Preliminary Simulation of Conjunctive Use in the Sacramento Valley Using C2VSIM

Presented to SVWMP Model Selection Committee
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Acknowledgements

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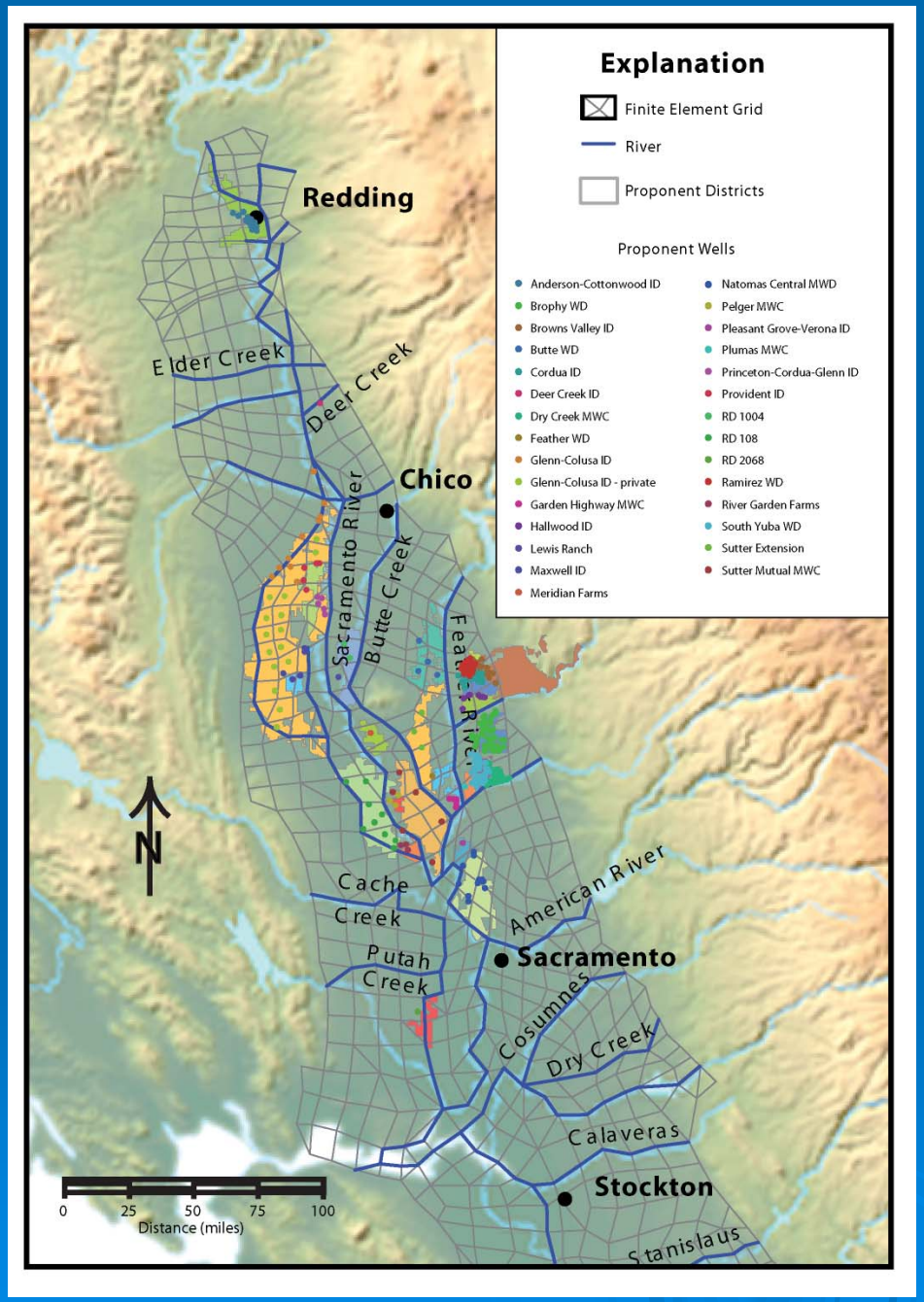
Outline

- SVWMP Modeling Goals
- Sacramento Valley Geology
- Modeling Tools: IWFM and C2VSIM
- C2VSIM Overview
- C2VSIM Calibration
- SVWMP Simulation
- Preliminary Findings
- Future Work

Sacramento Valley Water Management Program

- Sacramento Valley Water Mgmt. Agreement
  - SWRCB D-1641, A15
  - Sacramento Valley water users
  - California DWR
  - USBR
  - Export water users
- Conjunctive water management projects
  - Groundwater substitution for surface water
  - Approximately 30 proponents
  - Operate in non-wet years (Sacramento River Index)
  - 173 TAF/year, June 1 – October 31



SVWMP Wells

- 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 Valley Geology

- Formation dominated by inter-glacial cycles
  - Glacial melting drives large sediment volumes to valley
  - During inter-glacial periods, soil formation
  - Buried lakes and wetlands form low-impermeability lenses
  - Tilting and deformation of basement rocks
  - Result is a layer cake with wedge-shaped layers
- Differentiating properties from texture
  - Same source material
  - Same distance from source
  - Same transport mechanism
- Vertical flow barriers
  - Fault locations delineated on basement rock
  - Vertical projection and importance uncertain

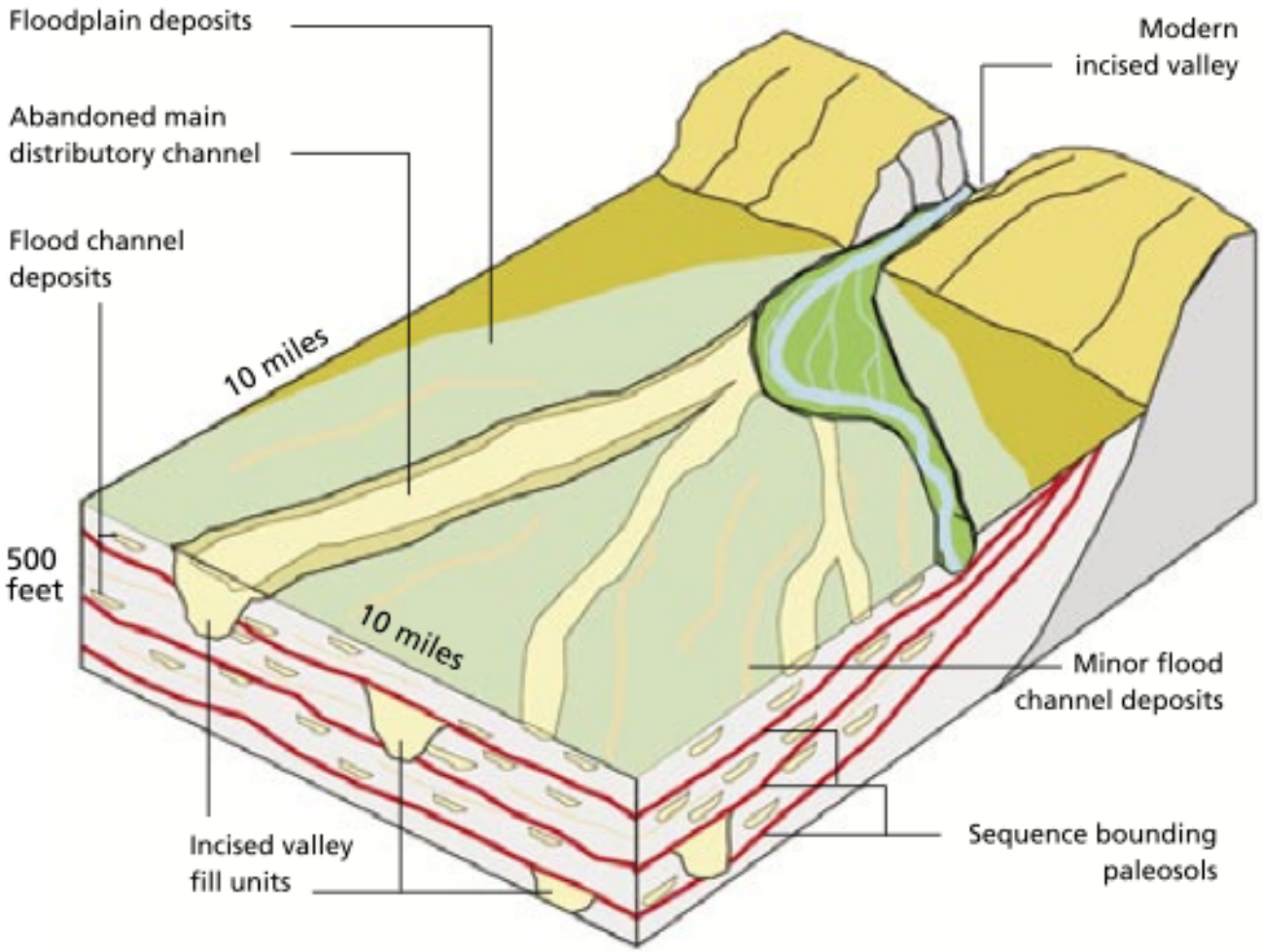


Fig. 2. Schematic diagram of the Kings River alluvial fan and its geologic elements.

Harter et al. 2005.

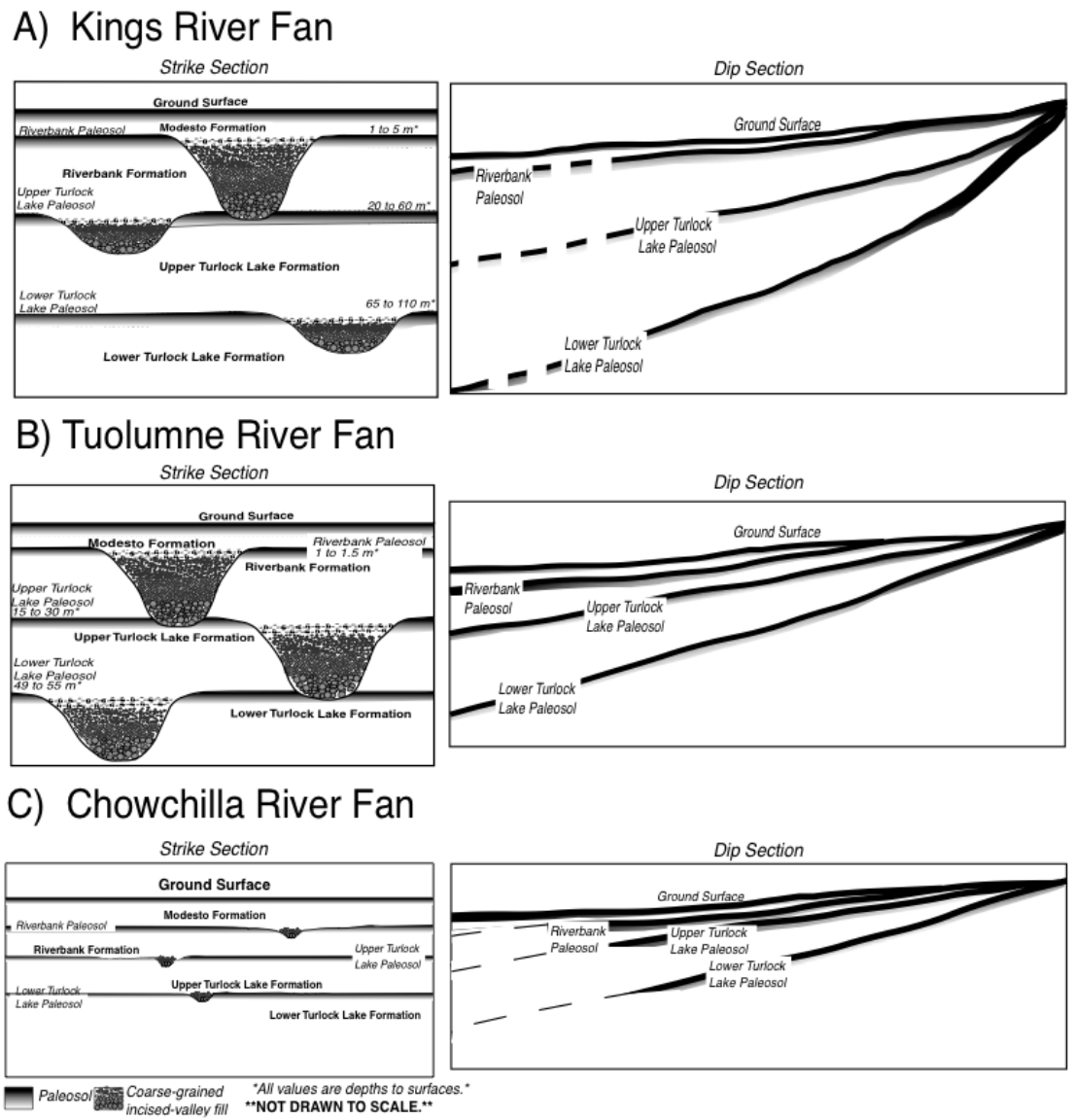
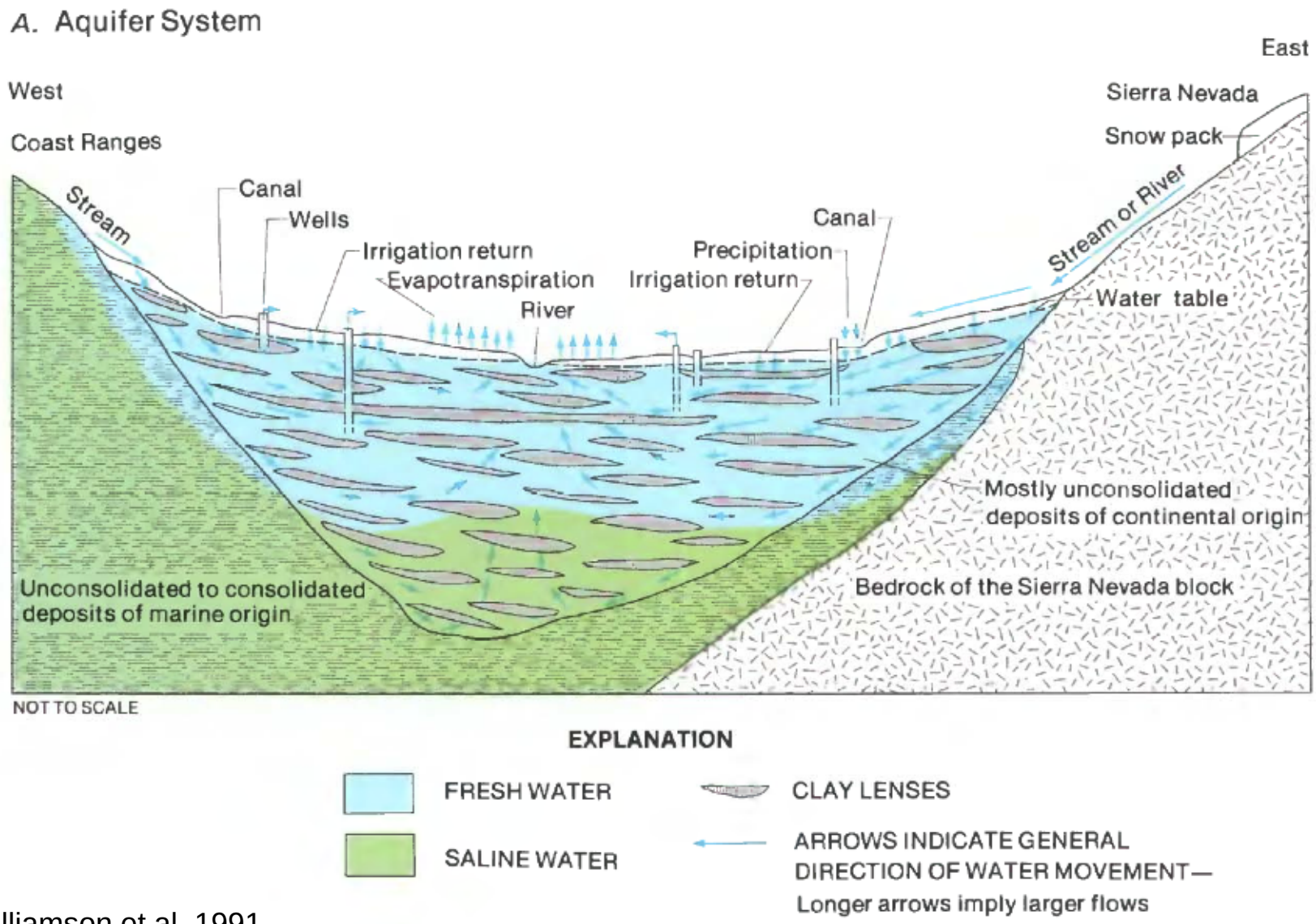
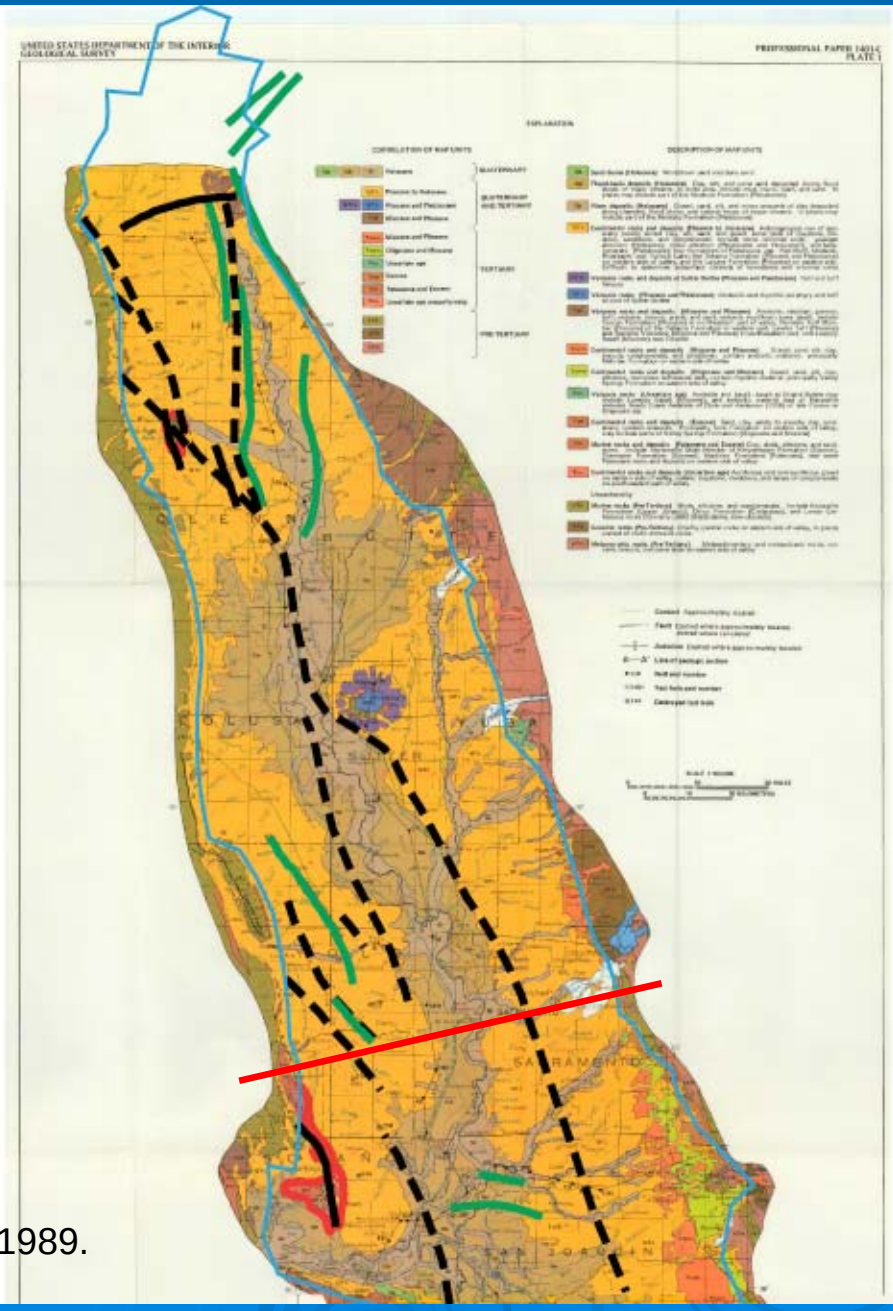


Fig. 6. Schematic cross-sections through: (**A**) the Kings River fluvial fan (based on Weissmann *et al*. 2002*a*, 2004); (**B**) the Tuolumne River fluvial fan (based on Burow *et al*. 2004); and (**C**) the Chowchilla River fluvial fan (based on Helley 1966).

