The California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM)

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Charles Brush

Hydrology & Operations, Bay-Delta Office

California Department of Water Resources

Sacramento, CA

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* currently with MBK Engineers

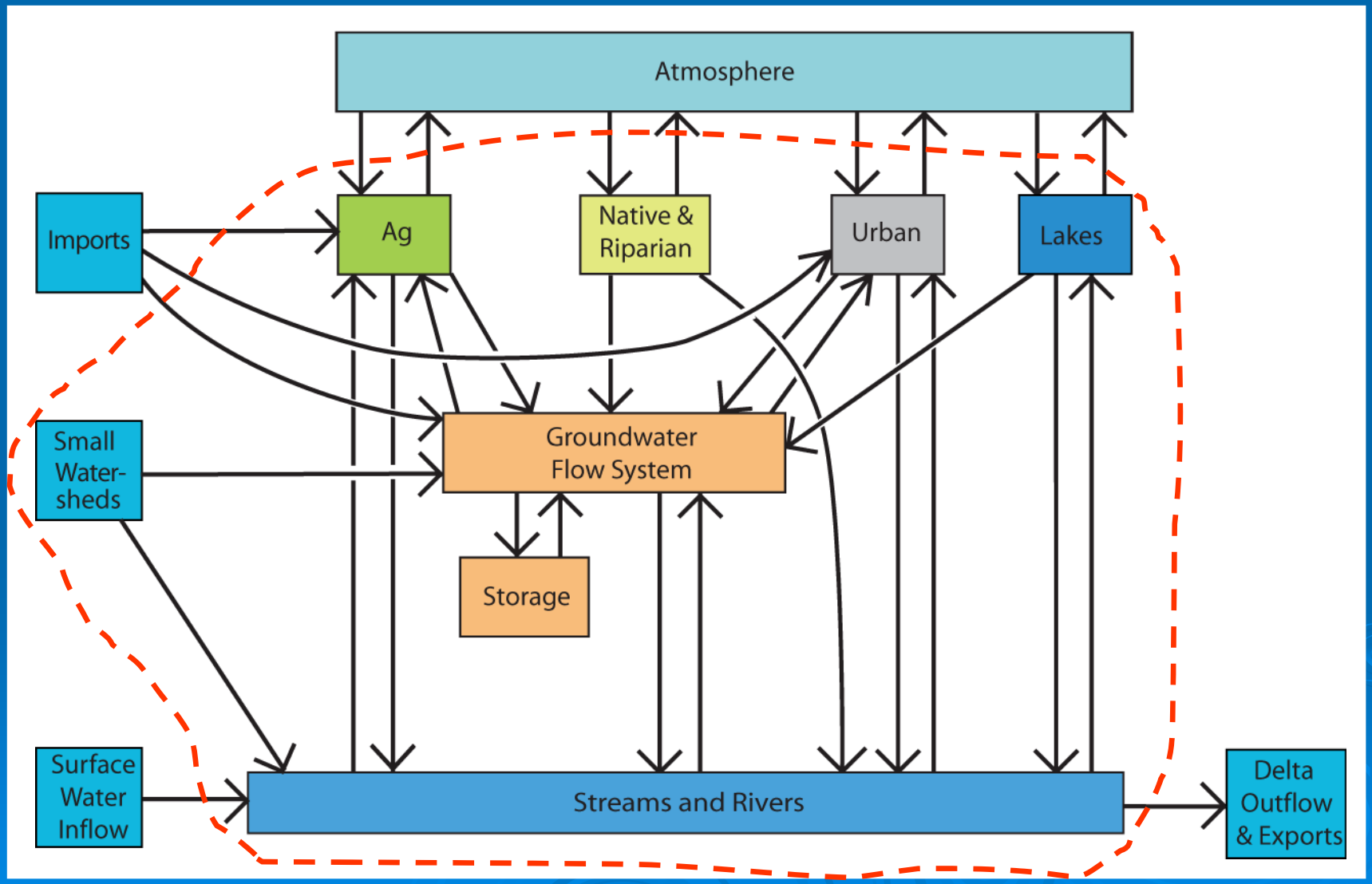
Outline

- Modeling Tools: IWFM and C2VSIM
- Overview of the C2VSIM model
- Geology of Central Valley Aquifer
- Model Calibration and Performance
- Scenarios
  - In-Lieu Conjunctive Use Scenario
  - Climate Change Scenarios
- Summary

IWFM - Integrated Water Flow Model

- Components
  - Groundwater Flow Process
    - Finite Element Grid
    - Saturated and unsaturated flow
  - Land Surface Process
    - Precipitation and Evapotranspiration
    - Land Type and Crop Acreages
    - Irrigation with Surface Water & Groundwater
  - Surface Water Processes
    - Streamflow routing
    - Lakes
    - Surface Water Diversions
  - Inflows from Ungaged Boundary Watersheds
- Outputs:
  - Water Budget Components
  - Estimated Groundwater Pumping

Integrated Model Components



C2VSIM Model Grid

Finite Element Grid

- 3 layers
- 1393 nodes
- 1392 elements

Surface Water System

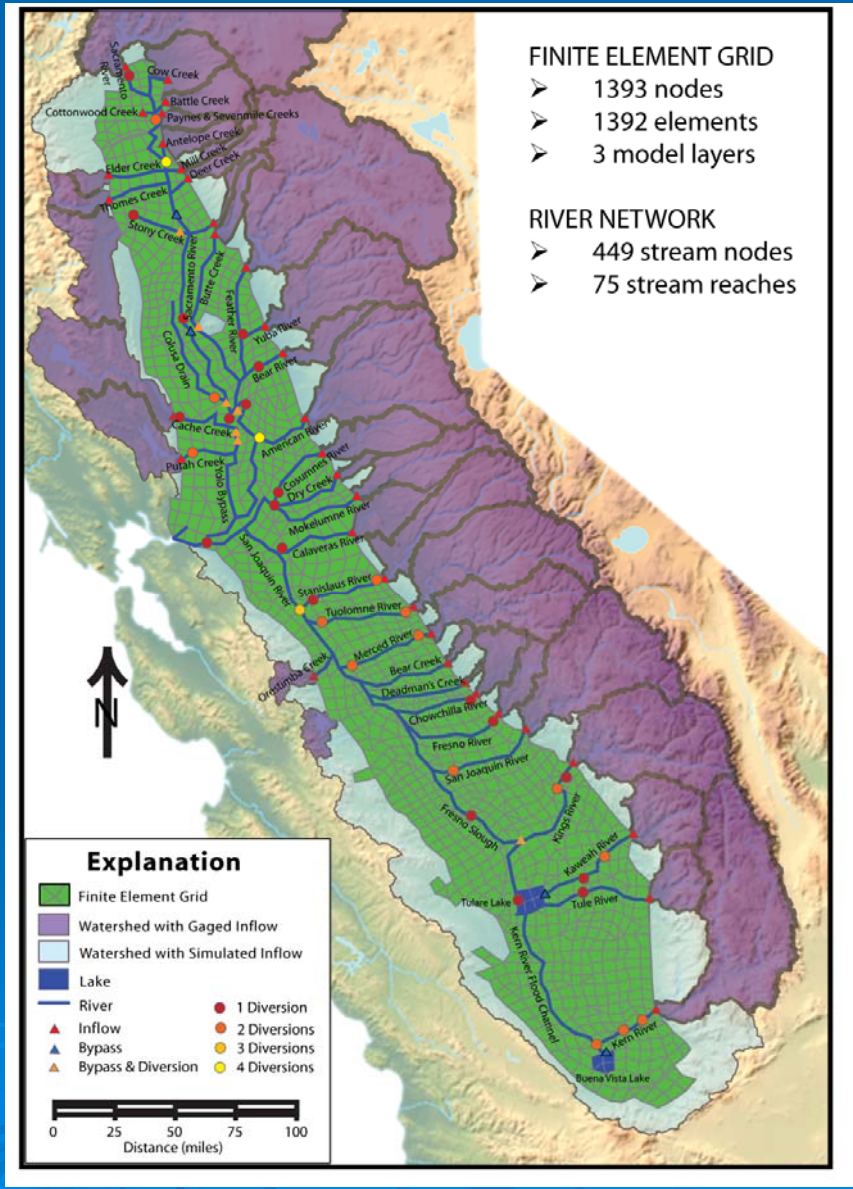
- 75 river reaches
- 2 lakes
- 97 surface water diversion points
- 6 bypasses

Land Use Process

- 21 subregions
- 4 Land Use Types
  - Agriculture
  - Urban
  - Native
  - Riparian

Simulation periods

- 10/1921-9/2003
- 10/1972-9/2003 (<4 min)



C2VSIM Subregions

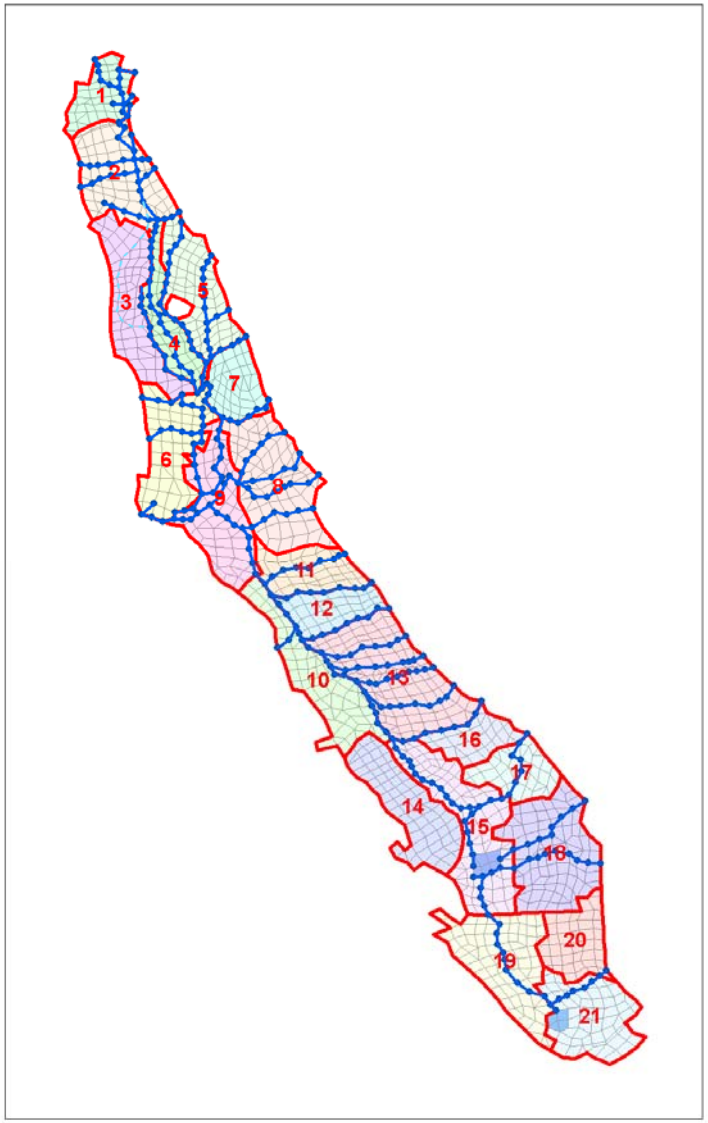
Water Budget Calculations

- Land use by element
- Aggregate to subregion

By land use in subregion:

