The California Central Valley Groundwater-Surface Water Simulation Model

Summary

CWEMF C2VSim Workshop

Charles Brush

Modeling Support Branch, Bay-Delta Office

California Department of Water Resources, Sacramento, CA

Acknowledgements

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Andy Draper and Jafar Faghih, MWH Global

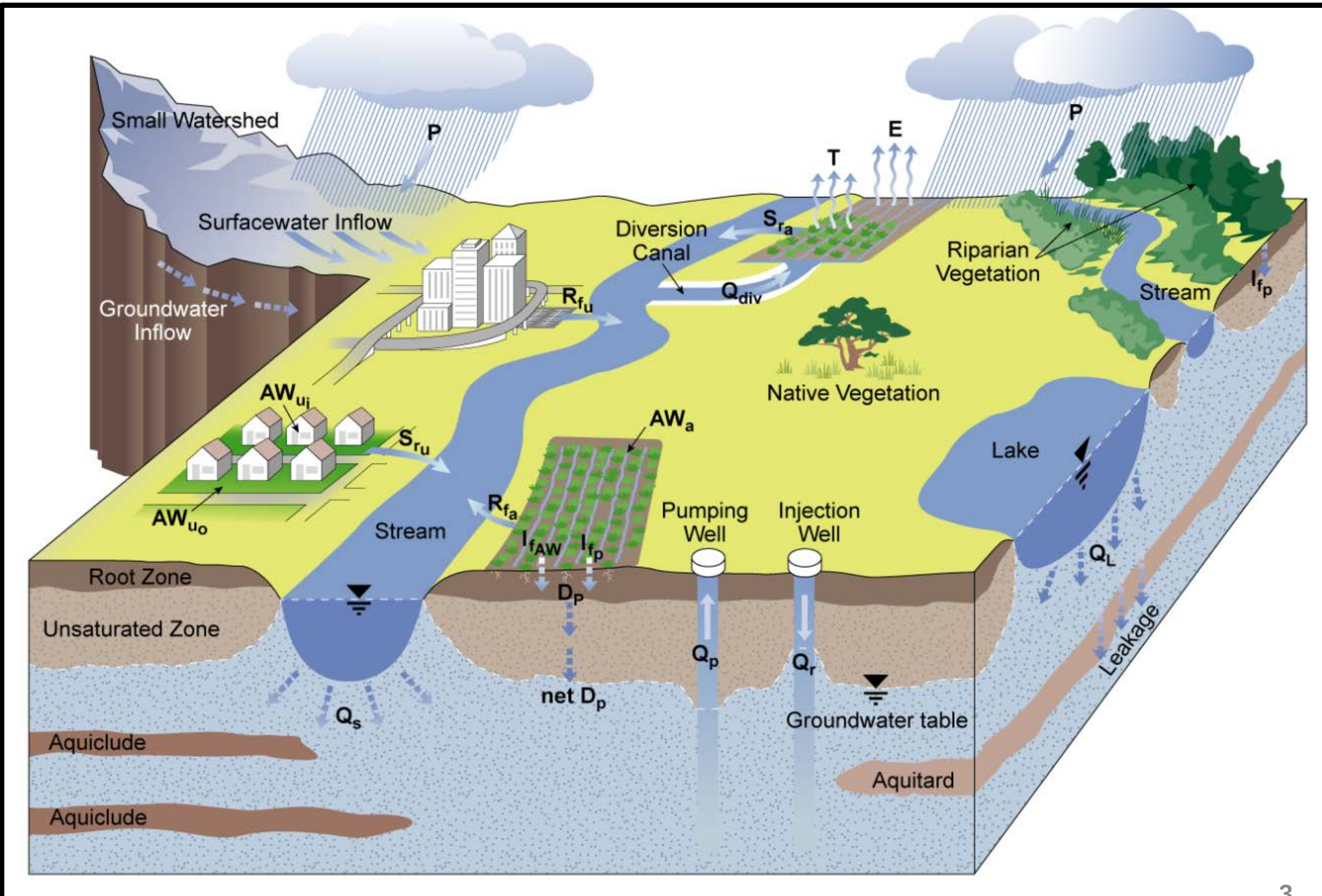
Ali Taghavi, Reza Namvar and Mesut Cayar, RMC-WRIME

Walter Bourez and Lee Bergfeld, MBK Engineers

Charles Burt and staff, ITRC; Claudia Faunt, USGS

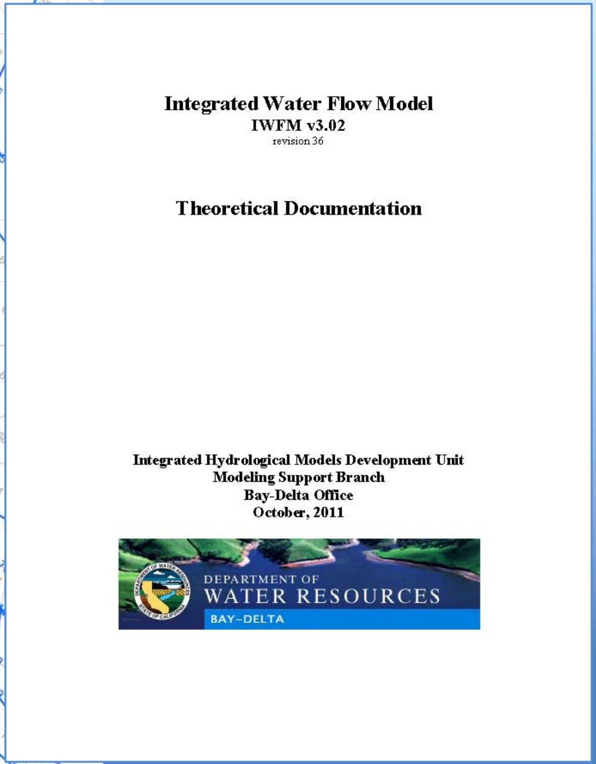
currently with: (1) MBK Engineers, (2) Groundwater Dynamics , (3) U. of San Francisco, (4) U. of Edinburgh

Integrated Water Flow Model (IWFM)



IWFM Documentation

- Theoretical documentation, user's manual, reports, technical memorandums, previous presentations and posters, user's group presentations, and published articles in peer reviewed journals are available at the IWFM web site (google "IWFM")
- Technical support by DWR staff



Integrated Water Flow Model
IWFM v3.02
revision 36

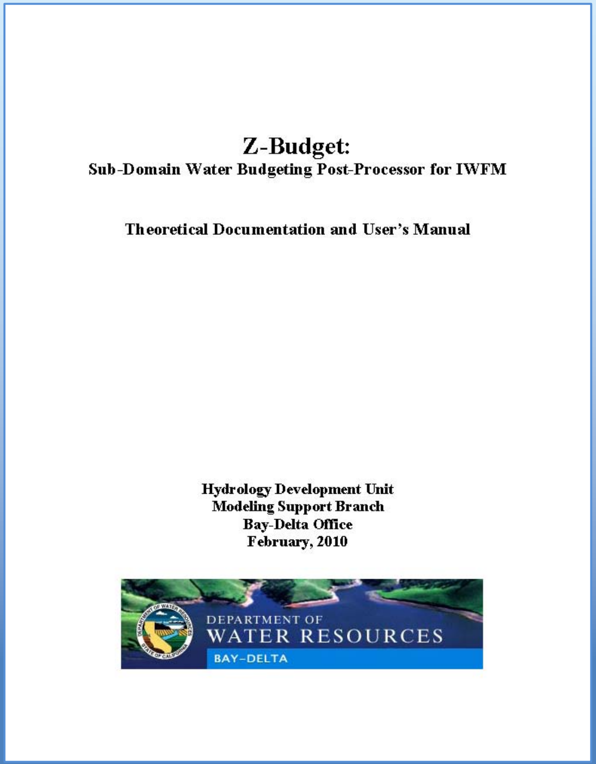
Theoretical Documentation

Integrated Hydrological Models Development Unit
Modeling Support Branch
Bay-Delta Office
October, 2011

Integrated Water Flow Model
IWFM v3.02
revision 36

User's Manual

Integrated Hydrological Models Development Unit
Modeling Support Branch
Bay-Delta Office
October, 2011



Z-Budget:
Sub-Domain Water Budgeting Post-Processor for IWFM

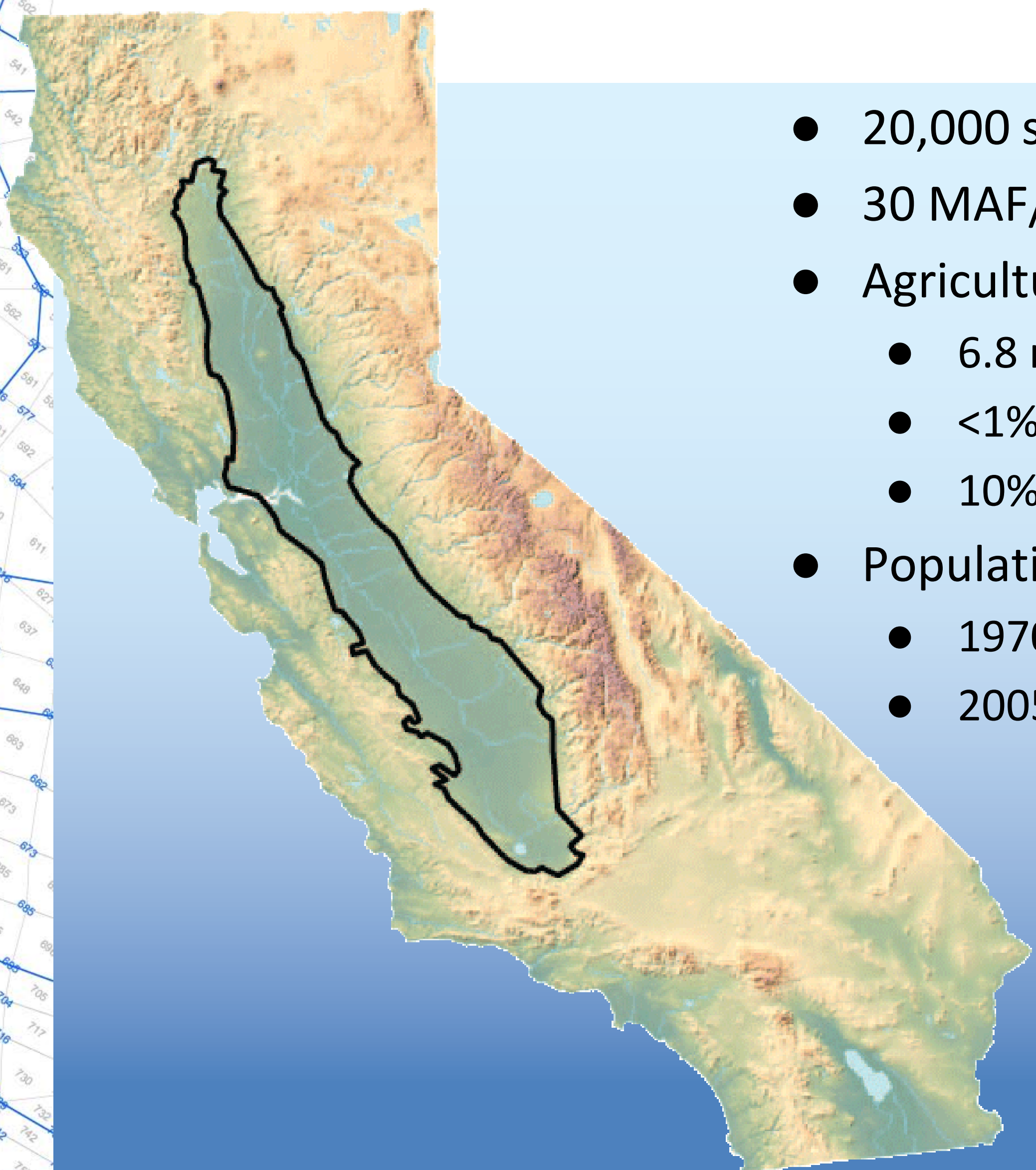
Theoretical Documentation and User's Manual

Hydrology Development Unit
Modeling Support Branch
Bay-Delta Office
February, 2010

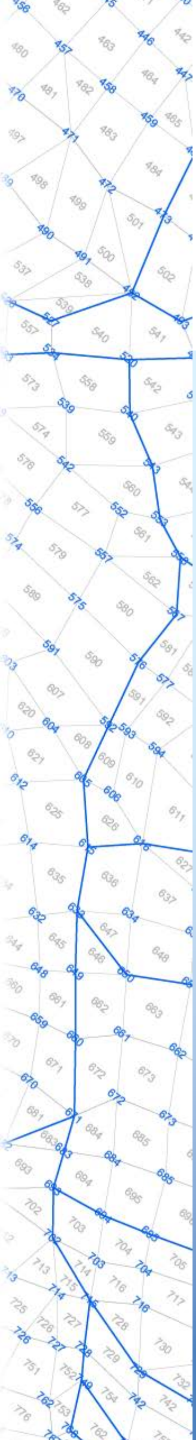
IWFM Applications

- California Central Valley Groundwater-Surface Water Model
- Butte County Groundwater Model (Heywood, CDM)
- Walla Walla River Basin Model (Petrides, OSU)
- Yolo County Integrated Model (DWR, UCD)
- Kings River Model (HydroMetrics)
- Merced Area (MAGPI, RMC)

California’s Central Valley



- 20,000 sq. mi. (55,000 sq. km.)
- 30 MAF/yr Surface Water Discharge
- Agricultural Production
  - 6.8 million acres (27,500 sq. km)
  - <1% of US farm land
  - 10% of US crops value in 2002
- Population Growth
  - 1970: 2.9 million
  - 2005: 6.4 million
- Groundwater Pumping
  - ~9 MAF in 2002
  - 10-18% if US pumping
  - Not measured or regulated



C2VSim Development

Derived from the CVGSM model

- WY 1922-1980 Boyle & JM Montgomery (1990)
- WY 1981-1998 CH_2M Hill for CVPIA PEIS

Steady modification

- DWR IWFM/C2VSim development began in 2000
- IWFM process and solver improvements
- C2VSim data sets reviewed and refined
- C2VSim input data extended through WY 2009

Calibration

- PEST parameter estimation program
- Three phases: Regional, Local, Nodal
- Calibration Period: WY 1973-2003 in phases 1 & 2, 1922-2004 in phase 3

C2VSim Versions

C2VSim CG 3.02 (R374): Release Version

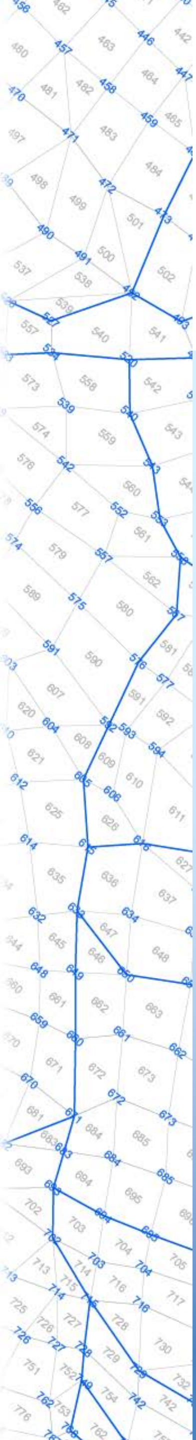
- Current version, updated June 2013
- Water Years 1922-2009, monthly time step
- IWFM version 3.02

C2VSim FG 3.02 (R374): Draft Version

- Based on C2VSim 3.02 CG
- Refine rivers, inflows, land use
- Update to current CG version
- Expected release in 2014

Planned Improvements

- C2VSim 3.02 CG/FG: Extend to WY 2011 or 2012
- C2VSim 4 FG: Element-level land use, crop and diversion data



Steady Improvement of C2VSim

R375: September 2013

- Make the supply adjustment flags easier to use

R376: November 2013

- Modify irrigation schedules in subregions 15-17
- Modify curve numbers in small watersheds 103-114
- Add M&I imports from Placer Co Water Agency
- Make irrigation fraction flags easier to use

R377: April 2014

- Remove ASR at end of the Tule & Kaweah Rivers
- Limit ASR on the Kern River Flood Channel to 1,000 cfs

R378: April 2014

- Modify basement altitude between Merced and Los Banos to match base of fresh water

C2VSim Coarse-Grid

"C2VSim CG-3.02"

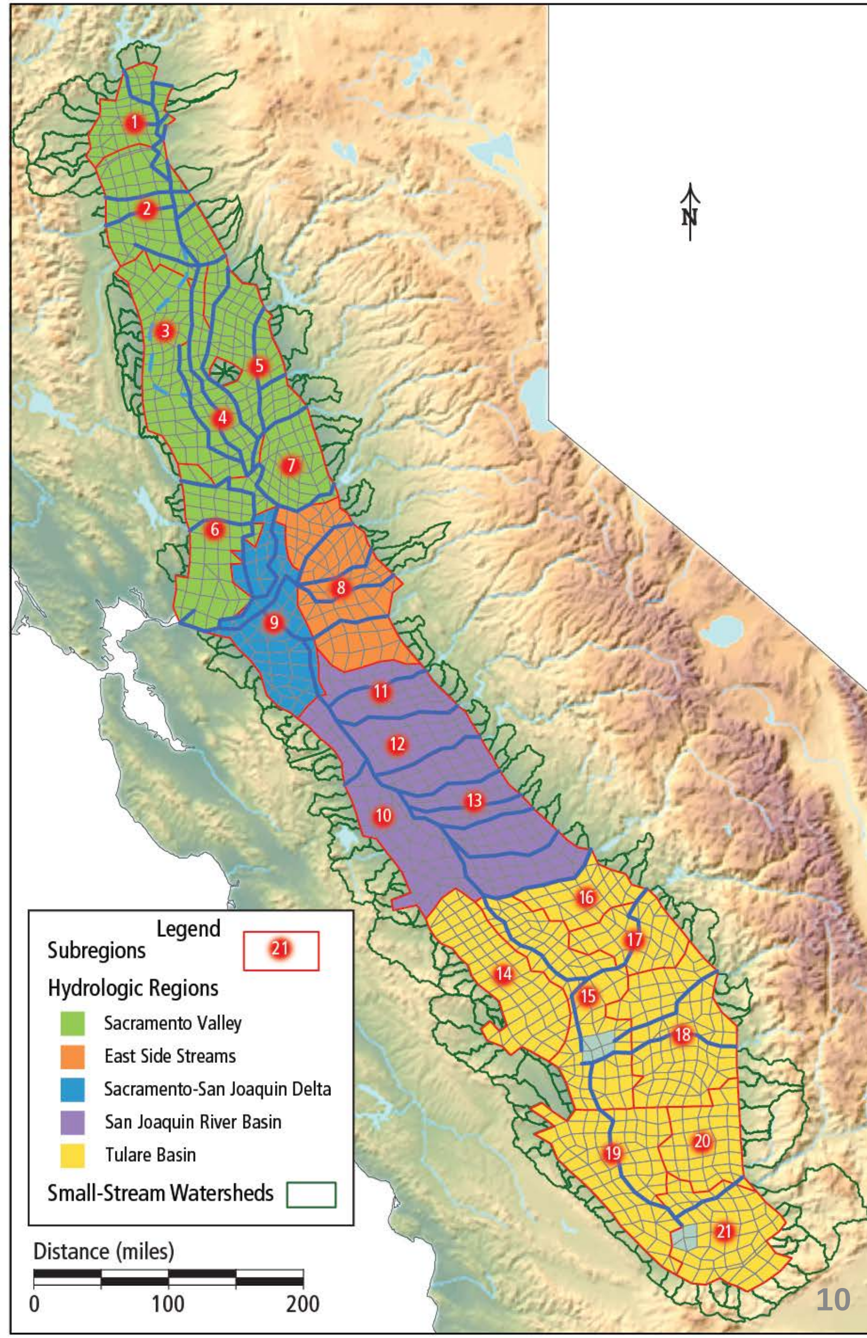
Finite Element Grid
- 3 Layers or 9 Layers
- 1393 Nodes & 1392 Elements

