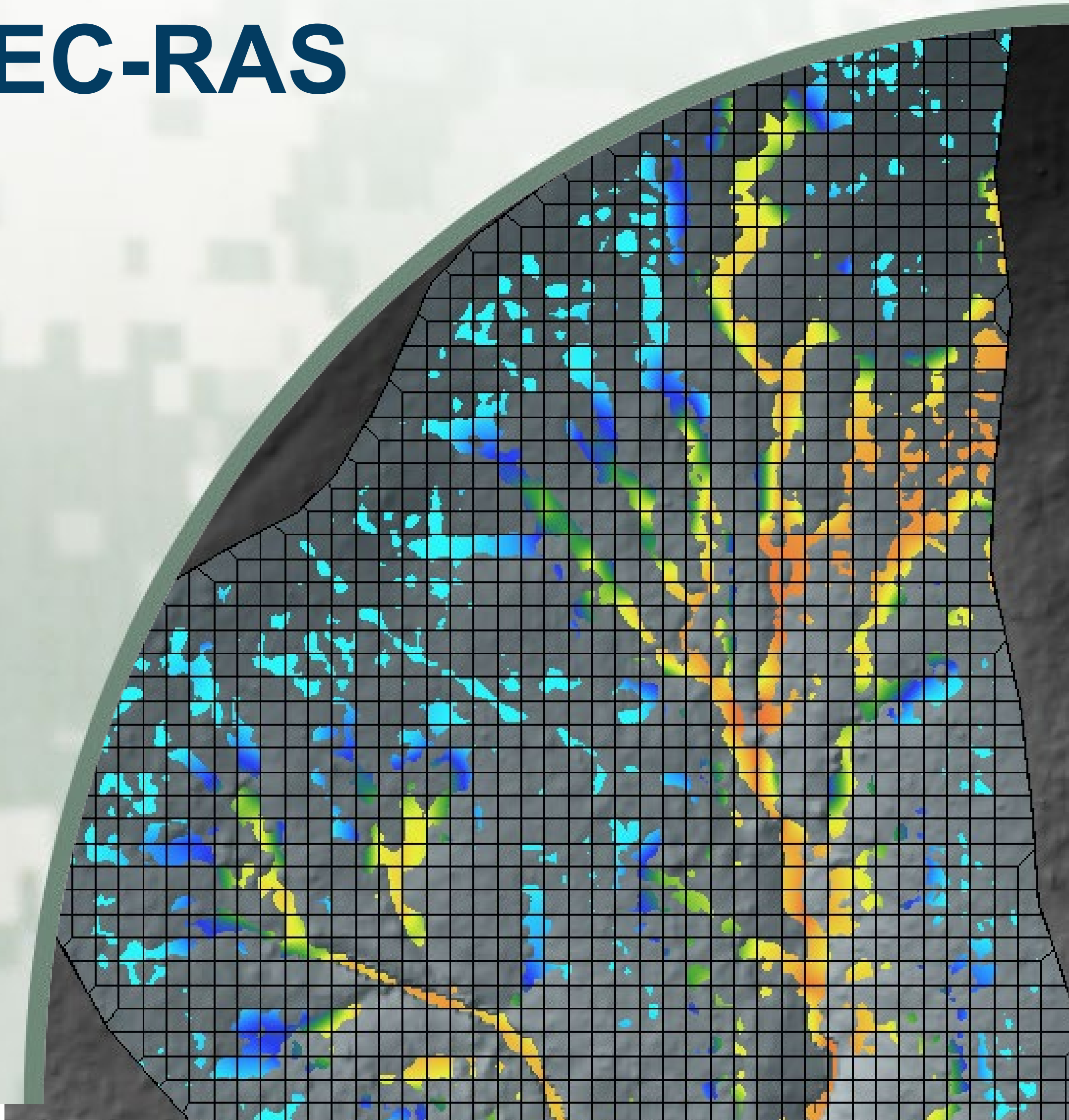
Two-Dimensional Subgrid Sediment Transport Modeling with HEC-RAS

