Real Talk about Model Calibration for Sea Level Rise and Resiliency Planning

Florida Stormwater Association Annual Conference 2023

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Project Objectives

- The Eastern Palm Beach County Flood Protection Level of Service (FPLOS) is funded by the SFWMD FPLOS program.

- SFWMD FPLOS program evaluates the ability of the **primary system** to manage and maintain stages below flood conditions under current and future sea level rise conditions.

- Objective of the model is to assess the performance measures (PM) of several SFWMD basins in the County:
    - Primary canals' capacities – PM 1, PM 2
    - Primary structures' capacities – PM 3
    - Watershed drainage capacities – PM 4
    - Flood prone areas (2D flood mapping) – PM 5, PM 6

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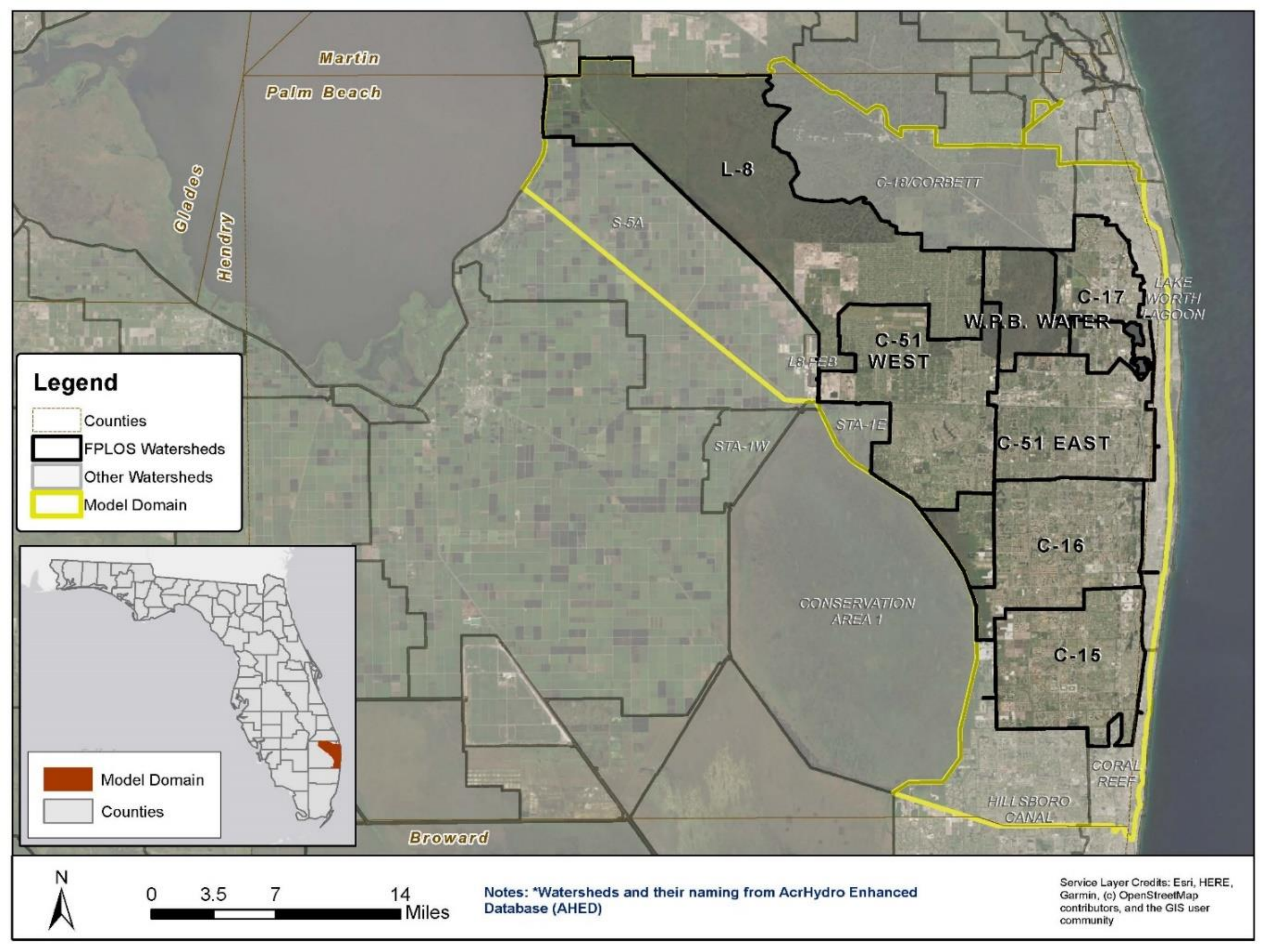
Study Area



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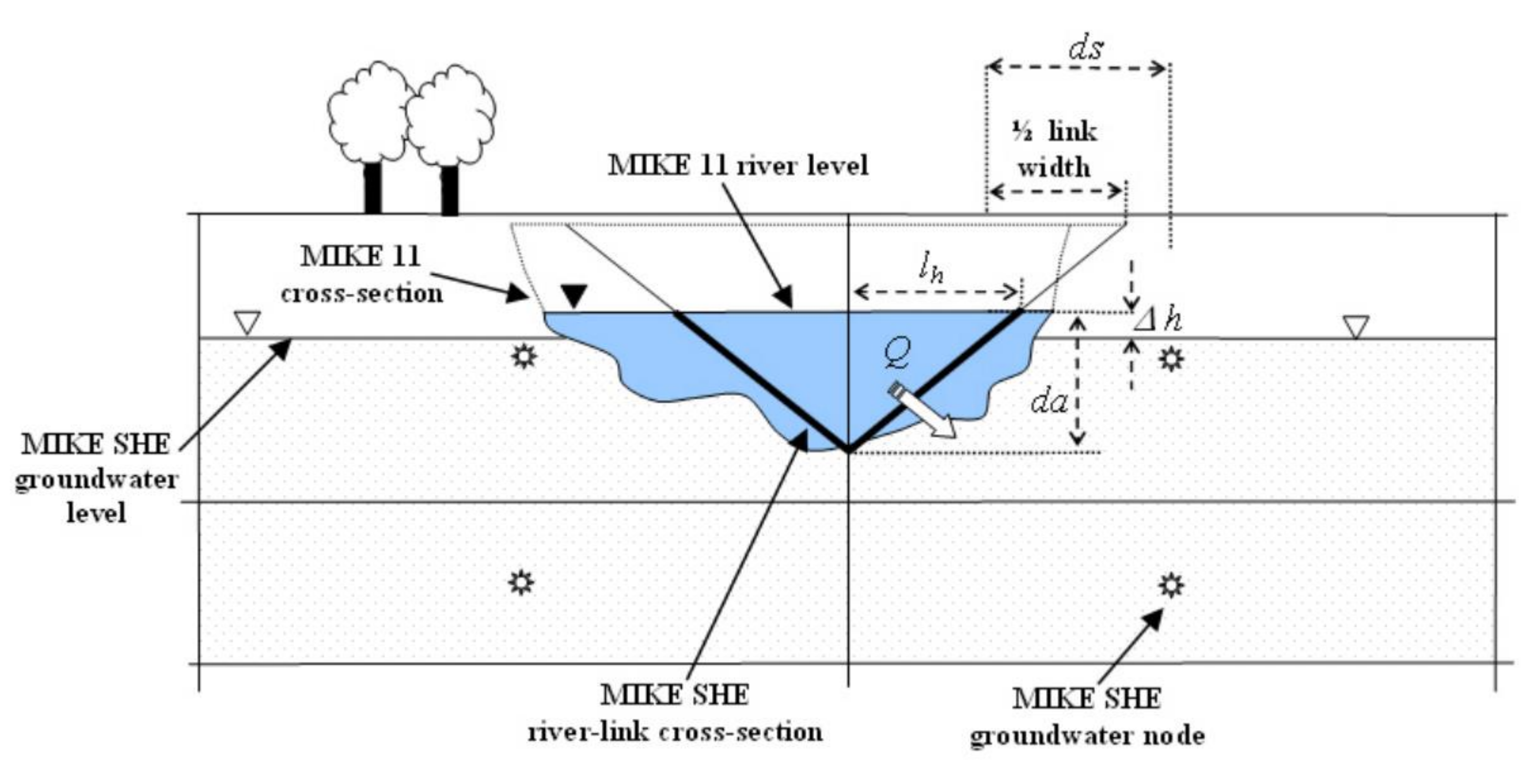
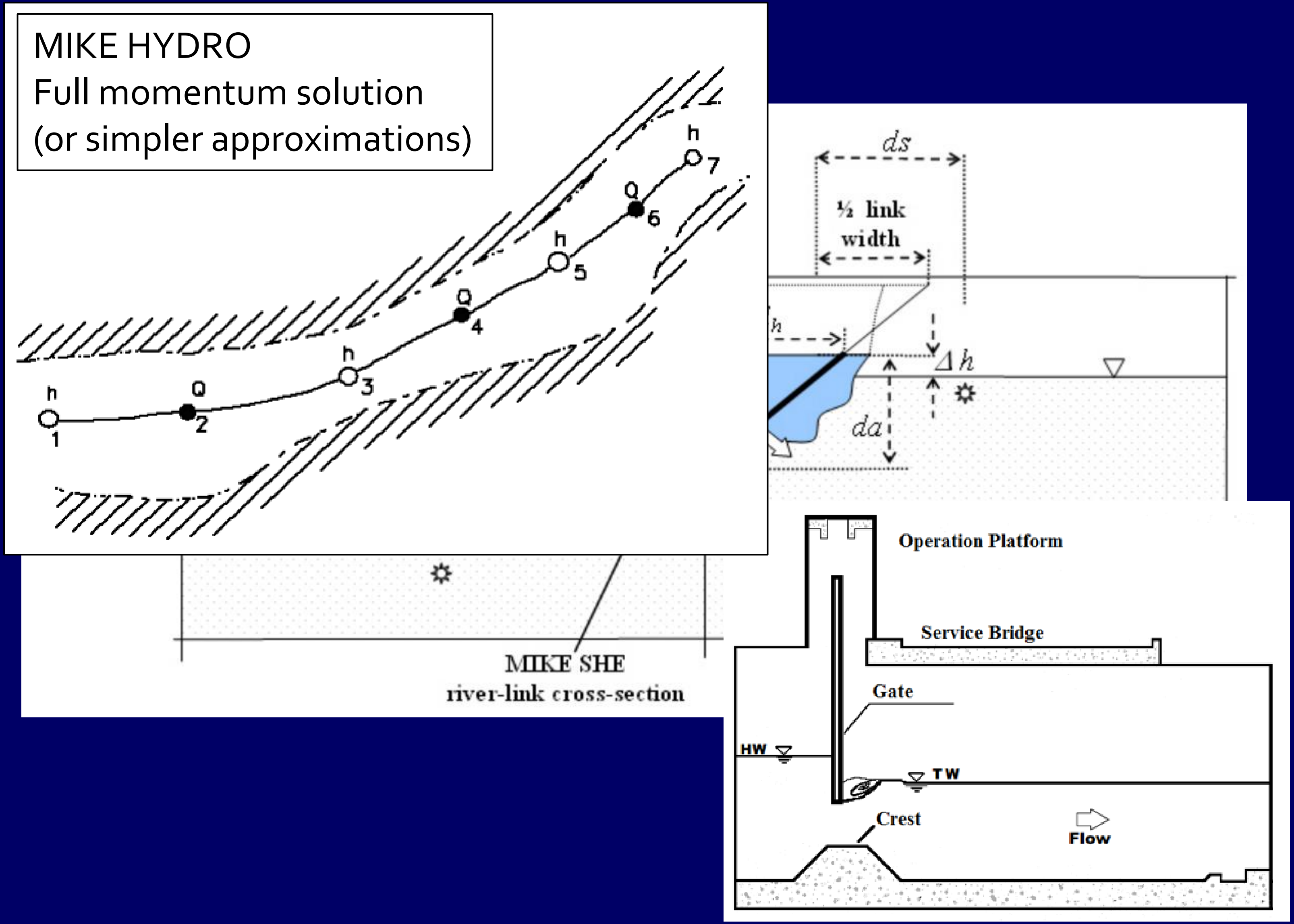
Model Tool – MIKE SHE / MIKE HYDRO



