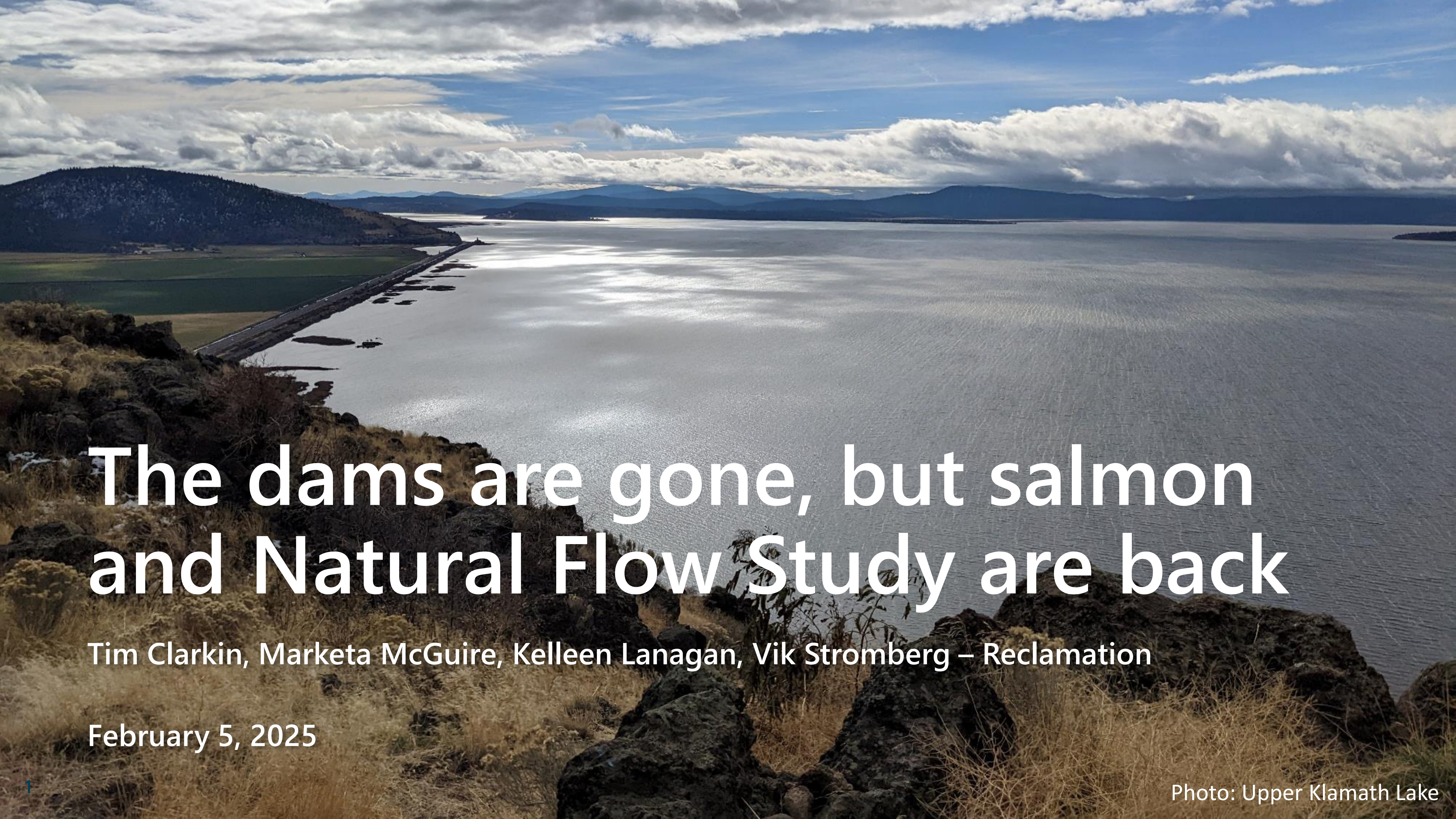


The dams are gone, but salmon and Natural Flow Study are back

Tim Clarkin, Marketa McGuire, Kelleen Lanagan, Vik Stromberg – Reclamation

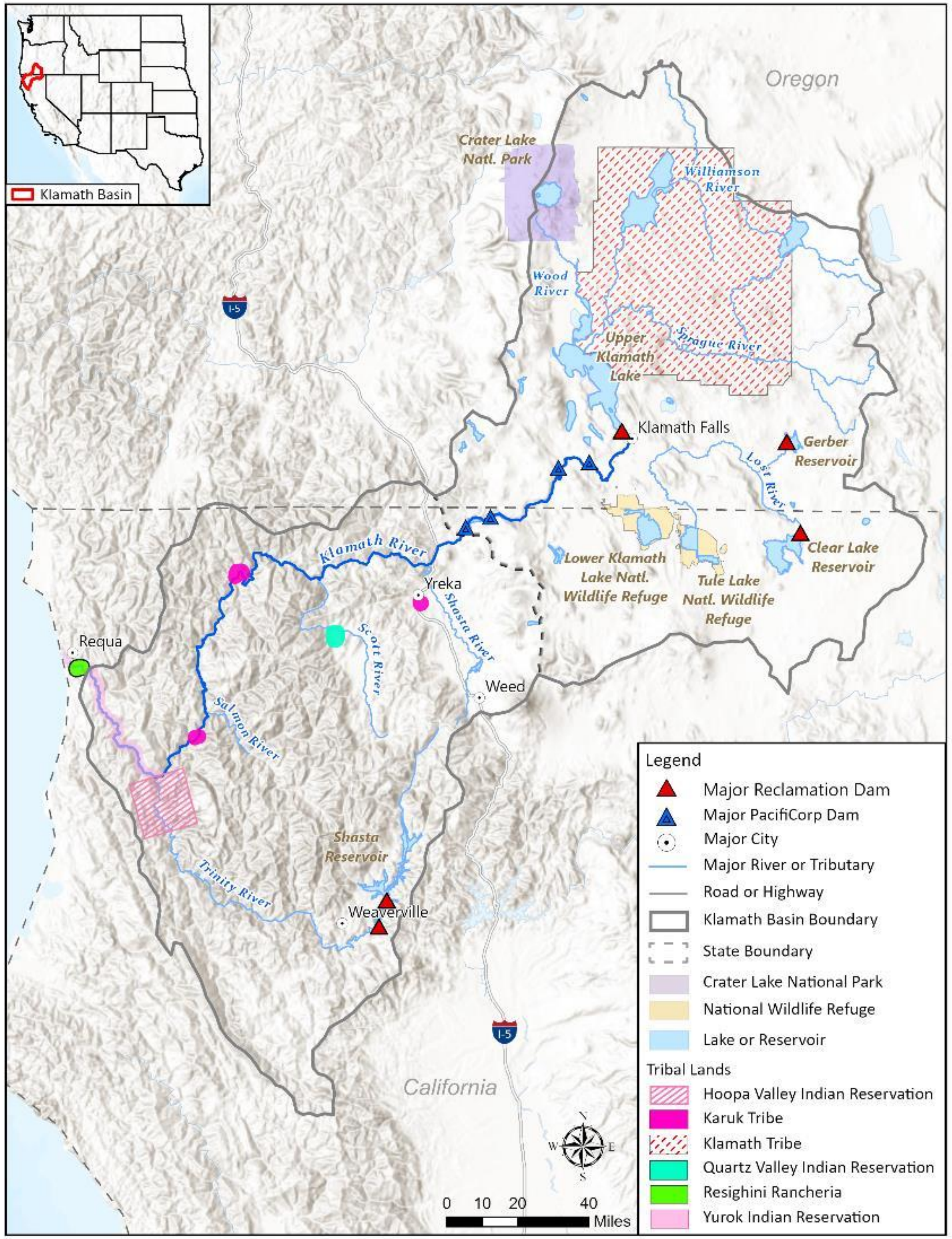
February 5, 2025

Photo: Upper Klamath Lake

Context

Klamath River

- Often described as an **upside-down** watershed: upper portions are flat and heavily populated; lower portions are mountainous and forested
- Frequent **Endangered Species Act** (ESA) consultations for Klamath Project
  - 1988 ESA listing of **Lost River sucker** and **shortnose sucker** as endangered
  - 1997 ESA listing of **SONCC coho salmon** as threatened species



