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# Klamath River Basin Revised Natural Flow Study

August 15, 2024

Phase I & II: Agricultural and Groundwater Data Investigations

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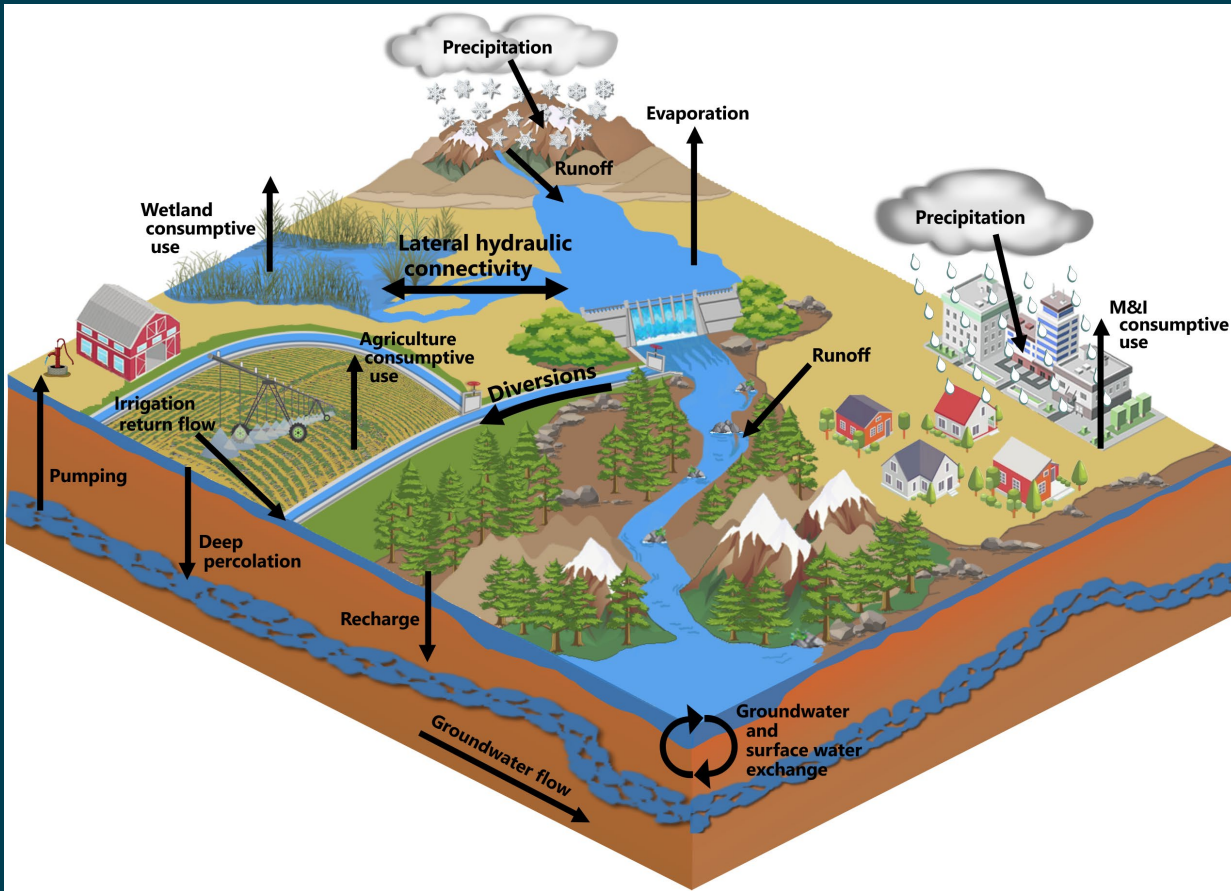
# Outline

- Agricultural data analysis
  - ET partitioning
  - Applied irrigation, and deep percolation
  - Defining water balance subsets
  - Surface water budget & deliveries
  - Recharge from canal seepage
  - Supplemental groundwater pumping
- Groundwater pumping for municipal and industrial uses
- Estimating baseflow
- Summary

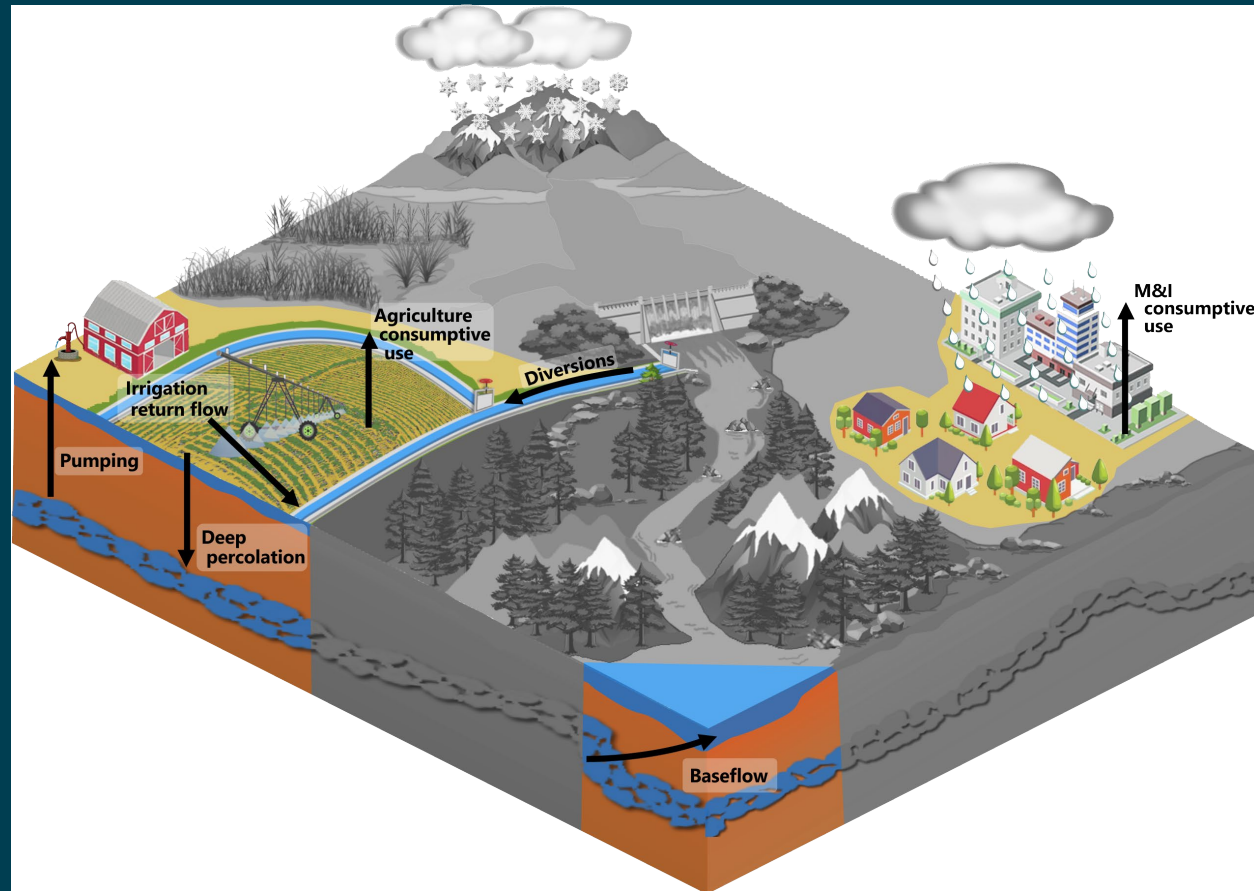


# General Approach

Big picture Klamath Natural Flow Study



Focus of this presentation





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# Agricultural data analysis

# Agricultural data analysis – motivation

- Often not much available data, but agriculture is important to model current conditions
  - Groundwater model
  - Surface water model
  - Water balance model
- Demands based approach (Deines et al., 2021)
  - Assumes crop consumptive use is met by irrigation



# ET partitioning – motivation

- Shallow groundwater likely influences many fields in the Phase 1 and 2 areas.
  - Field boundaries are in wetlands, riparian areas, and near seeps.
  - Part of actual evapotranspiration (AET) probably comes from shallow groundwater and soil moisture (subsurface ET).
- New approach to partition AET into components of subsurface ET and irrigation ET.
- Not partitioning leads to over-estimation of irrigation.



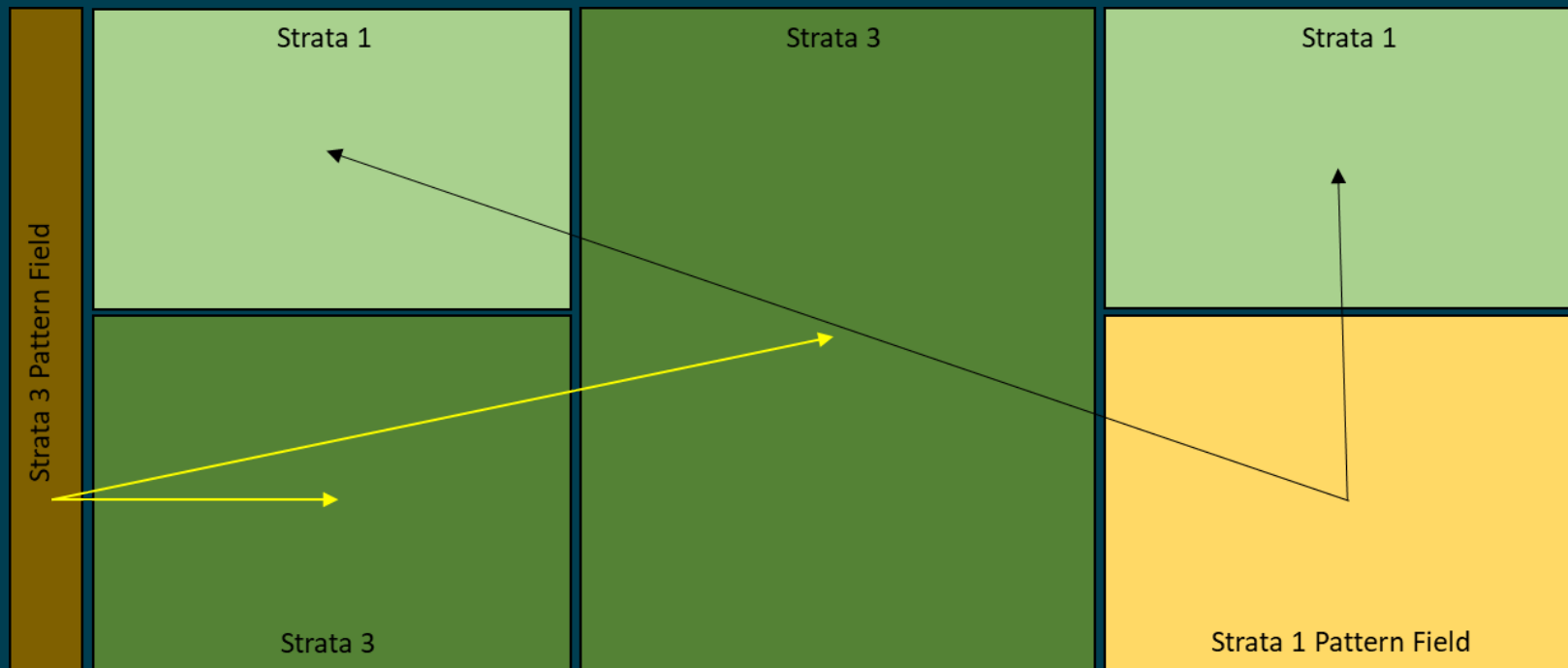
# ET partitioning – key assumptions

- **Fields with assumed access to shallow groundwater:**
  - A relative elevation model (REM) analysis serves as an index to approximate plant accessibility to shallow groundwater.
  - On an annual scale, all precipitation is effective and recharges the shallow groundwater.
    - Field runoff from precipitation equals field run-on.
    - No canopy interception.
- **Fields without assumed access to shallow groundwater:**
  - These fields are not partitioned.
  - Use effective precipitation estimates.



