BUREAU OF RECLAMATION

Klamath River Basin Revised Natural Flow Study

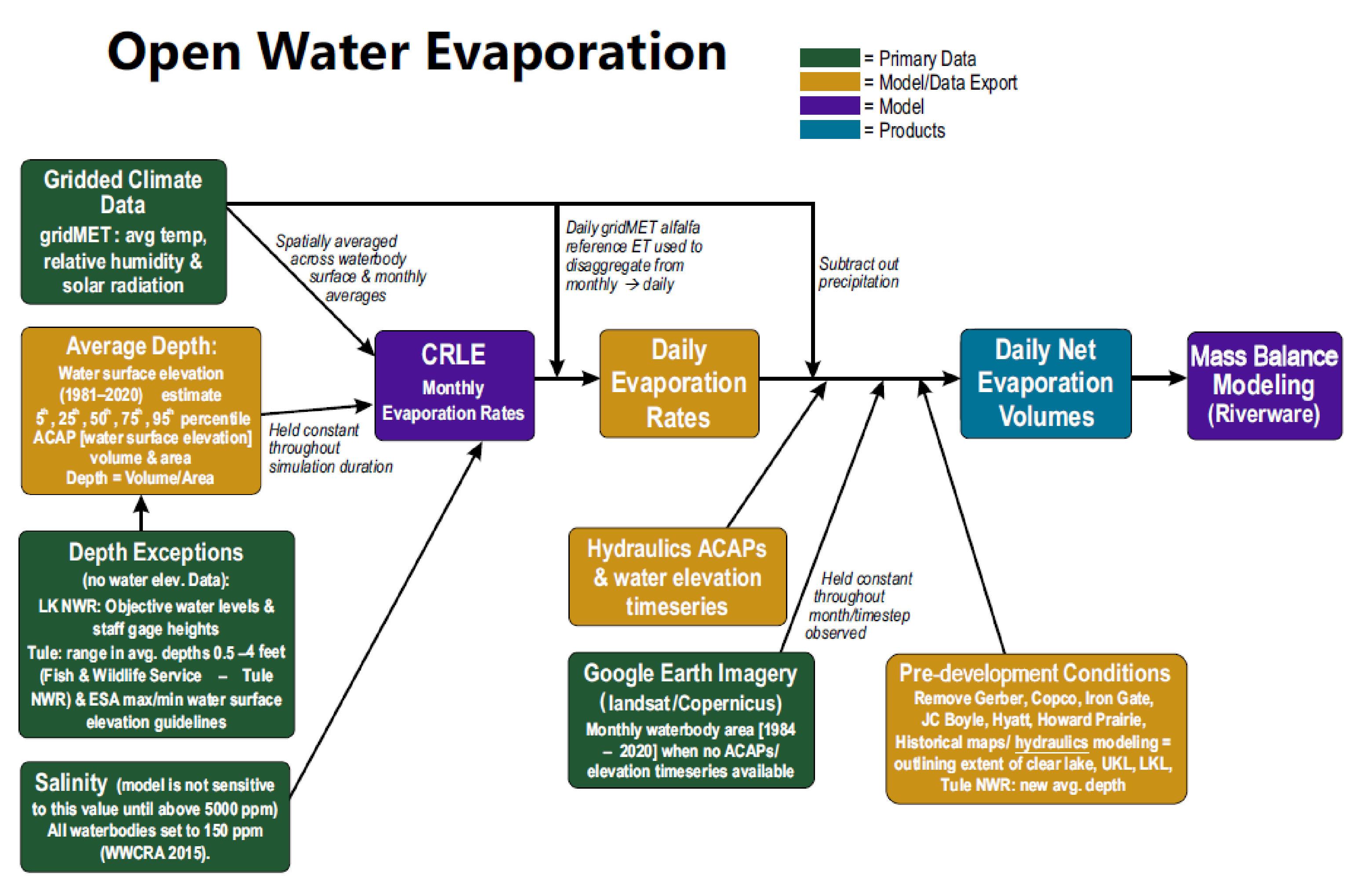
November 2 – 3, 2022
Stakeholder Workshop
Reservoir Evaporation Modeling