Alex Sánchez, PhD
Stanford Gibson, PhD

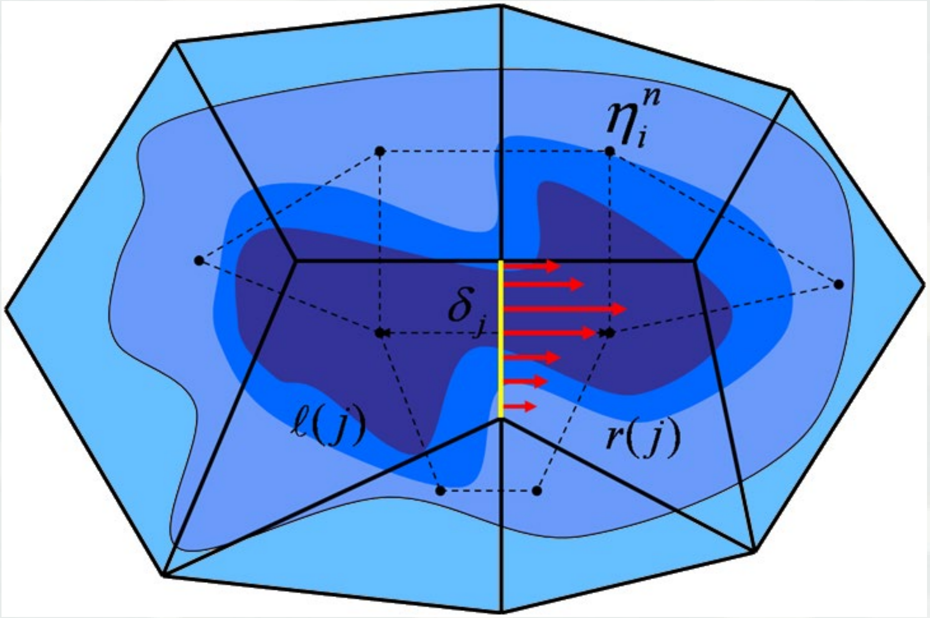
Hydrologic Engineering Center,
Institute for Water Resources,
U.S. Army Corps of Engineers, U.S.A.



US Army Corps of Engineers®

Hydrodynamics

- Governing Equations
  - Diffusion Wave Equation
  - Shallow Water Equations
- Subgrid Technology
- Boundary Conditions
  - Normal Depth
  - Stage time series
  - Rating curve
  - Flow time series
  - Precipitation



Sediment Transport

- Total-load Transport Equation

$$\frac{\partial}{\partial t}\left(\frac{hC_{tk}}{\beta_{tk}}\right)+\nabla\cdot(h\boldsymbol{U}C_{tk})=\nabla\cdot\left(\varepsilon_{tk}h\nabla C_{tk}\right)+E_{tk}-D_{tk}$$

U = Current velocity

h = Water depth

k = Grain class

β_{tk} = Total-load correction factor

ε_{tk} = Total-load diffusion coef.

C_{tk} = Total-load sediment conc.

- Erosion Rate

$$E_{tk}=r_A^{SS}E_{tk}^{SS}+r_A^{CF}E_{tk}^{CF}$$

- Deposition Rate

$$D_{tk}=r_A^{CF}D_{tk}^{CF}$$

- Any number of grain classes

E_{tk} → Total-load erosion rate

CF → Concentrated flow

SS → Splash and sheet flow

r_A^{SS} → Fraction of area with SS erosion

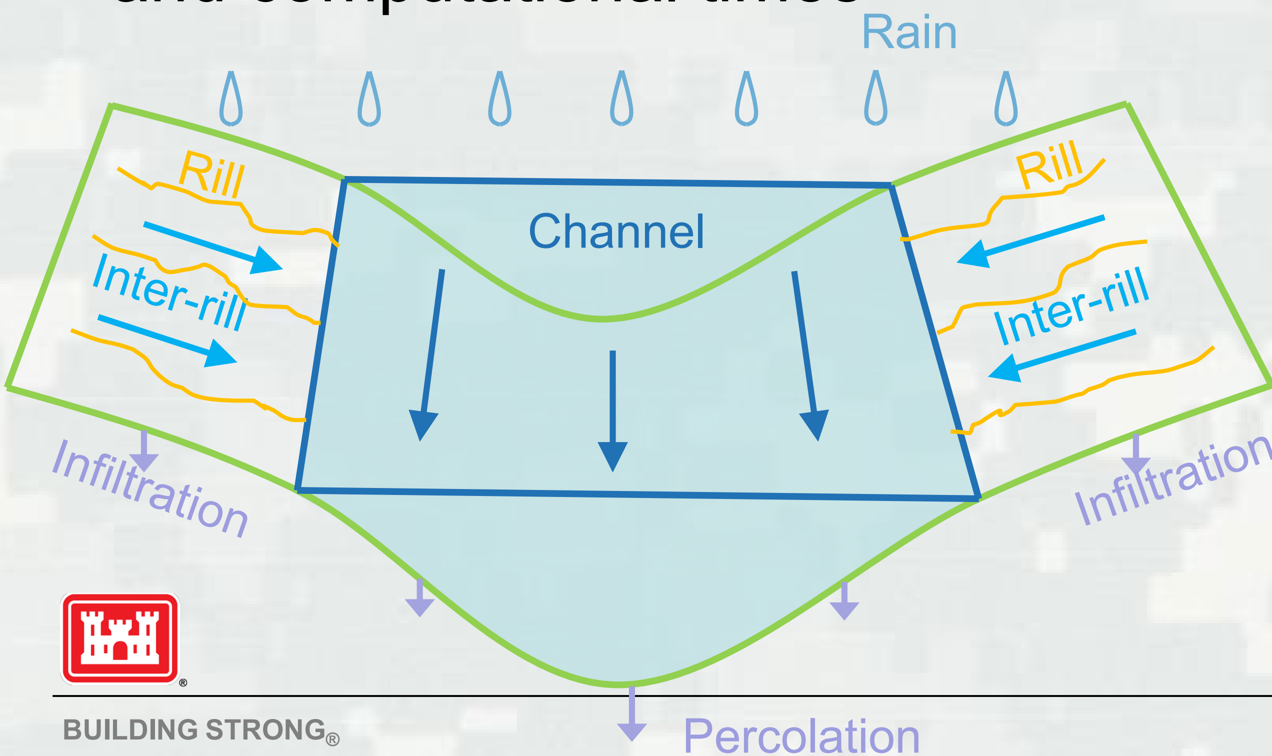
r_A^{CF} → Fraction of area with CF erosion

