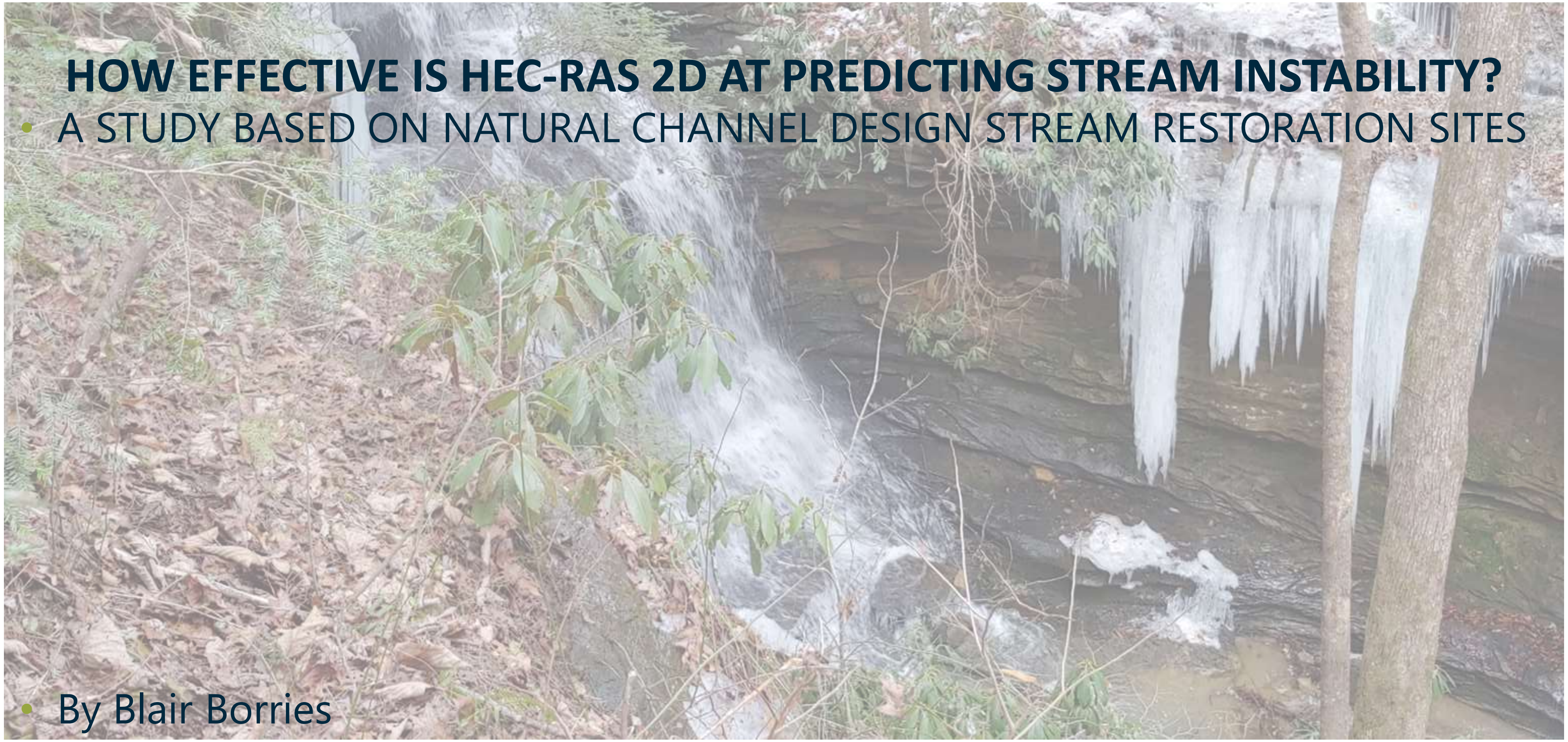


HOW EFFECTIVE IS HEC-RAS 2D AT PREDICTING STREAM INSTABILITY?

- A STUDY BASED ON NATURAL CHANNEL DESIGN STREAM RESTORATION SITES

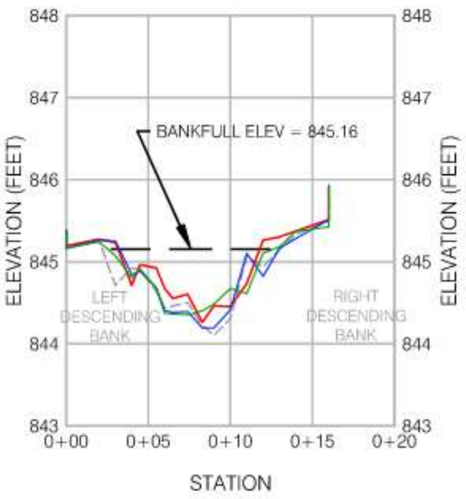
- By Blair Borries

HOW EFFECTIVE IS HEC-RAS 2D AT PREDICTING STREAM INSTABILITY?

A STUDY BASED ON NATURAL CHANNEL DESIGN STREAM RESTORATION SITES

- Past Conferences: 2D modeling suggested for designing proposed streambank stabilization, informing in-stream structure selection, and steering stream restoration design
- HEC-RAS 2D has made 2D modeling easy, free, and widely accessible - are models ever calibrated?
- The stream mitigation industry has generated a dataset of potential test sites for evaluating modeling effectiveness
- What can we learn from modeling as-built conditions and comparing to geomorphic stability monitoring?

The detailed monitoring and measurements of geomorphic conditions following stream mitigation projects has created a unique ability to study how accurately 2D modeling can predict instability



Study Sites

KDC JEFF STREAM MITIGATION

Clark County, Indiana

5 years of Monitoring
4 cross sections

WAUPACA STREAM MITIGATION

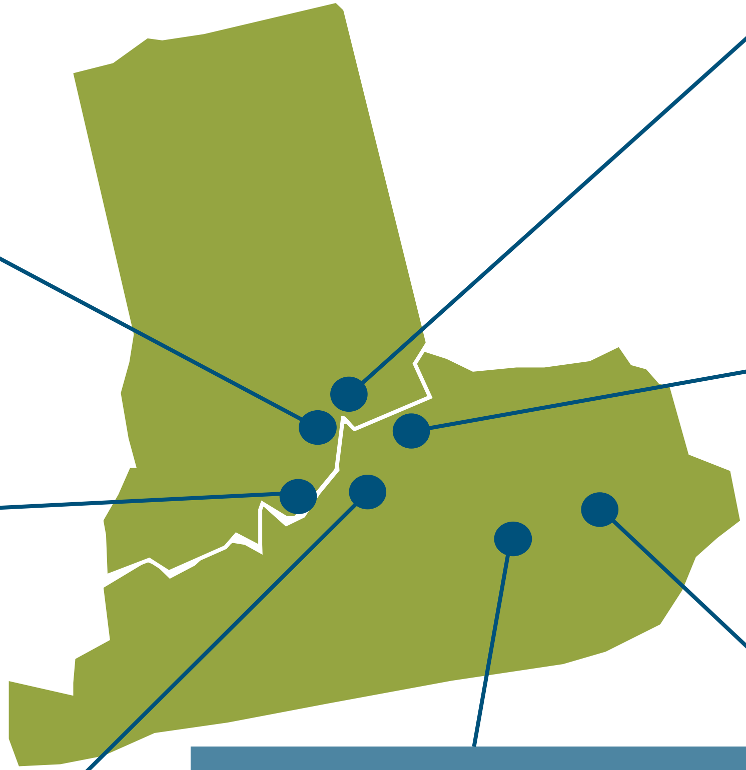
Perry County, Indiana

3 years of Monitoring
14 cross sections

BOURBON TRAIL STREAM MITIGATION

Bullitt County, Kentucky

6 years of Monitoring
8 cross sections



PAGE PROPERTY STREAM MITIGATION

Pulaski County, Kentucky

2 years of Monitoring
5 cross sections

MEDLINE STREAM MITIGATION

Clark County, Indiana

5 years of Monitoring
4 cross sections

OLDA POND 5 STREAM MITIGATION

Oldham County, Kentucky

3 years of Monitoring
9 cross sections

LAUREL CREEK STREAM MITIGATION

Elliott County, Kentucky

4 years of Monitoring
6 cross sections

Field Methods

Restoration Design/Construction

Analogous/Natural Channel Design

Re-establishment, Rehabilitation, Enhancement

46 – 858 acres (and a 2+ square mile karst watershed)

