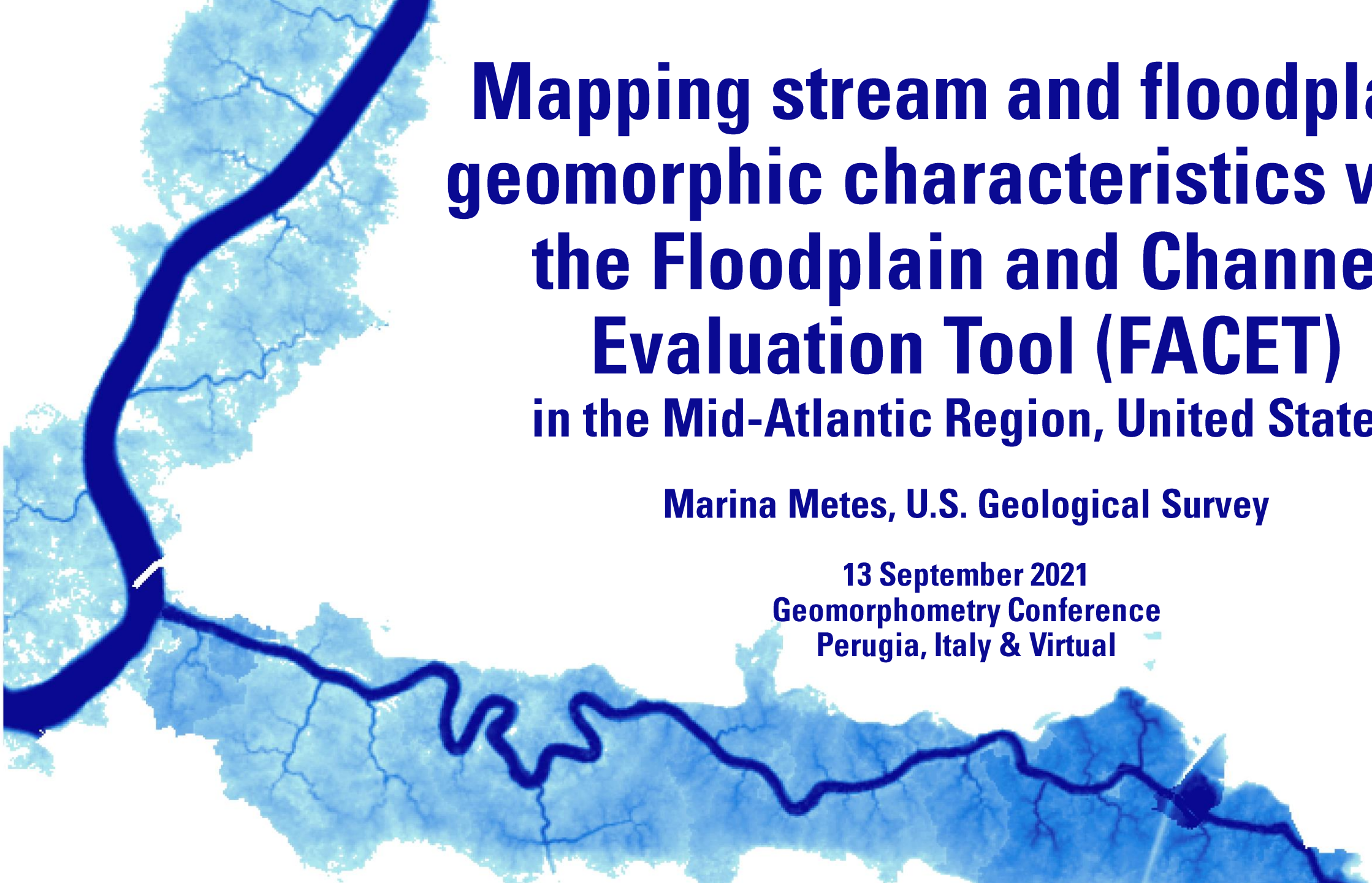

Mapping stream and floodplain geomorphic characteristics with the Floodplain and Channel Evaluation Tool (FACET)

in the Mid-Atlantic Region, United States

Marina Metes, U.S. Geological Survey

13 September 2021
Geomorphometry Conference
Perugia, Italy & Virtual

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Acknowledgements

Co-authors:

Krissy Hopkins[1], Labeeb Ahmed[1], Peter Claggett[1], Sam Lamont[2], and Greg Noe[1]

[1]U.S. Geological Survey (USGS), [2]One Concern, Inc.

Funding:

USGS Ecosystems Mission Area, USEPA Chesapeake Bay Program Office, William Penn Foundation Delaware Watershed Research Fund, and Smithsonian Institute

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Background

- I’m located in Baltimore, Maryland, USA
- The work presented here is based in the Mid-Atlantic region of the United States, within the Chesapeake Bay and Delaware River watersheds

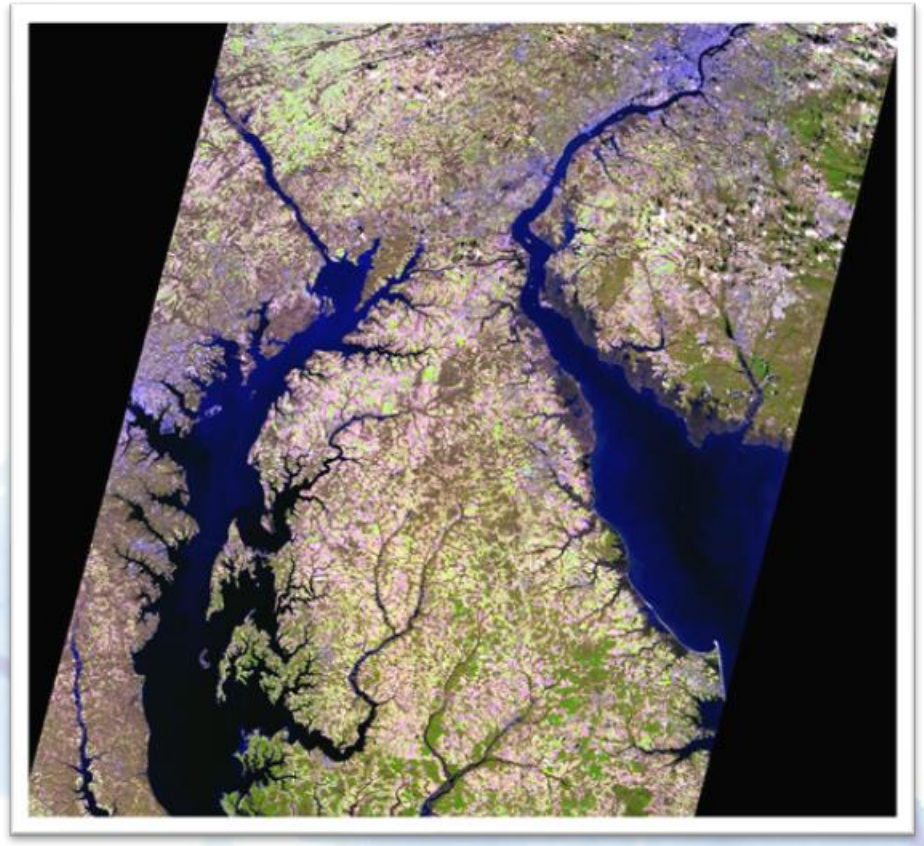

Image source: USGS

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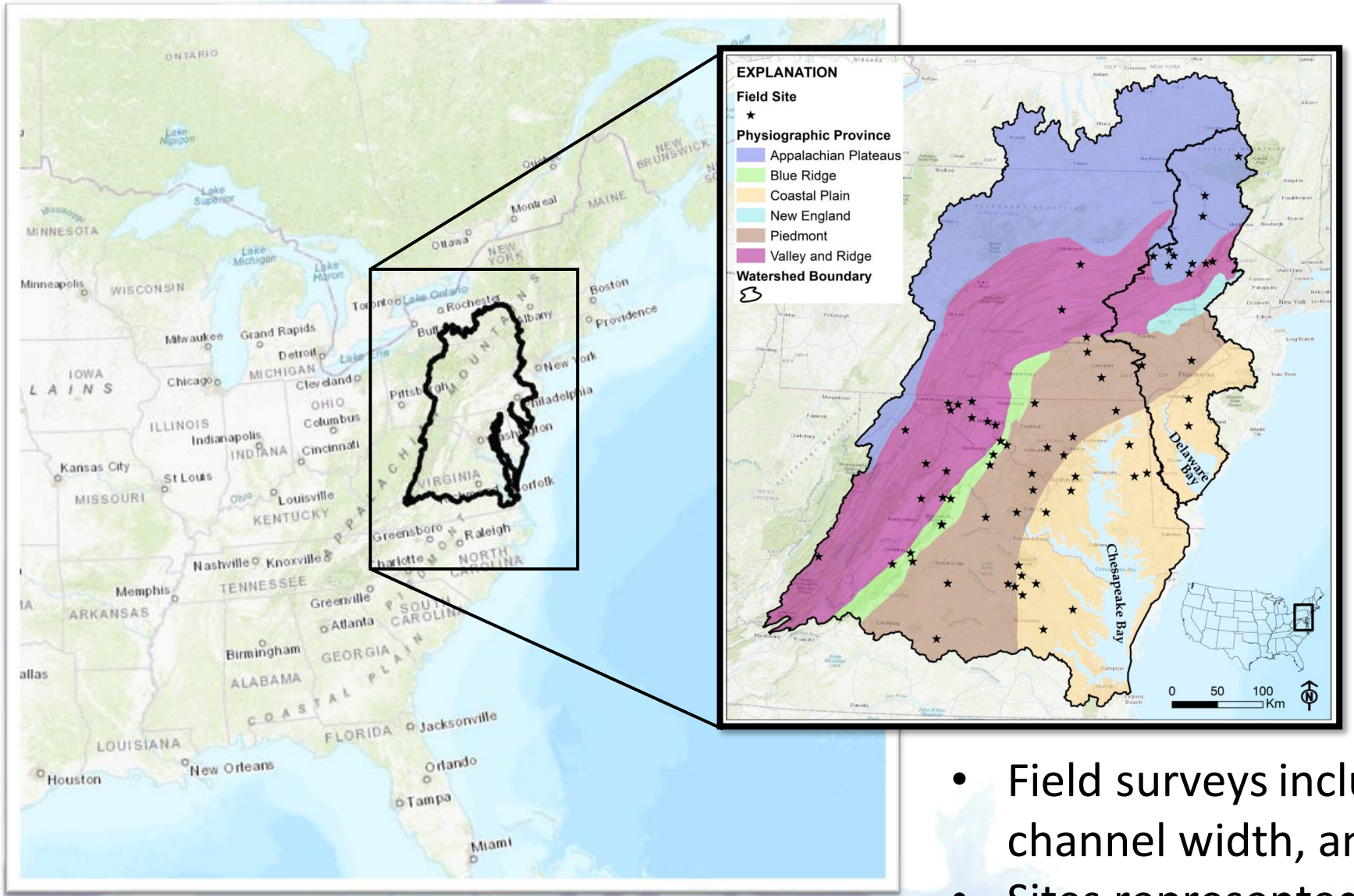
Project Motivation

Scale field measures of streambank erosion and floodplain sediment deposition regionally across large watersheds



- Field surveys include streambank height, channel width, and floodplain width
- Sites represented regional variability in drainage area, geology, topography, soils, hydrology, and land use

Source: Noe et al. 2020, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX.

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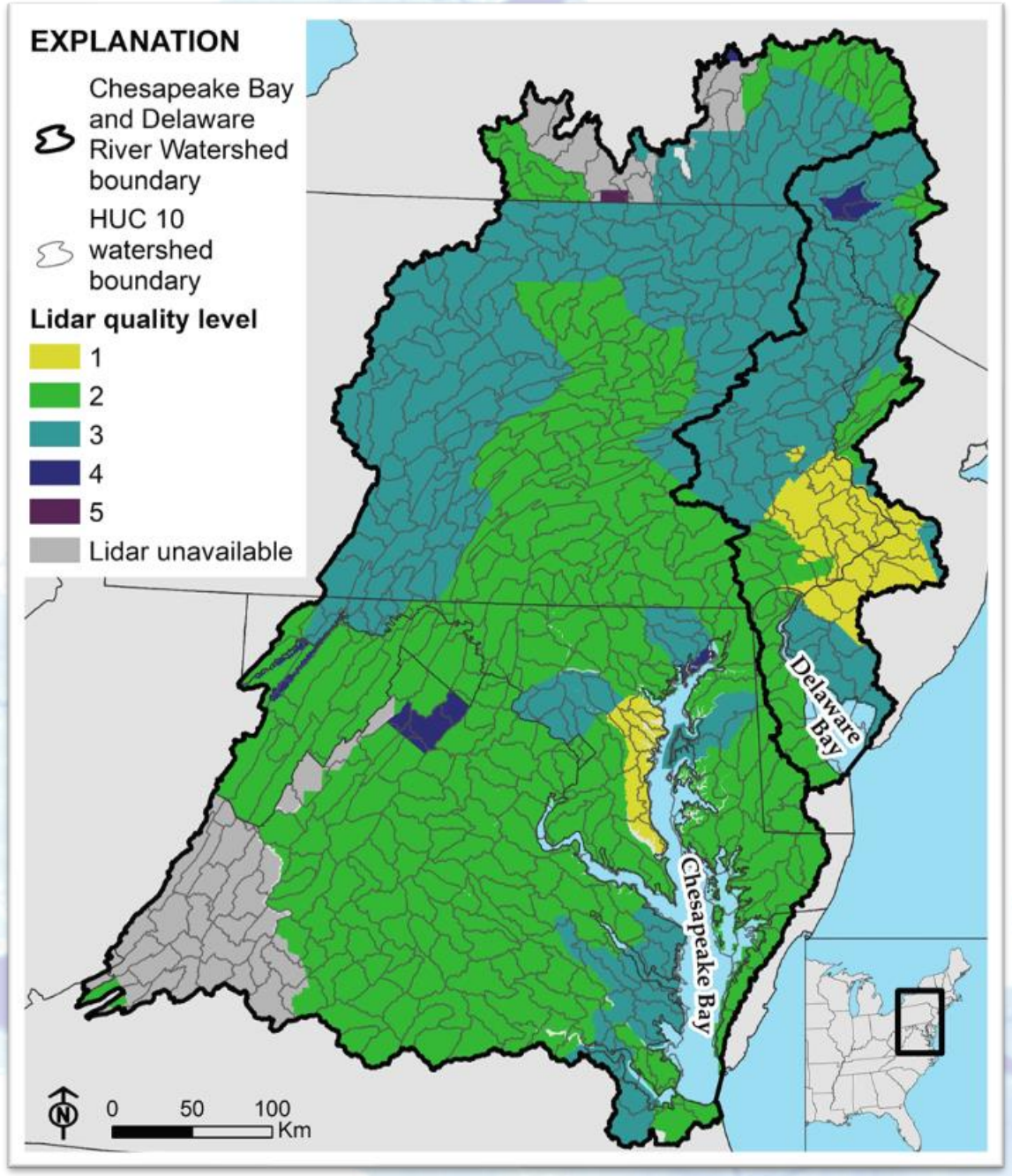

Lidar availability

- Lidar is available for most of the Mid-Atlantic region of the U.S.
- Multiple lidar collections are available between 2005 and 2018
- They include a range of vertical and horizontal accuracies, native DEM resolutions (1 - 3.4 m), point spacing, and overall quality level
- DEMs were resampled to 3 m (bilinear) and mosaiced by watersheds averaging 400 km^2 in drainage area.

