Water Management Benefits of Fully Integrated Hydrologic Models

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Acknowledgement

Integrated model simulation results from:

Ross, M., and Trout, K. (2017).“Assessment of the Integrated Northern Tampa Bay Model no groundwater pumping scenarios. ” Center for Modeling Hydrologic and Aquatic Systems, Department of Civil and Environmental Engineering, U. of South Florida, Tampa, FL. Prepared for Tampa Bay Water, Clearwater, FL

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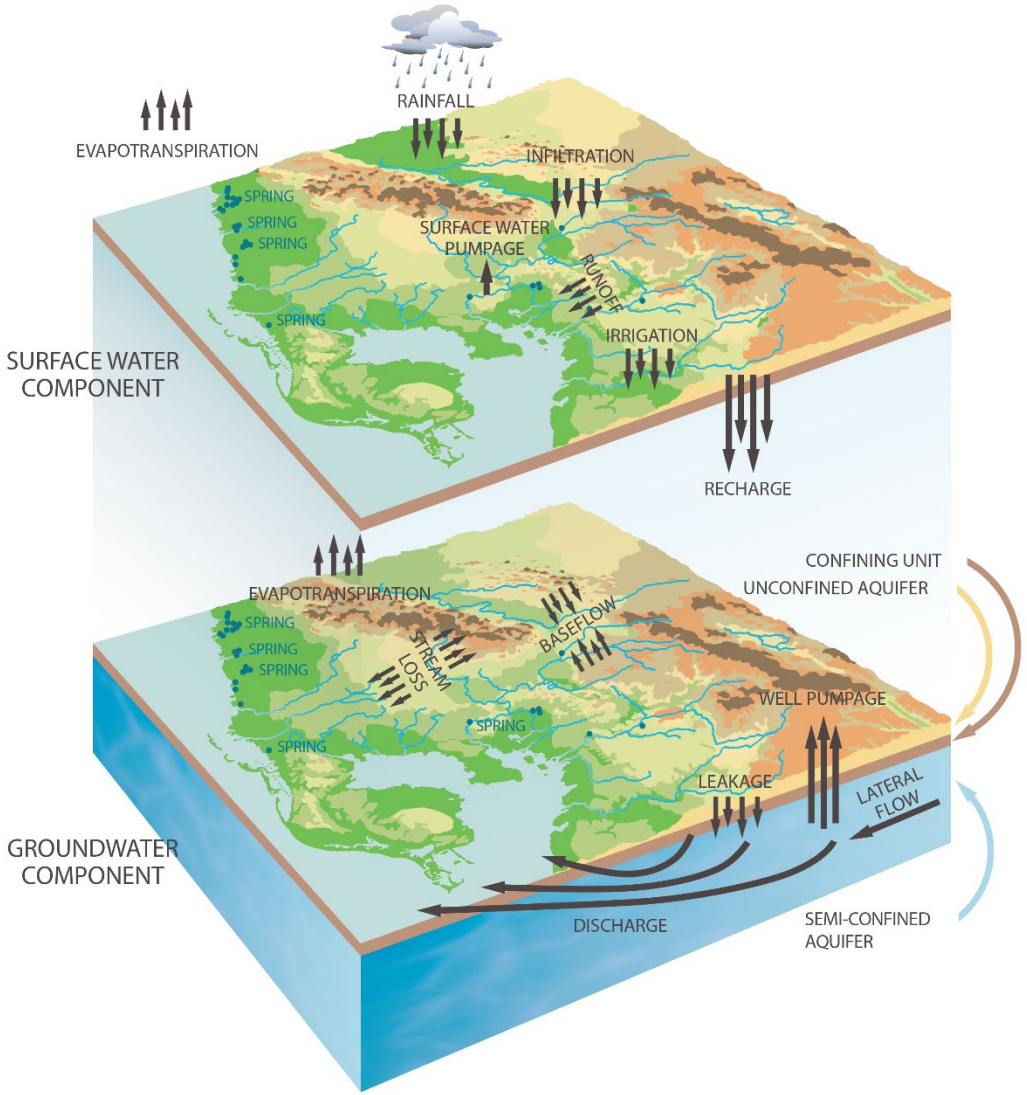
Outline

- Fully-integrated hydrologic model?
  - What is it?
  - When is it used or needed?
- Integrated Hydrologic Model (IHM) simulation engine
- Integrated Northern Tampa Bay Model, application of the IHM
- Case Study: Hydrologic responses to well pumping reduction
- Summary

Fully-Integrated Hydrologic Model
What is this simulation technology?



- Completely simulate hydrologic system & water table (WT) feedback
  - Uplands, water bodies, & GW
  - WT feedback: runoff, ET, recharge
- Interfacial boundary conditions (BC) for single-regime models replaced with dynamic simulation
  - Surface hydrology
    - Depth-to-water table(t)
    - Baseflow(t)
  - Groundwater hydrology
    - Recharge rate(t)
    - Maximum evapotranspiration rate(t)
    - Water-body stage(t)
    - Specific yield(t)

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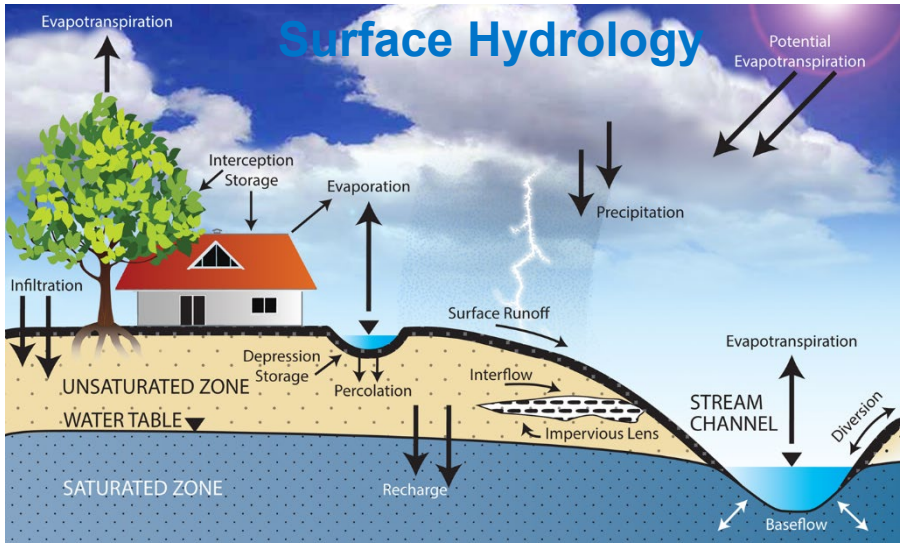
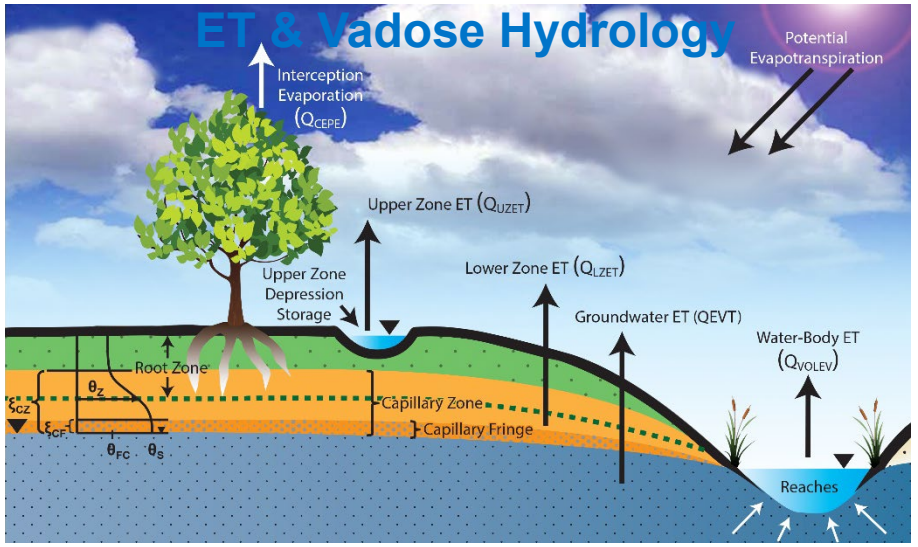
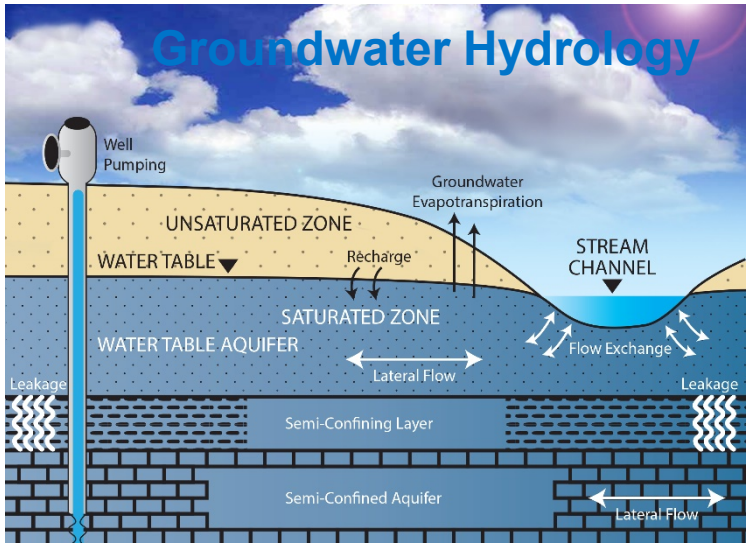
Fully-Integrated Hydrologic Model Simulates All Processes and WT Feedback







