UTAH DEPARTMENT of ENVIRONMENTAL QUALITY
WATER QUALITY

Utah Lake EFDC Model

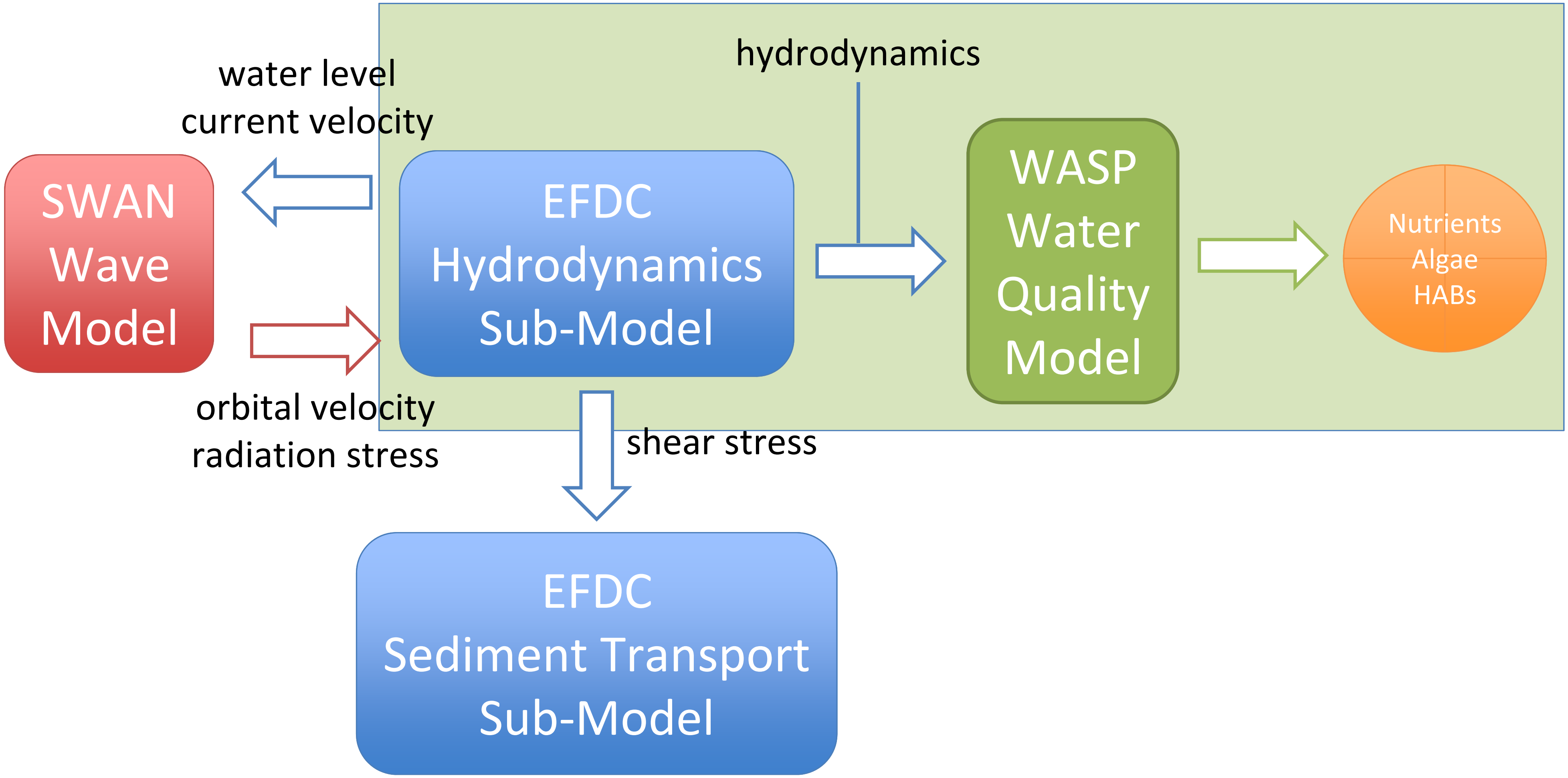
Nicholas von Stackelberg

Science Panel Meeting 9/18/2020

Topics

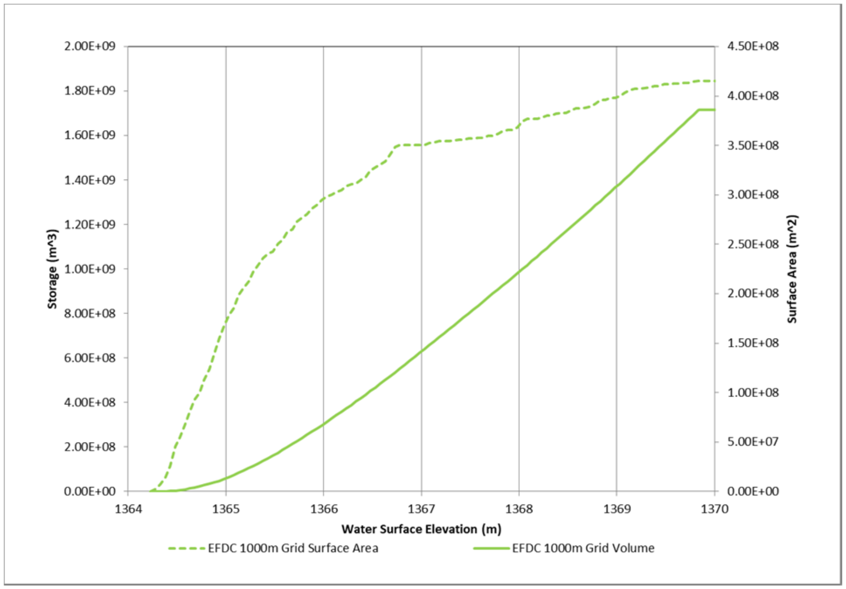
1) Utah Lake Model Framework
2) Utah Lake Model Build and Calibration Methods
3) EFDC Results

Model Framework

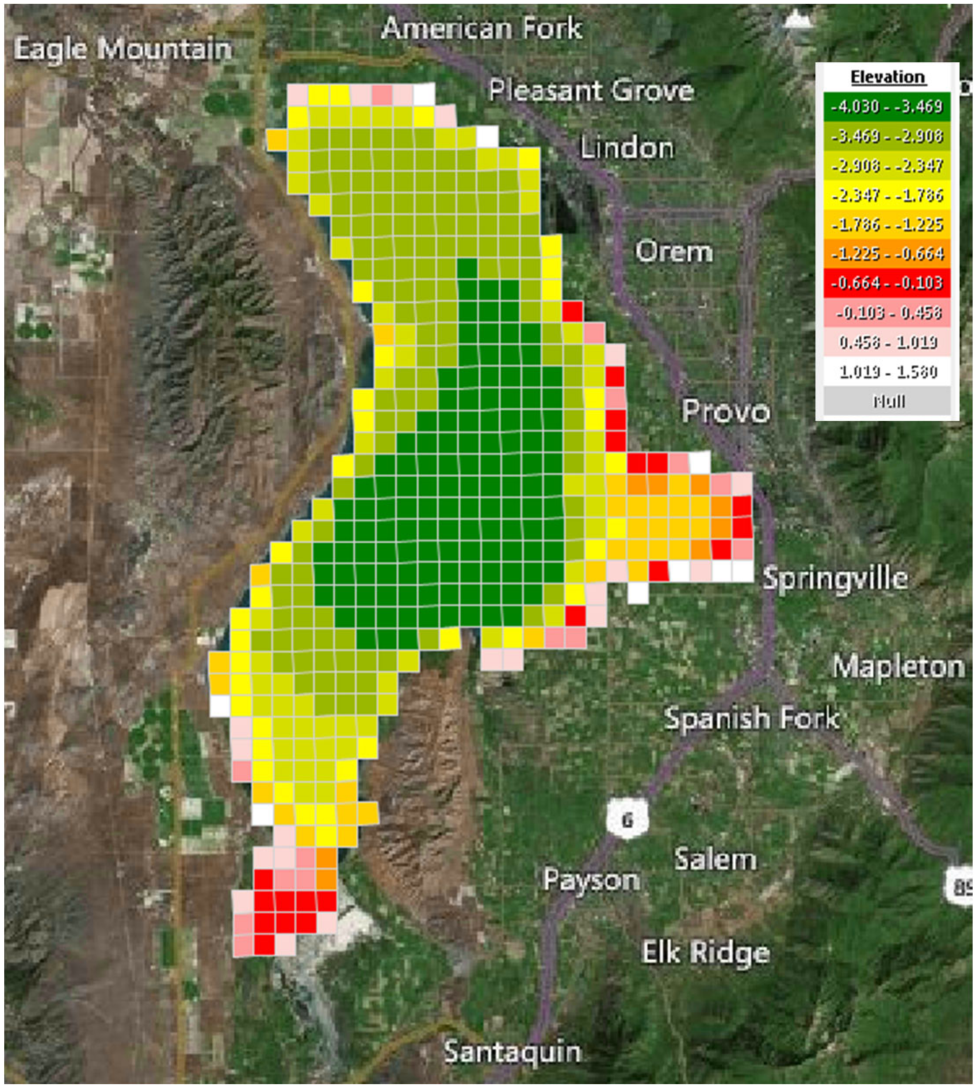


Model Structure

- Cartesian grid
- 1,000 m x 1,000 m cell size
- 3 vertical layers
  Variable depth (sigma stretched)
- 1,356 total segments



Stage-Surface Area-Storage



Bathymetry

Model State Variables (Water Column)

EFDC

- Flow
  - Depth
  - Velocity
  - Shear Stress
- Water Temperature
- *Inorganic Solids (3 classes)

* *Constituent not output to WASP*

WASP

Ammonia [NH_3 / NH_4^+]

Nitrate [NO_2^- + NO_3^-]

Dissolved Inorganic Phosphate [H_2PO_4 / HPO_4^- / PO_4^{2-}]

Dissolved Oxygen

Solids (3 classes)

- Sand, silt, clay

Water Temperature (from EFDC)

Alkalinity (not implemented yet)

pH (not implemented yet)

- Phytoplankton (4 classes)
  - Diatoms *(Bacillariophyta)*
  - Green Algae as Phytoplankton
  - Cyanobacteria *(Aphanizomenon gracile)*
  - Cyanobacteria *(Synechococcus; Not Nitrogen-fixed)*
- Periphyton
- Particulate Organic Matter (POM)
  - Particulate Organic Carbon (POC)
  - Particulate Organic Nitrogen (PON)
  - Particulate Organic Phosphorus (POP)
- Dissolved Organic Matter
  - CBOD Ultimate (1 class)
  - Dissolved Organic Nitrogen (DON)
  - Dissolved Organic Phosphorus (DOP)

Model Calibration

- Calibration period
  - EFDC: Water Year 2006-2018
  - WASP: Water Year 2006-2015
  - Significant data gaps in tributary loading and lake sampling
- Model review and comments from James Martin (April 2020)
- Detailed analysis period: water year 2009-2013
  - Period with roughly monthly tributary and lake sampling data
  - Some uncertainty associated with model inputs

Water Balance

Total inflow based on equation:

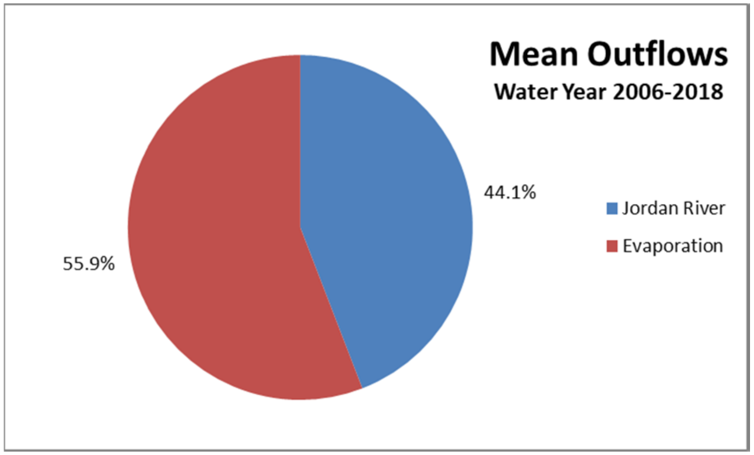
$$Q_I = \Delta S + Q_O + ET - P$$

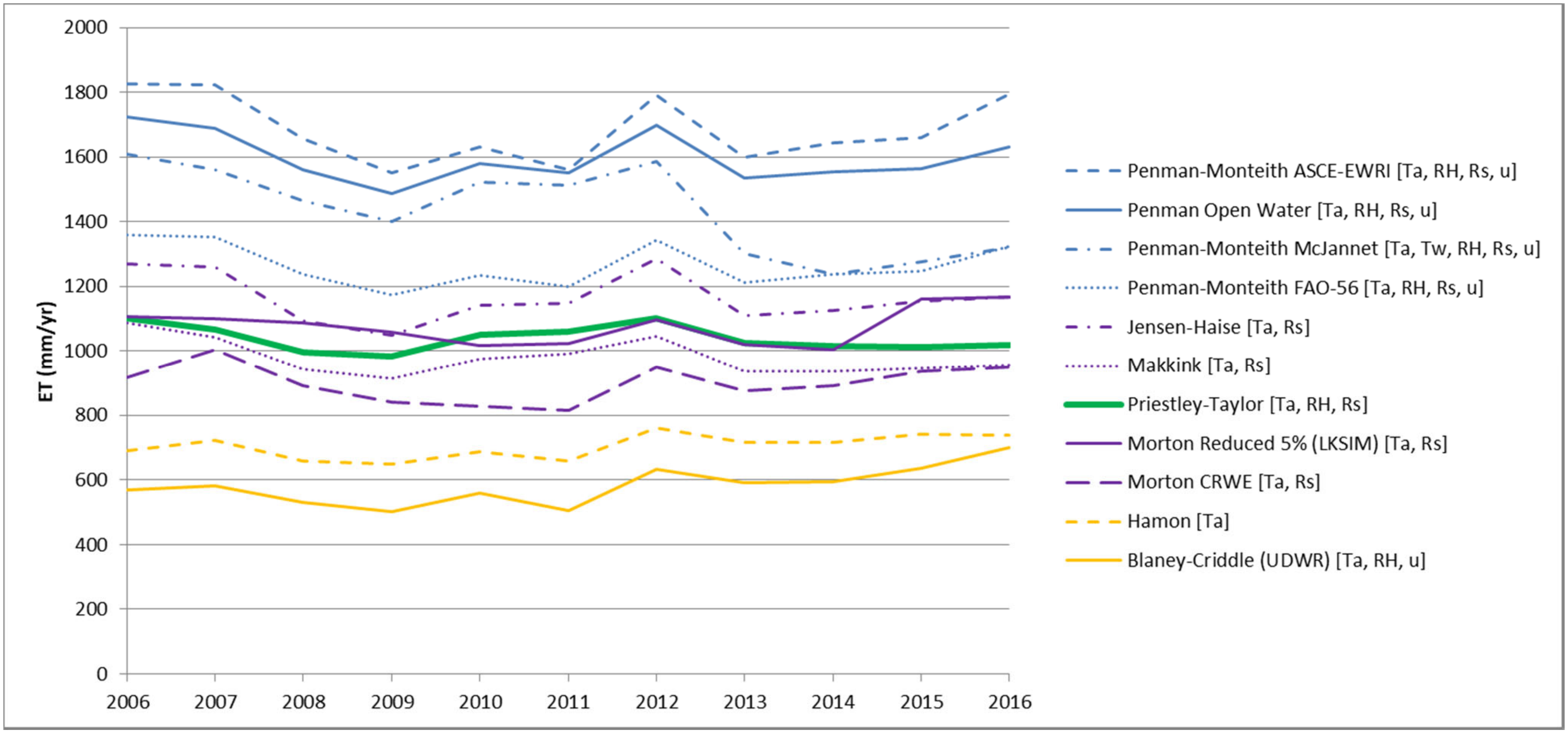
with

- Q_I: total lake inflow
- ΔS: storage volume change
- Q_O: Jordan River outflow
- ET: evapotranspiration
- P: precipitation

Evapotranspiration

- Priestley-Taylor formula selected
  - Function of air temperature (Ta), relative humidity (RH) and solar radiation (Rs)
  - Recommended for shallow lakes in published comparison studies
    (Stewart and Rouse 1976, Galleo-Elvira et al. 2010)
  - Middle of range of estimates
  - Comparable to LKSIM estimates (Morton formula reduced 5%)





