Remote sensing of river structure in the context of mapping hydraulic habitat at the reach scale.

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Objectives

- General Objectives:

- Develop novel approaches to describe meso, reach and 10km river scale habitat structure

- Detect river reach dependency (sensitivity) to damming and impacts on fish habitat

- Specific Objectives:

- Analyze the geomophology of the HydroNet study rivers to characterize the riverine habitat structure at different scales (river, reach, meso-habitat)

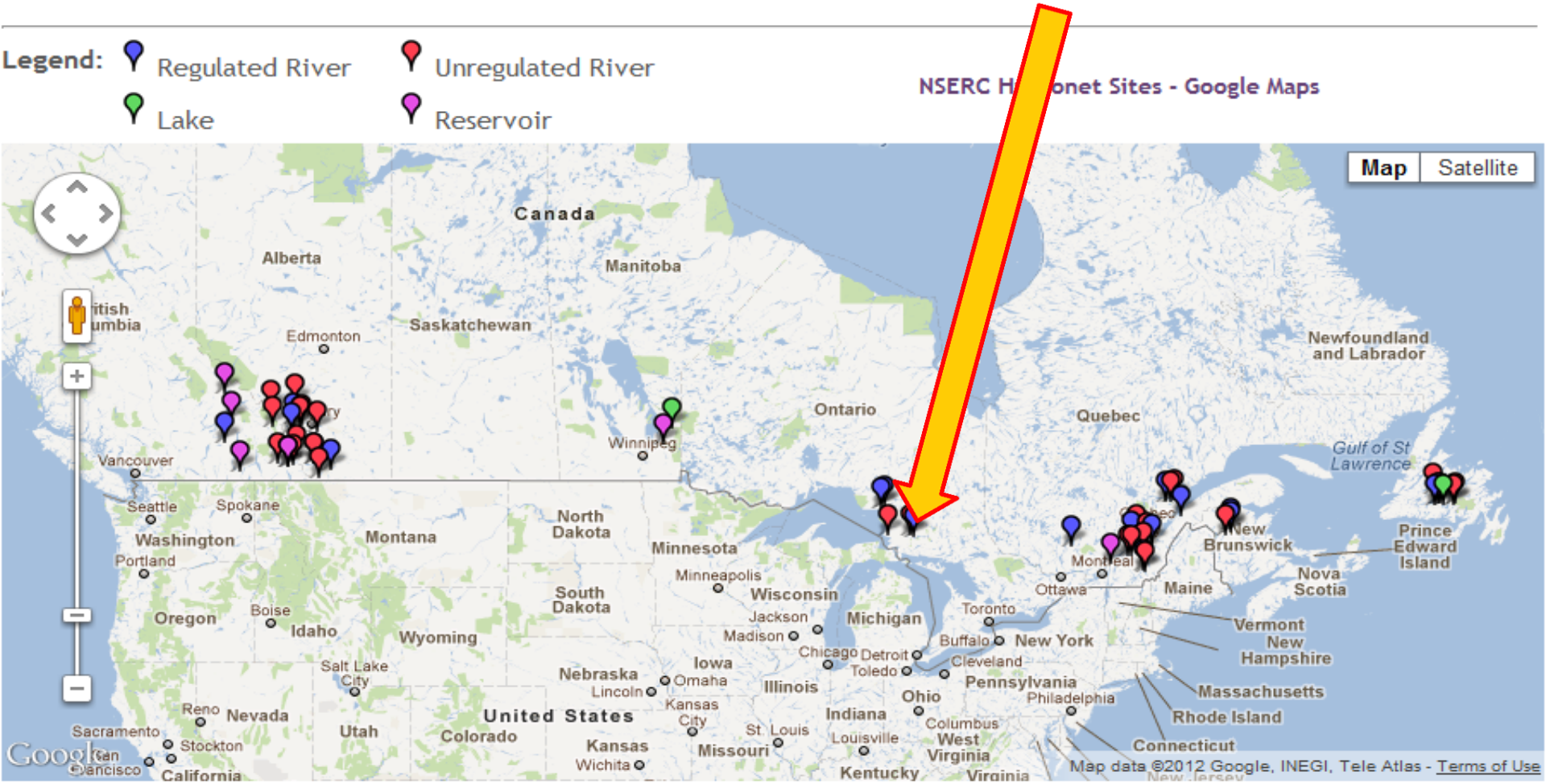
- Understand the longitudinal patterns of physical habitat variables (width, depth, slope, velocity, grain size, LOD, …)

- Study specific reaches where fish habitat variables (wetted width, spawning sites, substrate embeddedness, riparian vegetation,…) are more likely to be impacted by damming