Images from MIKE SHE and MIKE HYDRO Manuals and SFWMD

Model Tool – MIKE SHE / MIKE HYDRO



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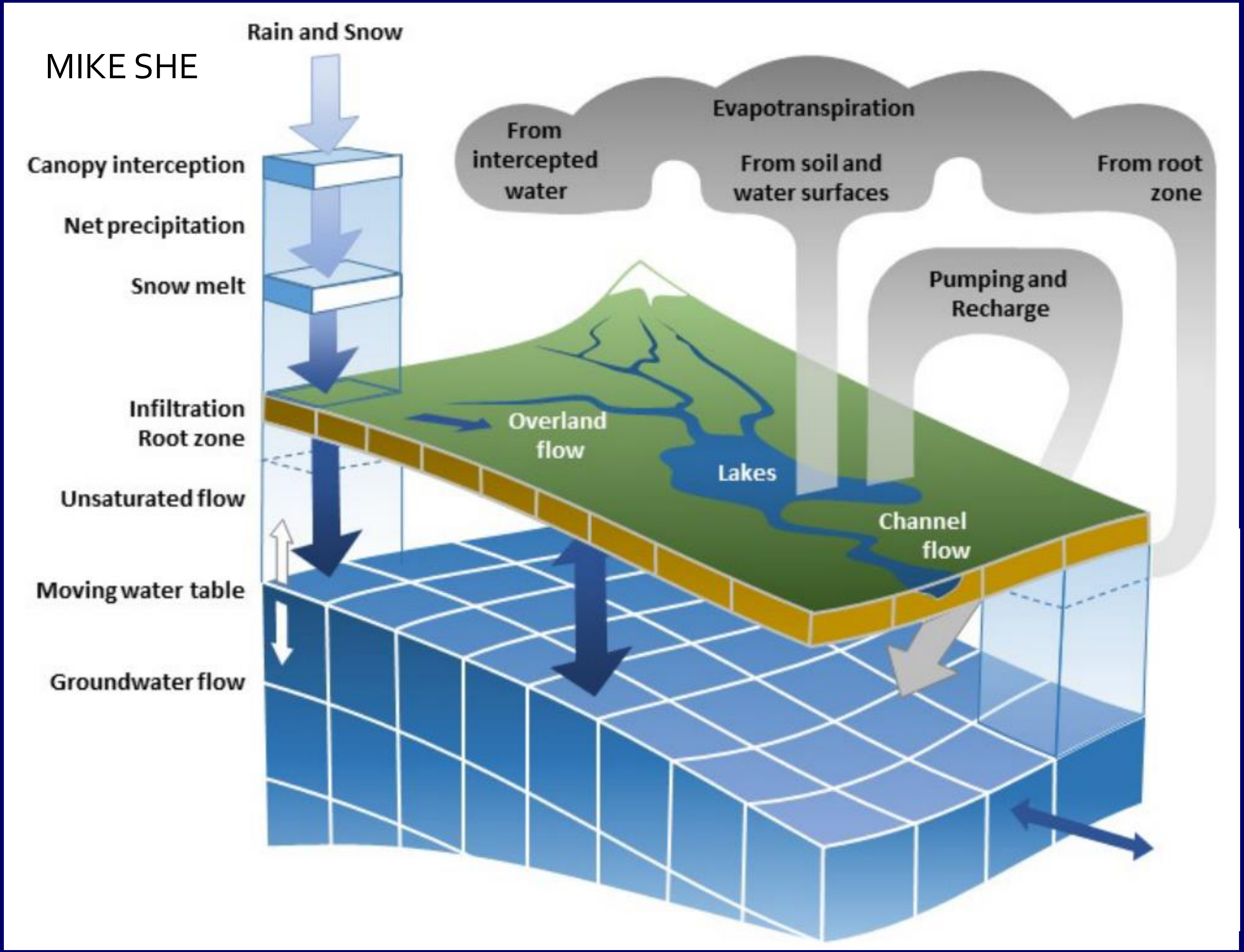
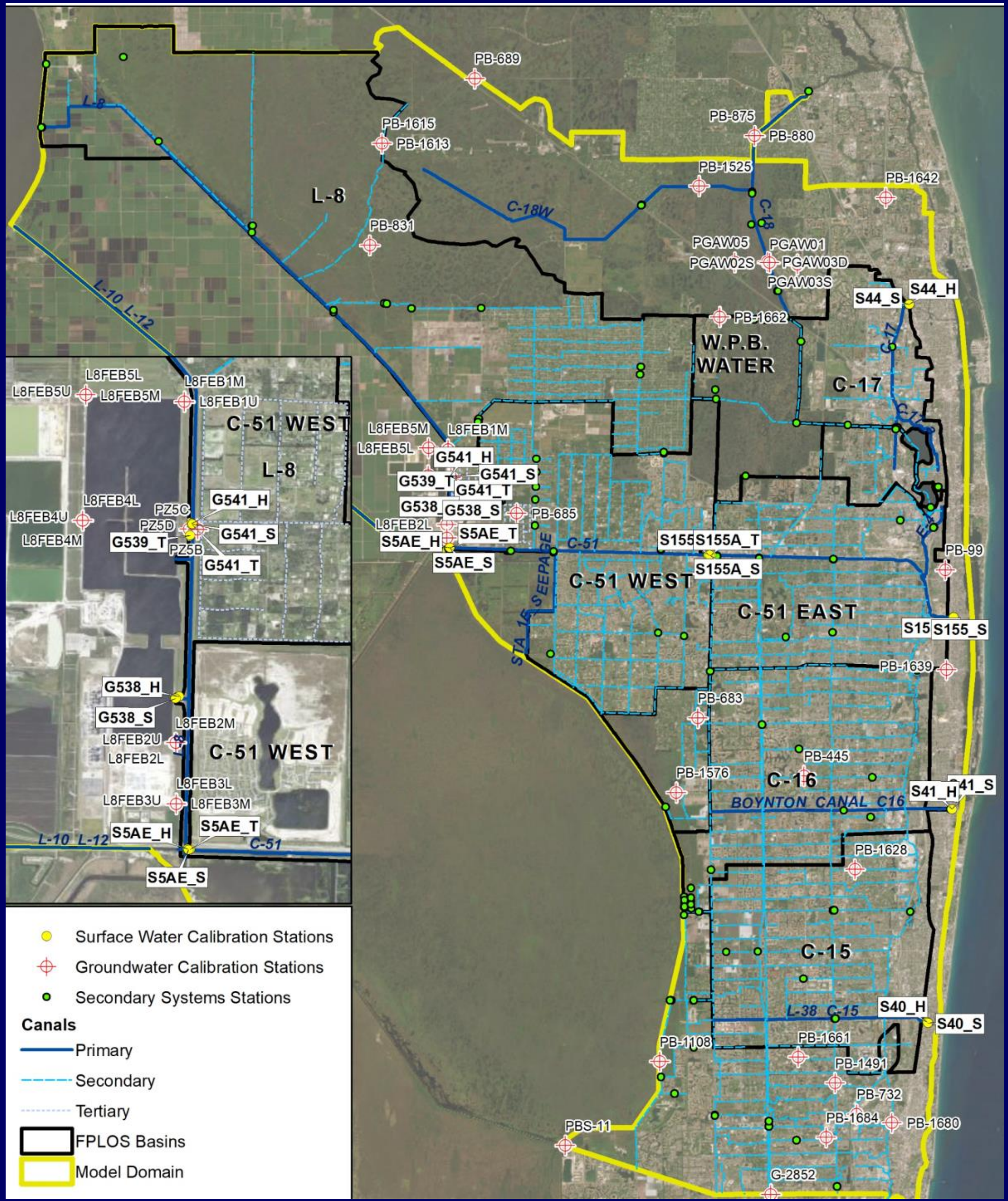
Model Tool – MIKE SHE / MIKE HYDRO



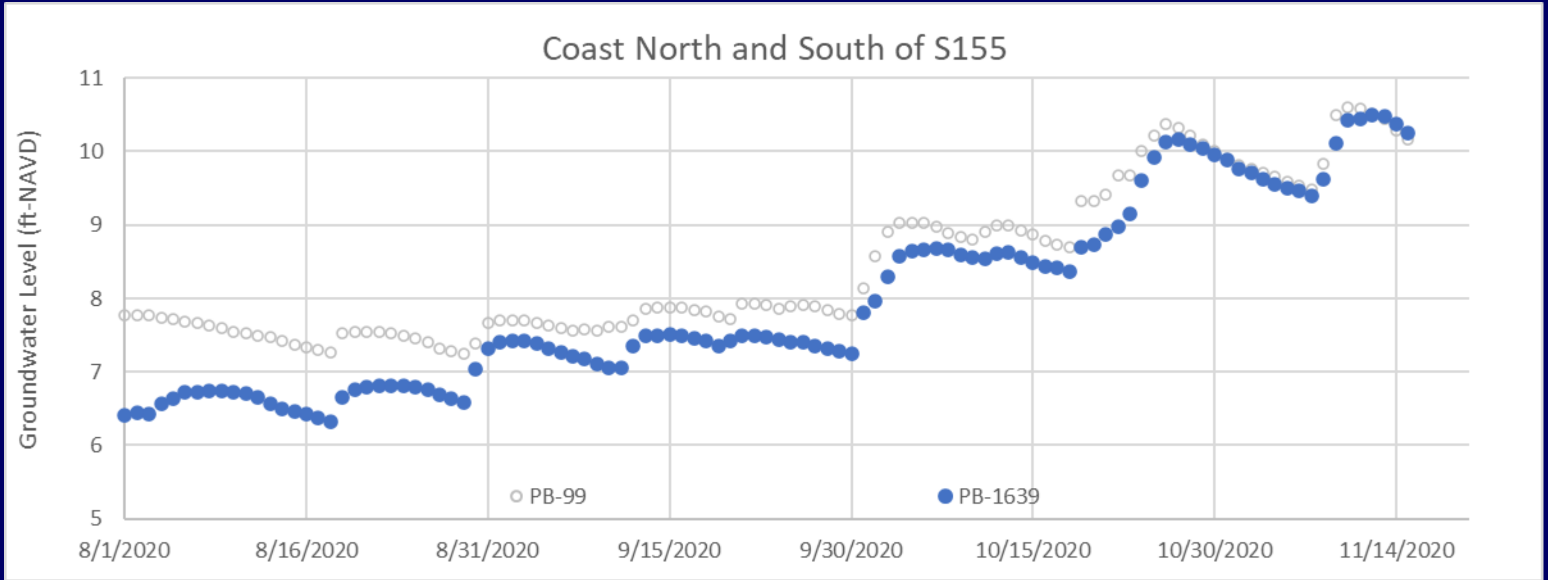
Images from MIKE SHE and MIKE HYDRO Manuals and SFWMD

Calibration Stations

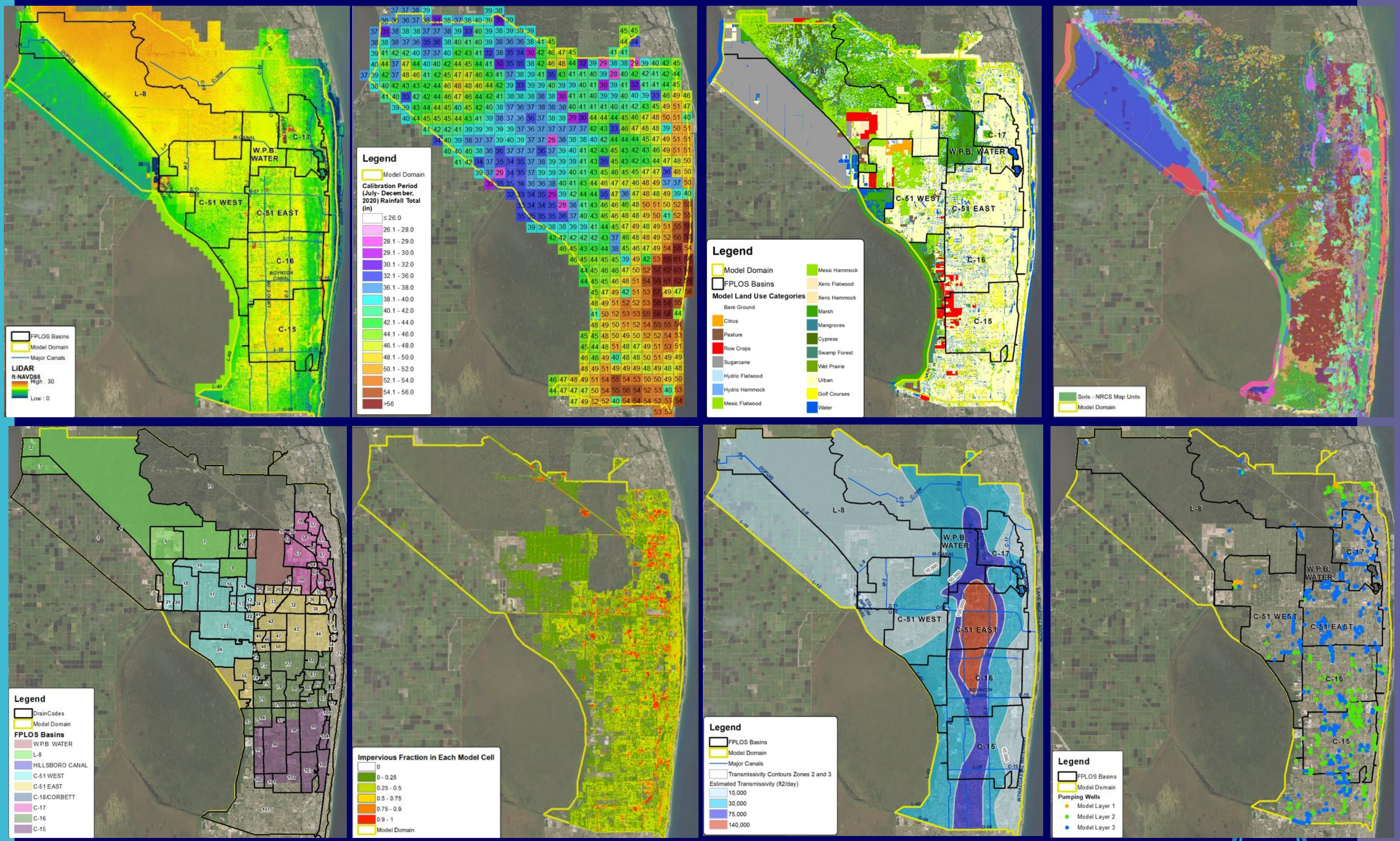


Calibration Period

- November 5 to 15, 2020 – Eta storm November 9, 2020.
- Around a 5-year event in PBC, higher in the south.
- Recent period, more data available.
- Storm occurring late in the wet season, higher water table.