Context

The Klamath River

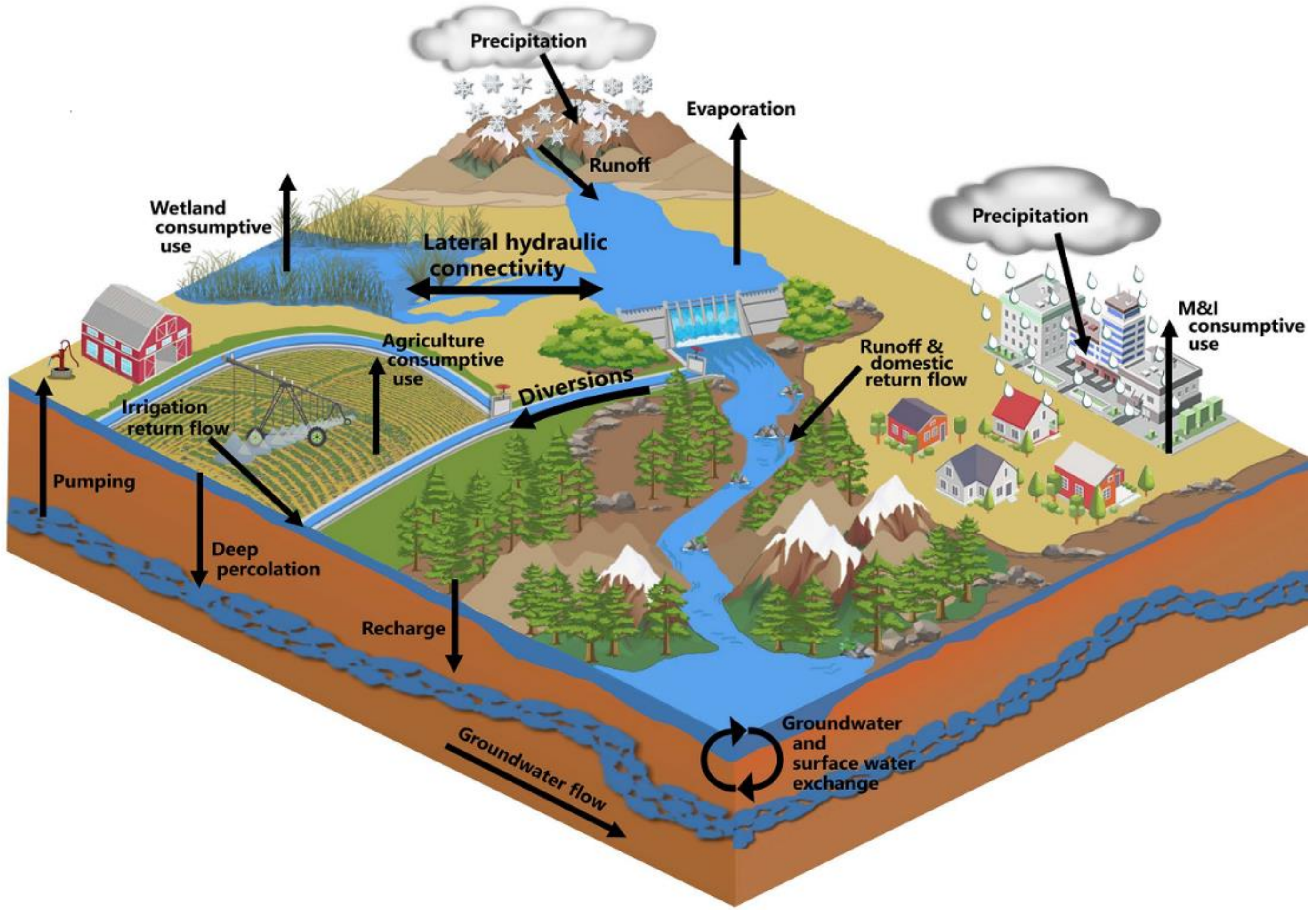
- Native American tribes led successful effort to **remove four dams** from Klamath River (Copco 2 shown to right)
- Removal of these four dams restores access to approximately **400 sq.mi. of habitat** for Salmon and other native species
- While not Reclamation dams, Reclamation has been tasked with seeking to understand the **natural flow** regime of the Klamath River prior to major development around 1900


The Copco 2 Dam, before. Photograph: Swiftwater Films


The Copco 2 Dam, after. Photograph: Swiftwater Films

Klamath Revised Natural Flow Study

- Purpose
  - Estimate daily **natural flows** at chosen locations in the Klamath River basin, removing the significant effects of human development
- Use of RiverWare
  - Integrates outputs from **process models** that simulate:
    - **1981-2020** conditions <u>and</u>
    - **pre-development** conditions

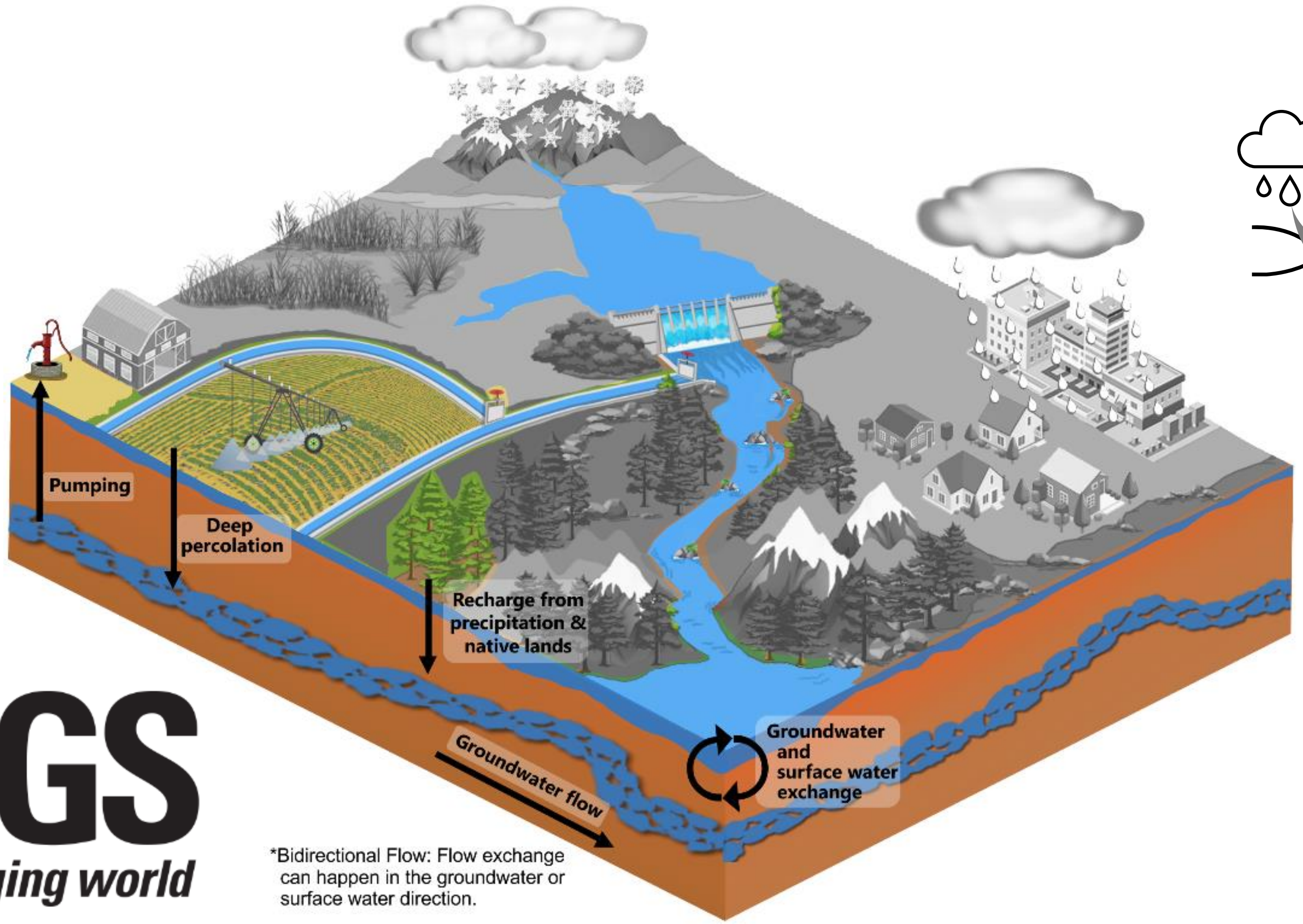


Process Models

Groundwater Hydrology

Surface Water Hydrology

Groundwater Hydrology



*Bidirectional Flow: Flow exchange can happen in the groundwater or surface water direction.

