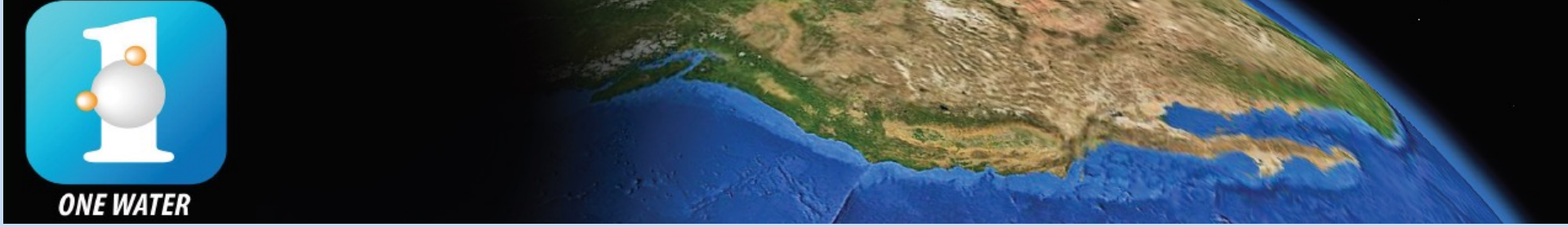


Higher-order Observations for Assessing Undesirable Results with SGMA Models

Randall T. Hanson

One-Water Hydrologic, LLC

www.one-waterhydrologic.com

(RandyTHanson@gmail.com)

California Water Environmental Modeling Forum

April 4, 2022

Todays Update

- ***What are "higher-order" observations (HOB's)***
- How do higher observations contribute to IHMs for SGMA and related issues?
- What are some examples?

Higher-Order Observations

HOB's are Change & Distribution Observations:

First derivatives in space or time, second derivatives, probabilities, frequencies, changes/lags in frequencies:

(1) Flows: Irrigation diversions, agricultural pumpage, and wellbore-flow logs (multi-layer flow contributions), supply-and-demand (agricultural flows), groundwater/surface-water rights, & Reservoir storage/releases

(2) Temporal Changes: Streamflow, River Stage & Width, GW Drawdown, Salinity (EM logs), Wet & Dry-period pumpage & actual ET, water quality (salinity leaching or artificial recharge), Reservoir stage

(3) Spatial Changes: Changes of state (storage depletion or streamflow inflows), streamflow gains/losses, subsidence, differential subsidence, vertical-head differences, extent of streamflow (baseflow & "daylight"-Heat maps)

(4) Frequencies: Streamflow exceedance/duration, climate variability, drain returnflows, lag between frequencies (baseflow vs precipitation)

Todays Update

- What are “higher-order” observations (HOB’s)
- ***How do higher observations contribute to IHMs for SGMA and related issues?***
- What are some examples?

HOB's for SGMA & Related Issues

One Water

SGMA related issues:

1) Time periods for Percent of Exceedance of UR's
2) Inclusion or exclusion of "Drought Years" in TM's
3) Time Periods used for SGMA evaluations
4) Different Aquifers-Different Water-Quality
5) Differential Land Subsidence
6) "Leaky Models" (Interlayer/Wellbores + GW/SW)

Ancillary SGMA Issues:

- Climate Variability ➔ Interannual + Mega Droughts & Larger Cycles
- Climate Change ➔ CMIP GCM scaling periods and forcings
- Adjudication as alternative to GSP ➔ Static proration of volumes & rates?
- CDFW Flow Targets (Flow/Depth) + GDE's (State/Habitat)
  (Ventura, Shasta, South Fork Eel Rivers & Mark West Creek (with DWR Bay Delta group))
- Entire Watersheds ➔ Runoff (Volumes/Rate)
- Recharge Credits ➔ Supply Mmgt (Rate)/ Demand Mmgt. (Rate)
- CVSALTS2 ➔ Water-Quality/Land Use Changes (Volumes/Rate)
- Effects from adjacent GSA's (gw, sw, qw)
- Changing Land Use: Agriculture and Harvest/Planting & Wild Fires

How to Further Constrain IHMs

One Water

Problem: Higher-Order Observations (HOBs) may not be used or available in commercial GUIs even though many hydrologic problems/analysis such as SGMA Undesirable Results (URs) are rate limited settings.

Proposal: Use selected spatial and temporal HOB's to provide more constraints and more information on calibration & conceptual (structural) analysis of IHMs. HOBs can further constrain & inform Integrated Hydrologic Models (IHMs) for SGMA, other uses, and give a better measure of the skill for projections & conceptual (structural) model issues. HOB's also can be used as observations in Parameter Estimation.

Are There Industry Standards for IHMs?

One Water

Problem: There are some guidance for groundwater flow models but nothing for more complete suite of processes and observations within an IHM. Many of these criteria don't address conceptual, subregional, or structural errors.

Guidance Examples: Groundwater model calibration guidance (ASTM, 2008, 2017), global correlation (Hill and Tiedeman, 2007), approaches to highly parameterized inversion (Doherty and Hunt, 2010), & DWR's best practices (DWR, 2016, https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents).

Proposal: Use selected spatial and temporal HOB's to provide more constraints, more support for conceptual model, and more information on calibration of IHMs for specific applications.

Todays Update

- What are “higher-order” observations (HOB’s)
- How do higher observations contribute to IHMs for SGMA and related issues?
- ***What are some examples?***