MIKE SHE Inputs



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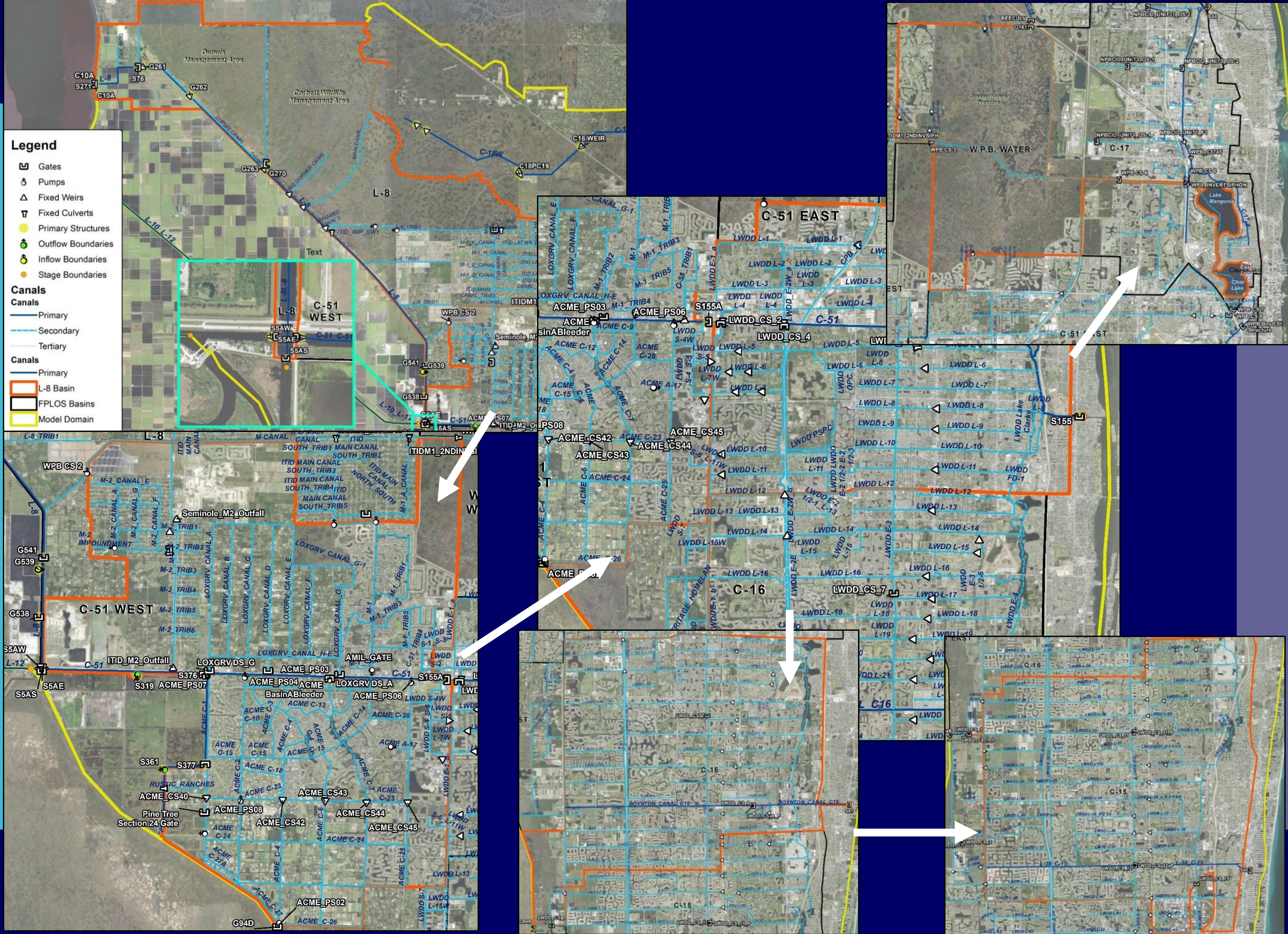
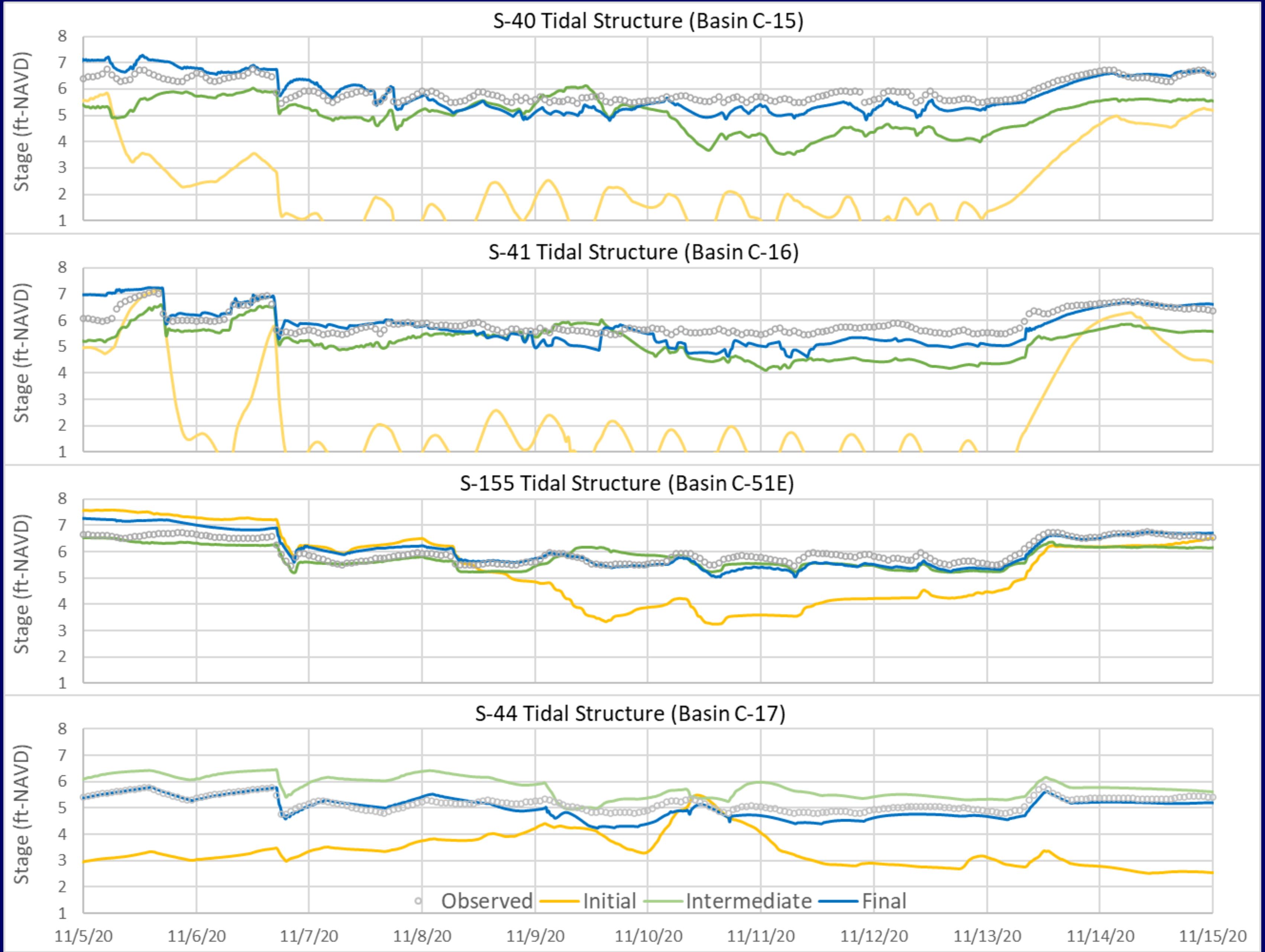
MIKE HYDRO Inputs



Why Calibration?



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Calibration Approach and Challenges

- Focus was on tidal structure headwater stages, but flow timing and volumes and interaction with upstream basins are important and critical to these stages.
- Mostly analytical, water budget driven approach to parameter adjustment but semi-automatic, automatic approaches were also used.
- Circular process - parameters need to be revisited because the effects, i.e., sensitivities are not always linear or consistent.
- Key Challenges
  - Initial conditions – adjusted set of parameters for short/event simulations may not result in the same initial conditions if applied to a longer simulation.
  - Secondary/tertiary operations – many unknowns
  - Running times of a complex regional model

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Calibration Approaches: Multi-Resolution

- Half the cell size increases running times by ~60%
- Lower resolution model resulted in 94% of the area flooded > 0.25 ft that resulted in the higher resolution model for the calibration simulation period.