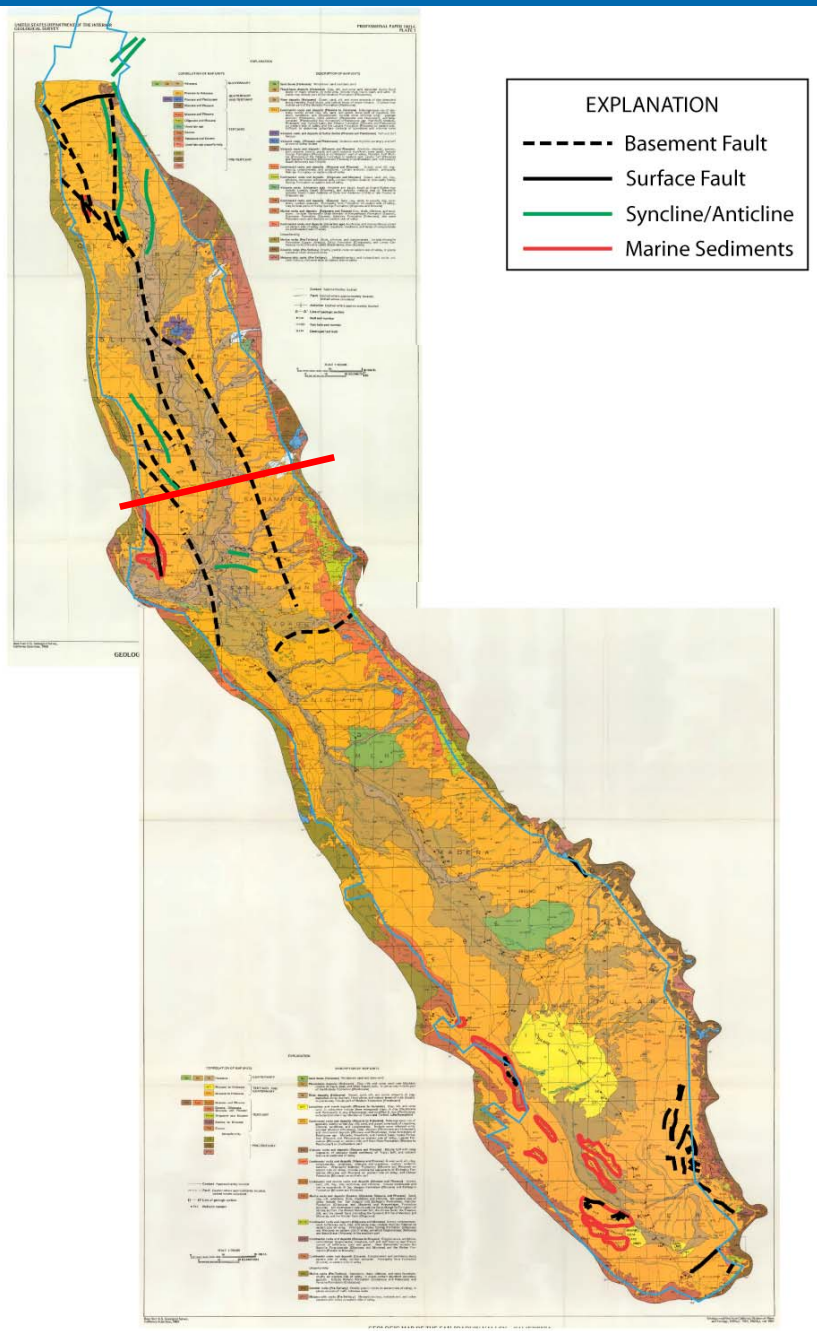
- Calculate water demands
- Apply soil moisture
- Apply surface water diversions
- Apply/estimate groundwater pumping
- Calculate soil moisture, recharge, return flows

Allocate to elements by land use areas

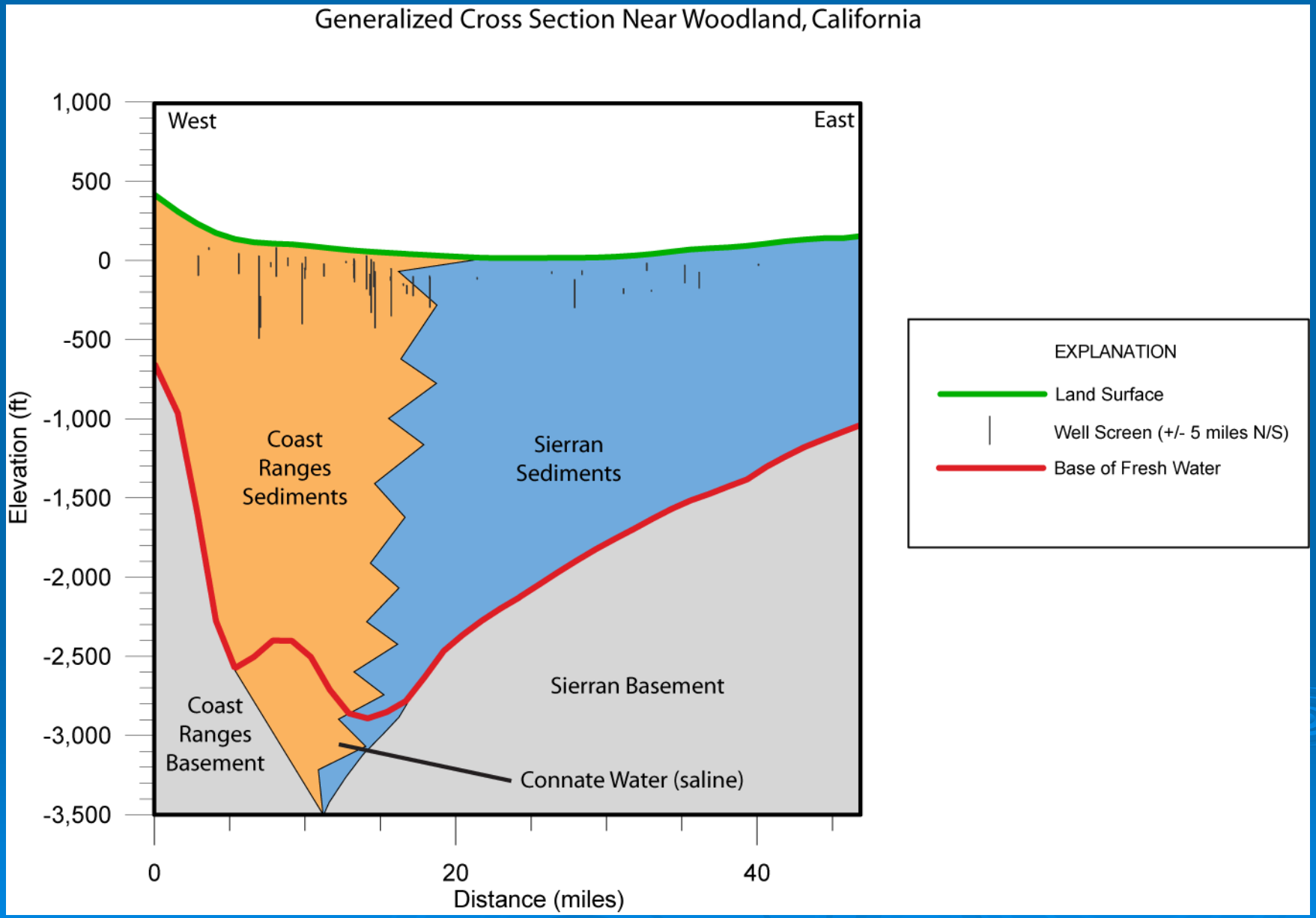


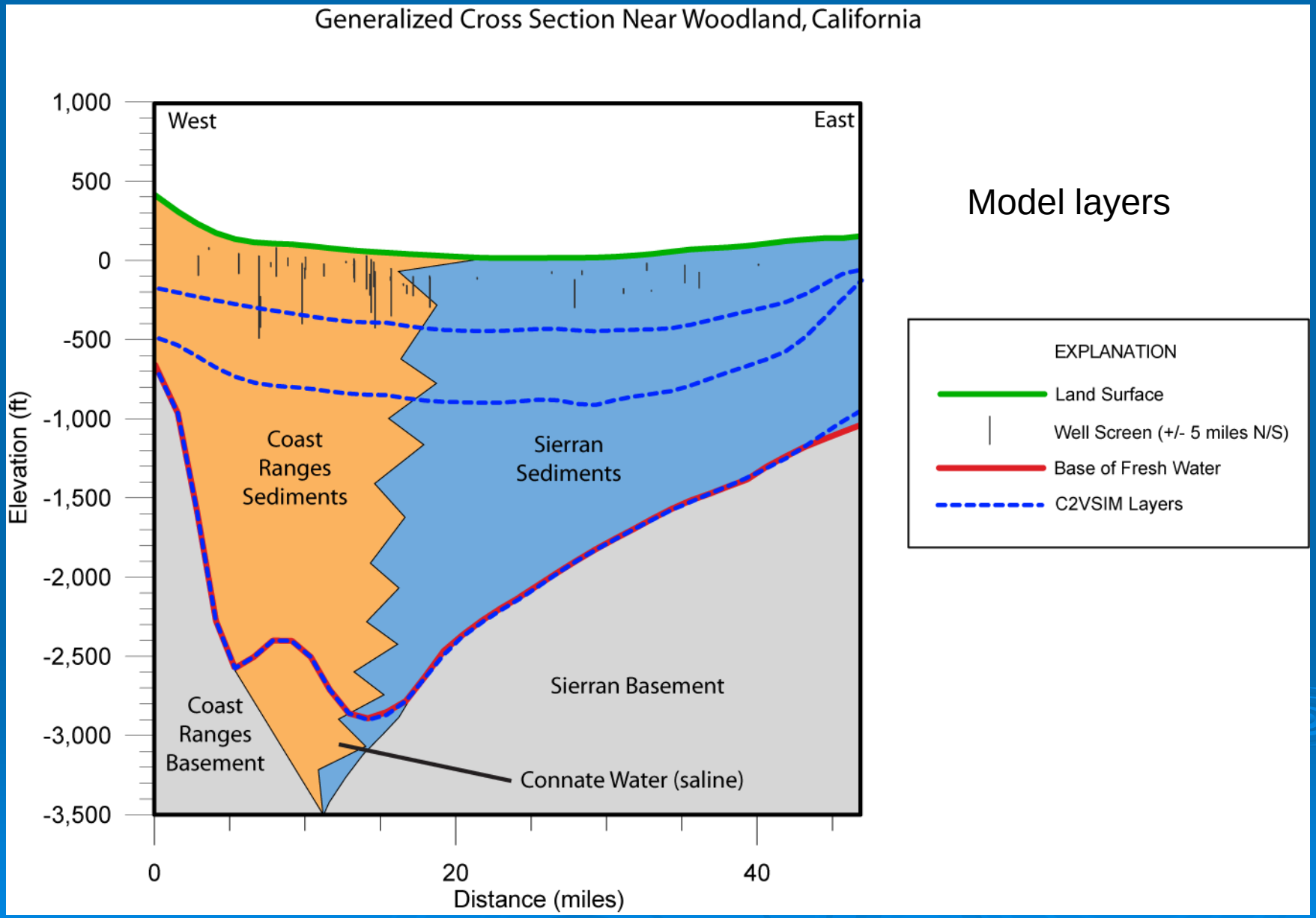
Groundwater Model Components

Component	Source
Parameters	calibration: WY 1973-2003
Initial conditions	water-level observations, 10/1921 or 10/1972
Boundary conditions	- Precipitation & evapotranspiration - Surface water inflows & diversions
Recharge & Pumping calc	- Land use & crop acreages - Crop coefficients - Soil type, SCS curve number - Pump locations (well database)



Page, Ronald W. 1986. Geology of the fresh ground-water basin of the Central Valley, California. Washington, DC: U.S. Geological Survey Professional Paper 1401C.