As-Built Geomorphological Survey

Conducted with total station equipment

Points collected along stream toe-of-slope, top-of-bank, thalweg, all in-stream structures and adjacent regraded area

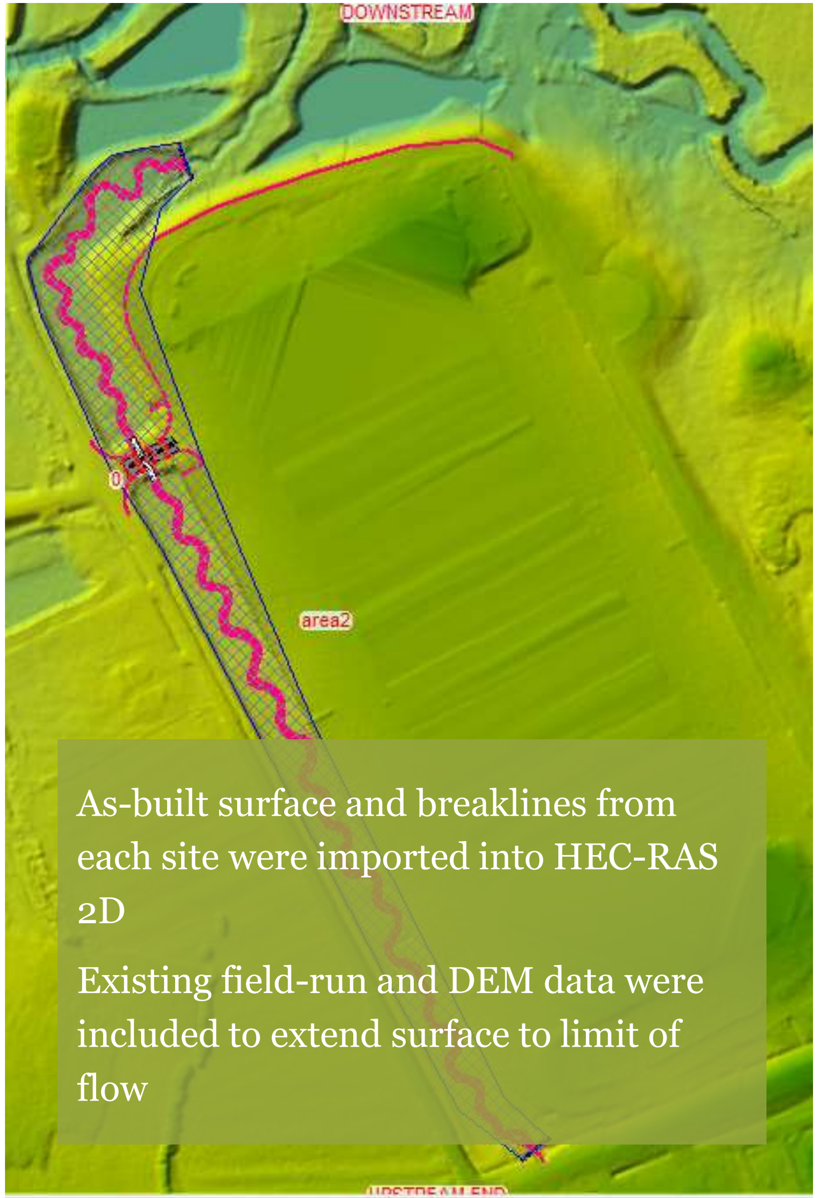
Survey processed with breaklines in CAD and surface and breaklines exported to HEC-RAS RasMapper

Geomorphological Stability Monitoring

Monitoring cross sections established at midpoints of riffles/cascades/steps and pools

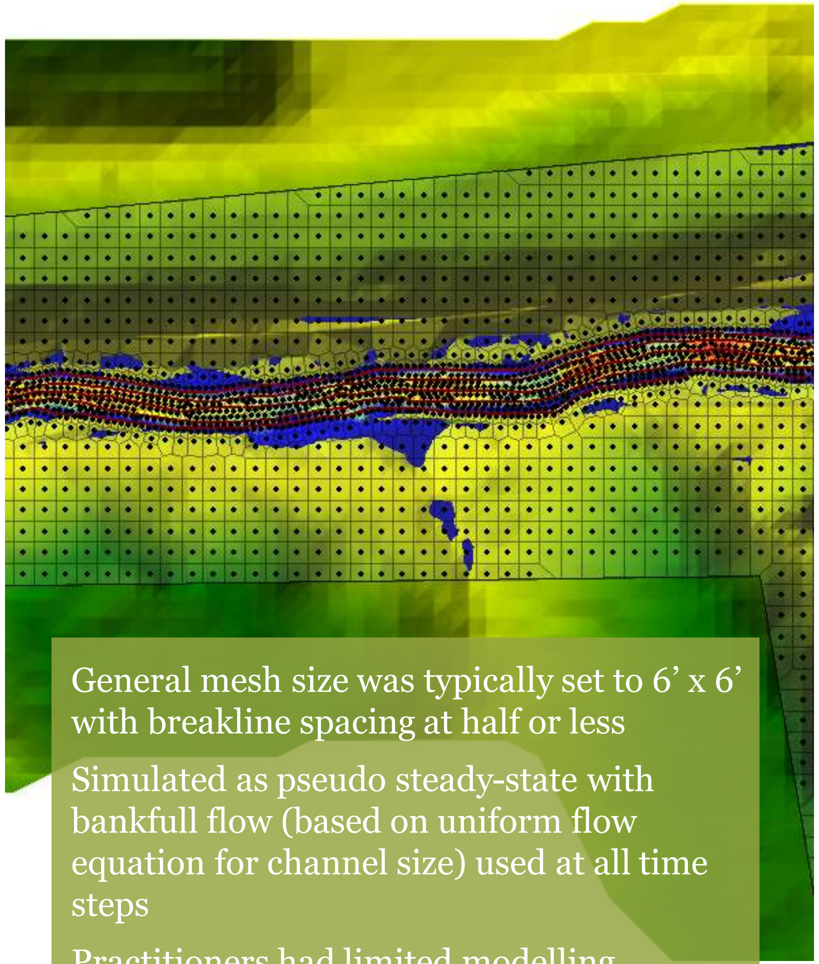
Rebar driven at endpoints to maintain consistency, measurements taken at same station each year

Modeling and Analysis



As-built surface and breaklines from each site were imported into HEC-RAS 2D

Existing field-run and DEM data were included to extend surface to limit of flow

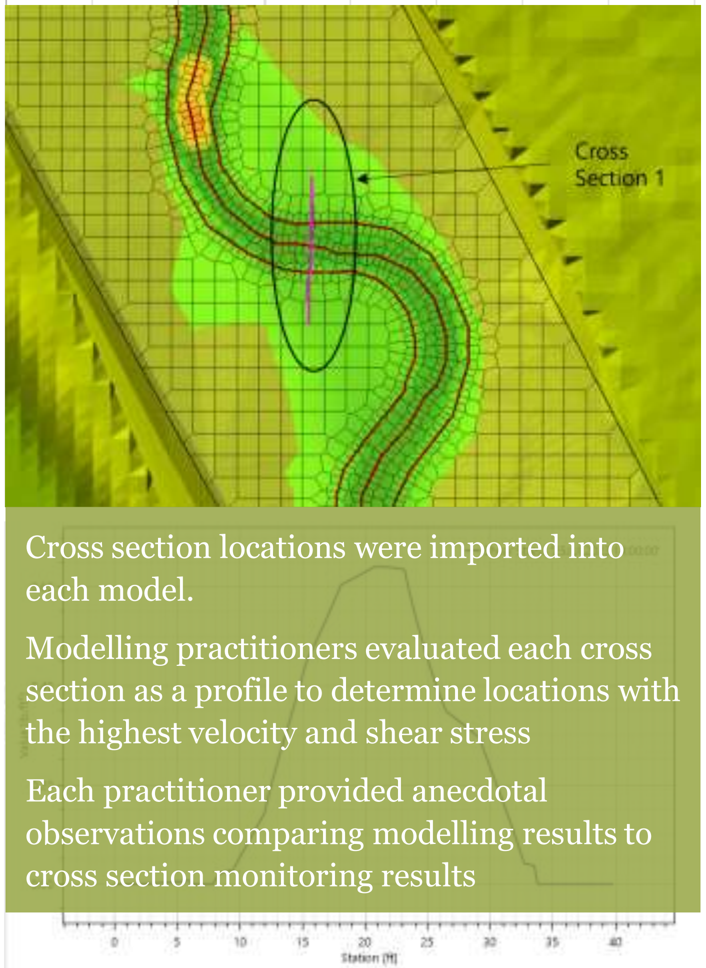


General mesh size was typically set to 6’ x 6’ with breakline spacing at half or less

Simulated as pseudo steady-state with bankfull flow (based on uniform flow equation for channel size) used at all time steps

Practitioners had limited modelling experience

		SS	V	Success Criteria			
	XS	32 cfs	32 cfs	BkfW	BkfA	MaxD	MeanD
riffle	1	0.24	1.92	9.4	36	3.3	41.6
pool	2	0.11	1.45	8.7	2.8	2.9	5.6
riffle	3	0.53	2.72	10.3	15	7.4	4.5
riffle	4	0.47	2.43	3	8.7	0.4	11.5
pool	5	0.19	1.67	36.5	7.2	35.6	69.3
riffle	6	0.64	2.98	19.5	10.6	20	7.1



Cross section locations were imported into each model.

