

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...

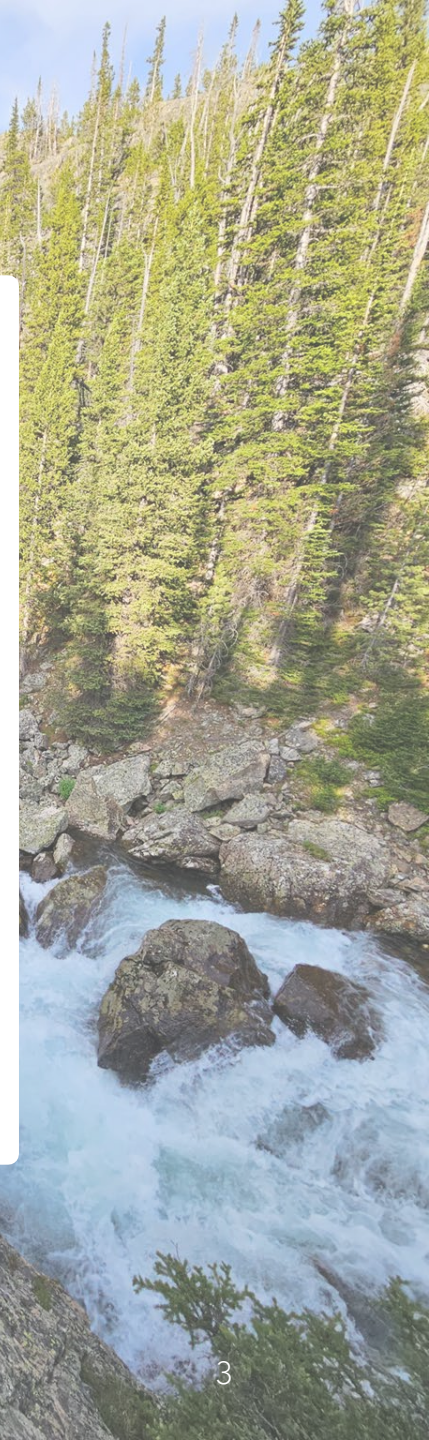
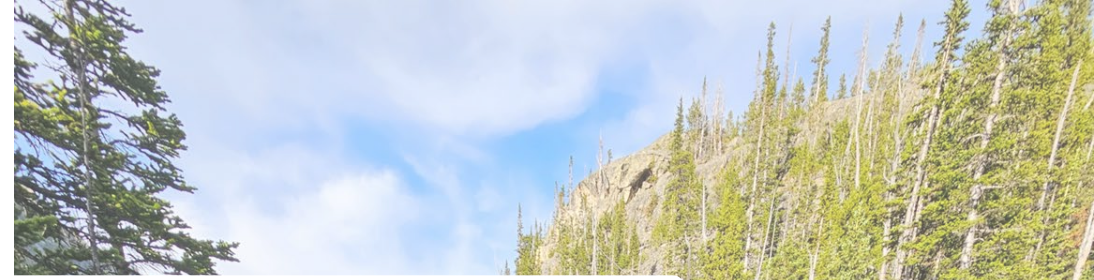


“INDIRECT DISCHARGE”

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



USES OF INDIRECT DISCHARGE

Paleo-Hydrology

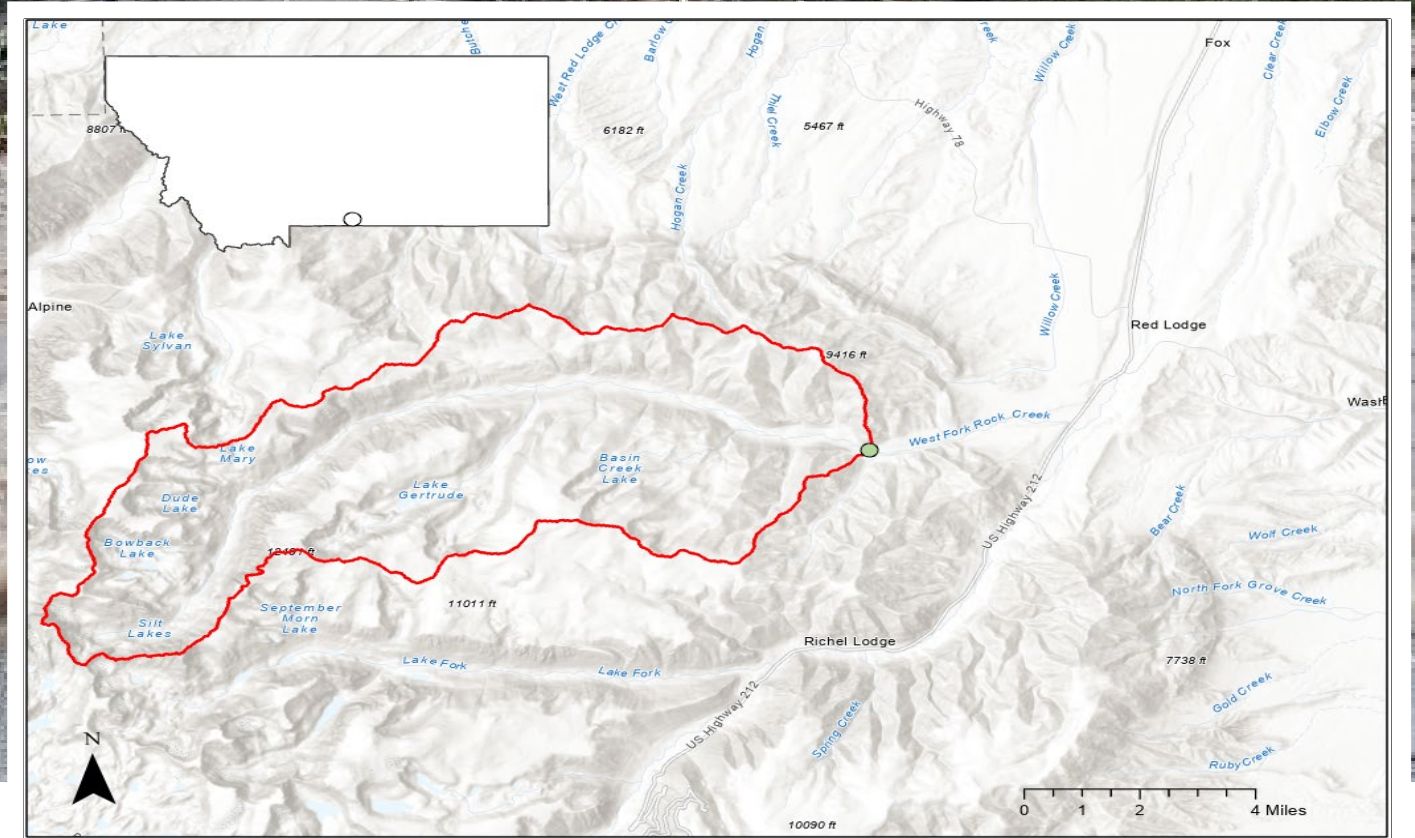
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Measurement of Stream Discharge

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Photo Credit: Sandra Haisler via Montana NPR