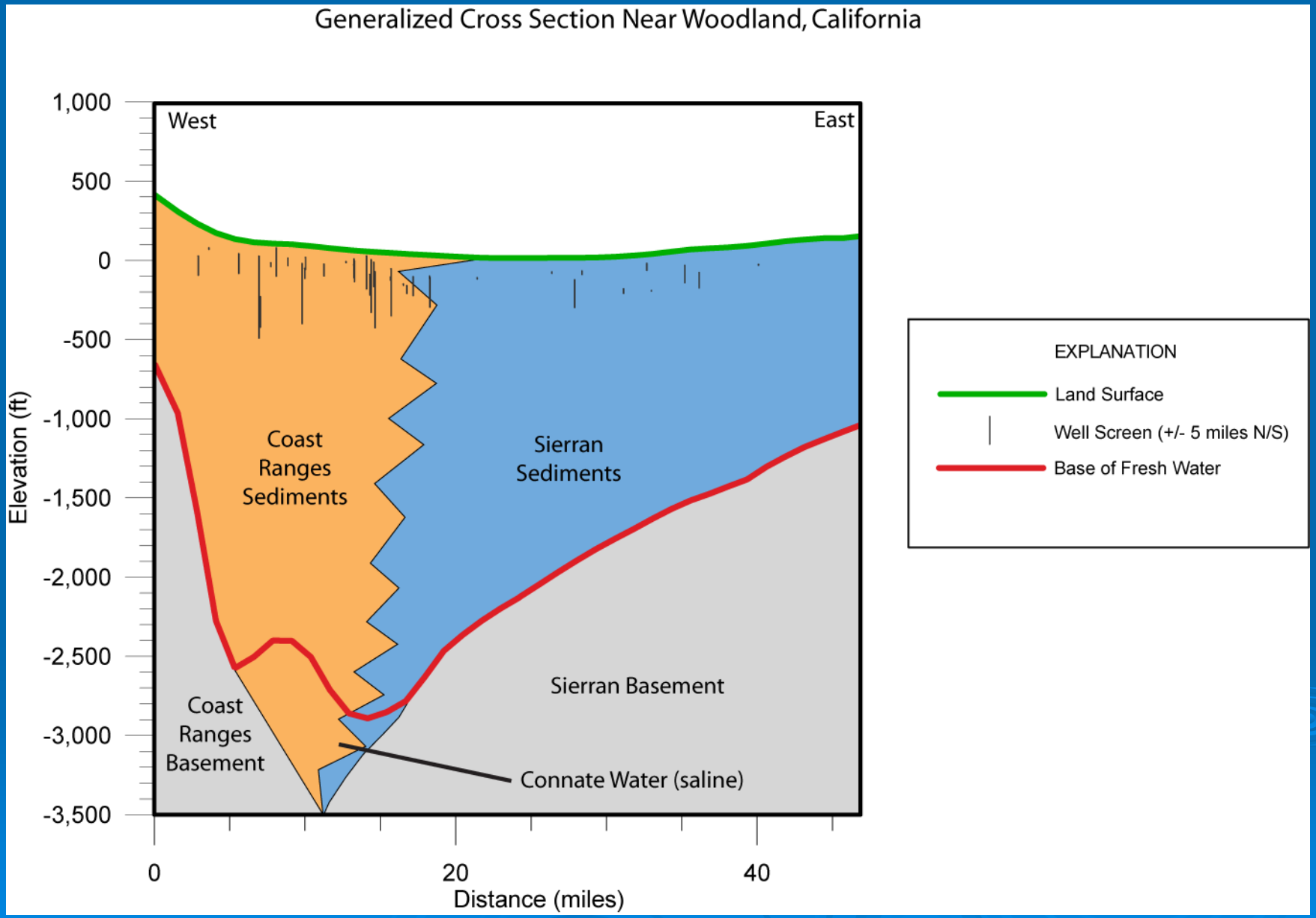
Weissmann et al. 2005.



Williamson et al. 1991.


UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
PROFESSIONAL PAPER 1601-C
PLATE 1
EXPLANATION
CORRELATION OF MAP UNITS
DESCRIPTION OF MAP UNITS

Page. 1989.


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

IWFM - Integrated Water Flow Model

- IGSM
  - Integrated groundwater with surface water & land surface
  - Finite-element groundwater flow simulation
  - Developed in 1980's
  - Peer review identified several issues
- IWFM
  - Developed by DWR staff (Can Dogrul), free
  - Uses IGSM input files with minor modifications
  - Correct issues identified in IGSM peer review
  - Modular structure facilitates component re-use
    - CALSIM 3: land surface and groundwater components
  - v4: saturated land uses: wetlands and rice
- Auxiliary utilities
  - PEST interaction facilitates model calibration
  - ArcGIS-based tools: grid generator, post-processor
  - MS Excel-based tools: post-processing
  - Ruby scripts: post-processing

IWFM - Integrated Water Flow Model

- 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
- Ungaged Boundary Watersheds
- Adjustments
  - Estimate surface water diversions vs. demand
  - Estimate groundwater pumping vs. supply & demand

IWFM Inputs and Outputs

Input Data

Precipitation

Evapotranspiration

Land use & crop acreages

Surface water inflows

Surface water diversions

Parameters

Pumping distribution

Crops: K_c, rooting depth

Soils: curve number, K_h

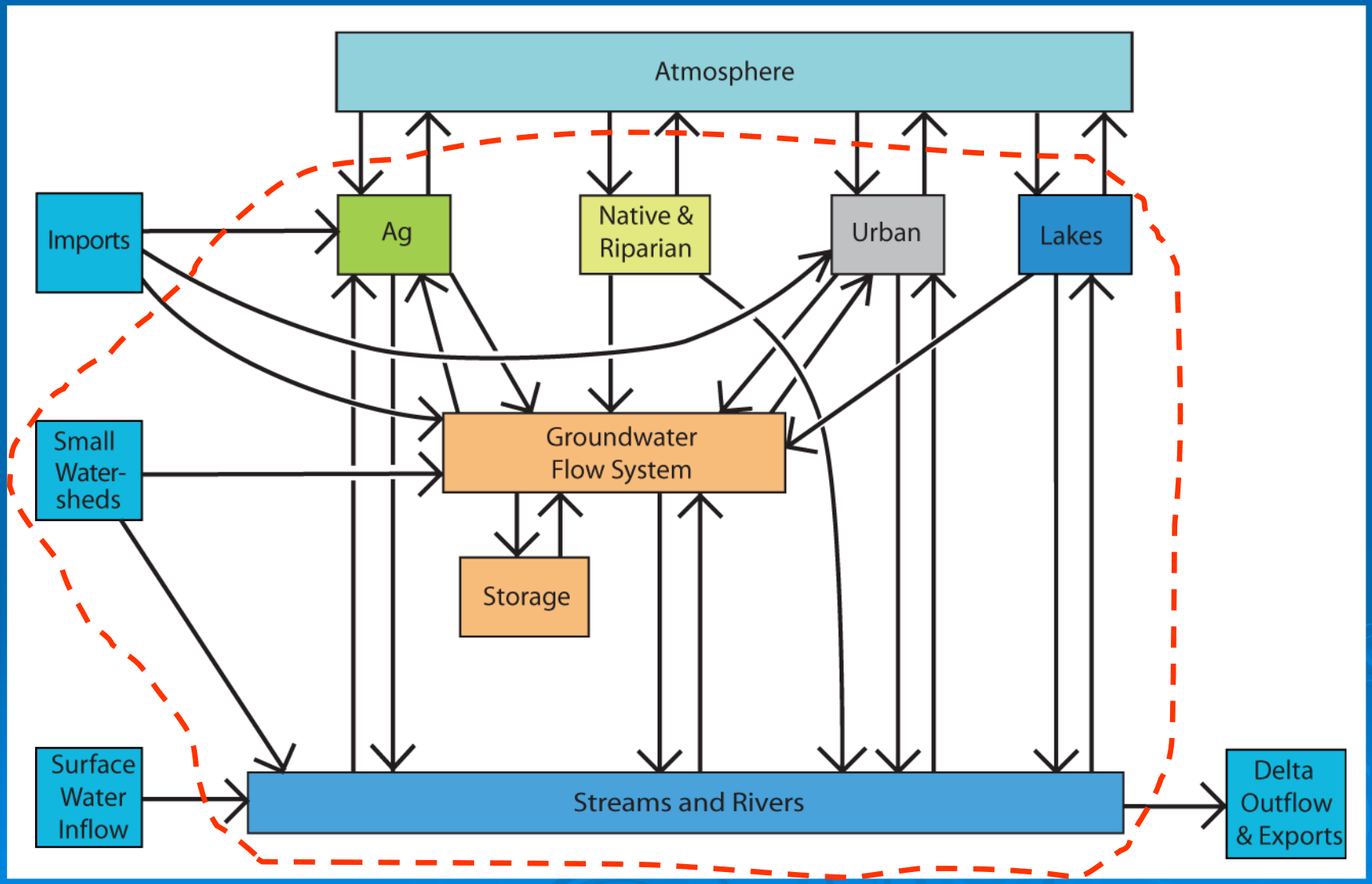
Output

Simulated heads & flows

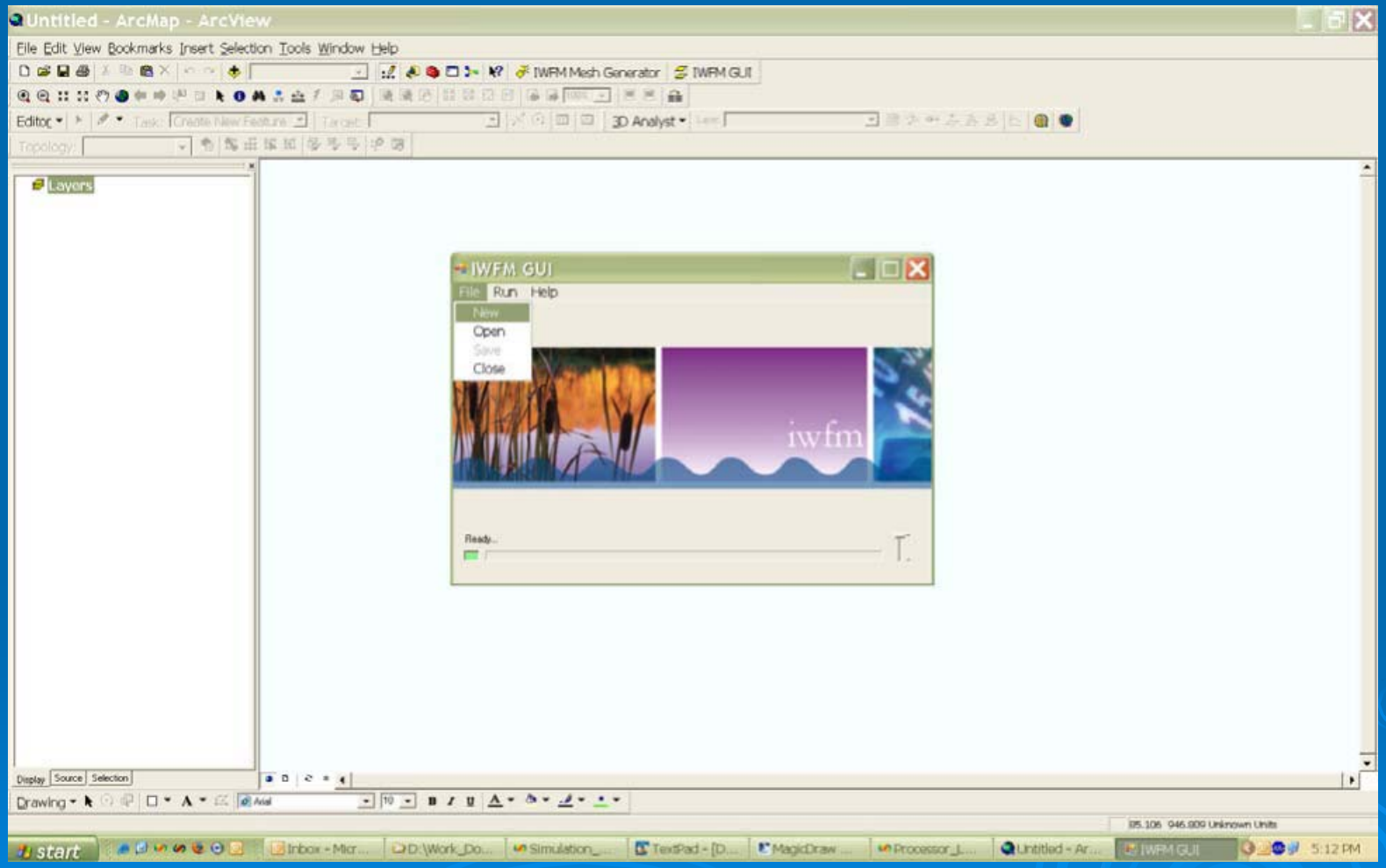
Detailed budgets including:

- Recharge to water table
- Crop water use
- Surface water reaches
- Surface water-Groundwater interaction
- Groundwater pumping
- Small watershed inputs

Integrated Model Components



IWFM – ArcGIS GUI



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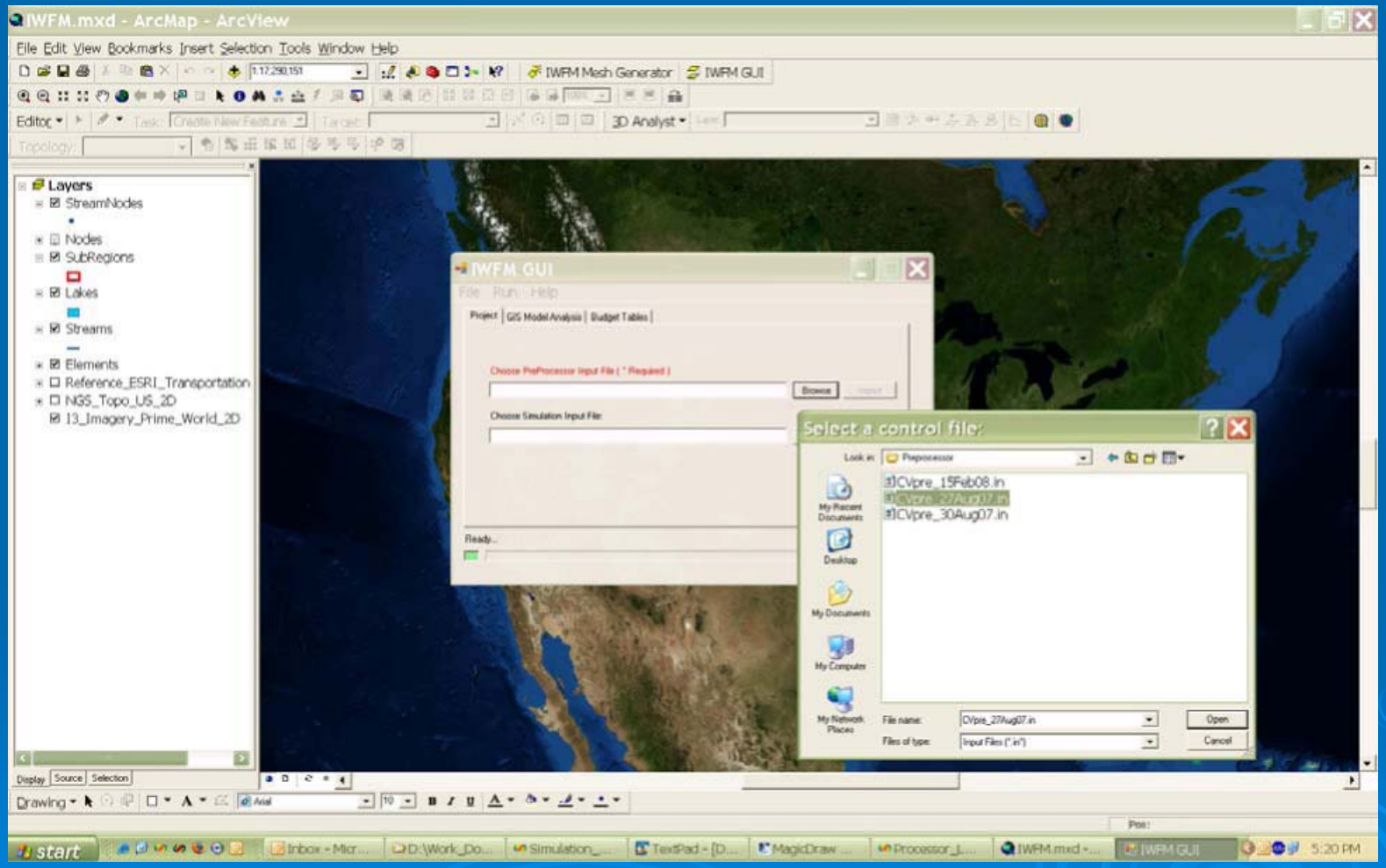