Estimated Inflows

Ungaged surface inflow calculated based on equation:

$$Q_{US} = Q_I - Q_{GW} + Q_{WW} + Q_{GS}$$

with

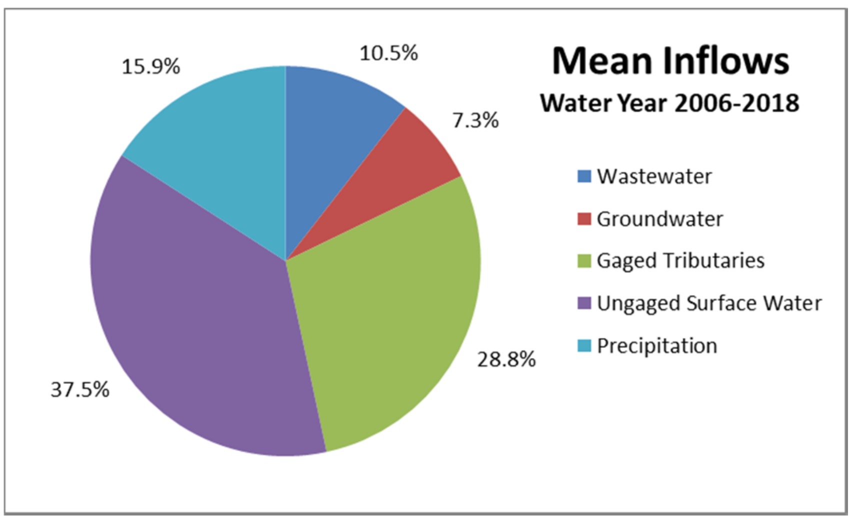
Q_I: total lake inflow

Q_{GW}: groundwater inflow

Q_{WW}: wastewater inflow

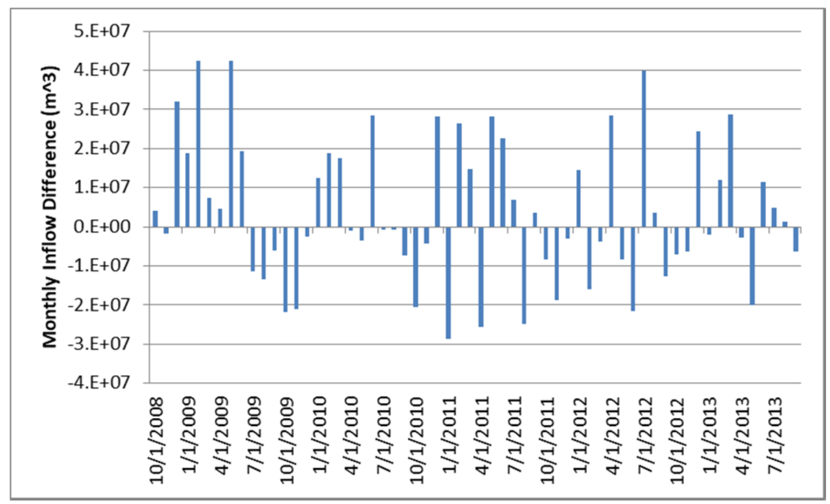
Q_{GS}: gaged surface inflow

Q_{US}: ungaged surface inflow



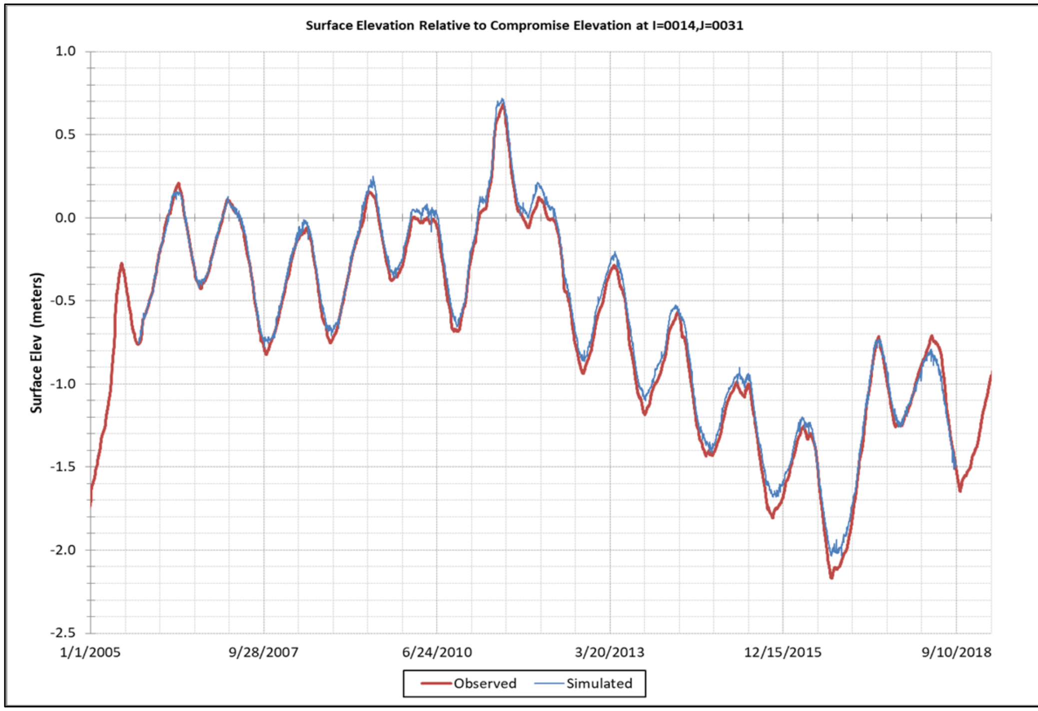
For WY 2009-2013,

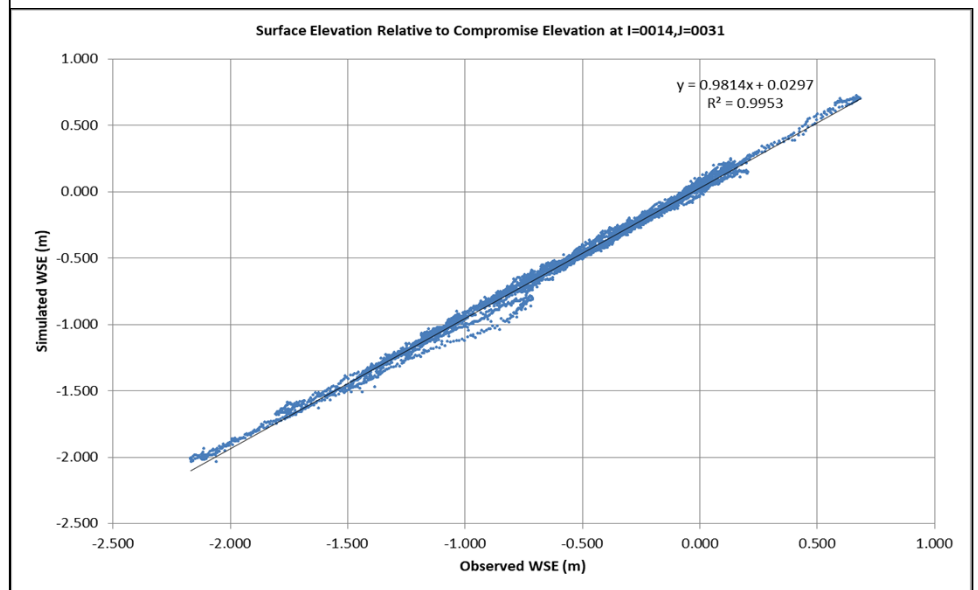
- Linear interpolation between monthly flow measurements
- Monthly difference between inflow estimated by flow measurements & water balance
- Q_{US} only 4% of Q_I cumulative



EFDC Results

Water Surface Elevation

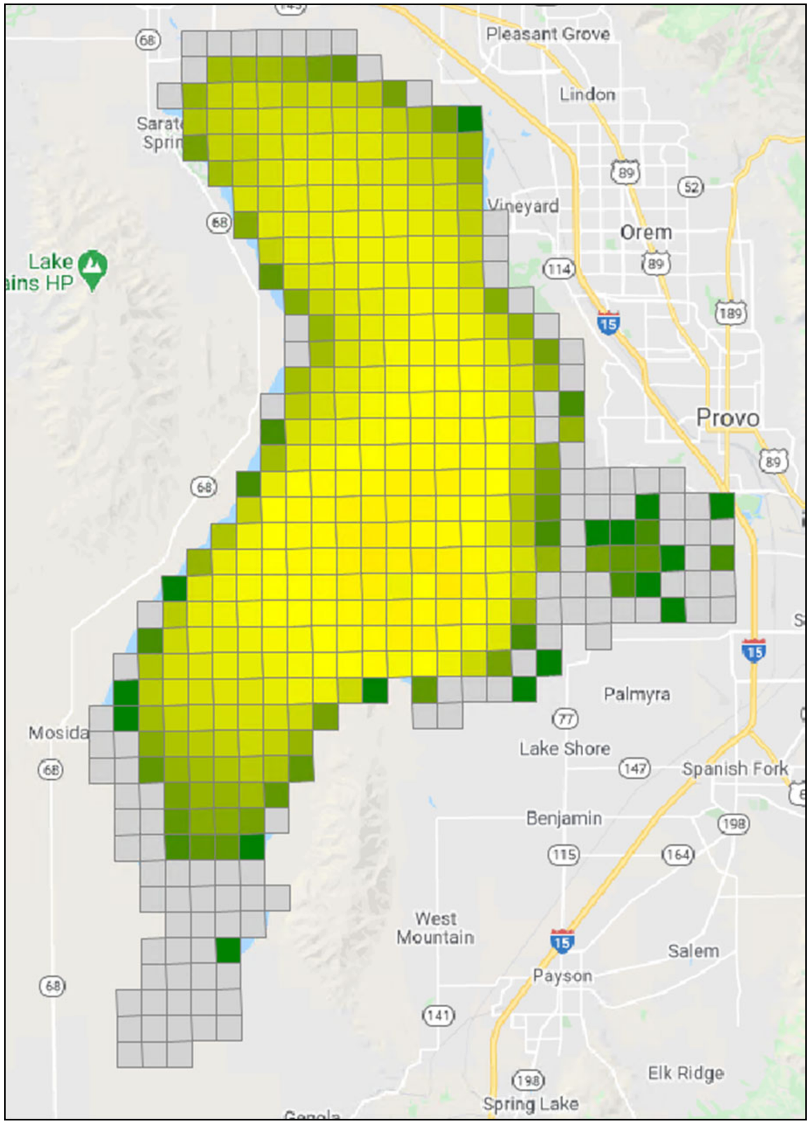




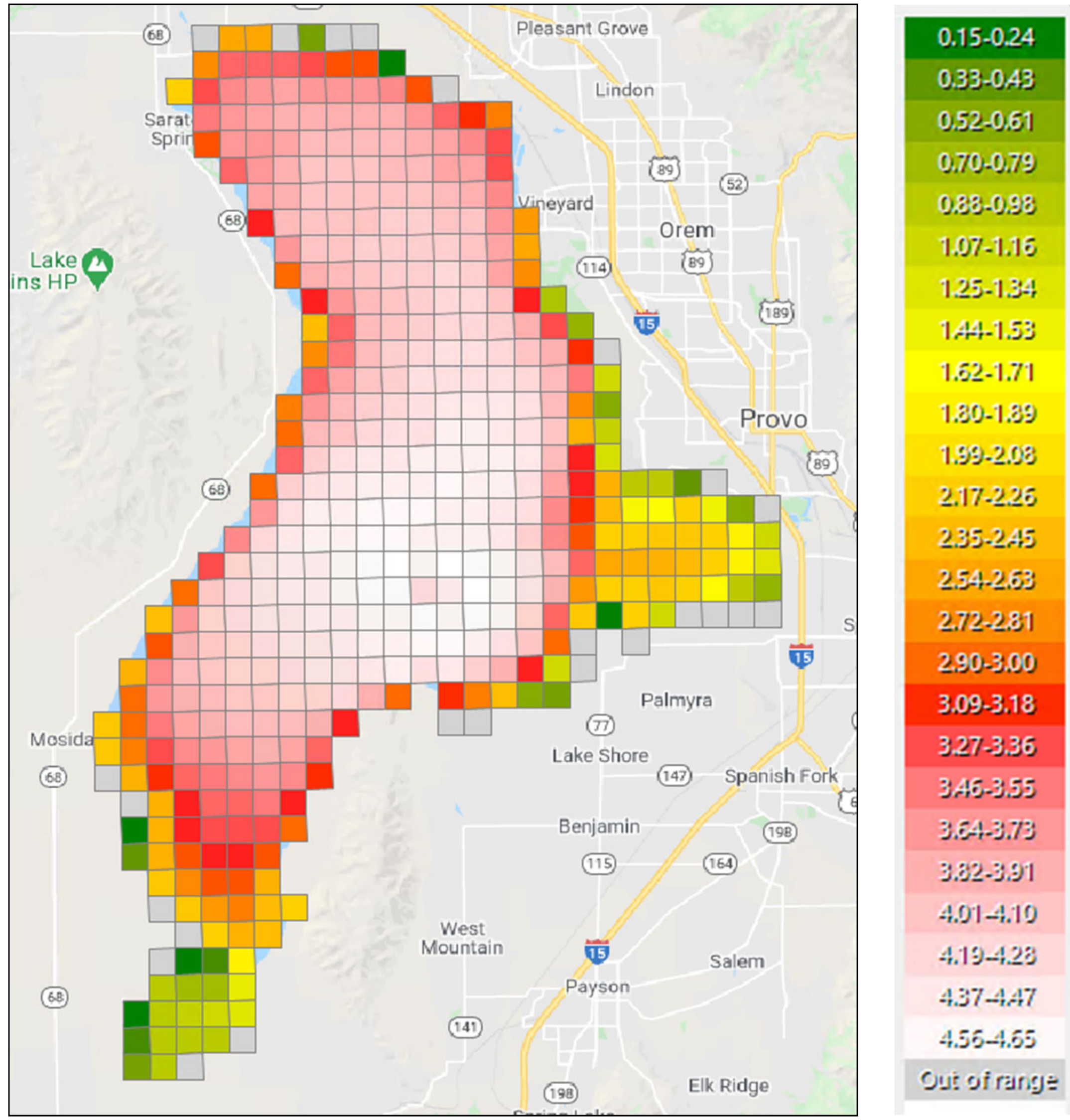
- Good fit between simulated and observed, as expected since water balance specified
- Discrepancy due to P and ET estimation on dry model cells