# ET partitioning – methods big picture

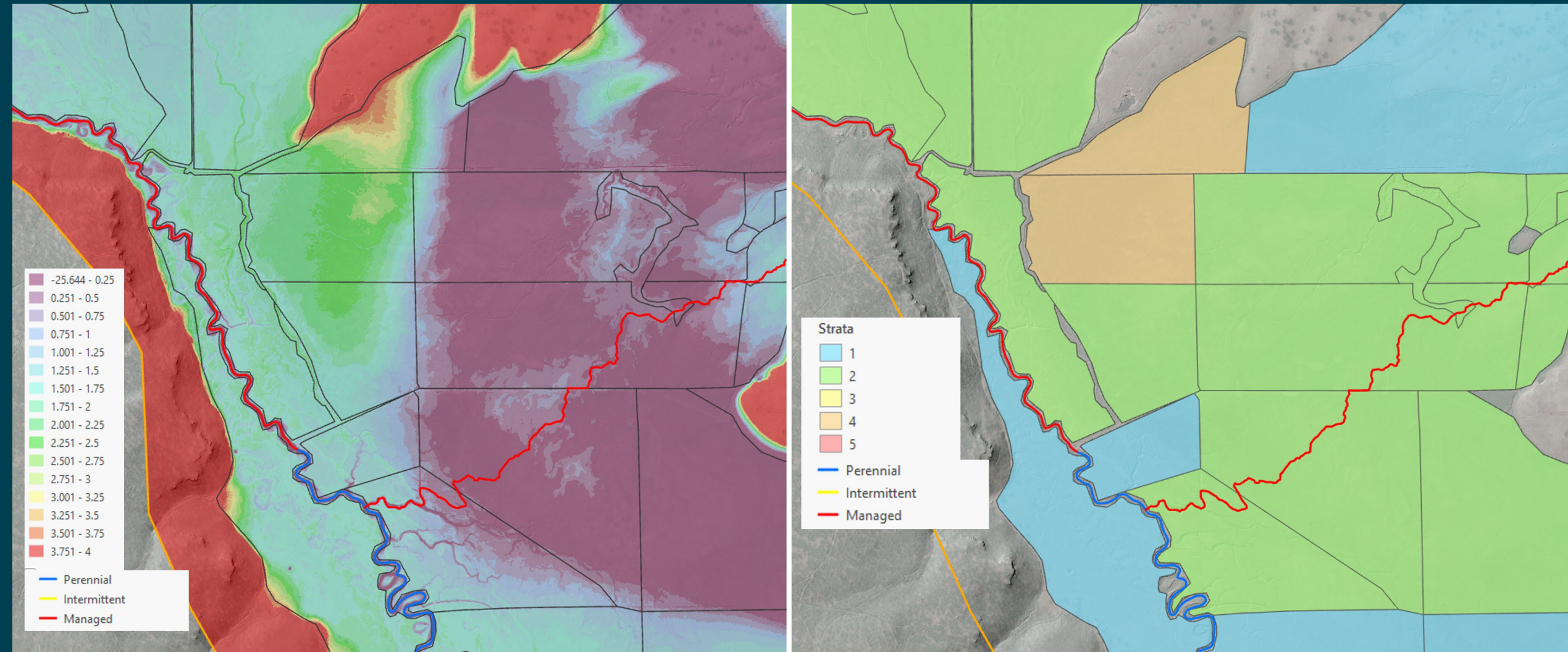
- Subsurface ET from an unirrigated field is used as subsurface ET pattern of nearby irrigated fields with similar assumed access to shallow groundwater.
  - REM used stratify (classify) fields
  - Identify unirrigated fields/areas (pattern fields)



# ET partitioning – REM

- REMs developed based on best available LiDAR derived Digital Elevation Model.
- Field strata assigned to each field based on proximity to nearest stream type and aggregated mean relative elevation.
  - Stream type:
    - Perennial
    - Intermittent and managed
  - Aggregated relative elevation bins:
    - <2m
    - 2 – 4m
    - >4m

# Example strata from REM analysis



# ET partitioning – pattern fields

- Full time series (FTS) pattern fields
  - Fields that do not appear to have been affected by irrigation WY 1981 – 2020
  - Areas outside of the field boundaries
- Year pattern fields
  - Years with known water curtailments
  - Years when fields were recorded to be fallowed
- Data
  - Records (leased fields)
  - Low ET years
  - IrrMapper
  - Visual inspection
    - Google Earth Pro
    - NAIP imagery



# ET partitioning – relating subsurface ET

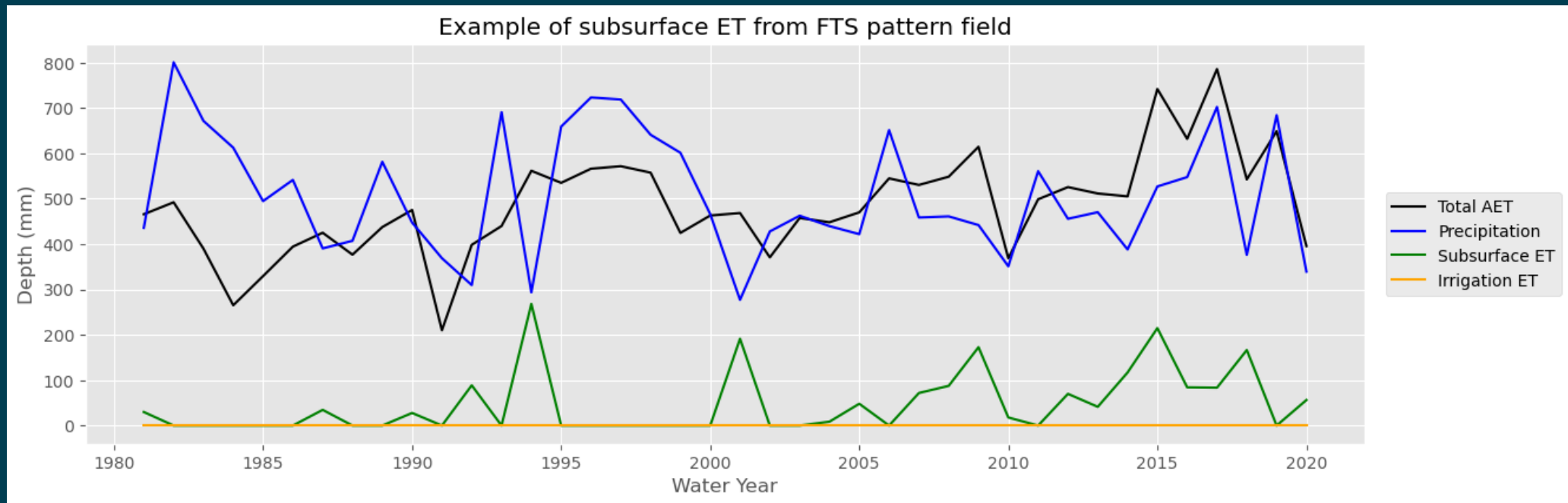
- ET terms review
  - Actual ET – from eeMetric
  - Reference ET – from GridMET and validated by local ag weather stations
  - Precipitation – from GridMET and validated by local ag weather stations
  - Effective precipitation (precipitation minus deep percolation and runoff) – from ET Demands model
  - \*ET fraction is the AET/Reference ET
  
- \*Subsurface ET fraction from the pattern field is related to the irrigated fields



# ET partitioning – pattern field ET calculation

$$ET_{gw+sm} = ET_A - P$$

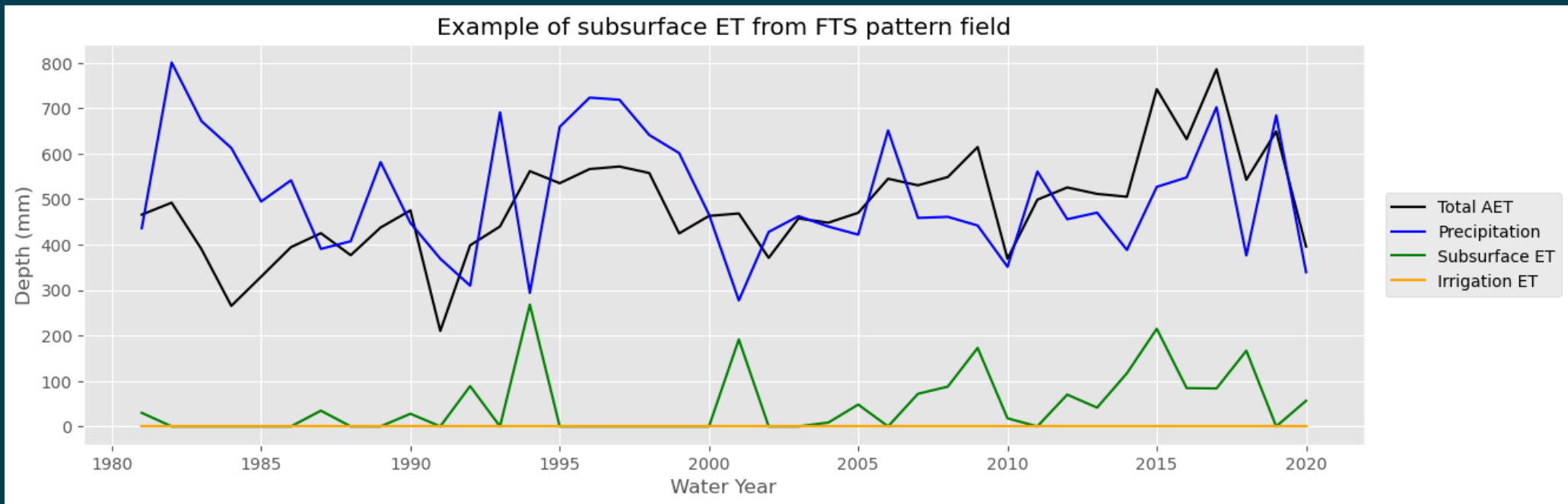
$ET_{gw+sm}$  is subsurface ET (green),  $ET_A$  is actual ET (black),  $P$  is precipitation (blue), and irrigation ET is 0 (orange).



