HEC-RAS Reservoir Transport Simulation of Three Reservoirs in the Lower Susquehanna River Basin

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Topics

- Background / Project Objectives
- Data Selection
  - Sediment and Geometric Input Data
- Sediment transport calibration / simulation
- Model results / issues

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Background

- USGS collected bathymetry and cores in 1990, 1993, 1996, 2001, and 2008
- Document change in sediment storage capacity and size composition
- Previous USGS HEC-6 Model (1995)
- Remaining Capacity – Implications
  - Chesapeake Watershed TMDL
  - PA/NY reduce more to meet goals

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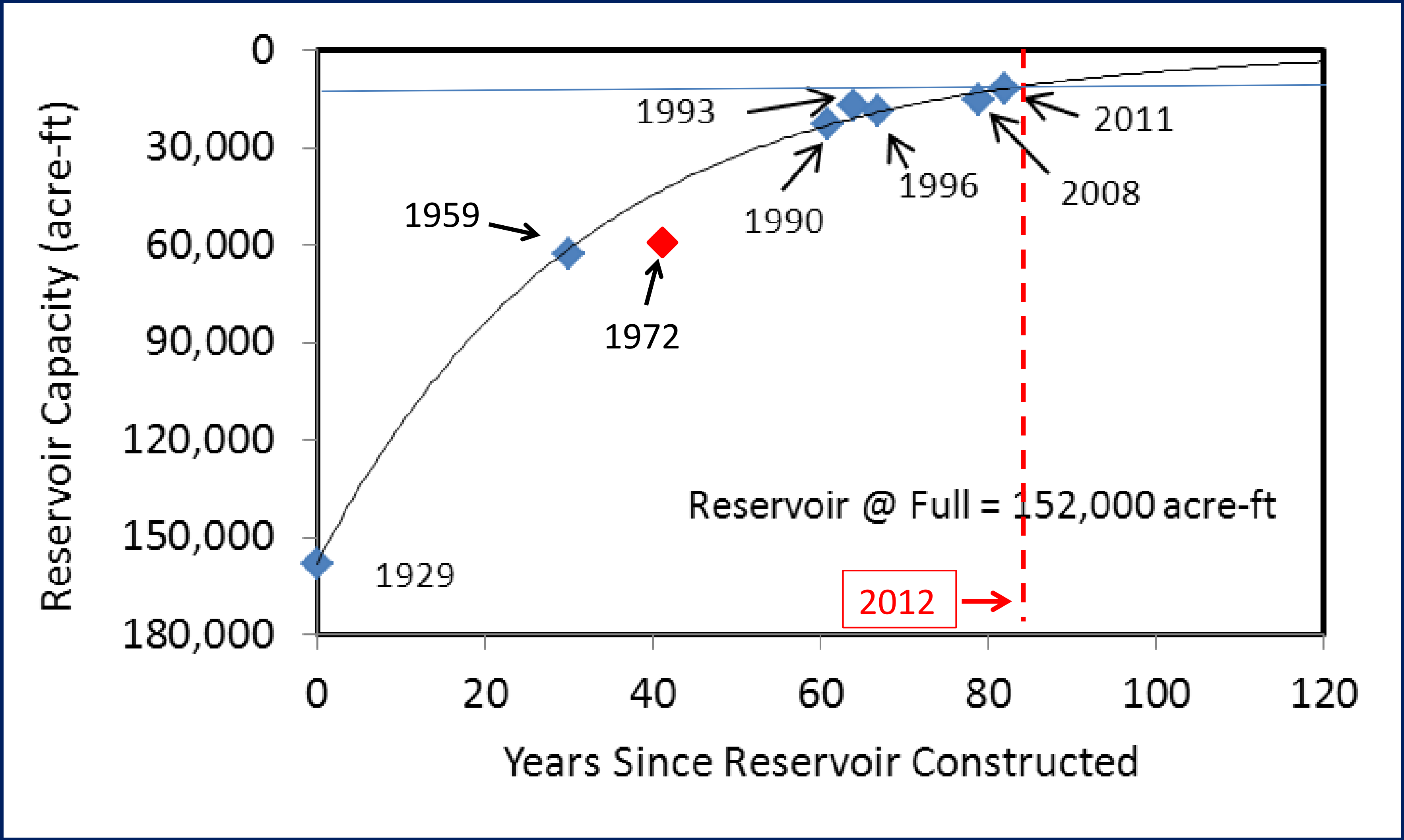
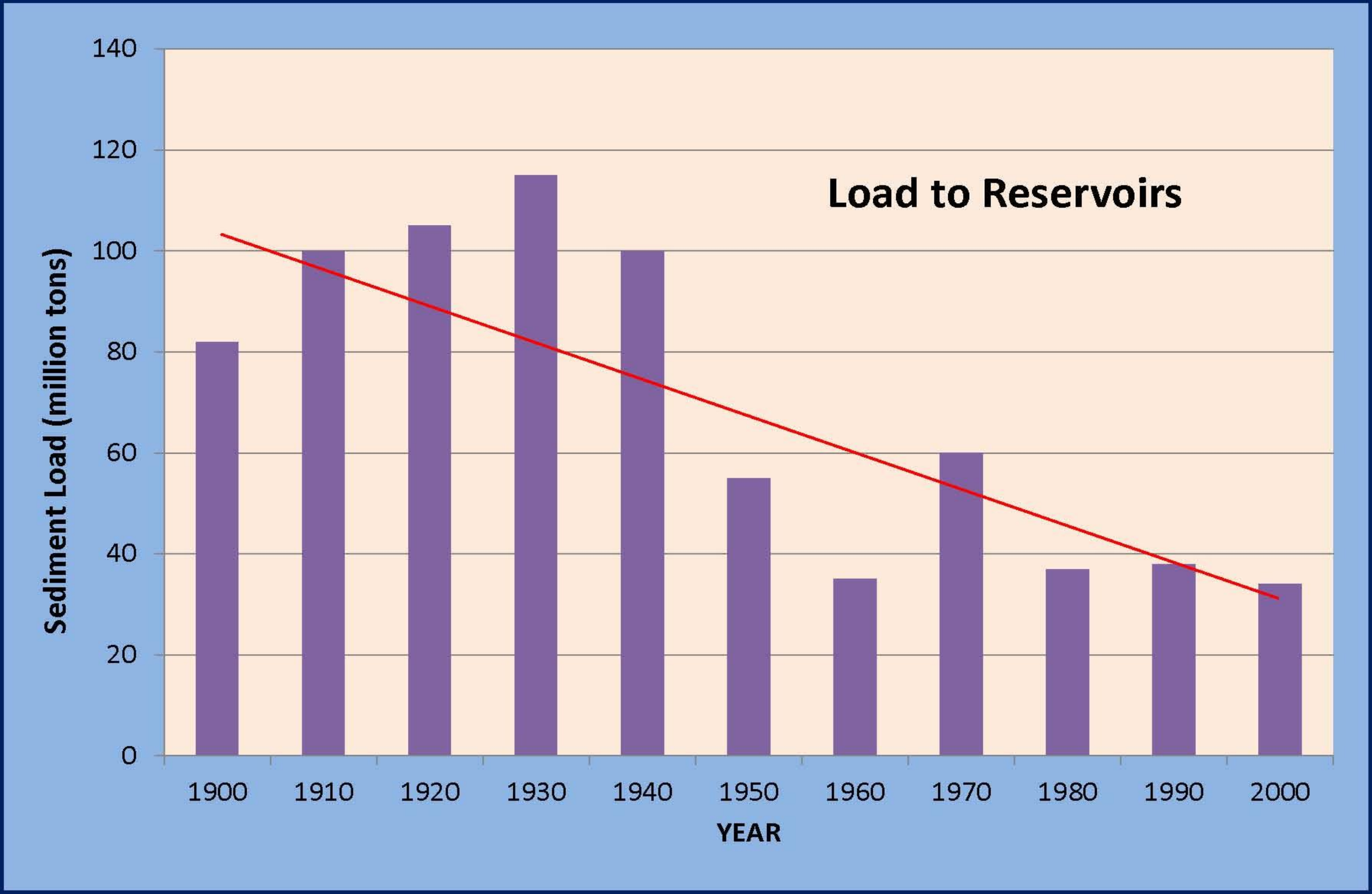
Changes in Bathymetry with Time



2012 – only 10-15% of original volume remains to fill to capacity

Sediment inputs have been decreasing (about 2/3 less)