TFDR vs Groundwater/Surface-Water Supplies & Reservoir Supplies

Vertical Head Differences

Streamflow Gains & Losses from Seepage Runs

Measured vs Simulated Agricultural Pumpage

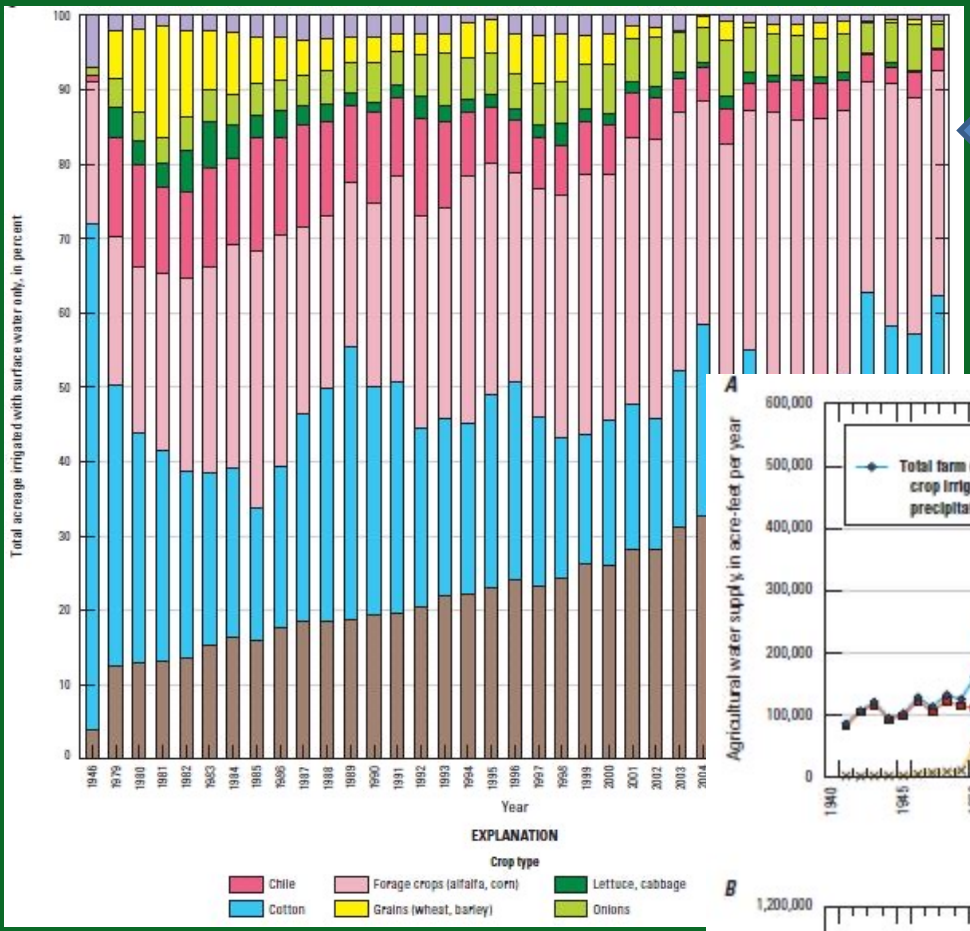
Streamflow Geometry and Exceedance

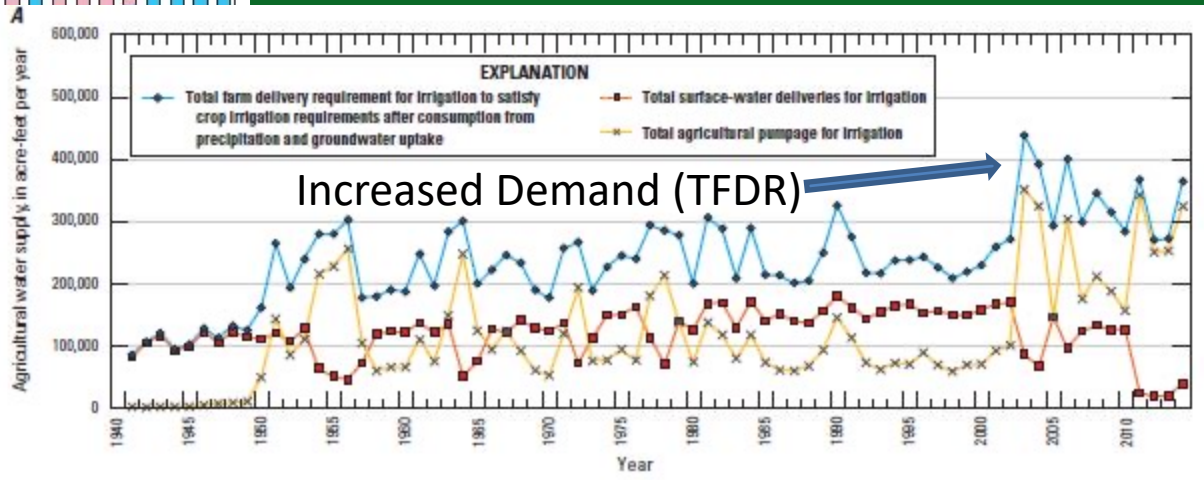
Wet-Dry Maps of Streamflow Extent

Climate Analysis Beyond SGMA

Increased Water Demand & Hardening of Demand

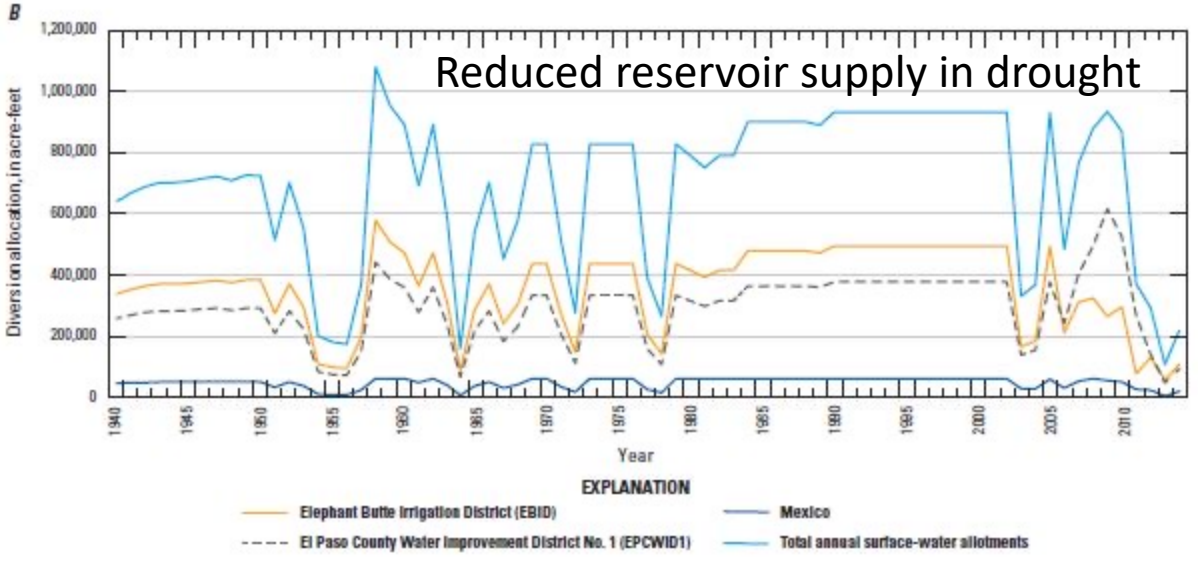
One Water





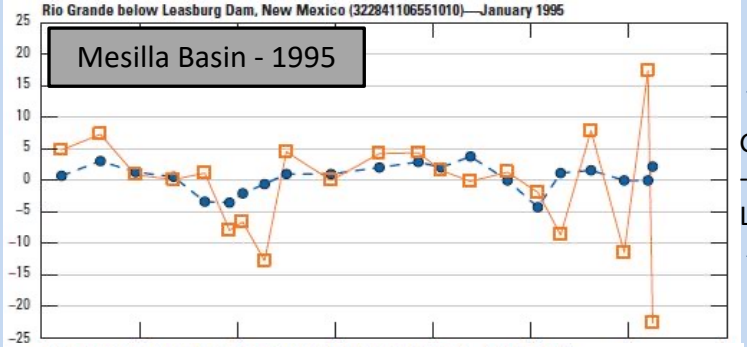
Increased TFDR and Groundwater use in dry years with less Reservoir surface-water allotments