# ET partitioning – pattern field ET fraction calculation

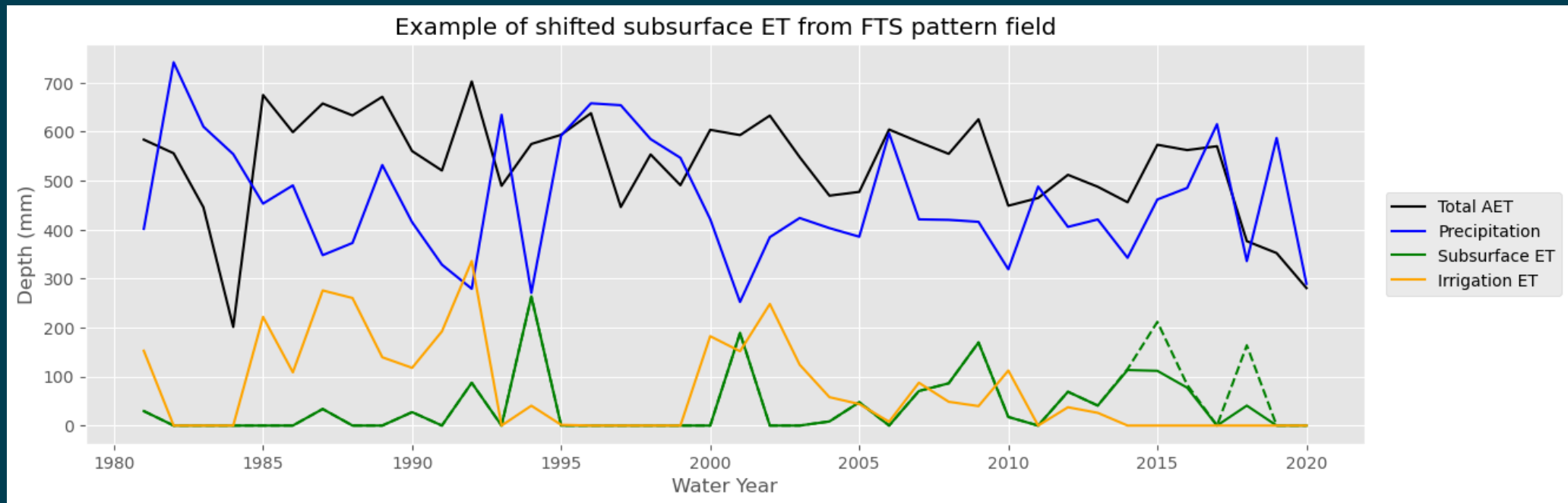
$$ET_{f(gw+sm)} = \frac{ET_{gw+sm}}{ET_0}$$

$ET_{f(gw+sm)}$  is the subsurface ET fraction,  $ET_{gw+sm}$  is subsurface ET,  $ET_0$  is reference ET.



# ET partitioning – pattern field to irrigated field

- Irrigated field subsurface ET comes from the pattern field's subsurface ET fraction and irrigated field's reference ET (dash green).
- Irrigation ET is the remaining ET not met by precipitation or subsurface ET (orange).
- Correction to adjust subsurface ET for mass balance (dash green to solid).



# ET partitioning – results

- Disaggregated annual partitioned results to monthly
- Fields that were not partitioned (ET from irrigation = AET – effective precipitation)
  - Strata with 4+ meter REM
  - Areas with known tile drains (TID)

The numbers below represent the annual crop ET from irrigation averaged over the basin area.

Basin	Annual Irrigation ET (ft)		
	25th percentile	50th percentile	75th percentile
Williamson River	0.14	0.21	0.23
Sprague River	0.42	0.48	0.57
Wood River	0.16	0.26	0.34
Upper Klamath Lake	0.29	0.37	0.48
Lost River	2.06	2.23	2.58
Butte	0.56	0.68	0.75
Upper Klamath	0.04	0.08	0.12



# Big picture partitioning methods

Motivation: Information under current condition supports groundwater and surface water modeling efforts. Partitioning was necessary to not overestimate crop ET from irrigation.

- Step 0
  - Use suite of ET and precipitation data
  - Motivation to find out where the water comes from to meet AET
- Step 1
  - Stratify fields
  - Identify pattern fields
- Step 2
  - Calculate subsurface ET of pattern fields
- Step 3
  - Use subsurface ET of pattern fields to calculate subsurface ET of irrigated fields
  - Calculate irrigation ET
- Step 4
  - Use irrigation ET as crop consumptive (demand) to calculate applied irrigation





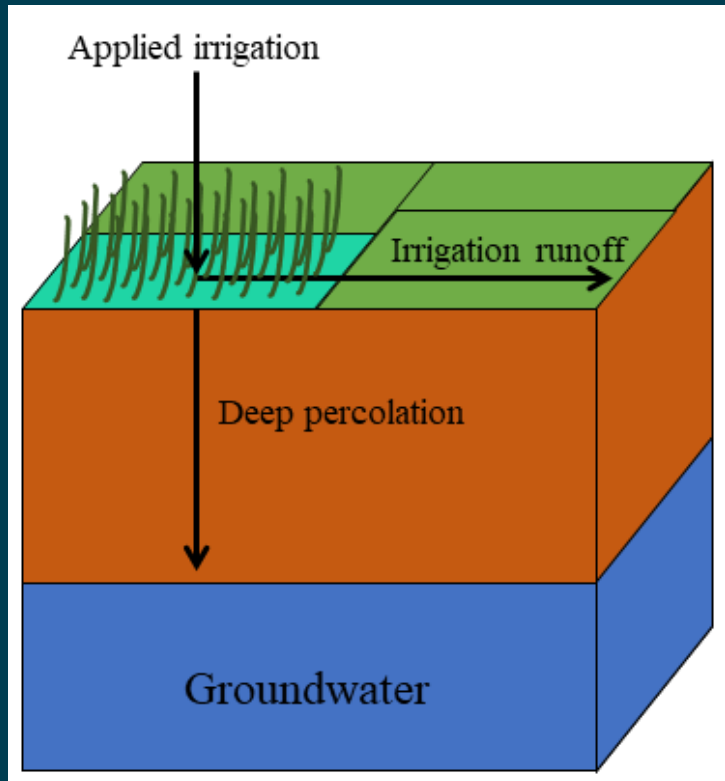
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# Break for questions

**Next section: Estimating applied irrigation, diversions, canal seepage, supplemental pumping using irrigation ET as demand**

# Applied irrigation and deep percolation

- Demand is irrigation ET



Applied Irrigation:

$$I_A = \frac{ET_{irr}}{E_a}$$

Deep Percolation:

$$R_{DP} = I_A(1 - E_a)F$$

Irrigation return flow:

$$Q_{IF} = I_A(1 - E_a)(1 - F)$$

$ET_{irr}$  = Monthly irrigation ET

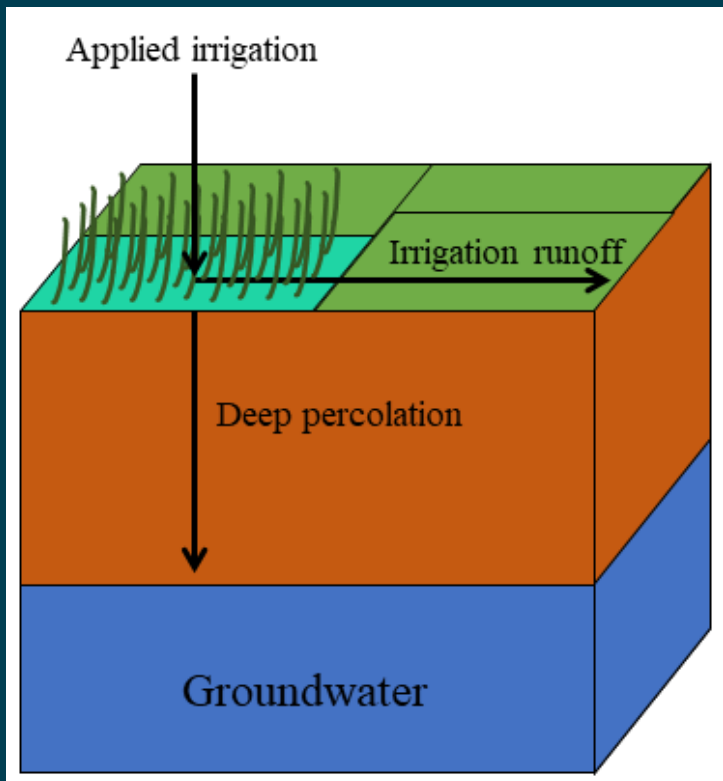
$E_a$  = Estimated typical on-farm efficiency

$F$  = Fraction of loss that becomes deep percolation



# Applied irrigation, and deep percolation

- Estimated typical irrigation efficiencies and fraction to recharge by irrigation type

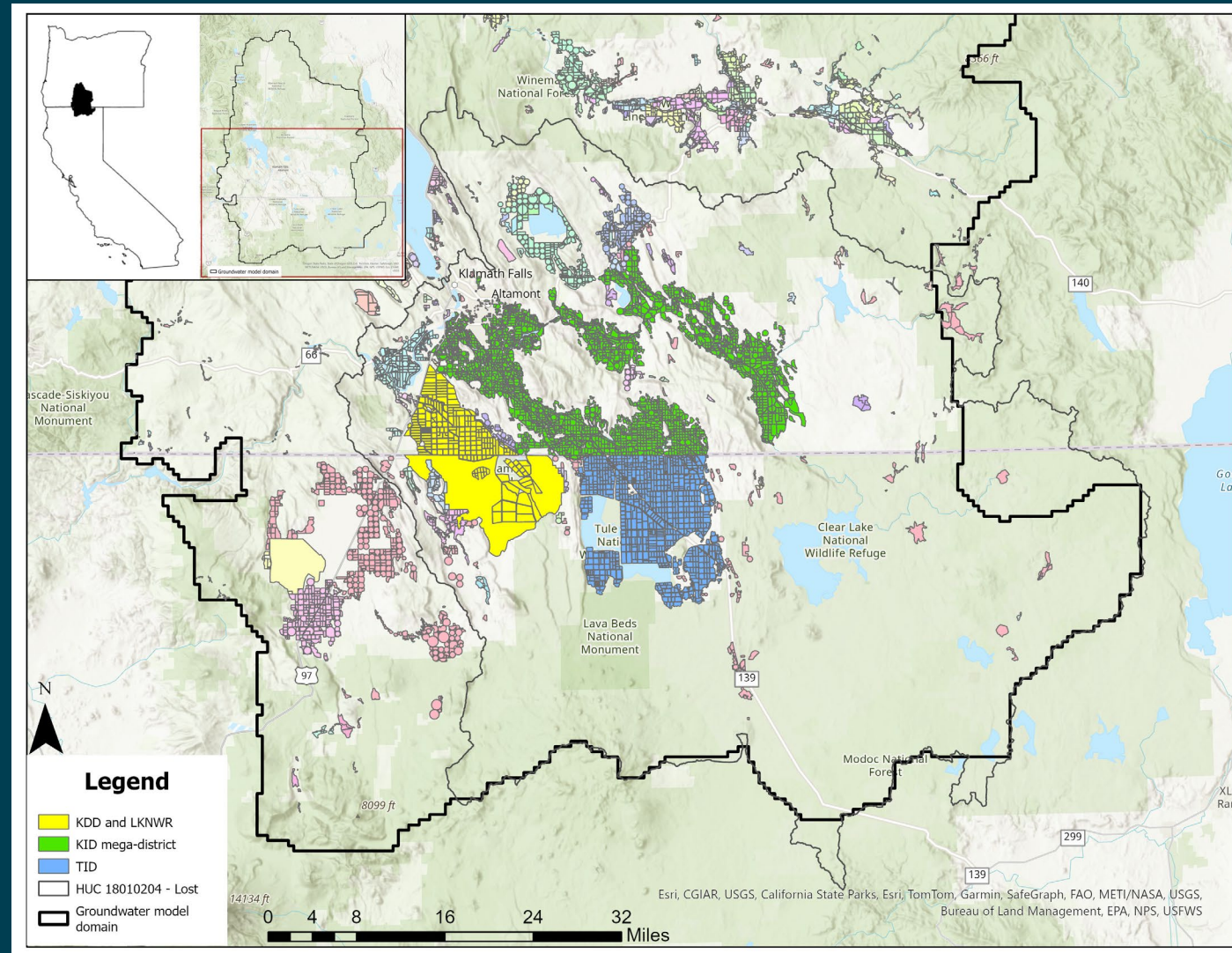


Irrigation type code	Irrigation type	On-farm efficiency	Fraction to recharge
1	Sprinkler pivot	0.85	0.8
2	Sprinkler other	0.75	0.6
3	Flood uncontrolled	0.50	0.2
4	Flood controlled	0.65	0.4
5	Micro	0.85	0.9