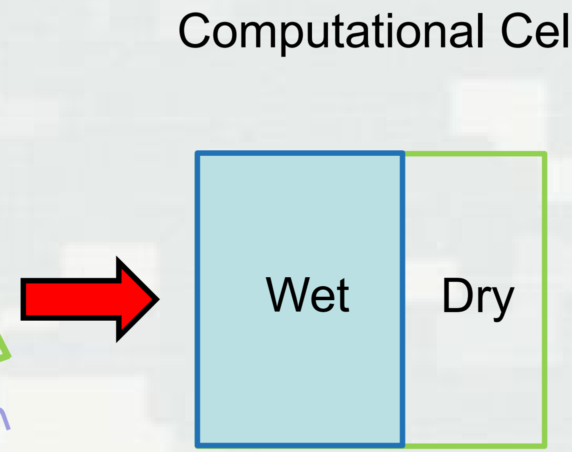
E_{tk}^{CF} → Total-load CF erosion rate

E_{tk}^{SS} → Total-load SS erosion rate

Subgrid Modeling

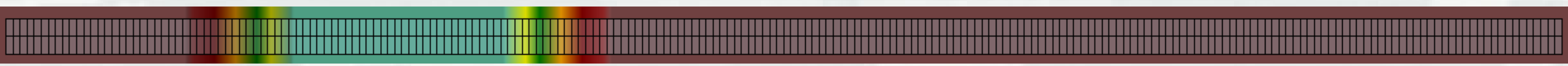
- Representation of the physical terrain and processes at a subgrid scale
- Allows for larger grid cells reducing computational cells, and computational times

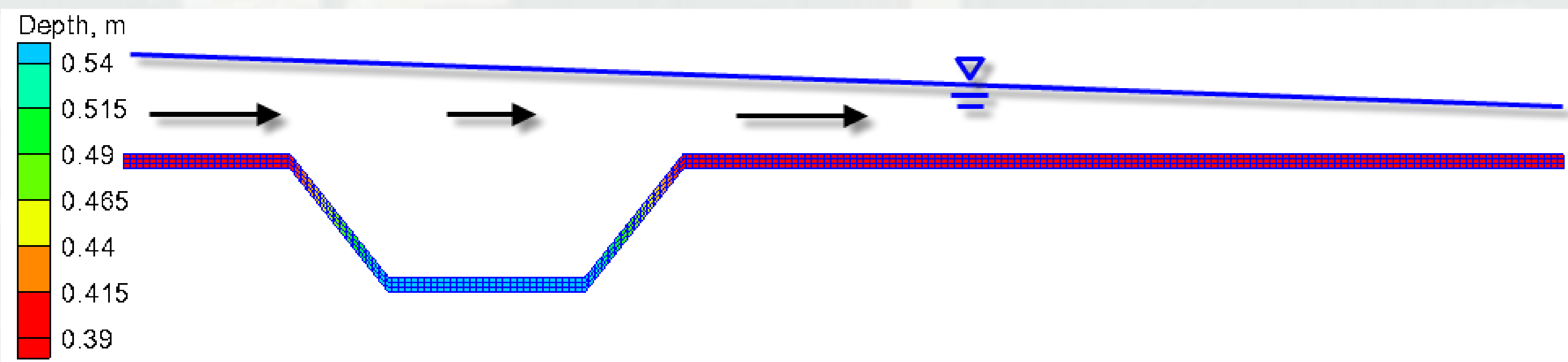




Validation: Galappatti and Vreugdenhil (1985)

- Flume Experiment
- Upstream current velocity: 0.51 m/s
- Downstream water depth: 0.39 m
- Mannings: 0.025 s/m$^{1/3}$
- Median grain size: 0.16 mm
- Upstream sediment flux: 0.04 kg/m/s
- Transport Potential: van Rijn (2007)





