West Turlock Subbasin Groundwater Sustainability Agency (WTSGSA)
East Turlock Subbasin Groundwater Sustainability Agency (ETSGSA)

Turlock Subbasin Groundwater Sustainability Plan (GSP) Technical Workshop No. 4

Joint Technical Advisory Committees (TACs) Meeting

December 12, 2019

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Agenda

- Background & Model Development
- Evaluation of DRAFT Model Calibration
  - Calibration Statistics- DRAFT
  - Groundwater Levels- DRAFT
  - Stream Hydrographs- DRAFT
- Review of Water Budgets
  - Land & Water Use Budgets- DRAFT
  - Groundwater Budgets- DRAFT

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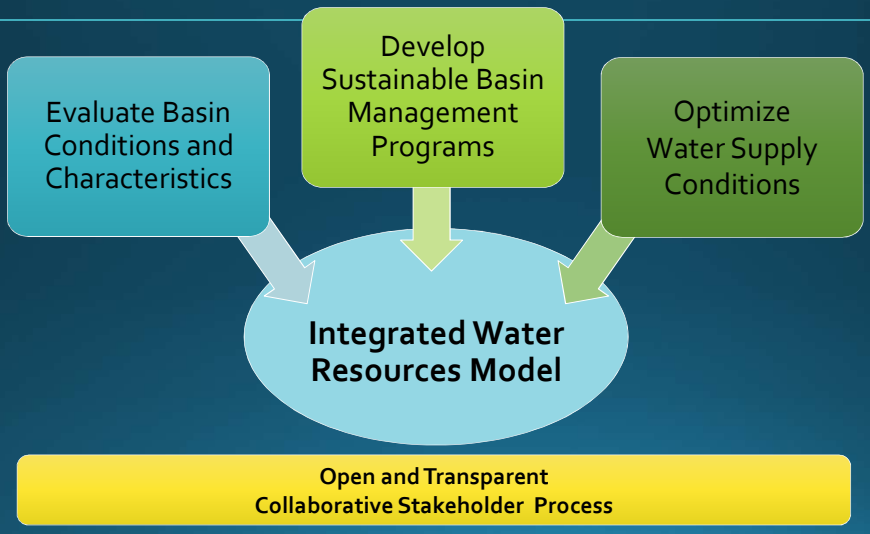
Goals for C2VSimFG-Turlock



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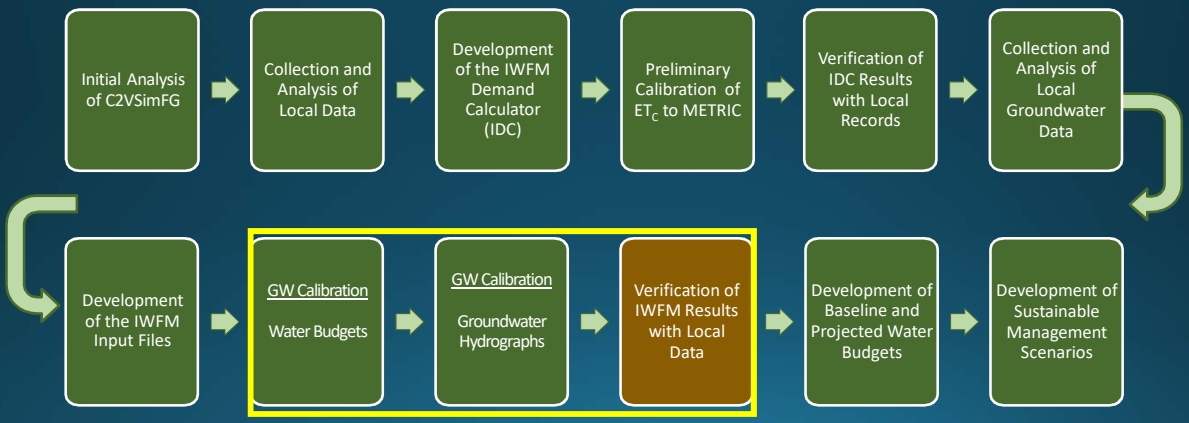
Model Development Process



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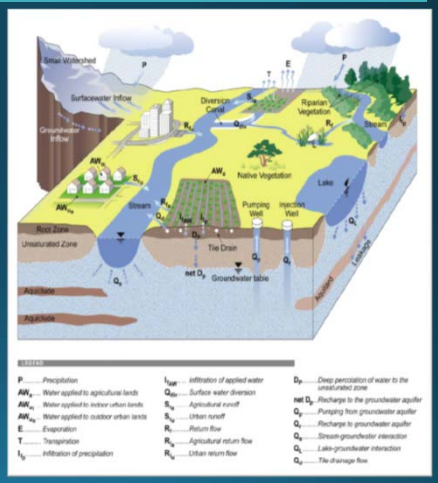
Numerical Model Platform

- **I**ntegrated **W**ater **F**low **M**odel (IWFM)
- Developed and Supported by DWR
- Will be used by DWR to evaluate GSPs
- Used in numerous basins throughout the state including the Modesto and Merced Subbasins.
- **Recommended by DWR for SGMA and GSP Development**



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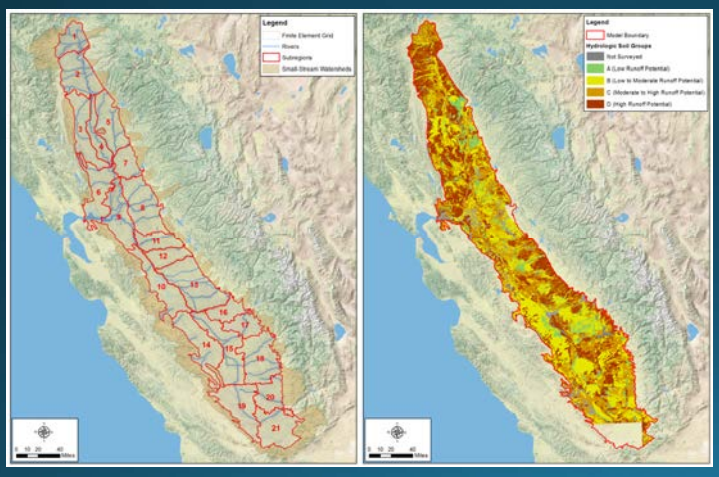
IWFM in the Central Valley



C2VSimFG Grid Statistics

- 30,179 Nodes
  - Stream Lines
  - Agency Boundaries
  - ¼ Mile Discretization
- 32,537 Elements
  - Ave. Size = 400 Acres
  - 13,256,118 Total Acres
- 110 Stream Reaches

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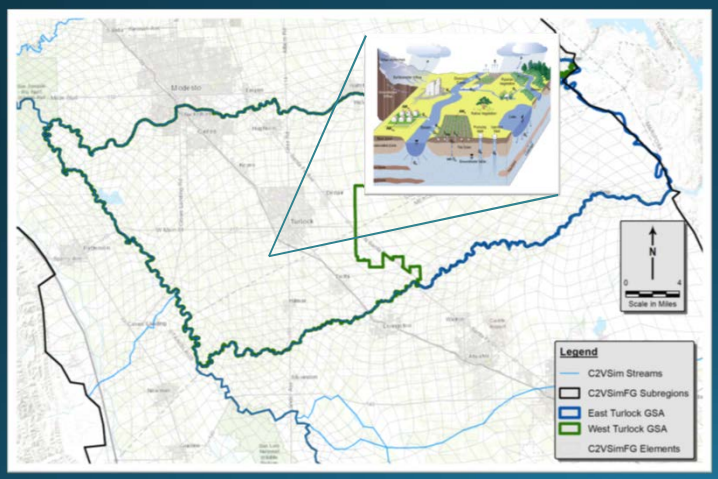
C2VSimFG in the Turlock Subbasin



Grid Statistics

- 865 Nodes
  - Follows Streams & DWR Demand Area Units
  - Avg 1.5-Mile Discretization
- 960 Elements
  - Ave. Size = 362 Acres
  - 348,000 Total Acres
- 3 Major Rivers
  - Merced River
  - San Joaquin River
  - Tuolumne River

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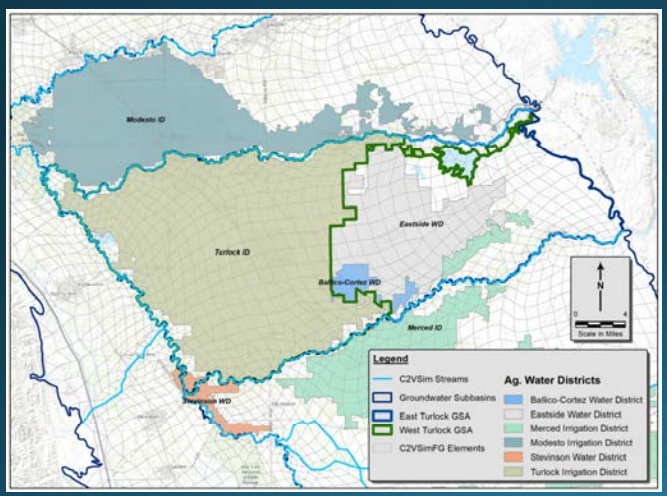
Turlock Subbasin Ag. Agencies



- Entirely encompasses:
  - Turlock ID
  - Eastside WD
  - Ballico-Cortez WD
- Partially encompasses:
  - Merced ID
  - Stevinson WD

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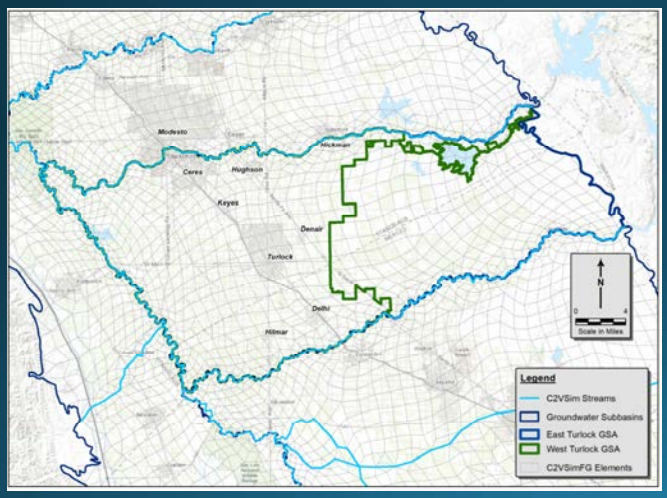
Turlock Subbasin Urban Areas



- West GSA:
  - Modesto
  - Ceres
  - Hughson
  - Keyes
  - Hickman
  - Denair
  - Delhi
  - Hilmar
  - Turlock
- East GSA:
  - Unincorporated Areas

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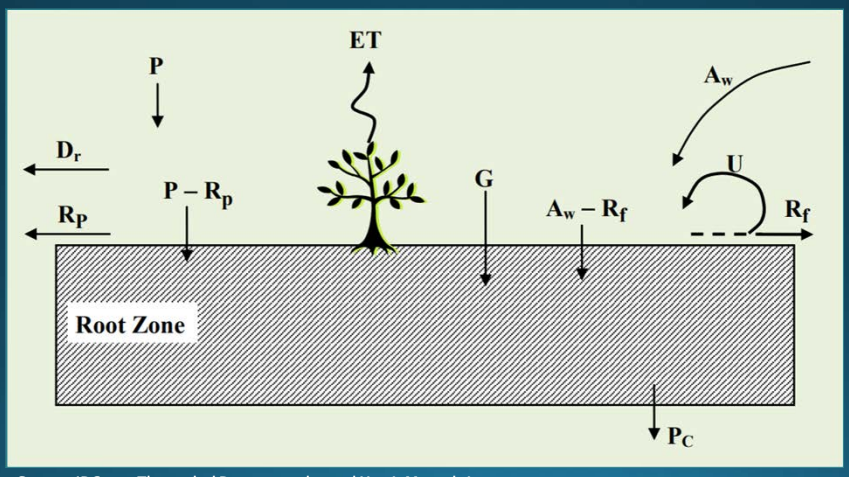
The IWFM Demand Calculator (IDC)