Surface Water System
- 75 River Reaches, 2 Lakes
- 243 Surface Water Diversions
- 38 Inflows, 11 Bypasses
- 210 Small-Stream Watersheds

Land Use Process
- 21 Subregions (DSAs)
- 4 Land Use Types

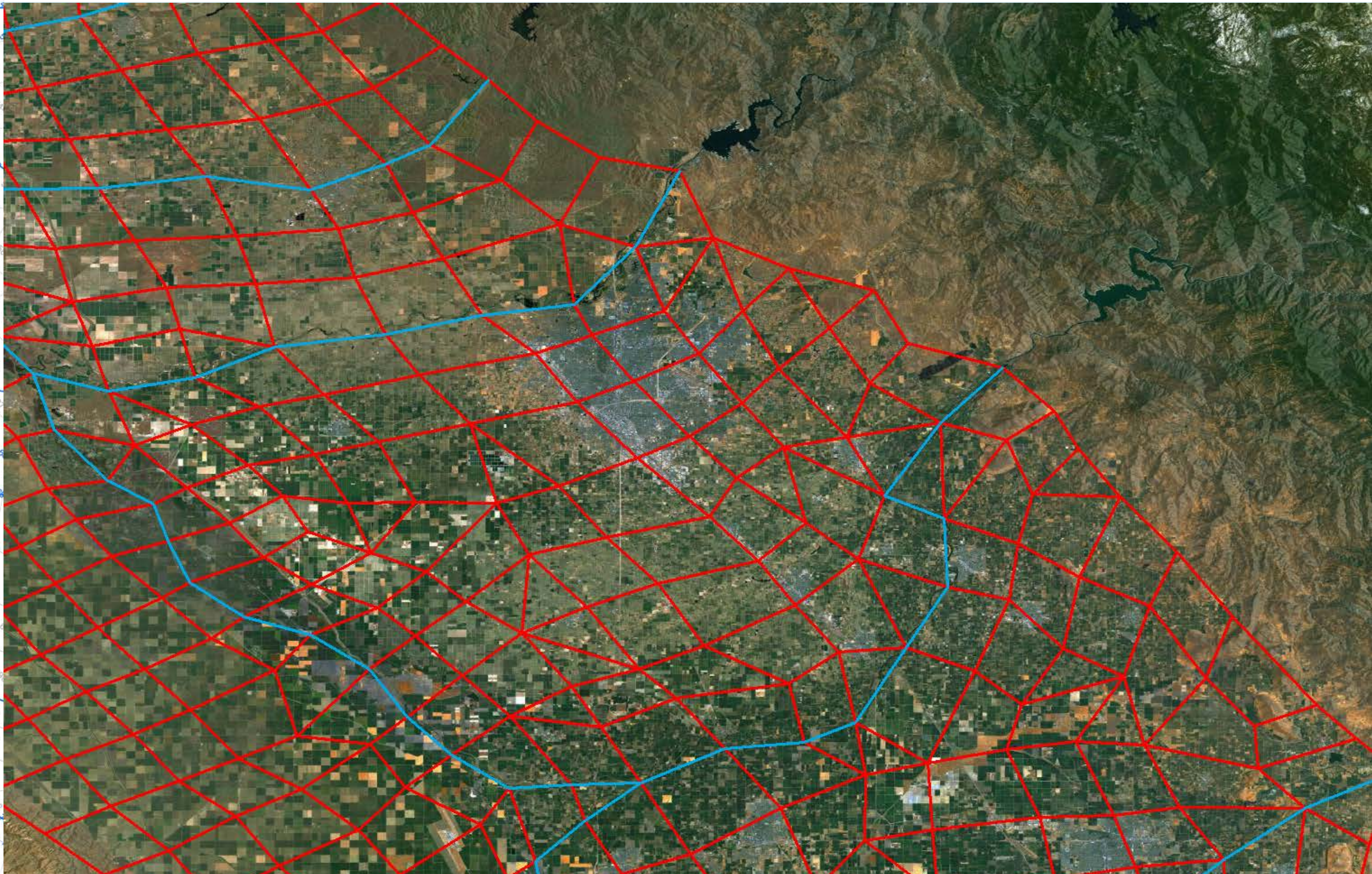
Simulation periods
- 10/1921-9/2009 (88 yrs)
- runs in 3-6 min

IWFM version 3.02



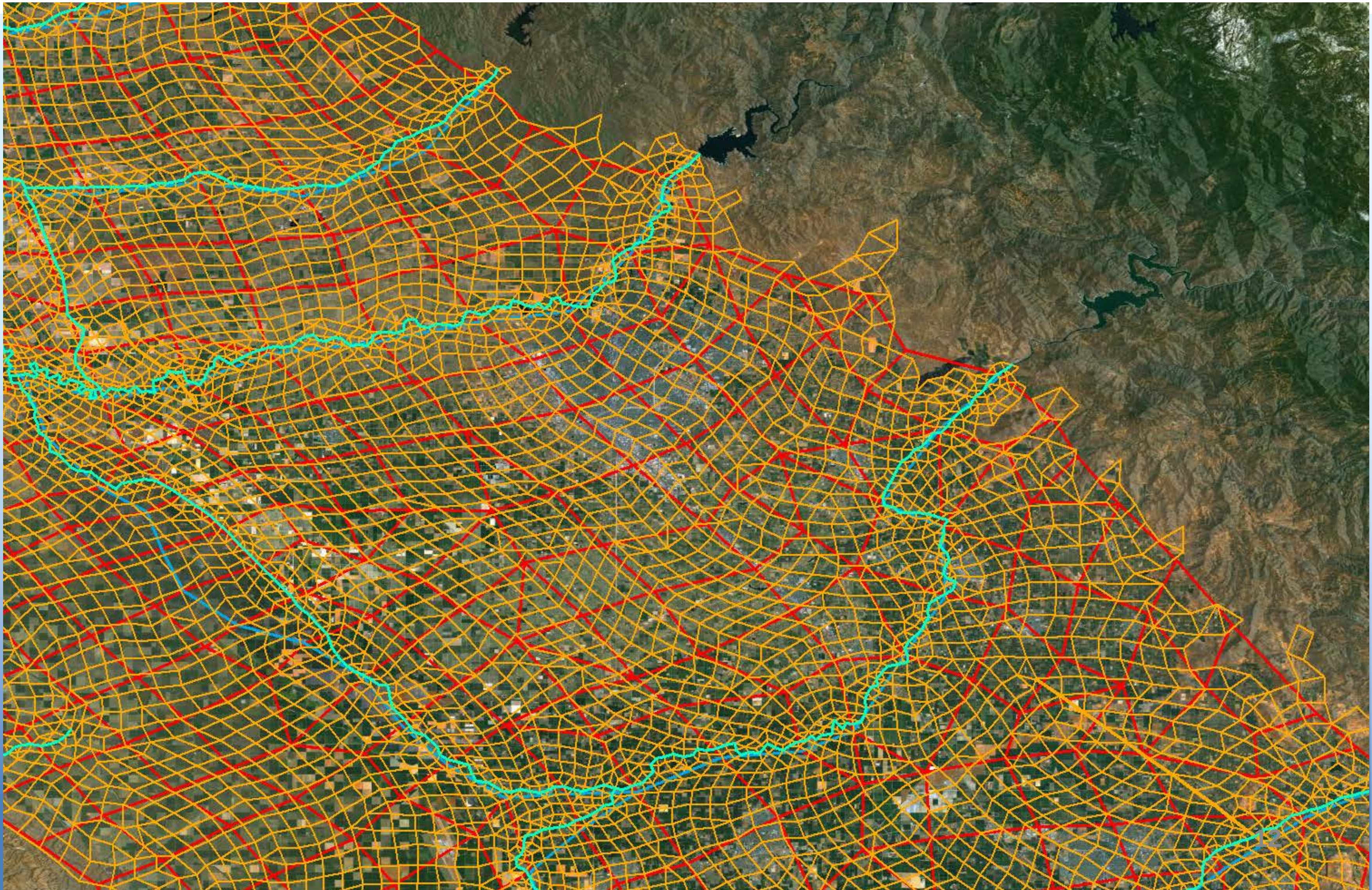
Coarse Grid

"C2VSim CG-3.02"



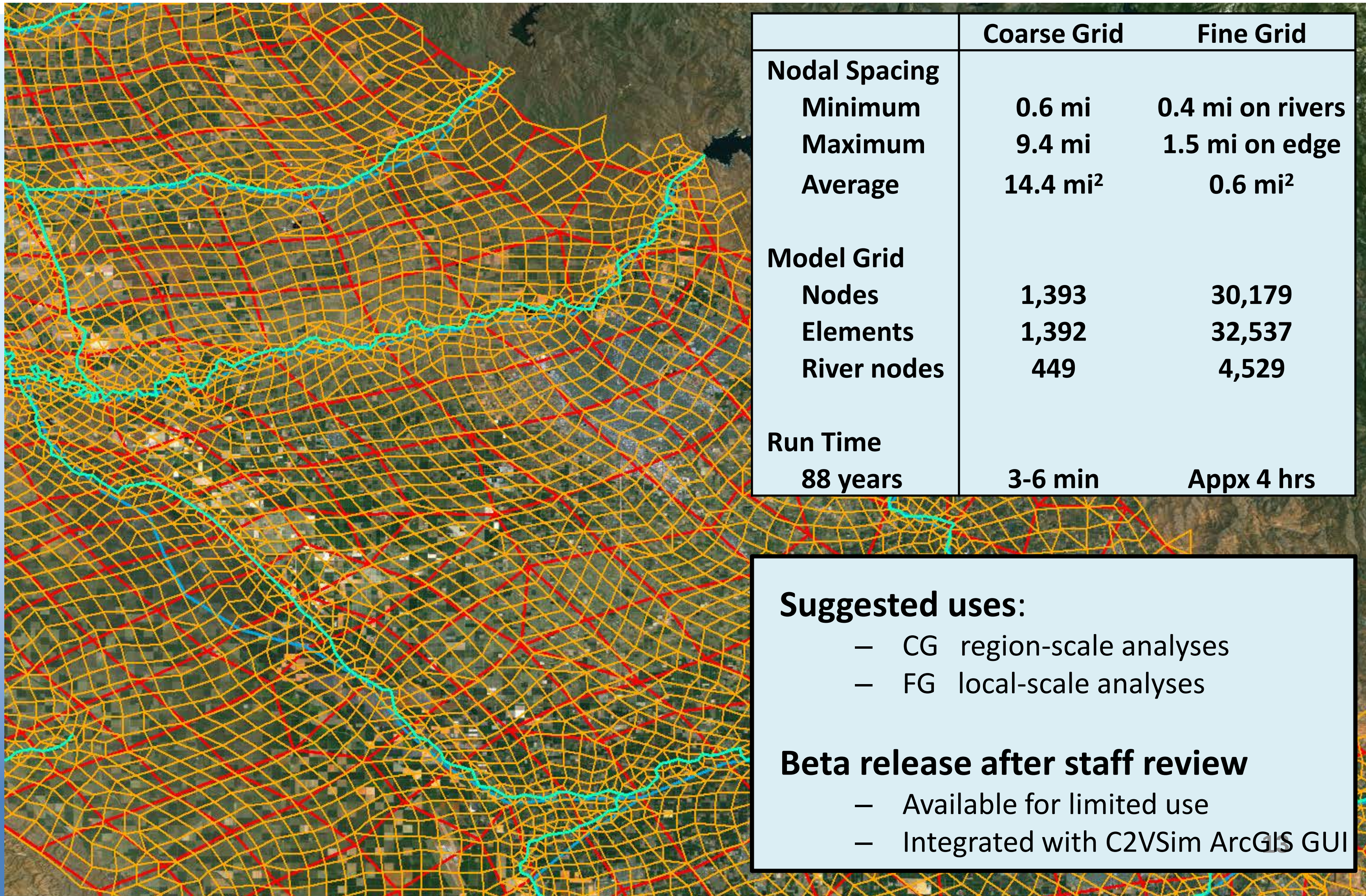
Fine Grid

"C2VSim FG-3.02"



Fine Grid

"C2VSim FG-3.02"



	Coarse Grid	Fine Grid
Nodal Spacing		
Minimum	**0.6 mi**	**0.4 mi on rivers**
Maximum	**9.4 mi**	**1.5 mi on edge**
Average	**14.4 mi²**	**0.6 mi²**
Model Grid		
Nodes	**1,393**	**30,179**
Elements	**1,392**	**32,537**
River nodes	**449**	**4,529**
Run Time		
88 years	**3-6 min**	**Appx 4 hrs**

Suggested uses:

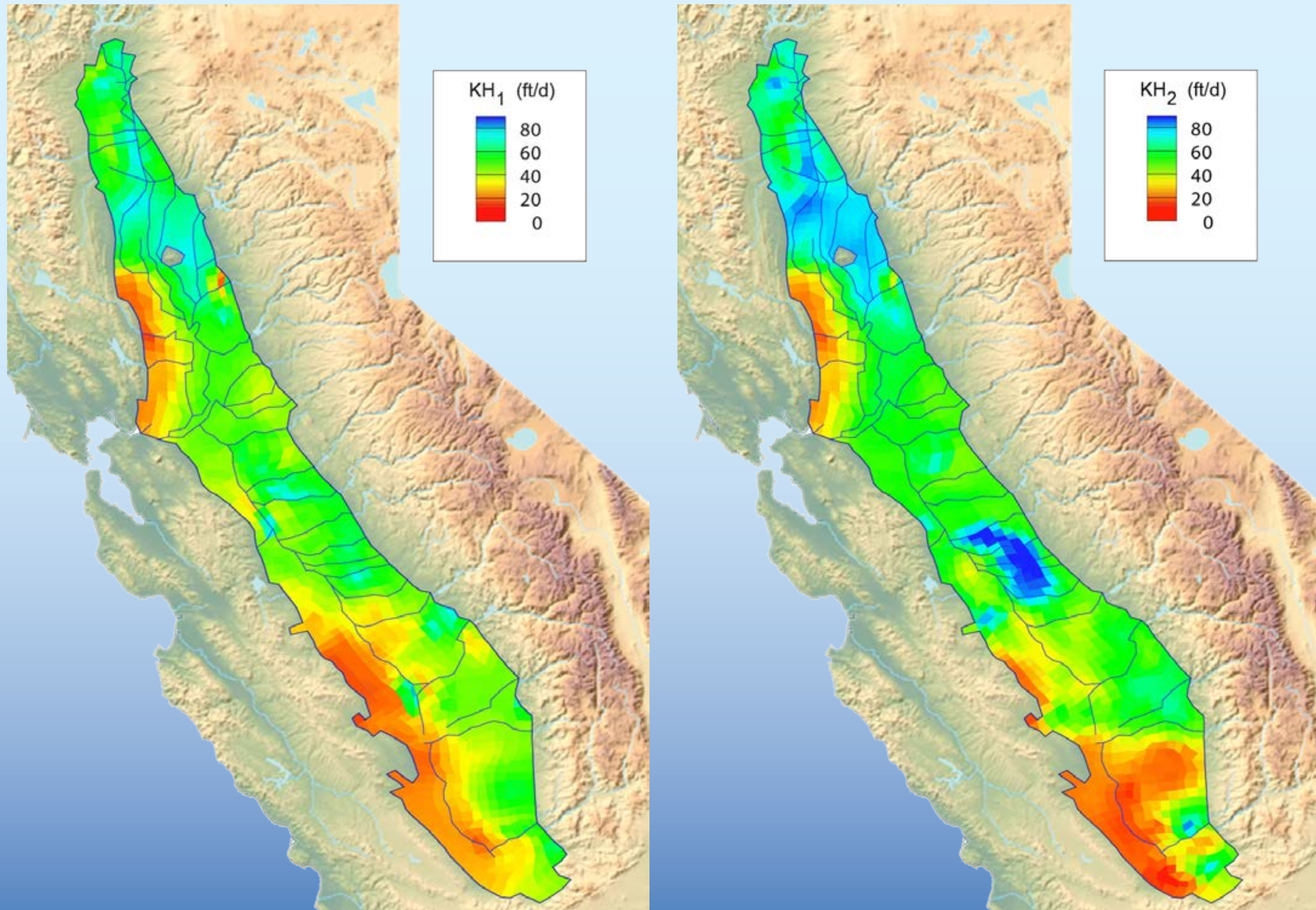
- CG region-scale analyses
- FG local-scale analyses