Generalized Cross Section Near Woodland, California
West
East
1,000
500
0
-500
-1,000
-1,500
-2,000
-2,500
-3,000
-3,500
Elevation (ft)
Coast Ranges Sediments
Sierran Sediments
Sierran Basement
Coast Ranges Basement
Connate Water (saline)
0
20
40
Distance (miles)
EXPLANATION
Land Surface
Well Screen (+/- 5 miles N/S)
Base of Fresh Water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Elevation (ft)
Coast Ranges Sediments
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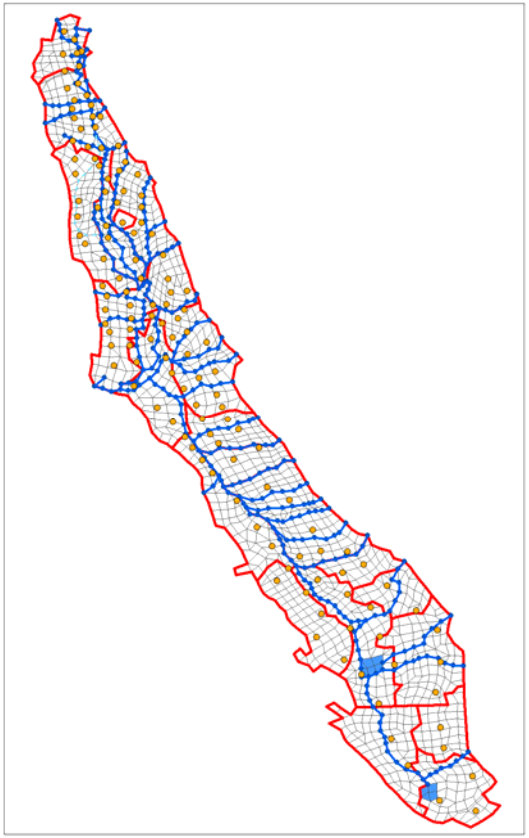
Sierran Basement
Coast Ranges Basement
Connate Water (saline)
0
20
40
Distance (miles)
Model layers
EXPLANATION
Land Surface
Well Screen (+/- 5 miles N/S)
Base of Fresh Water
C2VSIM Layers