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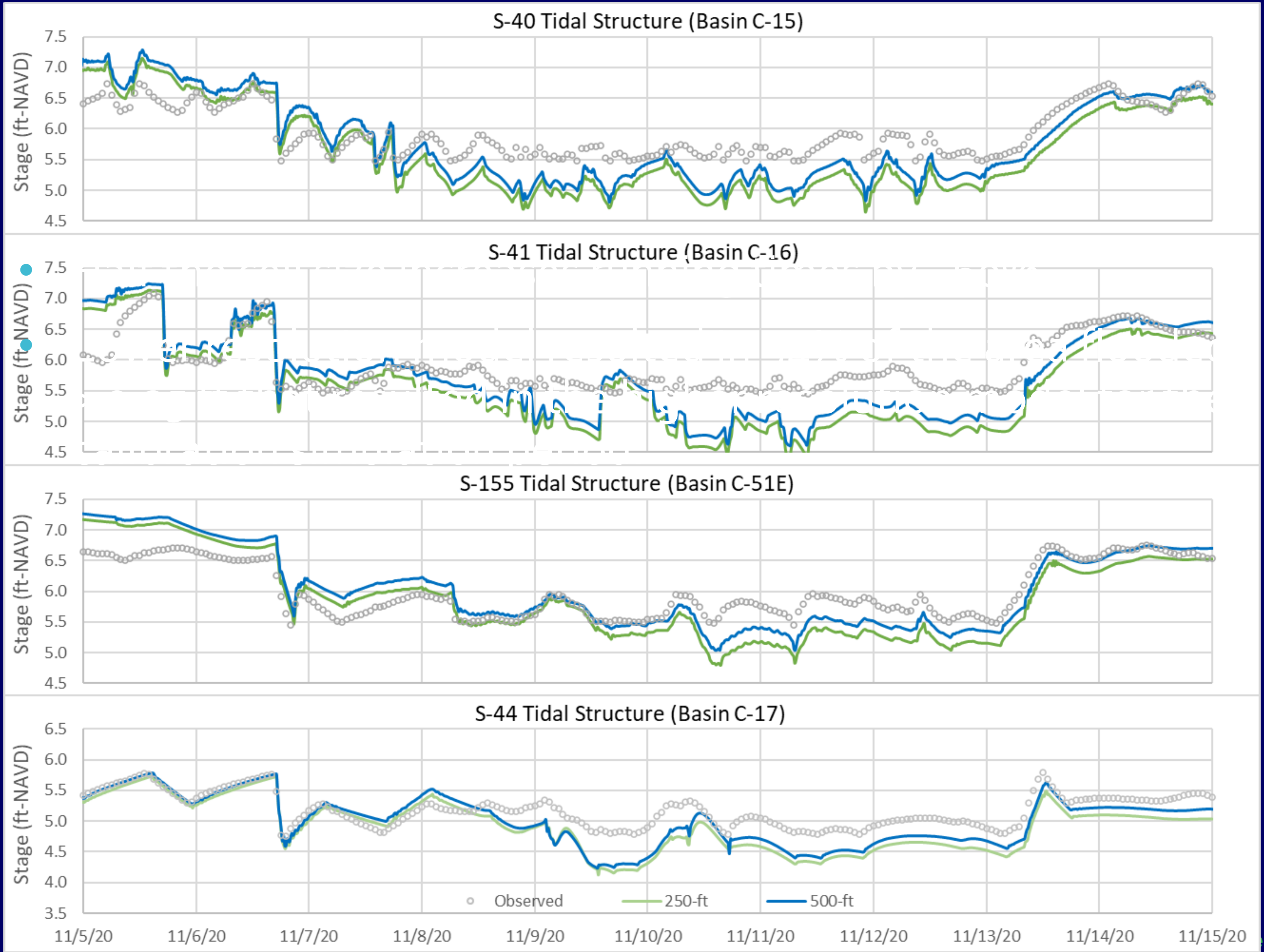
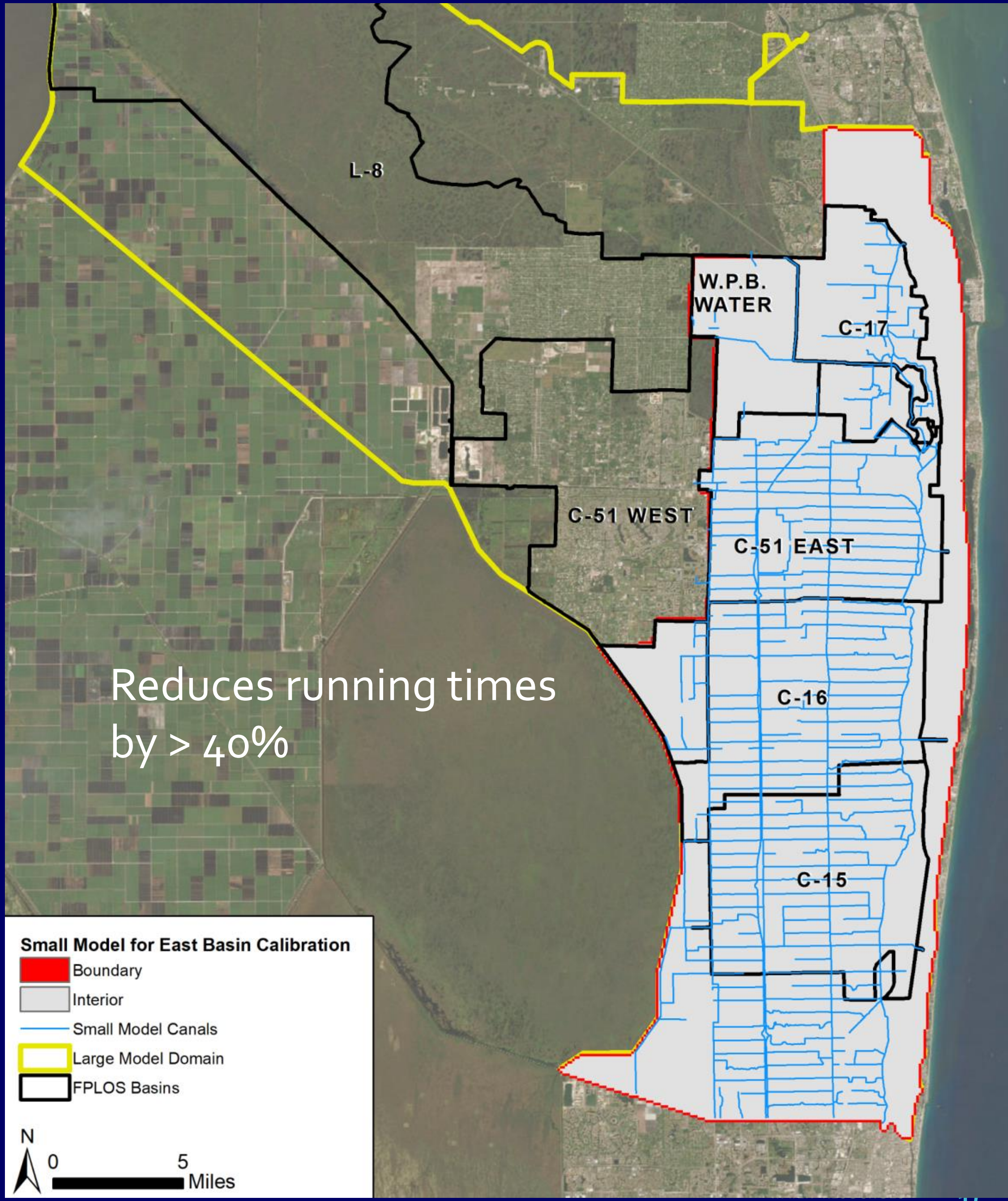
Calibration Approaches: Multi-Resolution



Calibration Approaches: Multi-Scale

- Used smaller model to in semi-automatic simulations to assess the sensitivities and calibrate three soil parameters for several soil map units: θsat, θ_{FC}, θ_{WP}
- Extract boundary conditions from larger model using the same baseline simulation.



Summary of Adjusted Parameters

Model Component	Parameters	Sensitivity[1]
MIKE HYDRO cross sections	Manning's n	Medium
MIKE HYDRO Structures (culverts, gates)	Manning's n, discharge coefficients	High
MIKE SHE ET	Vegetation crop coefficients	Medium
MIKE SHE Overland Flow	Manning's M	Low
	Detention storage	Low
	Paved area fraction	Medium
	Surface-subsurface leakage coefficient	High
MIKE SHE Overland Flow Ponded Drainage	Runoff coefficients	Medium
	Drainage inflow time constant	Medium
	Drainage outflow time constant	High
MIKE SHE Unsaturated Flow	Saturated moisture content	High
	Field capacity moisture content	High
	Wilting point moisture content	Low
MIKE SHE Saturated Zone	Horizontal hydraulic conductivity L1	High
	Vertical hydraulic conductivity L1	Medium
	Horizontal hydraulic conductivity L2	Medium
	Vertical hydraulic conductivity L2	Low
	Horizontal hydraulic conductivity L3	Low
	Drainage Levels	Low

[1]Qualitative sensitivity in the primary structure flow and stage output relative to other parameters

Calibration Process Focus Areas

- Description of calibration processes and challenges by basin follows in the next slides.
- Four focus areas:
  - C-51E, C-16, C15 – LWDD
  - C-17 – NPBCID
  - C51W – ACME, VRPB, ITID, Loxahatchee Groves
  - L-8 – ITID, Corbett WMA, Dupuis WMA

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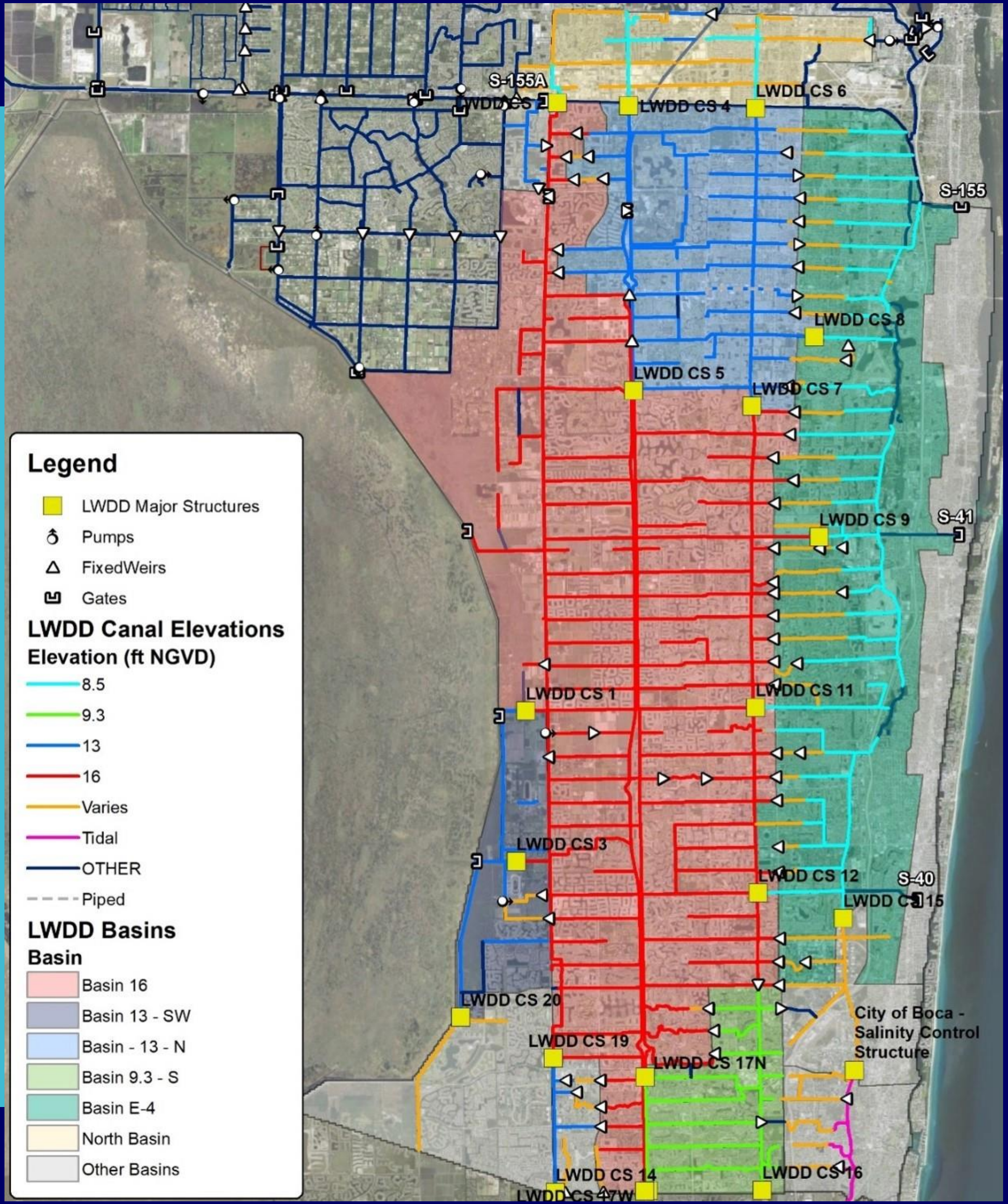
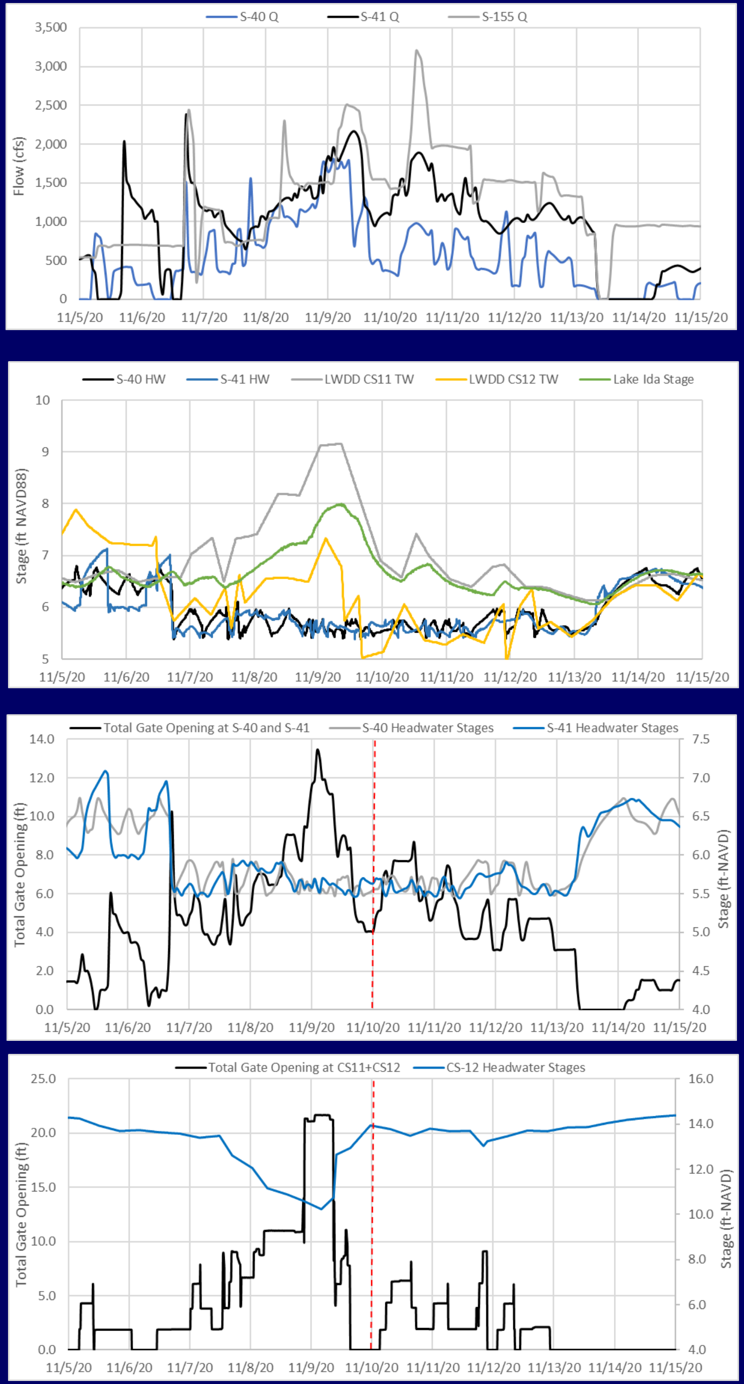
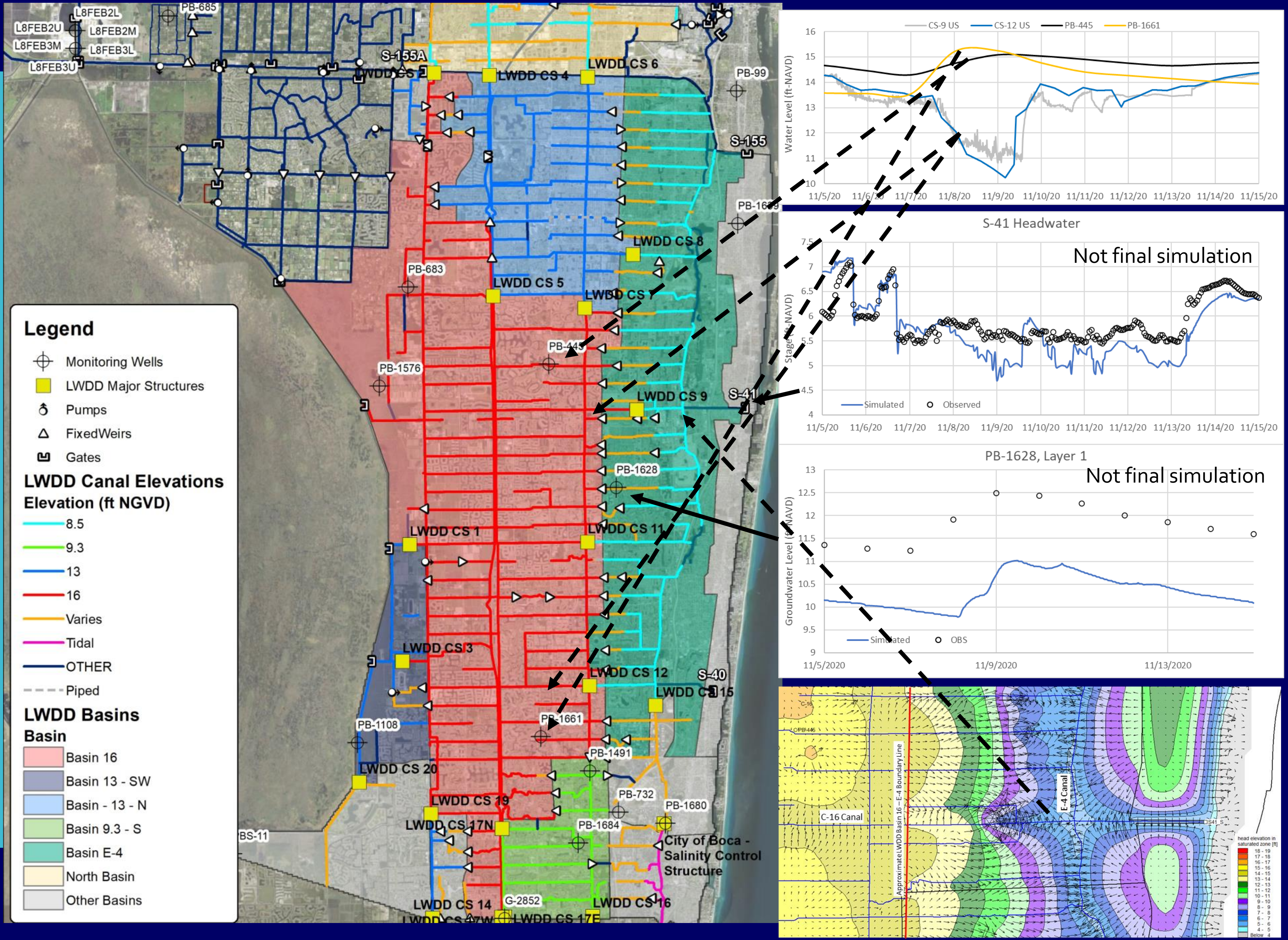
Lake Worth Drainage District (Basins C-15, C-16, C51E)