Objectives

- Construct, calibrate, and validate a 1-D sediment model for the entire Reservoir system (~33 miles)
- GOAL - Simulate the loads in and out, bed-form change, and particle size distribution
- Product - Produce input boundary condition files for Conowingo Reservoir for USACE 2-D model

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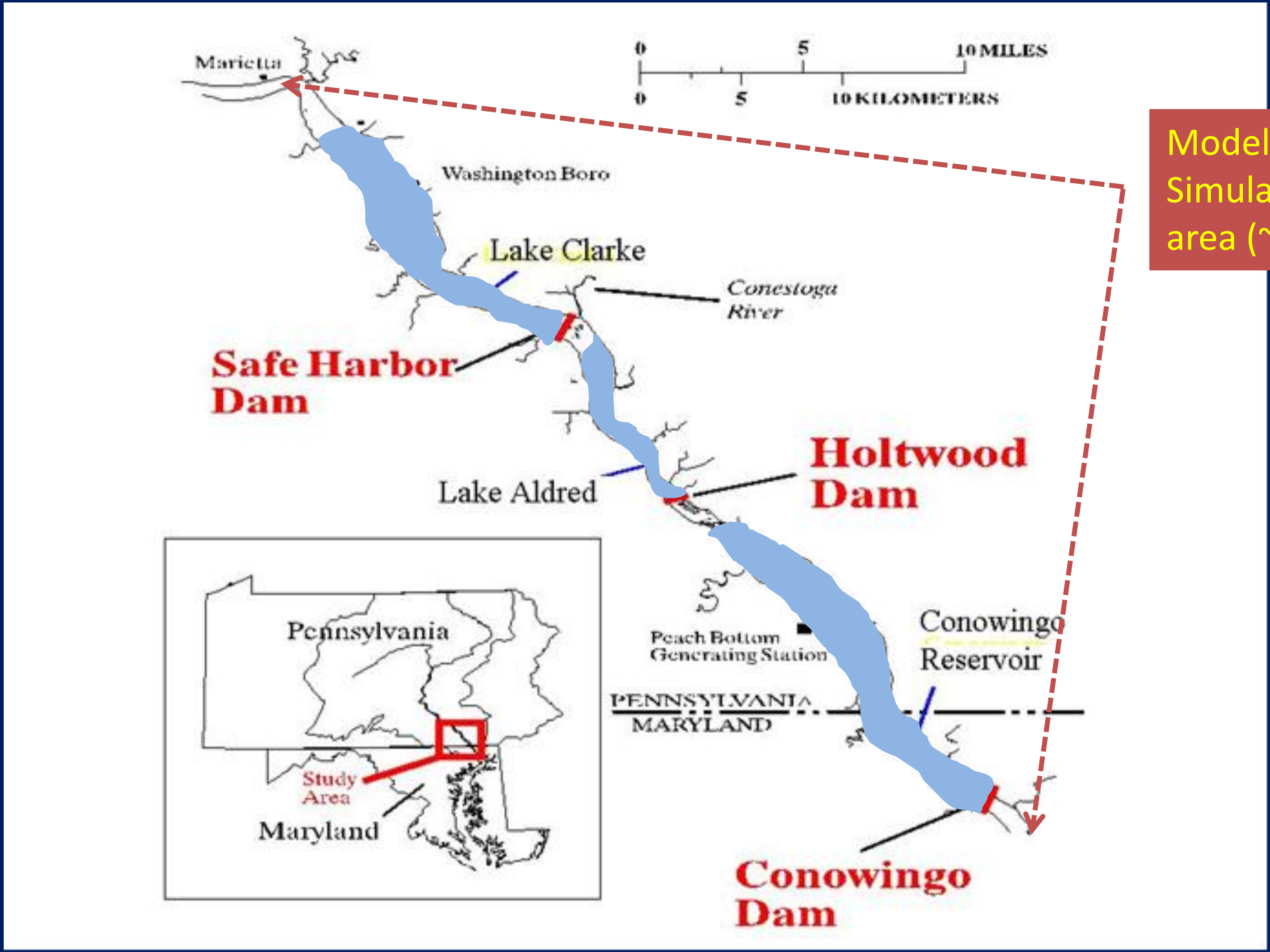
Definitions

- 1-D sediment model – model either erodes OR deposits, not both on same transect
- Shear stress (SS) – force of water acting on the channel sides and bed (different for each particle size) model can only have one)
- Critical Shear Stress (CSS) – shear stress required to mobilize sediments (model can only input one value)
- Generally, if SS < CSS, then deposition, if SS = CSS, then "equilibrium", if SS > SCC, then degradation (scour)

Susquehanna River Reservoirs



Model Simulation area (~33 m)

HEC-RAS Model – 3 main steps

1) Prepare Input data – sediment and flow

2) Construct Geometric and Hydraulic framework

3) Calibrate to observed data

Input Data

- Sediment - transport curves or estimated daily sediment loads and core data
- Flow – rating curve or actual daily flow data

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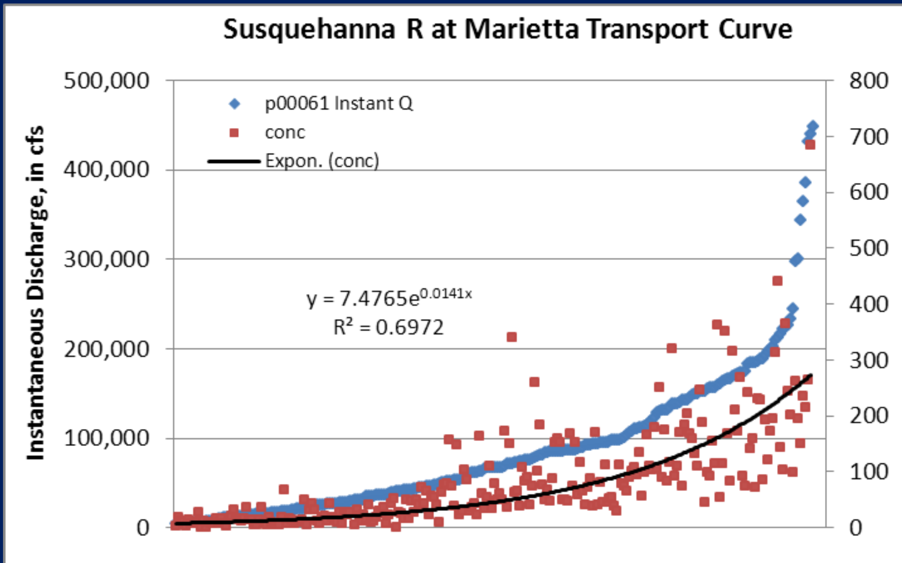
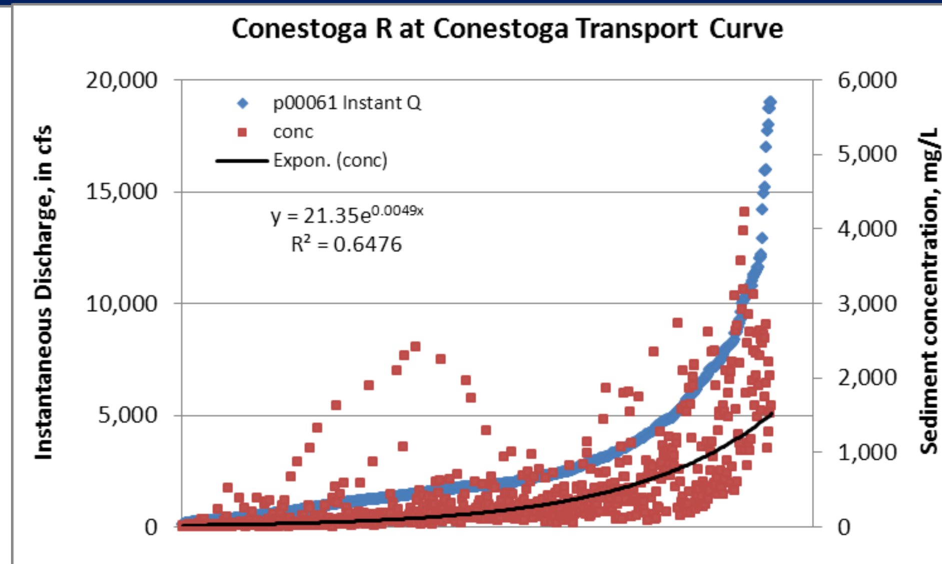
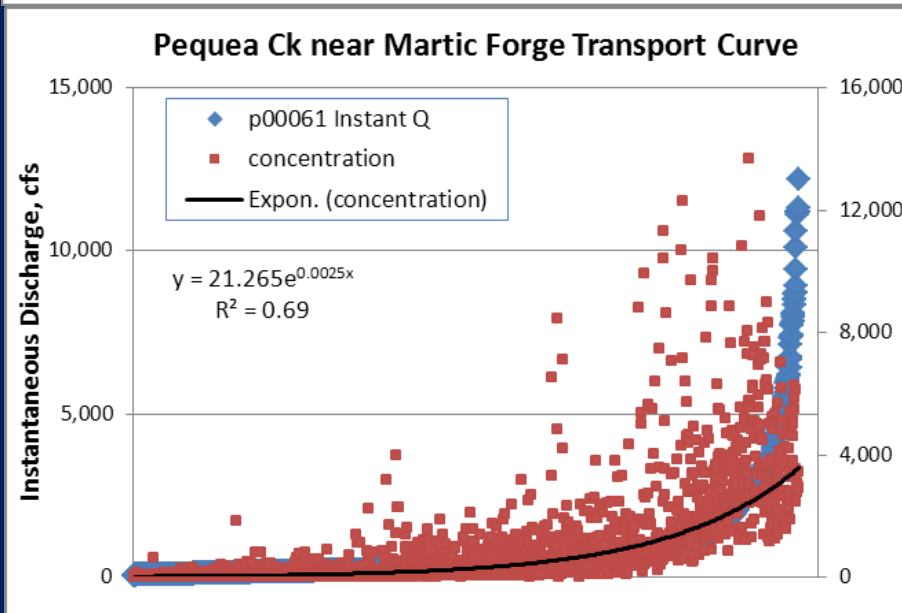
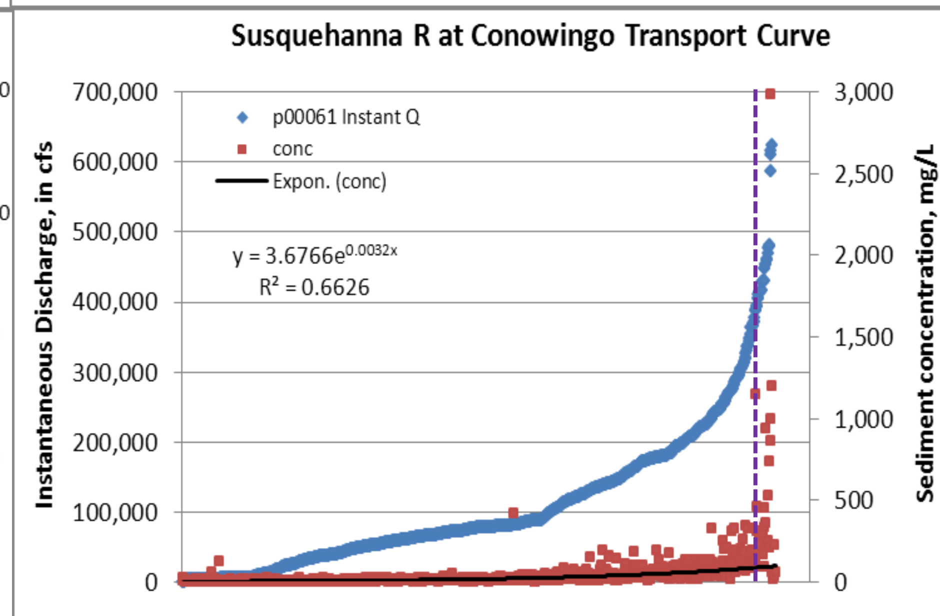
Sediment Transport Curves