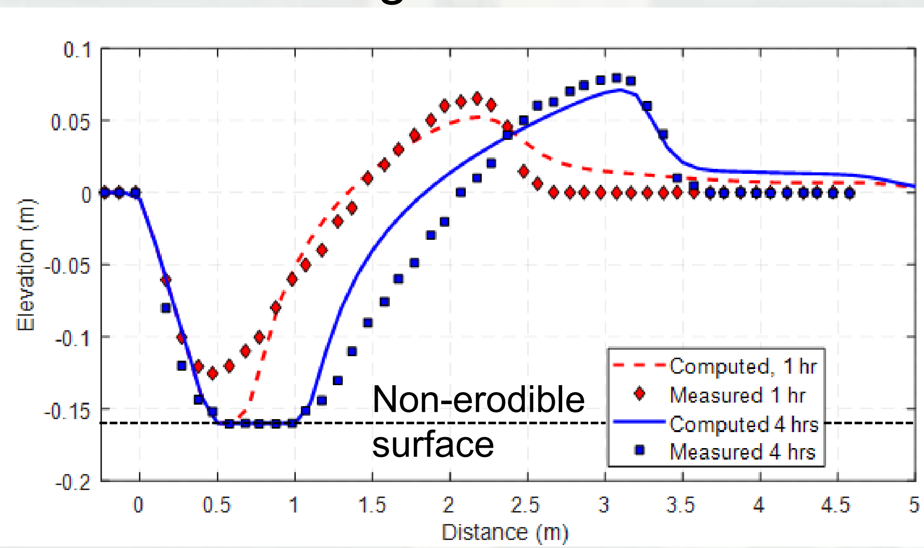
Results

Validation: Clear-water Scour

- Lab Experiment:
  - Thuc (1991)
- 16-cm layer of medium sand

Initial Current Velocity in m/s

Transects along centerline

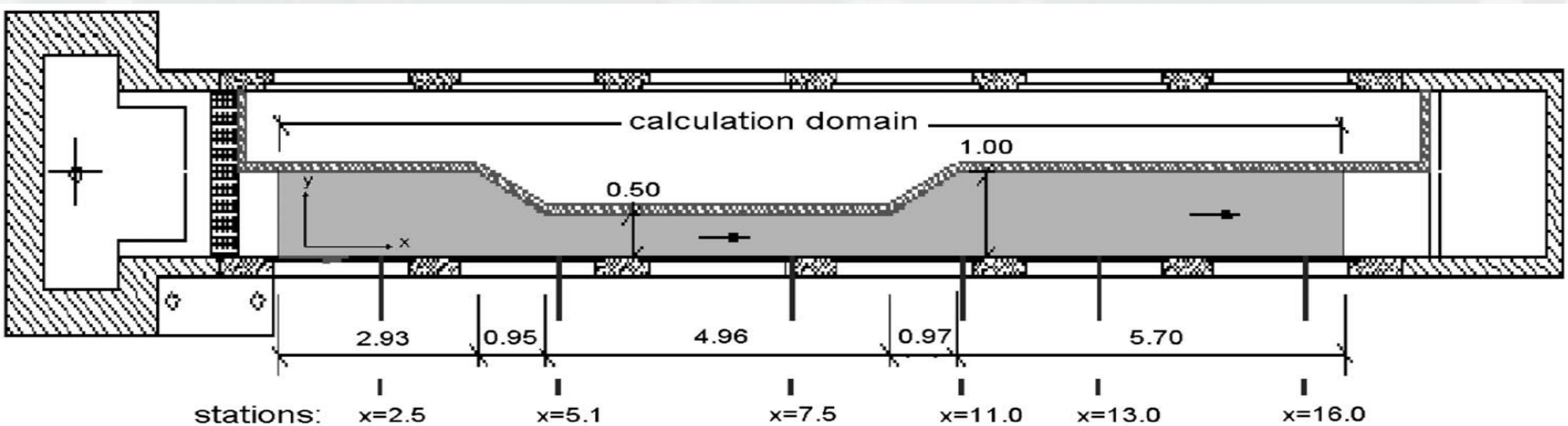


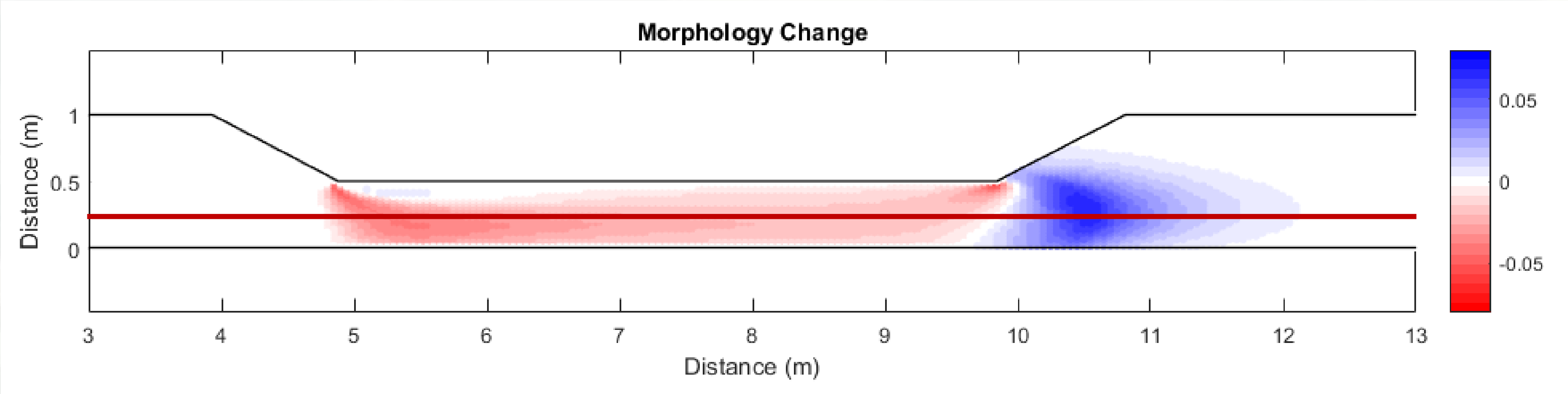