Wetting/Drying

Dry cells shown in gray

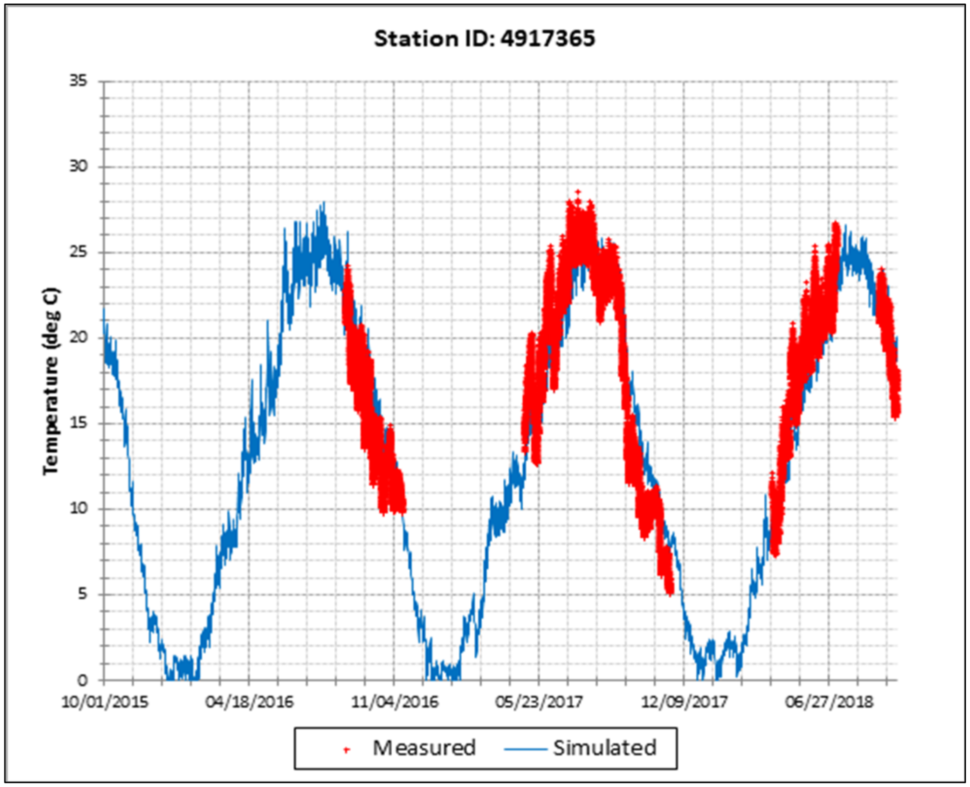


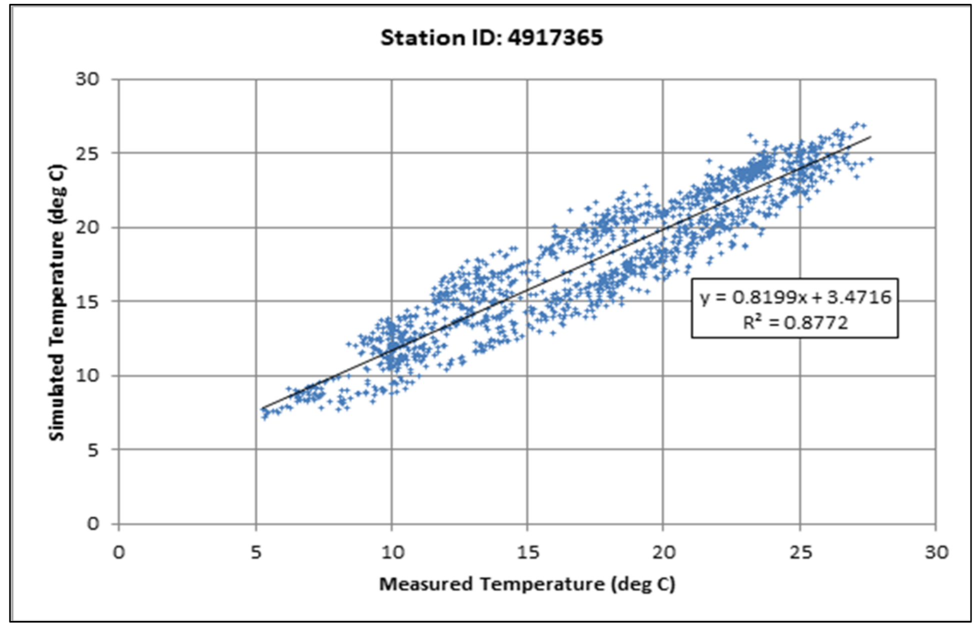
Min WSE 9/21/2016

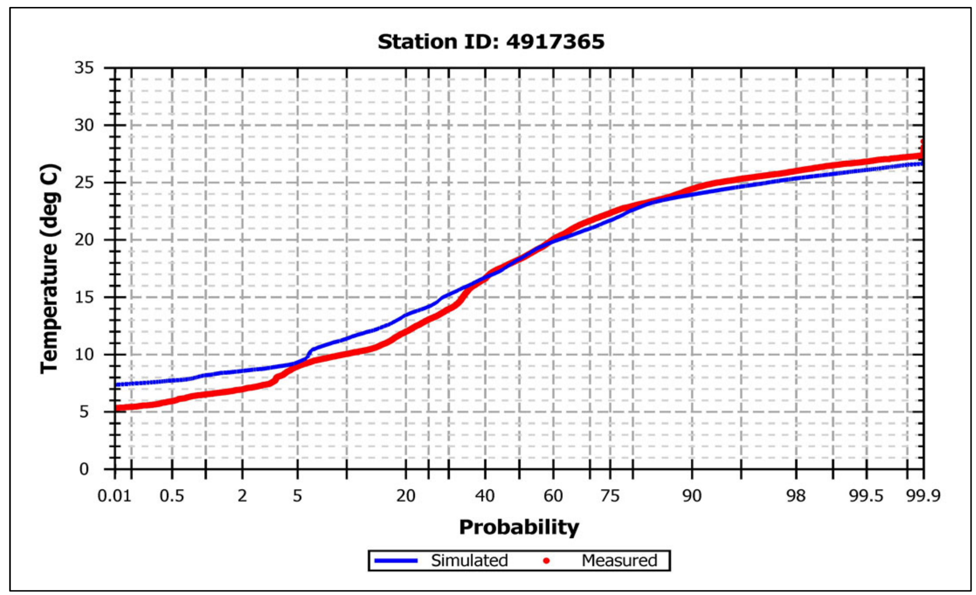


Max WSE 6/11/2011

Water Temperature



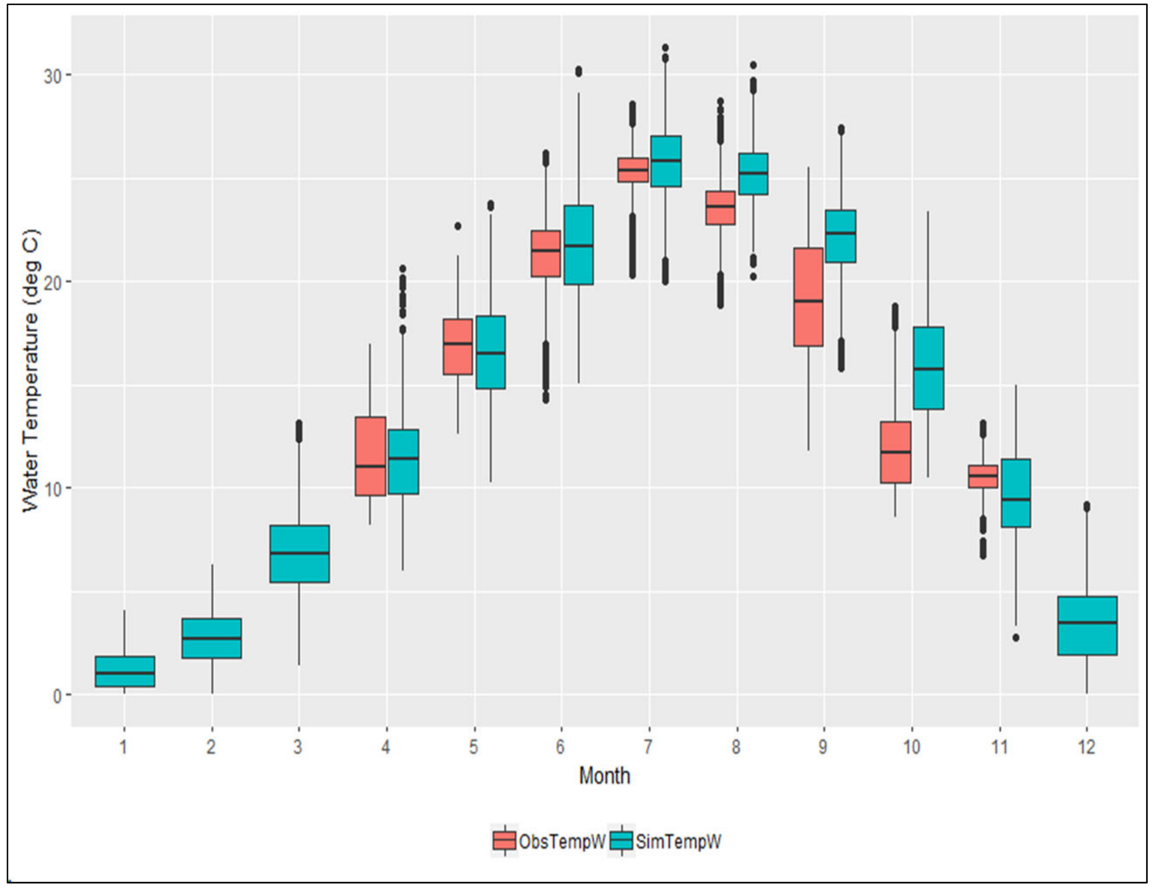




- Utah Lake 2 Miles W of Vineyard Buoy
- Surface layer
- Generally good fit between simulated and observed

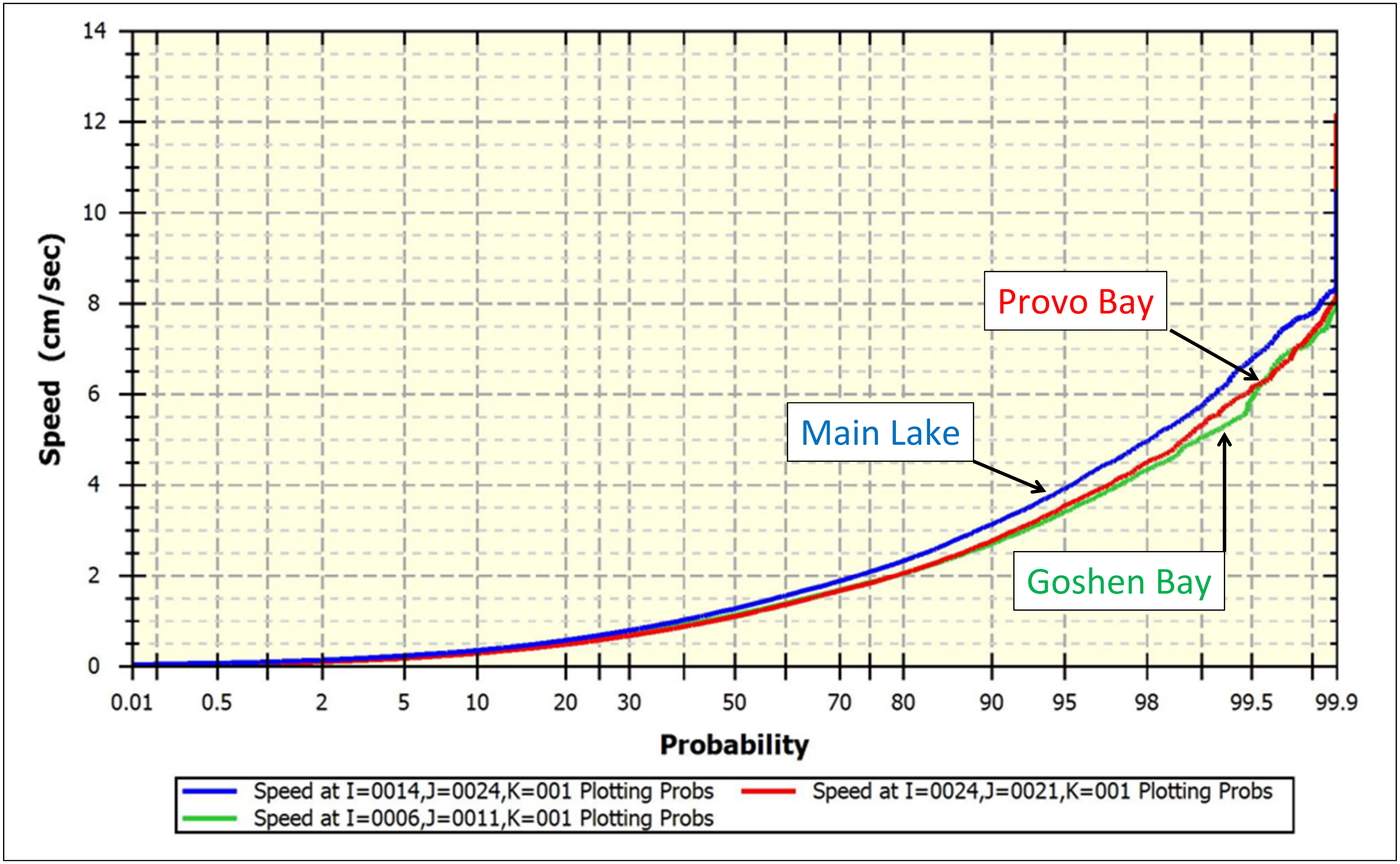
Water Temperature

- Over-prediction in fall
- Similar results for other buoys

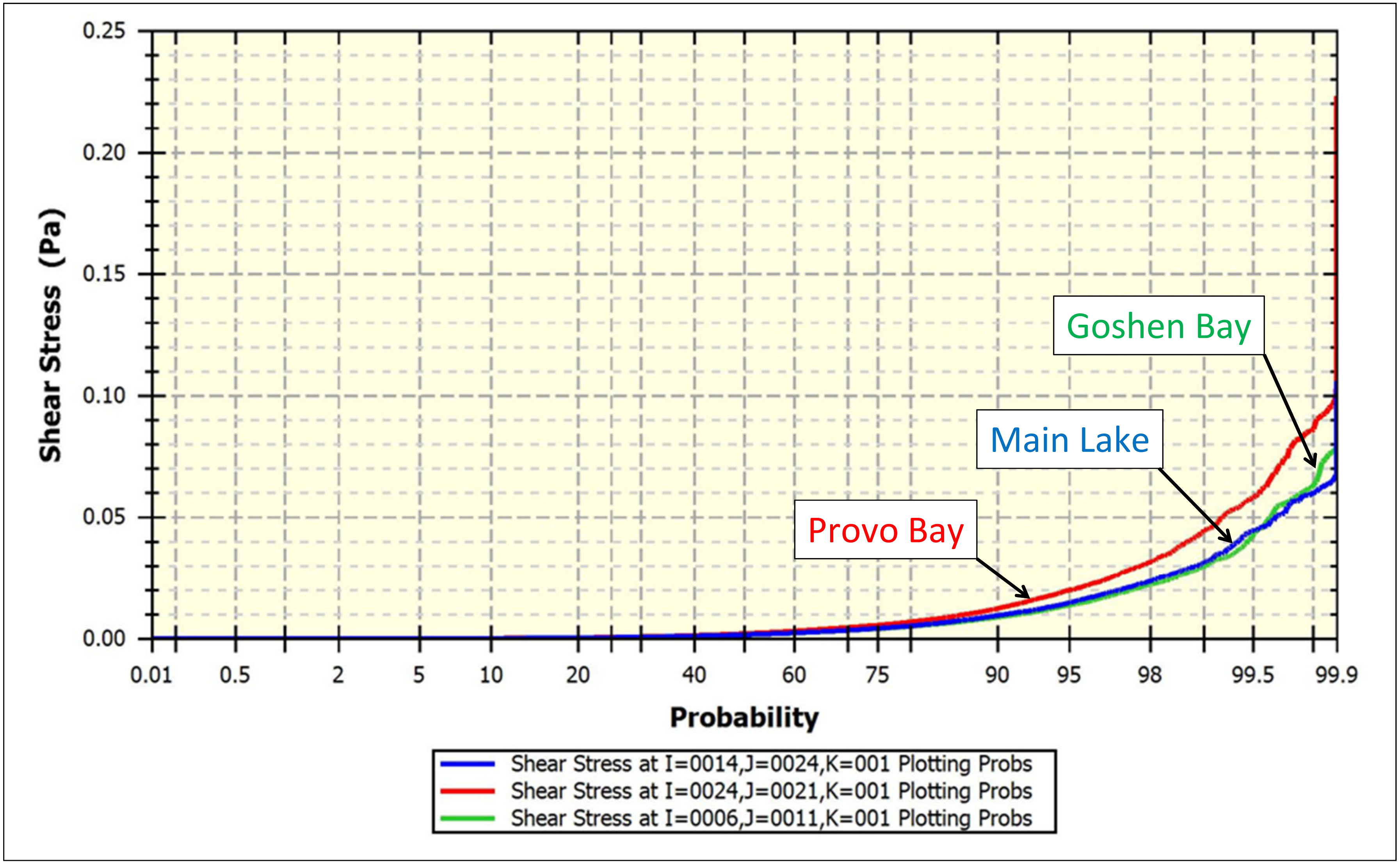


Station ID	Station Name	RMSE	R^2	NSE	PBIAS
4917365	Utah Lake 2 Miles W of Vineyard	1.98	0.88	0.87	-1.9%
4917390	Utah Lake 1 Mile W of Provo Boat Harbor	1.94	0.86	0.86	-1.1%
4717715	Utah Lake Outside Entrance to Provo Bay	1.80	0.91	0.89	-3.5%

Current Velocity



Shear Stress due to Currents



Ideas for Continued EFDC Development

1) Calibrate to ADCP/ADV velocity data
2) Incorporate higher resolution inflow data
3) Build and couple SWAN wave model
4) Incorporate additional wind data stations
5) Refine grid
   - Improve connection between Provo Bay and open water
   - Note still experiencing significant run time issues with re-parameterizing WASP model
6) Improve numerical stability on wet/dry cells
   - Remove precipitation/ET from dry cells
7) Sediment resuspension and transport

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THE UNIVERSITY OF UTAH

Utah Lake WASP Calibration

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Utah Lake Water Quality Study (ULWQS) Science Panel Meeting

September 2020

Presentation Outline

- General Overview of Model Calibration Report, Models, and Notes
- Model Build and Note over Sediment Diagenesis Work
- Model Sensitivity
- Model Simulation and Calibration Work
  - Animation(s) over Distinct/Selected Constituents
  - General Commentary over Model Calibration Results
  - General Commentary over Model Numerical Stability
- Extended Model Build: Water Year 2009 to 2013 Time Period

Documentation over Utah Lake WASP Work…

Su, J.-Y., von Stackelberg, N. (2020). Utah Lake Hydrodynamic (EFDC) and Water Quality (WASP) Model Report. Department of Civil and Environmental Engineering, University of Utah, Salt Lake City, UT. Submitted to Division of Water Quality, Utah Department of Environmental Quality, Salt Lake City, UT. 187 pp.

Revision History: March 2020 (Initial Report Submission to UDWQ), April 2020 (Revised EFDC Model Build, Revised Phytoplankton Grouping, Revised Sensitivity and Calibration Plots, Appendix on Water Balance), June 2020 (Inclusion of Water Year 2009-2013 Simulation with R Scripts)

Model Calibration Report

- Section 1: Introduction, Background to WASP
- Section 2: Model Build (EFDC and WASP; details on Water Balance in Appendix C)
- Section 3: Model Sensitivity (WASP Sensitivity also documented in Appendix A)
- Section 4: Model Calibration and Parameterization (WASP Calibration Performance Plots and Tables in Appendix B)
- Section 5: Model Additional Build
- Appendix D: R Scripts for Utah Lake WASP

Supplemental Notes for Utah Lake WASP

- Section 8.2 on Notes over the Utah Lake WASP
  - Issues with pH and Alkalinity ➔ Need to be addressed to EPA (e.g., Developers of the WASP Program)
  - Need a Revised “multi-algae.dll” file from the WASP Program Developers for Avoiding Model Crash due to Mass Check > 10 for at least 50 Times throughout the Model Simulation
  - Model Simulation Time Potentially a Function of: Time Step of Output, Parameters to-be-outputted into BMD2 file, etc.
  - WASP Model can NOT be simulated through Linux Version of WASP 8.32 ➔ Need to be addressed to EPA (e.g., Developers of the WASP Program)

Models Received for WASP

WASP832_UtahLake_WY2006-2015_HYD20191024.wif

- EFDC Linkage Version: 2019/10/24 Version
- File Size: Approximately 15.4 MB
- Model Simulation: Approximately 9-14 Hours (on Univ. of Utah CHPC Beehive) if Output every 6 Hours

WASP832_UtahLake_WY2009-2013_HYD20200511.wif

- EFDC Linkage Version: 2020/05/11 Version
- File Size: Approximately 226 MB (due to hourly inflow quality data)
- Model Simulation: Approximately 6-9 Hours (on Univ. of Utah CHPC Beehive) if Output every 6 Hours

Model Build for Water Year 2006-2015 WASP

Inflow Quality Data Sources, Data Approximation, Atmospheric Deposition, Associated Experimental Work and Methodologies

Phytoplankton Grouping

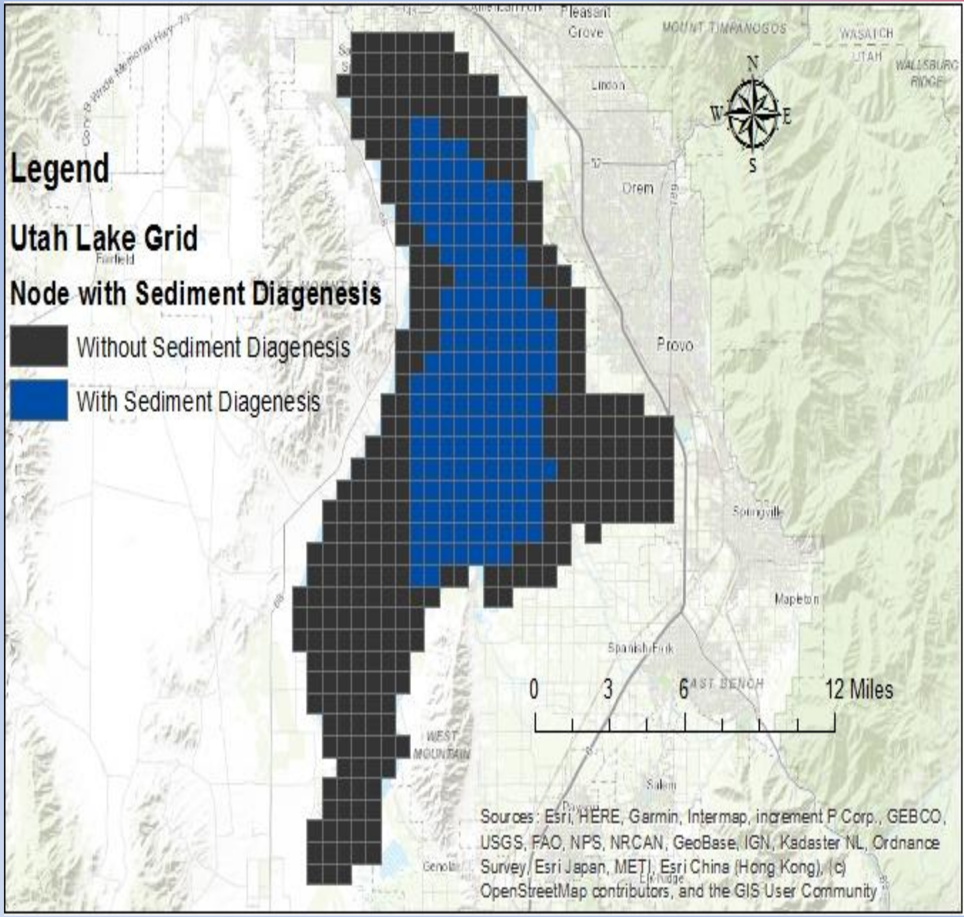
- Diatoms, emphasis on *Bacillariophyta* (Group 1)
- Nitrogen-Fixed Cyanobacteria, emphasis on *Aphanizomenon Gracile* (Group 2)
- Non-nitrogen-fixed Cyanobacteria, emphasis on *Synechococcus* (Group 3)
- Green Algae as Phytoplankton for K = 2 and K = 3 layers, emphasis on *Stigeoclonium Subsecundum* (Group 4)

General Approach for Sediment Diagenesis, Characterization, and Initial Conditions

- Added Spatial/Geographical Coordinates to sampled sites along Utah Lake
- Added Neighboring Sites to the Sampled Sites with Approximated Values for Ensuring Full Coverage of Utah Lake
- Applied Spatial Interpolation (Inverse-Distance Weighing for the exercise)
- Applied Zonal Statistics for calculating Mean Values per Utah Lake Node

