What You Don’t Know Can Hurt You

RiverSmart Communities and the Importance of Fluvial Geomorphology Assessments in Massachusetts

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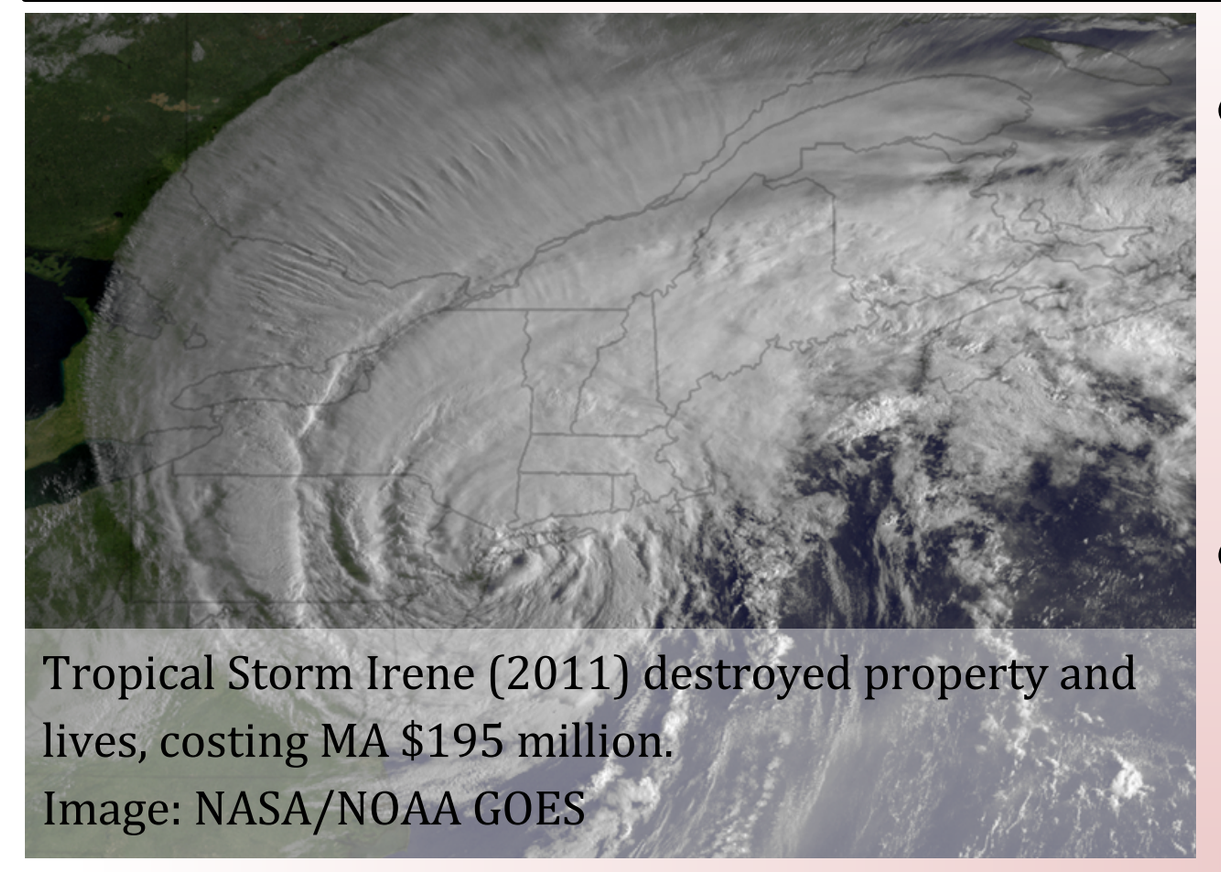
UMASS AMHERST geosciences — UMass Extension — The Center for Agriculture, Food and the Environment — riversmart communities

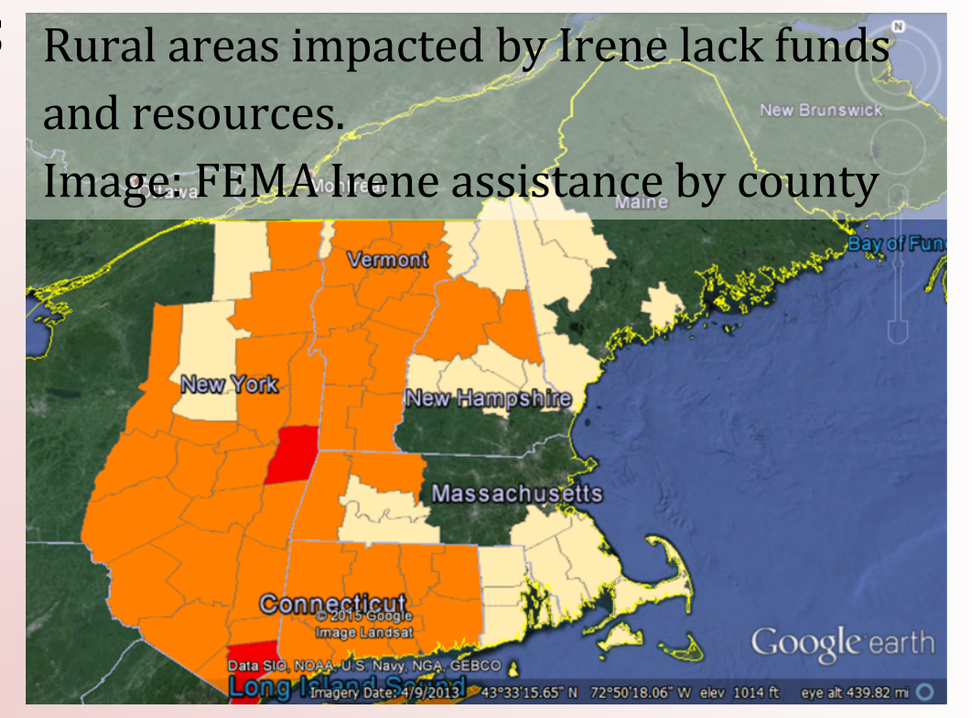
RiverSmart Communities

What We Do



Tropical Storm Irene (2011) destroyed property and lives, costing MA $195 million.
Image: NASA/NOAA GOES