Source: IDC 2015 Theoretical Documentation and User's Manual, August 2017

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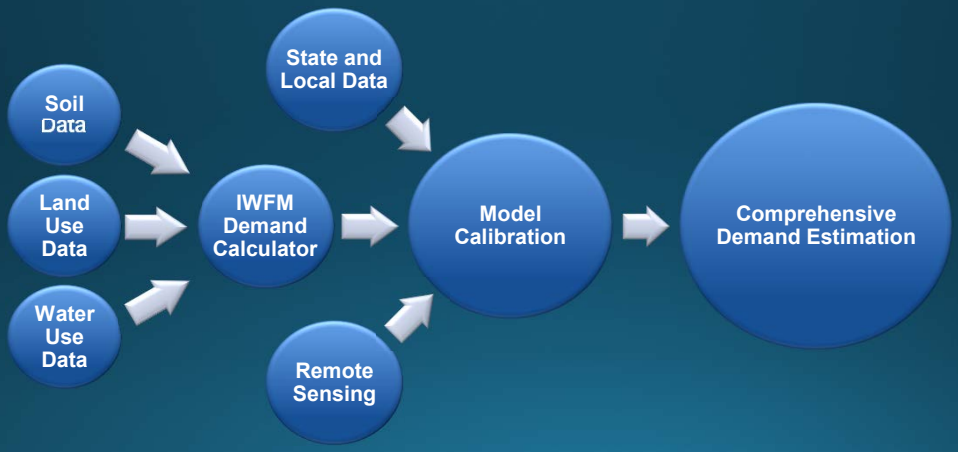
C2VSimFG-Turlock IDC Development



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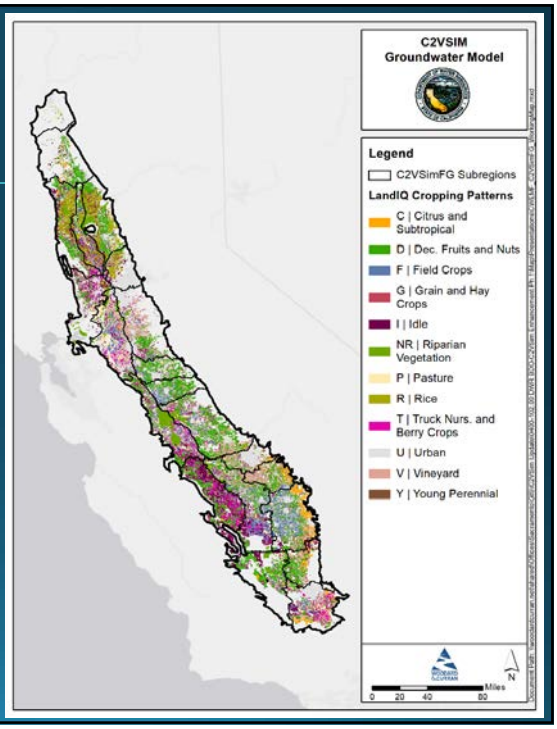
Land Use Data

Data Sources

- DWR County Land Use Surveys
- DWR Statewide (LandIQ) Land Use
- DWR Quad Map-Based Land Use
- DWR Decadal Estimated Land Use
- Locally Refined Data
  - Stanislaus County (2002 to 2015)
  - Merced County (2011-2015)



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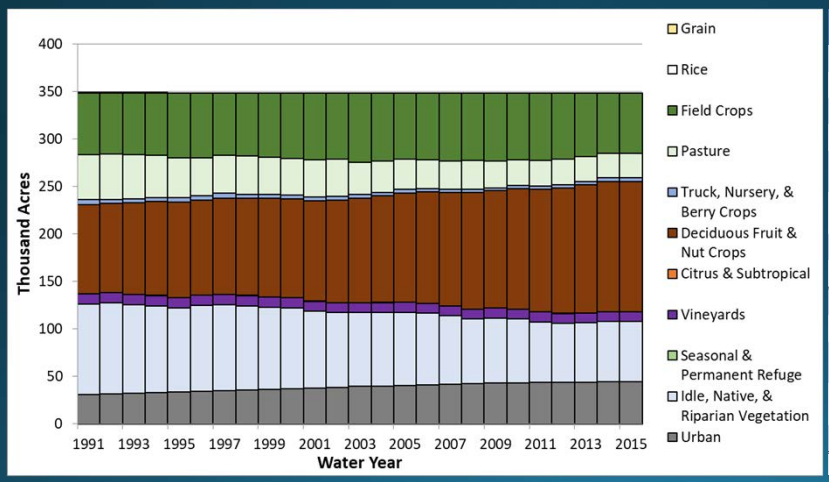
Turlock Subbasin
Land Use



Land Use	2015 Acres
Grain	0
Rice	0
Field Crops	63,149
Pasture	26,124
Truck, Nursery, & Berry Crops	3,554
Deciduous Fruit & Nut Crops	137,427
Citrus & Subtropical	140
Vineyards	10,151
Total Ag. Acreage	240,545
Seasonal & Permanent Refuge	0
Idle, Native, & Riparian Vegetation	63,549
Urban	44,245
TOTAL	348,338

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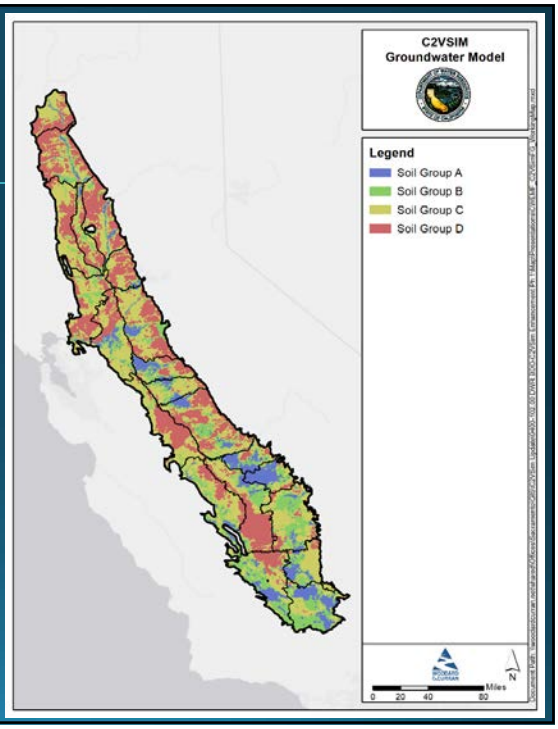
Soil Parameters

SSURGO and STATSGO

- Elemental Discretization
- Soil Hydrologic Group
  - Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups based on the soil's physical characteristics.
- Input Parameters
  - Hydraulic Conductivity
  - Pore Size Distribution Index
  - Total Porosity
  - Field Capacity
  - Wilting Point



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Root-Zone Parameters

	Wilting Point	Field Capacity	Porosity	Pore Size Distribution Index	Hydraulic Conductivity[1]
clay loam	0.211	0.350	0.439	0.15	0.3
sandy clay loam	0.153	0.261	0.397	0.16	7.8
loam	0.120	0.241	0.392	0.18	9.9
sandy loam	0.077	0.158	0.384	0.37	19.2
loamy sand	0.022	0.081	0.400	1.02	29.7
sand	0.005	0.038	0.424	2.65	36.7

[1] Units of hydraulic conductivity are in feet per day

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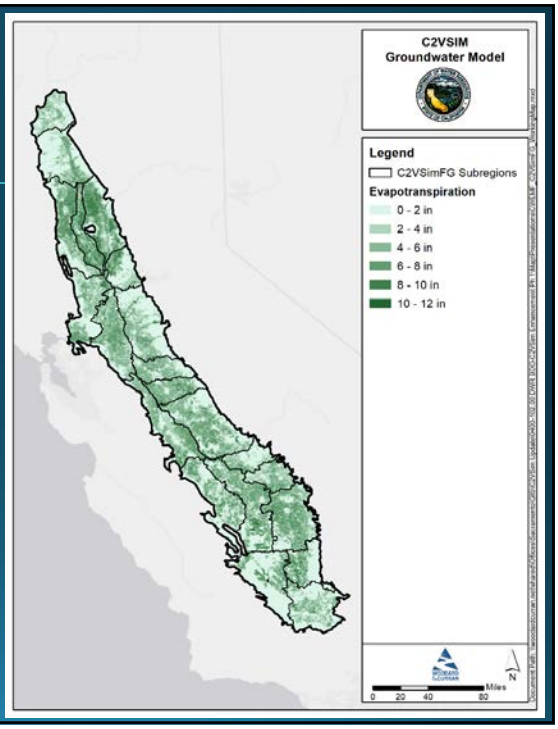
Evapotranspiration

Data Sources

- Irrigation Training and Research Center (ITRC)
- Locally Refined Data (AWMP)
- Remote Sensing
- Per. Comm with Local ID Representatives



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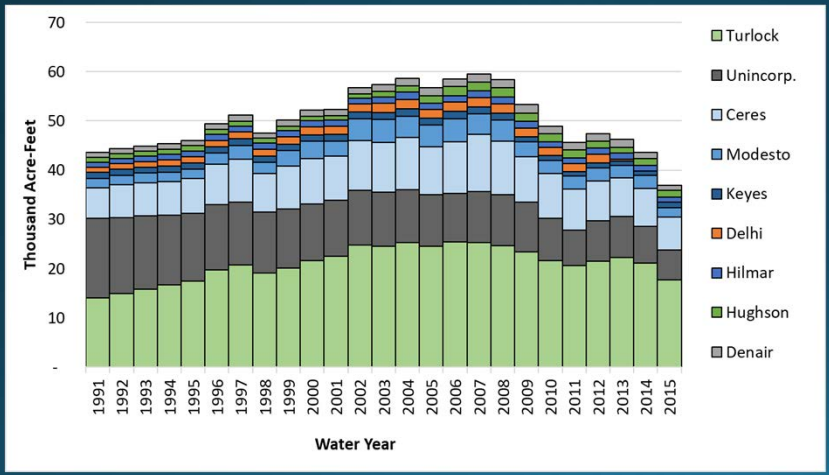
Turlock Subbasin

Total Urban Demand



Water Year	AF
1991	39,855
1992	40,139
1993	40,678
1994	41,035
1995	44,723
1996	48,002
1997	49,924
1998	45,885
1999	49,131
2000	52,526
2001	53,620
2002	57,144
2003	57,106
2004	58,775
2005	56,645
2006	57,870
2007	57,821
2008	57,464
2009	54,041
2010	48,078
2011	45,890
2012	47,563
2013	47,454
2014	46,649
2015	40,096

Note: City of Modesto pumping is limited to production wells within the Turlock Subbasin

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Hydrologic Period

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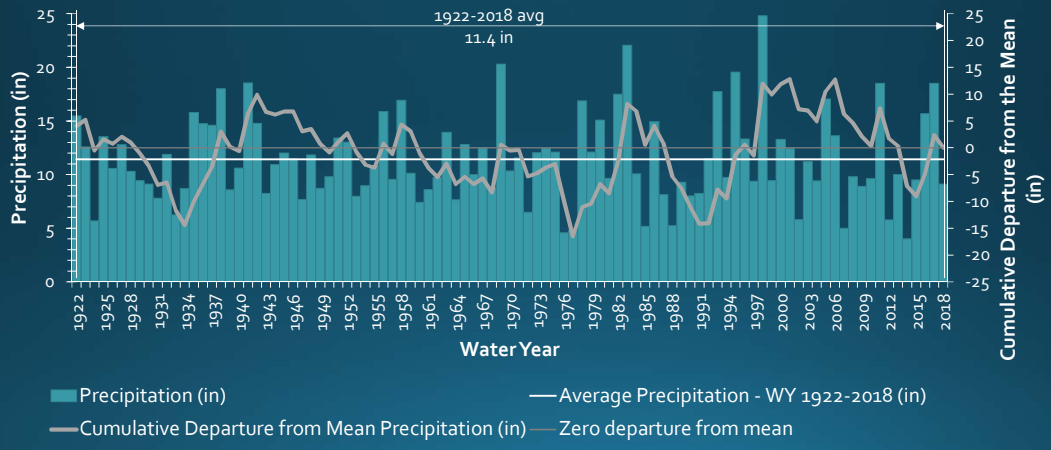
Precipitation



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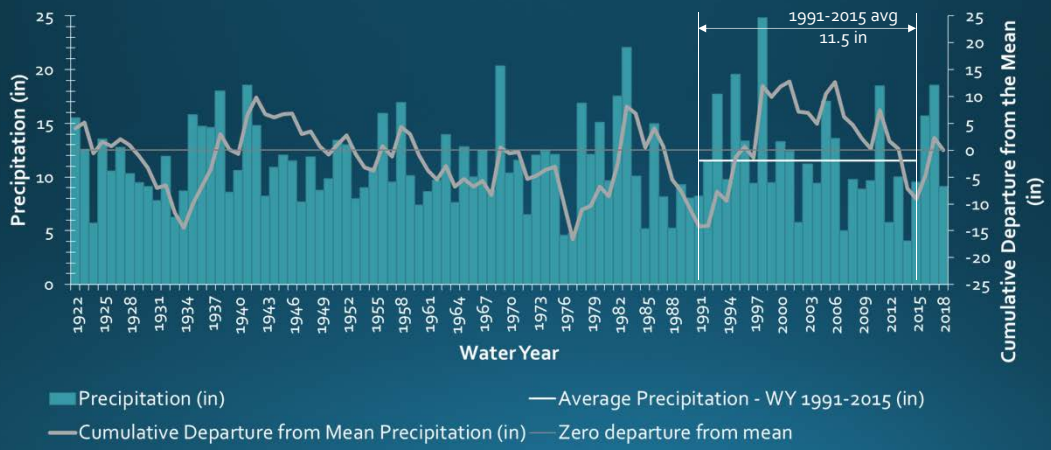
Precipitation



