Lower Susquehanna River Reservoir System Proposed Modeling Enhancements

Presented at the
Chesapeake Bay Program
Scientific and Technical Advisory Committee
(STAC) Workshop

January 13, 2016

WEST Consultants, Inc.
HDR
Exelon Generation®

Overview

- Due to the lack of storms which have occurred since 2011 and the looming TMDL Midpoint Assessment deadline, the focus of the Lower Susquehanna River Integrated Sediment and Nutrient Monitoring Study has shifted from data collection to modeling enhancements in support of the CBP modeling efforts.
- This presentation will focus on proposed Lower Susquehanna River Reservoir System modeling enhancements, including:
  - ✓ Development of a HEC-RAS Unsteady Sediment Transport Model from Marietta, PA to Holtwood Dam, and
  - ✓ Development of a coupled hydrodynamic sediment transport and nutrient flux model of Conowingo Pond.
- The ultimate goal of these efforts will be to 1) improve the parameterization of the CBP Watershed Model from Marietta, PA to Holtwood, and 2) improve the input parameters to be used in WQSTM.
- Following this workshop, the Exelon team will be submitting a detailed work plan to STAC and the CBP Modeling Workgroup for review.

HEC-RAS Unsteady Sediment Transport Modeling –

Marietta, PA to Holtwood Dam

Topics

- Background – Previous Studies
- Current Study
  - ✓ General
  - ✓ Boundary Conditions
  - ✓ Hydraulics
  - ✓ Sediment
- Preliminary Results
- Measured Reservoir Volume Changes
- Next Steps

Holtwood Dam, September 10, 2011
(TheGates1210 on YouTube)

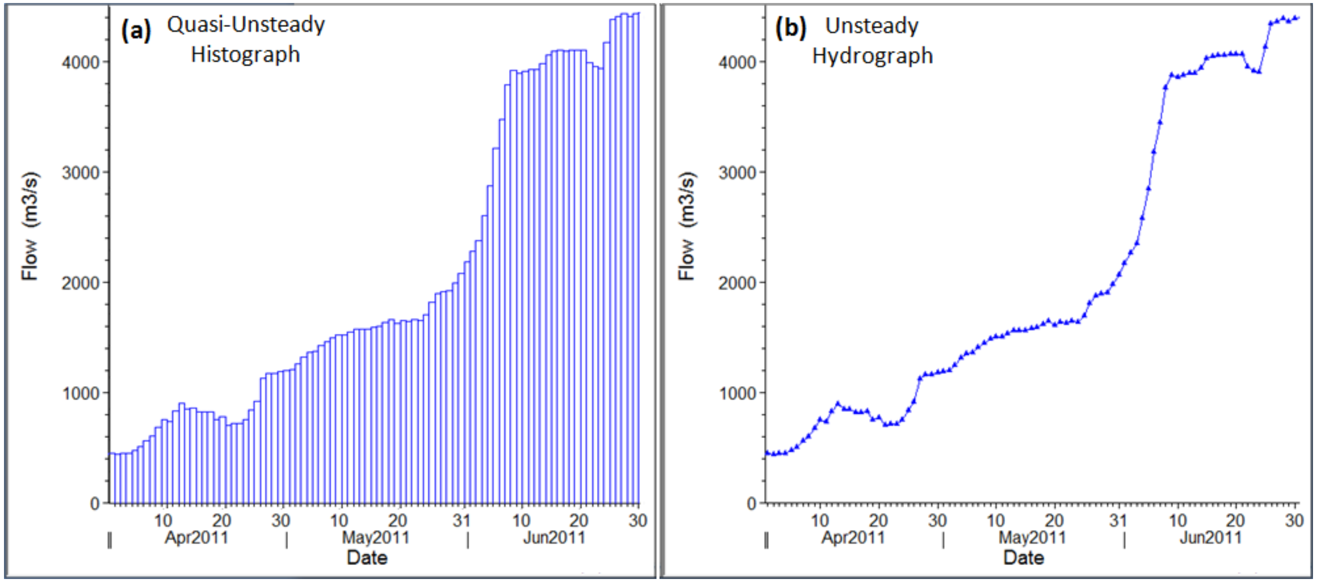
Background – Previous Sediment Transport Studies

- **Hainly, Reed, Flippo & Barton (WRIR 95-4122, 1995)**
  - ✓ U.S. Army Corps of Engineers HEC-6 Model (quasi-unsteady)
  - ✓ Marietta, PA to Conowingo Dam
  - ✓ Cohesive & non-cohesive sediments
  - ✓ Calibrated to calendar year 1987 flows, verified with 1988-1989 events
  - ✓ Computed trap efficiency low compared to measured trap efficiency over entire system, coarsened inflow sediment sizes to compensate

- **Langland & Koerkle (2014)**
  - ✓ U.S. Army Corps of Engineers HEC-RAS Model (quasi-unsteady)
  - ✓ Marietta, PA to Conowingo Dam, cross sections based on 2008/1996 bathymetry
  - ✓ Calibrated to computed volume changes 2008-2011 and measured sediment outflows at Conowingo Dam
  - ✓ Two models: 2008-2011 (net deposition), September 7-13, 2011 (TS Lee, net scour)

Current Study

- **General**
  - ✓ U.S. Army Corps of Engineers HEC-RAS 5.0 Beta Model (**unsteady**)
    - ✓ Instead of approximating the hydrodynamics as a series of steady flows, unsteady sediment transport solves the unsteady flow equation, routing flow through the model and explicitly accounting for storage and travel time
    - ✓ Unsteady flow conserves volume, important in reservoir systems
  - ✓ Marietta, PA to Holtwood Dam
  - ✓ Cohesive & non-cohesive sediments



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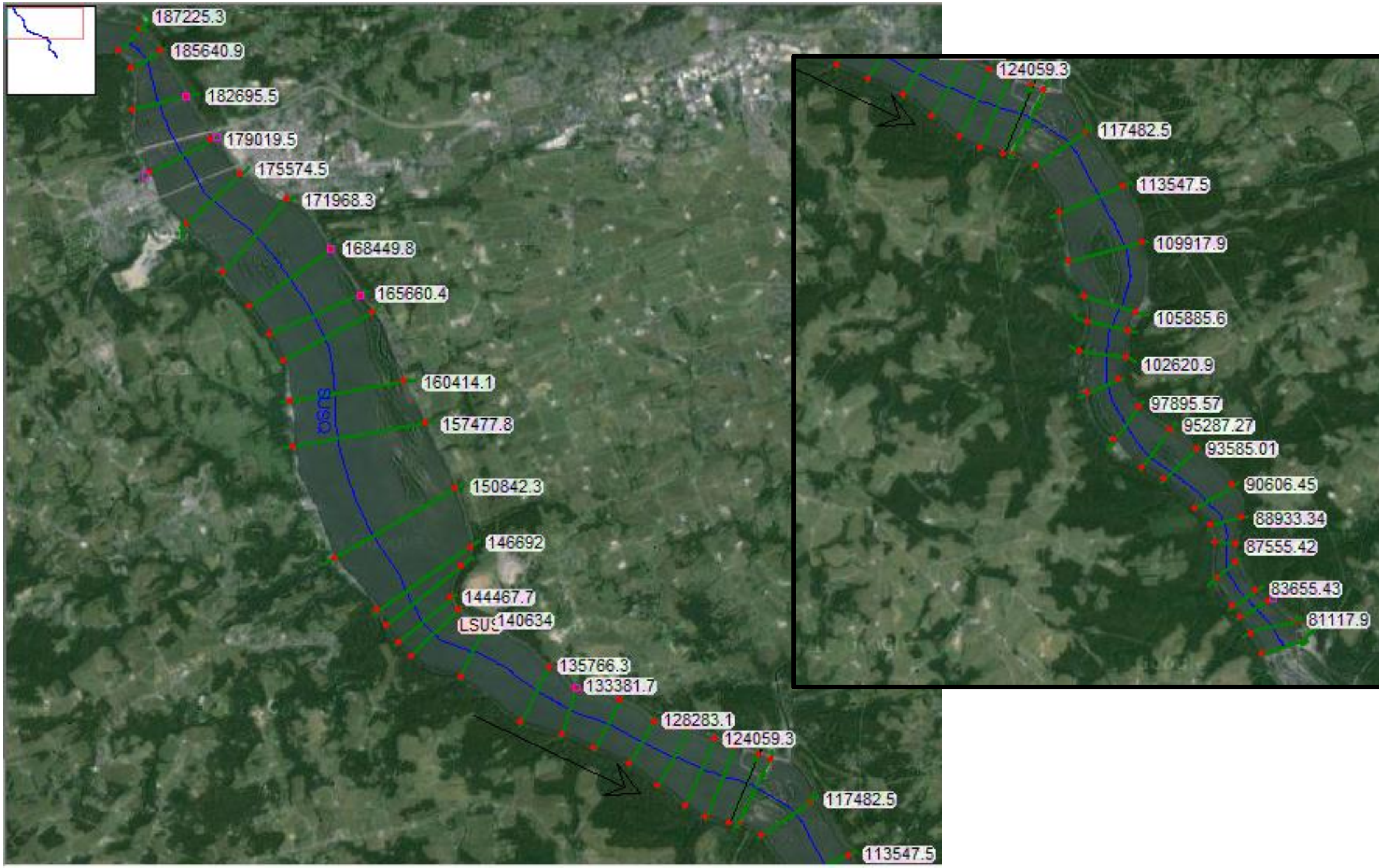
Current Study (cont'd)