Study site

NSERC HydroNet CRSNG

Mississagi River



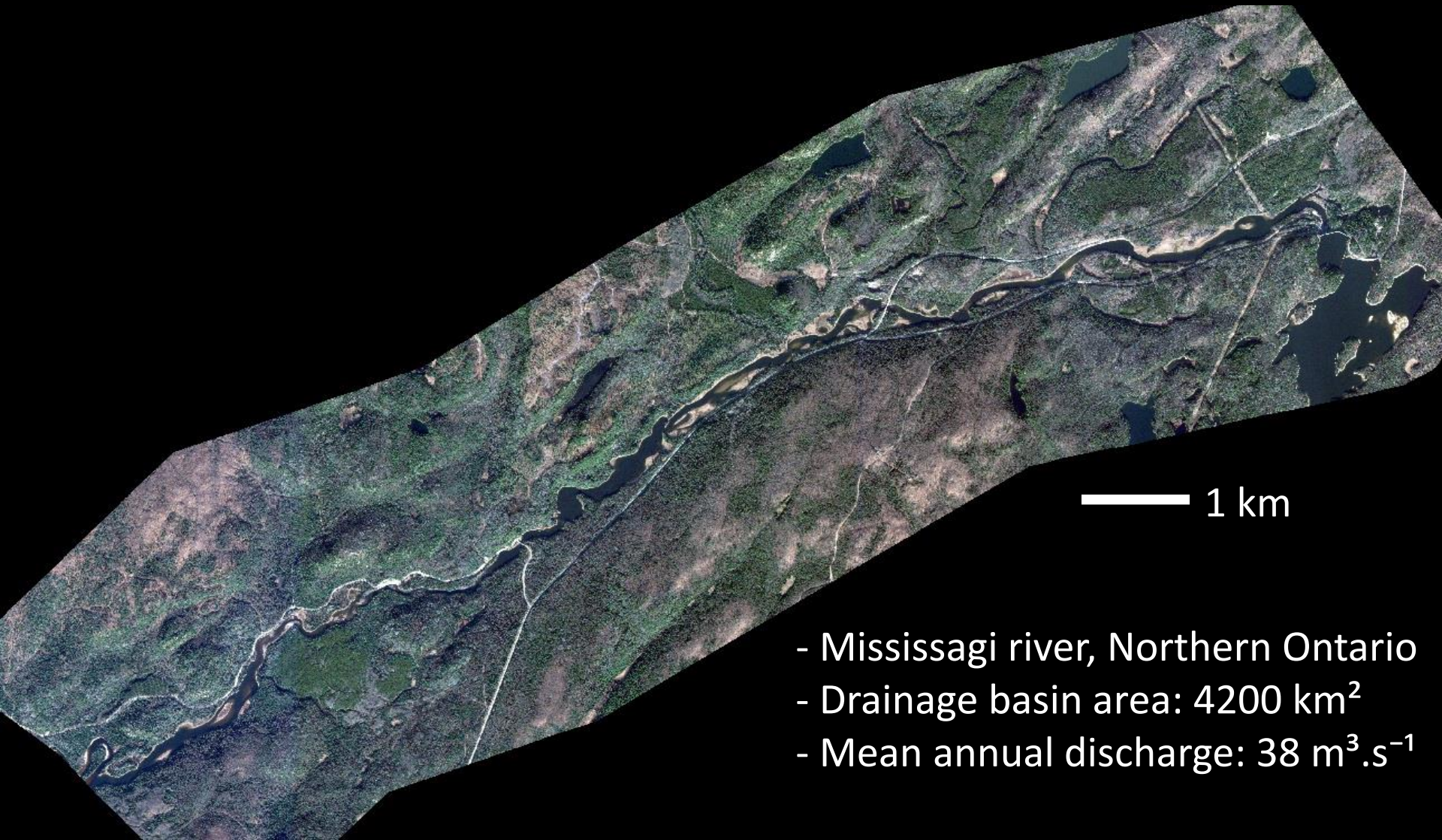
Study site

WorldView-II Satellite image

Acquisition date: 2010-Nov-08

Multispectral: 8 Bands (VIS-NIR) / 2 m resolution

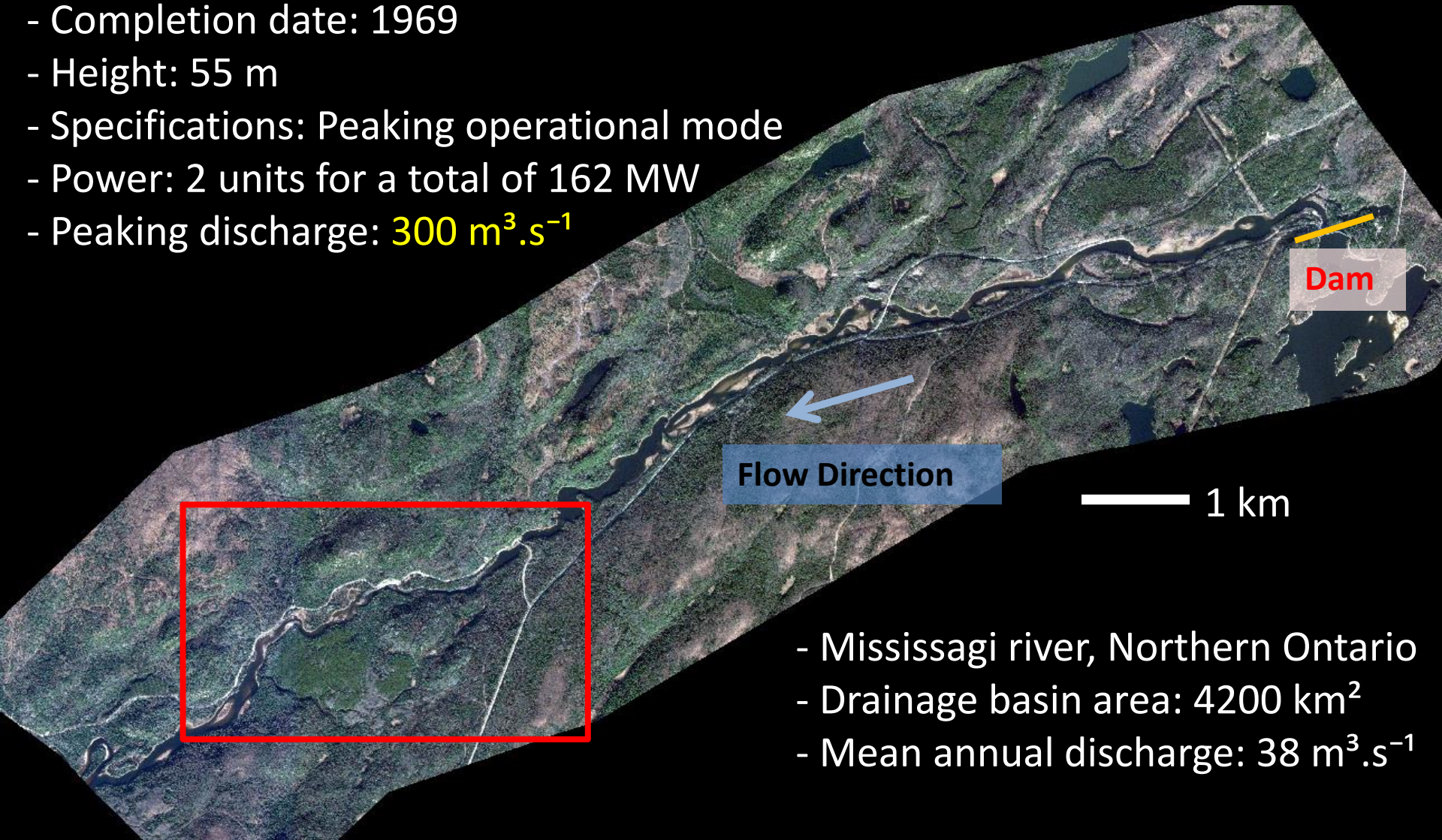
Panchromatic: 50 cm resolution



- Mississagi river, Northern Ontario
- Drainage basin area: 4200 km²
- Mean annual discharge: 38 $m^3.s^{-1}$

Study site

- Dam Name: Aubrey Falls
- Owner: operated by Brookfield renewable power
- Completion date: 1969
- Height: 55 m
- Specifications: Peaking operational mode
- Power: 2 units for a total of 162 MW
- Peaking discharge: 300 $m^3.s^{-1}$



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- Mean annual discharge: 38 $m^3.s^{-1}$

Zoom in a complex structure area

≈ 5 km of river reach

Study area

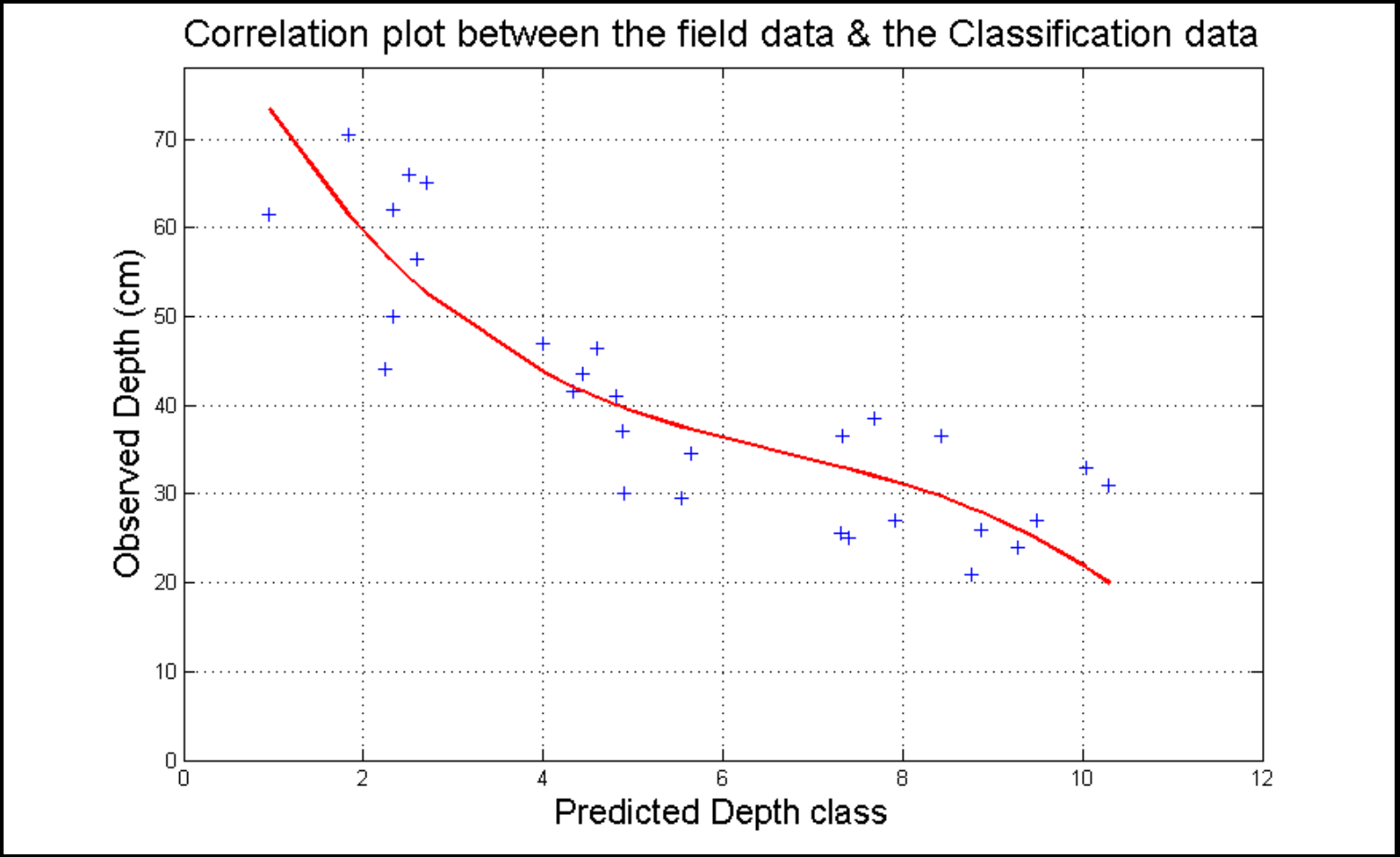
Biology crew sampling patches = 36 plots (plot size = 300 m²)

- Electro-fishing & visual fish survey
- Physical variables survey

Depth Map

- Spectrally based method
- Supervised classification
- Depth calibration with HydroNet field data

Depth Calibration



- x = Depth class from the image
- y = Observed depth in the field

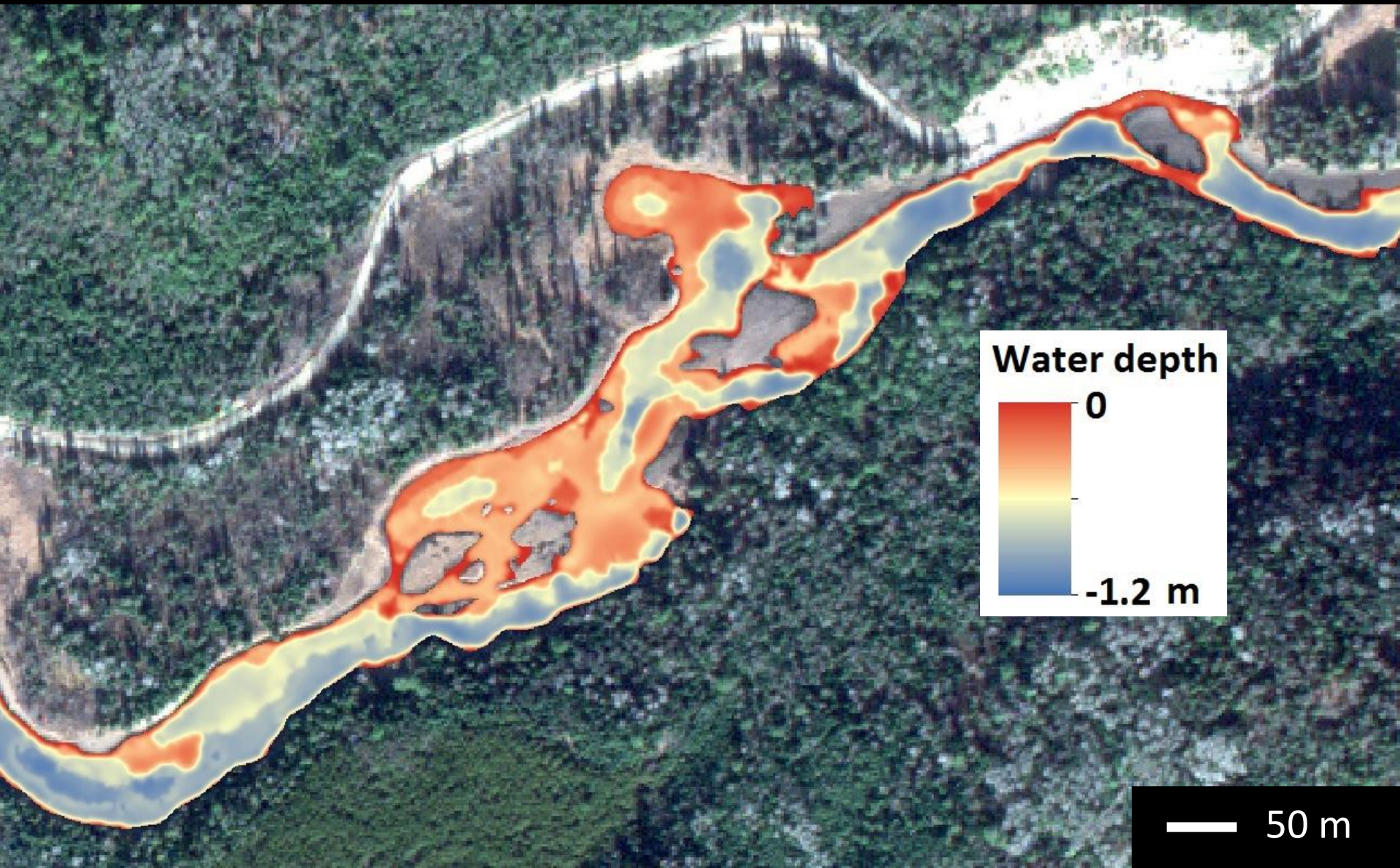
$$y = -0.129\,x^3 + 2.607\,x^2 - 19.967\,x + 90.134$$