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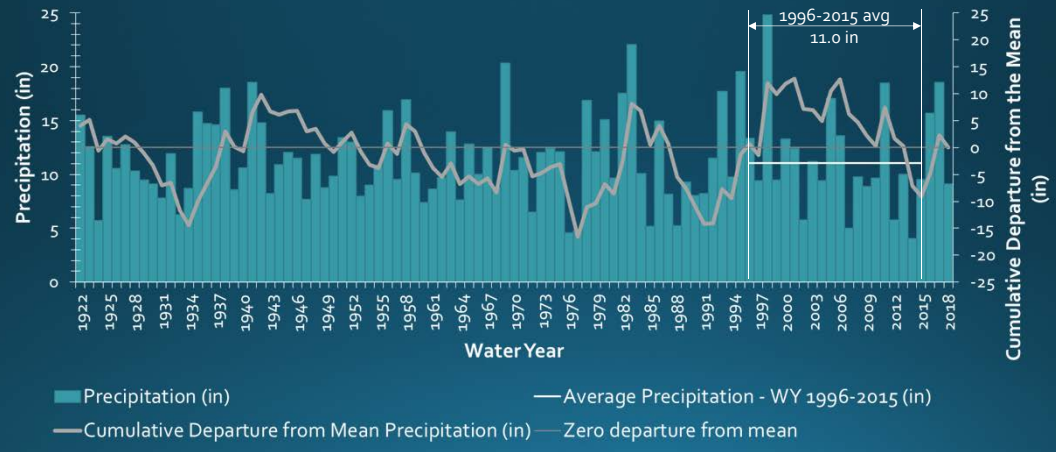
Precipitation



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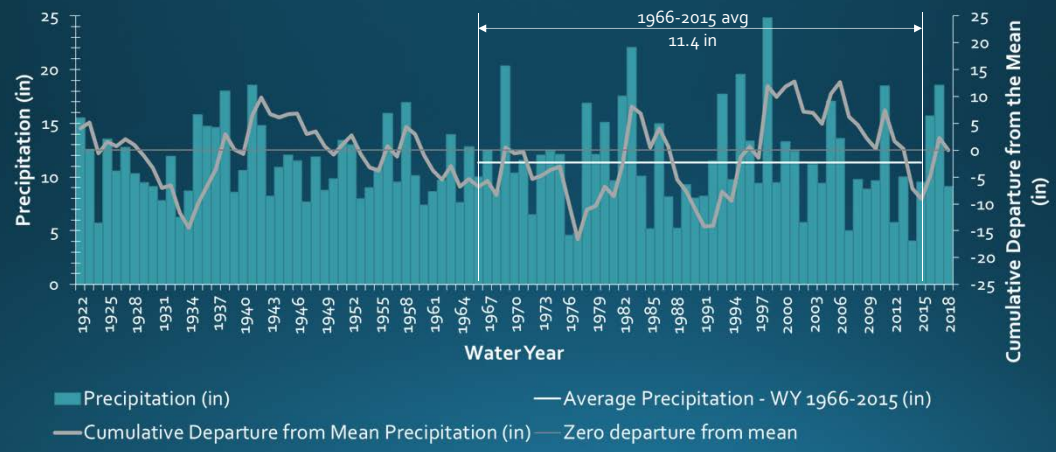
Precipitation



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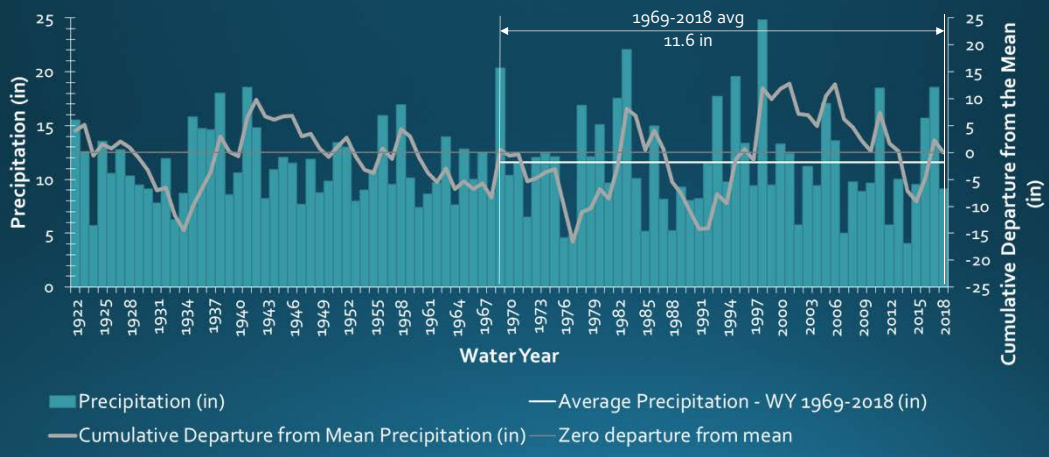
Precipitation



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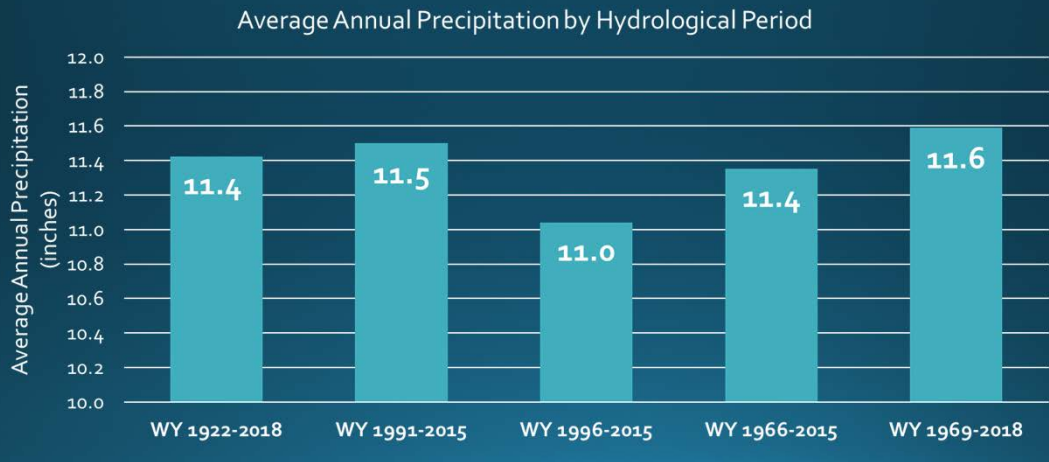
Precipitation

Water Year	1922-2018	1991-2015	1996-2015	1966-2015	1969-2018
Average Annual Precipitation (inches)	11.4	11.5	11.0	11.4	11.6



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Precipitation

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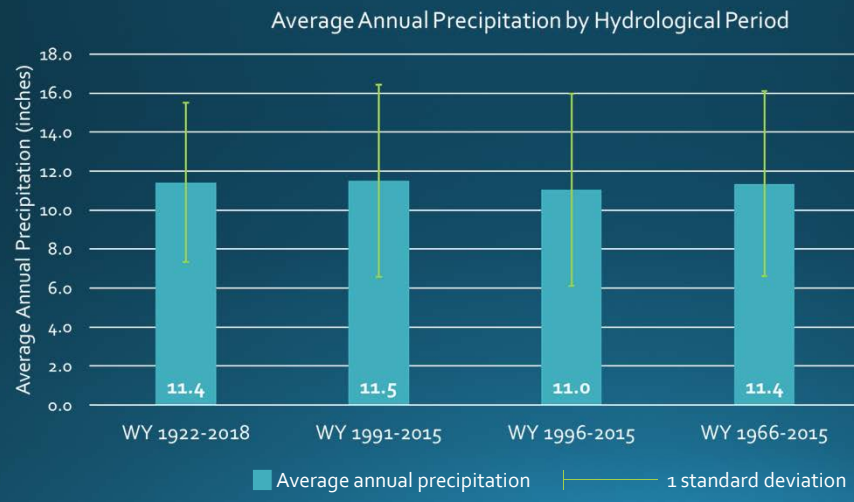

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Model Basic Features

- Historical Period: 1922-2015
- Calibration Period: 1991-2015
- Hydrogeologic Layering:
  - 4 Basic Model Layers
  - 3 Principal Aquifers
    1. Upper Aquifer, above Corcoran on the West
    2. Lower Aquifer, below Corcoran on the West
    3. One Principal Aquifer to the East)
- GSAs boundaries are delineated as close as possible using the C2VSim-FG Grid
- Hydrologic Features:
  - Merced, San Joaquin, & Tuolumne Rivers

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Model Calibration

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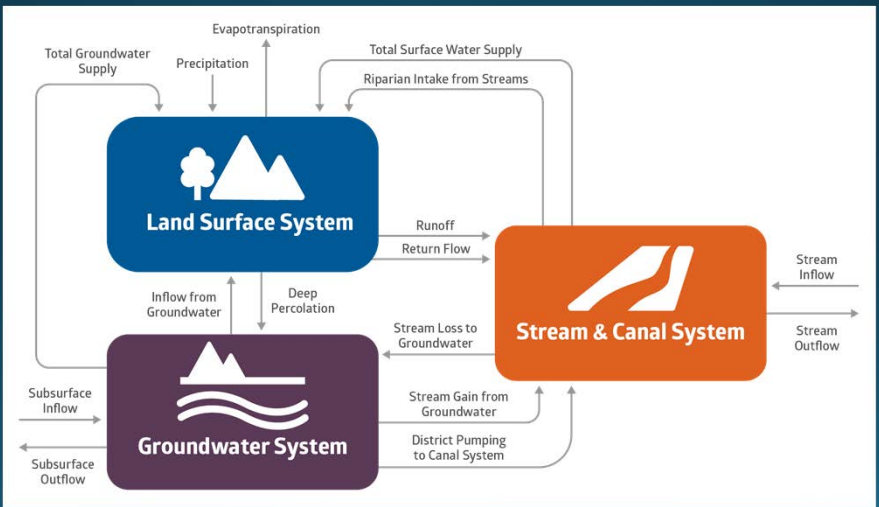
Model Modules Inter-Relationship



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Calibration Process

- **Calibration Goals:**
  - Produce water budgets that are reasonable and defensible and are comparable with other published reports
    - Land & Water Use
    - Groundwater
    - Stream
  - Minimize differences between simulated and observed GW levels at:
    - GW levels at select wells used for model calibration
    - Streamflow at select gaging stations
- Adjust and refine parameters governing the root zone and land surface processes for the IDC simulation
- Adjust and refine aquifer hydrogeologic parameters to achieve calibration goals
- Iterate between the IDC and full IWFM to achieve appropriate balance between the land surface processes and groundwater processes in achieving a calibrated comprehensive model

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Modeling Uncertainties are Due to Various Factors:

- **Structural Uncertainties**
  - Theoretical Concepts and Representation of the Natural and Physical System
  - Formulation, Code Development, Solution Techniques and Assumptions
  - Representation of Physical Features
  - Model Spatial and Temporal Resolution
- **Data Uncertainties**
  - Data and Information Accuracy, Data Gaps and Estimations
  - Data Spatial and Temporal Resolution
- **Calibration Uncertainties**
  - Calibration Approach, Target Characteristics, Accuracy
  - Estimates of Hydrologic and Hydrogeologic Parameters
- **Projection Uncertainties**
  - Primarily due to Data Projections and Forecasting Methods on:
    - Land Use and Population
    - Water Supply Conditions
    - Climatic Conditions

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Model Limitations

- Spatial resolution and grid size relative to:
  - Physical features (e.g., streams, geologic conditions, jurisdictional boundaries, land surface topography, etc.)
  - Operational features (Wells, canals, land parcels, etc.)
- Spatial and temporal resolution of data
- Data gap analysis
- Modeling a complex physical system