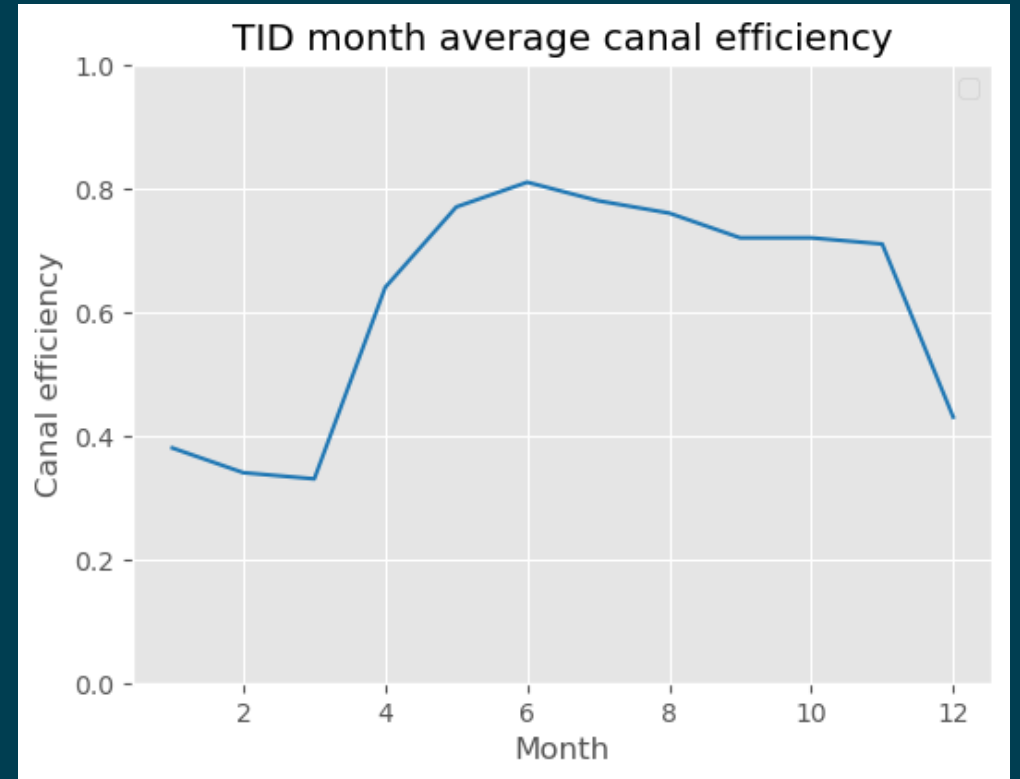
# Defining water balance subsets

- Groups of fields based on inflows and outflows
  - Diversion data from irrigation districts
  - Points of diversion and places of use
- 225 water balance subsets
  - Inflows and deliveries
  - Canal seepage recharge
  - Supplemental groundwater pumping



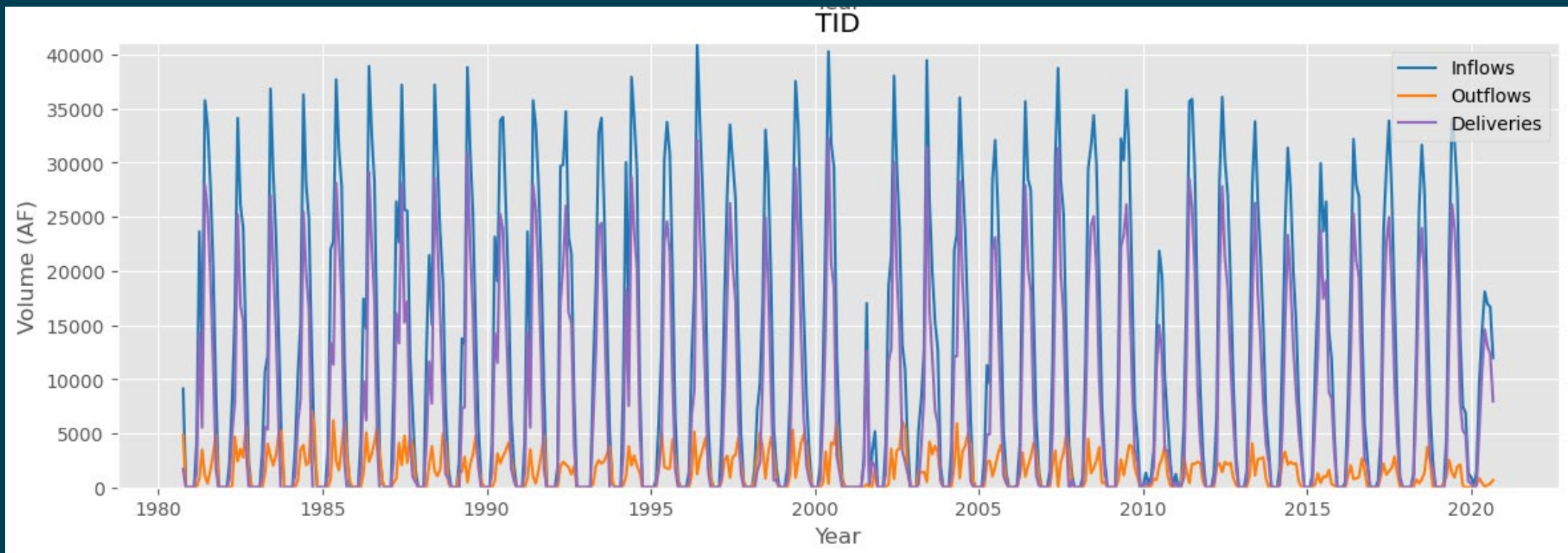
# Surface water budget & deliveries – canal efficiency

- TID has loss and net water supply data.
- TID month average (average Jan., Feb., etc.) canal efficiency used for TID and KID monthly canal efficiency.
- All other places use 0.75 canal efficiency, which is the overall average annual canal efficiency.



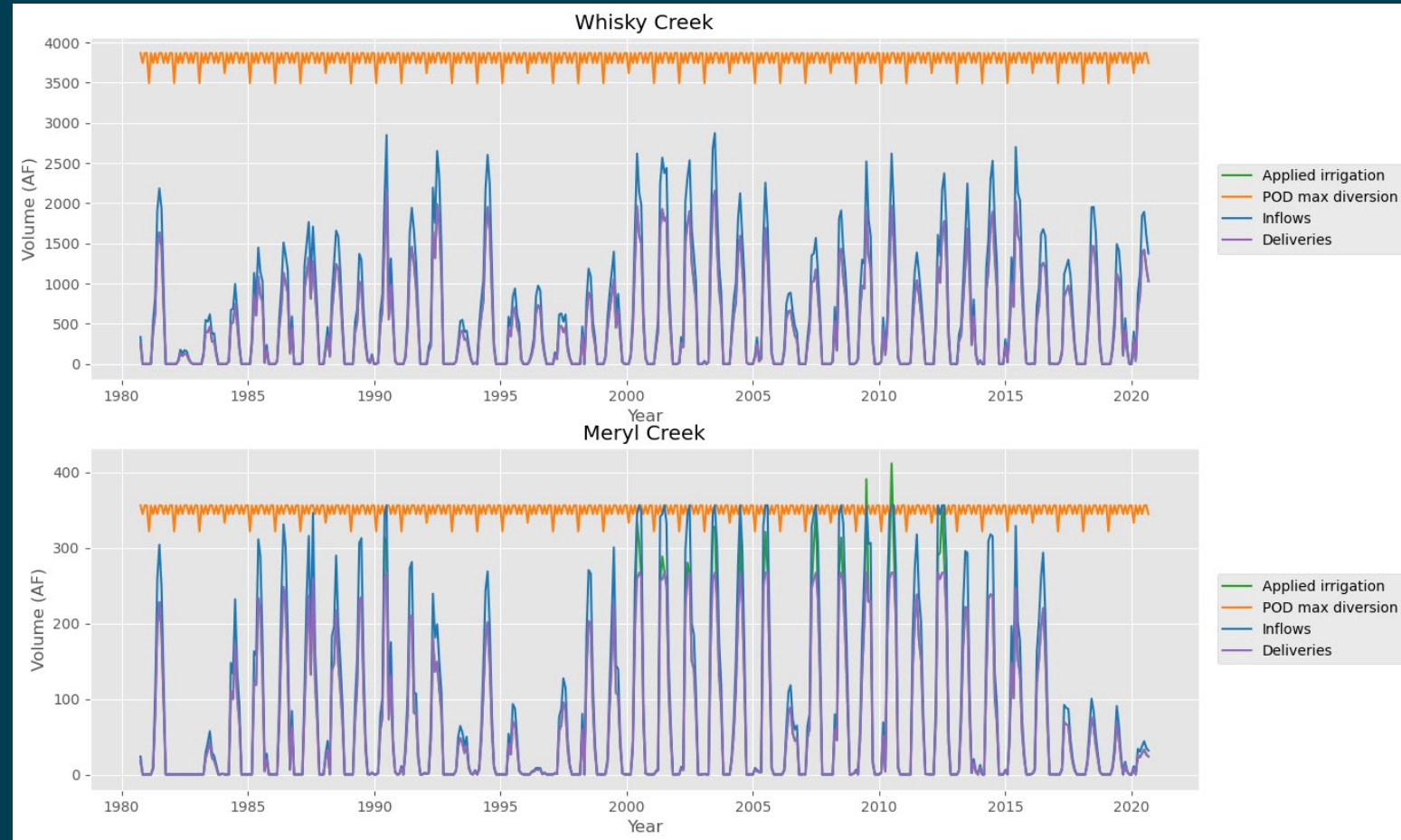
# Surface water budget & deliveries

- Areas with diversion data (Klamath Project – TID example)
  - Mass balance
  - Inflow – Outflow