Lidar source: https://coast.noaa.gov/inventory/

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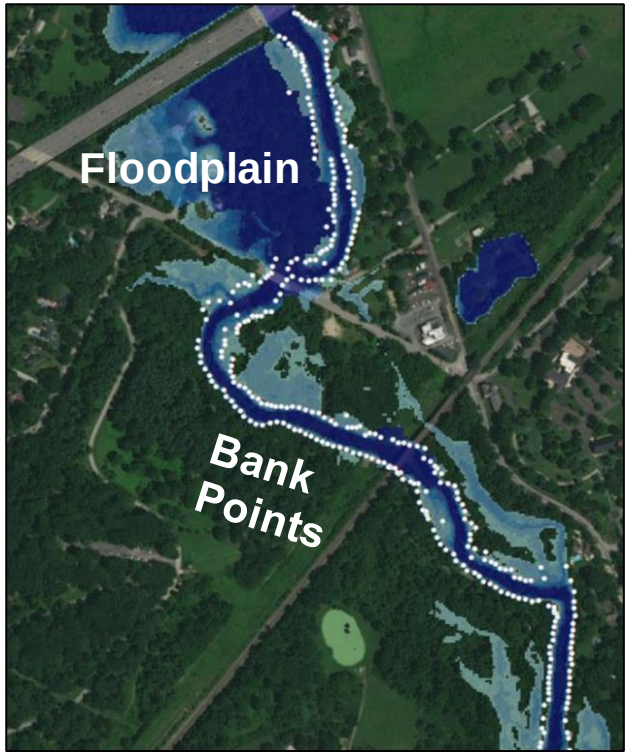
The USGS Floodplain and Channel Evaluation Tool (FACET) Overview



GIS tool automated to measure fine-scale geomorphometry

- Open-source Python tool
  - Code available at code.usgs.gov/water/facet
- Tool inputs
  - Digital elevation model (3 m or finer)
  - Existing stream network (and optional road/railroad/culvert shapefile)
  - User-defined parameters based on regional setting

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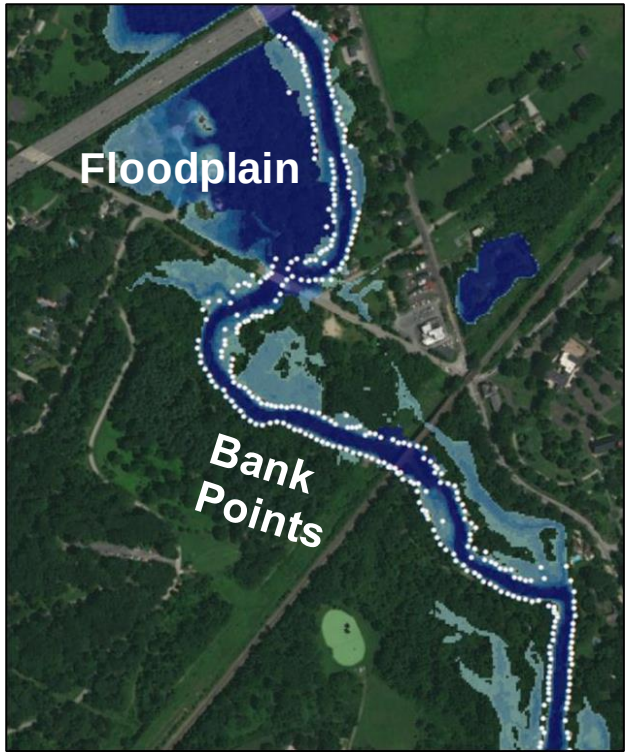

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- Tool inputs
  - Digital elevation model (3 m or finer)
  - Existing stream network (and optional road/railroad/culvert shapefile)
  - User-defined parameters based on regional setting
- Tool outputs
  - Streambank locations (**cross section-**based and **pixel-**based methods)
  - Measures of bank height and channel width
  - Extent of active, frequently flooded floodplain
  - Reach-scale summaries of channel and floodplain geomorphometry

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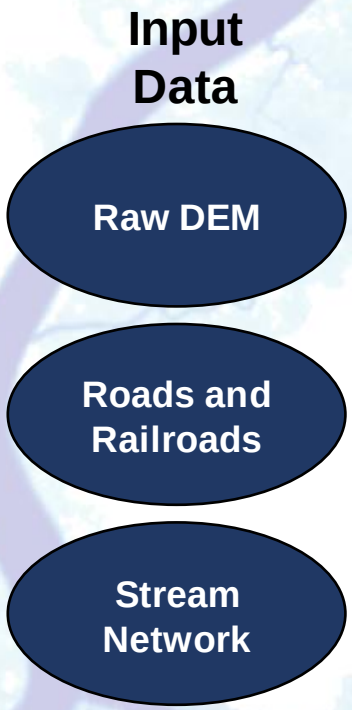
FACET Workflow



Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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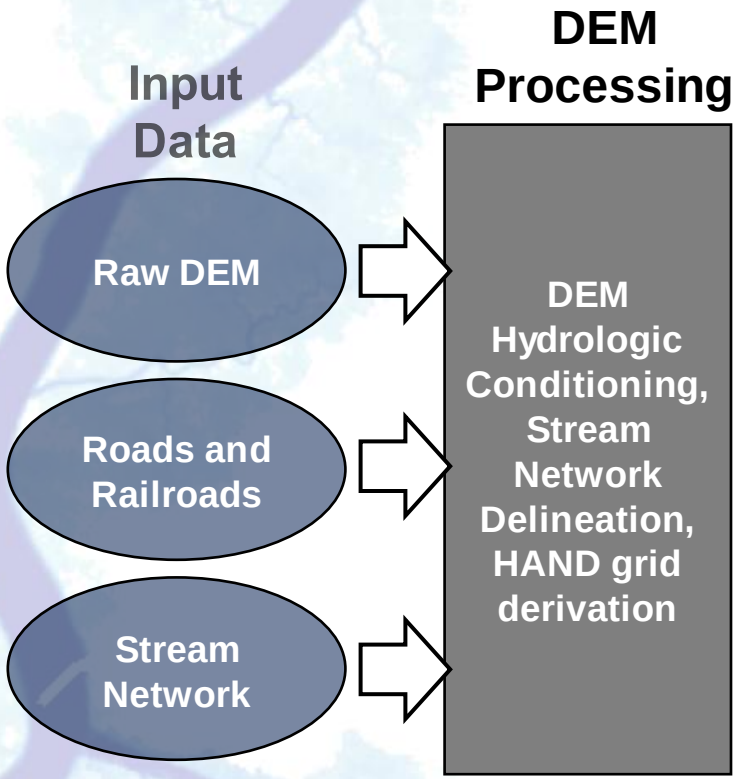
FACET Workflow



1) Hydrologically condition DEM

- Road-stream and railroad-stream intersections identified and breached

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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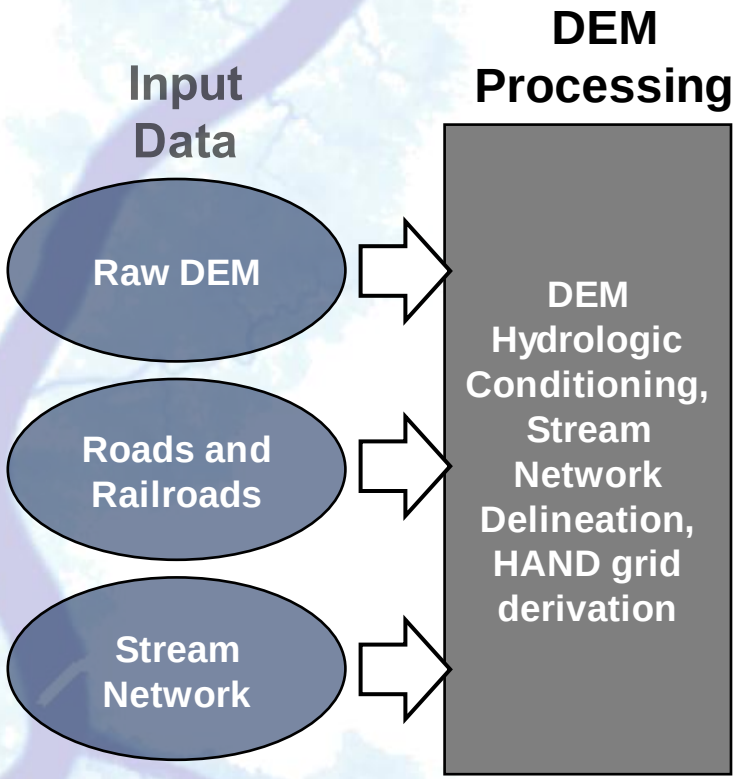
FACET Workflow



1) Hydrologically condition DEM

- Road-stream and railroad-stream intersections identified and breached
- Whitebox Tools *Breach Depressions* (Lindsay, 2016) to resolve any remaining pits in the DEM

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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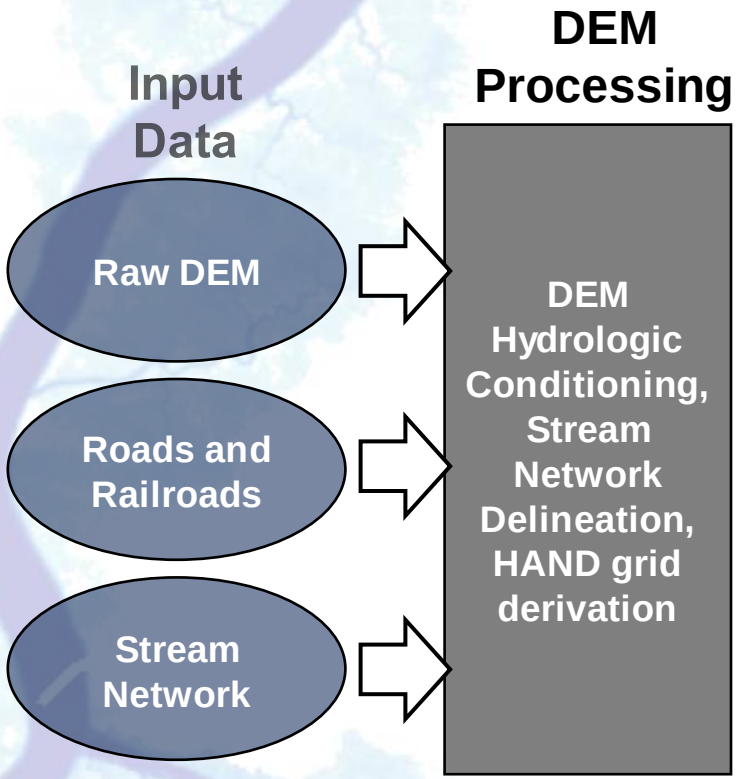
FACET Workflow



1) Hydrologically condition DEM

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2) Generate Stream network

- TauDEM (Tarboton, 1997) *D8 Flow Direction*, *D8 Contributing Area*, *Stream Reach and Watershed*

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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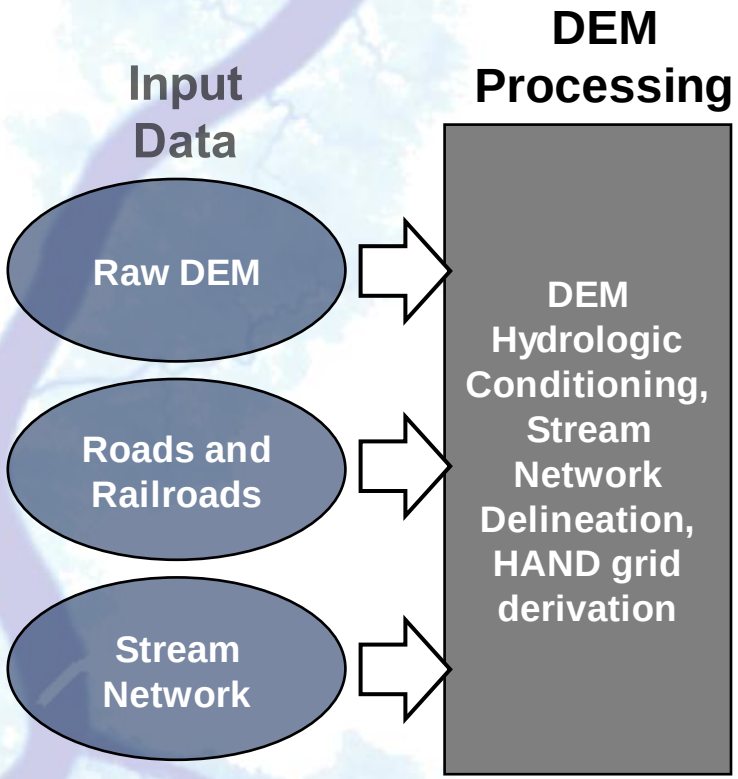
FACET Workflow



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3) Generate Height Above Nearest Drainage (HAND)

- TauDEM *D-Infinity Distance Down*

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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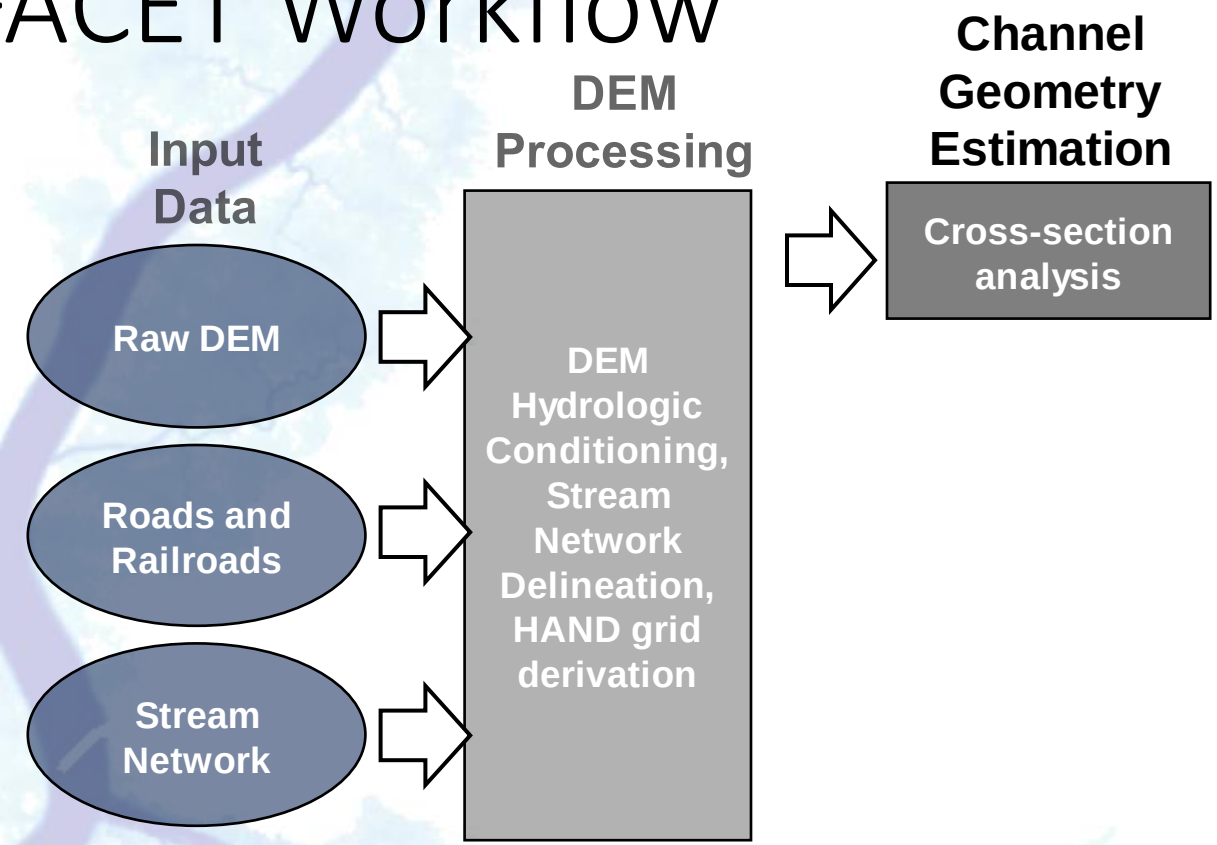
FACET Workflow



Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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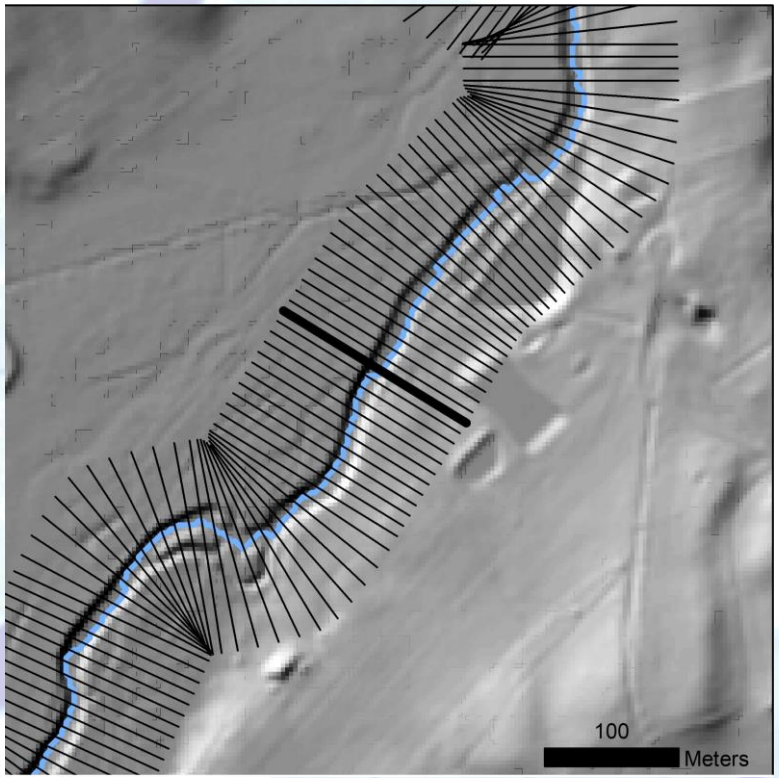
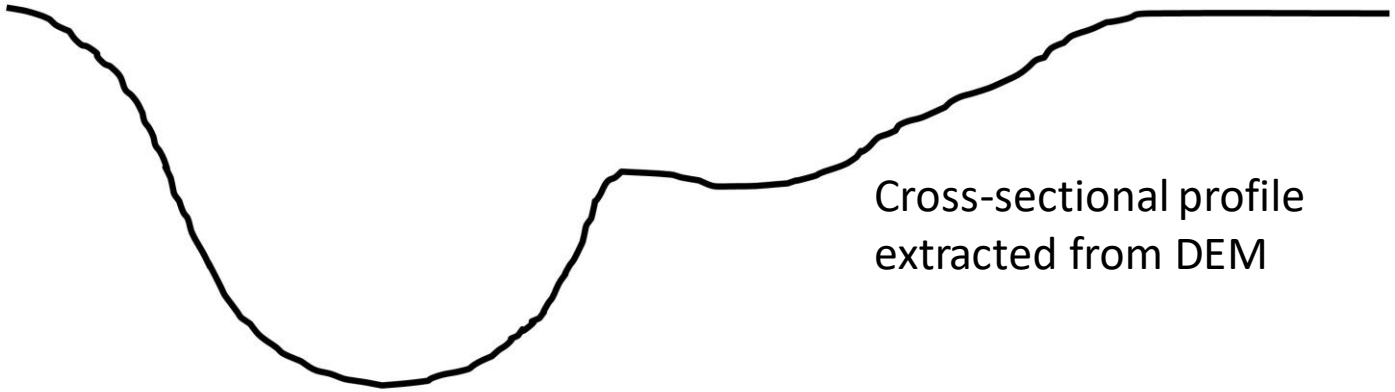
Cross section analysis



Channel Geometry Estimation

Cross-section analysis



Cross-sectional profile extracted from DEM

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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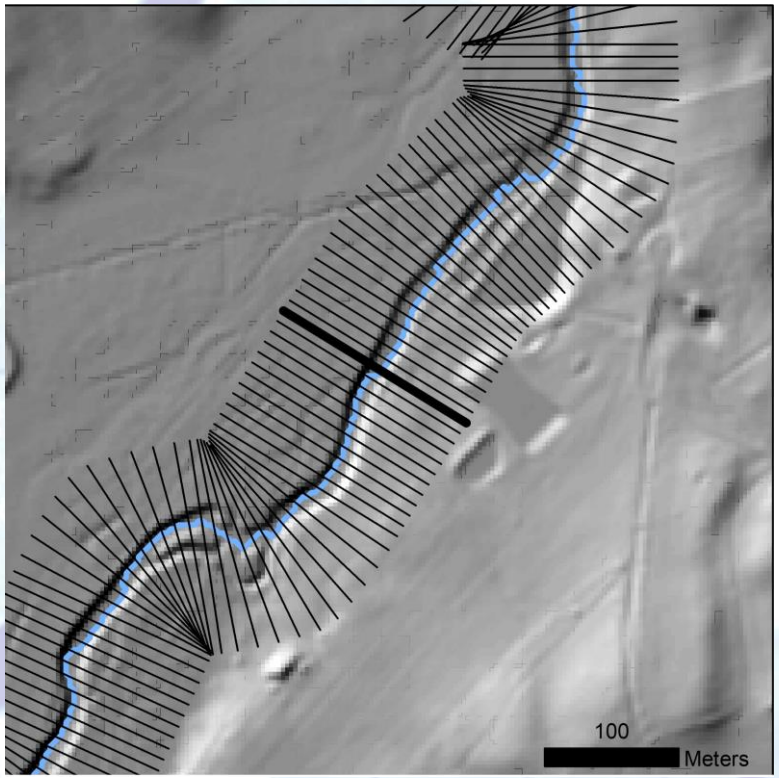
Cross section analysis



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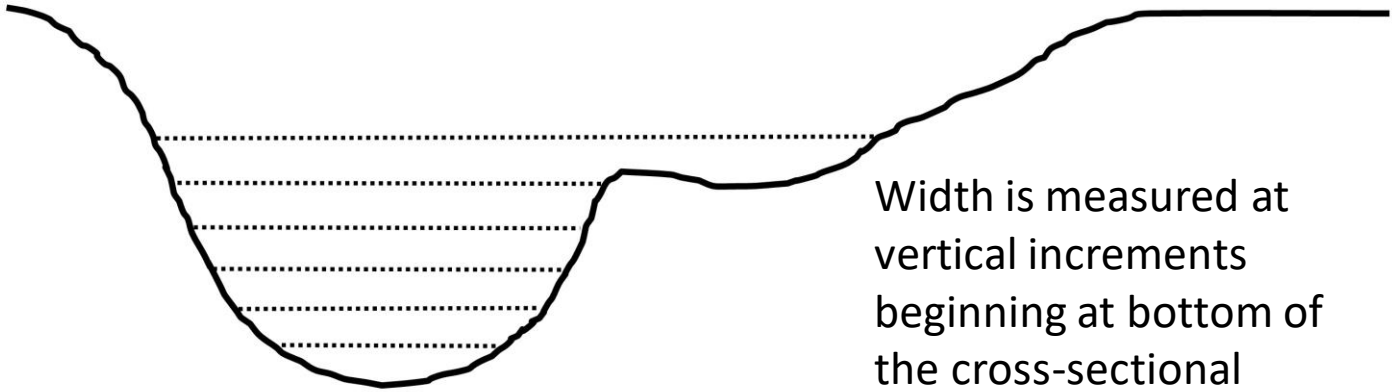

Width is measured at vertical increments beginning at bottom of the cross-sectional profile

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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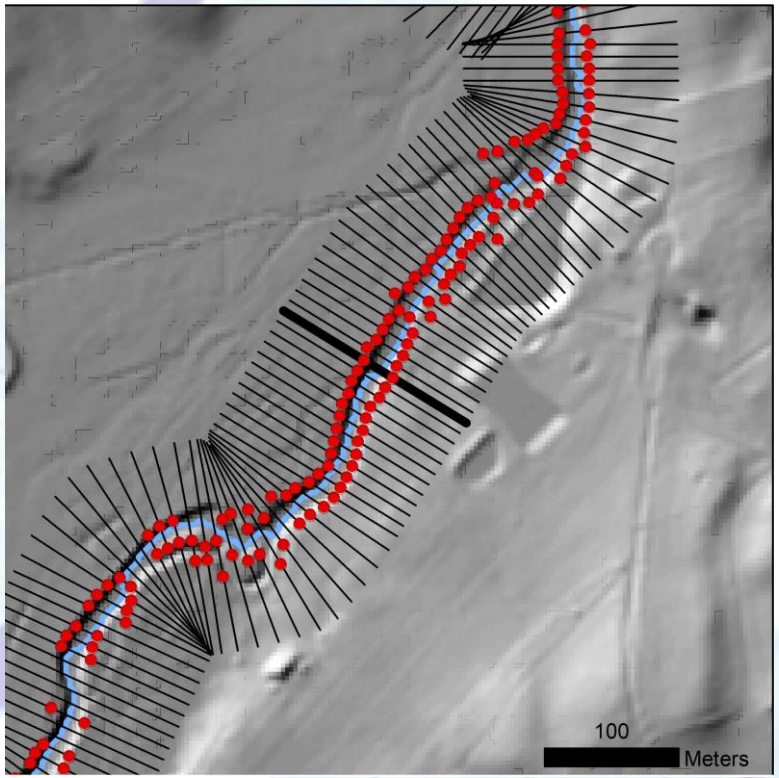
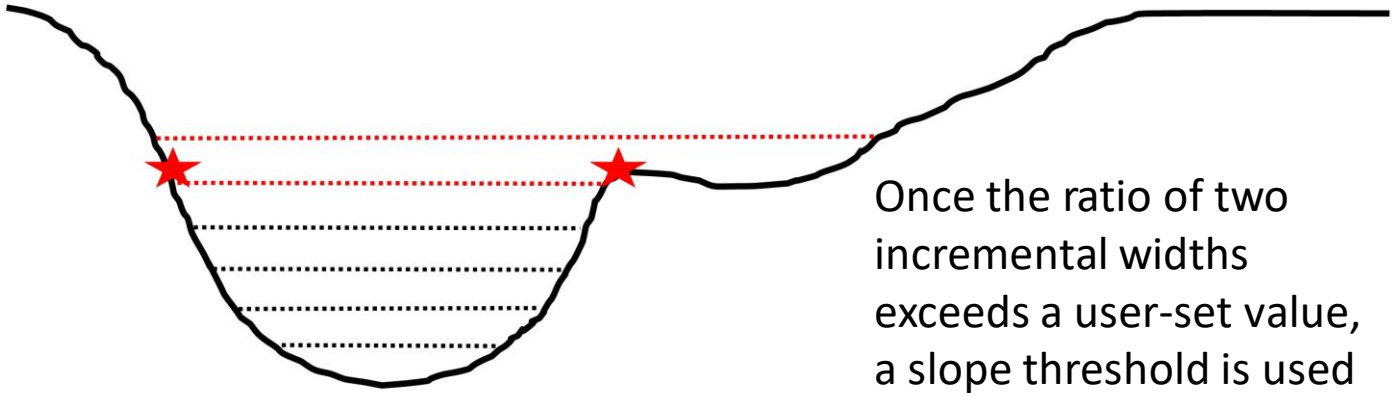
Cross section analysis



Channel Geometry Estimation

Cross-section analysis



Once the ratio of two incremental widths exceeds a user-set value, a slope threshold is used to identify streambanks

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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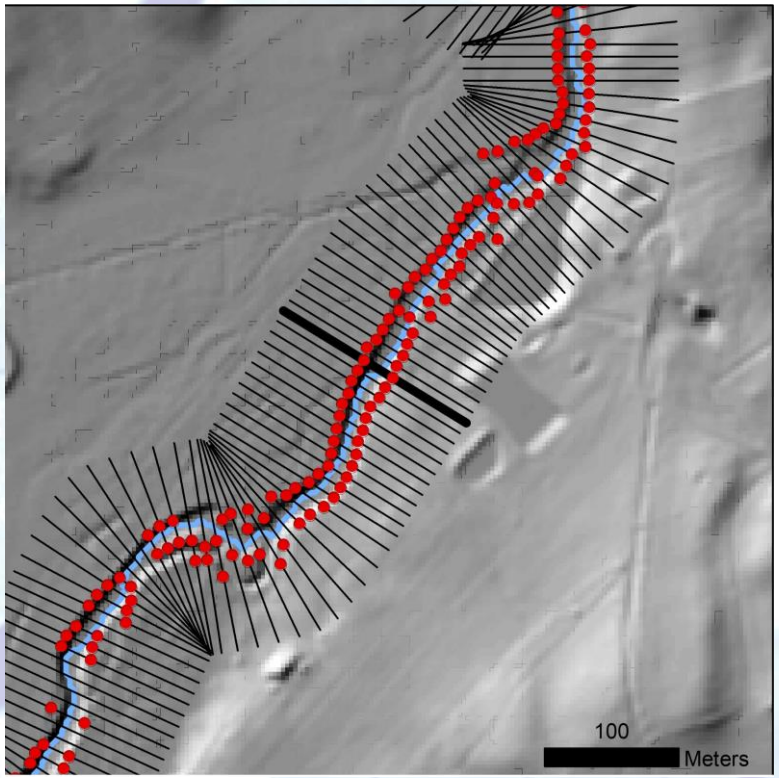
Cross section analysis