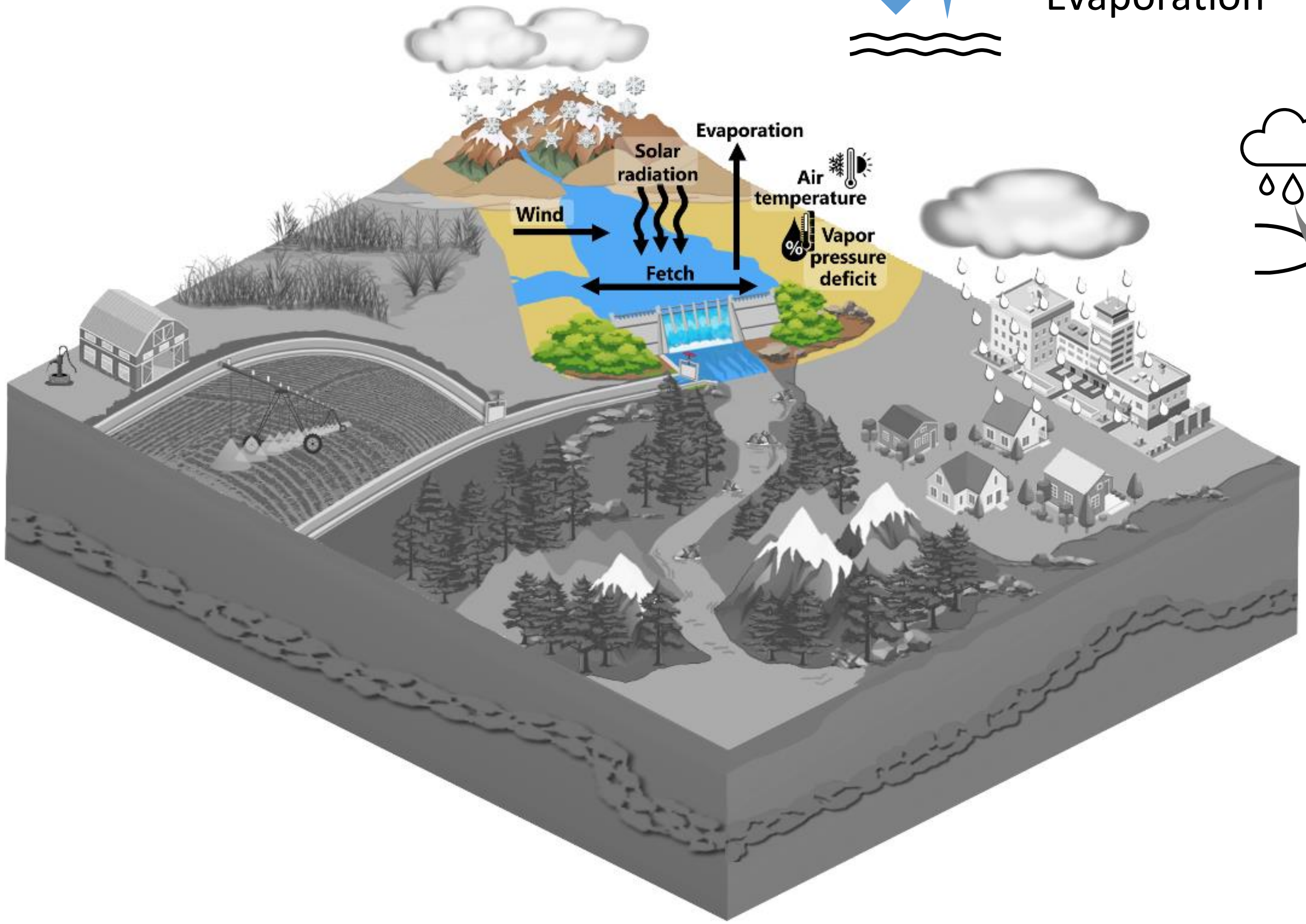
science for a changing world

Process Models

Open Water Evaporation

Open Water Evaporation

Surface Water Hydrology



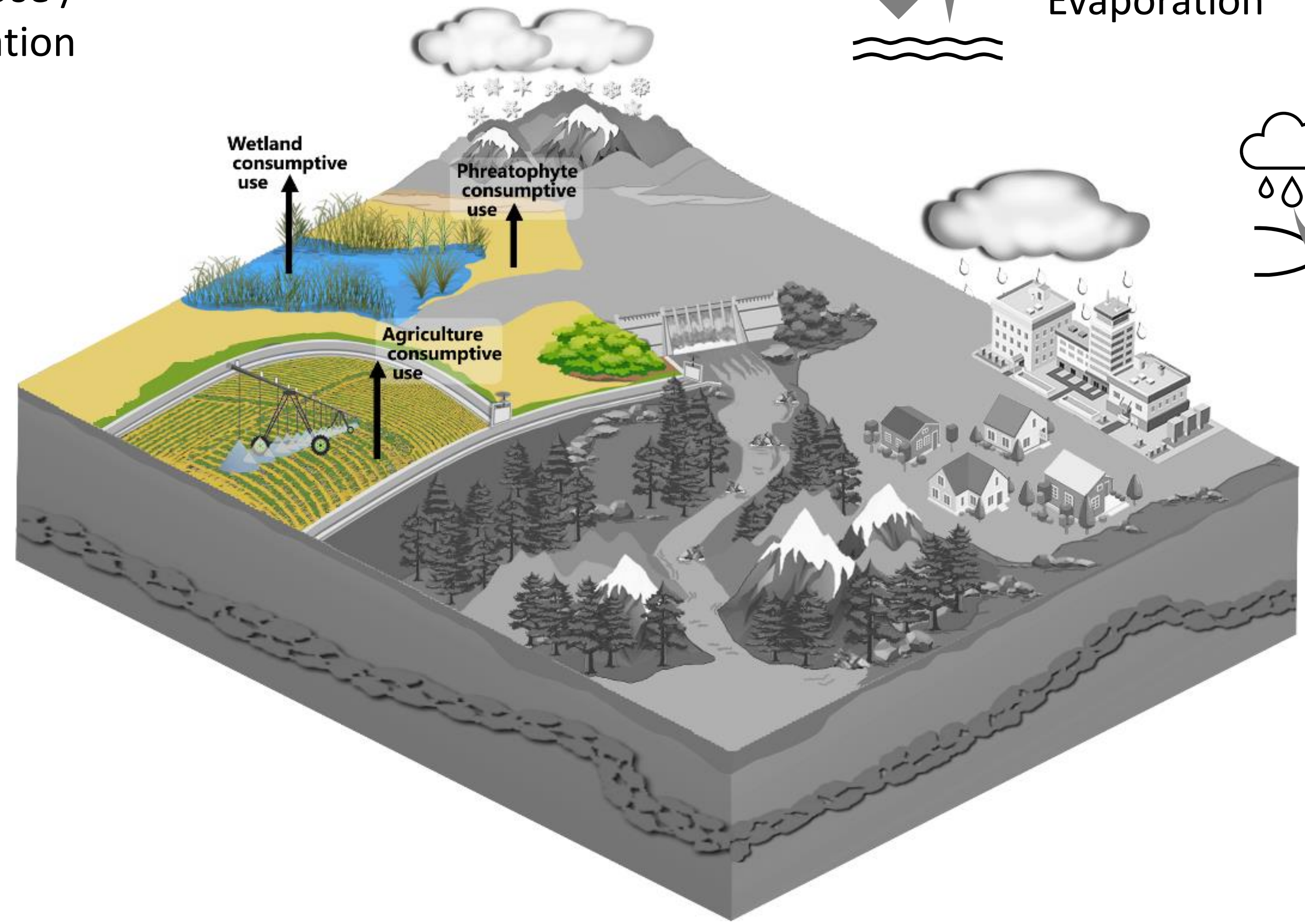
Groundwater Hydrology

Process Models

Consumptive Use

Consumptive Use / Evapotranspiration

Agricultural Processes



Open Water Evaporation

Surface Water Hydrology

Desert Research Institute

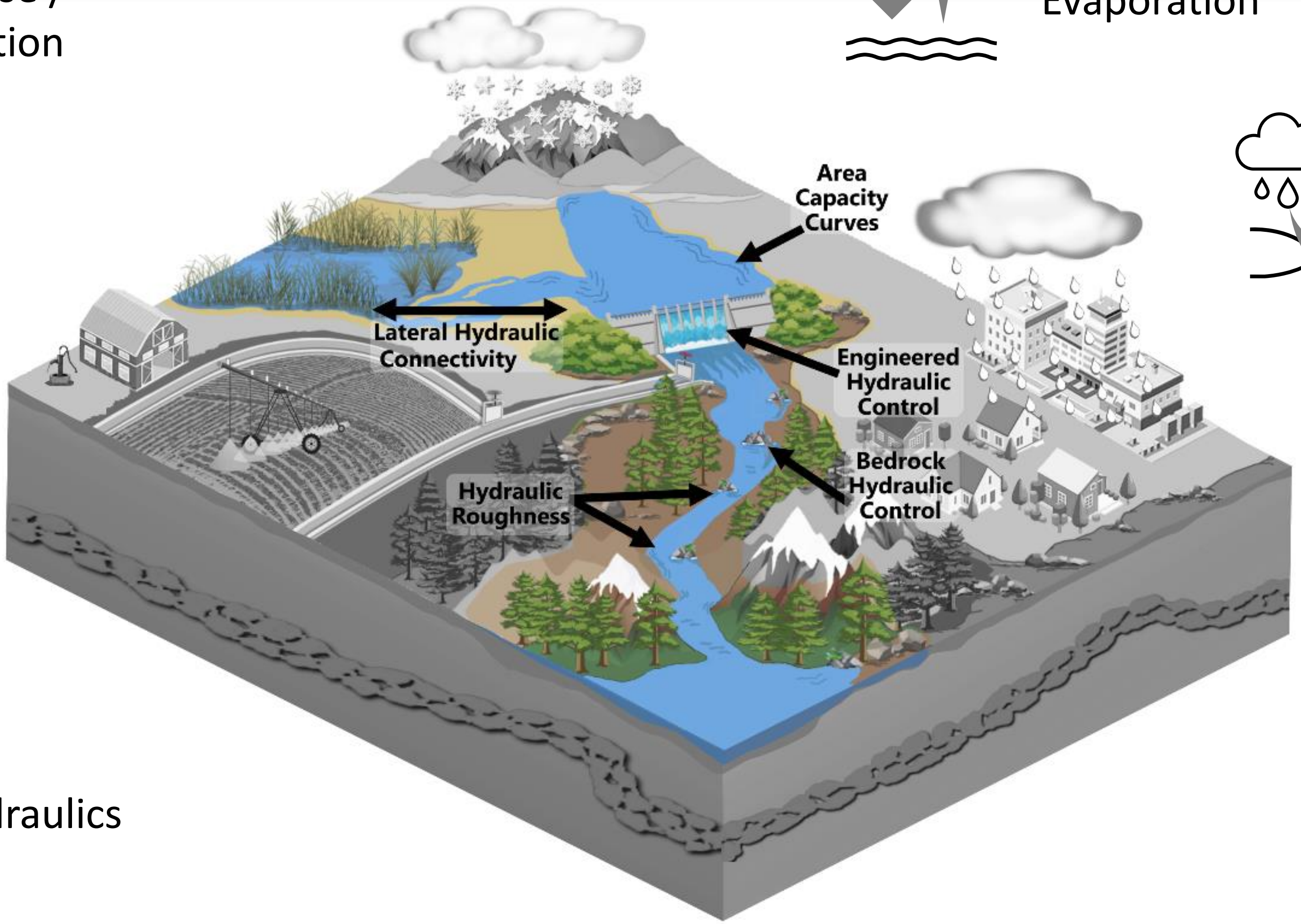
Process Models

Hydraulics

Consumptive Use / Evapotranspiration