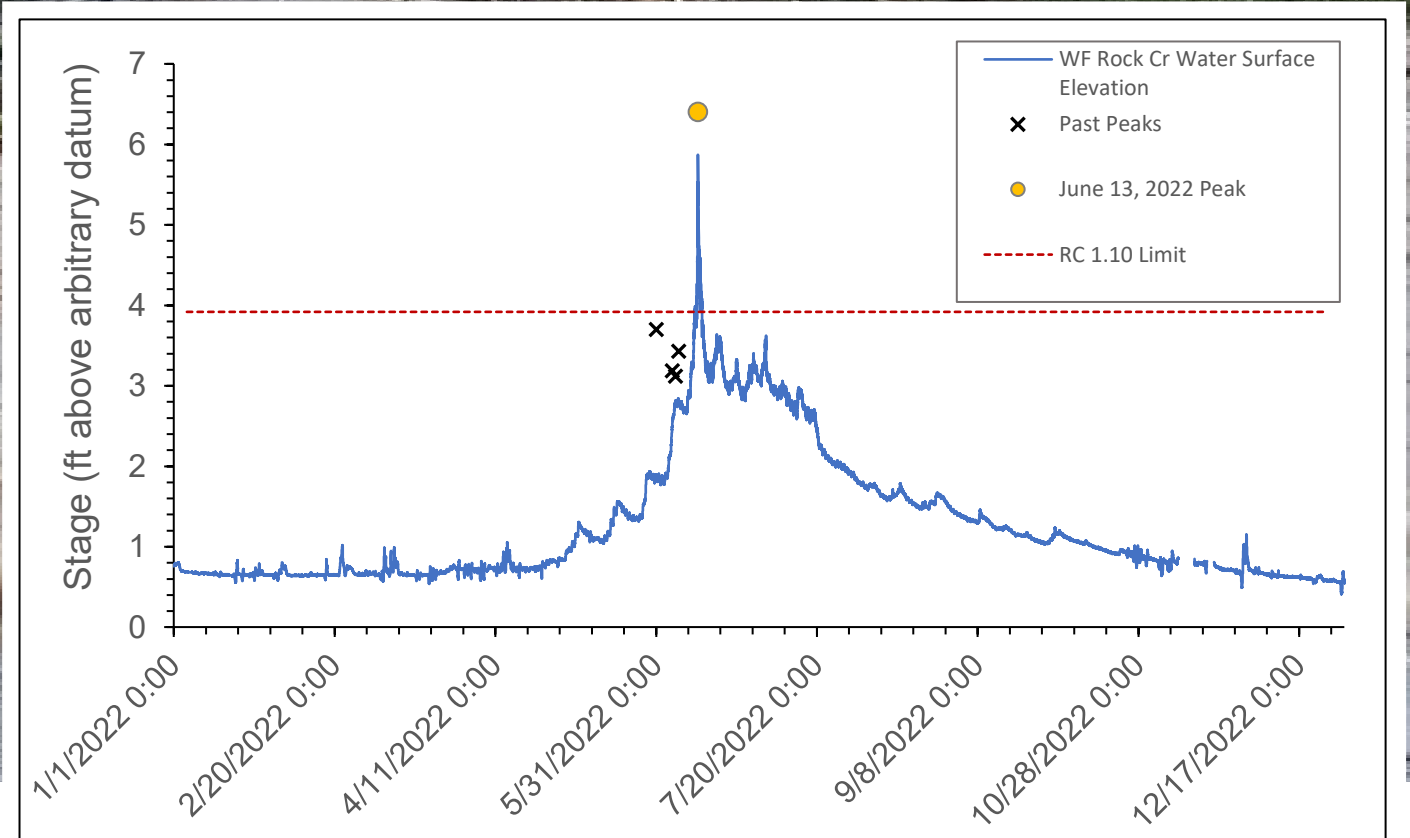


YELLOWSTONE BASIN FLOODING, JUNE 2022

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

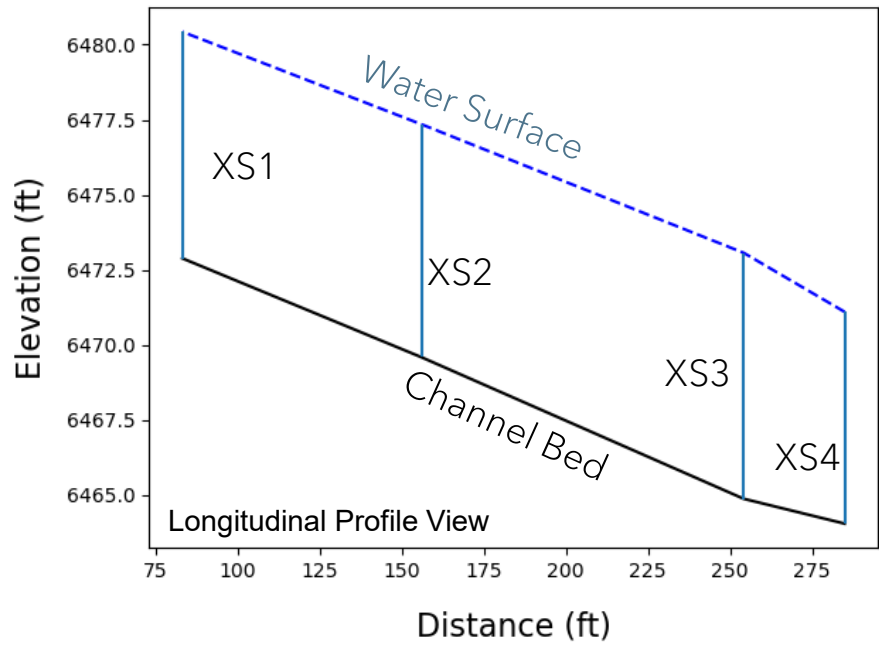


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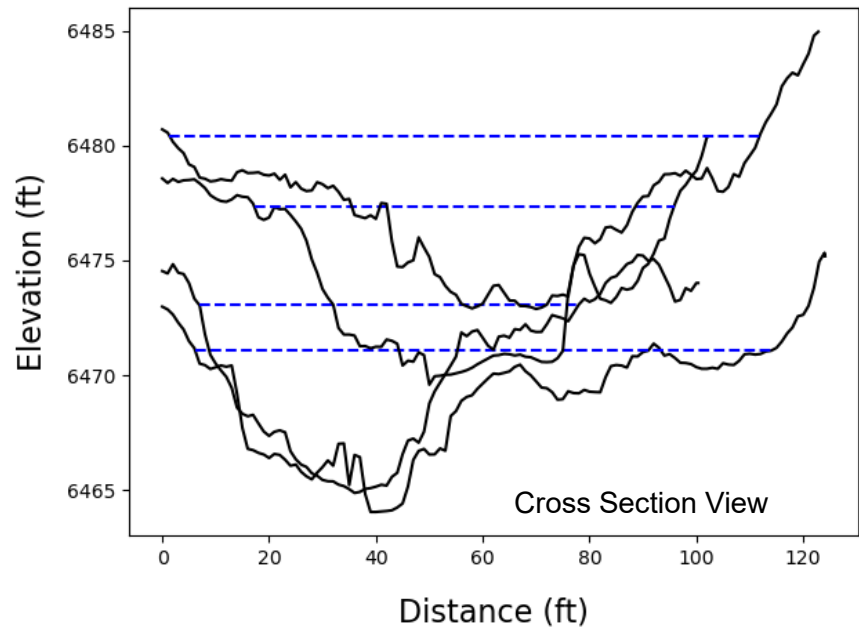
CONVENTIONAL INDIRECT METHOD SLOPE-AREA METHOD

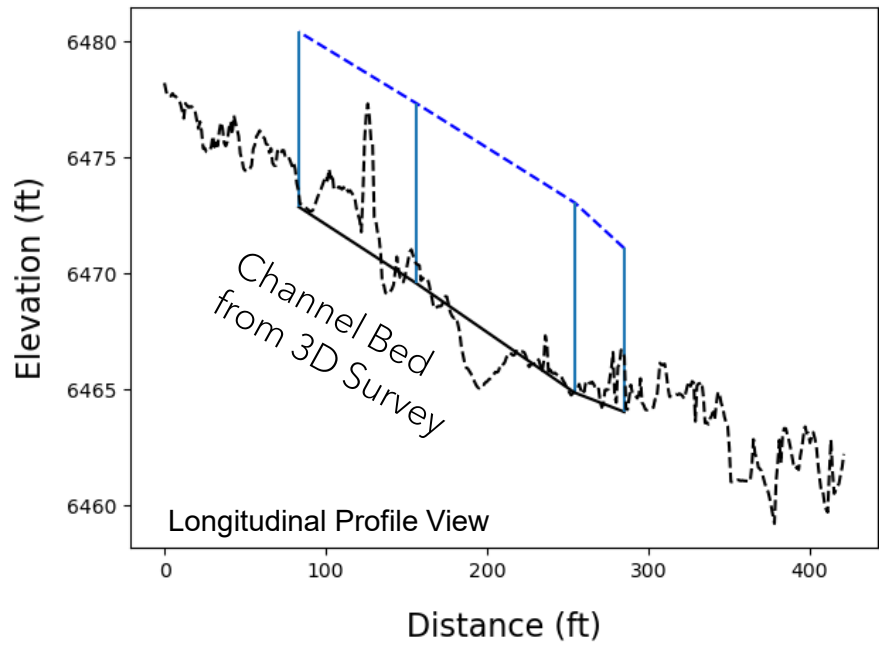
Based on Conservation of Energy Principles

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

Steps:

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

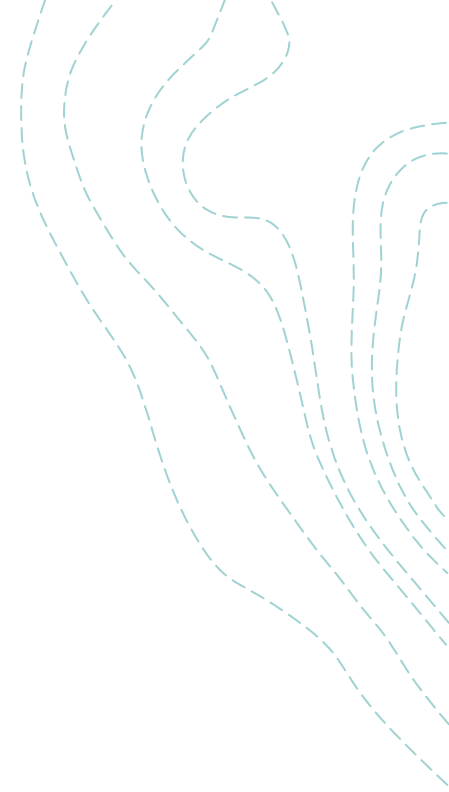
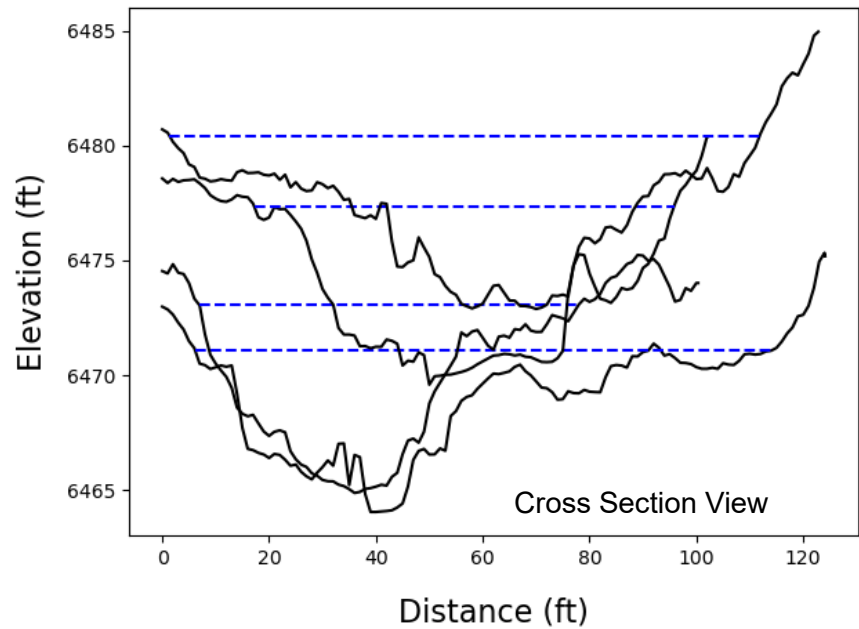




CONVENTIONAL INDIRECT METHOD SLOPE-AREA METHOD

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

Montana AWRA 2023



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

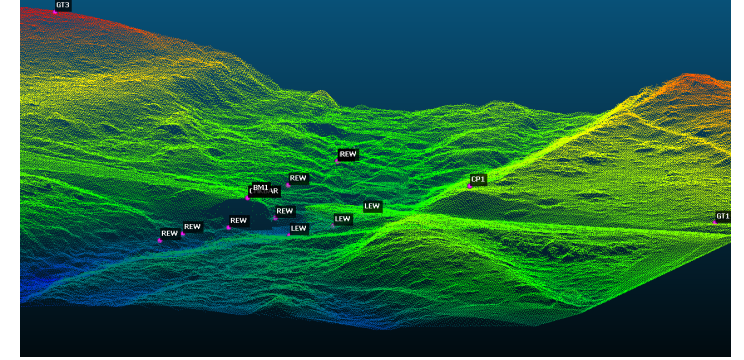
Is extra survey and processing effort worth it?