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Groundwater Levels

Model Calibration

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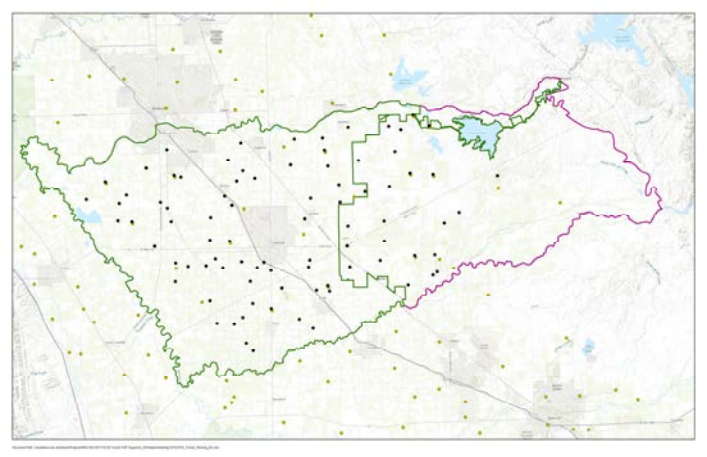
Calibration Well Selection



- 125 Calibration Wells
- Considerations:
  - Period of Record
  - Dedicated monitoring location
  - Availability of construction information
  - Minimal outliers

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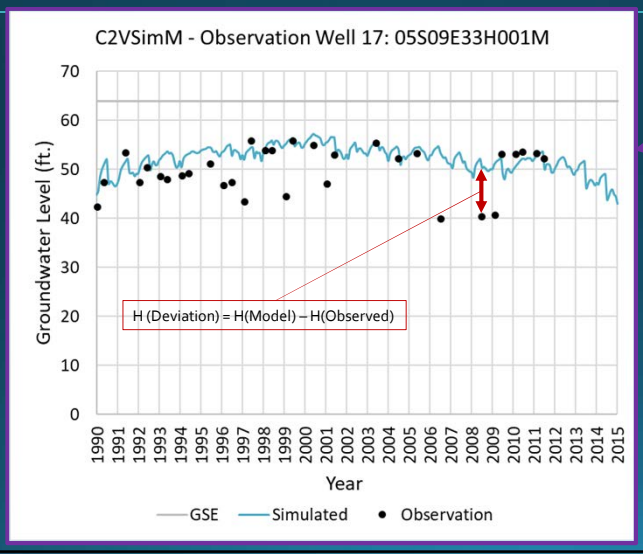
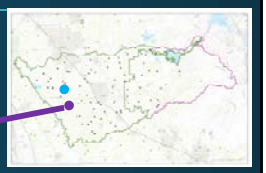
Groundwater Hydrographs- Example





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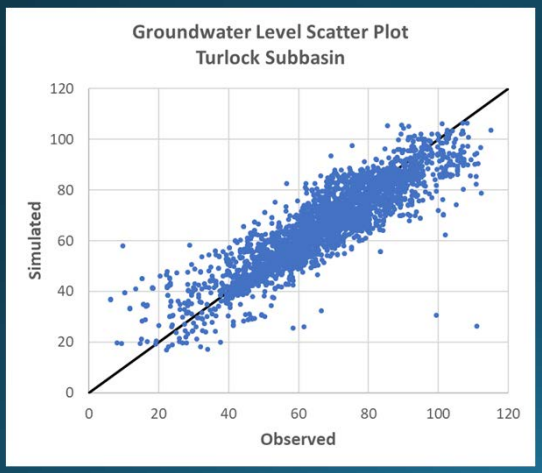
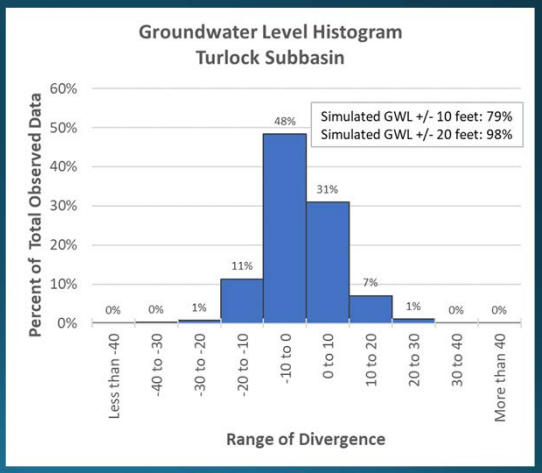
Calibration Statistics: Turlock Subbasin





Units: Feet

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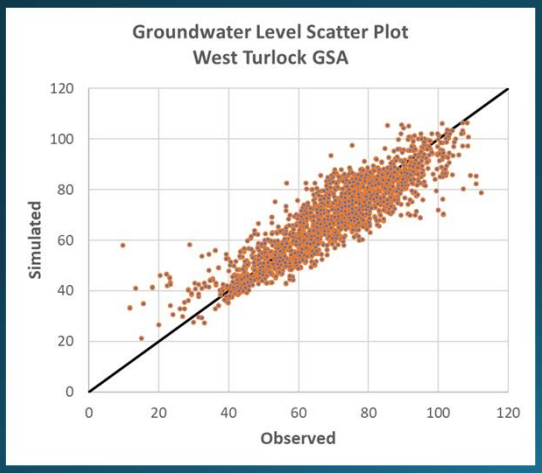
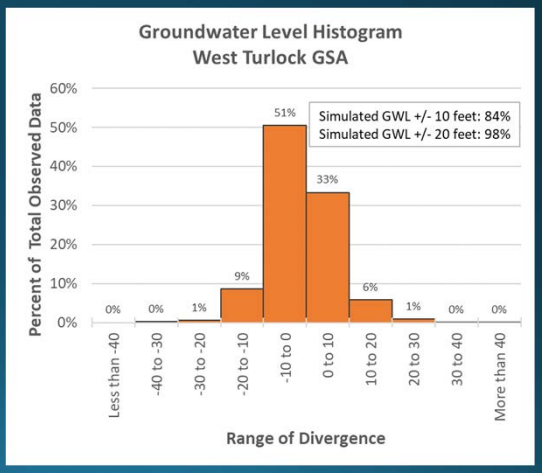
Calibration Statistics: West Turlock GSA





Units: Feet

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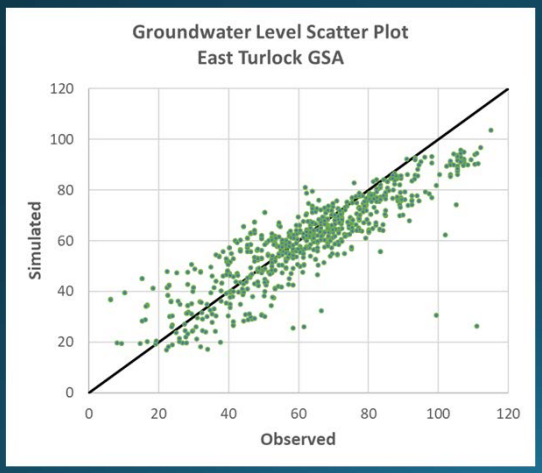
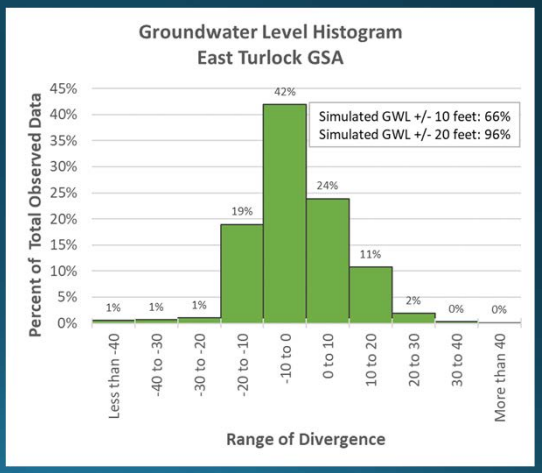
Calibration Statistics: East Turlock GSA





Units: Feet

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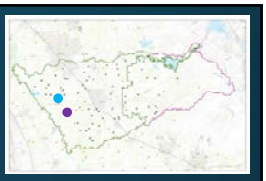
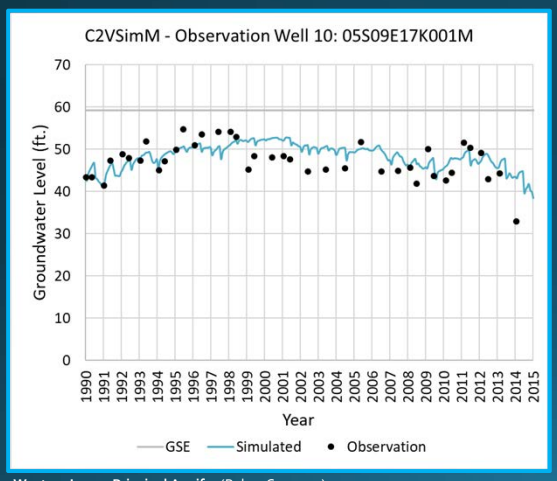
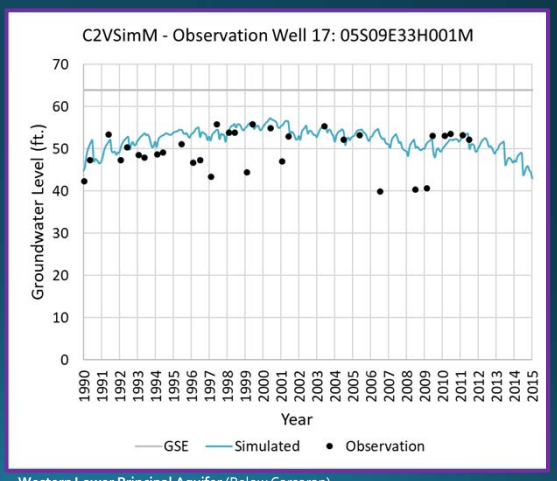
Groundwater Hydrographs





Western Lower Principal Aquifer (Below Corcoran)



Western Lower Principal Aquifer (Below Corcoran)

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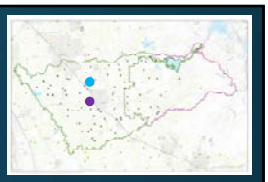
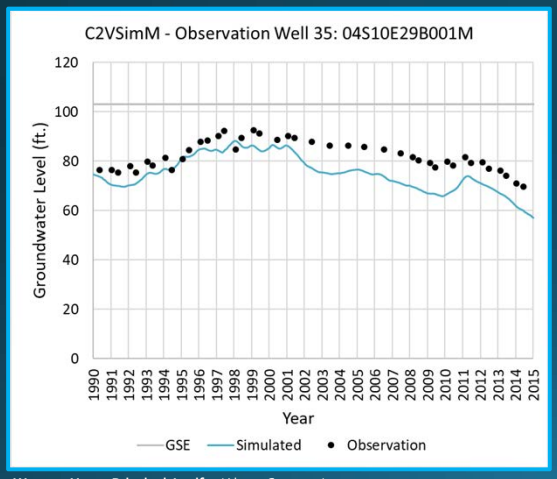
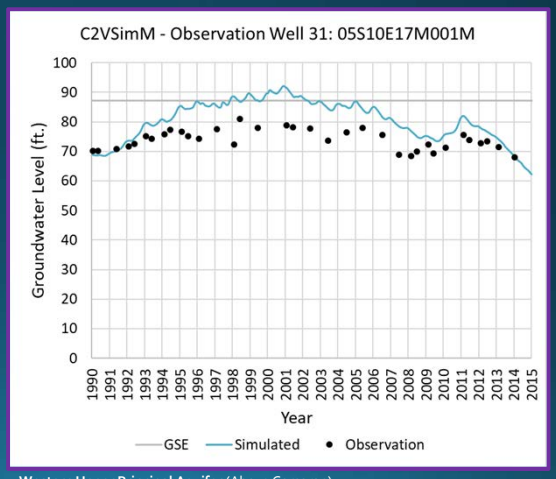
Groundwater Hydrographs





Western Upper Principal Aquifer (Above Corcoran)



Western Upper Principal Aquifer (Above Corcoran)

