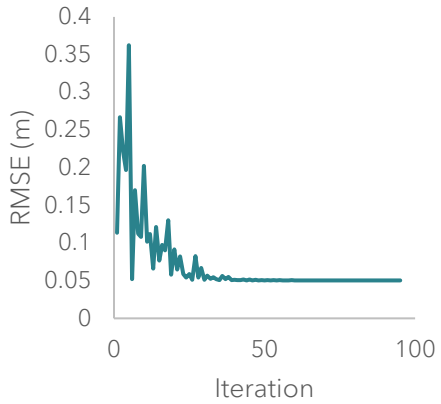
MULTIPLE PARAMETERS

2 DEDICATED CALIBRATION RUNS

1 CONCURRENT

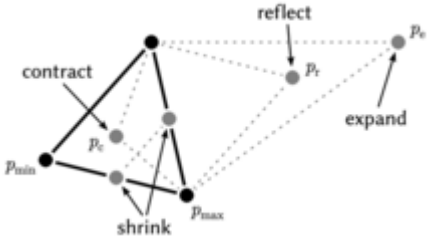
Delineate Manning's n regions

Site Specific (4 channel, 4 floodplain)



Choose Objective Function

Minimized RMSE



Used Nelder-Mead Method

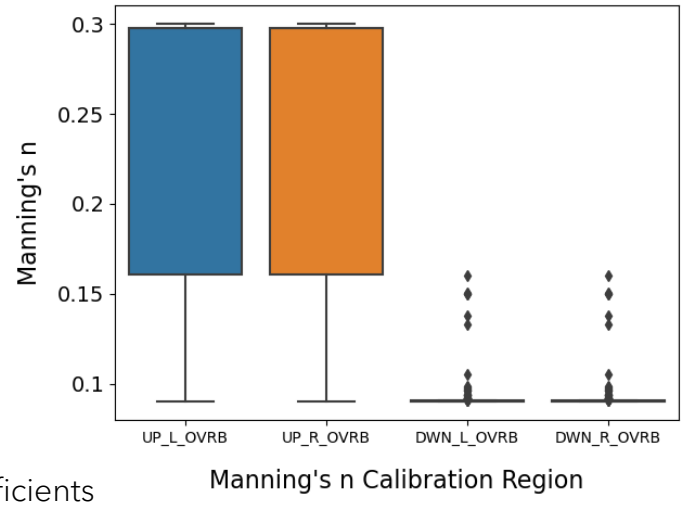
Multi-parameter algorithm

Model Automation for Multiple Runs

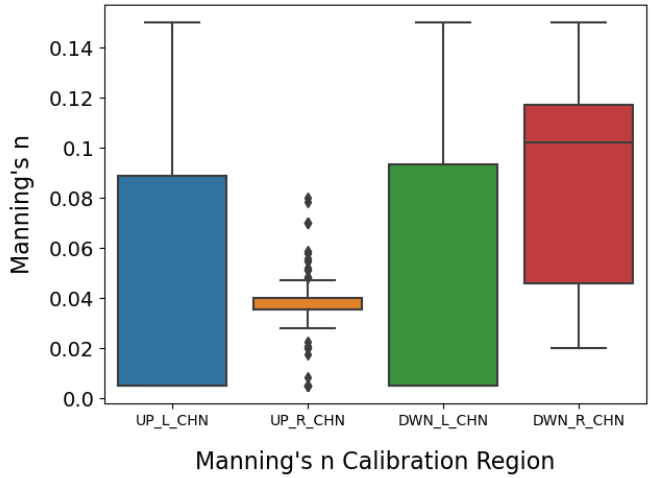
Developed a Python Package for model control

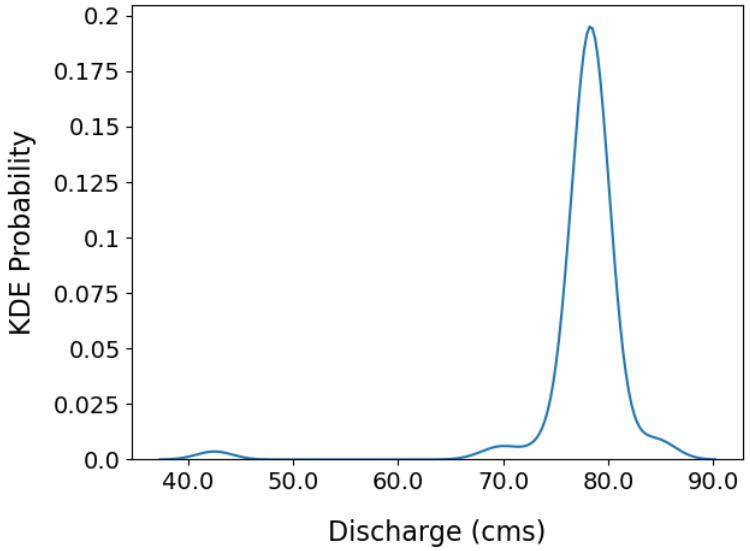
PHOTOGRAMMETRY BASED MODEL RESULTS

Channel Roughness Coefficients

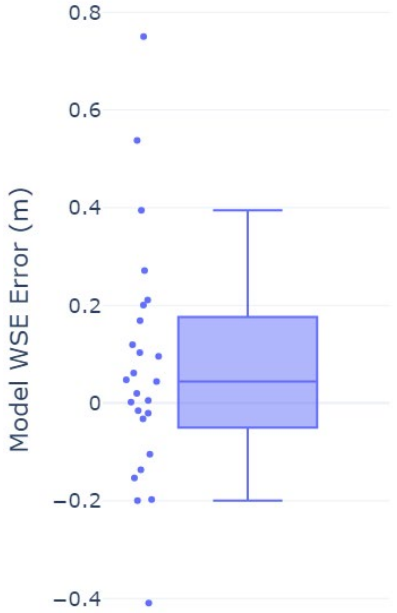


Floodplain Roughness Coefficients





Distribution of Model Error



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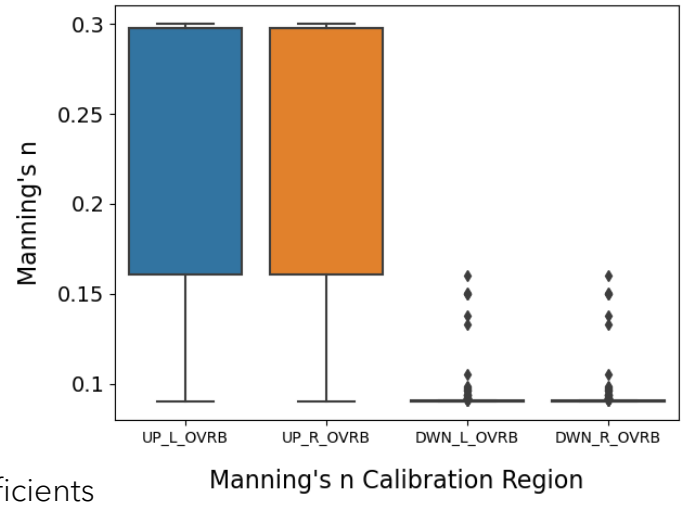

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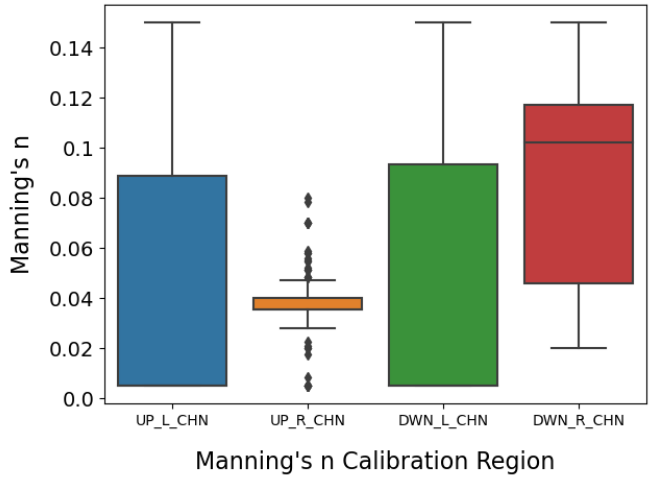