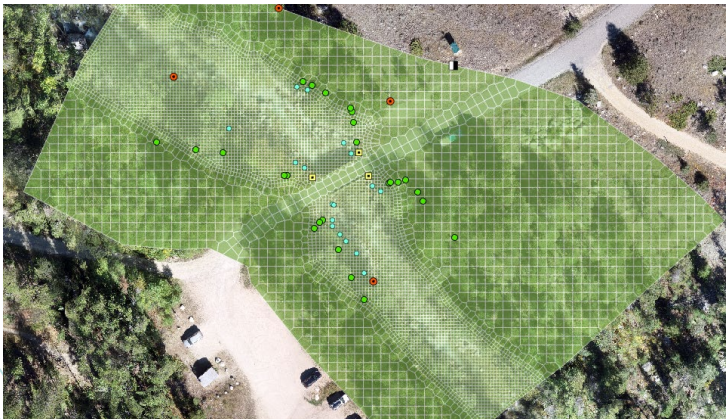
STEPS FOR USING A 2D HYDRAULIC MODEL



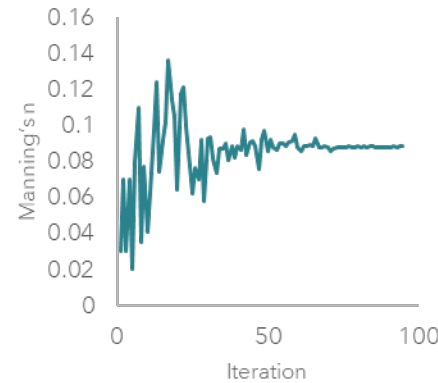
3D Channel Survey
Aerial Topography and Bathymetry



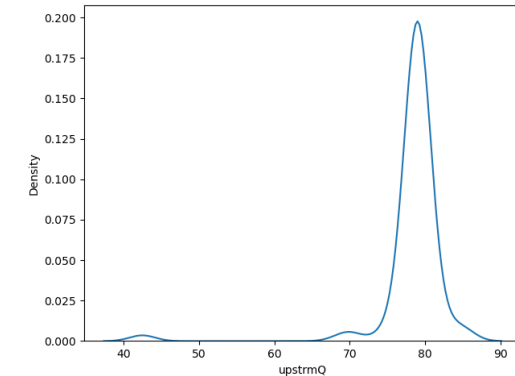
Process Terrain Data for use in Model
Point Cloud to DEM



Build a 2D Model
Used HEC-RAS 6.4.1



Calibration of Channel Roughness
Using water surface elevation of a known
discharge

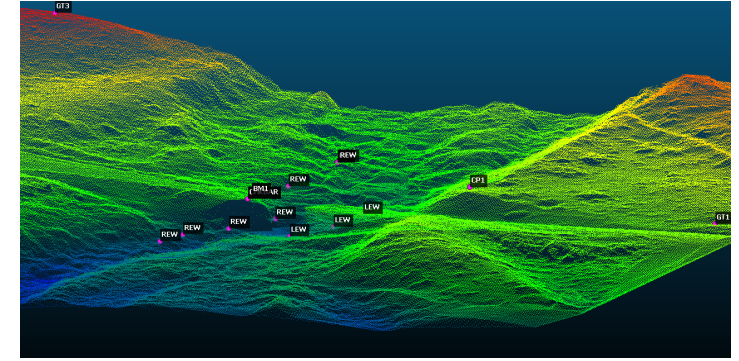


Optimization treating discharge as an
unknown
Same process as calibration

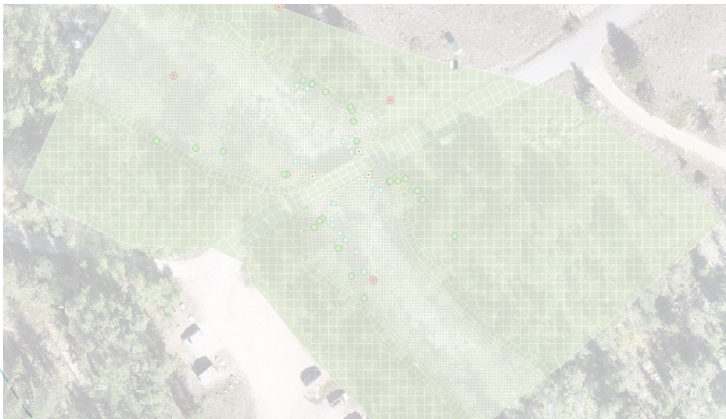
WE'RE COMPARING 2 DIFFERENT SURVEY METHODS...



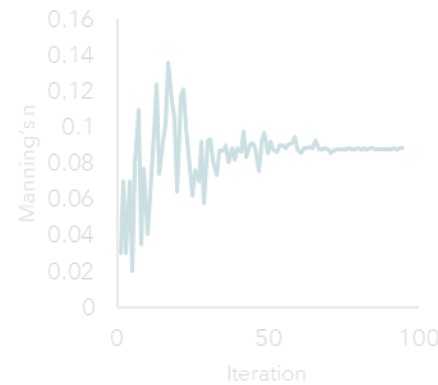
3D Channel Survey
Photogrammetry vs. LiDAR



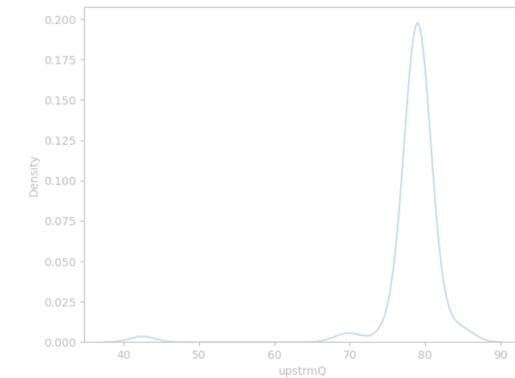
Process Terrain Data for use in Model
Different Process for each



Build a 2D Model
Used HEC-RAS 6.4.1



Calibration of Channel Roughness
Using water surface elevation of a known
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Optimization treating discharge as an
unknown
Same process as calibration

MODEL CALIBRATION

1 VARIABLE

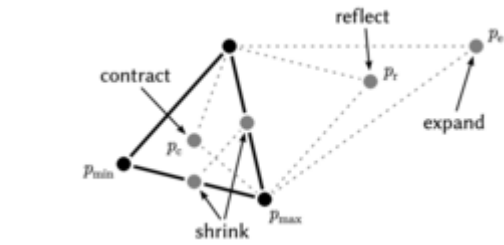
MULTIPLE PARAMETERS

2 DEDICATED CALIBRATION RUNS

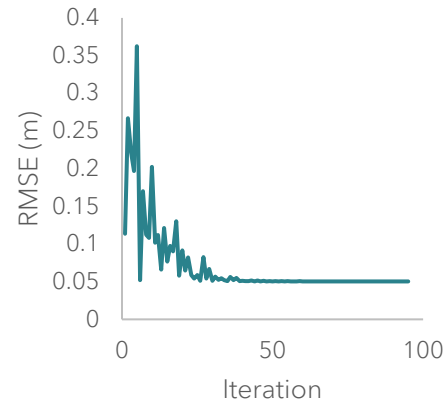
1 CONCURRENT



Delineate Manning's n regions
Site Specific (4 channel, 4 floodplain)