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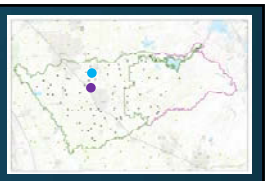
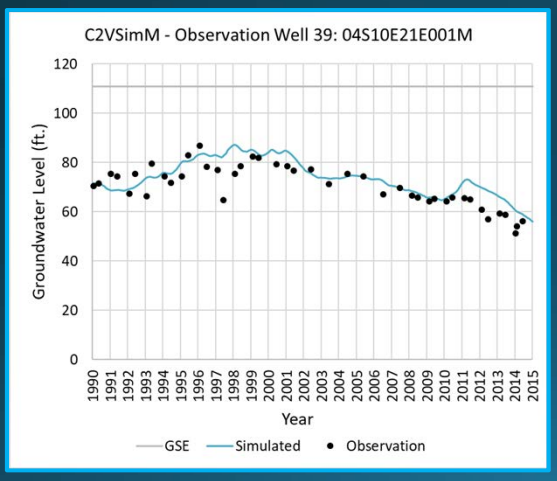
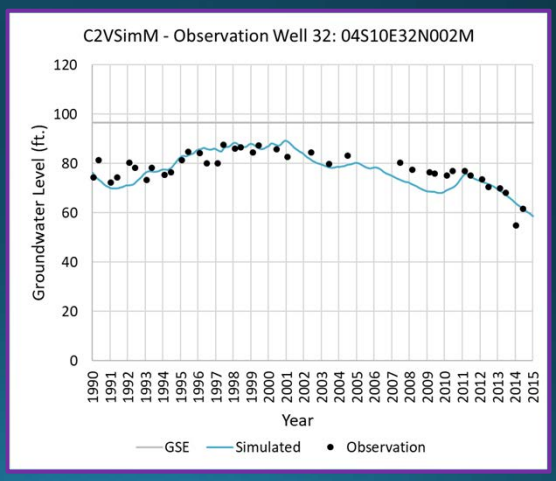
Groundwater Hydrographs





Eastern Principal Aquifer



Eastern Principal Aquifer

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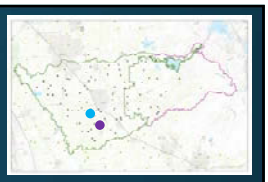
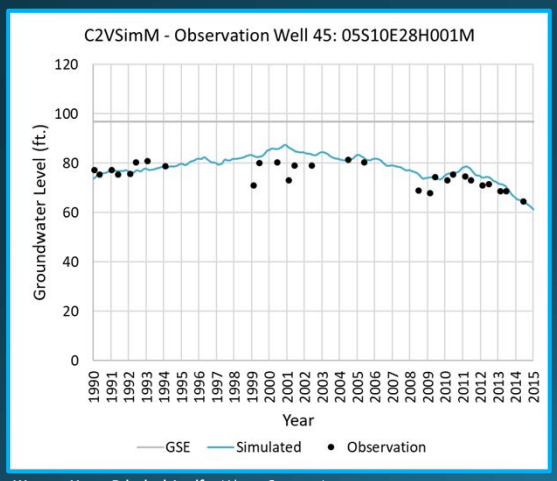
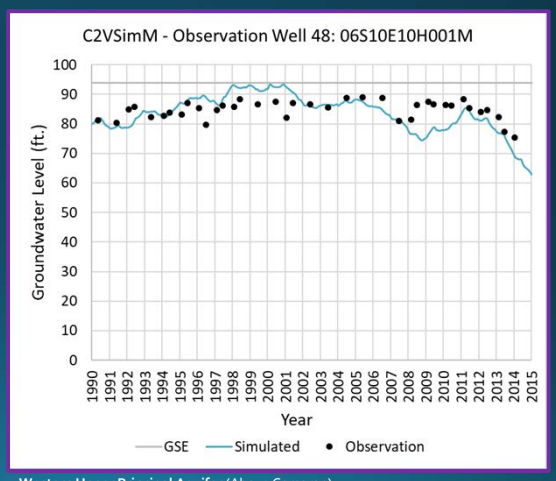
Groundwater Hydrographs





Western Upper Principal Aquifer (Above Corcoran)



Western Upper Principal Aquifer (Above Corcoran)

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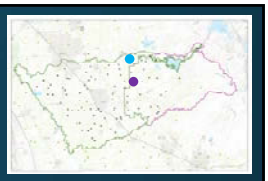
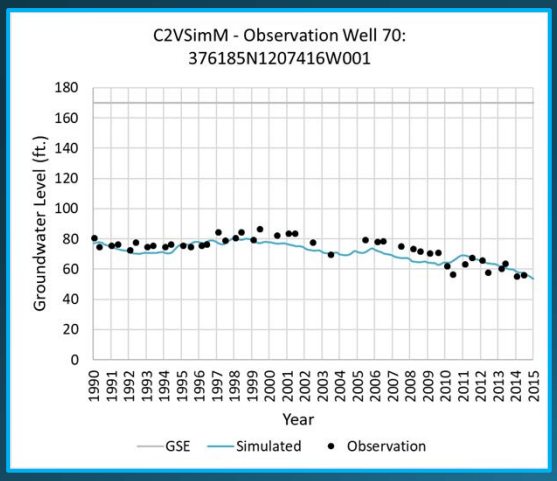
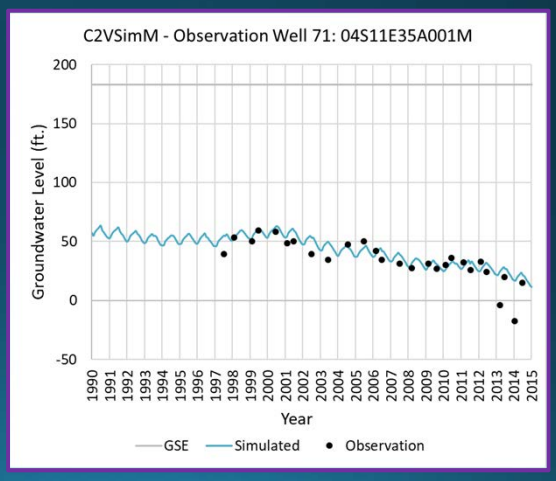
Groundwater Hydrographs





Eastern Principal Aquifer



Eastern Principal Aquifer

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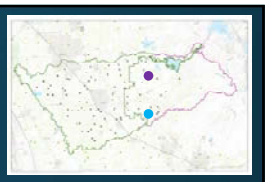
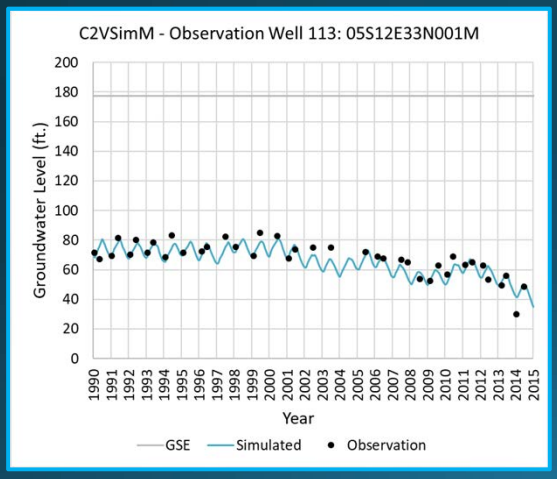
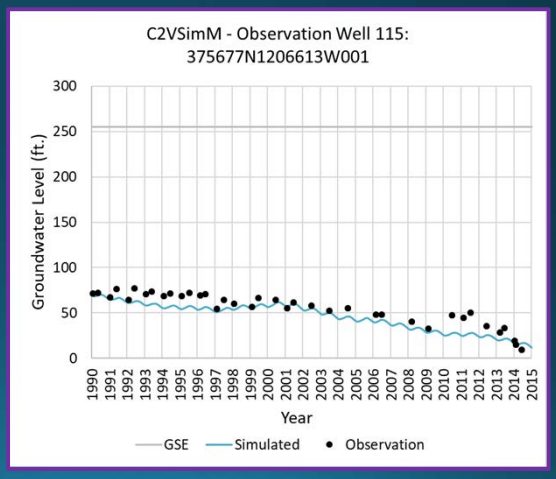
Groundwater Hydrographs





Eastern Principal Aquifer



Eastern Principal Aquifer

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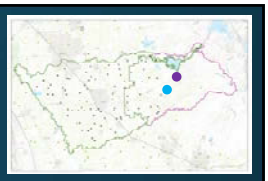
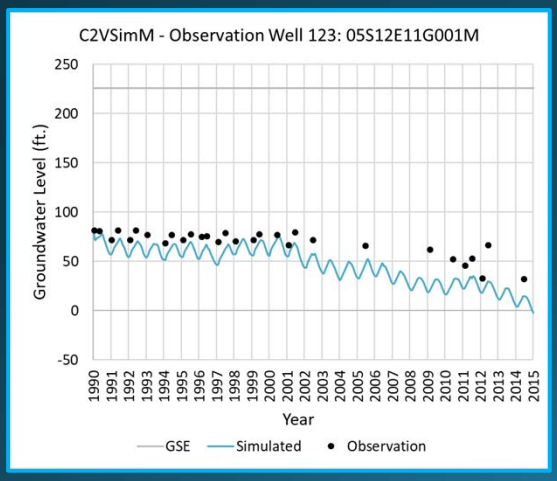
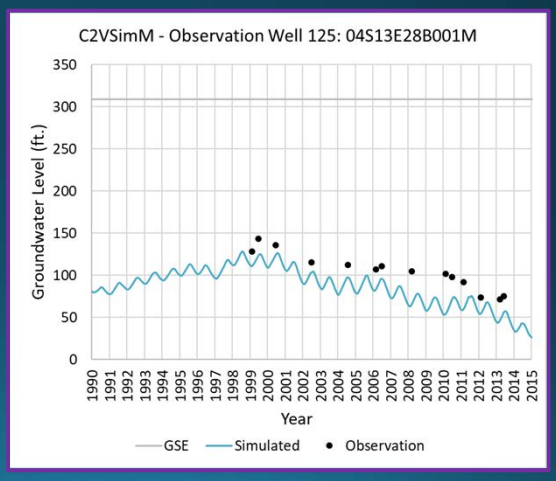
Groundwater Hydrographs





Eastern Principal Aquifer



Eastern Principal Aquifer

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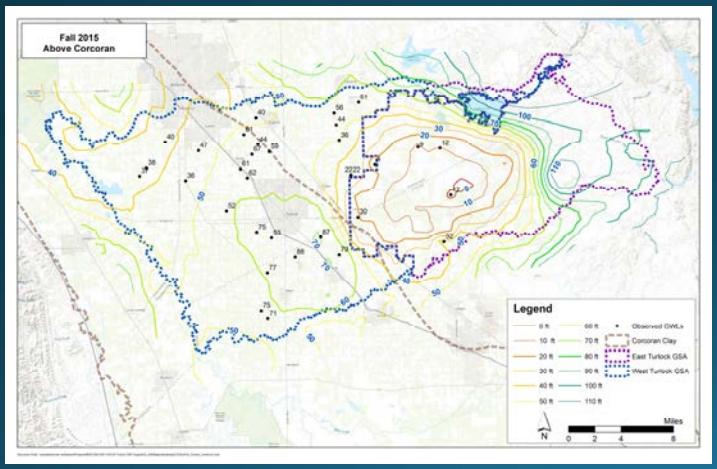
Model Groundwater Level Contours



Model: C2VSimTM_vo.1.18 || Date Produced: 12-2-2019

- Period: Sep 2015
- Principal Aquifers: Western Upper (Above Corcoran) and Eastern (deeper zones)
- San Joaquin Valley Water Year Index: Critical

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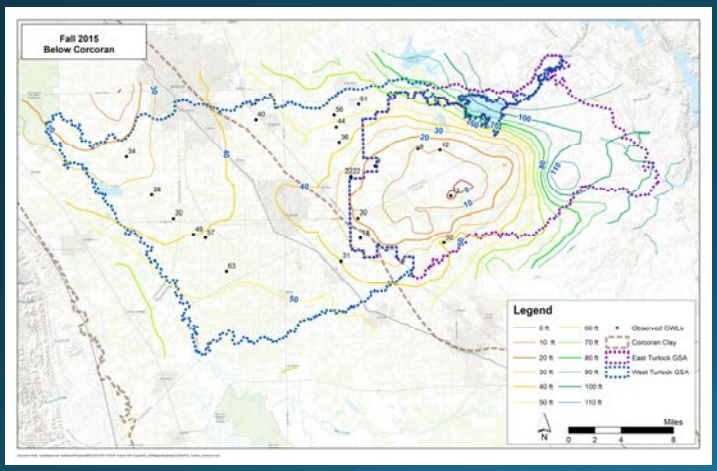
Model Groundwater Level Contours



Model: C2VSimTM_vo.1.18 || Date Produced: 12-2-2019

- Period: Sep 2015
- Principal Aquifers: Western Lower (Below Corcoran) and Eastern (deeper zones)
- San Joaquin Valley Water Year Index: Critical

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Upper Aquifer Parameters

	Vertical Hydraulic Conductivity[1]	Specific Storage	Specific Yield	Corcoran Vertical Conductivity[1]	Aquifer Vertical Conductivity[1]
Minimum	12.17	1.45 E-06	0.0396	0.0010	0.1217
First Quartile	40.65	3.03 E-06	0.0467	0.0050	0.4065
Average	66.85	6.23 E-06	0.0551	0.0050	0.6685
Third Quartile	97.24	5.67 E-05	0.1643	0.0050	0.9724
Maximum	100.00	9.88 E-05	0.1848	0.0080	1.0000