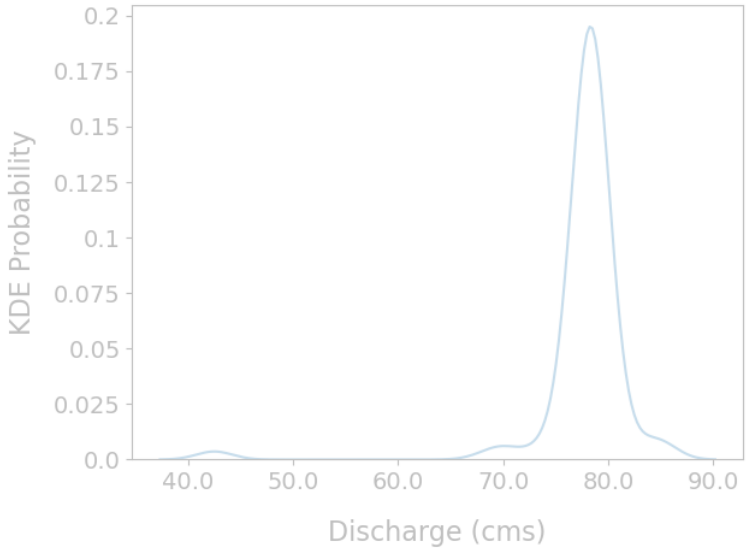

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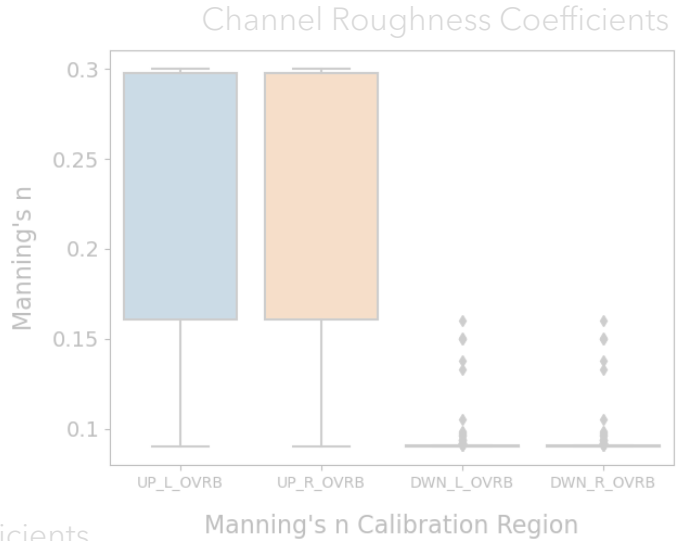