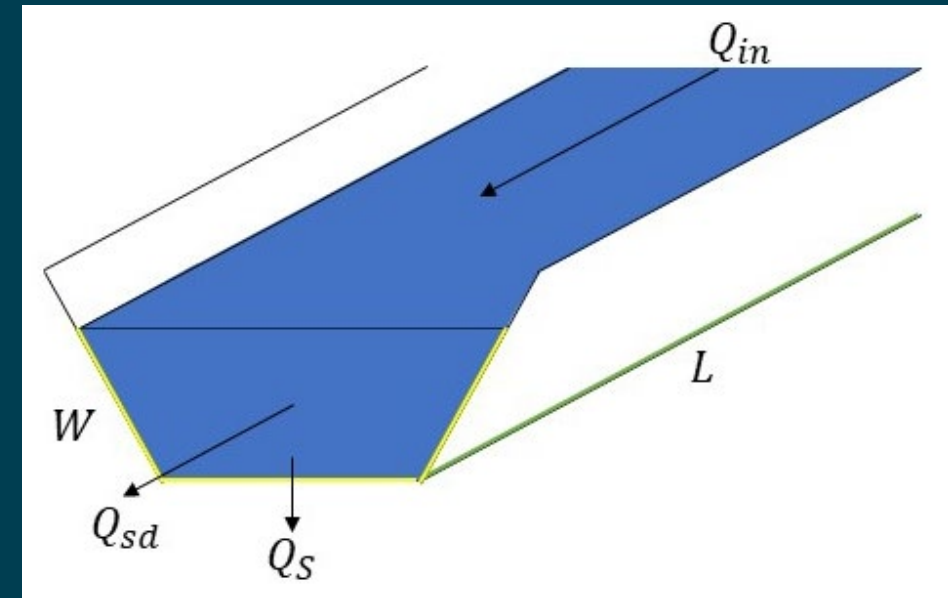
# Surface water budget & deliveries

- Areas without diversion data (outside Klamath Project)
  - Demands-based estimate
  - Divert water to meet demand until reported point of diversion rate is met



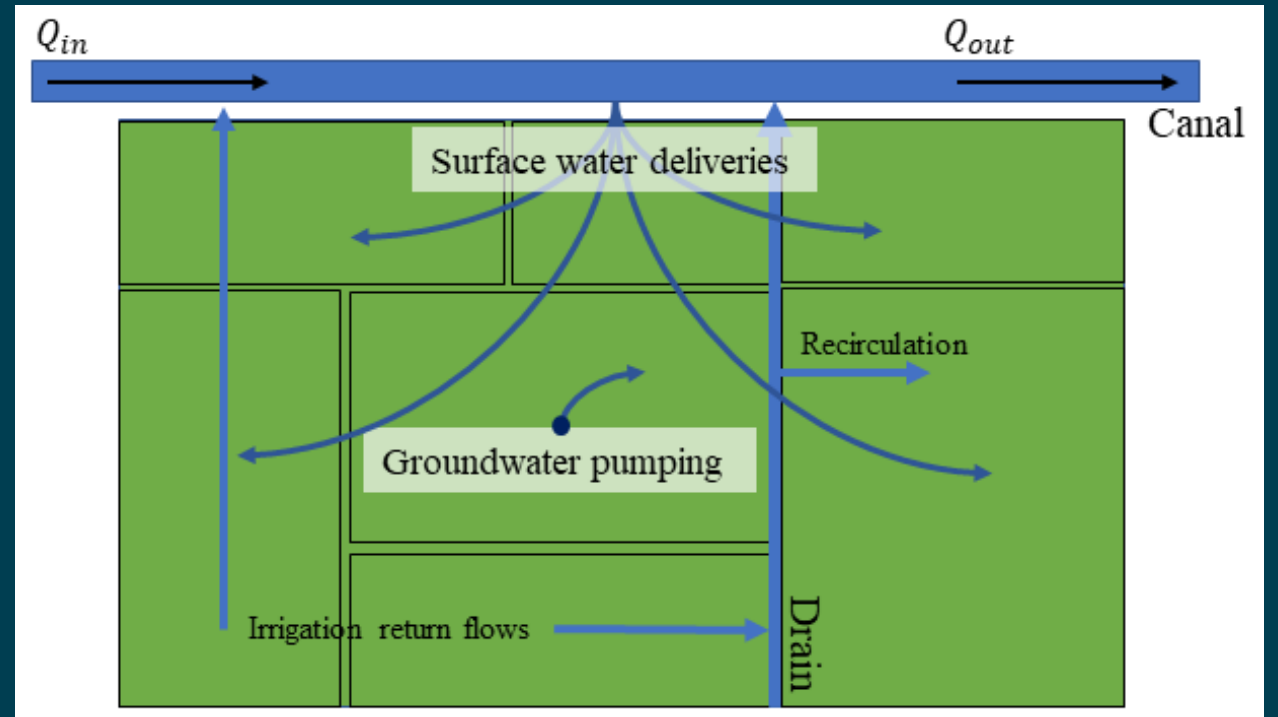
# Recharge from canal seepage

- Some portion of diverted water recharges groundwater through seepage ( $Q_s$ ).
- Canal dimensions estimated average from LiDAR and 42 cross sections.
- Seepage rates:
  - KDD: 0 – 0.39 ft/day
  - KID: 0 – 0.46 ft/day  
(1 anomalous month 1.03 ft/day)
  - TID: 0 – 0.35 ft/day
- Ranges appear reasonable (<0.5 ft/day)



# Supplemental groundwater pumping– methods

- Remaining demand not met by SW deliveries is met by supplemental groundwater pumping.
- Recirculation and reuse
  - Some areas, especially in the project, have a lot of recirculation and reuse
  - No pumping in KDD prior to 2001



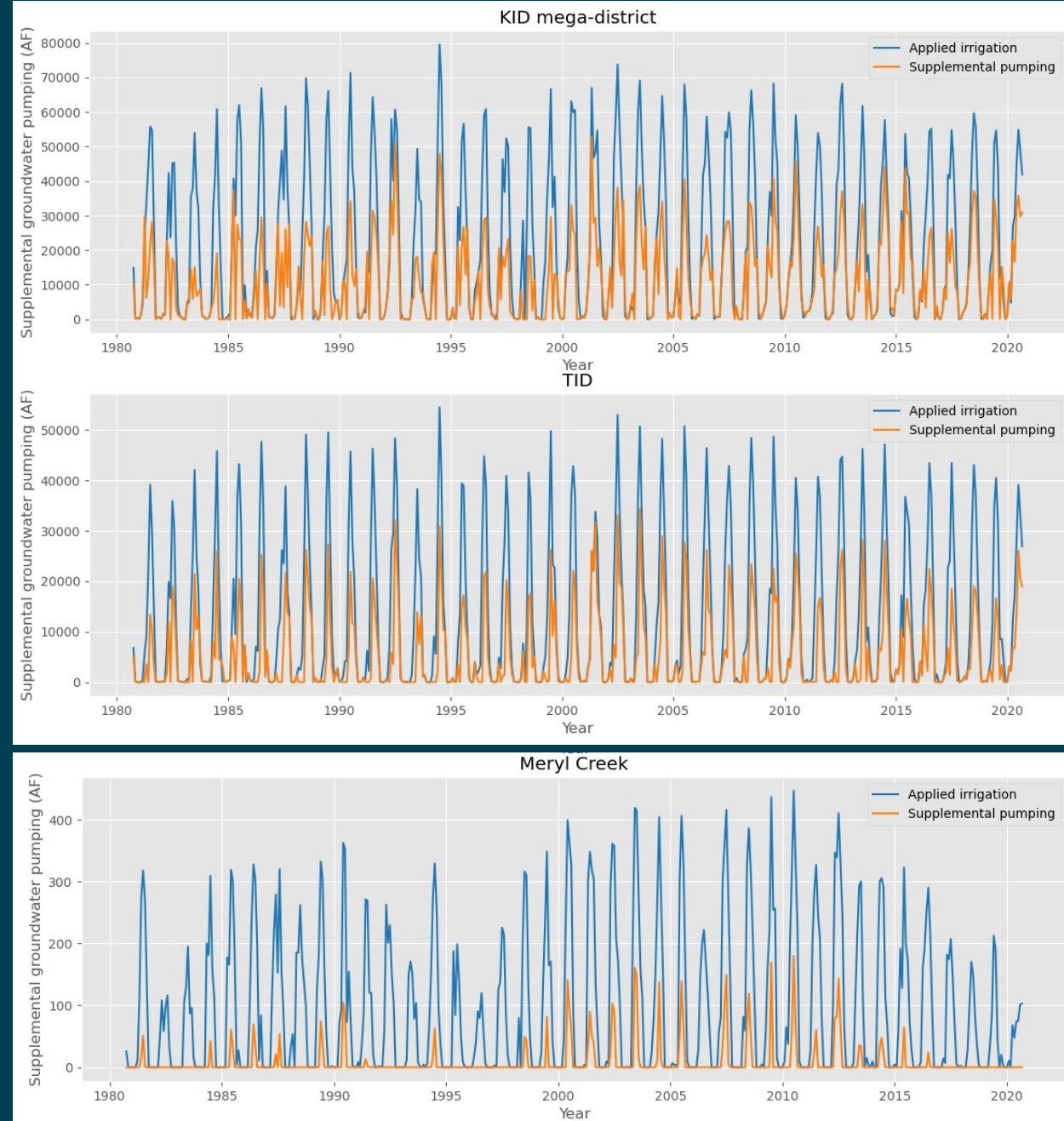
# Supplemental groundwater pumping

Groundwater pumping:

$$Q_{gp} = I_A - Q_{sd}$$

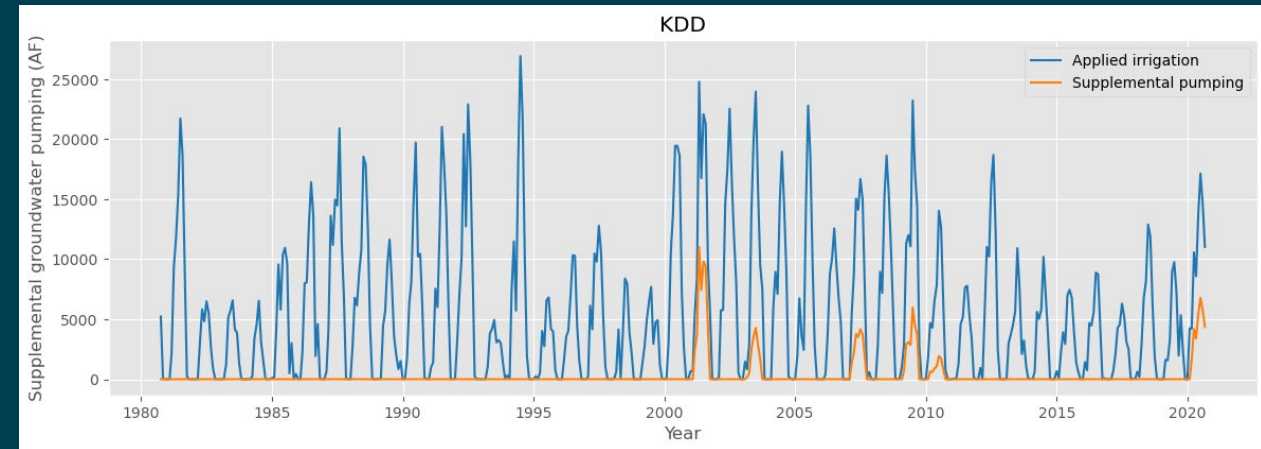
$I_A$  is the monthly applied irrigation summed across the entire water balance subset

$Q_{sd}$  is the surface water deliveries to the WBS



# Supplemental groundwater pumping

- Assumed no pumping prior to 2001.
- Developed a recirculation and reuse term from pumping estimates prior to 2001 and applied the average from 2001 – 2020.