Mesh and 4-hr Bed Change in m

HEC-RAS 2D Sediment Validation: Flume Experiment of Weise (2002)

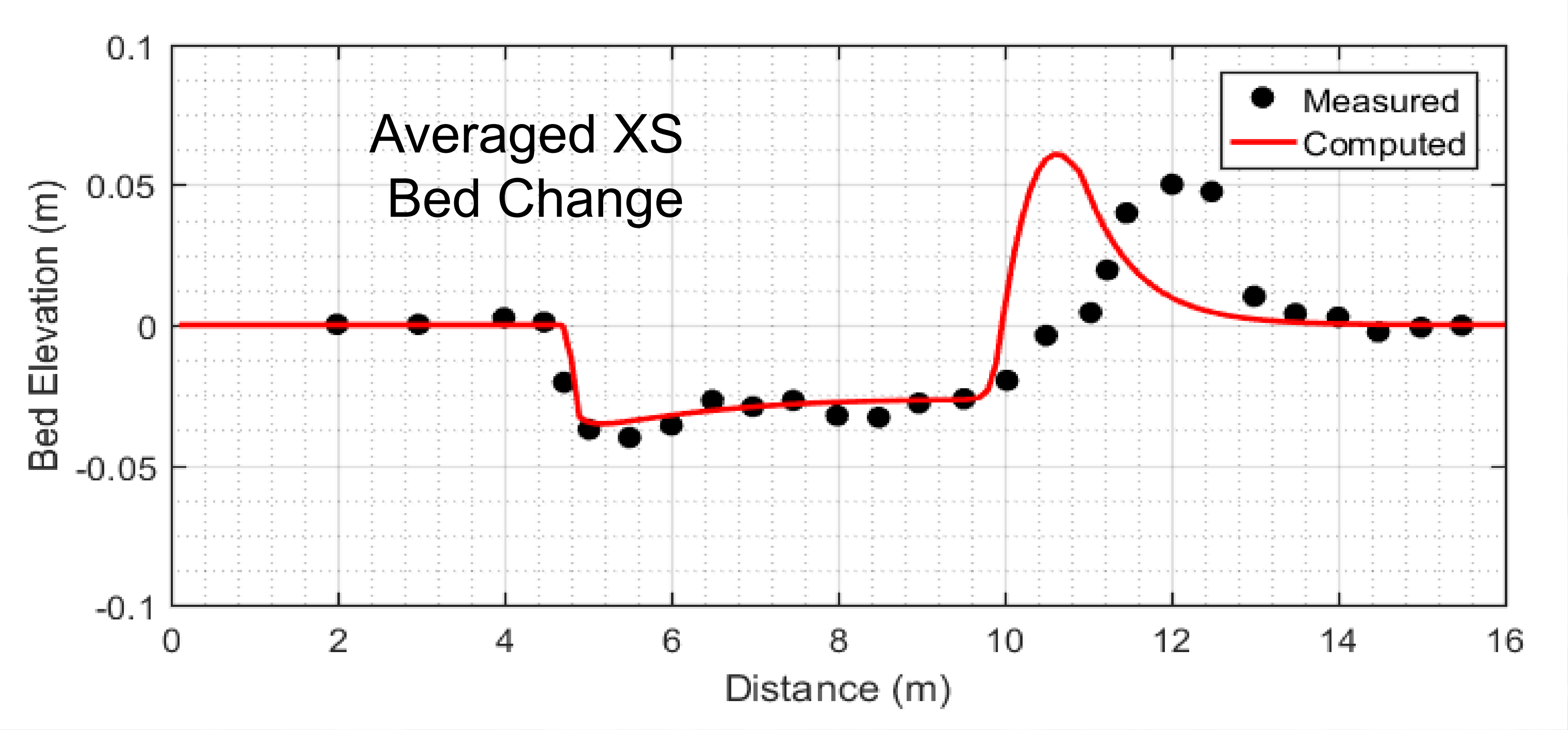
- Flow
  - Upstream flow: 150 l/s
  - Downstream depth: 0.312 m
- Sediment
  - Mean grain size: 5.5 mm
  - Geometric Standard Deviation: 1.47
- Duration:130 min