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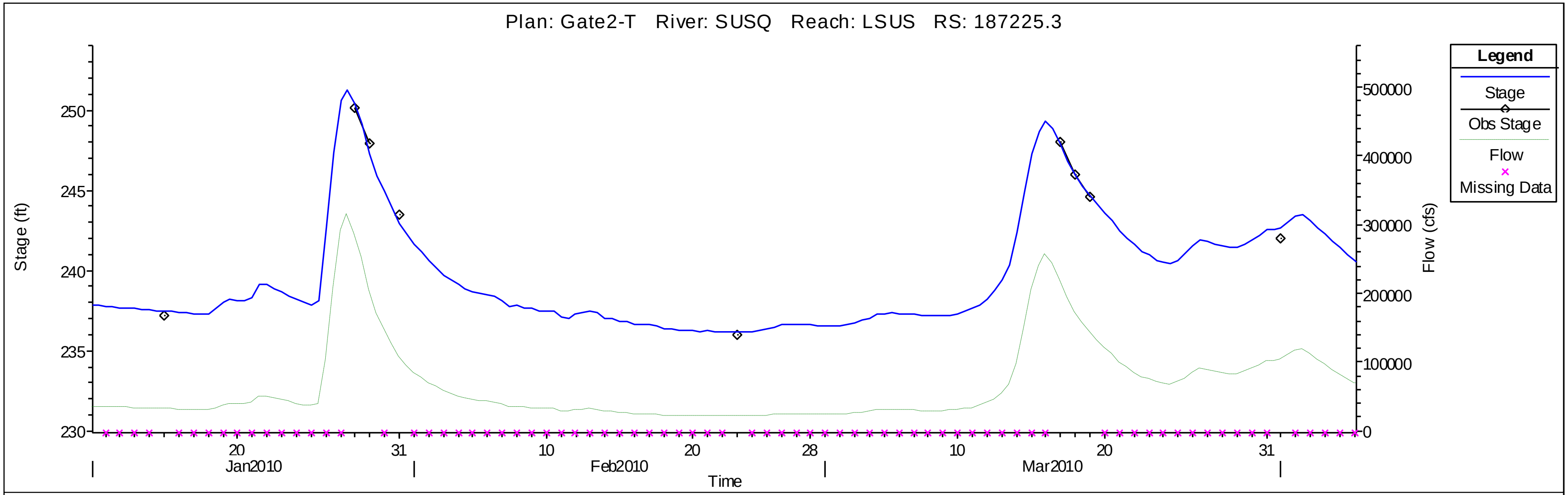
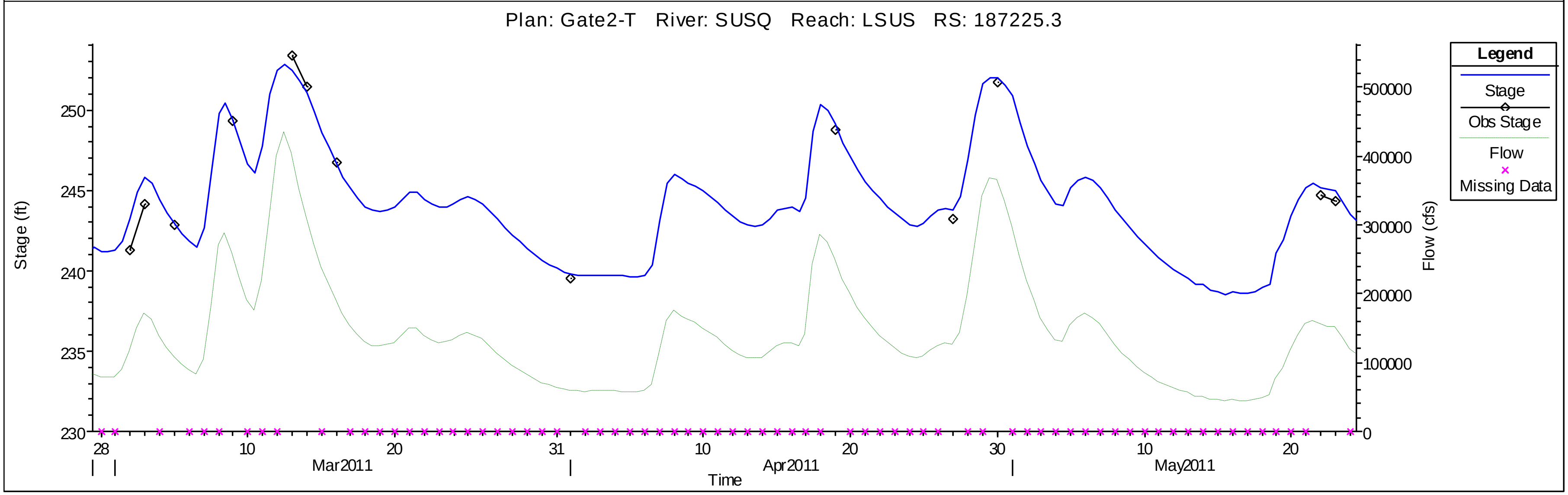
Current Study (cont'd)

- **Boundary Conditions**
  - ✓ Flow, inflowing sediment load at Marietta (USGS gage)
    - ✓ 24-hr time series combining gage data when available and rating curve-generated data when not OR
    - ✓ Sediment-discharge rating curve
  - ✓ Tributary flows and sediment loading from Conestoga River and Pequea Creek only (USGS gages)
    - ✓ No accounting for other tributary water or sediment inflows
  - ✓ *Stage at Holtwood – water surface elevation versus discharge rating curve*
  - ✓ *Gate operations at Safe Harbor*

- **Hydraulics**
  - ✓ Plan to use cross sections from Langland RAS model (2008/1996 bathymetry), adjusted hydraulic property tables, minor XS properties
  - ✓ Preserved roughness, but adjusted via factors during calibration
  - ✓ Calibrated computed water surface elevations (WSELs) to measured WSELs at Marietta via blanket roughness multiplication factors by flow rate and season 2008-2011
  - ✓ Unsteady flow simulation conserves volume in the system