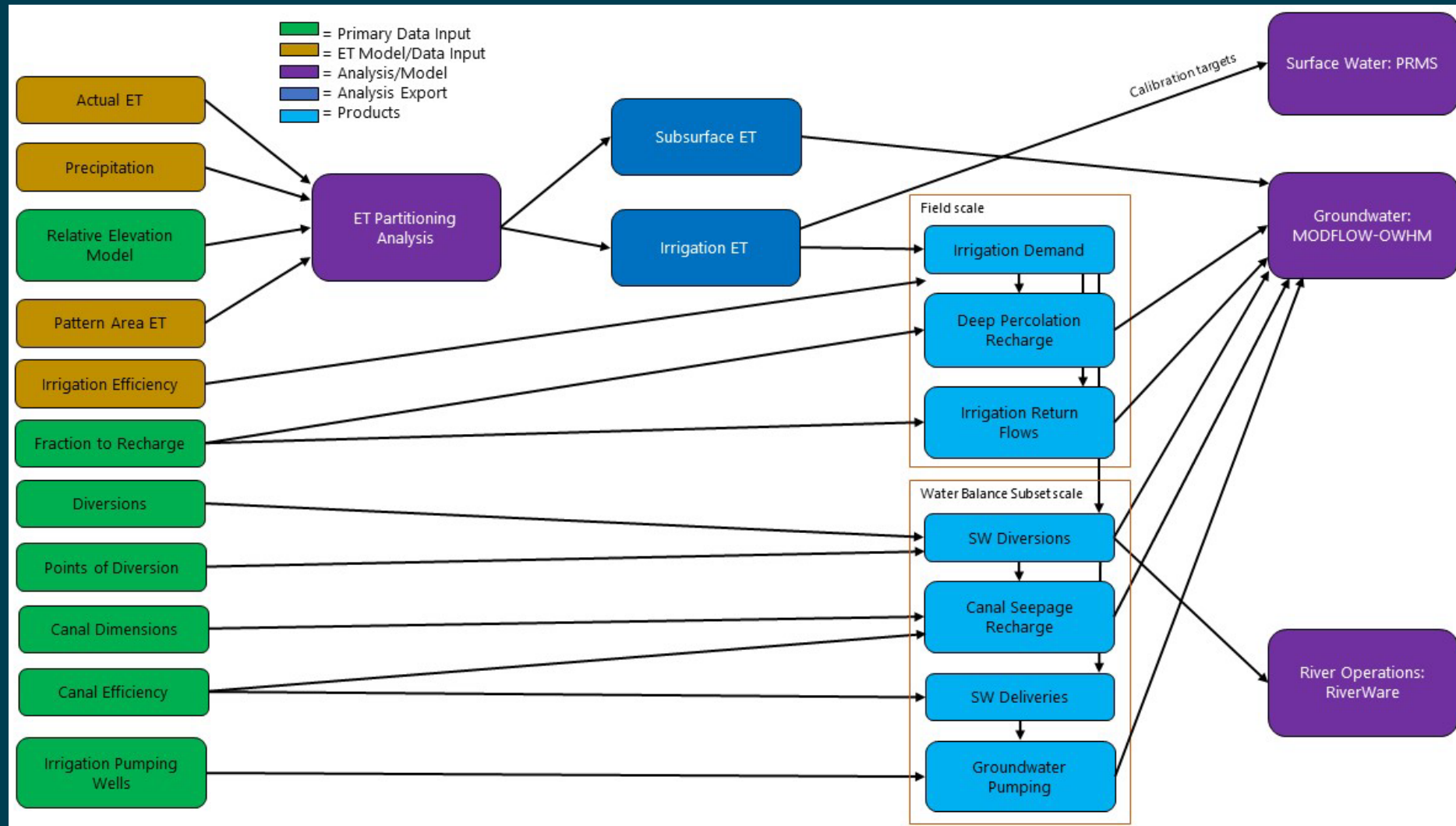


# Applications

- **Surface water model**
  - Irrigation consumptive use to estimate naturalized streamflow for calibration targets
- **Groundwater model**
  - Subsurface ET data input
  - Deep percolation data input
  - Irrigation return flow data input
  - Canal seepage data input
  - Supplemental groundwater pumping data input
- **Water balance model**
  - Diversions and return flow data input



# Big picture – data inputs and KNFS model connections



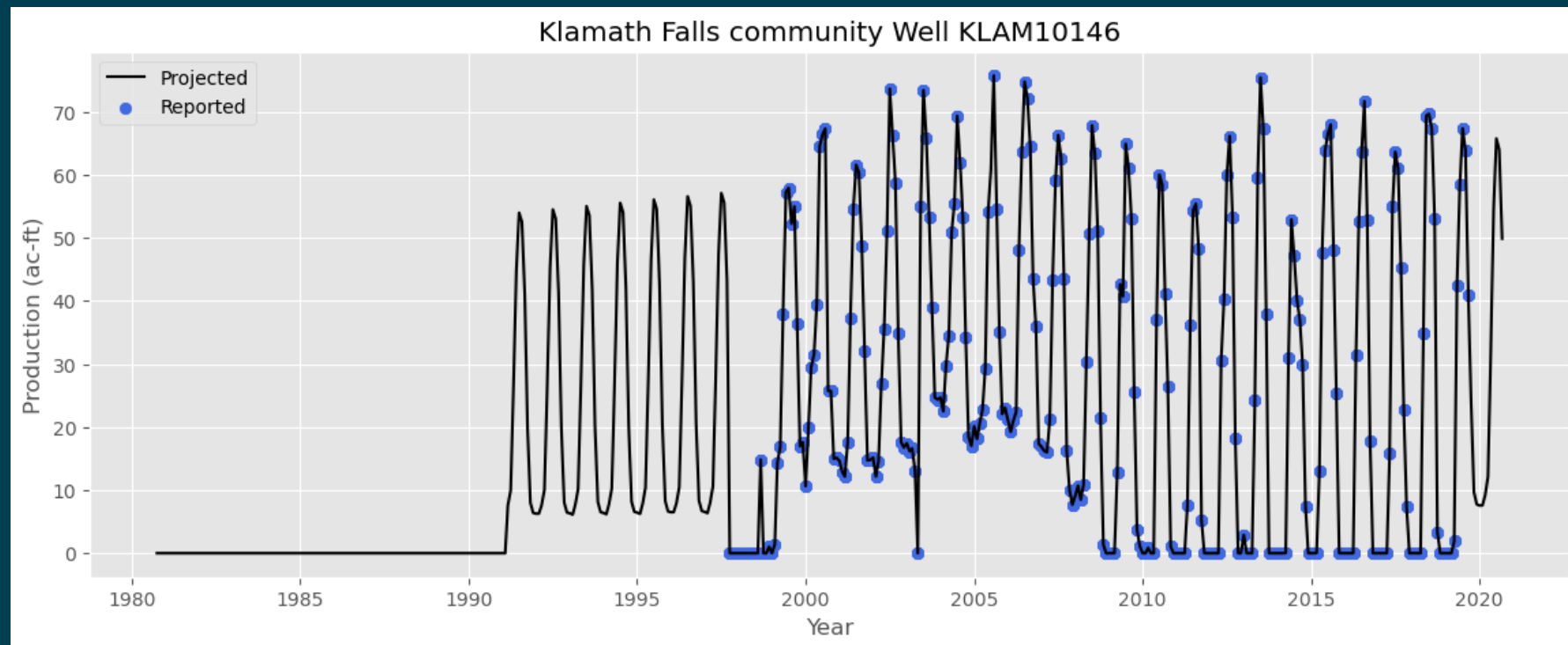


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# Groundwater pumping for municipal and industrial uses

# Methods

- Wells with population and production data
  - Related per capita use estimates to times without production data.
  - Assigned dates before well completion to be 0.



# Methods

- Wells with population and no production data
  - Average annual USGS Water Use database Klamath County
    - Domestic: 142.6 gallons per person per day
    - Public Supply: 193.0 gallons per person per day
  - Average annual ODOT and USFS per capita estimates for rest stops and camps
  - Distributed by month using pattern of wells with production data and same use type
  - Related per capita use to population

Per capita by use type in gallons per person per day

Month	Domestic	Community
1	54	156
2	51	137
3	59	140
4	72	146
5	177	224
6	289	274
7	293	283
8	286	234
9	193	253
10	114	183
11	65	139
12	59	148



# Methods

- Wells with no population nor production data
  - Average monthly production volumes for wells of same use type

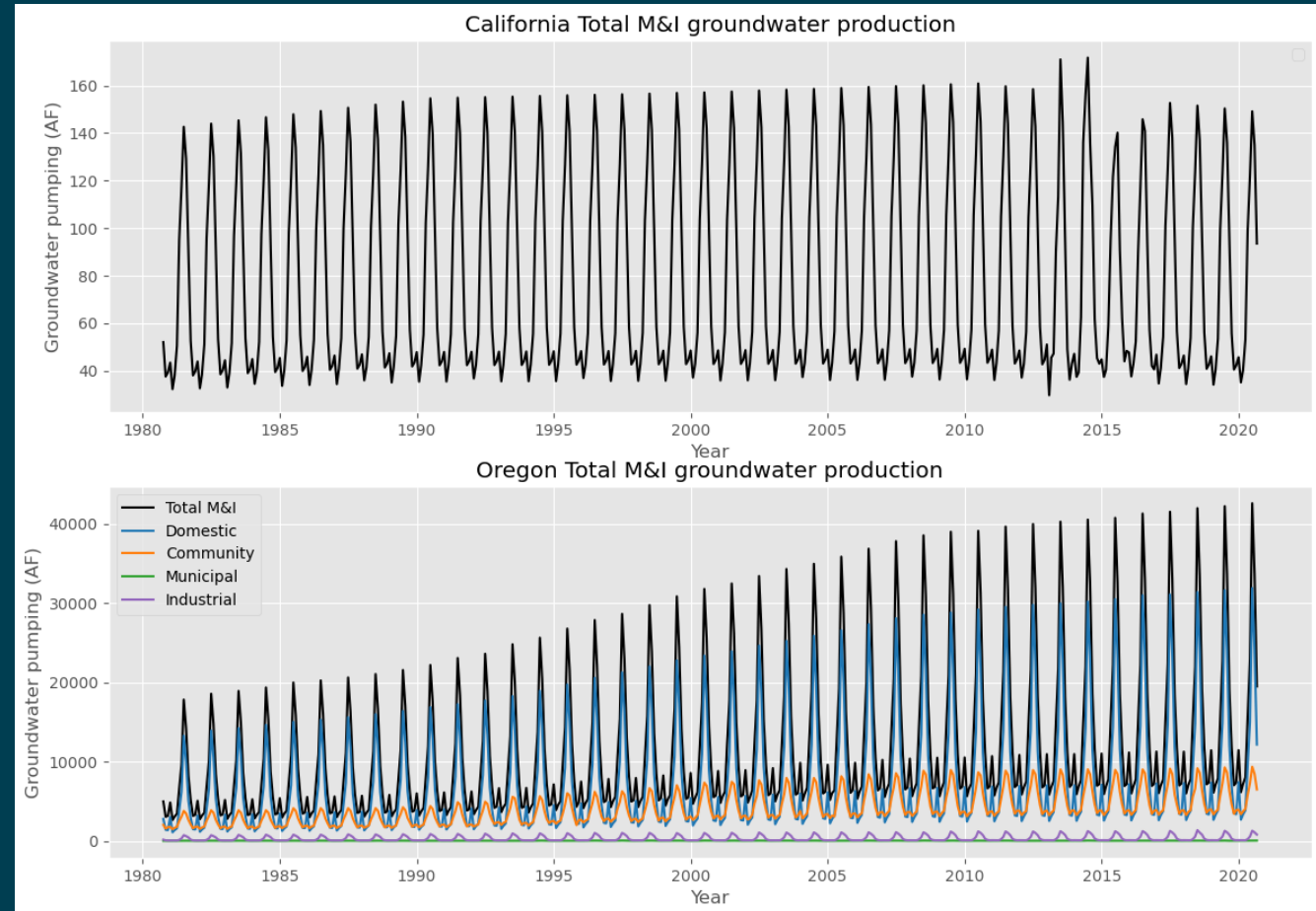
Average month production by use type in acre-feet