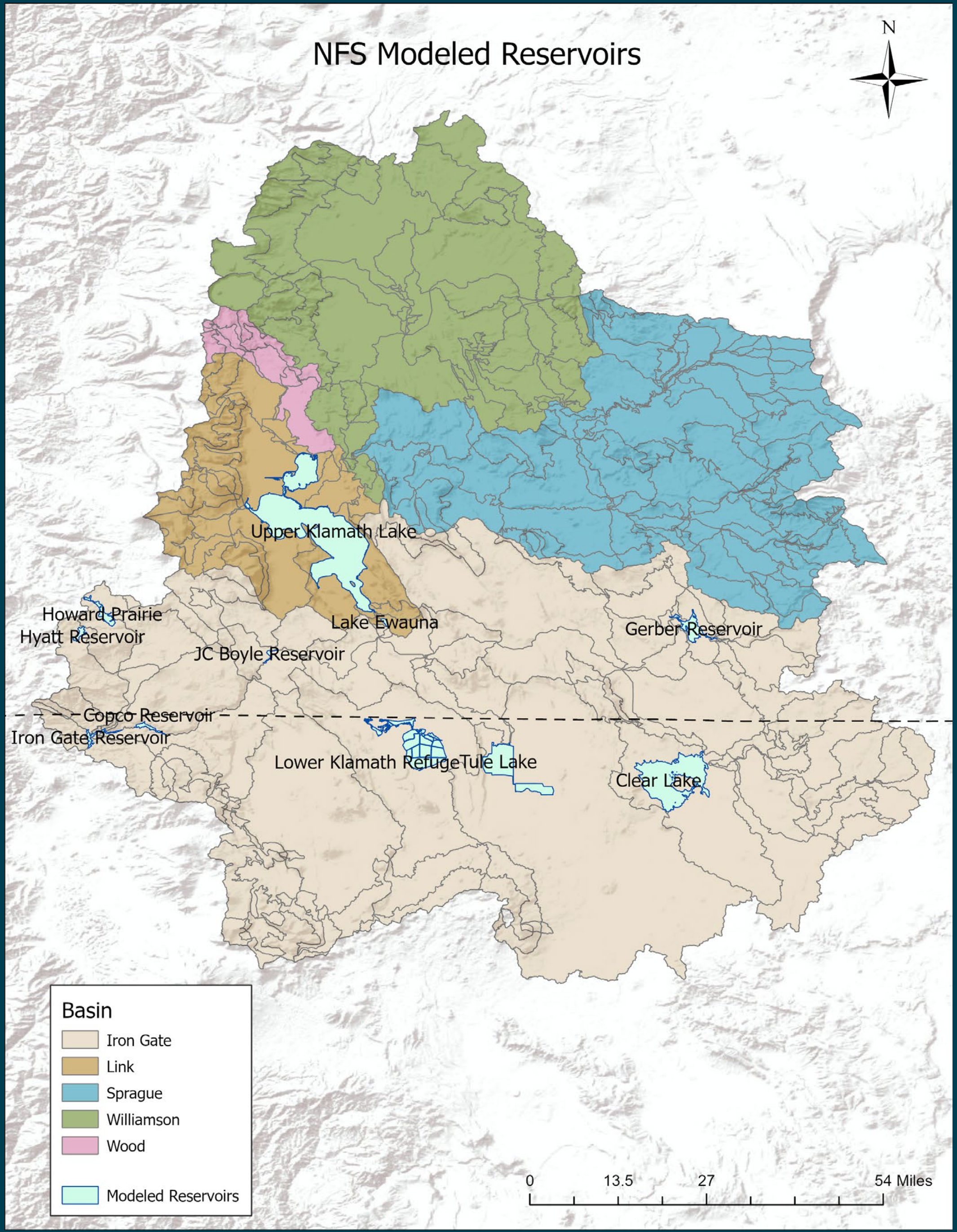
Outline

- Model Purpose
- Model Selection
- Input Data
- Methodology
- Natural Flow Representation
- Sensitivity & Uncertainty Analysis

Model Purpose

- To quantify how open water evaporation rates have changed from current to pre-project conditions.