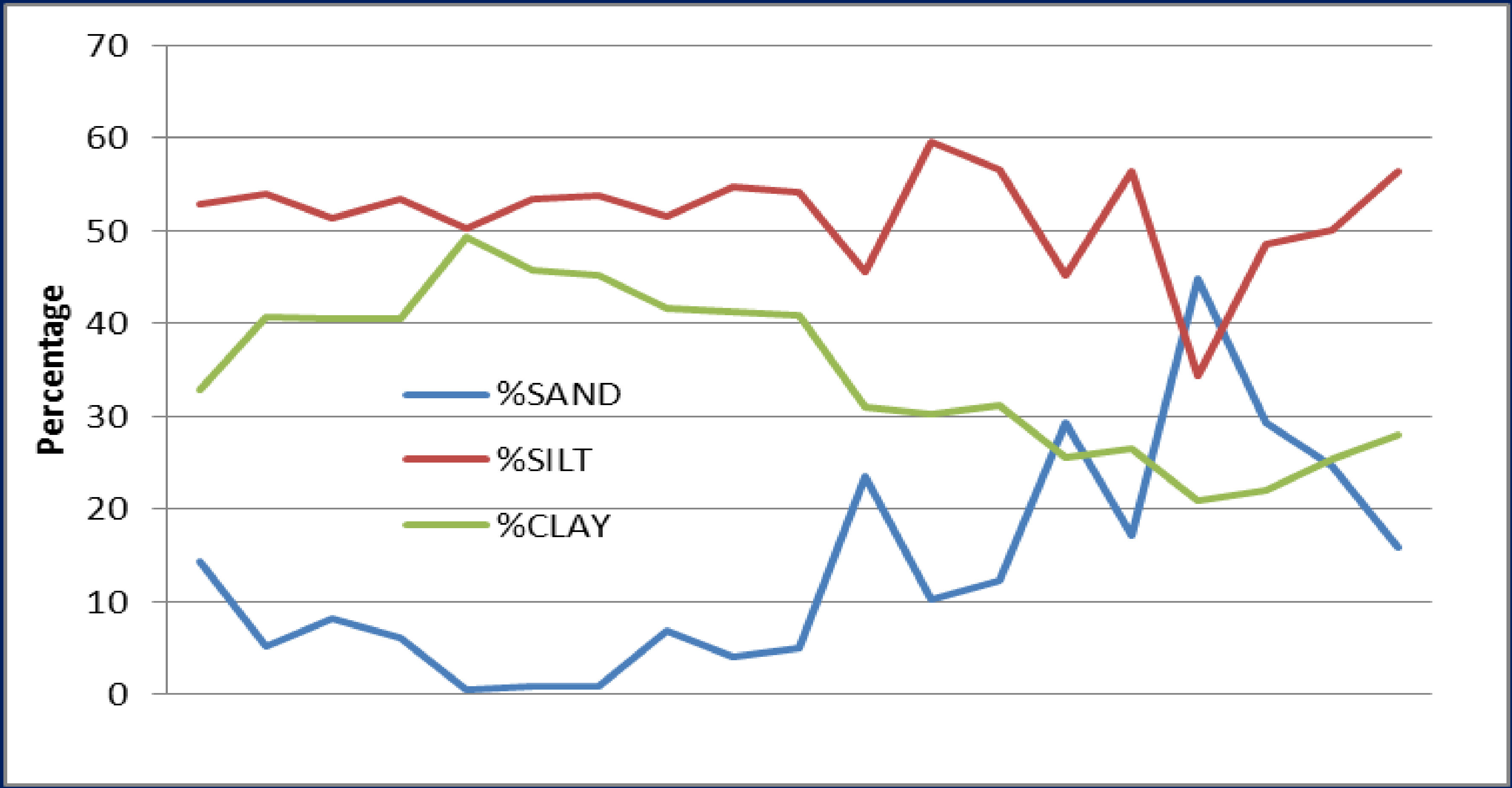




*Transport curves yielded low mass, used actual sediment data

Bed Material Particle Size (cores)

Generally, more sand, less silt and clay as upstream distance increases. (19 locations in Conowingo)