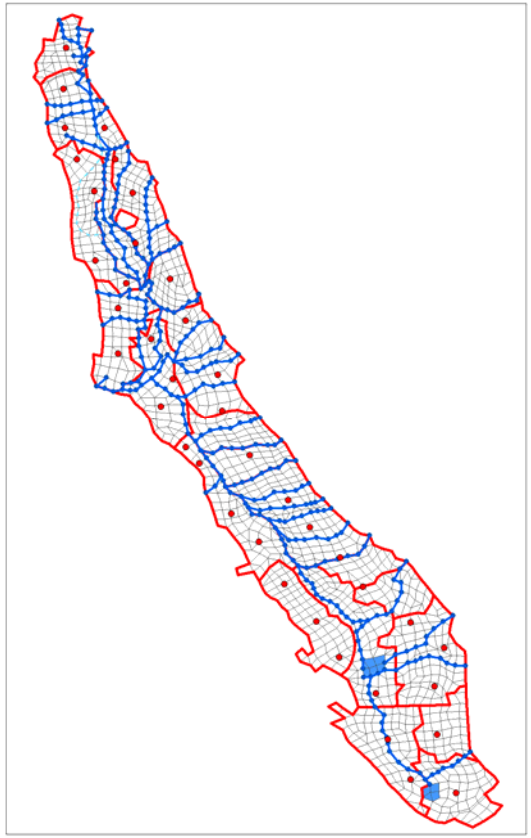
C2VSIM Initial Calibration

Pilot Points

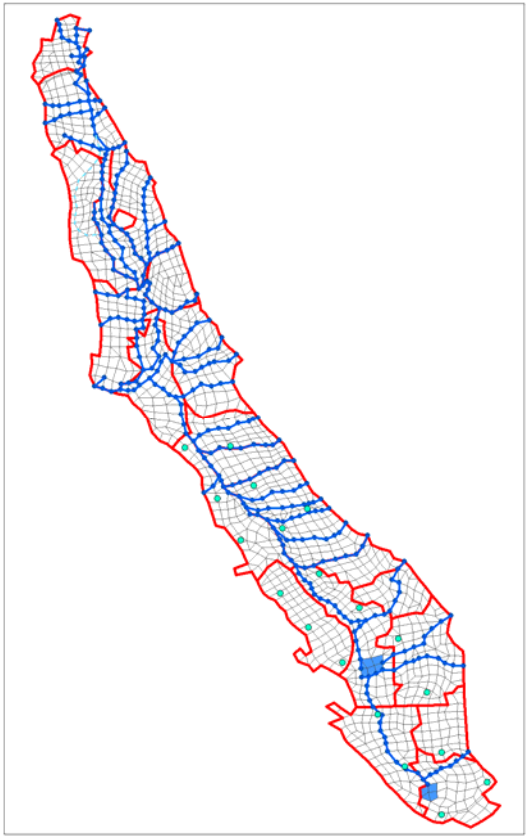
140 in layers 1 & 2



39 in layer 3



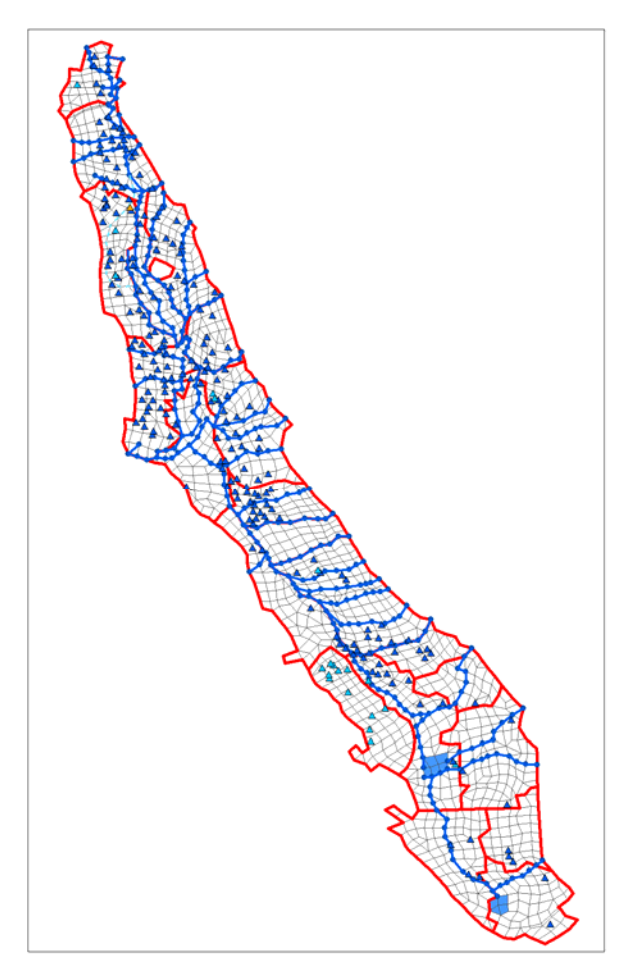
19 for Corcoran Clay



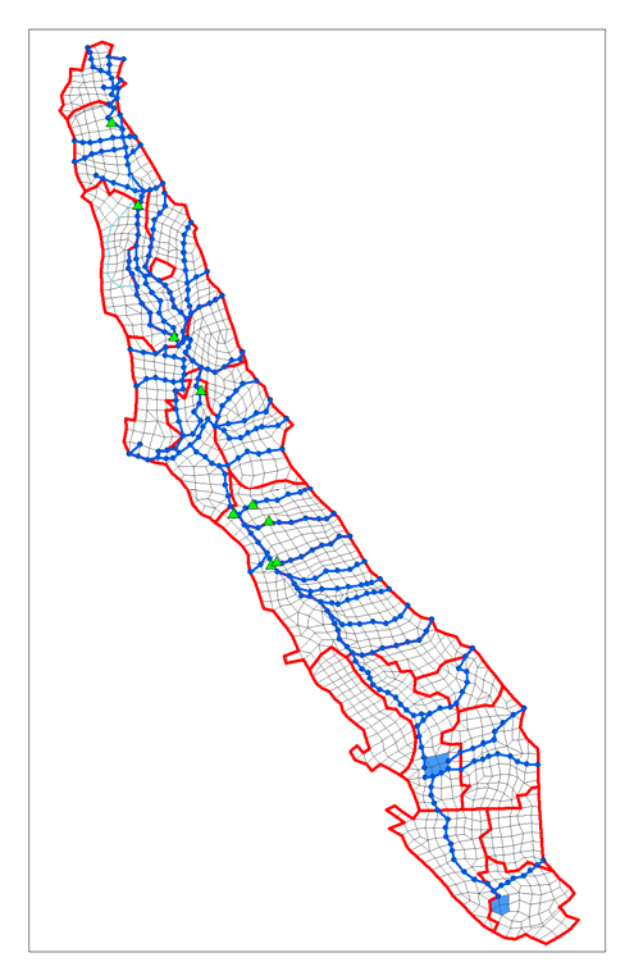
C2VSIM Initial Calibration

Observations

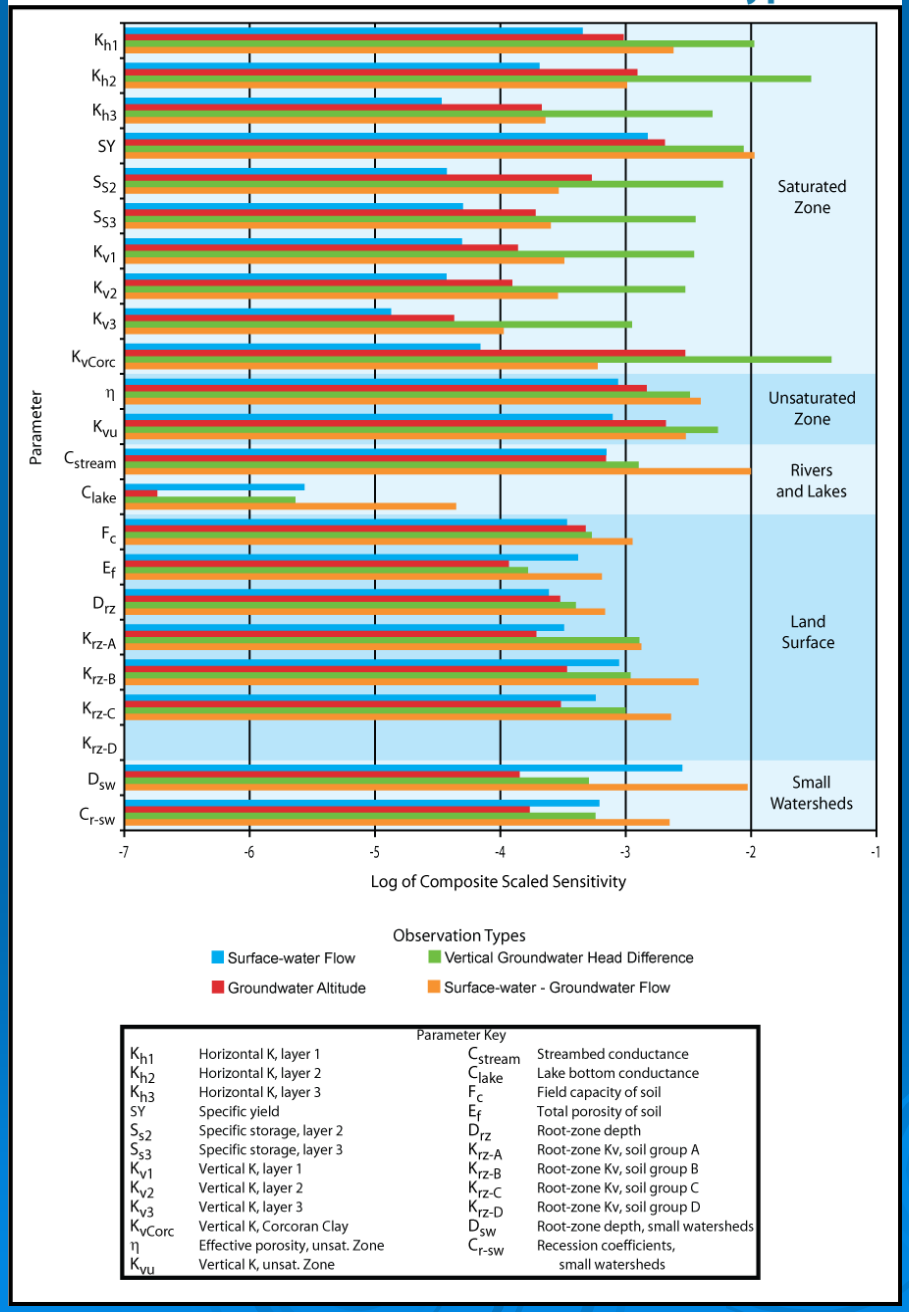
221 groundwater head
9 head gradient



9 river flow
34 stream-groundwater



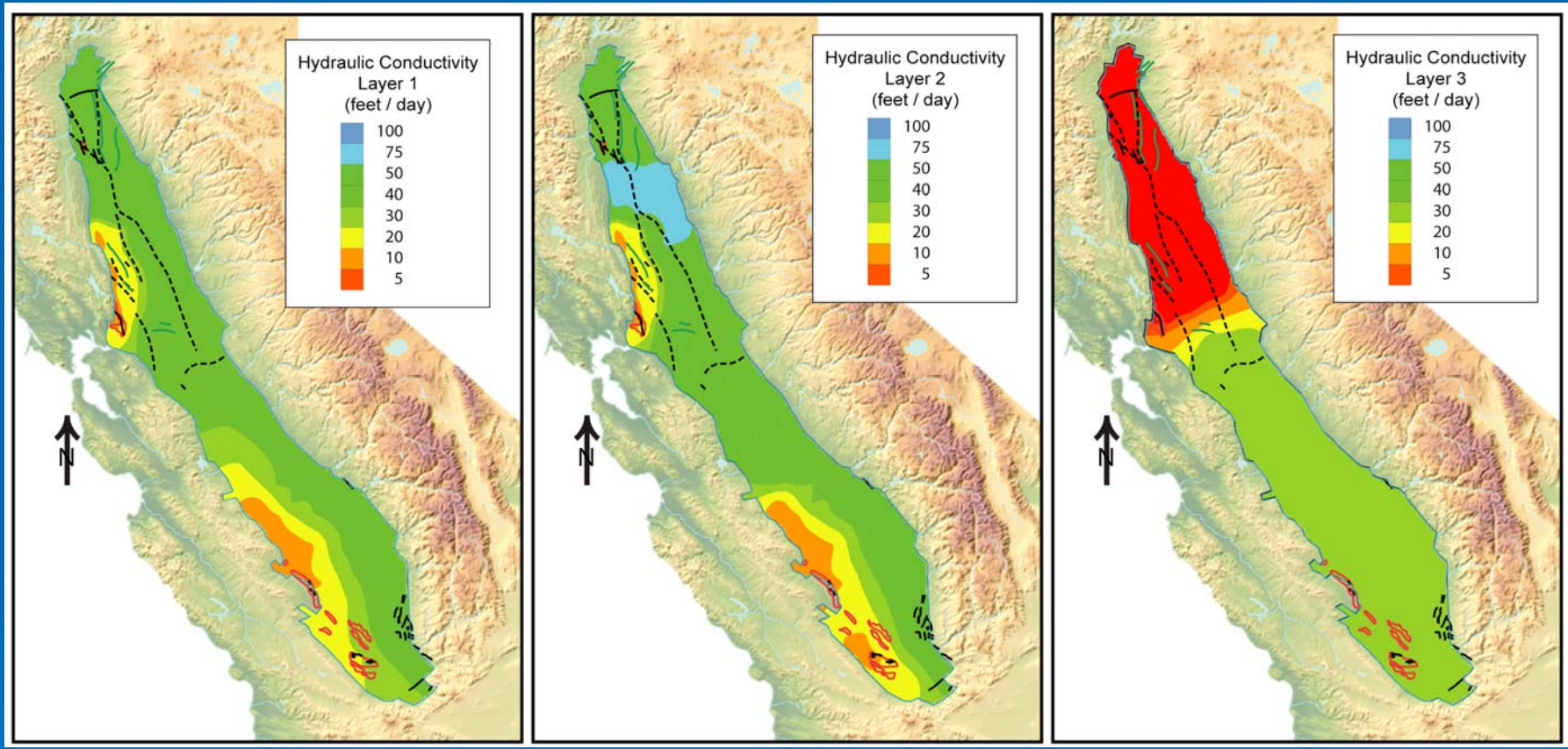
Parameter Sensitivities vs. Observation Types



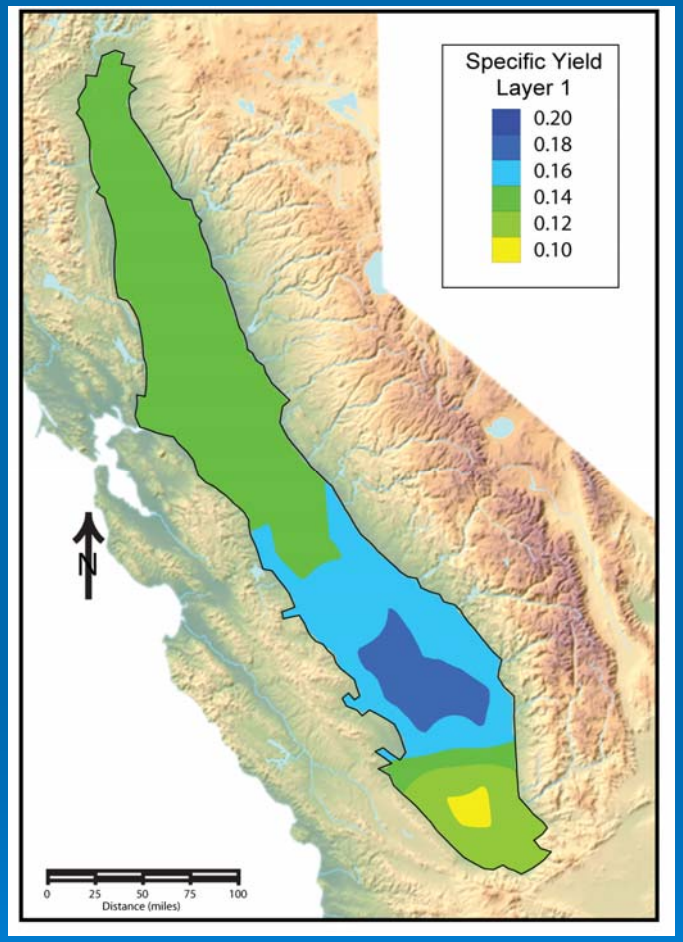
Parameter Key

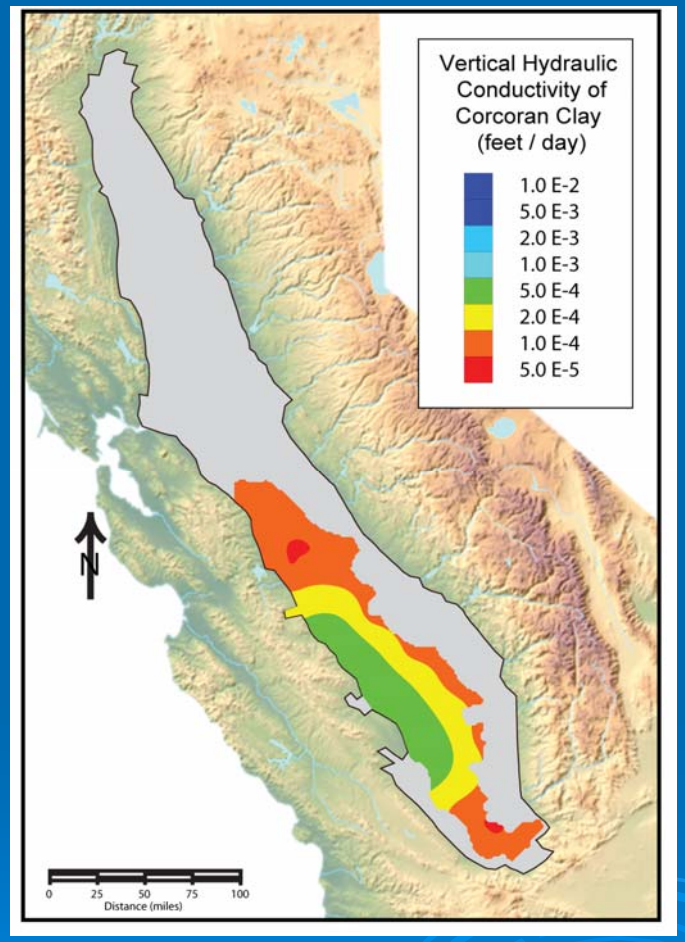
K_{h1}	Horizontal K, layer 1	C_{stream}	Streambed conductance
K_{h2}	Horizontal K, layer 2	C_{lake}	Lake bottom conductance
K_{h3}	Horizontal K, layer 3	F_c	Field capacity of soil
SY	Specific yield	E_f	Total porosity of soil
S_{s2}	Specific storage, layer 2	D_{rz}	Root-zone depth
S_{s3}	Specific storage, layer 3	K_{rz-A}	Root-zone Kv, soil group A
K_{v1}	Vertical K, layer 1	K_{rz-B}	Root-zone Kv, soil group B
K_{v2}	Vertical K, layer 2	K_{rz-C}	Root-zone Kv, soil group C
K_{v3}	Vertical K, layer 3	K_{rz-D}	Root-zone Kv, soil group D
K_{vCorc}	Vertical K, Corcoran Clay	D_{sw}	Root-zone depth, small watersheds
η	Effective porosity, unsat. Zone	C_{r-sw}	Recession coefficients, small watersheds
K_{vu}	Vertical K, unsat. Zone		