Beta release after staff review

- Available for limited use
- Integrated with C2VSim ArcGIS GUI

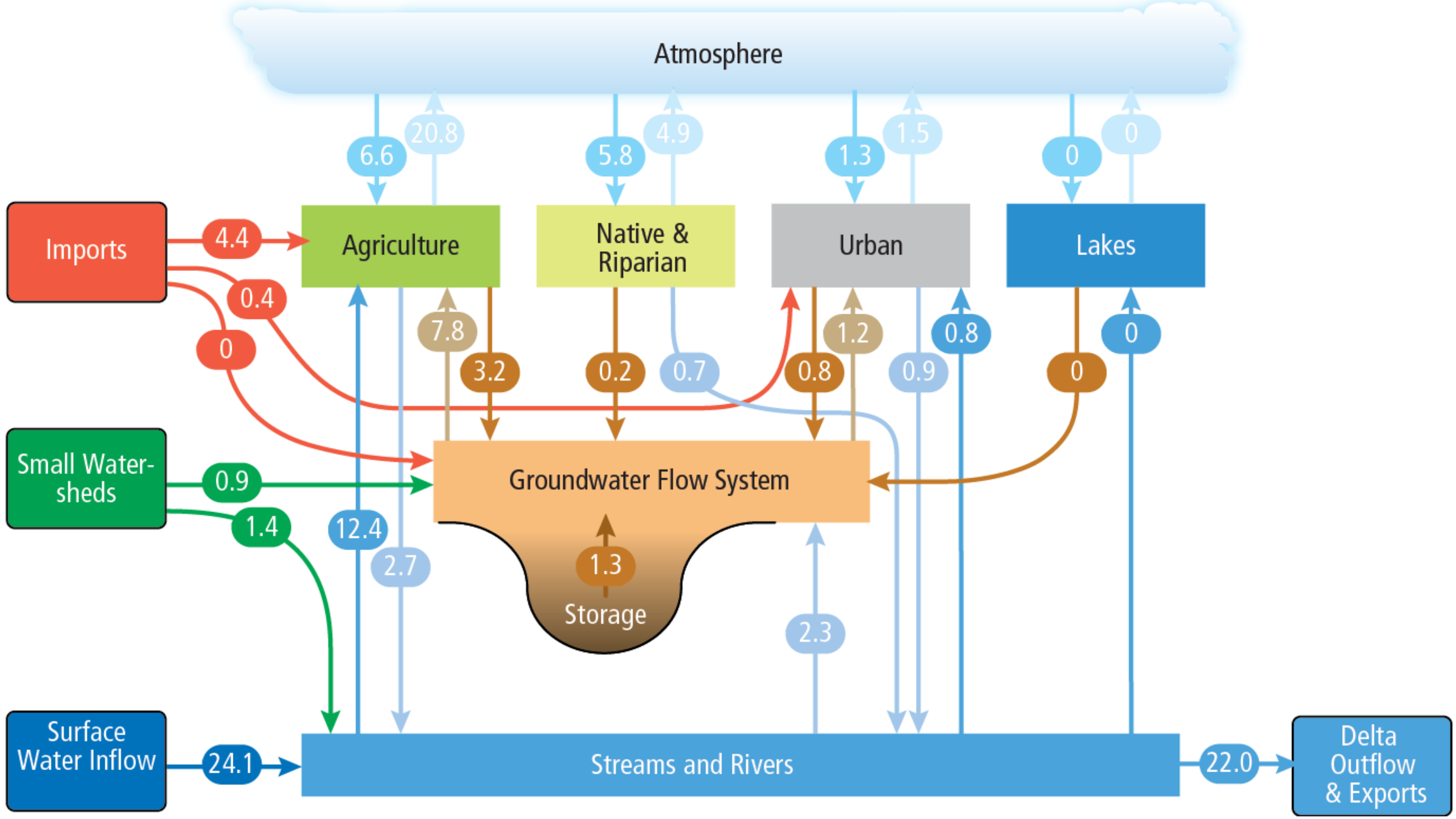
Hydraulic Conductivity

Layer 1 **Layer 2**



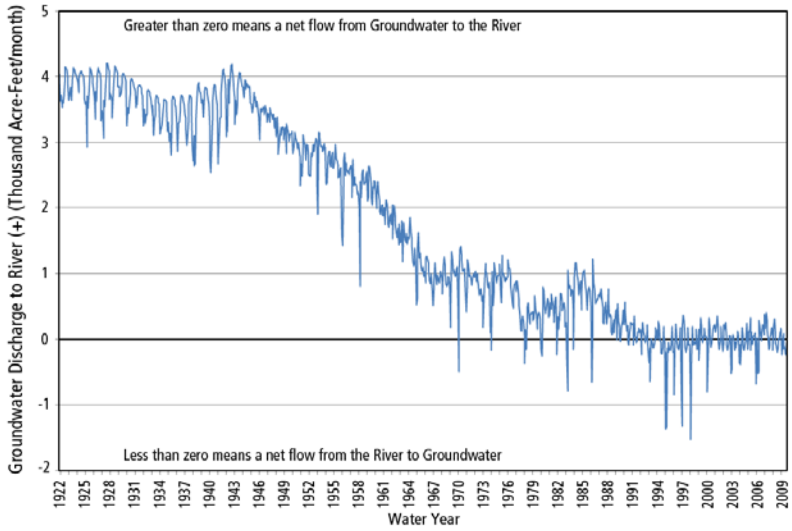
Simulated Annual Water Budget

Average Flows for water years 2000-2009
[Million Acre-Feet/Year]

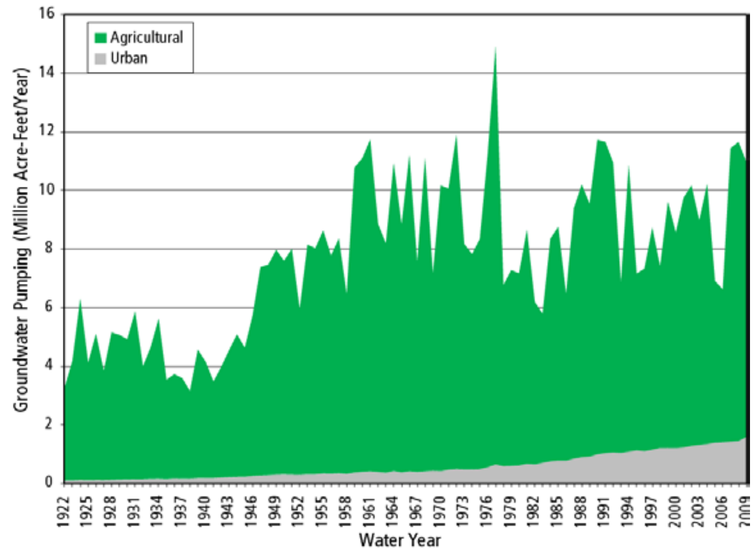


River-Groundwater Flows

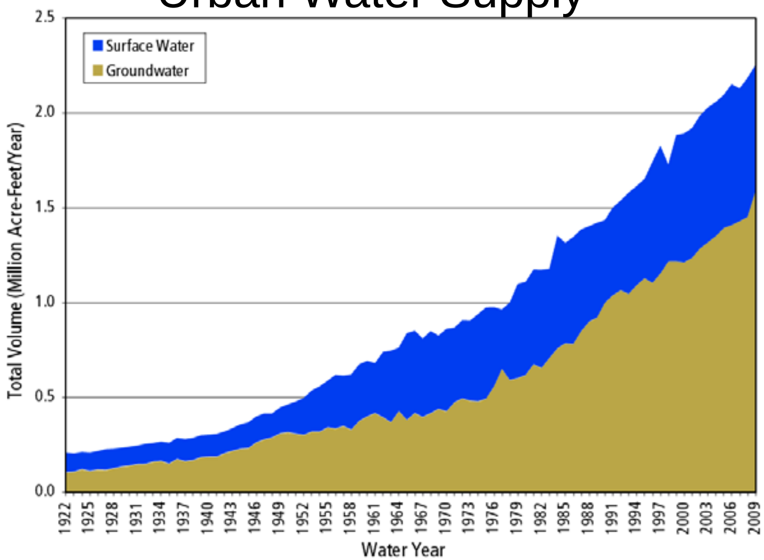
Sacramento River reach near Chico



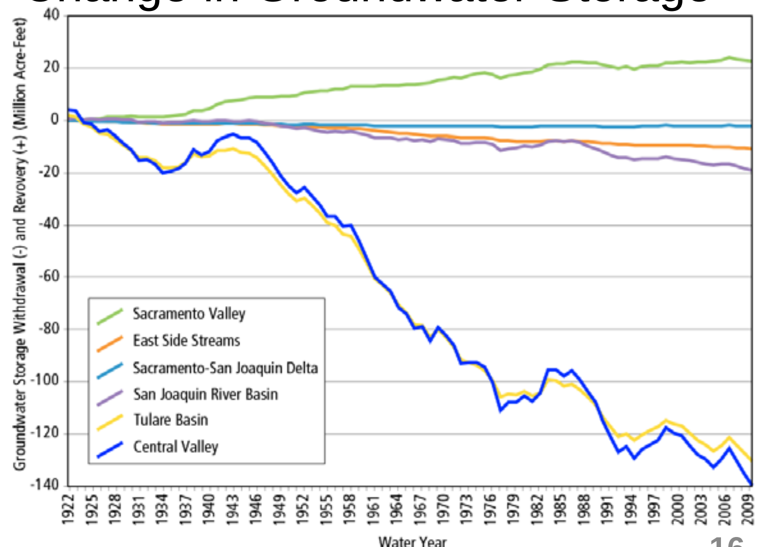
Groundwater Pumping



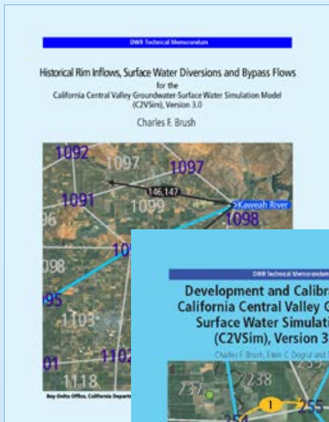
Urban Water Supply



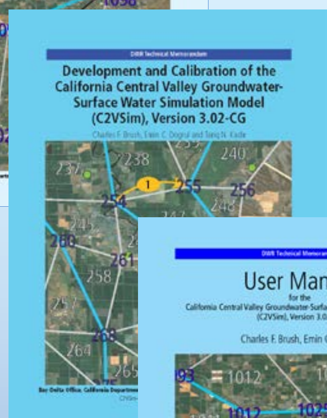
Change in Groundwater Storage



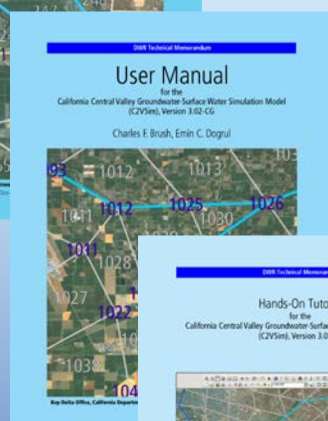
C2VSim Publications



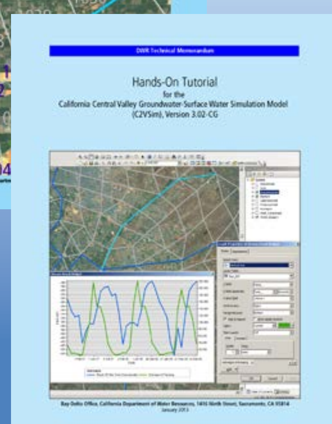
C2VSim Surface Water Inflows, Diversions and Bypass Flows



C2VSim Development and Calibration

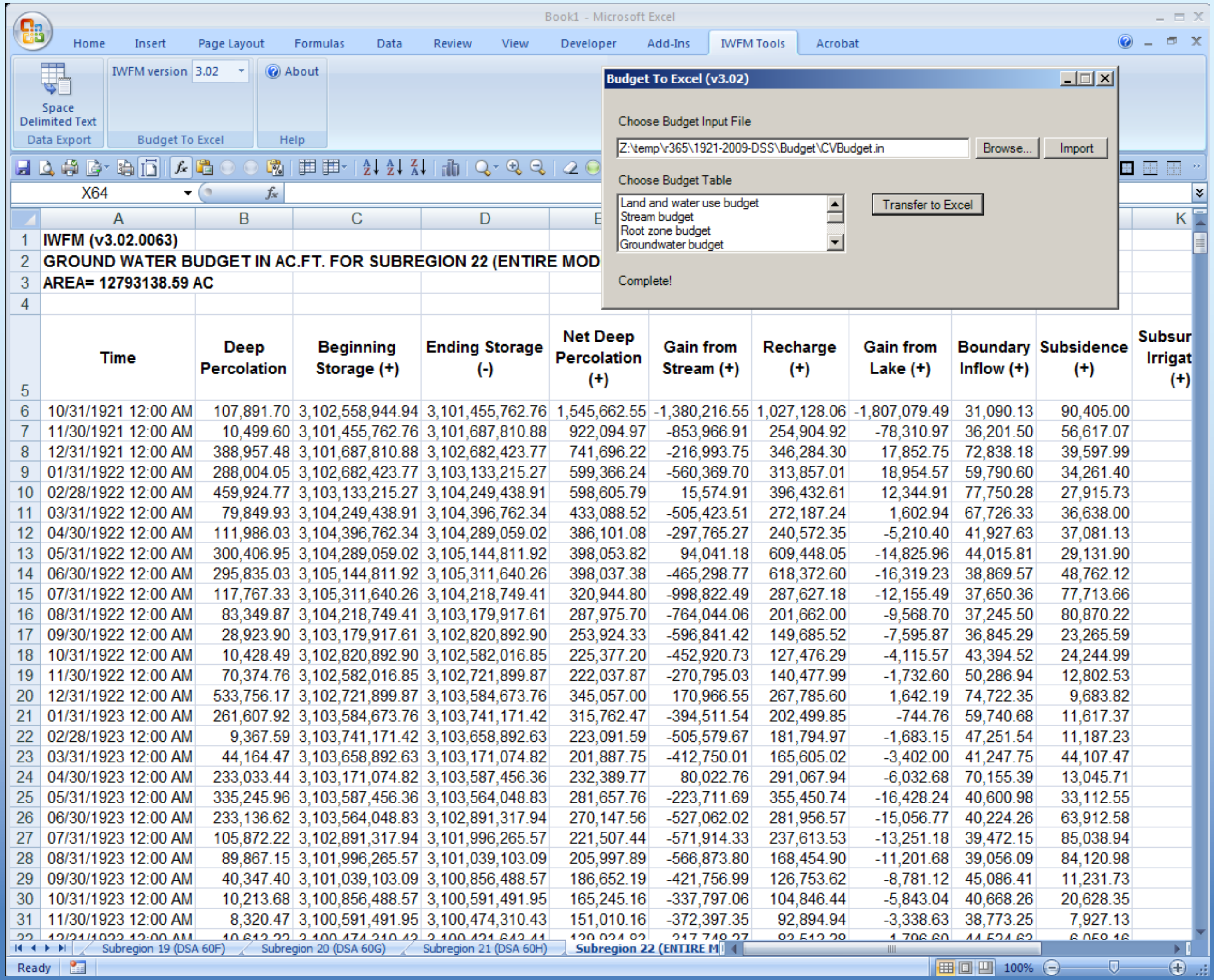


C2VSim User Manual



C2VSim Tutorial (draft)