(Hanson et al, 2020)



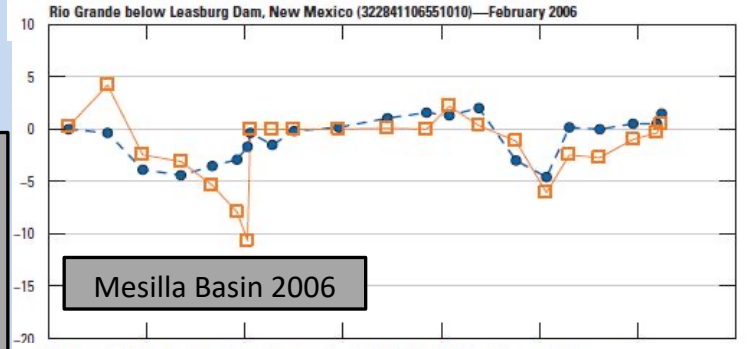
Surface-Water River Winter Seepage Runs:

Temporally Variable + Other Factors (?)



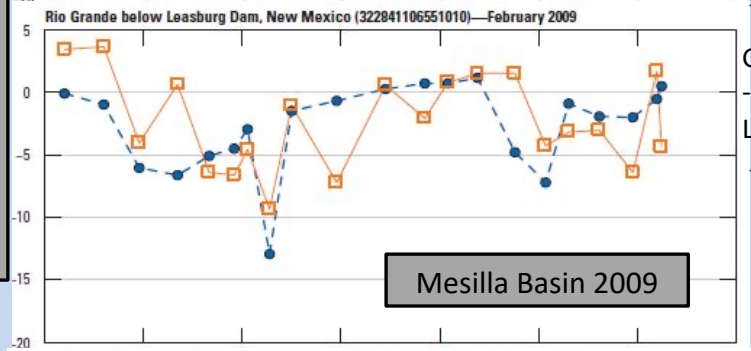
Gains

Losses



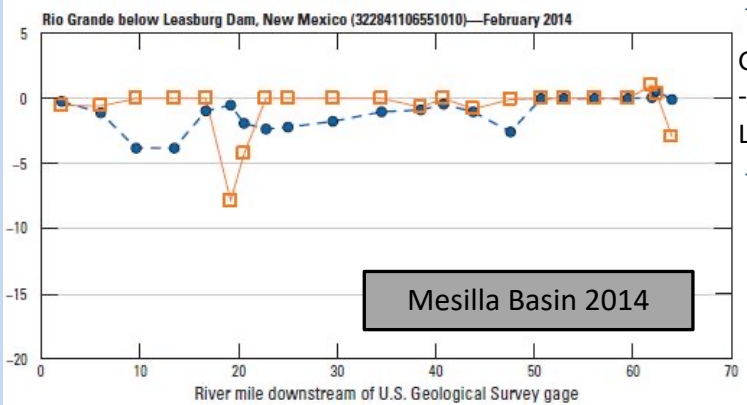