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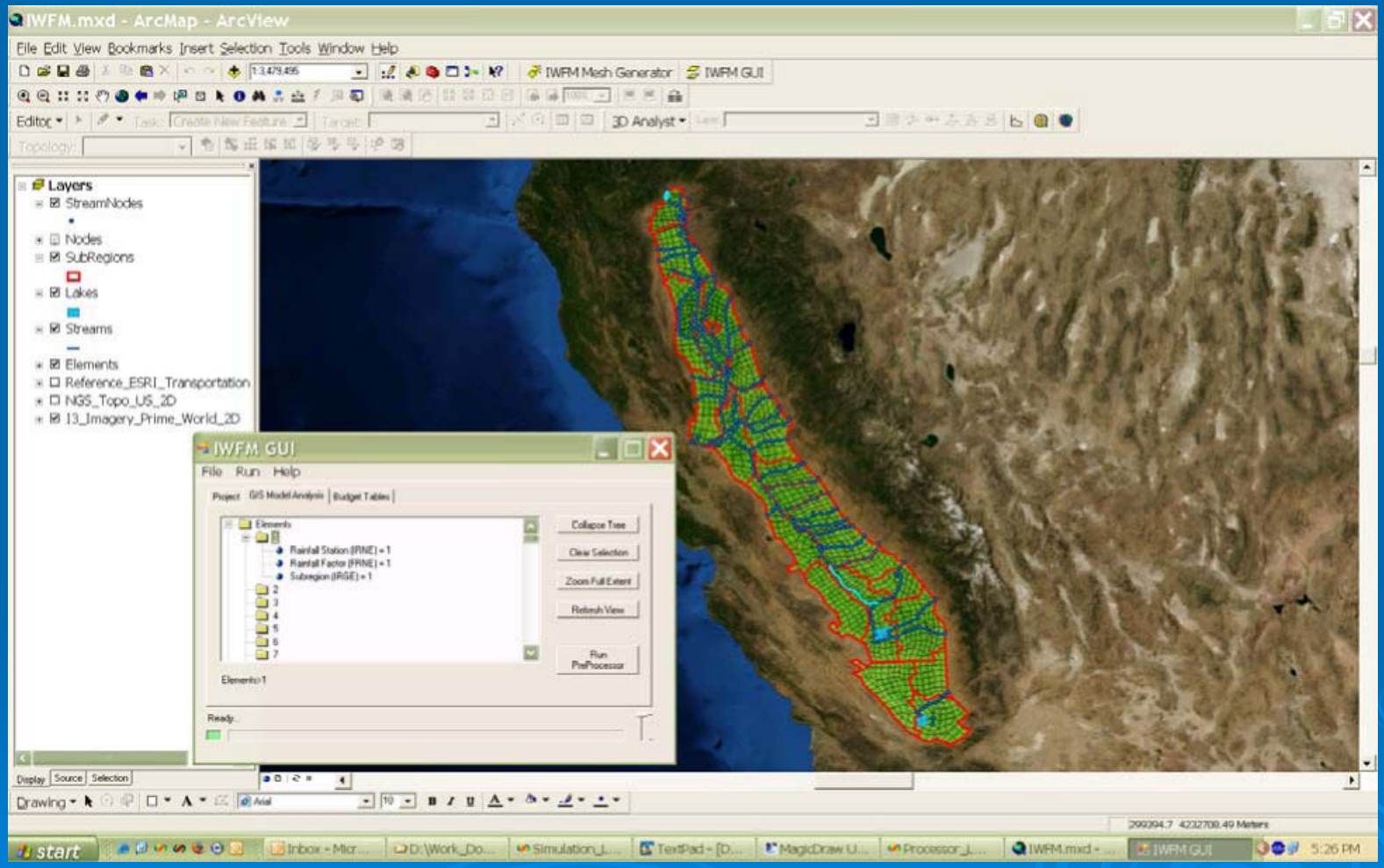

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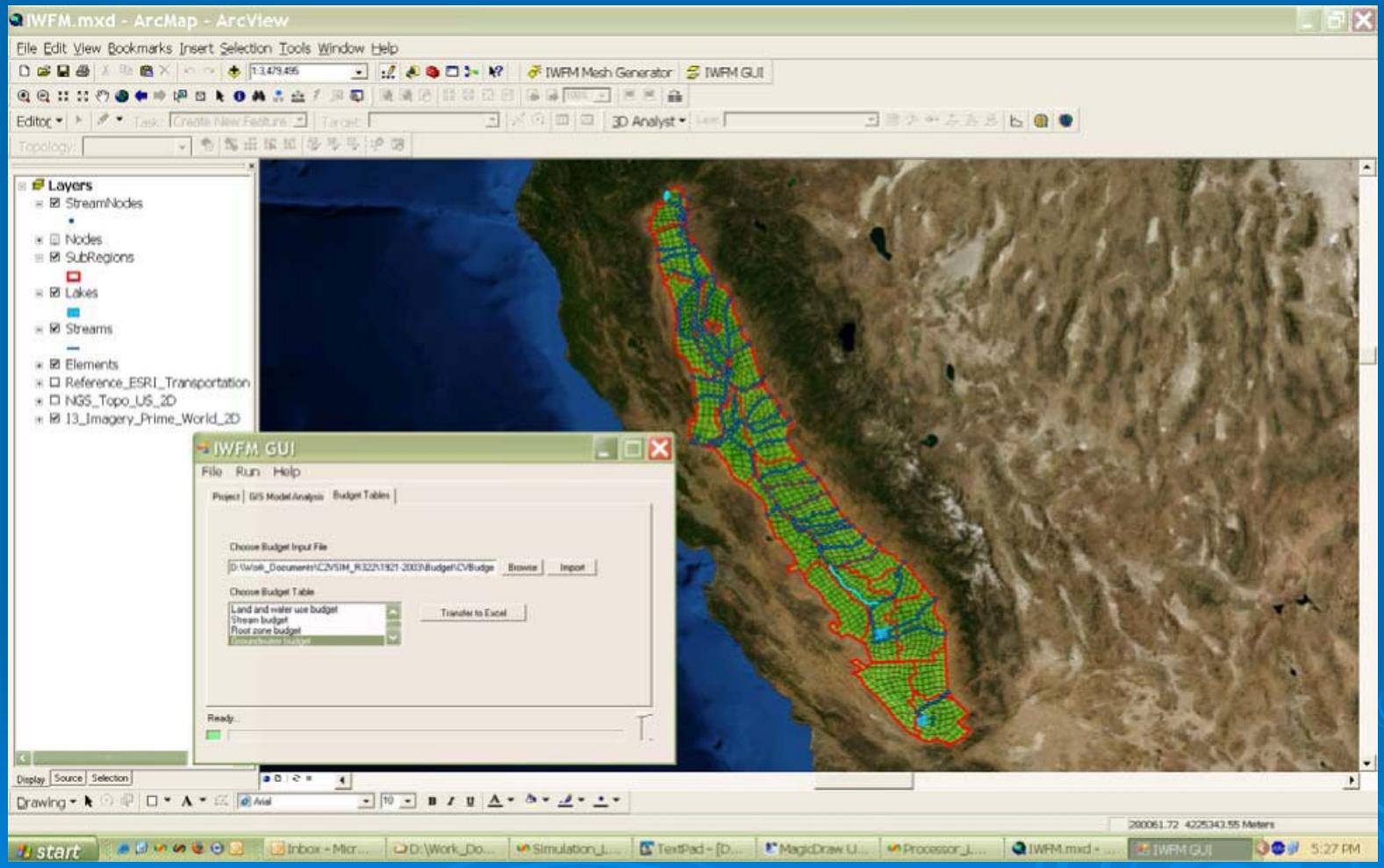
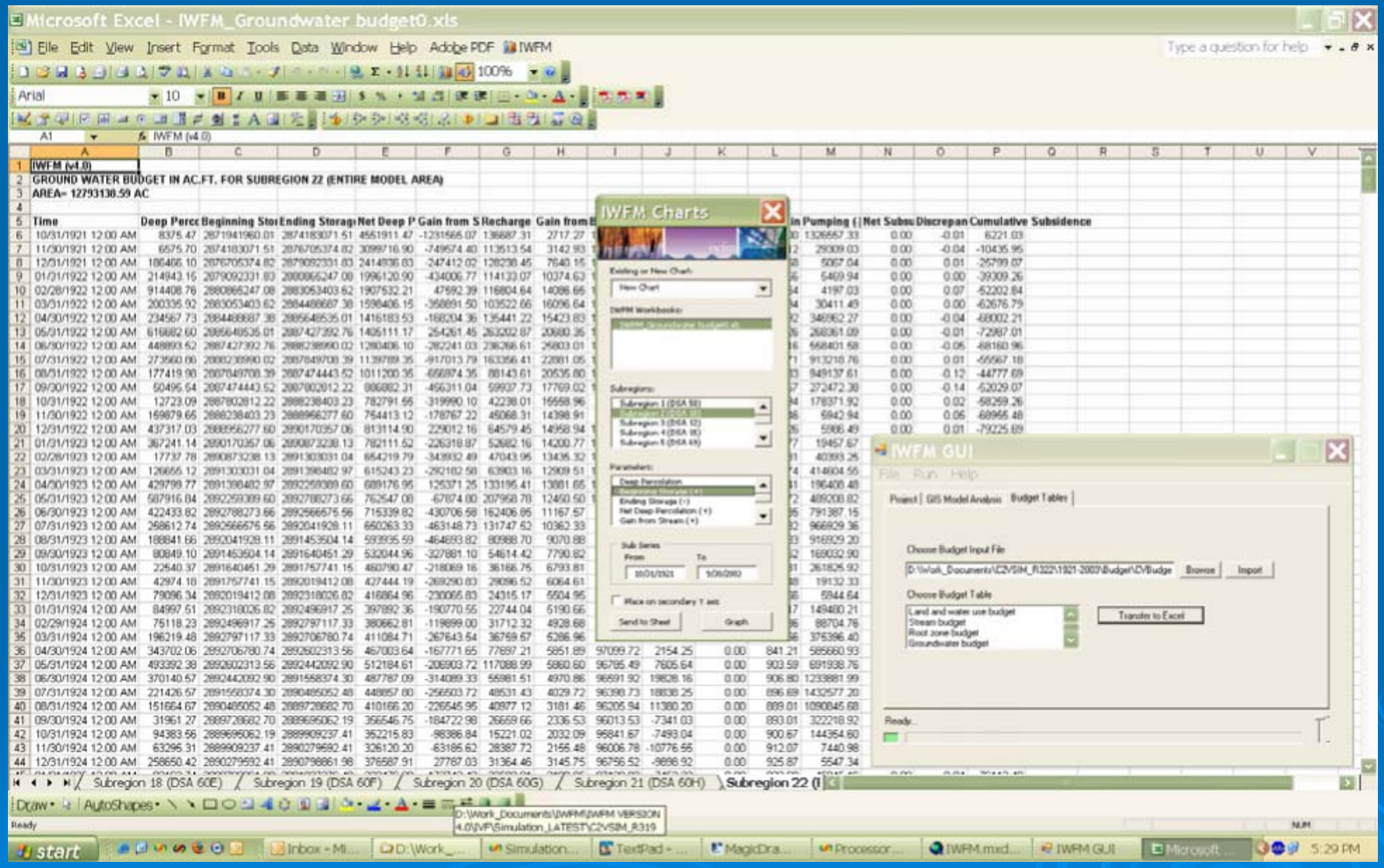
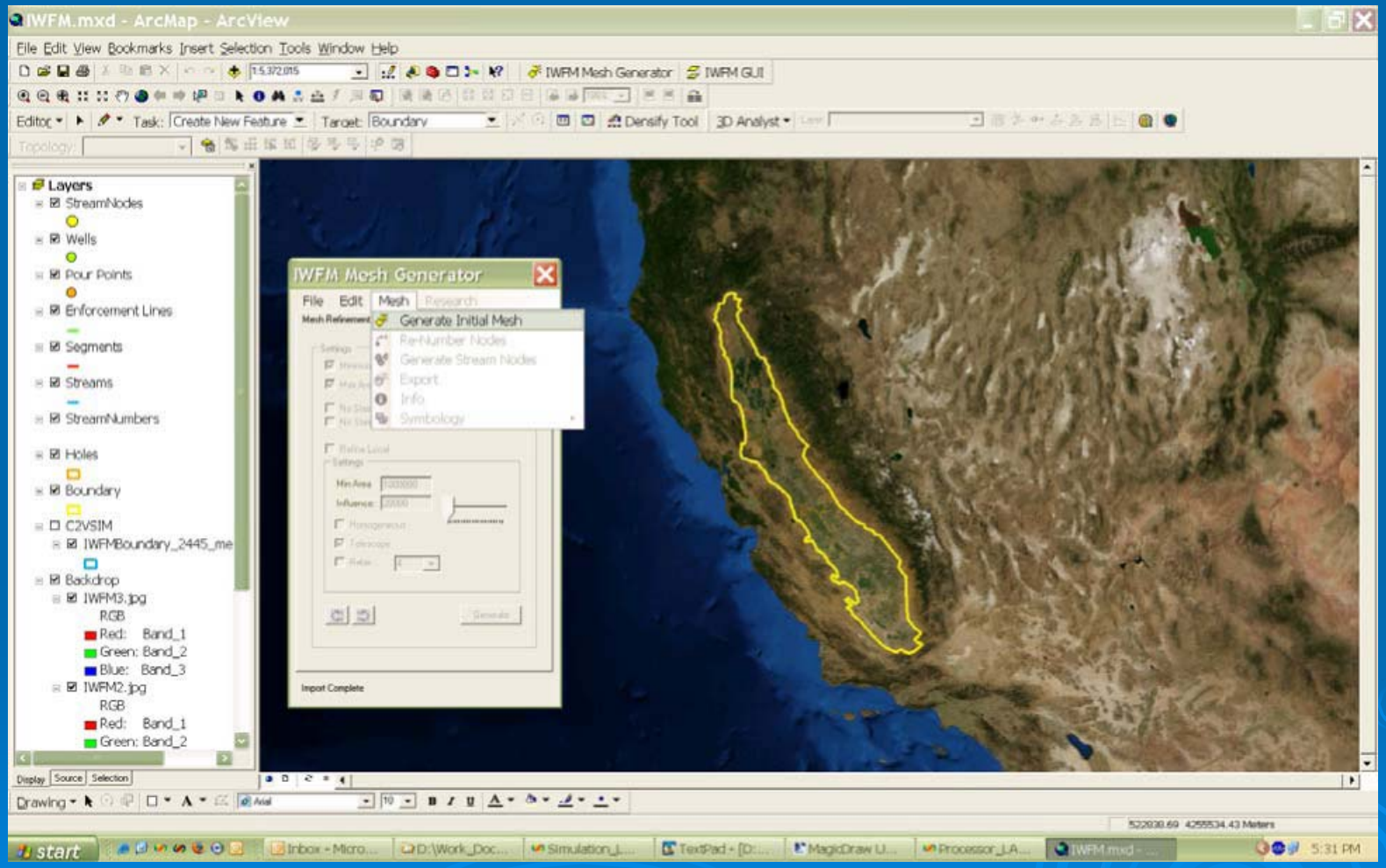


IWFM – Post-Processing



IWFM – Mesh Generator



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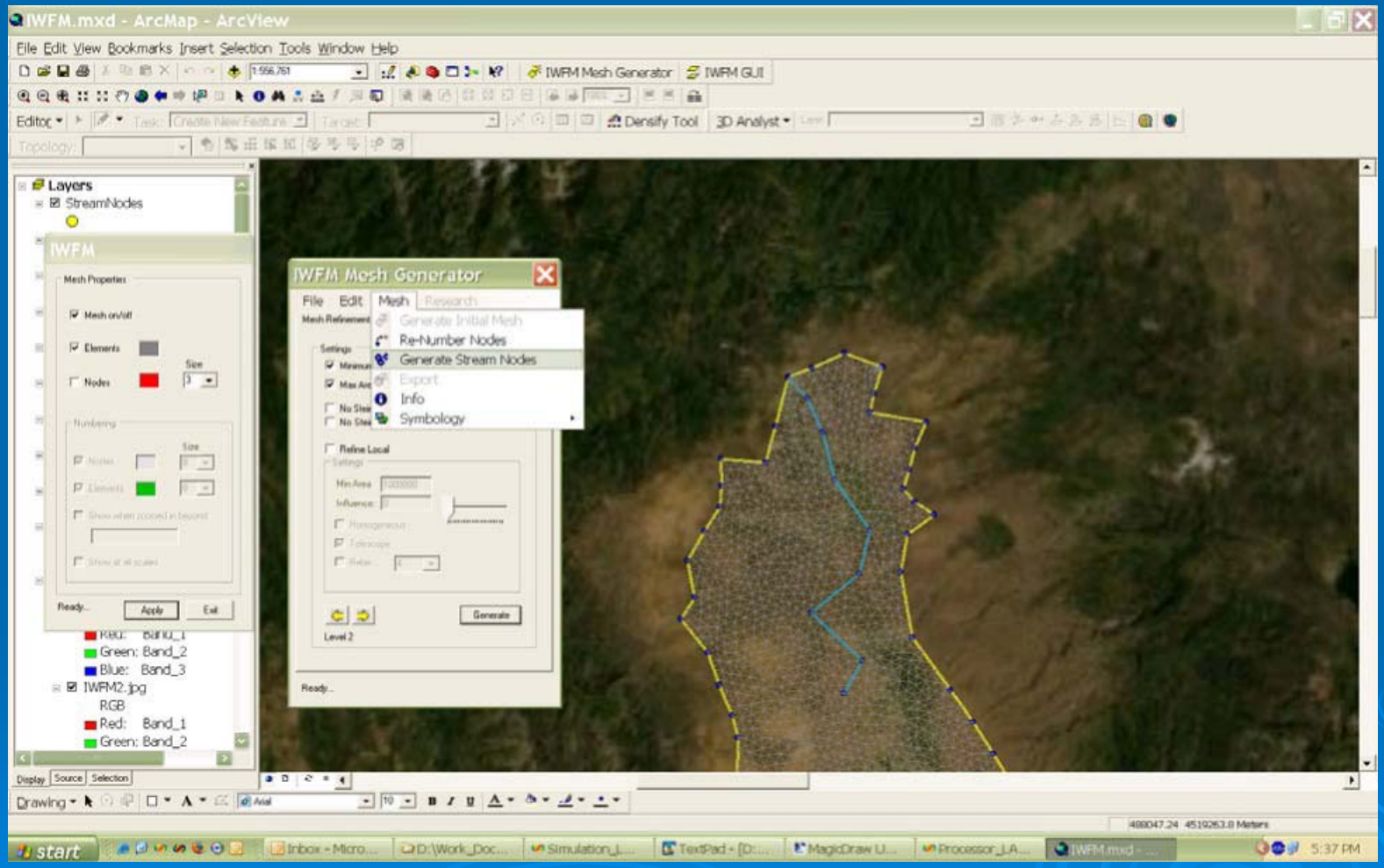
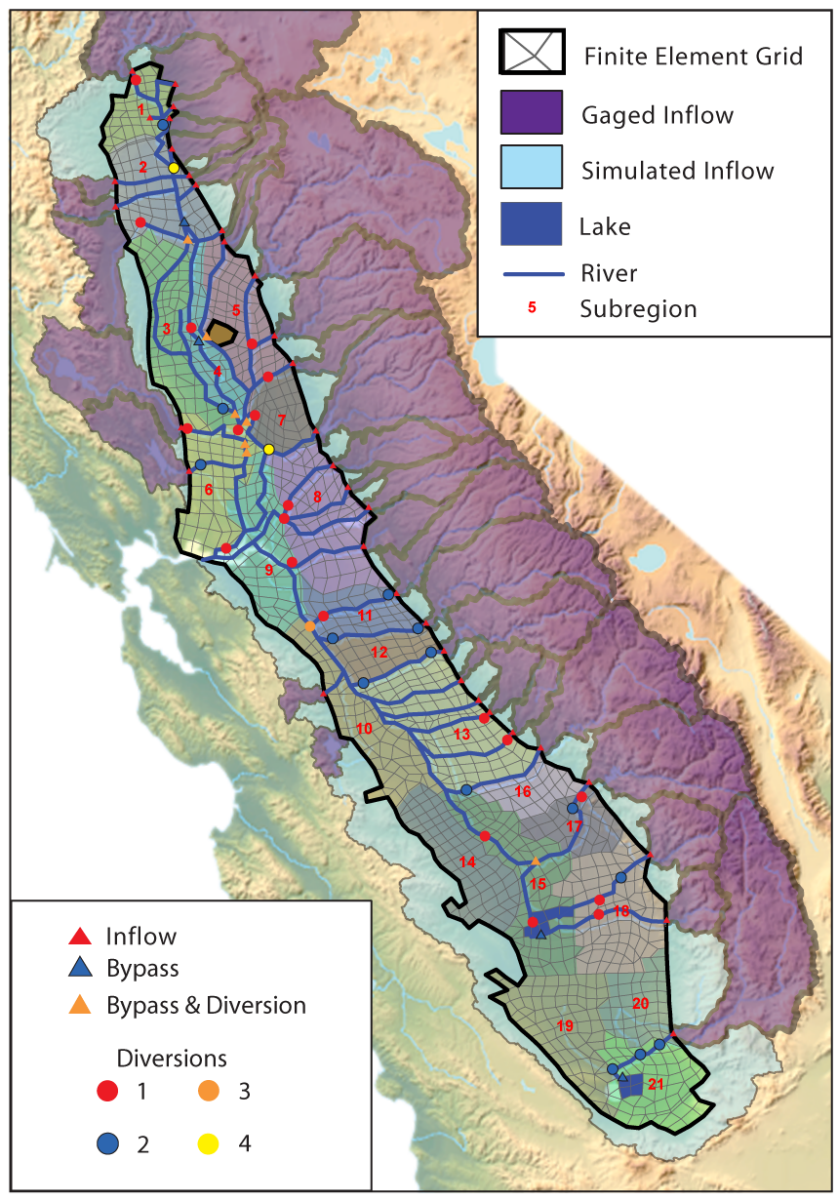