- Destructive, expensive floods have cost New England billions of dollars and thousands of lives.
- Management obstacles:
  - Education
  - Lack process-based regulatory framework

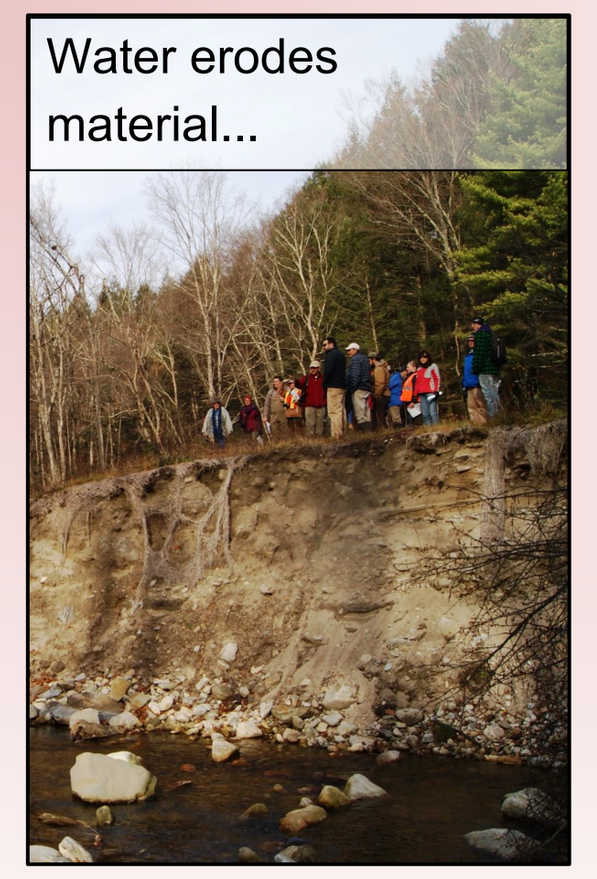


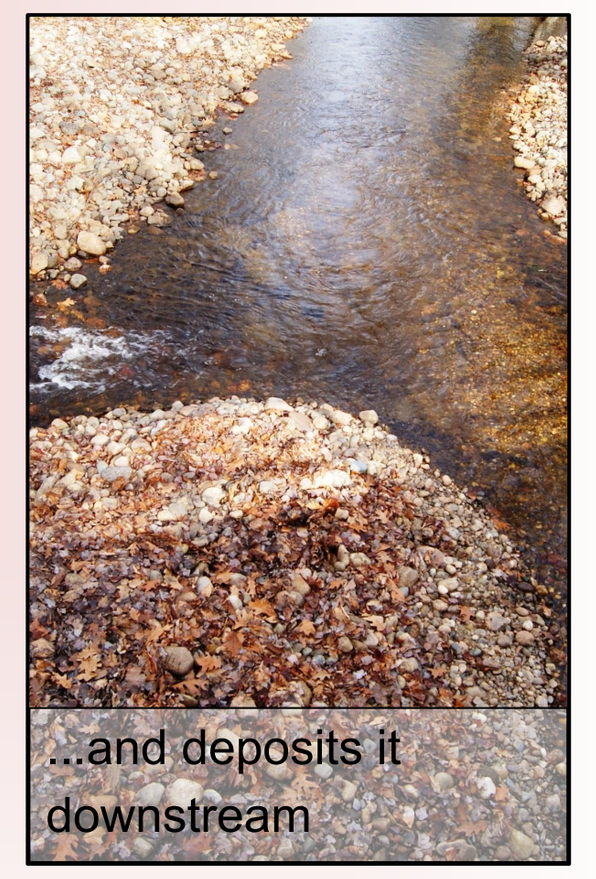
Rural areas impacted by Irene lack funds and resources.
Image: FEMA Irene assistance by county

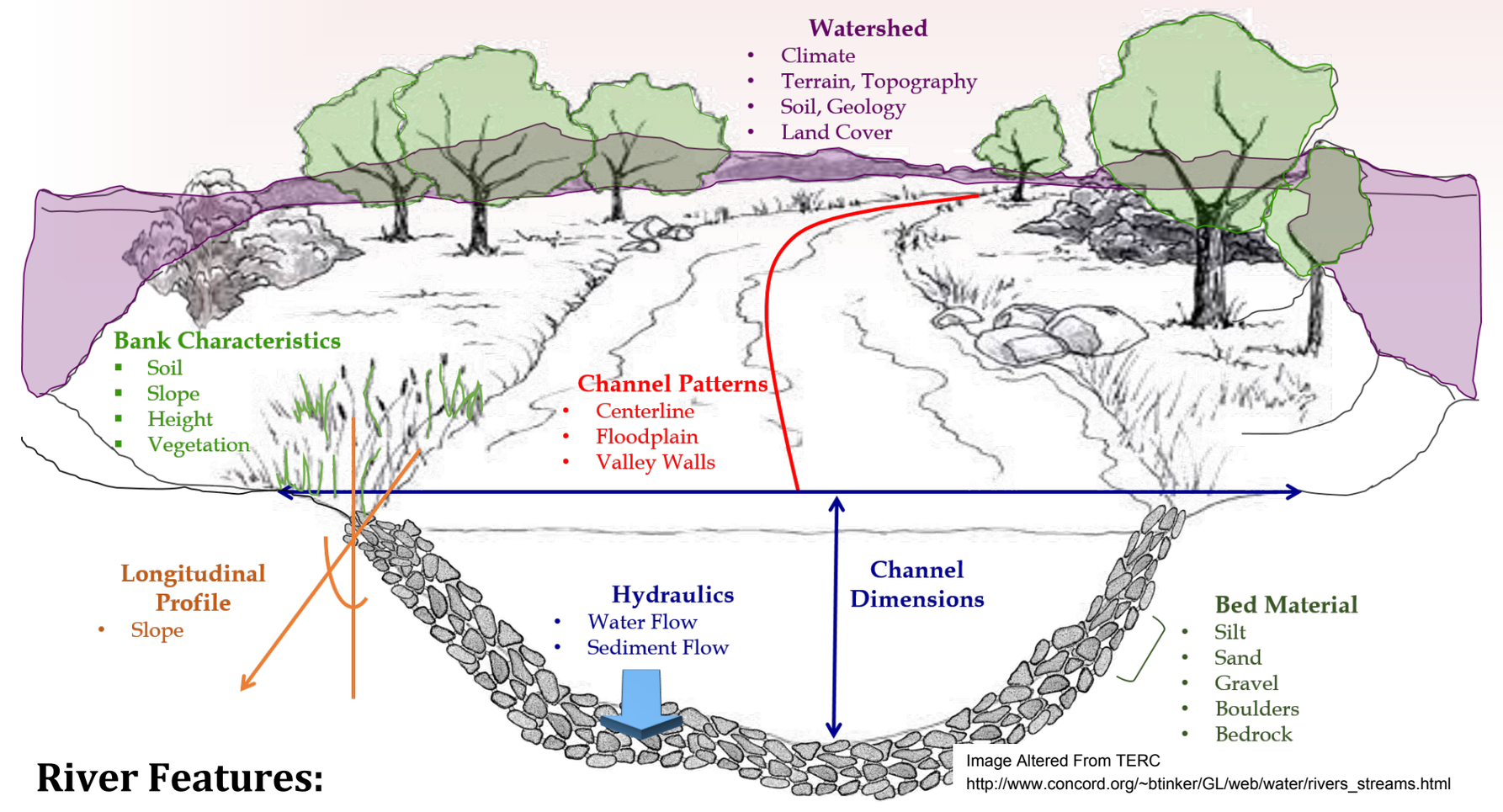
- RiverSmart Communities Project aims to address these obstacles in the following ways:
  - Assess Needs and Strengths of Communities
  - Determine Best Practices for Process-based Management
  - Produce Outreach and Education Material