[1] Units of hydraulic conductivity are in feet per day

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Lower Aquifer Parameters

	Vertical Hydraulic Conductivity[1]	Specific Storage	Specific Yield	Corcoran Vertical Conductivity[1]	Aquifer Vertical Conductivity[1]
Minimum	6.35	1.99E-06	0.0369	0.0010	0.0635
First Quartile	13.62	3.86E-06	0.0447	0.0050	0.1362
Average	20.98	7.61E-06	0.0530	0.0050	0.2098
Third Quartile	26.92	6.80E-05	0.1494	0.0050	0.2692
Maximum	40.88	1.21E-04	0.1793	0.0080	0.4088

[1] Units of hydraulic conductivity are in feet per day

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Stream Flow Hydrographs

Model Calibration

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Streamflow Gaging Stations Used for Model Calibration

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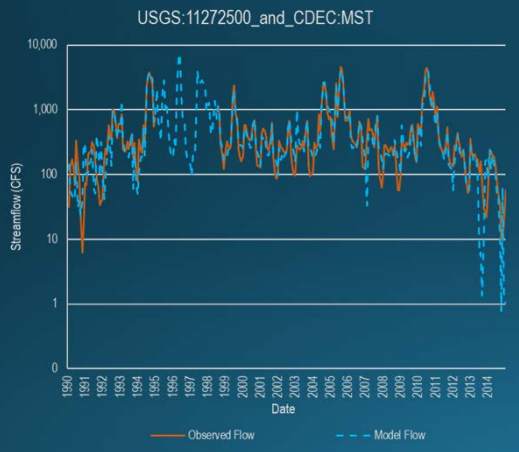
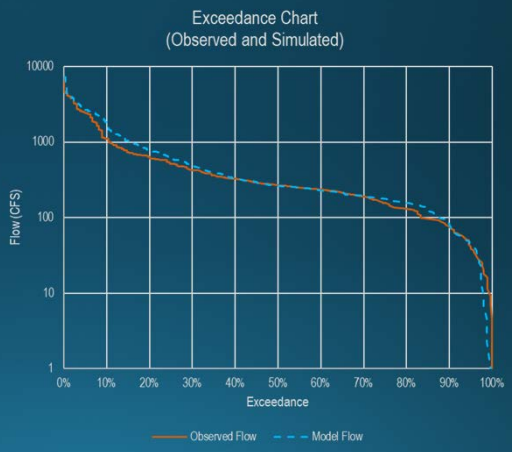
Stream Hydrographs





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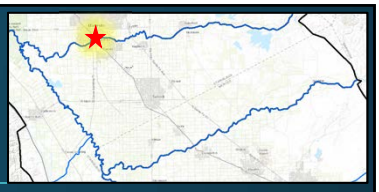
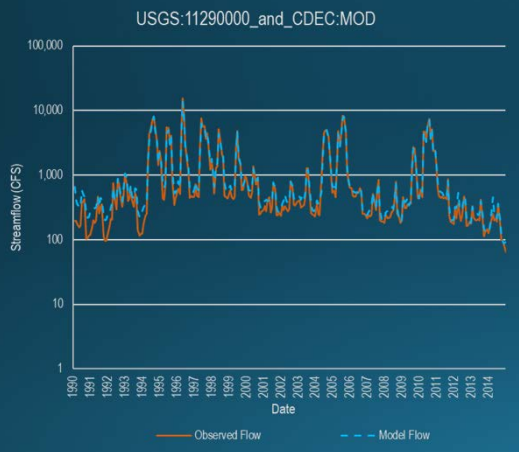
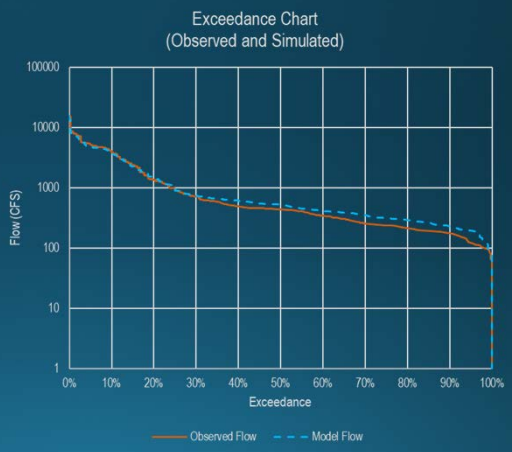
Stream Hydrographs







Calibration of the Modesto Subbasin is ongoing and includes additional refinements to the Tuolumne and the San Joaquin River

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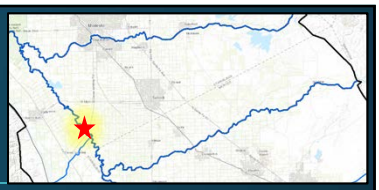
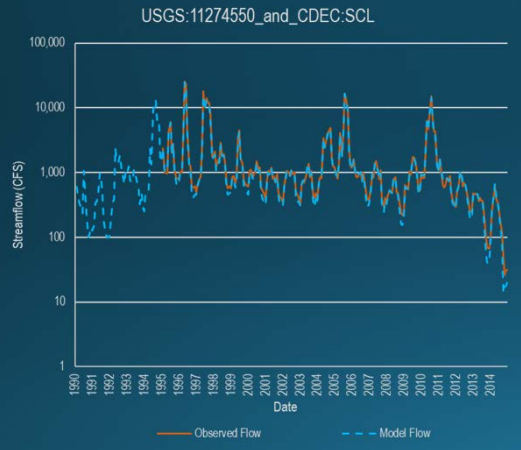
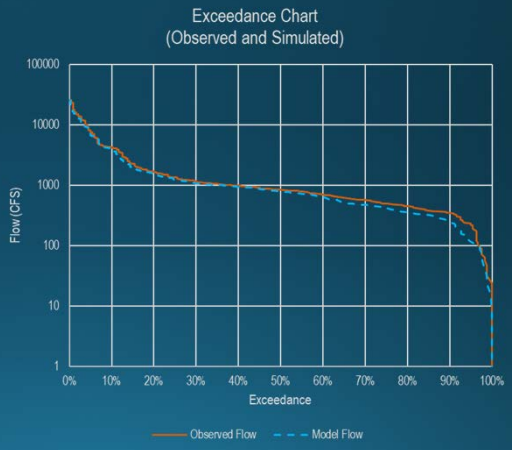
Stream Hydrographs







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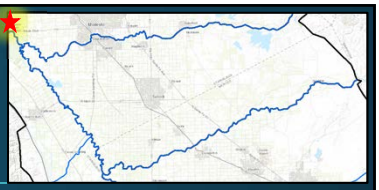
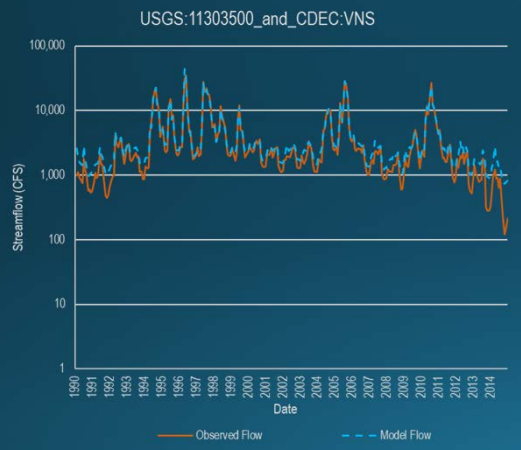
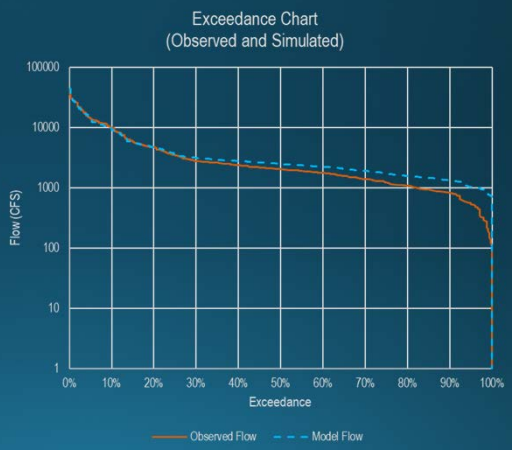
Stream Hydrographs







Calibration of the Modesto Subbasin is ongoing and includes additional refinements to the Tuolumne and the San Joaquin River

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Land and Water Use

Water Budgets

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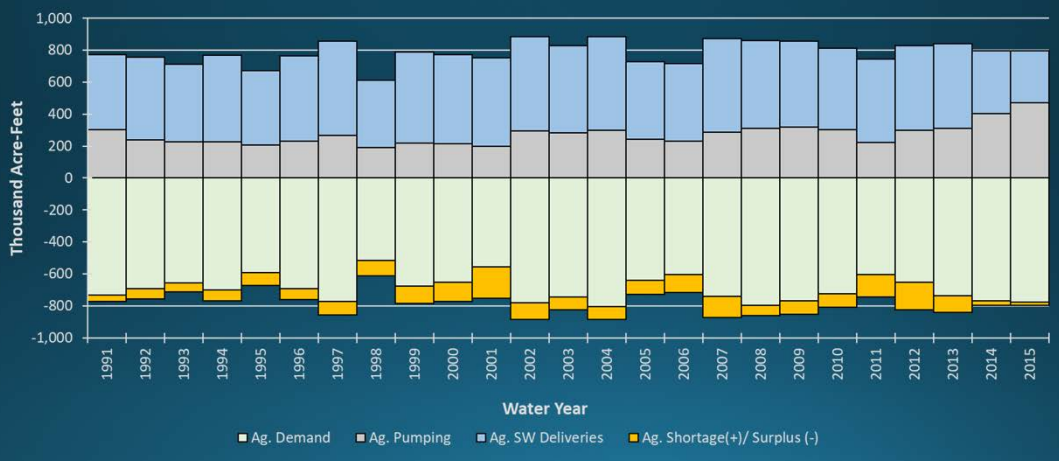
Turlock Subbasin: Agricultural



Shortage (+) : Amount of applied water that is not available to meet estimated water demand
Surplus (-) : Amount of applied water in excess of estimated water demand

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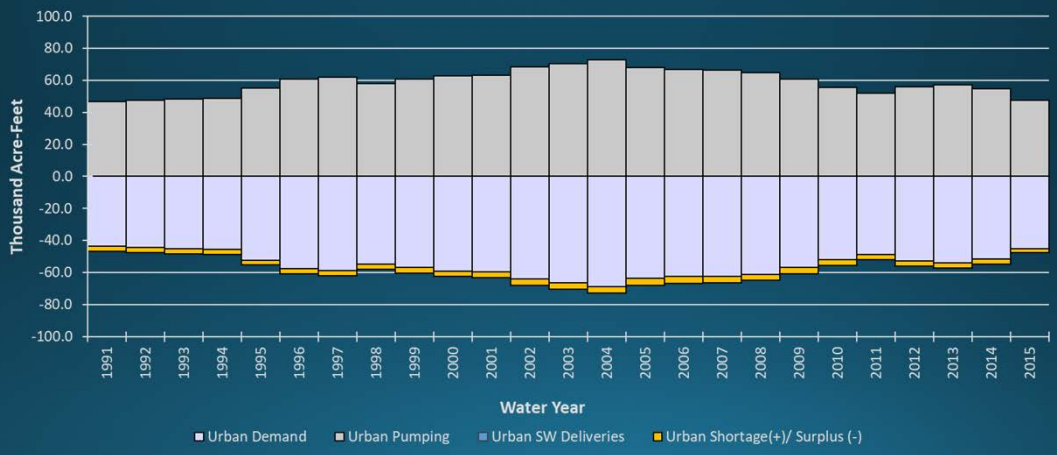
Turlock Subbasin: Urban



Shortage (+) : Amount of applied water that is not available to meet estimated water demand
Surplus (-) : Amount of applied water in excess of estimated water demand