Depth Map

From multispectral satellite image to …

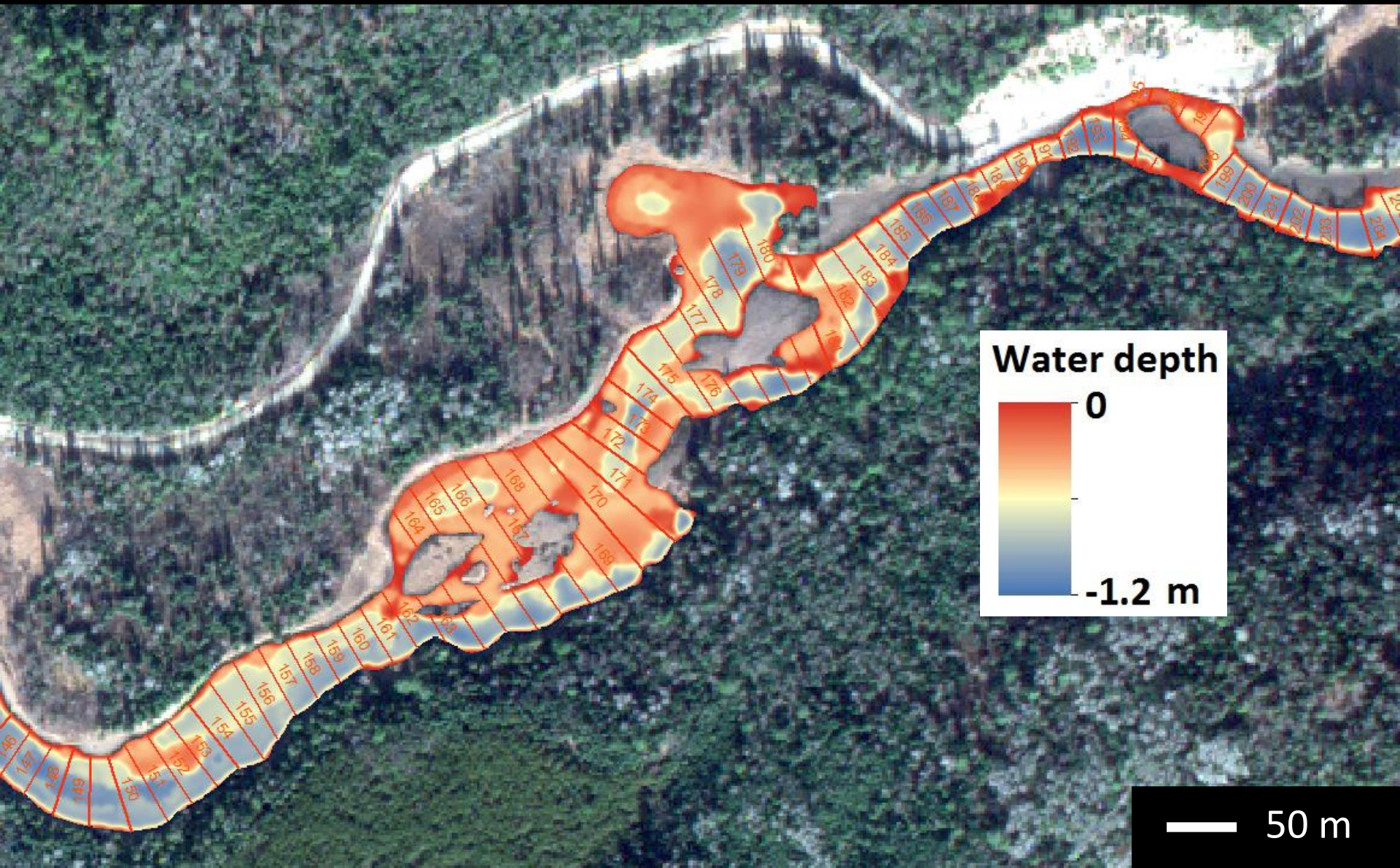
Depth Map

… continuous depth map (1 m pixel resolution)



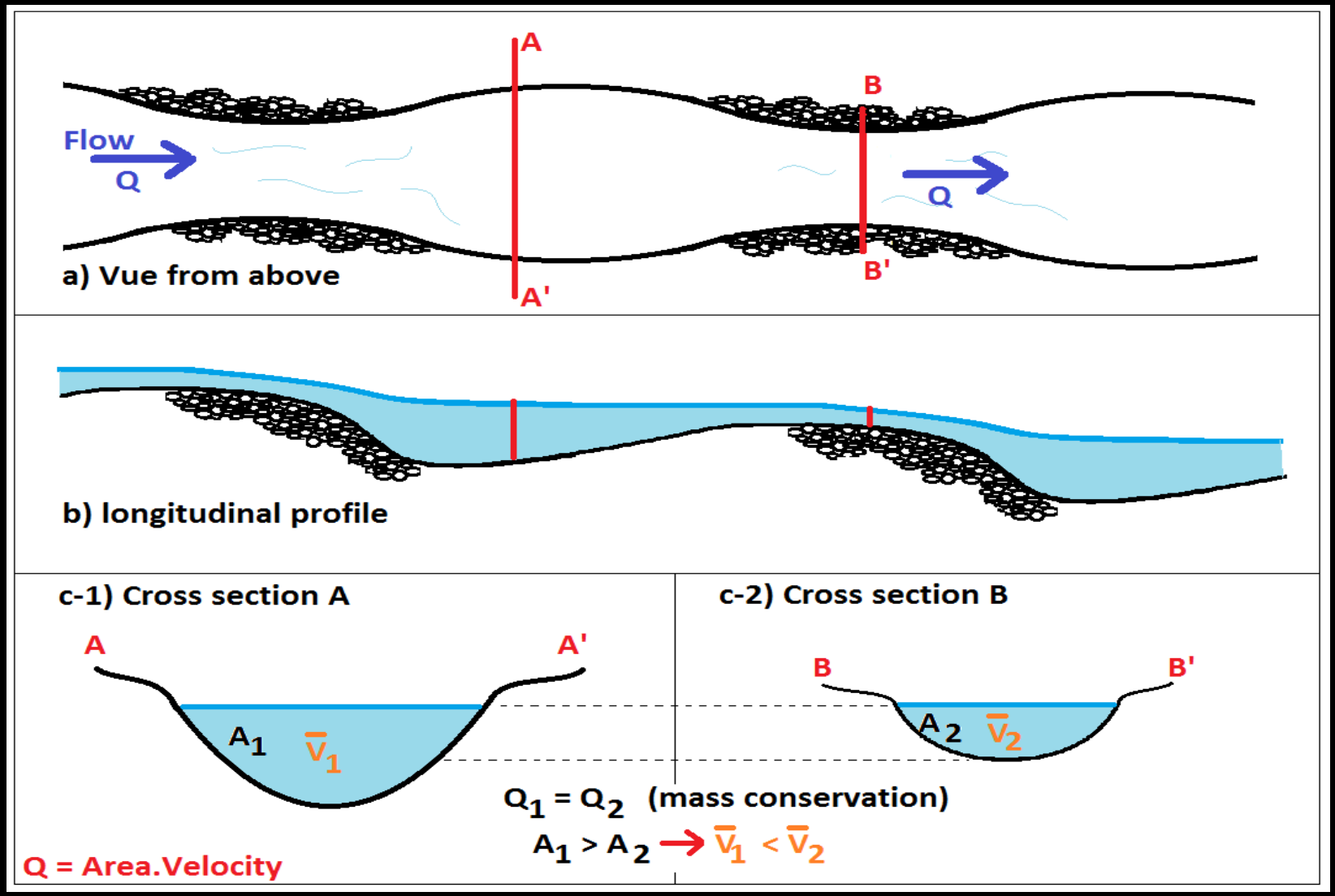
Velocity Cross-sections

Velocity computation on several cross sections



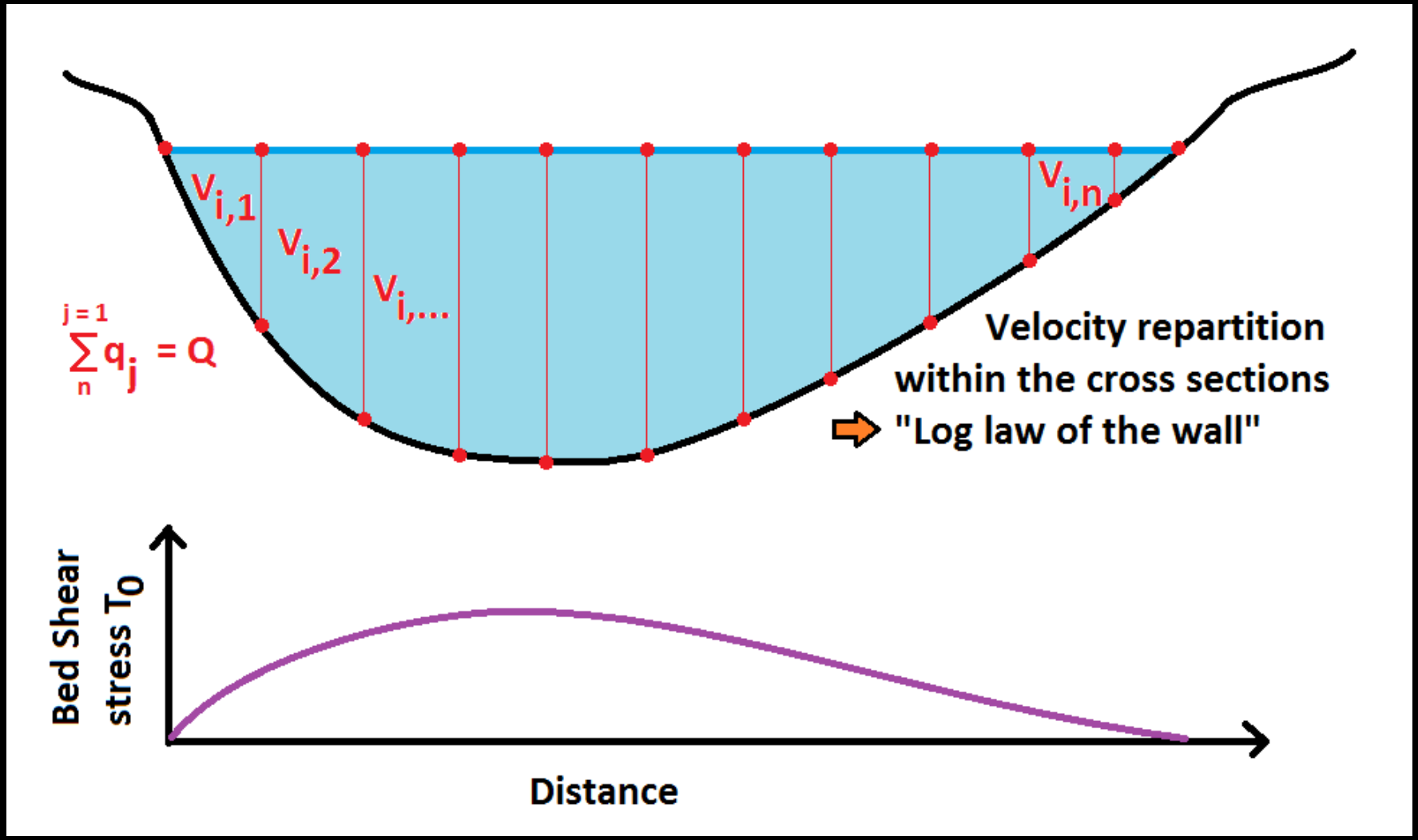
Pseudo-2D Velocity estimates

- Continuity equations + Semi-empirical hydraulic rules
- Based on extracted cross-section on the image
- (Manning's law, Du Boys, Log profile law)