C2VSIM Model Grid

Finite Element Grid
- 3 layers
- 1393 nodes
- 1392 elements

Surface Water System
- 72 stream reaches
- 97 surface water diversion points
- 2 lakes
- 8 bypass canals

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



C2VSIM Subregions

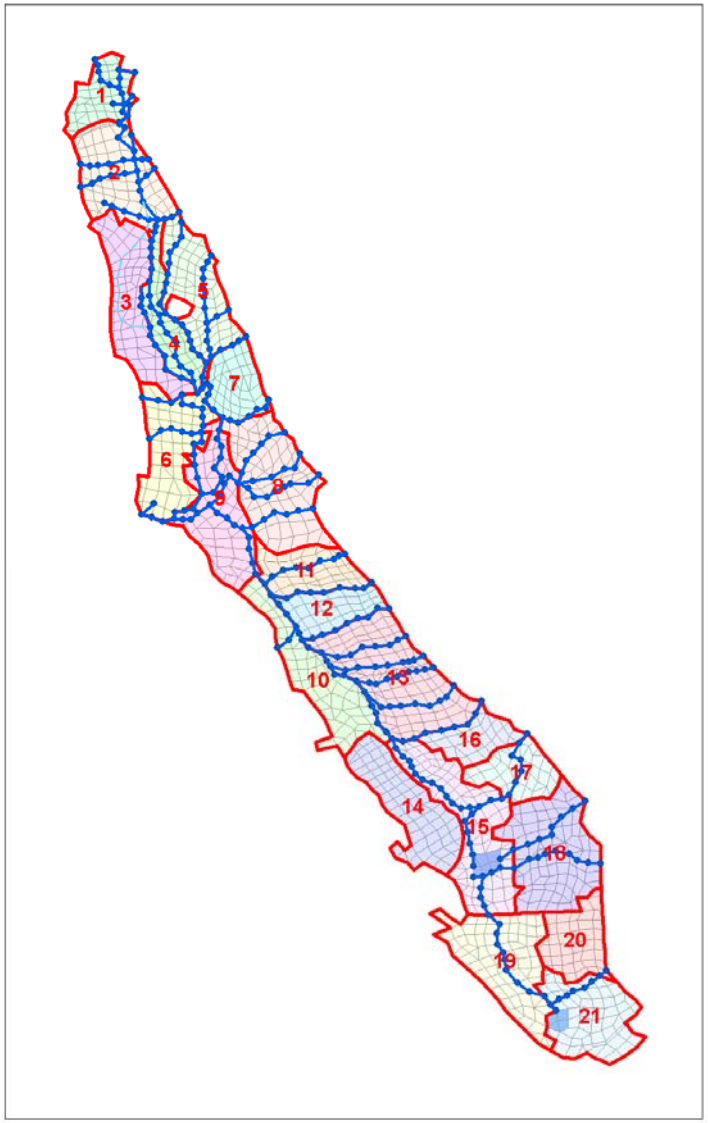
Water Budget Calculations

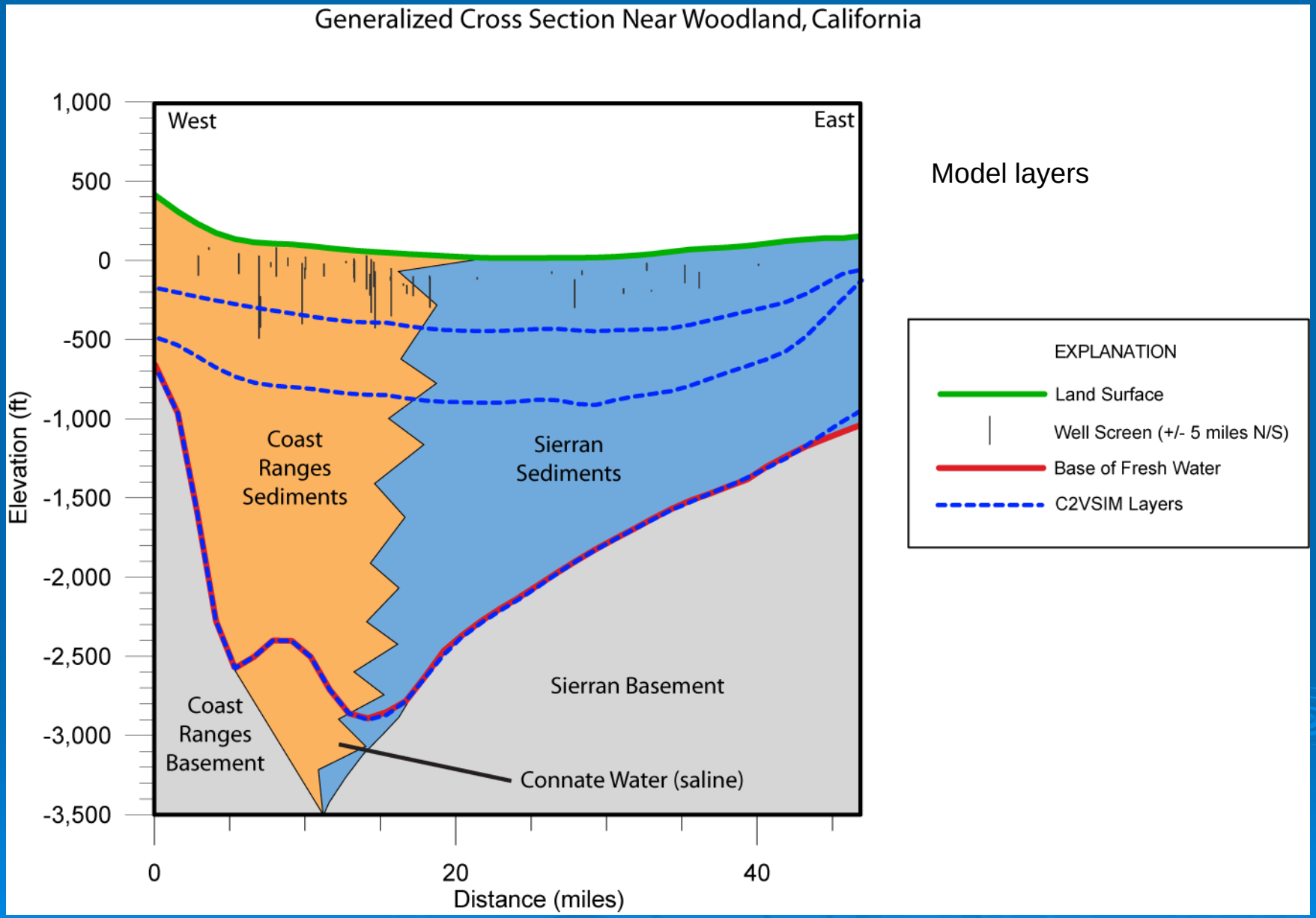
- Land use by element
- Aggregate to subregion

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

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Connate Water (saline)
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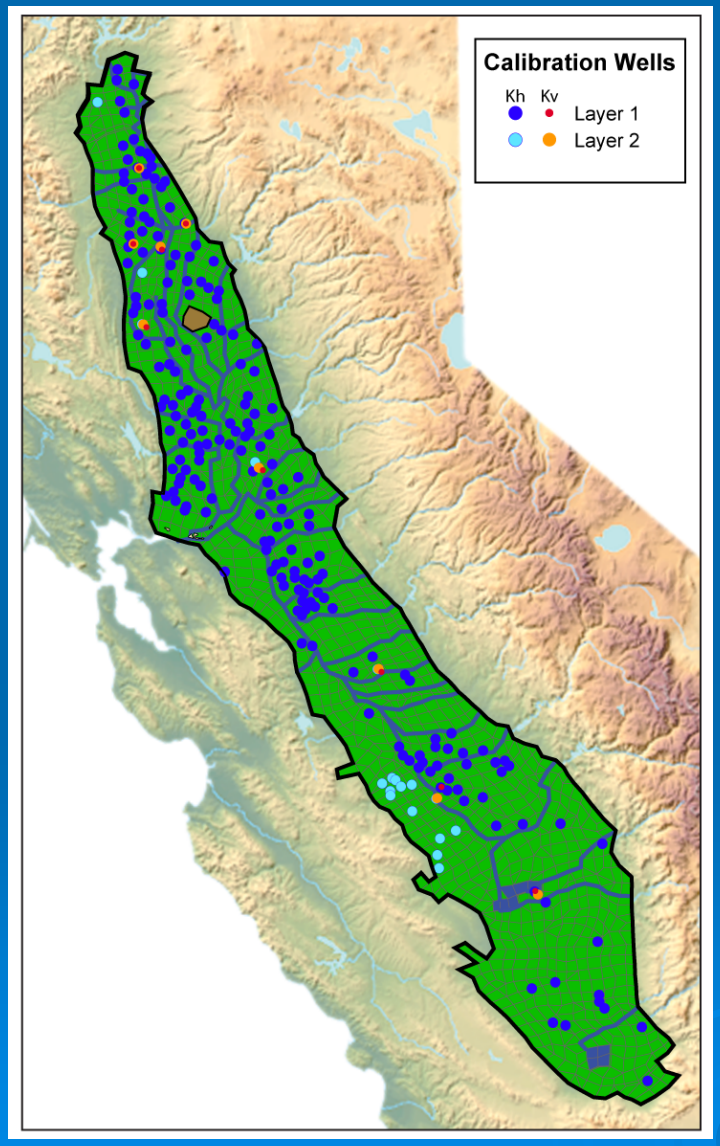
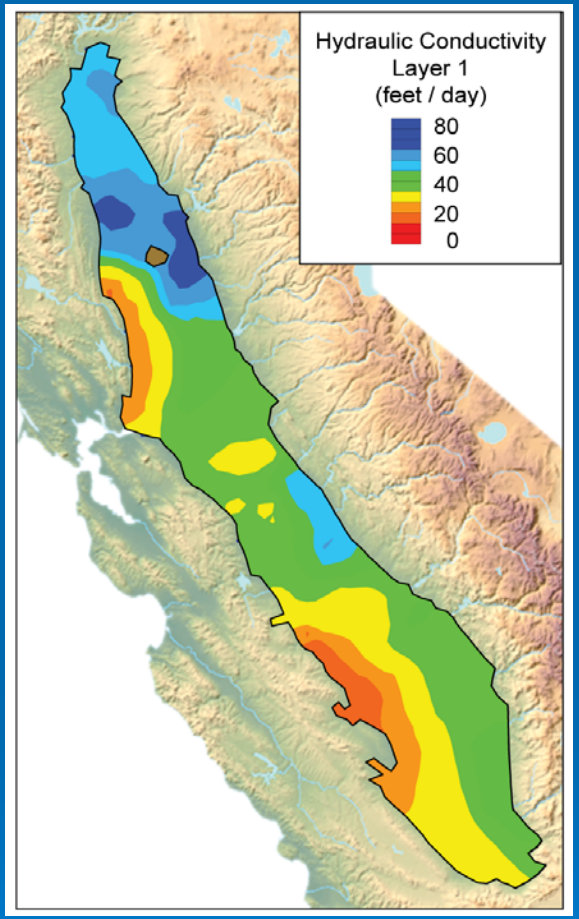
Distance (miles)
Model layers
EXPLANATION
Land Surface
Well Screen (+/- 5 miles N/S)
Base of Fresh Water
C2VSIM Layers

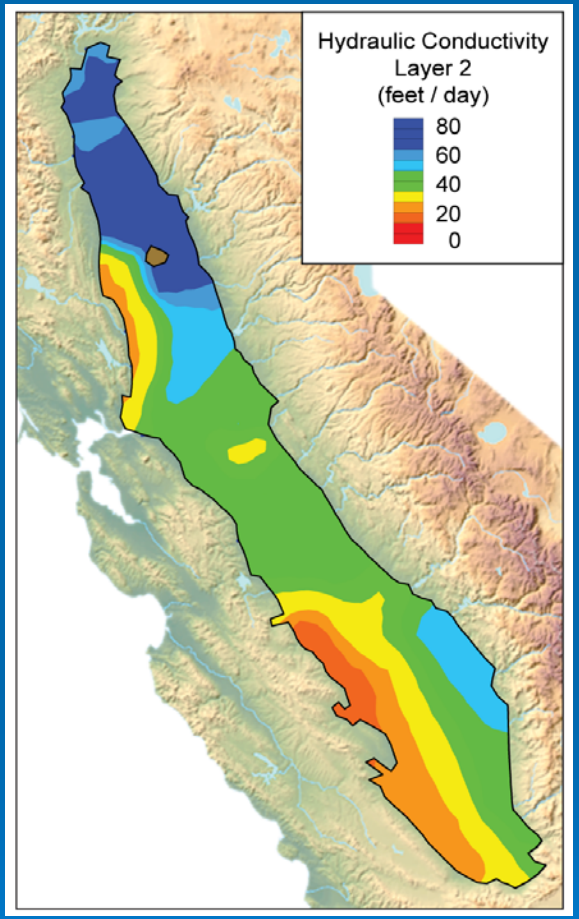
C2VSIM Calibration

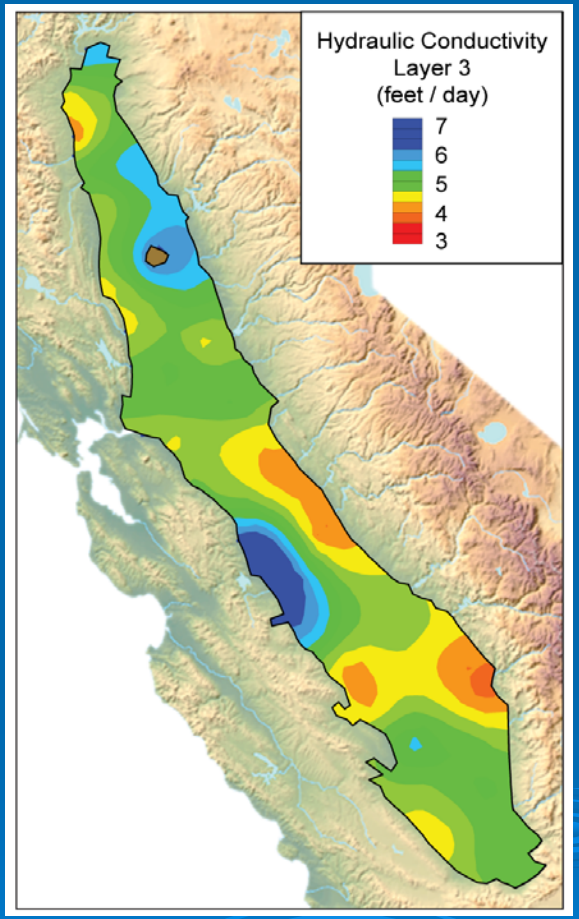


- Water Years 1972-2003
- PEST & regional pilot points
- 1976 head maps, layers 1 & 2
- Head observations at 221 wells
  - Single screen coincides with model layering
  - Measurements 1977-1997
  - No more than one well per model element
- Vertical head gradients at 9 locations
- Average stream accretions and depletions
- Parameters: K_h, K_v, K_s, S_y , S_s