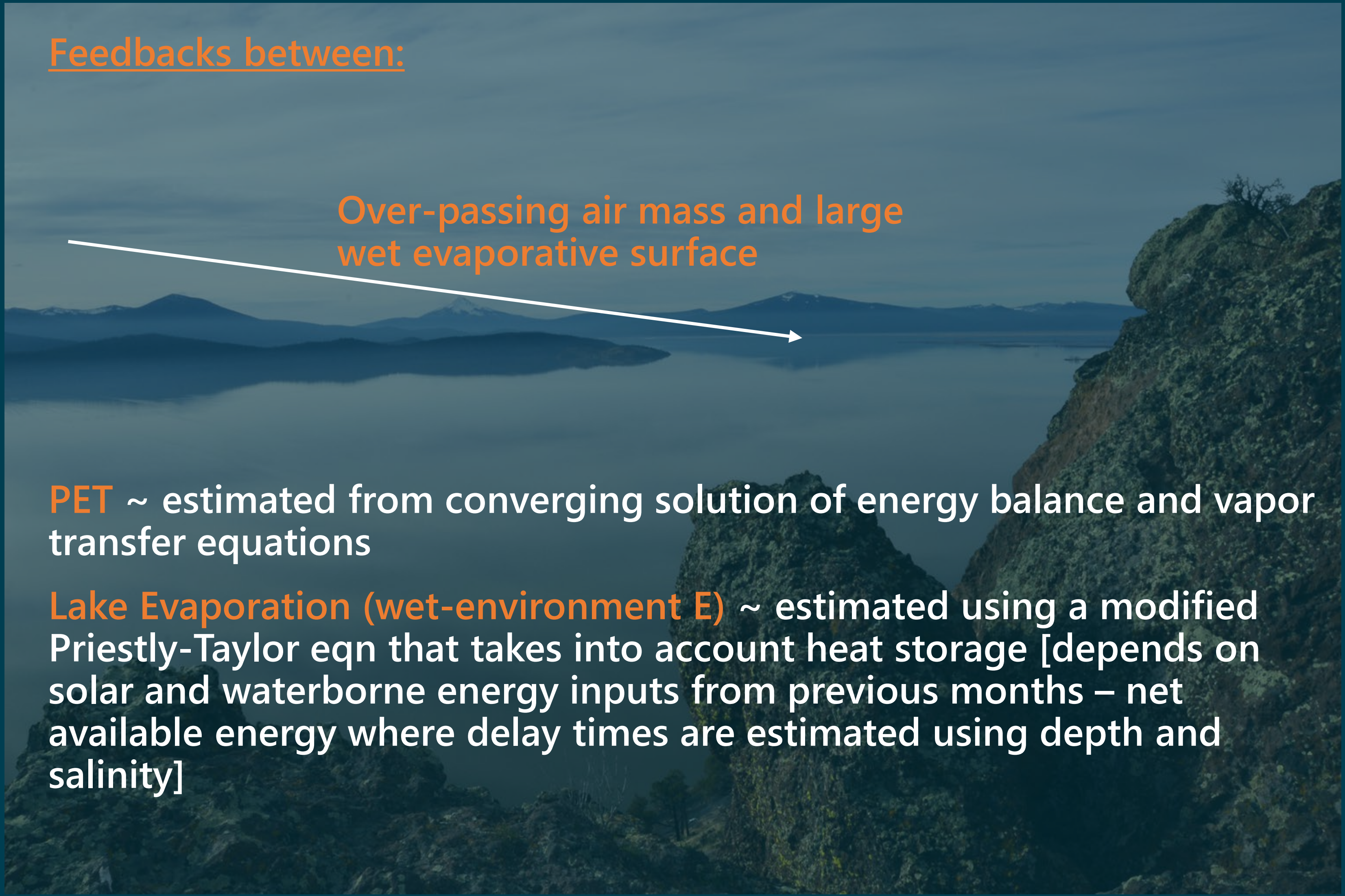


Model Extent

- Upper Klamath Lake
- Lower Klamath National Wildlife Refuge
- Tule Lake National Wildlife Refuge
- Clear Lake
- Gerber Reservoir
- Howard Prairie
- Hyatt Reservoir
- Lake Ewauna
- JC Boyle Reservoir
- Copco Reservoir
- Iron Gate Reservoir

Complementary Relationship Lake Evaporation (CRLE) model

- The CRLE model accounts for water temperature, albedo, emissivity, and heat storage effects to estimate monthly surface water evaporation.