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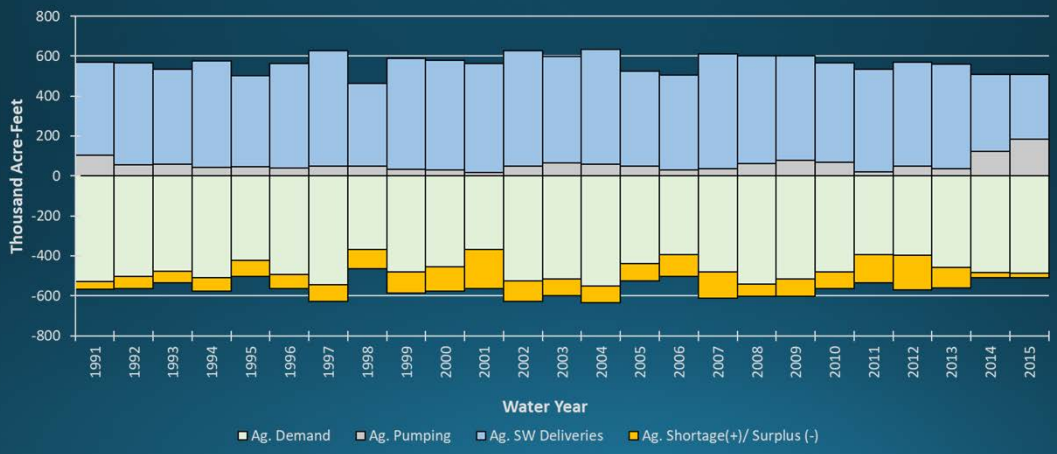
West Turlock GSA: Agricultural



Shortage (+) : Amount of applied water that is not available to meet estimated water demand
Surplus (-) : Amount of applied water in excess of estimated water demand

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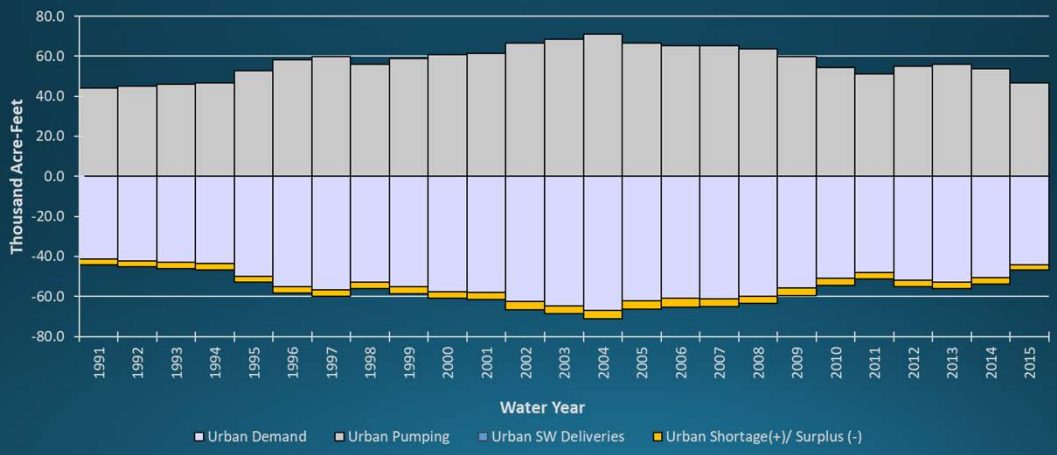
West Turlock GSA: Urban



Shortage (+) : Amount of applied water that is not available to meet estimated water demand
Surplus (-) : Amount of applied water in excess of estimated water demand

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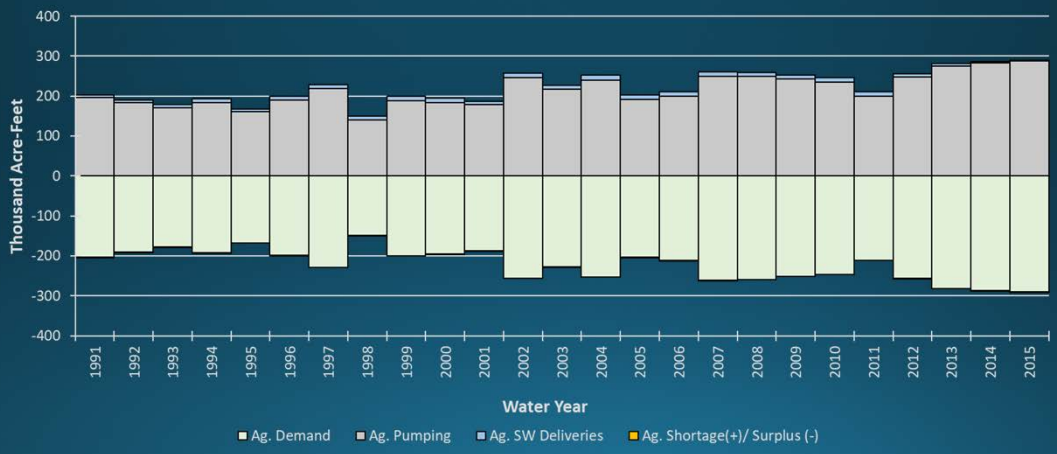
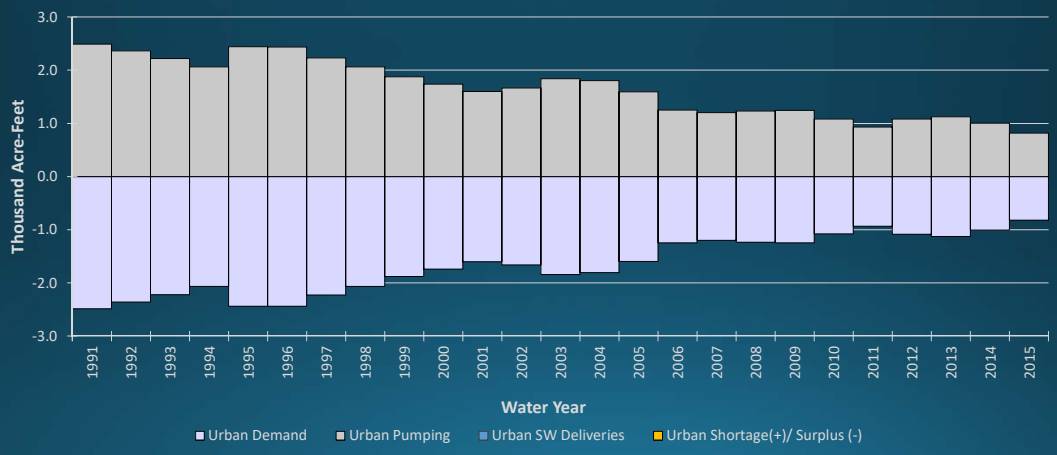
East Turlock GSA: Agricultural



Shortage (+) : Amount of applied water that is not available to meet estimated water demand
Surplus (-) : Amount of applied water in excess of estimated water demand

60

East Turlock GSA: Urban



Shortage (+) : Amount of applied water that is not available to meet estimated water demand
Surplus (-) : Amount of applied water in excess of estimated water demand

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Groundwater

Water Budgets

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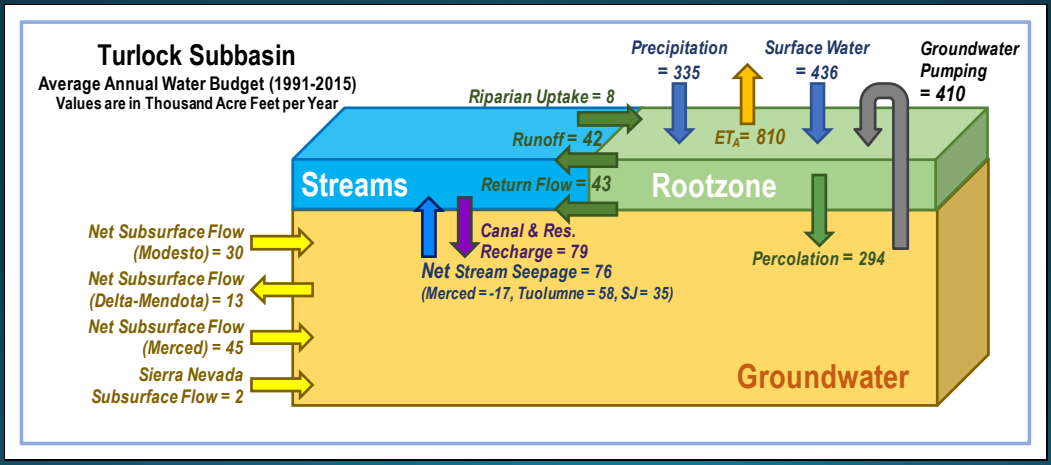
Water Budget Diagram



Note: Diagram is illustrative of water budget interactivity, water budget may include rounding error.
Percolation is water leaving the soil zone into the unsaturated zone.
Deep percolation is water leaving unsaturated zone to the water table, and is presented in the water budget tables.

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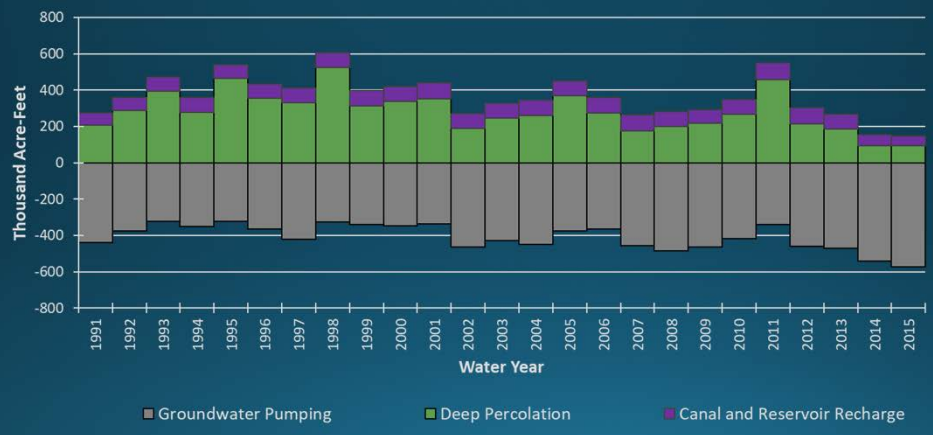
Turlock Subbasin: Recharge/Extraction



Deep Percolation: All percolation resulting from precipitation and applied waters across ag, urban, and native lands.
Canal and Reservoir Recharge: Canal and reservoir seepage from Turlock and Merced Irrigation Districts and riparian surface water diverters.

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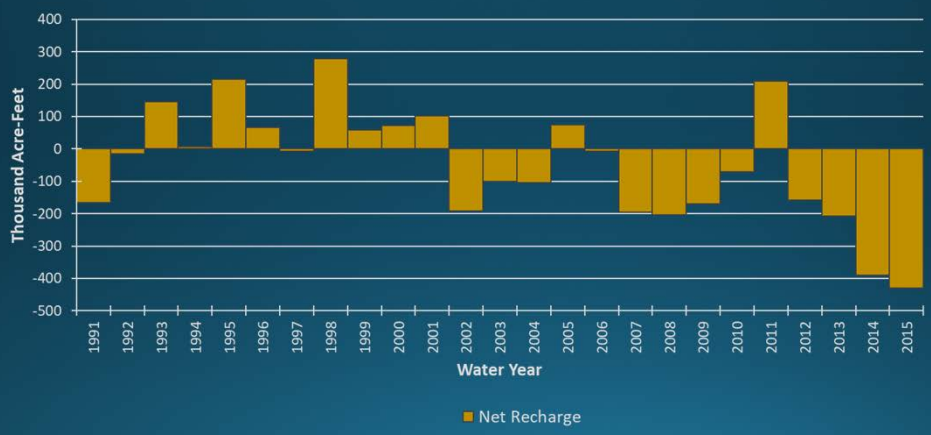
Turlock Subbasin: Net Recharge



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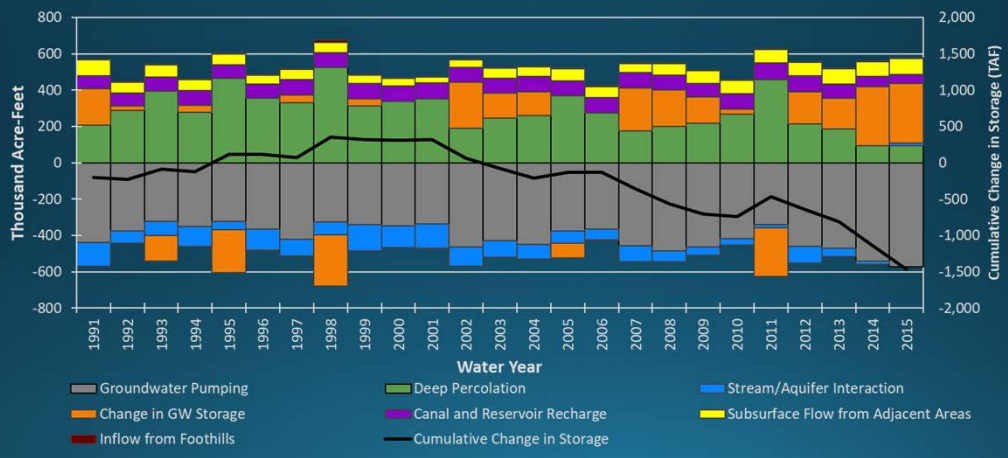
Turlock Subbasin: Groundwater Budget



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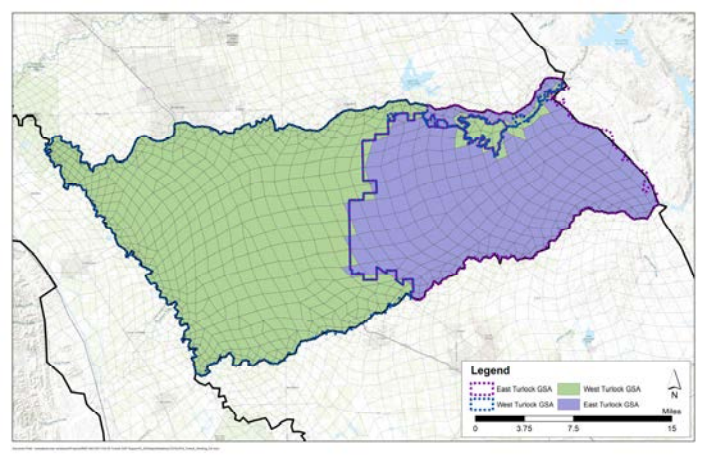
GSA Water Budgets



Water budgets, available at the element level, are aggregated to reflect data at a resolution beyond the subbasin.