Open Water Evaporation

Agricultural Processes



Surface Water Hydrology

Groundwater Hydrology

Hydraulics

Process Models

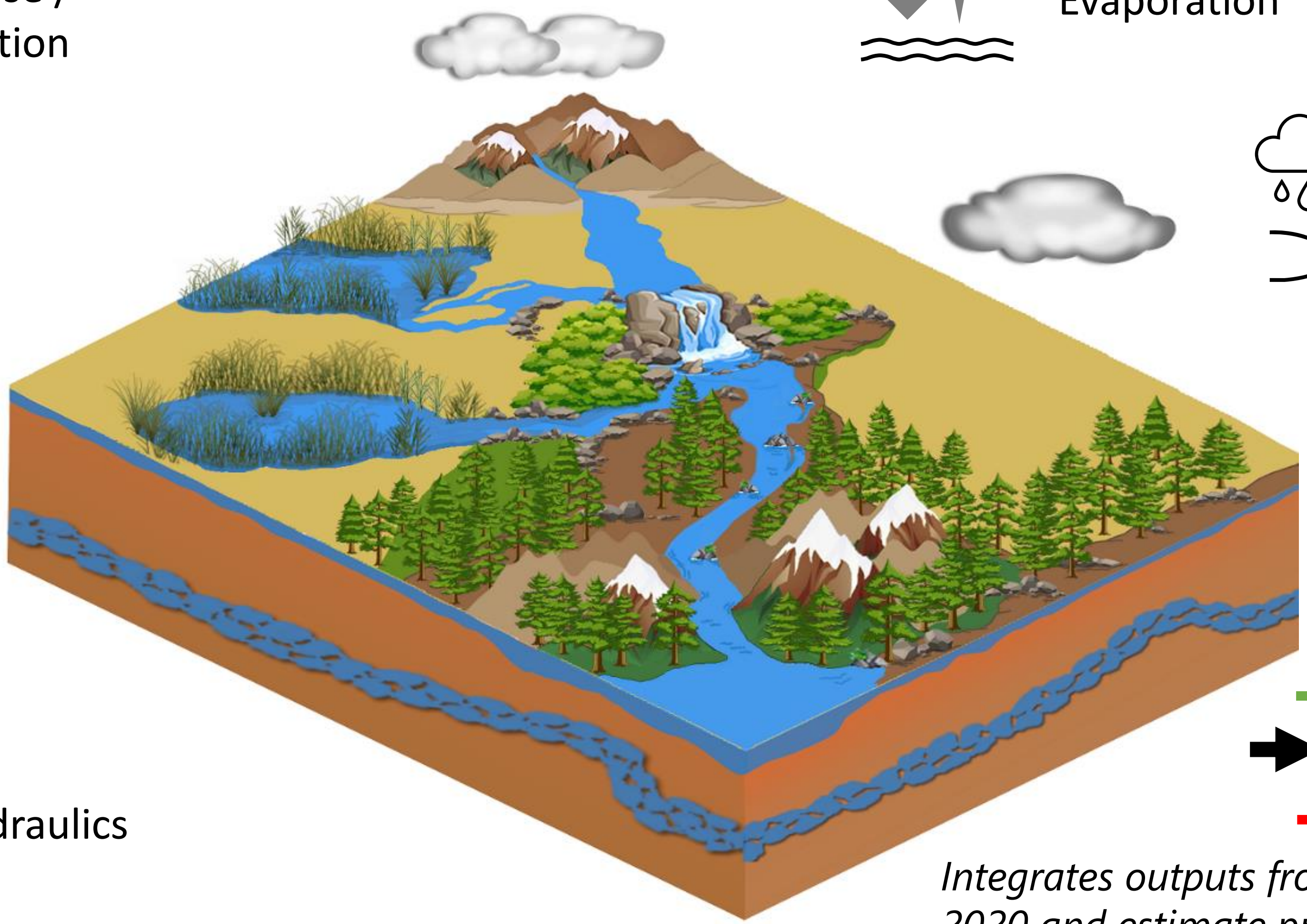
Mass Balance

Consumptive Use / Evapotranspiration

Agricultural Processes

Groundwater Hydrology

Hydraulics



Open Water Evaporation

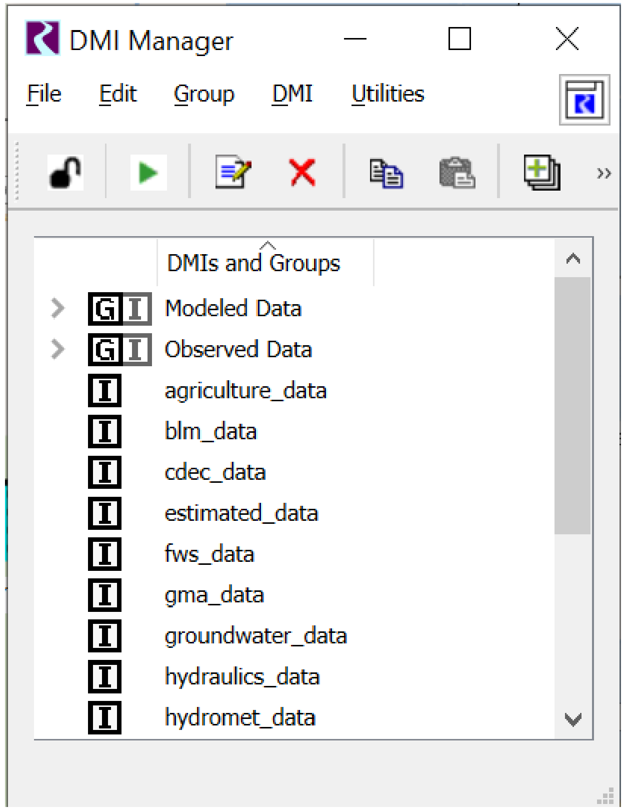
Surface Water Hydrology

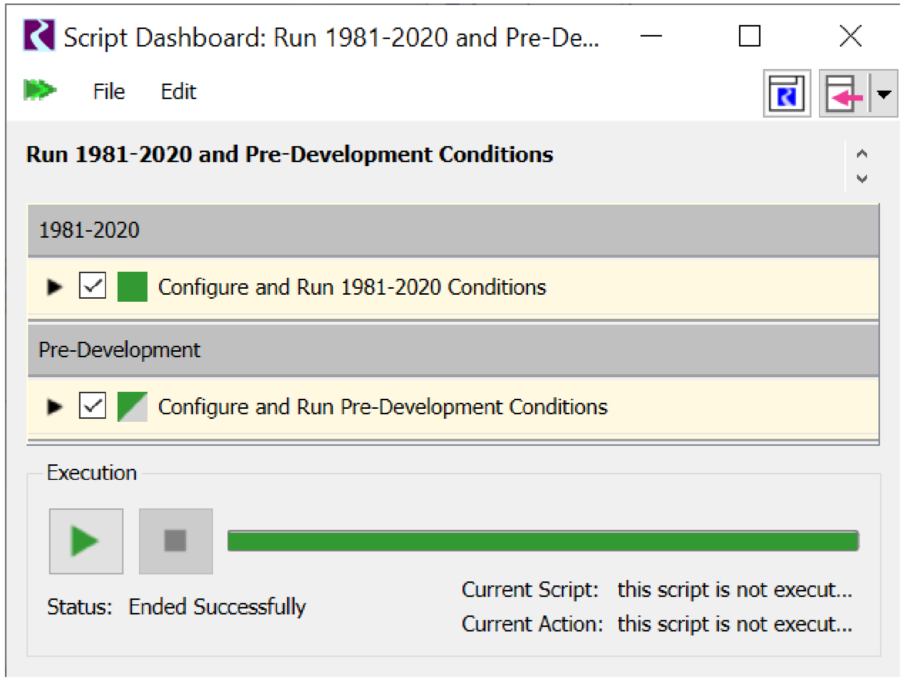
Mass Balance

Integrates outputs from models to simulate 1981-2020 and estimate pre-development conditions