Feedbacks between:

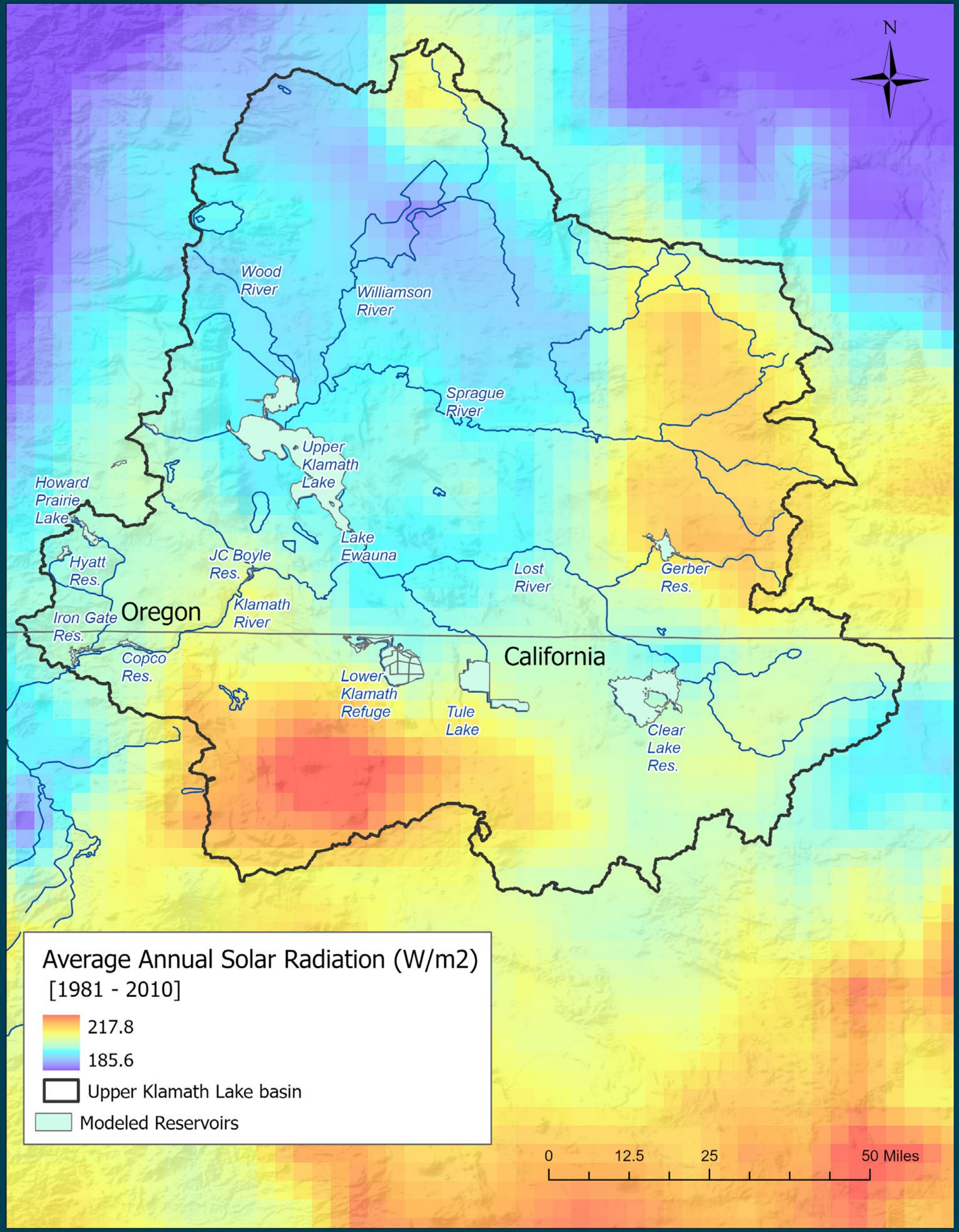
Over-passing air mass and large wet evaporative surface

PET ~ estimated from converging solution of energy balance and vapor transfer equations

Lake Evaporation (wet-environment E) ~ estimated using a modified Priestly-Taylor eqn that takes into account heat storage [depends on solar and waterborne energy inputs from previous months – net available energy where delay times are estimated using depth and salinity]

Input Data

- gridMET: monthly avg. temp, solar radiation, & relative humidity
- Salinity
- Average reservoir depth (held constant throughout simulation)
  - Estimated 5th, 25th, 50th, 75th, 95th percentile of water surface elevation timeseries [1980-2020]. ACAP then used to calculate volume at respective water surface elevation. Depth = volume/area.
  - Tule: 0.5ft – 4ft avg. depth range for Sump 1A and 1B (CCP Appendix F).
  - Lower Klamath NWR: area-weighted depths were determined based on objective water levels & staff gage heights for each relevant section (seasonal and permanent wetlands only) of the refuge.