Gains

Losses

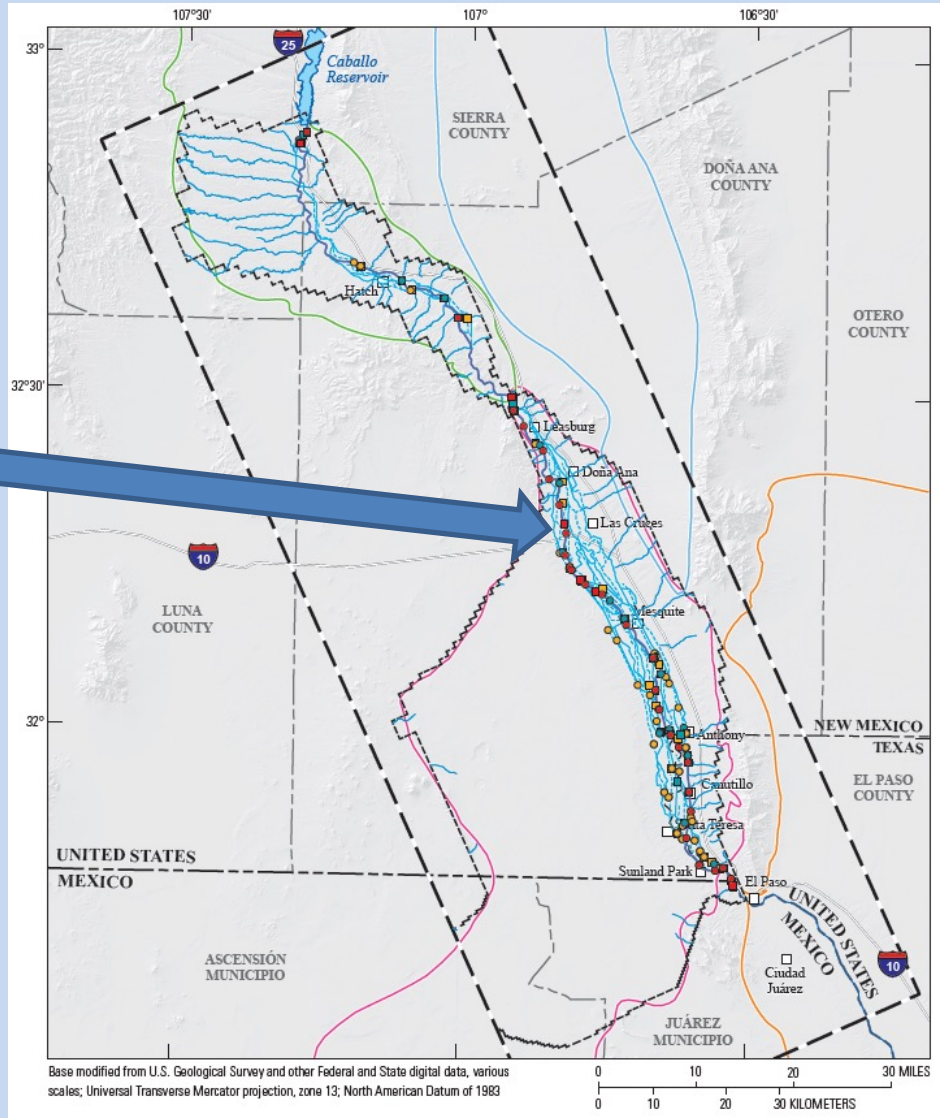


Gains

Losses



Flow, in cubic feet per day



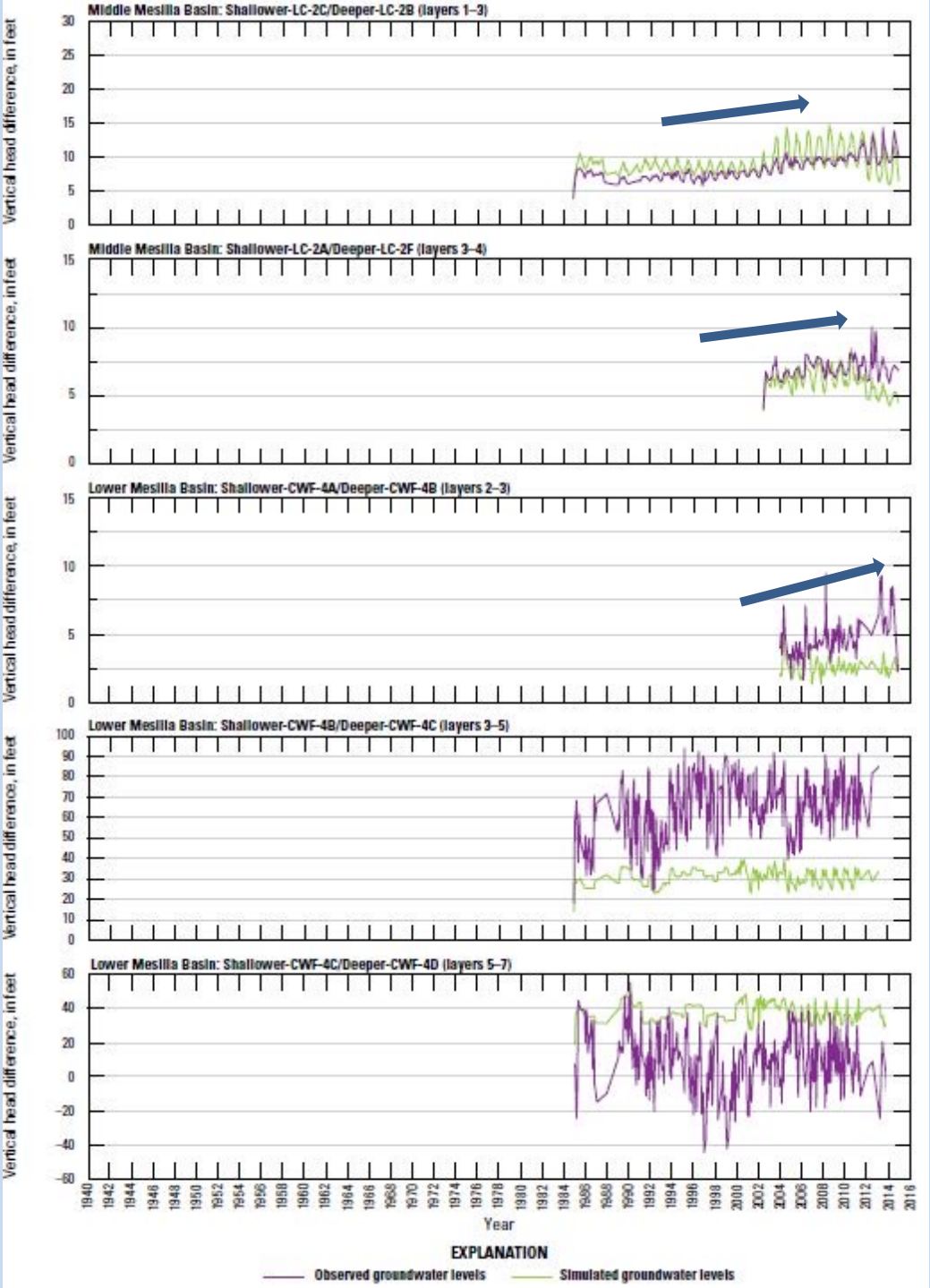
Simulated

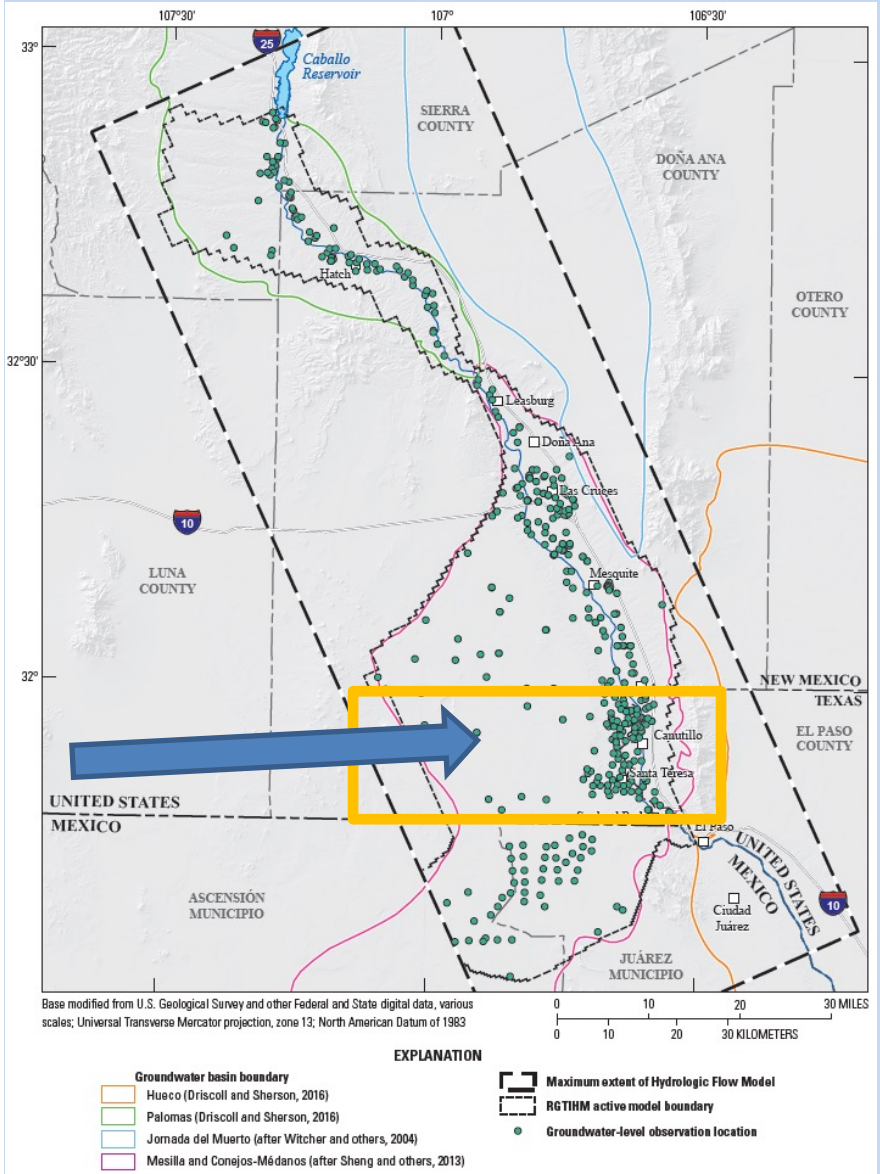
Measured (1988-2014)