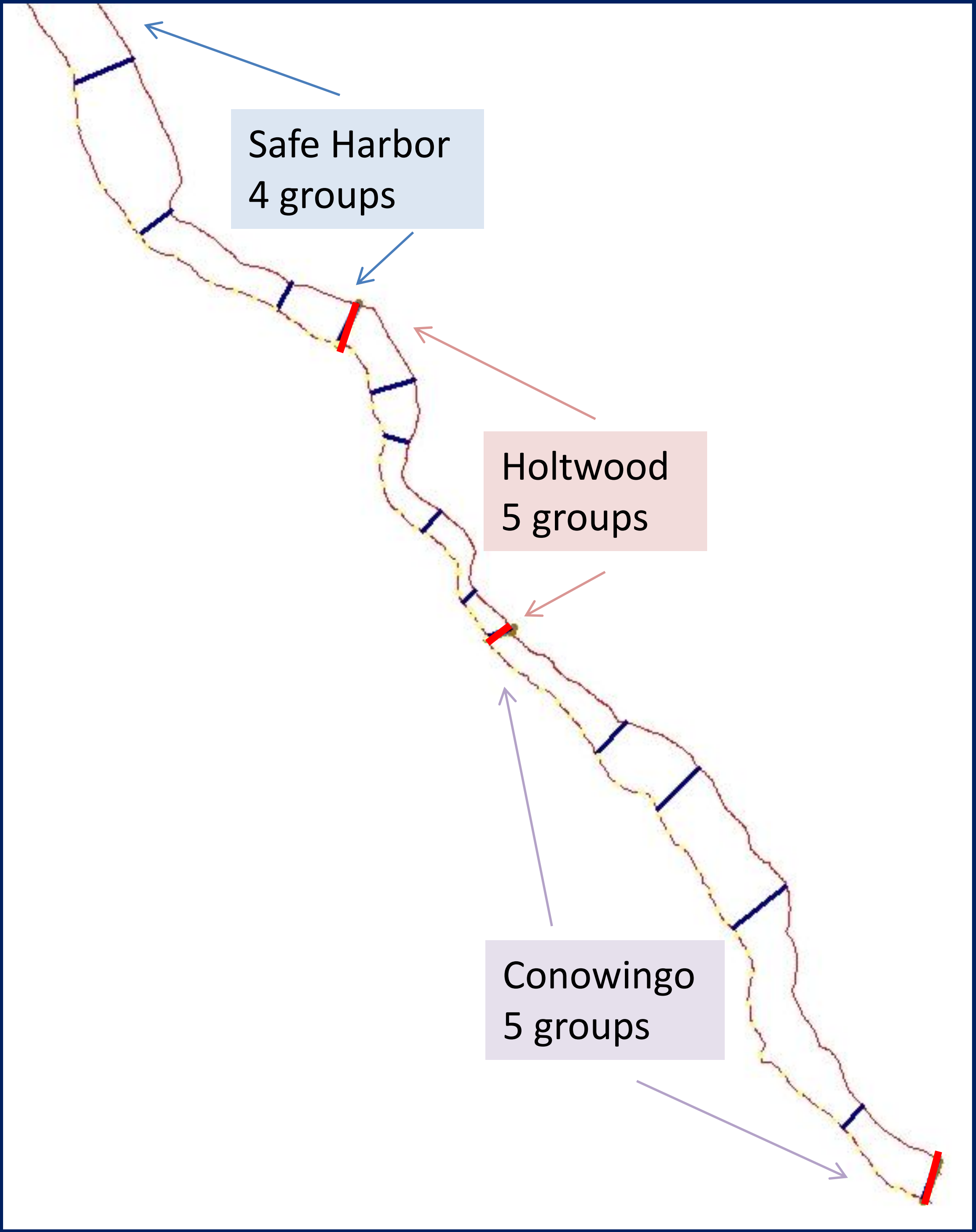
DOWN STREAM

UPSTREAM

Bed Material Grouping (cores)

Based on particle size and bed thickness

Assigned average shear stress based on USACE Sediment Flume data



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Model Geometry

Geometric Options :

- Adapt previous HEC-6 model (USGS, 1995)
- Convert HEC-2 (FIS) model to RAS sediment model
- Construct new RAS sediment model

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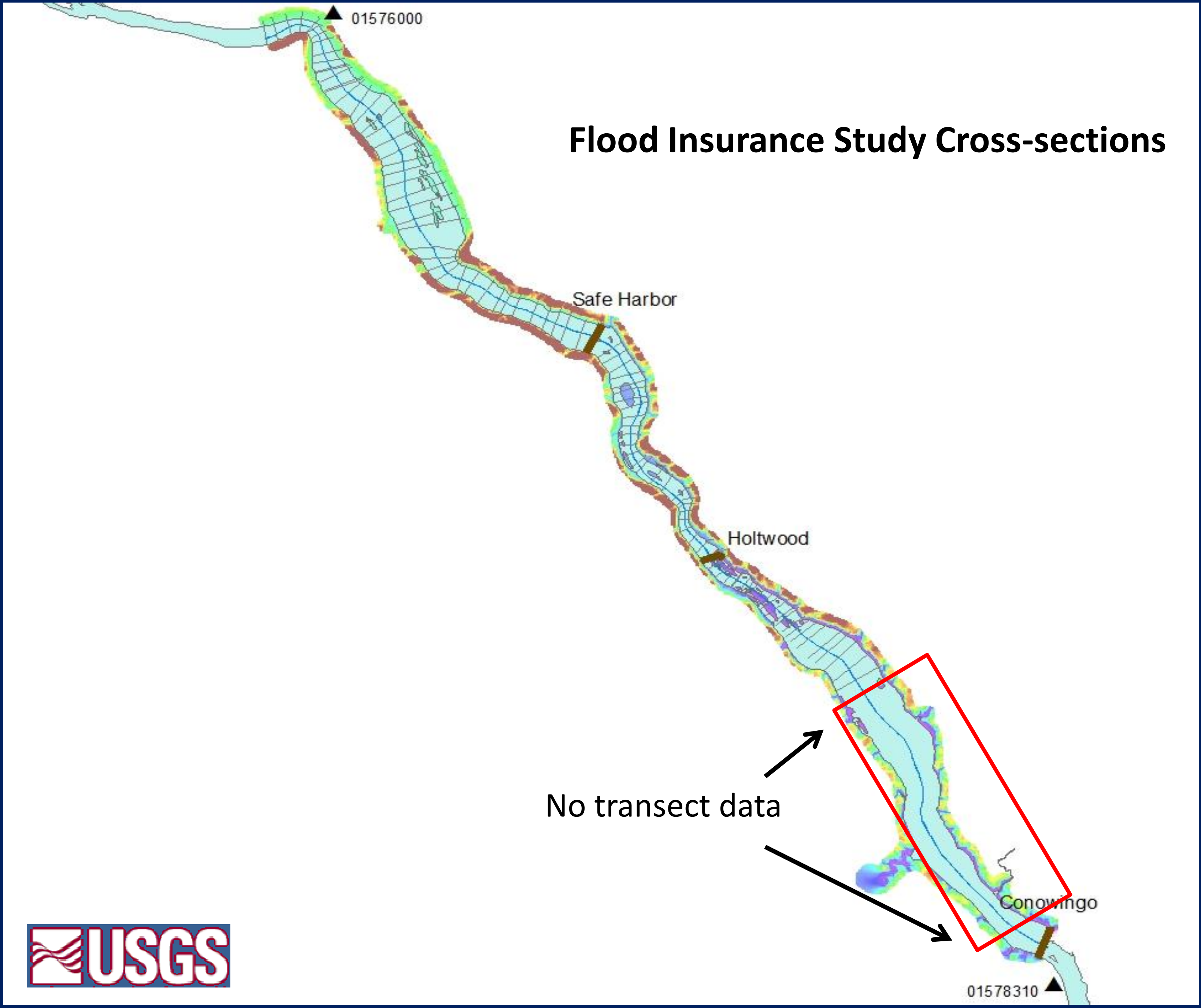
Options :

- Adapt HEC-6 model (USGS, 1995)
  - Performed poorly, no digital files
- Convert HEC-2 (FIS) model to RAS sed model
  - Covers 75% of reach, XS stationing errors, no XS bathymetry, and poor alignment current bathymetry
- Construct new RAS model
  - Alignment of XS cut lines with current bathymetry
  - Model geometry better suited for sediment model (i.e., no structures, fewer XS)
  - Use Lidar-derived topography for channel banks