Month	Domestic	Community	Municipal	Industrial
1	1.0	35.5	4.4	0.9
2	0.3	30.2	3.7	0.8
3	0.4	33.4	4.0	0.9
4	0.5	35.7	4.2	0.8
5	1.2	51.1	5.6	2.1
6	2.0	64.3	8.3	5.4
7	4.1	82.3	10.7	12.5
8	3.1	76.6	9.0	10.4
9	1.6	56.1	6.7	7.6
10	0.9	41.4	4.5	2.7
11	0.5	31.5	3.9	1.3
12	0.4	35.1	4.4	0.8



# Results

- California
  - Overall trends reflects changes in population in Dorris and Tulelake.
- Oregon
  - Domestic:
    - 7844 wells, 63% total production
  - Community:
    - 112 wells, 34% total production
  - Municipal:
    - 3 wells, <1% total production
  - Industrial:
    - 100 wells, 3% total production



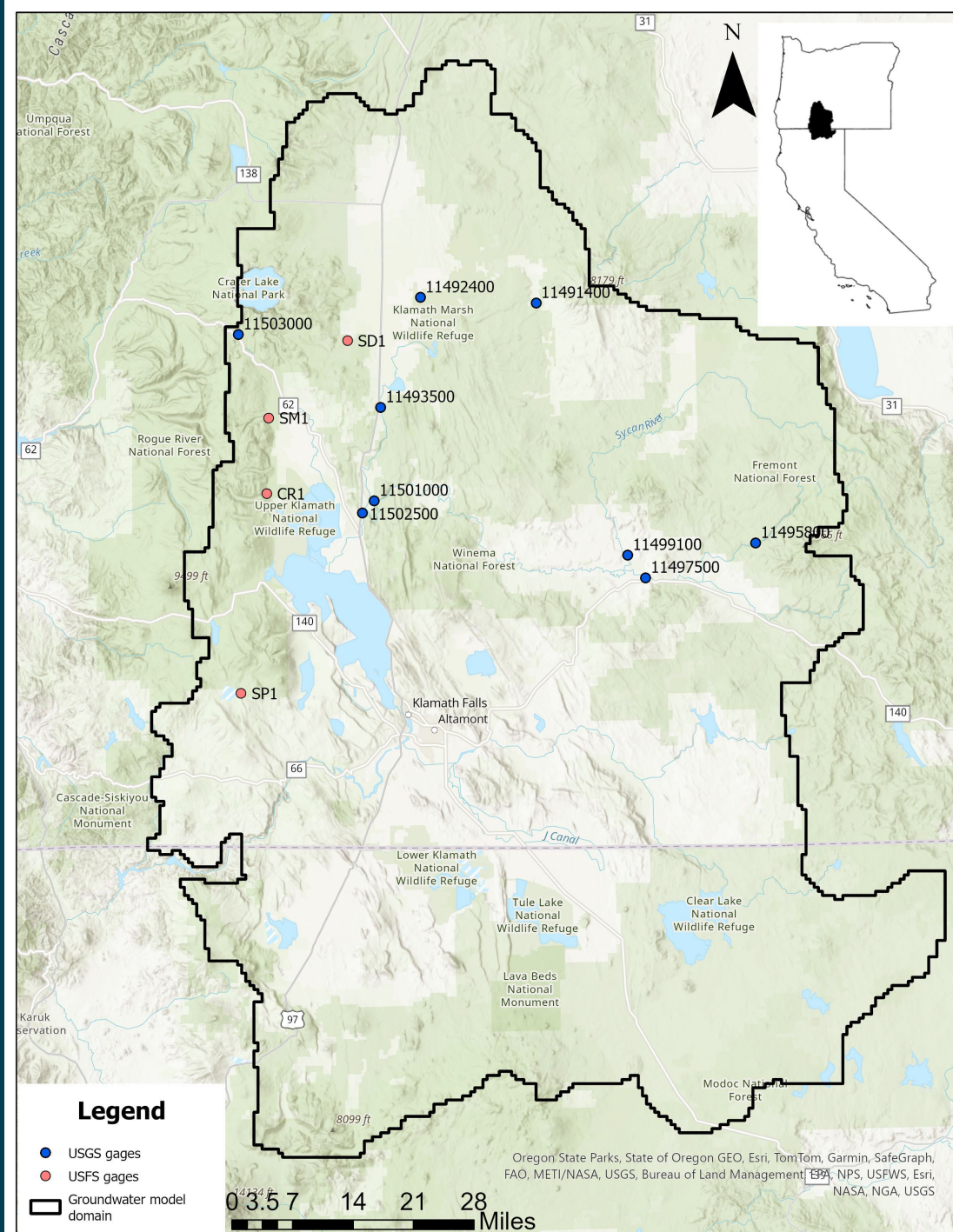


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# Estimating baseflow

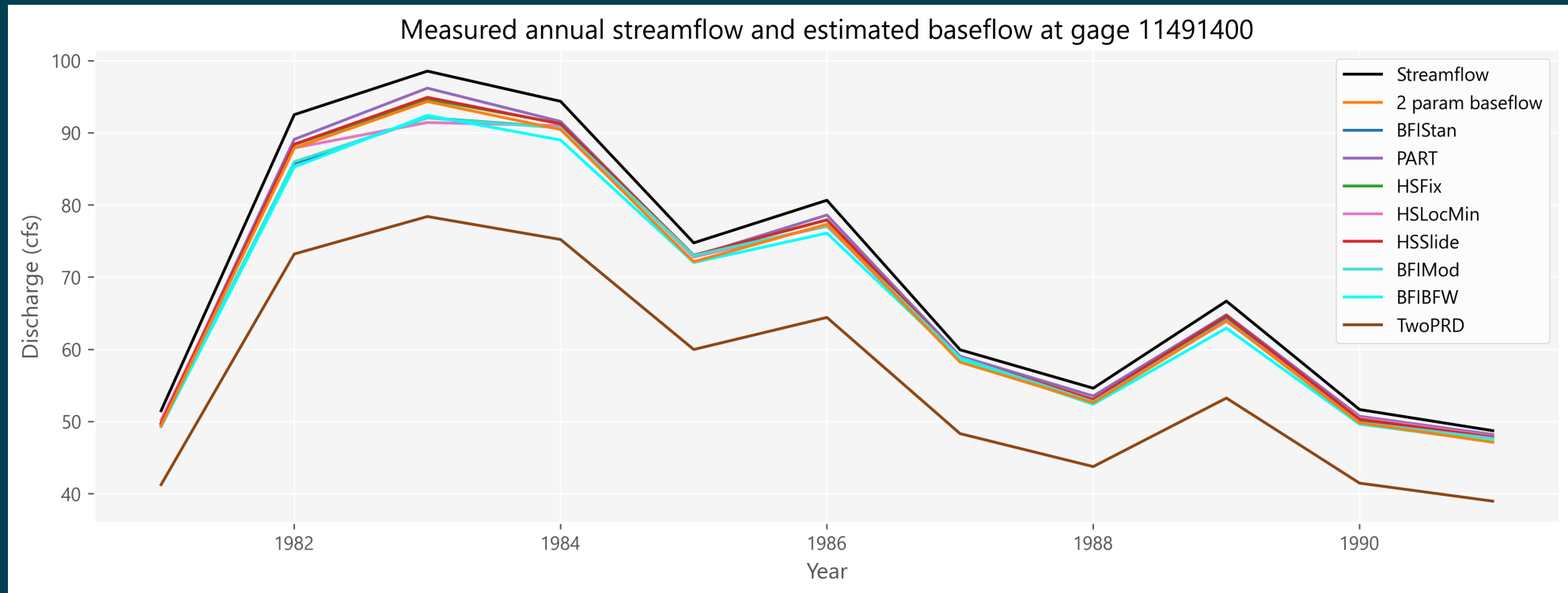
# Methods

- 2 parameter digital filter hydrograph separation method (Eckhardt, 2005)
  - Performs best on unmanaged streams
  - 13 gages throughout the study area were selected
- USGS Groundwater Toolbox
  - Tools to estimate the 2 parameters
  - Baseflow separation tool