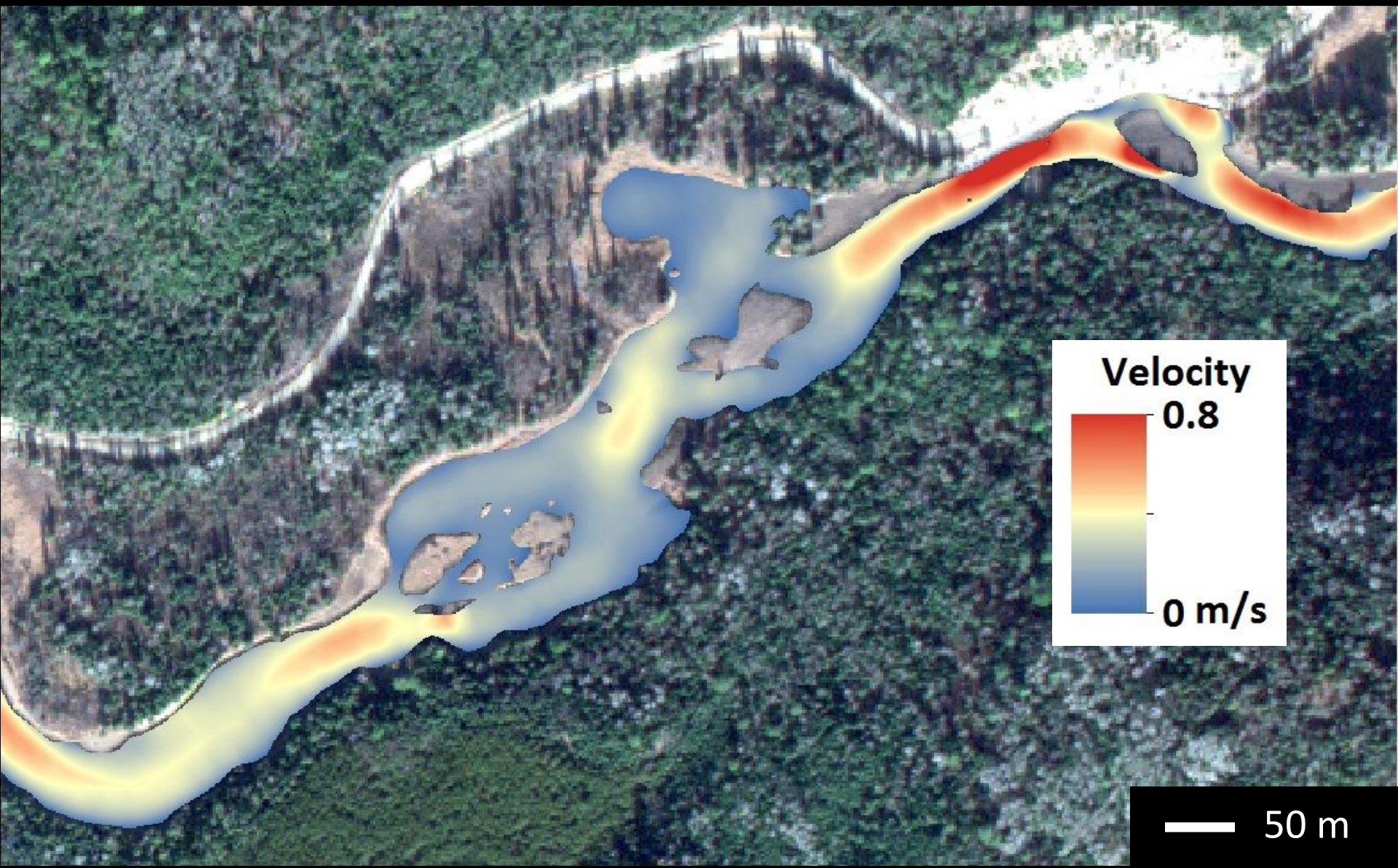
Velocity reconstruction

- For each cross section,
  the velocity is distributed with respect to the local depth value



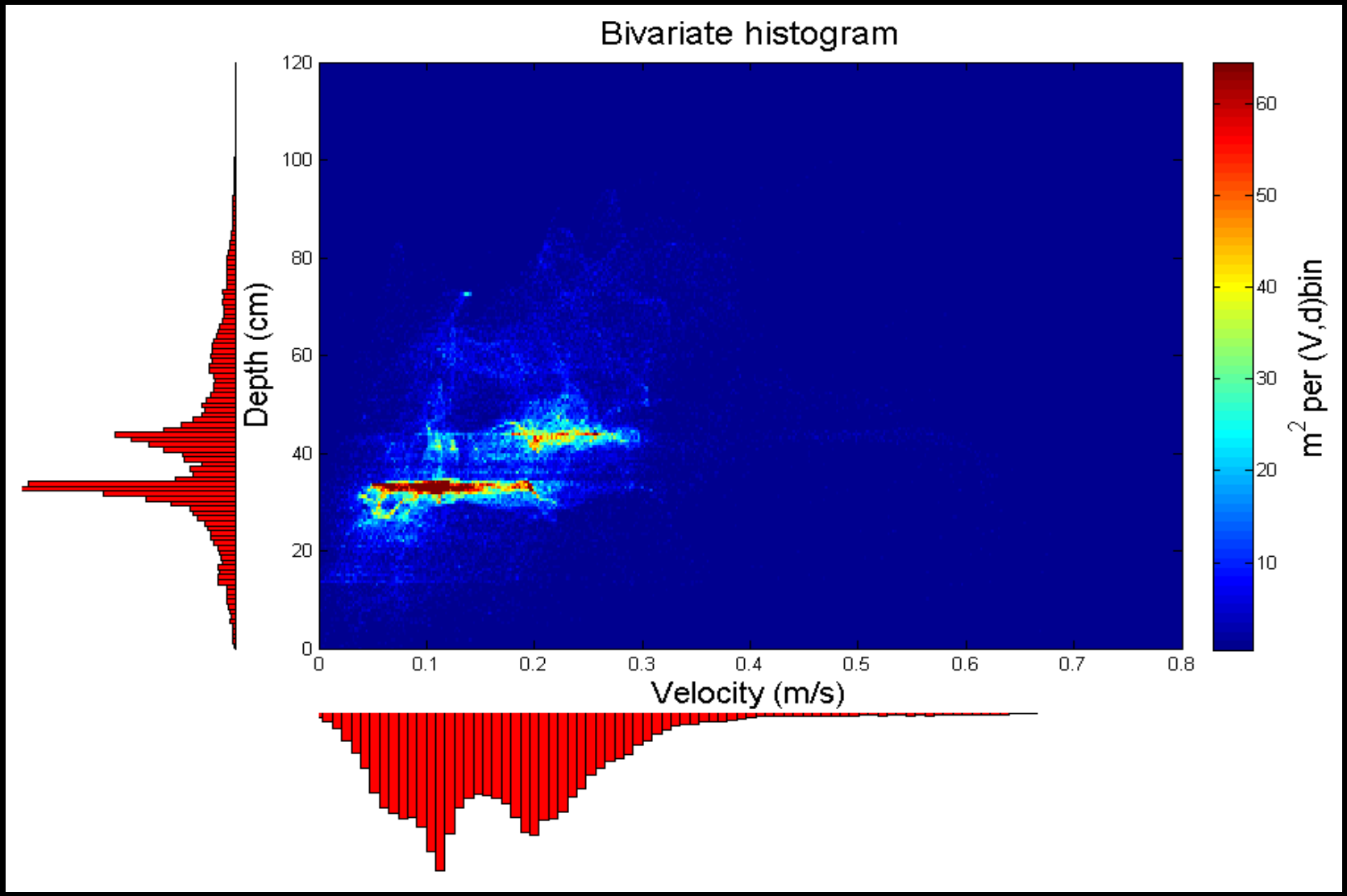
Velocity Map

Velocity extrapolation within the river network



Depth – Velocity combination

Availability of habitat (e.g. for Brook Trout) described by the depth – velocity combination



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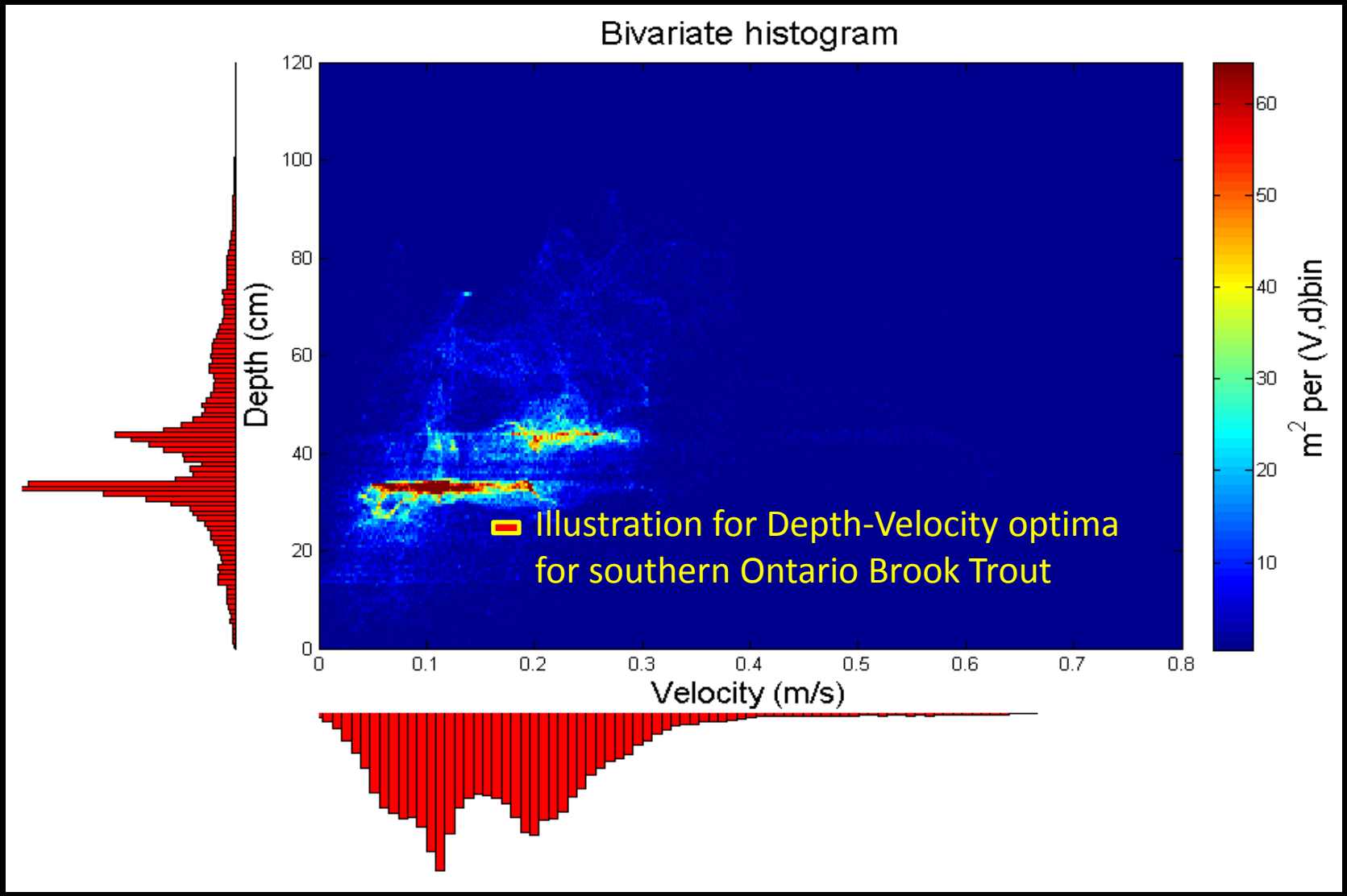