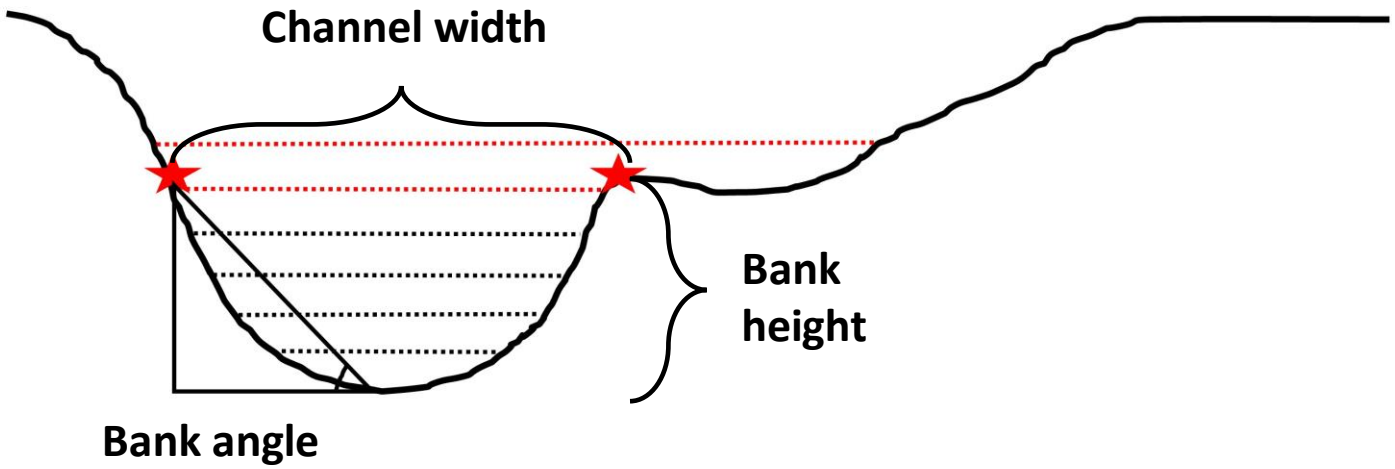


Channel Geometry Estimation

Cross-section analysis

Geomorphic Measurements

Metrics at each cross section and bank point



Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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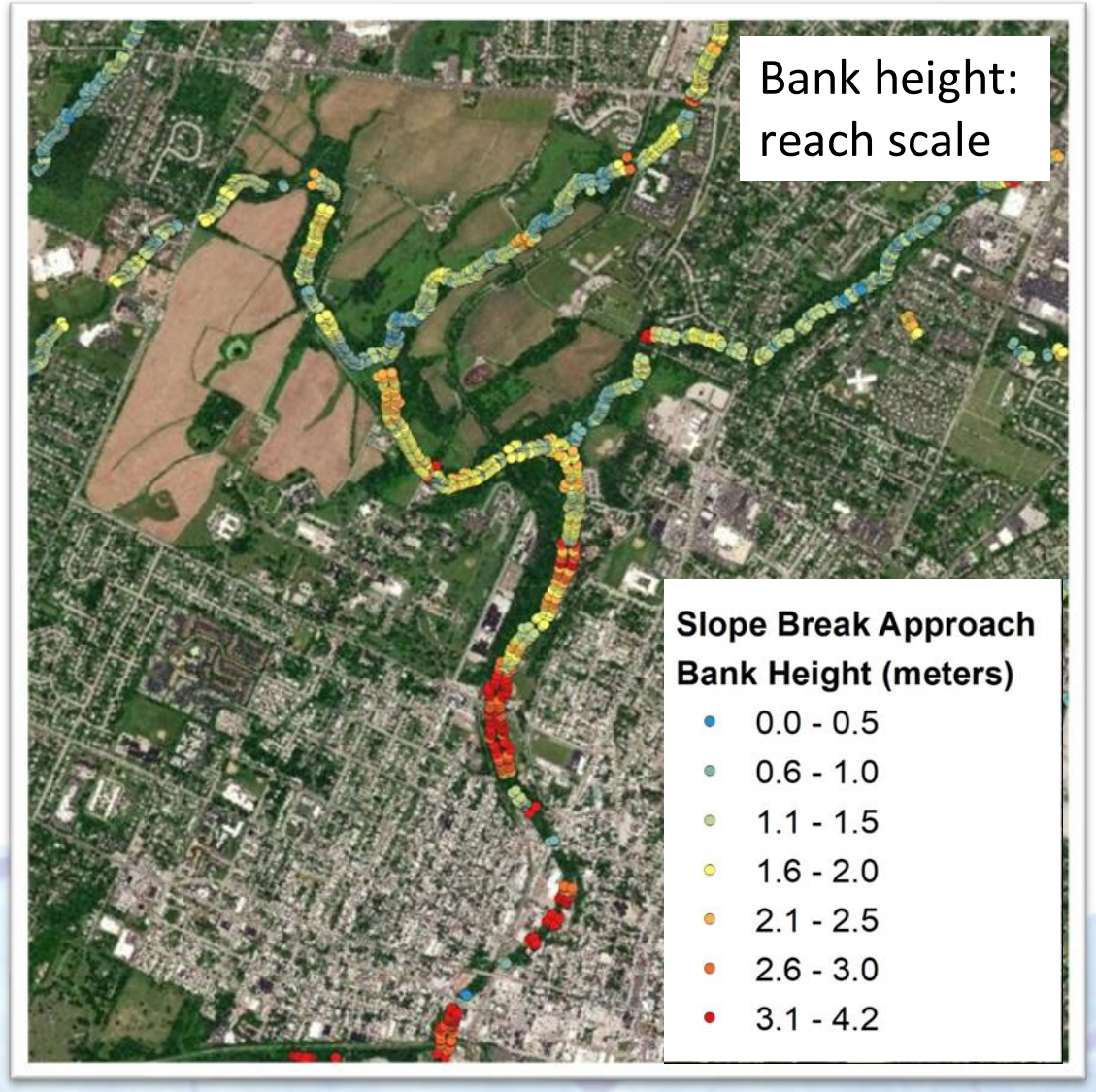
Example of bank height measurements



Source: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1

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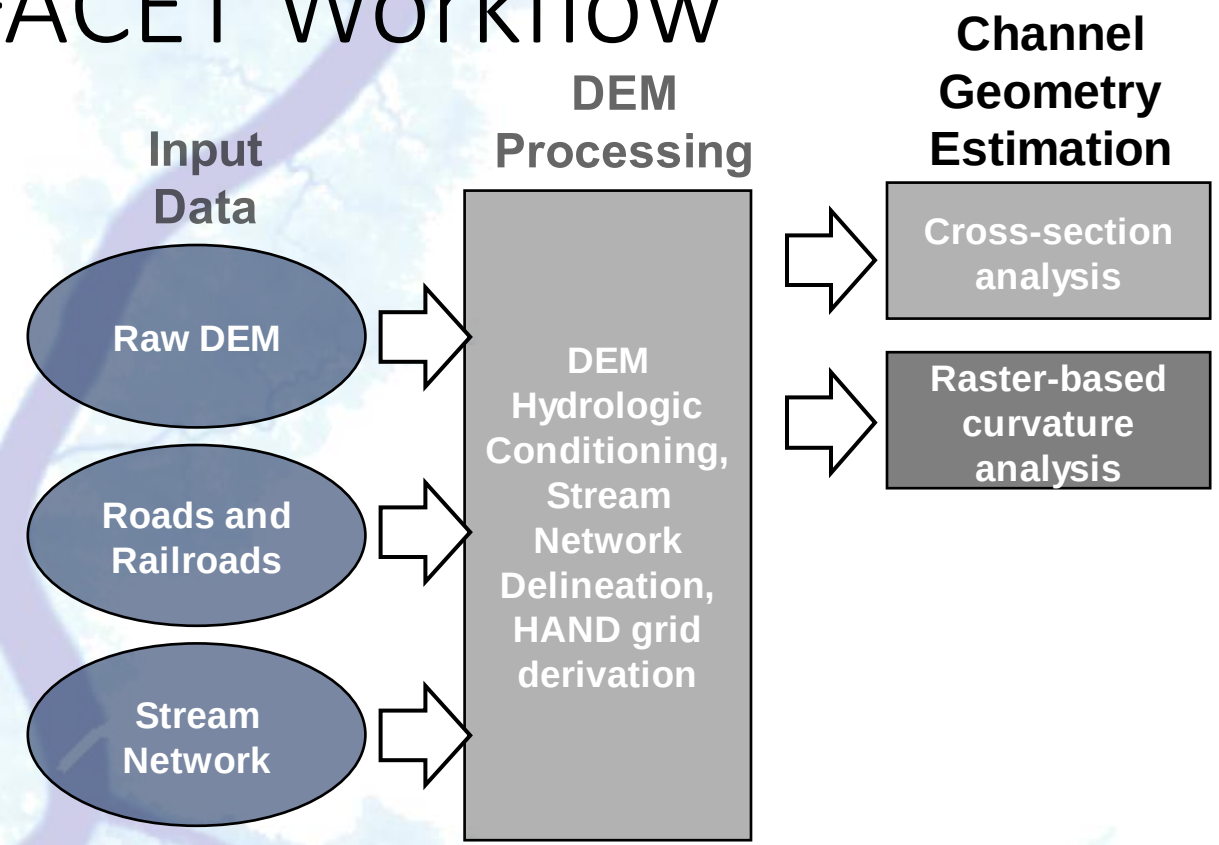
FACET Workflow



Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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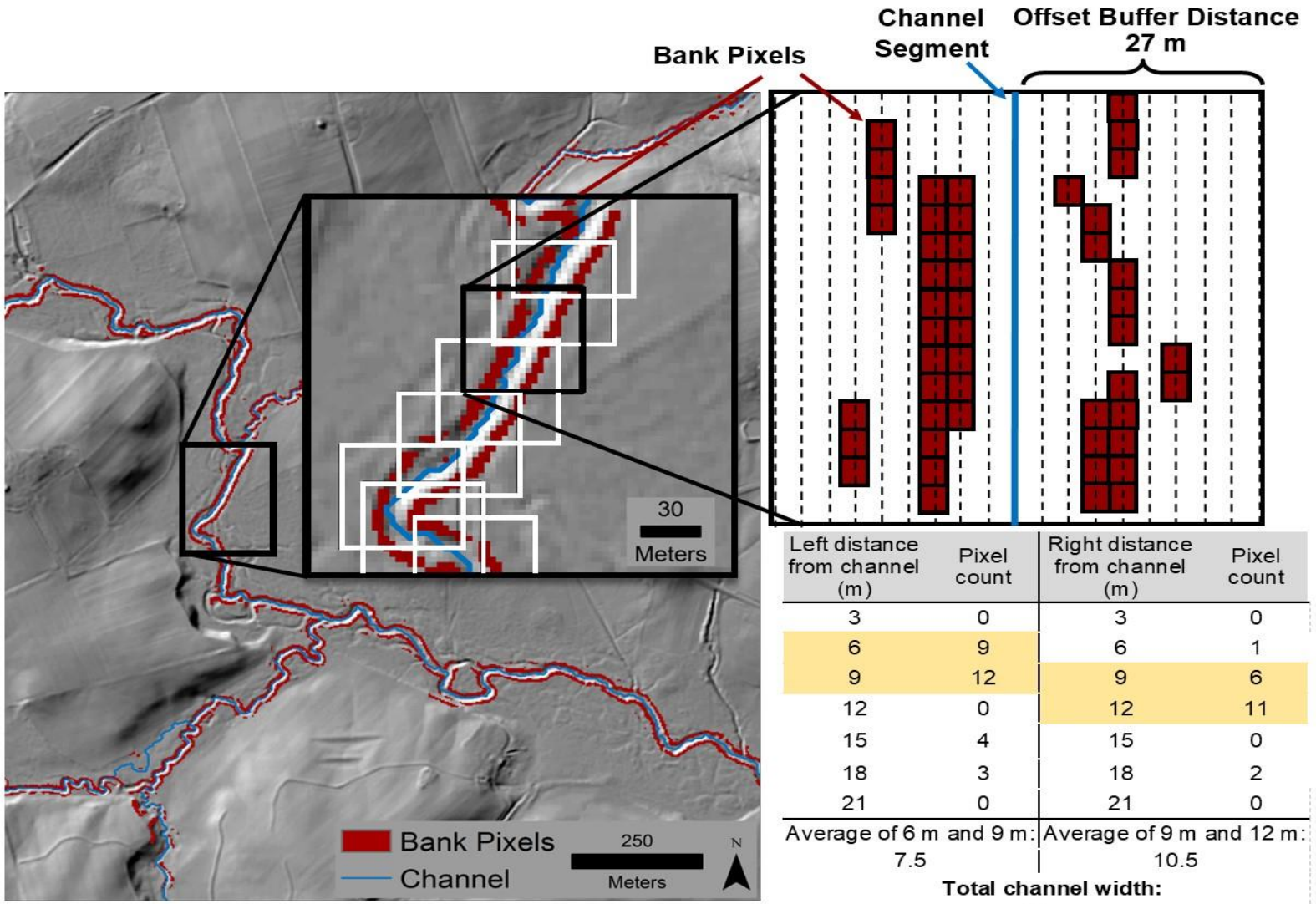
Raster-based curvature analysis



Left distance from channel (m)	Pixel count	Right distance from channel (m)	Pixel count
3	0	3	0
6	9	6	1
9	12	9	6
12	0	12	11
15	4	15	0
18	3	18	2
21	0	21	0
Average of 6 m and 9 m: 7.5		Average of 9 m and 12 m: 10.5	

Total channel width: 18 m

- Wavelet-based curvature smooths parts of the DEM while maintaining characteristics proximal to the stream
- Moving windows traverse the stream network, and pixels exceeding 30% of the maximum curvature within each window are identified as banks

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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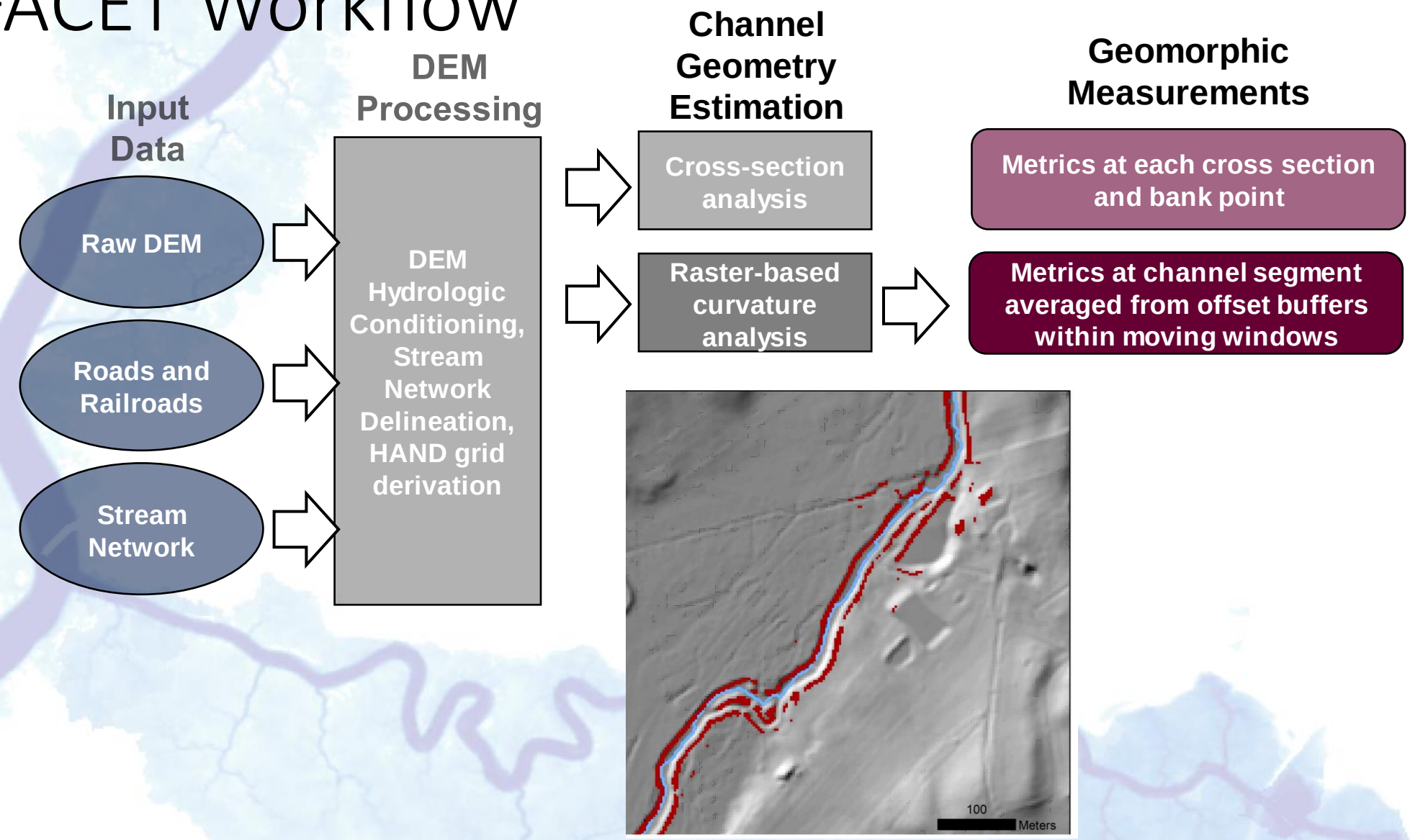
FACET Workflow