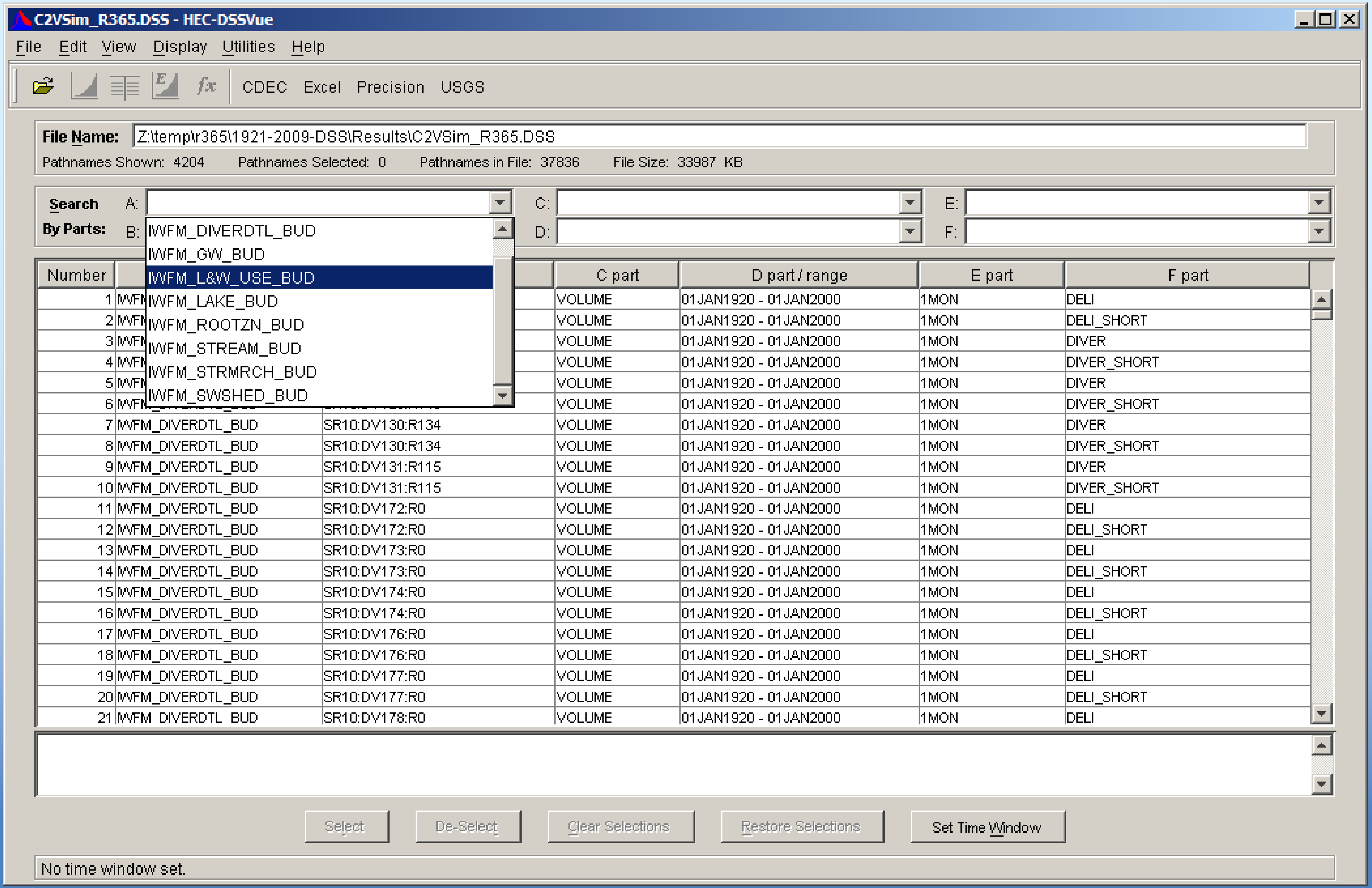
Excel Add-In



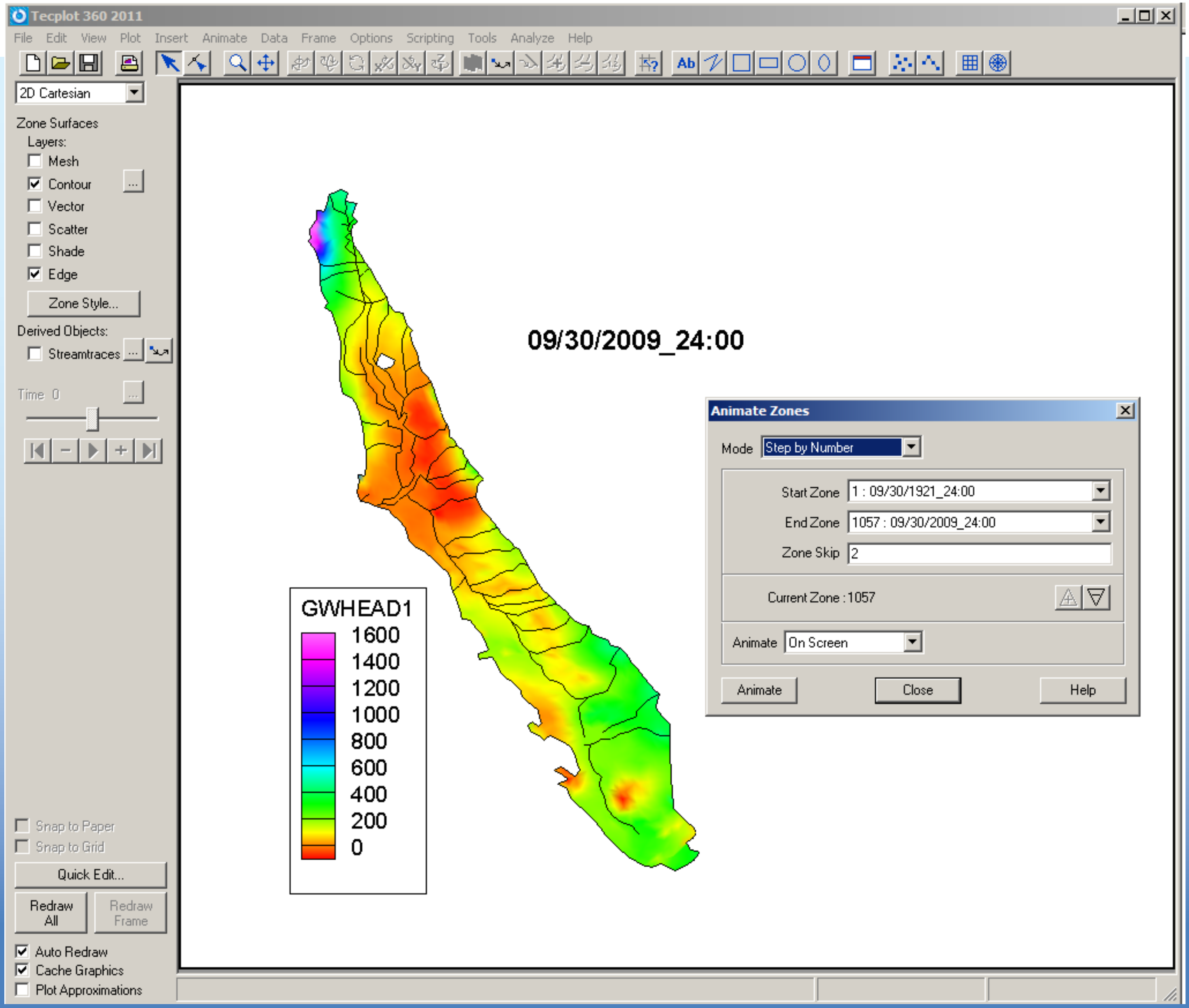
IWFM (v3.02.0063)
GROUND WATER BUDGET IN AC.FT. FOR SUBREGION 22 (ENTIRE MOD
AREA= 12793138.59 AC

Time	Deep Percolation	Beginning Storage (+)	Ending Storage (-)	Net Deep Percolation (+)	Gain from Stream (+)	Recharge (+)	Gain from Lake (+)	Boundary Inflow (+)	Subsidence (+)	Subsur Irrigat (+)
10/31/1921 12:00 AM	107,891.70	3,102,558,944.94	3,101,455,762.76	1,545,662.55	-1,380,216.55	1,027,128.06	-1,807,079.49	31,090.13	90,405.00	
11/30/1921 12:00 AM	10,499.60	3,101,455,762.76	3,101,687,810.88	922,094.97	-853,966.91	254,904.92	-78,310.97	36,201.50	56,617.07	
12/31/1921 12:00 AM	388,957.48	3,101,687,810.88	3,102,682,423.77	741,696.22	-216,993.75	346,284.30	17,852.75	72,838.18	39,597.99	
01/31/1922 12:00 AM	288,004.05	3,102,682,423.77	3,103,133,215.27	599,366.24	-560,369.70	313,857.01	18,954.57	59,790.60	34,261.40	
02/28/1922 12:00 AM	459,924.77	3,103,133,215.27	3,104,249,438.91	598,605.79	15,574.91	396,432.61	12,344.91	77,750.28	27,915.73	
03/31/1922 12:00 AM	79,849.93	3,104,249,438.91	3,104,396,762.34	433,088.52	-505,423.51	272,187.24	1,602.94	67,726.33	36,638.00	
04/30/1922 12:00 AM	111,986.03	3,104,396,762.34	3,104,289,059.02	386,101.08	-297,765.27	240,572.35	-5,210.40	41,927.63	37,081.13	
05/31/1922 12:00 AM	300,406.95	3,104,289,059.02	3,105,144,811.92	398,053.82	94,041.18	609,448.05	-14,825.96	44,015.81	29,131.90	
06/30/1922 12:00 AM	295,835.03	3,105,144,811.92	3,105,311,640.26	398,037.38	-465,298.77	618,372.60	-16,319.23	38,869.57	48,762.12	
07/31/1922 12:00 AM	117,767.33	3,105,311,640.26	3,104,218,749.41	320,944.80	-998,822.49	287,627.18	-12,155.49	37,650.36	77,713.66	
08/31/1922 12:00 AM	83,349.87	3,104,218,749.41	3,103,179,917.61	287,975.70	-764,044.06	201,662.00	-9,568.70	37,245.50	80,870.22	
09/30/1922 12:00 AM	28,923.90	3,103,179,917.61	3,102,820,892.90	253,924.33	-596,841.42	149,685.52	-7,595.87	36,845.29	23,265.59	
10/31/1922 12:00 AM	10,428.49	3,102,820,892.90	3,102,582,016.85	225,377.20	-452,920.73	127,476.29	-4,115.57	43,394.52	24,244.99	
11/30/1922 12:00 AM	70,374.76	3,102,582,016.85	3,102,721,899.87	222,037.87	-270,795.03	140,477.99	-1,732.60	50,286.94	12,802.53	
12/31/1922 12:00 AM	533,756.17	3,102,721,899.87	3,103,584,673.76	345,057.00	170,966.55	267,785.60	1,642.19	74,722.35	9,683.82	
01/31/1923 12:00 AM	261,607.92	3,103,584,673.76	3,103,741,171.42	315,762.47	-394,511.54	202,499.85	-744.76	59,740.68	11,617.37	
02/28/1923 12:00 AM	9,367.59	3,103,741,171.42	3,103,658,892.63	223,091.59	-505,579.67	181,794.97	-1,683.15	47,251.54	11,187.23	
03/31/1923 12:00 AM	44,164.47	3,103,658,892.63	3,103,171,074.82	201,887.75	-412,750.01	165,605.02	-3,402.00	41,247.75	44,107.47	
04/30/1923 12:00 AM	233,033.44	3,103,171,074.82	3,103,587,456.36	232,389.77	80,022.76	291,067.94	-6,032.68	70,155.39	13,045.71	
05/31/1923 12:00 AM	335,245.96	3,103,587,456.36	3,103,564,048.83	281,657.76	-223,711.69	355,450.74	-16,428.24	40,600.98	33,112.55	
06/30/1923 12:00 AM	233,136.62	3,103,564,048.83	3,102,891,317.94	270,147.56	-527,062.02	281,956.57	-15,056.77	40,224.26	63,912.58	
07/31/1923 12:00 AM	105,872.22	3,102,891,317.94	3,101,996,265.57	221,507.44	-571,914.33	237,613.53	-13,251.18	39,472.15	85,038.94	
08/31/1923 12:00 AM	89,867.15	3,101,996,265.57	3,101,039,103.09	205,997.89	-566,873.80	168,454.90	-11,201.68	39,056.09	84,120.98	
09/30/1923 12:00 AM	40,347.40	3,101,039,103.09	3,100,856,488.57	186,652.19	-421,756.99	126,753.62	-8,781.12	45,086.41	11,231.73	
10/31/1923 12:00 AM	10,213.68	3,100,856,488.57	3,100,591,491.95	165,245.16	-337,797.06	104,846.44	-5,843.04	40,668.26	20,628.35	
11/30/1923 12:00 AM	8,320.47	3,100,591,491.95	3,100,474,310.43	151,010.16	-372,397.35	92,894.94	-3,338.63	38,773.25	7,927.13	

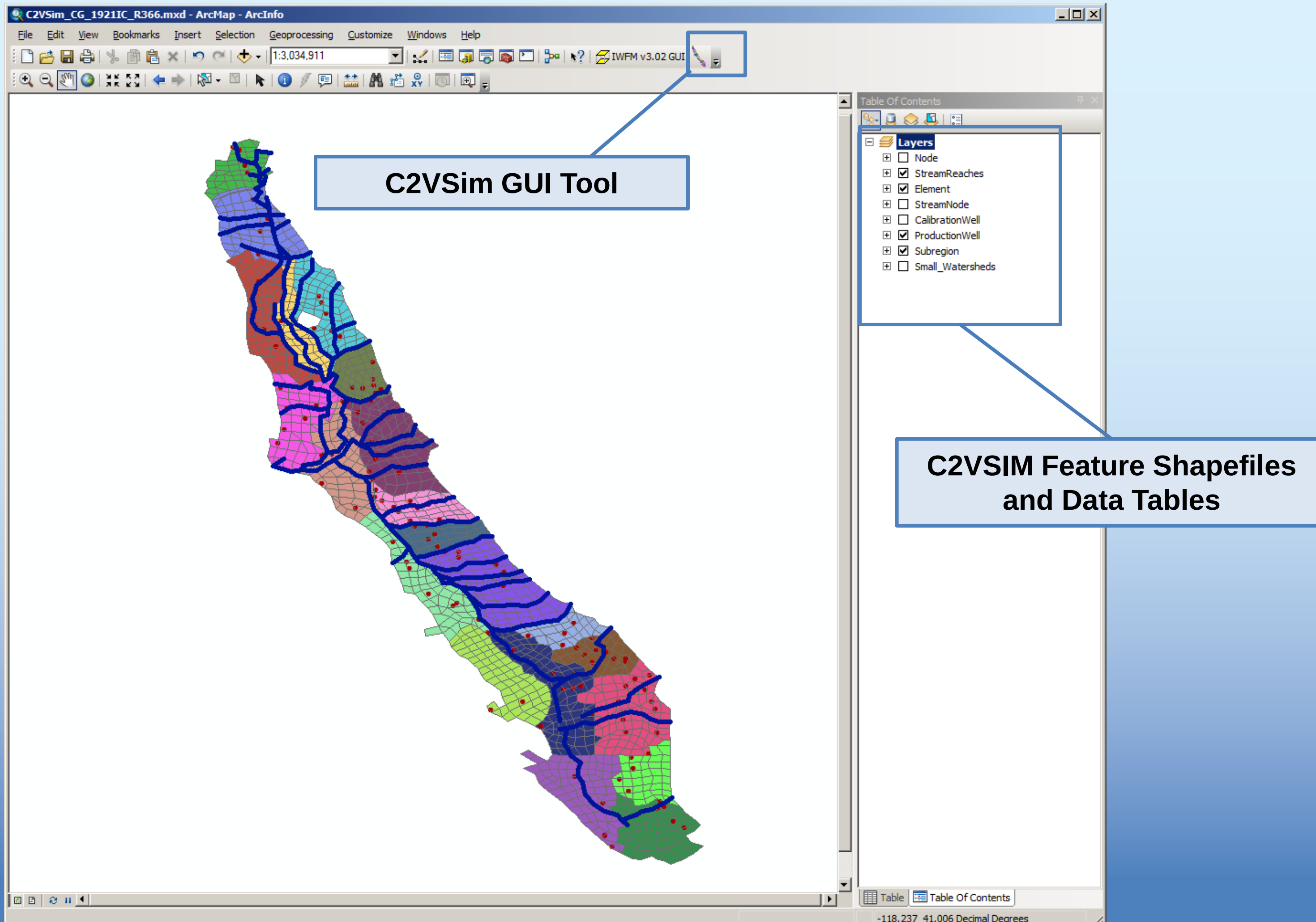
HEC-DSS


C2VSim_R365.DSS - HEC-DSSVue
File Edit View Display Utilities Help
CDEC Excel Precision USGS
File Name: Z:\temp\r365\1921-2009-DSS\Results\C2VSim_R365.DSS
Pathnames Shown: 4204 Pathnames Selected: 0 Pathnames in File: 37836 File Size: 33987 KB
Search By Parts: A: B: C: D: E: F:
IWFM_DIVERDTL_BUD
IWFM_GW_BUD
IWFM_L&W_USE_BUD
IWFM_LAKE_BUD
IWFM_ROOTZN_BUD
IWFM_STREAM_BUD
IWFM_STRMRCH_BUD
IWFM_SWSHED_BUD
Number
C part
D part / range
E part
F part
1 VOLUME 01JAN1920 - 01JAN2000 1MON DELI
2 VOLUME 01JAN1920 - 01JAN2000 1MON DELI_SHORT
3 VOLUME 01JAN1920 - 01JAN2000 1MON DIVER
4 VOLUME 01JAN1920 - 01JAN2000 1MON DIVER_SHORT
5 VOLUME 01JAN1920 - 01JAN2000 1MON DIVER
6 VOLUME 01JAN1920 - 01JAN2000 1MON DIVER_SHORT
7 IWFM_DIVERDTL_BUD SR10:DV130:R134 VOLUME 01JAN1920 - 01JAN2000 1MON DIVER
8 IWFM_DIVERDTL_BUD SR10:DV130:R134 VOLUME 01JAN1920 - 01JAN2000 1MON DIVER_SHORT
9 IWFM_DIVERDTL_BUD SR10:DV131:R115 VOLUME 01JAN1920 - 01JAN2000 1MON DIVER
10 IWFM_DIVERDTL_BUD SR10:DV131:R115 VOLUME 01JAN1920 - 01JAN2000 1MON DIVER_SHORT
11 IWFM_DIVERDTL_BUD SR10:DV172:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI
12 IWFM_DIVERDTL_BUD SR10:DV172:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI_SHORT
13 IWFM_DIVERDTL_BUD SR10:DV173:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI
14 IWFM_DIVERDTL_BUD SR10:DV173:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI_SHORT
15 IWFM_DIVERDTL_BUD SR10:DV174:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI
16 IWFM_DIVERDTL_BUD SR10:DV174:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI_SHORT
17 IWFM_DIVERDTL_BUD SR10:DV176:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI
18 IWFM_DIVERDTL_BUD SR10:DV176:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI_SHORT
19 IWFM_DIVERDTL_BUD SR10:DV177:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI
20 IWFM_DIVERDTL_BUD SR10:DV177:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI_SHORT
21 IWFM_DIVERDTL_BUD SR10:DV178:R0 VOLUME 01JAN1920 - 01JAN2000 1MON DELI
Select
De-Select
Clear Selections
Restore Selections
Set Time Window
No time window set.