Plan View of Flume





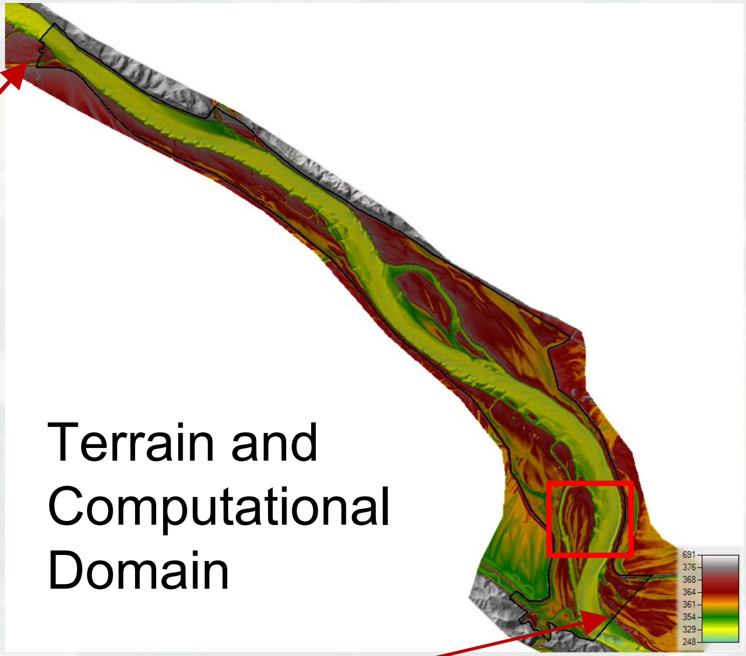
Morphology Change
Distance (m)
Distance (m)
0.05
0
-0.05

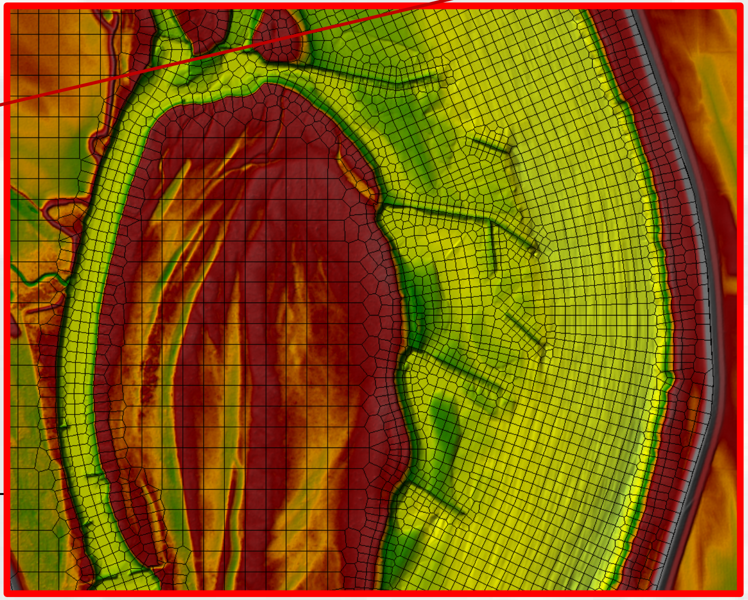


Averaged XS
Bed Change
Measured
Computed
Bed Elevation (m)
Distance (m)

Validation: Upper Mississippi

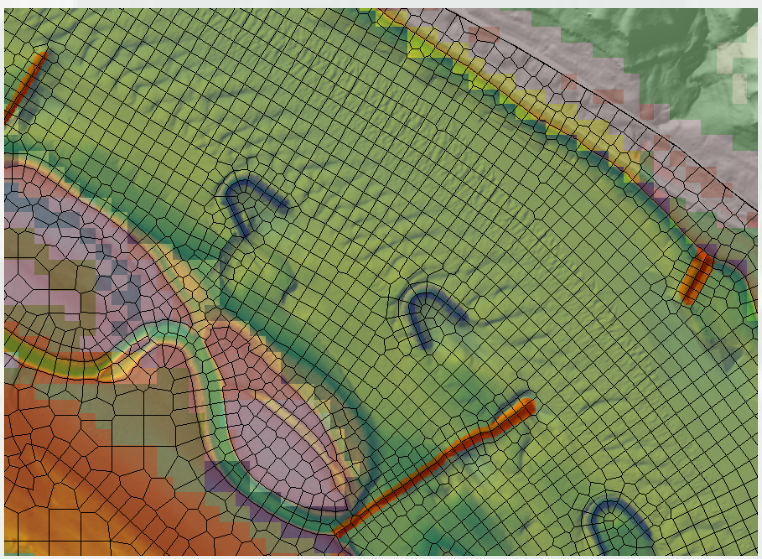
- **Time Period:** 2014 to 2016
- **Study Extent:** River Station 110 (Chester Gage) to River Station 92 (two miles downstream of Red Rock Gage)
- **Upstream Boundary Condition:** Chester Flow Hydrograph
- **Downstream Boundary Condition:** Normal Depth, Red Rock Rating Curve