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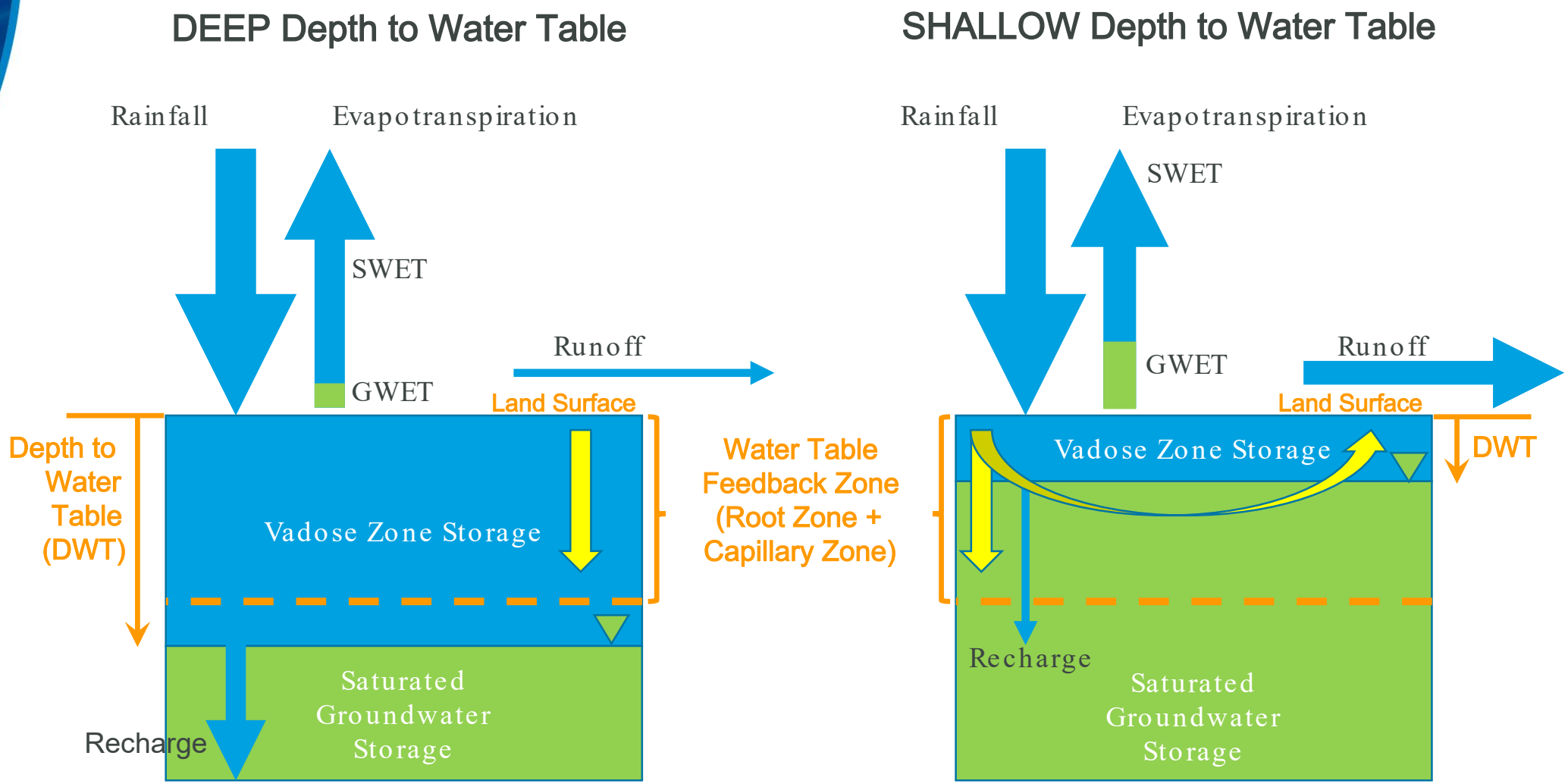
Relative Change in Flux Magnitude
Deep vs Shallow Depth-To-Water Table



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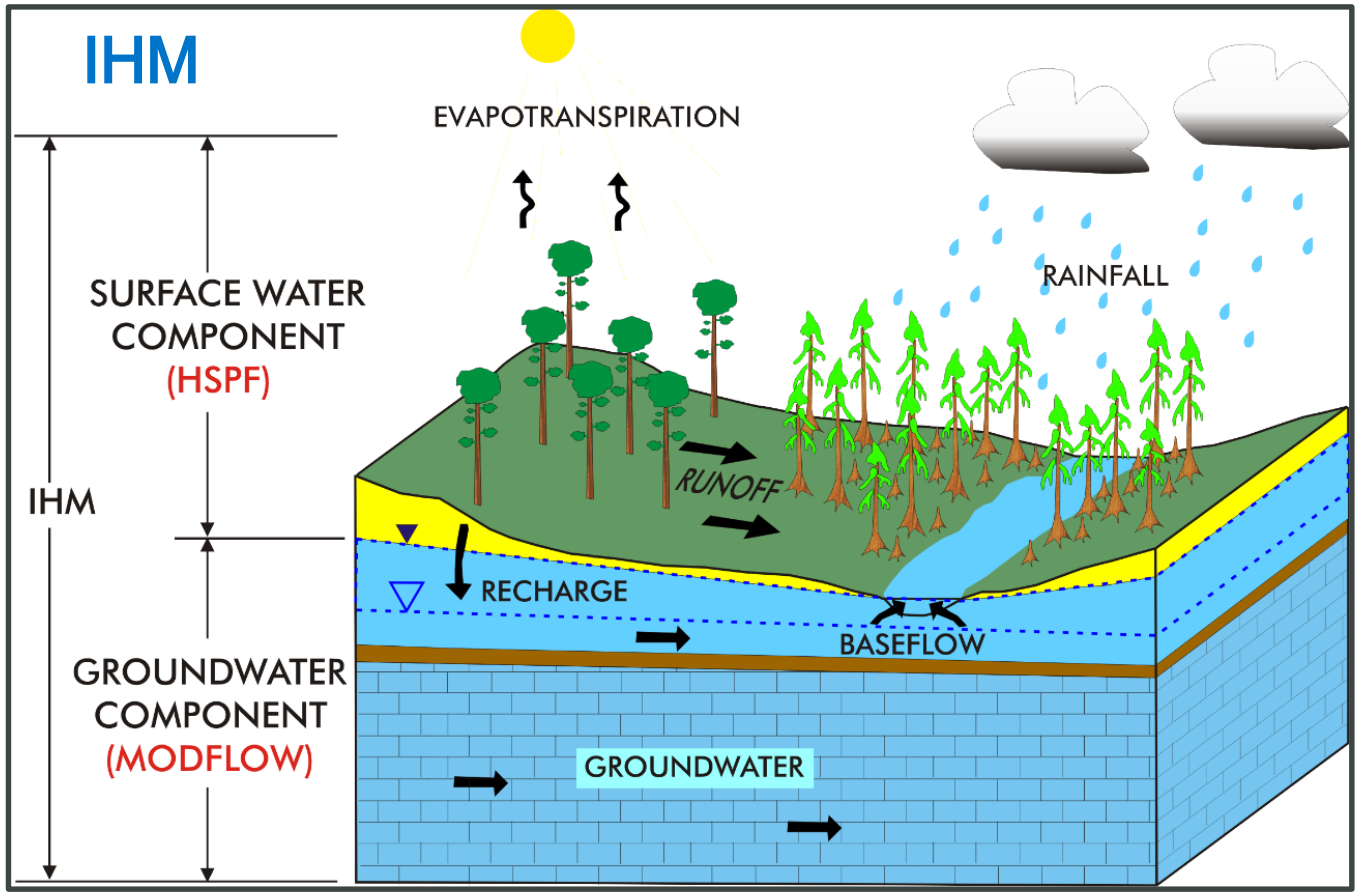
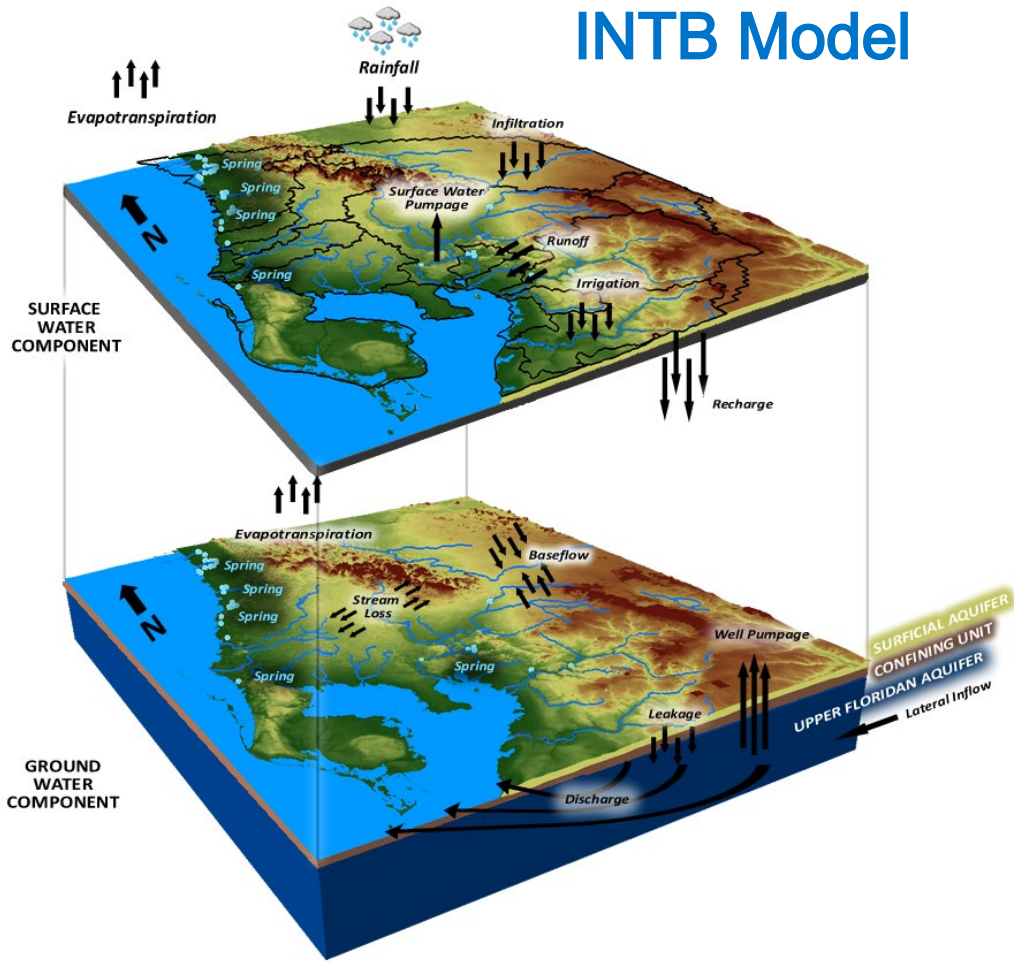
Fully-Integrated Hydrologic Model
When is this simulation technology used or needed?