Hydraulic Calibration at Marietta





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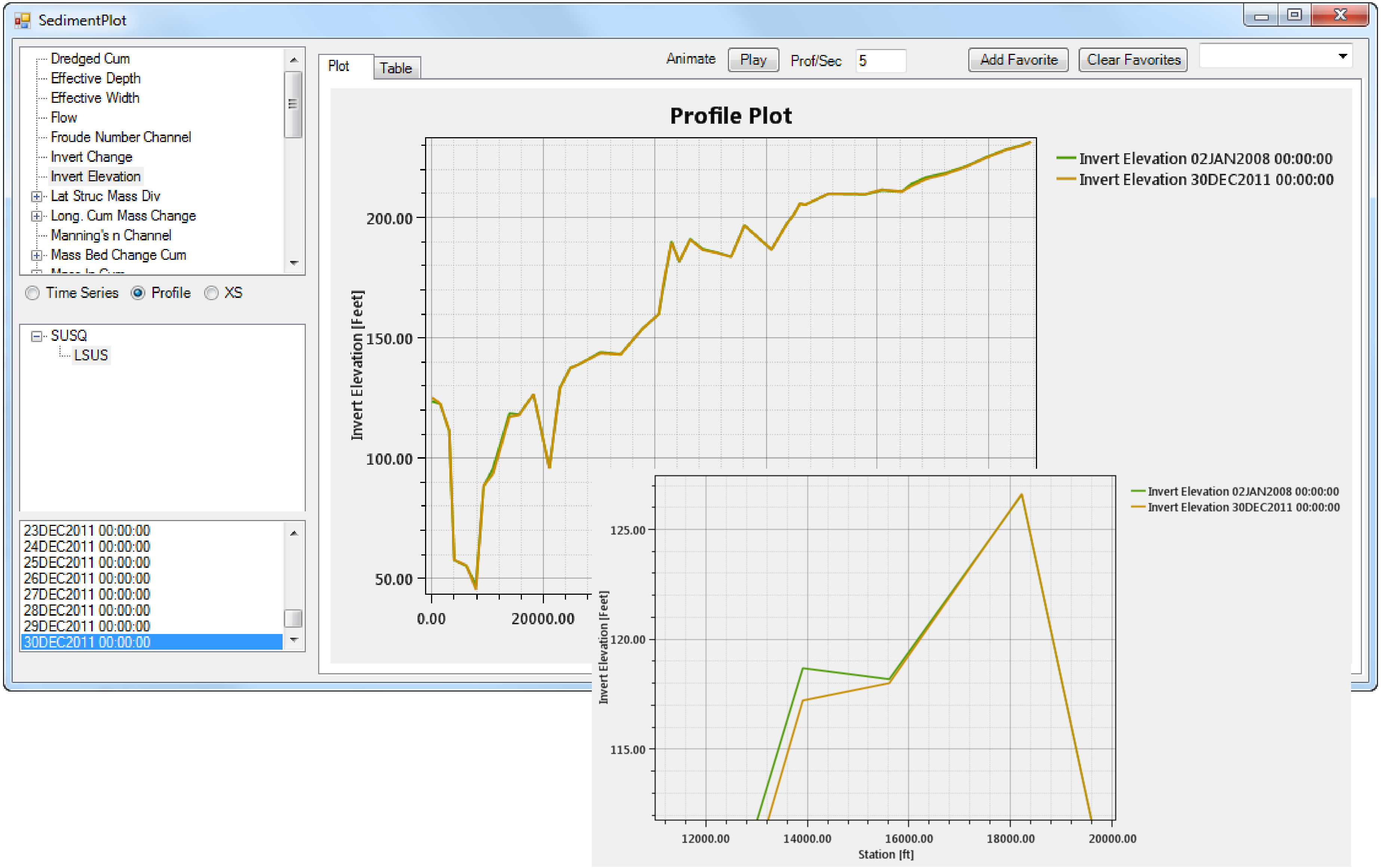
Current Study (cont'd)

- **Sediment**
  - ✓ Susquehanna inflowing sediment from Marietta gage, added in 2% for unmeasured/bed load.
  - ✓ Additional inflows from Conestoga and Pequea tributaries.
    - ✓ Created rating curves relating discharge and load. Combined data from USGS and SRBC records; used over 1800 records from 1984 - 2014 for Conestoga and almost 2000 records from 1977 - 2014 for Pequea. Size fractions in inflowing sediment initially taken from HEC-6 model after examining few available gradation curves.
    - ✓ Very limited suspended particle size distribution data; relationships weak and opposite expected (higher percentage of coarse particles at lower discharges) .
  - ✓ Bed sediment properties - grouped by location, 10 averaged gradations for the two reservoirs. For cross sections without nearby sediment data, applied gradation from closest cross section.
  - ✓ Cohesive properties – looked at ranges of applicable shear stresses from Conowingo SedFlume data. No apparent correlation with grain size or density of samples. Work in progress.
  - ✓ Started with Laursen-Copeland transport method and Report 12 fall velocity method.
  - ✓ Unsteady simulation allows for varying discharges and shear stresses at different points in the system at any given time.

Preliminary Results



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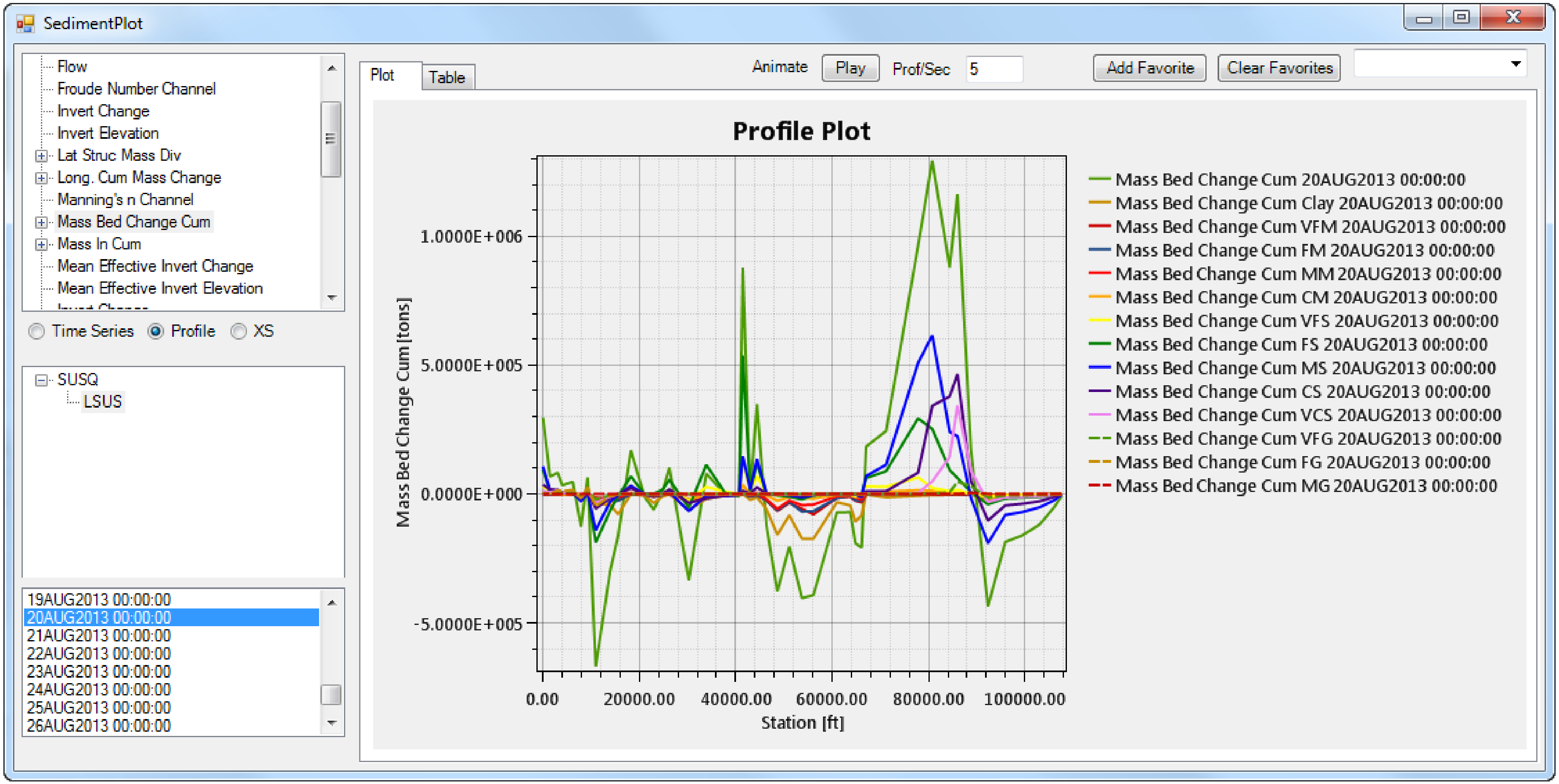
Preliminary Results