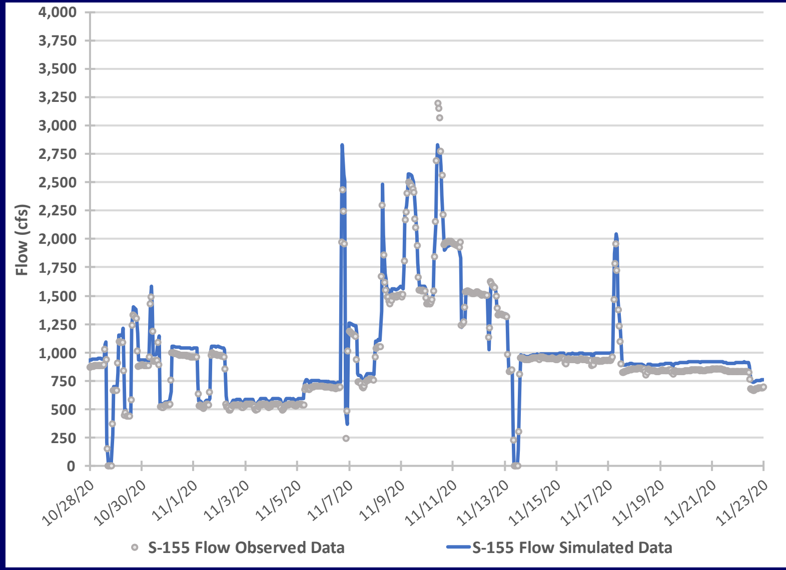


Lake Worth Drainage District (Basins C-15, C-16, C51E)

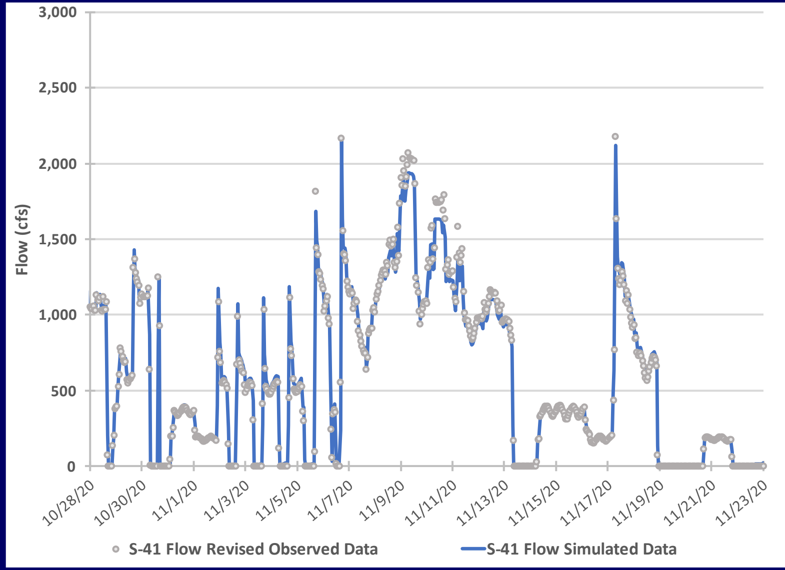


Lake Worth Drainage District (Basins C-15, C-16, C51E)

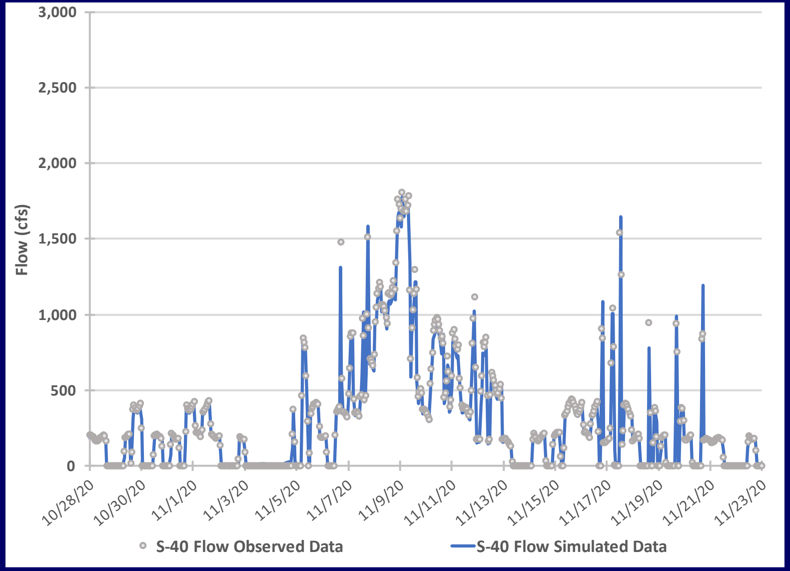
S-155 Tidal Structure Flow



S-40 Tidal Structure Flow



S-40 Tidal Structure Flow



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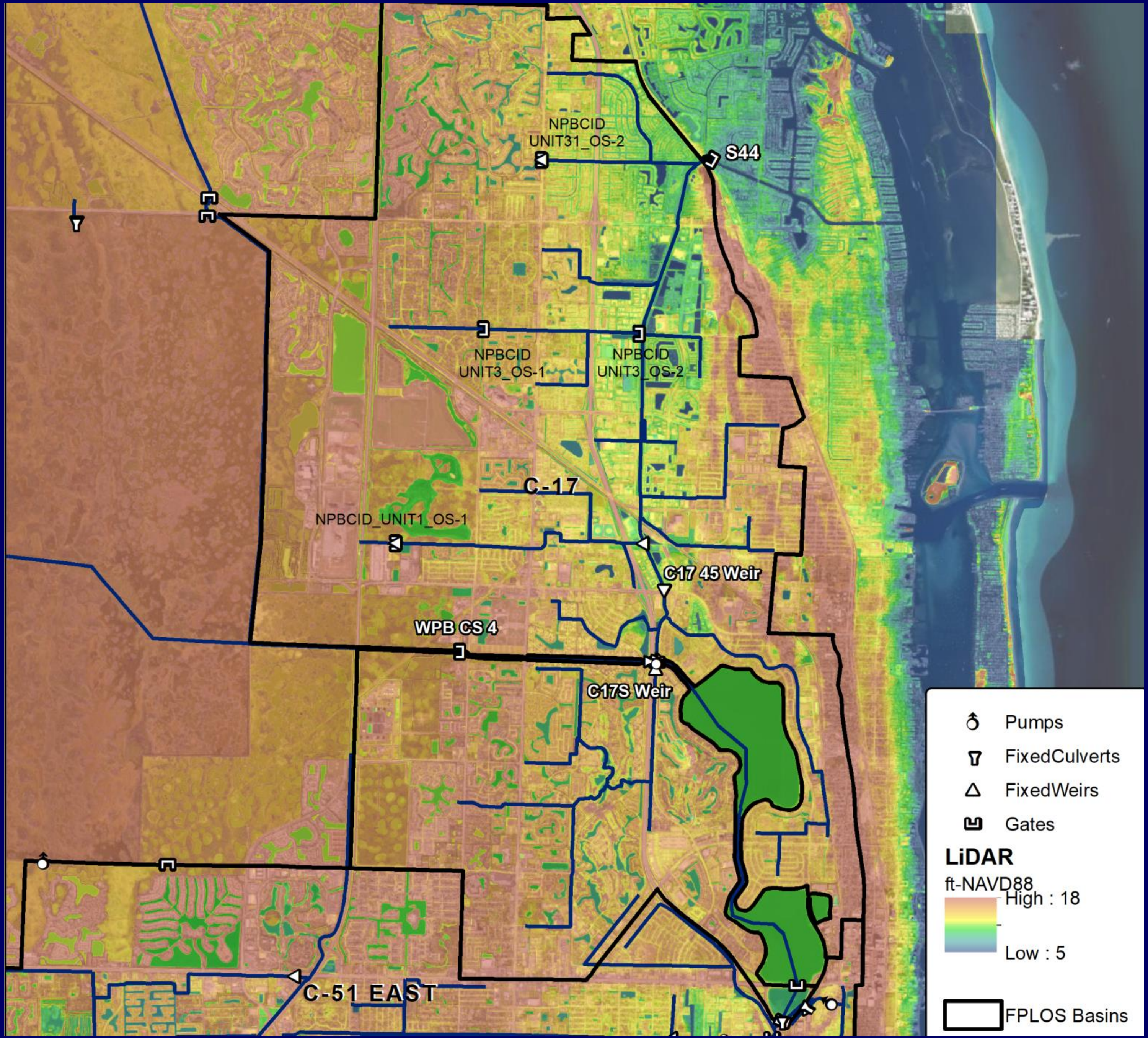
C-17 Basin - Challenges