Hydraulic Conductivity

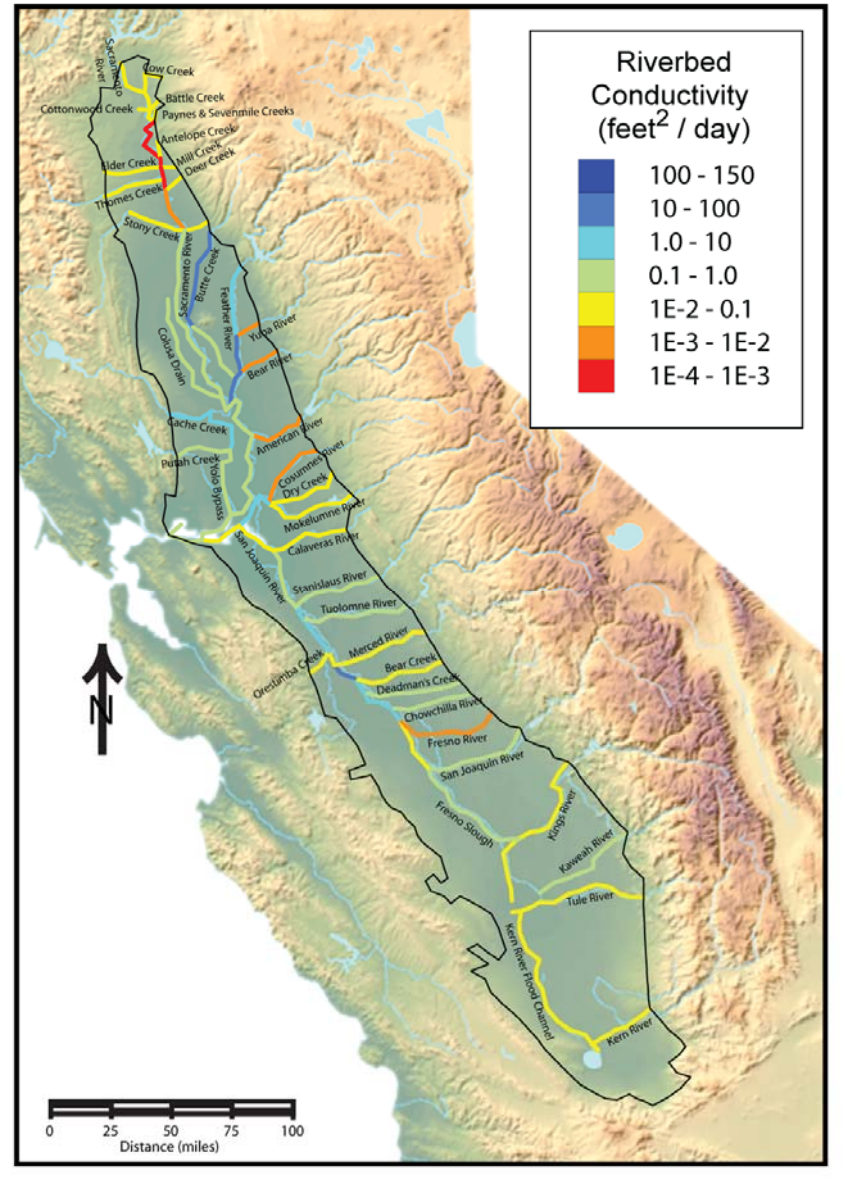


Specific Yield & Kv of Corcoran Clay

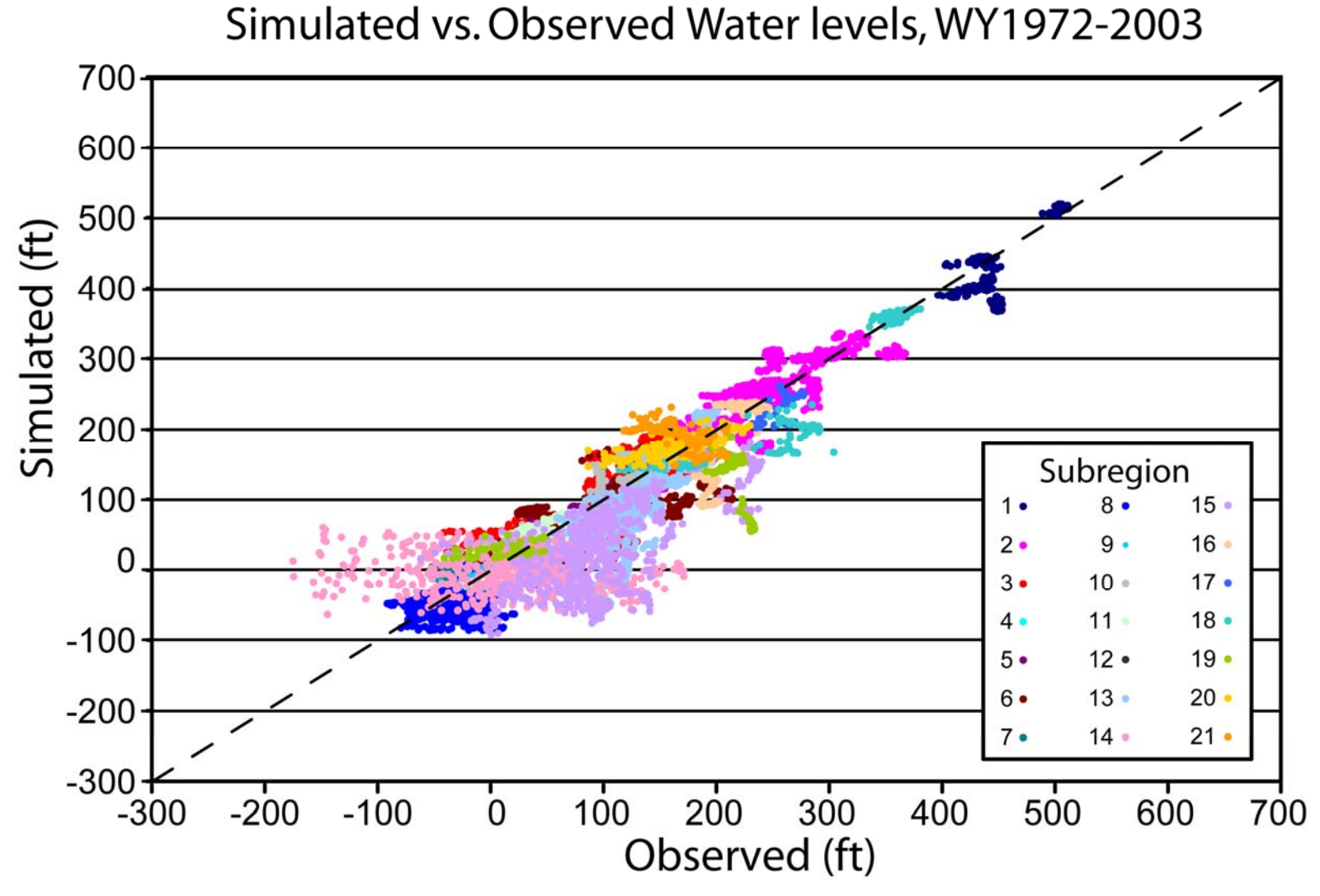




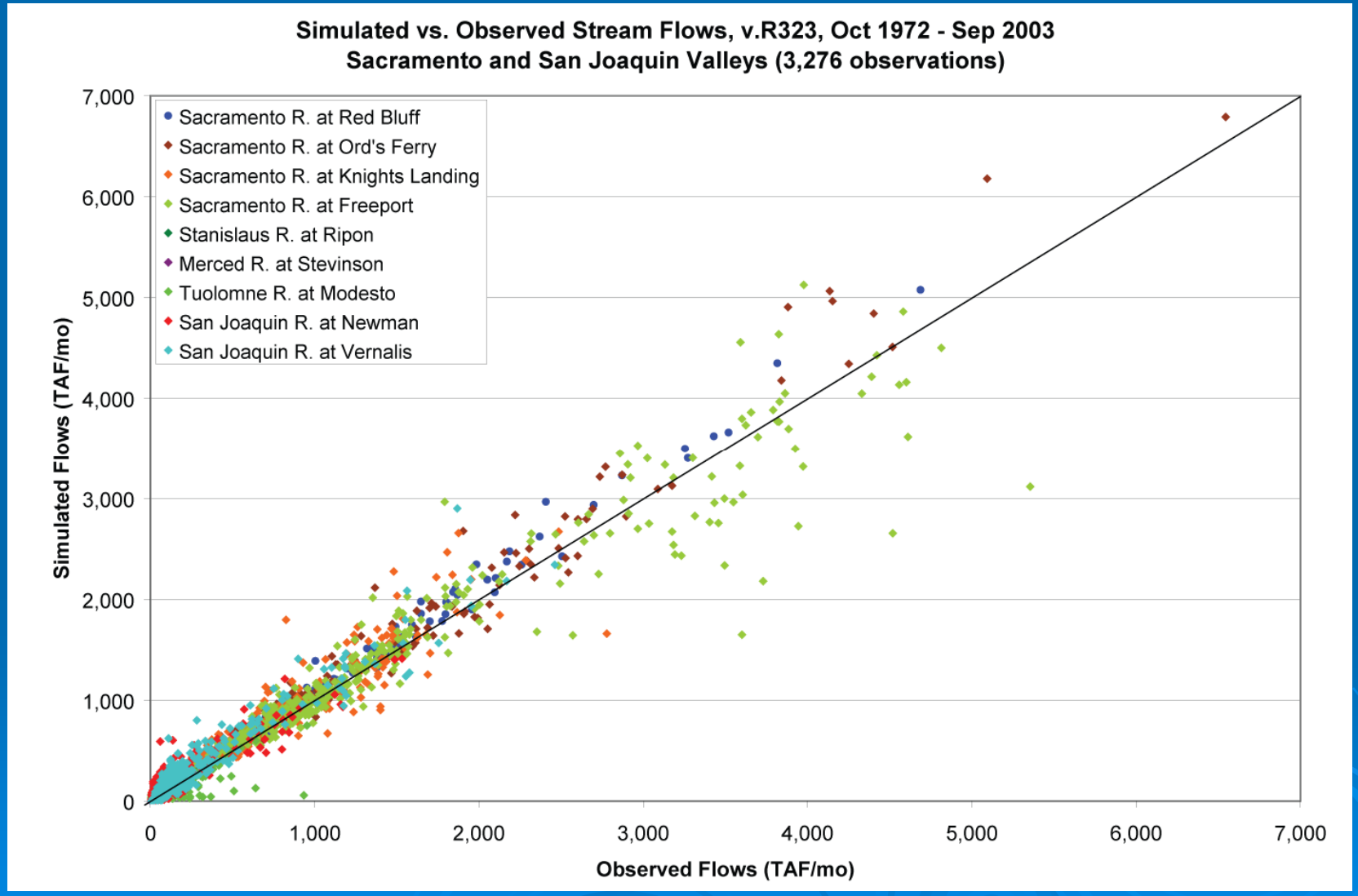
Streambed Conductance



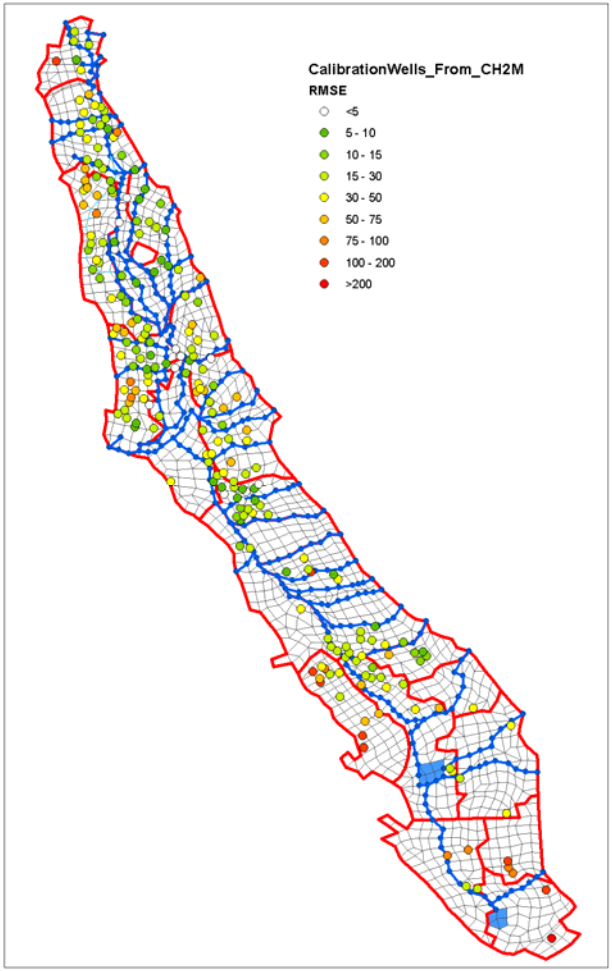
C2VSIM Performance – Heads

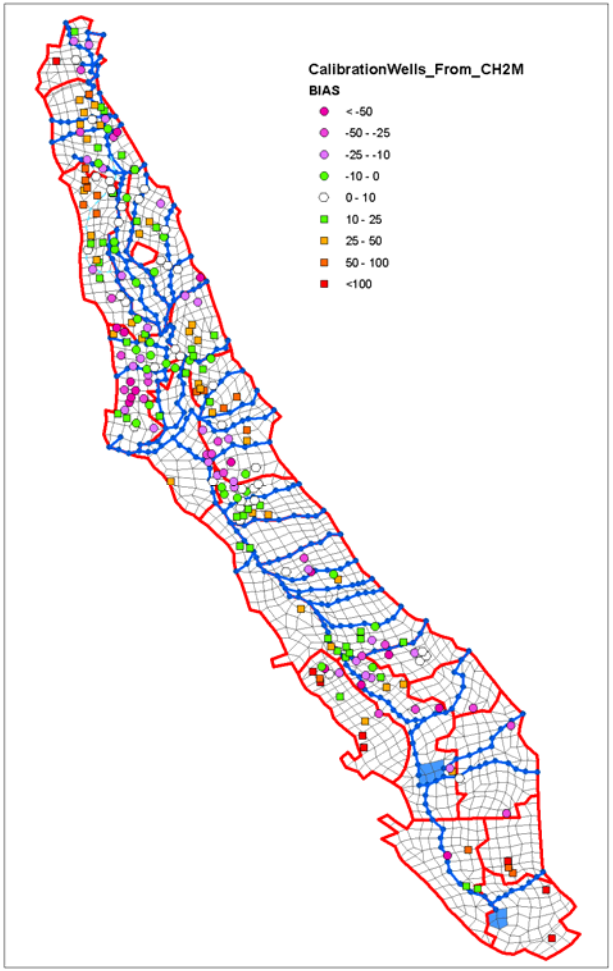


C2VSIM Performance - Flows

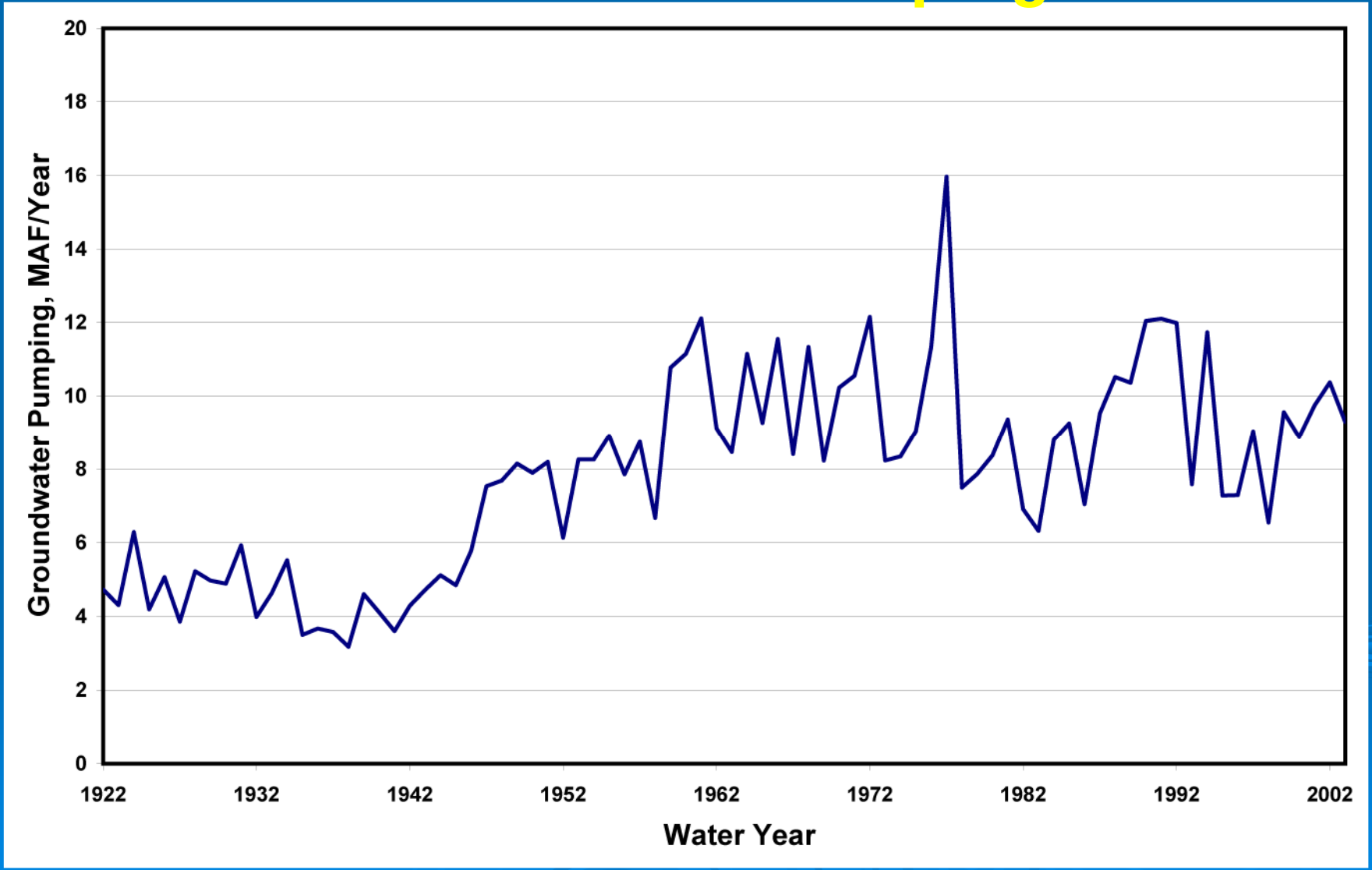


C2VSIM Performance – RMSE and BIAS

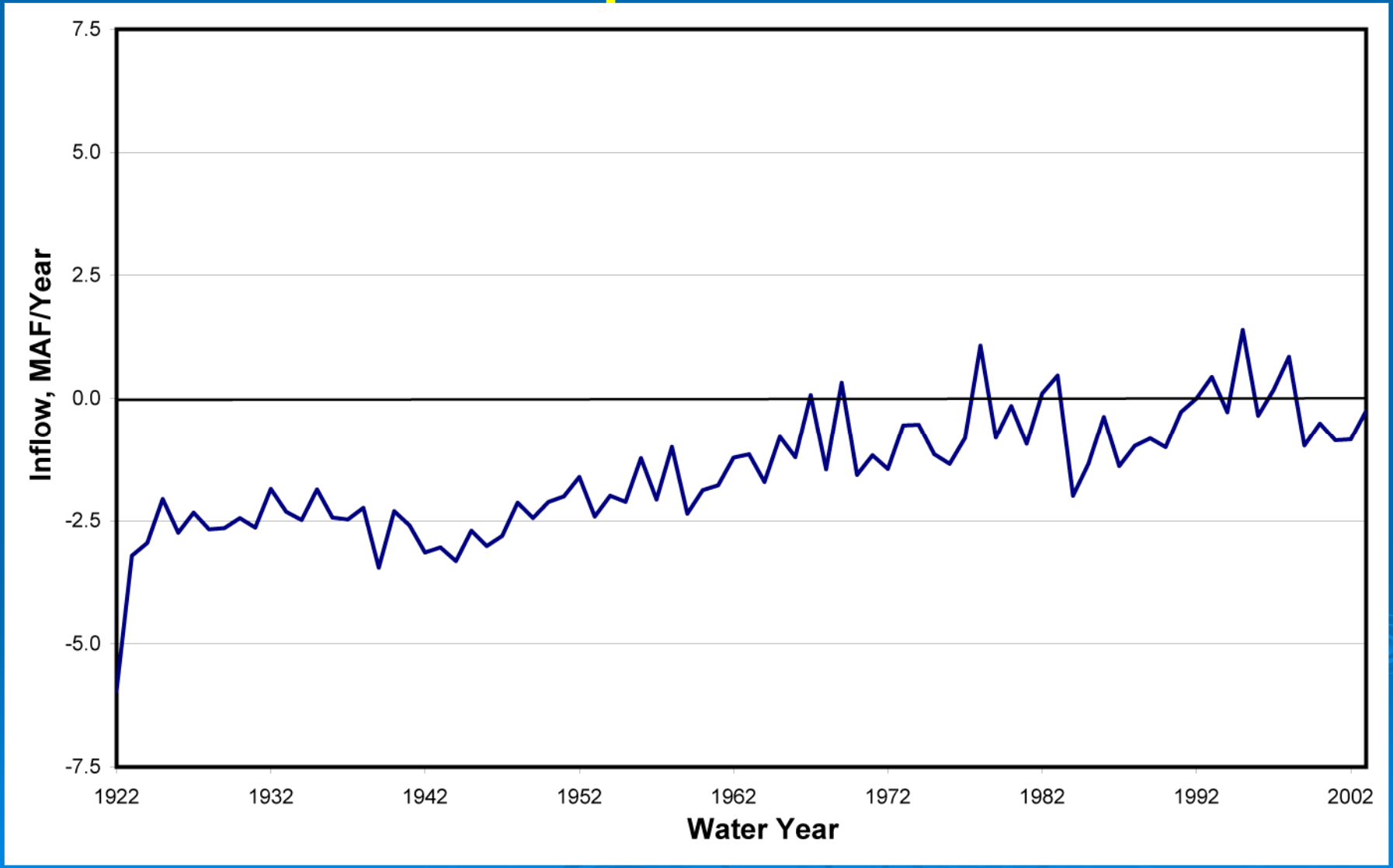




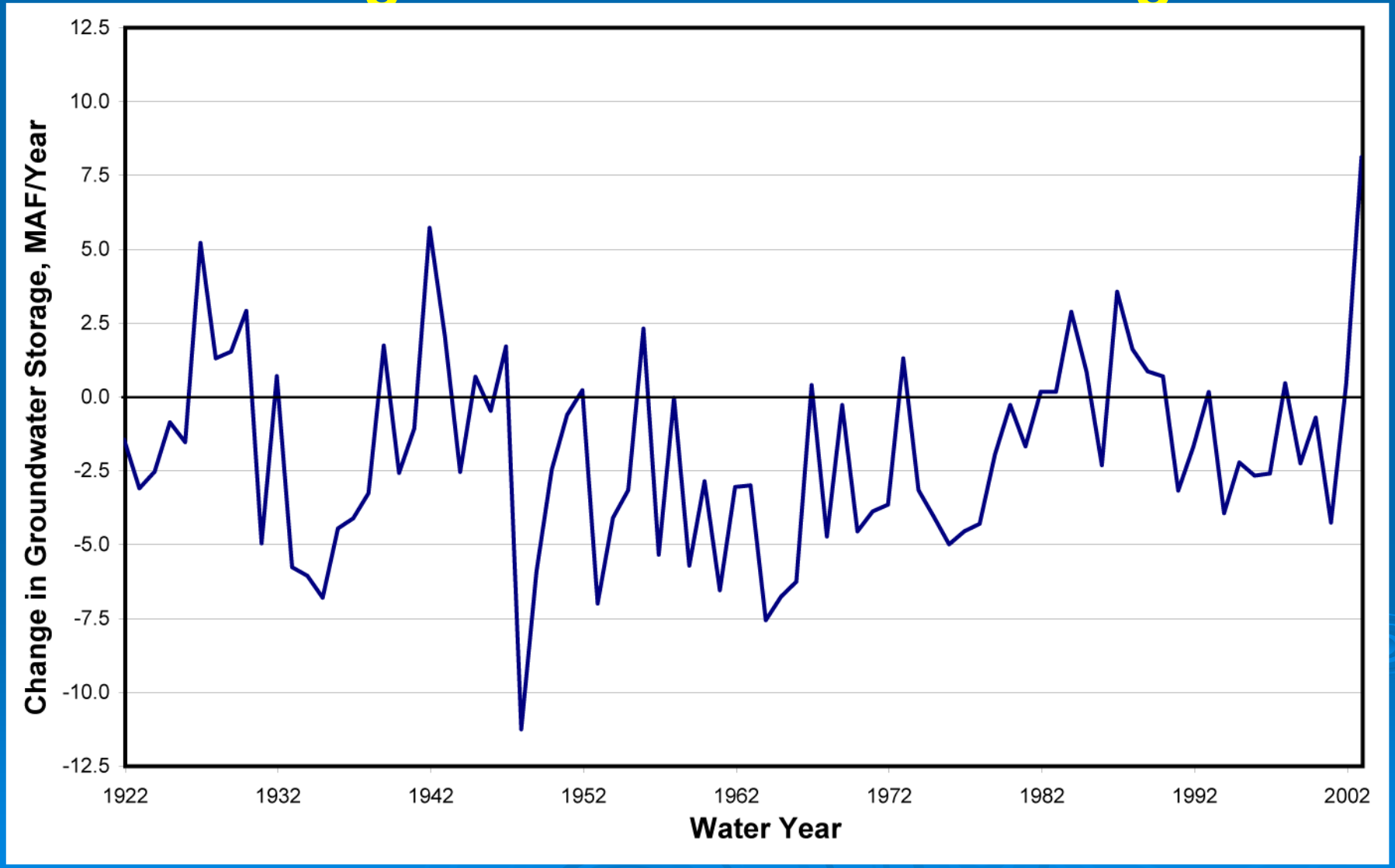
Groundwater Pumping



Stream-Aquifer Interaction



Change in Groundwater Storage



Simulated Water Budget Components

Average Annual Rates for Water Years 1975-2003

	Storage	Stream Leakage	Subsidence	Pumpage	Recharge	Interbasin Flows
Sacramento Valley	200,174	-350,859	51	-2,089,333	2,225,060	14,908
Delta	-82,464	-30,188	-105	-204,022	430,915	-114,136
Eastside Streams	139,029	109,888	50	-771,925	308,327	214,631
San Joaquin Basin	150,969	-499,100	798	-1,414,172	1,935,691	-174,196
Tulare Basin	-2,109,300	-485,561	-9,533	-3,807,986	6,350,697	58,794
Model Area	-1,701,592	-1,255,821	-8,739	-8,287,438	11,250,690	0