RiverWare Modeling Approach

Python/R Script Pre-Processing → Data Import using Control File DMIs → Run configuration and execution using scripts



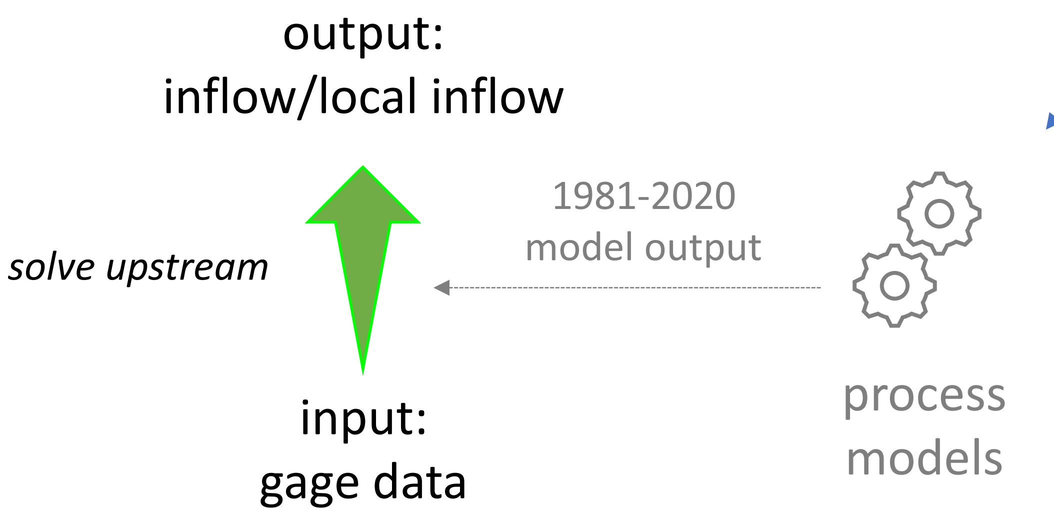


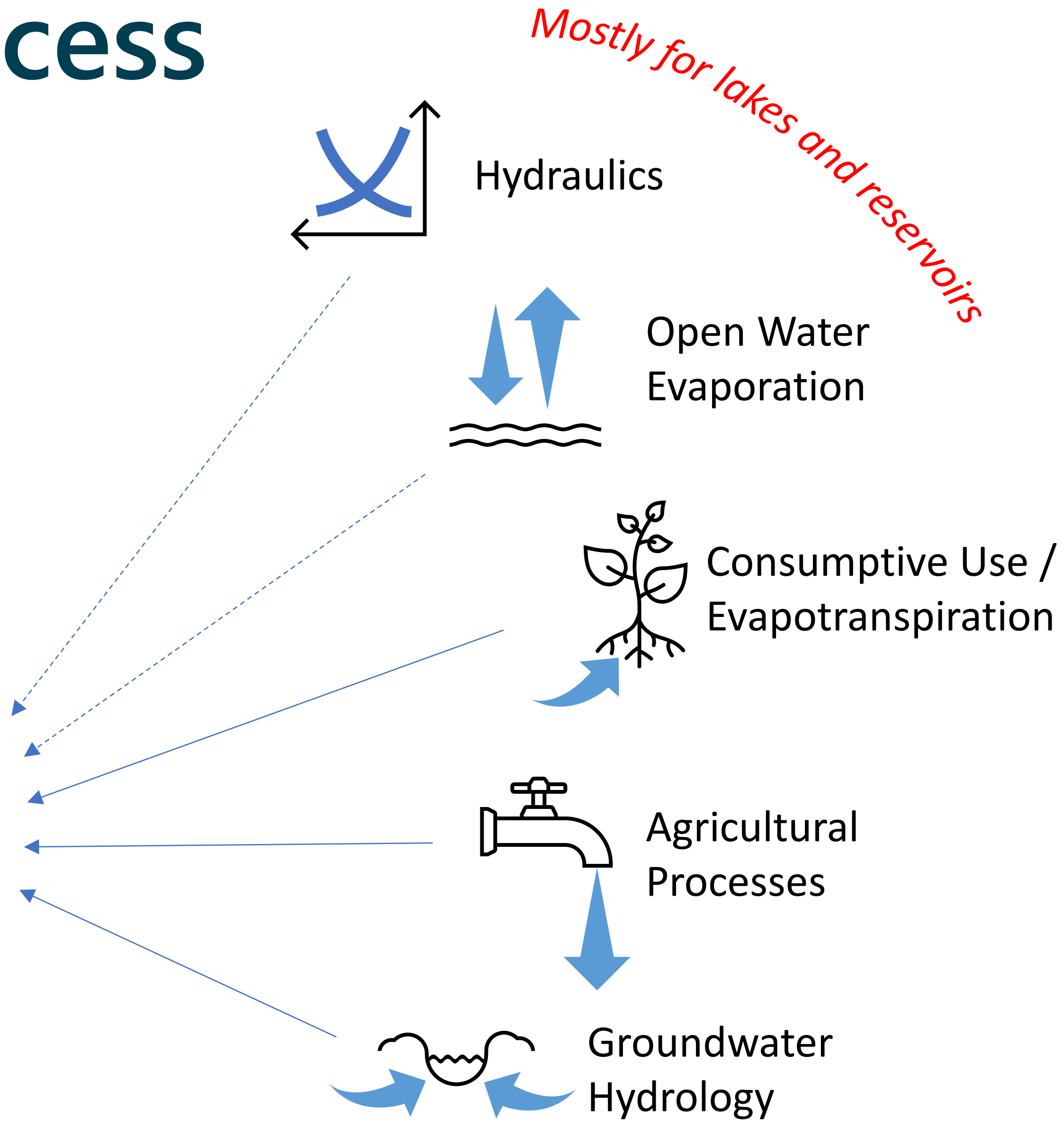
Two-step simulation process

RiverWare Modeling Approach

Two-step simulation process

- Run 1: 1981-2020
    - Begins with **gage data**
    - Incorporates process model output (e.g., net diversions, gain from groundwater, etc.) to **solve upstream**
    - Solves for **local inflow** and headwater **inflow** for use in run 2

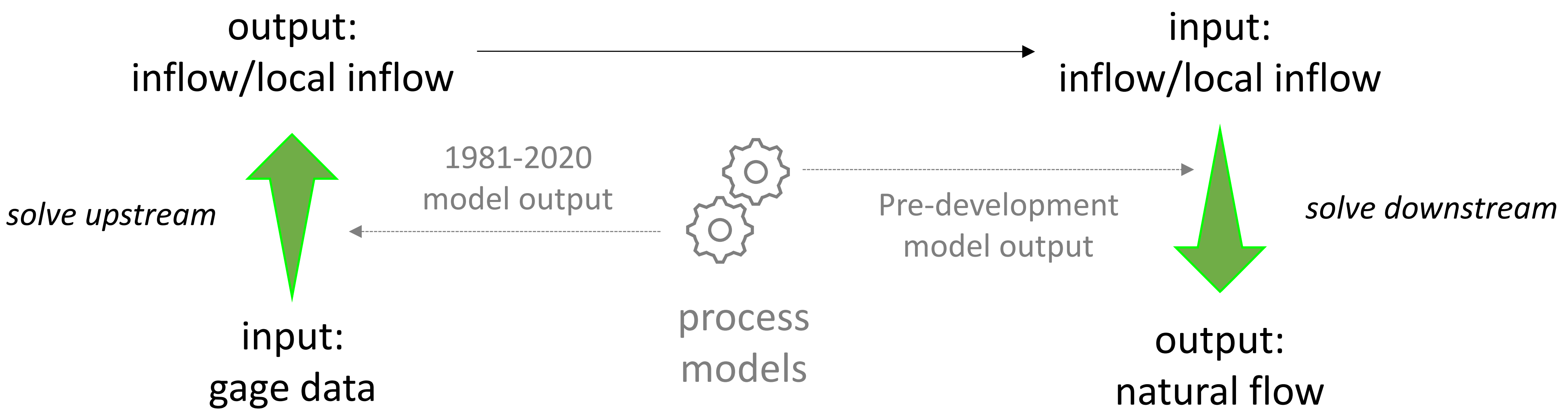




RiverWare Modeling Approach

Two-step simulation process

- Run 1: 1981-2020
  - Begins with **gage data**
  - Incorporates process model output (e.g., net diversions, gain from groundwater, etc.) to **solve upstream**
  - Solves for **local inflow** and headwater **inflow** for use in run 2
- Run 2: Pre-Development
  - Begins with **local inflow** and headwater **inflow**
  - Incorporates process model output (e.g., wetland ET, gain form groundwater, etc.) to **solve downstream**
  - Estimates **natural flow** throughout model