Number of Sediment Diagenesis Segments

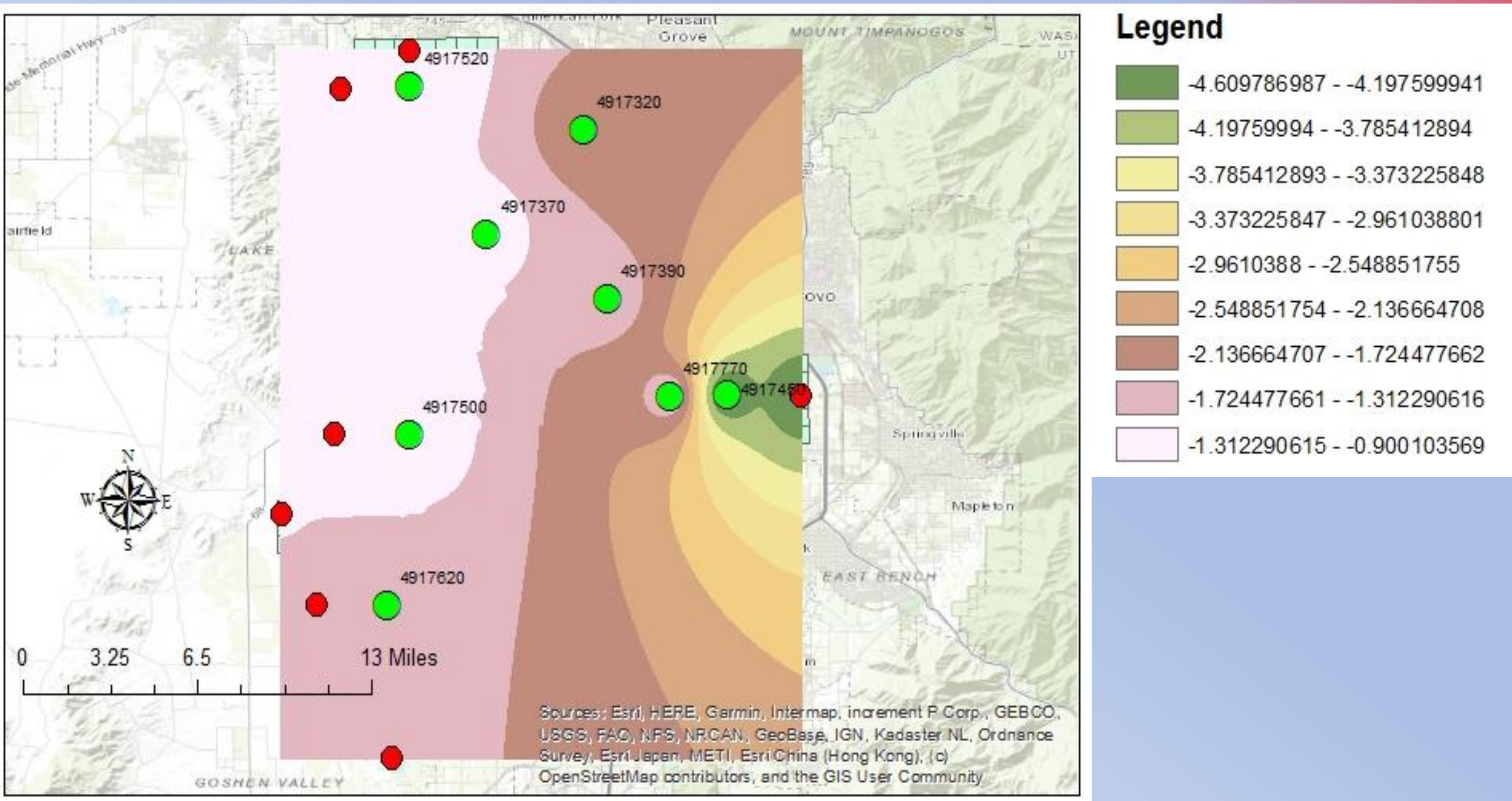
- Sediment Diagenesis upon all K = 1 Nodes yields lengthy simulation times
- Applied upon nodes with the following criteria:
  - o I $\geq$ 10
  - o Elevation below -3.25 m relative to compromise
  - o 157 out of 452 K = 1 Nodes with Sediment Diagenesis



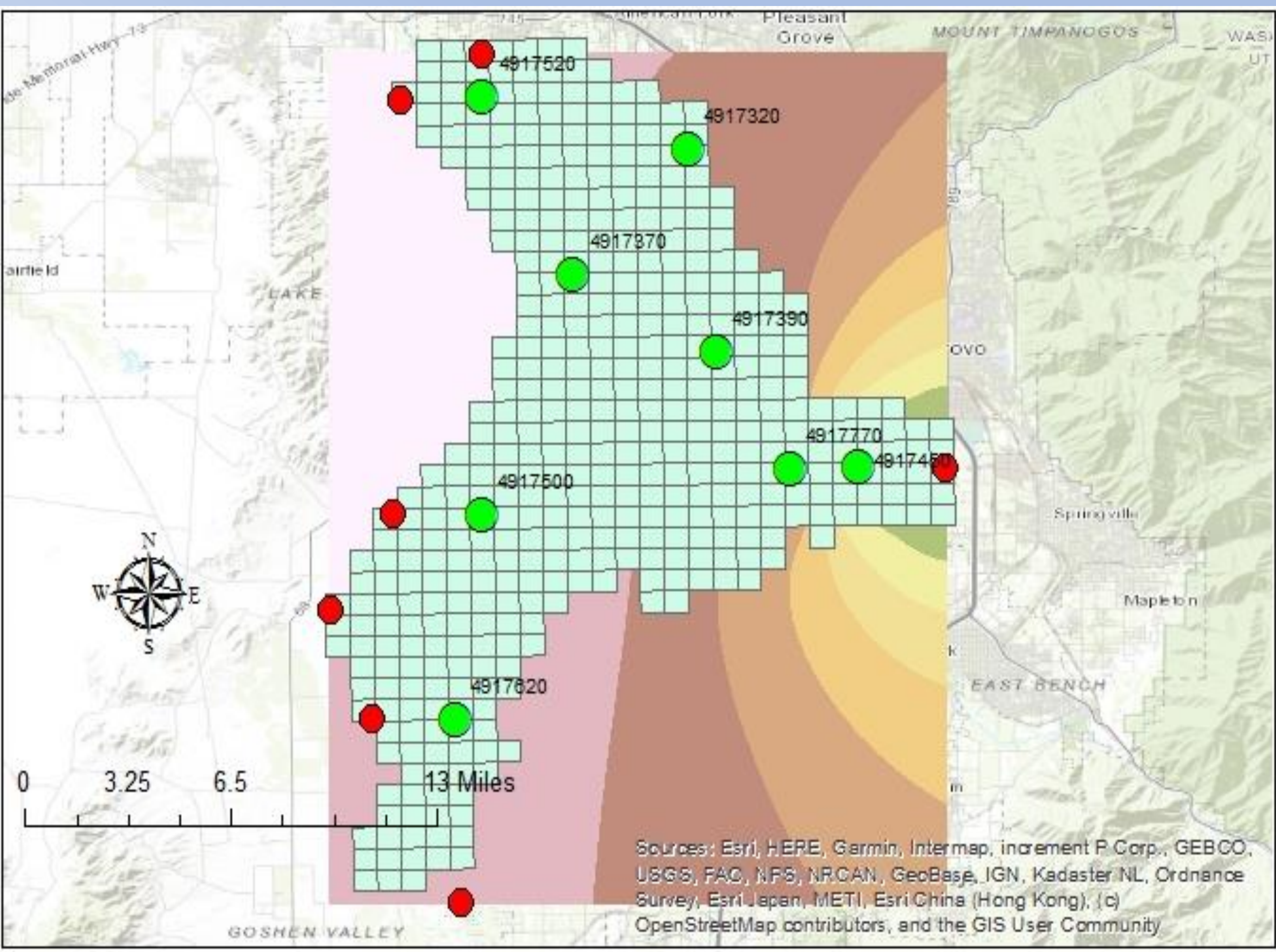
Sediment Diagenesis (continued)

- "Ideal" Approach for Addressing Sediment Diagenesis issues in WASP
  - Sediment Diagenesis for 157 out of 452 K = 1 cells
  - Apply Hogsett et al. (2019) data for…
    - Prescribed SOD
    - Benthic Ammonia Flux
    - Benthic DIP Flux
    - (All values included into Utah Lake WASP)
    - Single Value per Node allowed in WASP; SOD values adjusted based on water temperature correction coefficient (1.07)
  - WASP: Can Only do either Sediment Diagenesis *or* Prescribed Fluxes

Prescribed SOD (g O_2/m^2-day)…



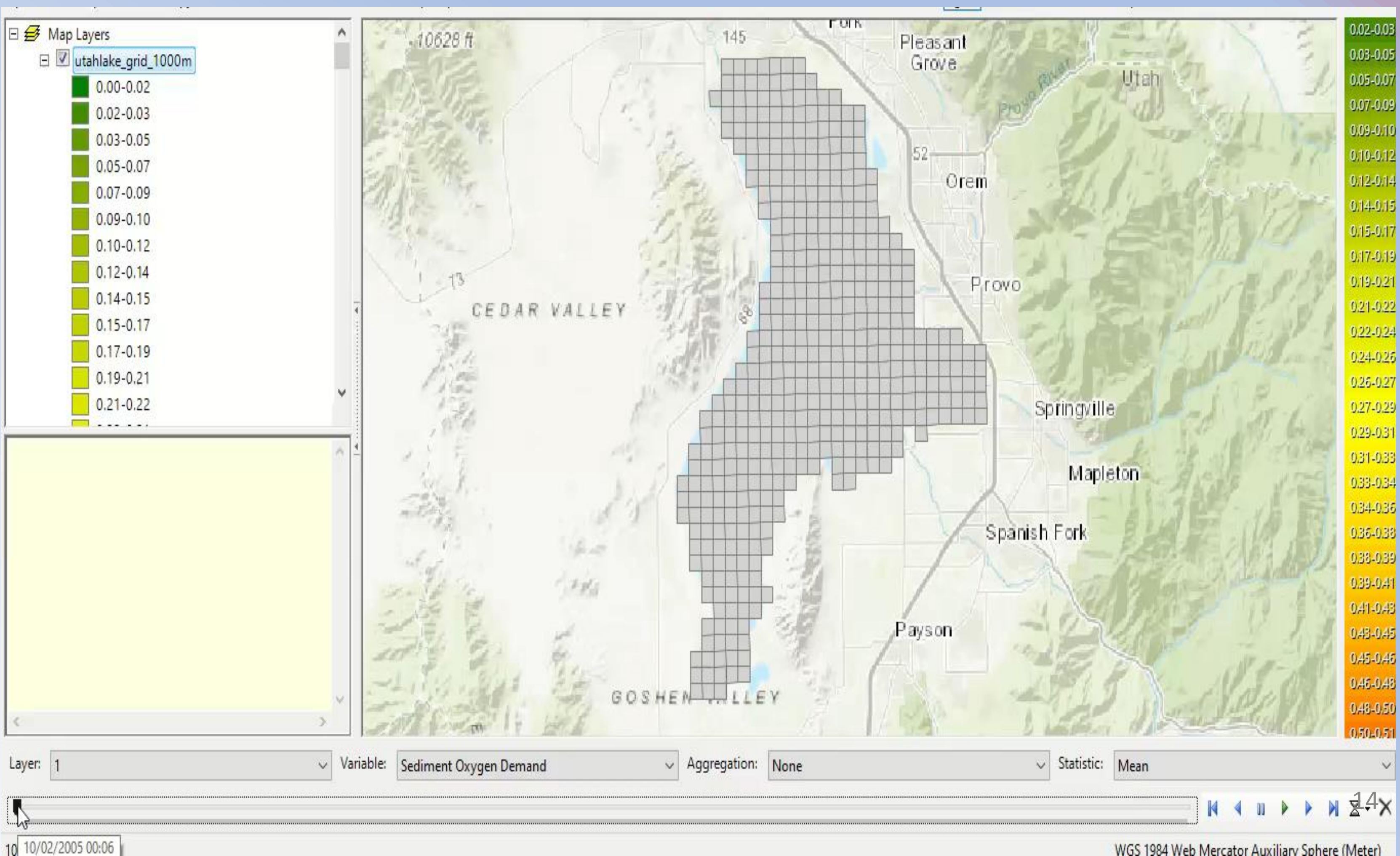
Prescribed SOD (g O_2/m^2-day)…



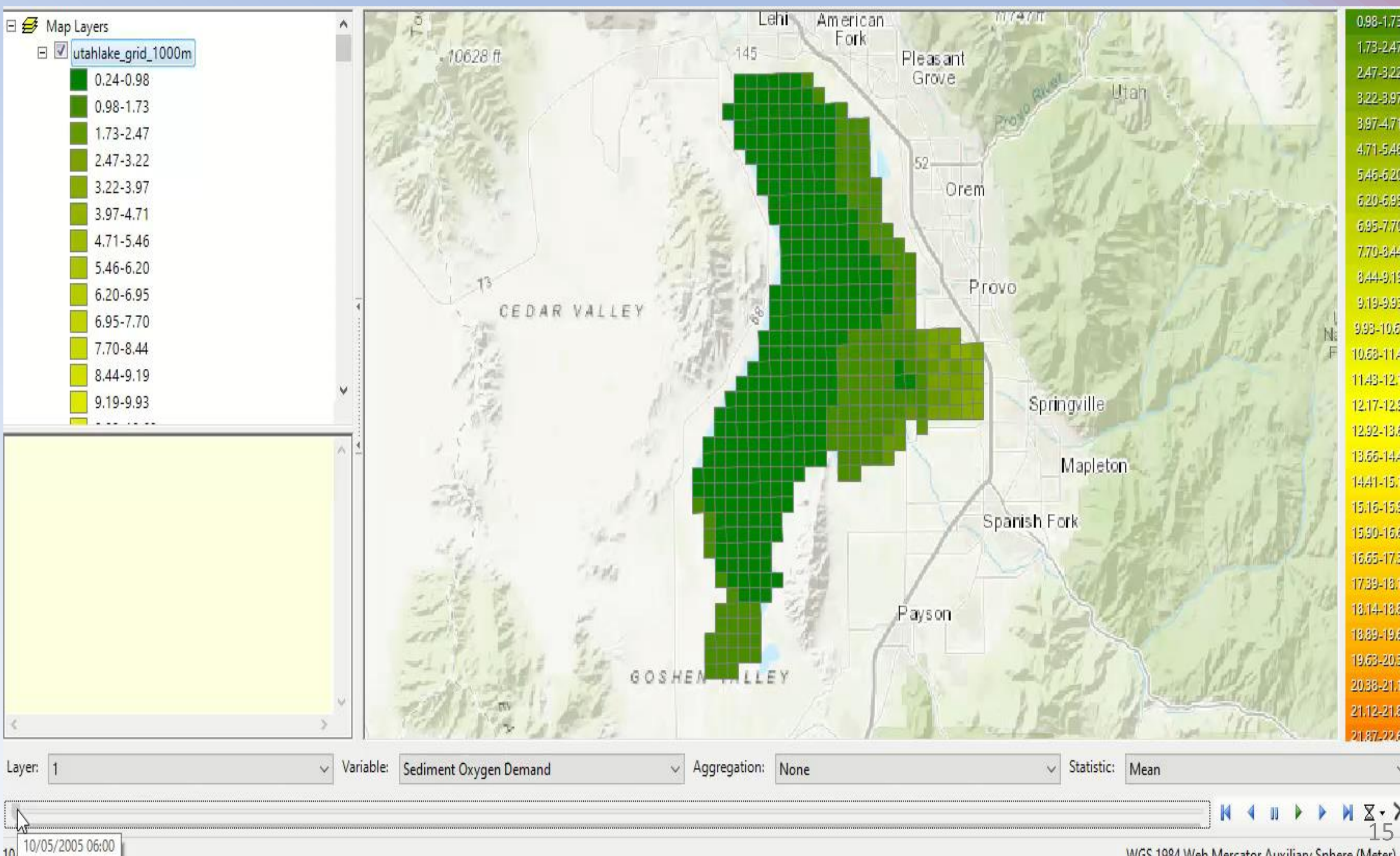
Legend

- -4.609786987 - -4.197599941
- -4.19759994 - -3.785412894
- -3.785412893 - -3.373225848
- -3.373225847 - -2.961038801
- -2.9610388 - -2.548851755
- -2.548851754 - -2.136664708
- -2.136664707 - -1.724477662
- -1.724477661 - -1.312290616
- -1.312290615 - -0.900103569

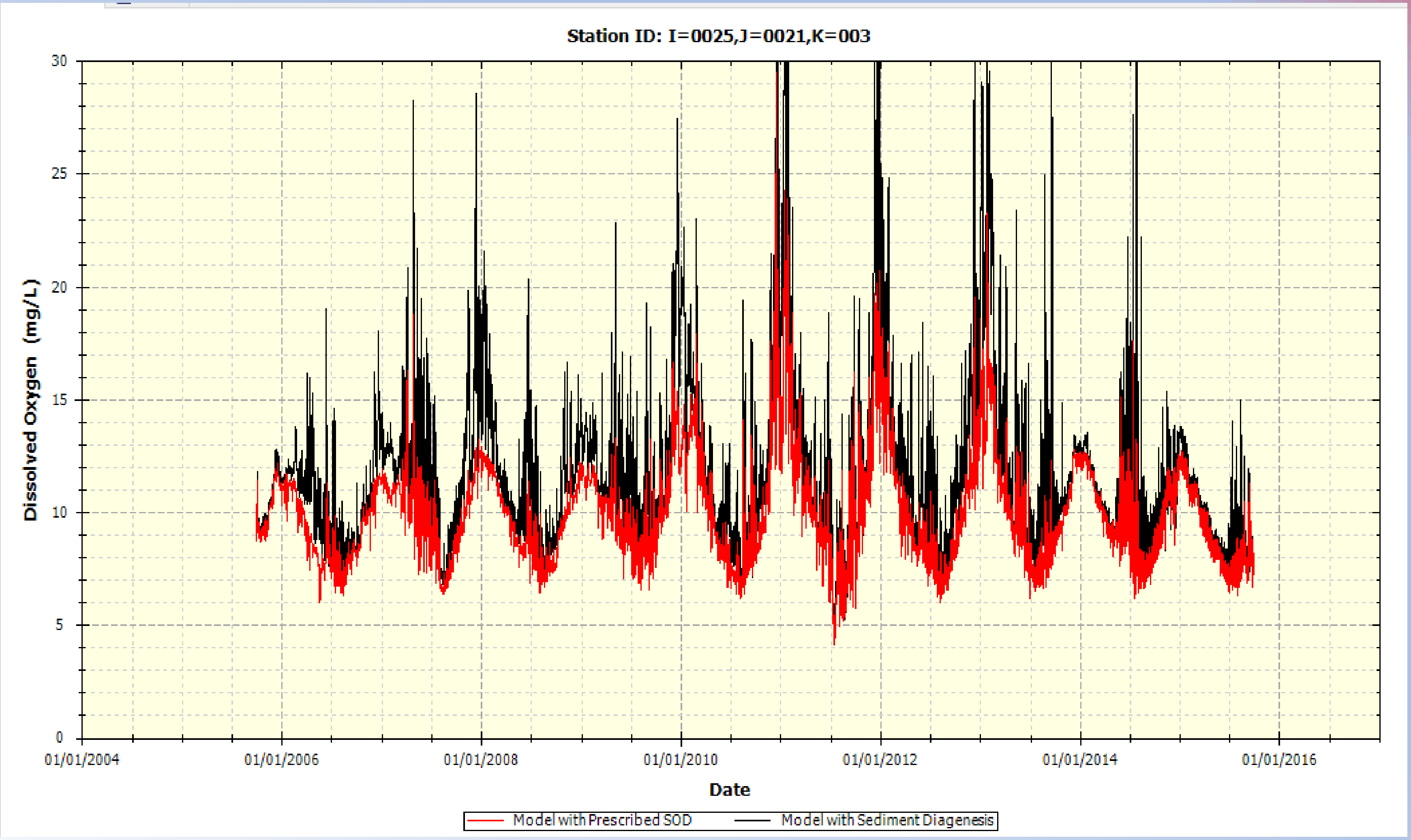
Utah Lake SOD (g O_2/m^2-day) (0 (Green) to 0.86 (White); Increments of 0.02 g O_2/m^2-day)