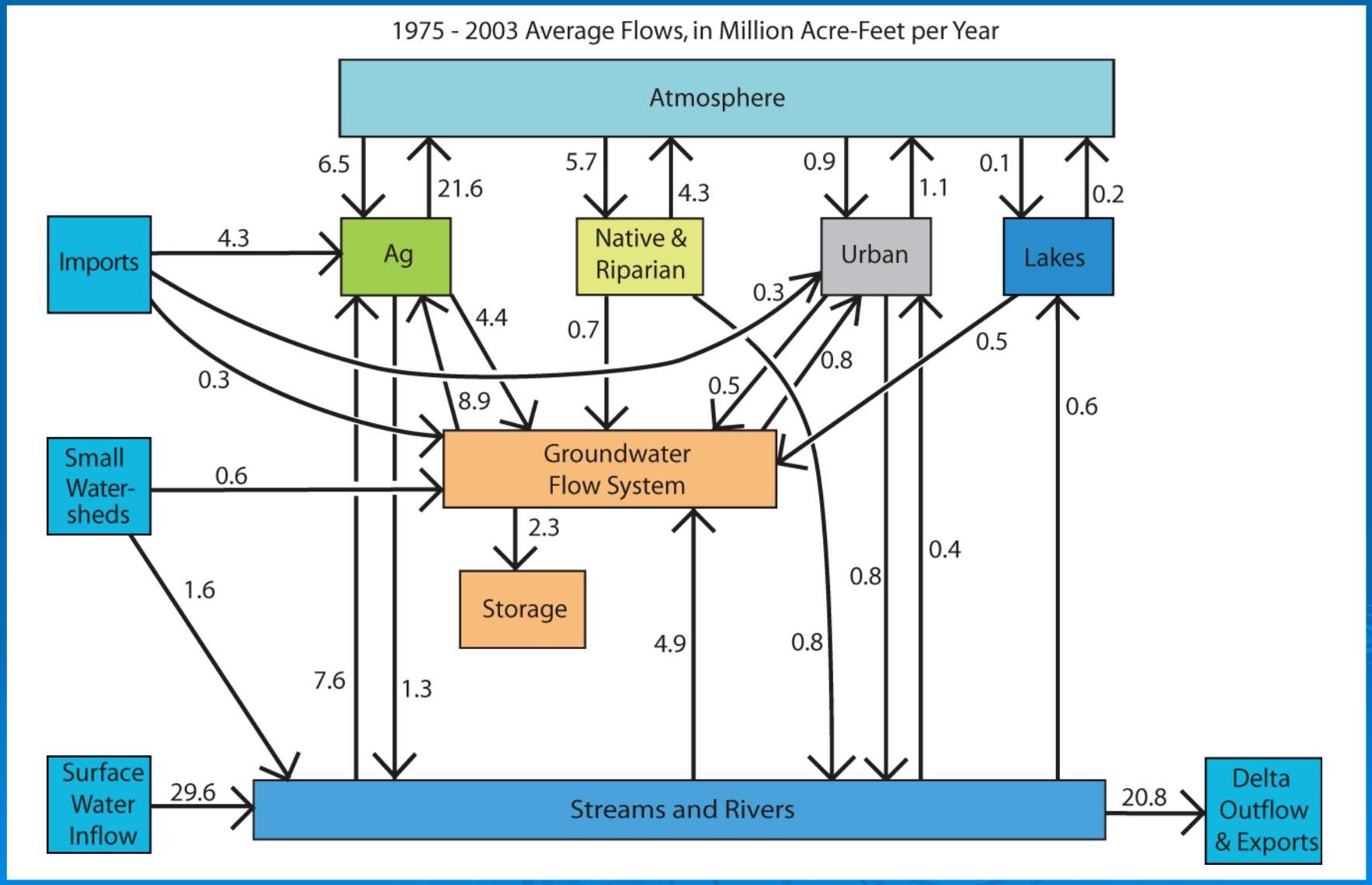
Simulated Water Budget Components

Average Annual Rates for Water Years 1975-2003

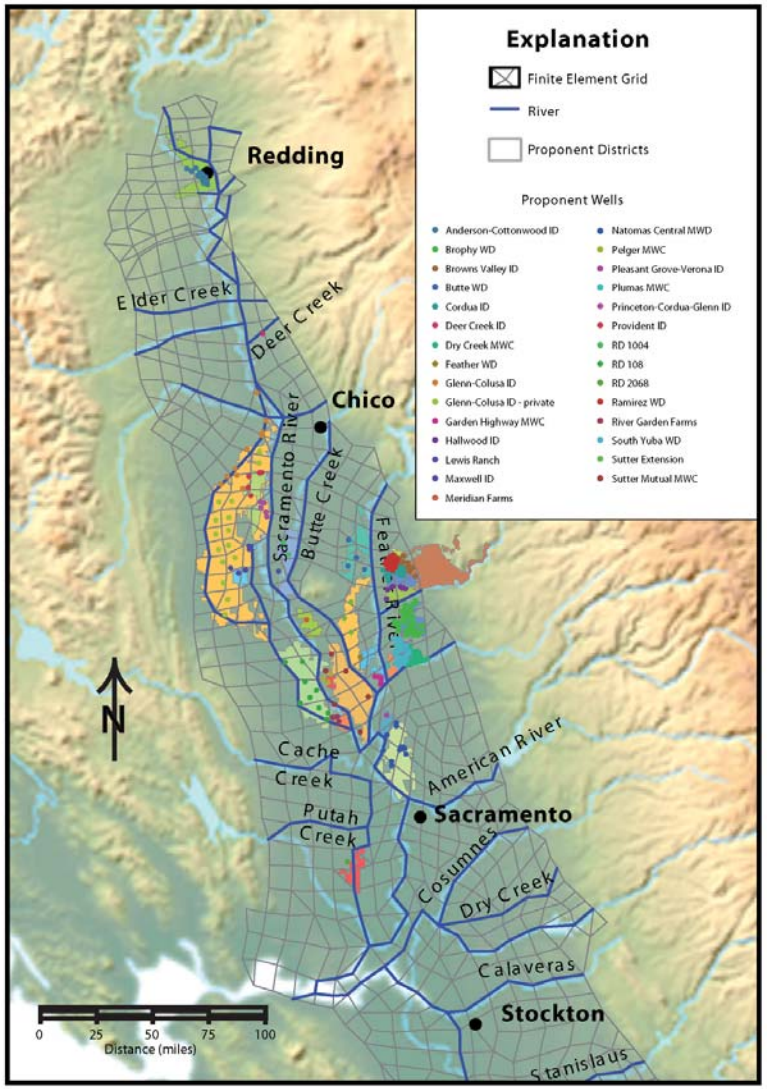
	Surface Water Inflows*	Surface Water Outflows*	Precipitation	Actual Evapo-transpiration
Sacramento Valley	19,955,538	17,759,801	6,849,346	8,472,276
Delta	31,005,209	25,564,486	926,265	1,533,207
Eastside Streams	1,307,325	1,443,871	1,405,900	1,683,961
San Joaquin Basin	5,820,154	4,535,437	2,521,049	5,544,759
Tulare Basin	3,220,309	1,179,001	3,584,871	10,596,423
Model Area	30,923,480	26,783,332	15,287,431	27,830,625

* Surface water inflows and outflows do not add up across hydrologic regions

Water Budget



Analyze a Conjunctive Use Scenario (In-Lieu Pumping)



Proposed Participants

- 29 Districts
- 293 wells
- 187,633 AF/year

Operate “non-wet” years

- 1973 1 yr
- 1976-81 6 yrs
- 1985 1 yr
- 1987-94 8 yrs
- 2000-03 4 yrs

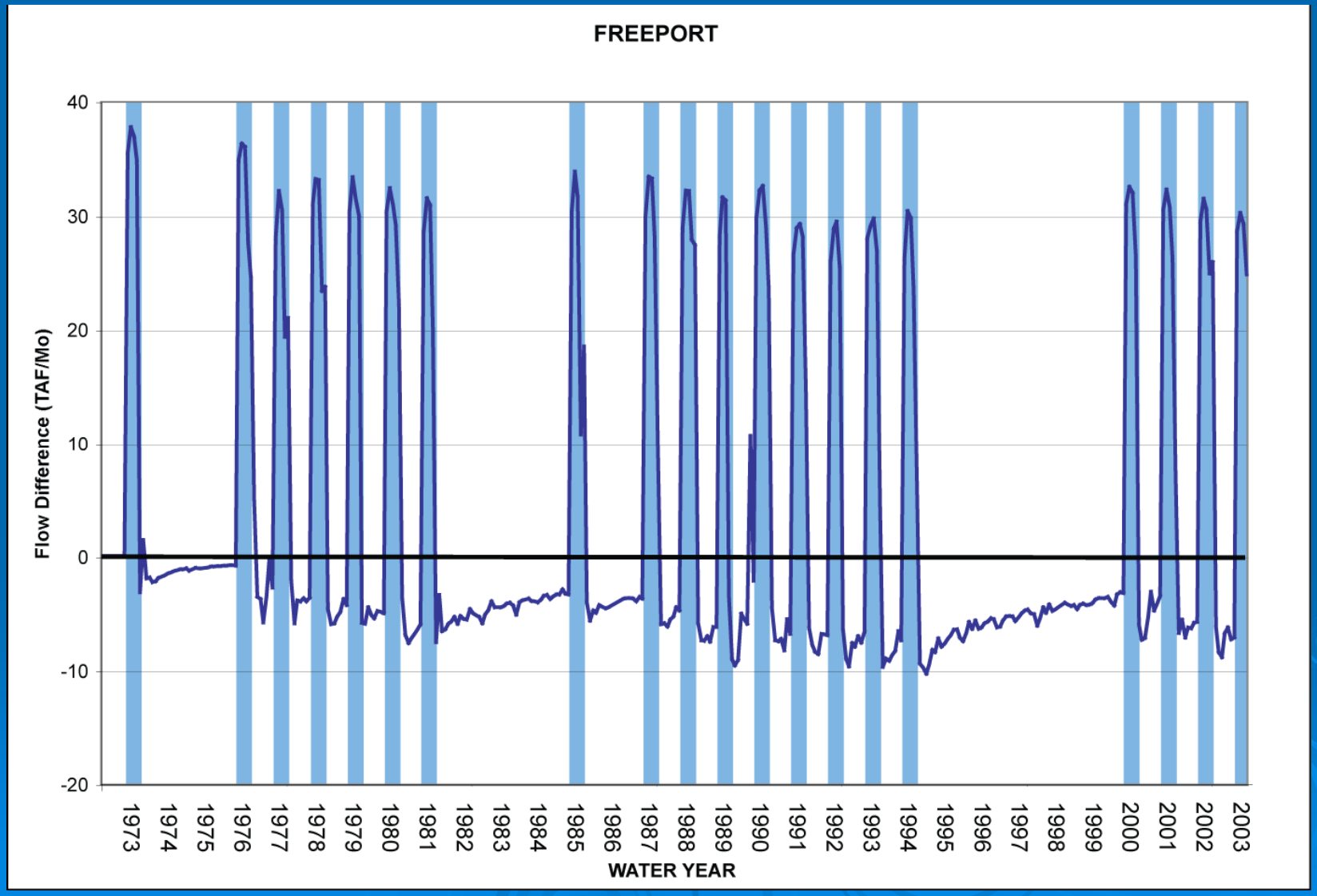
Sacramento River Index

Water Year	WY Index Index	WY Index Yr-type	Project Operation	Water Year	WY Index Index	WY Index Yr-type	Project Operation
1972	7.29	BN	-	1988	4.65	C	ON
1973	8.58	AN	ON	1989	6.13	D	ON
1974	12.99	W	OFF	1990	4.81	C	ON
1975	9.35	W	OFF	1991	4.21	C	ON
1976	5.29	C	ON	1992	4.06	C	ON
1977	3.11	C	ON	1993	8.54	AN	ON
1978	8.65	AN	ON	1994	5.02	C	ON
1979	6.67	BN	ON	1995	12.89	W	OFF
1980	9.04	AN	ON	1996	10.26	W	OFF
1981	6.21	D	ON	1997	10.82	W	OFF
1982	12.76	W	OFF	1998	13.31	W	OFF
1983	15.29	W	OFF	1999	9.8	W	OFF
1984	10	W	OFF	2000	8.94	AN	ON
1985	6.47	D	ON	2001	5.76	D	ON
1986	9.96	W	OFF	2002	6.35	D	ON
1987	5.86	D	ON	2003	8.21	AN	ON