Process-Based Management and Fluvial Geomorphology

- **Fluvial Geomorphology (FGM):**
  - physical processes shape a river and its features
- **FGM Assessments:**
  - evaluate river processes
  - analyze locations and types of change
  - provide data for long-term, resilient management
- **Process-Based Management:**
  - approaches a river as a series of connected processes
  - incorporates FGM assessments







River Features:
A river is made up of physical forms, objects, and processes.
Metrics allow features to be quantified and measured.
Assessment protocols vary in their features of interest.

An assessment Protocol integrates river features, assessment methods, and assessment products, to create a tool that addresses specific needs.

Vary in topic of interest, approach, and:
- features assessed
- methods suggested
- spatial scale
- ease of application
- product type

Common Assessment Protocol Topics of Interest

Topic	Description	Features of Interest	Example Protocols
Habitat	The river’s ability to sustain permanent and diverse wildlife populations	•food sources •access to spawning areas •migratory connectivity •shelter availability •water quality	RHS (2003) BURP (IDEQ, 2007) AIP (Moore et al 2008) RBP (Barbour et al 1999) SRMG (KDOW, 2007)
Water Quality	The suitability of the river as a water source for human consumption. The prevention of high sediment yields	•water chemistry •microorganism populations •turbidity •sediment sources	PSSW (ADEQ, 2012) SIH (USFS, 2009) USM (USACE, 2007)
Fluvial Hazards	Delineation of areas where erosion or inundation may threaten life, property, or economy	•slope, profile •channel dimensions •planform shape •bed and bank materials •vegetation	WARSSS (Rosgen, 2007) VTSGA (Kline et al 2003) SEDG (MEI, 2008) GEEHZ (COAWPD, 2013)
Project Design	Definition of hydraulic and sediment transport properties relevant to specific engineering plans	•hydrography •lithology •debris sources	WARSSS (Rosgen, 2007) SEDG (MEI, 2008)

Remote Assessment

Possibilities in Remote Assessment

- Remote sensing allows for less expensive, large scale, rapid assessment
  - prioritization of efforts
  - first-pass analysis
  - proof-of-concept of FGM-hazard relationship
- Improvements in remote sensing technologies have created new opportunities.
- Thesis Research: **Explore ability of remote assessment tools to estimate metrics from digital elevation models (DEMs) created in different ways**

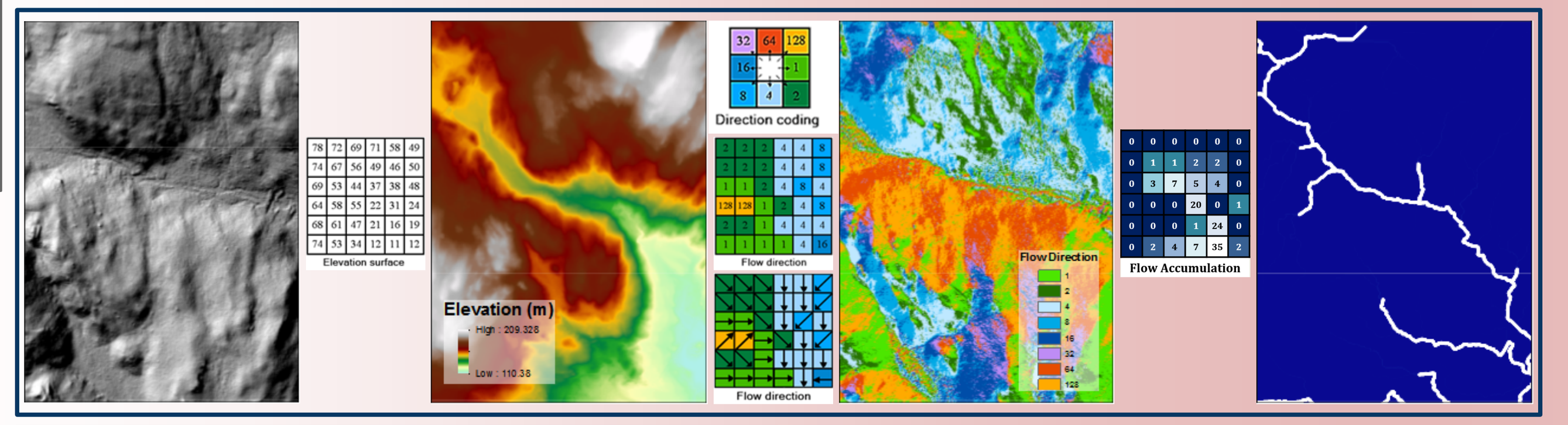
Data Sources

Data Type	Source	Resolution	Year
Field Data (Width)	MA Geological Survey, NEEInc	< 1 meter	2012
Field Data (Width)	Will Ouimet,PhD. UConn	< 1 meter	2013
Channel Centerlines	National Hydrography Dataset	1:24K (10m errors)	1944-1981
Aerial Imagery (Width)	USGS	< 1 meter	2011, 2012
Elevation	USGS, National Elevation Dataset	⅓ Arc-Second (9.07x9.07 m)	1944 - 1981
Elevation	LiDAR	1x1 m OR 2x2 m	2011, 2012