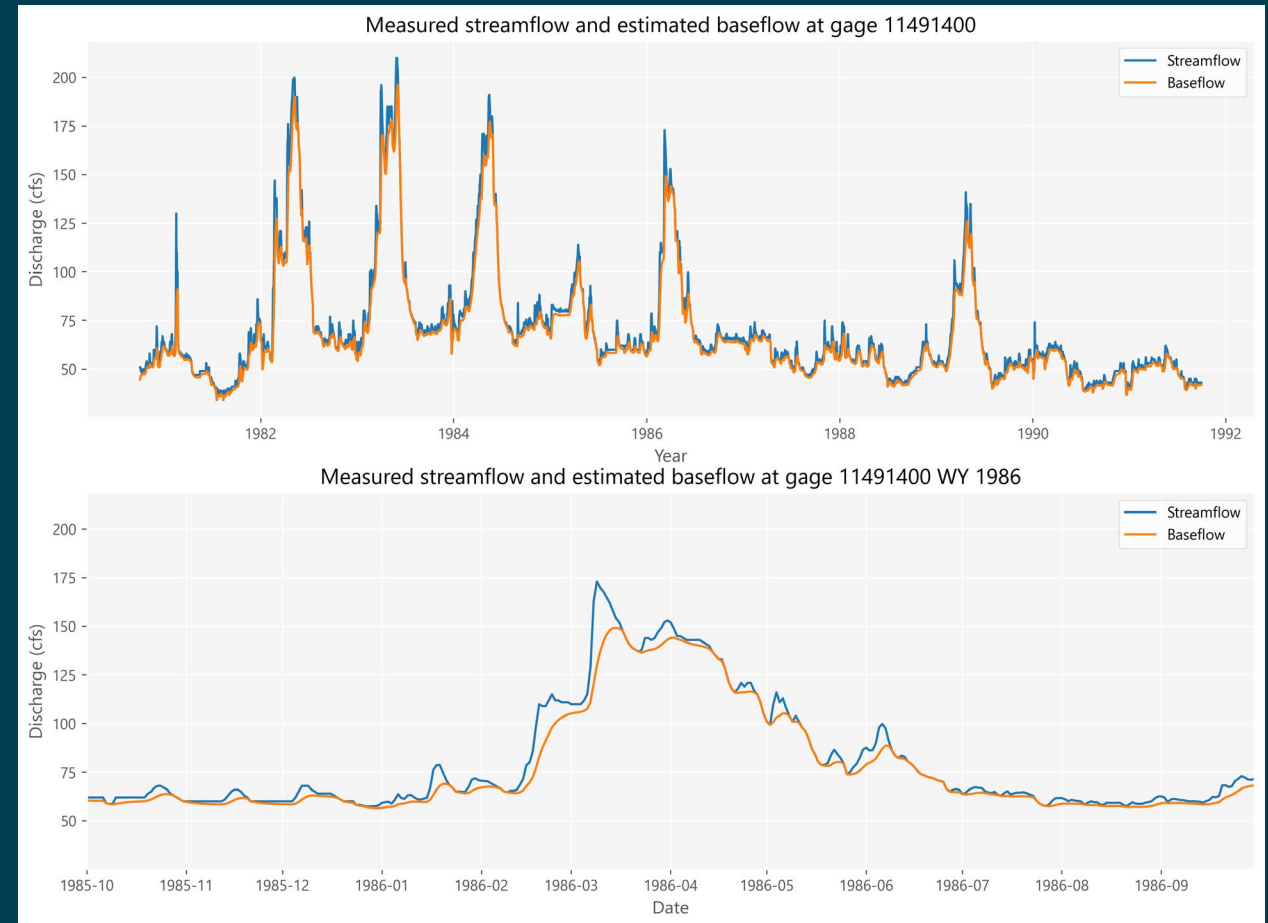
# Methods

- OWRD statewide baseflow separation analysis using various methods.
- Reclamation's estimates are comparable to OWRD's estimates.



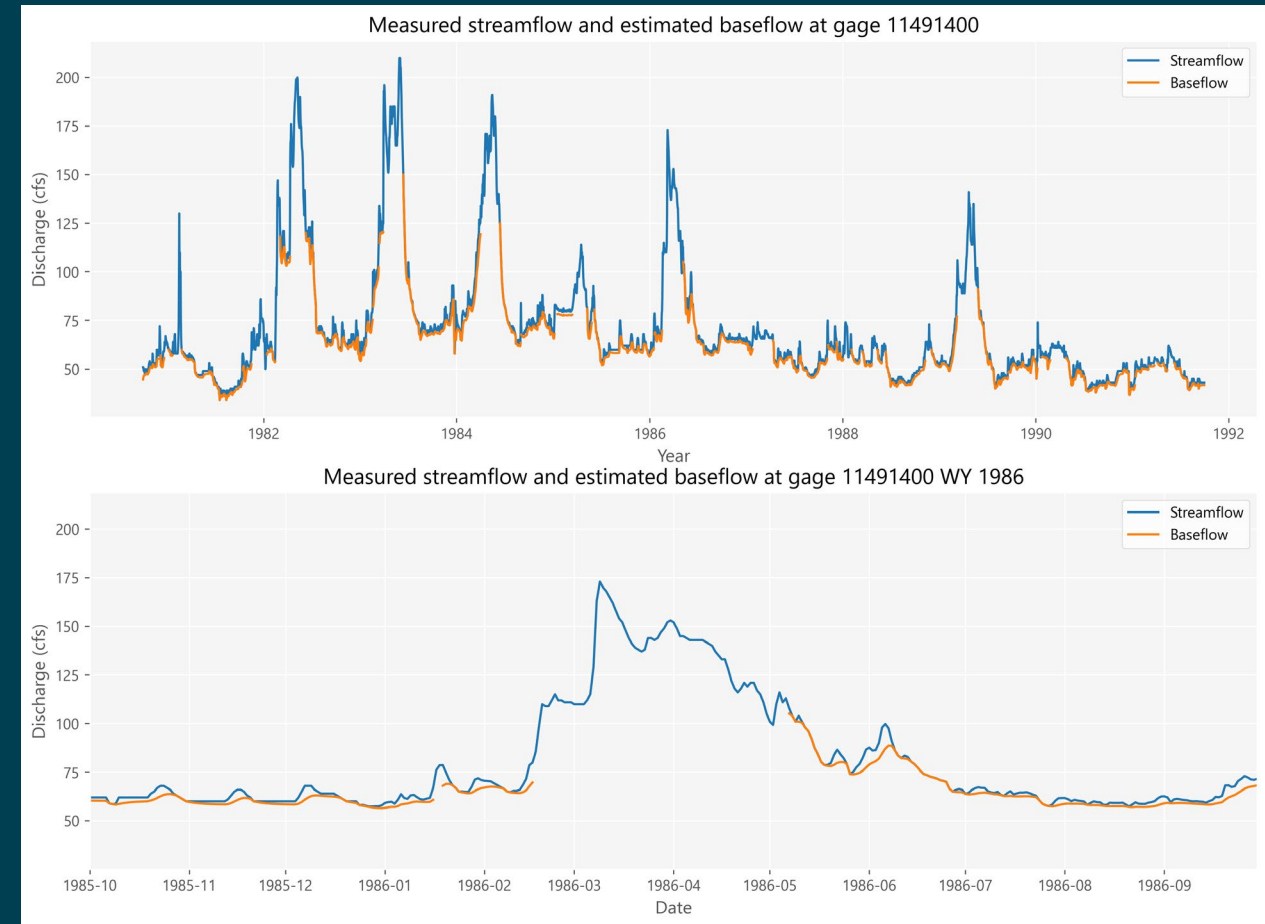
# Methods

- Low flow periods look reasonable
- High flow periods look high
- To address the uncertainties in high flow periods, additional filtering criteria were developed.



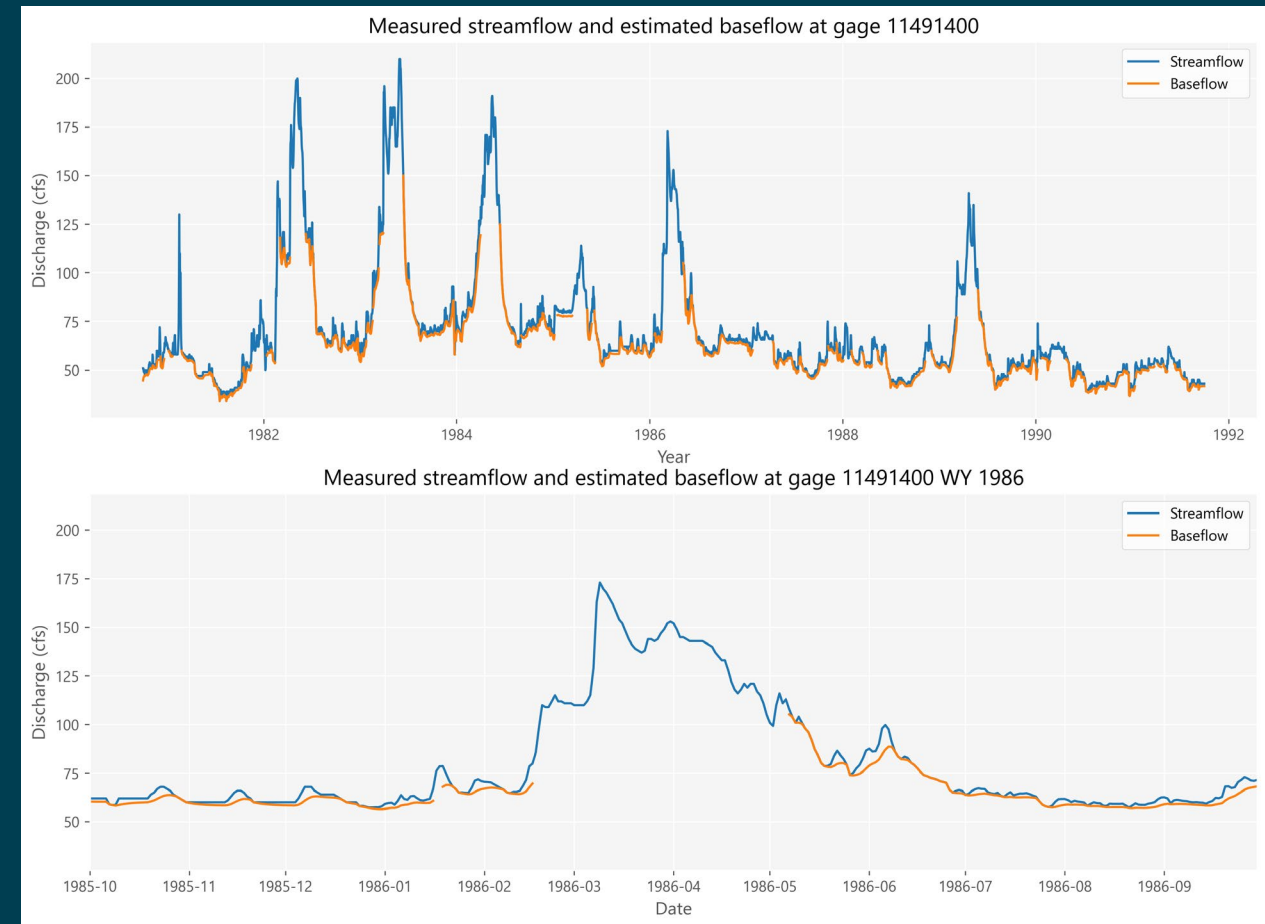
# Results – developing a weighted dataset

- 3 additional data filters
  - Days of high flows :  
80<sup>th</sup> percentile or more of annual streamflow
  - Days of high surface water runoff:  
ratio of baseflow to streamflow 0.85 or less
  - Consecutive data:  
Fewer than 10 consecutive days of data



# Application

- Calibration targets for the Groundwater model
- The groundwater model has other calibration targets during the times baseflow is weighted as 0



# Summary

- **Agricultural data analysis**
  - Demands based approach to estimate various agricultural processes
  - Inputs to the surface water model, groundwater model, and mass balance model
- **M&I pumping data analysis**
  - Related wells with production data or population data to wells with the same use type
  - Inputs to the groundwater model
- **Baseflow separation analysis**
  - 2 parameter digital filter to separate baseflow from hydrograph data
  - Additional weighting scheme to keep more confident value
  - Calibration targets for the groundwater model



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# Additional questions and discussion



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