(Hanson et al, 2020)

Vertical Differences in Groundwater-Levels: Seasonal and growing between Alluvium and Upper Santa Fe

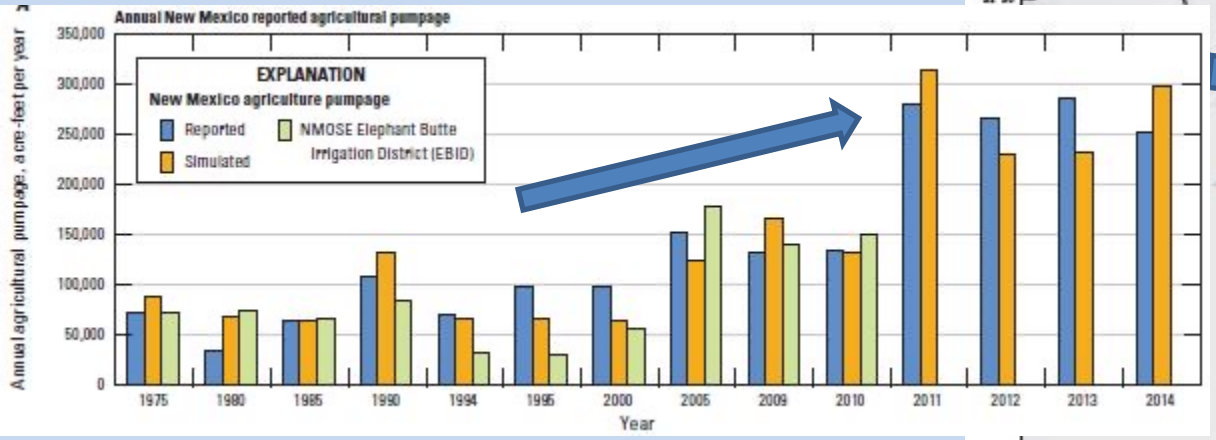
One Water



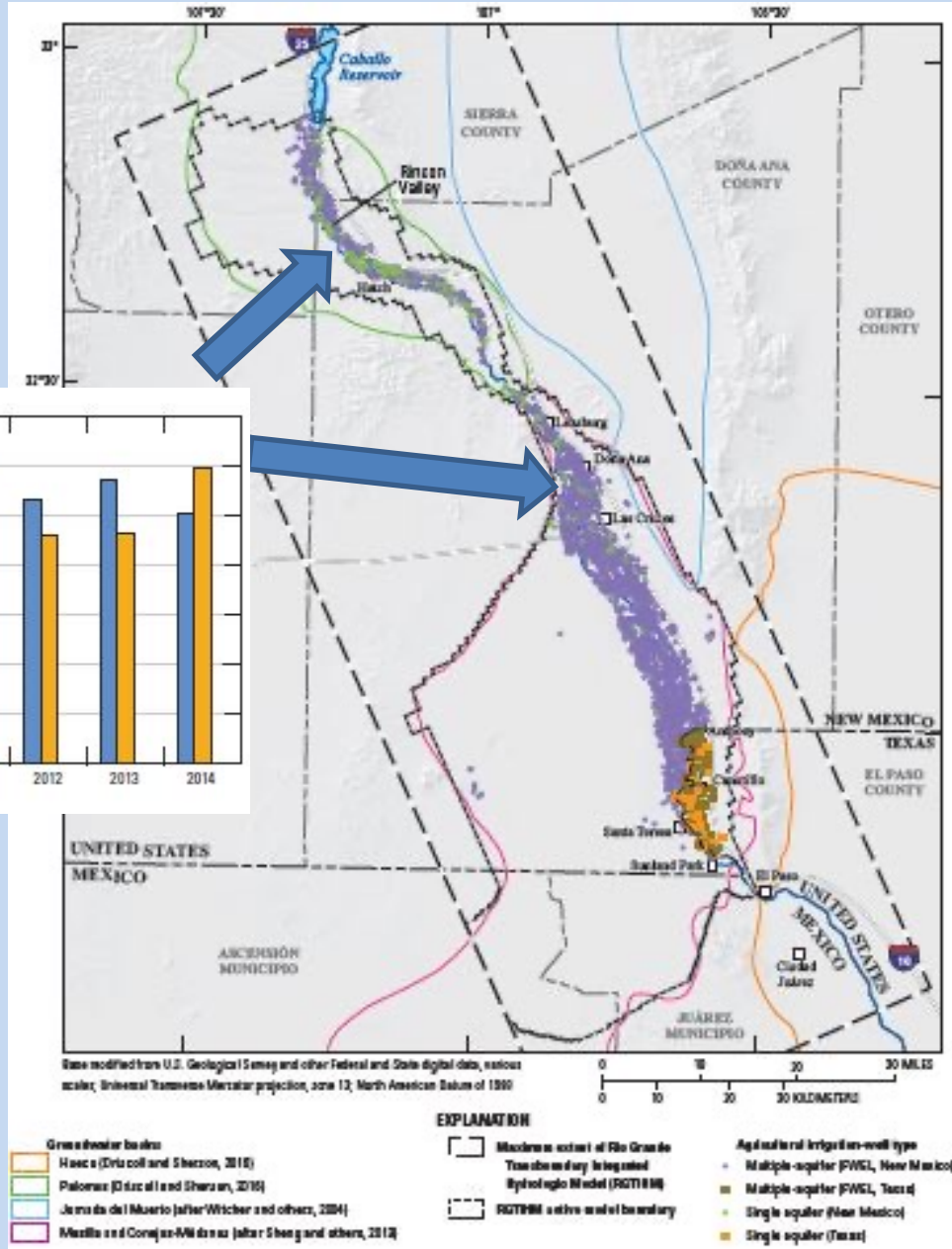


AGRICULTURAL PUMPAGE COMPARISON

Annual Ag GW Pumpage, New Mexico from thousands of wells

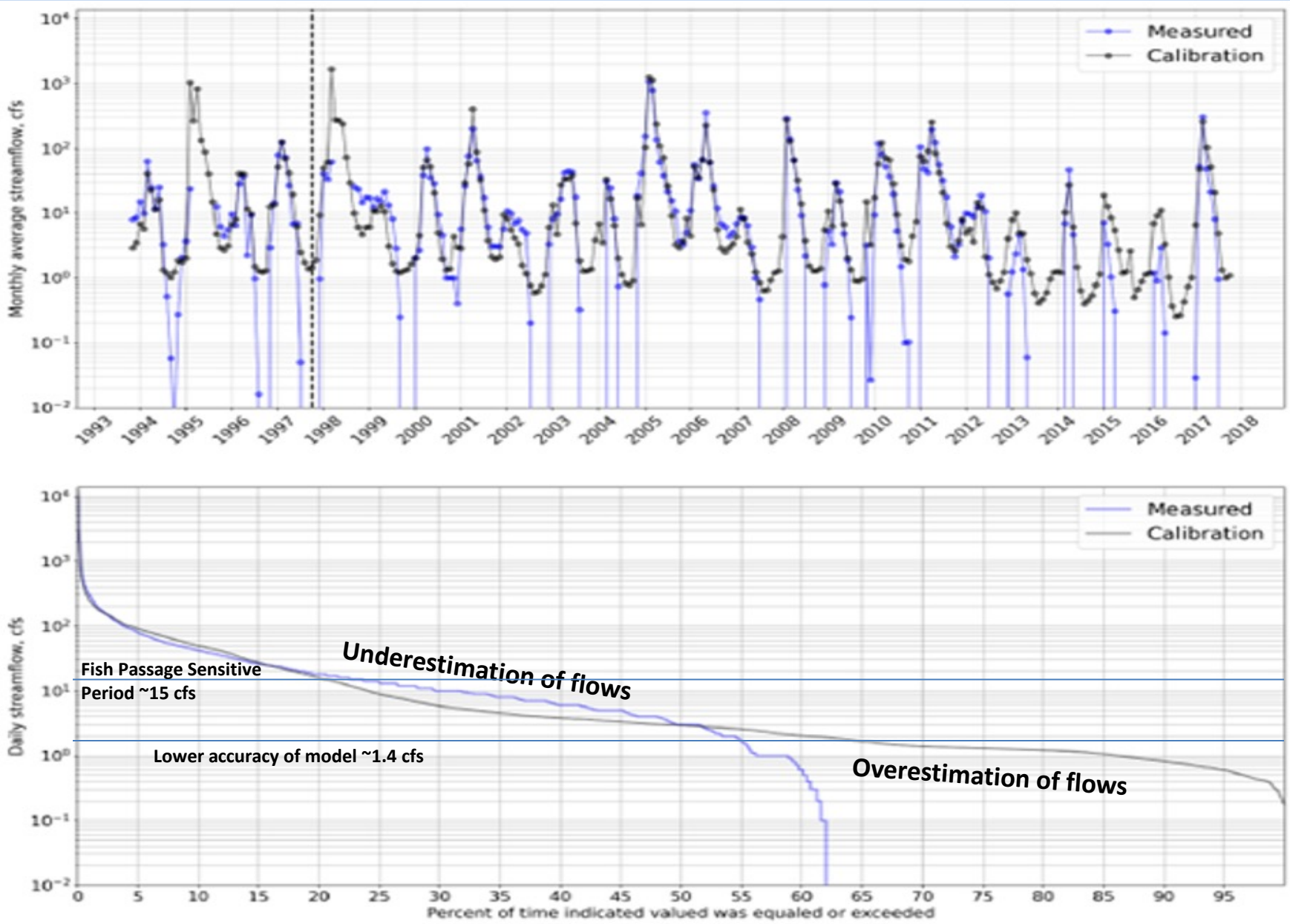


Matches Reported Annual Pumpage:
(~6% Average Annual Percent Error)