Modelling practitioners evaluated each cross section as a profile to determine locations with the highest velocity and shear stress

Each practitioner provided anecdotal observations comparing modelling results to cross section monitoring results

Results

(Pictured: Medline Stream Mitigation before the storm and 30 minutes later)

Bourbon Trail Stream Mitigation

- Background:
  - 4,000 feet intermittent re-establishment, built in 2016
  - 8 cross sections monitored, 6 riffles and 2 pools
  - A culvert divides the stream in the middle
- Riffle Cross section 6 had the highest velocity (2.98 ft/s) and shear stress (0.64 lb/ft^2) and continues to meet success criteria (<25% Deviation) after 6 years
- Riffle Cross section 1 and Pool Cross Section 5 failed to meet success criteria, both have shear stress below 0.25 lb/ft^2 and velocity below 2 ft/s
- Based on field observation, does not reflect where cross sectional changes fail to meet criteria

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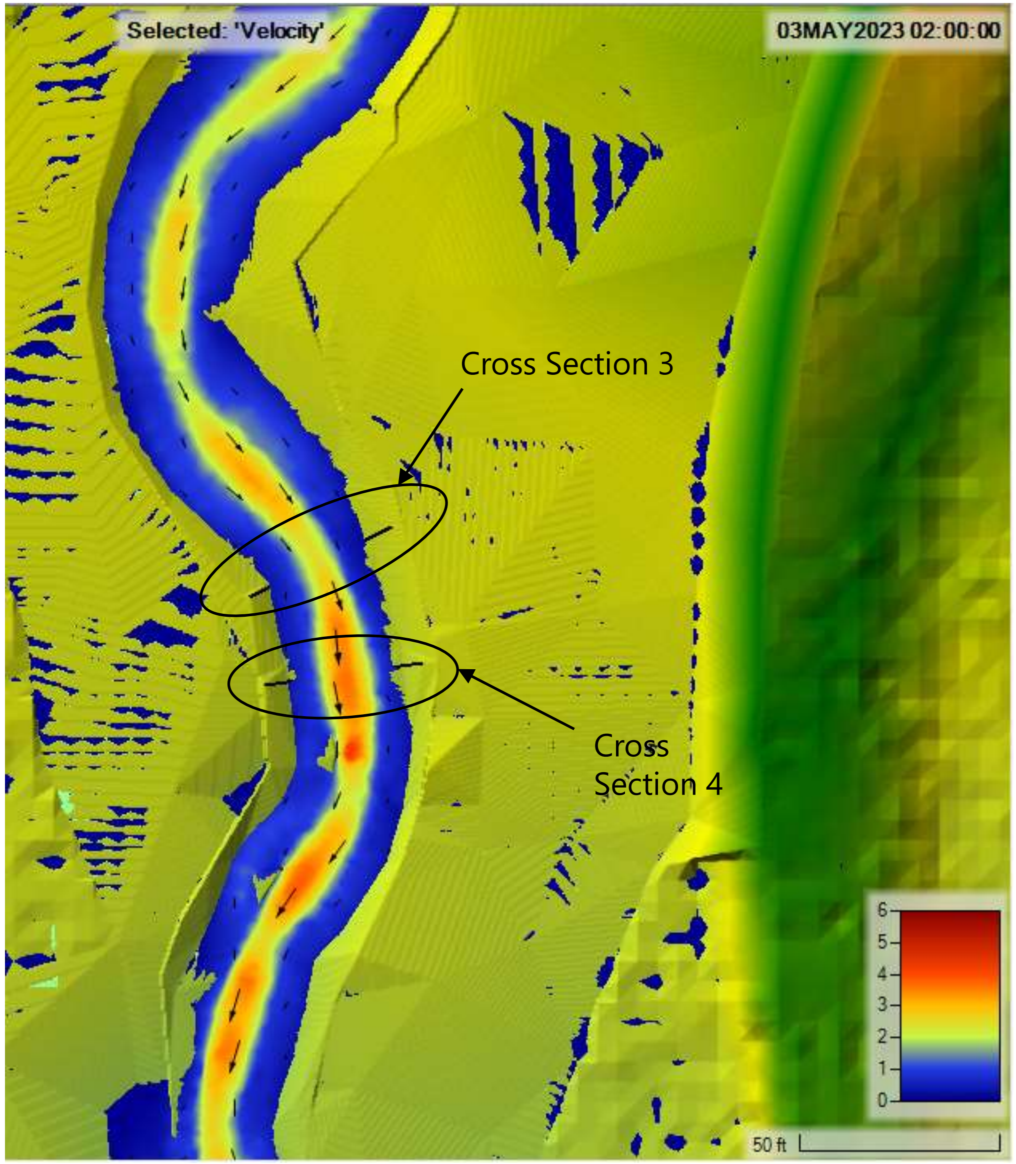
Bourbon Trail Stream Mitigation

Cross section 6 looking upstream (2022)

Cross section 5 looking downstream (2022)

Medline Stream Mitigation

- Background:
  - 1,100 feet intermittent rehabilitation, built in 2018
  - 4 cross sections monitored: 2 riffles and 2 pools
  - Karst watershed >2 sq miles, stream sized for much small watershed downstream of sinkholes
- Riffle Cross section 4 had the highest velocity (3.61 ft/s) and shear stress (0.92 lb/ft^2) and continues to meet success criteria (<25% Deviation) after 6 years
- Pool Cross section 2 and 3 failed to meet success criteria for bankfull depth and area, both have shear stress below 0.4 lb/ft^2 and velocity below 2.6 ft/s
- Based on field observation, does not reflect where cross sectional changes fail to meet criteria; especially in terms of vertical scour depth



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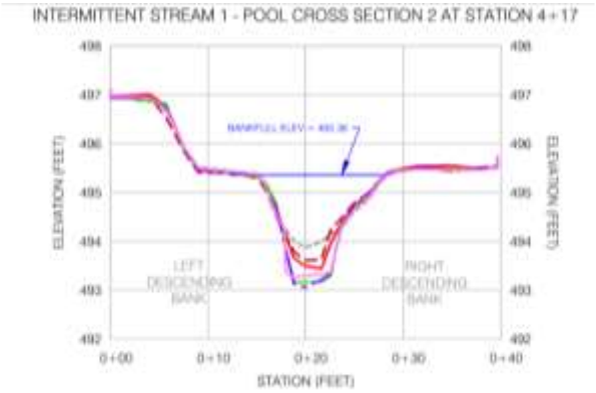
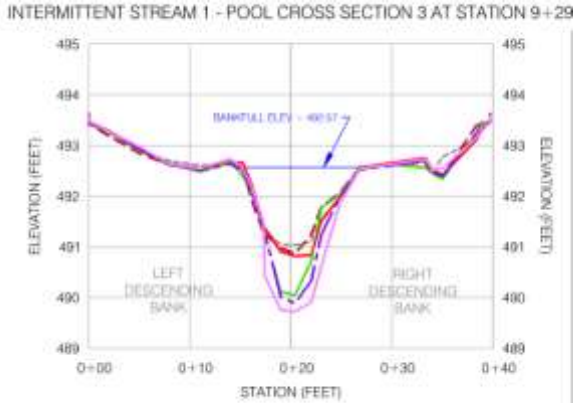
Medline Stream Mitigation

Cross section 2 looking downstream (2023)