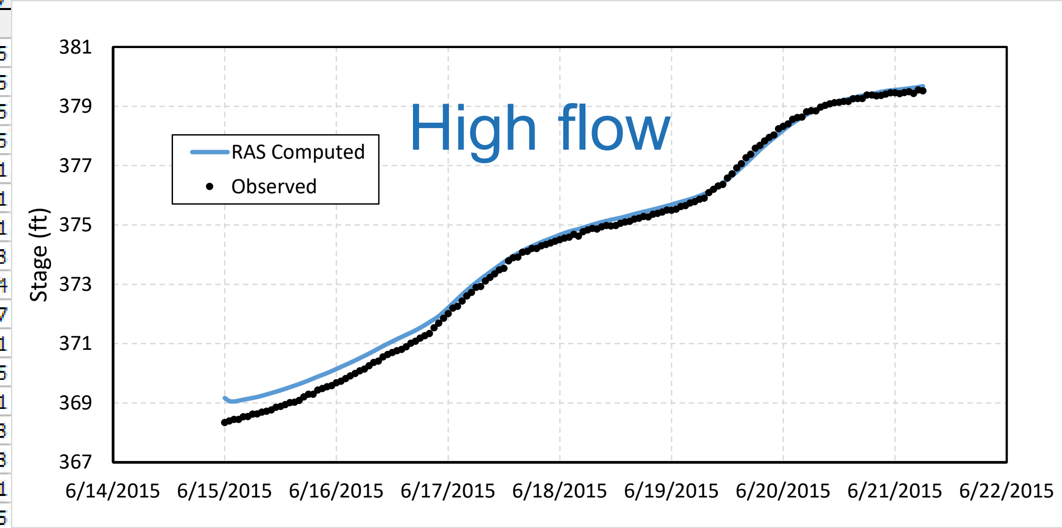


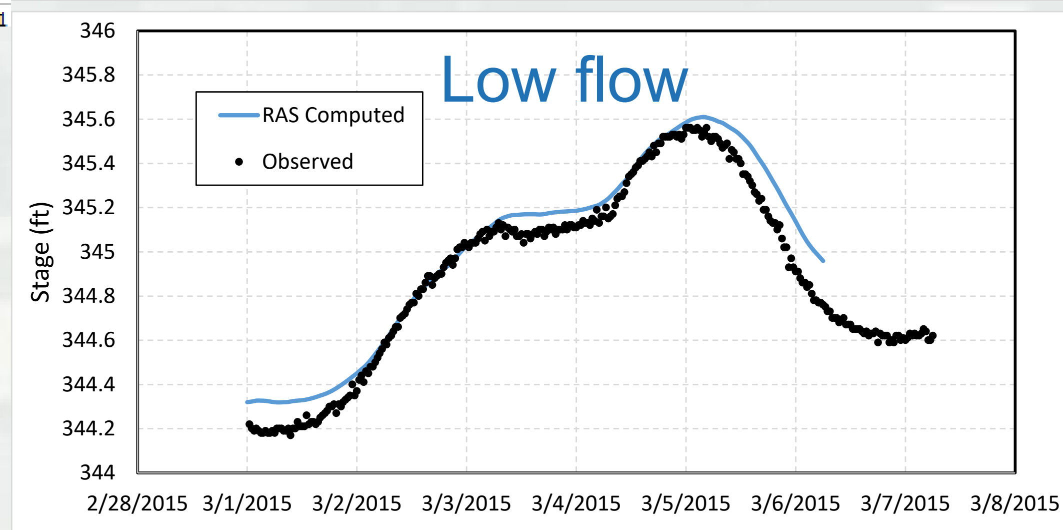


Calibration - Hydrodynamics

	Name	Default Mann n	Base Mann n (blank for default)
1	nodata		
2	255		0.045
3	barren land rock/sand/clay	0.025	0.025
4	chevron	0.05	0.05
5	cultivated crops	0.035	0.035
6	deciduous forest	0.16	0.1
7	developed, high intensity	0.15	0.1
8	developed, low intensity	0.1	0.1
9	developed, medium intensity	0.08	0.08
10	developed, open space	0.04	0.04
11	emergent herbaceous wetlands	0.07	0.07
12	evergreen forest	0.16	0.1
13	grassland/herbaceous	0.035	0.035
14	mixed forest	0.16	0.1
15	open water	0.04	0.028
16	pasture/hay	0.03	0.028
17	shrub/scrub	0.1	0.1
18	wingdam	0.05	0.05
19	woody wetlands	0.12	0.1