- Hydrologic, hydrogeologic, climate, & anthropogenic attributes
  - Near-surface water table causes dynamic feedback among processes
    - Uplands, water bodies, & groundwater
  - Changes to anthropogenic stresses or climate
    - Dynamically alter WT feedback & interfacial BC (e.g., depth-to-water table, recharge)
- Strategic decision support needs
  - Increase simulation accuracy, capability, & flexibility (e.g., dry & wet, MFL)
  - Quantitatively partition causes of changes for flows & levels
    - Climate, well pumping, surface-water diversions, landuse

Integrated Hydrologic Model (IHM) and Integrated Northern Tampa Bay (INTB) Model

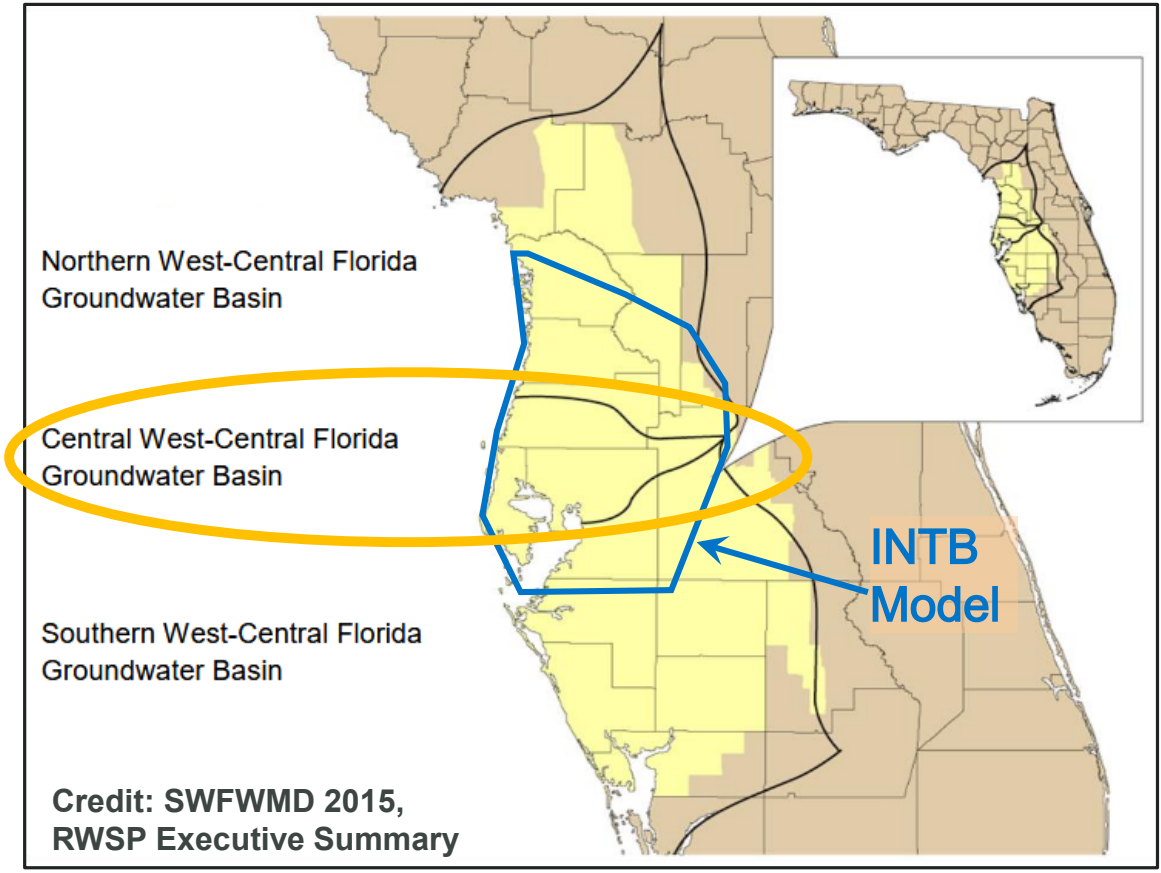


IntegratedHydrologicModel.org



Integrated Northern Tampa Bay (INTB) Model Pumping Scenarios Within CWC Florida GW Basin

- Compare two scenarios
  - Historical well pumping (200 MGD)
  - No well pumping
- Compare scenario responses
  - Depth-to-water table & recharge
  - Streamflow, surface runoff, baseflow, & runoff fraction of streamflow
  - Upland ET & water-body ET
  - Groundwater above land
  - Water-body stage



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GW Pumping Reduction: DWT & Recharge Change