Used Nelder-Mead Method
Multi-parameter algorithm



Choose Objective Function
Minimized RMSE

```

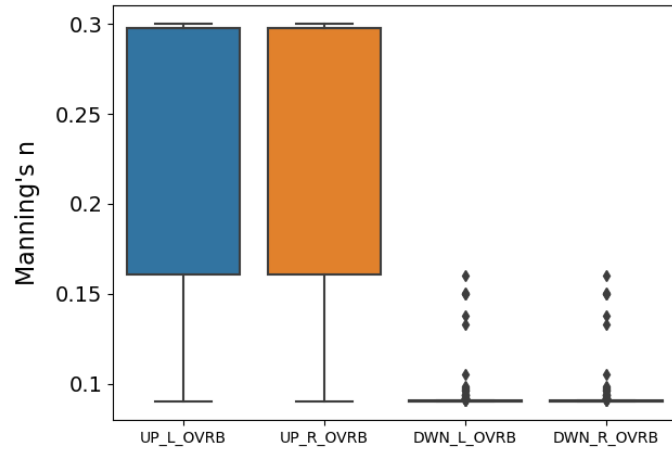
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3 from datetime import datetime
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7
8 # Read the output files
9 output_dir = Path("D:\2022-08-Project\01_River\01_0000001_Outputs")
10
11 # Read the model files
12 model_files = Path("D:\2022-08-Project\01_River\01_0000001_Model")
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100

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Model Automation for Multiple Runs
Developed a Python Package for model control

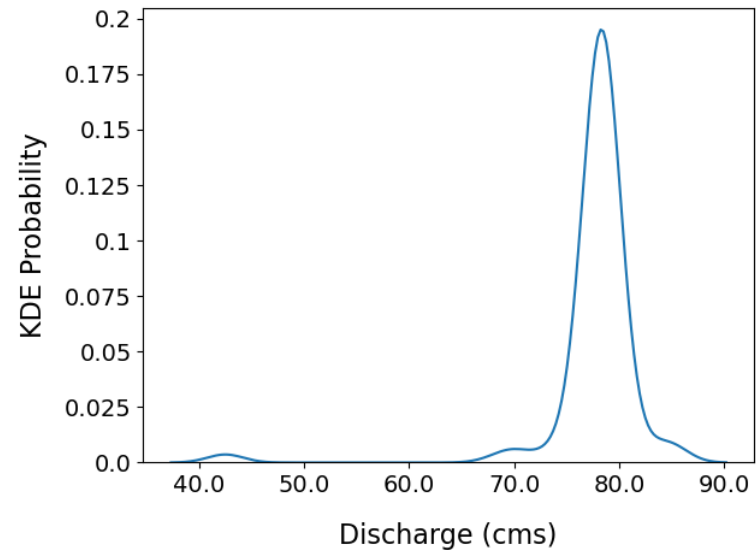
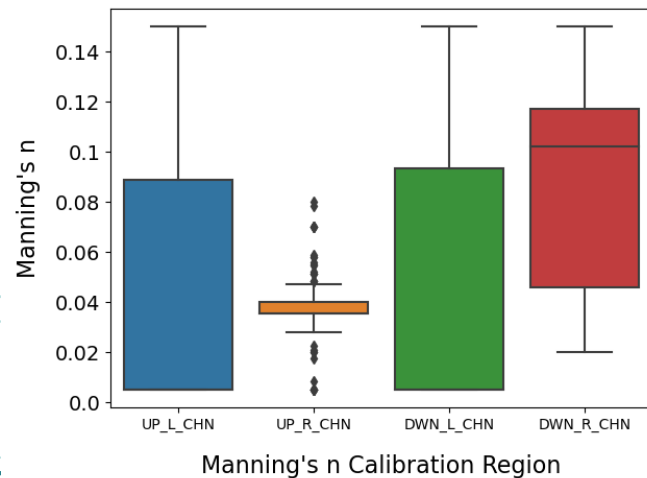
PHOTOGRAMMETRY BASED MODEL RESULTS

Channel Roughness Coefficients

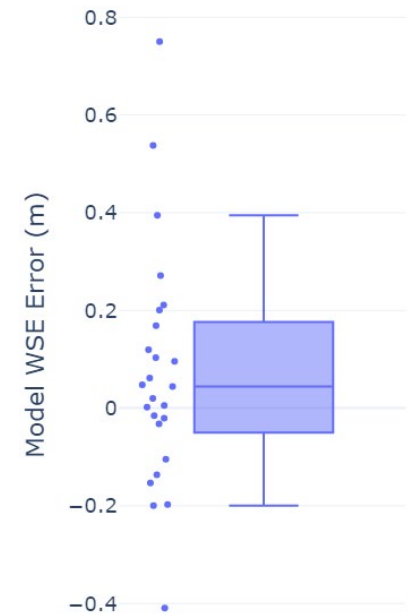


Floodplain Roughness Coefficients

Manning's n Calibration Region