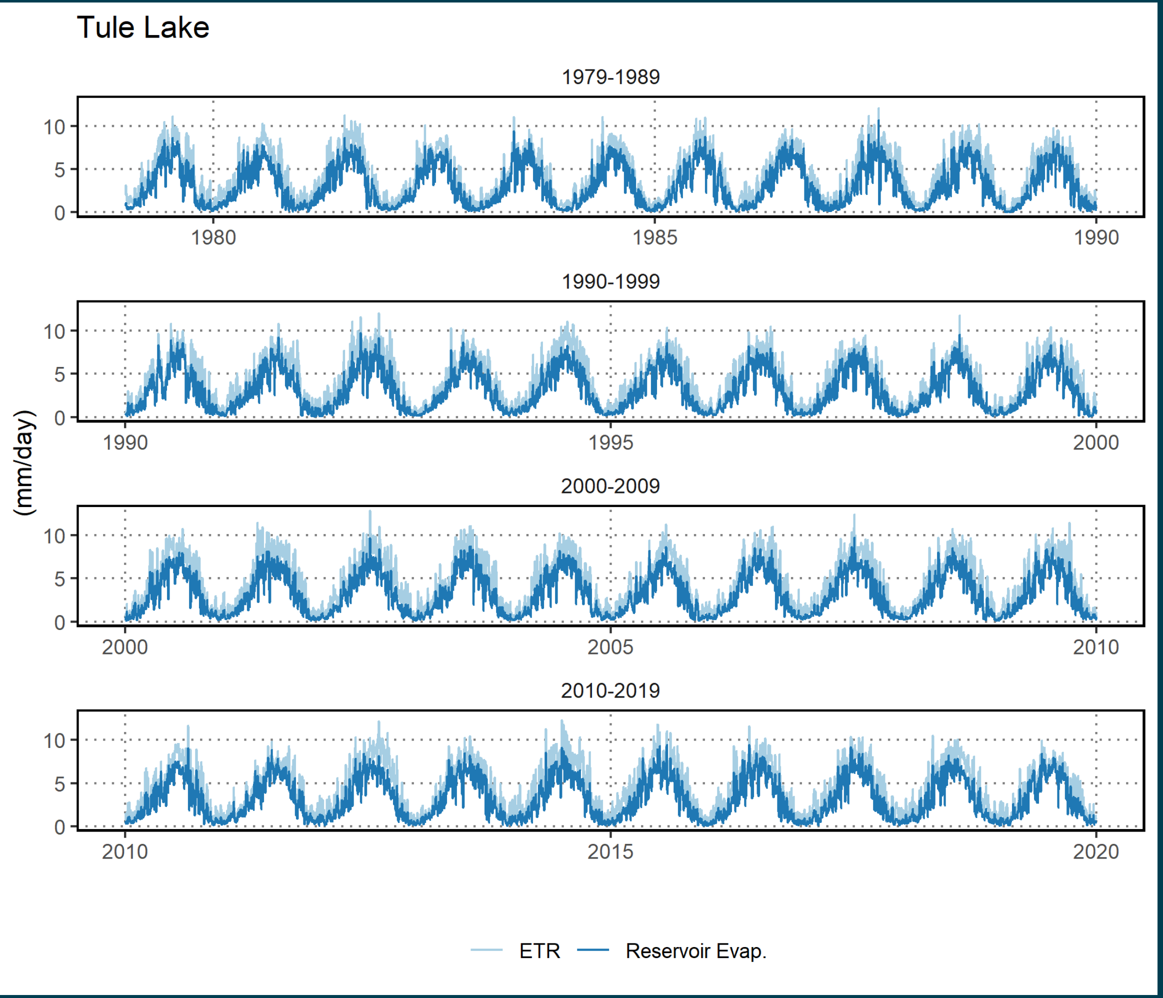


Model Methodology

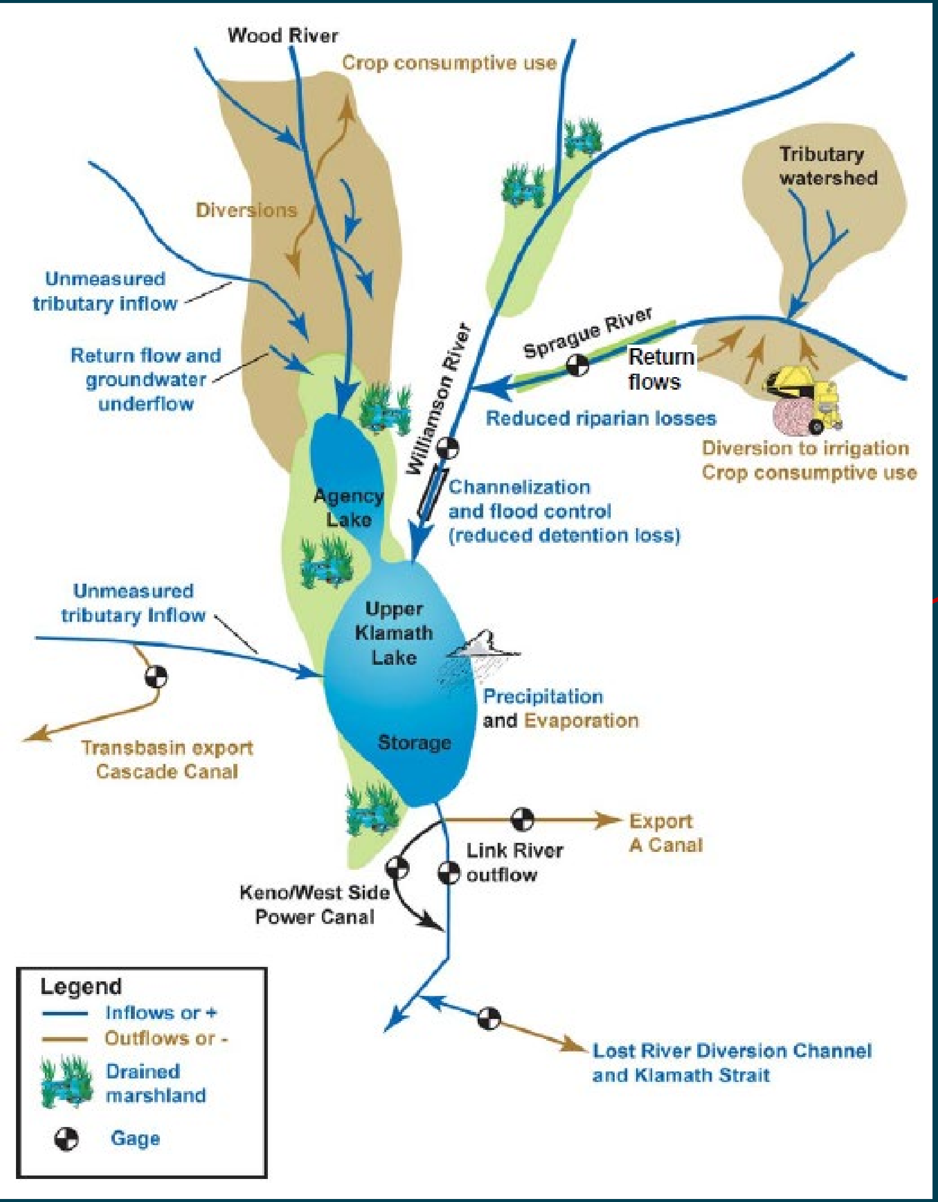
- No calibration needed – two constants in the modified Priestly-Taylor equation were 'once calibrated' using water-budget estimates of lake evaporation from seven lakes situated throughout the United States.

- Dissaggregation from monthly to daily evaporation estimates – using daily gridMET ETr as a training dataset

- Volumetric Evaporation (in RiverWare): areas estimated using ACAP/water elevation timeseries or remotely sensed imagery