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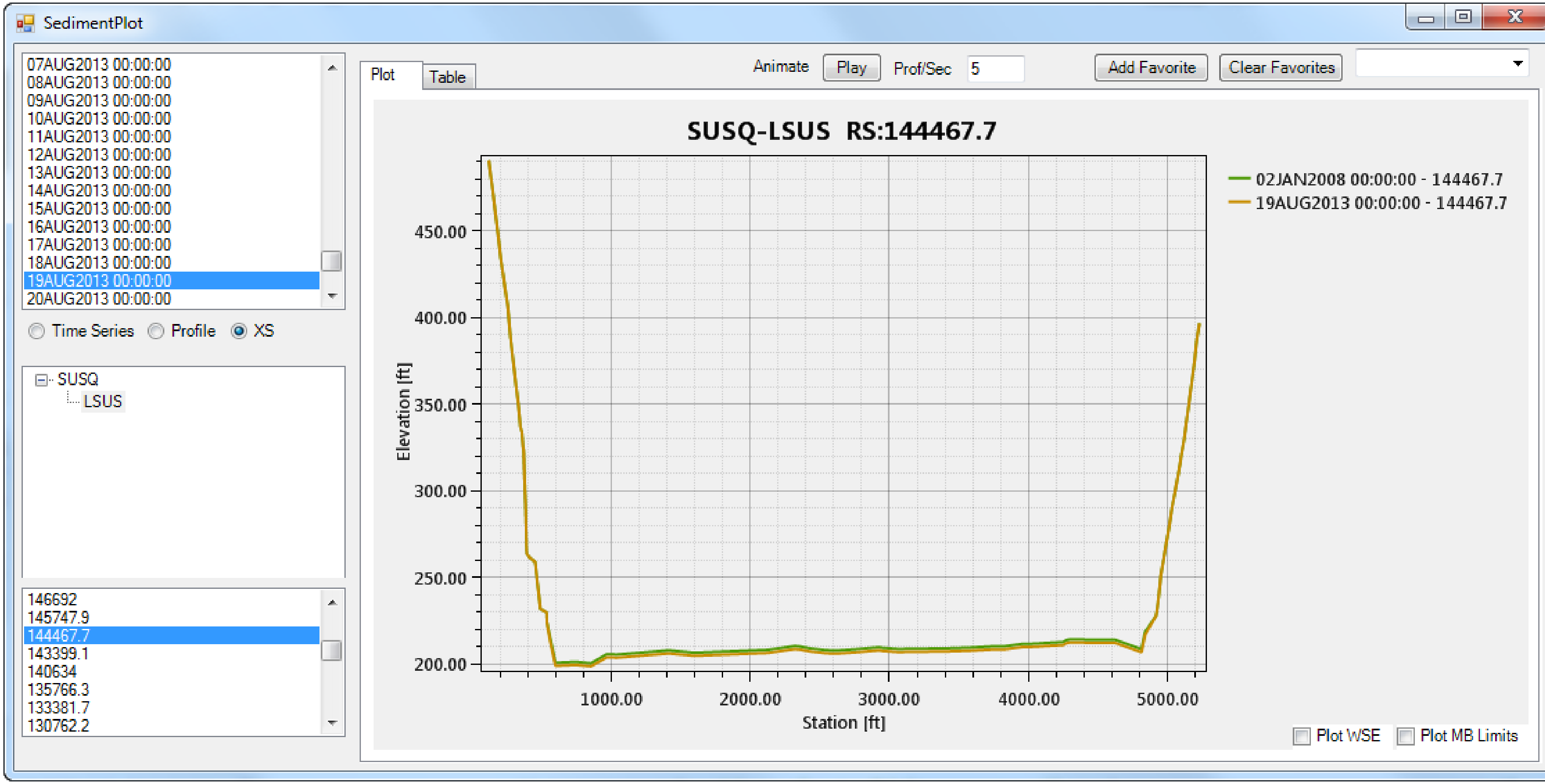
Preliminary Results



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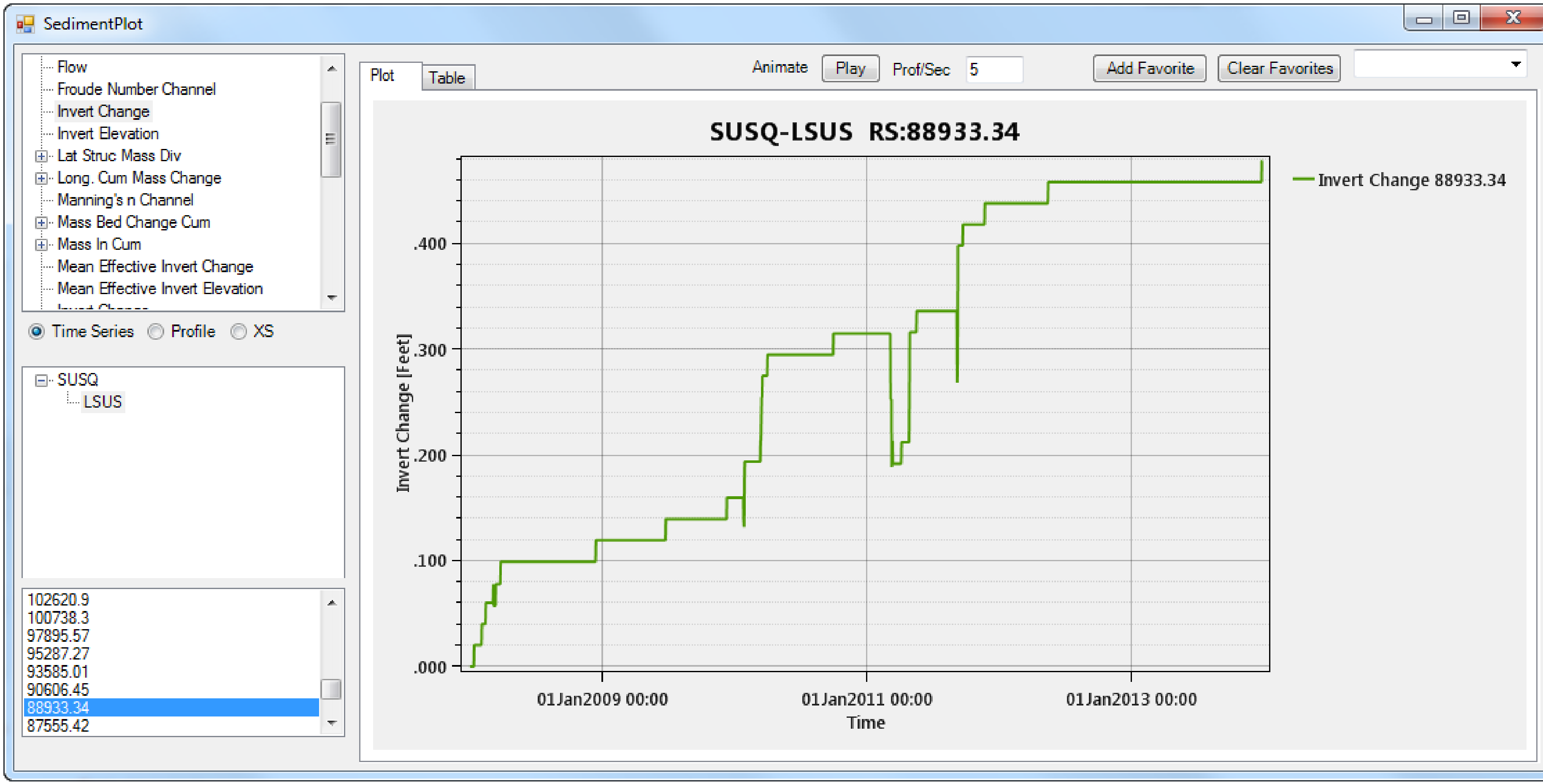
Preliminary Results



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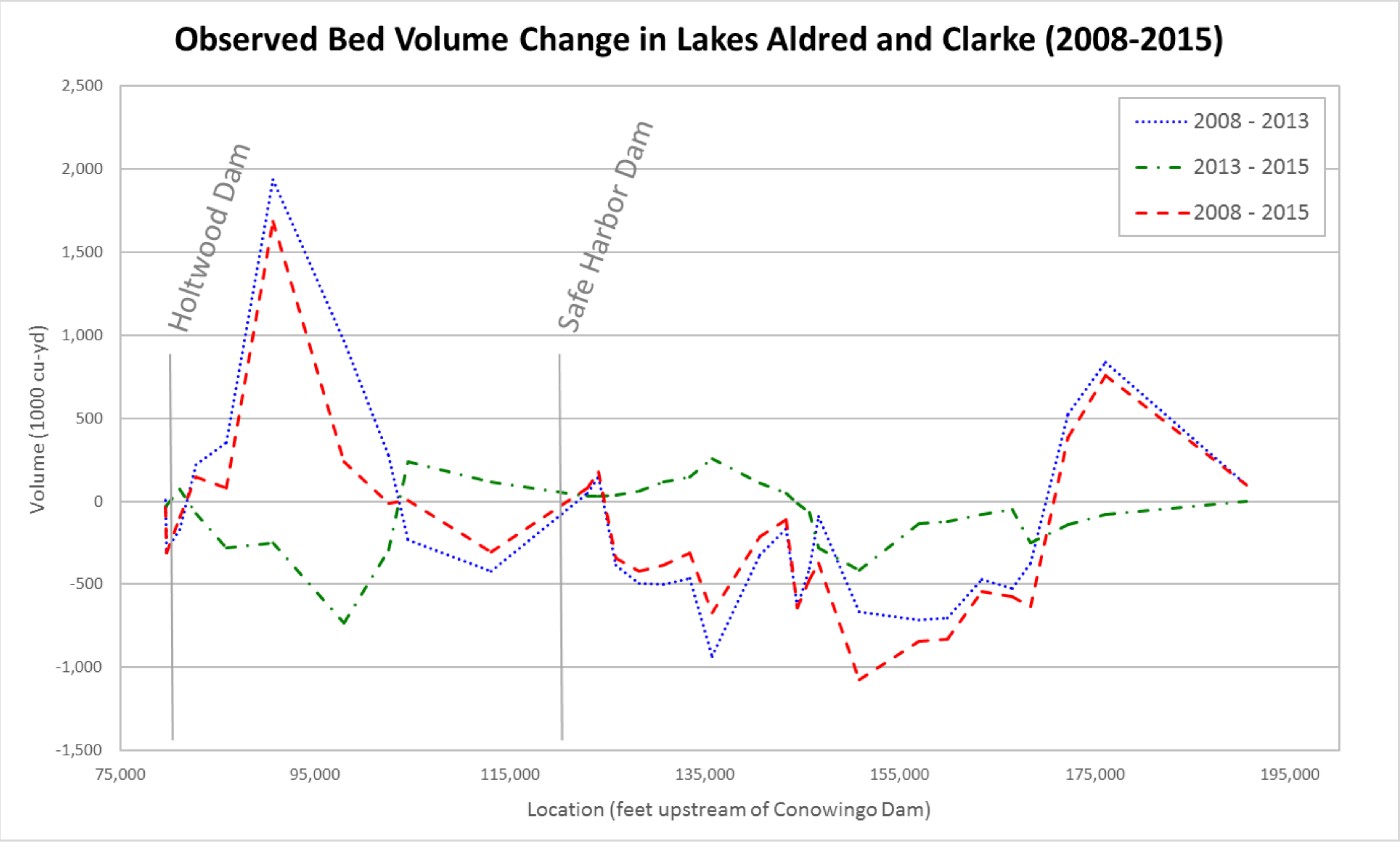
Measured Reservoir Volume Changes