Utah Lake SOD (g O_2/m^2-day) (Prescribed SOD; 0 (Green) to 37.54 (White); Increments of 0.75 g/m^2-day)



Sediment Diagenesis vs. Prescribed SOD Only



Model Sensitivity

General Commentary over Sensitivity Analyses Conducted

Model Sensitivity…

- Applied upon…
  - Nutrient Kinetics
  - Phytoplankton Kinetics (applied upon all groups simultaneously)
  - **Macro/Benthic Algae O_2:C Production Rate**
  - POM and Sediment Diagenesis Parameters List of Parameters Included in Table 3.1 of Model Report
- General Commentary of Model Sensitivity in Section 3.2 of Model Report
- Detailed List of Values provided in Appendix A.1
- Sensitivity Plots for Randomly-Selected Nodes and upon Selected Constituents in Appendix A.2

Model Sensitivity (continued)

- Model Appearing to Run "very slowly" when applying sensitivity upon…
  - Initial POC/POP/PON Sediment Conditions (Sediment Diagenesis; if value is too high, such as over 50 mg/g sediment (mg O_2 equivalents/g sediment for POC, mg-N/g sediment for PON, mg-P/g sediment for POP))
  - Fraction of Class G_1/G_2/G_3 (Sediment Diagenesis)
  - Phytoplankton Maximum Growth Rate at 20 degrees Celsius (if value is too high, such as over 15 per day)

Model Calibration Efforts

Animations of Selected Constituents over Selected Vertical Layers of Utah Lake, General Commentary over Utah Lake Calibration Work, Evaluation of Numerical Stability of Utah Lake WASP

General Commentary over Calibration Work

- Calibration Work over Utah Lake WASP (Section 4.1.2 on Calibration Approaches in Model Report)
  - Graphical Approaches (Appendices B.1 for Time-Series, B.2 for Scatter Plots, B.3 for Probability Plots)
    - Time-Series of Simulated vs. Measured, Scatter Plots of Simulated vs. Measured, Cumulative Probability Plot: **DO**, **NH_3-N**, **Total Phytoplankton Chlorophyll-a**
    - Time-Series Plots of Simulated vs. Measured: All other Constituents (NO_2-NO_3-N, TP, CBOD, TSS)
  - Statistical Approaches (Appendix B.2 for all constituents)
    - Descriptive Statistics (Mean, Median, 25th Percentile, 75th Percentile of Simulated Results vs. Measured Data)
    - Coefficient of Determination (R^2)
    - Mean Absolute Error
    - Root-Mean Square Error
    - Normalized Root-Mean Square Error
    - Index of Argument

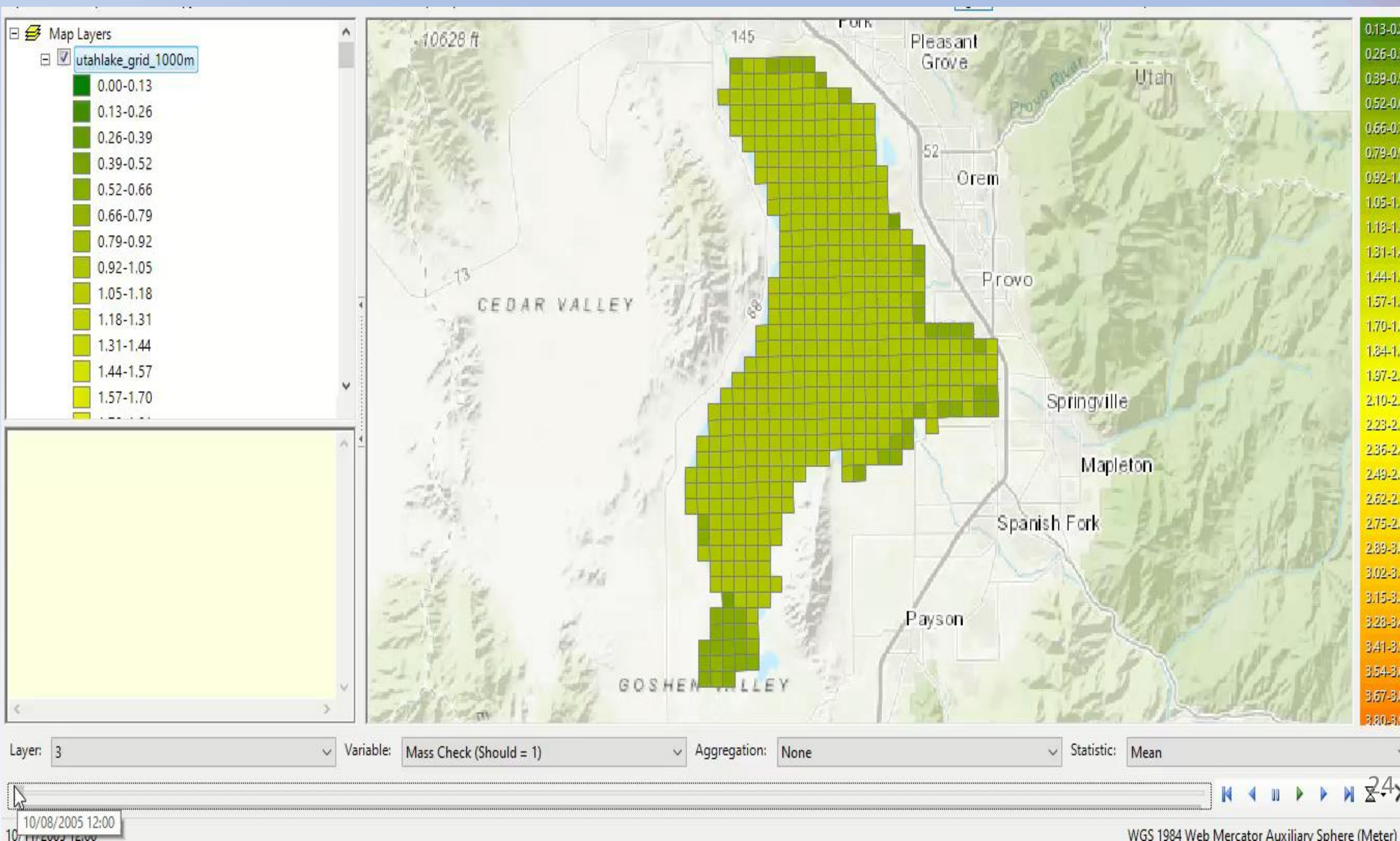
General Commentary over Calibration Results (Section 4.2.2 of Report)

- Based on Simulated Results vs. Measured Data
  - Underprediction of NO_2-NO_3-N, likely for NH_3-N (General Agreement appearing observed for some nodes)
  - Overprediction of TP, TSS
  - Slight Overprediction of DO; General Agreement appearing observed for some nodes
  - Slight Overprediction of particular nodes for Total Phytoplankton Chlorophyll-a
  - CBOD: Inconclusive due to lack of Measured Data
- Model Calibration Performance: Recommend Reviewing Characteristics of WASP for Performance
  - Sediment Diagenesis Simulations over Utah Lake ➔ SOD, DIP Benthic Flux, Ammonia Benthic Flux
  - Nitrogen-Fixed Cyanobacteria (Phytoplankton Group 2) appearing to "dominate"
  - Several Model Underlying Parameters (e.g., Sediment Diagenesis Constants, Solids Transport Constants, etc.) can be revisited

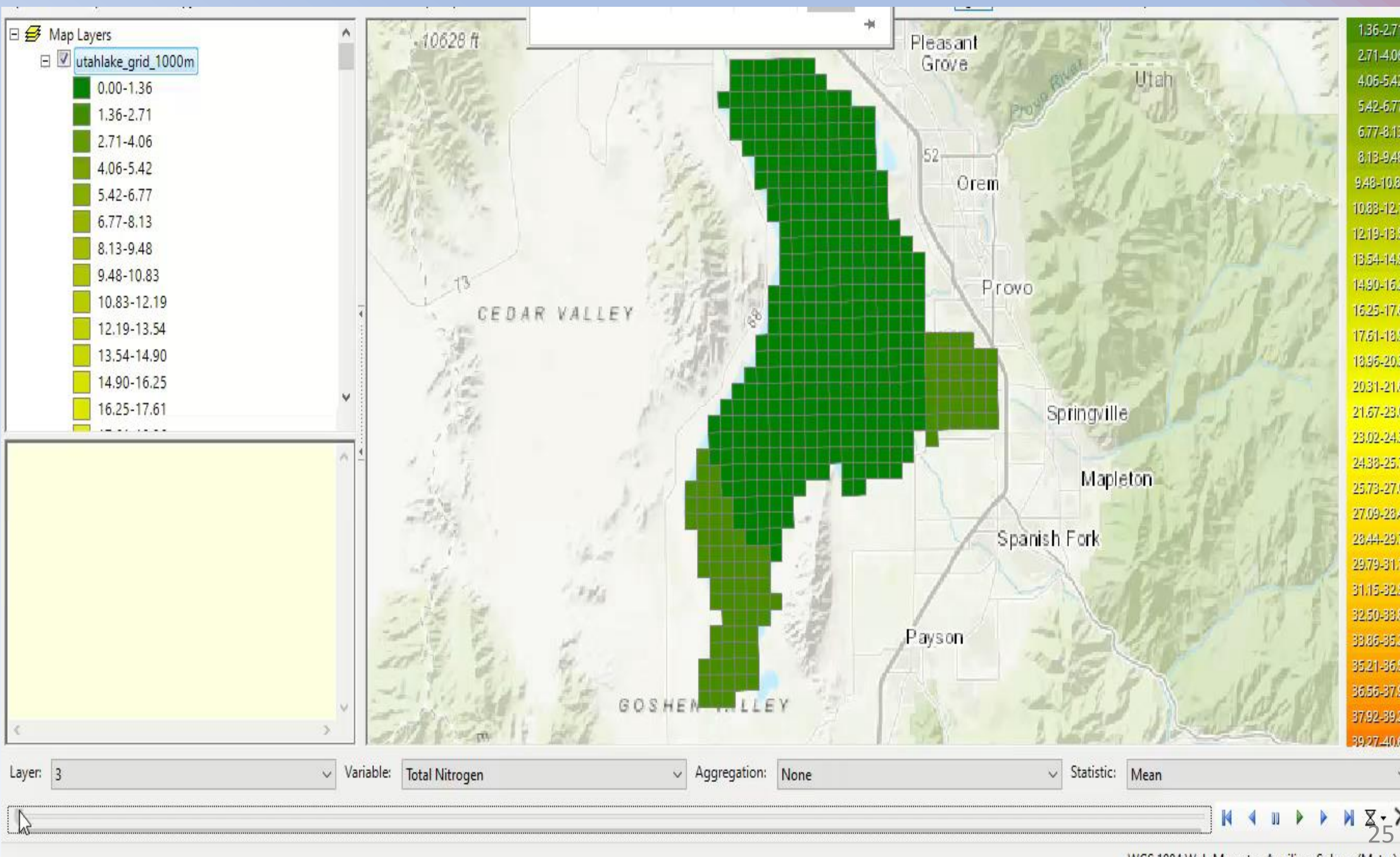
Model Calibration vs. Stability?

- Potential Numerical Instability Likely for the Utah Lake WASP (Mass Check Values >> 10)
- How the system performs at nodes with measured data from UDWQ AWQMS sites ≠ Model is Numerically Stable throughout all of Utah Lake
  - Viewing all time-series, scatter plots, probability plots, etc. for ALL 1356 Utah Lake nodes? Task appearing similar to the "blind men and the elephant"
  - Animations over Utah Lake WASP through WRDB GIS
  - High Values for Several WQ Constituents (e.g., Nitrogen Species, DO, Total Phytoplankton Chlorophyll-a, etc.) appearing observed for parts of Utah Lake for nodes <u>without</u> any monitoring data ➔ Potential Numerical Instability?

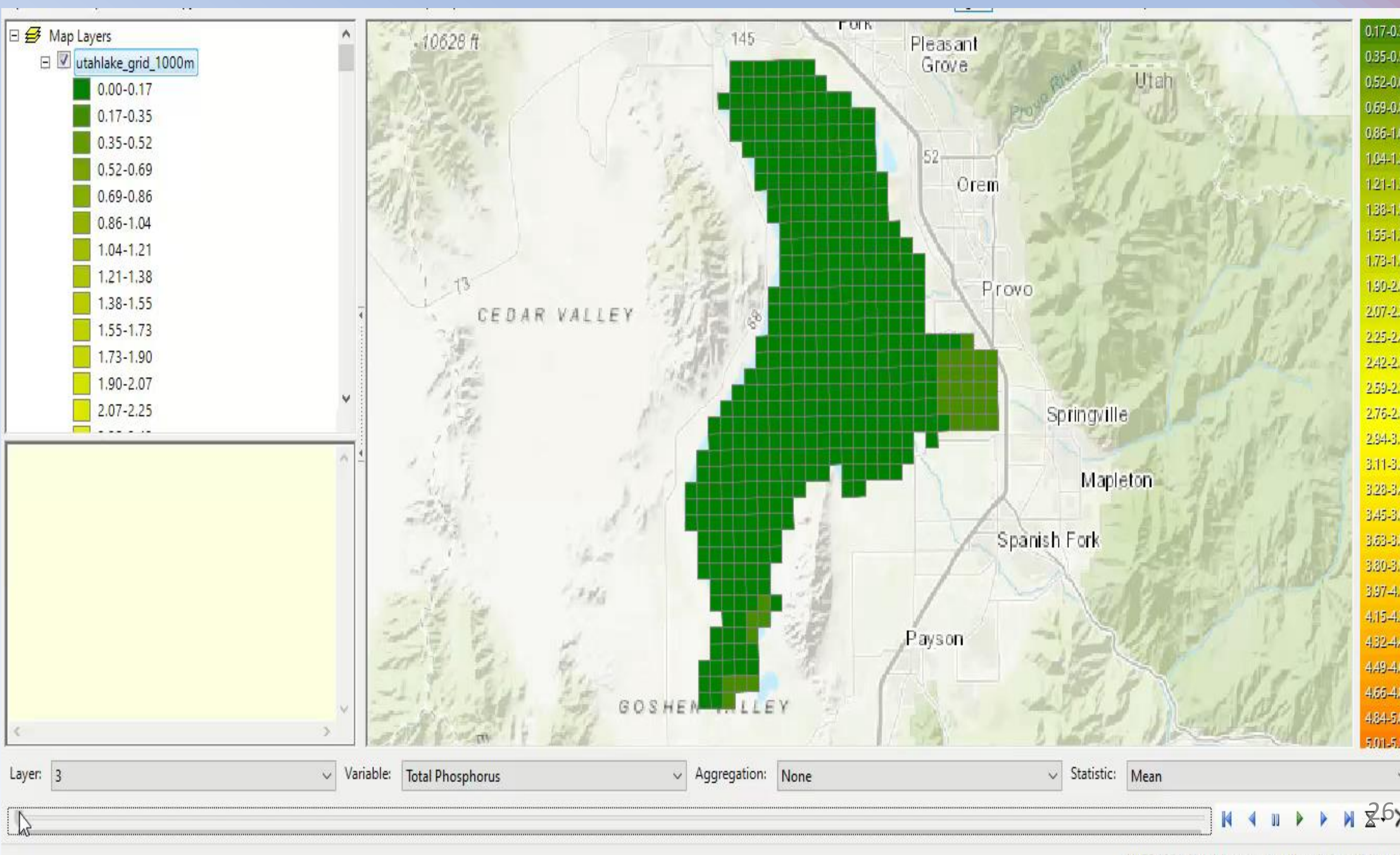
Utah Lake Mass Check ("Conservative Tracer") at K = 3 (0 (Green) to 6.56 (White); Increments of 0.13)