RiverWare Modeling Approach

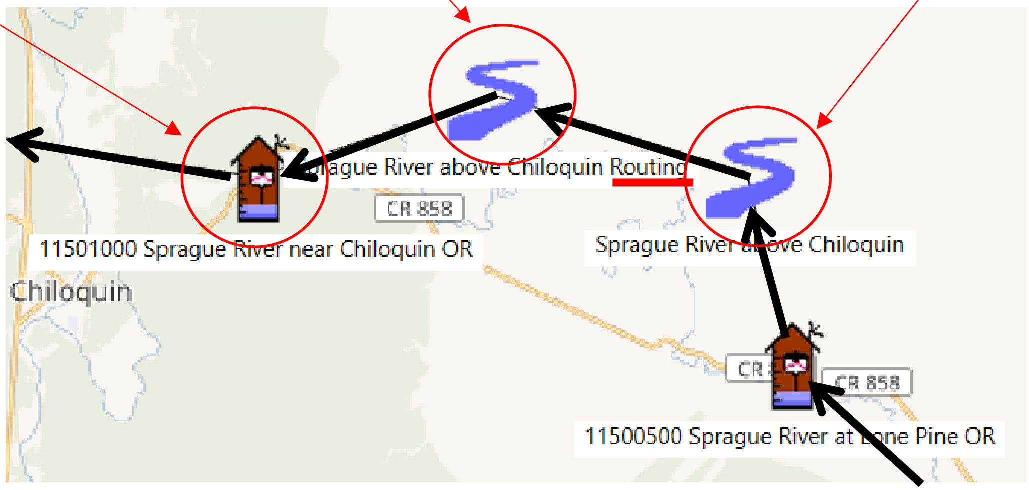
Example: Sprague River

"Routing Reaches" handle <u>only</u> routing throughout model

Observed data handled at stream gage objects

"Computation Reaches" handle process model output:

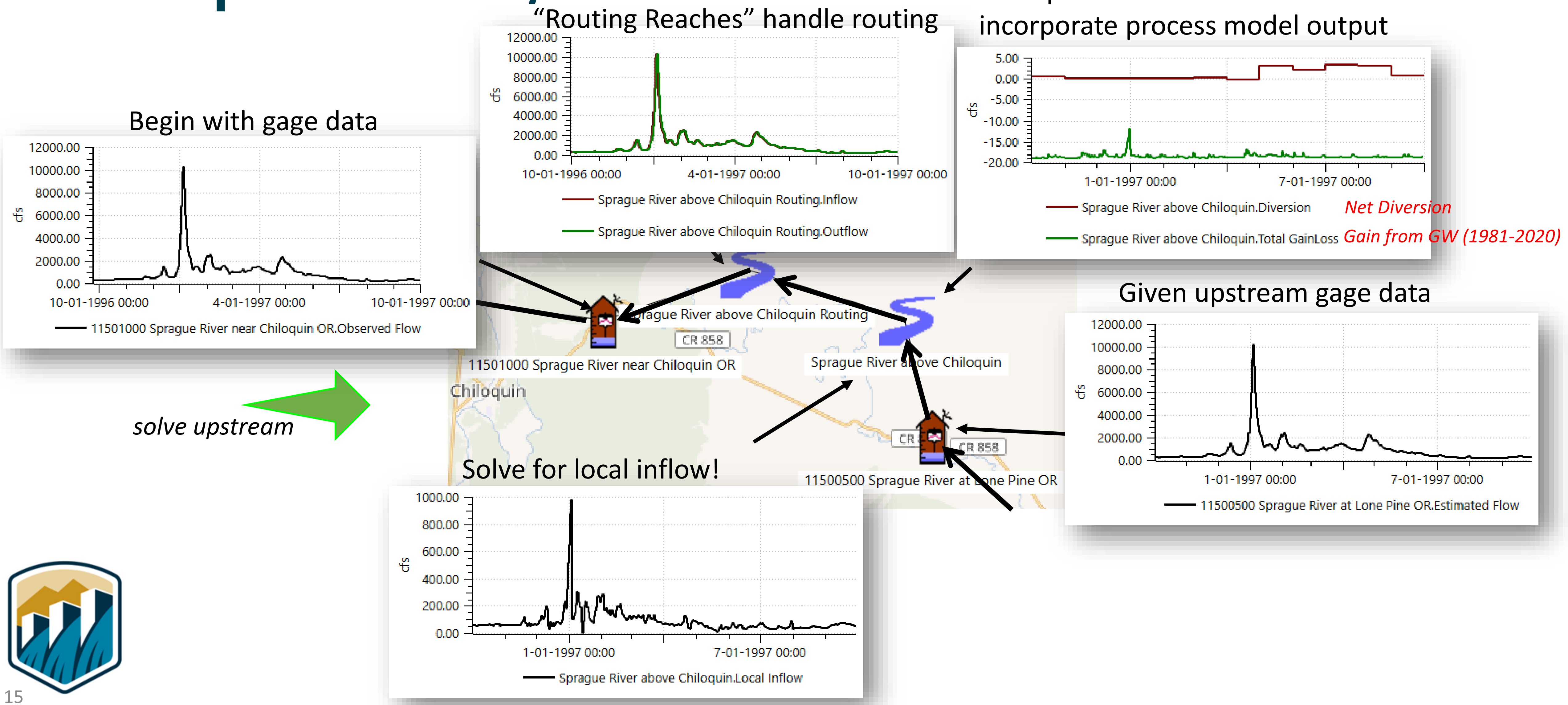
- *Modelled gain from groundwater in .Total LossGain slot*
- *Modelled net diversions in .Diversion slot*



All data and results shown are preliminary using non-final process model runs!

RiverWare Modeling Approach

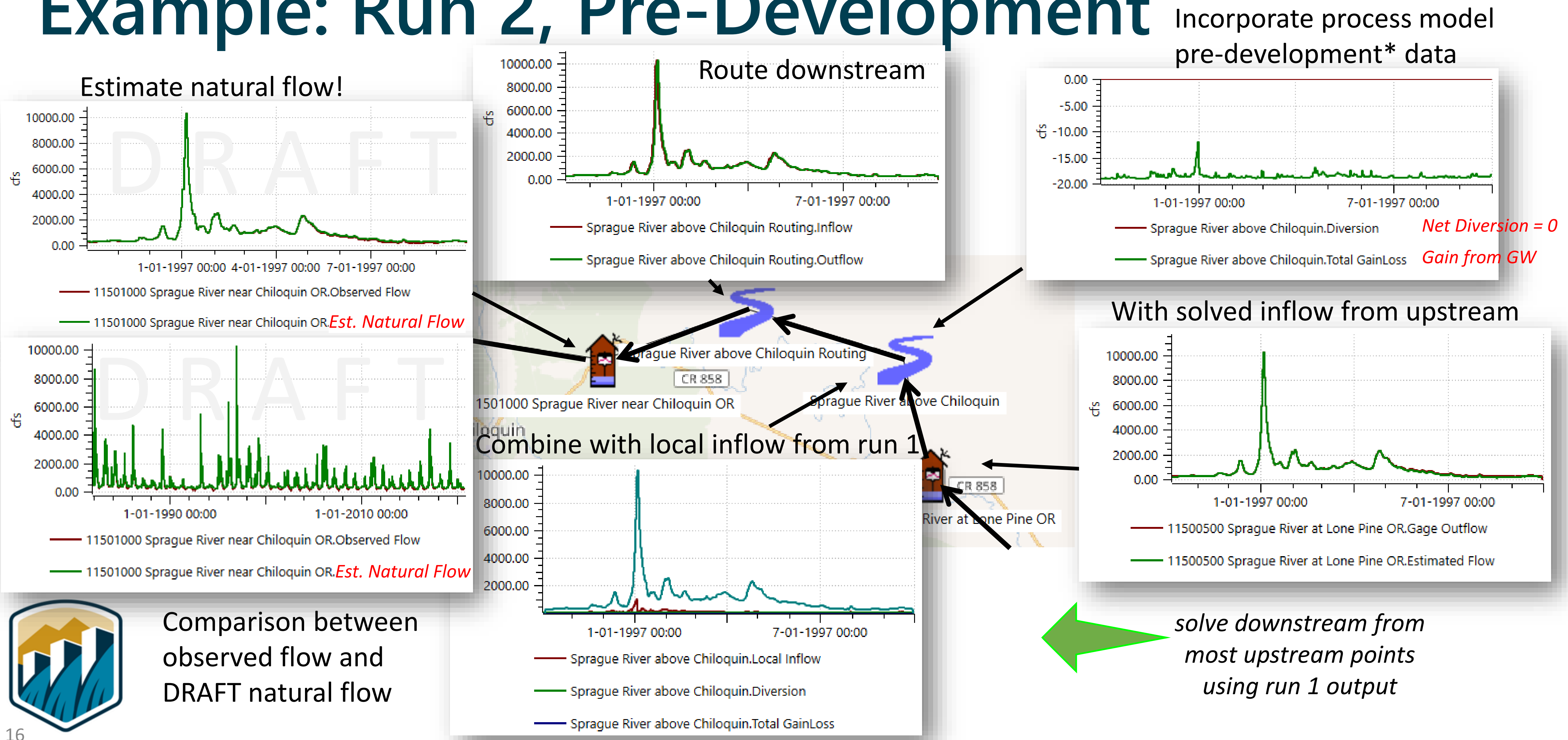
Example: Run 1, 1981-2020



**Pre development process models represent best estimates of the wetlands, overbank geometry, etc., that existed pre-1900.*