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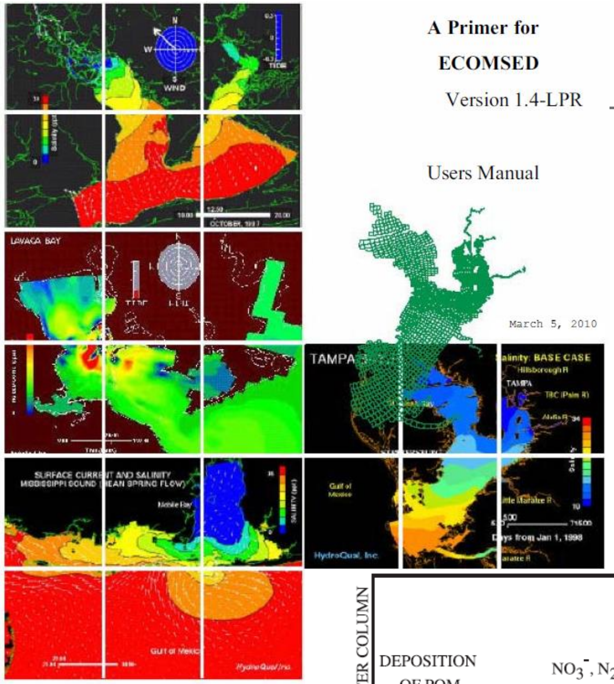
Next Steps

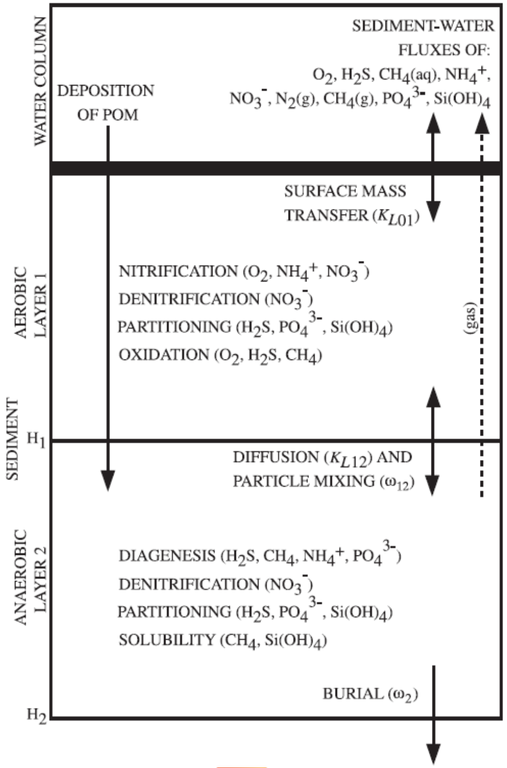
- Model Calibration
  - ✓ Compare computed volume changes to measured changes 2008-2013
  - ✓ Adjust model parameters to achieve reasonable match
- Model Verification
  - ✓ Take calibrated model, run simulation for the 2013-2015 period
  - ✓ If computed results are not good compared to observations, return to calibration and make further adjustment, compare results for both calibration and verification periods
- Sediment Rating Curves
  - ✓ Sediment outflow by size class versus discharge at Holtwood Dam
  - ✓ To be used with re-parameterization of HSPF, input to HDR Conowingo model

CONOWINGO POND MASS BALANCE MODEL

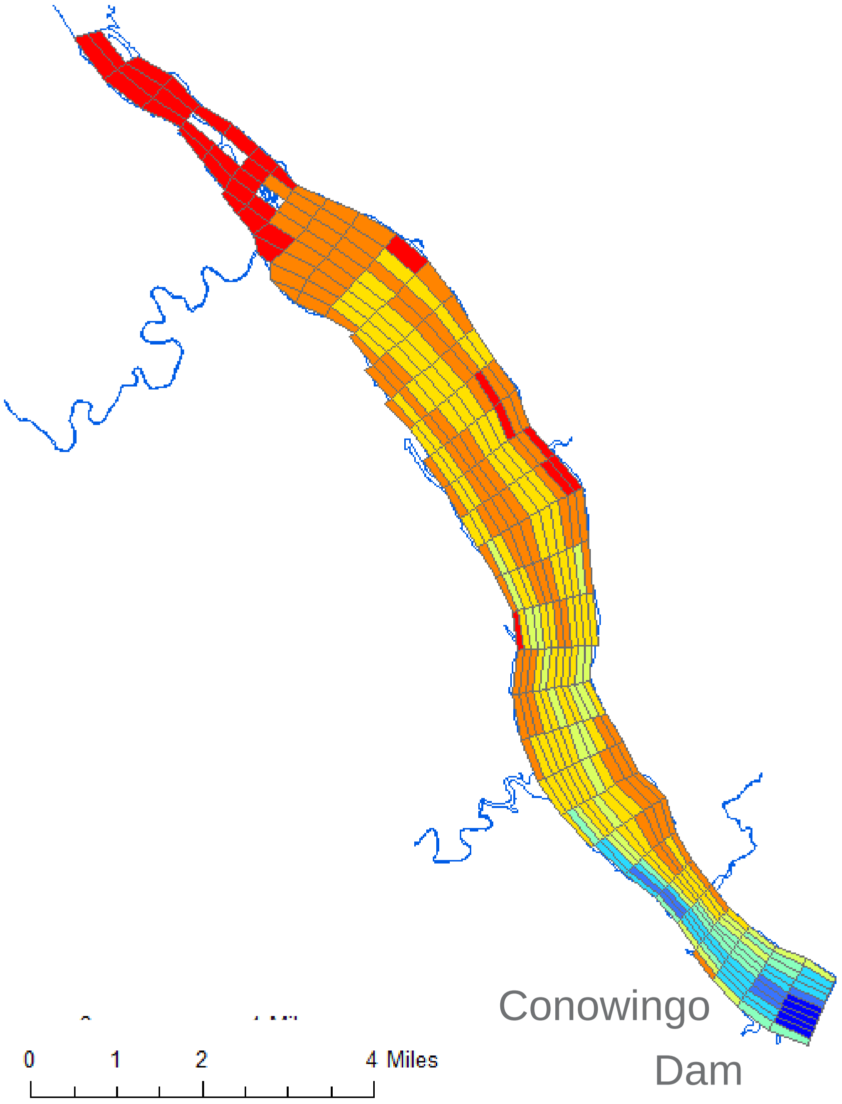
Model Frameworks

- ECOMSED:
  - Integrated hydrodynamic & sediment transport model
  - ECOM: Estuarine & Coastal Ocean Model (rivers too!)
  - SED: Mixed cohesive, non-cohesive sediment transport, (based on research at UCSB (Ziegler, Lick, Jones) → "SEDZLJ"
  - ***Similar to USACE AdH modeling effort but with 3D hydrodynamics***
- RCA/SFM: Sediment Flux Model
  - *Part of RCA water quality model → details coming up…*