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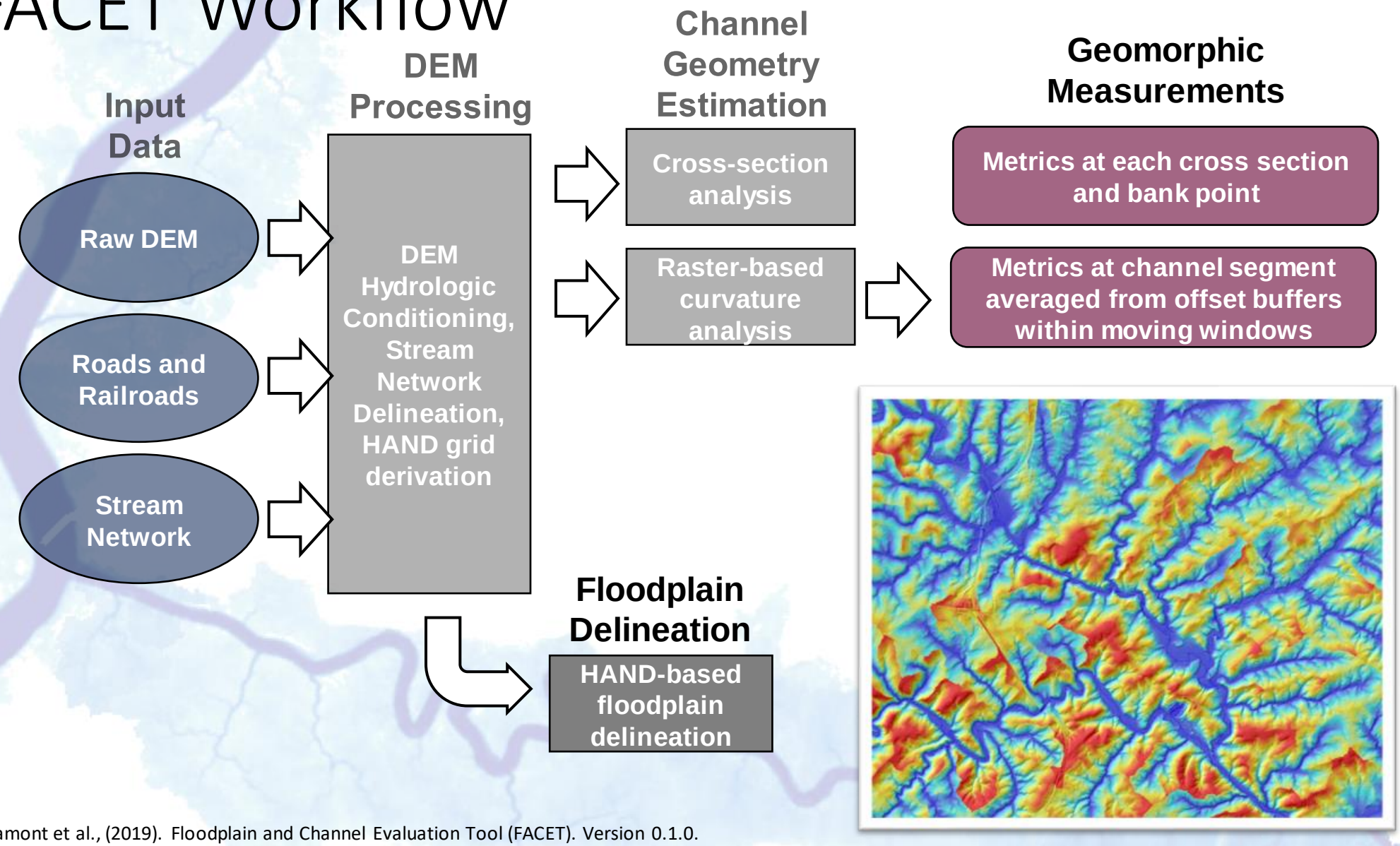

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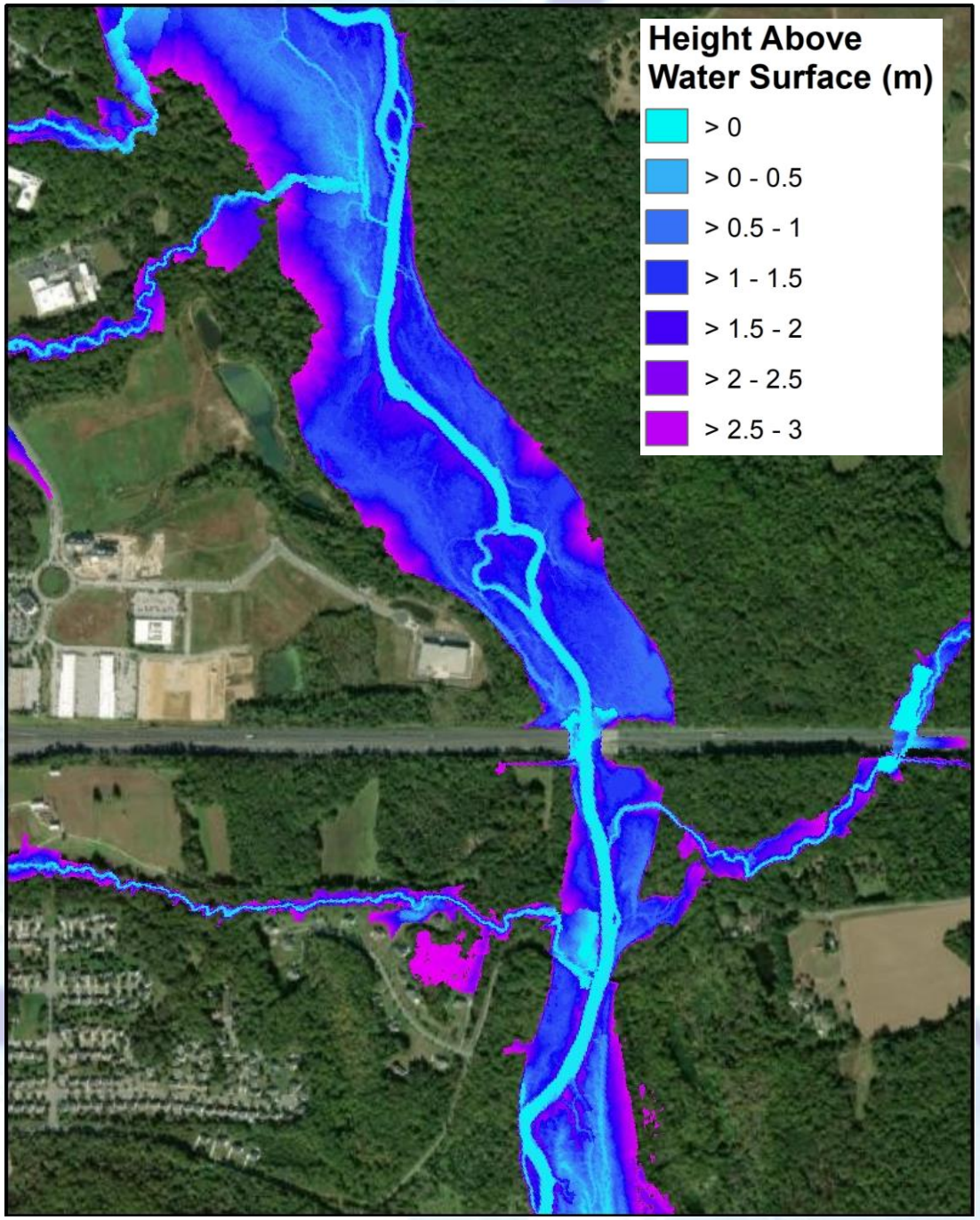

Calculating floodplain extent using HAND

Step 1: Identify geomorphically active floodplain extent in field based on topography, vegetation, evidence of recent flooding (e.g. fine sediment deposits, debris deposits aligned perpendicular to the channel).

Source: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1

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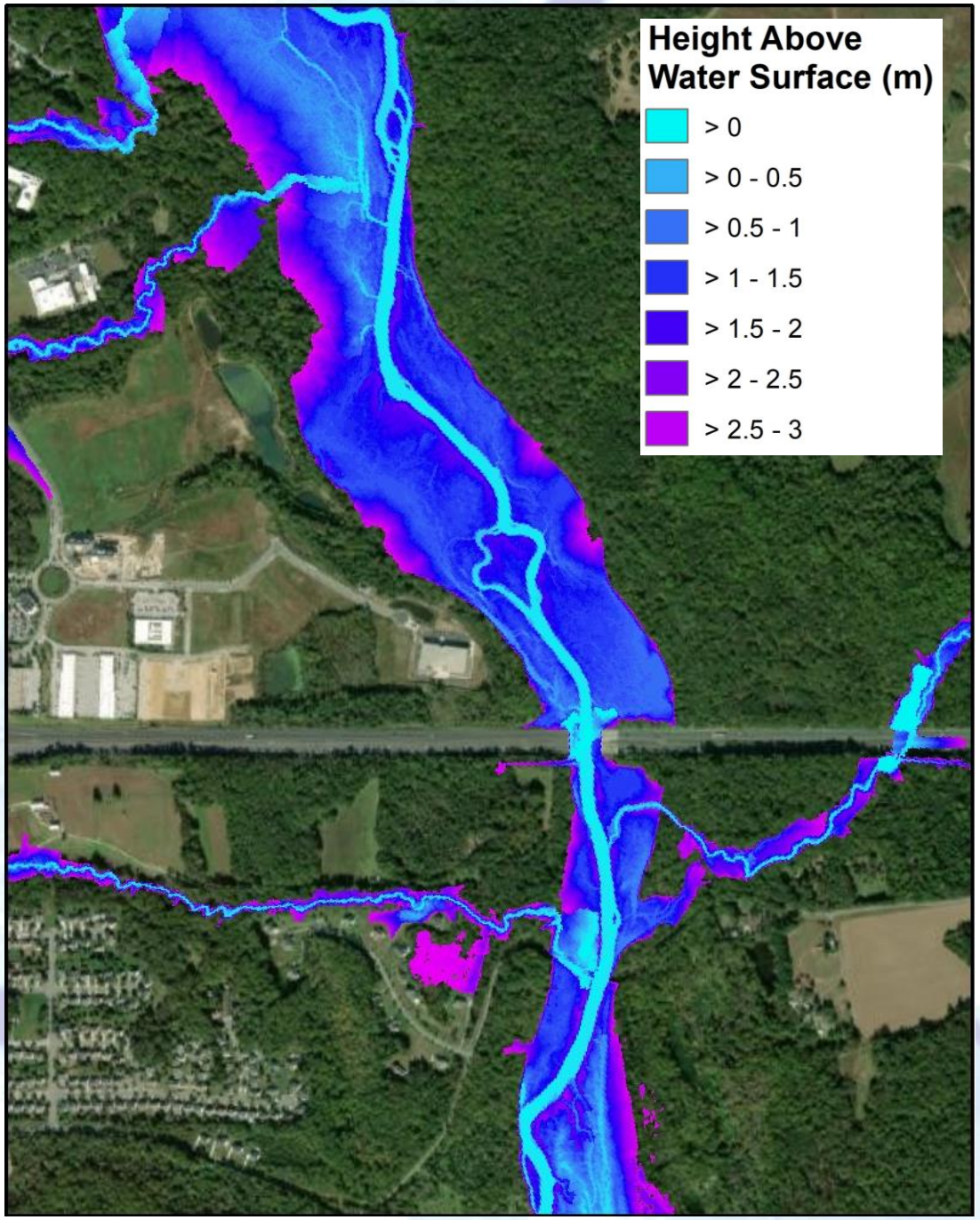

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Step 2: Identify Height Above Nearest Drainage (HAND) threshold aligning with field-measured floodplain extent at each field site.

Source: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1

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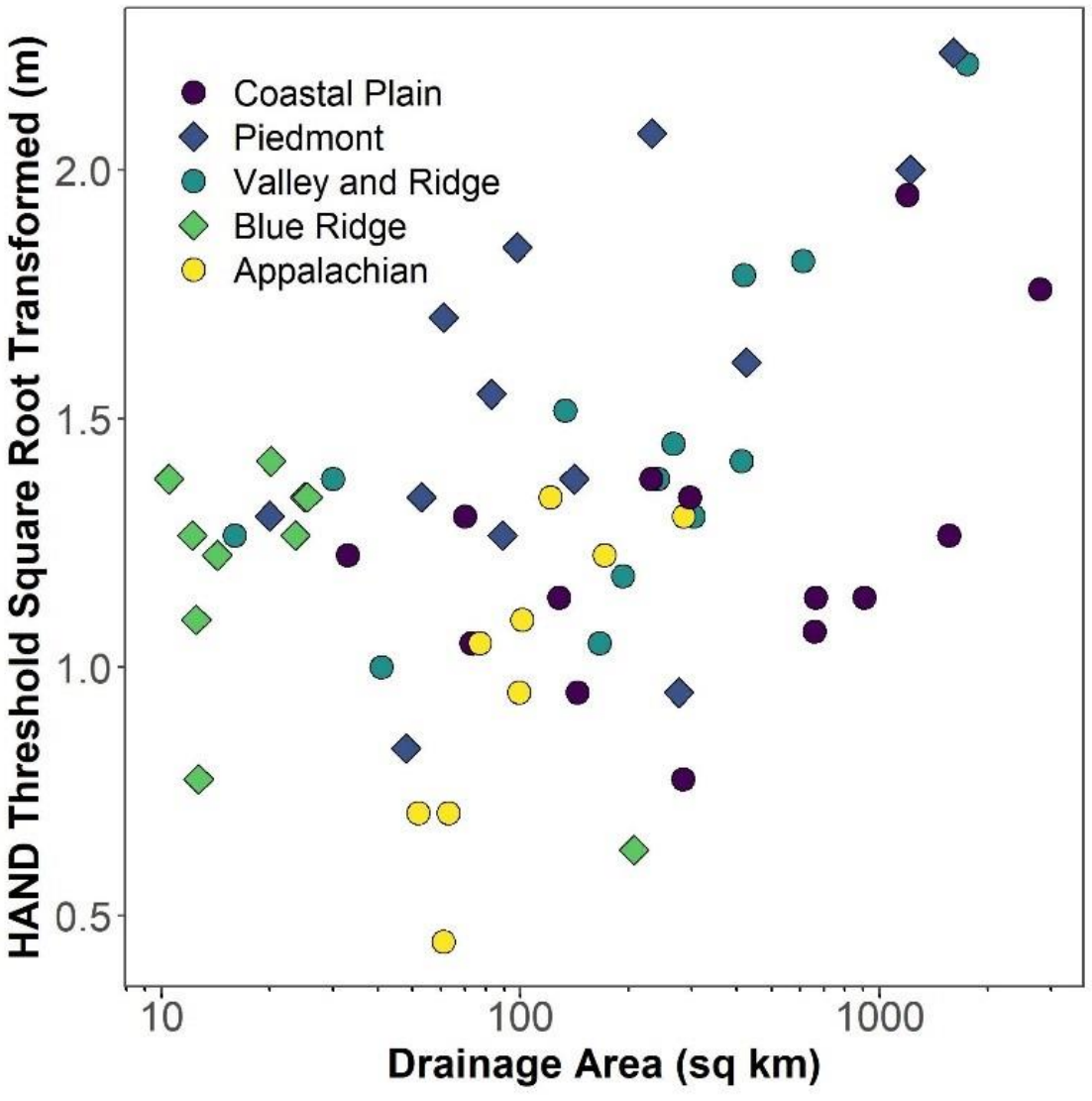
Calculating floodplain extent



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Step 2: Identify Height Above Nearest Drainage (HAND) threshold aligning with field-measured floodplain extent at each field site.