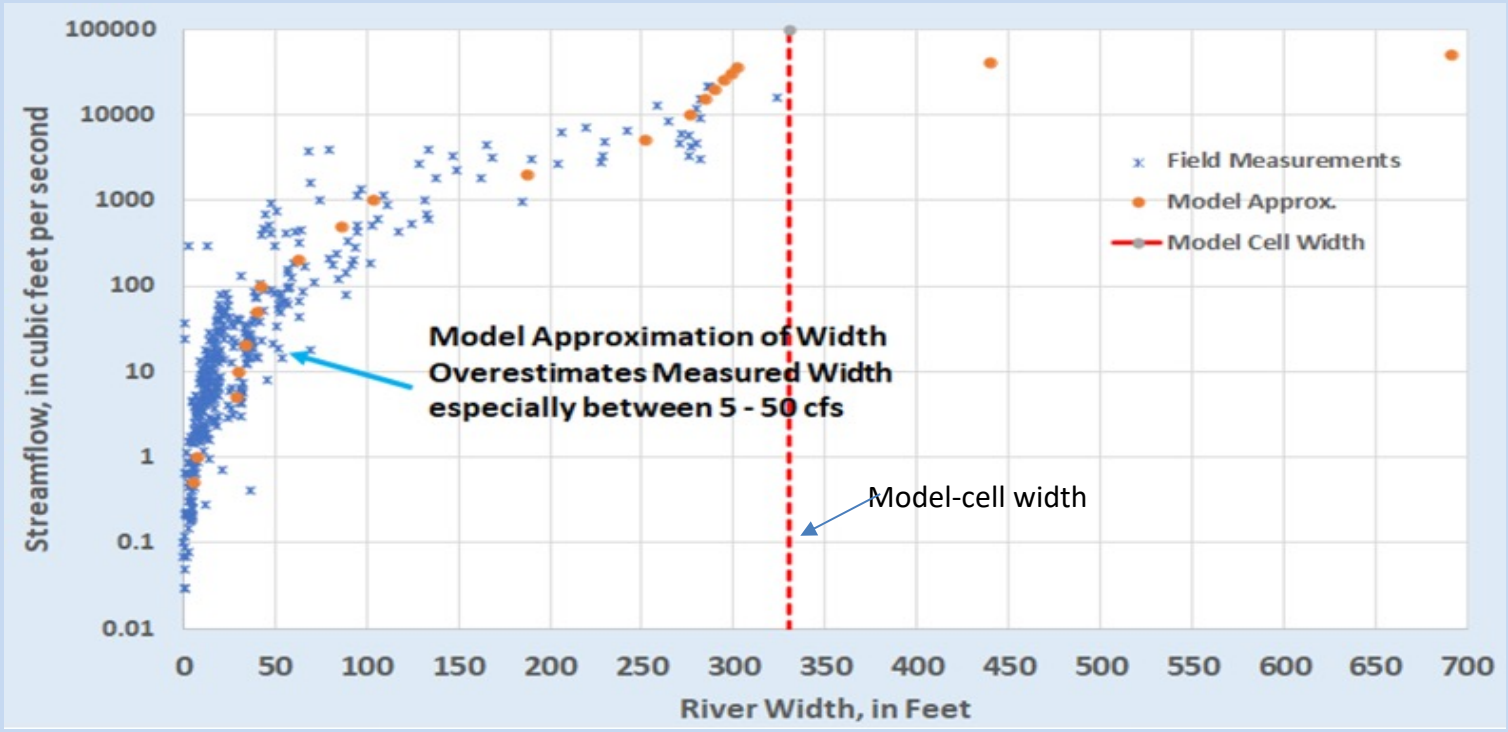
One Water

Streamflow Comparisons using Streamflow Duration

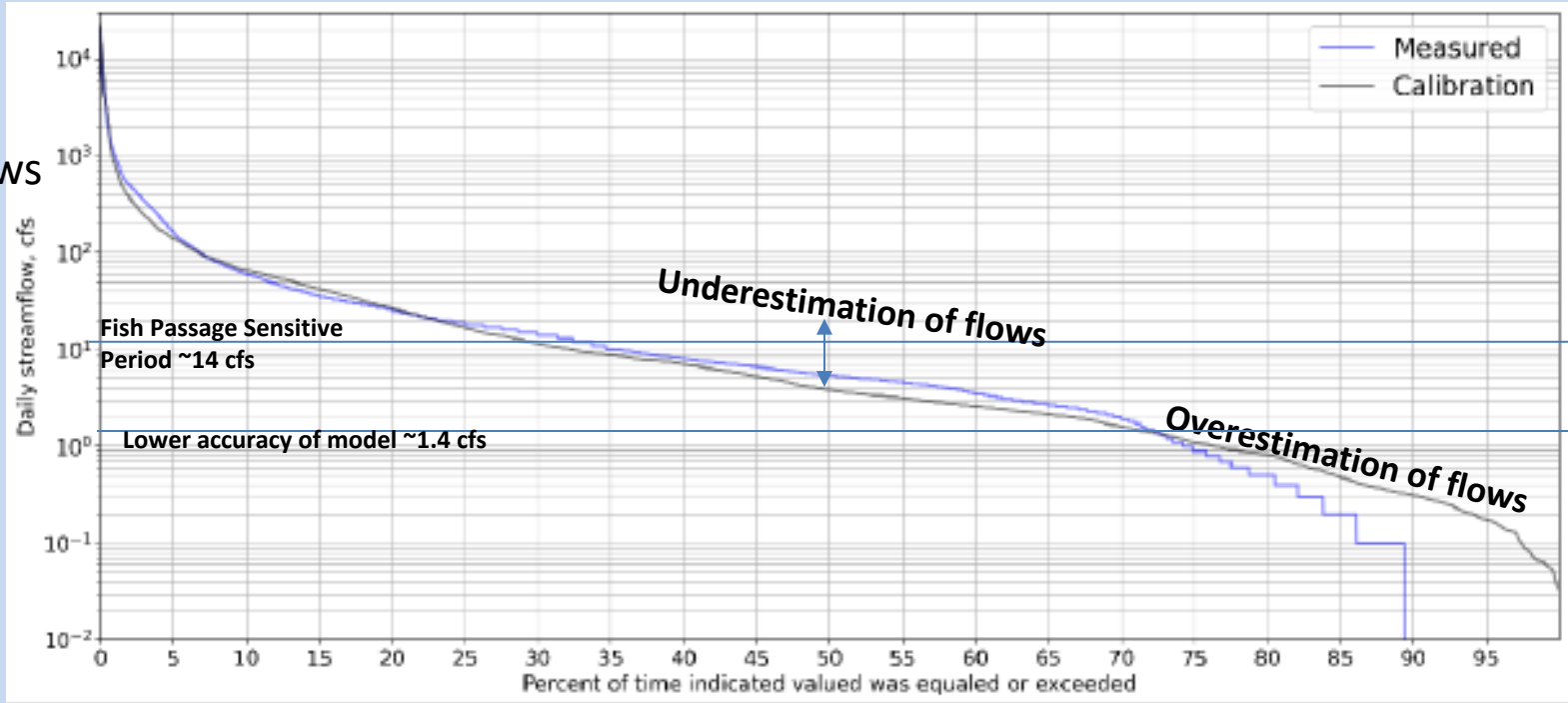


One Water

Streamflow Comparisons of Flow vs Width, and Duration (Exceedance)