Model Grid and Spatial Resolution



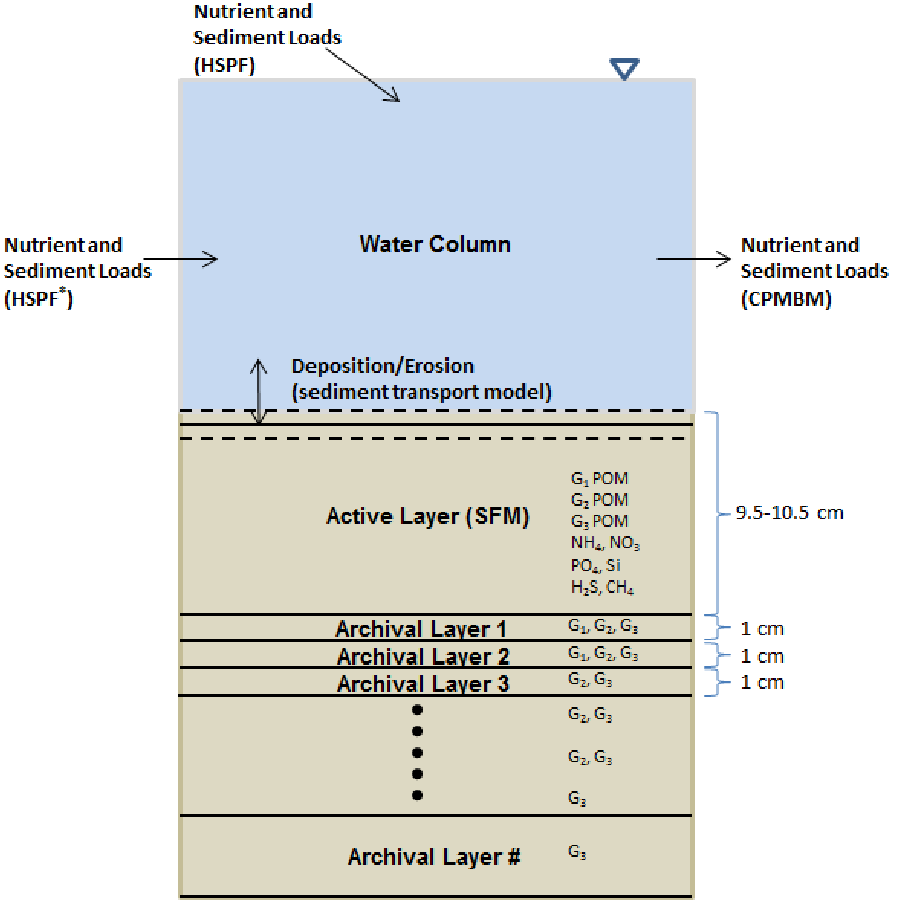
- Resolves primary features of physical system:
  - Remnant channels
  - Depth changes
- Provides 305 cells
  - More detail where Pond is wider
  - 5 vertical (sigma) layers
- Balance spatial resolution and computational burden
- Referenced to full pool:
  - 109.2 ft NGVD29
  - 2015 bathymetry shown

Hydrodynamics – Sediment Transport

- Goal: represent spatial and temporal dynamics of flow and sediment transport in and export from Conowingo Pond
- Will be coupled with water quality/sediment flux model
  - Calibration: 2008-2014
  - Confirmation: 1996-2014, Extended confirmation: 1984-2014
- Hydrodynamics:
  - Calibrate bed roughness/fraction factor to reproduce water surface elevations and temperature
  - Based on flow and temperature (and sediment) data from HSPF
- Sediment Transport:
  - Propose four size classes (coarser sand, finer sand, silt, clay)
  - Erosion properties based on SEDFLUME core results
  - Dynamic bed (water depths change with erosion & deposition)
  - Calibrate to suspended solids in water, bed composition, bathy

Water Quality Model

- SFM active layer varies in depth from 9.5-10.5 cm
- When deposition builds active layer of SFM up to 10.5 cm, one cm of mass of POM and nutrients get pushed down to the first layer of the archive, layer 1 gets pushed down to layer 2, etc.
- Erosion is the reverse of deposition -> active layer of SFM "erodes" to water column and archive layers pushed up
- G_1, G_2 continue to react in the archive layers building up inorganic nutrients
- Output – loads of G_1, G_2, G_3 POM and inorganic nutrients

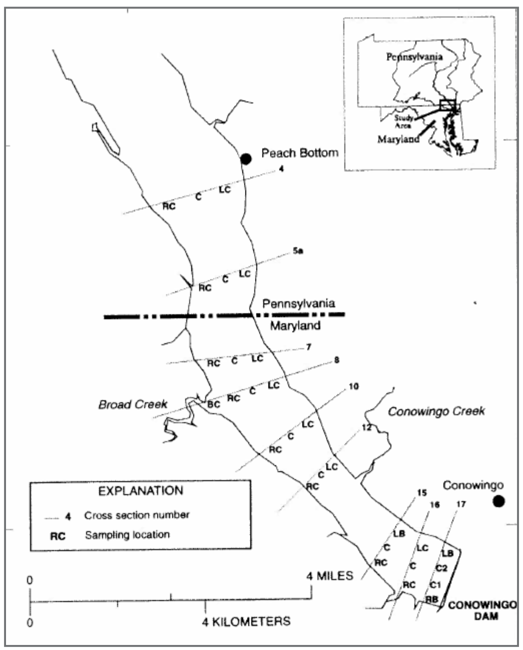


Calibration / Confirmation

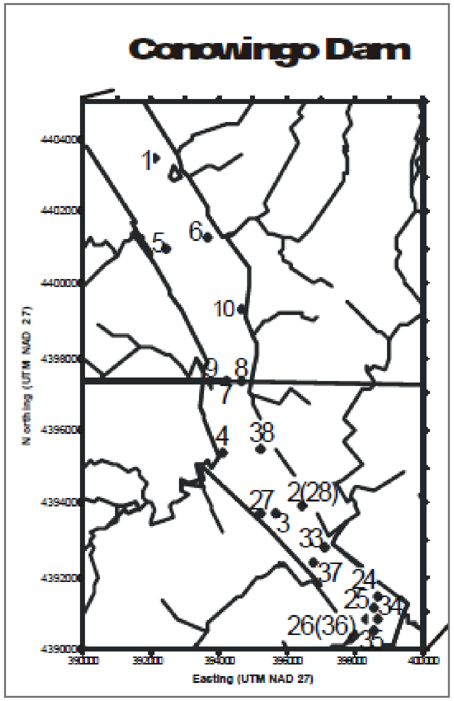
- Initial calibration focus: 2008-2014 – best bathymetric and forcing information
- Model confirmation: 1996-2014
- Potential additional model confirmation: 1984-2014 to match TMDL approach
- Goal to reproduce long-term trends/changes in bathymetry and sediment bed composition (sand, silt, clay and nutrients) as well as data at Conowingo outlet
- Utilize loading information from CBPO watershed model (Holtwood and direct load from Conowingo watershed)
- Watershed model may be informed by current monitoring program and HEC-RAS models of Lake Clarke and Lake Aldred
- SFM will be informed by current UMCES research

Available Nutrient Data

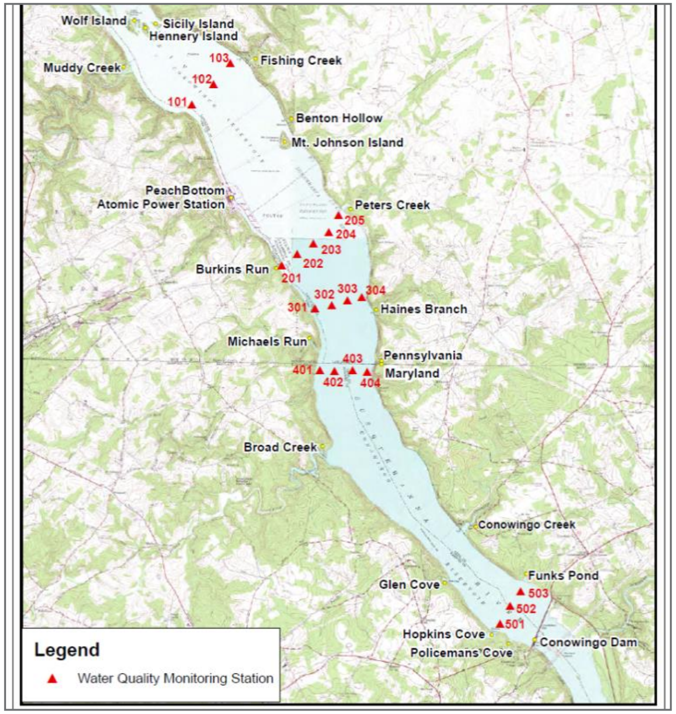
- 1996 (Durlin and Schaffstall, USGS) and 2000 (Edwards, SRBC) sediment cores
- 1996 program – summer 1996 – 29 cores – single depth; 2000 program – May-Sept 2000 – 21 cores – multiple depths
- Temp and DO profiles – 2010 – Normandeau/ Gomez and Sullivan