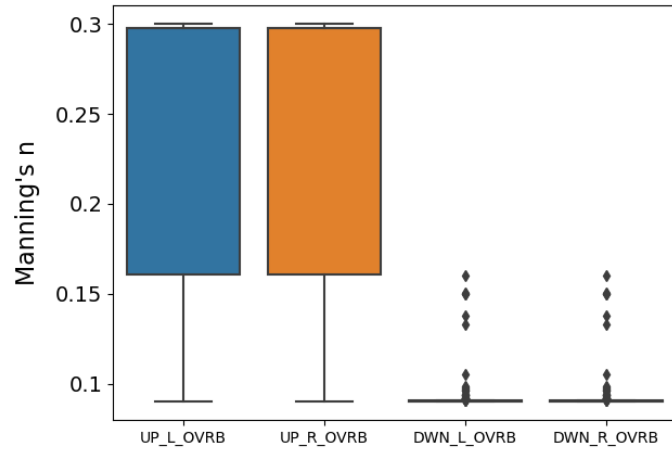


Distribution of Model Error



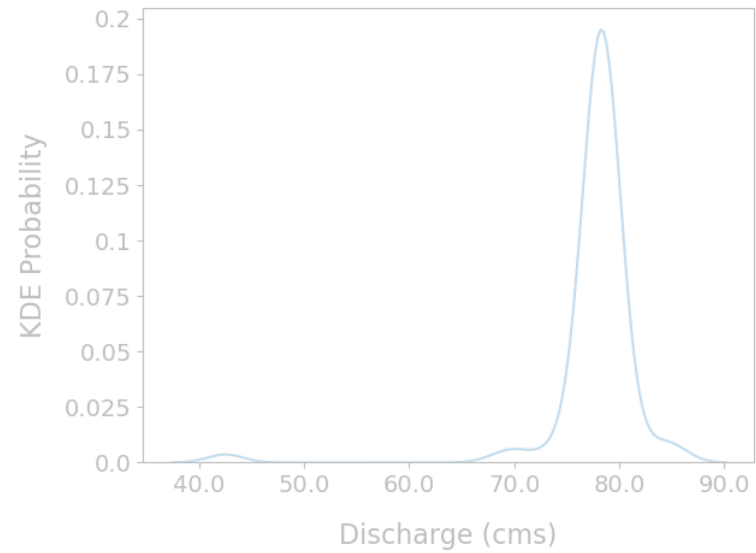
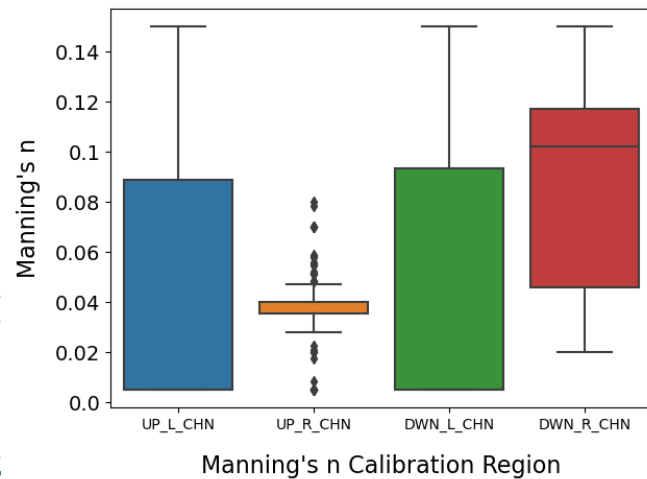
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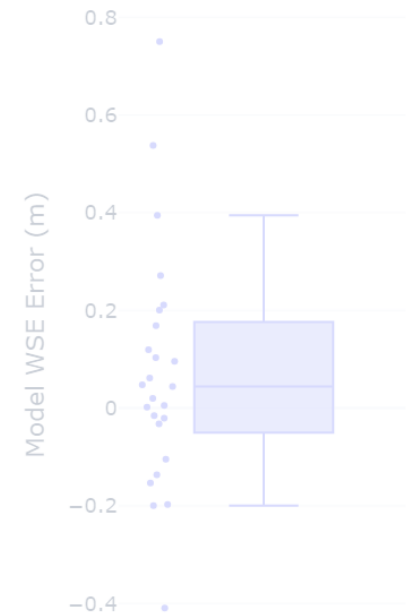


Floodplain Roughness Coefficients

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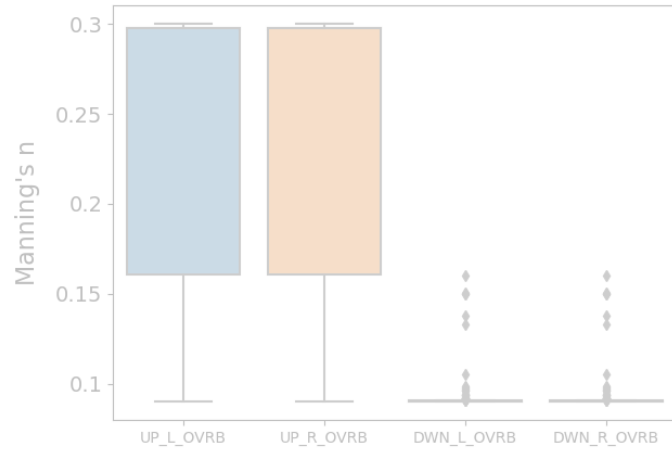


Distribution of Model Error



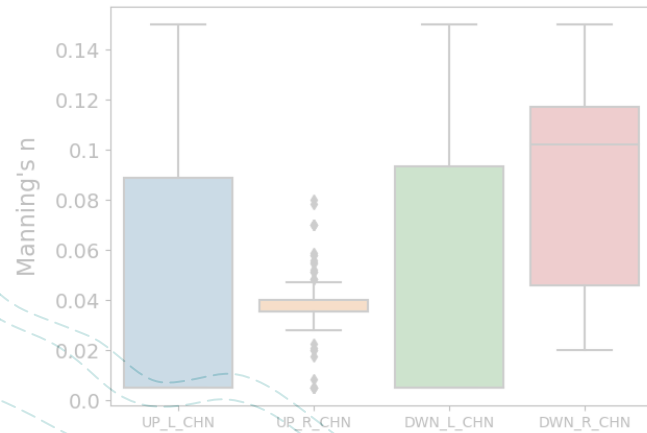
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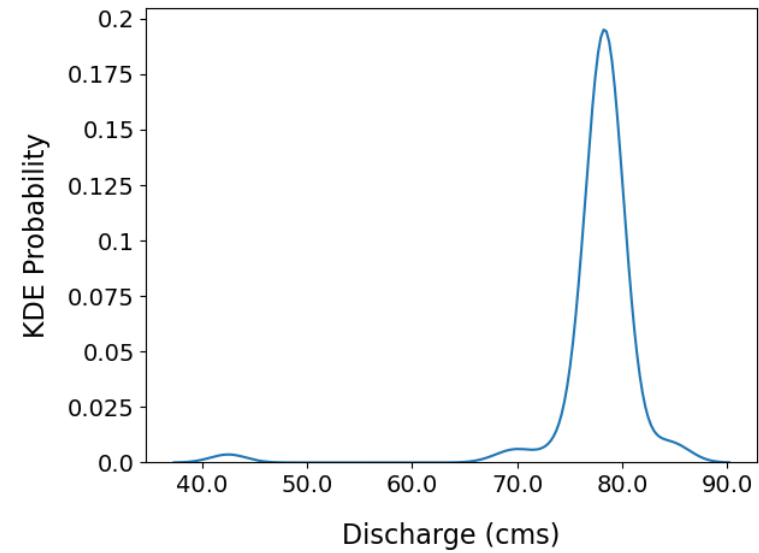


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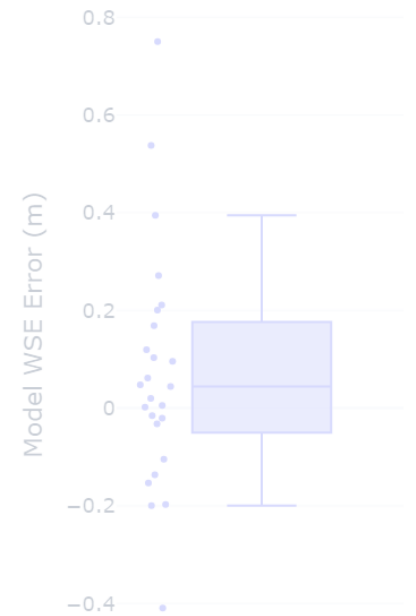
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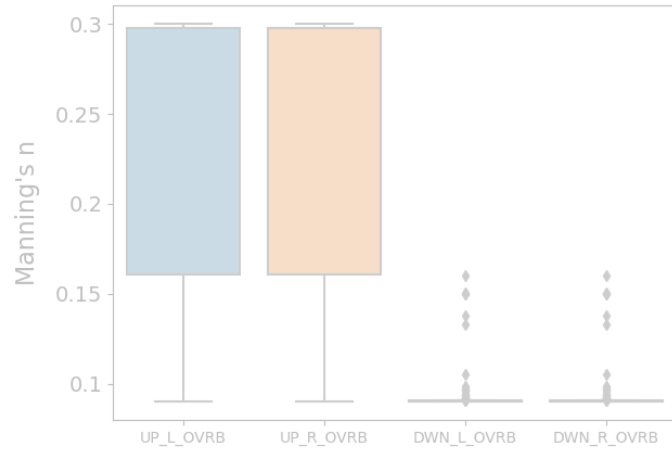


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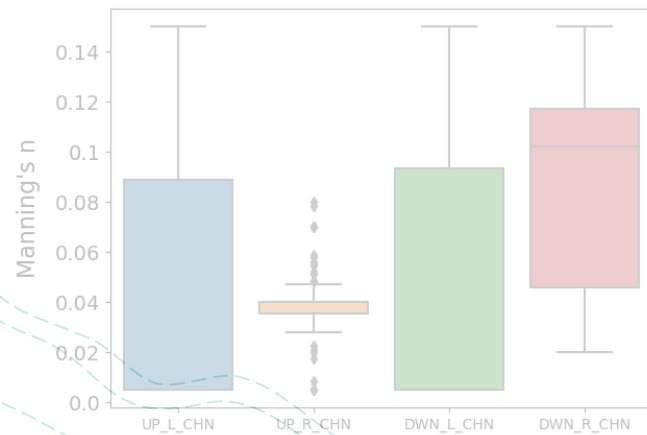
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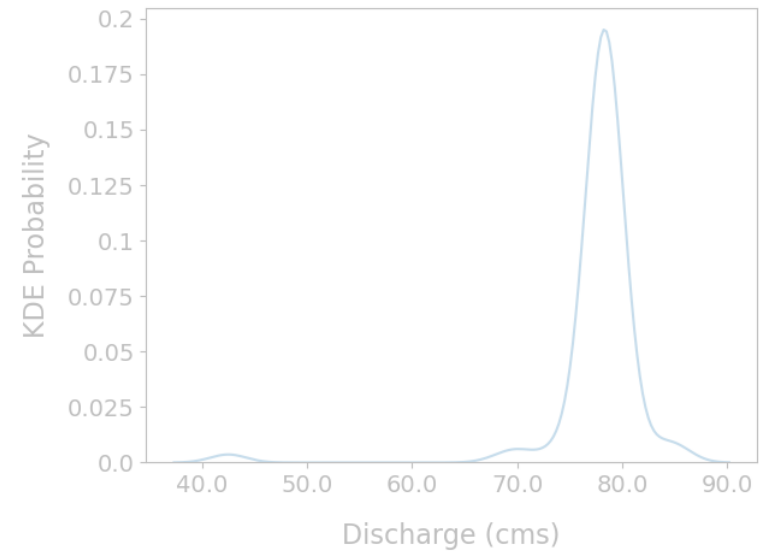