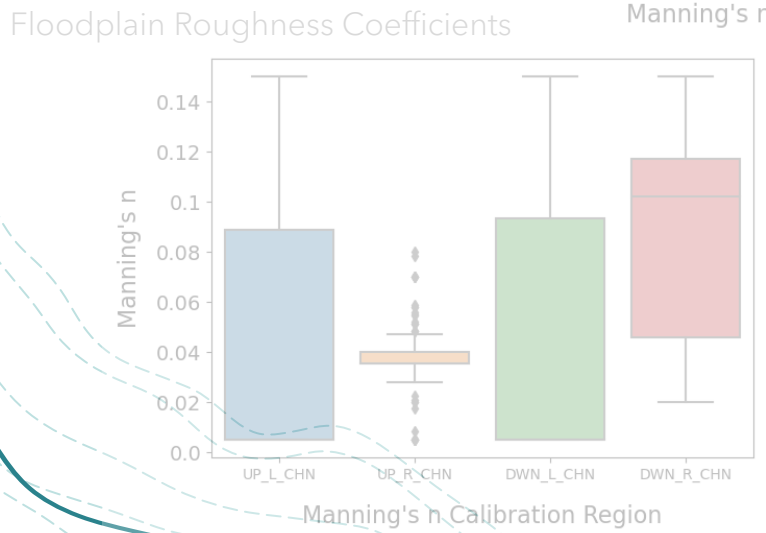

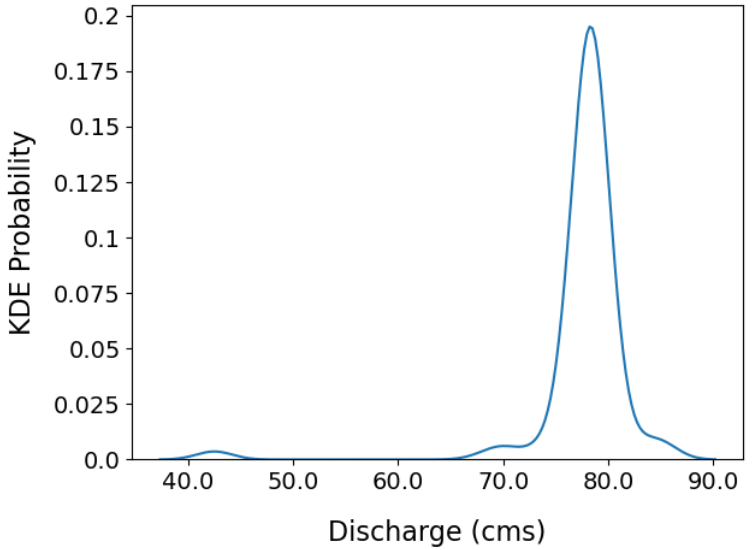

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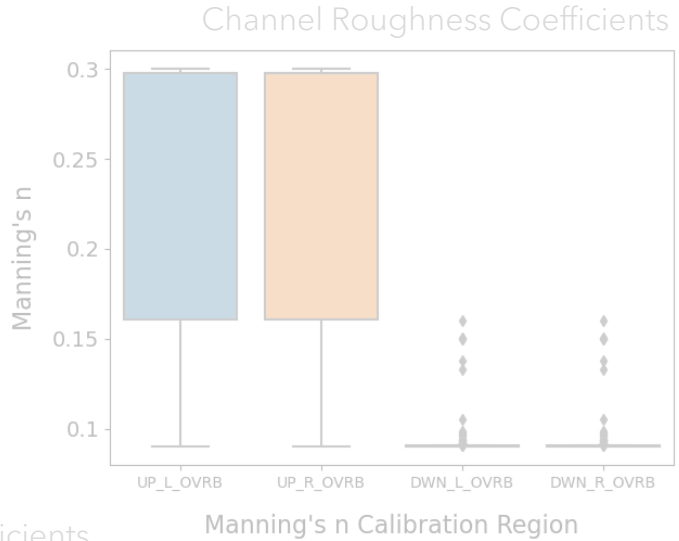
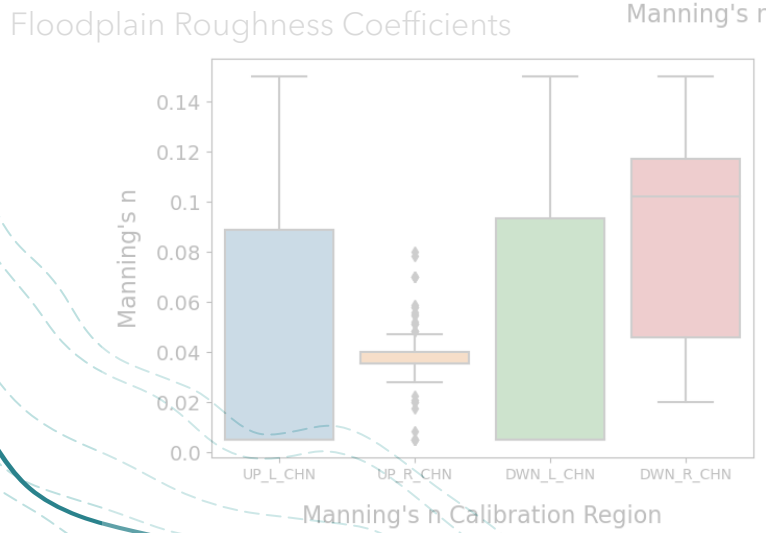
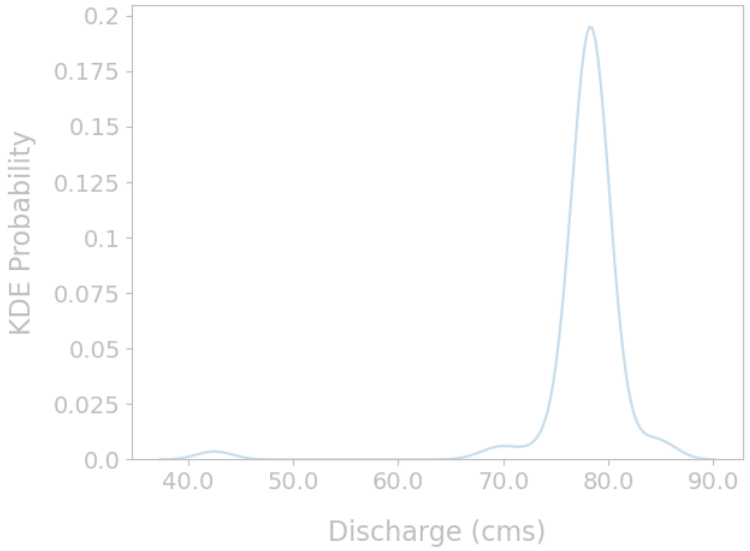
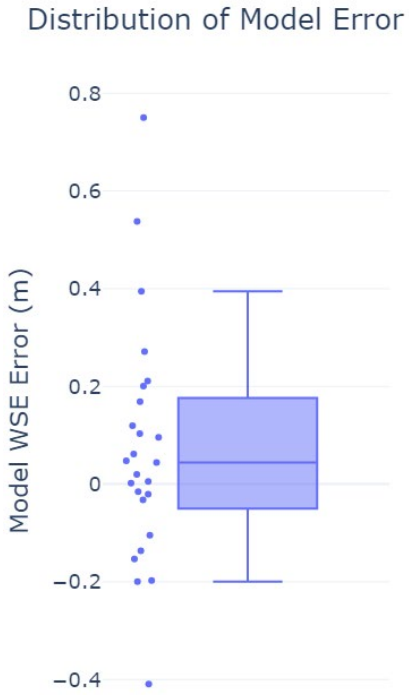


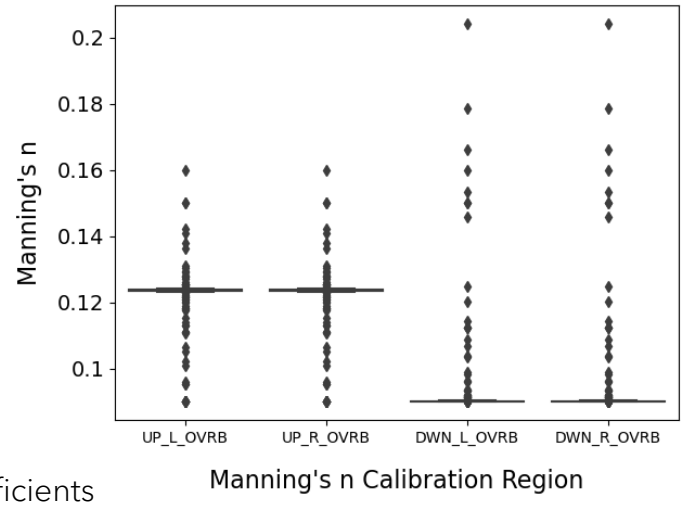




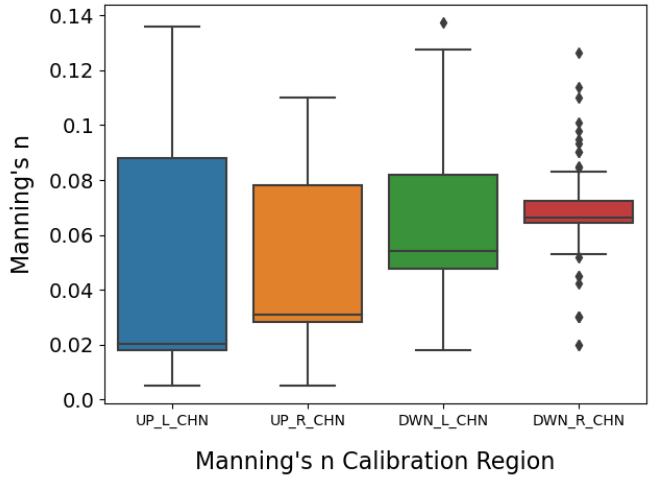


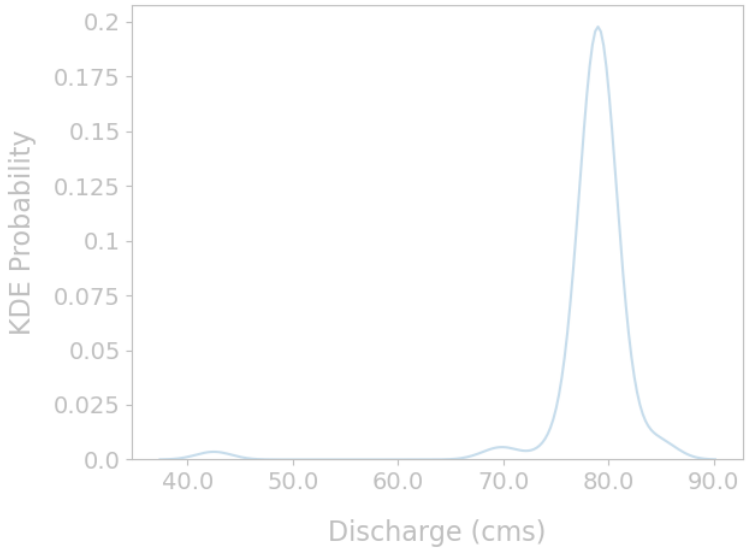
LIDAR BASED MODEL RESULTS

Channel Roughness Coefficients



Floodplain Roughness Coefficients





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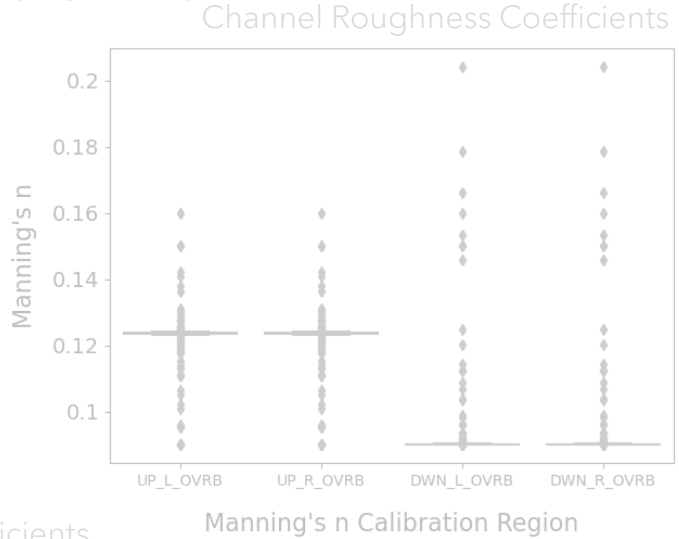