TecPlot-Ready Output



C2VSim ArcGIS Tool



C2VSim Uses

- CalSim 3 groundwater component
- Integrated Regional Water Management Plans
- Stream-groundwater flows
- Climate change assessments
- Groundwater storage investigations
- Planning studies
- Ecosystem enhancement scenarios
- Infrastructure improvements
- Impacts of operations on Delta flows

Example C2VSim Applications

- Groundwater Substitution Water Transfer: Sacramento Valley Water Management Program
- Potential Impacts of Climate Change I: Aquifer Response to Extended Drought
- Potential Impacts of Climate Change II: Aquifer Response to Extended Drought with Economic Adaptation
- GRACE Collaboration: Downscaling Remote Sensing Observations with C2VSim

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 participants
  - Operate in non-wet years (Sacramento River Index)
  - 173 TAF/year, June 1 – October 31

C2VSIM Simulation of the SVWMP

- Identify individual wells and pumping rates
- Prepare IWFM input files
  - October 1972 - September 2003 Hydrology
  - Pumps run Jun-Oct 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 Valley Water Management Program

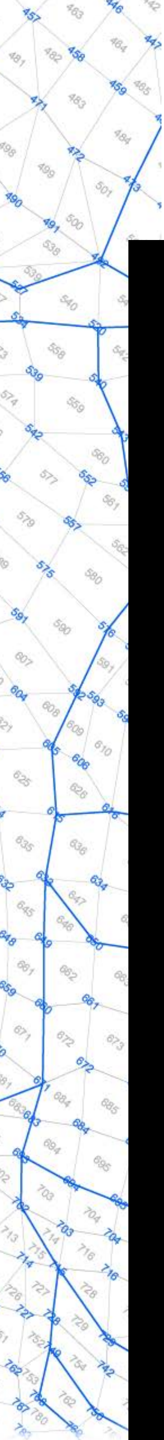
[redacted]

Use groundwater in lieu of surface water

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

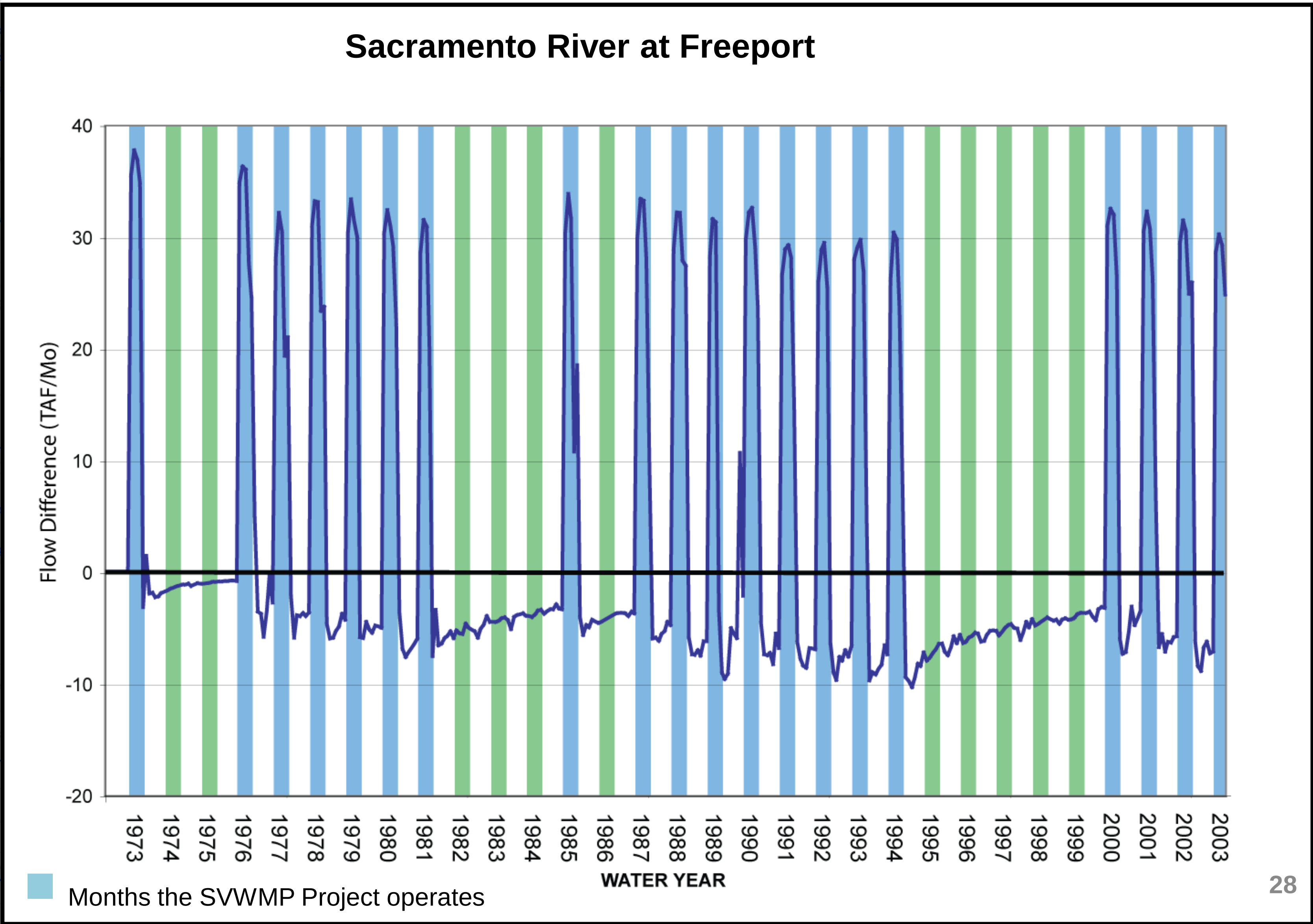


Sacramento Valley Water Management Program

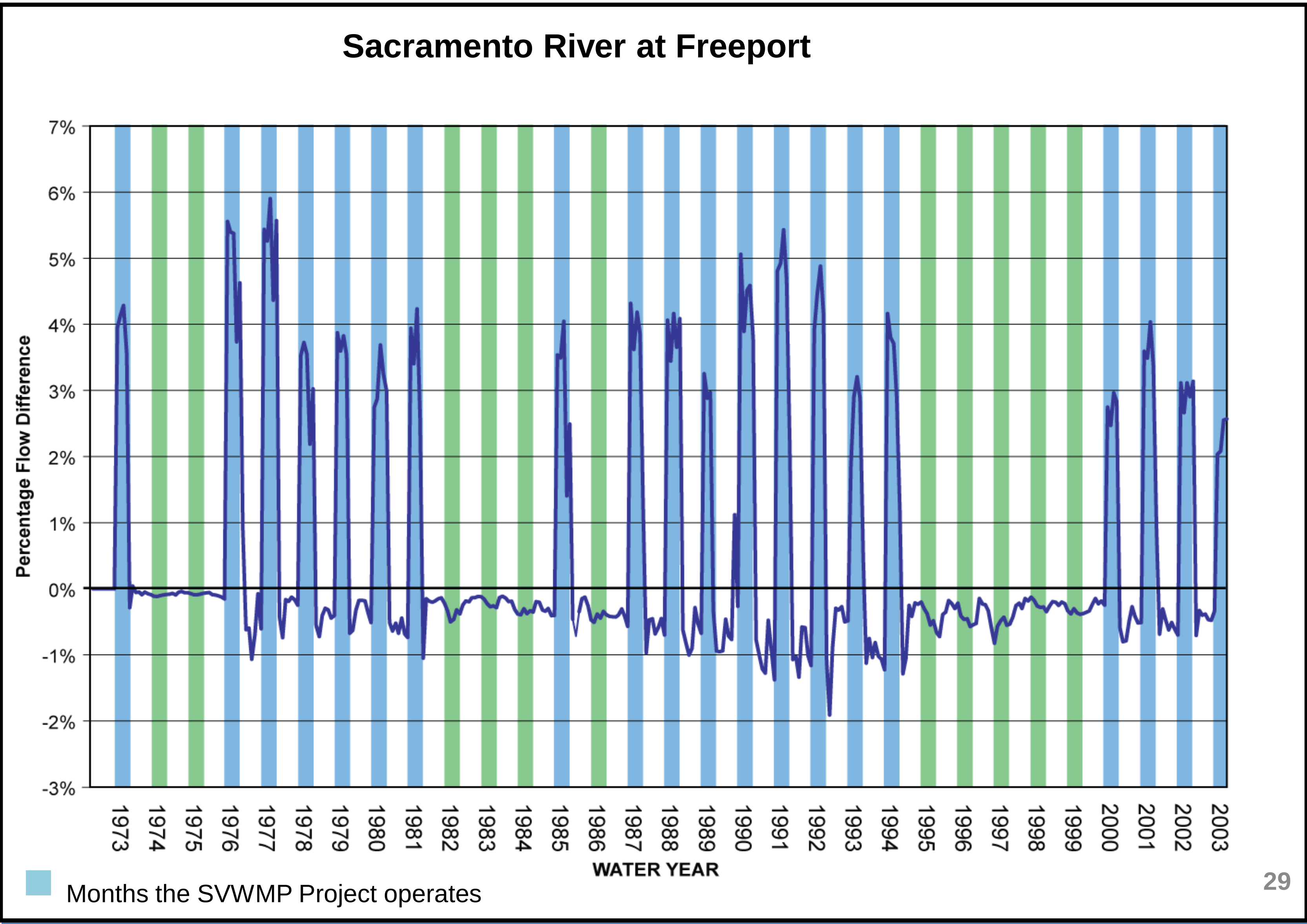
C2VSIM Diversions

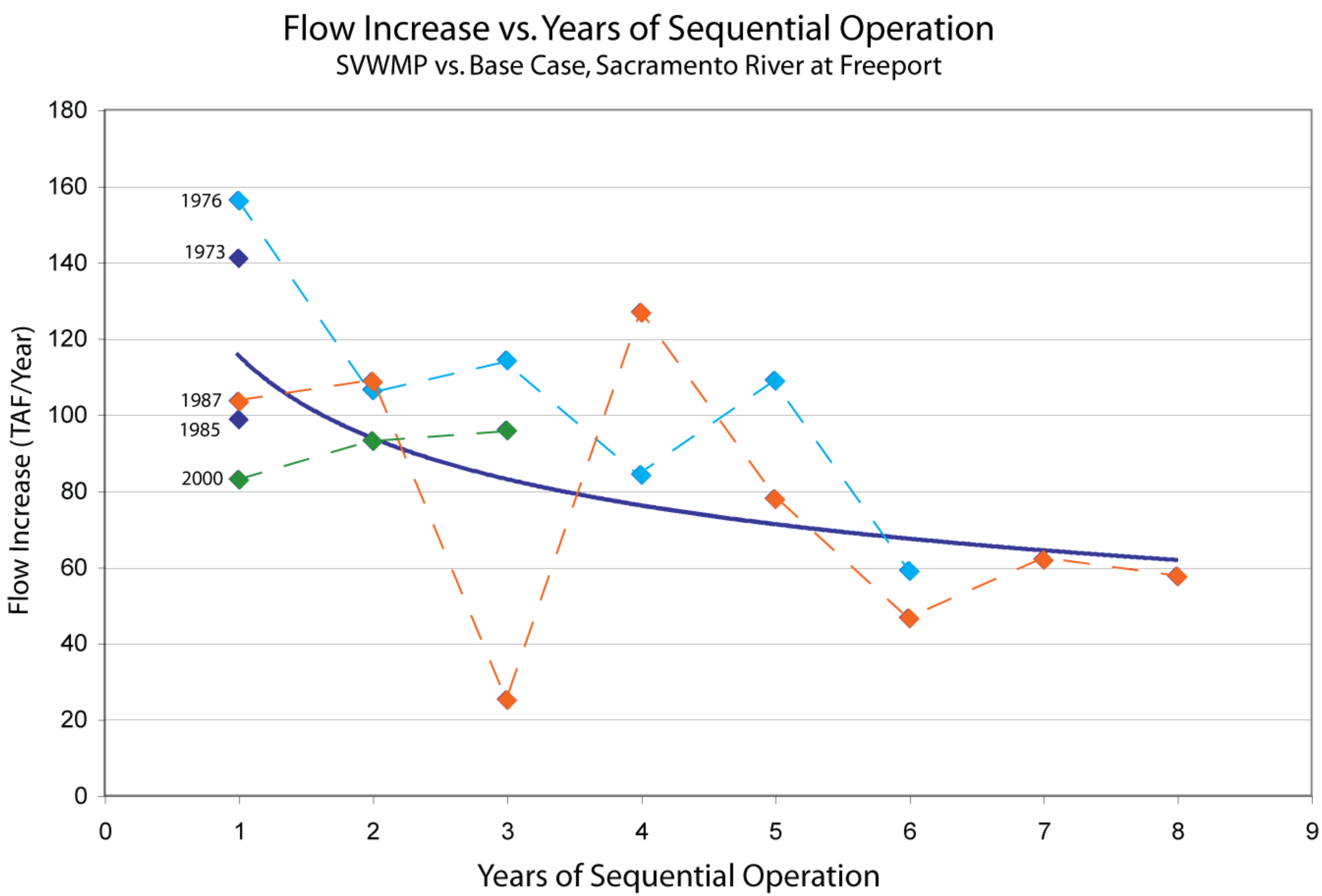
- Adjusted:
  - 19 diversions above Freeport
- Unadjusted:
  - 11 imports
  - 2 exports

Flow Difference (SVWMP – Base Case)

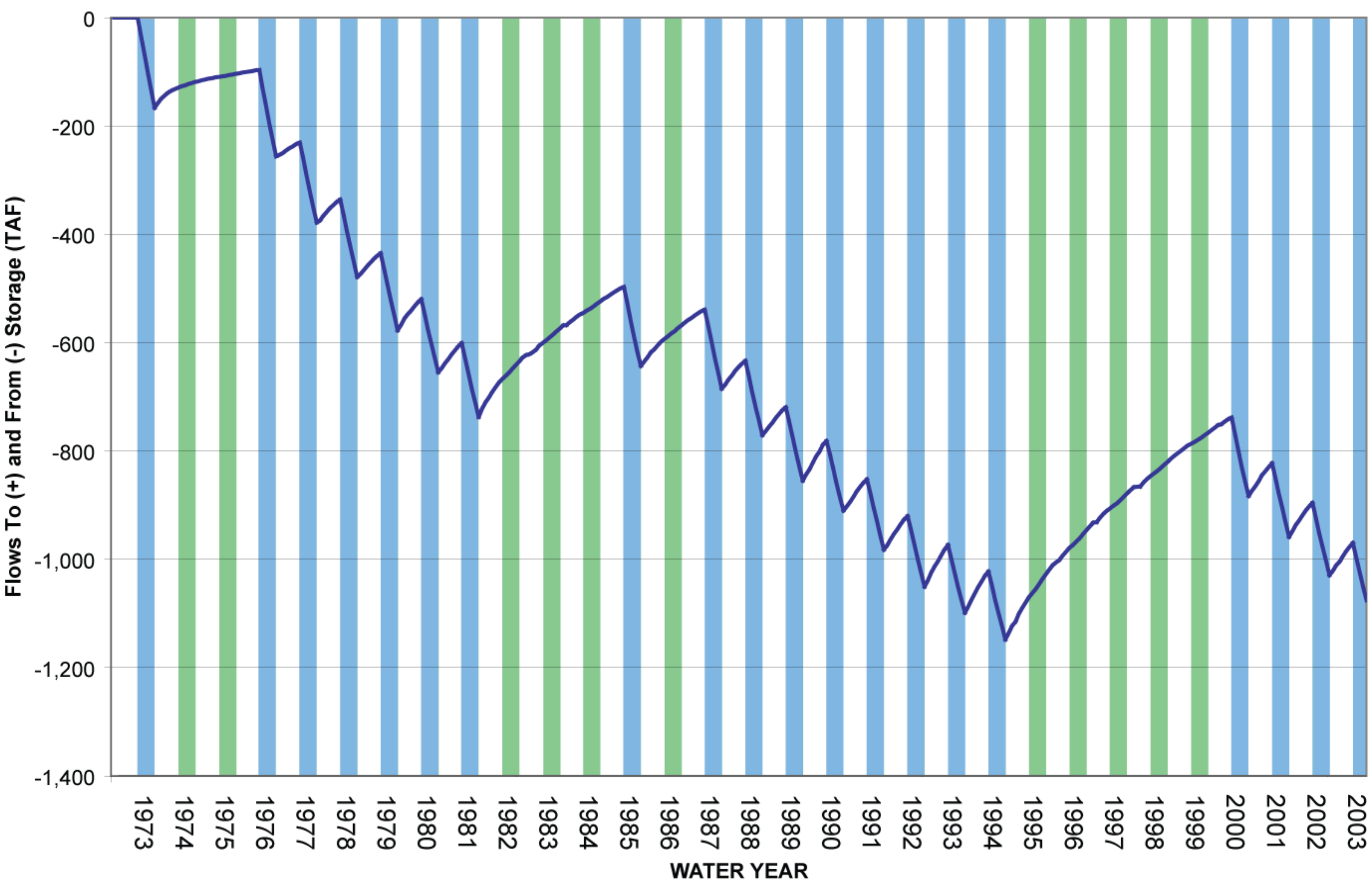


Percent Flow Difference (SVWMP – Base Case)

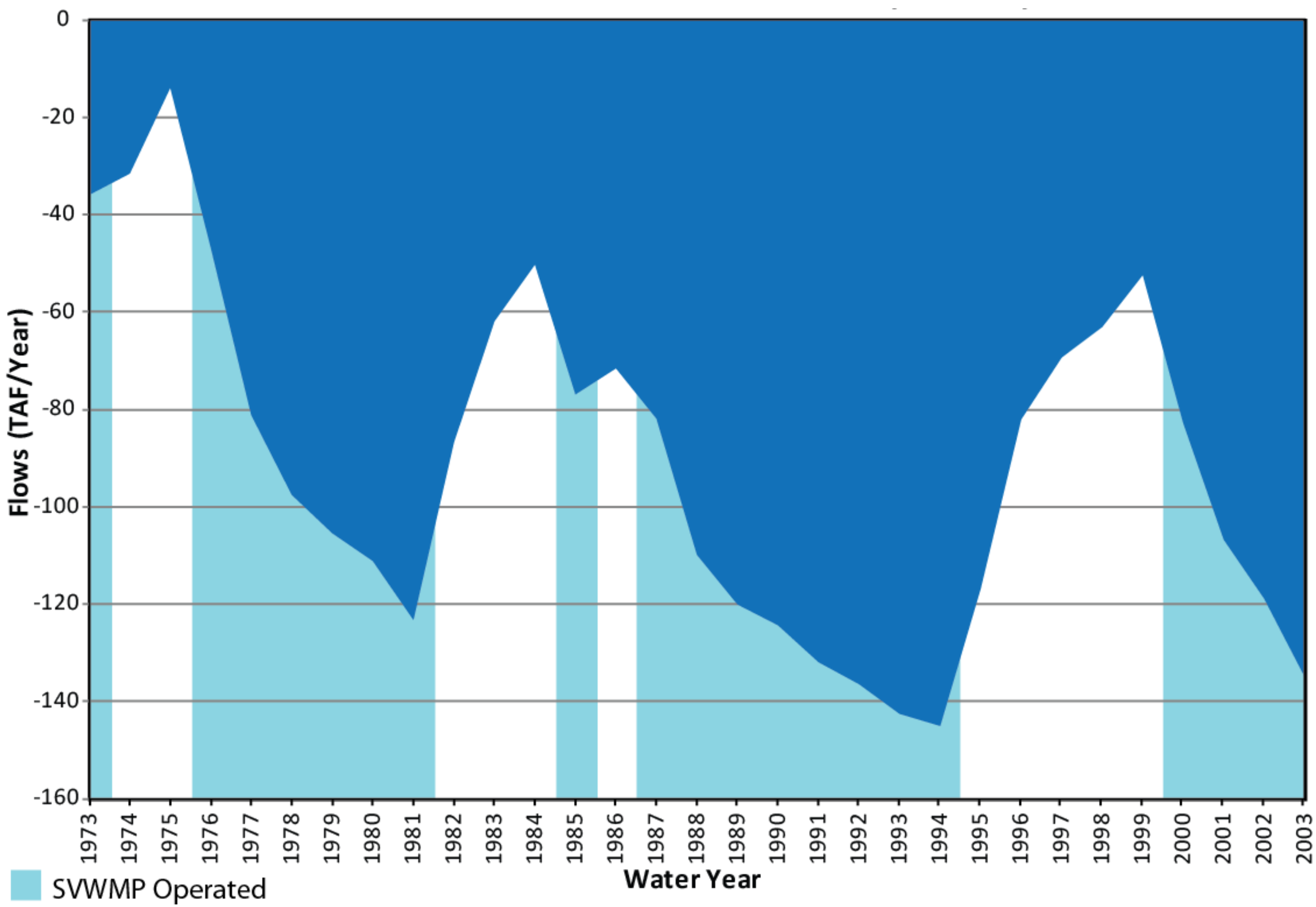



Flow Increase vs. Years of Sequential Operation
SVWMP vs. Base Case, Sacramento River at Freeport
Flow Increase (TAF/Year)
Years of Sequential Operation
1976
1973
1987
1985
2000
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9