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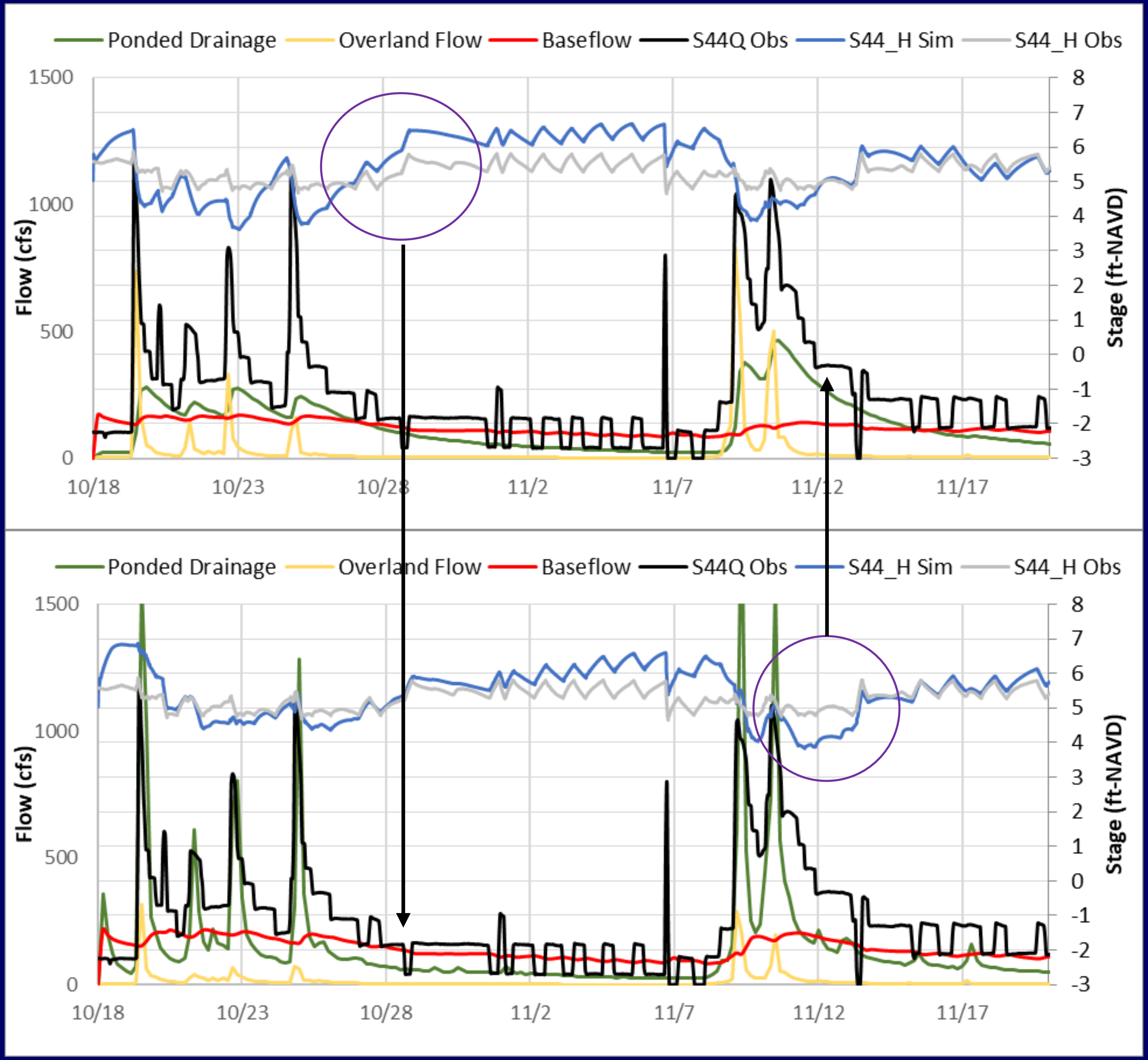
C-17 – Time Varying Water Budgets



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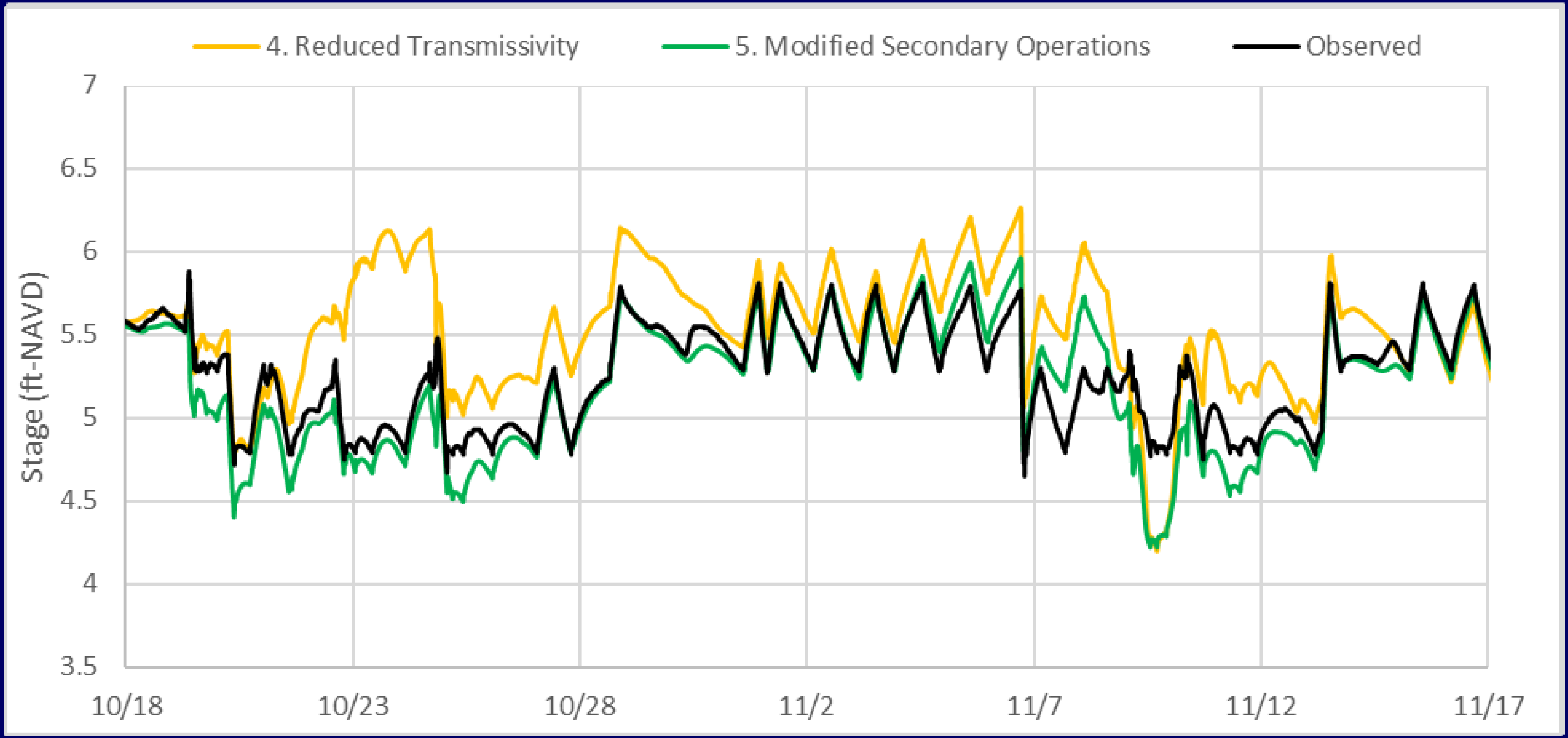
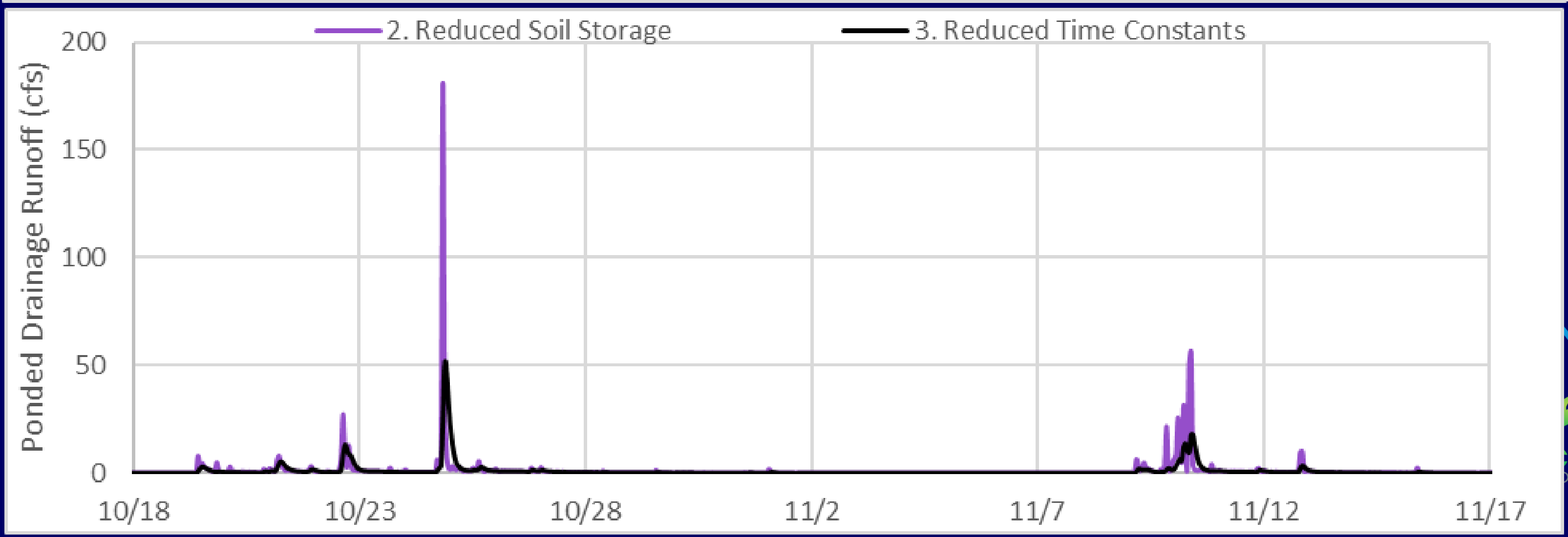
S-44 Tidal Structure Headwater Stages