Flood Insurance Study Cross-sections



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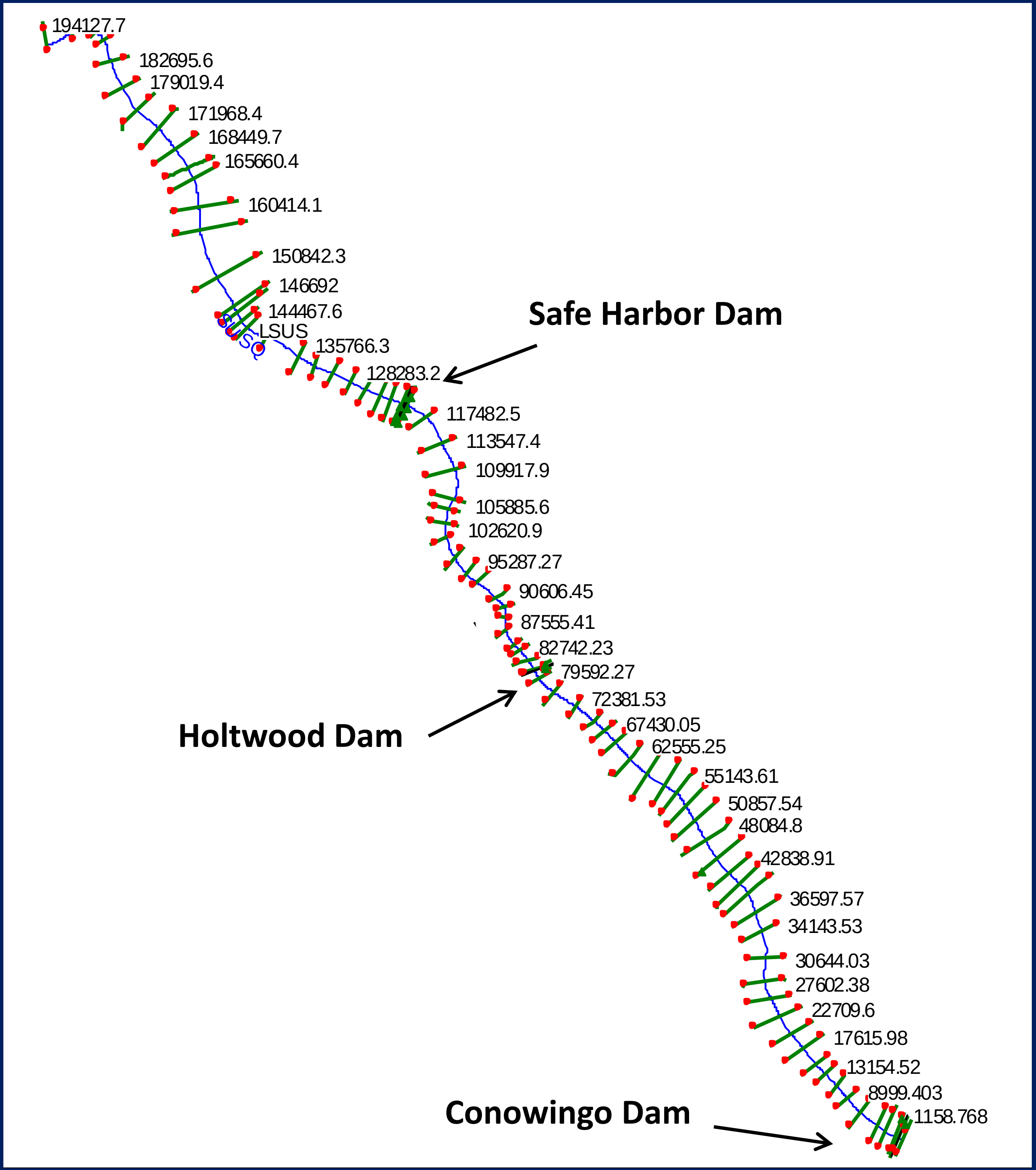
Final Model Cross-sections

34 in Conowingo
18 In Holtwood
28 in Safe Harbor
80 X-sections

Avg one X-section every 0.4 mile



Hydraulics

Hydraulic Options :

- Discharge Rating Curve
- Actual daily value discharge

Gate and Spillway Simulation

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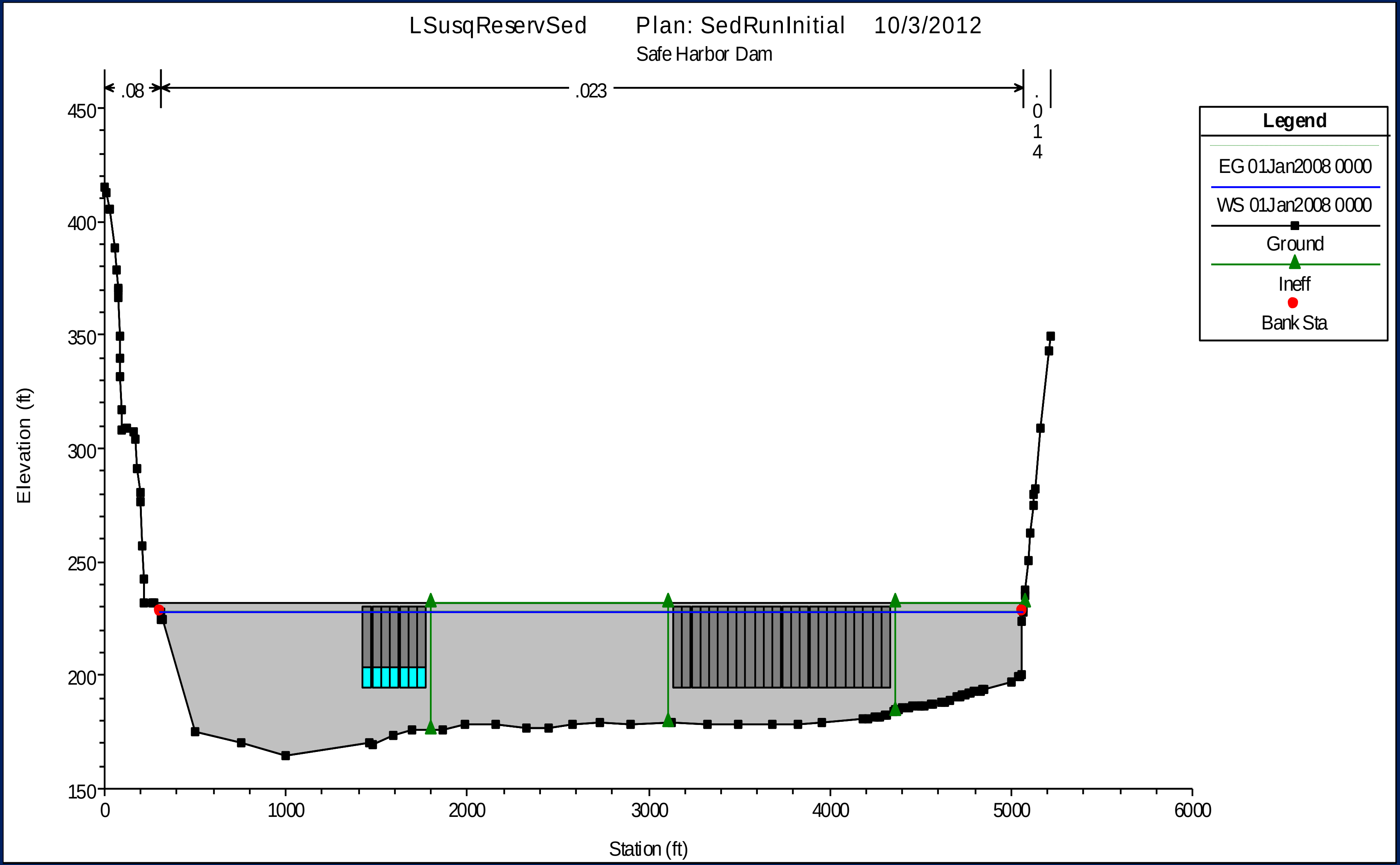
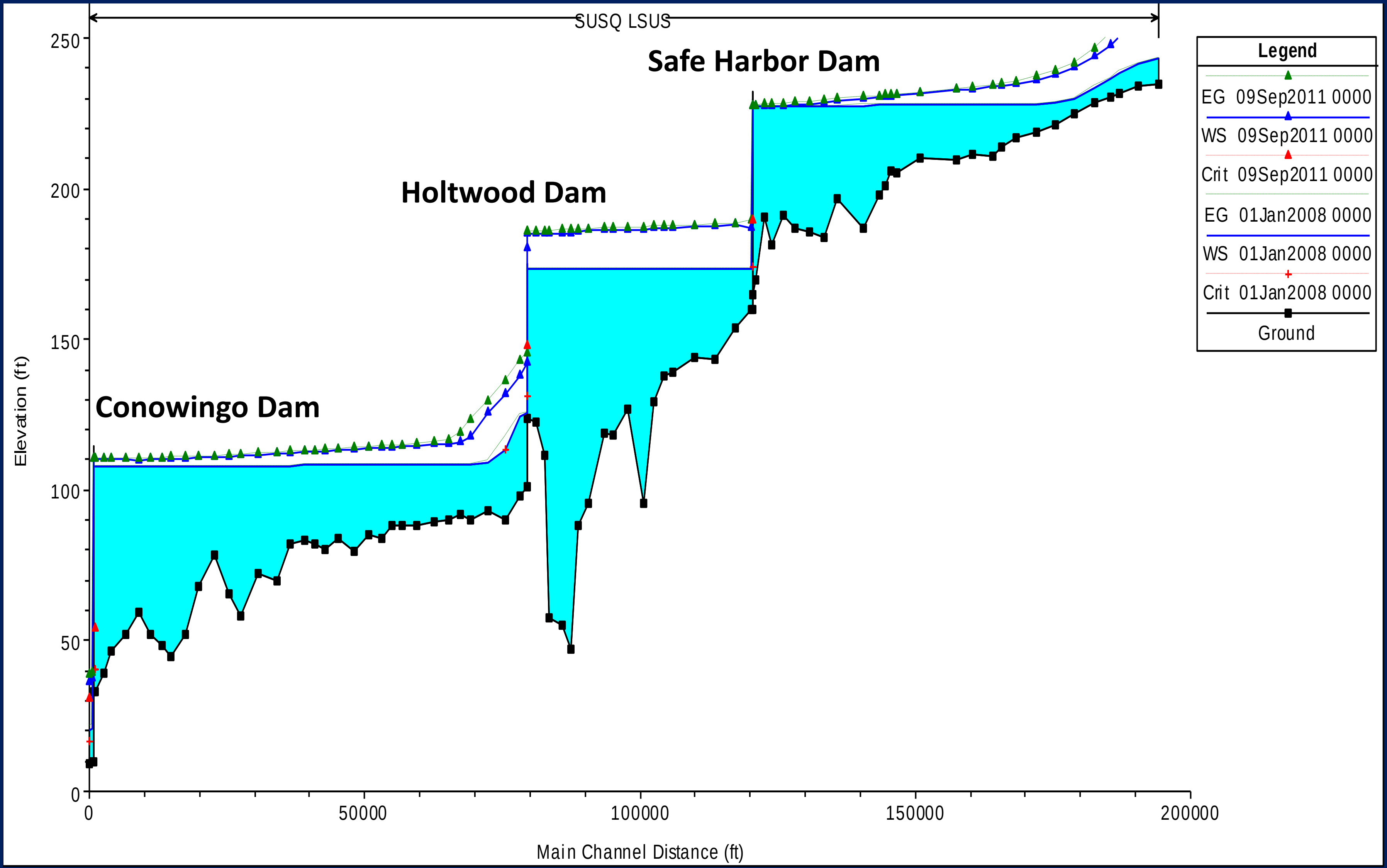
Gate Representation (Safe Harbor)