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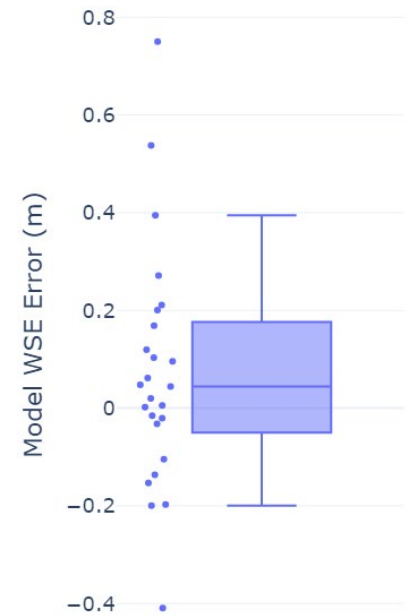
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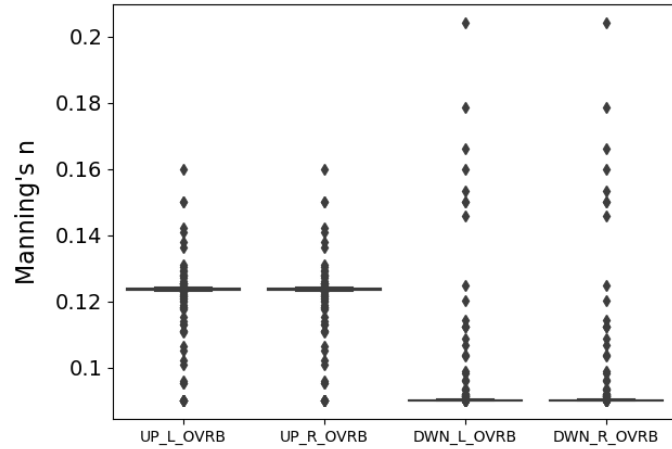


Distribution of Model Error



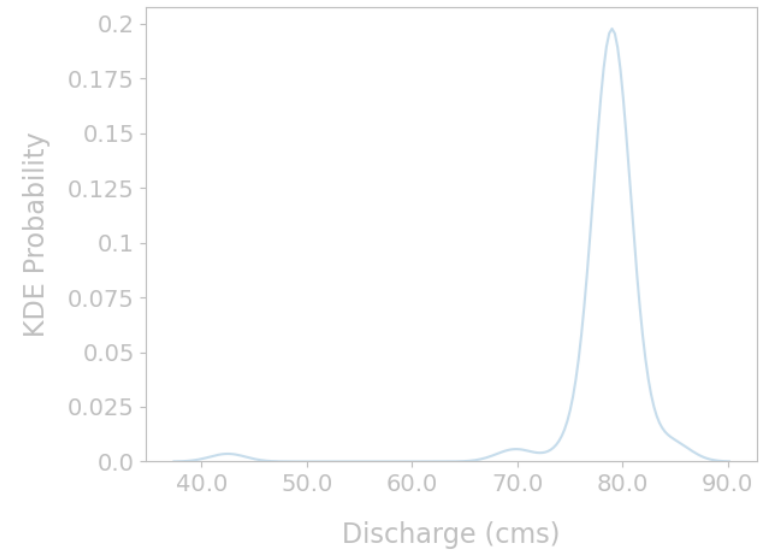
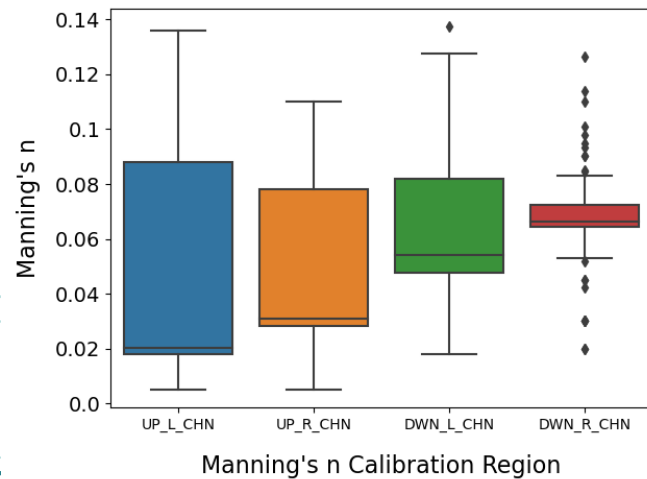
LIDAR BASED MODEL RESULTS

Channel Roughness Coefficients

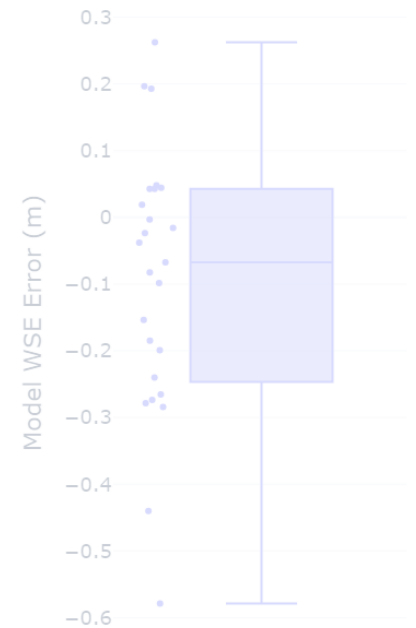


Floodplain Roughness Coefficients

Manning's n Calibration Region

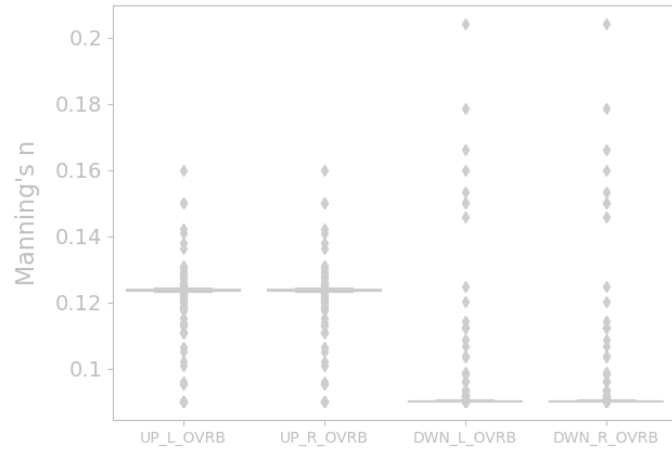


Distribution of Model Error



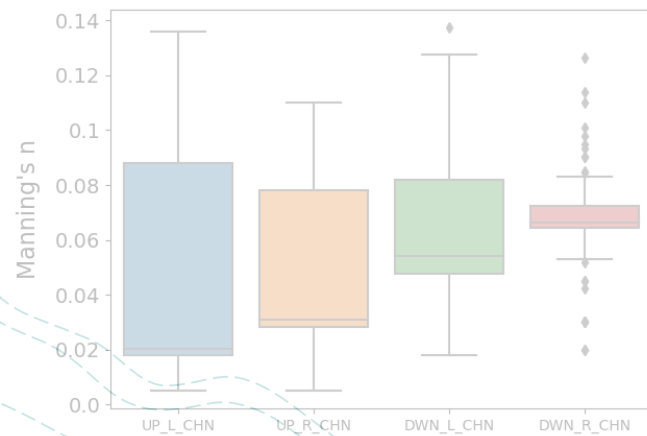
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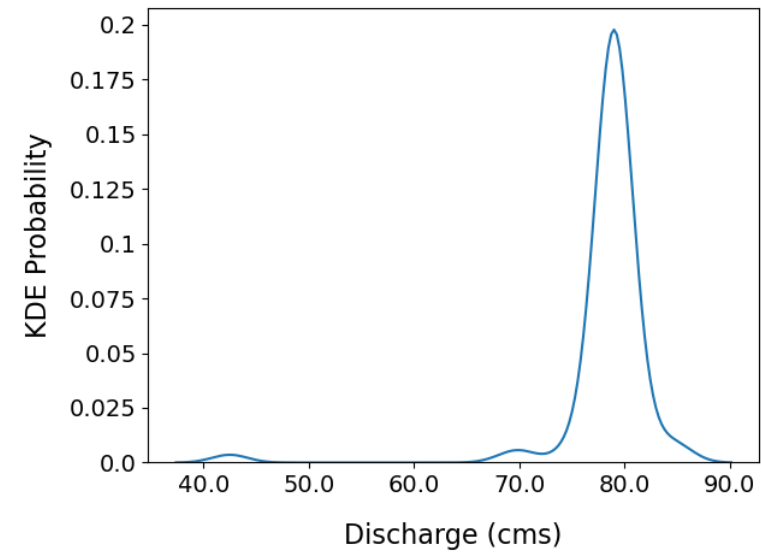


Floodplain Roughness Coefficients

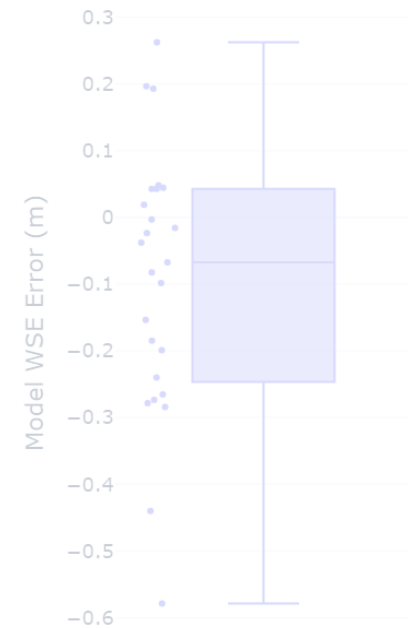
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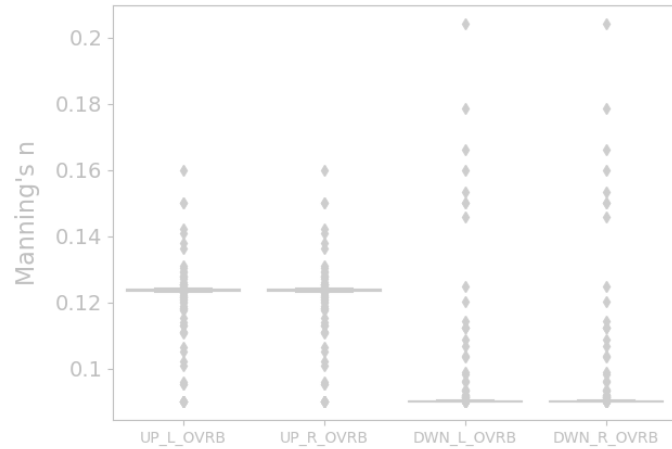


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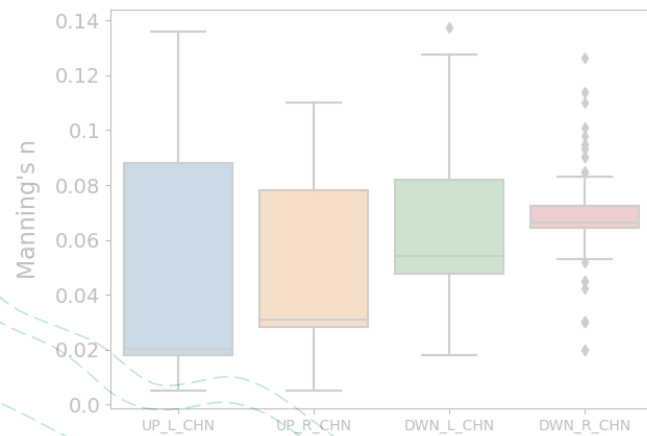