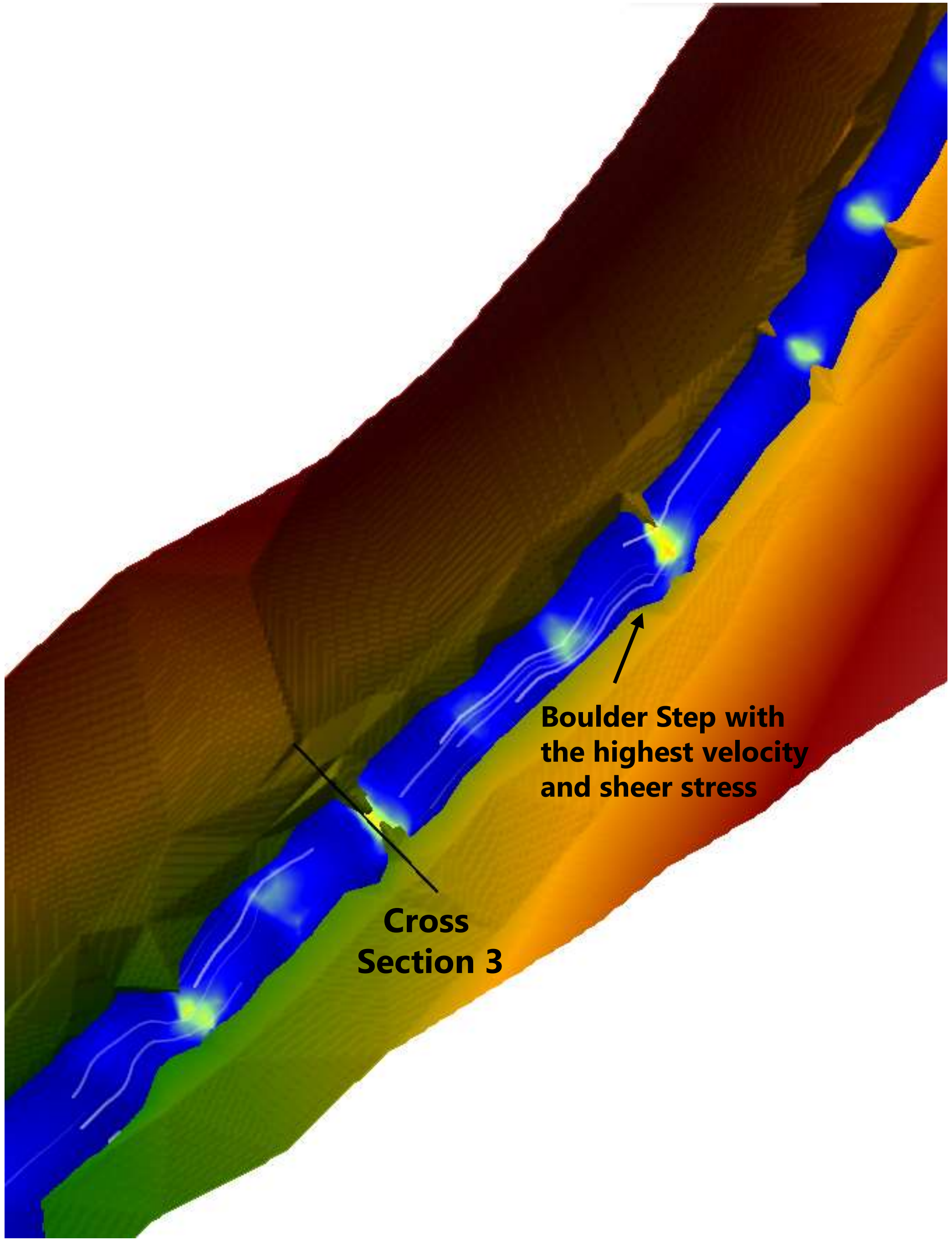


Cross section 3 looking downstream (2022)



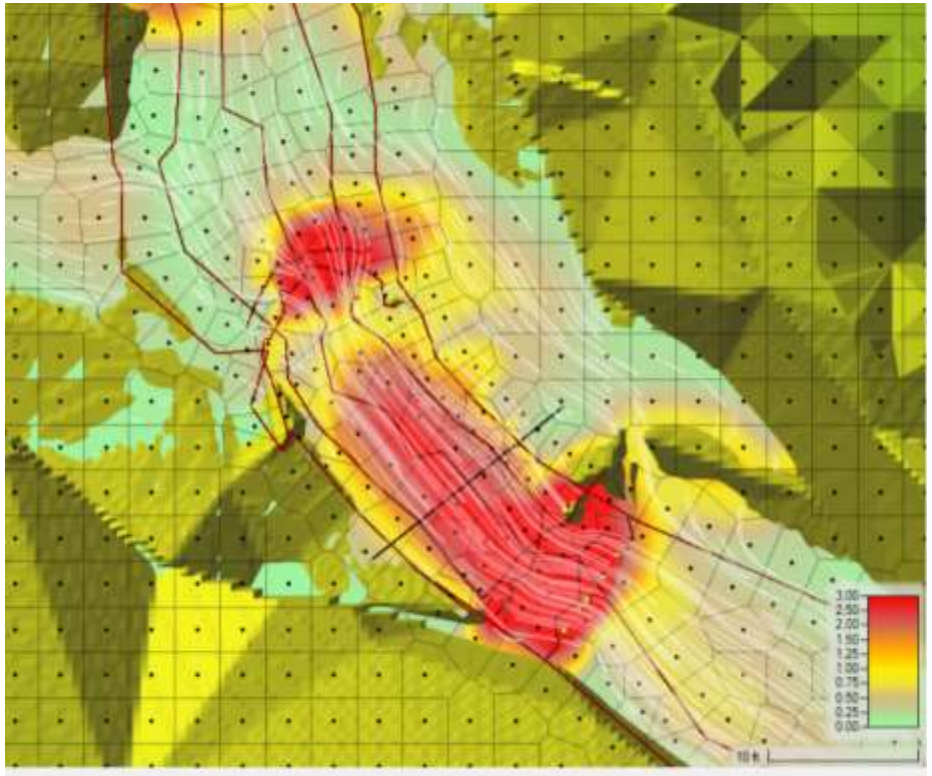
KDC Jeff Stream Mitigation Project

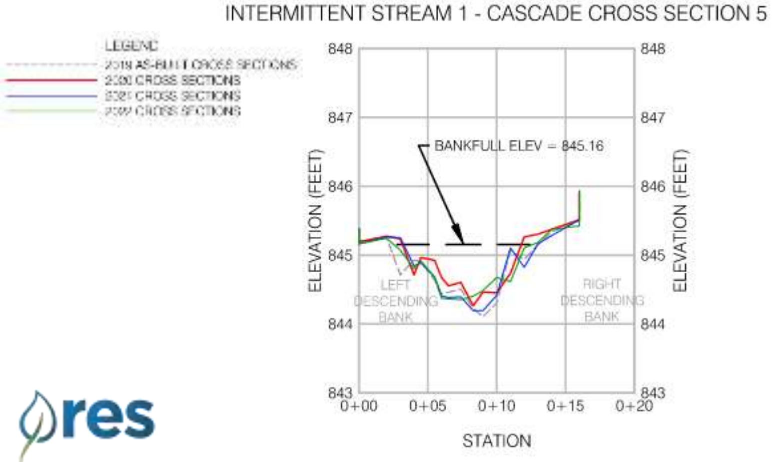
- Background:
  - 1,460 feet ephemeral re-establishment and rehabilitation, built in 2017
  - 4 cross sections monitored: 2 riffles and 2 pools
  - Located in aa confined urban area that begins at a culvert
- Cross Section 3 (boulder step) had the highest maximum velocity (5.38 ft/sec) and sheer stress (2.63 lb/ft^2). This cross section also came the closest to exceeding the bankfull depth success criteria with a 22.73% deviation from the as-built.
- One upstream boulder structure had the highest velocity (7.601 ft/sec) and sheer stress (4.84 b/ft^2).