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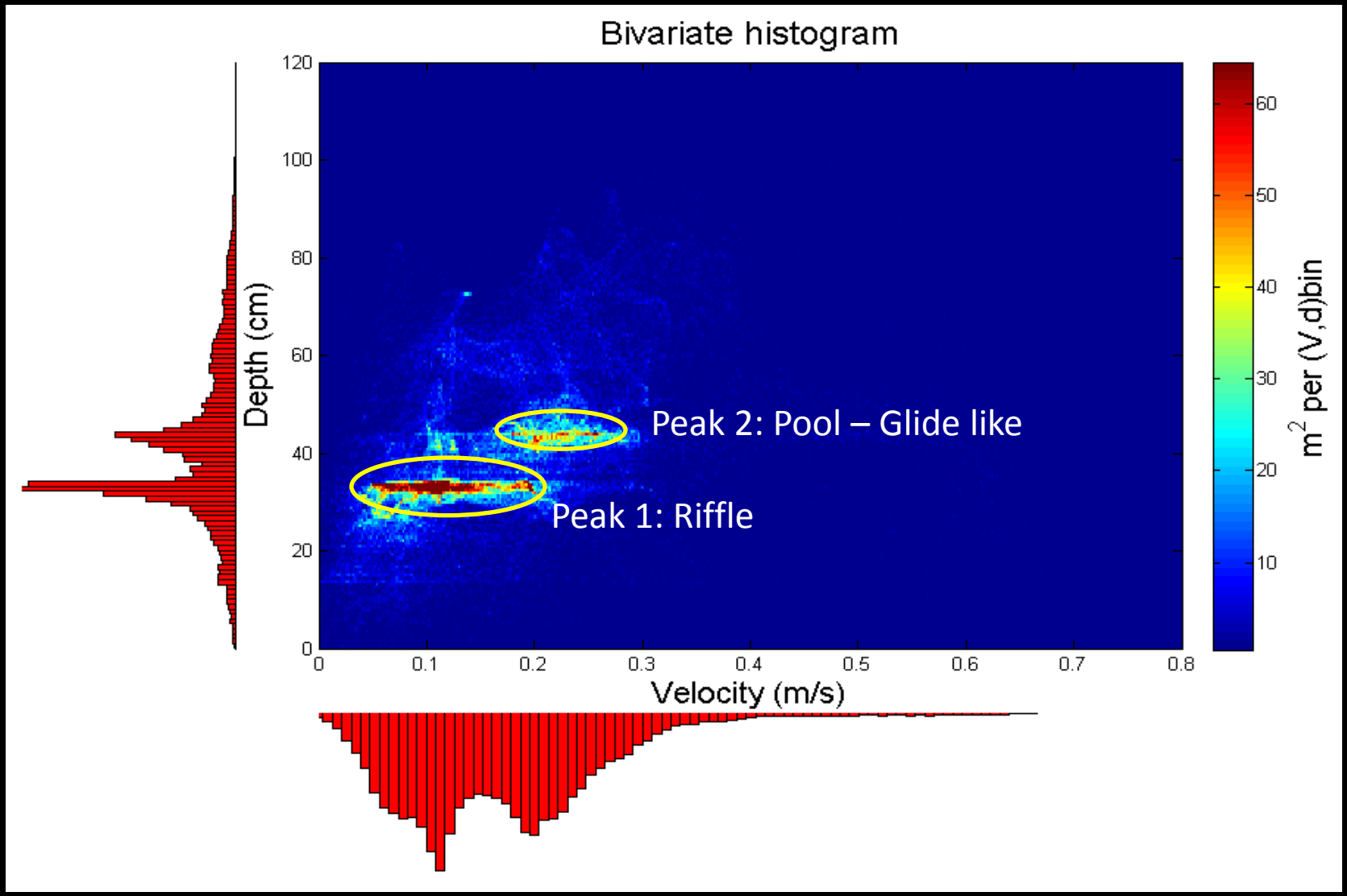

Depth – Velocity combination: meso-habitat mapping

From fine scale (pixel size) to meso-habitat scale: Surface area for the depth – velocity combination at the meso, reach and river scale

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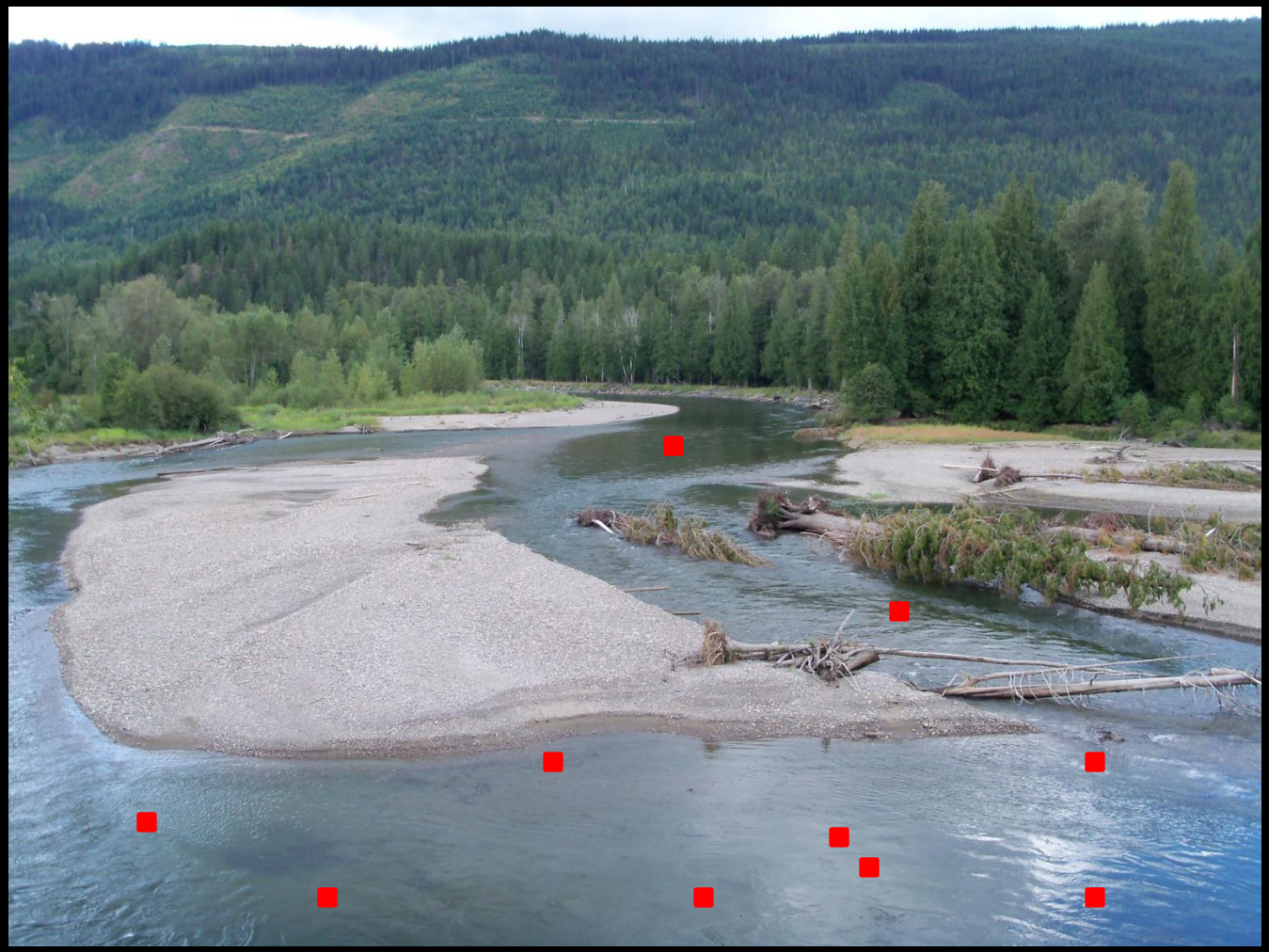
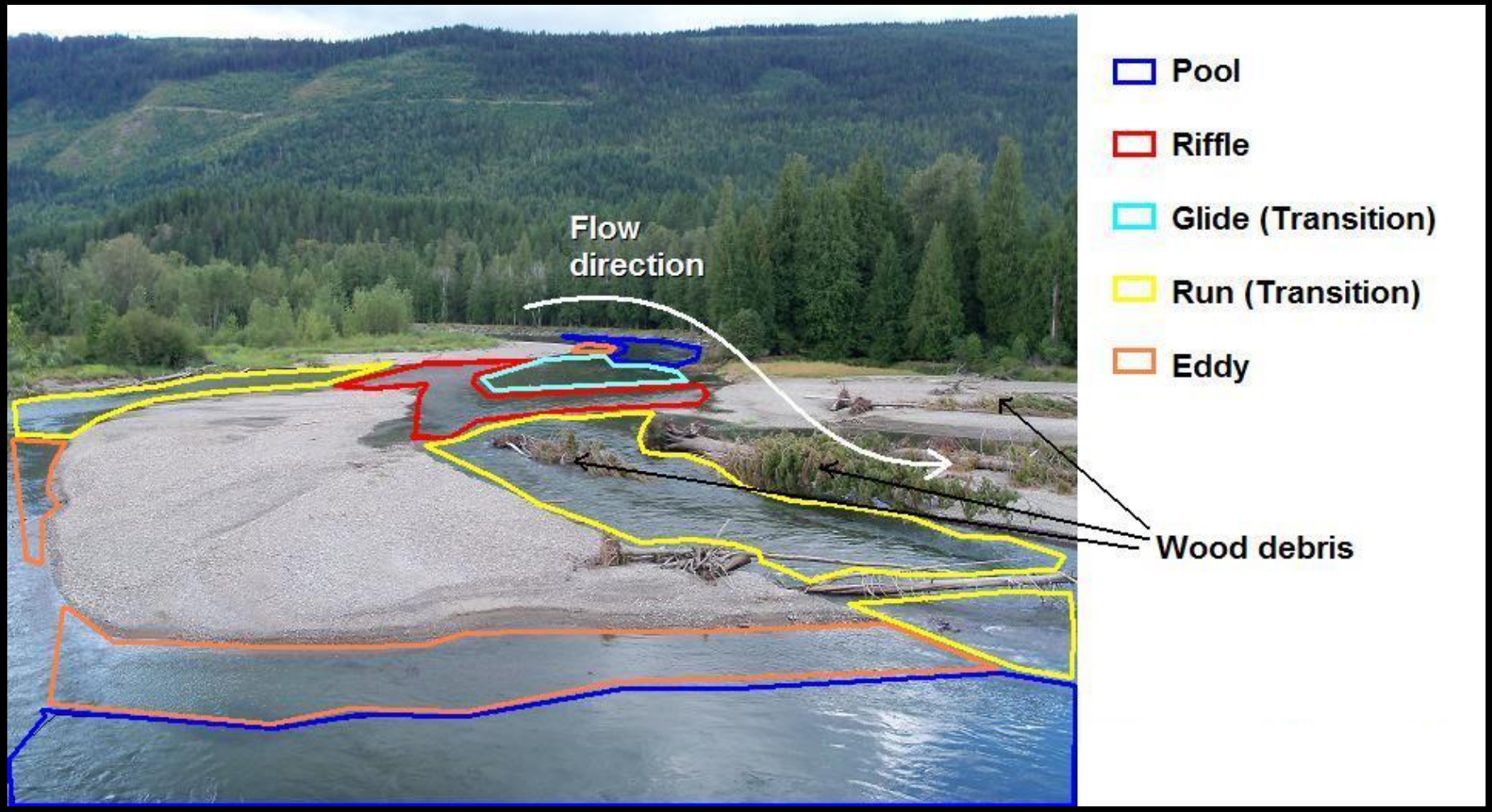