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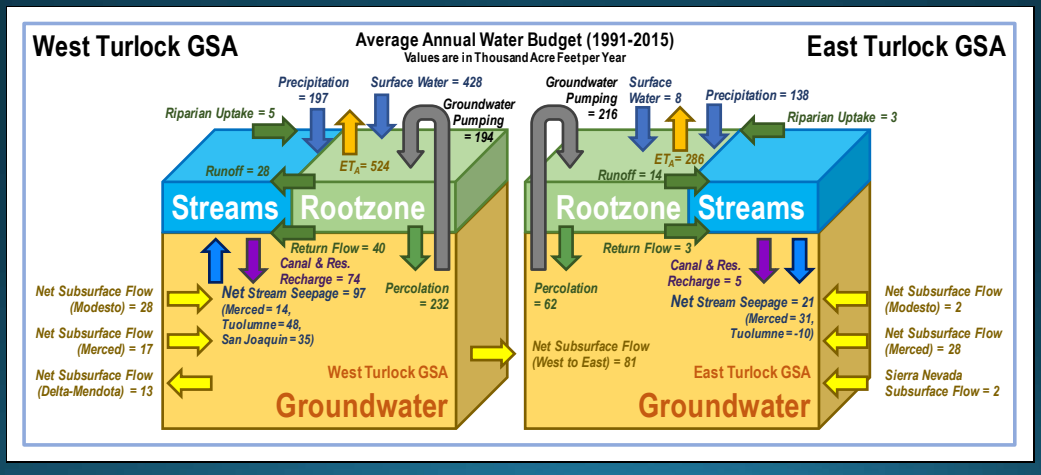
Water Budget Diagram



Note: Diagram is illustrative of water budget interactivity, water budget may include rounding error.
Percolation is water leaving the soil zone into the unsaturated zone.
Deep percolation is water leaving unsaturated zone to the water table, and is presented in the water budget tables.

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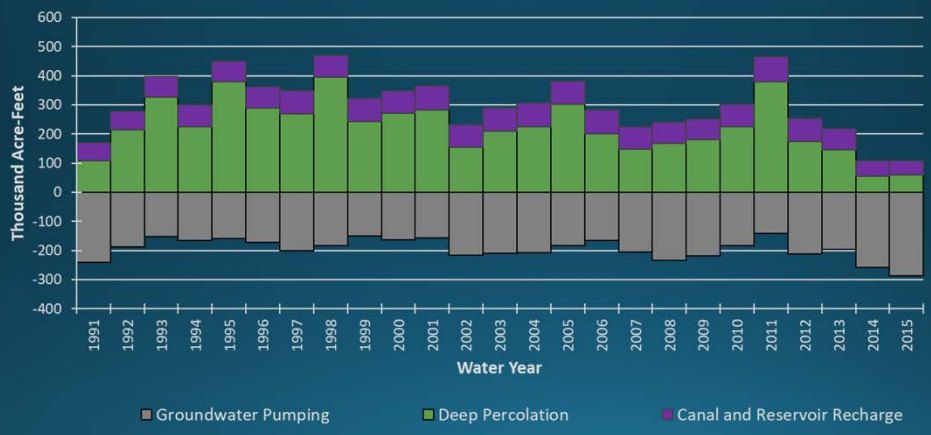
West Turlock: Recharge/Extraction



Deep Percolation: All percolation resulting from precipitation and applied waters across ag, urban, and native lands.
Canal and Reservoir Recharge: Canal and reservoir seepage from Turlock and Merced Irrigation Districts and riparian surface water diverters.

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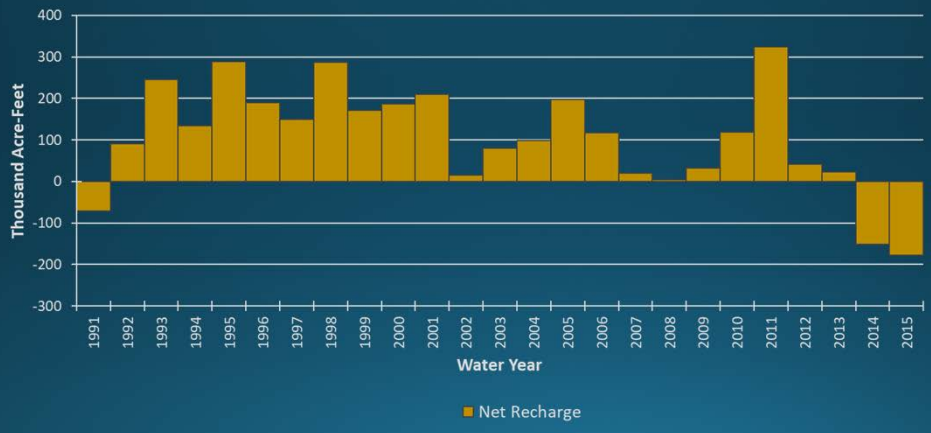
West Turlock: Net Recharge



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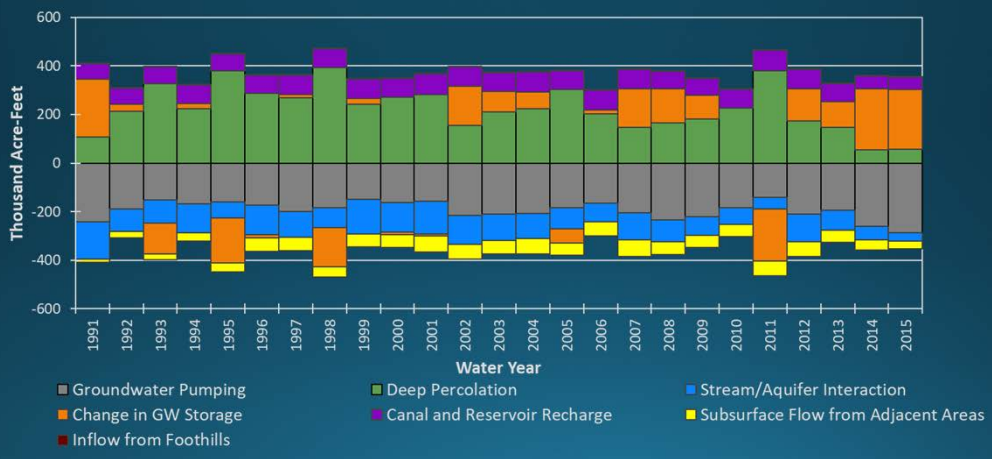
West Turlock: Groundwater Budget



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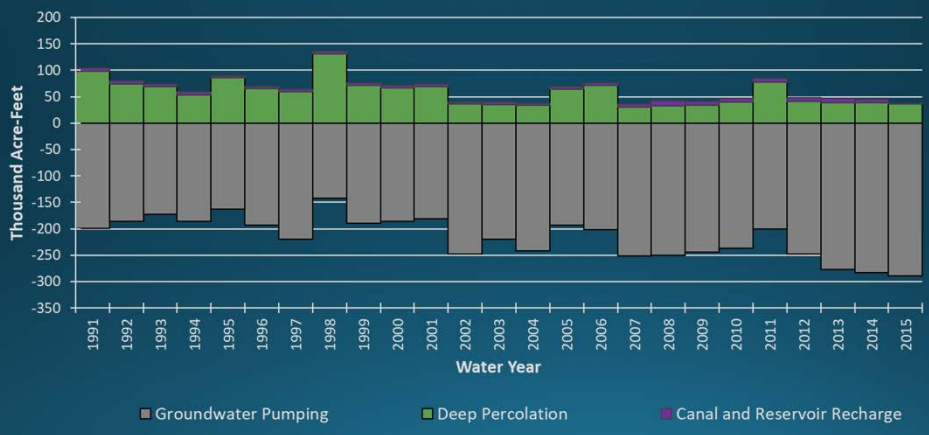
East Turlock: Recharge/Extraction



Deep Percolation: All percolation resulting from precipitation and applied waters across ag, urban, and native lands.
Canal and Reservoir Recharge: Canal and reservoir seepage from Turlock and Merced Irrigation Districts and riparian surface water diverters.

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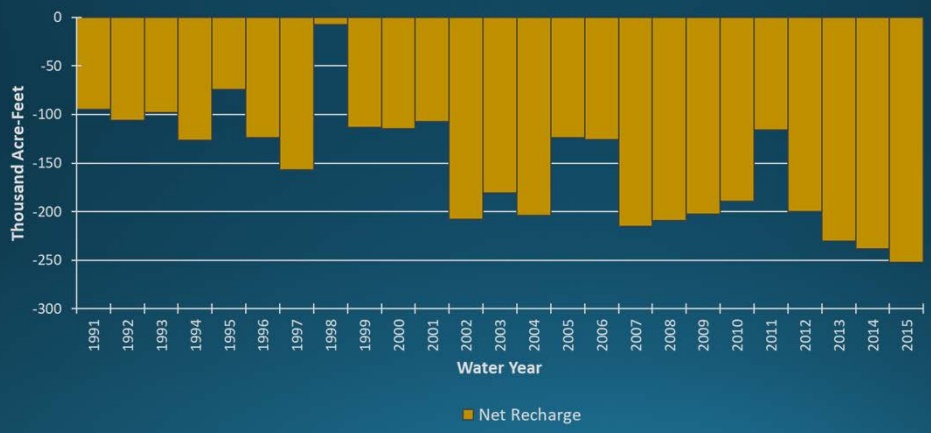
East Turlock: Net Recharge



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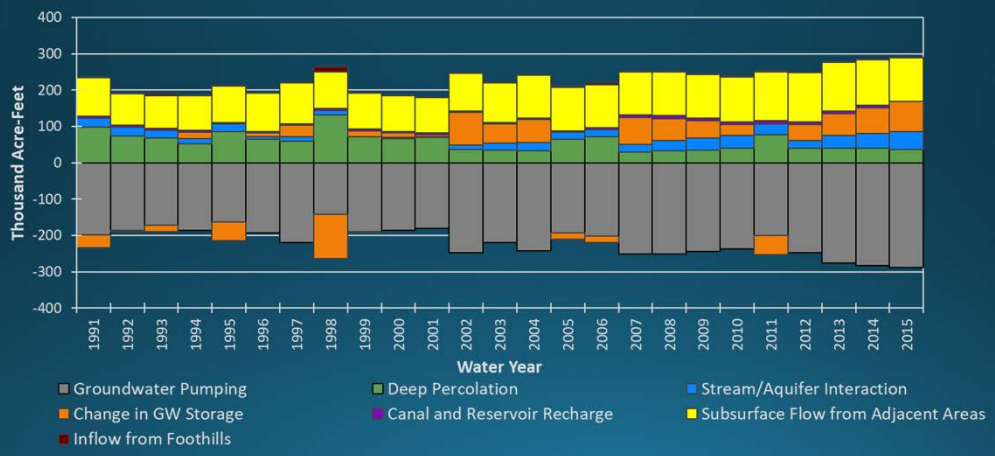
East Turlock: Groundwater Budget



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Next Steps

- Address Comments on Model Calibration, as appropriate
- Develop Baseline Model Scenario
- Analyze GW Sustainability Management Scenarios

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