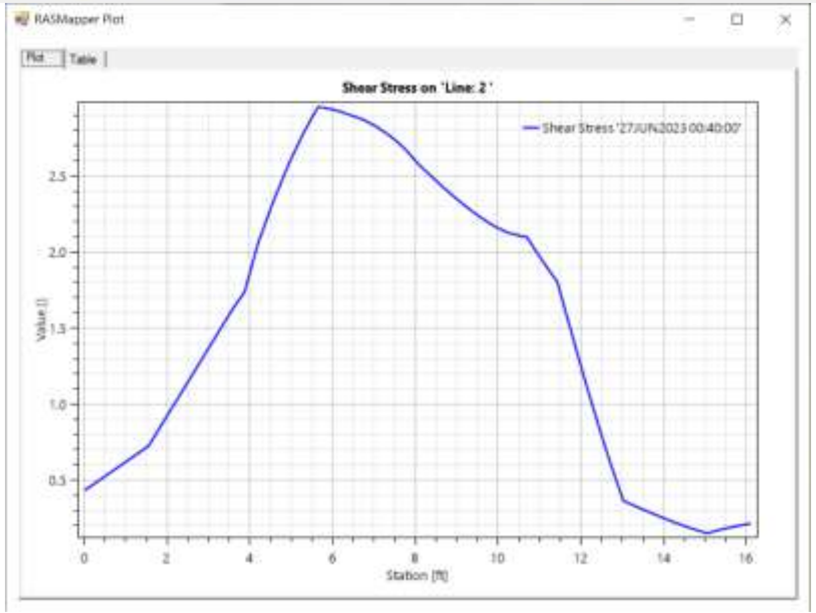
Laurel Creek

- Background:
  - 2,200 feet intermittent re-establishment, enhancement, and rehab, built in 2019
  - 6 cross sections monitored: 2 riffles, 1 step, 1 cascade, and 2 pools
- Cascade Cross Section 5 displayed the highest maximum shear stress, roughly 20% greater than the next highest monitored cross section. This cross section met the success criteria in the most recent monitoring cycle but was the closest to exceeding the allowable deviation.
- Despite the large shear stress values, Cross Section 5 appears stable due the quantity of large rocks composing the cascade.






Photograph 22: View of cascade Cross Section 5 along Intermittent Stream 1, facing downstream. February 24, 2022.



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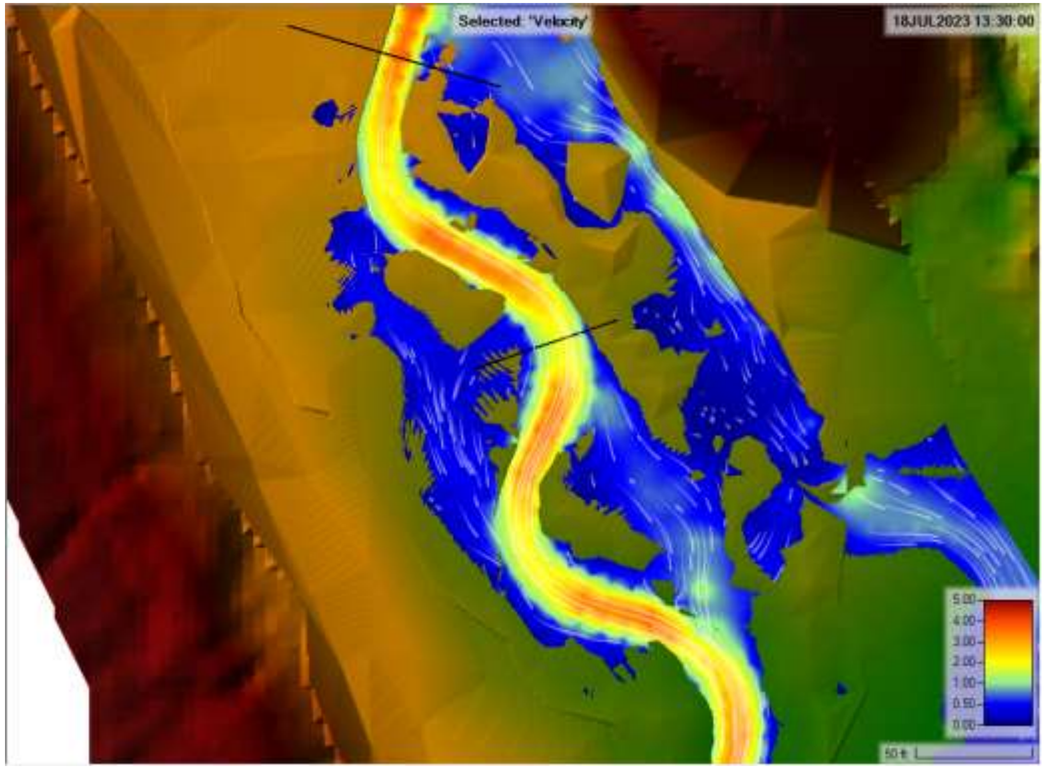
Page Property

- Background:
  - 1,800 feet re-establishment, built in 2020
  - 5 cross sections monitored, 3 riffles and 2 pools
- Riffle Cross section 2 had the highest velocity (3.54 ft/s) and shear stress (0.59 lb/ft^2) and continues to meet success criteria (<25% Deviation) after 2 years
- Riffle Cross section 4 had similar but slightly lower shear stress (0.57 lb/ft^2) and velocity (3.37 ft/s) yet had higher deviation, though still within success criteria
- The stream experienced numerous points of instability during the first year after construction following failure of coir mat that resulted from high bedload. This was repaired in 2022.



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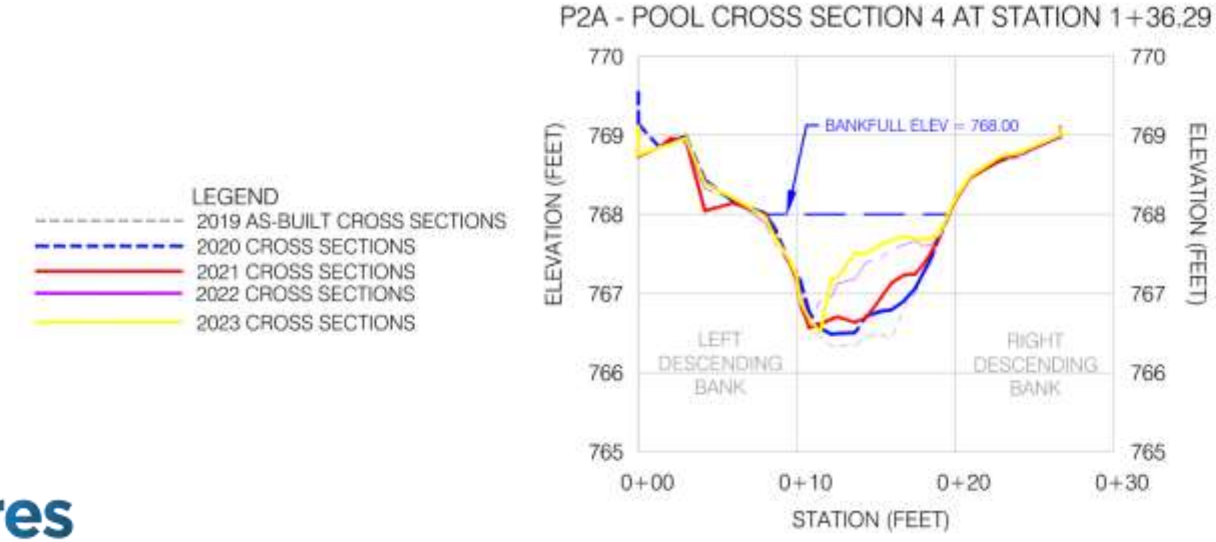
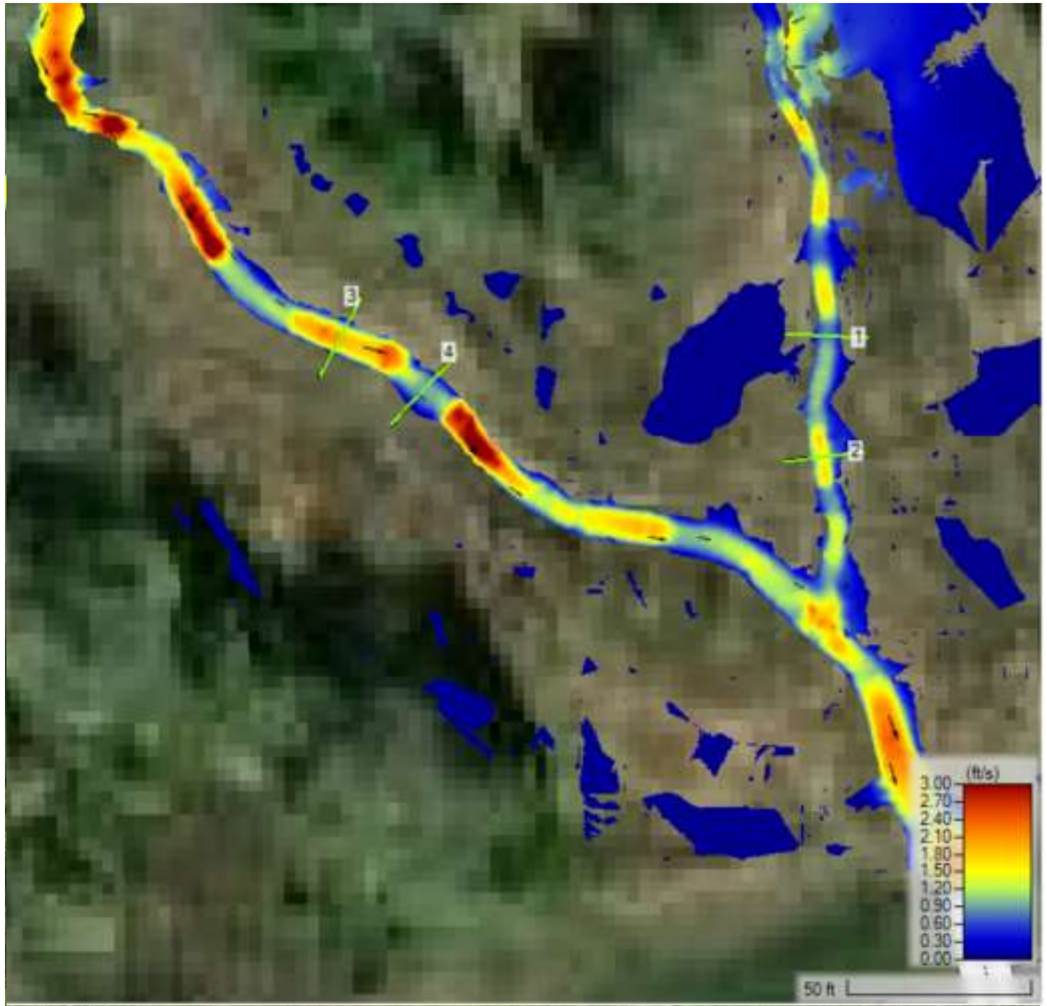
Pond 5 Mitigation Project