1996

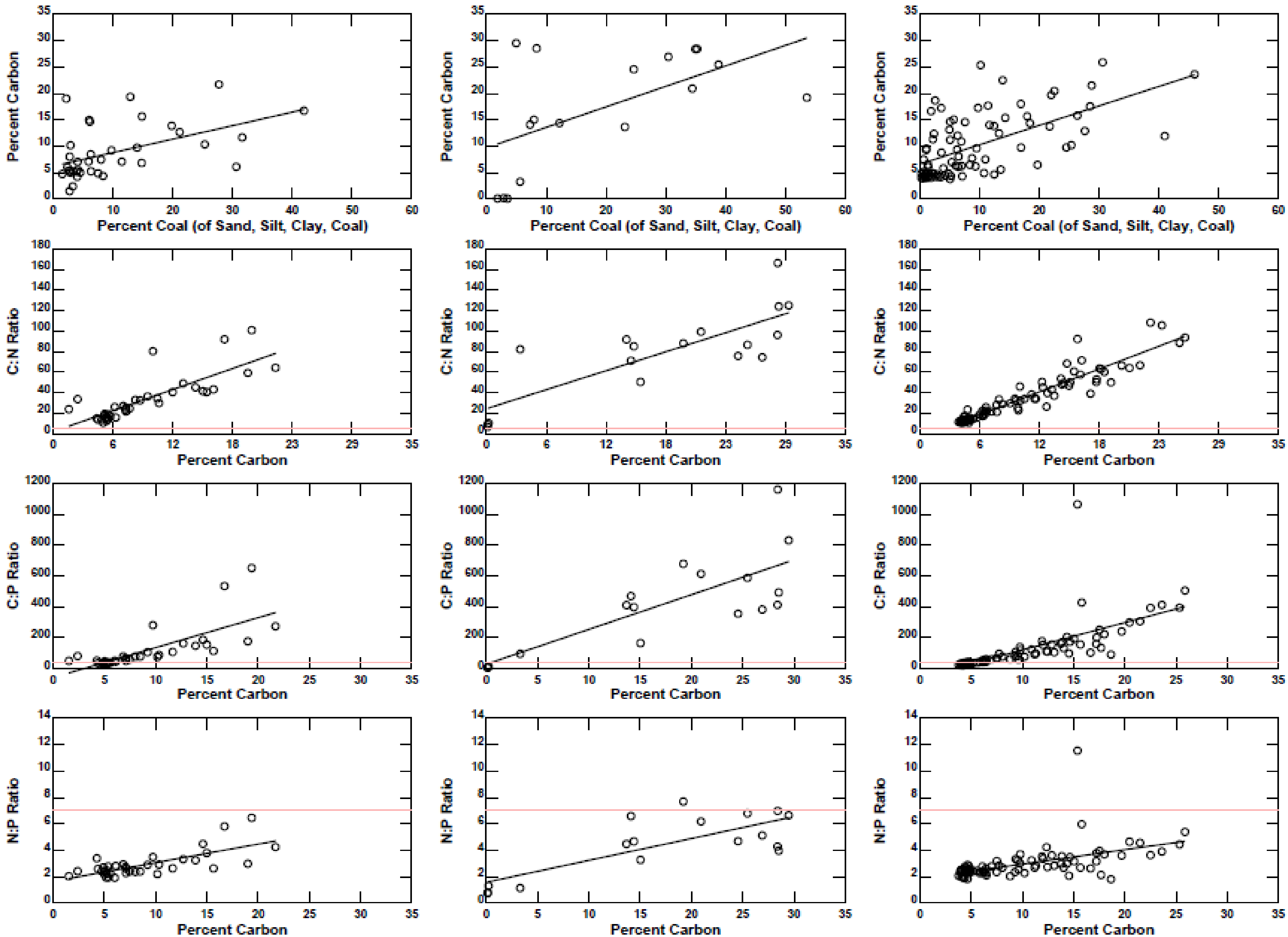


2000



2010

2000 Core Data

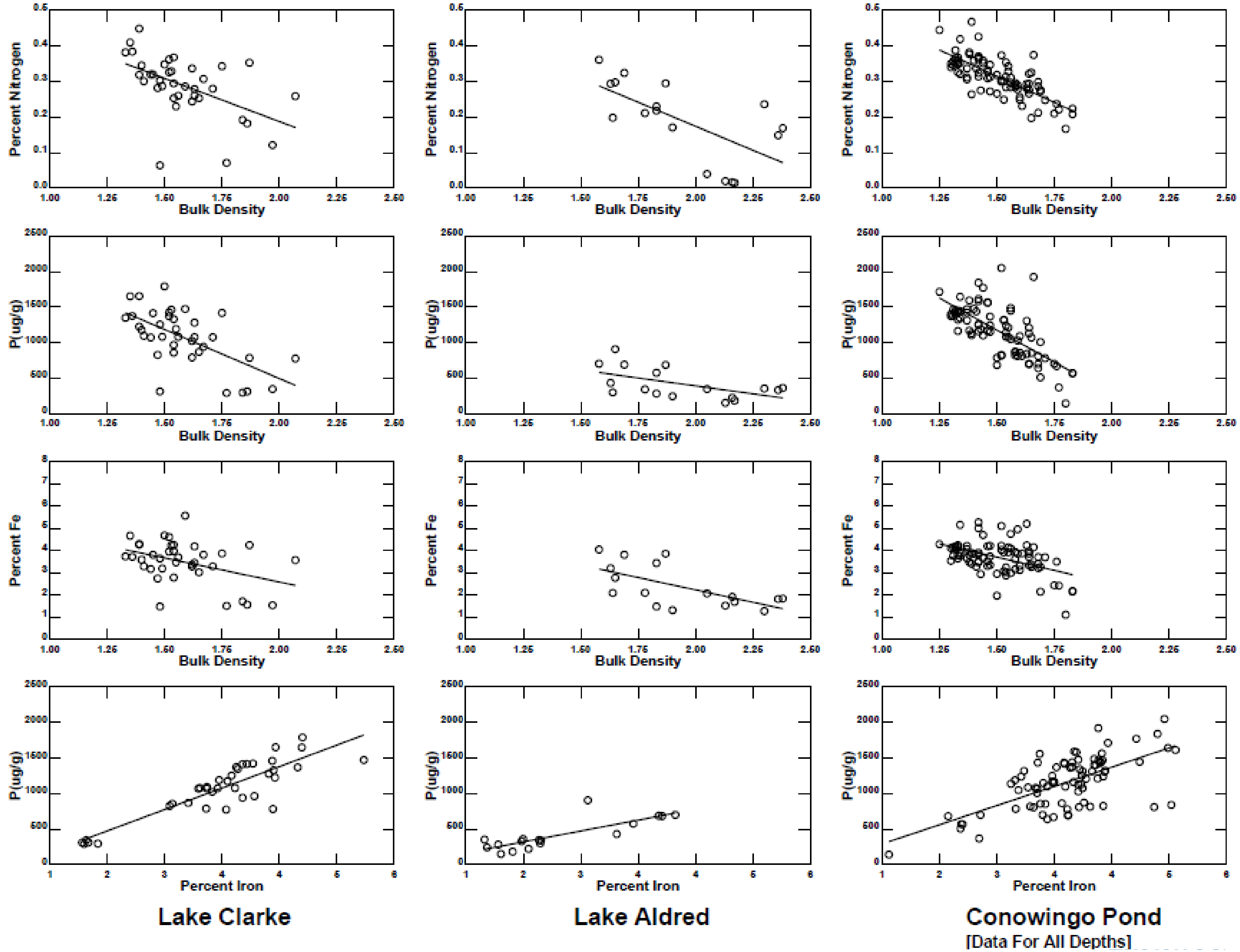


Lake Clarke

Lake Aldred

Conowingo Pond
[Data For All Depths]

2000 Core Data (cont'd)



2010 Water Column Data

FIGURE 4-19: EXAMPLE OF VERTICAL WATER TEMPERATURE PROFILES AT STATION 502 (MID POINT) IN CONOWINGO POND, APRIL-OCTOBER 2010.