Reservoir System Hydraulic Representation



HEC-RAS Model – 3 main steps

1) Prepare Input data – sediment and flow

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Simulation targets ("calibration" data)

- Reasonable estimates of particle size distributions and sediment depth's in the Reservoir System.
- Bathymetry from 2008 and 2011 surveys
- Daily streamflow and sediment loads for 2008-2012
- More detailed sediment load from Sept. 2011 flood (Tropical storm Lee)

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Model Calibration Issues

- 2008-2011 Bathymetry data indicates both deposition and scour in same X-Section, 1-D model simulates only one occurrence
- Modeled “fall velocity” (silts and clays) about 2X lower (lack of deposition) then expected from literature values and 2-D model, and could not adjust values
- Model only allows one critical shear stress value, SEDFLUME data indicates wide variability (8x)
- Increasing the critical shear resulted in an increase in scour (contradictory effect)

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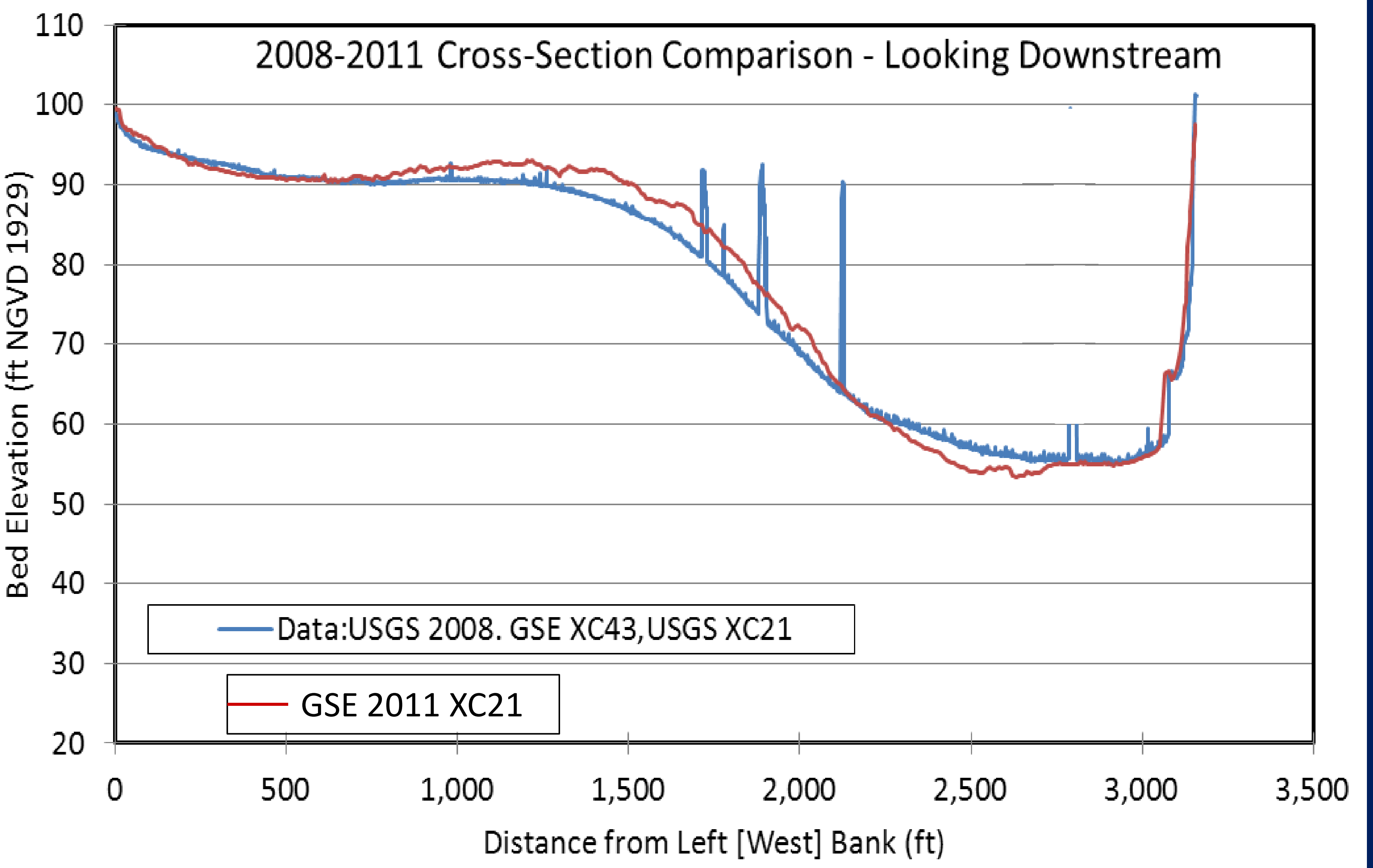

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
30
20
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Distance from Left [West] Bank (ft)
Data:USGS 2008. GSE XC43,USGS XC21
GSE 2011 XC21

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Results – Model Development

- Due to uncertainty (fall-velocity and bed sorting), built and verified 2 models, one net "depositional" one net "scour"
- Both boundary condition outputs delivered to Steve (USACE) for 2-D model
- "Depositional" model recommended and produced "best" overall results
- "Scour" model performed better for T.S. Lee and other short-term high flow scour events
- Allows for range in uncertainty