- Background:
  - 1,800 feet re-establishment, built in 2020
  - 9 cross sections monitored, 3 riffles, 1 cascade, and 5 pools
  - This site has three inlets, multiple wetland areas, and a box culvert.
- The cross section with the highest maximum velocity (2.53 ft/s) and highest shear stress (0.88 lb/in²) did not exceed success criteria. The cross sections that exceeded success criteria were at pools where deposition occurred on inside bends as seen on cross section 4 (v_{max}=0.99 ft/s τ_{max}=0.08 lb/in²).





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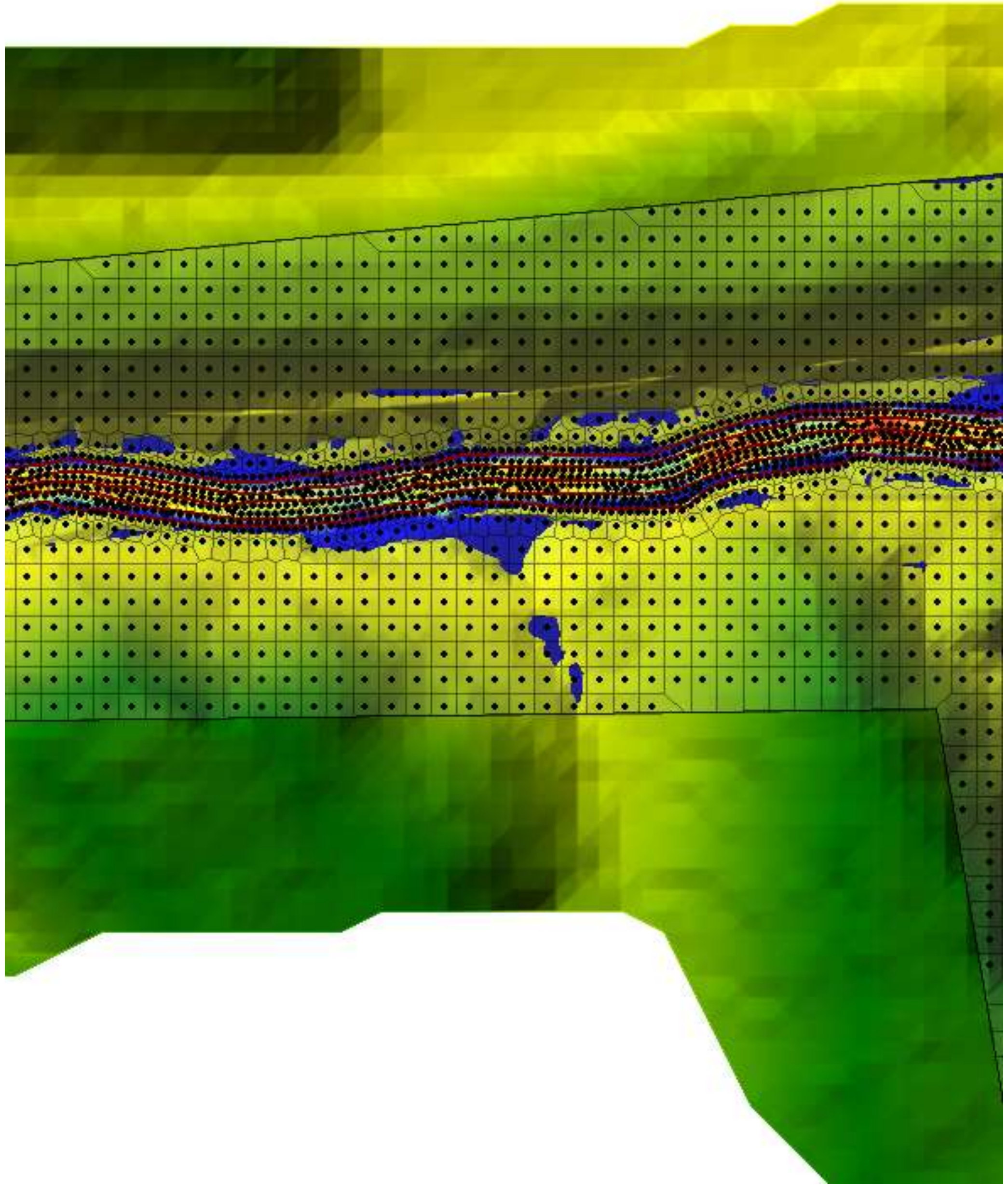
Waupaca

- Background:
  - 4,600 feet of intermittent re-establishment and rehabilitation, built in 2020
  - 13 cross sections monitored: 7 riffles and 6 pools
  - This site contains a monofill to the north with steep slopes and a catch basin before flow can reach the stream from overland flow.
- Riffle cross section 10 had the highest velocity (3.3 feet/sec) and highest shear stress (1.15 lbs/sq ft) and exceeded success criteria for bankfull width (40.5%). This cross section also had the highest deviation in the maximum depth criteria (15.9%) compared to other cross sections



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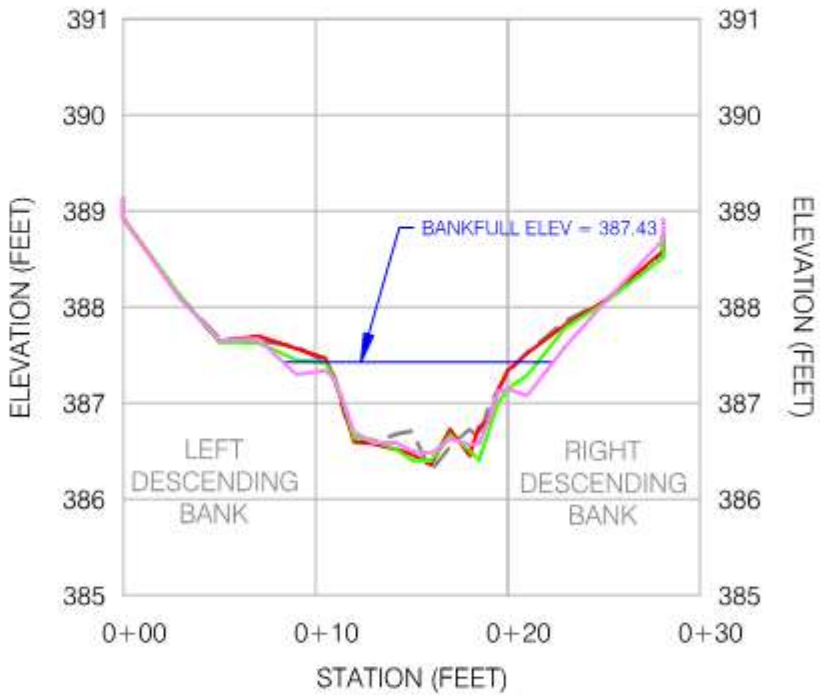
Waupaca Stream Mitigation