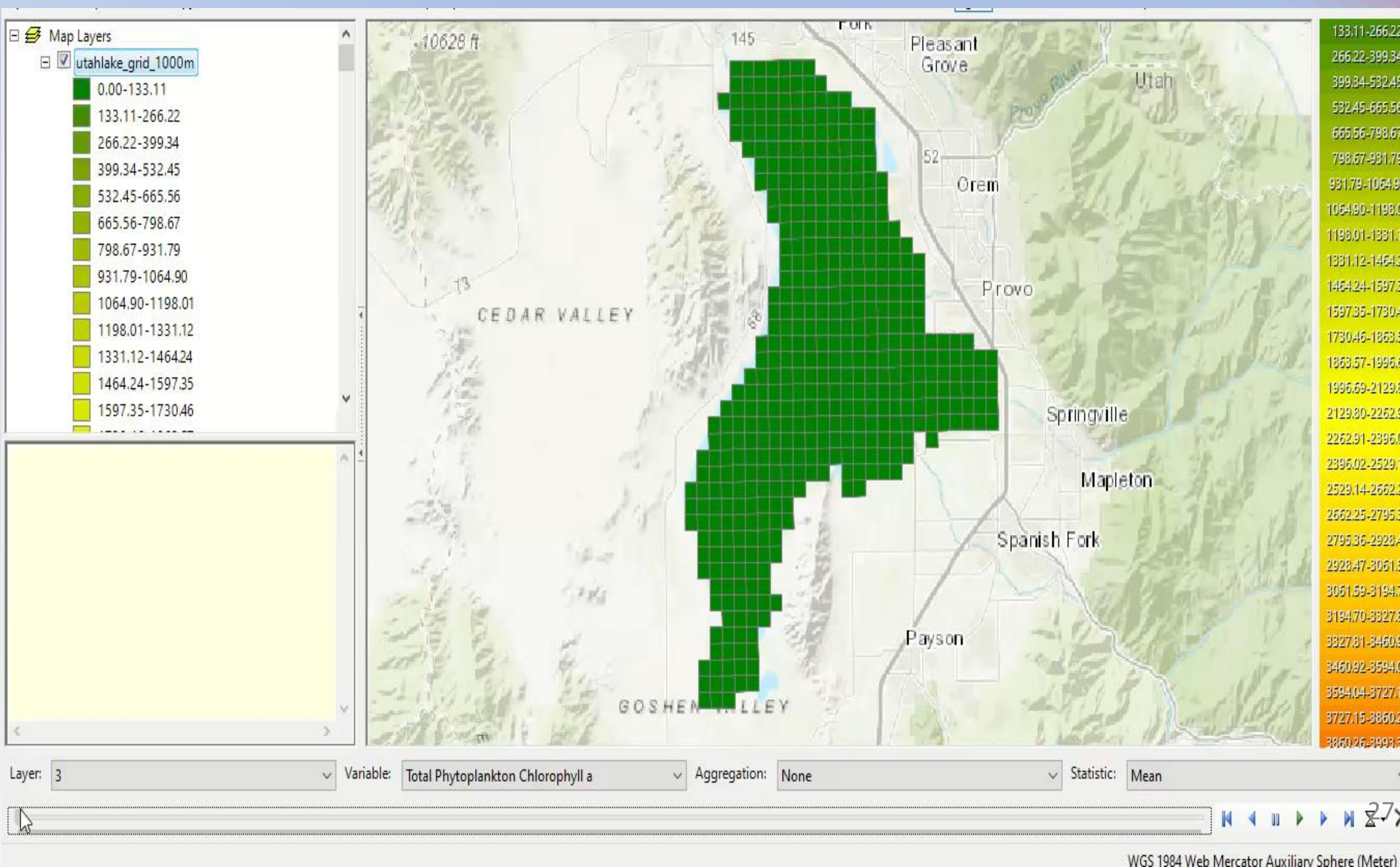
Utah Lake Total Nitrogen (mg/L), K = 3 (0 mg/L (Green) to 67.71 mg/L (White); Increments of 1.36 mg/L)



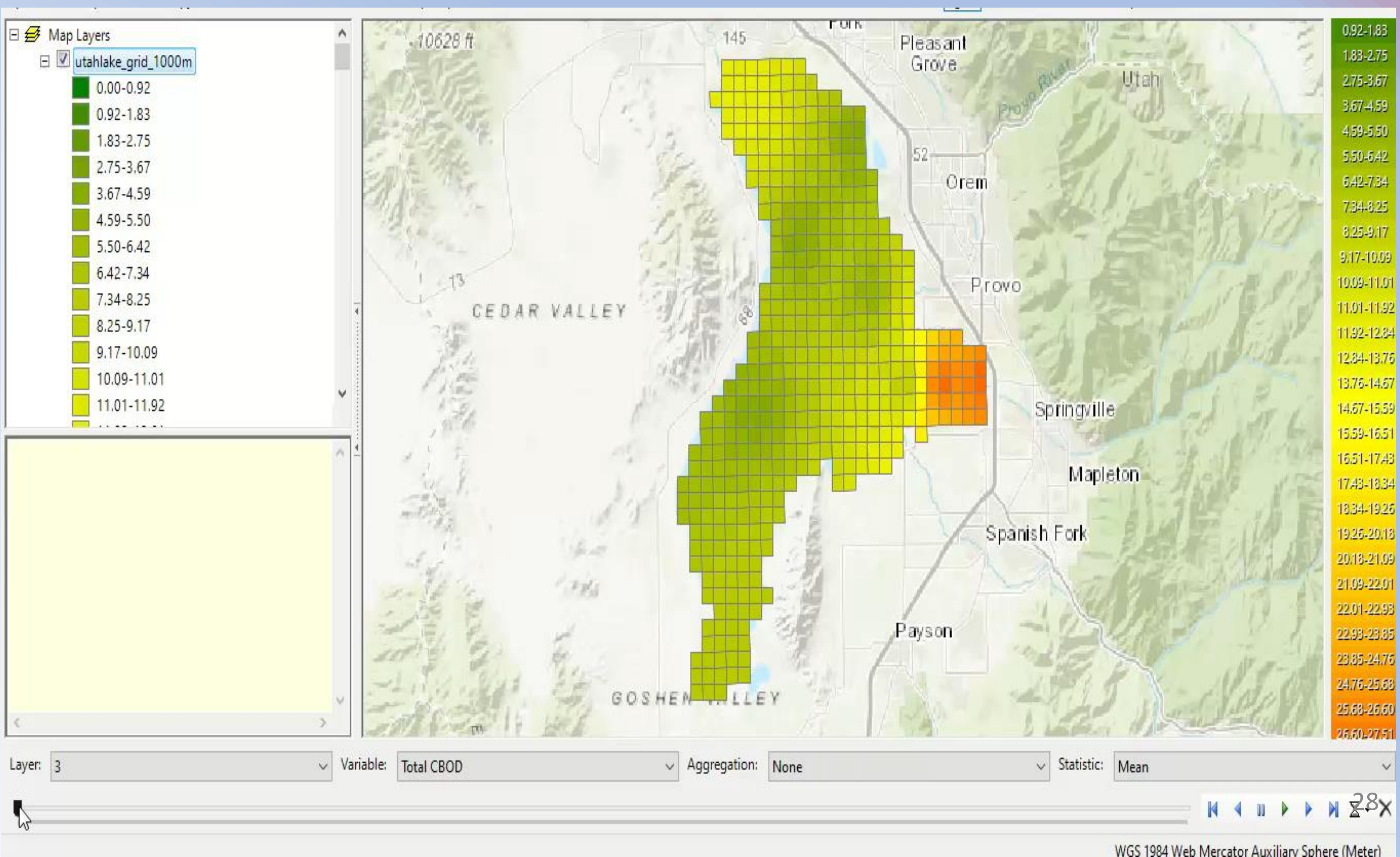
Utah Lake Total Phosphorus (mg/L), K = 3 (0 mg/L (Green) to 8.64 mg/L (White); Increments of 0.18 mg/L)



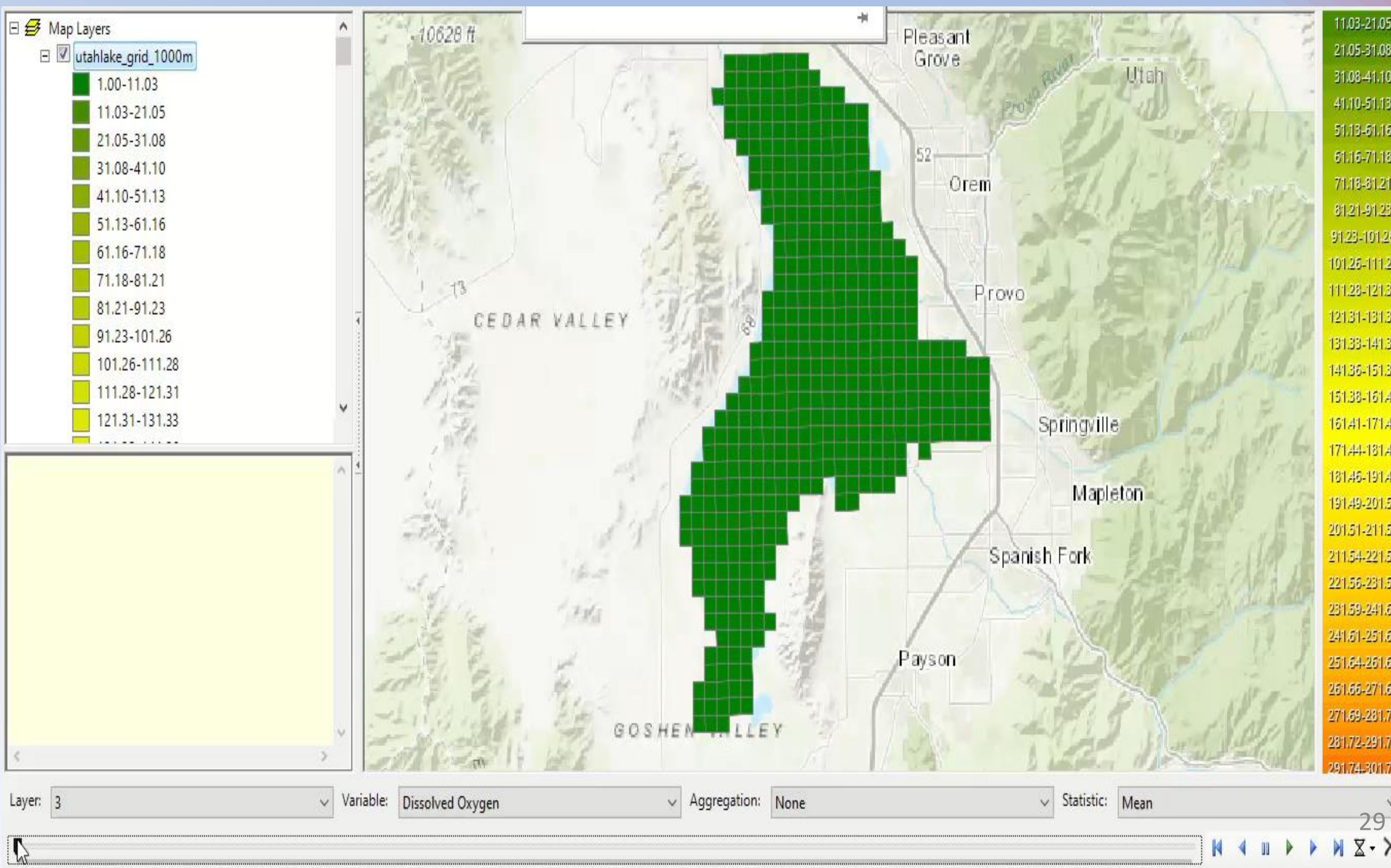
Utah Lake Total Phytoplankton Chlorophyll-a (μg/L), K = 3 (0 mg/L (Green) to 6.65562 mg/L (White); Increments of 133.11 μg/L)



Utah Lake CBOD (mg/L), K = 3 (0 mg/L (Green) to 45.86 mg/L (White); Increments of 0.92 mg/L)



Utah Lake DO (mg/L), K = 3 (0 mg/L (Green) to 502.28 mg/L (White); Increments of 11.03 mg/L)



Animations over Utah Lake WASP

- Numerical Instability over Utah Lake WASP?
  - High Mass Check Values (>>10) along/near Utah Lake Boundary (Not shown in BMD2 file, but documented in OUT file)
  - High Phytoplankton Chlorophyll-a, DO along Provo Bay/near Provo River Outfall
  - High CBOD values along the boundaries of Utah Lake
  - High Values of Nitrogen and Phosphorus likely along American Fork River area, Lindon Drain, Timpanogos WWTP outfall
- May Need Revisit of Utah Lake Node Development, Numerical Stability, Model Performance for both EFDC and WASP

Additional Model Build

Water Year 2009 to 2013 Model Development, R Scripting

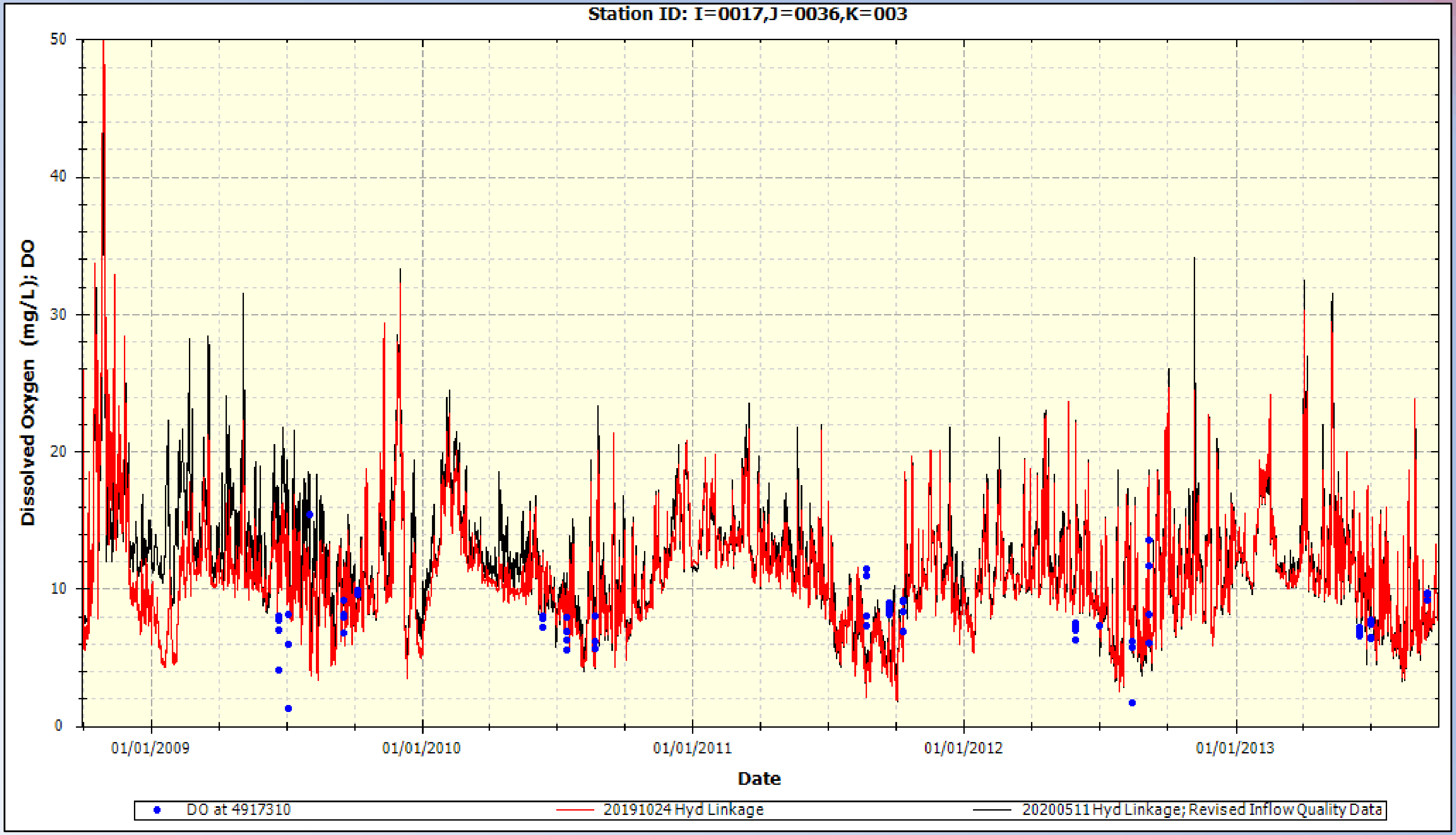
Additional Model Development?

- UDWQ AWQMS Sites NOT Covering Model Calibration Period (Water Year 2006-2015); Most UDWQ AWQMS Sites for Outfalls primarily from **March 2009 to August 2013**
- Several Outfalls Represented as WWTP Outfalls rather than the actual ones themselves
  - Benjamin Slough/Beer Creek as Payson + Salem WWTP
  - Dry Creek South as Spanish Fork WWTP
  - Mill Race as Provo + Springville WWTP
  - Powell Slough as Orem WWTP
- Particular Inflows (e.g., Currant Creek, Dry Creek North, etc.) included as "Blank Inflow Data" (e.g., No Inflow Quality Data Populated)

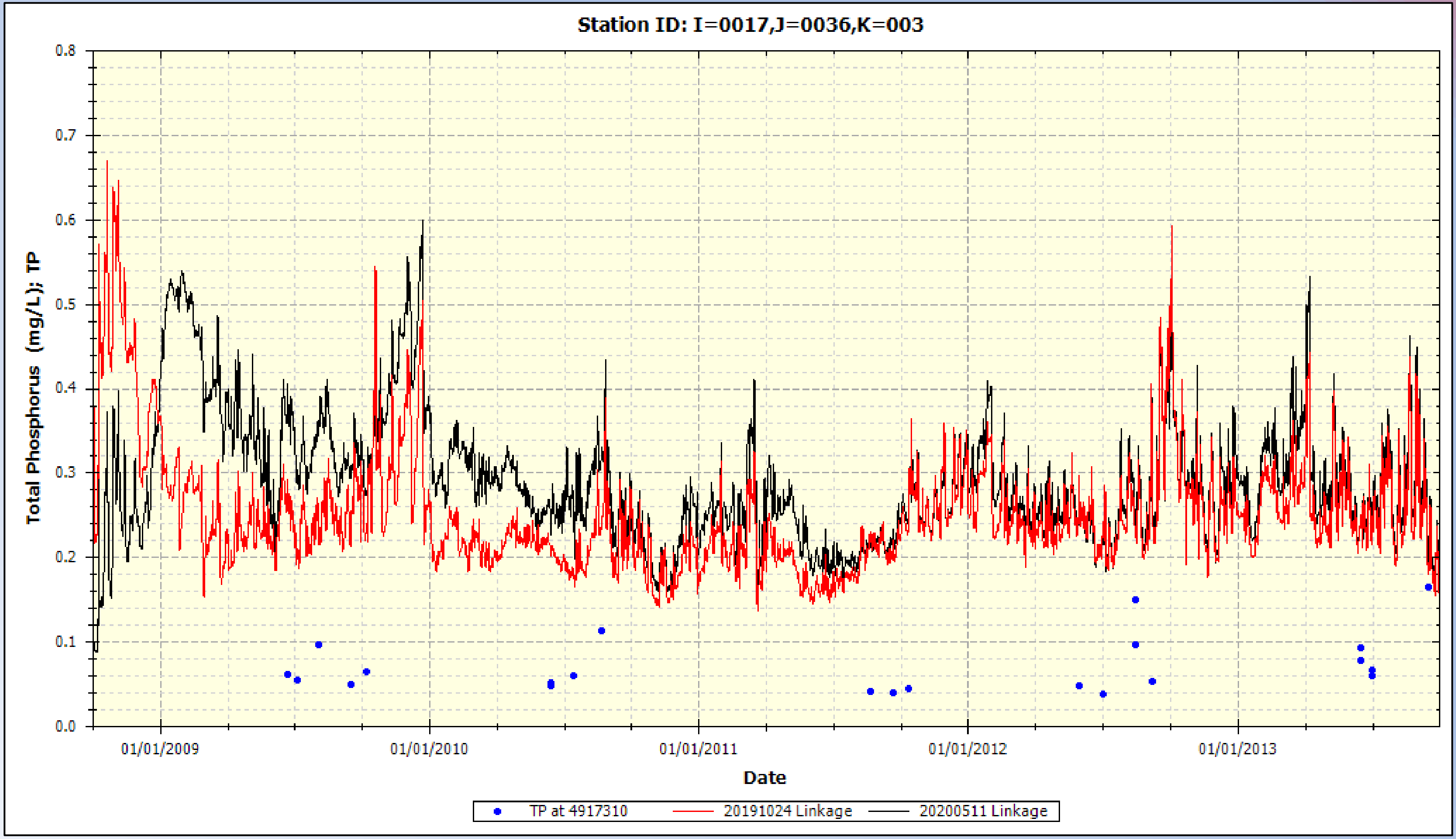
Model under Revised Time Period

- Water Year 2009 to 2013 (October 1, 2008 to September 30, 2013)
- List of Revised Inflow Quality Data Sources for Particular Inflows in Table 5.2 of Report
  - Inflow as Only WWTP Outfalls to Inflow as Combined UDWQ AWQMS Site upstream of WWTP + WWTP Outfall, Combination of Multiple UDWQ AWQMS sites Downstream of WWTPs, etc.
  - Need for Conducting Several Elemental Mass Balances → R Script Development (Sample Script in Appendix D of Model Report)
- Revised Approaches for TP Speciation (POP = TP – DP rather than DOP = TP – DP, with DP speciation from Yang and Toor (2018))
- ALL Other Inputs (e.g., Phytoplankton Grouping, Sediment Diagenesis, Atmospheric Deposition, etc.) SAME as Water Year 2006-2015 Period