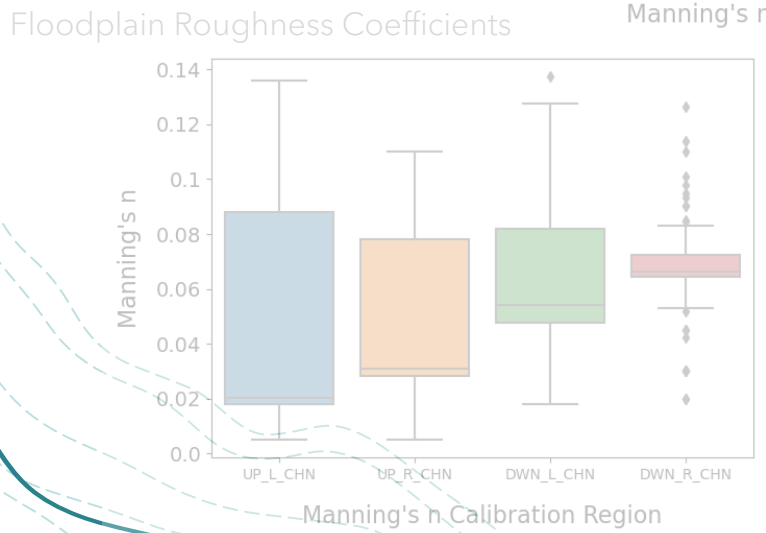

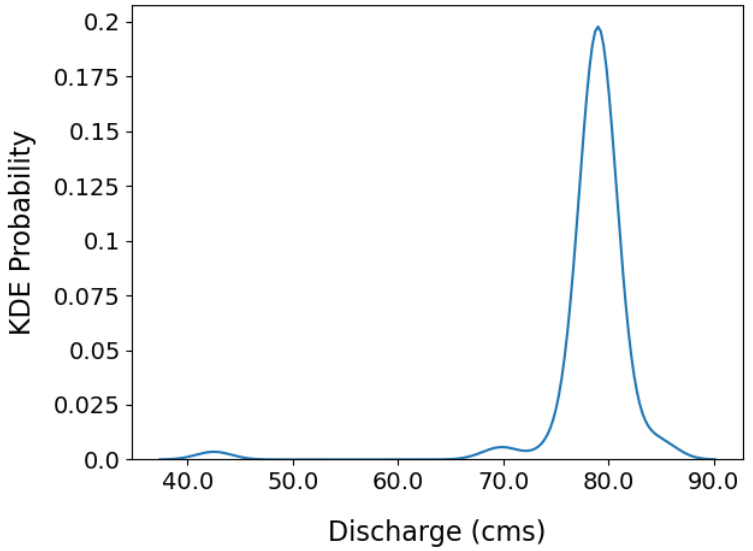

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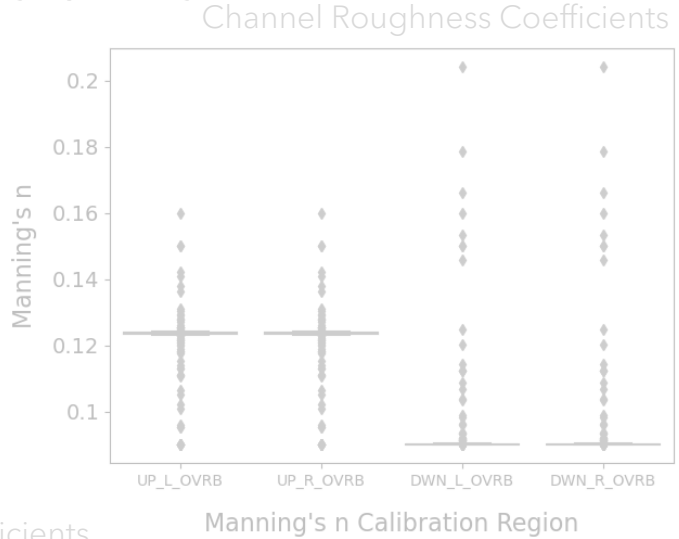
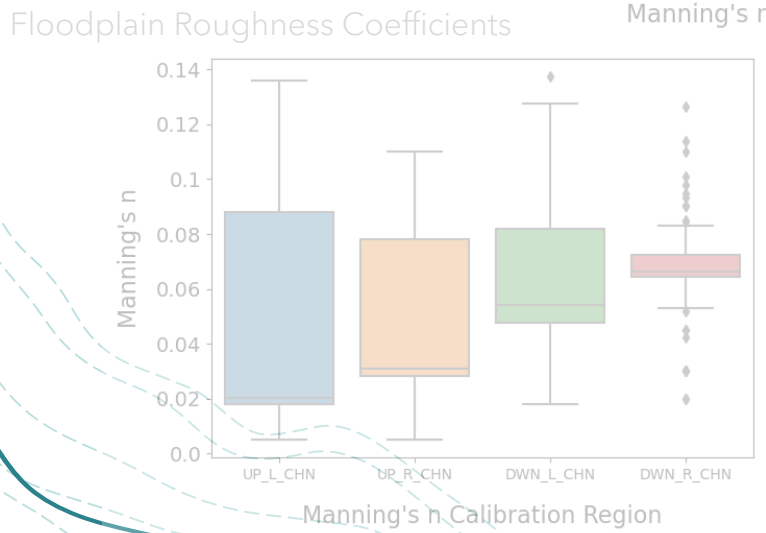
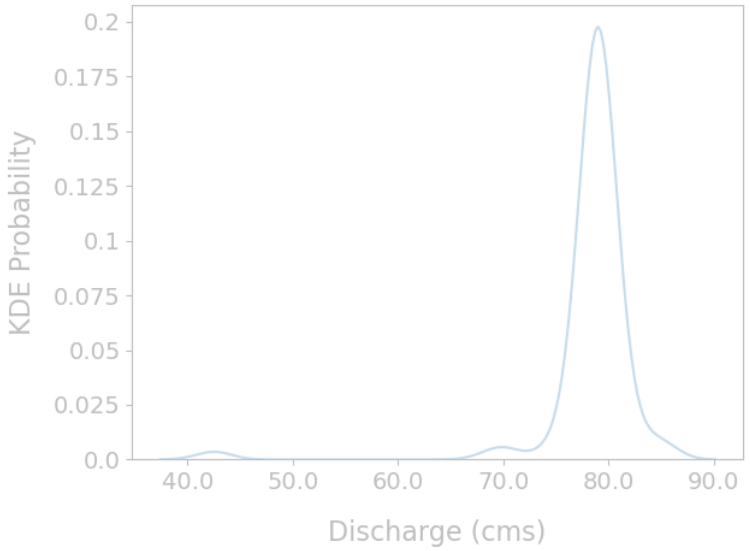
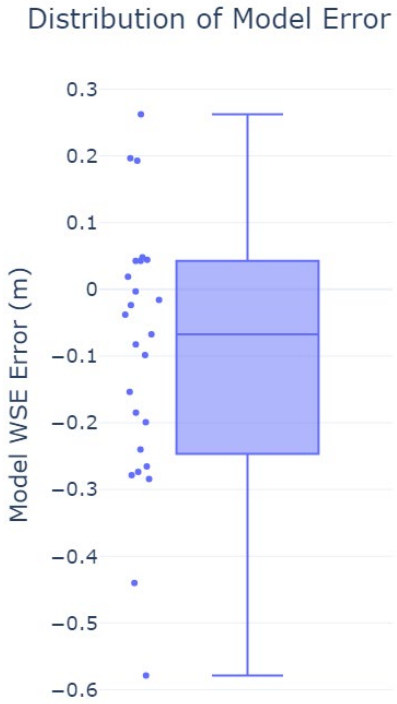