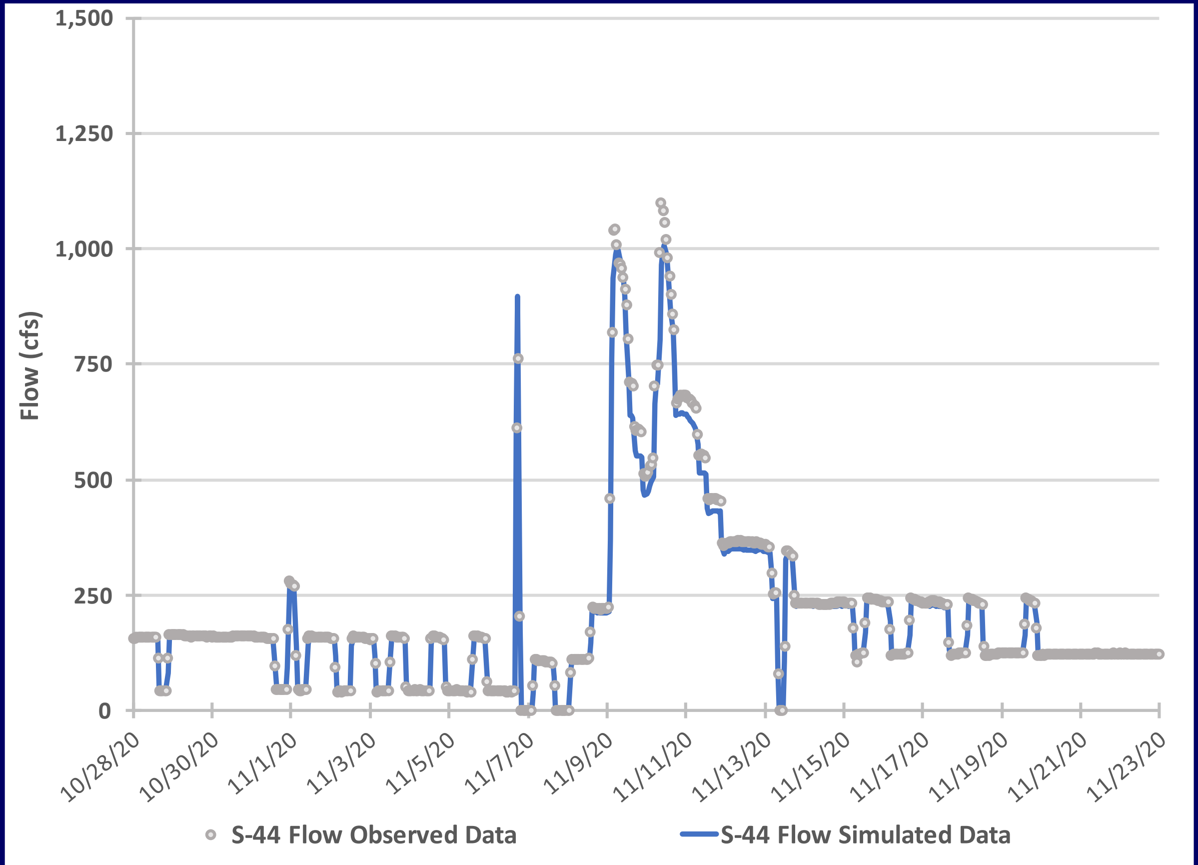
C-17 – Effects of Key Parameters





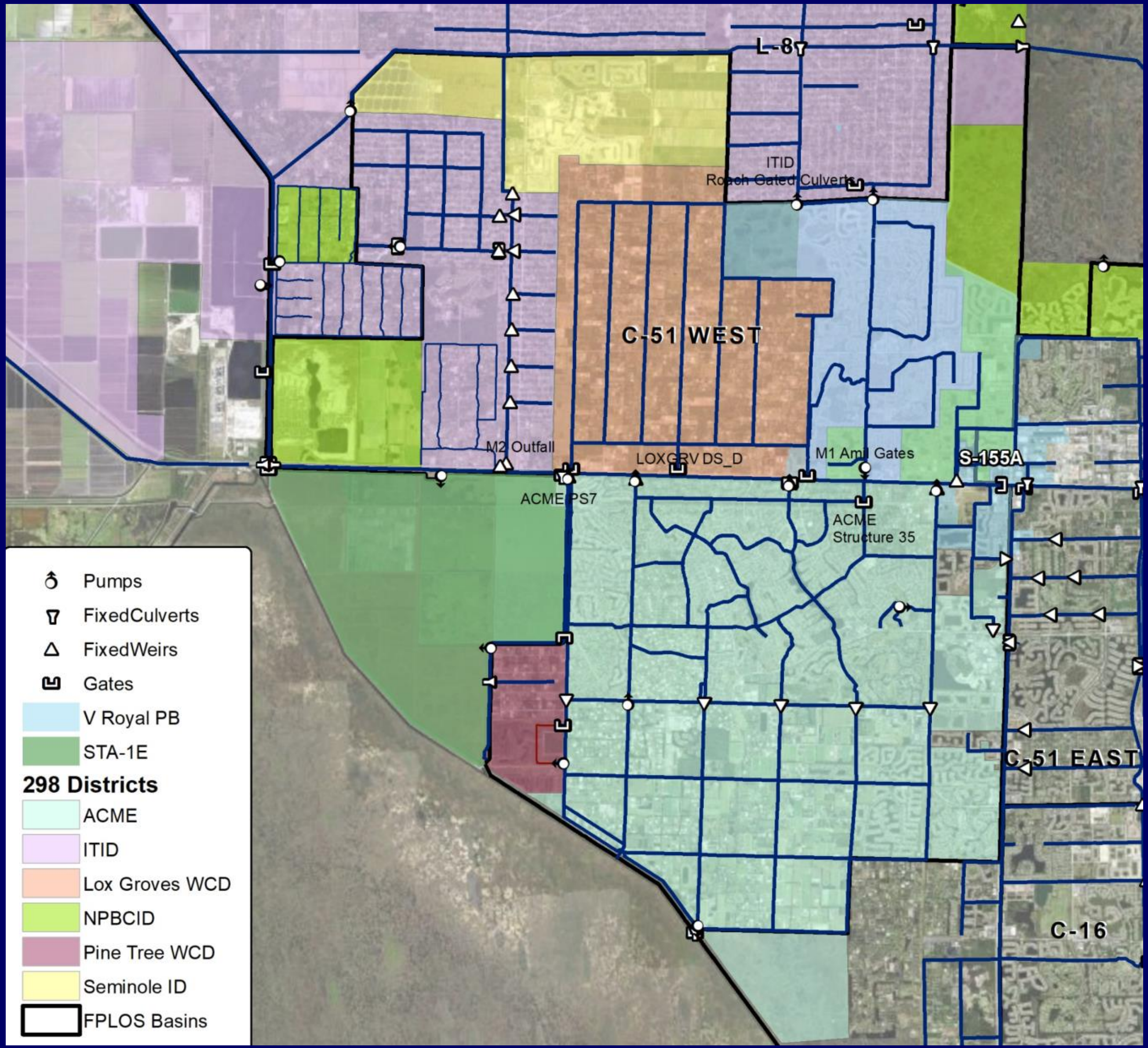
C-17
Calibrated Flow

S-44 Tidal Structure Flow

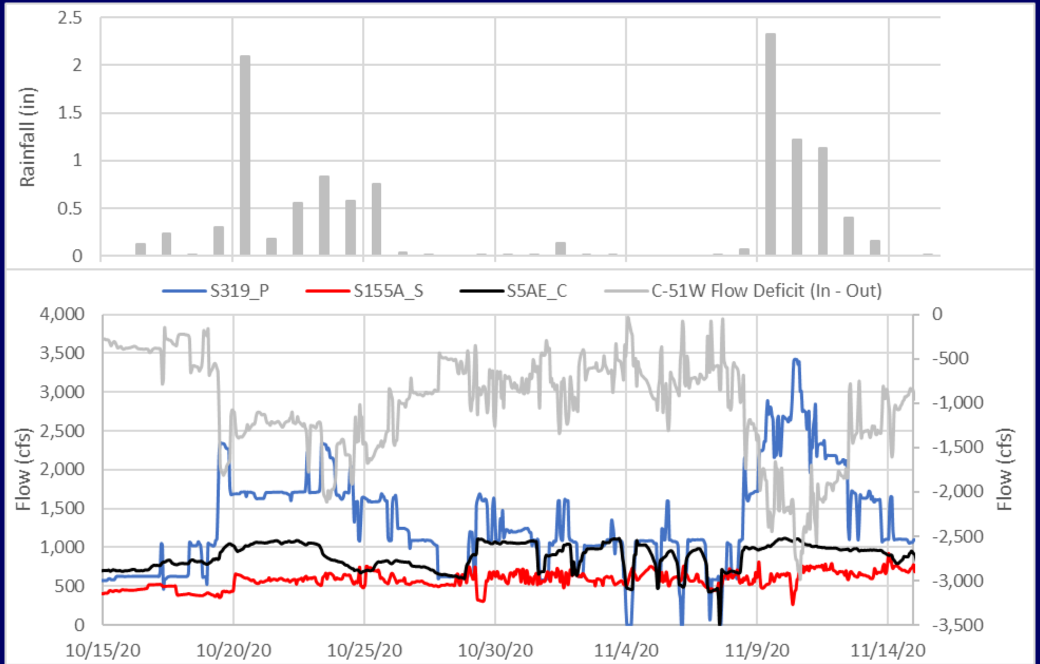


The accuracy of the head losses in the C-51 Canal is important for this project. Accurate flow and stages in C-51 Canal west of divide structure (S-155A) are key, particularly when the structure is open.