Cumulative Change in Groundwater Storage, SVWMP vs. Base Case



Annual River Flow Losses to Groundwater, SVWMP vs. Base Case



Preliminary Findings

- C2VSIM simulation of SVWMP operations
  - SVWMP simulation is easy to implement in C2VSIM
  - Summer flow increase at Freeport averages 128 MAF (68%)
  - Multi-year impacts are very important
  - Annual flow loss at Freeport as groundwater recovers
  - Lots of information – areal recharge, storage, GW-SW

- Issues regarding C2VSIM and SVWMP
  - Scale: C2VSIM is a ‘regional’ model
  - Water budget: Subregional ‘virtual farms’
  - All currently being addressed in continued development of C2VSIM and IWFM

Potential Impacts of Climate Change

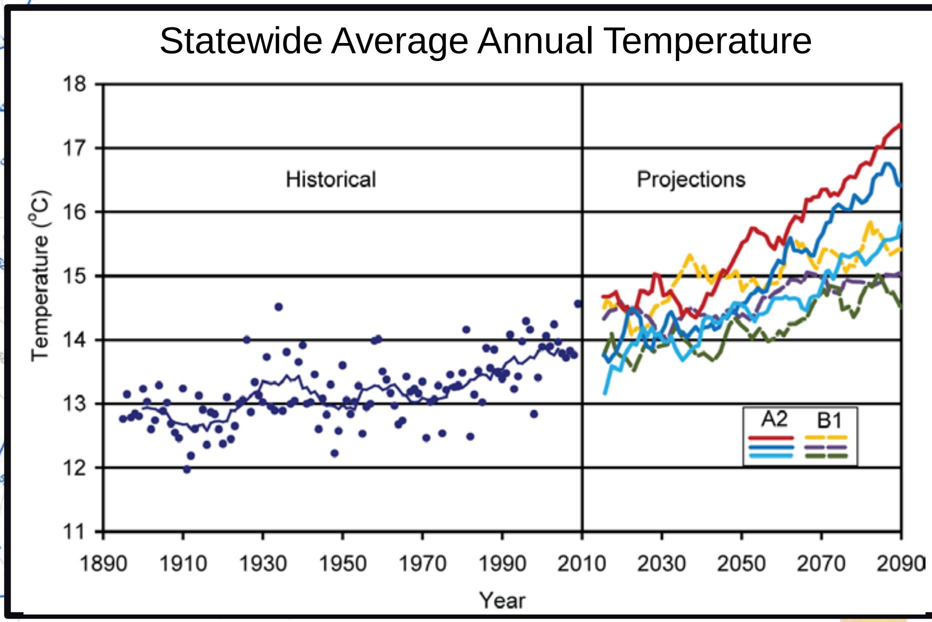
- I: Aquifer Response to Extended Drought
- II: Linking Economic and Hydrologic Models to Study Impacts with Economic Adaptation

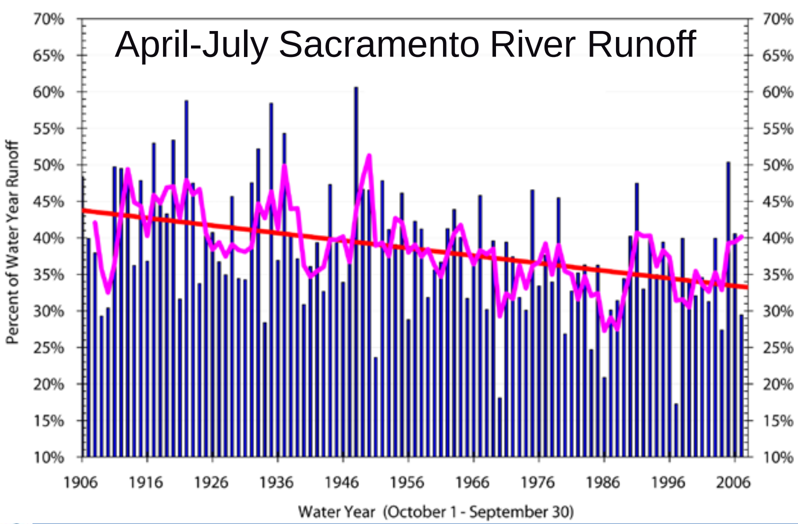
Norman L. Miller and Larry L. Dale, Lawrence Berkeley national Laboratory and UC Berkeley

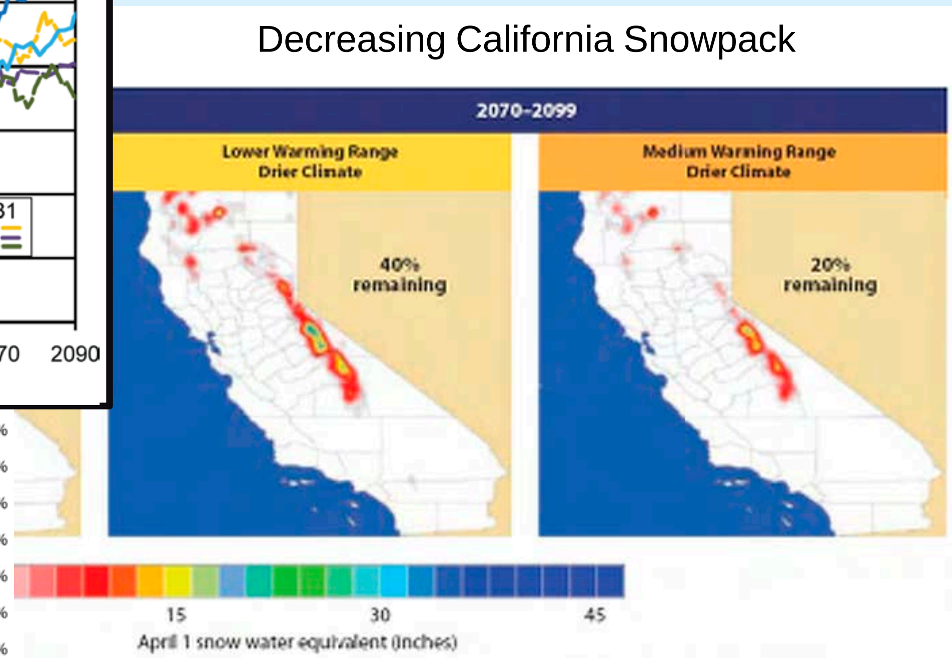
Sebastian D. Vicuna, UC Berkeley and Centro Interdisciplinario de Cambio Global, Pontificia Universidad Catolica de Chile

Charles F. Brush, Emin C. Dogrul, Tariq N. Kadir and Francis I. Chung, California Department of Water Resources

Climate Variability







Sources: DRI 2008, 2009; CalEPA 2009; CNRA 2009; Mosher et al. 2009

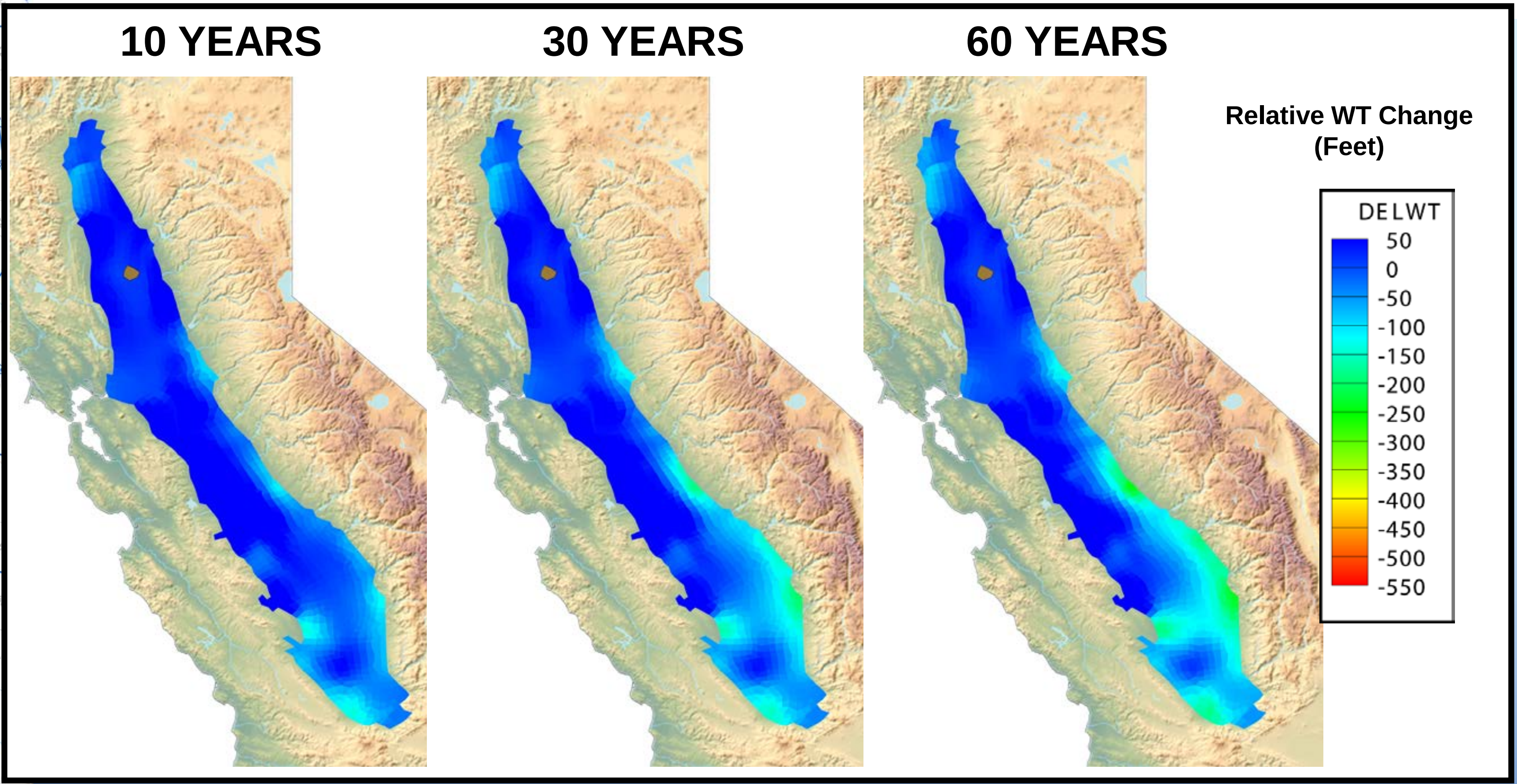
Methods

- Use historical 1972-2003 data to construct 10-year monthly valley-rim inflows for (1) base case, (2) slight, (3) moderate and (4) severe droughts
- Develop diversion scenarios using CALSIM-II
- Determine economic parameters using CVPM
- Integrated hydrologic simulations with C2VSIM
  - 10-year spin-up at ‘average’ conditions
  - 10-, 20-, 30- or 60-year drought
  - 30-year recovery period
  - Calculate groundwater pumping to meet demands
- Incorporate economic factors using Logit functions
  - Fixed agricultural water demand
  - Variable agricultural water demand

Central Valley Water Table 'Relative' Response

Joint LBNL-DWR Drought Simulation

30-percent reduction in surface water inflows

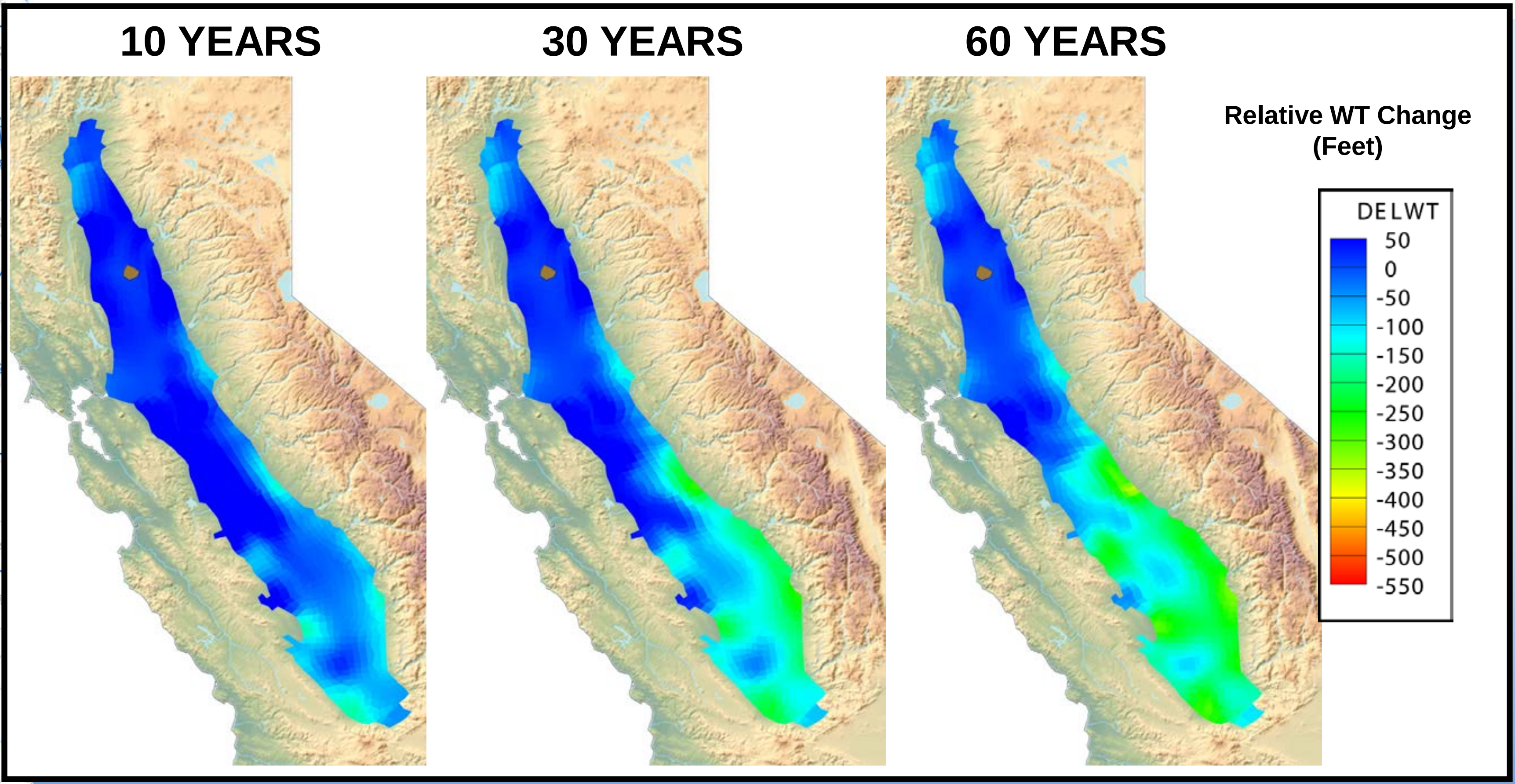


"Drought Resilience Of The California Central Valley Surface-Groundwater-Conveyance System" by N. L. Miller et al. Submitted to J. Am. Water Res. Assoc. April 2008.