Tools

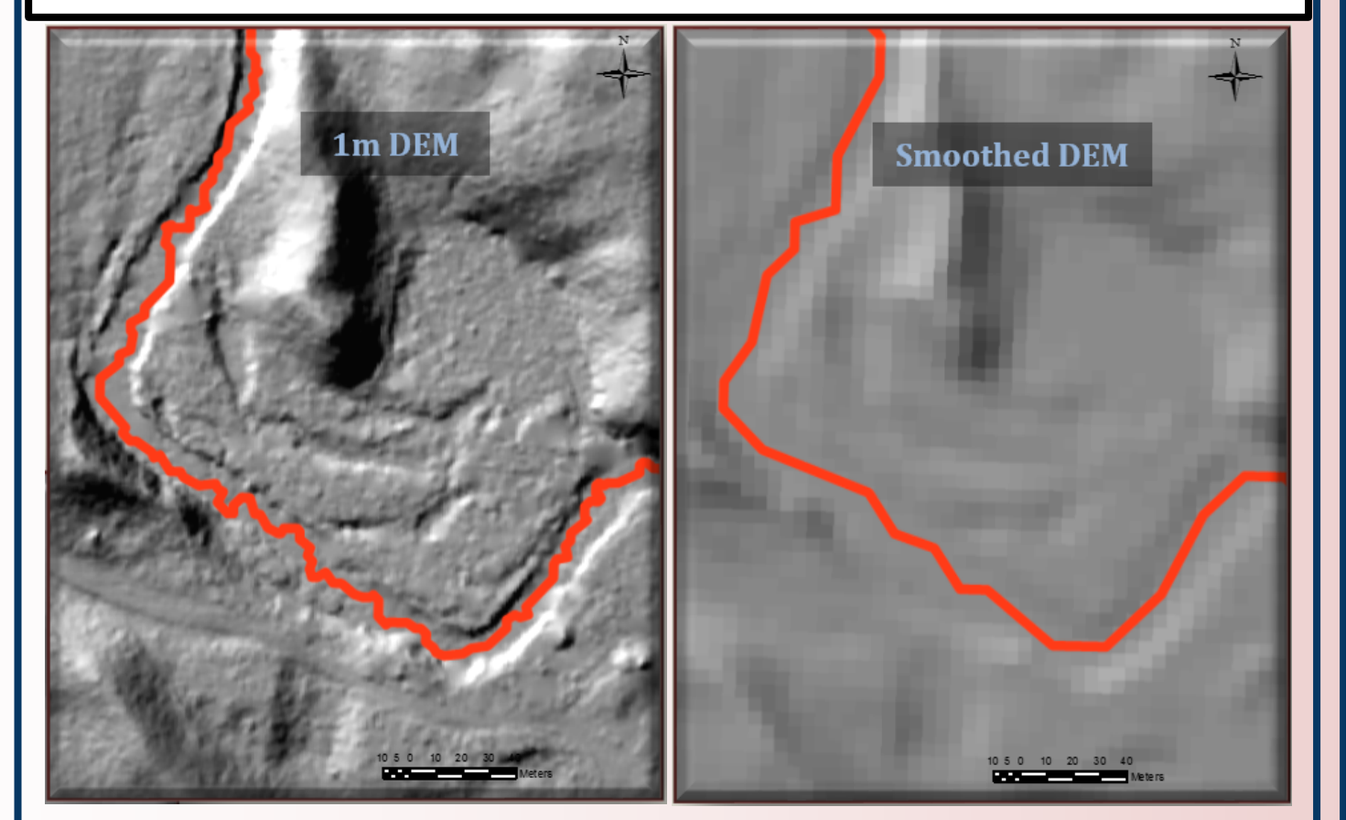
Fill - Flow Direction - Accumulate

Basic Flow Accumulation
Flow direction based on lowest adjacent cell. Accumulation based on number of “upstream” cells.
O’Callaghan & Mark, 1984