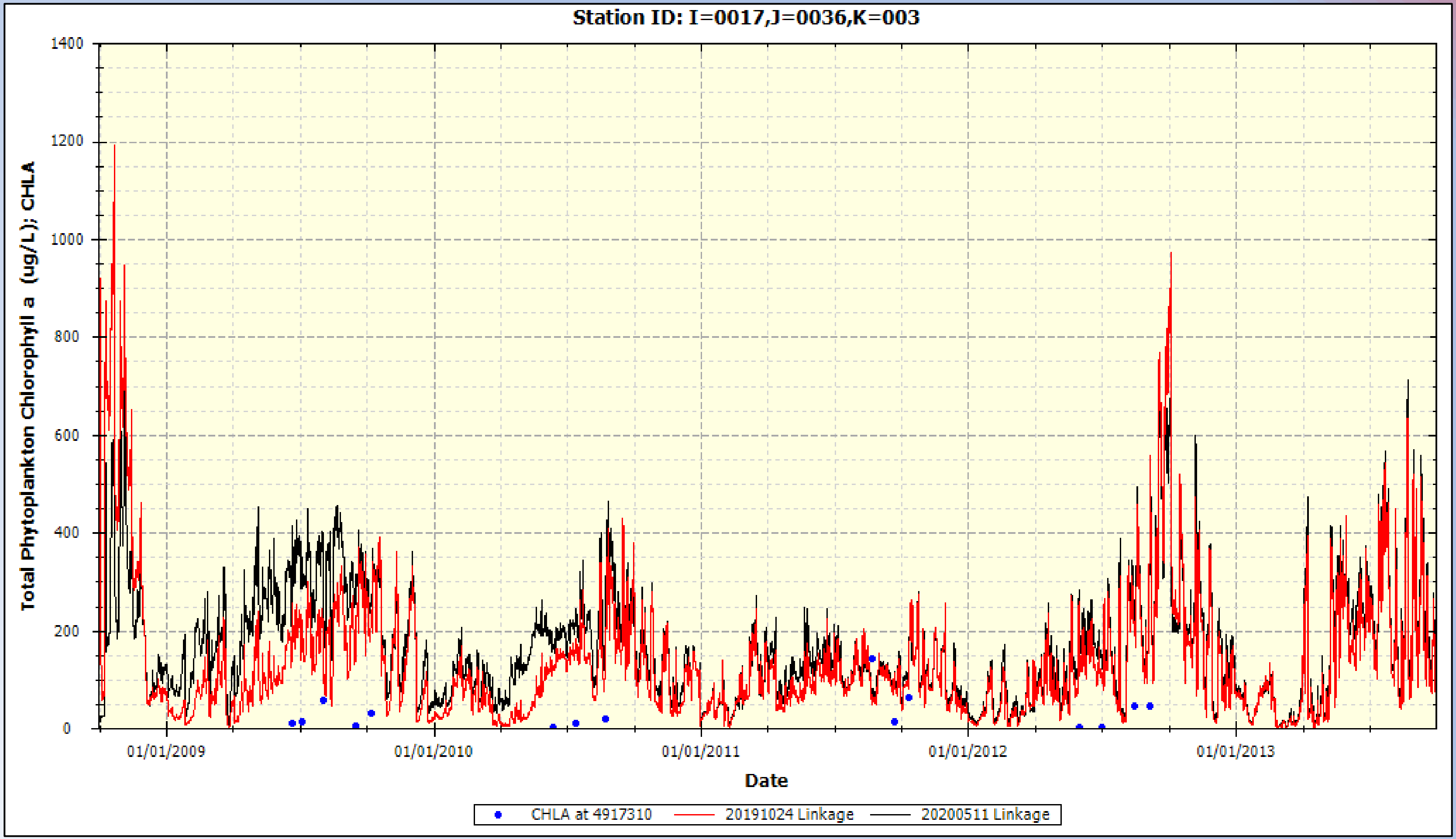
Comparison of Revised Time Period vs. Water Year 2006-2015 Calibration Period: DO (mg/L) (Figure 5.1 of Model Report)



Comparison of Revised Time Period vs. Water Year 2006-2015 Calibration Period: TP (mg/L) (Figure 5.4 of Model Report)



Comparison of Revised Time Period vs. Water Year 2006-2015 Calibration Period: Total Phytoplankton Chlorophyll-a (μg/L) (Figure 5.5 of Model Report)



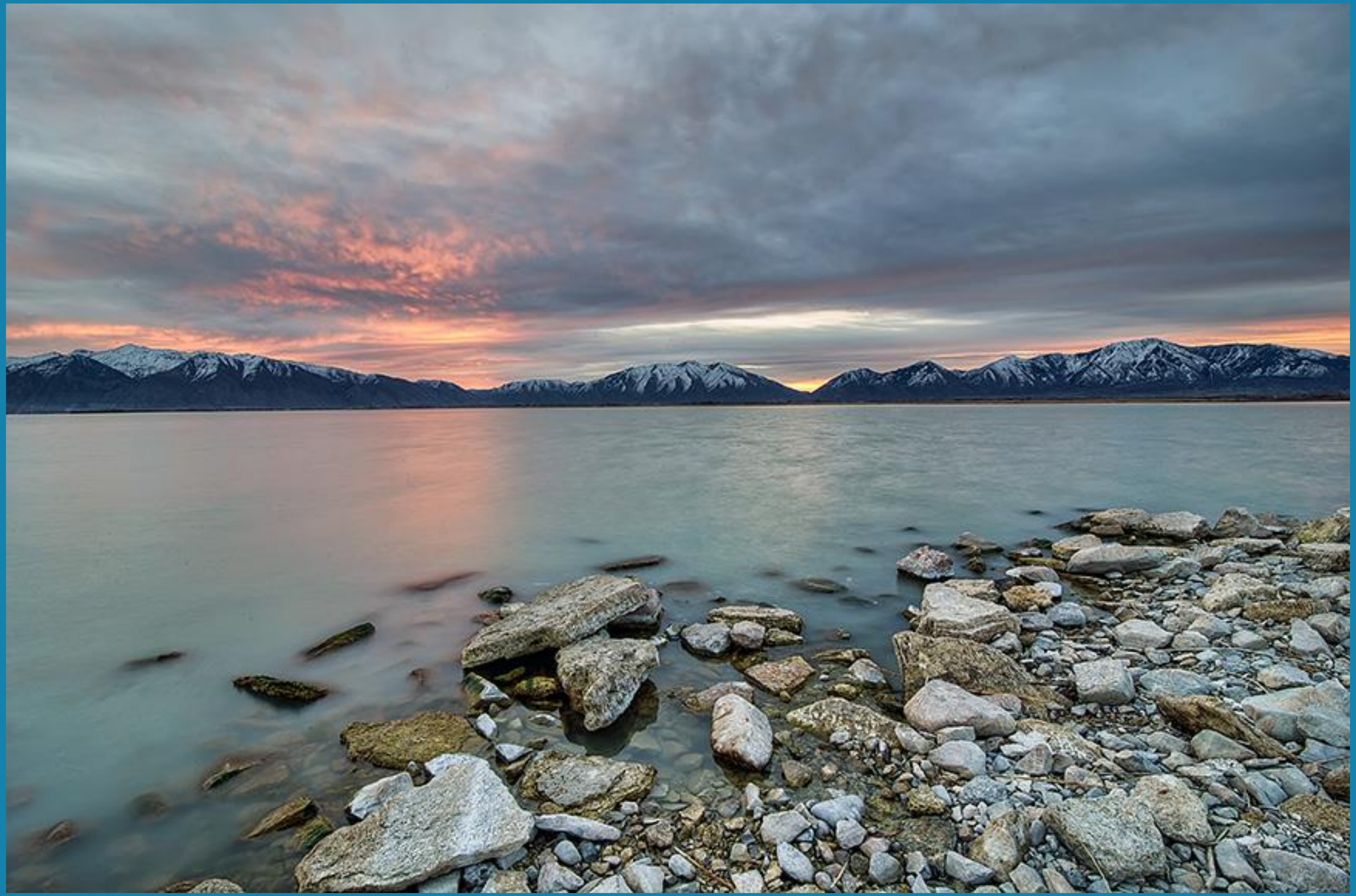
General Conclusions and Summary

- More Details on the Inflow Data Sources, Approximations of Several Input Parameters (Atmospheric Deposition, Phytoplankton Speciation/Grouping, Sediment Diagenesis, Sediment Characterization, etc.), Model Sensitivity Analyses, Model Calibration Efforts/Plots in Model Calibration Report (Su and von Stackelberg 2020)
- Numerical Stability vs. Model Performance
- Water Year 2009-2013 Model Build vs. Water Year 2006-2015 Model Calibration Period

Questions? Thank you for Viewing the Presentation!

Department of
Civil & Environmental Engineering
THE UNIVERSITY OF UTAH

Juhn-Yuan Su, M.S., E.I.T., Ph.D. Candidate, u1087209@umail.utah.edu

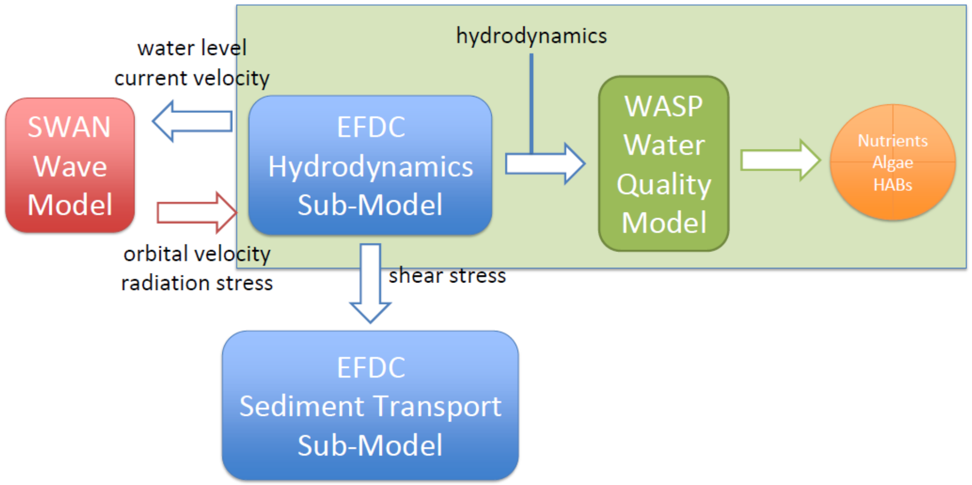


MECHANISTIC MODELS DISCUSSION

Utah Lake Water Quality Study
Science Panel Meeting
September 18, 2020

DISCUSSION: ULWQS MECHANISTIC MODEL ASSESSMENT OF MODEL PERFORMANCE

Model Framework

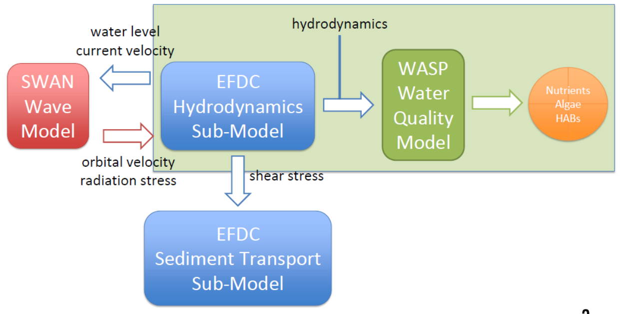


1. Assessment of current model performance
2. Summary of previously identified model limitations
3. Science Panel discussion of model limitations to be addressed in the next phase of model development

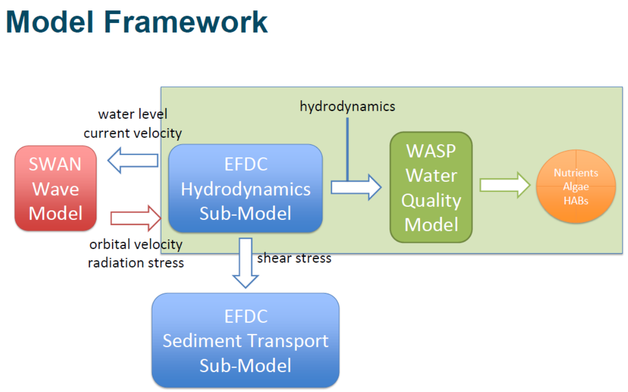
DISCUSSION: ULWQS MECHANISTIC MODEL PART A: ASSESSMENT OF CURRENT MODEL PERFORMANCE

- UtahLakeModelQAPP_v1.10 (e.g. performance criteria)
- Other presentations and discussions on the model, model performance objectives, and model limitations
- Presentation 9/18/2020 by Nicholas von Stackelberg and Juhn-Yuan Su
- Utah Lake Hydrodynamic (EFDC) And Water Quality (WASP) Model Report; June 30, 2020 (includes graphical and statistical evaluation of model predictions)
- Additional materials for WRDB
    - Observed Database file (WRDB format): use for evaluation of available data as well as for comparison with model predictions (see tutorial and online tutorials on WRDB)
    - GIS Model Grid (shape files for plotting in WRDB)
    - WRDB Graph files (to aid in plotting specific results)
    - UtahLakeMonitoringLocations.pdf
    - EFDC Output files (BMD2 format)
    - WASP output files (BMD2 format)

Model Framework

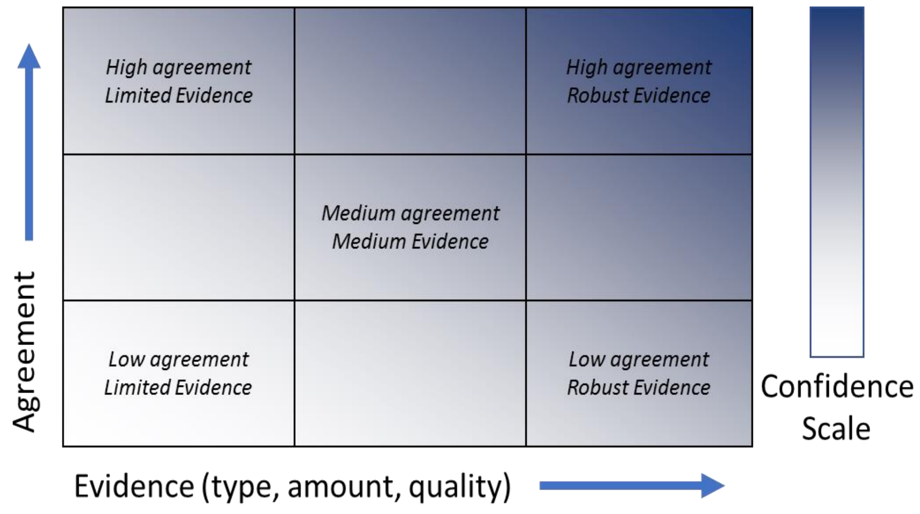


DISCUSSION: ULWQS MECHANISTIC MODEL PART A: ASSESSMENT OF CURRENT MODEL PERFORMANCE; POTENTIAL NEXT STEPS



Evaluate the current models and model data

- Data Limitations and Quality Issues (e.g. for model forcings and for model evaluation)
- Model Structure Limitations (e.g. grid, model state variables, parameterization)
- Model Performance Limitations (e.g. in comparison to observed data)



WASP variable	Station	Grade	WASP variable	Station	Grade
Chlorophyll *a*	MB	Very Good	DO	MB	Very Good
	WB	Very Good		WB	Very Good
	MR	Very Good		MR	Very Good
	FR	Very Good		FR	Good
Mineral nitrogen	MB	Good		WB1	Very Good
	WB	Good		WKBB1	Very Good
	MR	Very Good		WKBB2	Very Good
	FR	Good		WKBB4	Very Good
	WB1	Fair		WKBB5	Good
	WKBB1	Fair		WKBB6	Very Good
	WKBB2	Very Good	CBOD	WB1	Good
	WKBB4	Poor		WKBB1	Very Good
	WKBB5	Very Good		WKBB2	Very Good
	WKBB6	Fair		WKBB4	Good
Mineral TP	MB	Very Good		WKBB5	Very Good
	WB	Very Good		WKBB6	Good
	MR	Very Good	TSS	WB1	Very Good
	FR	Very Good		WKBB1	Very Good
	WB1	Very Good		WKBB2	Very Good
	WKBB1	Very Good		WKBB4	Very Good
	WKBB2	Very Good		WKBB5	Very Good
	WKBB4	Very Good		WKBB6	Very Good
	WKBB5	Very Good			
	WKBB6	Very Good			

Figure 5. Quality of calibration and validation of Weeks Bay water quality model (source: Appendix B, Table 9 in GOMA 2013).