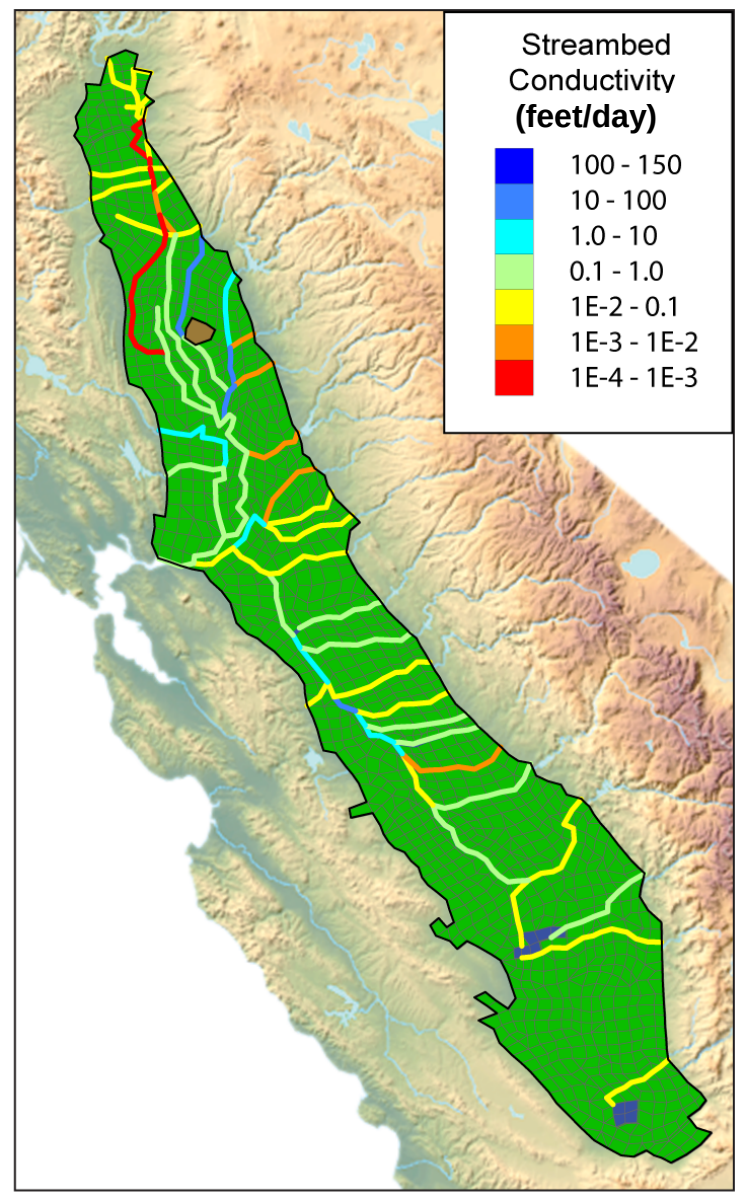
Hydraulic Conductivity



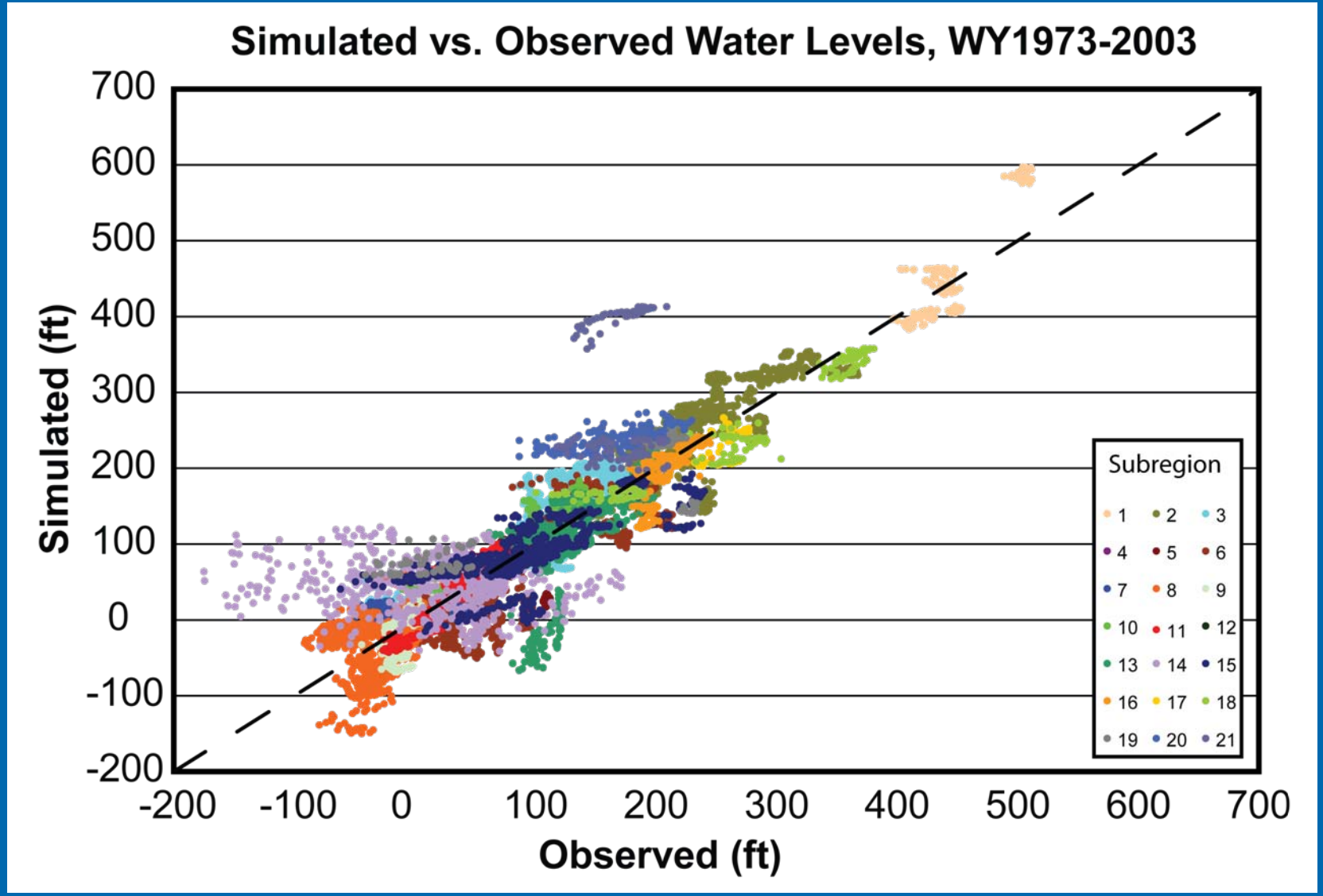




Streambed Conductance



Calibration Results - Heads



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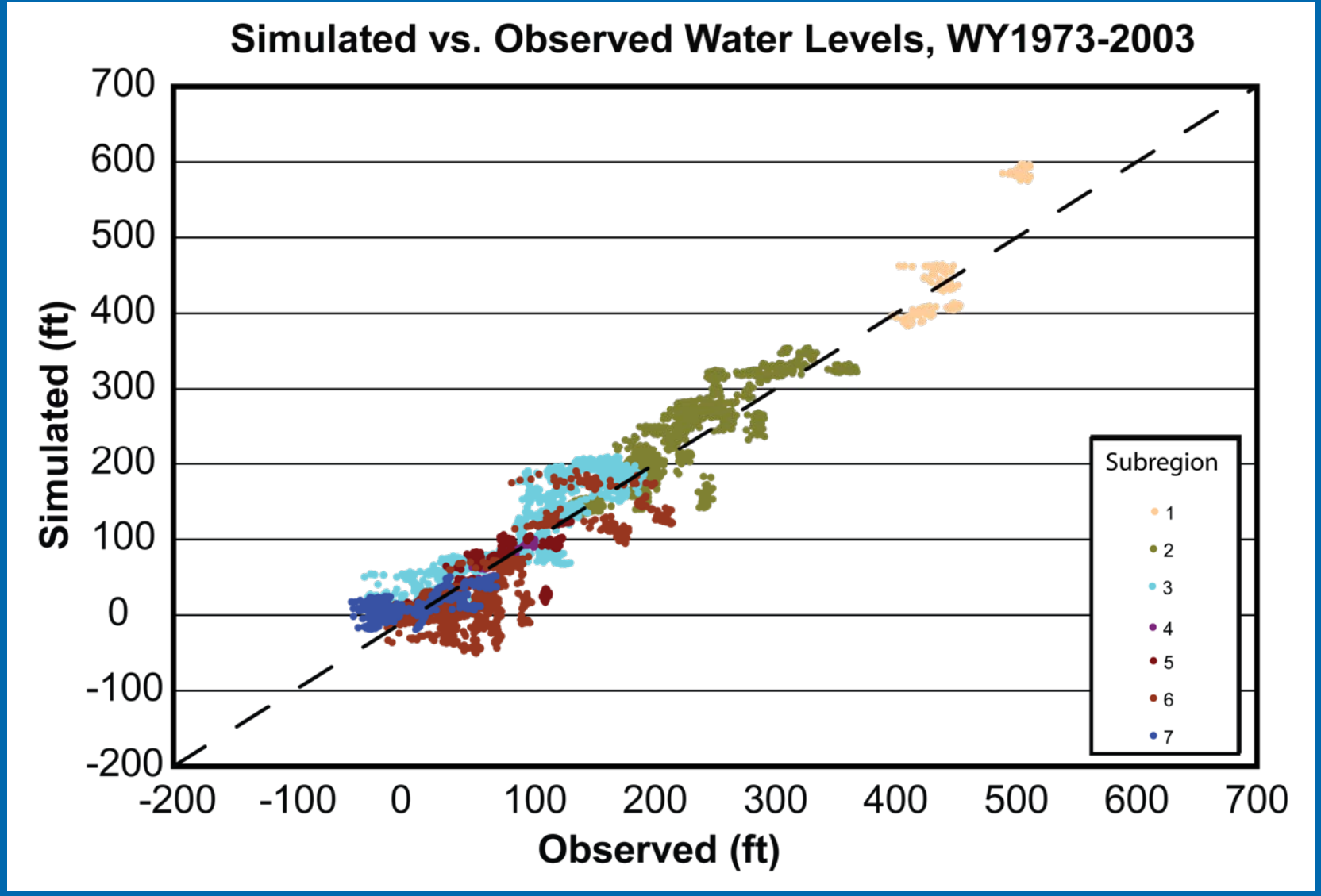
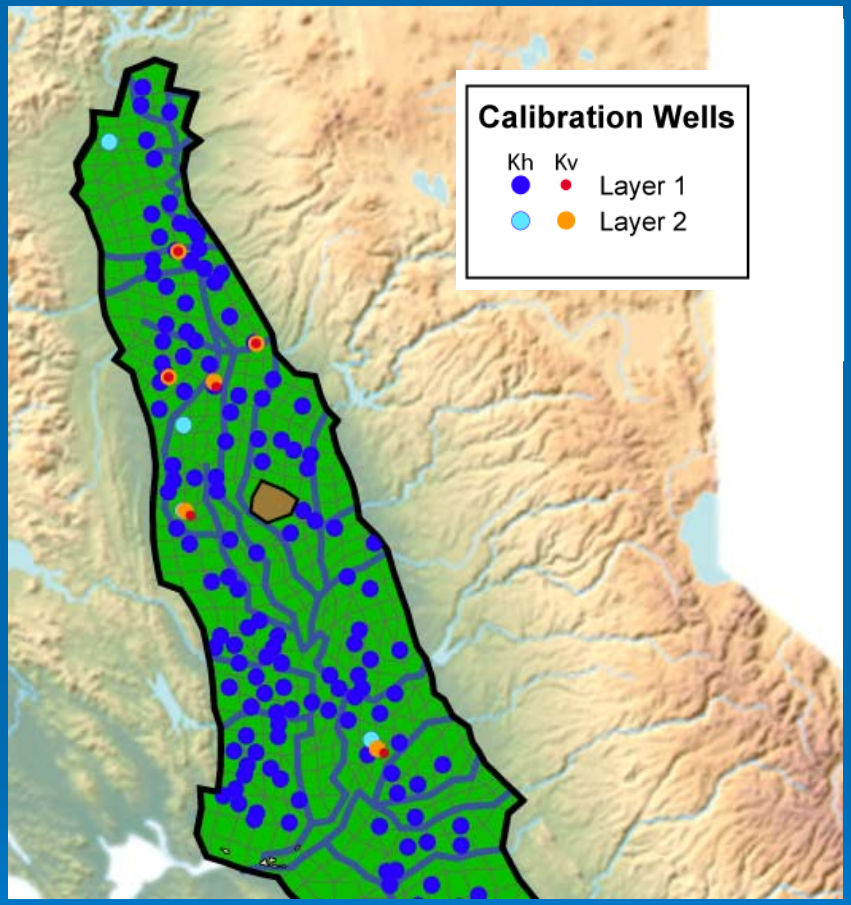
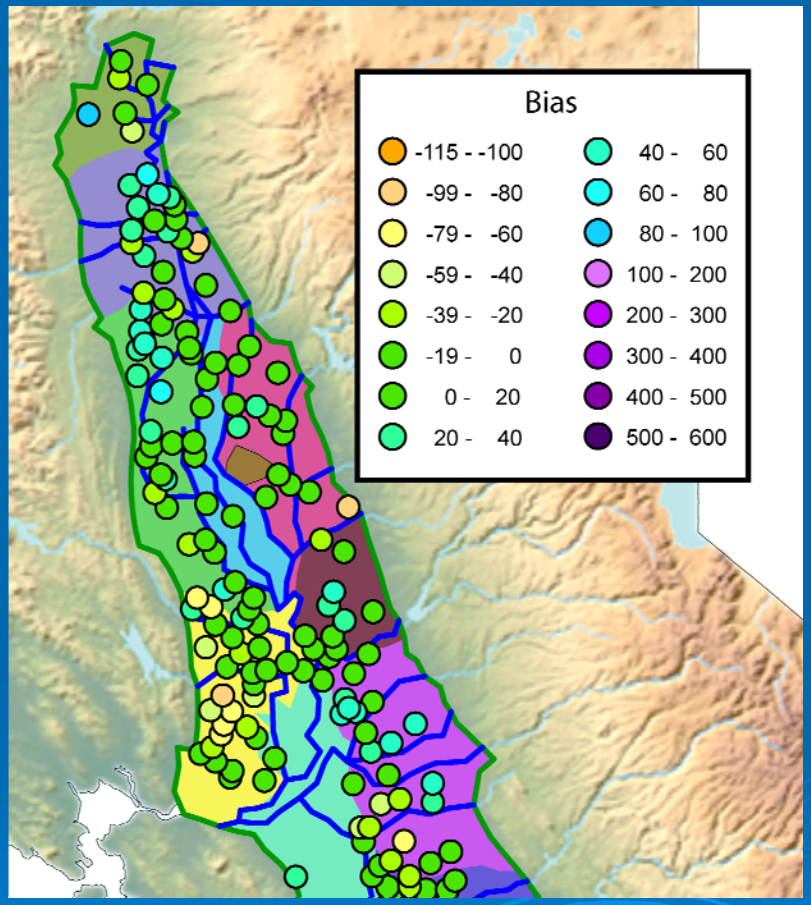


Calibration Results – Sacramento Valley

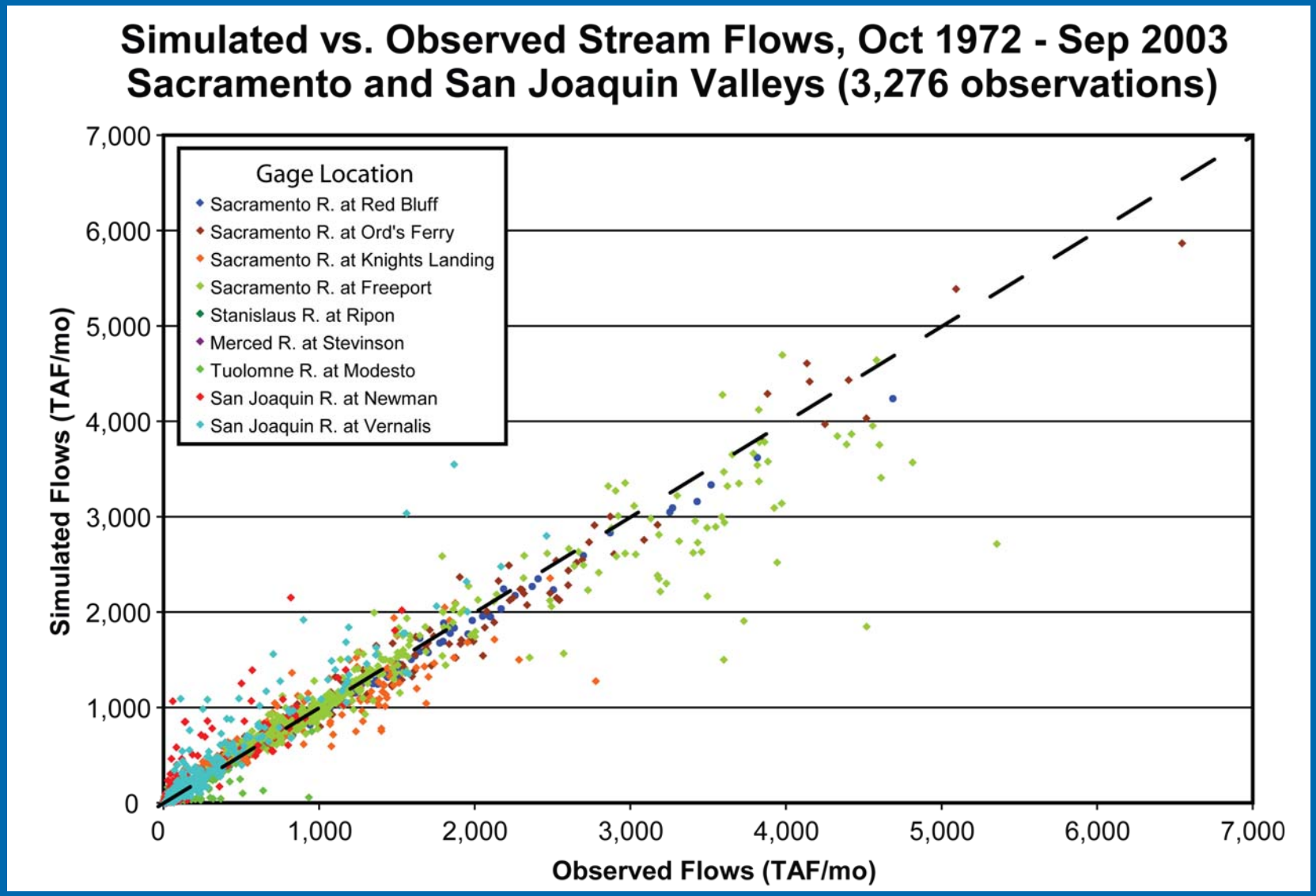
Groundwater Observations (ft)					
Subregion	DSA	Wells	Obs	RMSE	Bias
1	58	6	328	41.4	-2.3
2	10	26	1,403	32.8	-6.3
3	12	28	1,599	31.1	-15.5
4	15	7	372	7.4	4.2
5	69	14	755	26.1	-0.2
6	65	28	1,440	41.5	24.8
7	70	9	464	26.1	-12.3
		118	6,361	33.0	-0.5