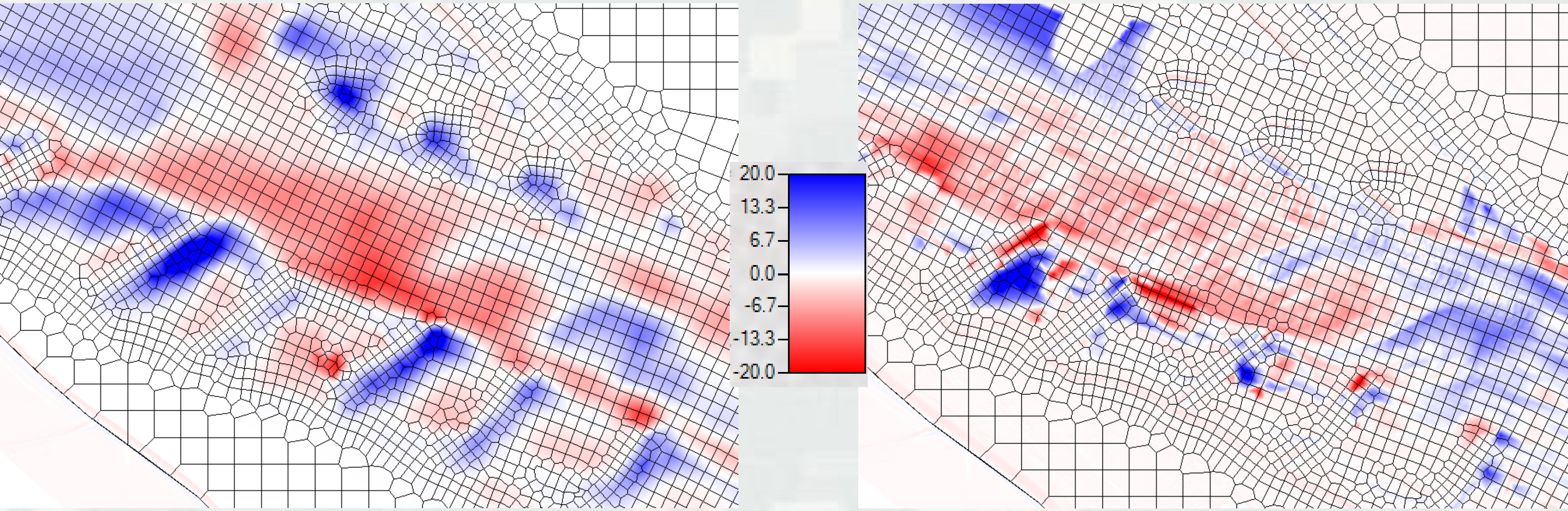






Results – In Progress Calibration

Comparison of measured and computed bed change



Computed

Measured

https://www.hec.usace.army.mil/training/webinars.aspx

Hydrologic Engineering Center

US Army Corps of Engineers

ABOUT NEWSLETTERS SOFTWARE PUBLICATIONS TRAINING V CO[redacted]

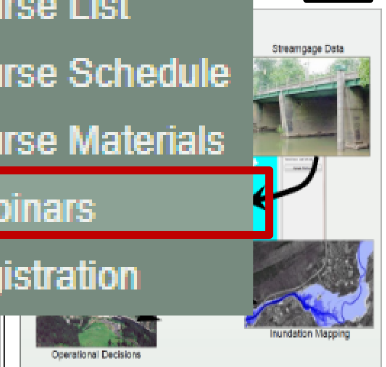
- Course List
- Course Schedule
- Course Materials
- Webinars
- Registration

HOME > TRAINING > WEBINARS

Training

- Training
- Course List
- Course Schedule
- FY2020 Proposed PROSPECT Course Schedule NEW
- Course Materials
- Webinars NEW
- Course Registration

CWMS/HEC-RTS and HEC-WAT for the American Society Engineers



Intro to Sediment Transport:

(Part 1 of 3 - Quasi Unsteady Flow)

(Part 2 of 3 - Sediment Data)

(Part 3 of 3 - Simulation and Analyzing Results)

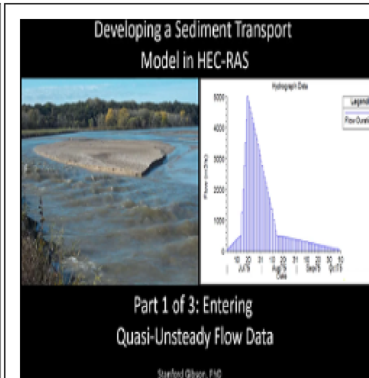
These three videos introduce users to the sediment transport capabilities in HEC-RAS. The first video introduces the Qusai-Unsteady flow data and editors. The second video describes the sediment data requirements and demonstrates how to enter these data. And the third video demonstrates how to run a simulation and analyze results. The third video also covers a few big-picture best practices for sediment modeling. Each video has HEC-RAS and data files that you can download, which will start you off at the same point as the video, and solution files that include the completed model.

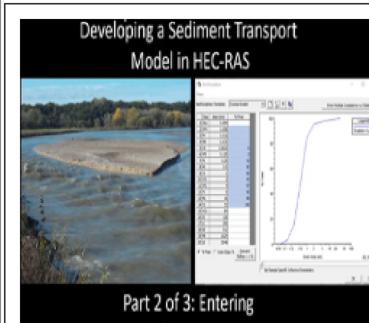
Supporting Files:

Sediment Demo 1

Sediment Demo 2

Sediment Demo 3





HEC-RAS Sediment