C2VSIM Simulation of a Proposed In-Lieu Groundwater Pumping Program

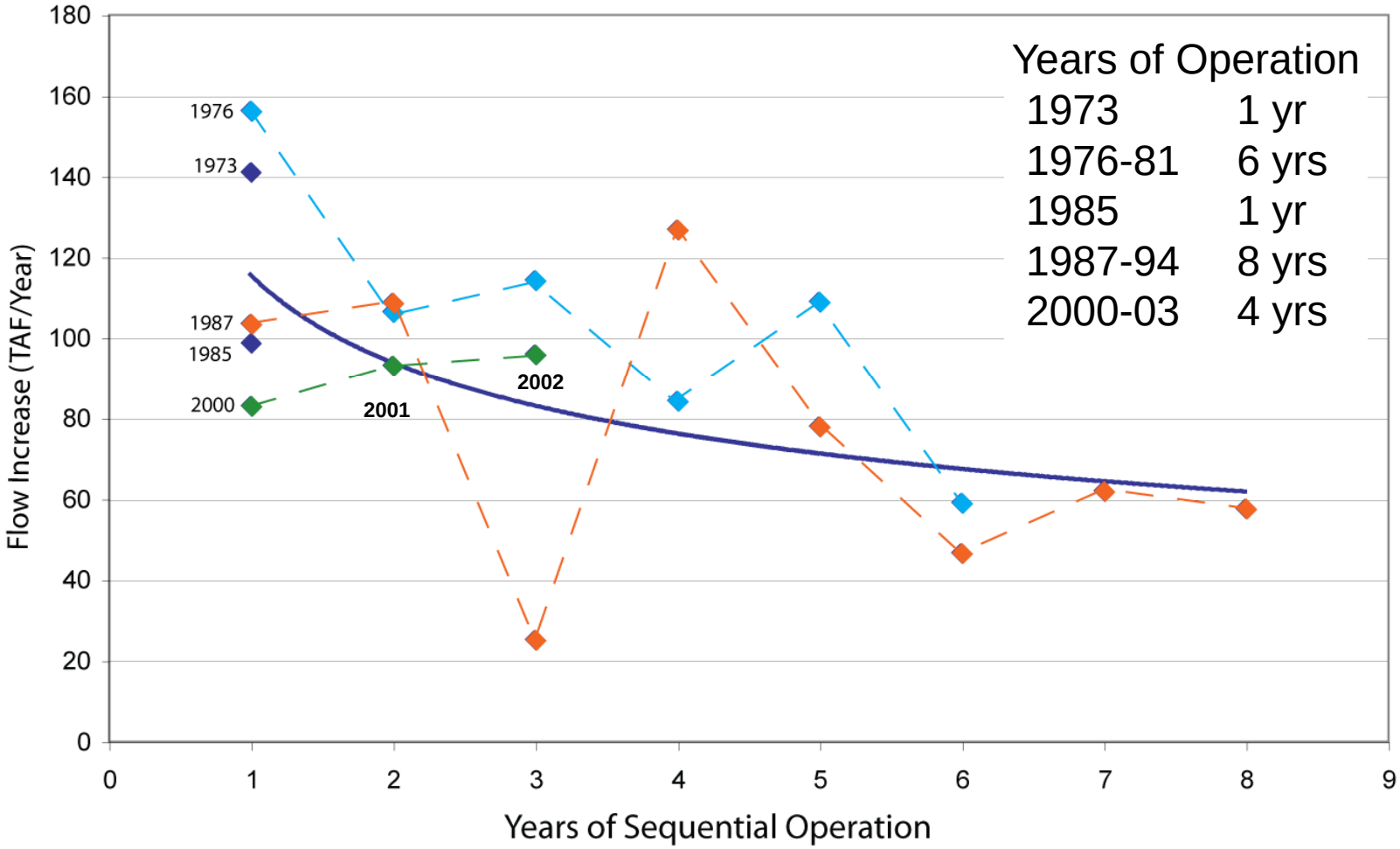
- Identify individual wells and pumping rates
- Prepare IWFM input files
  - October 1972 through September 2003
  - Pumps on in non-wet years
- C2VSIM runs
  1. Turn on groundwater adjustment
  2. Turn on surface water adjustment
  3. Turn on SVWMP wells & reduce diversions in non-wet years (Sacramento River Index)

Change in River Flow at Freeport



Summer Flow Increase at Freeport vs. Years of Sequential Operation

Scenario vs. Base Case, Sacramento River at Freeport



C2VSIM Simulation of Reduced Surface Water Availability Scenarios

Joint LBNL-DWR Project

- 30%, 50% and 70% reduction
- 10, 20, 30 and 60 years
- Climate model results to Calsim for rim inflows
  - Prepare C2VSIM inflow & diversion files
- C2VSIM runs
  - October 2003 as initial condition
  - 10-yr run-up, drought period, 10-yr recovery

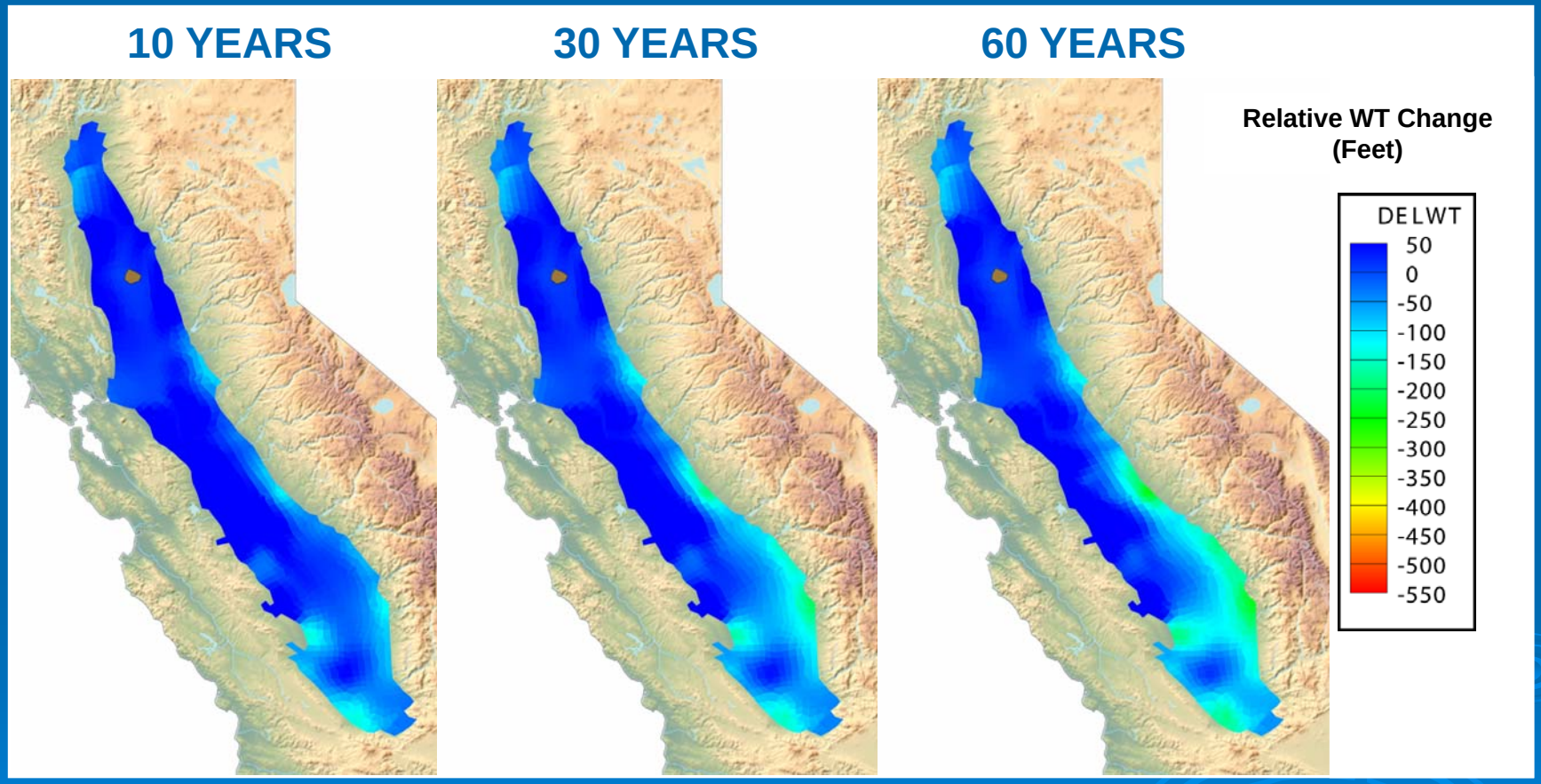
  1. Turn on groundwater adjustment
  2. Post-process results

"Drought Resilience Of The California Central Valley Surface-Groundwater-Conveyance System" by N. L. Miller et al. Submitted to J. Am. Water Res. Assoc. April 2008.

Central Valley Water Table 'Relative' Response

Joint LBNL-DWR Drought Simulation

30-percent reduction in surface water inflows



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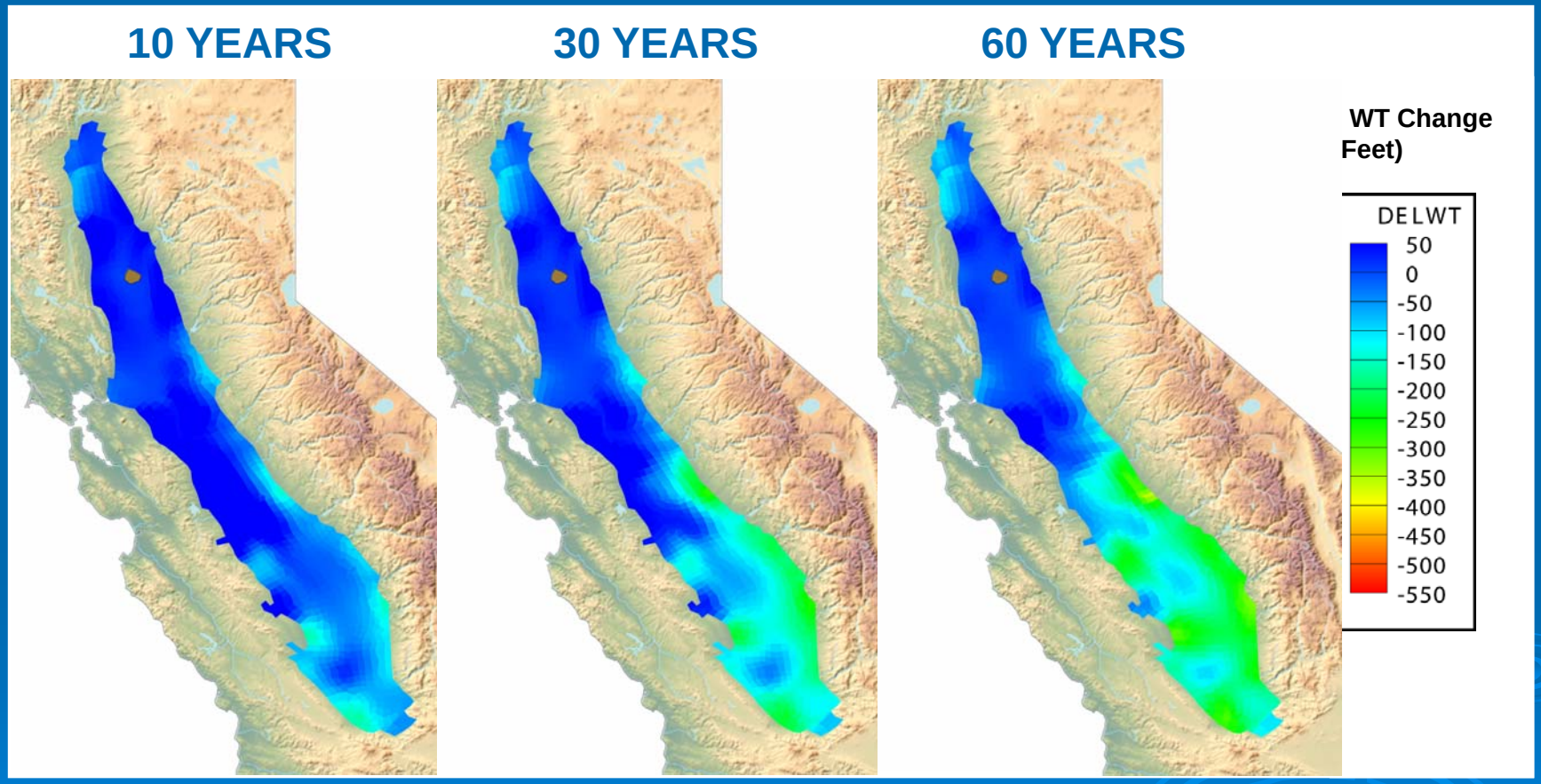
Central Valley Water Table 'Relative' Response

Joint LBNL-DWR Drought Simulation

70-percent reduction in surface water inflows



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Summary

- C2VSIM model performs well
  - Regional parameters replicate geological features
  - Lots of information – areal recharge, storage, GW-SW
  - Groundwater pumping estimates look reasonable
  - Subregional ‘virtual farms’ limit spatial resolution

- Model improvements
  - Need to refine parameters for Kern County
  - Further spatial refinement of parameters (pilot points)
  - Refine geological information
  - Increase calibration data set (observations)
    - Vertical head gradients
    - Stream-groundwater flow
    - Subsidence