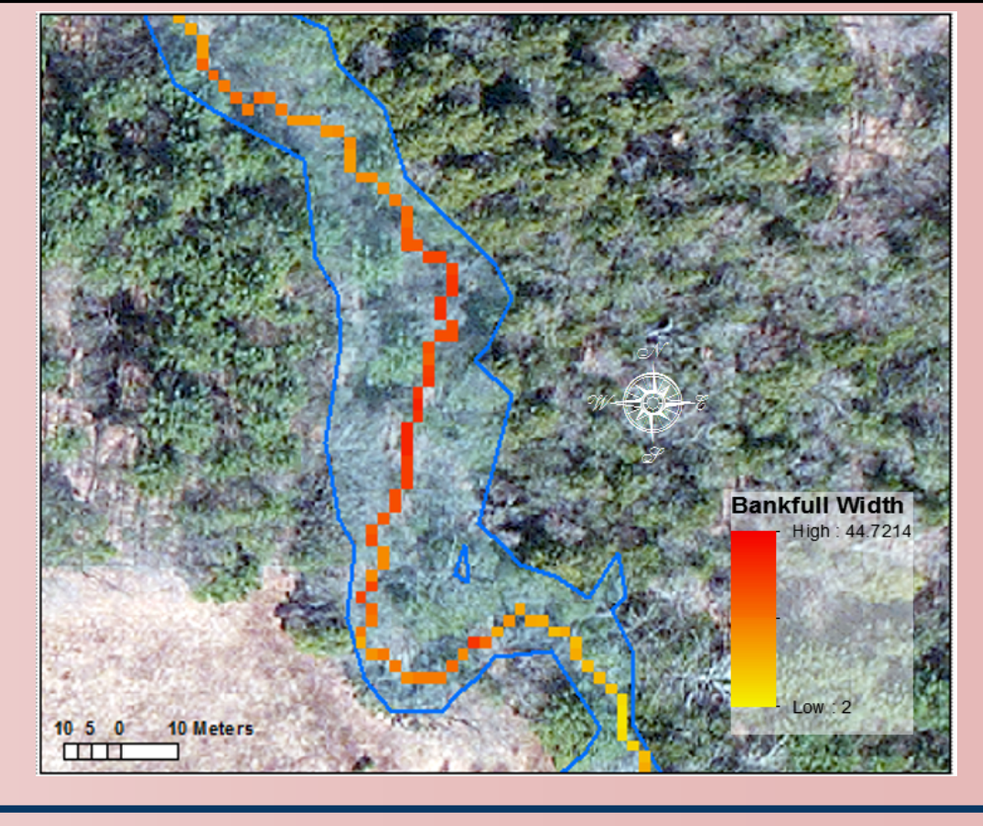


Centerline Location & Shape

LiDAR Smoothing
Resample high-resolution data to eliminate excess sinuosity, while retaining channel location.
Biron *et al.* 2013

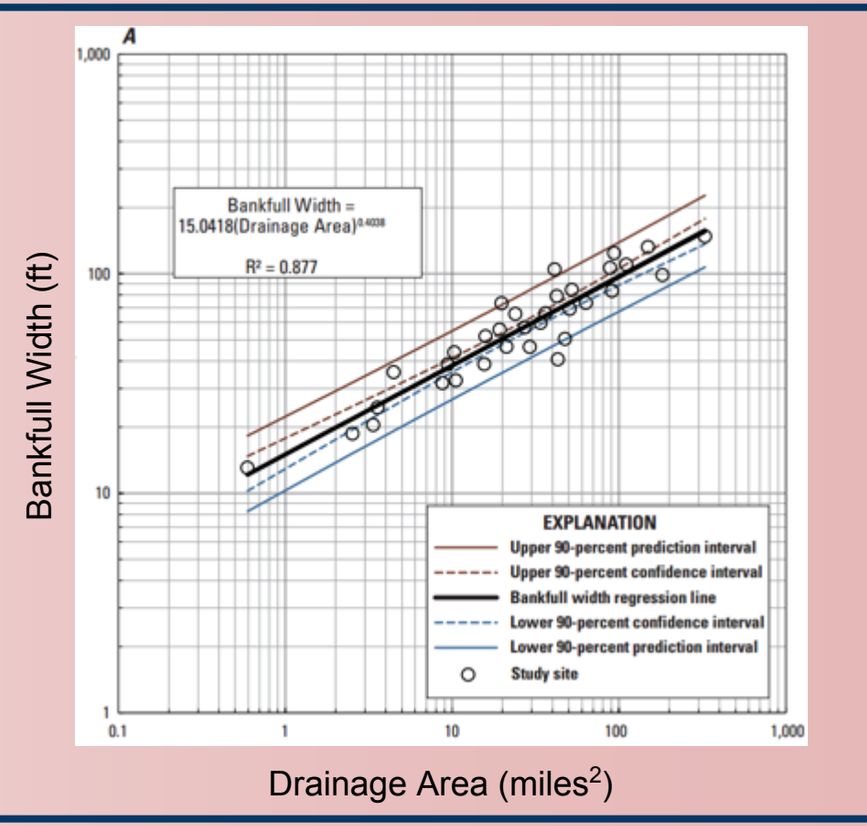


“HGM” Toolkit
Elevation & slope change with distance from the centerline. At a user-defined threshold change, the channel boundary is defined.
Johansen *et al.* 2011; Biron *et al.* 2013