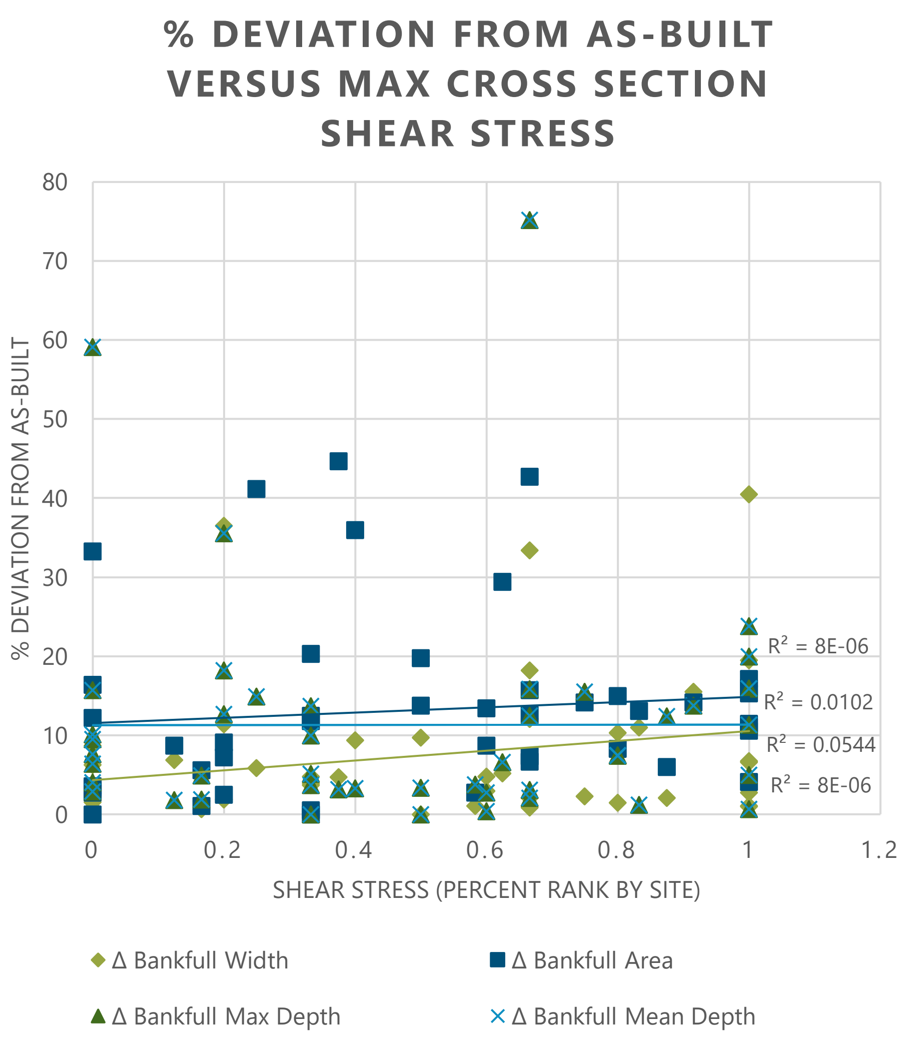
INTERMITTENT STREAM 1 - RIFFLE CROSS SECTION 10 AT STATION 33+04

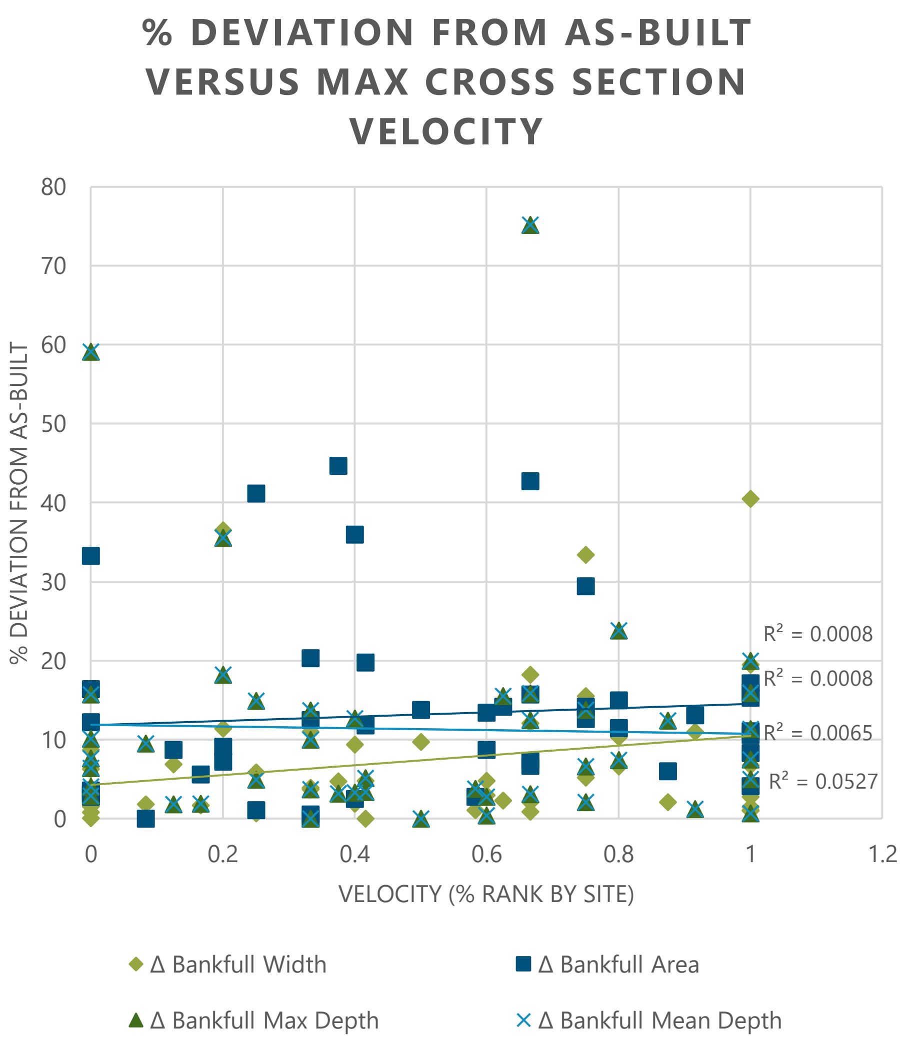


RIFFLE	AS-BUILT (2021)	YEAR 1 (2021)	YEAR 2 (2022)	YEAR 3 (2023)	% DEVIATION (AS-BUILT TO YEAR 3)
BANKFULL WIDTH (FT):	10.02	9.91	11.06	14.08	40.5%
BANKFULL AREA (FT^2):	6.59	7.01	7.53	7.60	15.3%
MAXIMUM DEPTH (FT):	1.13	1.07	1.03	0.95	15.9%
MEAN DEPTH (FT):	0.66	0.71	0.68	0.54	18.2%

Cross section 10 looking downstream (2023)