Step 3: Predictive linear model relating HAND height thresholds to drainage area and physiographic province

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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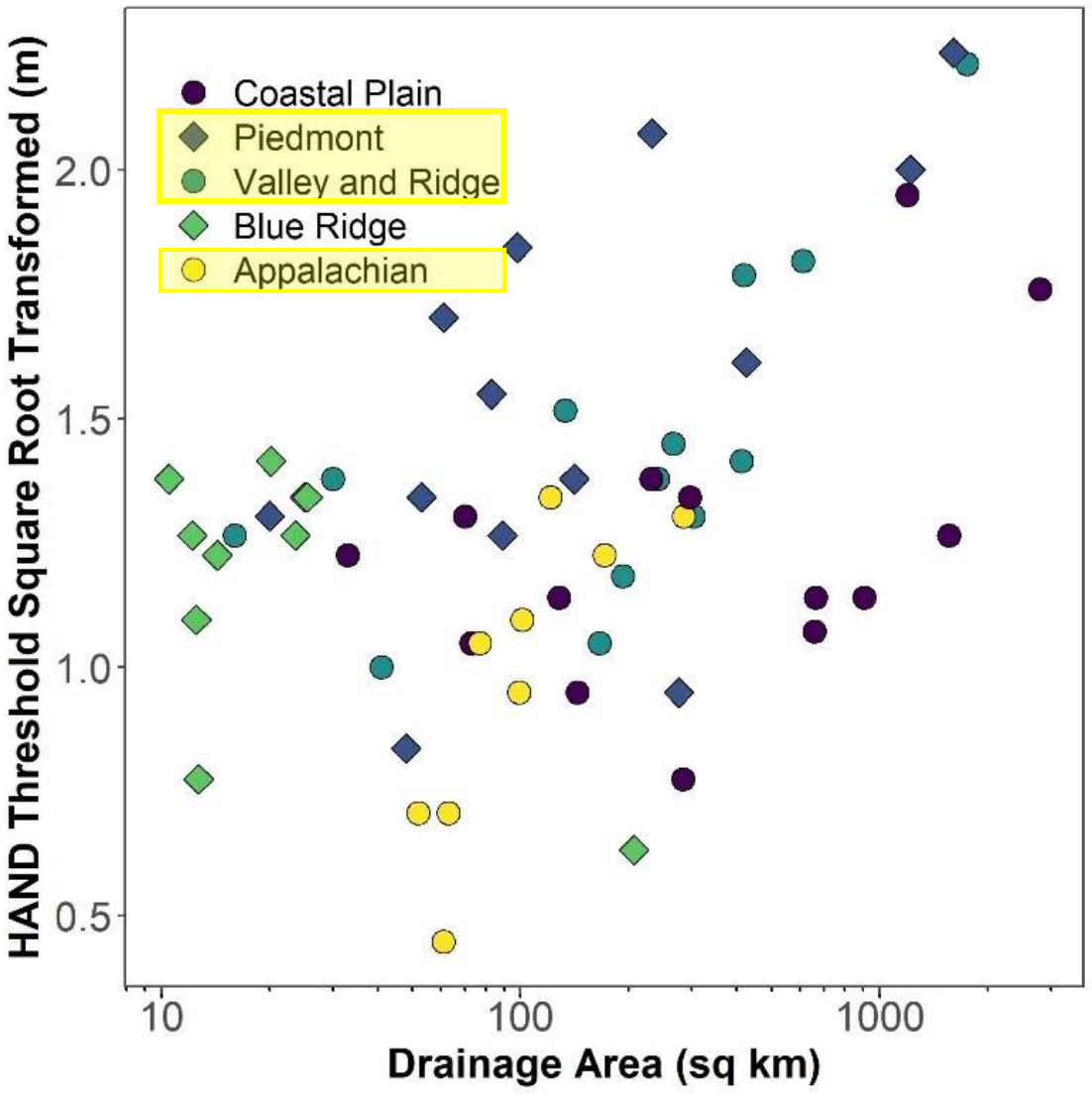
Calculating floodplain extent



The **mean HAND threshold** for the **Coastal Plain sites (1.65 m)** and **Blue Ridge (1.56m)** were used to define the active floodplain (There was no significant relationship between HAND threshold drainage area in these provinces)

For the other three provinces, a **linear model was developed relating the HAND threshold to drainage area and physiographic province ($R^2 = 0.59$, $p < 0.001$)**

Source: Lamont et al., (2019). Floodplain and Channel Evaluation Tool (FACET). Version 0.1.0. [Software release]. U.S. Geological Survey. DOI: https://doi.org/10.5066/P9PI94Z1./

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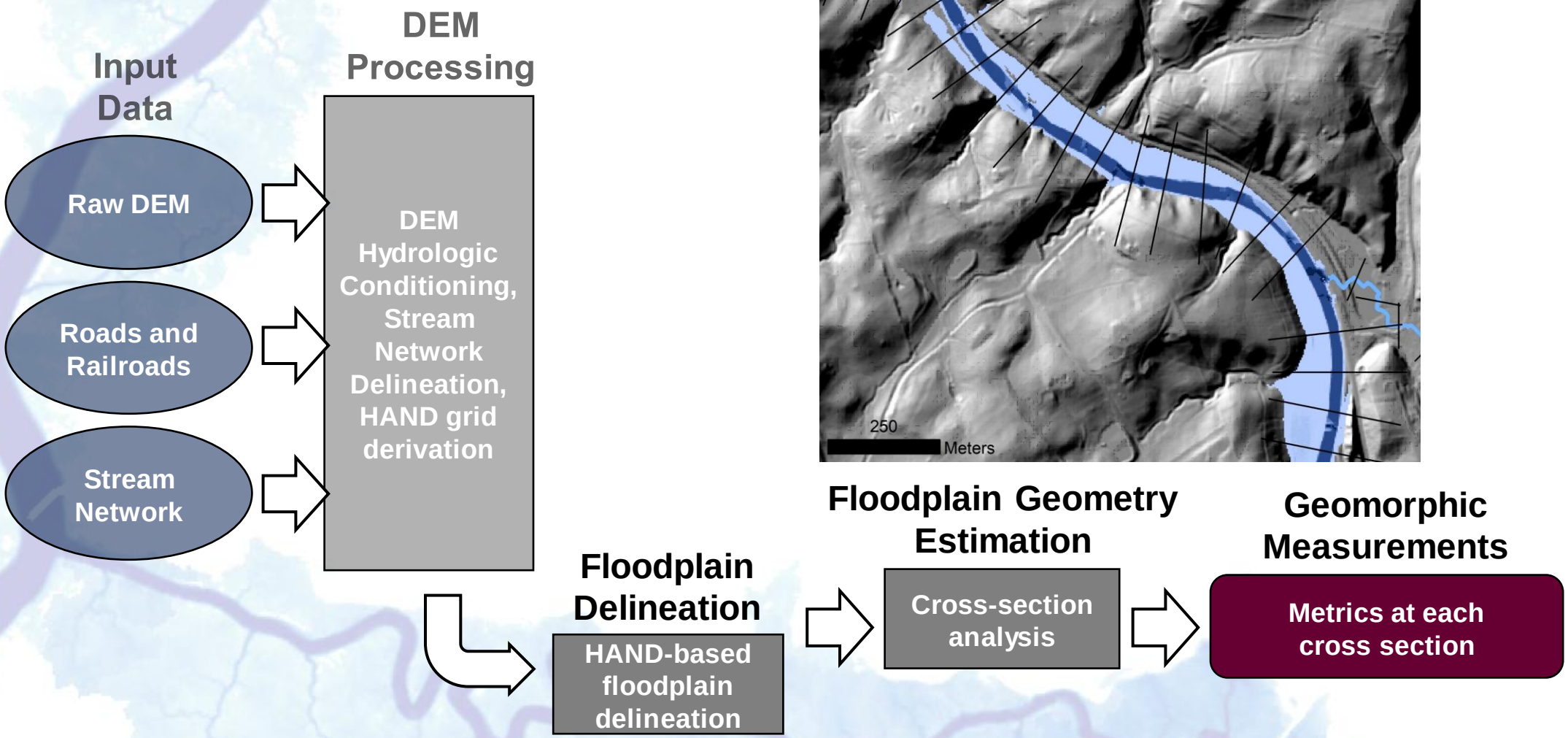
FACET Workflow



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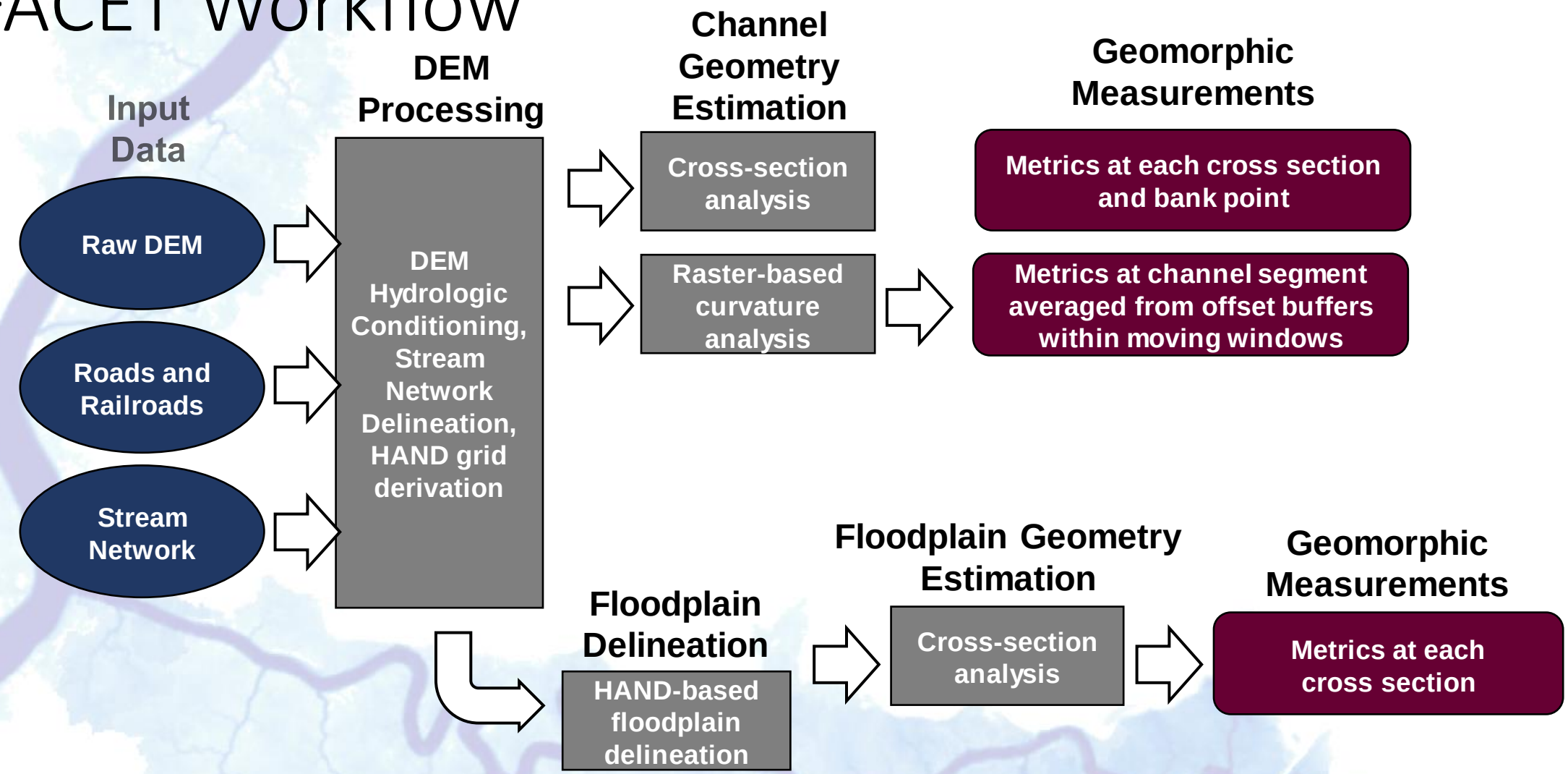
FACET Workflow



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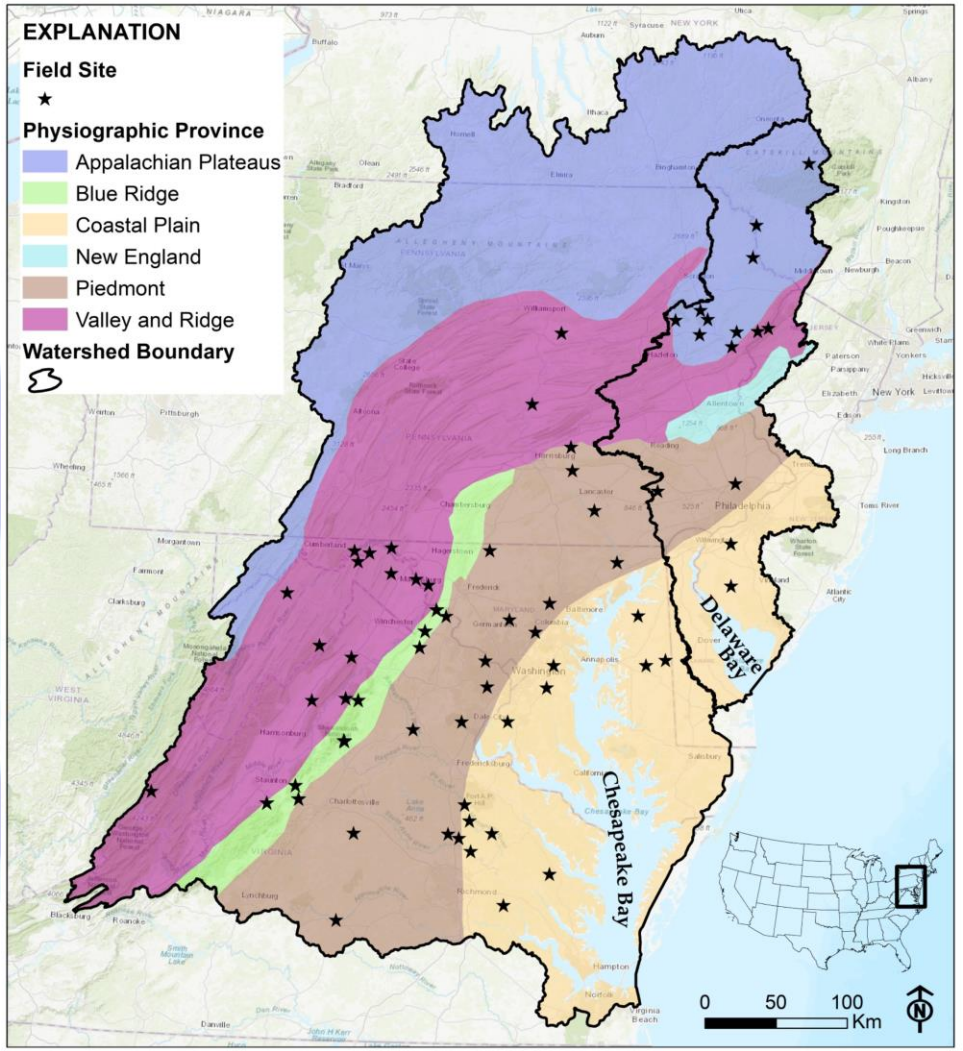
FACET Accuracy



Field Site Information

- 68 sites
- 5 physiographic provinces
- Drainage area 3 km^2 – 3,000 km^2
- Urban, rural, forested, agricultural land use

Field Measurement Information

- Bank height
- Channel width
- Floodplain width

FACET was tested on both 3 m DEMS, and 1 m DEMs where available

Source: Noe et al. 2020, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX.