2005 Natural Flow Study Conceptual Model

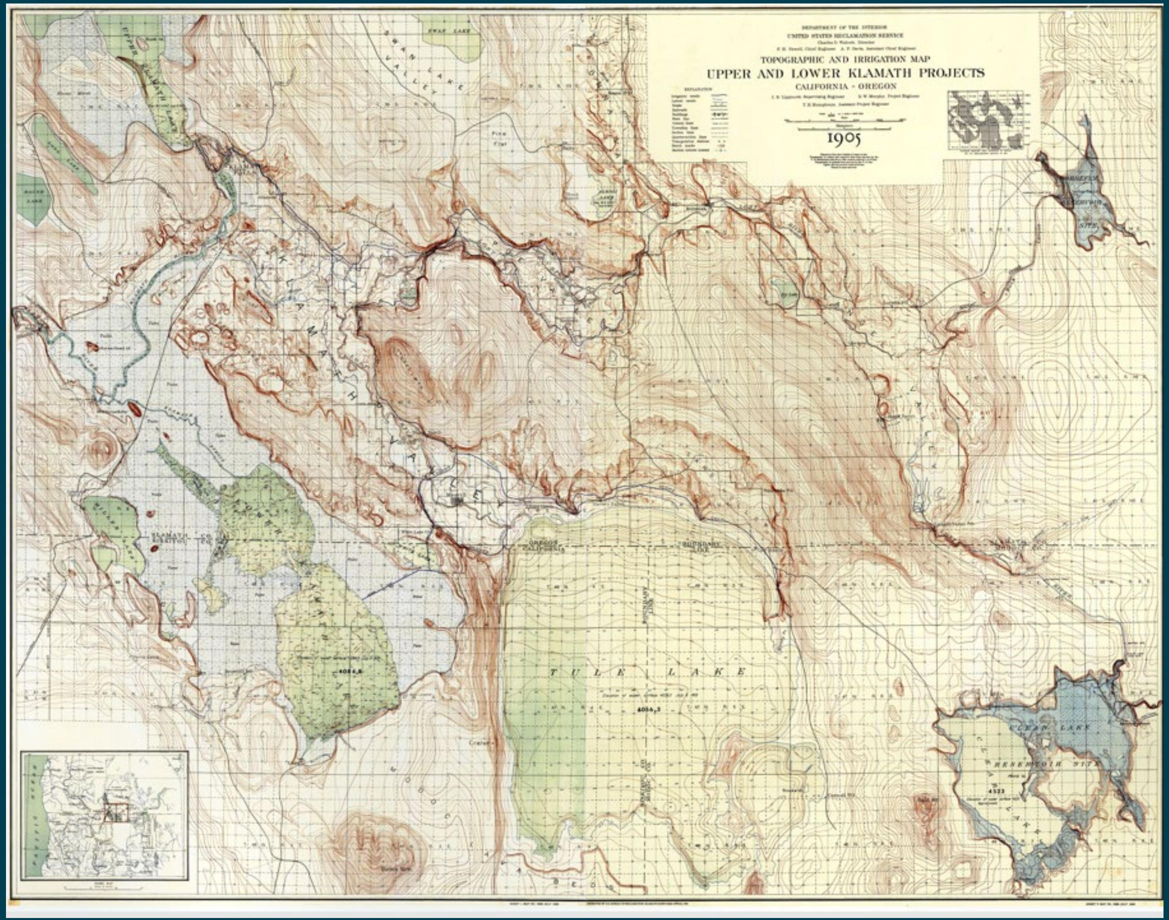


Comparison to 2005 Natural Flow Study

- 2005 study 'Natural Lake Simulations'
  - Monthly water budget approach for UKL (only) accounting for inflow, storage & outflow.
  - Open water evaporation estimated using the Hargreaves eqn. (uses air temp. & latitude)