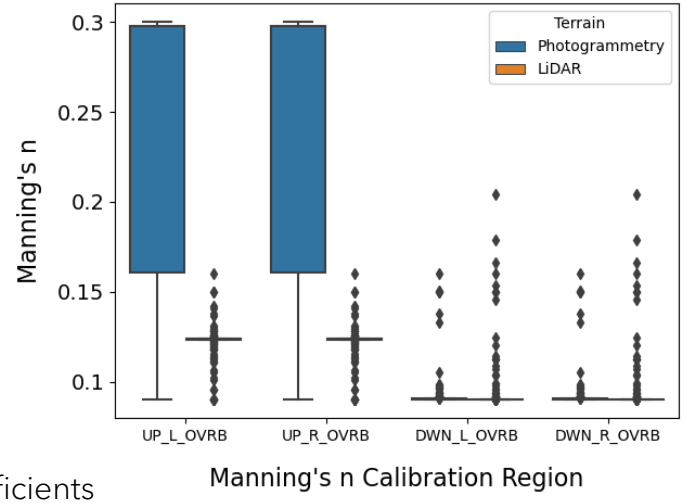




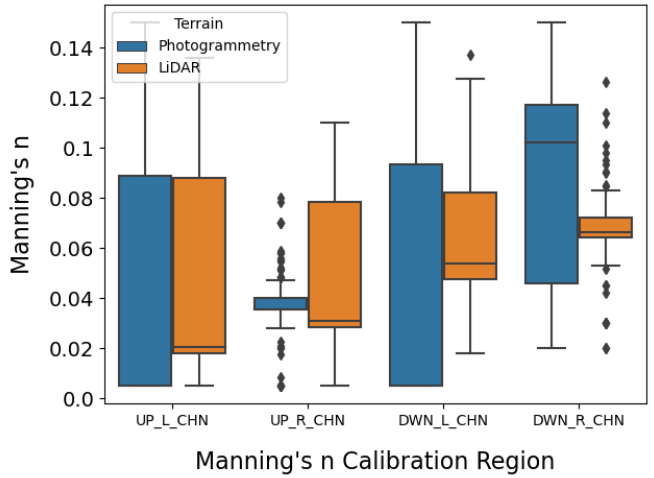


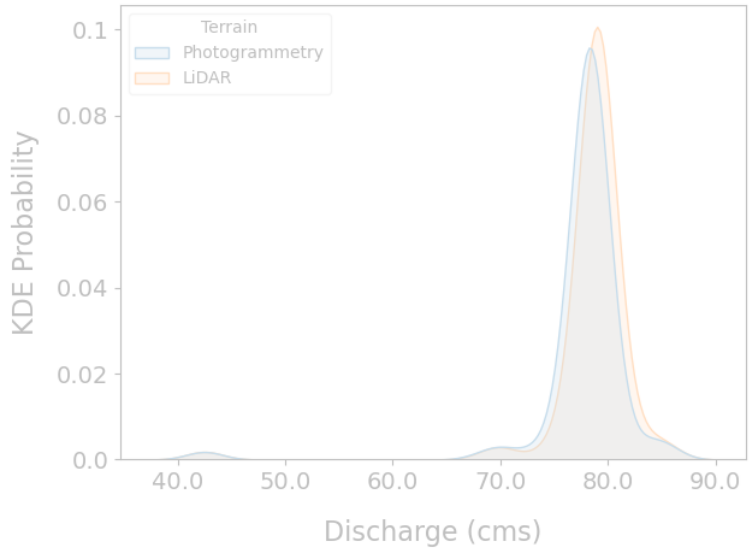
COMPARISON OF 2D MODELS

Channel Roughness Coefficients



Floodplain Roughness Coefficients





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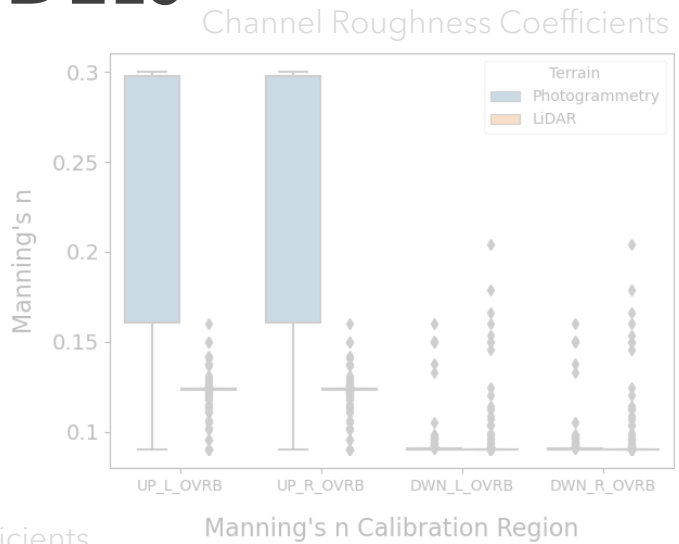

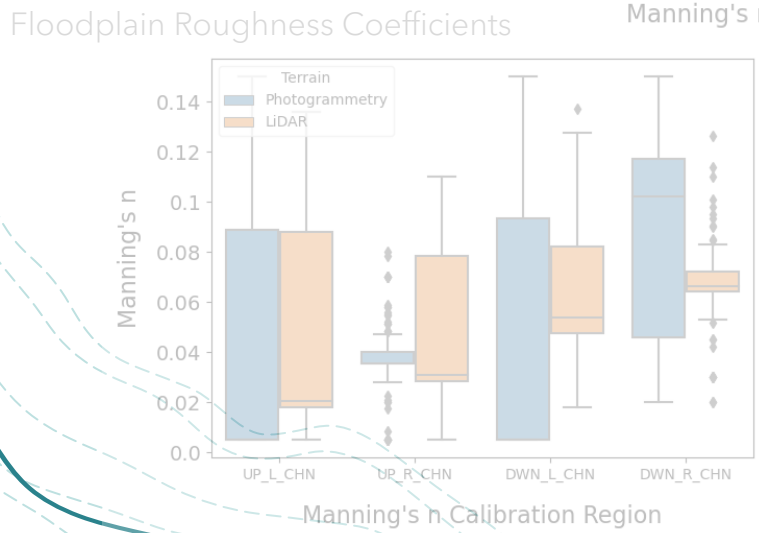

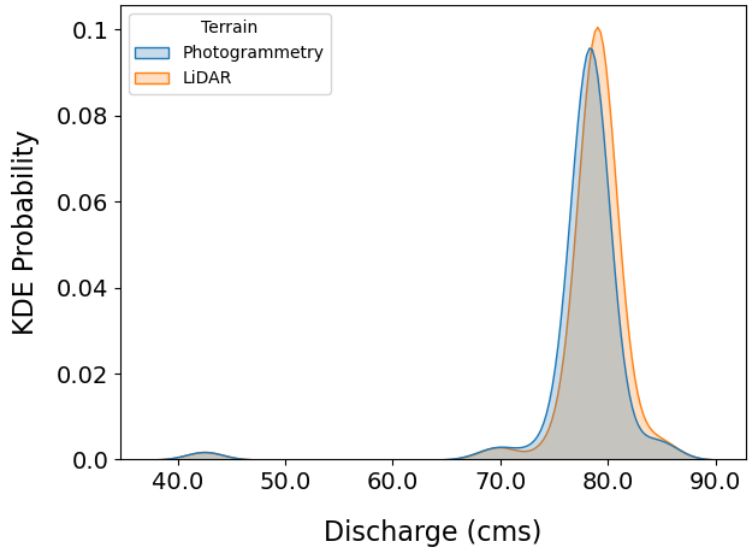

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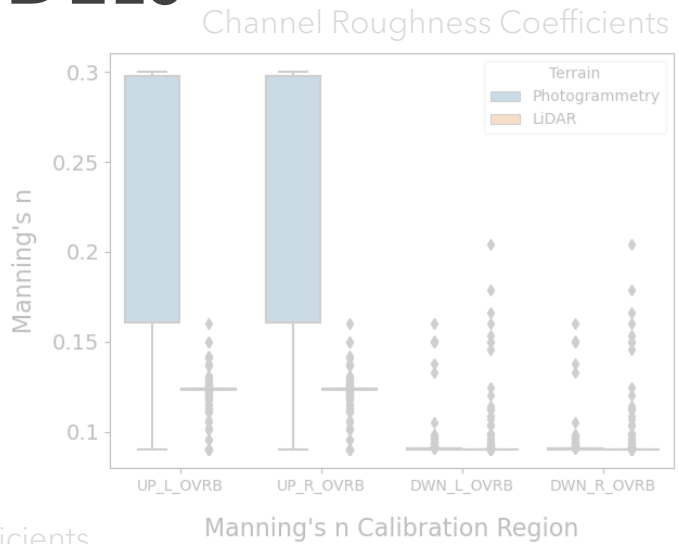