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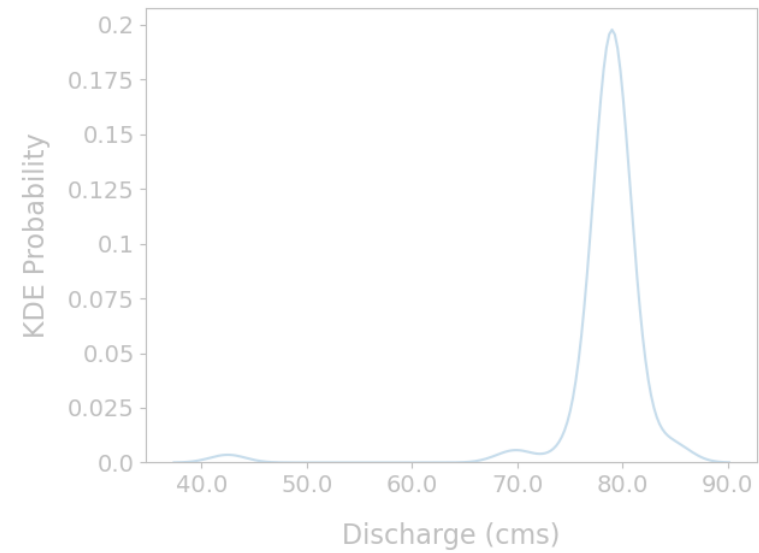


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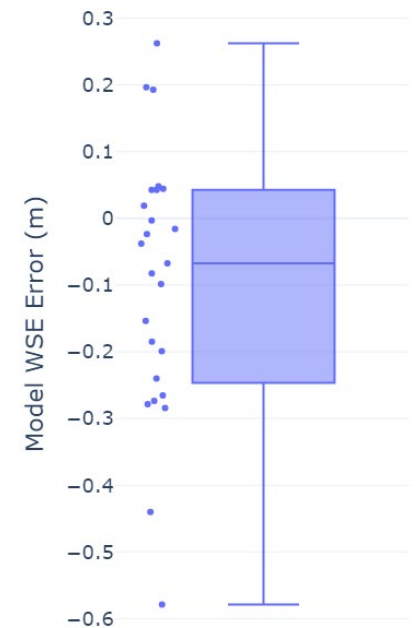
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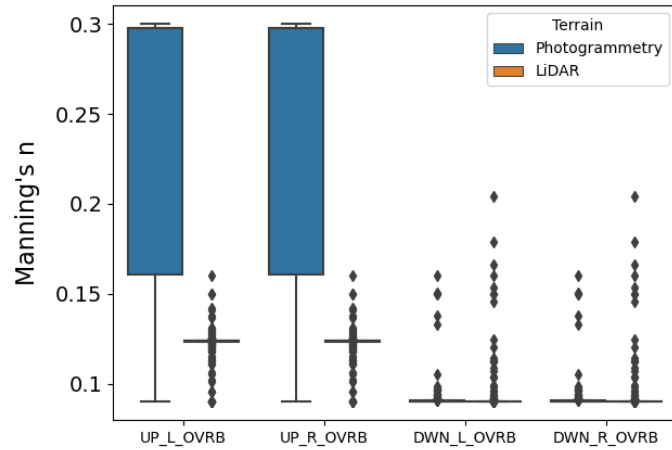


Distribution of Model Error

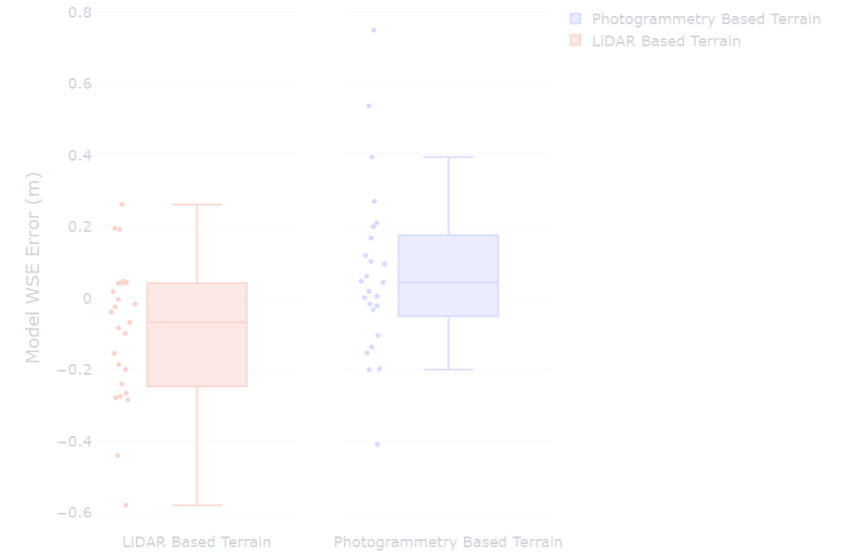


COMPARISON OF 2D MODELS

Channel Roughness Coefficients

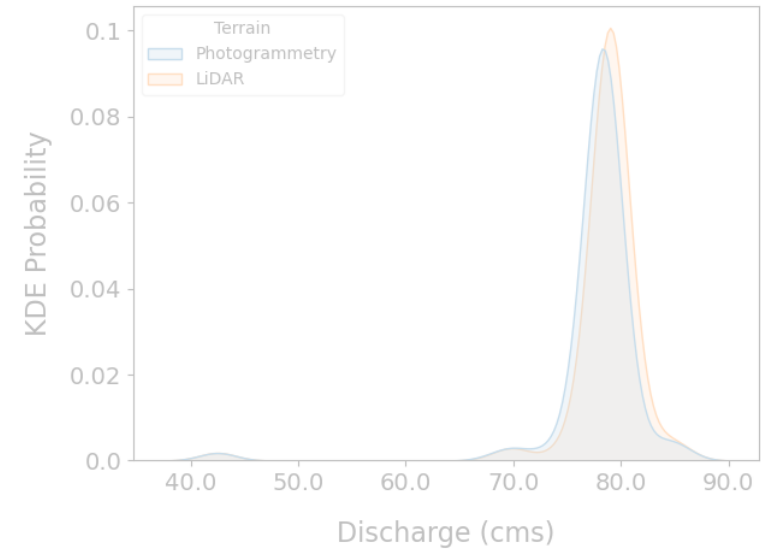
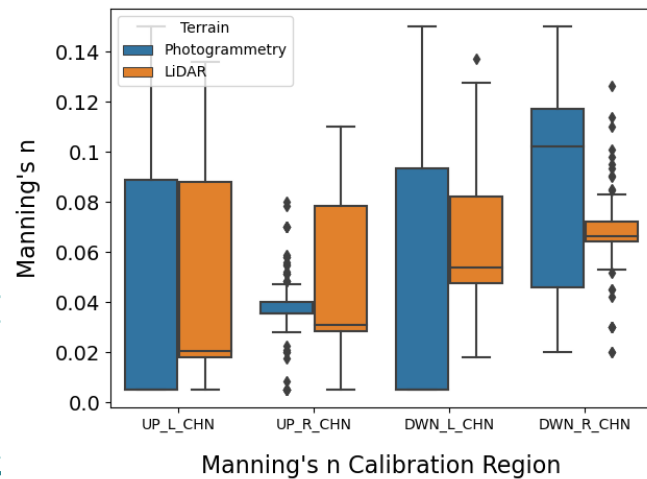


Distribution of Model Error



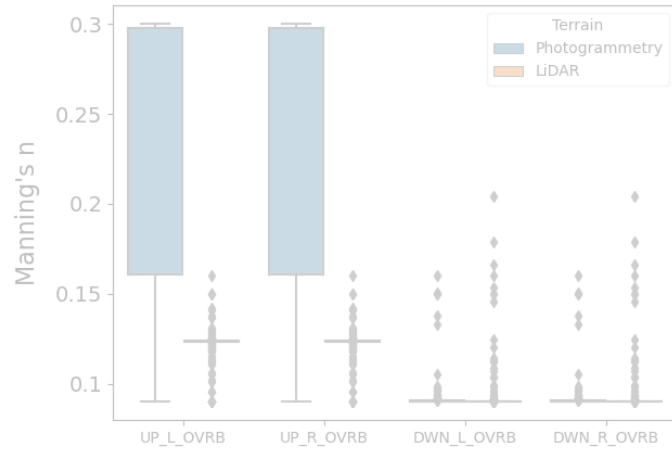
Floodplain Roughness Coefficients

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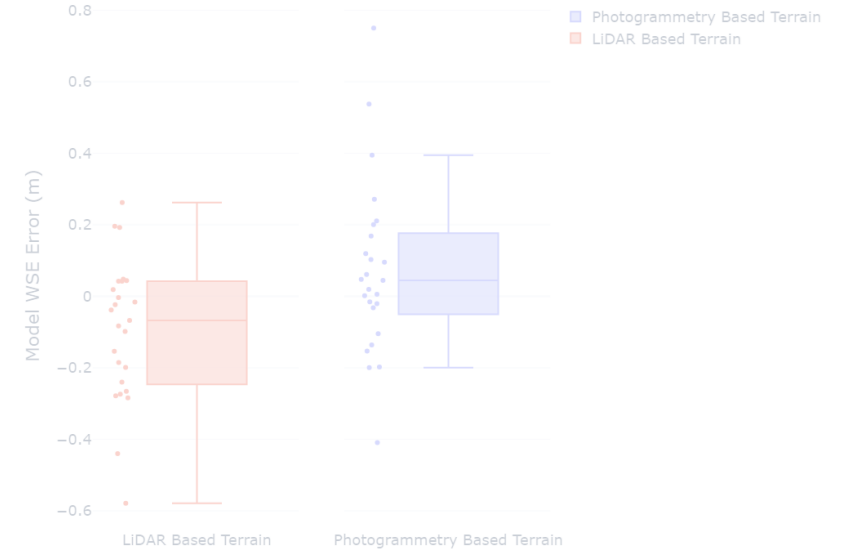


COMPARISON OF 2D MODELS

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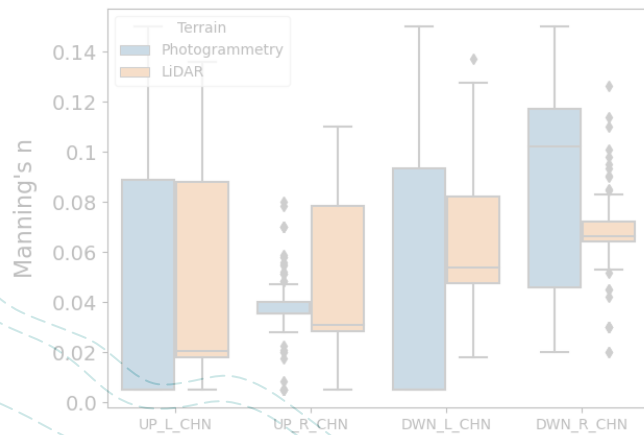


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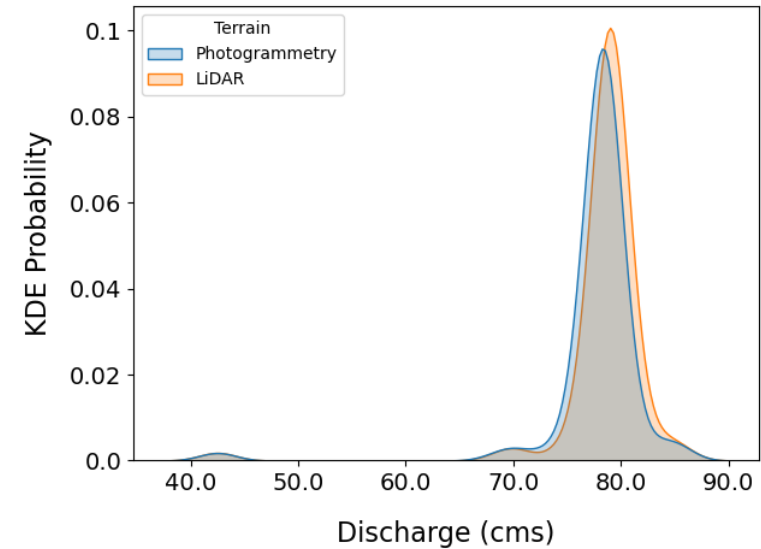


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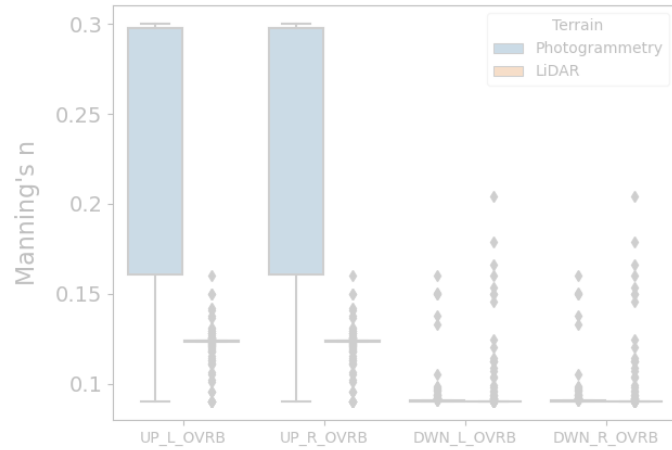