RiverWare Modeling Approach

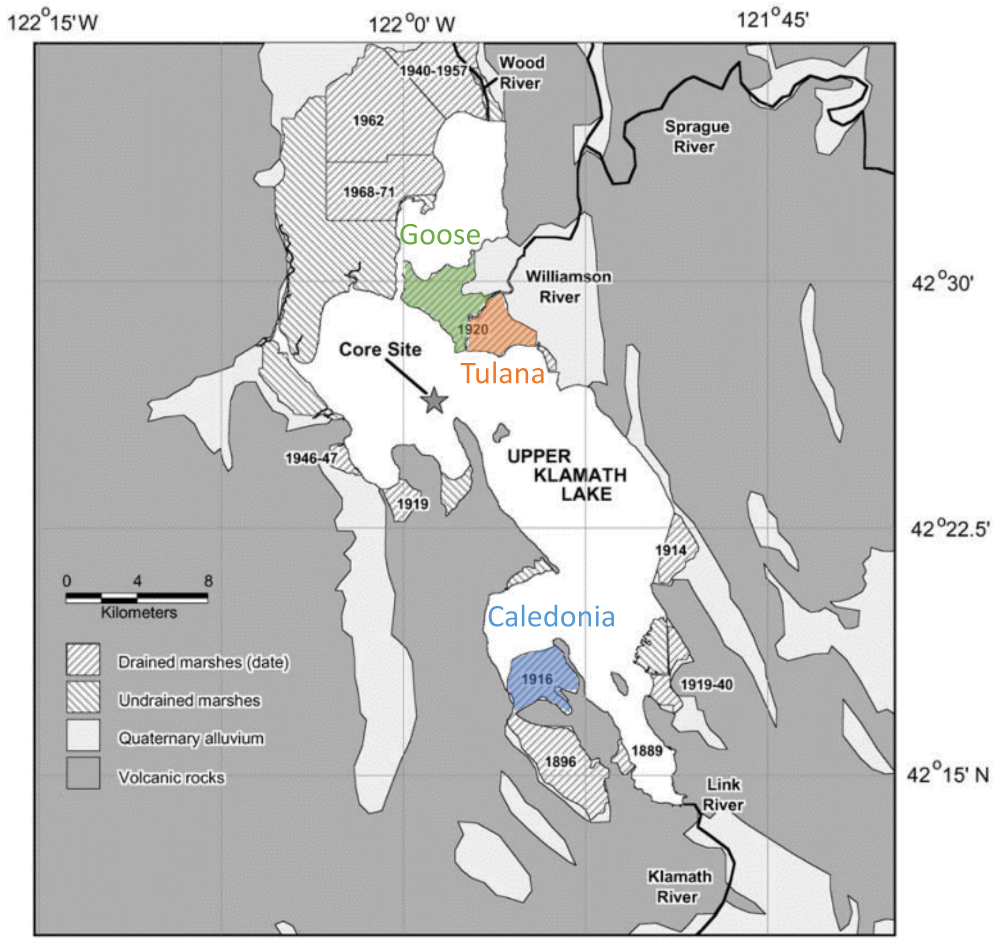
Example: Run 2, Pre-Development



Roadblocks

Dynamic Reservoirs

- Upper Klamath Lake underwent multiple changes between 1981 and 2020
- These changes impact the area-capacity relationship for the lake
- Expected solution: handling with multiple storage reservoirs or added capability to change area-capacity information during simulation



Annotations added to base figure from Bradbury, J.P., Colman, S.M., and R.L. Reynolds, 2004. *The history of recent limnological changes and human impact on Upper Klamath Lake, Oregon*. Journal of Paleolimnology 31: 151-165, 2004.

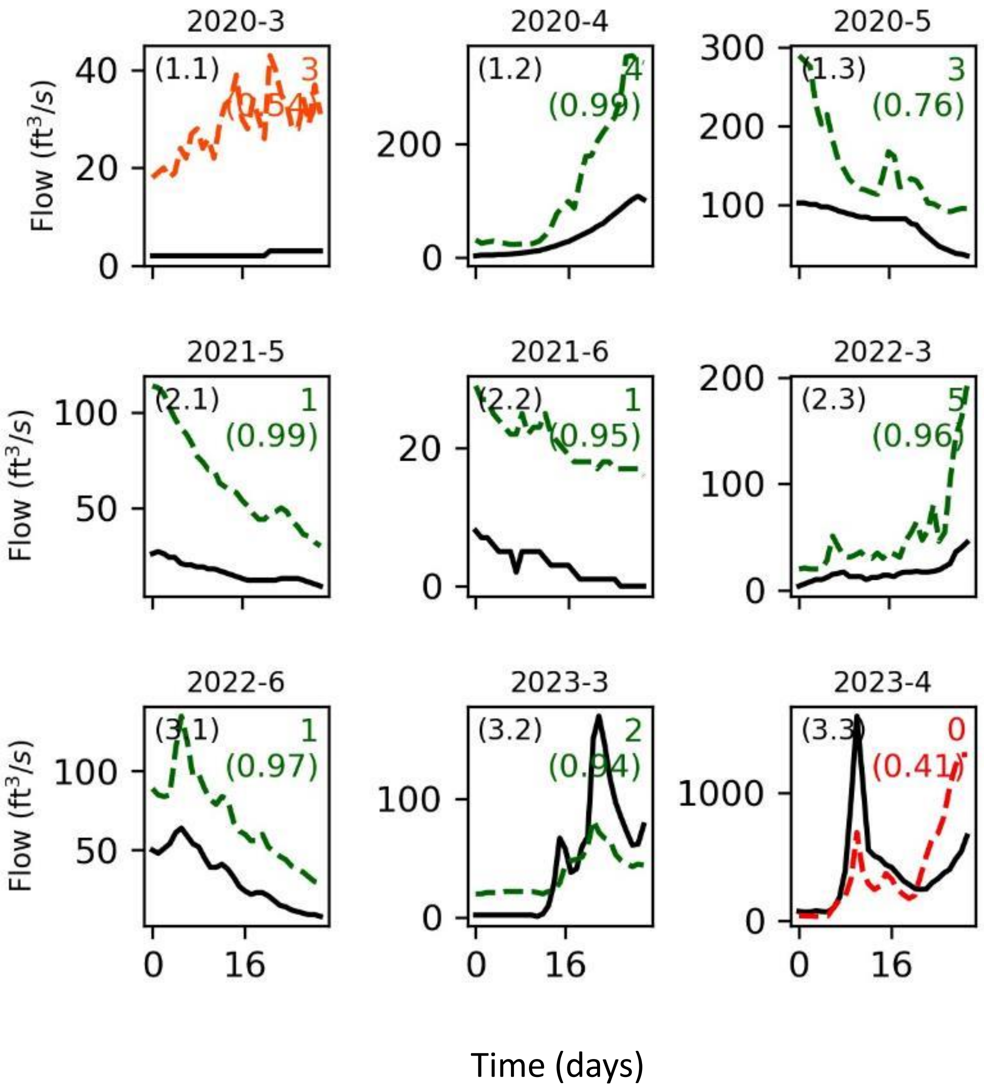
Table A- 1.—The historic time periods associated with each observed Upper Klamath Lake configuration

UKL Configuration	Time Period
UKL w/o Caledonia, Tulana, or Goose Bay	8/31/1980–7/7/2006
UKL w/ Caledonia	7/8/2006–12/31/2006
UKL w/o Caledonia, Tulana, or Goose Bay	1/1/2007–10/30/2007
UKL w/ Tulana	10/31/2007–11/17/2008
UKL w/ Tulana and Goose Bay	11/18/2008–12/31/2020

Roadblocks

Reach Routing

- Most rivers have variable routing characteristics depending on seasonal and/or flow conditions
- Only the lag reach routing method can be used to solve upstream
- Expected solution: simplify subbasin representation to use only lag method or work with CADSWES to develop new method for variable lag that can be solved upstream...