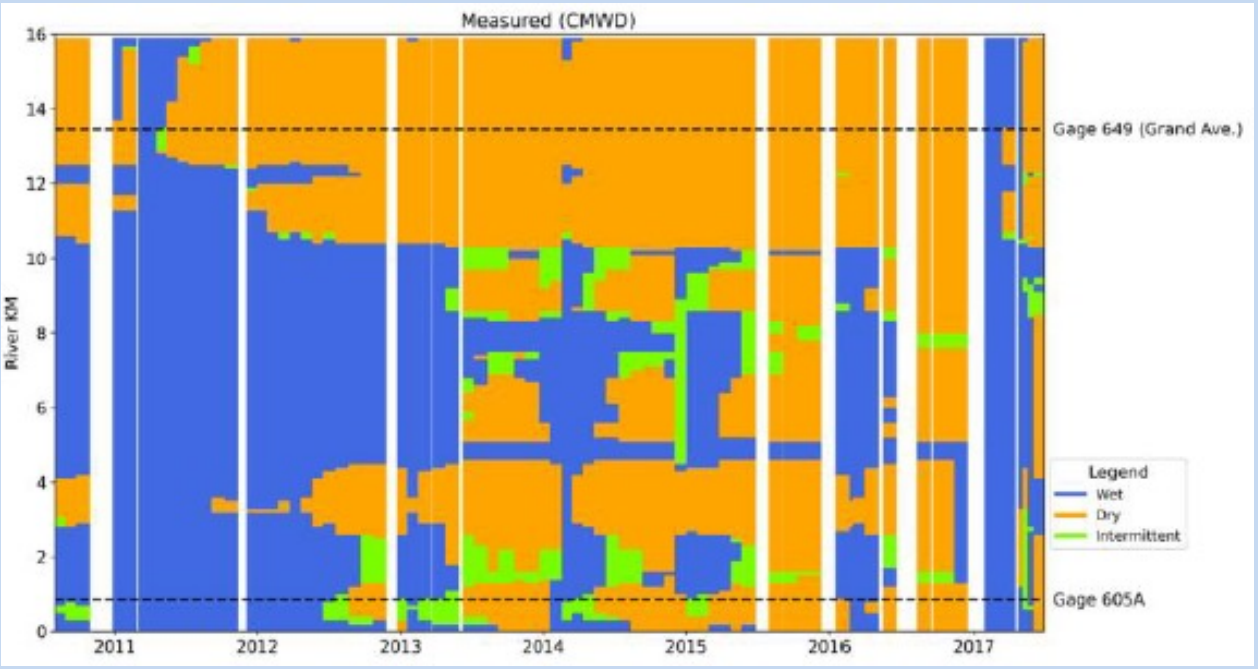


Model Period
WY1994-2017
Median Daily Flows
All Years: 5.6 cfs
Wet Years: 20 cfs
Dry Years: 4.3 cfs



One Water

Streamflow Comparisons with Wet-Dry Mapping (Heat Maps)