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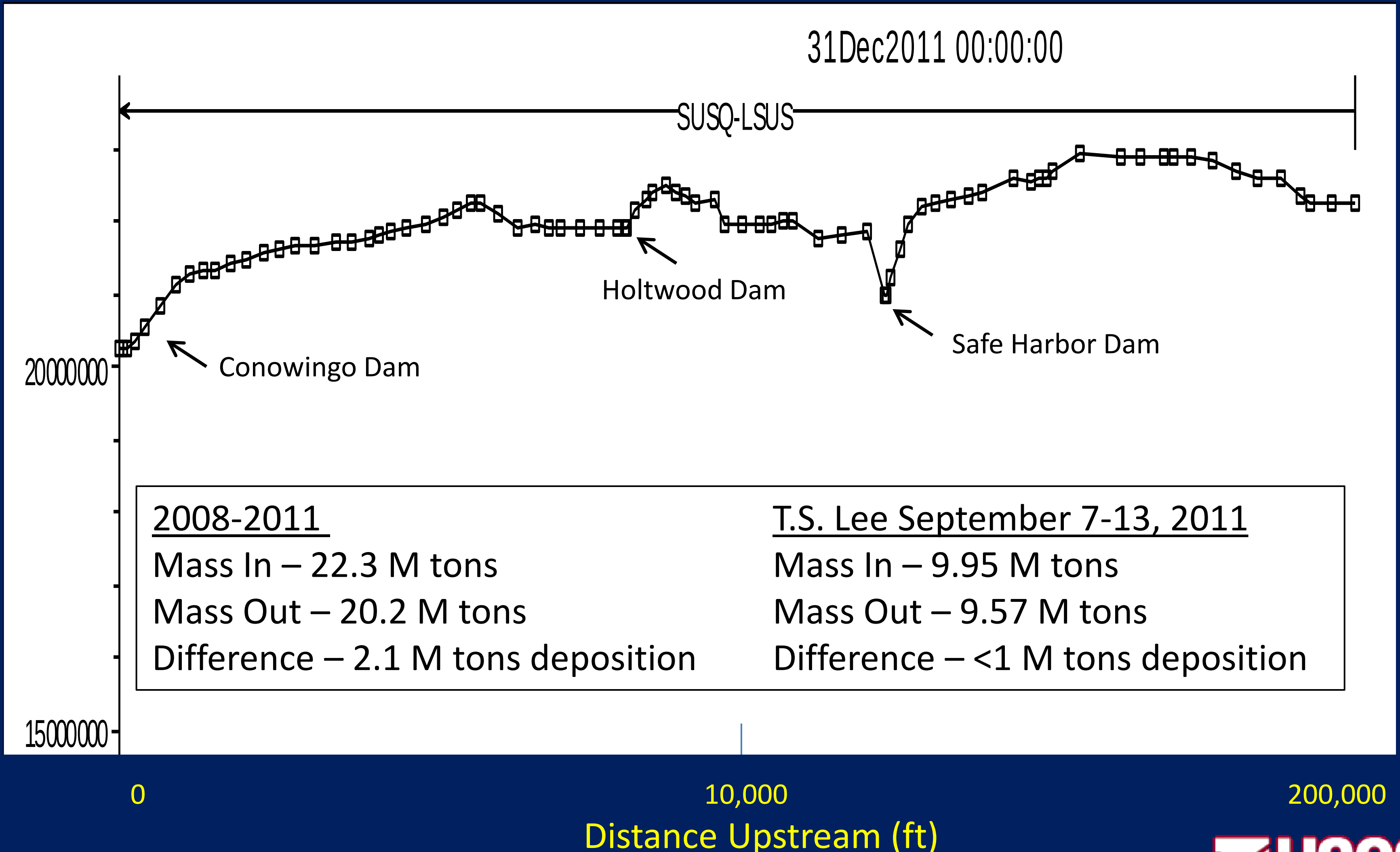
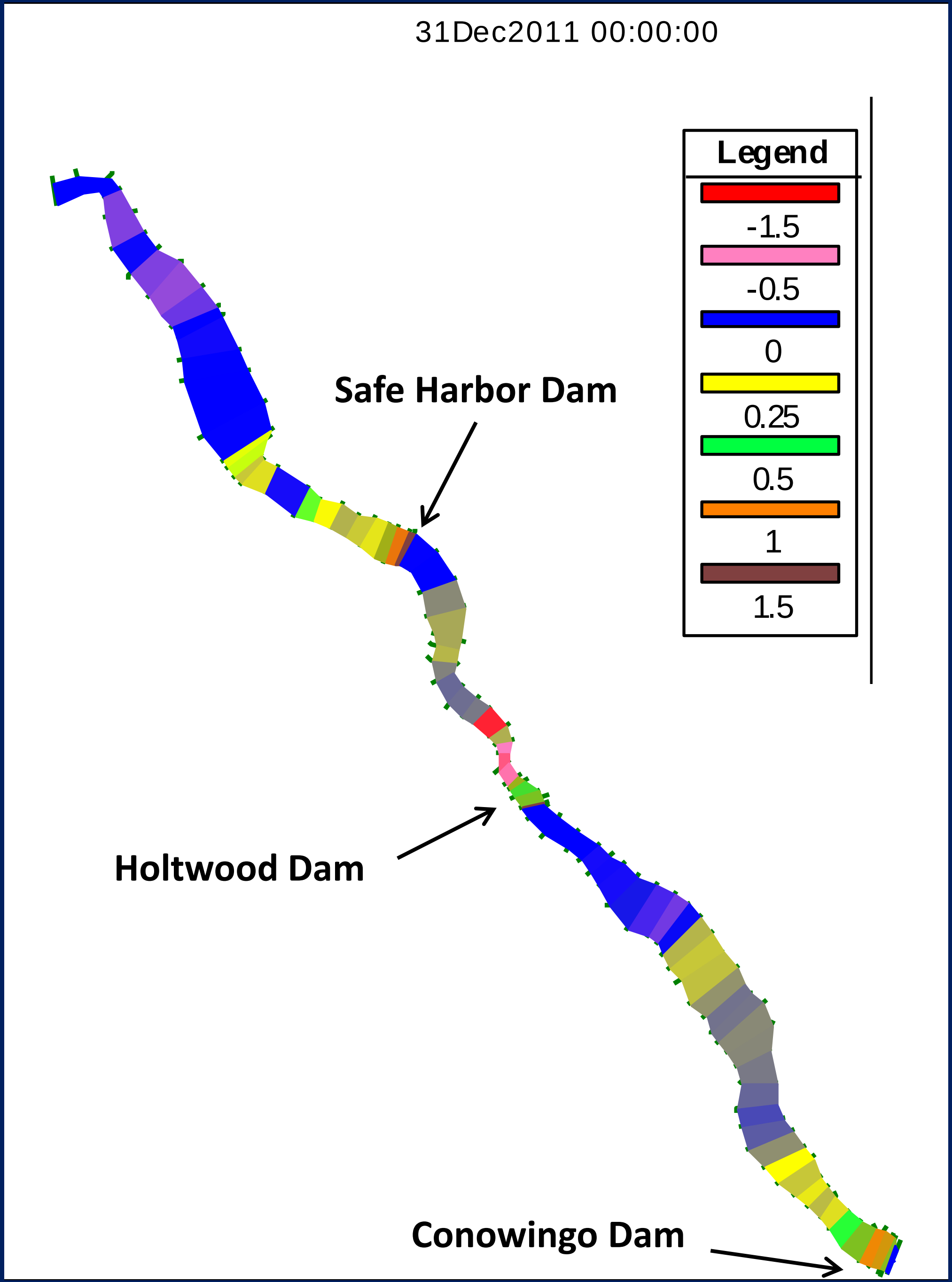
HEC-RAS Deposition Model

(Transport Function – *Laursen (Copeland)*, Sorting Method – *Exner5*, Fall Velocity Method – *Ruby*, Cohesive shear – *0.018 lbs/sqft*))