C2VSIM Calibration





Calibration Results - Flows



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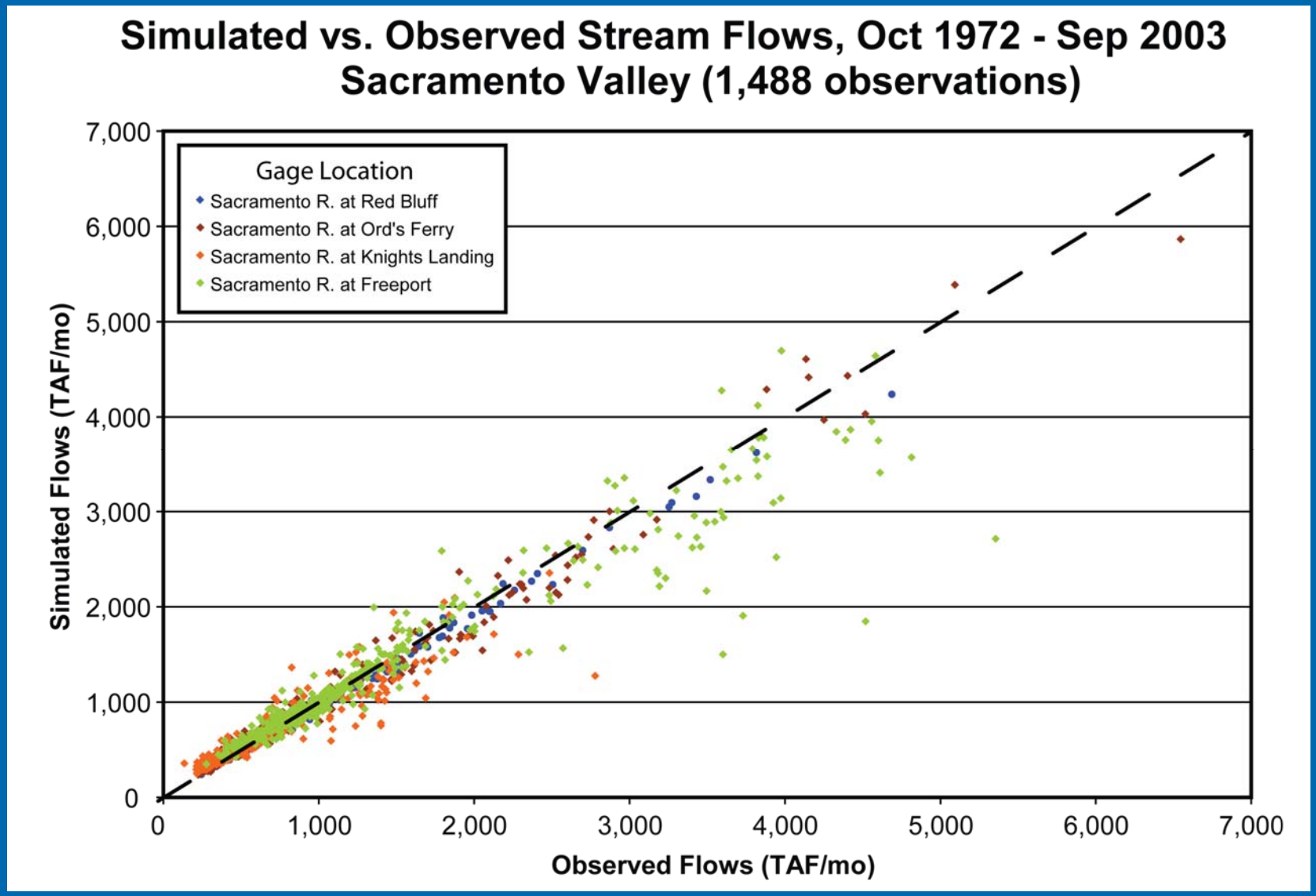
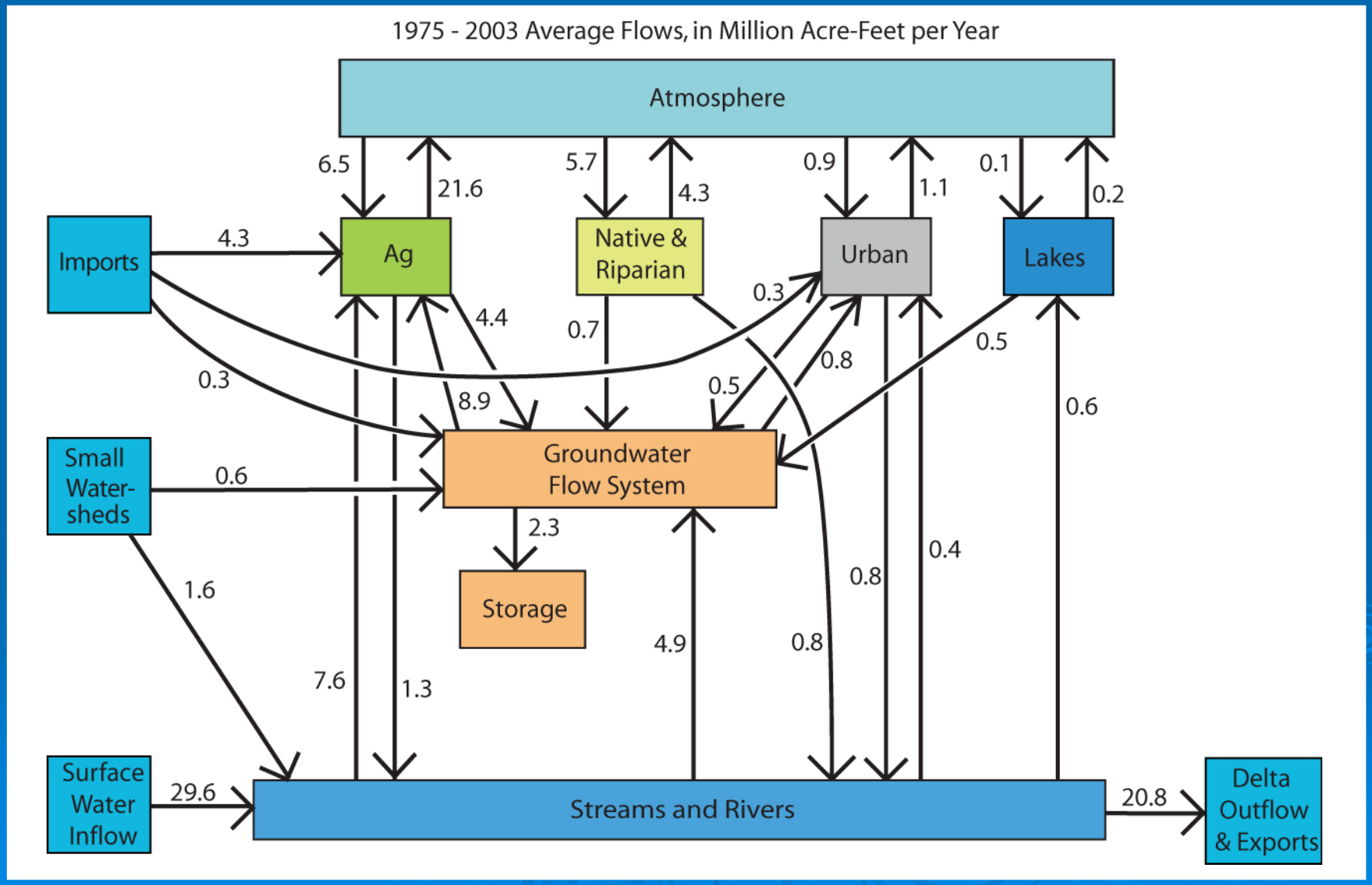


Calibration Results – Sacramento Valley

Surface Water Observations (TAF/mo)					
Gage	Obs	Bias	RMSE	Max	Min
Sacramento River at Red Bluff	372	6.3	56.6	4,688	242
Sacramento River at Ords Ferry	372	-15.3	118.9	6,546	223
Sacramento River at Knights Landing	372	0.4	166.3	2,779	135
Sacramento River at Freeport	372	63.2	364.8	5,356	276
Sacramento River		13.7	211.0		
San Joaquin River at Vernalis	372	-69.9	201.3	2,462	6
San Joaquin River at Newman	372	-46.4	153.7	1,532	2
Tuolomne River at Modesto	372	12.8	74.2	953	1
Merced River near Stevinson	300	-1.6	13.9	337	0
Stanislaus River at Ripon	372	-0.1	9.8	386	0
San Joaquin River		-21.8	120.6		
	3276	-5.7	167.8		

Water Budget



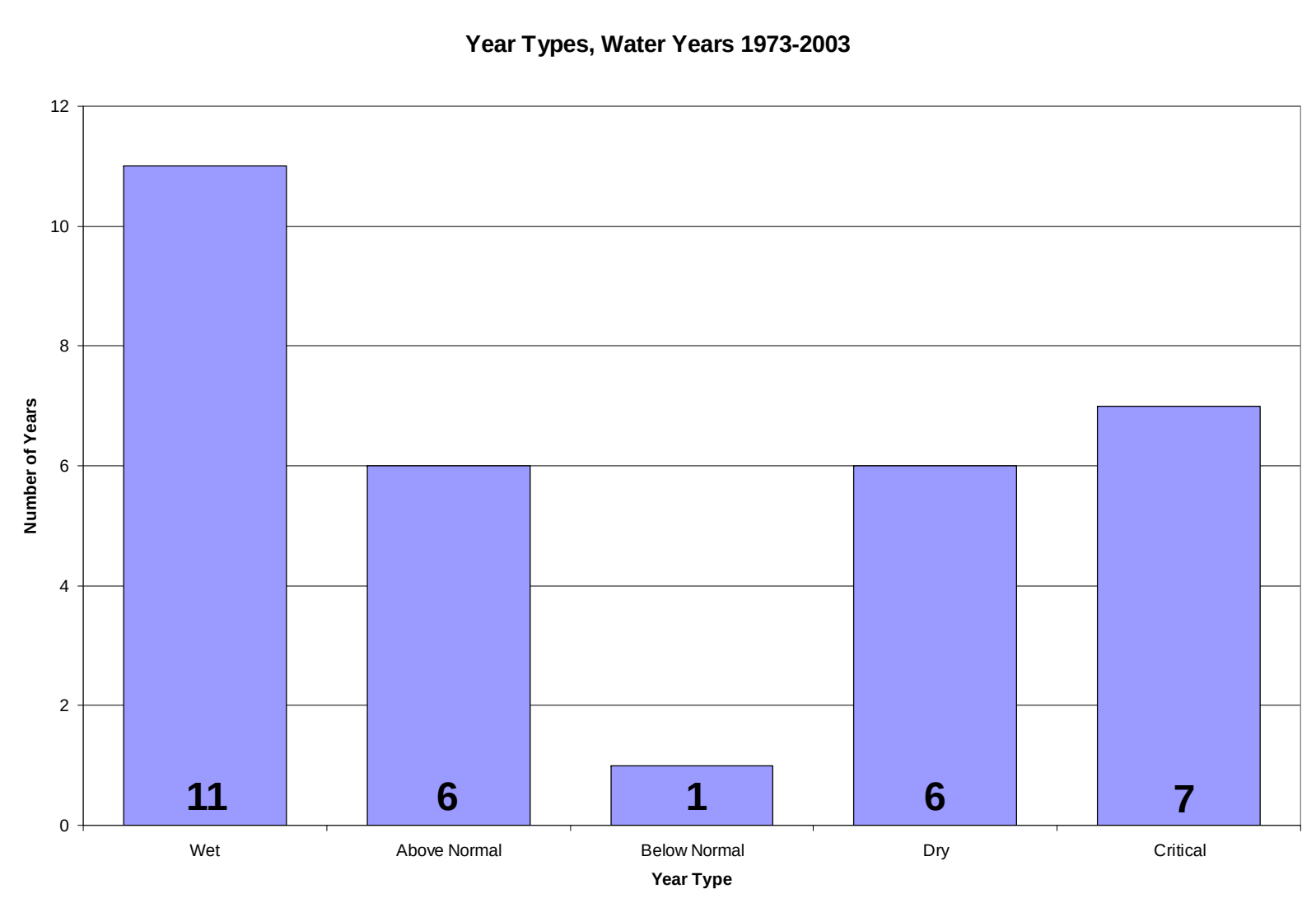
C2VSIM Simulation of the Sacramento Valley Water Management Program

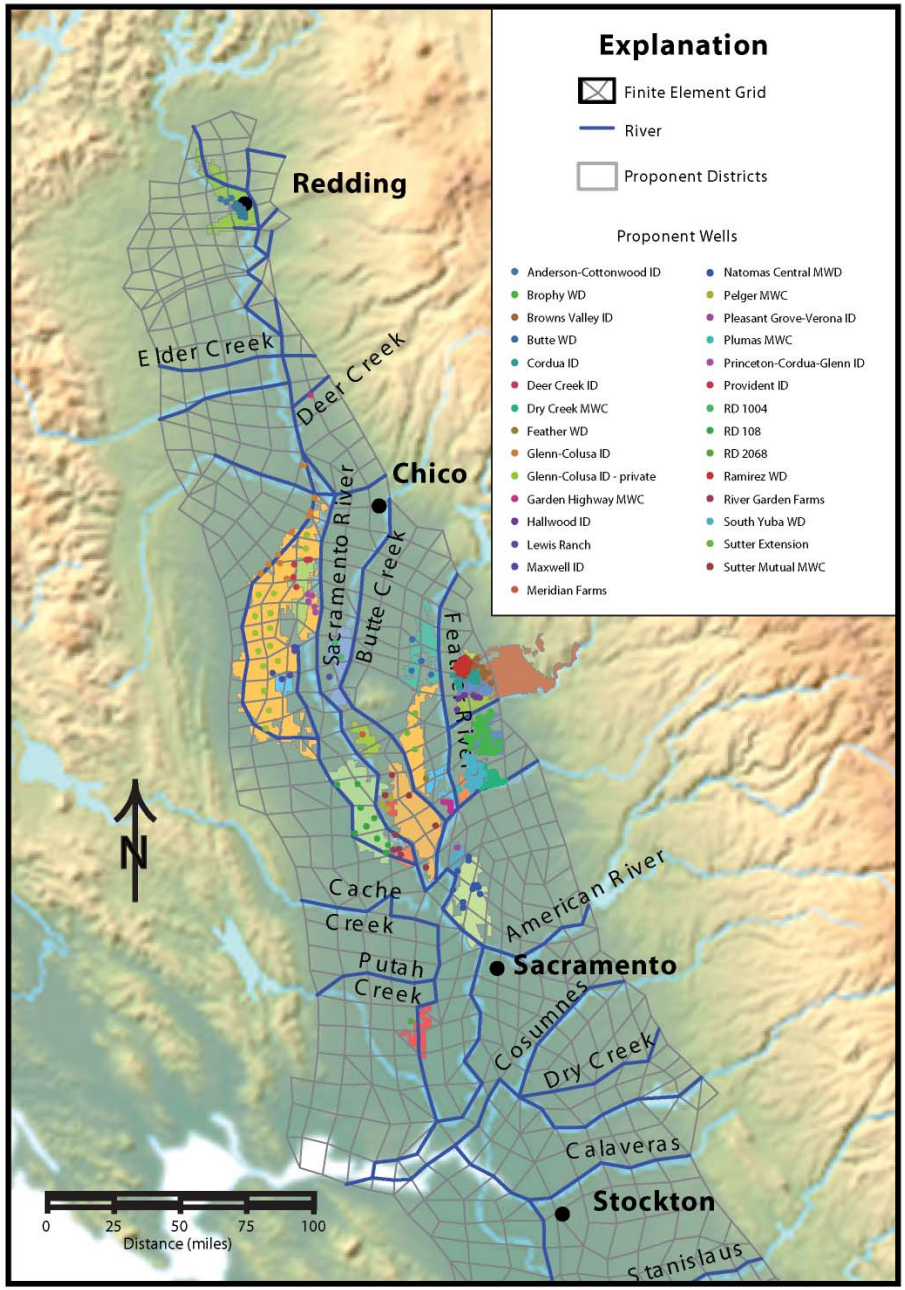
- Identify individual wells and pumping rates
- Prepare IWFM input files
  - October 1972 through September 2003
  - Pumps on in non-wet years
- C2VSIM runs
  1. Turn on groundwater adjustment
  2. Turn on surface water adjustment
  3. Turn on SVWMP wells & reduce diversions in non-wet years (Sacramento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

Sacramento River Index

Water Year	WY Index Index	WY Index Yr-type	SVWMP Operation	Water Year	WY Index Index	WY Index Yr-type	SVWMP 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