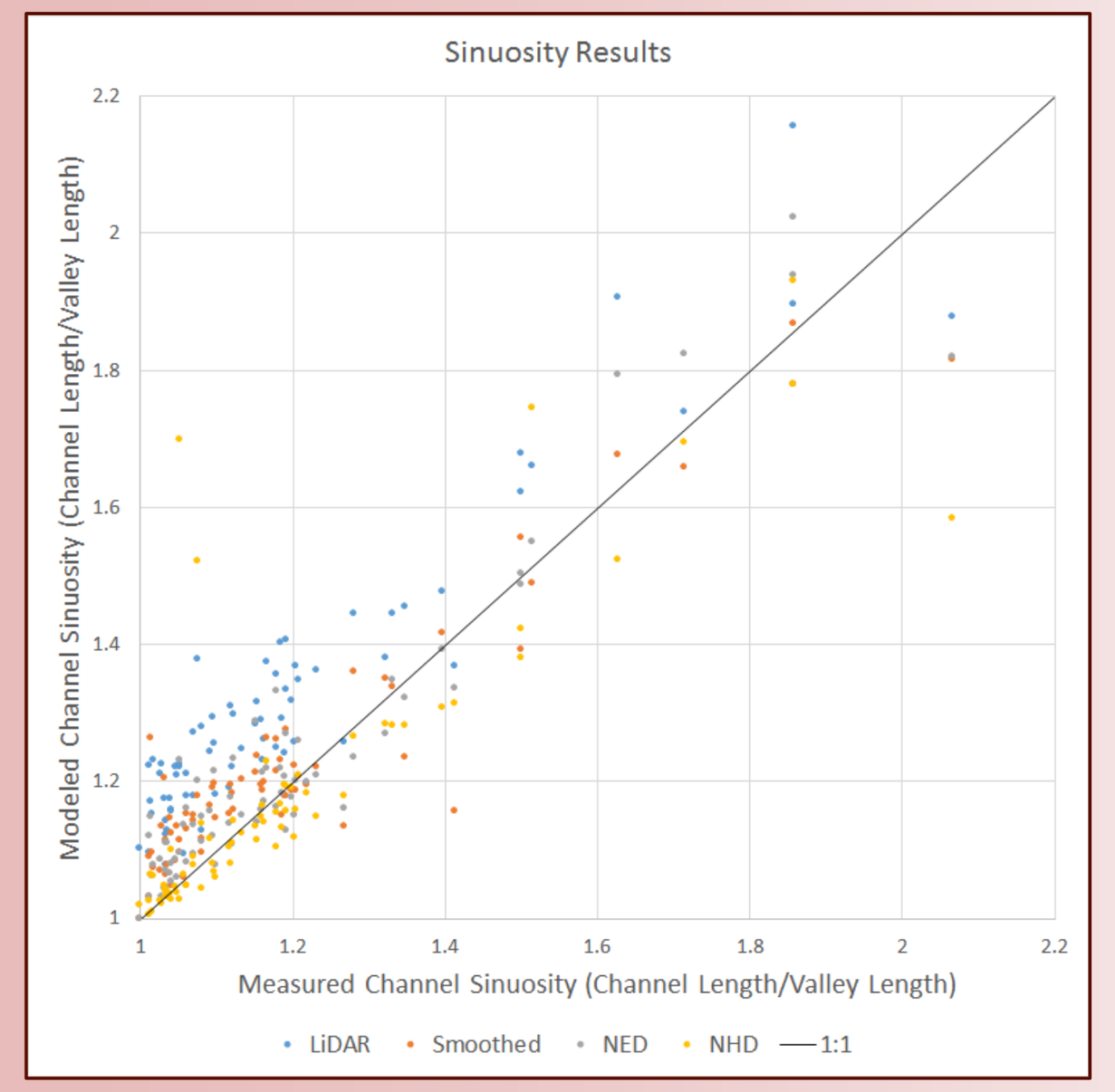


Slope and Geometry

Regional Hydraulic Curves
Empirical observations used to build regression curves relating upstream area and channel slope to discharge and channel dimensions
Bent and Waite, 2013