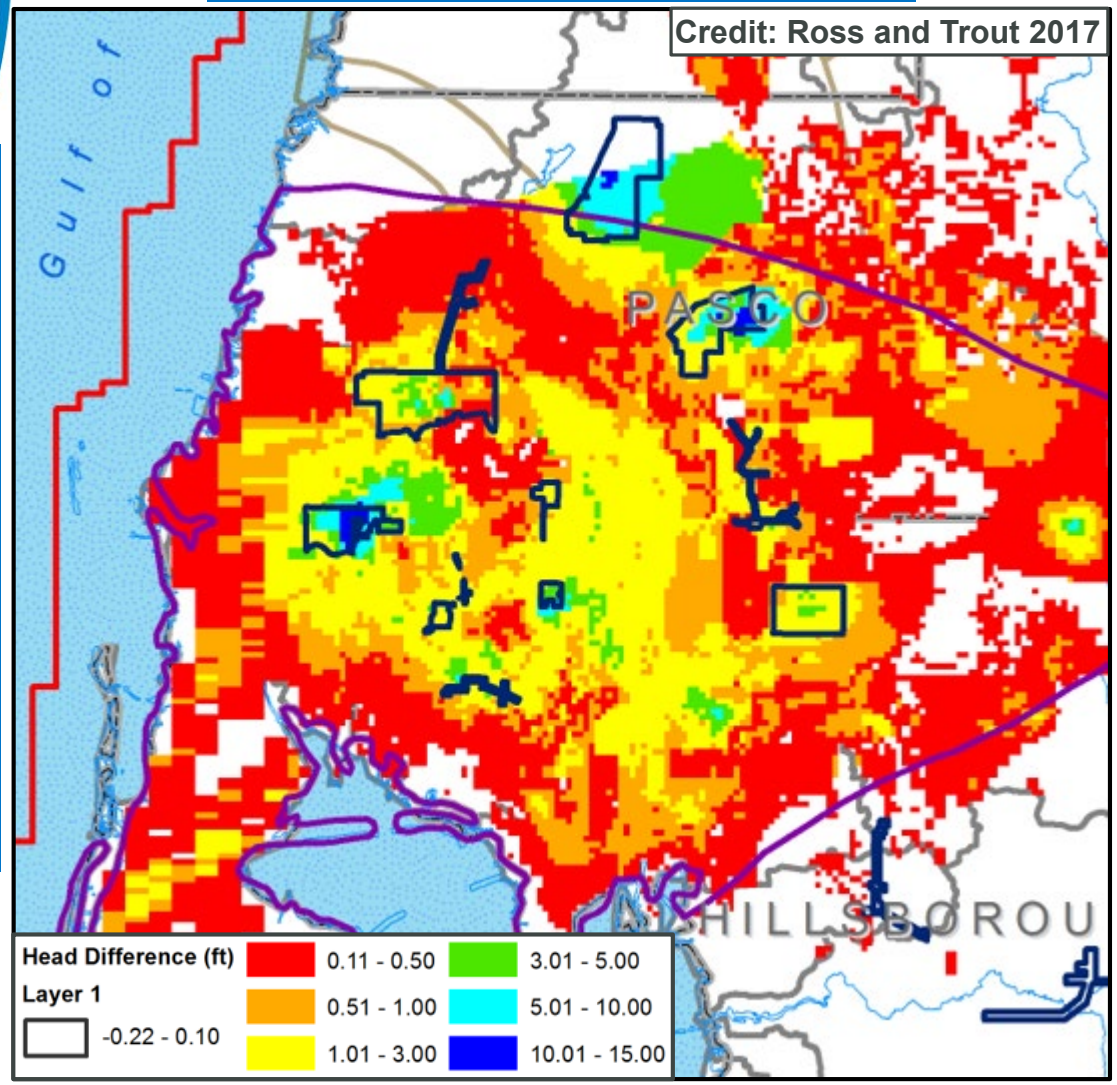
WT Elevation
*Increase

Depth to WT
*Decrease
*Transition DEEP to SHALLOW

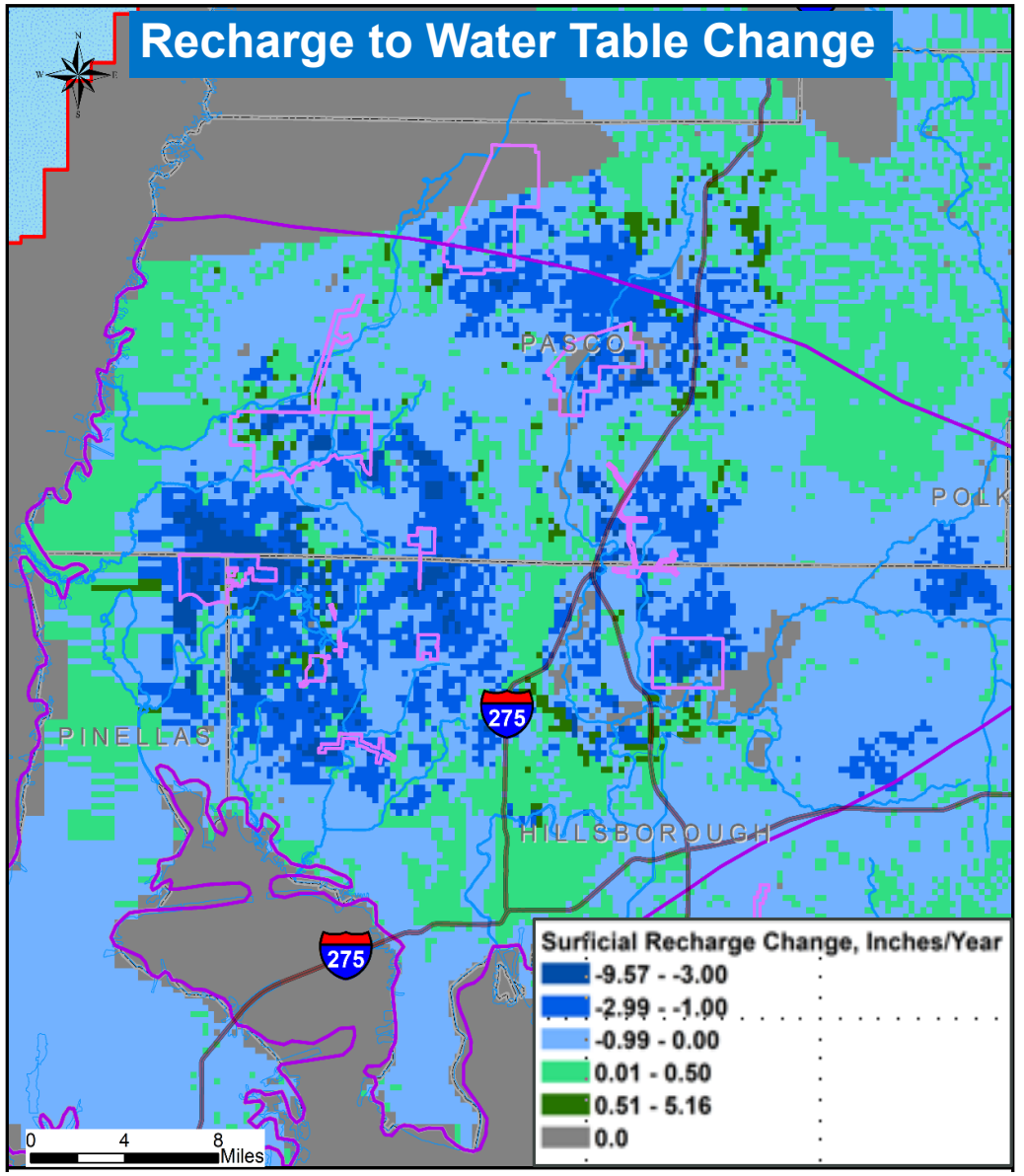
Recharge
*Decrease

Δ Related to Pumping Rate

Water Table Elevation Change



Recharge to Water Table Change



Areas with increase in recharge is outcome of a basin that includes shallow and deep depth-to-water table; occurs over deep DWT

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GW Pumping Reduction: Streamflow Change

Streamflow
*Increase by Factor 1.05 to 20

Streamflow = Runoff+Baseflow
*Increase both components
*ΔRunoff causes up to 42% of Δstreamflow