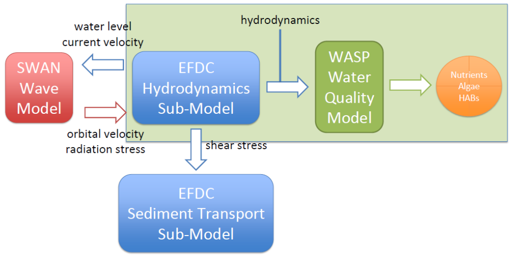
Table 1. General calibration/validation targets for EFDC/WASP7 applications

State variable	% Difference between simulated and observed values		
	Very good	Good	Fair
Salinity	< 15%	15%–25%	25%–40%
Water temperature	< 7%	8%–12%	13%–18%
Water quality/D.O.	< 15%	15%–25%	25%–35%
Nutrients/chl *a*	< 30%	30%–45%	45%–60%

Weeks Bay water quality model (2011)

Utah Lake Water Quality Study—
Numeric Nutrient Criteria Technical Framework

Model Framework

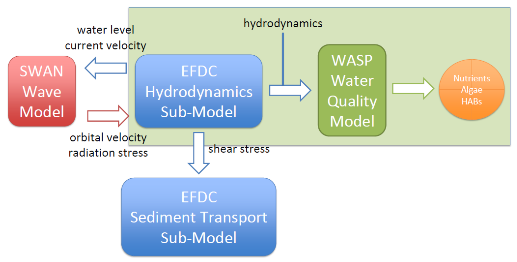


DISCUSSION: ULWQS MECHANISTIC MODEL PART A: ASSESSMENT OF CURRENT MODEL PERFORMANCE; POTENTIAL NEXT STEPS

- Determine if the model in its present form can be used to address specific questions/issues (e.g. Strategic Plan; Framework document)
- Determine improvements needed in order for the model to be considered suitable for application to numeric nutrient criteria development
  - Determine information/study needs to support design of model modifications
  - Support implementation and testing of model modifications (potentially by consultant)

DISCUSSION: ULWQS MECHANISTIC MODEL PART A: ASSESSMENT OF CURRENT MODEL PERFORMANCE; POTENTIAL NEXT STEPS

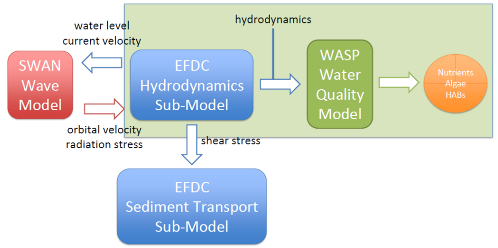
Model Framework



- Example Design Tasks for Modeling SOW
  - Current Model Transfer and Testing
  - External Review and Model QA/QC for existing Model
  - Development of Modeling Plan
  - Development of documentation for Data quality issues and Quality Assurance (QA) Planning
  - Develop strategy for addressing model limitations/deficiencies
  - Model Refinement and Testing
  - Evaluation and Assembly of Model Data
    - Model Grid
    - Boundary Conditions and Loads
    - Initial Condition Data
  - Assemble and documentation of calibration and evaluation data
  - Development and evaluation of Model Input
  - Test and Calibrate the model
  - Conduct sensitivity and uncertainty analyses
  - Apply the model to address identified conditions and model scenarios

DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS

Model Framework

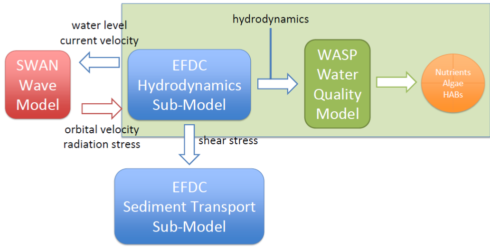


- Model Limitations have been discussed in previous meetings and documented
- Model Limitations Include:
  - Data Limitations and Quality Issues (e.g. for model forcings and for model evaluation)
  - Model Runtime Issues (e.g. model components not performing as expected)
  - Model Performance Limitations (e.g. in comparison to observed data)
  - Model Structure Limitations (e.g. grid, model state variables, parameterization)
  - Model Uncertainty Issues (see Uncertainty Guidance; not as yet performed)

DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: DATA LIMITATIONS; SUPPORTING PROJECTS

		Combined Rank
	Original Ideas	
1	How Large is Internal vs External Loading (How long would recovery take?)	1.9
2	Calcite Scavenging (how bioavailable is SRP – does bioassay address?)	3.4
3	Sediment Budgets (C, N, and P; nutrient flux chambers)	3.9
4	Adding modules to the WQ models (sediment diagenesis, calcite scavenging)	5.2
5	Lake Level (Effect on Macrophytes~~; Effect on Biogeochemistry~~)	9.0
6	Carp Effects on Zooplankton (and does this influence algal response)	9.6
7	Recreational Surveys (not universal support)	9.6
8	Carp Effects on Macrophytes ~~(and linkage to biogeochemistry)~~	9.9
9	Macrophyte recovery potential (Provo Bay demo)	10.7
10	Turbidity Effect on Primary Producers	10.6
11	Macrophyte role (to biogeochemistry)	11.1
12	Alternative models (PCLake – cyano/macrophyte state change)	12.0
13	Toxin Production and N Species	12.3
	Novel Ideas- Group 1	
1	Carp effects on nutrient cycling	3.7
2	Environmental controls on toxin production	5.0
3	Lake-level effects on biogeochemistry and nutrient cycling	8.0
	Novel Ideas- Group 2	
1	Bioassays that incorporate sediment (next phase mesocosms)	4.3
2	Resuspension rates from bioturbation	9.0
3	Additional atmospheric deposition data	9.8

Model Framework

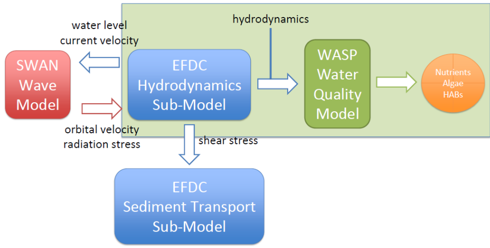


Current Projects

- Atmospheric Deposition
- Bioassay study
- Calcite-P Binding Study
- CNP Budget Study
- Engaging Sources of Information
- Littoral Sediment Study
- Paleo Study
- Sediment Study
- TSSD Study

DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: DATA LIMITATIONS; SUPPORTING PROJECTS

Model Framework



Analysis Report

Carp Excretion
Algal Cell count and pigment relationships
Sonde Data analysis
plankton spatial analysis
- Phytoplankton and zooplankton temporal dynamics
- Phytoplankton and zooplankton spatial dynamics
- Dynamics in plankton pattern related to nutrients
- Dynamics in plankton pattern related to lake level
- Dynamics in plankton pattern related to other factors
- Dynamics in plankton pattern related to climate

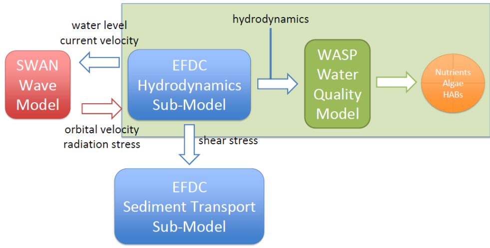
Environmental requirements of diatoms and macrophytes
Wind and turbidity
turbidity and macrophytes
Light extinction

Strategic Plan

Internal vs. external loading
Sediment budgets (C, N, and P; nutrient flux chambers)
Calcite scavenging
Adding modules to the WQ models (sediment diagenesis, calcite scavenging)
Carp effects on nutrient cycling
Lake level effects on macrophytes
Bioassays that incorporate sediment (next phase mesocosms)
Macrophyte recovery potential (Small scale demonstration)
Lake-level effects on biogeochemistry and nutrient cycling
Environmental controls on toxin production
Turbidity effects on primary producers
Resuspension rates from bioturbation
Carp effects on zooplankton
Carp effects on macrophytes
Toxin Production and N Species
Recreational surveys
Macrophyte role (to biogeochemistry)
Additional atmospheric deposition data

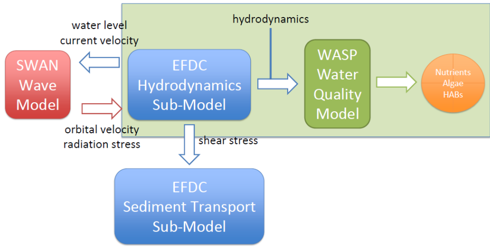
DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: DATA LIMITATIONS; SUPPORTING PROJECTS

Model Framework



- There has been an ongoing discussion of study and model limitations (e.g. ULWQS Thoughts on Univ of Utah Modeling December 2018)
- The Draft Memorandum (this meeting) Model Limitations with the purpose of documenting the model gaps, limitations and performance issues identified by the Science Panel and the recommended approach to resolve them in order for the model to be considered suitable for application to numeric nutrient criteria development. It is anticipated that a consultant will be procured by UDWQ to complete some or all of the recommended tasks.

Model Framework

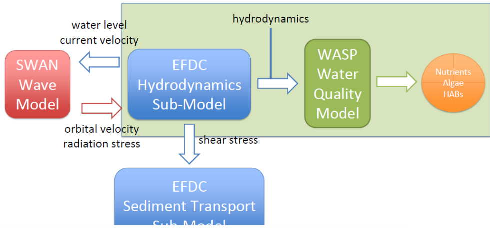


DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: DATA LIMITATIONS; SUPPORTING PROJECTS

- In this section we will review these limitations in order to initiate
  - How many and which of these issues and limitations will be addressed by ongoing projects?
  - What additional information and or projects are needed to identify and implement data and or model refinements to resolve these limitations
  - Can we prioritize the remaining issues and limitations in order to design and implement supporting studies

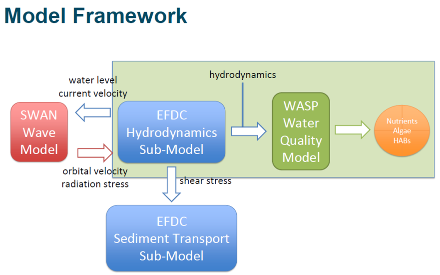
DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: DATA LIMITATIONS

Model Framework



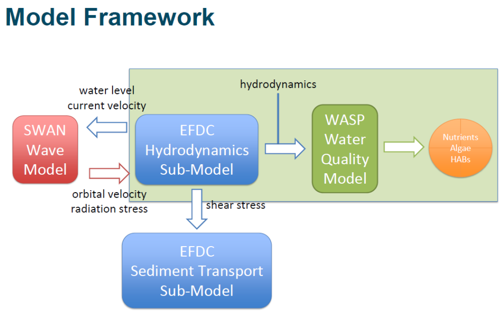
#	Model Performance	Recommended Refinement	Sources of Information	Tasks
1	Incomplete flow and water quality concentration data from tributaries, as well as in-lake water quality data, was available for the calibration period (Water Year 2009-2013), which introduced significant uncertainty to the model inputs and limited model performance evaluation.	Validate and refine model calibration utilizing more data rich time period, i.e. post-2016.		Select model application period and evaluate data for driving the model (e.g. boundaries and loads) and assessing model performance
	Incomplete data on POM and settling fluxes			
2	Other Issues?		Current Projects: • Atmospheric Deposition Study	

DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: MODEL RUNTIME ISSUES



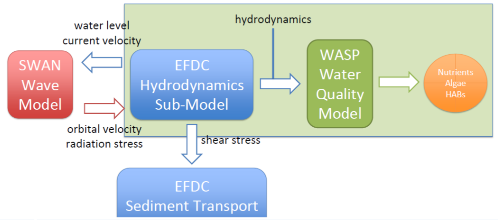
#	Model Performance	Recommended Refinement	Sources of Information	Tasks
2	Wetting and Drying Issues associated with runtimes and model stability	Resolve model run time issues and apply sediment diagenesis to all wet cells.		Coordinate with USEPA (Tim Wool) for resolution
5	The model does not produce reasonable results for pH and alkalinity, but should have this capability.	Coordinate with EPA WASP model developers to resolve this issue.		Coordinate with Bob Ambrose (developer of these routines)
6	The EFDC model does not simulate the effects of wave action on shear stress at the lake bottom.	Build and calibrate a wave model such as SWAN and couple with EFDC to simulate the effect of wave action on shear stress and sediment resuspension.		Create task in SOW?
	Stability and Mass Balance Issues			Coordinate with USEPA (Tim Wool) to identify cause of mass imbalances (model error or input error)

DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: MODEL PERFORMANCE ISSUES



#	Model Performance	Recommended Refinement	Sources of Information	Tasks
4	Phosphorus concentrations in the water column are consistently over-predicted by the model.	Refine model calibration utilizing more data rich time period, i.e. post-2016.		Investigate causes of overprediction and Refine Model Calibration
5	Other performance issues TBD from model review			Review, reevaluate performance criteria; Refine model calibration

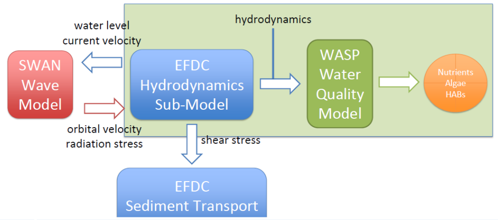
DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: STRUCTURAL ISSUES



#	Limitation	Resolution	Sources of Information	Tasks
1	<u>Cyano toxins</u>: Model does not simulate toxin production by cyanobacteria.	No modification required to model. Need to develop correlations between cyanobacteria and toxin production.	Research Projects: Environmental Controls on Toxin Production; Toxin production and N species	Develop strategy
2	<u>Food web</u>: The model does not simulate nutrient cycling through the food web	Develop separate food web model that can be used to support specification of rate constants in water quality model.	Research Projects: Carp studies (excretion, nutrient cycling; effects on zooplankton, macrophytes;	Develop strategy
3	<u>Bioturbation</u>: The model does not simulate bioturbation and sediment resuspension resulting from the activities of benthivorous fish.	Evaluate relative importance of bioturbation on sediment resuspension.	Research projects: • Turbidity effects on primary producers • Resuspension rates from bioturbation	Develop strategy for incorporation of bioturbation on sediment resuspension (it is in the diagenesis model)

DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: STRUCTURAL ISSUES

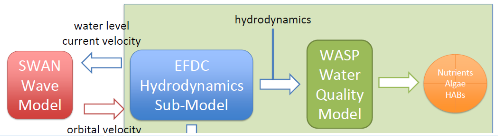
Model Framework



#	Limitation	Resolution	Sources of Information	Tasks
4	Microbes: The model does not simulate microbial biomass. The effect of microbes on organic matter decomposition is specified through rate constants.	No modification required to model. Additional investigation of organic matter decomposition and nutrient mineralization rates.	???	Develop strategy

DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: STRUCTURAL ISSUES

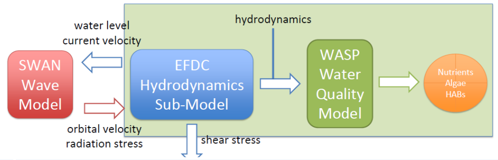
Model Framework



#	Limitation	Resolution	Sources of Information	Tasks
5	<u>Calcite bound phosphorus</u>: The formation of calcite and binding with phosphorus is not simulated by the model. Several approaches have been proposed to incorporate this mechanism into the model.	To be addressed through the Phosphorus Binding Strategic Research Project.	Current Projects: • Sediment Phosphorus Binding study • Internal vs. external loading • Sediment budgets (C, N, and P; nutrient flux chambers) • Calcite scavenging • Adding modules to the WQ models (sediment diagenesis, calcite scavenging)	Select Approach for Model Incorporation
6	<u>Iron bound phosphorus</u>: Phosphorus sorption to sediment is specified via a partition coefficient in the model that is not dependent on pH and redox conditions. Therefore, mineral bound phosphorus (iron, manganese, aluminum) sorption processes are not dynamically simulated..	To be addressed through the Phosphorus Binding Strategic Research Project.	Current Projects: • Sediment Phosphorus Binding study • Other research projects listed above	Select Approach for Model Incorporation

DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS: STRUCTURAL ISSUES

Model Framework

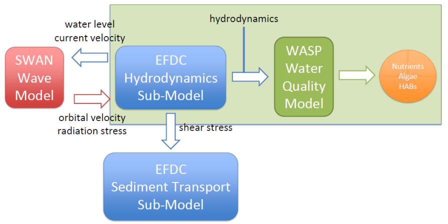


#	Limitation	Resolution	Sources of Information	Tasks
7	<u>Wetting/Drying</u>: The effect of wetting and drying of shallow areas on sediment diagenesis and nutrient fluxes between the sediments and water column is not fully represented. The model only simulates sediment diagenesis and nutrient fluxes on cells that are wet throughout the simulation period.	Evaluate relative importance of wetting/drying on sediment diagenesis and nutrient fluxes through Strategic Research Project and use results of the research to determine any necessary modifications to the model.	Current Projects • Littoral Study	Develop and implement strategy for model incorporation
	Adequate characterization of light penetration and light extinction (note this was not on the list but was discussed last teleconference)		• Project on Light Extinction (analysis report);	Incorporate CDOM and light extinction formulations in model Develop and implement strategy for model incorporation

DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS

#	Limitation	Resolution	Sources of Information	Tasks
8	<u>Macrophytes</u>: The model does not simulate macrophyte establishment and growth, including nutrient uptake from sediments, which has implications for simulating historical condition and lake restoration and management scenarios.	TBD	Current Research Projects: • Lake level effects on macrophytes • Macrophyte recovery potential (Small scale demonstration) • Carp effects on macrophytes • Macrophyte role (to biogeochemistry)	Develop and implement strategy for model incorporation

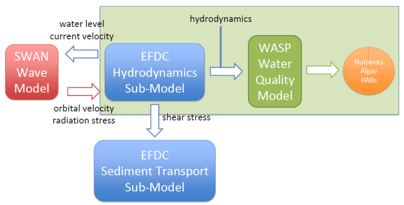
Model Framework



DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS

#	Limitation	Resolution	Sources of Information	Tasks
8	<u>Sediment Diagenesis</u> Only simulated on cells “wet” throughout simulation period EITHER sediment diagenesis is simulated OR SOD/nutrient flux is prescribed for model	TBD	• Littoral study • Previous measurements of SOD and nutrient fluxes • Adding modules to the WQ models (sediment diagenesis, calcite scavenging) • Sediment budgets (C, N, and P; nutrient flux chambers)	Develop and implement strategy for refinement and application of diagenesis model

Model Framework

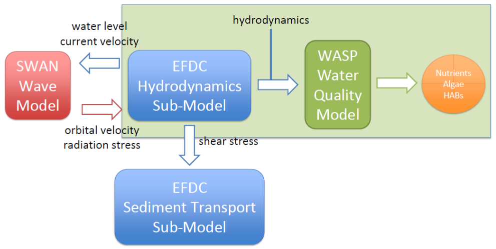


DISCUSSION: ULWQS MECHANISTIC MODEL PART B: REVIEW OF MODEL LIMITATIONS

Discussion

- Need for additional studies
- Strategies
- Prioritization (Scott)

Model Framework



QUESTIONS/DISCUSSION