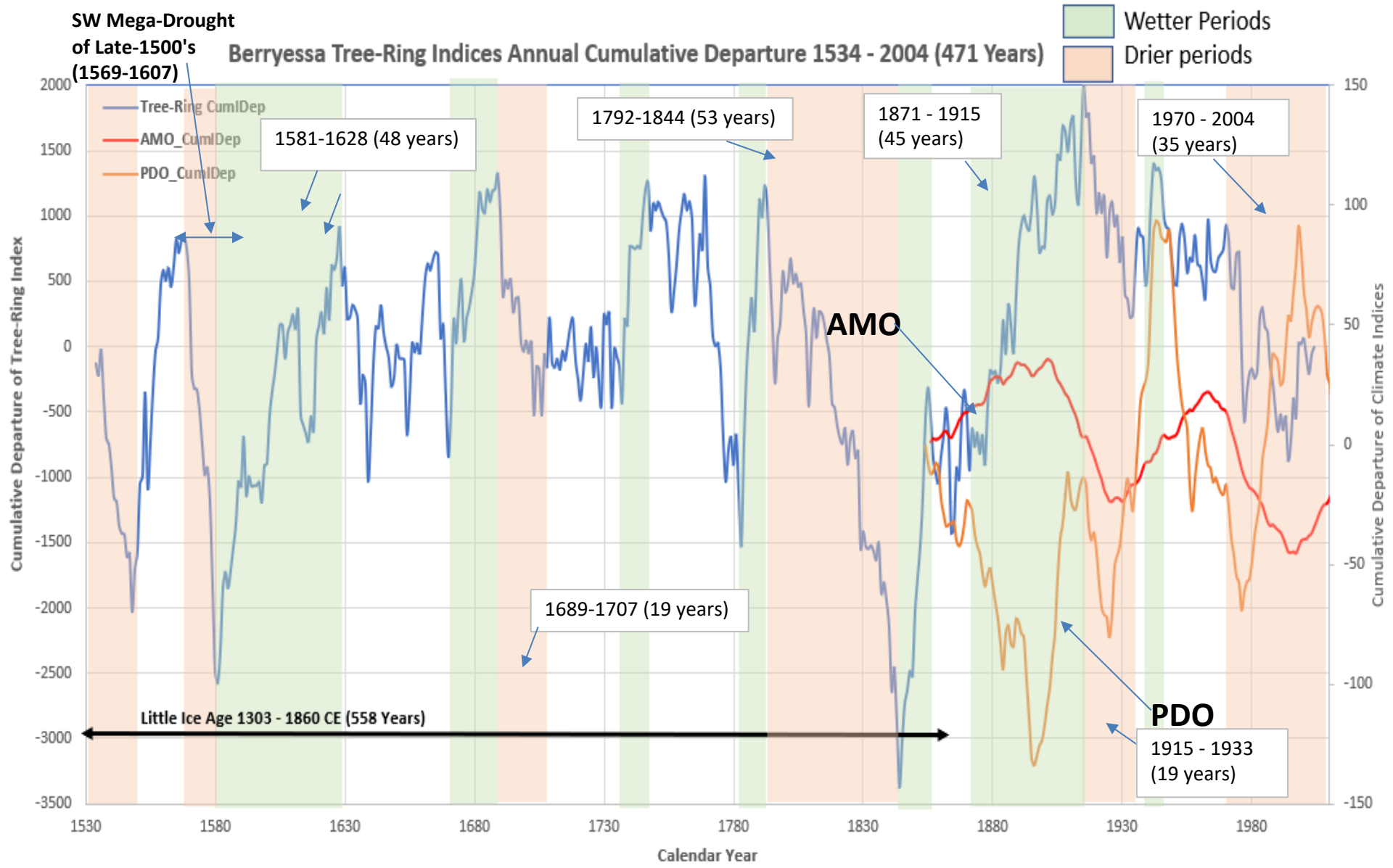
San Antonio Creek,
Ojai Basin

Lower Ventura River,
Ventura River Watershed

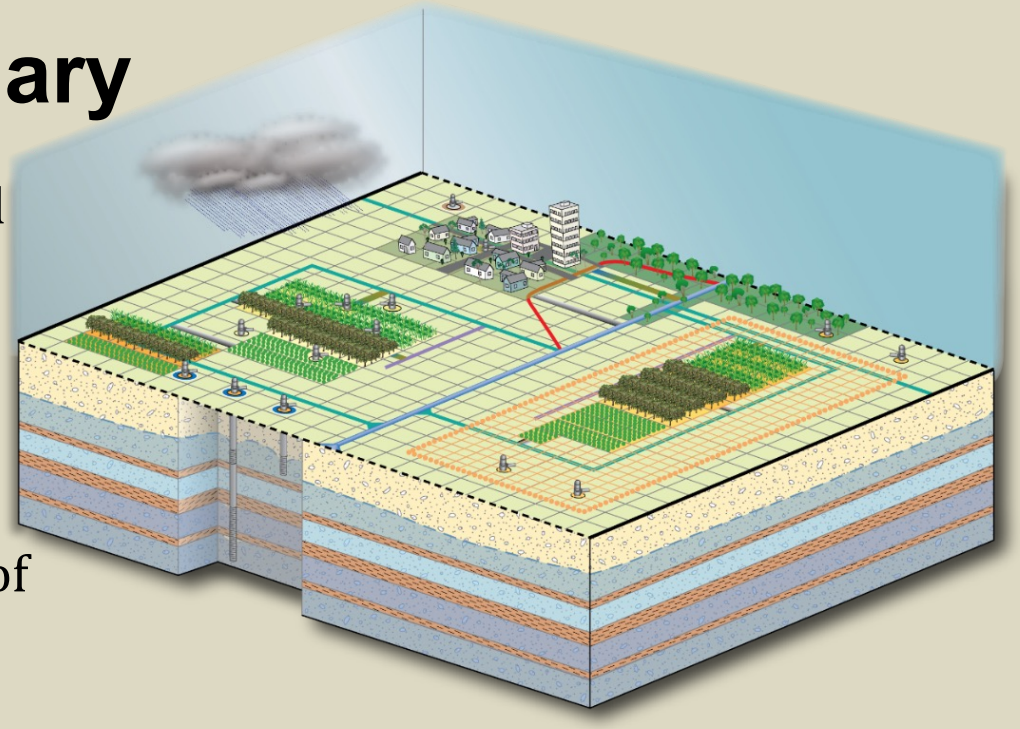
(Scott Lewis, CMWD)

One Water

Climate Variability: Climate Indices show similar phases & periods to Tree-ring indices This can be compared to frequencies in groundwater levels, Streamflow, Reservoir releases, etc. ➔ Are you getting similar interannual-interdecadal variability in model?



Conclusions & Summary



- HOB's aid in constraining additional attributes of IHMs
- HOB's allow analysis of model skill for other applications
- HOB's can delineate more levels of change & exchange as well as state of the combine gw/sw flow, climate, and land use systems
- HOB's can be filtered & applied as additional observation for model analysis, conceptual/structural analysis, & parameter estimation