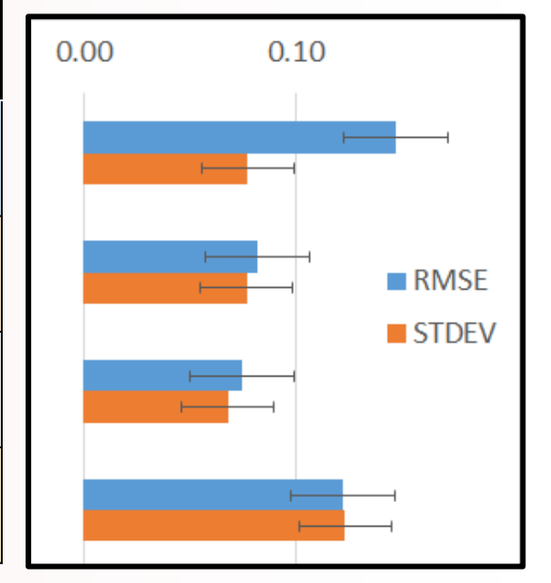


Results



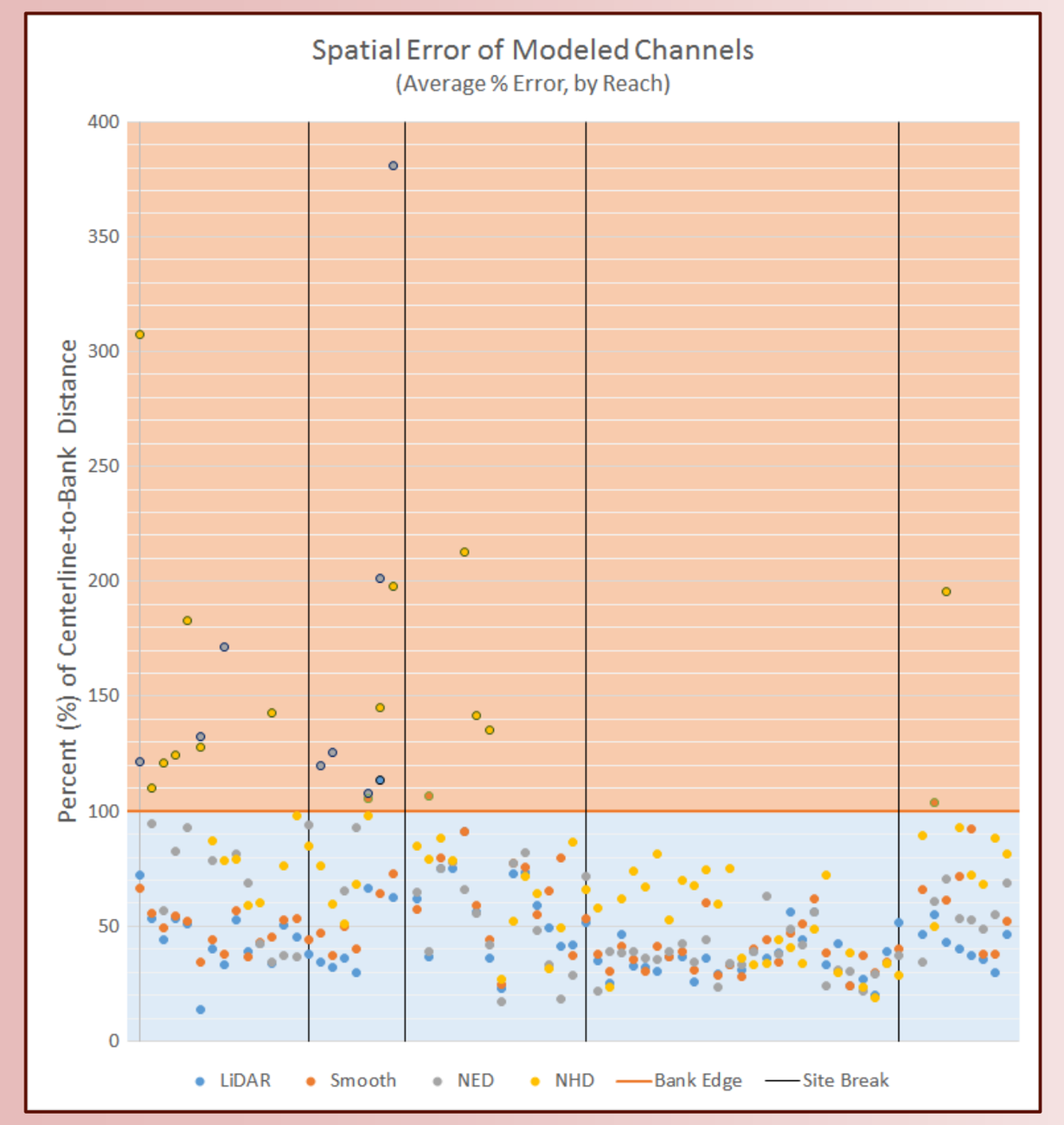
Sinuosity Errors

	RMSE	STDEV
LiDAR	1.06	0.08
Smooth	0.25	0.08
NED	0.27	0.07
NHD	0.02	0.12



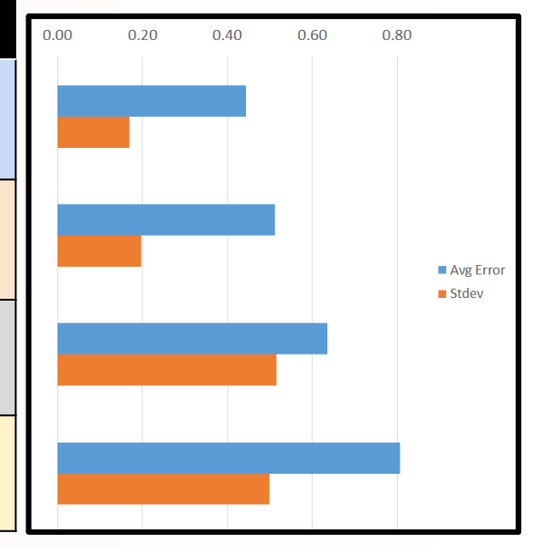
Sinuosity = Channel Length / Valley Length

Measure of planform shape accuracy.
Connected to channel slope measurement.

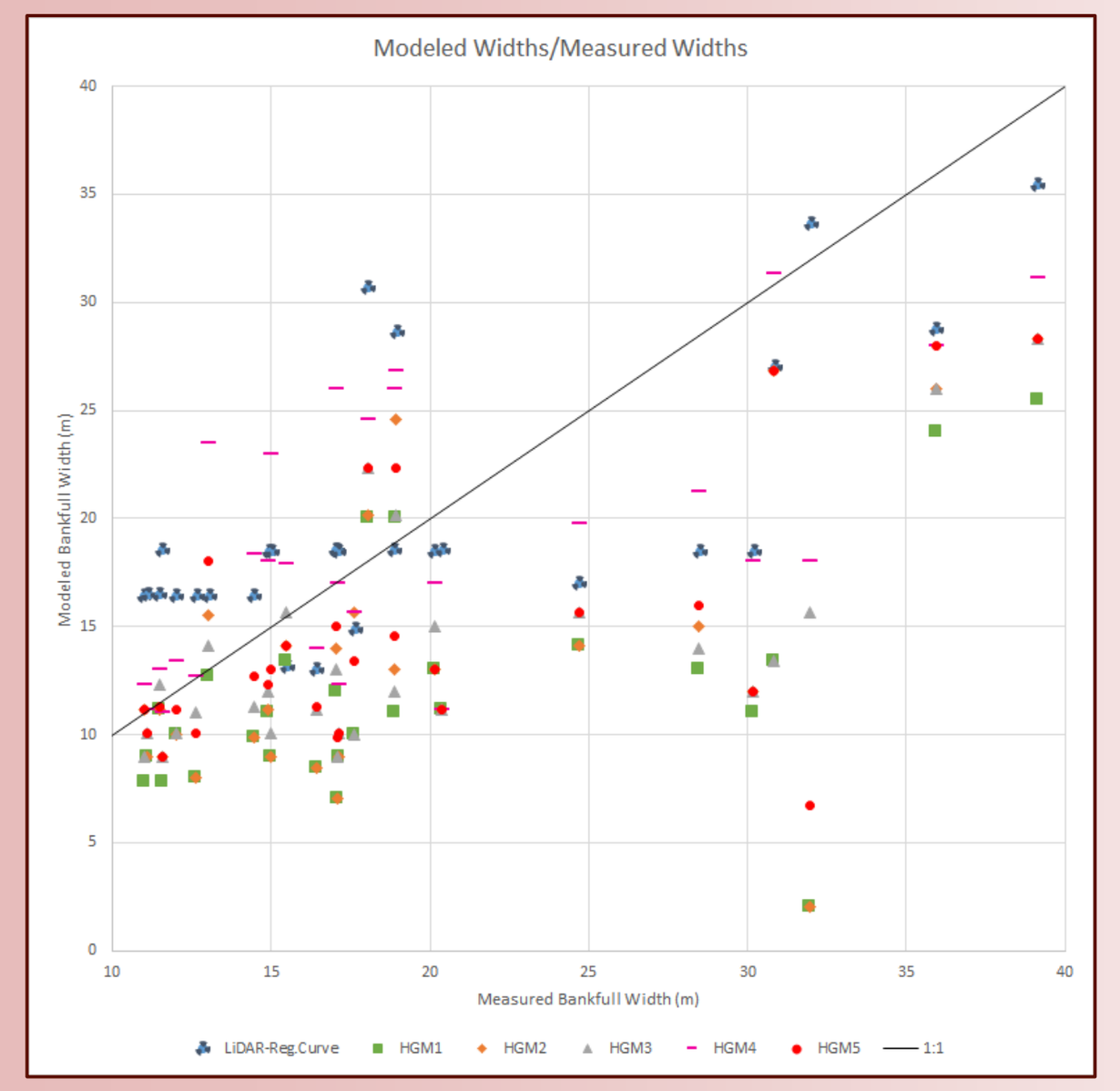


Centerline Spatial Errors

	Avg Error % bank distance	STDEV
LiDAR	0.44	0.17
Smooth	0.51	0.20
NED	0.64	0.52
NHD	0.81	0.50