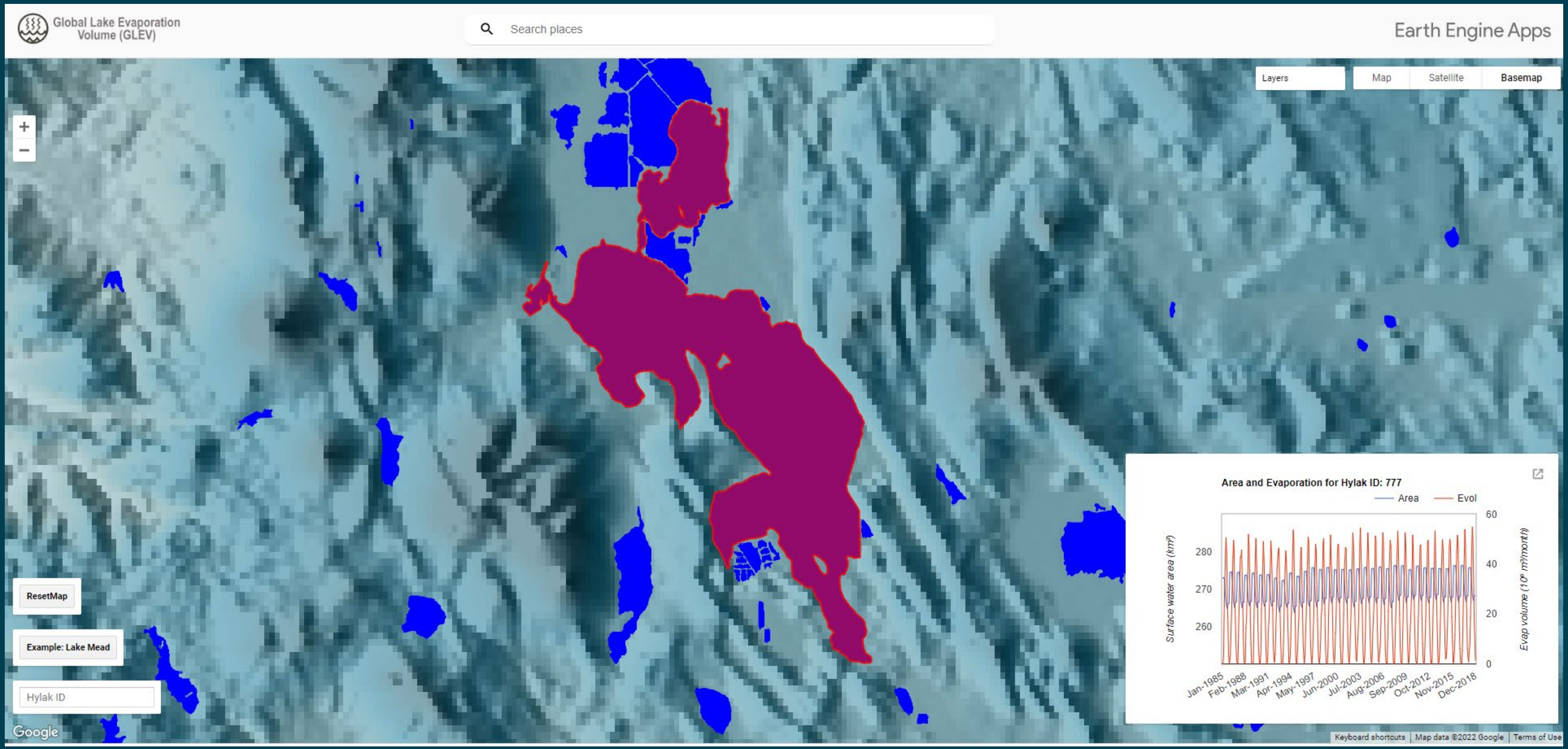
Natural Flow Representation

- Remove all reservoirs: Gerber, Copco, Iron Gate, JC Boyle, Hyatt, Howard Prairie
- Re-estimate average depths of natural lakes from hydraulic modeling & historic maps: Clear Lake, UKL, Lower Klamath Lake, Tule Lake.
- (In Riverware) – Waterbody areas (for volumetric evap) estimated from historic maps, assume stationary?



Sensitivity & Uncertainty Analysis

- CRLE is most sensitive to average depths. Ran model at 5th, 25th, 50th, 75th, and 95th avg. depth percentiles.
- Will compare to the new 'glev' (global lake evaporation volume) remotely sensed reservoir evaporation dataset.



*Zhao et al. 2022. Evaporative water loss of 1.42 million global lakes. Nature Communications.

Summary

- Used the CRLE model to simulate open-water evaporation rates
  - Datasets include gridMET climate data, ACAP, water elevation timeseries
  - Dissaggregate monthly evaporation rates to daily using gridMET ETr
- Improved upon the 2005 Study by:
  - Using an energy-aerodynamic approach for estimating reservoir evaporation
  - Modeling open-water evaporation at all large bodies of water that have changed between pre-project and current conditions
  - Daily timestep
- Natural flow represented by:
  - Removing all man-made reservoirs
  - Calculating pre-project average depths for all natural lakes

*Upper Klamath Lake (https://www.flickr.com/photos/usbr/)

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Questions and Additional Discussion

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