Central Valley Water Table ‘Relative’ Response

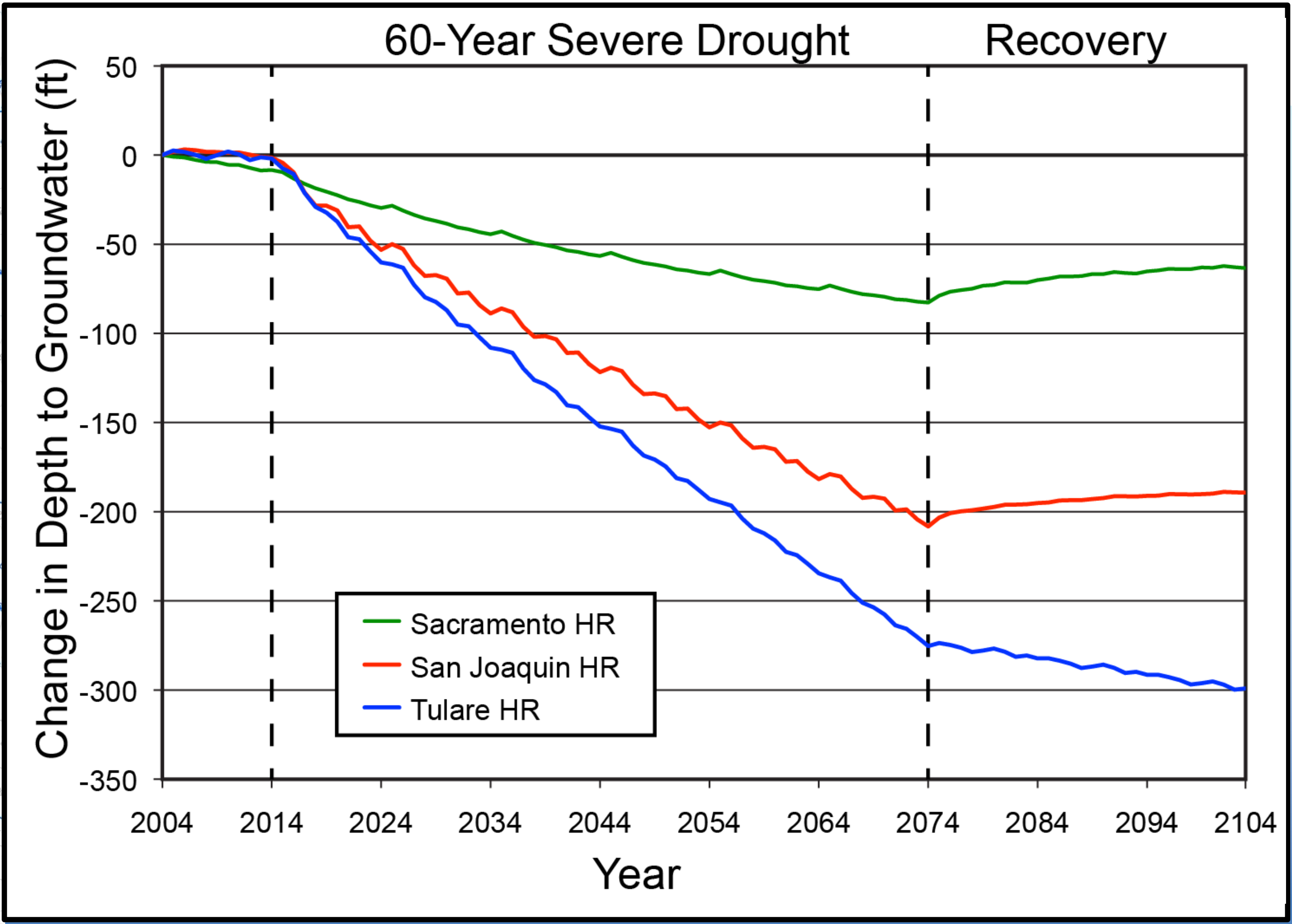
Joint LBNL-DWR Drought Simulation

70-percent reduction in surface water inflows



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

Depth to Groundwater – Constant Crops



Incorporating Variable Demand

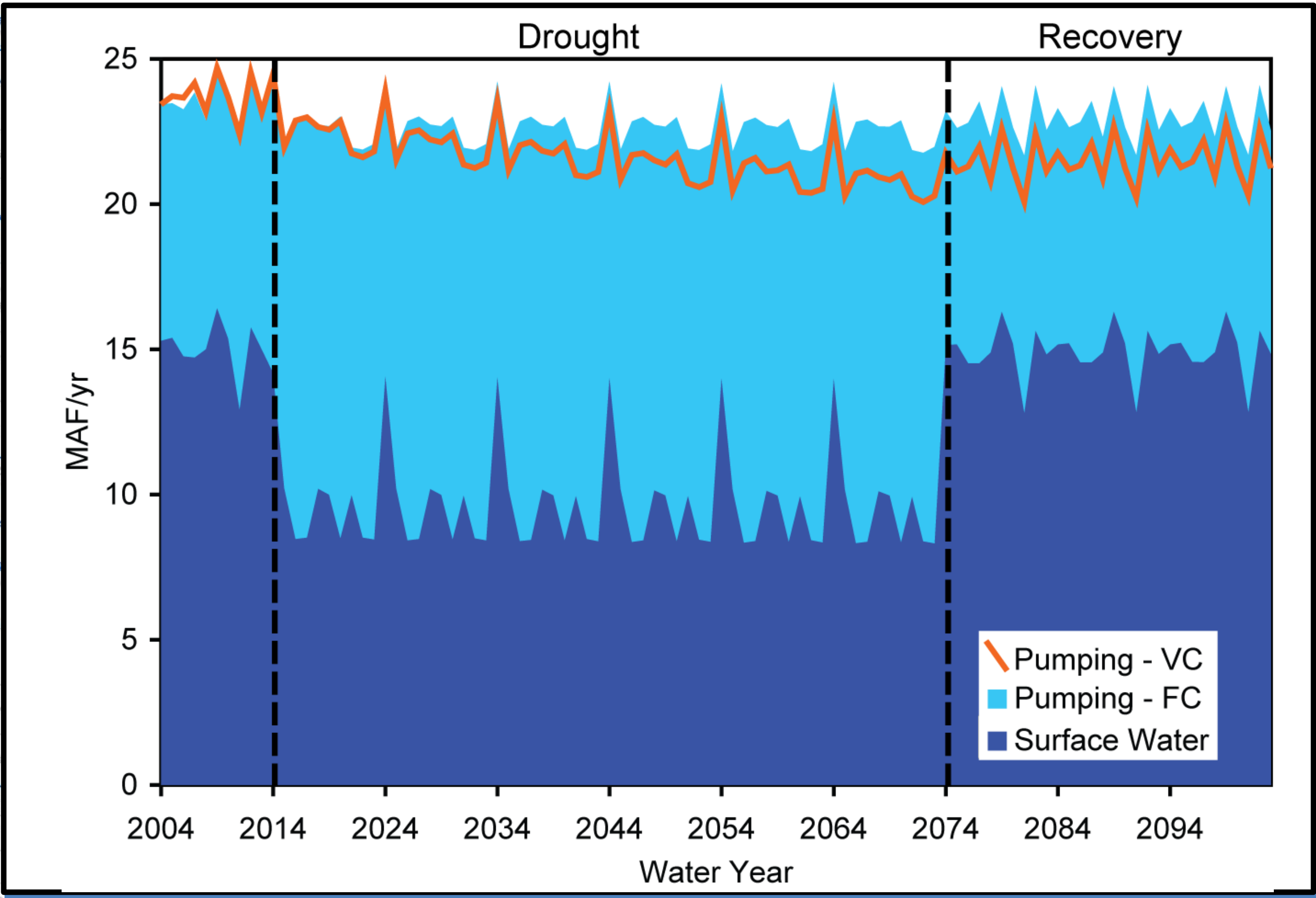
- Crop mix is a function of water cost
  - Surface water availability
  - Depth to groundwater
  - Crop water demand
  - Crop production costs and returns
- Incorporate Logit equation in IWFM application

$$\alpha_{ir} = \frac{e^{x_r \beta_{ir}}}{1 + \sum_j e^{x_r \beta_{jr}}}$$

- Determine Logit equation parameters from a series of simulations conducted with the Central Valley Production Model