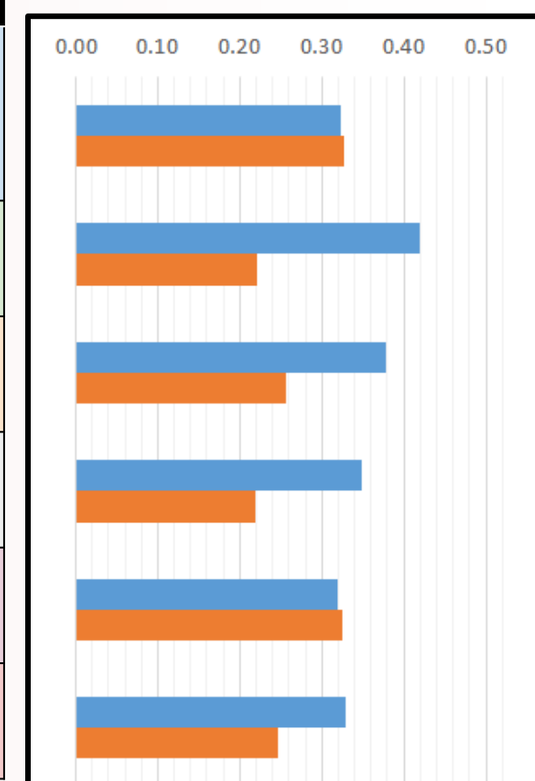
Measure of centerline placement within landscape.



Bankfull Width Errors

$$\text{RMSPE} = \sqrt{\frac{\sum\left(\frac{(\text{Value}_{modeled}) - (\text{Value}_{measured})}{(\text{Value}_{measured})}\right)^2}{\text{Number of Values}}}$$

	RMSPE	STDEV
Regnl Curve	0.34	0.33
HGM-1	1.96	0.22
HGM-2	1.54	0.26
HGM-3	1.50	0.22
HGM-4	0.06	0.33
HGM-5	1.21	0.25



HGM Run →	1	2	3	4	5
Elevation Change Threshold (m)	0.5	1	0.5	1	0.75
Slope Change Threshold (degrees)	12	12	20	20	15

Conclusions and Further Work

Centerline Mapping
- LiDAR – accurate centerline location
- Smoothed LiDAR – accurate centerline location, explore improved resampling parameters
- NED (1/3 Arc-Second) – fairly accurate centerline shape AND location
- NHD – accurate centerline shape, poor spatial placement

Width Estimation
- HGM – Large variation based on thresholds. Has potential for improvement.
- Regional Curves – do not perform well on wide streams

Further Work
- Complementary Tool Use – build on strengths of different tools
- Incorporate Landscape Details – mappable features can inform tool parameters
  - Local changes in geology, land-use, vegetation, etc.
- Deeper Results Analysis – spatial patterns in tool performance

Protocol Analysis

Sample List of River Assessment Protocols

Protocol	Source	Summary
WARSSS	Rosgen, D. 2007. **Watershed Assessment of River Stability and Sediment Supply (WARSSS)**	Four-phases classify streams, measure features for channel evolution and sediment models. Guides "natural channel design."
VTSGA	Kline, M., et al. Various Dates (2003, rev. 2004). **Stream Geomorphic Assessment Protocol Handbooks**.	Three-phase protocol for watershed planning, hazard mapping. Emphasizes river corridor, is incorporated into state legislation.
PSWQS	ADEQ Surface Water Section. 2012. **Standard Operating Procedures for Surface Water Quality Sampling, Arizona.**	Manual of assessment methods, based on Rosgen. Focus is water quality. Part of statewide surface water monitoring program.
BURP	IDEQ. 2007. **Beneficial Use Reconnaissance Program Field Manual for Streams**.	Guidance for assessment planning, preparation, fieldwork, and reporting. Focus is biological condition and habitat availability.
AIP	Moore, K., et al. 2008. **Aquatic Inventories Project: Methods for Stream Habitat Surveys, Version 17.1**.	Quantifies habitat condition by assigning numeric values to stream, riparian, and valley geomorphic features.
SIH	USFS. 2009. **Stream Inventory Handbook: Level I & II, Version 2.9.**	Set of inventory protocols geared towards various watershed management activities. Focus and level of detail are flexible.
CMA	USACE and USEPA, 2008. **Compensatory Mitigation for Losses of Aquatic Resources; Final Rule**	Determine requirements to offset impacts. Available for New England, VA, NC, SC, GA, AL, MS, IA, IL, WI, MN, OK, TX, KY.
SEDG	Mussetter Engineering, Inc. 2008. **Sediment and Erosion Design Guide**.	Delineates Lateral Erosion Envelope (LEE) using bank retreat equations based on bank material and incision depths.
GEEHZ	City of Austin Watershed Protection Department, 2013. **Guidance on Establishing an Erosion Hazard Zone**	Estimates surface and subsurface erosion hazard zones based on future incision and channel migration. Has legislative force.
Mont-Buff	Montgomery, D. R. and J. M. Buffington. 1998. **Channel Processes, Classification, and Response**	Energy and mass-balance equations are used to classify reaches, assess condition and predict disturbance response.
RSF	Brierley, G., & Fryirs, K. 2005. **Geomorphology and River Management: Applications of the River Styles Framework**	Divides river into Geomorphic Process Zones based on sediment dynamics, remediation aims for best-possible “sustainable river.”
RHS	The RHS Team, 2003. **River Habitat Survey in Britain and Ireland: Field Survey Guidance Manual, 2003 version**	Applied rapidly by non-experts, scores habitat based on physical stream structure. Conforms to EU Water Framework Directive.
MQI	Rinaldi, M., et al. 2012. **A method for the assessment and analysis of the hydromorphological condition of Italian streams: The Morphological Quality Index (MQI).**	Grades habitat from continuity, morphology, vegetation quality. Uses remote sensing. Conforms to EU WFD.
ARA	Smith, M., et al. 2008. **The Active River Area: A Conservation Framework for Protecting Rivers and Streams.**	Delineates river corridor susceptible to channel migration based on elevation models.

Analysis Categories

Relevance	Detail	Applicability	Accessibility	Ease of Use	Output
What is protocol goal? How directly related is it to user goal?	How detailed are, and what is resolution of, results?	How widely applicable is protocol (topically, geographically)?	Ability to access, instructions, technology required, etc	Time, data, research input, expertise required, etc	Utility and clarity of output (maps, text, equations, etc)

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