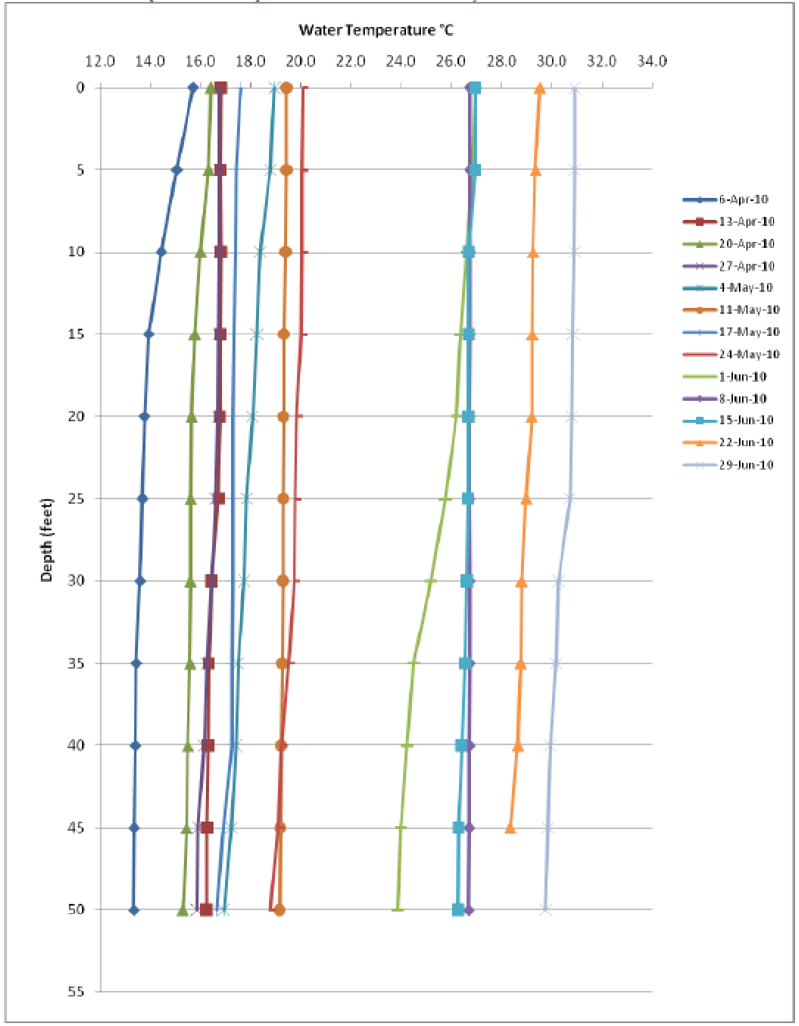
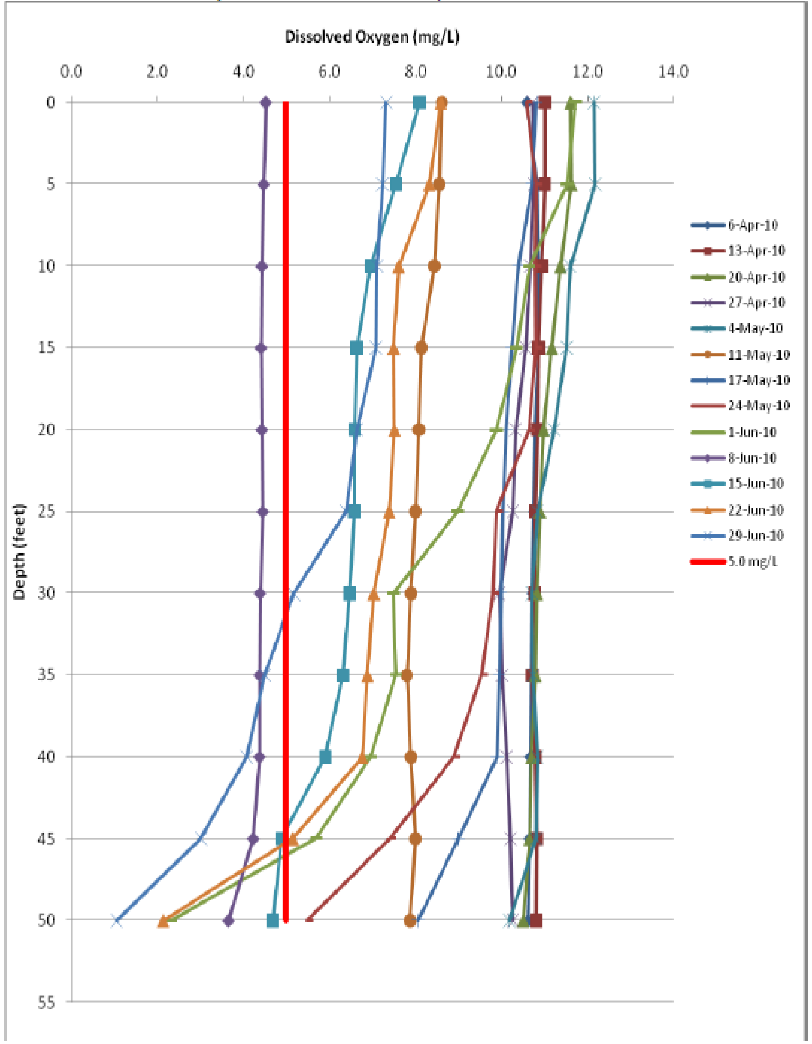
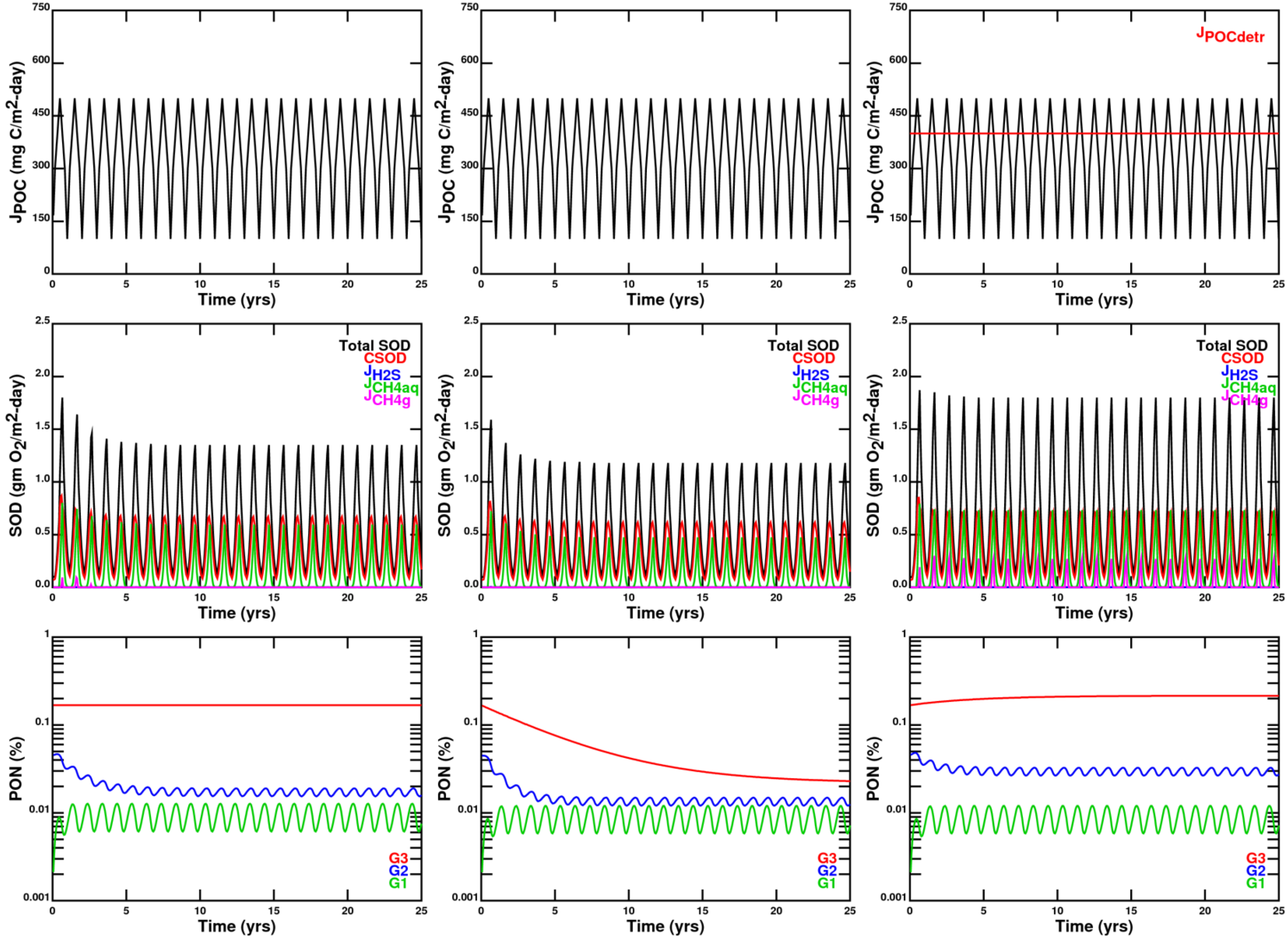


FIGURE 4-20: EXAMPLE OF DO VERTICAL DISTRIBUTION AT STATION 502 (MID POINT) IN CONOWINGO POND, APRIL-OCTOBER 2010.



SFM Analysis



V_{burial} = 0.25 cm/yr | V_{burial} = 2 cm/yr | V_{burial} = 2 cm/yr

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