META-ANALYSIS





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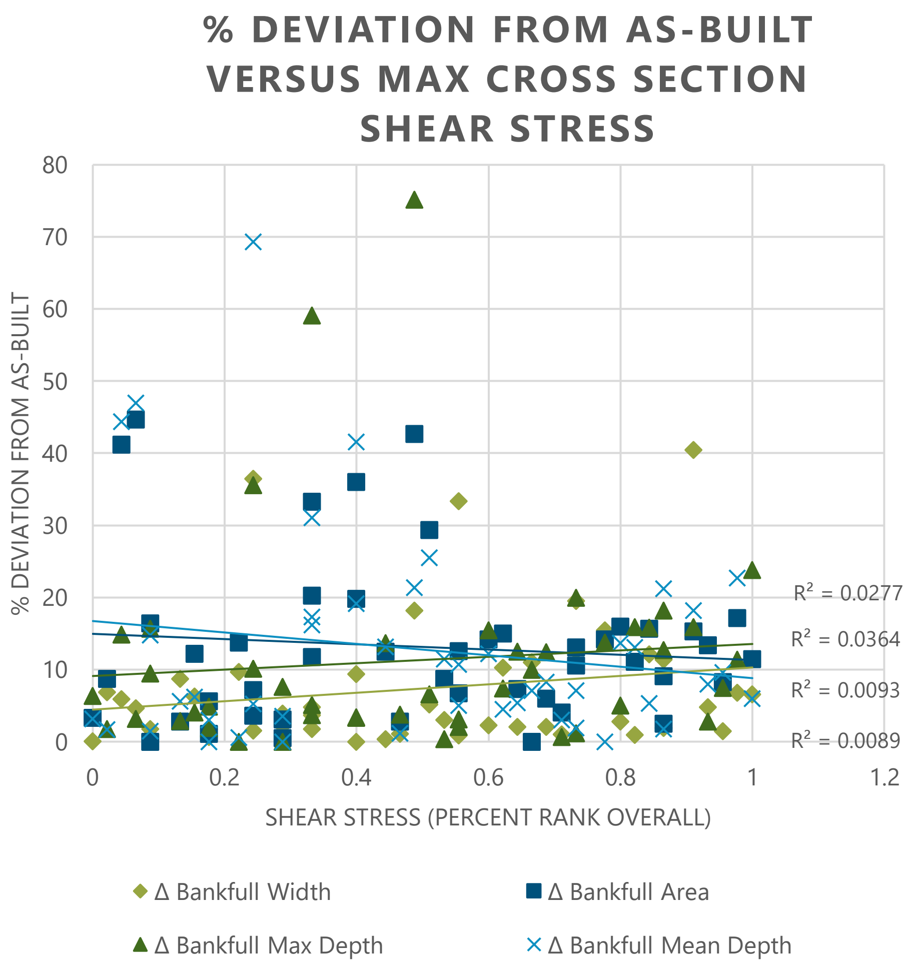
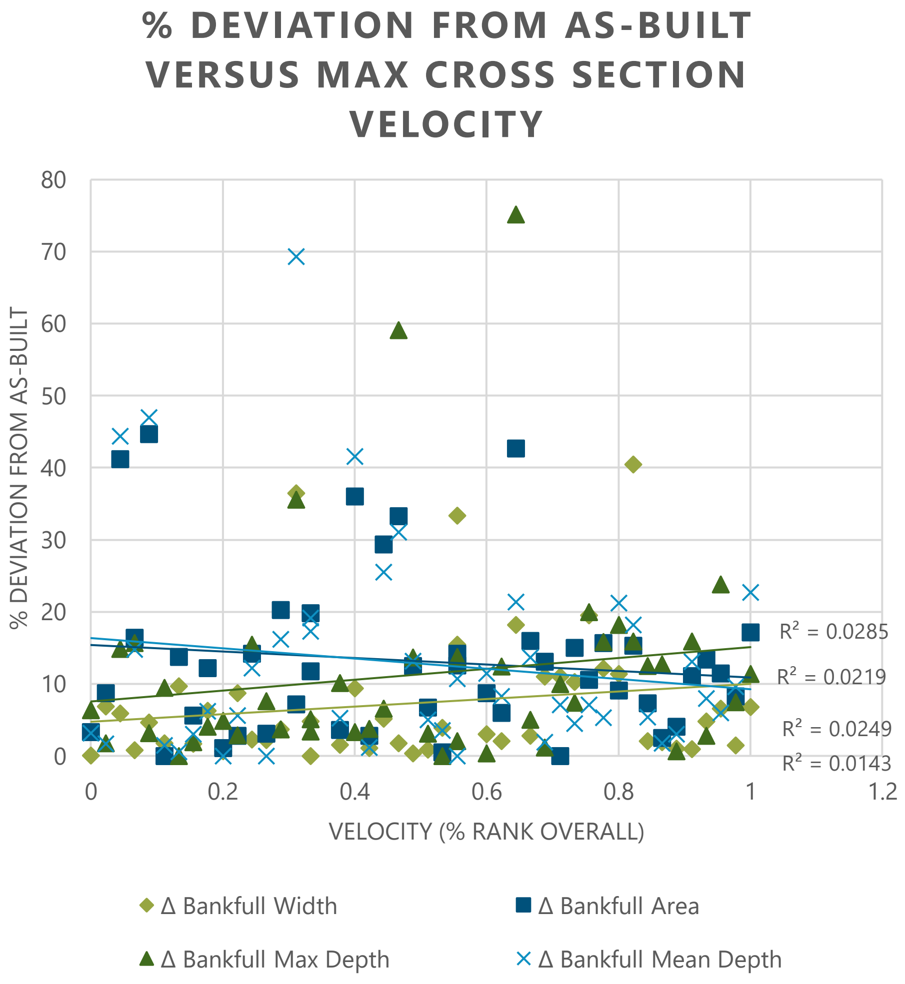
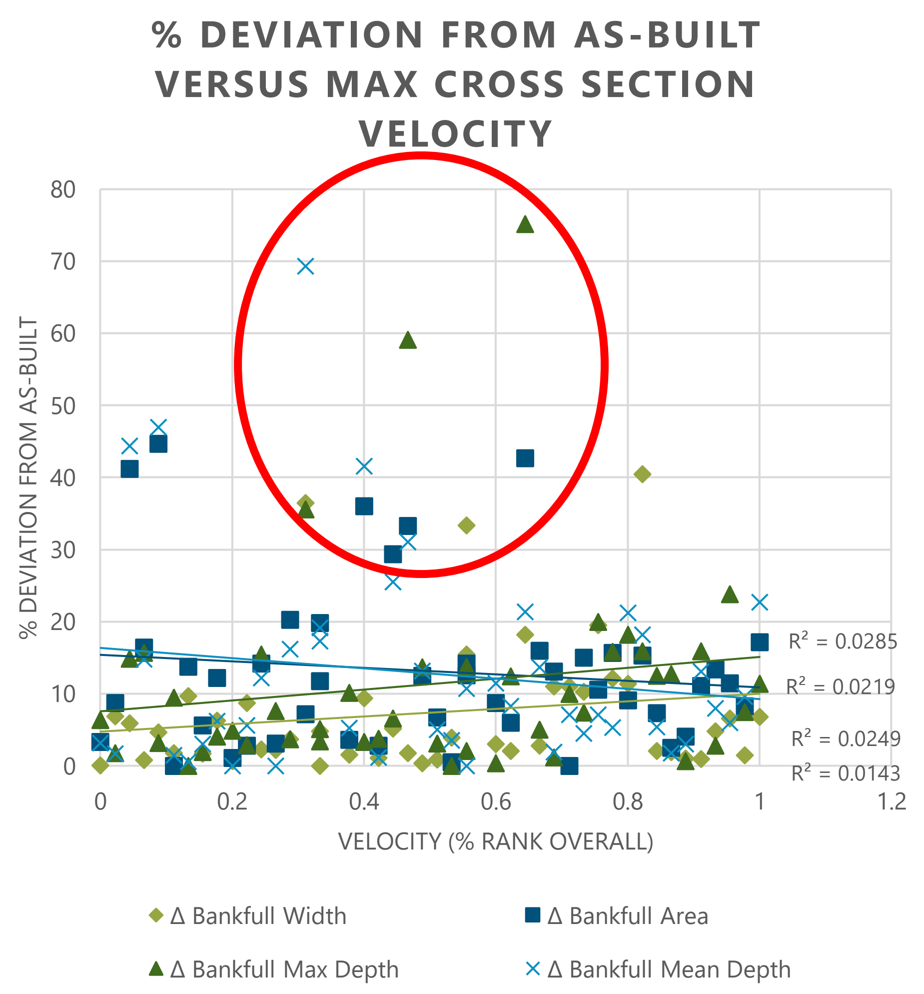
META-ANALYSIS





CLOSING THOUGHTS

- Is HEC-RAS bad at predicting instability OR is it human tendency to ignore the middle ground?
- 2D modelling was not used in the design process on these projects, but other modelling was
- If we only pay attention to the extremes, do the middle areas suffer?
- Special thanks to our modellers and presentation collaborators Johnathon Brantley, Melanie Pugh, Brandon Rail, Samantha Stevenson, Laura Whittaker, Matthew Wyatt with RES!



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