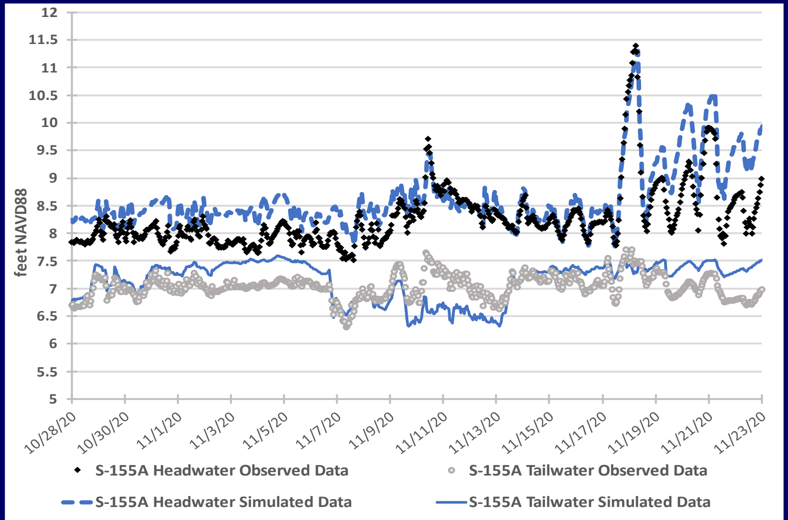
C-51W Basin Contributors

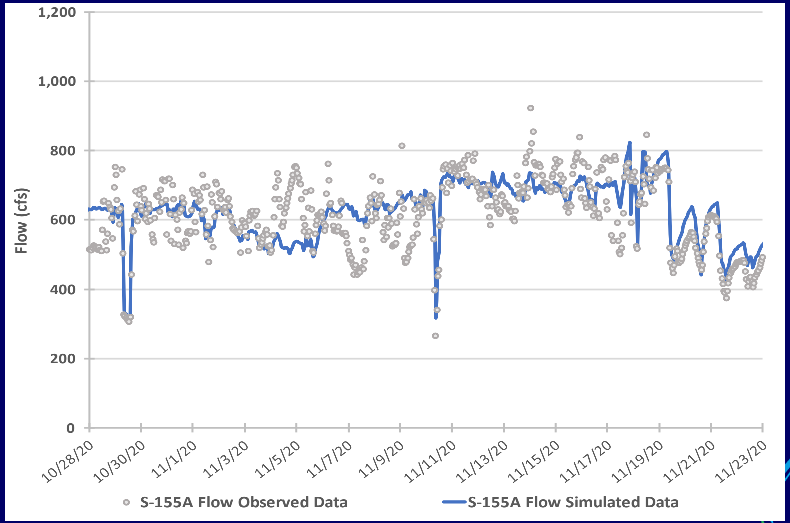


C-51W – Observed Water Budgets, Calibration Plots



- Seepage flows from STA-1E
- ITID system and flows to the L-8 Basin





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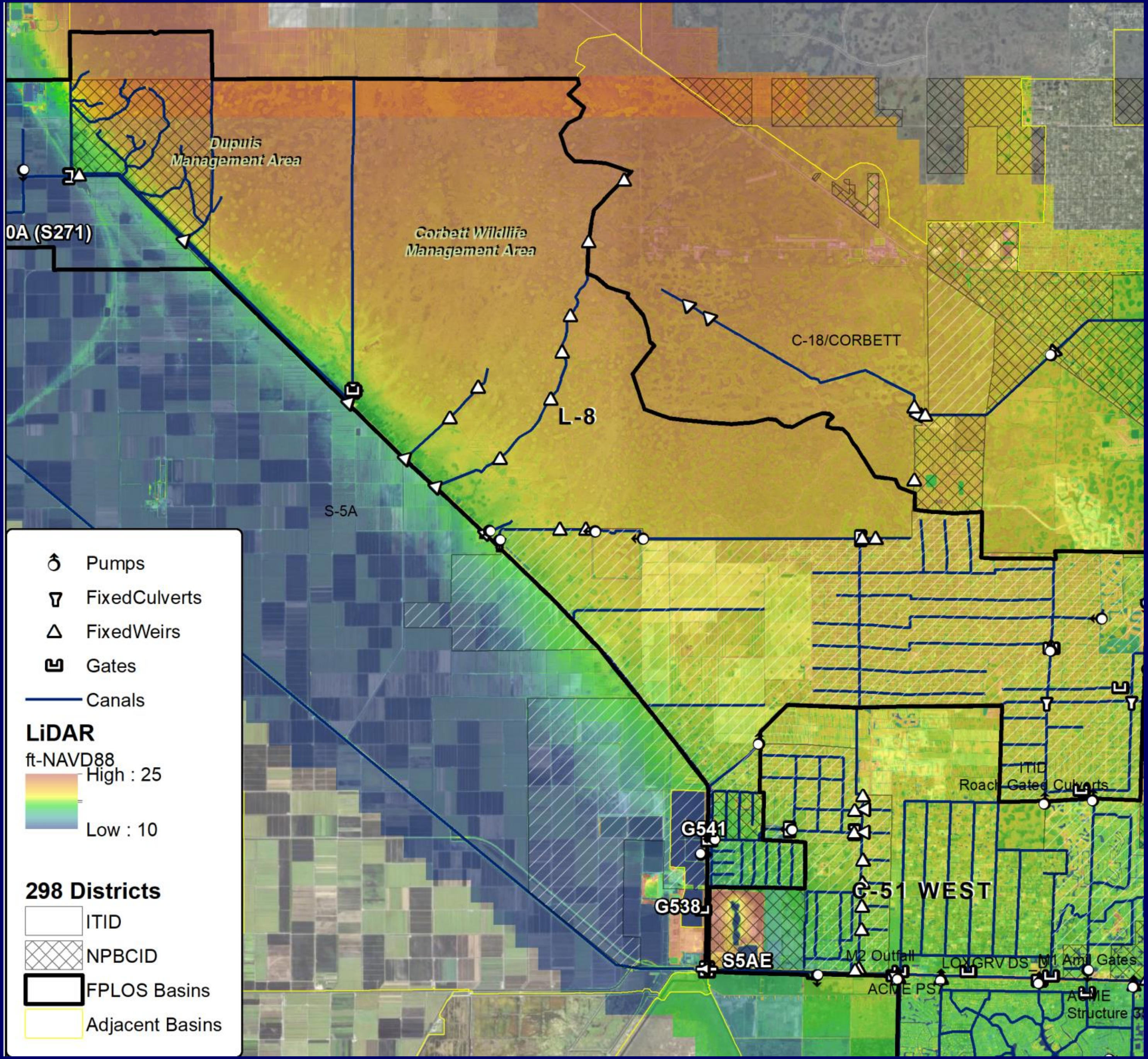
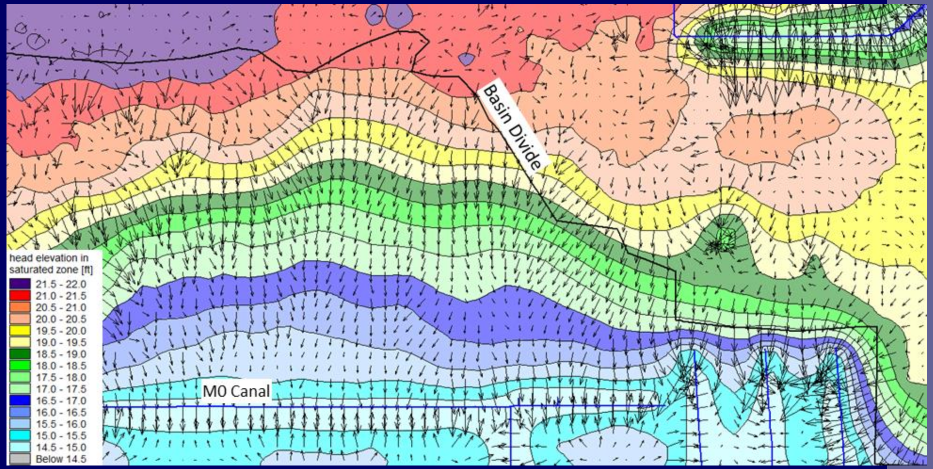
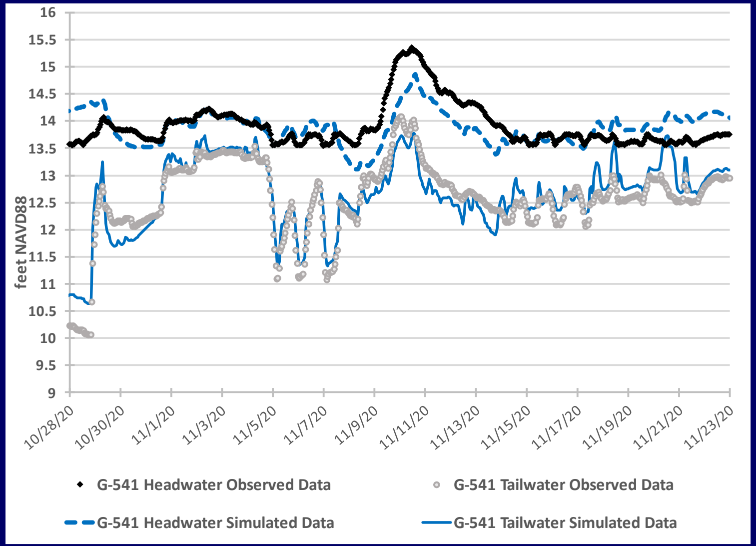
L-8

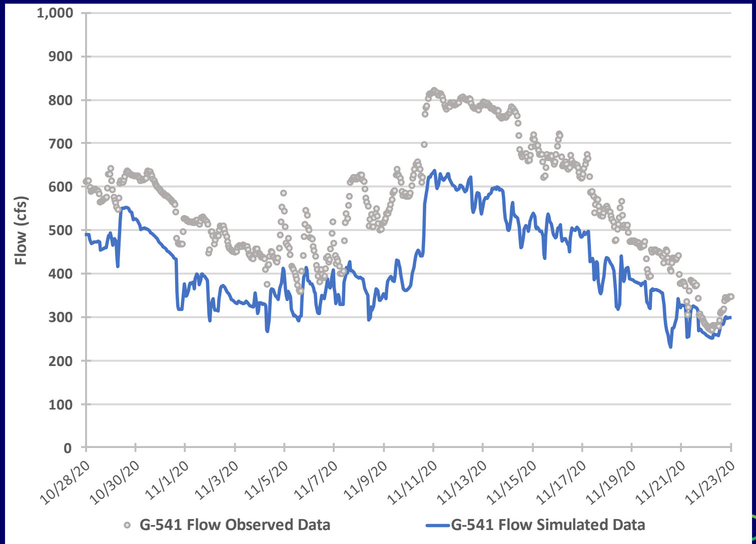

Dupuis Management Area
Corbett Wildlife Management Area
0A (S271)
C-18/CORBETT
L-8
S-5A
G541
G538
S5AE
C-51 WEST
ITID Roach Gated Culverts
M2 Outfall
ACME PS
LOXGRV DS
ACME Structure
Pumps
FixedCulverts
FixedWeirs
Gates
Canals
LiDAR
ft-NAVD88
High : 25
Low : 10
298 Districts
ITID
NPBCID
FPLOS Basins
Adjacent Basins

L-8 Calibration Plots

- Flow from C-18 Basin
- High portion of the basins is undeveloped or rural residential.
- Runoff from ITID Lower (to C-51W) vs. Upper Basin (to L-8)
- Farm runoff from EAA







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Calibration Statistics Surface Water

Stage

Basin	Station Name	ME (ft)	RMSE (ft)	Correlation Coefficient	Nash-Sutcliffe
L-8	G-541_H	-0.3	0.4	0.77	0.33
	G-541_T	0.0	0.3	0.94	0.85
	G-539_T	-0.1	0.3	0.95	0.84
	G-538_H	-0.2	0.4	0.92	0.72
	S5AE_H	-0.2	0.4	0.93	0.74
C51W	S5AE_T	0.2	0.2	0.94	0.41
	S155A_H	0.2	0.3	0.86	0.48
C51E	S155A_T	-0.2	0.4	0.30	-1.43
	S155_H	0.0	0.3	0.88	0.63
C16	S41_H	-0.2	0.4	0.85	0.11
C15	S40_H	-0.1	0.4	0.90	0.05
C17	S44_H	-0.2	0.3	0.87	0.11

Flow

Basin	Station Name	Peak Difference	Total Volume Difference	Correlation Coefficient	Nash-Sutcliffe
L8	G-541	-22%	-27%	0.95	0.95
	S-5AE	1%	-11%	0.91	0.91
C51W	S-155A	-20%	2%	0.67	0.67
C51E	S-155	-12%	2%	0.98	0.98
C16	S-41	-8%	-3%	0.99	0.99
C15	S-40	-2%	-5%	0.99	0.99
C17	S-44	-8%	-5%	0.99	0.99

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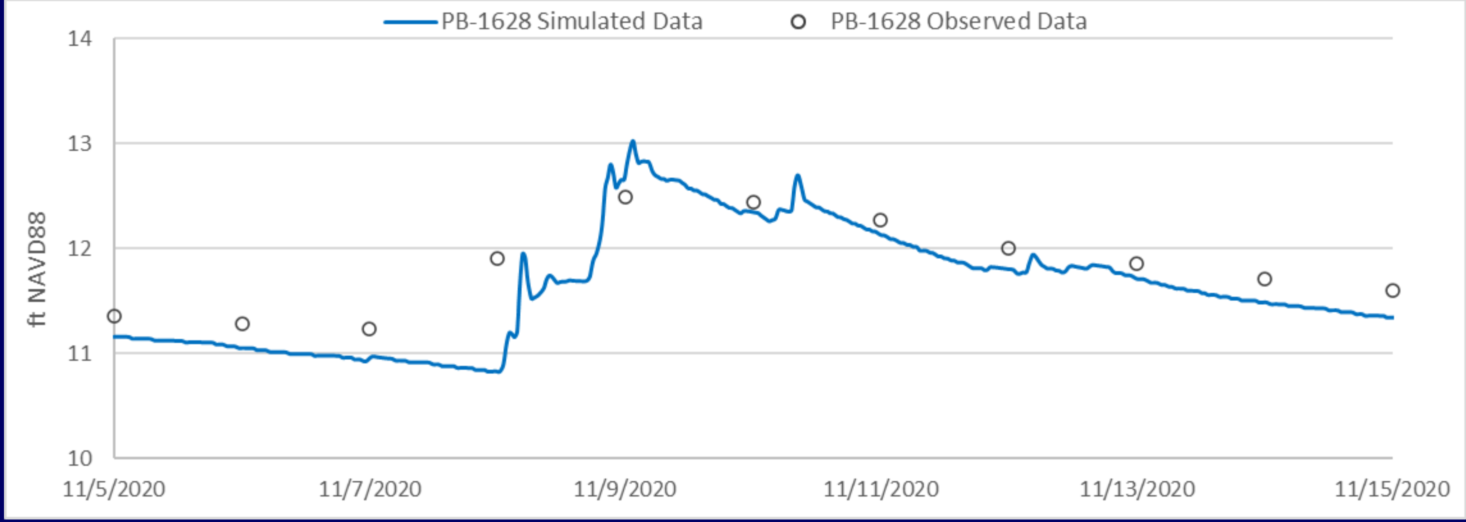
Calibration Statistics Groundwater

Basin	Layer	Well	ME	MAE	RMSE	Correlation Coefficient
L8	1	PB-1615	-0.2	0.2	0.2	0.9
	1	PB-831	-0.1	0.1	0.2	0.8
	3	PB-1613	-0.3	0.3	0.3	0.9
C51W	1	PB-685	-0.1	0.5	0.6	0.8
	1	PZ8A	0.1	0.3	0.4	0.7
C51E	1	PB-1639	0.3	0.3	0.4	0.8
	1	PB-683	0.2	0.3	0.4	0.8
	1	PB-99	0.3	0.4	0.4	0.8
	3	PB-1576	0.0	0.2	0.2	0.2
C16	1	PB-445	0.9	0.9	1.0	0.7
C15	1	PB-1628	-0.2	0.3	0.4	0.9
WPB Water	1	PB-1662	0.3	0.3	0.4	0.8
Hillsboro	1	PB-1661	0.6	0.9	1.2	0.5



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Conclusions

- High performance was achieved in both surface water and groundwater in the primary system and in most of the secondary stations.
- Scaling methods can help advance calibration efforts, focus on key areas, constraint uncertainties.
- The timing of flow and the flow pathways balance are critical in matching relatively even stages with large variability in gate openings.
- Model conceptualization future improvements
    - Secondary basin storage, drainage constraints, and operations are key
    - Better understanding and representation of unsaturated zone processes
    - Subsurface storage features

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Key Data Needs

- Canal surveys (major secondary canals - e.g., E-4 basin)
- Secondary system major structure flow and gate level measurements
- Minor structure information - culverts, subdivision controls
- Subbasin control elevations, storages – a database of permit design information would be great!
- Higher frequency and spatially distributed groundwater levels

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Thank You