Sacramento River Index



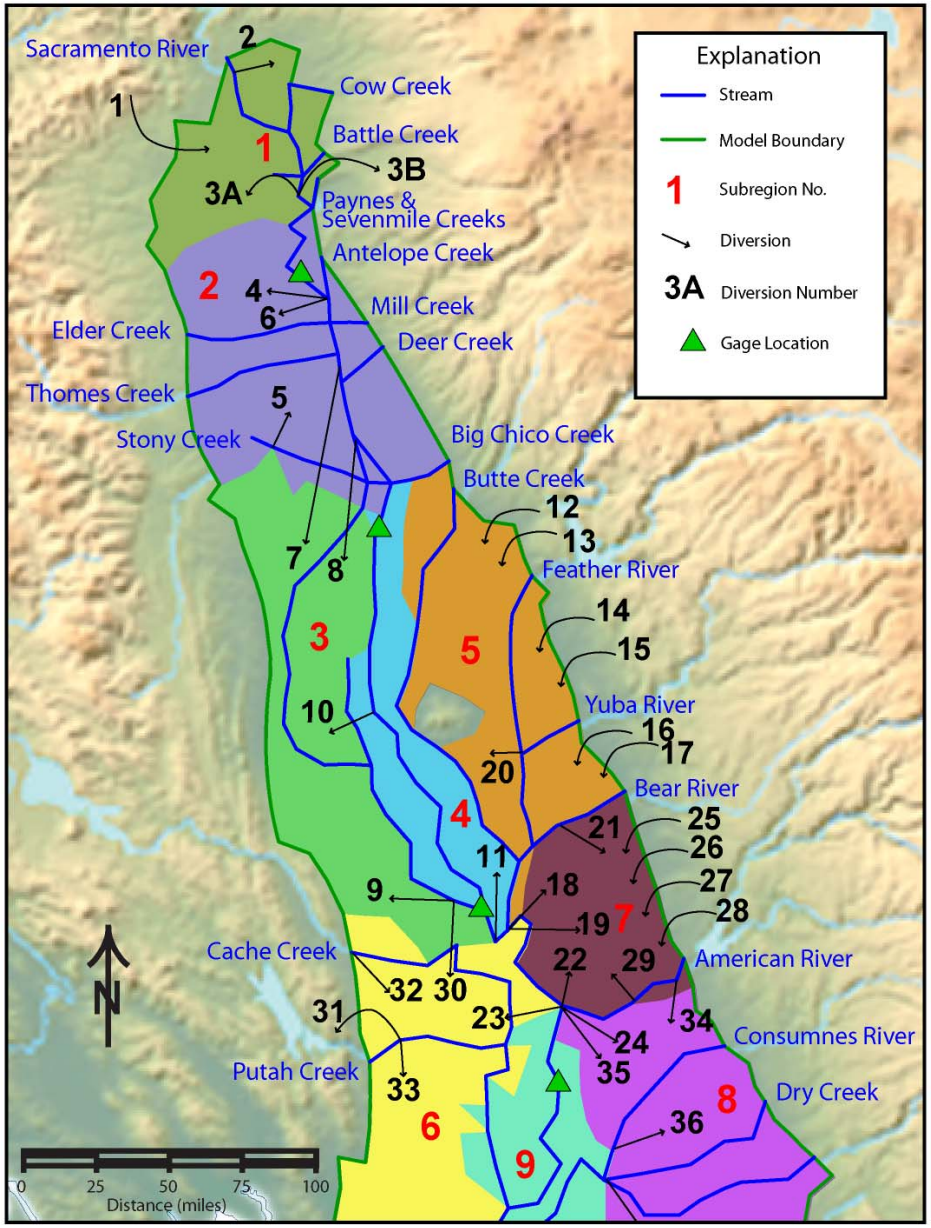


SVWMP Wells

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

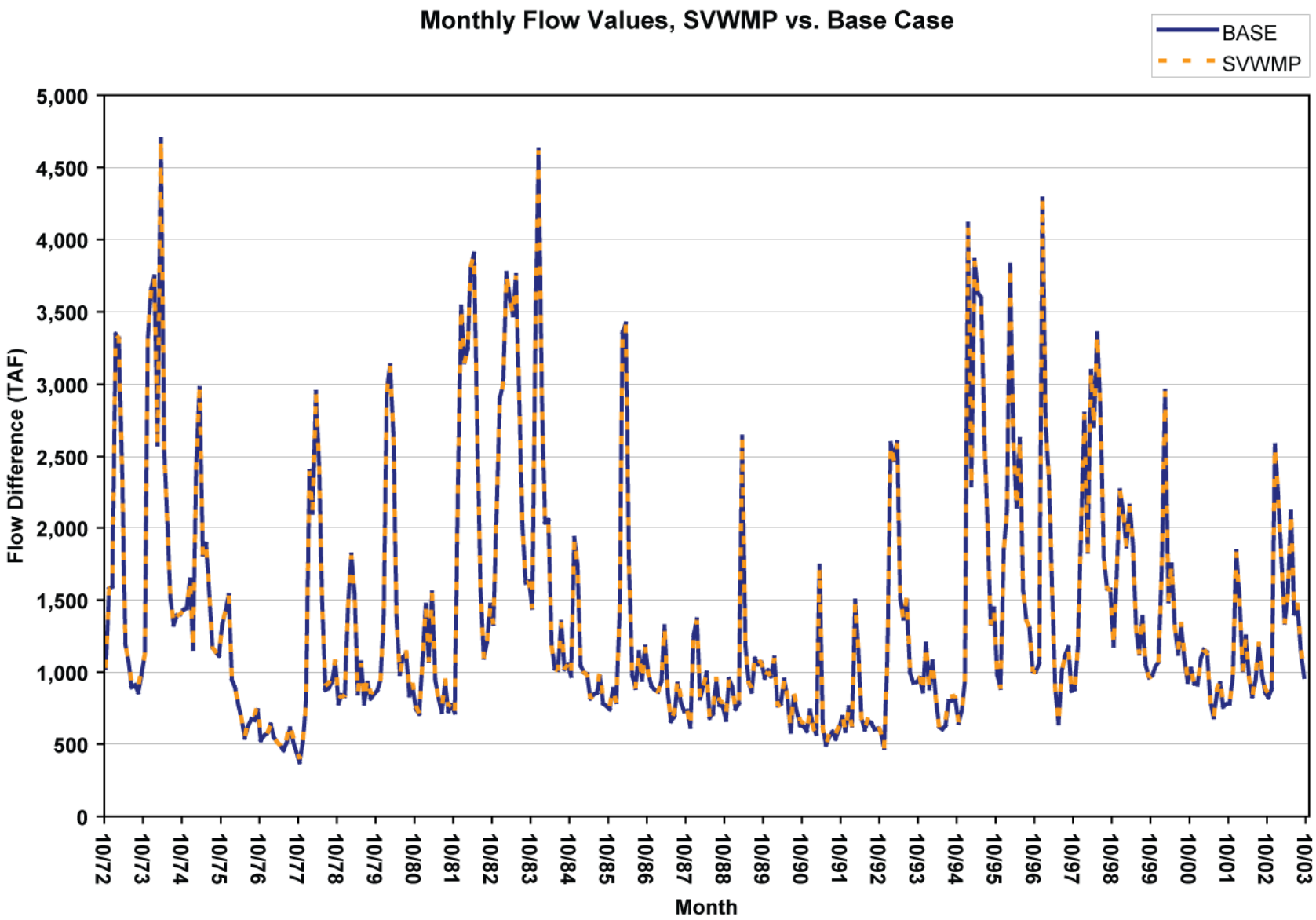
Operate non-wet years

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



C2VSIM Diversions

- Adjusted:
  - 19 diversions above Freeport
- Unadjusted:
  - 11 imports
  - 2 exports


Monthly Flow Values, SVWMP vs. Base Case
BASE
SVWMP
Flow Difference (TAF)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
10/72
10/73
10/74
10/75
10/76
10/77
10/78
10/79
10/80
10/81
10/82
10/83
10/84
10/85
10/86
10/87
10/88
10/89
10/90
10/91
10/92
10/93
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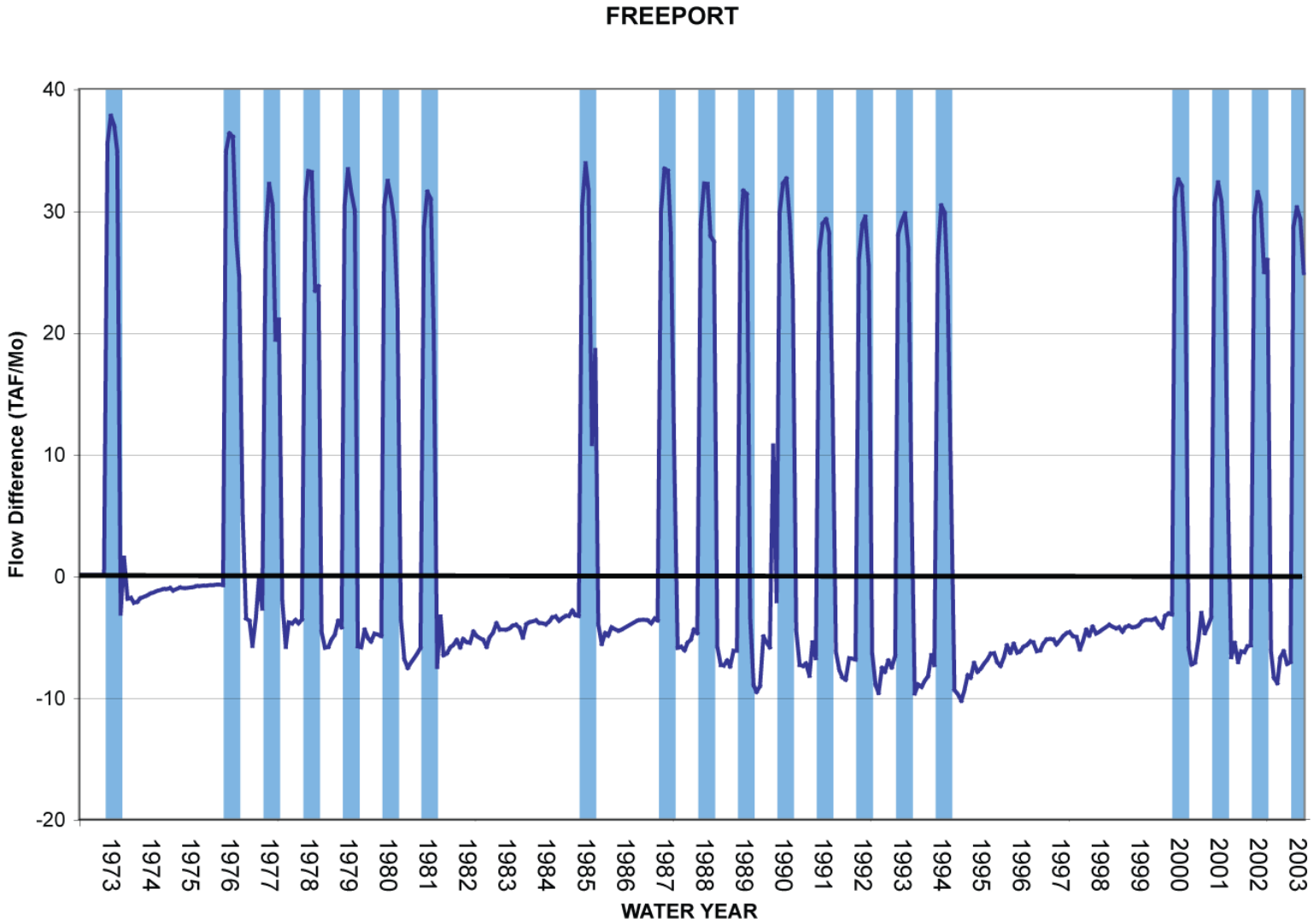
10/97
10/98
10/99
10/00
10/01
10/02
10/03
Month


FREEPORT
Flow Difference (TAF/Mo)
40
30
20
10
0
-10
-20
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
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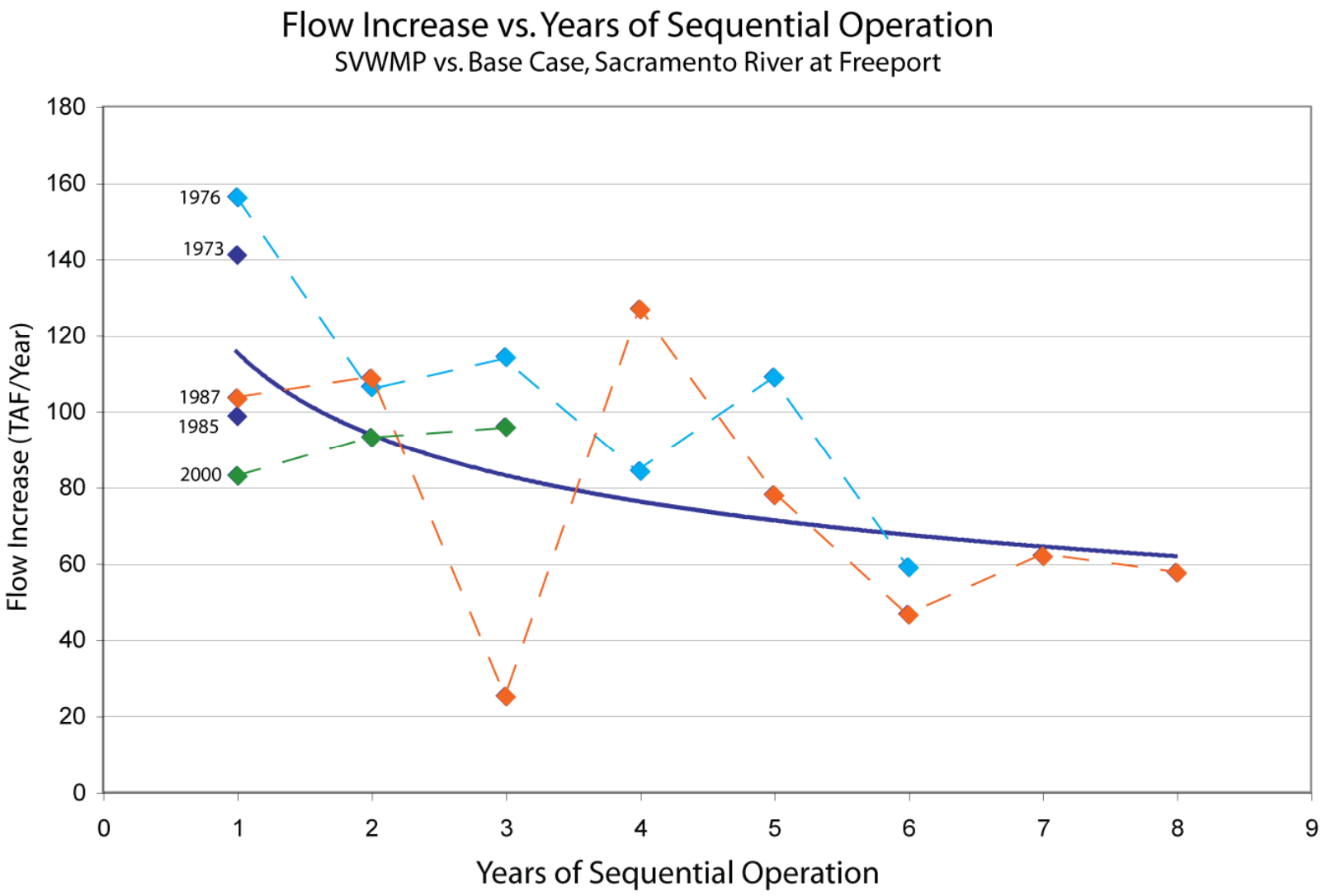
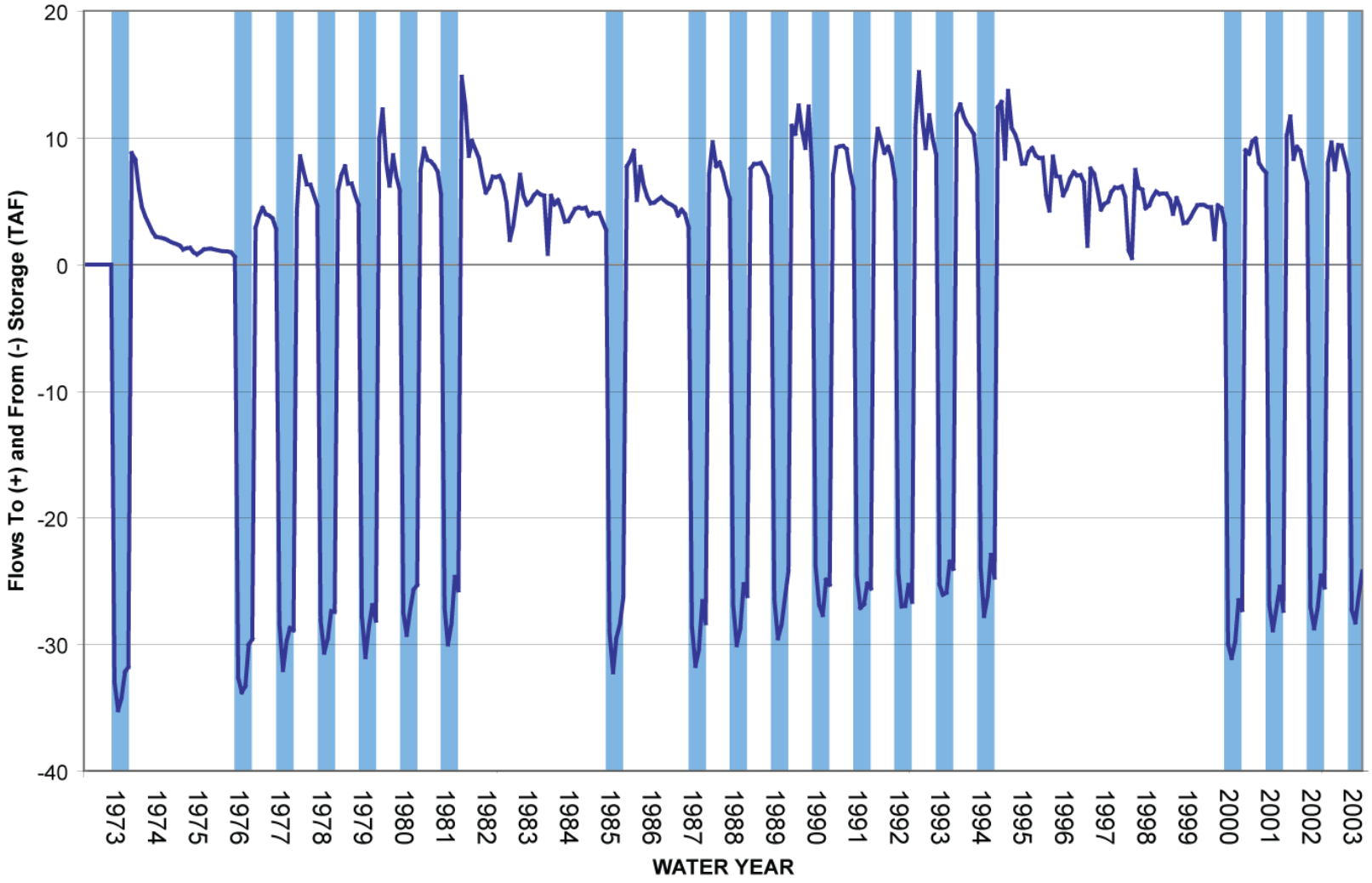
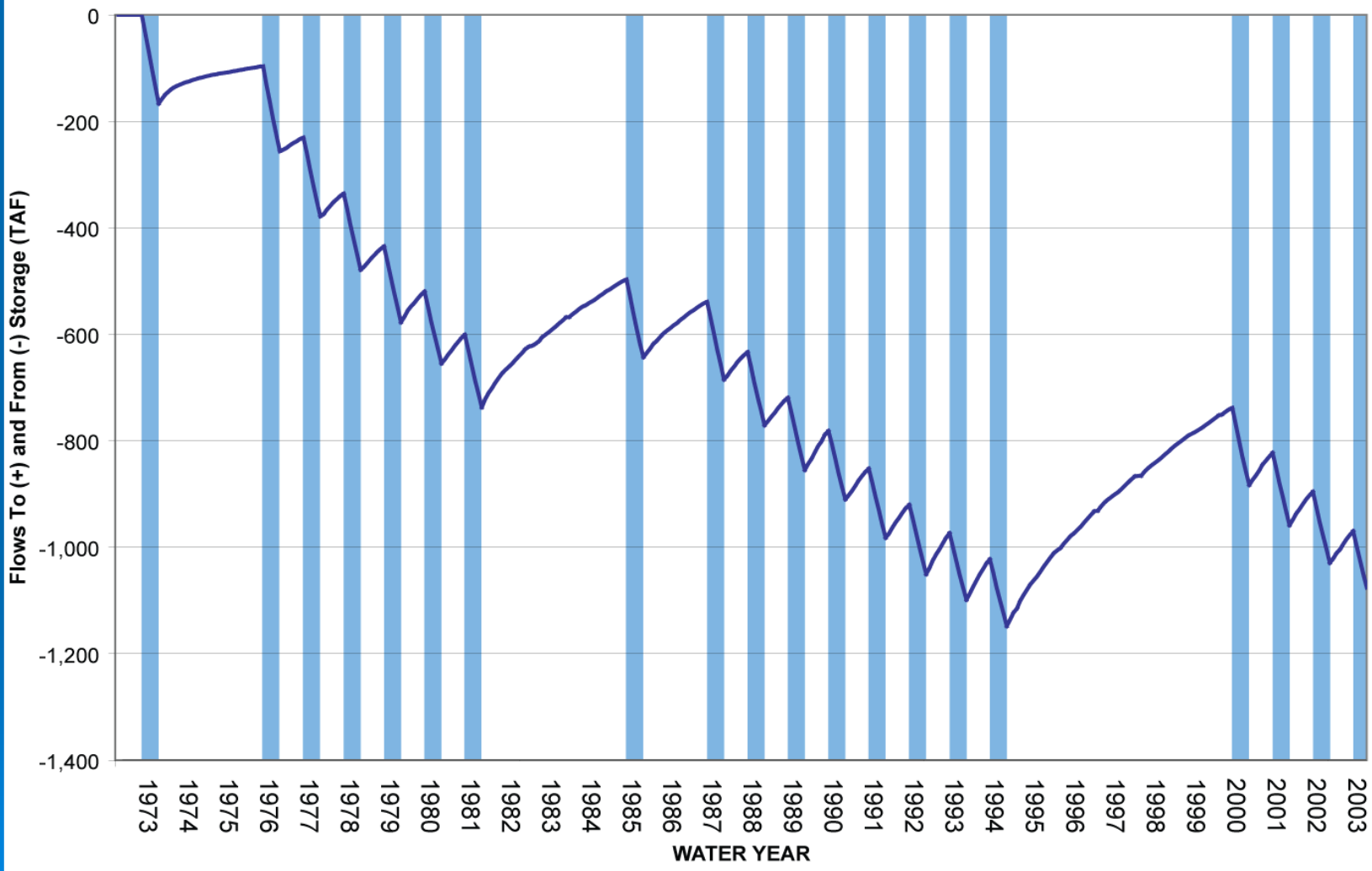
1997
1998
1999
2000
2001
2002
2003
WATER YEAR