Runoff Fraction
*Decrease

Δ Related to Pumping Rate

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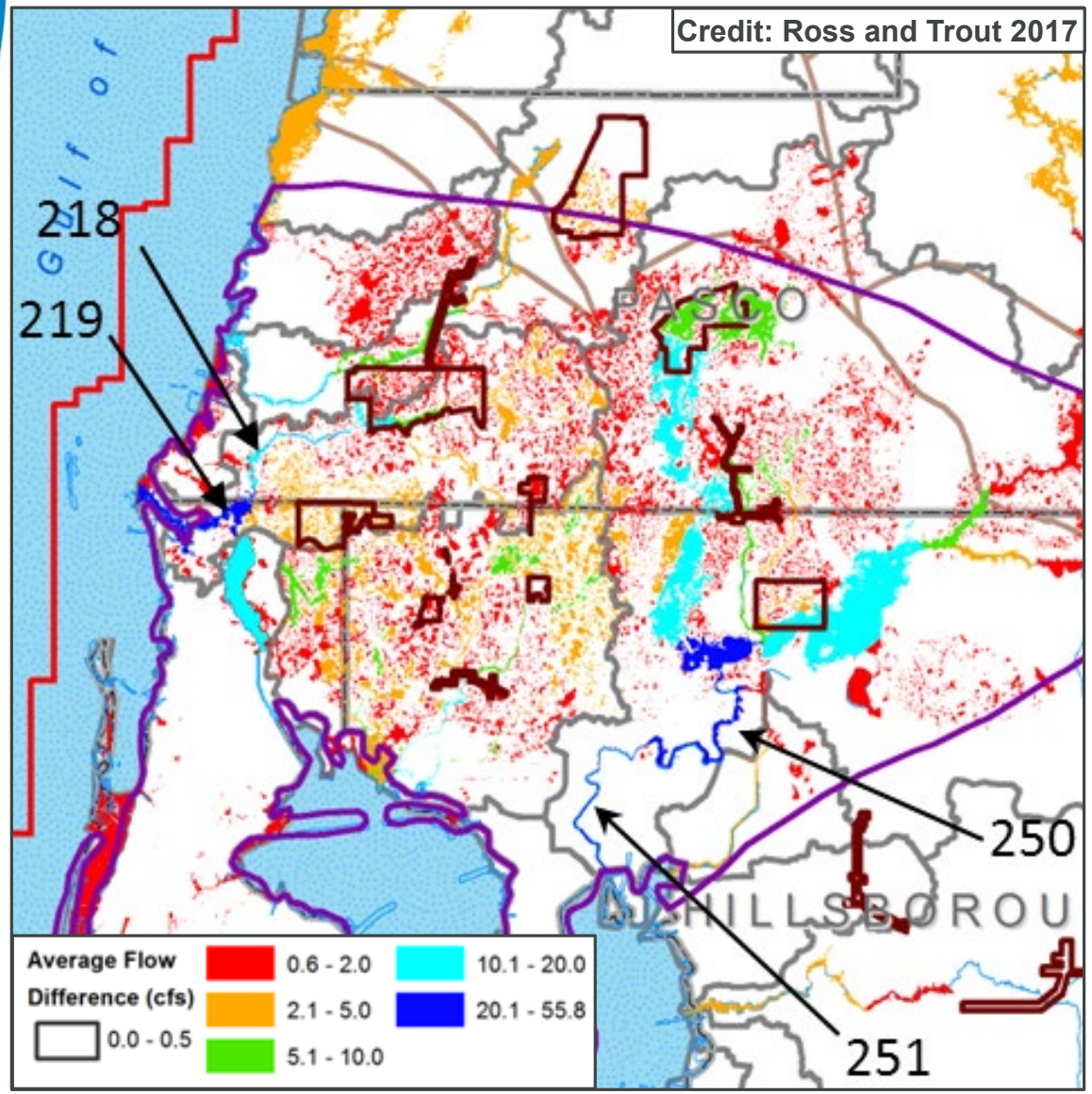
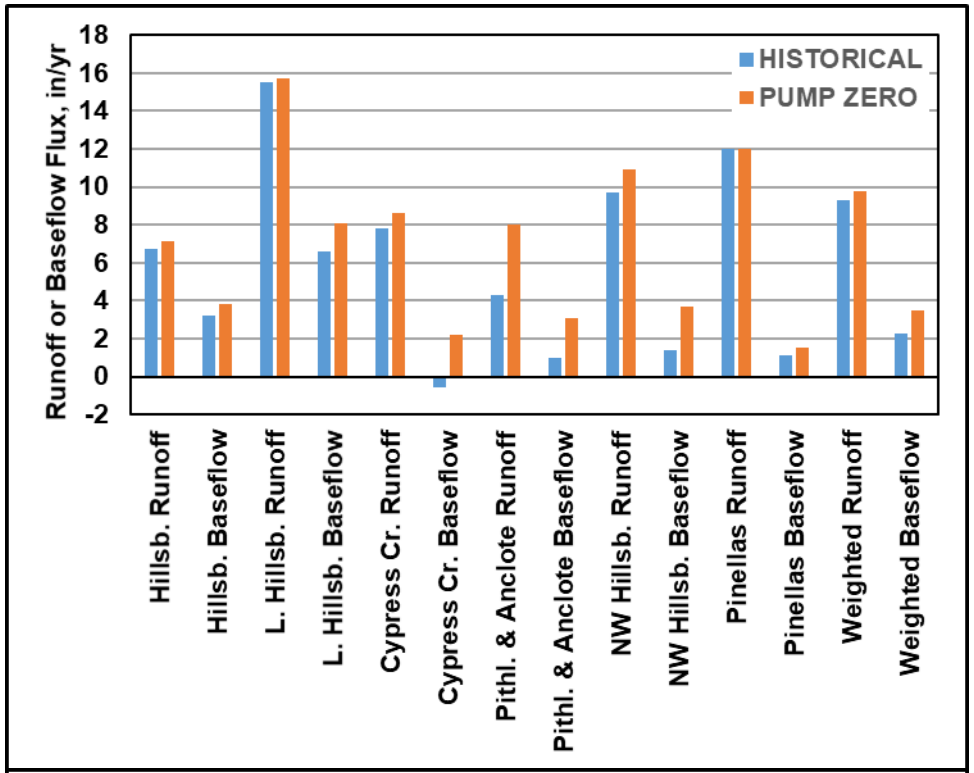
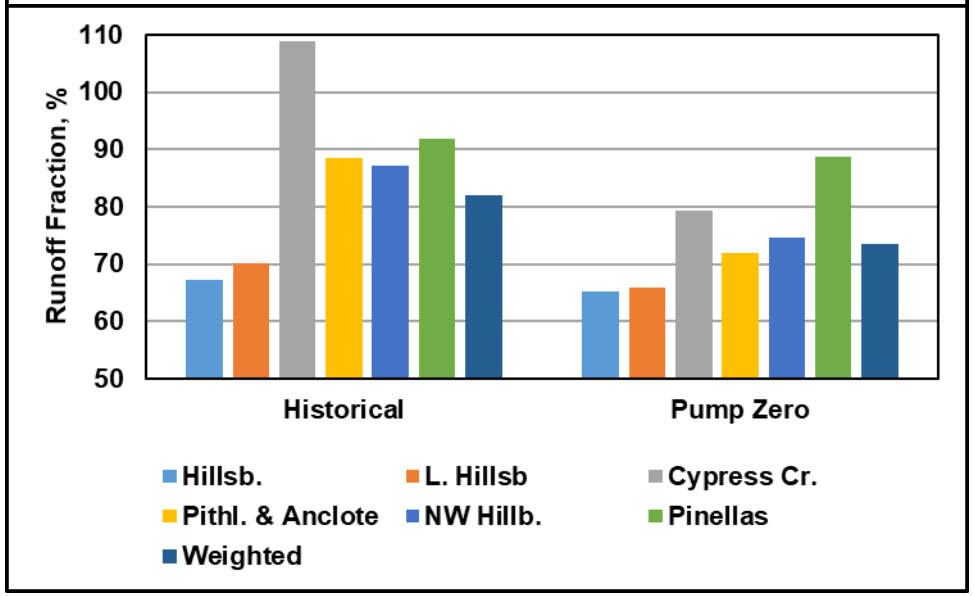






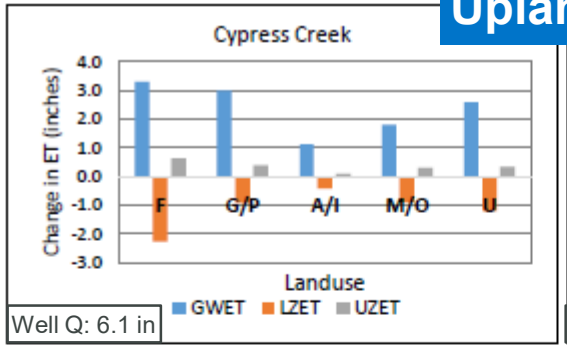
GW Pumping Reduction: ET Change

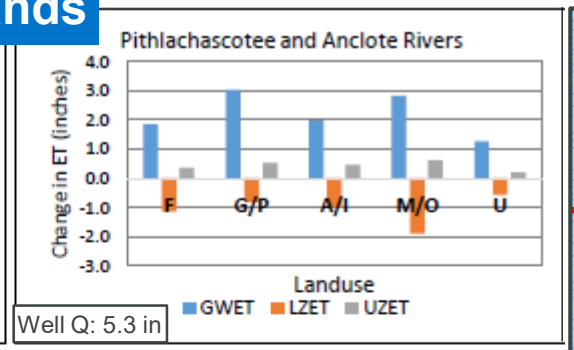
Uplands ET
*Decrease vadose
*Increase GW
*Net increase