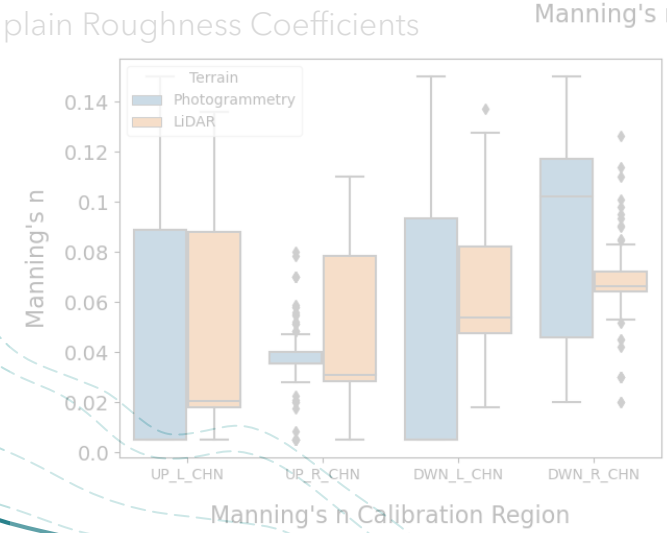

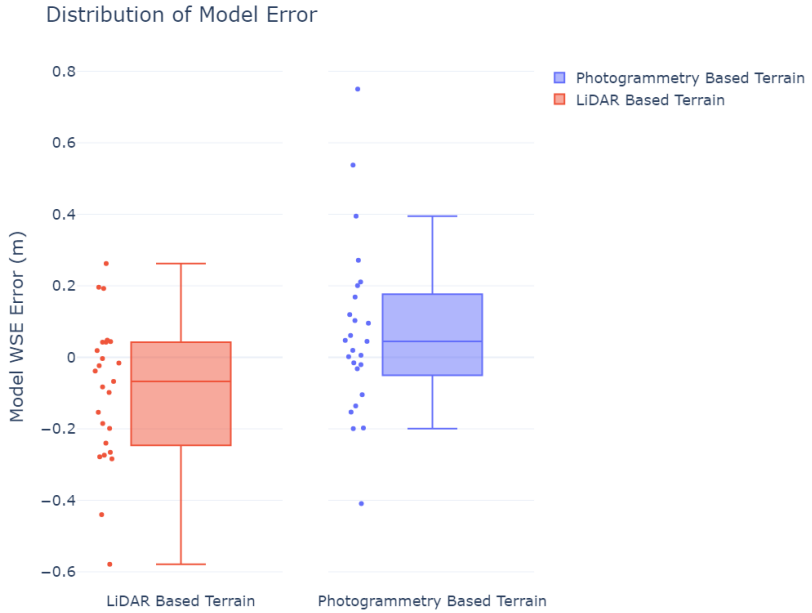

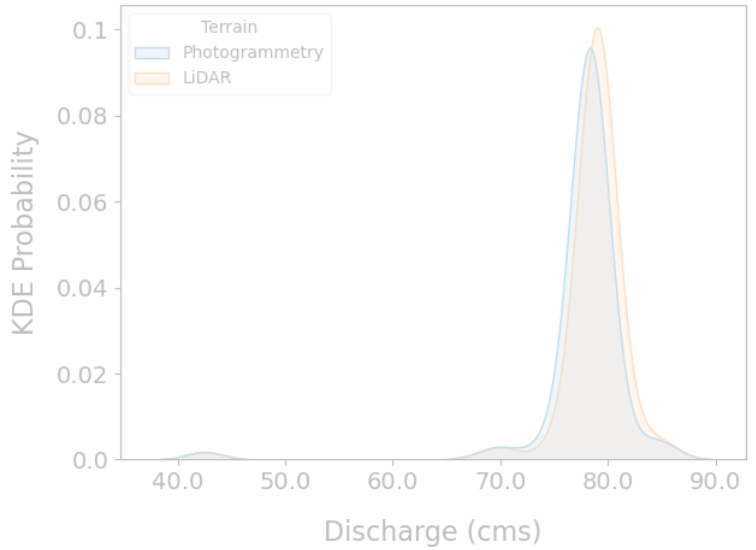

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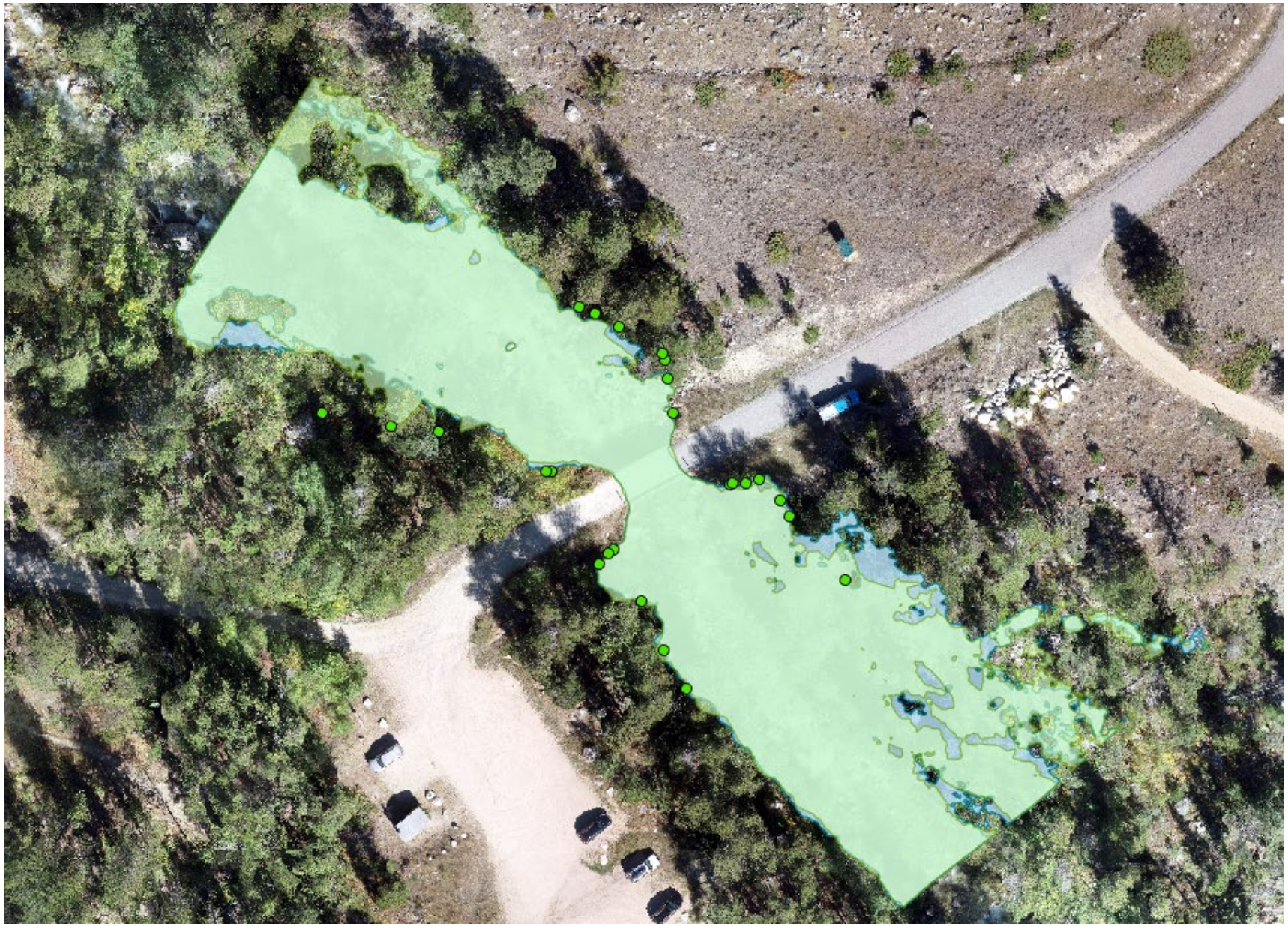