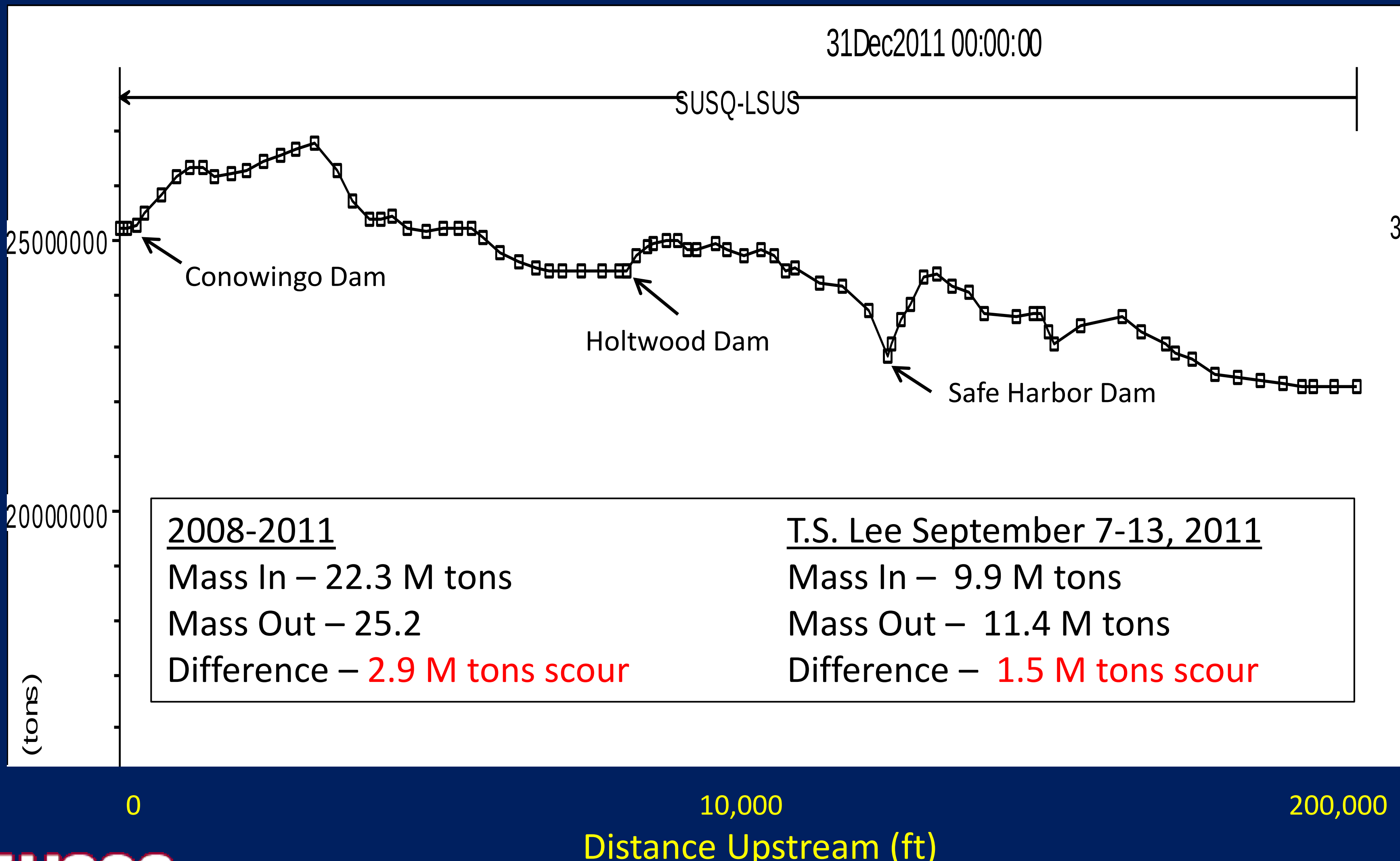


HEC-RAS Deposition Model – Bed Elevation Change (ft)



HEC-RAS Scour Model

(Transport Function – *Laursen (Copeland)*, **Sorting Method - *Active Layer***, **Fall Velocity Method – *Van Rijn***, Cohesive shear – *0.018 lbs/sq ft*))



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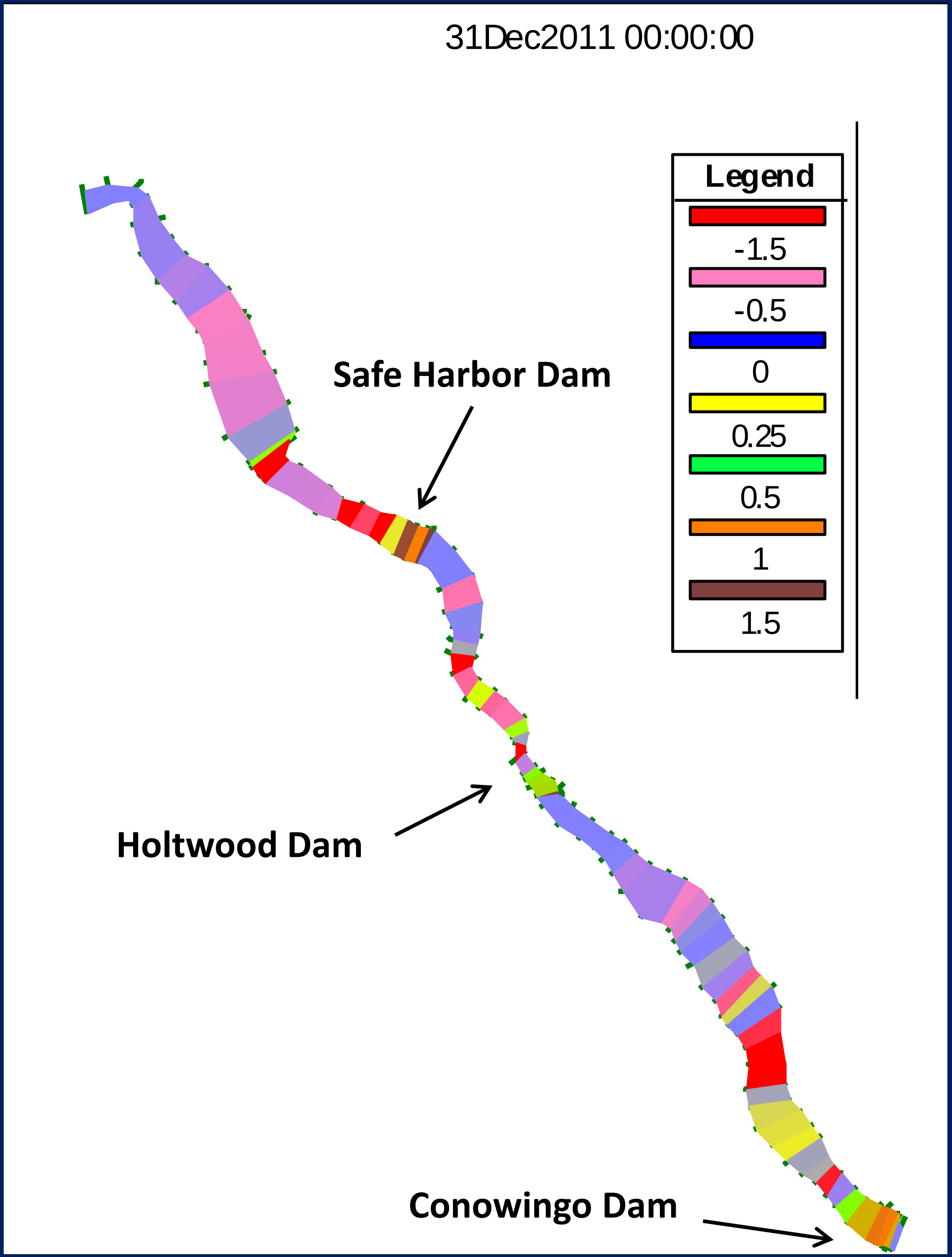
HEC-RAS Scour Model – Bed Elevation Change (ft)



Model Results – Sediment Transport (tons)

	Loads (tons)			
HEC-RAS (depositional)	CY 2008-2011	difference	TS Lee (Sept 7-13, 2011)	difference
Marietta IN	22,300,000		9,950,000	
Conowingo IN	22,100,000	200,000	10,100,000	-150,000
Conowingo OUT	20,200,000	2,100,000	9,570,000	530,000
HEC-RAS (scour)				
Marietta IN	22,300,000		9,950,000	
Conowingo IN	24,400,000	-2,100,000	10,300,000	-350,000
Conowingo OUT	25,200,000	-800,000	11,400,000	-1,100,000
USGS ESTIMATOR				
Marietta IN	22,300,000	--	9,950,000	--
Conowingo OUT	21,100,000	1,200,000	13,500,000	-3,500,000
WRTDS (B. Hirsch)	WY 2008-11		TS Lee	
Conowingo OUT	27,500,000	--	18,800,000	--

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Model results – Particle Size

HEC-RAS (depositional)	Particle Size		Historic Particle Size
	2008-2011	TS Lee	
	Sand/Silt/Clay	Sand/Silt/Clay	Sand/Silt/Clay
Marietta IN	10 / 47 / 42	10 / 47 / 42	9 / 47 / 44
Conowingo IN	3 / 47 / 50	5 / 50 / 45	n/a
Conowingo OUT	1 / 32 / 67	2 / 50 / 48	1 / 51 / 48

HEC-RAS (Scour)	2008-2011	TS Lee	Historic P.S.
	Sand/Silt/Clay	Sand/Silt/Clay	Sand/Silt/Clay
Marietta IN	10 / 47 / 42	10 / 47 / 42	9 / 47 / 44
Conowingo IN	2 / 48 / 50	5 / 51 / 44	n/a
Conowingo OUT	1 / 45 / 54	2 / 52 / 46	1 / 51 / 48

- Minor differences between models
- Good correspondence with historic particle size

Summary

- HEC-RAS generally not condusive for cohesive (silts/clays) simulations
- The 2 models provide a range of uncertainty in the boundary condition files
- Estimated total sediment transport most likely underestimated but “reasonable”
- Both models indicate upper 2 reservoirs still play a “role” in sediment transport

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