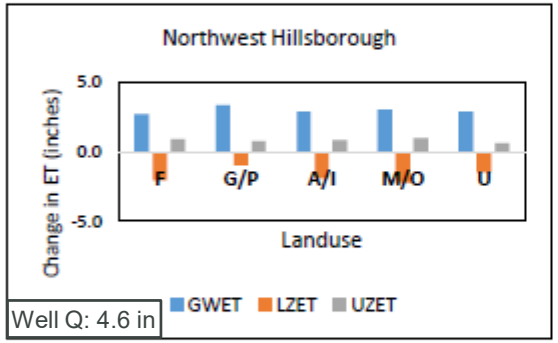
Water-Body ET
*Increase

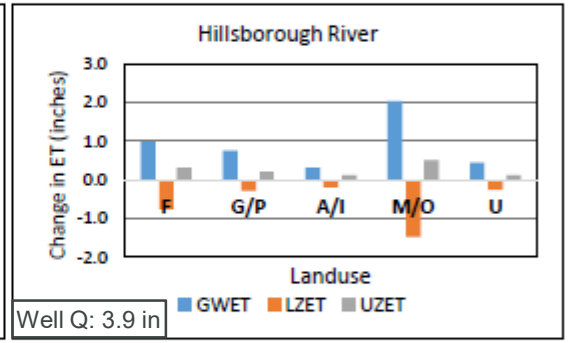
ΔET Related to Pumping Rate

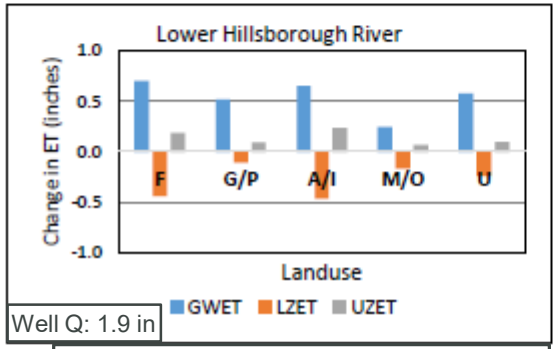
Uplands

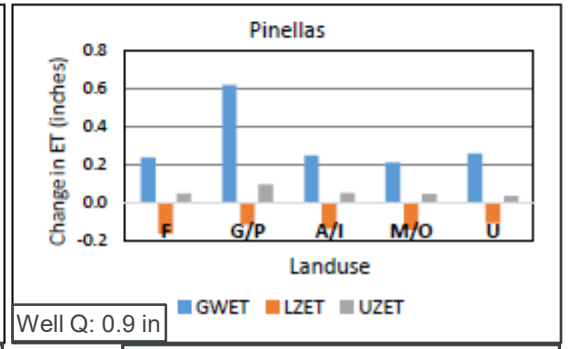








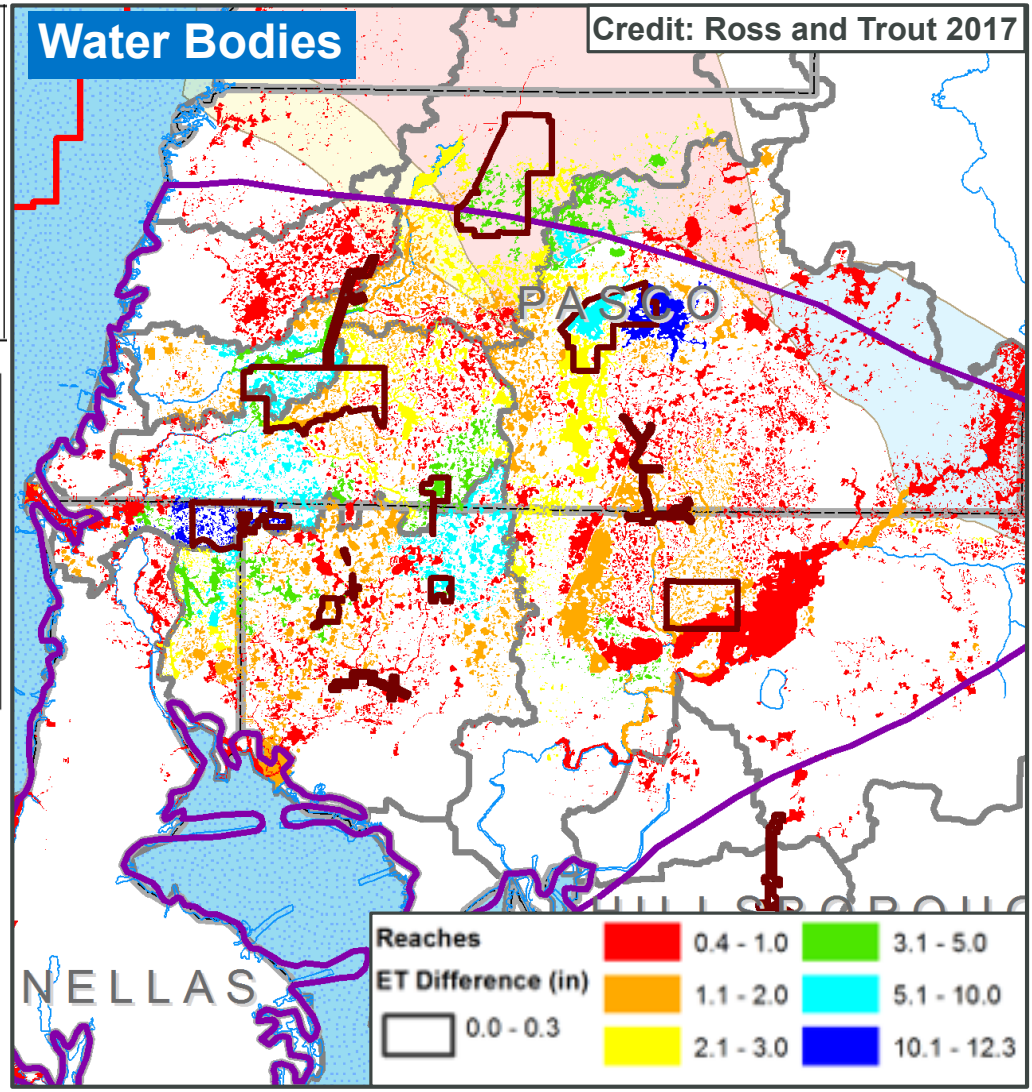




Legend:
F=Forested; G/P=Grass/Pasture
A/I=Agric/Irrigated, U=Urban
M/O=Mining/Other

Credit: Ross and Trout 2017

Water Bodies



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Benefits of Fully-Integrated Hydrologic Models

- Simulate all processes, WT feedback, & interfacial BC
- Strategic application conditions
  - Near-surface depth-to-water table with dynamic WT feedback
  - Change to anthropogenic stress or climate alters dynamic WT feedback & interfacial BC
  - Natural systems or water supplies currently or anticipated to be stressed

- Decision support requires more accuracy, capability, or flexibility
- Quantitatively partition causes of changes in flows & levels
- One model to assess changes to all flows & levels

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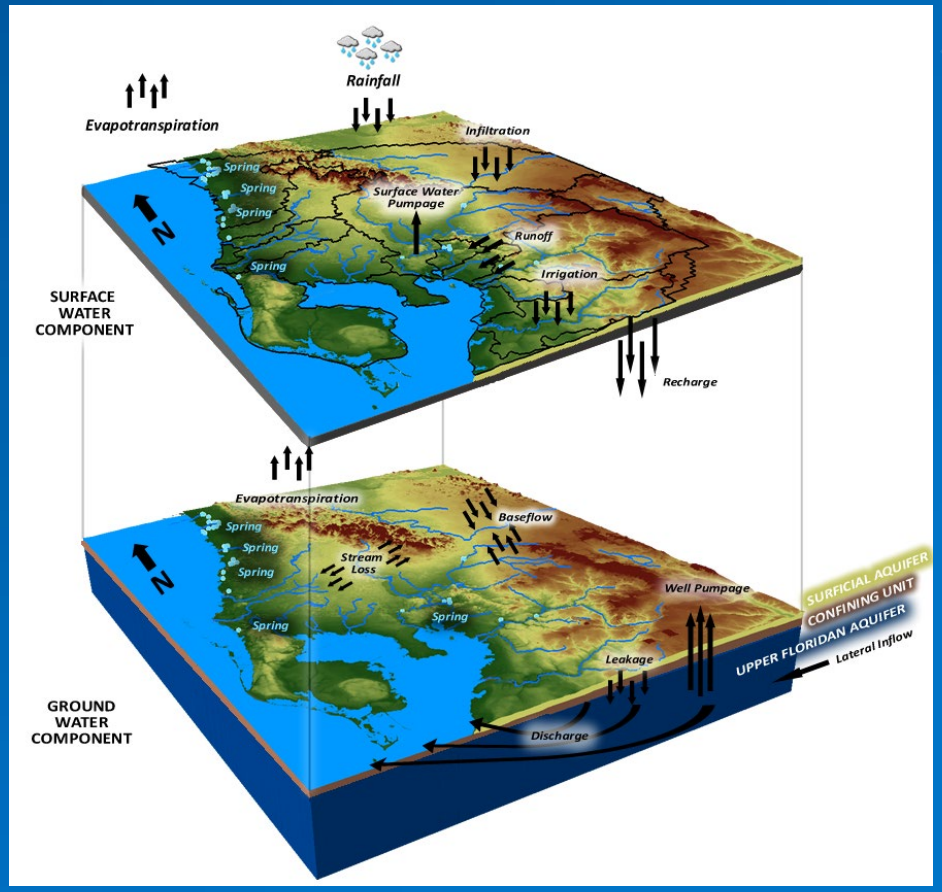