COMPARISON OF "EFFORT"

	Field Survey	Channel Survey Data Processing	Model Building	Calibration & Indirect Calculations	TOTAL
LiDAR 2D Model	9	8	2	3	22
Photogrammetry 2D Model	25	12	2	3	42
Conventional Cross-Section based Methods	16	2	0	1.5	19.5

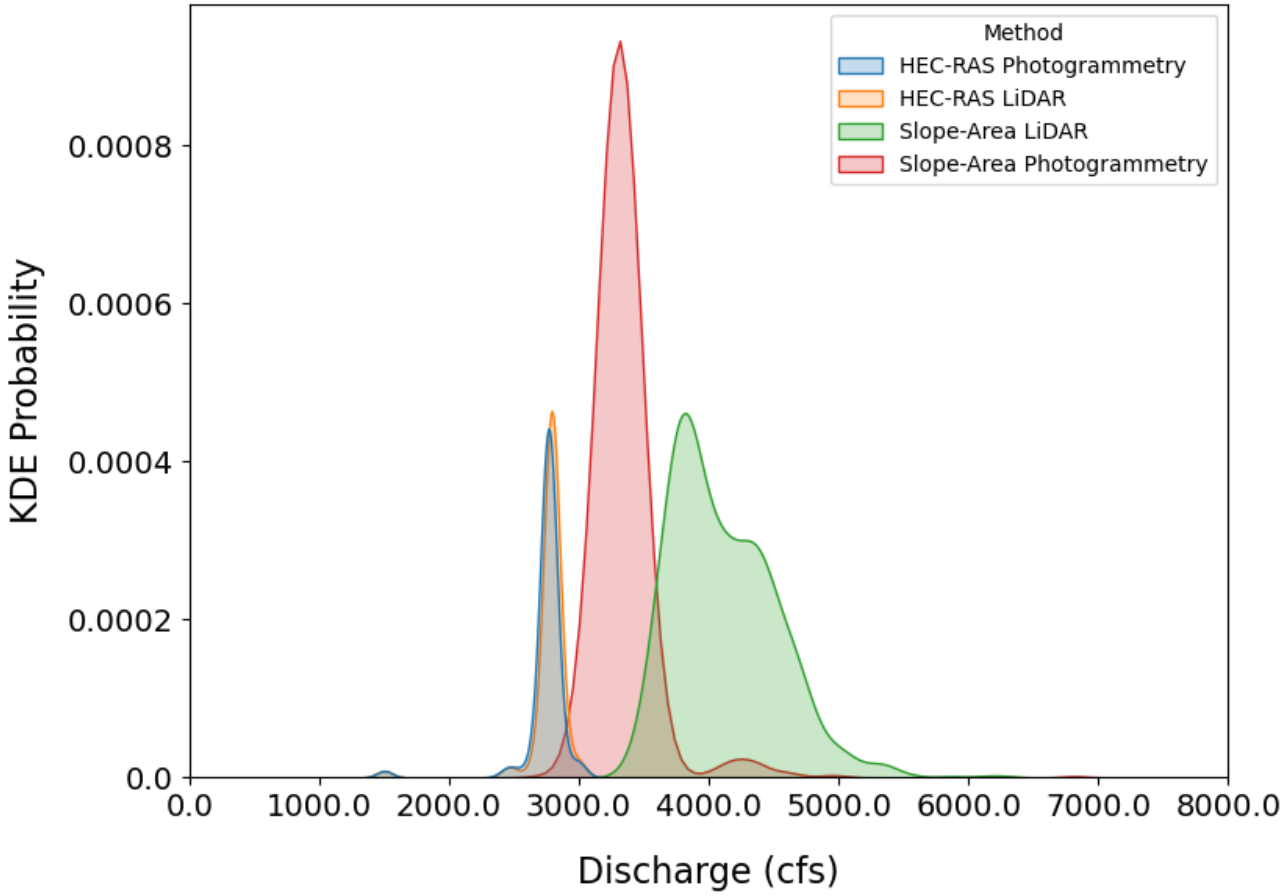
* Values are combined staff hours for each task.

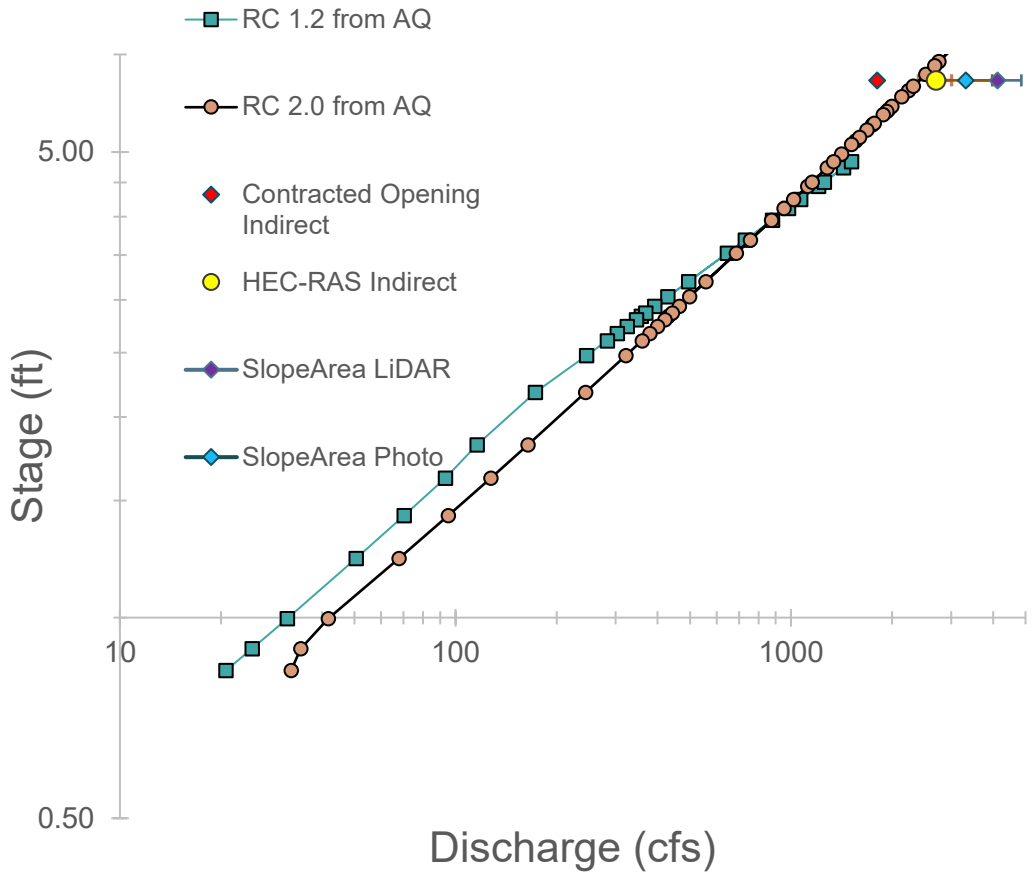
COMPARISON OF LOGISTICAL RESULTS

	Field Survey	Channel Survey Data Processing	Model Building	Calibration & Indirect Calculations	TOTAL
LiDAR 2D Model	9	8	2	3	22
Photogrammetry 2D Model	25	12	2	3	42
Conventional Cross-Section based Methods	16	2	0	1.5	19.5

* Values are combined staff hours for each task.