- Pixel size extrapolated to give continuous maps at the 10km river scale

Depth – Velocity combination: meso-habitat mapping

Classic meso-habitat classification

→ Delimitation of habitat units with subjectivity



Depth – Velocity combination: meso-habitat mapping

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"Peak 1": Riffles V = [0.05 ; 0.2] m/s d = [30 ; 35] cm

Depth – Velocity combination: meso-habitat mapping

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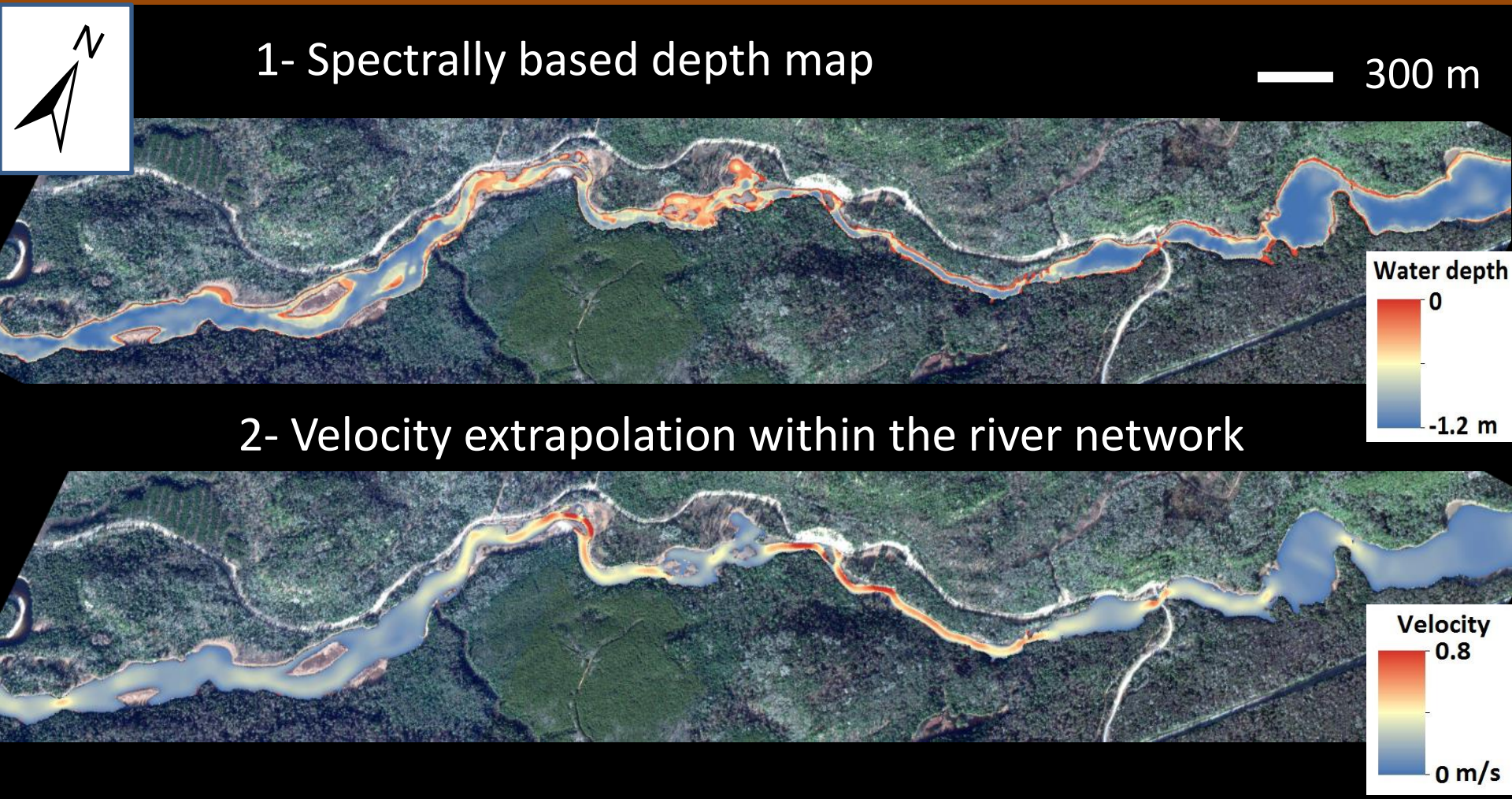
"Peak 2": Pool-Glide like V = [0.2 ; 0.3] m/s d = [40 ; 45] cm

River structure at the reach scale

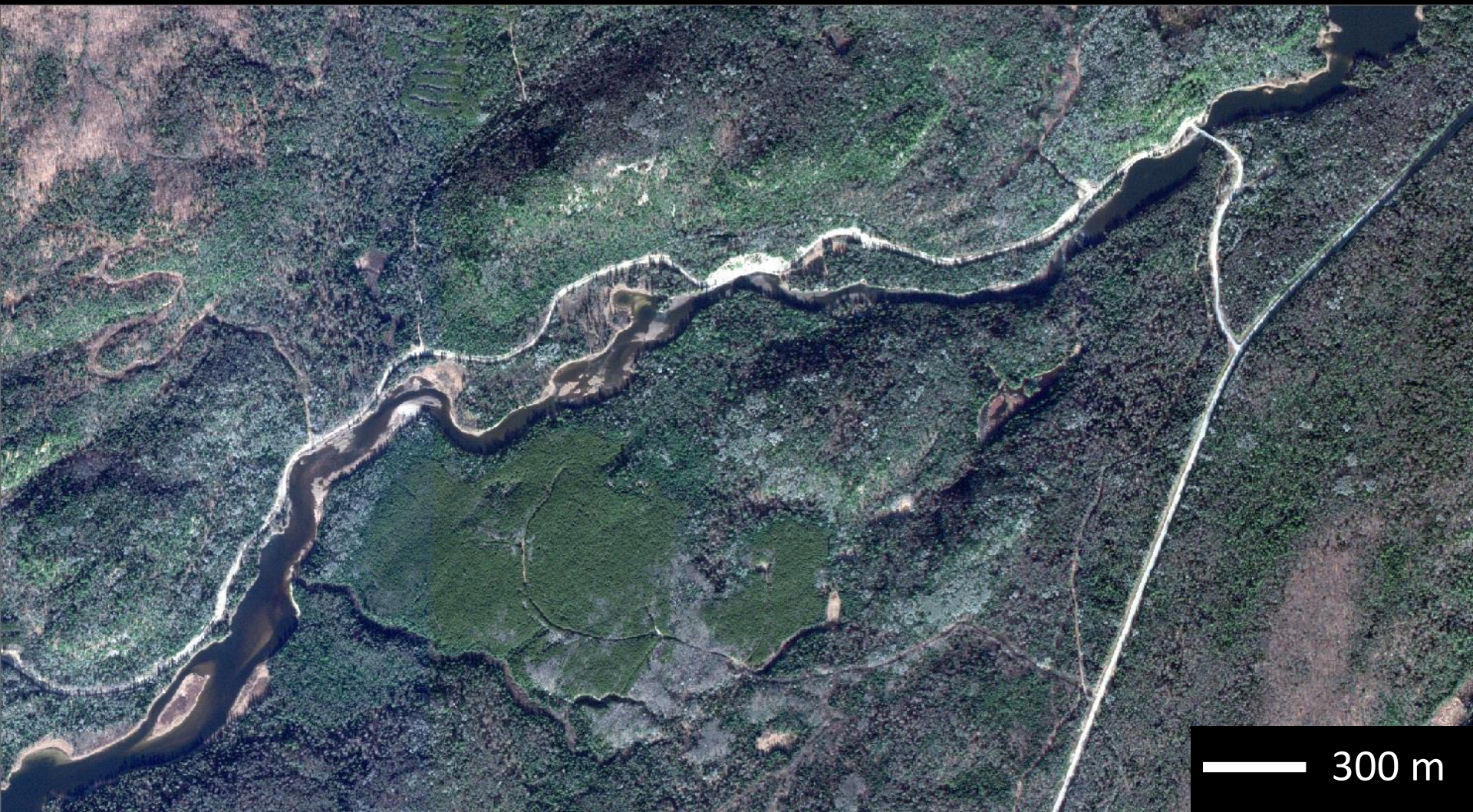


- Sections with deep large pools & low velocity
- Sections with higher velocity & simple or complex structure