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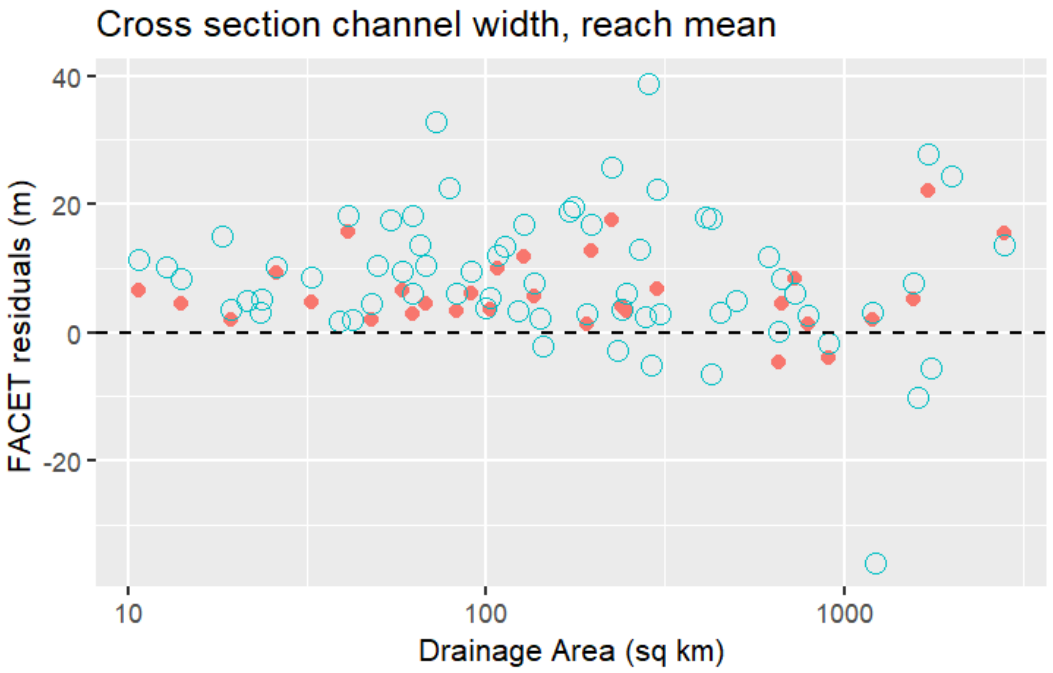
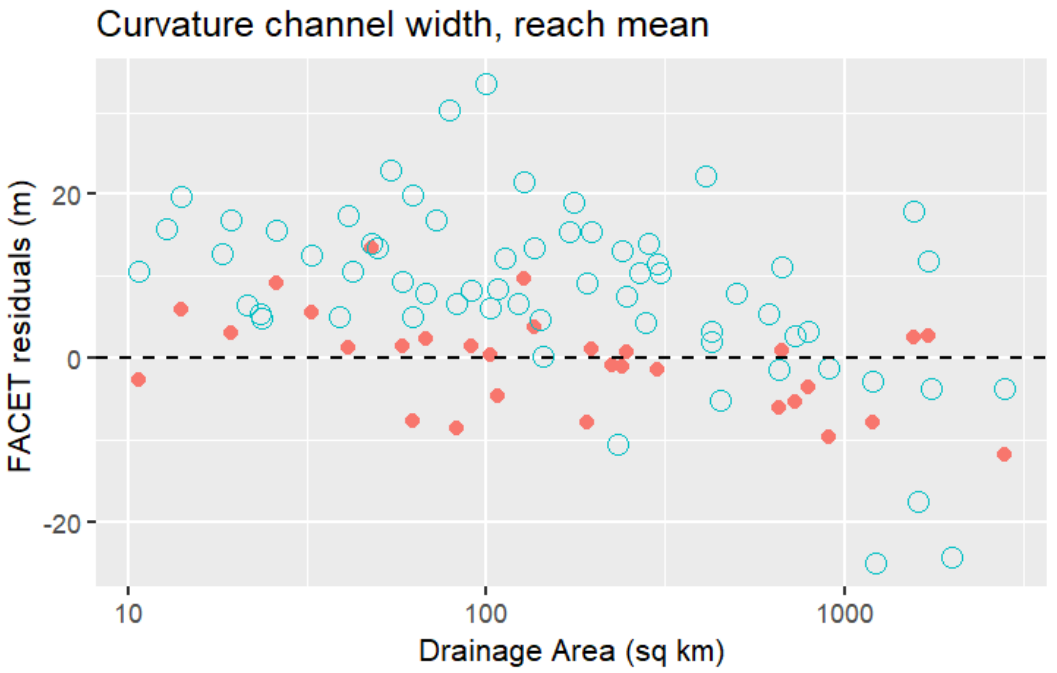
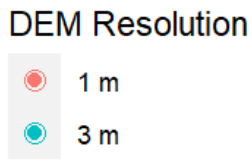
FACET Accuracy – Channel width

Root Mean Square Error		
Method	1 m DEM	3 m DEM
Cross Section	**7.9 m**	**12.6 m**
Raster Curvature	**5.7 m**	**12.9 m**







Sources: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1;
Noe et al. 2020, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX; https://coast.noaa.gov/inventory/.

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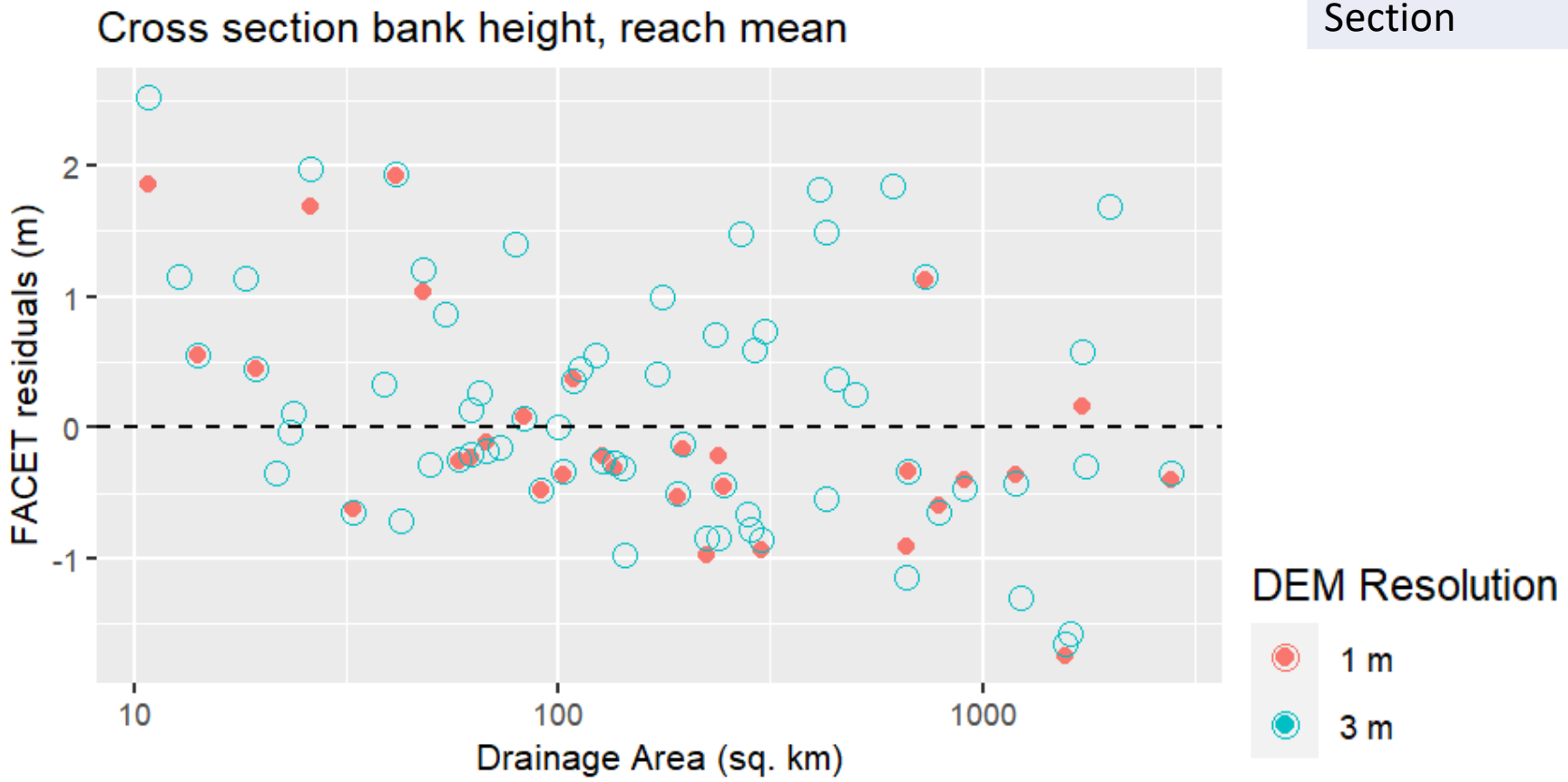
FACET Accuracy – Bank height

Root Mean Square Error		
Method	1 m DEM	3 m DEM
Cross Section	**0.81**	**0.92**



Sources: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1;
Noe et al. 2020, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX; https://coast.noaa.gov/inventory/.

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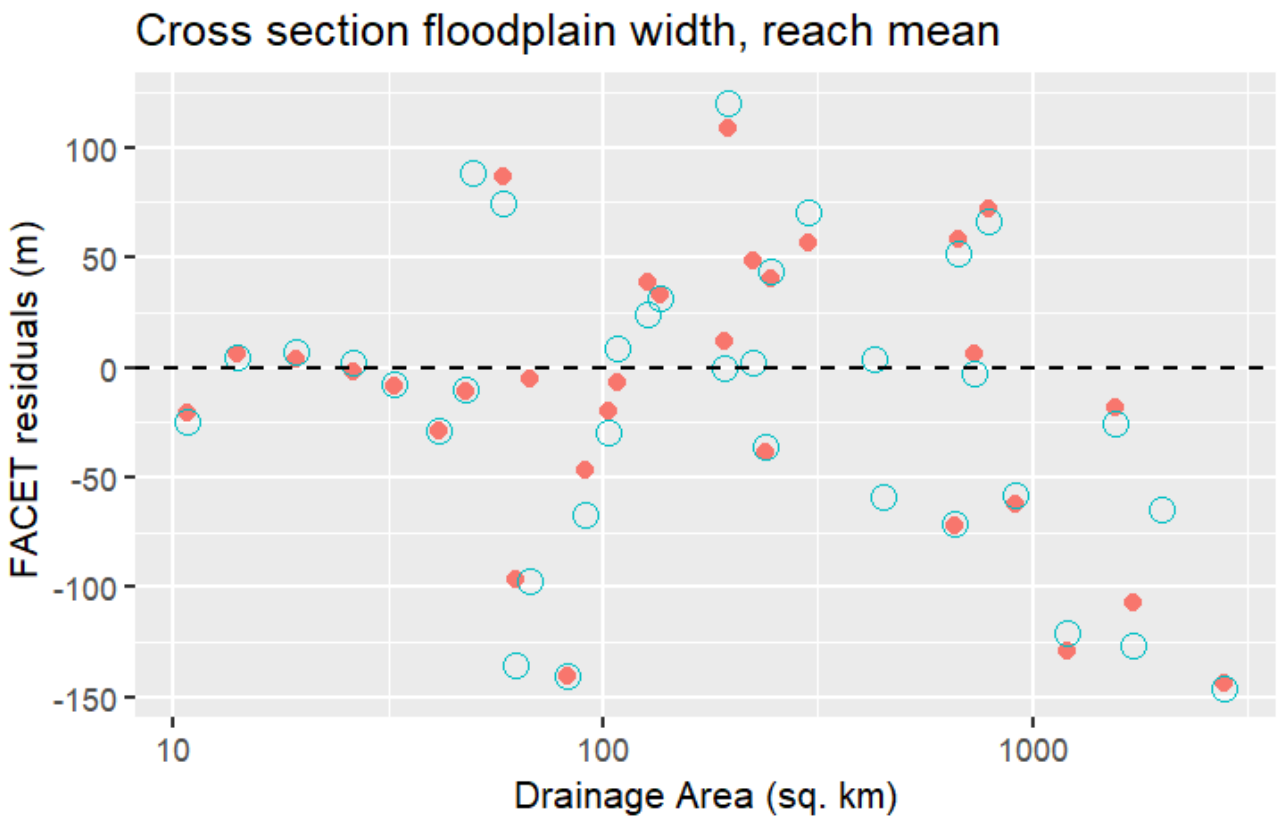
FACET Accuracy – Floodplain width



Root Meat Square Error		
Floodplain Method	1 m DEM	3 m DEM
Cross Section	**62.8 m**	**58.9 m**

Sources: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1;
Noe et al. 2020, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX; https://coast.noaa.gov/inventory/.