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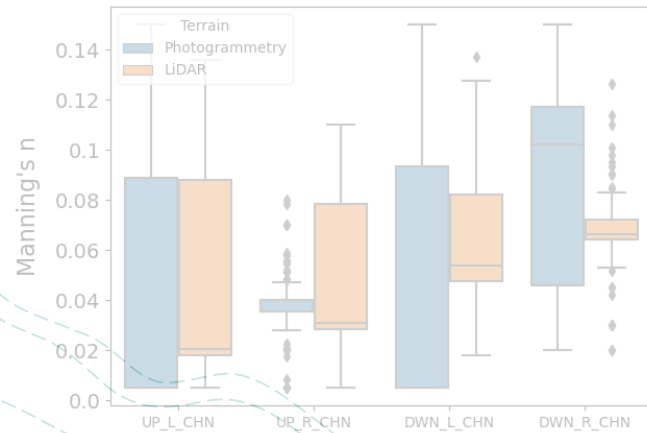
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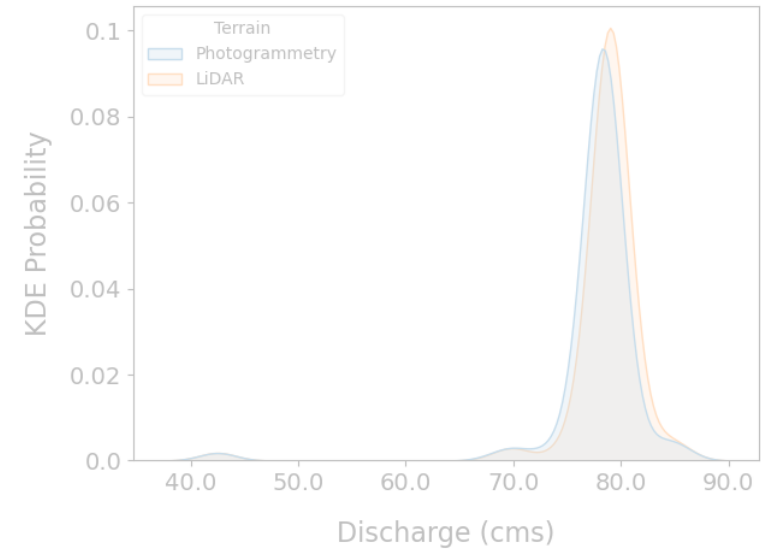
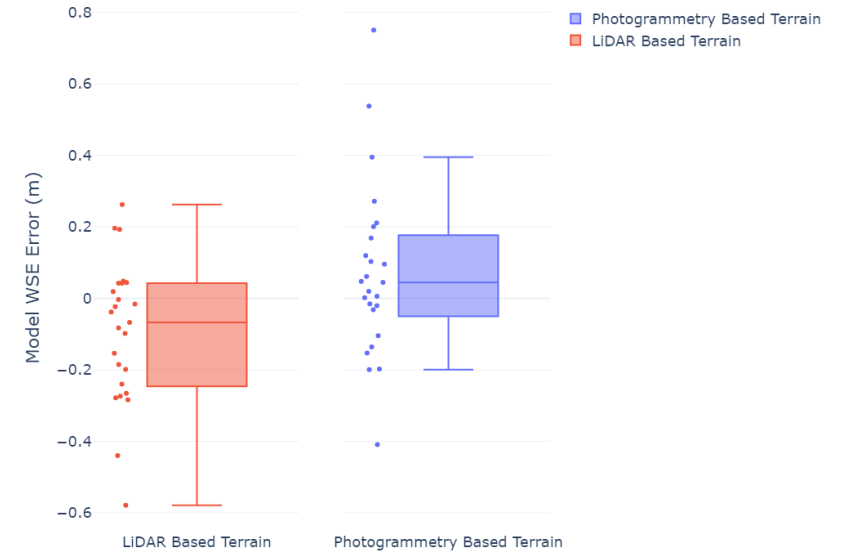
Floodplain Roughness Coefficients

Manning's n Calibration Region



Manning's n Calibration Region

Distribution of Model Error



COMPARISON OF 2D MODELS



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

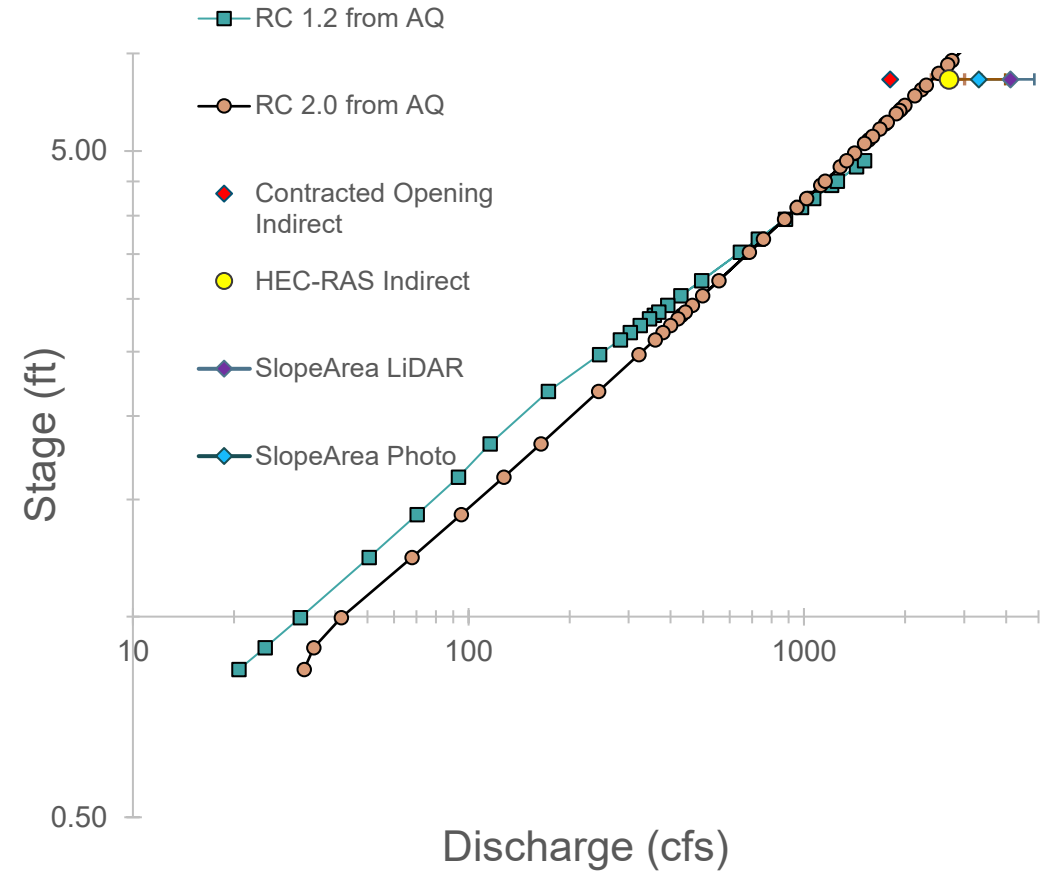
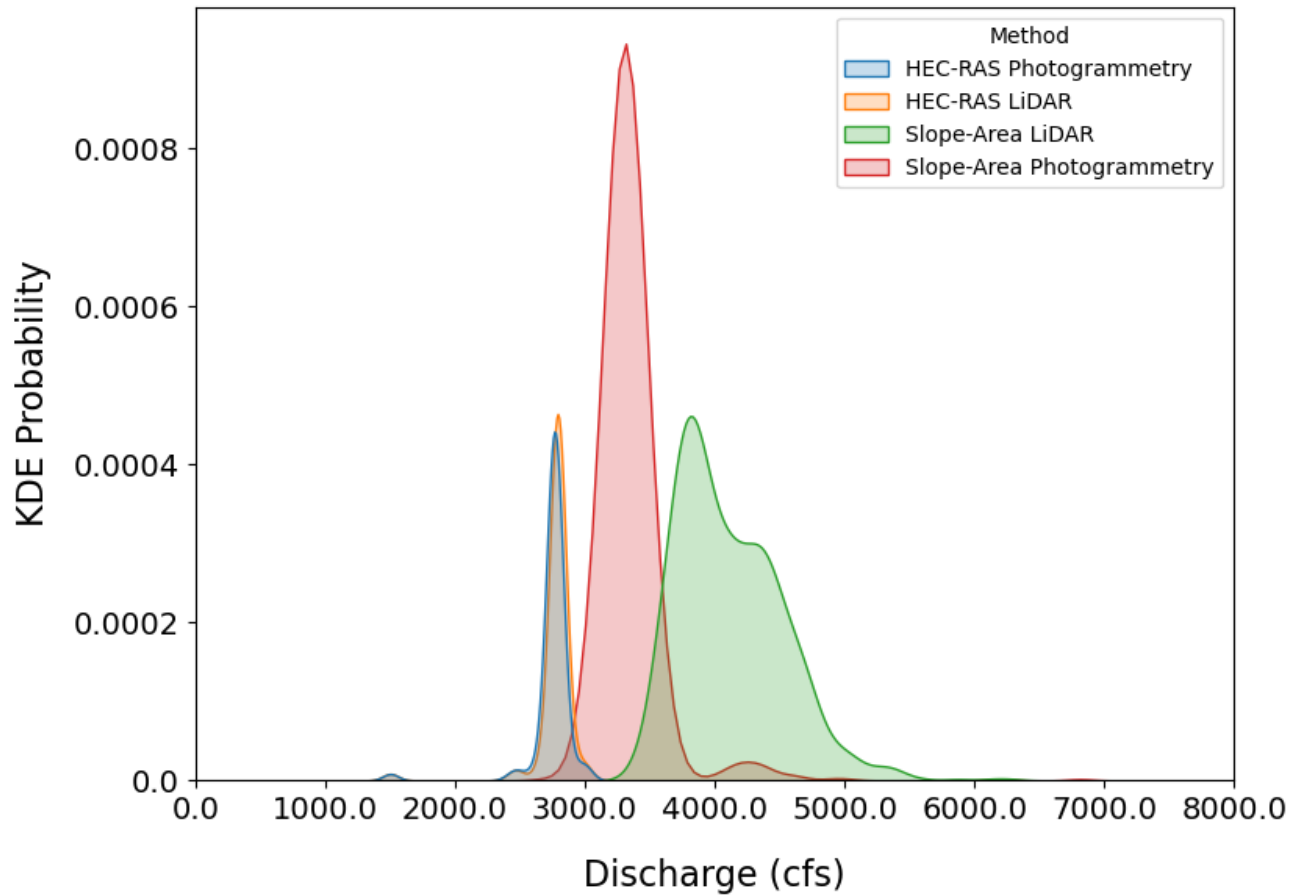
* Values are combined staff hours for each task.

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.

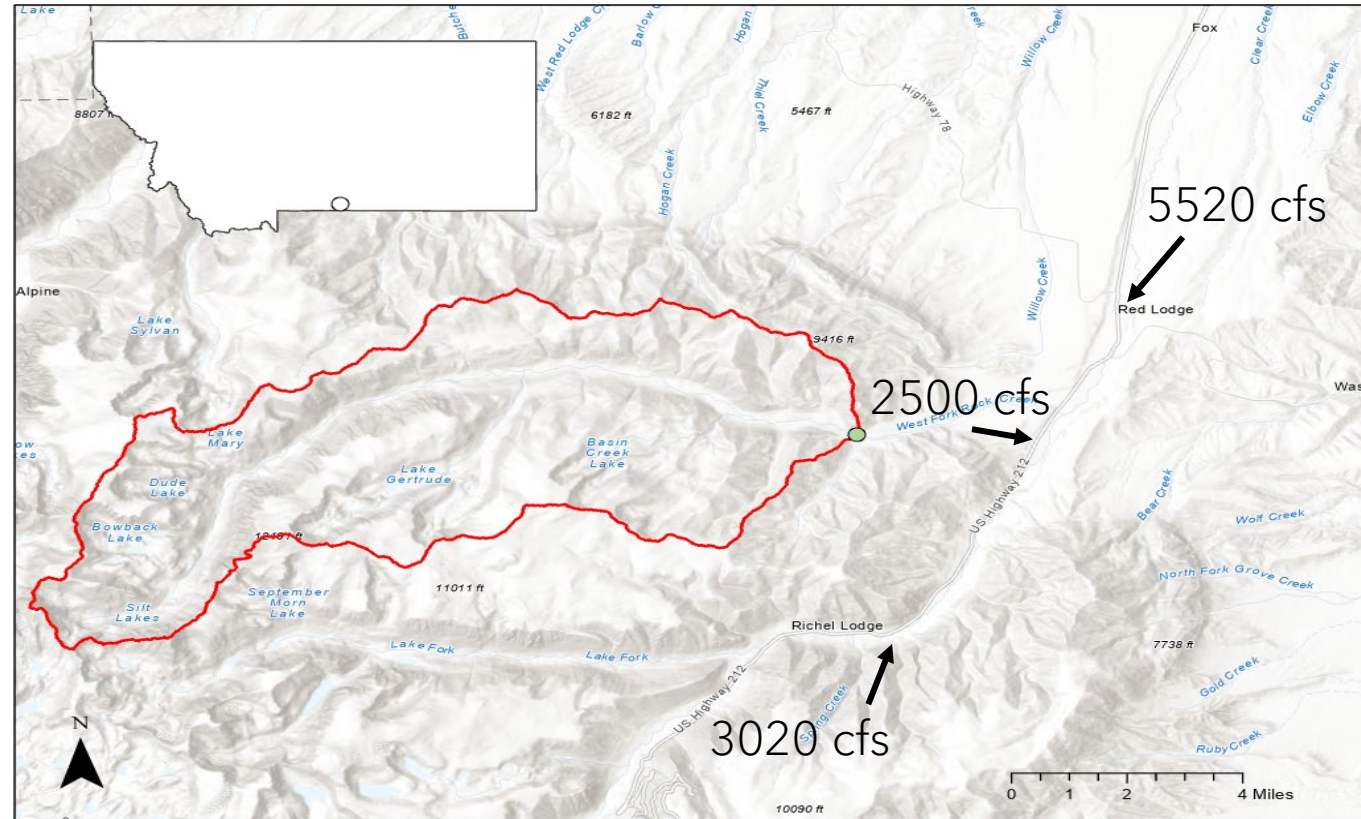
INDIRECT DISCHARGE VALIDATION



INDIRECT DISCHARGE VALIDATION

USGS Indirect
Flows in the
Area

2D Model
Estimate
 2700 ± 200 cfs





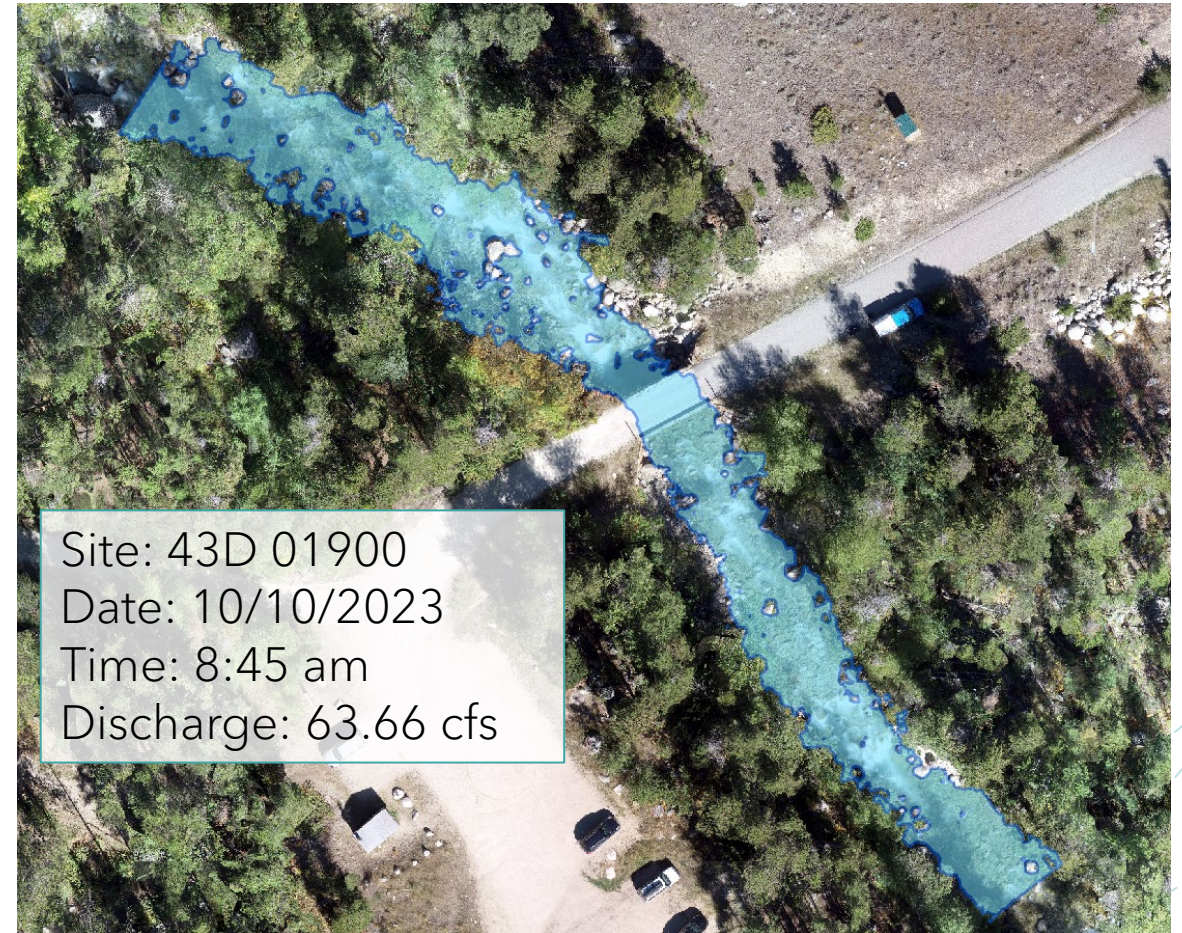
CONCLUSIONS SO FAR

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