Flow Increase vs. Years of Sequential Operation
SVWMP vs. Base Case, Sacramento River at Freeport
Flow Increase (TAF/Year)
Years of Sequential Operation
1976
1973
1987
1985
2000
0
20
40
60
80
100
120
140
160
180
0
1
2
3
4
5
6
7
8
9

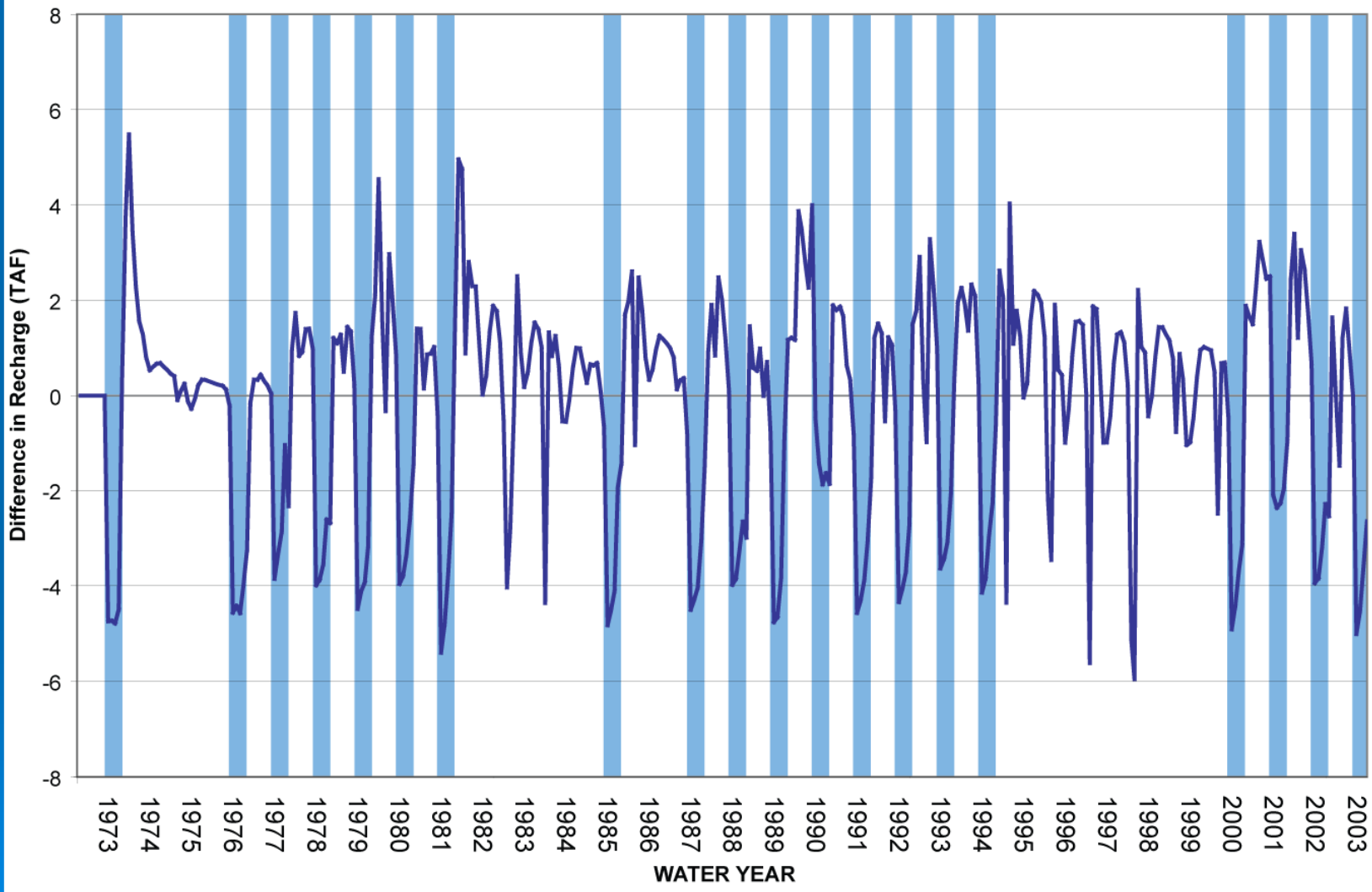
Difference in Groundwater Storage, SVWMP vs. Base Case



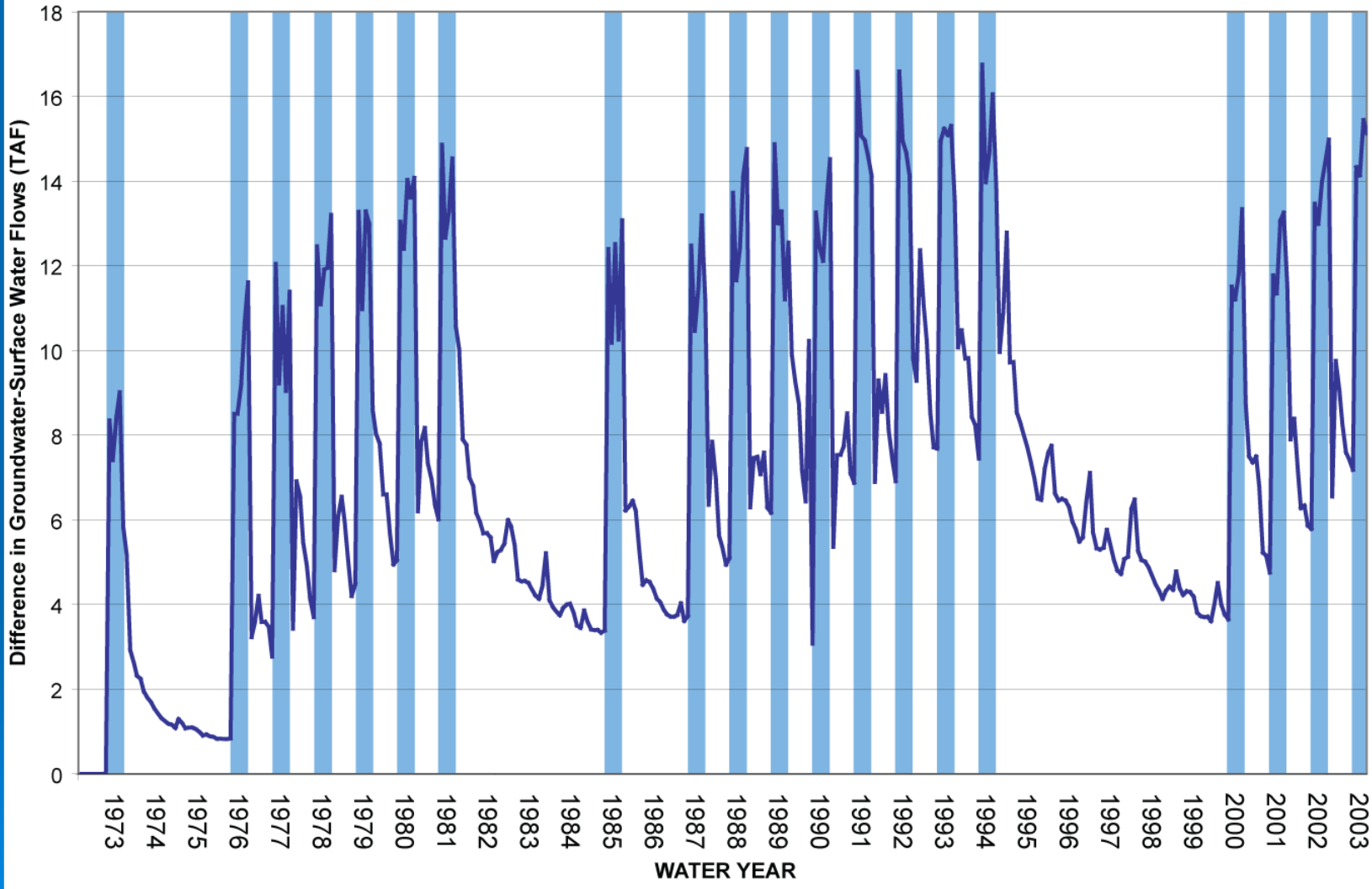
Cumulative Difference in Groundwater Storage, SVWMP vs. Base Case

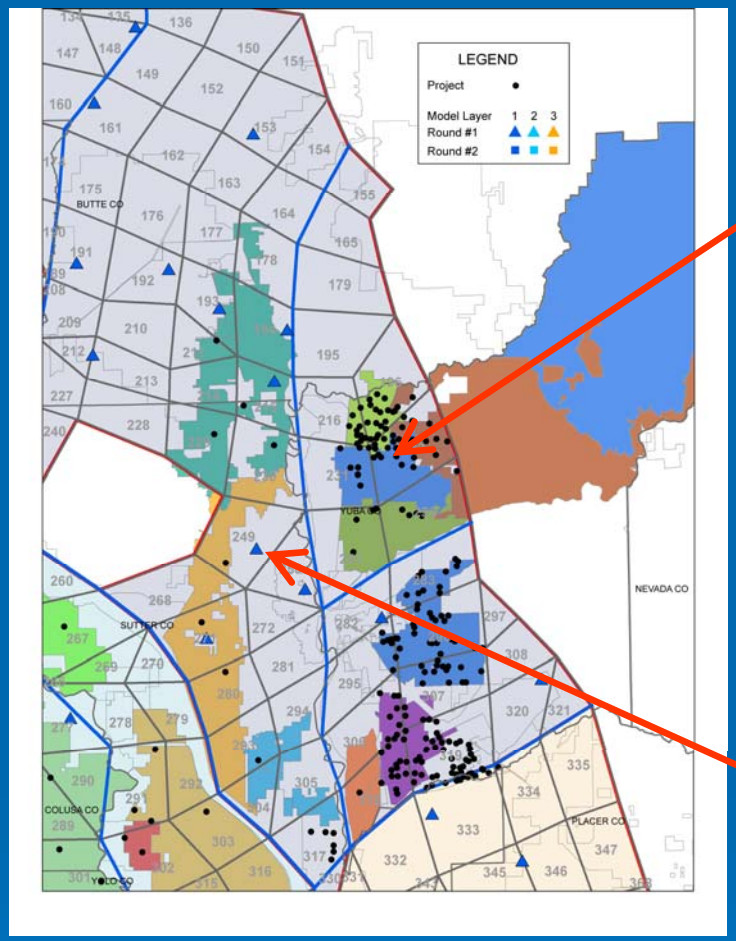


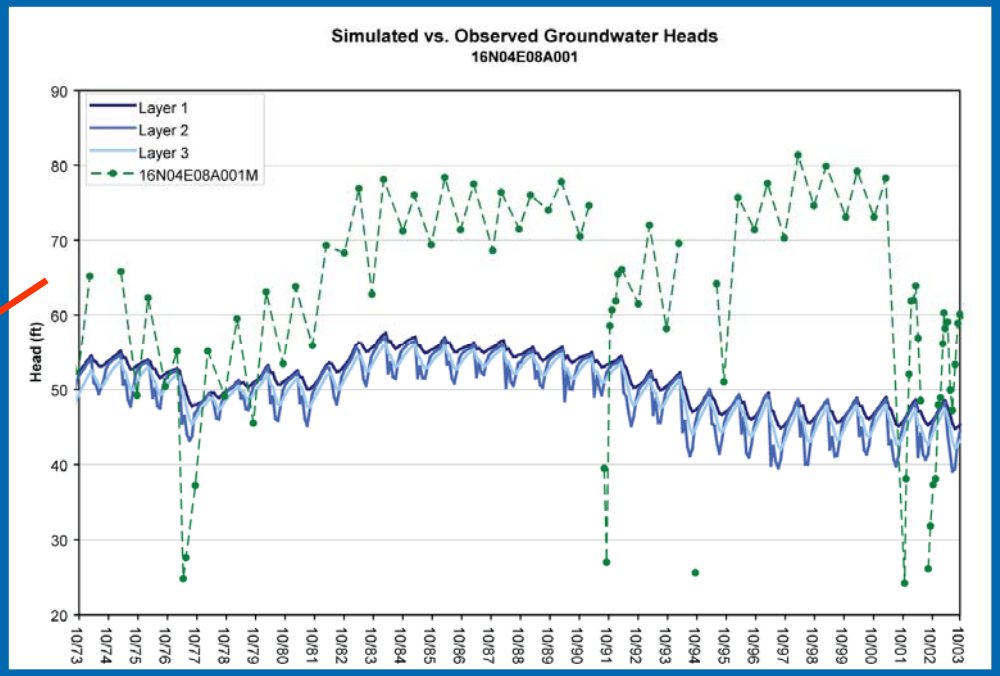
Difference in Recharge, SVWMP vs. Base Case

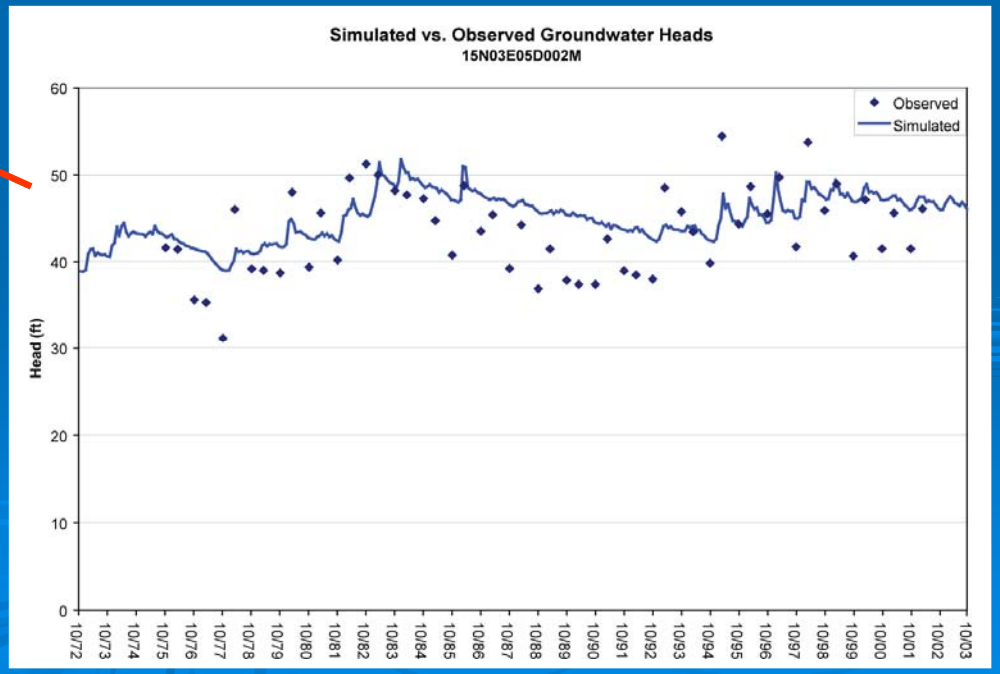


Difference in Groundwater-Aquifer Flows, SVWMP vs. Base Case




LEGEND
Project
Model Layer 1 2 3
Round #1
Round #2
BUTTE CO
SUTTER CO
COLUSA CO
YOLO CO
PLACER CO
NEVADA CO


Simulated vs. Observed Groundwater Heads
16N04E08A001
Layer 1
Layer 2
Layer 3
16N04E08A001M
Head (ft)


Simulated vs. Observed Groundwater Heads
15N03E05D002M
Observed
Simulated
Head (ft)

Preliminary Findings

- C2VSIM simulation of SVWMP operations
  - SVWMP simulation is easy to implement in C2VSIM
  - Average flow increase at Freeport is 128 MAF (68%)
  - Lots of information – areal recharge, storage, GW-SW

- Issues regarding C2VSIM and SVWMP
  - Scale: C2VSIM is a ‘regional’ model
  - Water budget: Subregional ‘virtual farms’
  - Calibration data set: few deep wells
  - Groundwater pumping: largely unknown (estimated)
  - All currently being addressed in continued development of C2VSIM and IWFM

Future Work

- Refine C2VSIM calibration & water budgets
  - Increase accretions-depletions data set
  - Calibrate small watershed parameters
  - Modify pumping distribution (spatial and vertical)
  - High wet-season diversions (refuges?)
  - Crop ET looks high in some areas
- Refine SVWMP simulation
  - Identify individual pumping wells
  - Directly reduce diversions (vs. automated)