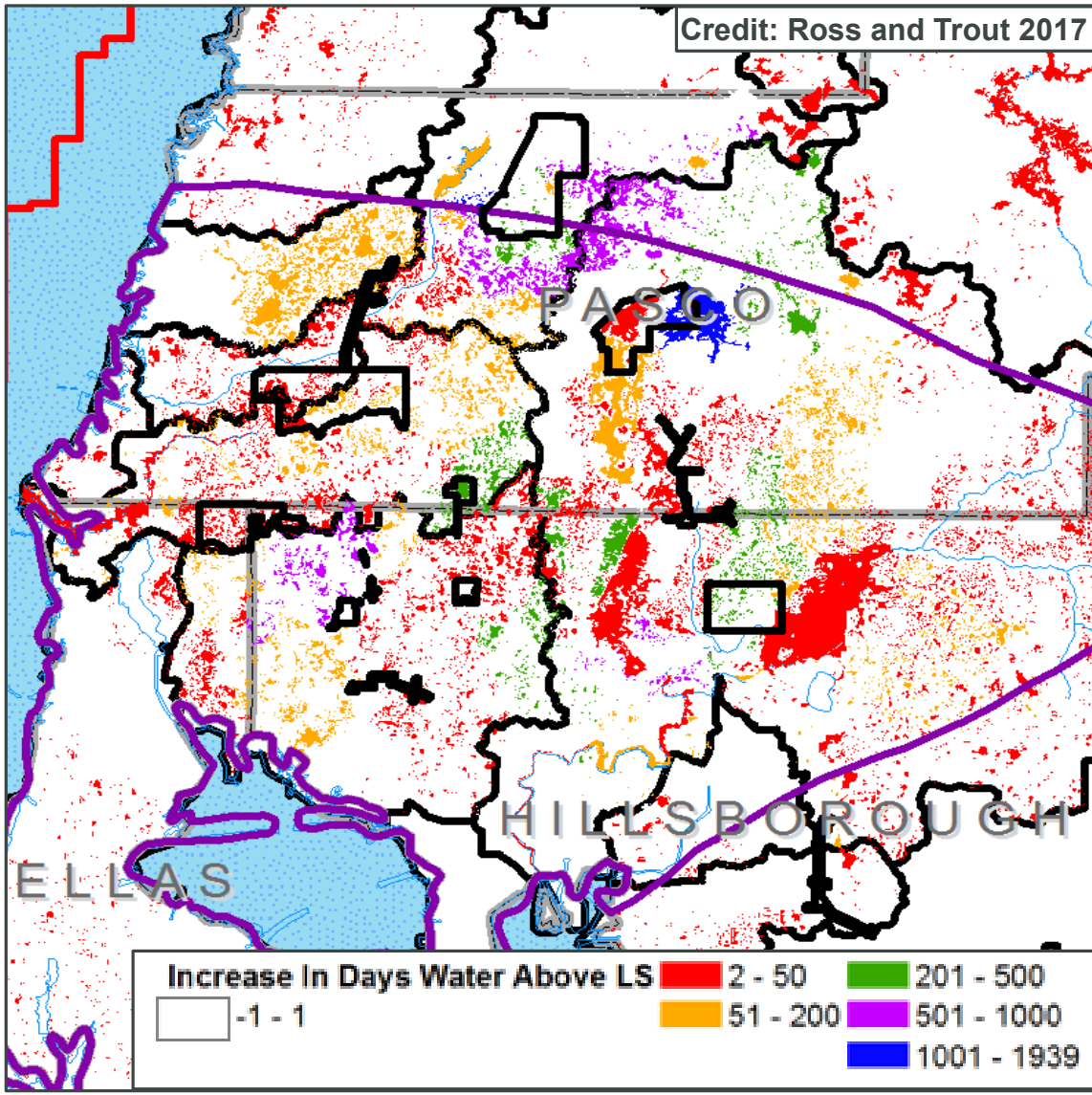
Questions

INTEGRATED HYDROLOGIC MODEL

IHM website: IntegratedHydrologicModel.org

GW Pumping Reduction Water Above Land

- Integrated model has increase in days where water is above land
  - Locations coincide with water bodies
  - Dynamic conversion of recharge to runoff and ET minimizes water above land in upland areas
- Very difficult for groundwater models to avoid water above land in upland areas
  - Water above land in upland areas can cause overestimate of change to baseflow, springflow, and heads for a pumping reduction



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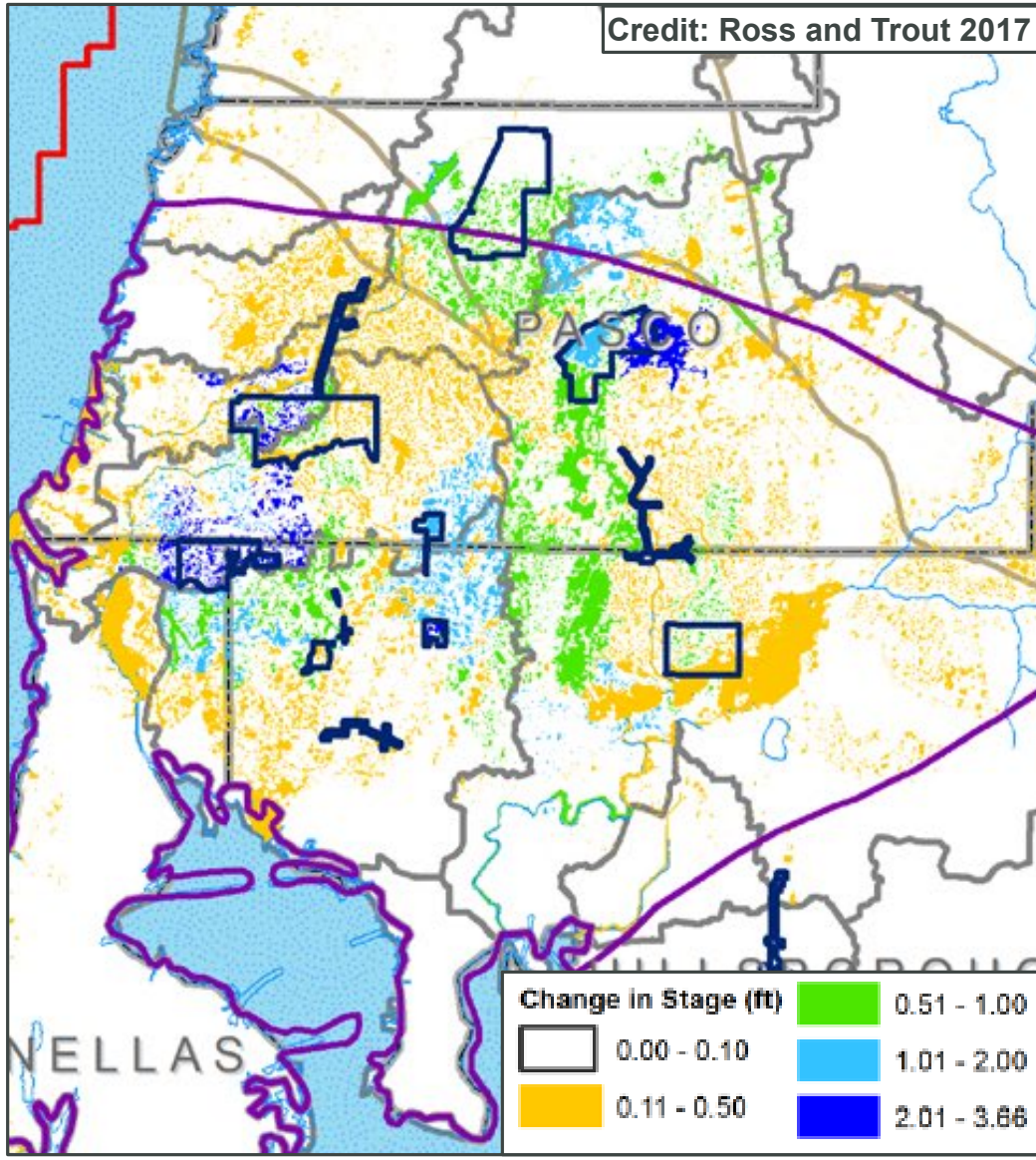
GW Pumping Reduction Water-Body Stage Change

- Integrated model shows increase in water-body stage caused by net effects of:
  - Increase in runoff and baseflow
  - Increase or decrease in water-body leakage
  - Increase in water-body ET
- Very difficult for groundwater model to simulate changes to water-body stage
  - Without change in water-body stage, baseflow change can be overestimated for a pumping reduction