INDIRECT DISCHARGE VALIDATION

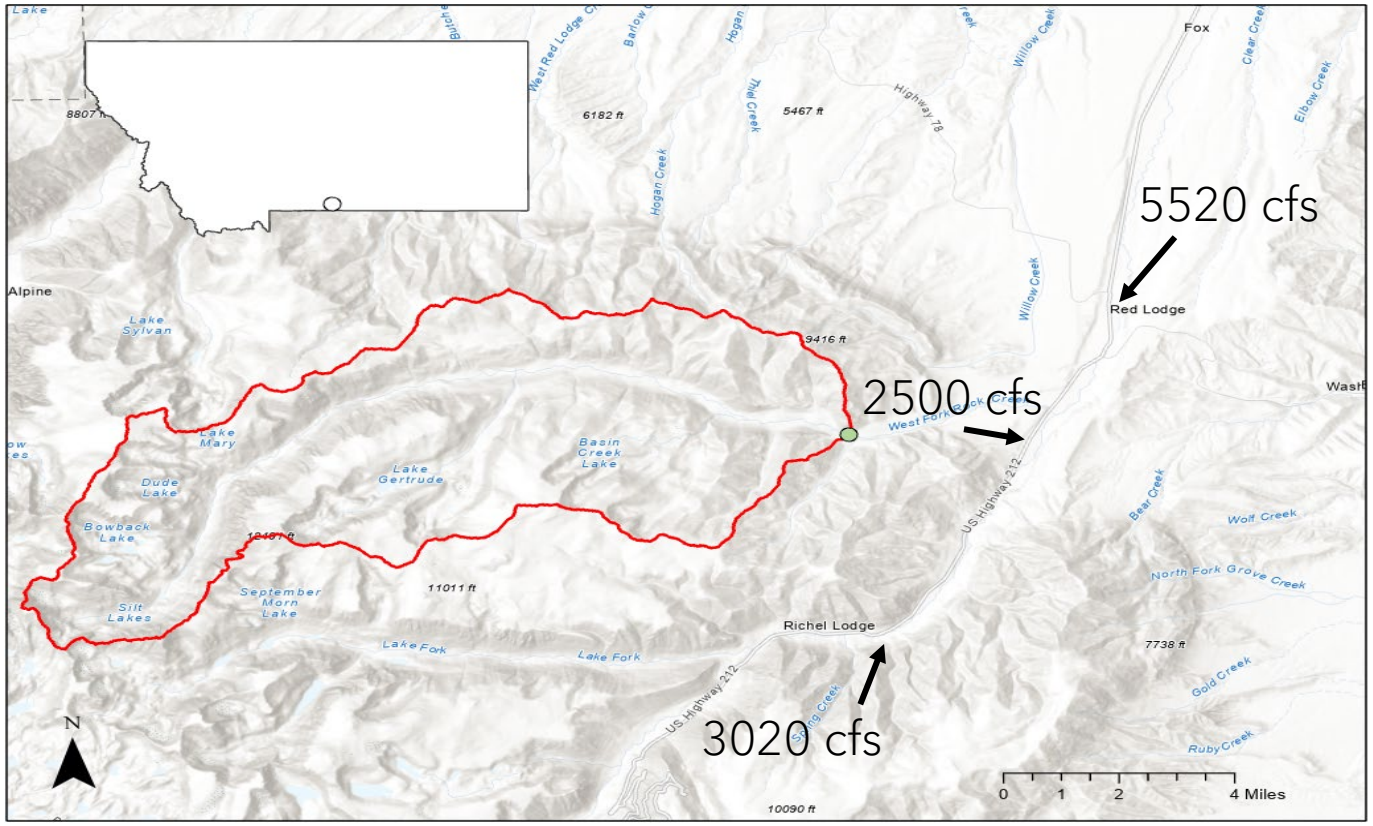




INDIRECT DISCHARGE VALIDATION

USGS Indirect Flows in the Area

2D Model Estimate
$2700 \pm 200\ cfs$



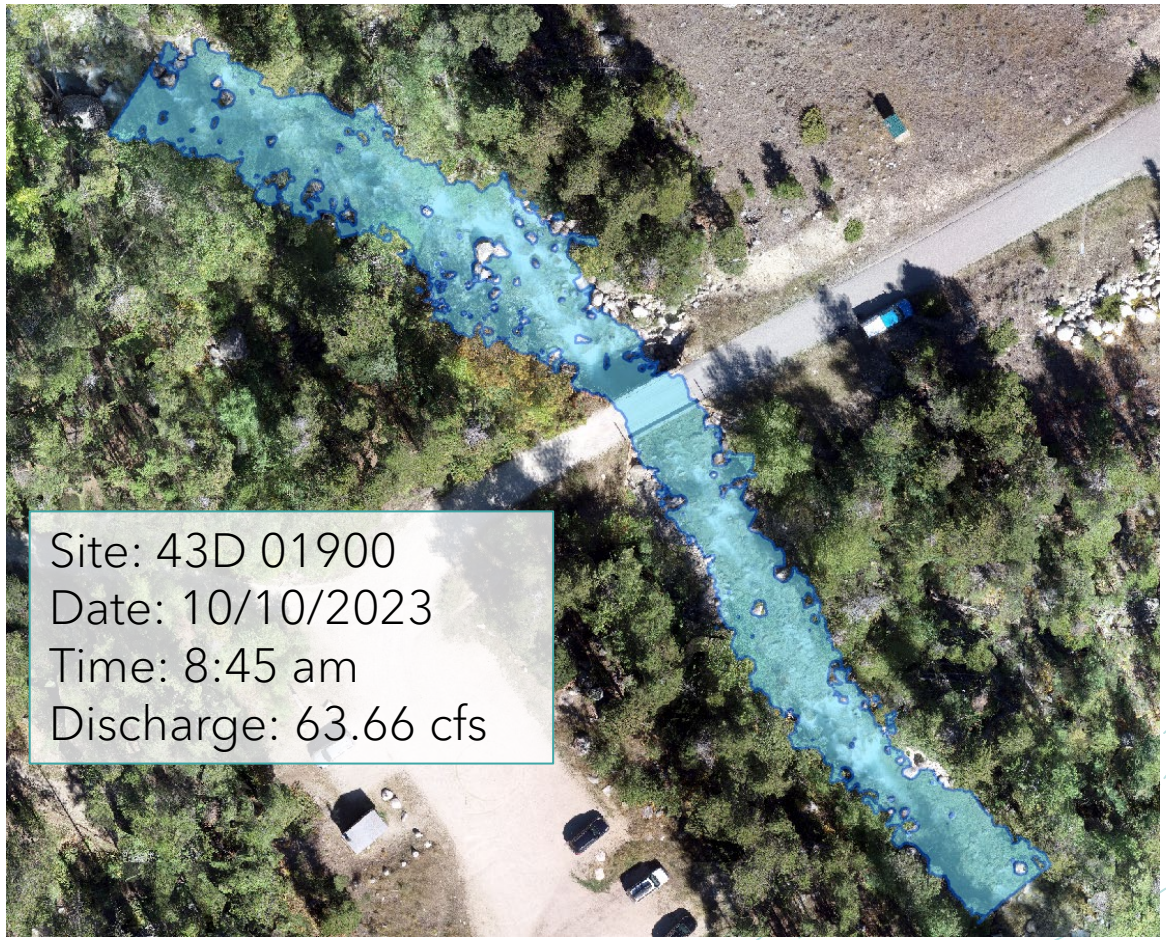
CONCLUSIONS SO FAR

Is it better in 2D??

- 2D Model provides lower uncertainty bounds than “cross section” based methods
- Better error diagnostics
- Takes more effort overall
- Allows for additional uses:
  - Flood Warning
  - Real-time Depth/Inundation at sites
- LiDAR produces a better calibrated model with minimal effort
- 3D Channel survey is most flexible

WHAT NEXT?

- Technical Methods Report
- Adoption of Standard Practices
- Build models for all DNRC gage sites
- Incorporate into Integrated Modeling Work
  - Real-time inundation at DNRC gage sites
- Continue to improve model automation



THANK YOU

CO-AUTHORS AND DNRC WATER COLLOGUES

DNRC IT/GIS

USGS COLLEAGUES

QUESTIONS?

Todd Blythe

todd.blythe@mt.gov

MT DNRC

Water Sciences Bureau