Segmentation

Segmentation of the river stretch depending on the morphology

→ 4 identifiable sections

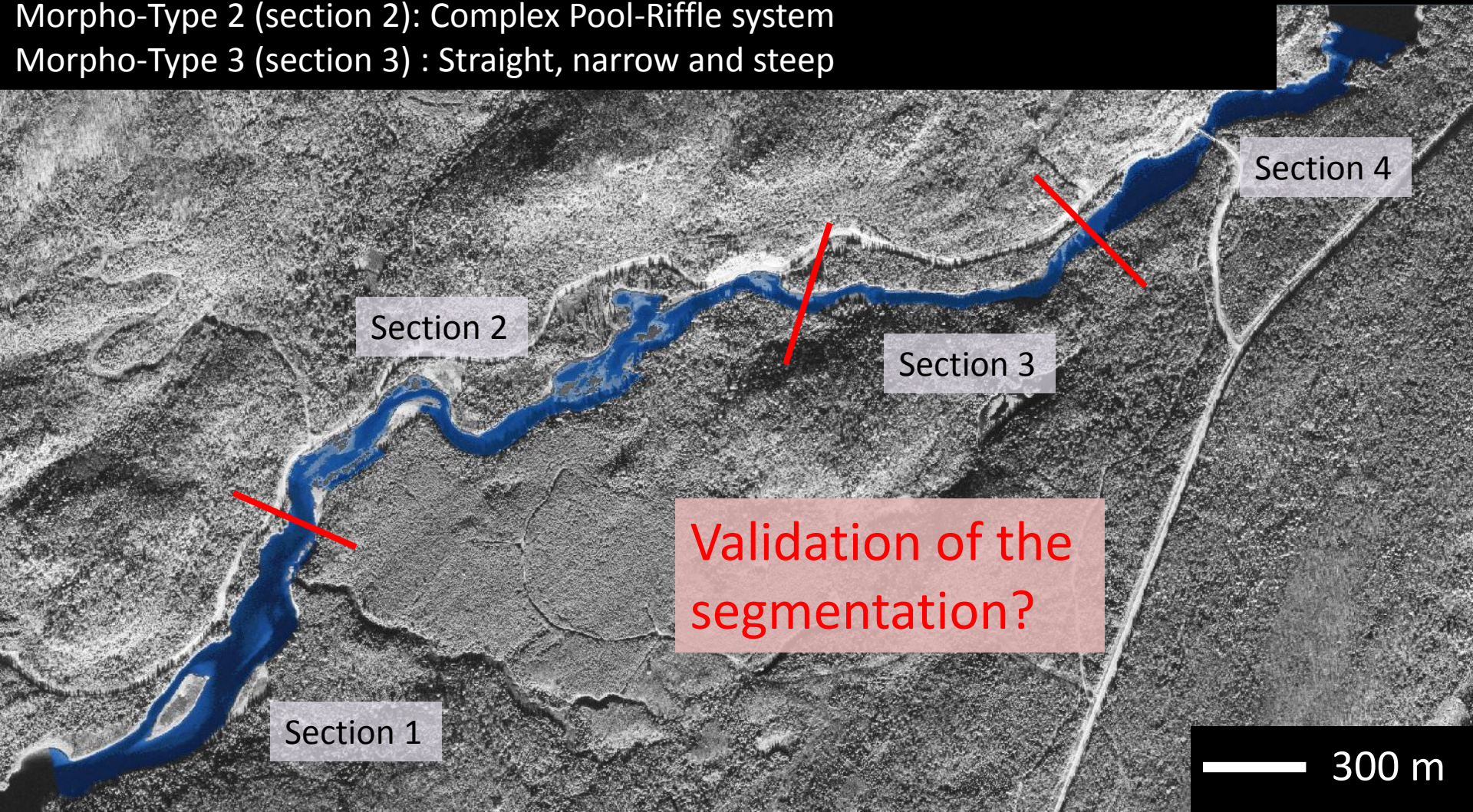


Segmentation

Segmentation of the river stretch depending on the morphology

→ 4 identifiable sections

Morpho-Type 1 (section 1, 4): Wide, deep, slow, mostly composed of massive pools
Morpho-Type 2 (section 2): Complex Pool-Riffle system
Morpho-Type 3 (section 3) : Straight, narrow and steep



Segmentation: Depth – Velocity combination

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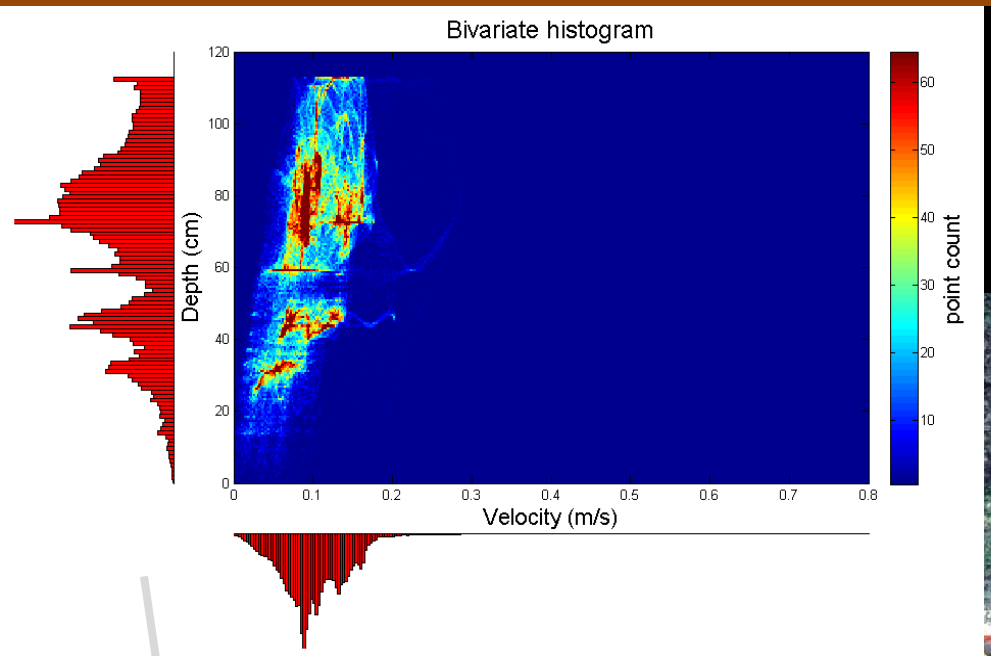