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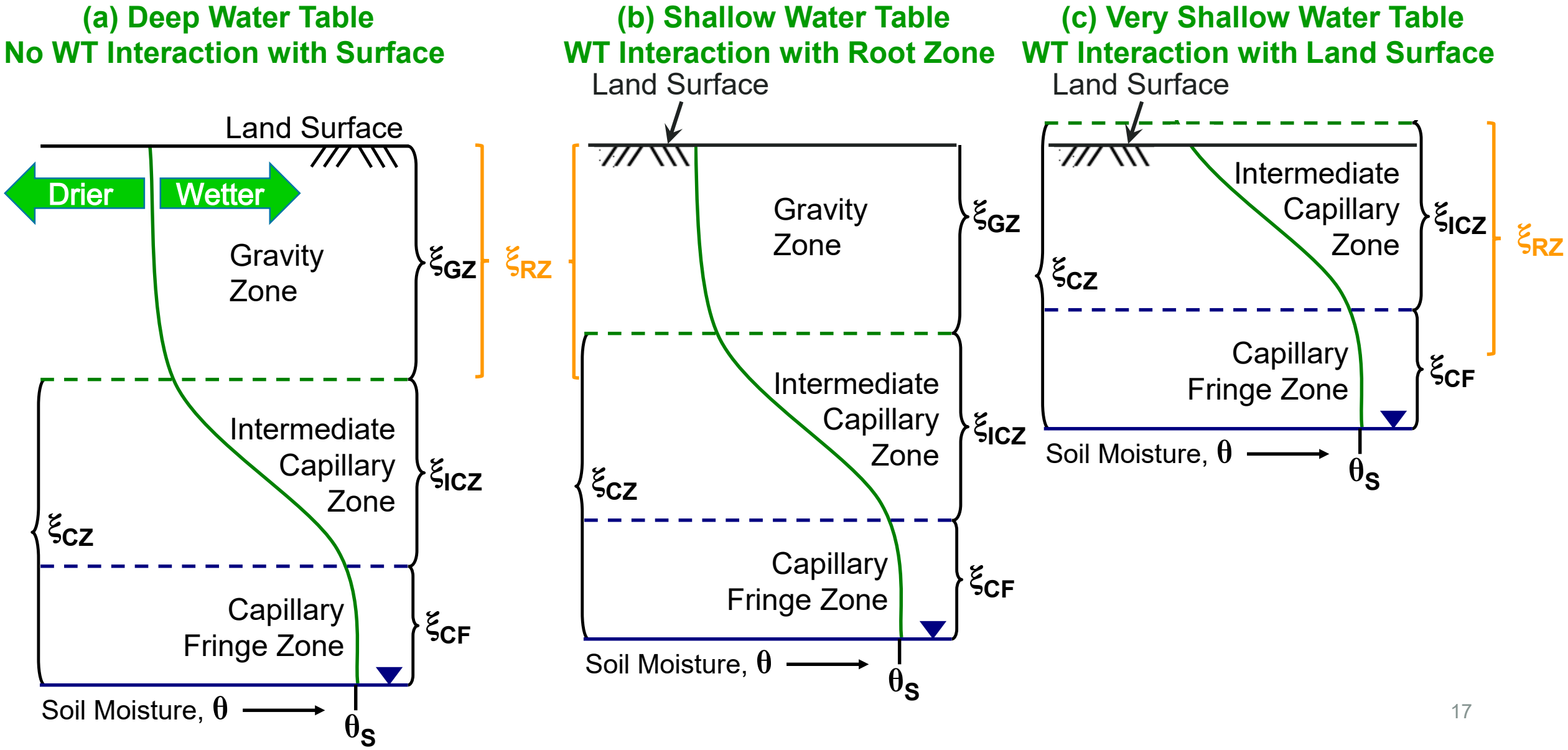
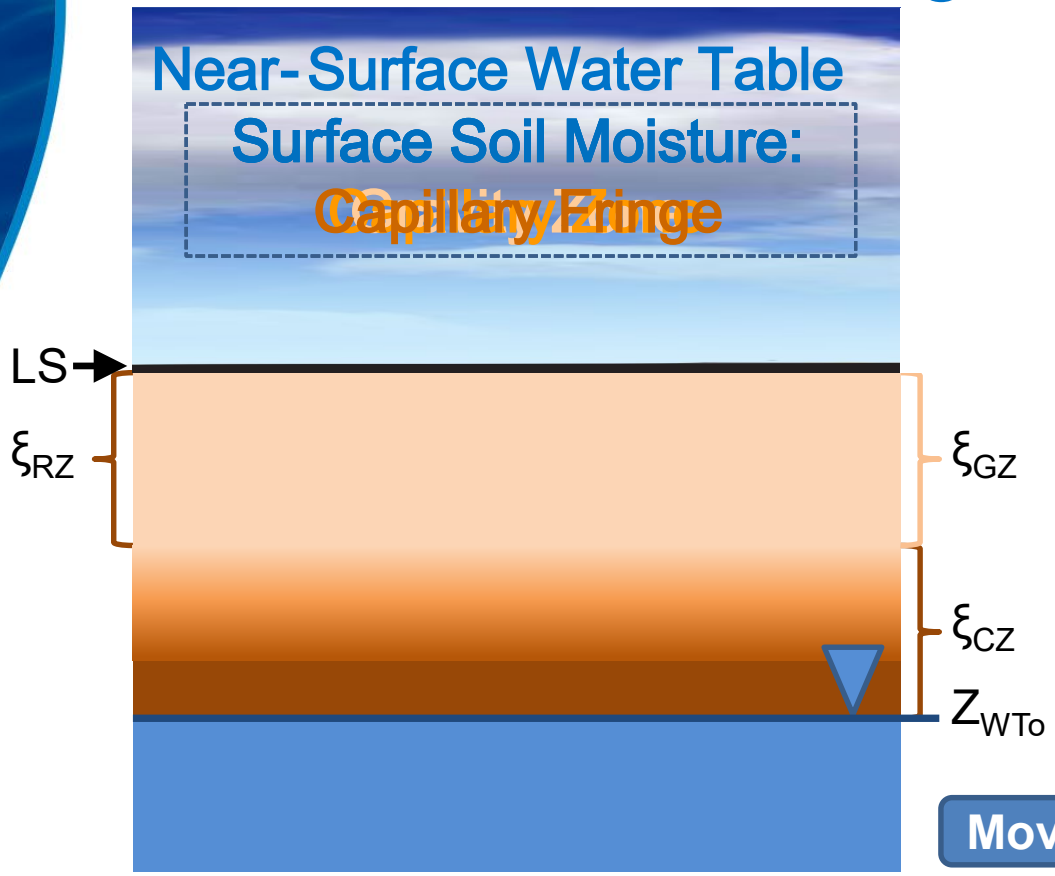
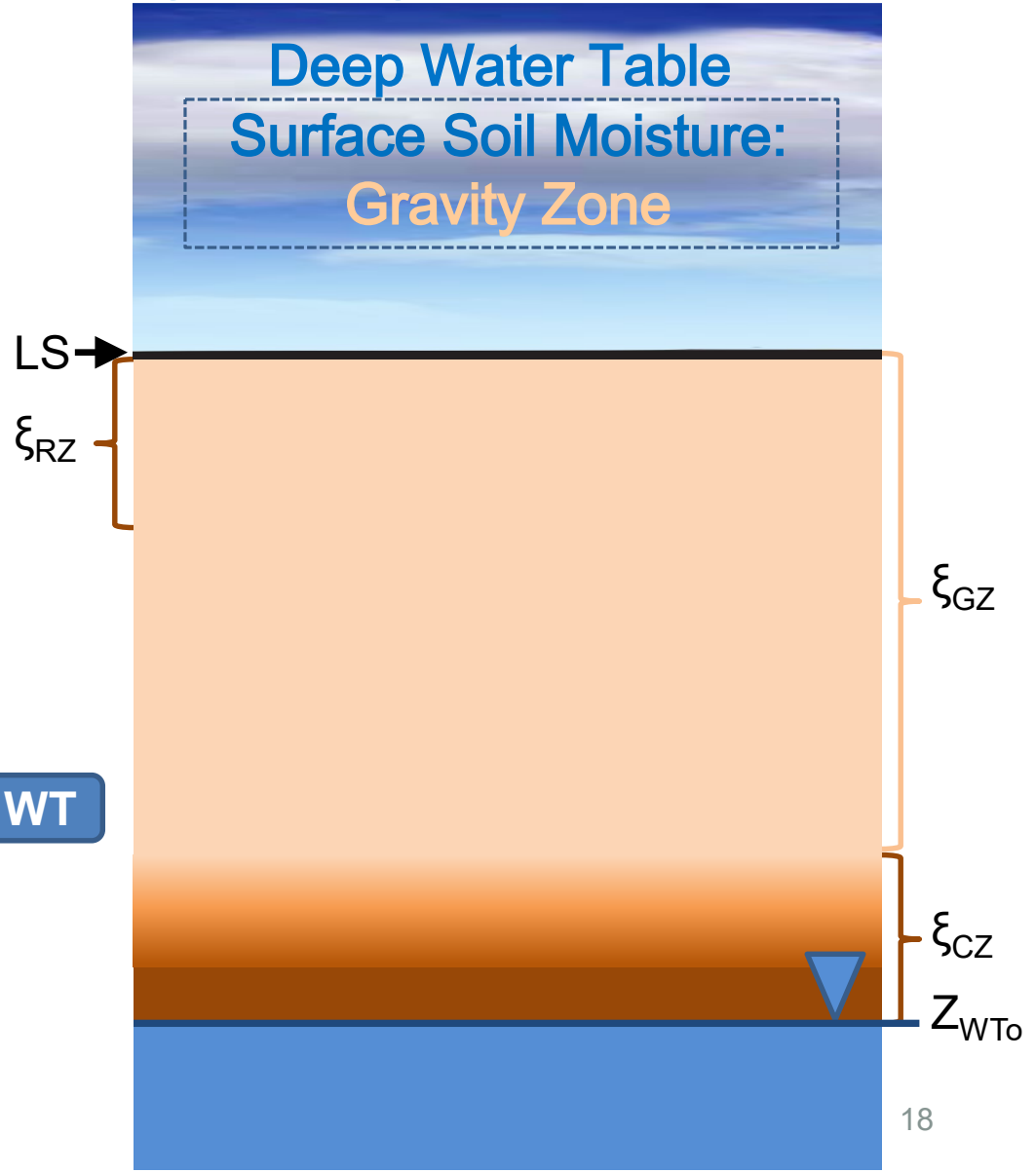
Surface-Groundwater Flow Exchange
Water Table Influence Through Capillary Forces



Areas With Near-Surface Depth-To-Water Table Assessment Advantages Using Integrated Models





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