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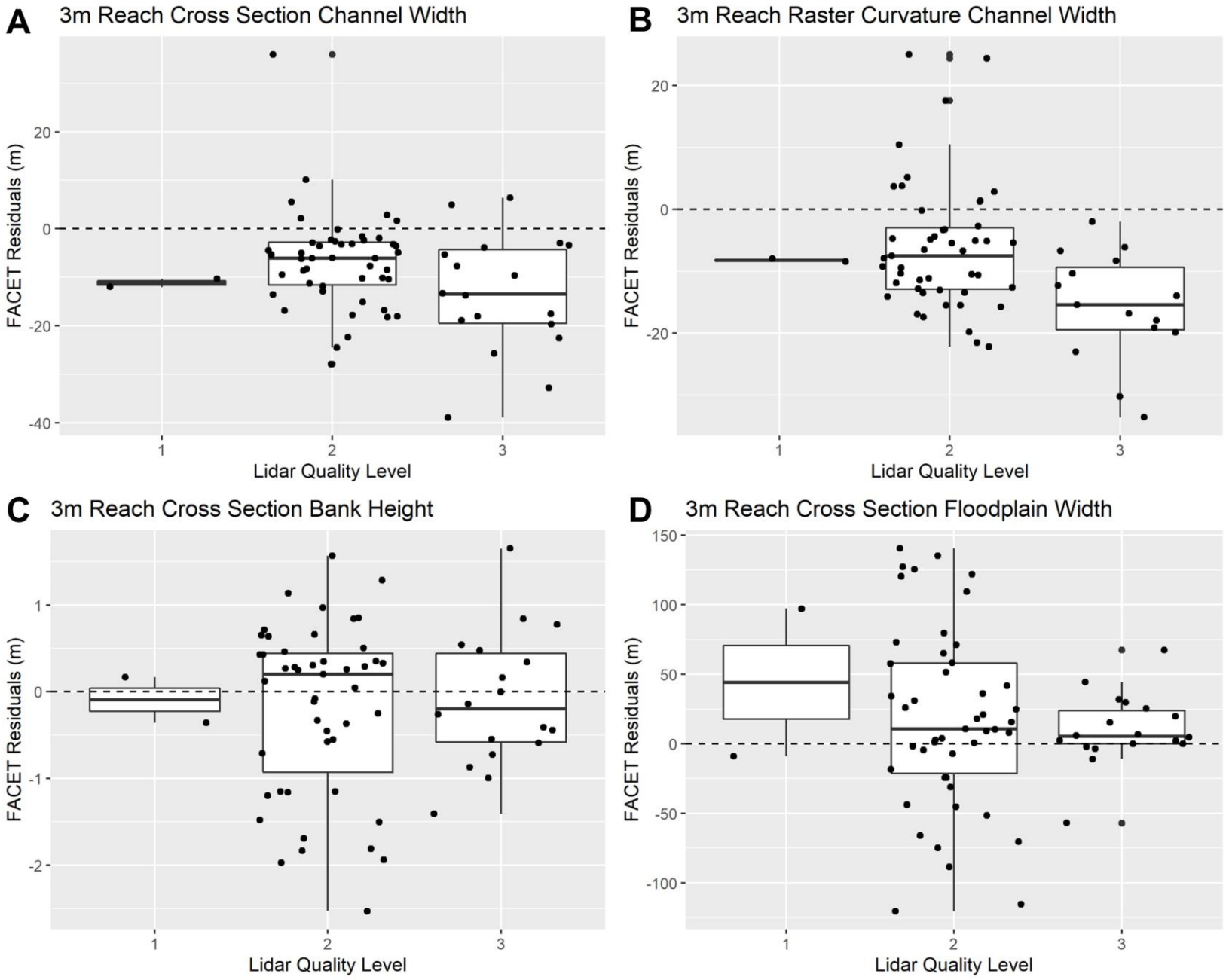
Influence of Lidar Accuracy



Sources: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1;
Noe et al. 2020, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX; https://coast.noaa.gov/inventory/.

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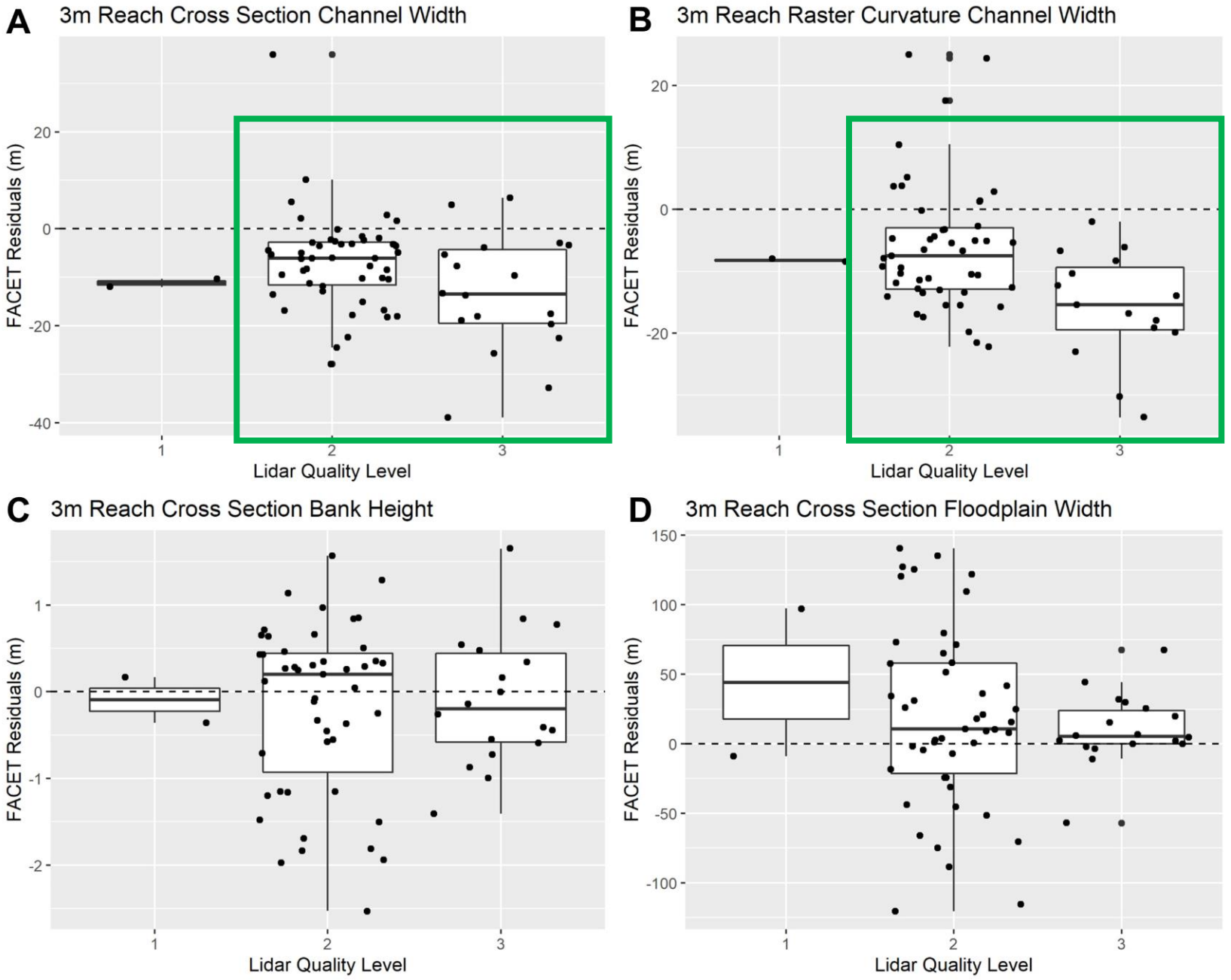

Influence of Lidar Accuracy

- **Channel width** measurements do tend to be more accurate with better quality lidar

Sources: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1;
Noe et al. 2020, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX; https://coast.noaa.gov/inventory/.

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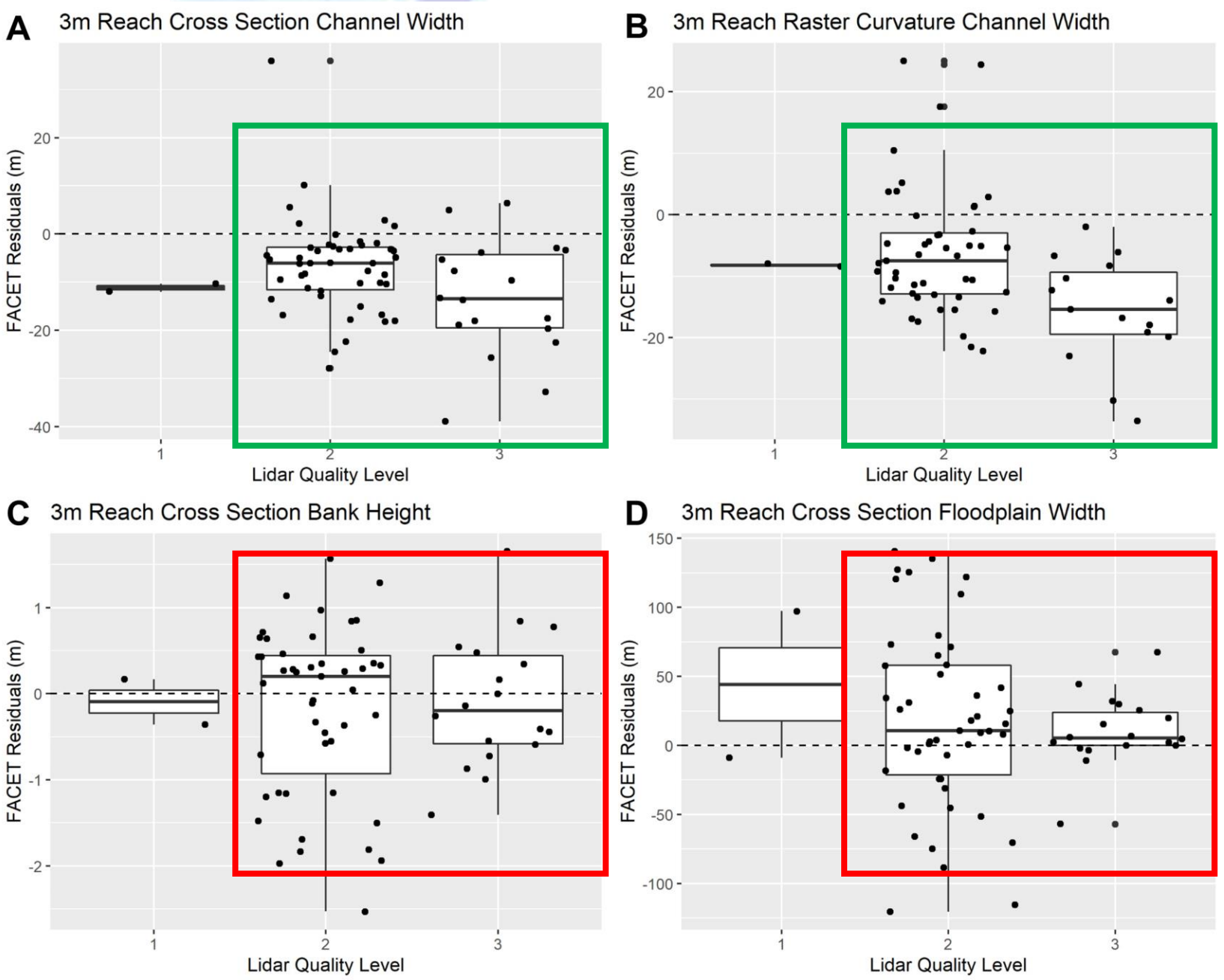

Influence of Lidar Accuracy

- **Channel width** measurements do tend to be more accurate with better quality lidar
- There is less of an influence on **bank height** and **floodplain width**

Sources: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1;
Noe et al. 2020, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX; https://coast.noaa.gov/inventory/.

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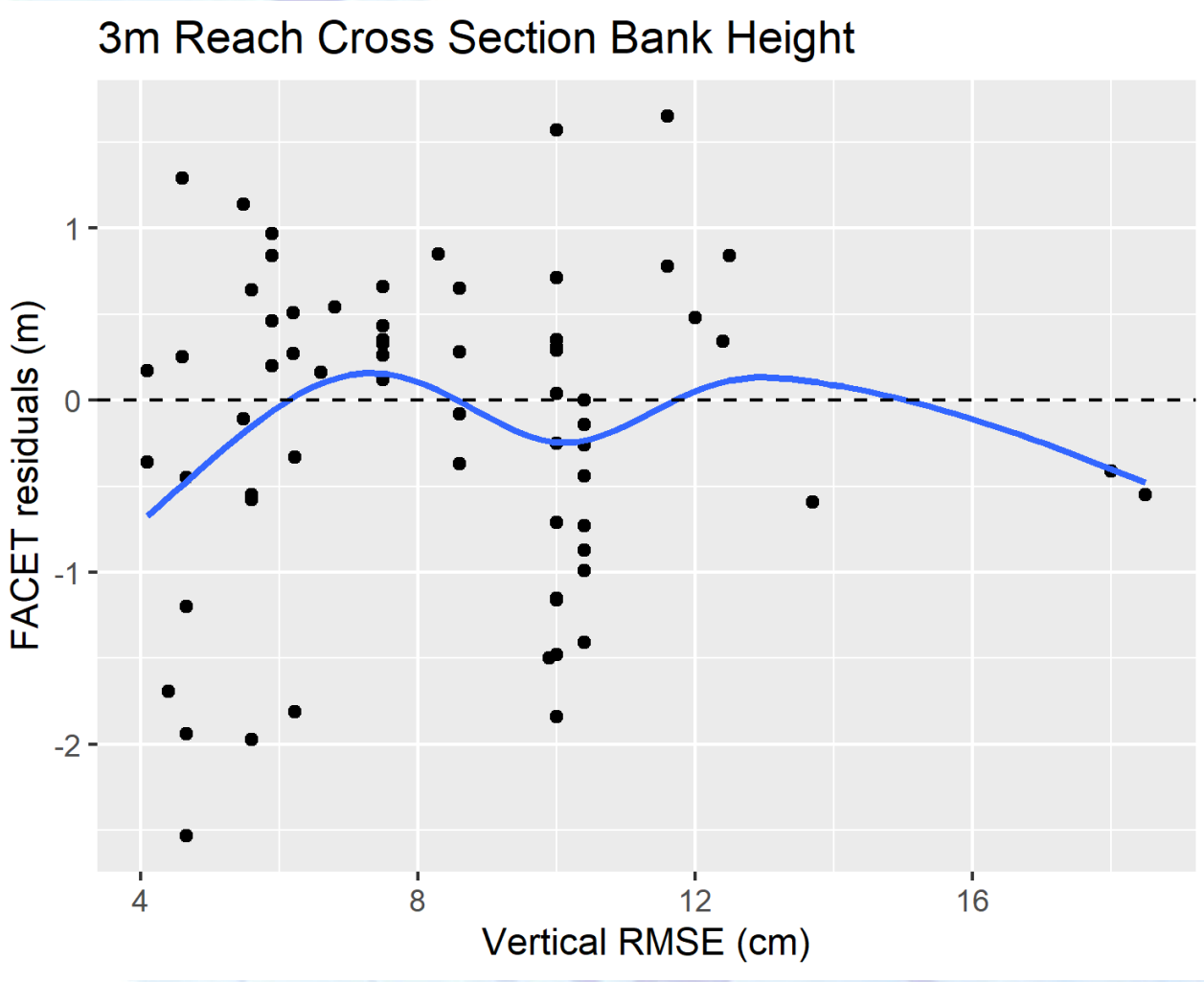
Influence of Lidar Accuracy



- Vertical lidar accuracy does not appear to have an influence on bank height accuracy

Sources: Hopkins et al. 2020, U.S. Geological Survey Data Release, https://doi.org/10.5066/P9RQJPT1;
Noe et al. 2020, U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX; https://coast.noaa.gov/inventory/.

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Conclusions

- FACET is an open-source tool that can be used to calculate stream channel and floodplain geomorphometry on watersheds > 400 km^2 using 3 m DEMS; 1 m DEMs can be used in smaller watersheds.
- Channel width is most sensitive to DEM resolution and lidar accuracy.
- Floodplain extent is calibrated from field-based evidence of flooding; ongoing research will attempt to add floodplain extent based on recurrence intervals.
- FACET is currently calibrated for the Mid-Atlantic Region of the USA; research is ongoing to expand beyond this region.

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Code repository and additional information:
code.usgs.gov/water/facet

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