Section 1: Large pools, wide

1

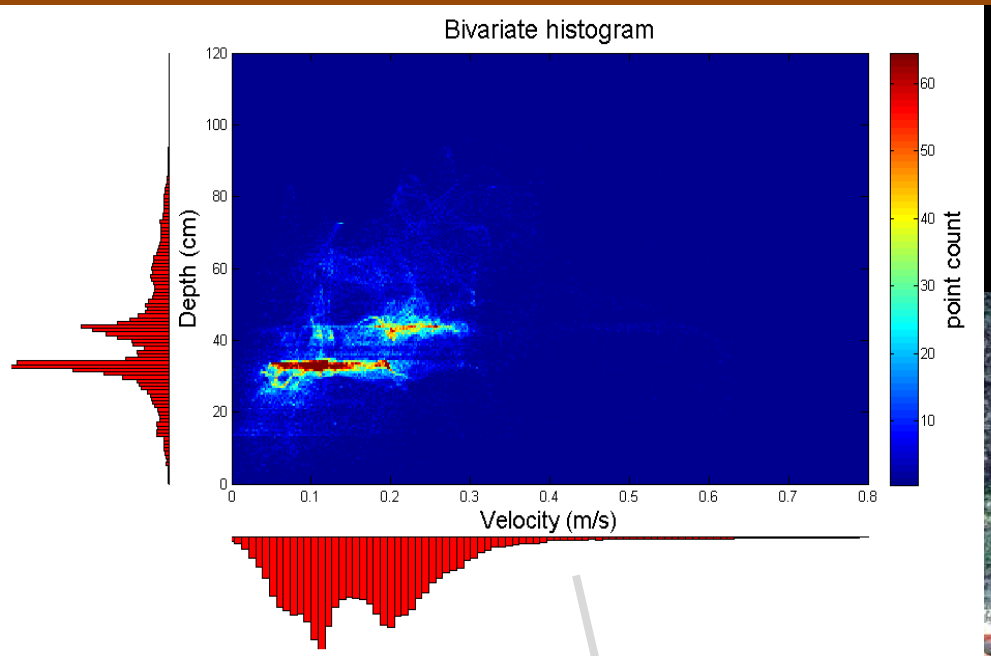
2

3

4

300 m

Segmentation: Depth – Velocity combination



Section 2: Variable, shallow

1

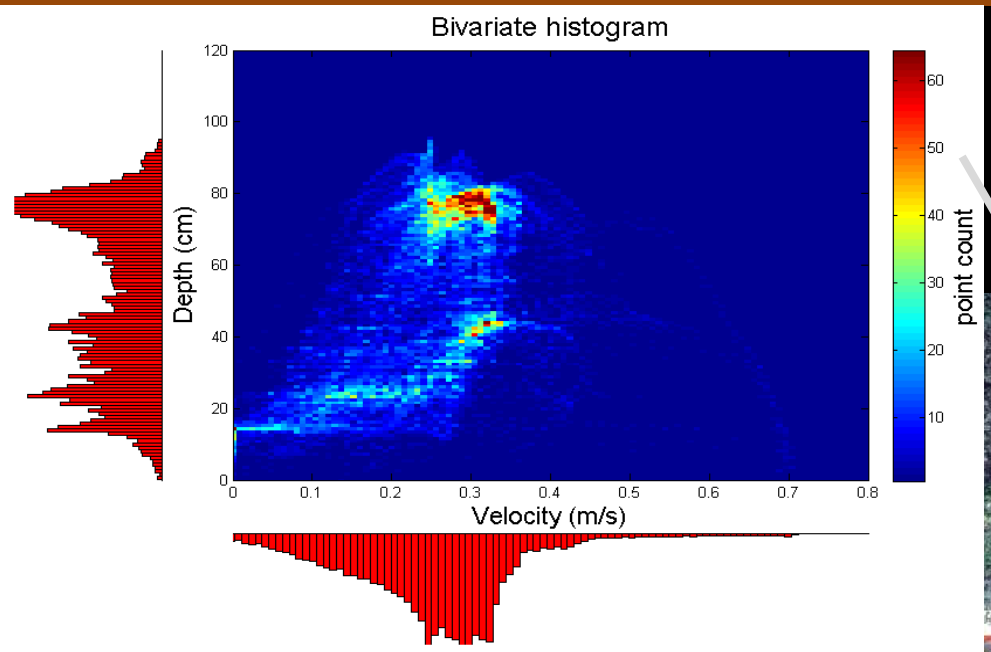
2

3

4

300 m

Segmentation: Depth – Velocity combination



Section 3: Straight, narrow

1

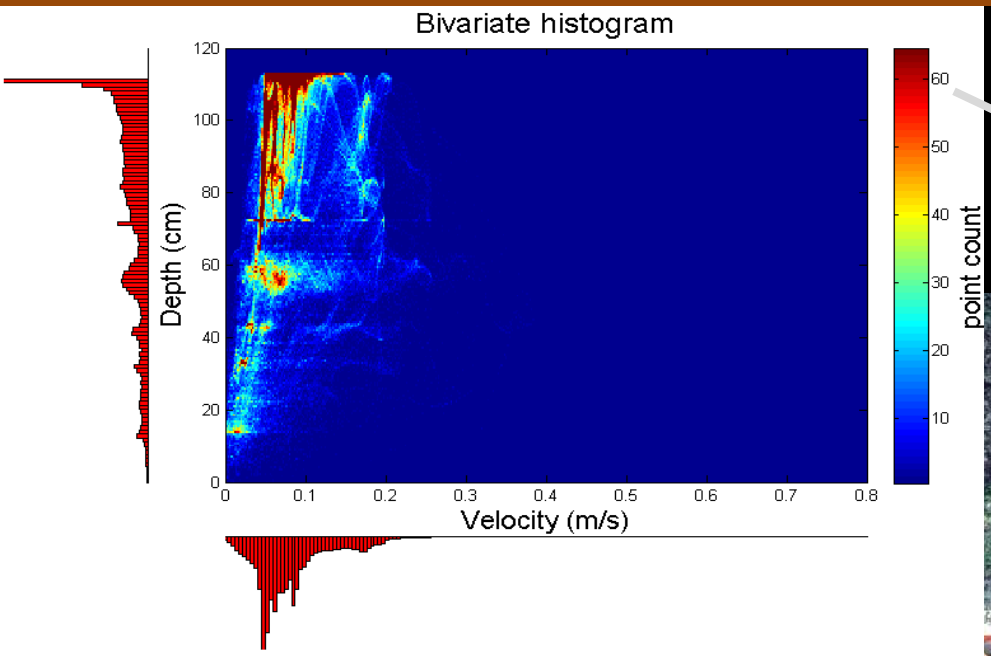
2

3

4

300 m

Segmentation: Depth – Velocity combination



Section 4: Large deep pools, slow

1

2

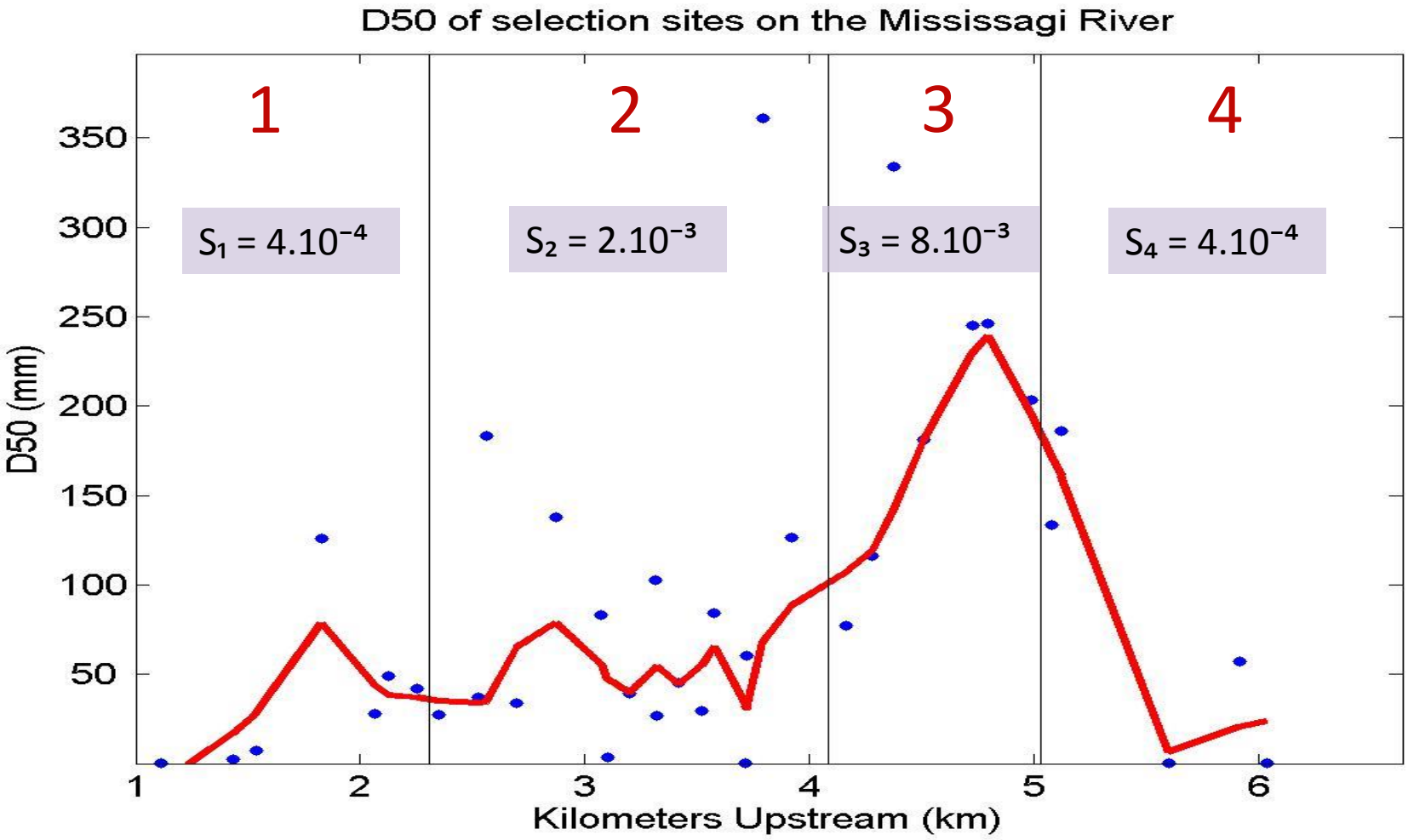
3

4

300 m

Sediment grain size & river slope

Distribution of the mean sediment size along the Rkm line:
- Link between the river slope (energy) and the grain size



Flow analysis & Bed mobility

Flow pattern:

- Peaking regime
- Reduction in mean annual flood discharge

Sediment transport response (bed mobility):

- Based on field mobility estimates = mobility of the substrate has been reduced / or eliminated in section 2 and 3)

Cross Section	Max Recorded Shear Stress (1 year of data)	Critical Shear Stress required to entrain the measured D50	D50 that would be mobile (% finer)
Mississagi 1 (Section 3)	118 Pa	184 Pa	36%
Mississagi 2 (Section 2)	9 Pa	75 Pa	88%

No Mobility

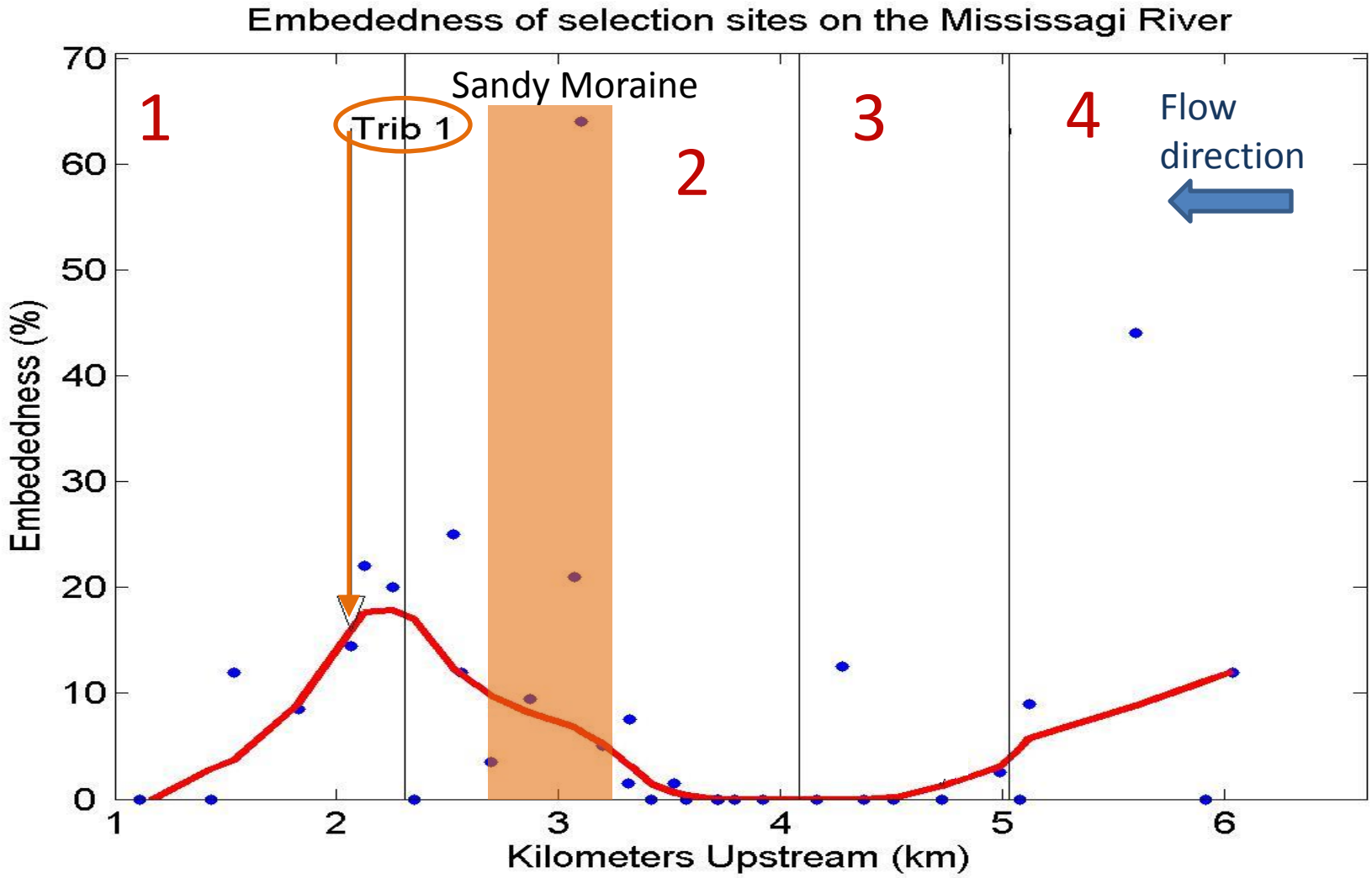
River reach structure & habitat sensitivity

General picture of the sediment input in the study area.
The habitat sensitivity is related to geomorphologic processes.

Embeddedness

Distribution of the embeddedness along the Rkm line:

- Link between the sediment source and the embeddedness location.
- Peaking flow regime might influence embeddedness formation.



Conclusion

Continuous depth map

+

Continuous velocity estimations

=

From the pixel size…

- Habitat variability assessment:

- With less subjectivity than the classic mesohabitat classification
- For 200+ km of rivers (HydroNet sites)
- Linkage of fish species V-d preferency

…to the meso, reach & river scales.

- Mapping of habitat sensitivity to upstream damming:

- River channel response to new flow regime
- Impact on fish populations

Perspectives:

- Improve depth calibration
- Implementation of riparian cover, LOD, in the mesohabitat mapping
- Inter-region habitat variability study & Regulated Vs. Natural rivers


Thank you !
Questions ?