Roadblocks
Unknown Marshes

- Sycan and Klamath Marshes attenuate (and store) flow, but have little information to inform representation in modeling
- Expected solution: using Google Earth Engine to process aerial imagery to reconstruct historical open water area; potentially representing marshes as storage reservoirs

Google Earth Engine

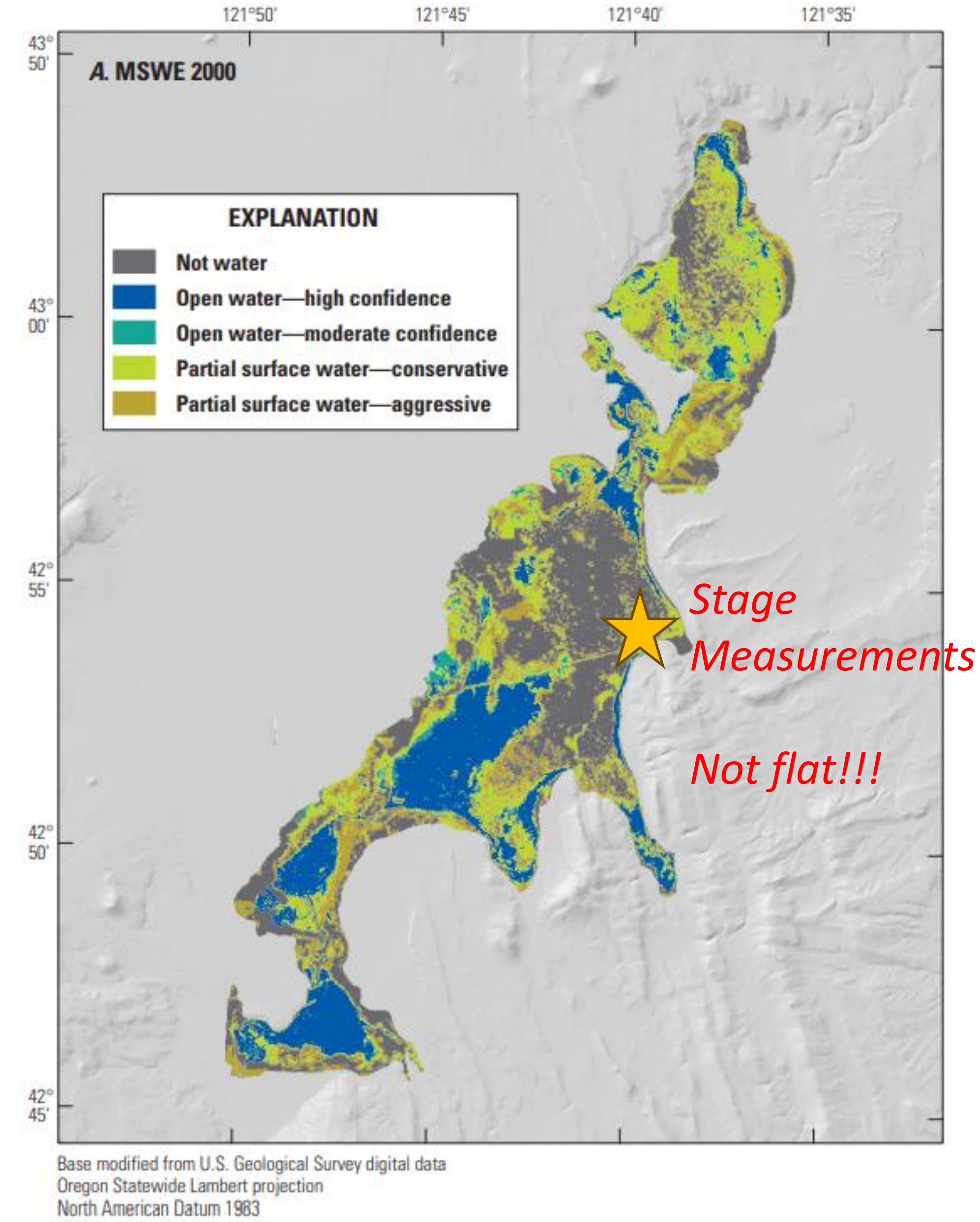
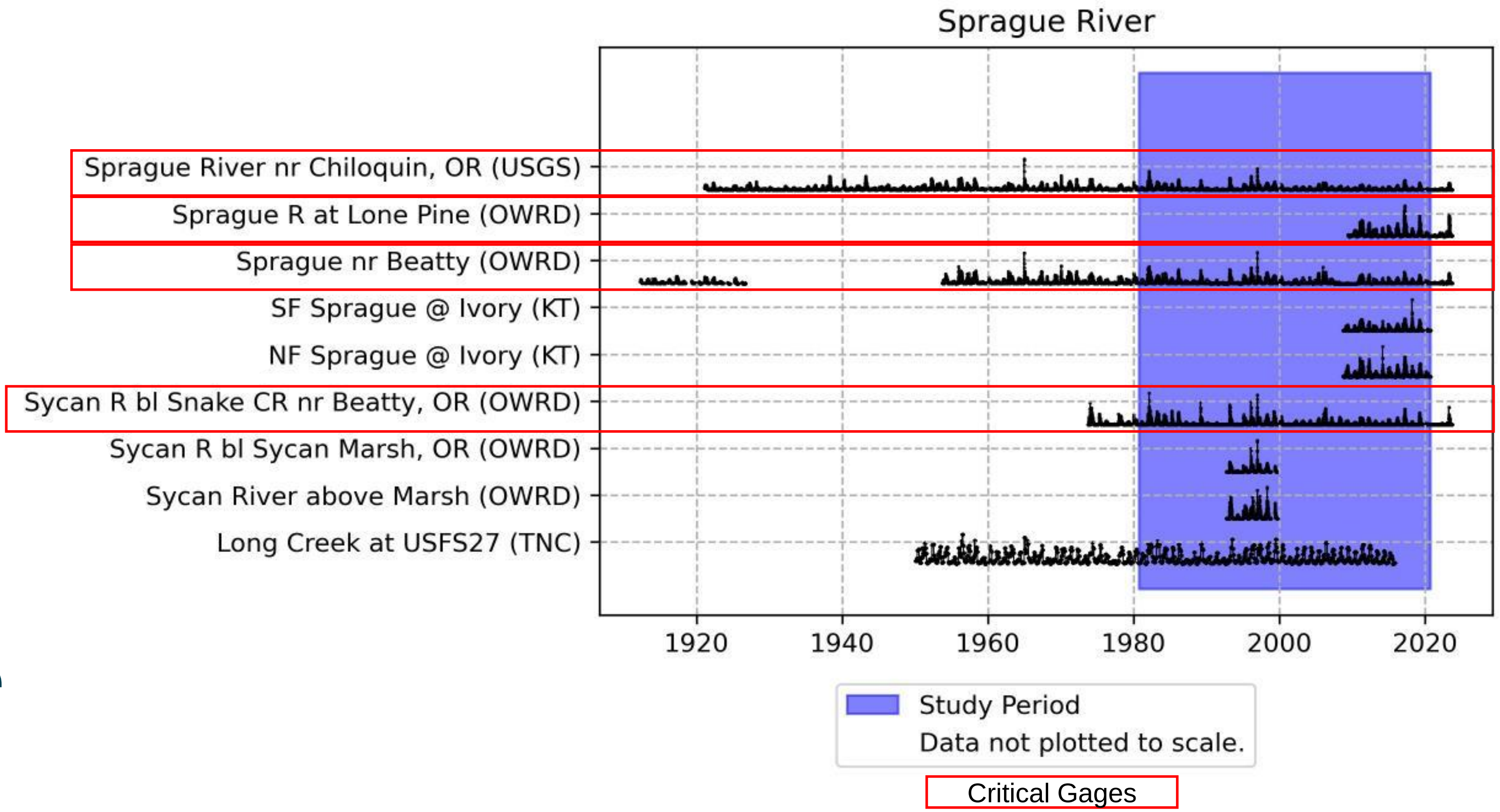


Figure of Klamath Marsh from Kennedy, J.J., Johnson, H.M., and Gingerich, S.B., 2024, Assessment of long-term changes in surface-water extent within Klamath Marsh, south-central Oregon, 1985–2021: U.S. Geological Survey Scientific Investigations Report 2024–5033, 32 p., https://doi.org/10.3133/sir20245033.

Roadblocks

Missing Gage Records

- Many gages have short records or have missing records
- Flow is heavily affected by groundwater and traditional data filling methods may not be adequate
  - Expected solution: use machine learning techniques to estimate missing records



Wrap up

- As we continue to seek to understand the **natural flow** regime of the Klamath River, next steps are:
  - Continue pursuing resolutions to current “roadblocks”
  - Wait on process models to produce final results

Photo: Klamath Straits Drain

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