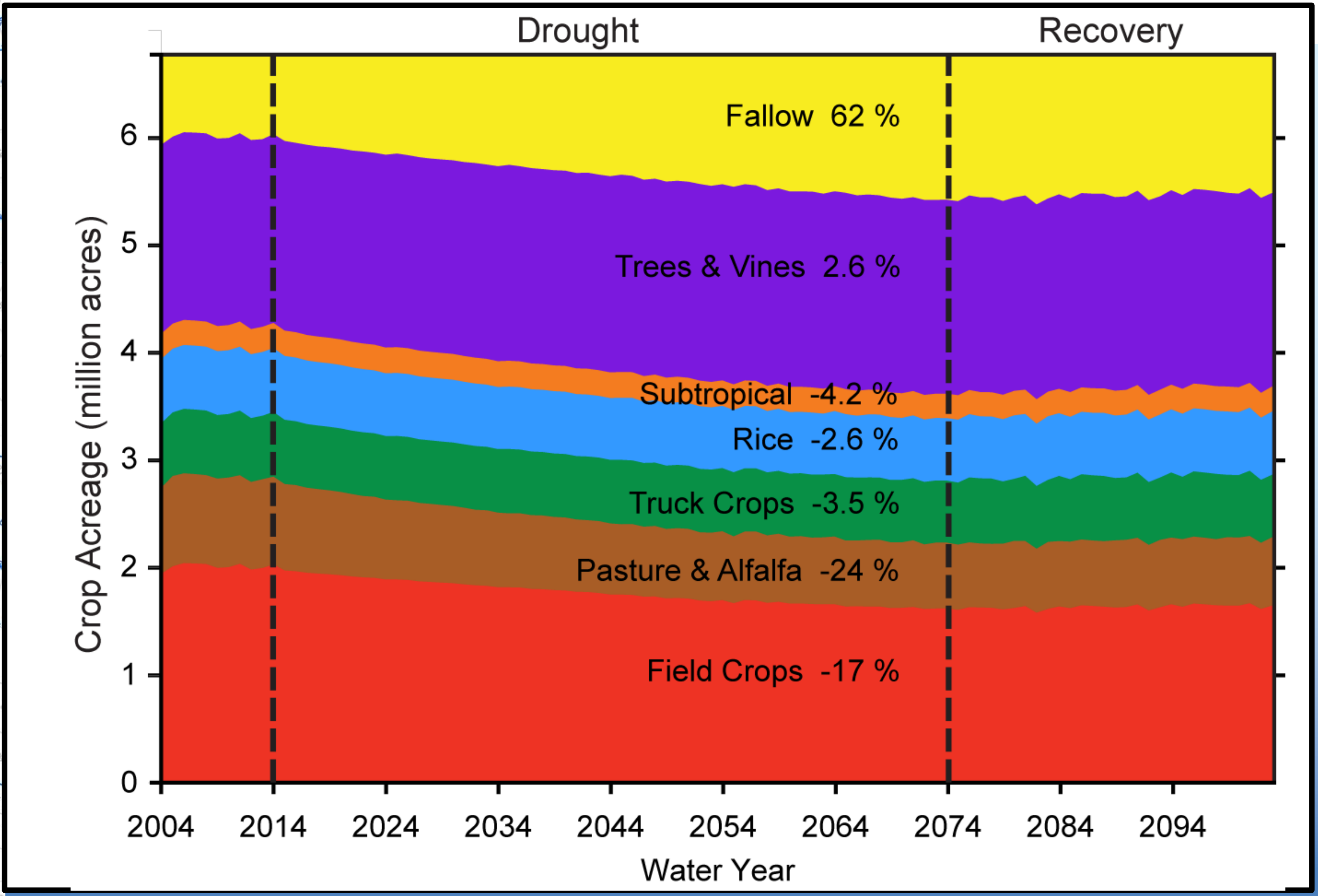
Water Use

Severe drought for 60 years



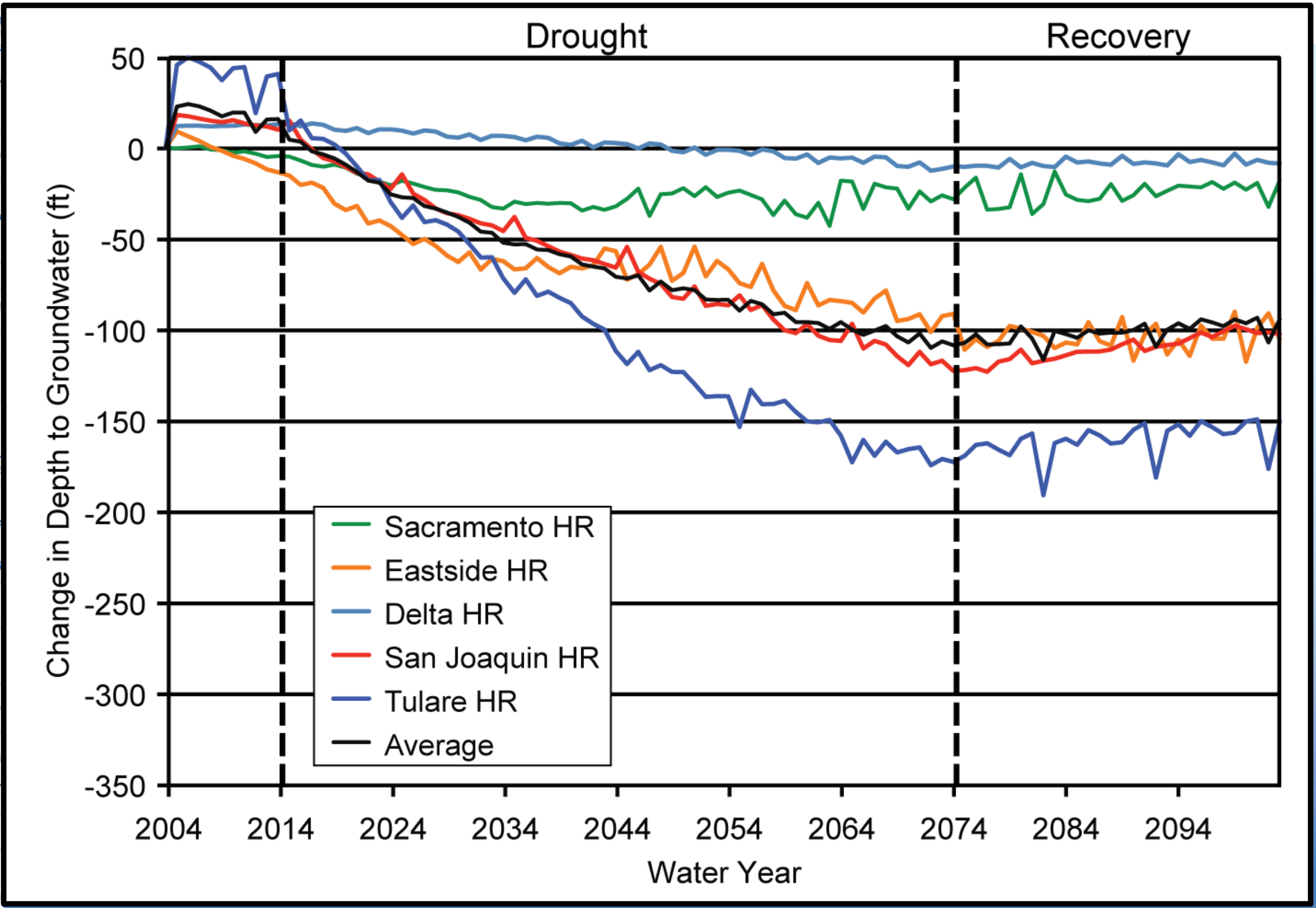
Crop Changes

Severe drought for 60 years

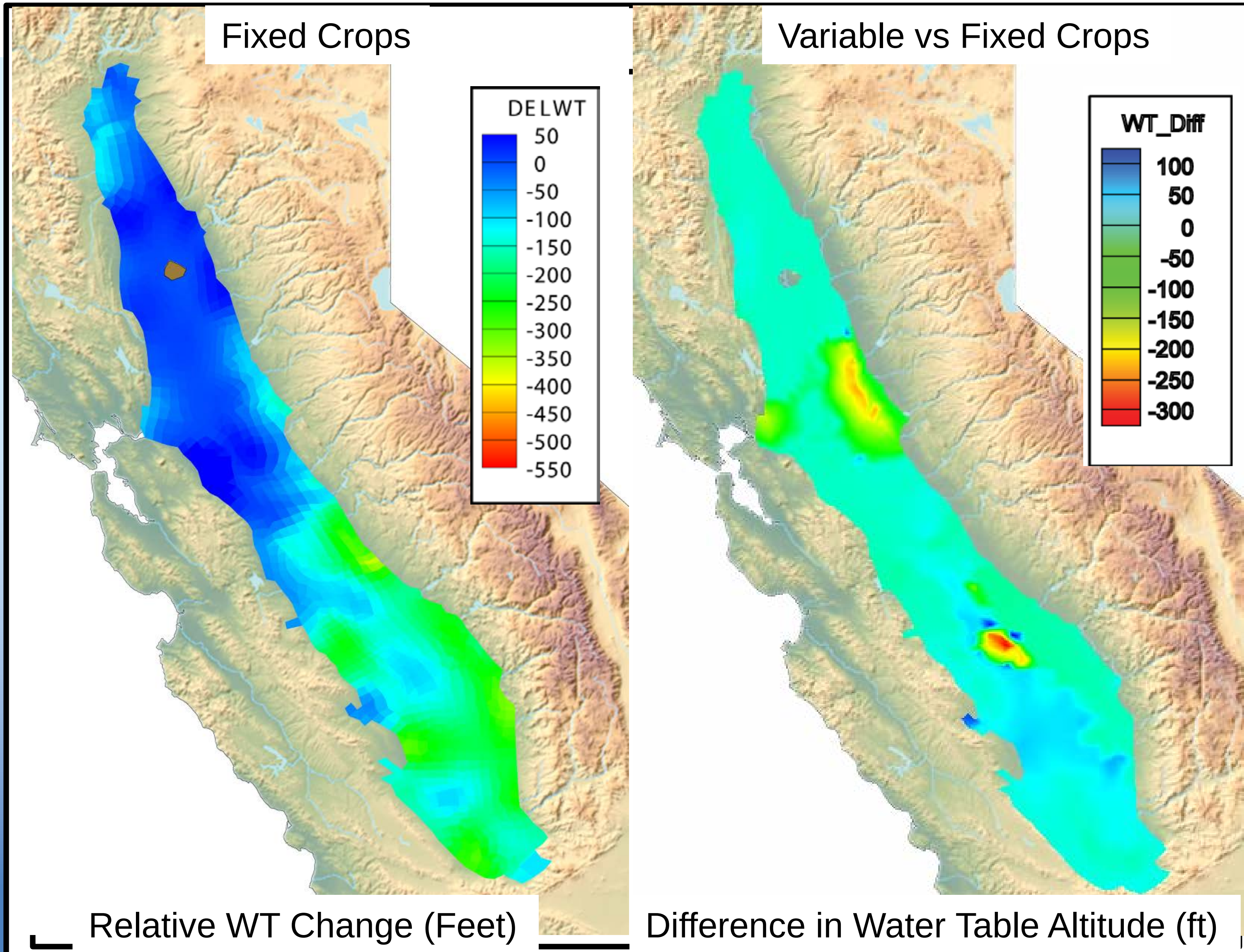


Depth to Groundwater

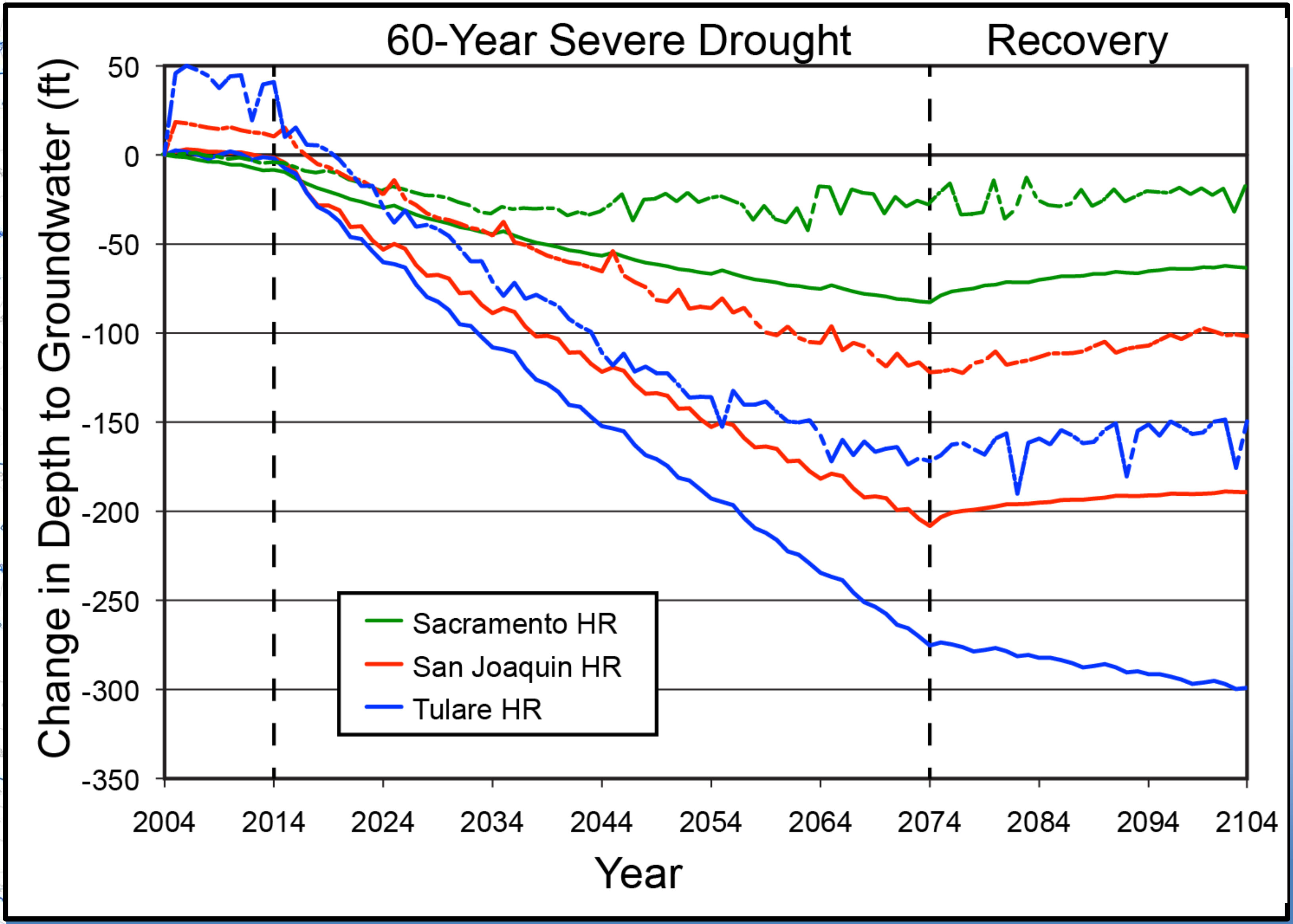
Severe drought for 60 years



Water Table at End of Drought



Depth to Groundwater – Compare



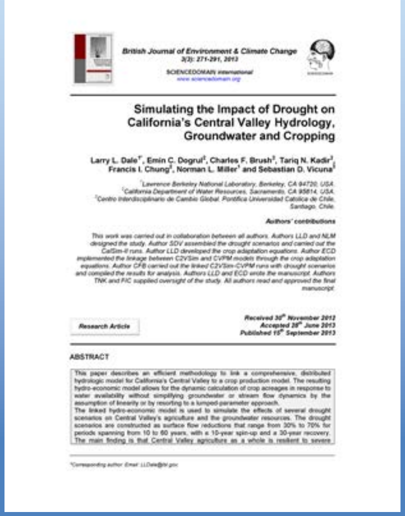
Findings

- Regional impacts of extreme drought
  - Moderate in north (Sacramento River Basin)
  - Locally severe in middle (San Joaquin River Basin)
  - Severe in south (Tulare Basin)
- Economic behavior may significantly reduce drought impacts below levels projected using a fixed level of future development
- The C2VSIM integrated model with CVPM emulation
  - performs as expected
  - can provide valuable insights into the impacts of climate change on Central Valley aquifers and on Central Valley agriculture

Publications

Miller, Dale, Brush, Vicuna, Kadir, Dogrul and Chung. 2009. Drought resilience of the California Central Valley surface-groundwater-conveyance system. JAWRA 45:857-866.

Dale, Dogrul, Brush, Kadir, Chung, Miller, and Vicuna. 2013. Simulating the Impact of Drought on Central Valley Hydrology, Groundwater, and Cropping. British Journal of Environment and Climate Change 3:271-291.



Future Work

- Develop more realistic drought scenarios
  - Downscale GCM precipitation and use VIC to simulate rim inflows
  - Monte Carlo simulations
  - Changes in amount and timing of crop water demands
  - Changes in amount and timing of reservoir releases
  - More elaborate economic model

- More complex variable-crop drought simulations
  - Economic parameters from SWAP
  - More detailed model subregions

Downscaling GRACE Satellite Data for Small-scale Groundwater Storage Estimates in California's Central Valley

NASA DEVELOP Team:

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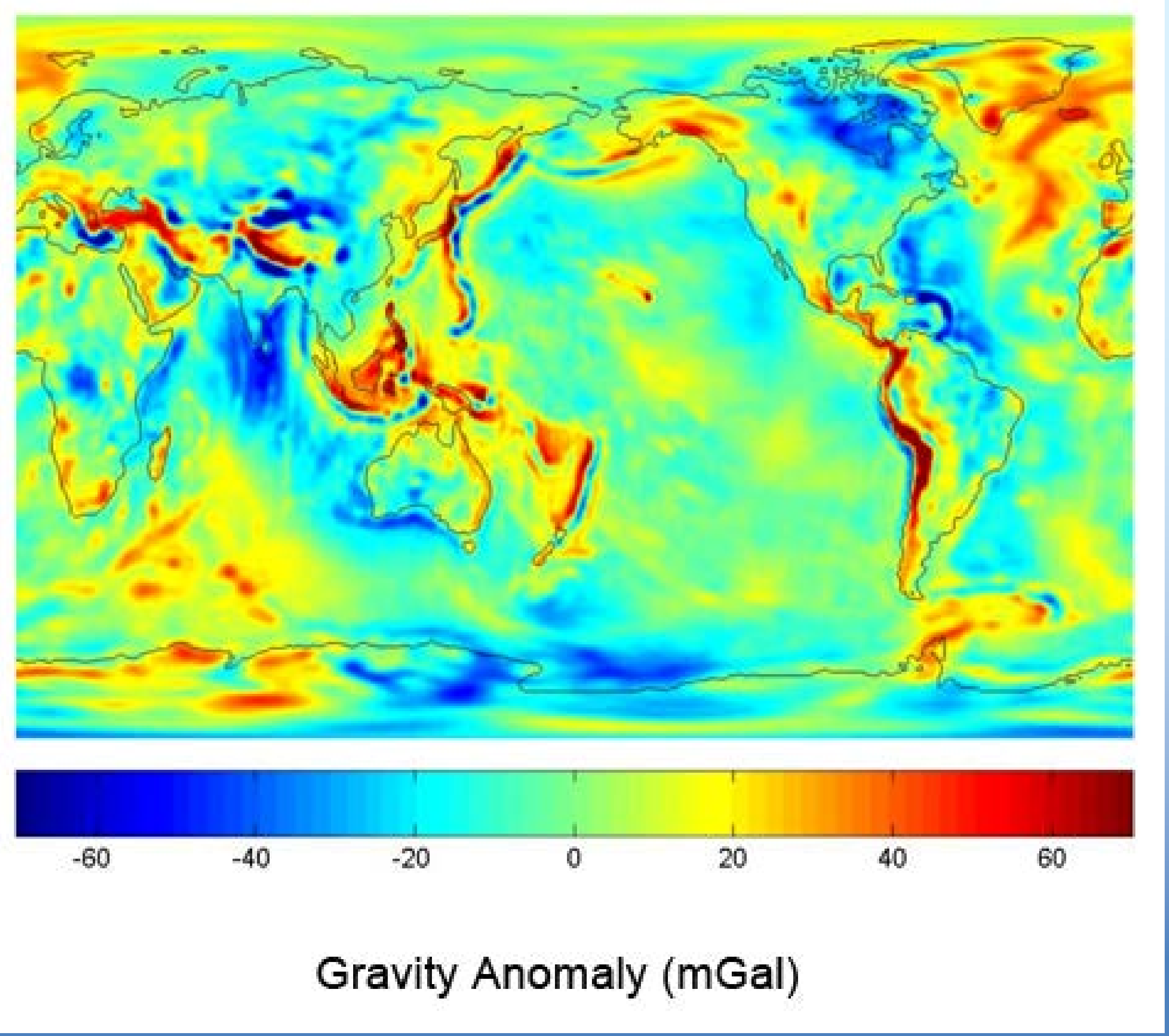
Cindy Schmidt[1, 7]

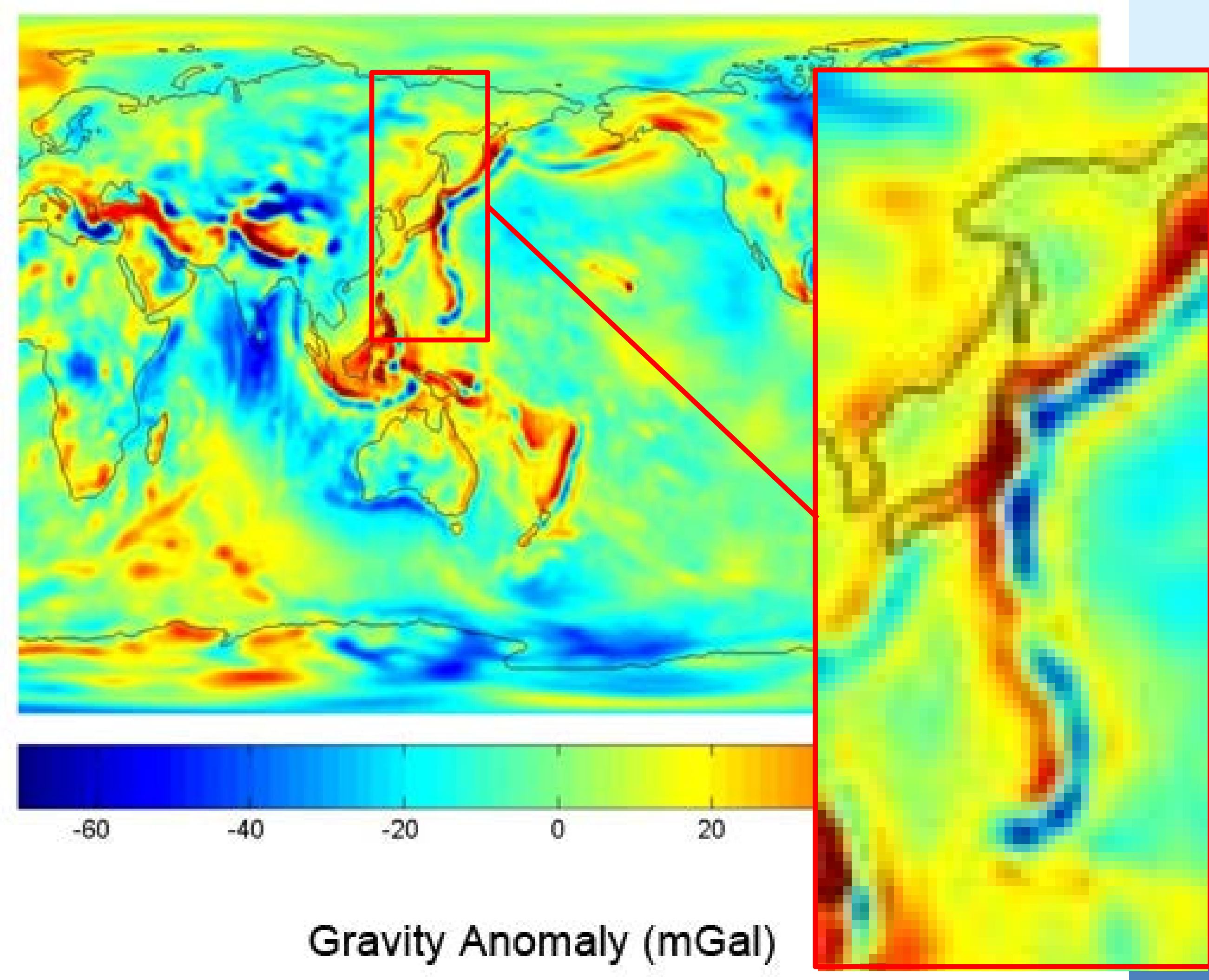
[1]NASA Ames DEVELOP, [2]University of California, Santa Cruz, [3]University of California, Berkeley, [4]Carnegie Mellon University, [5]Saint Francis High School, [6]NASA Jet Propulsion Laboratory, [7]Bay Area Environmental Research Institute

GRACE Satellites

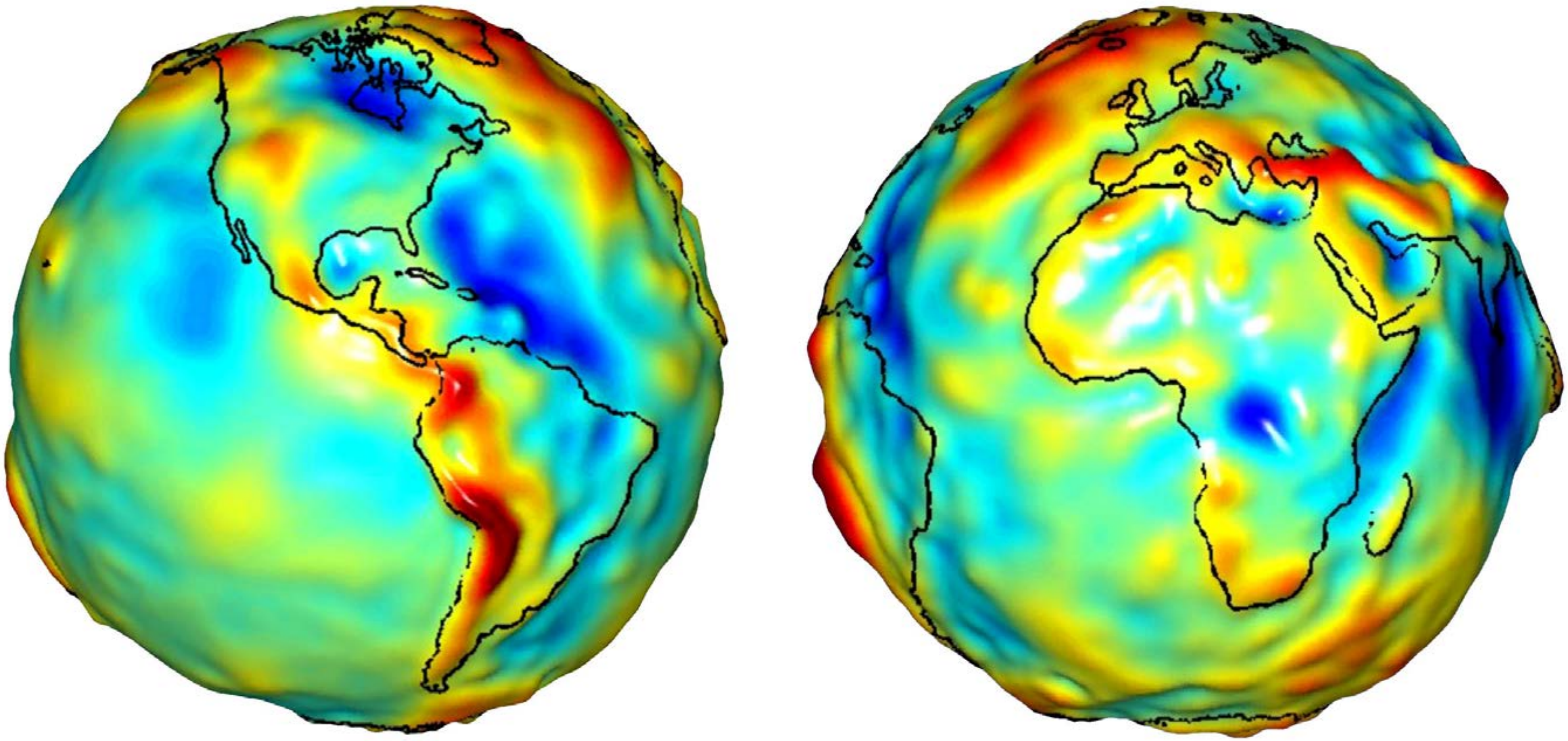
GRACE Earth Gravity Anomaly



GRACE Earth Gravity Anomaly



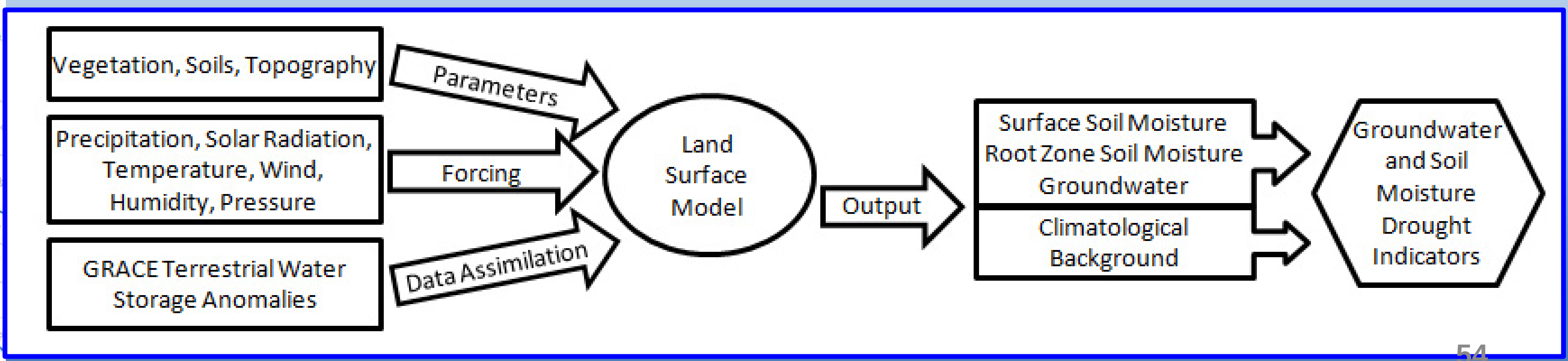
GRACE Gravity Model



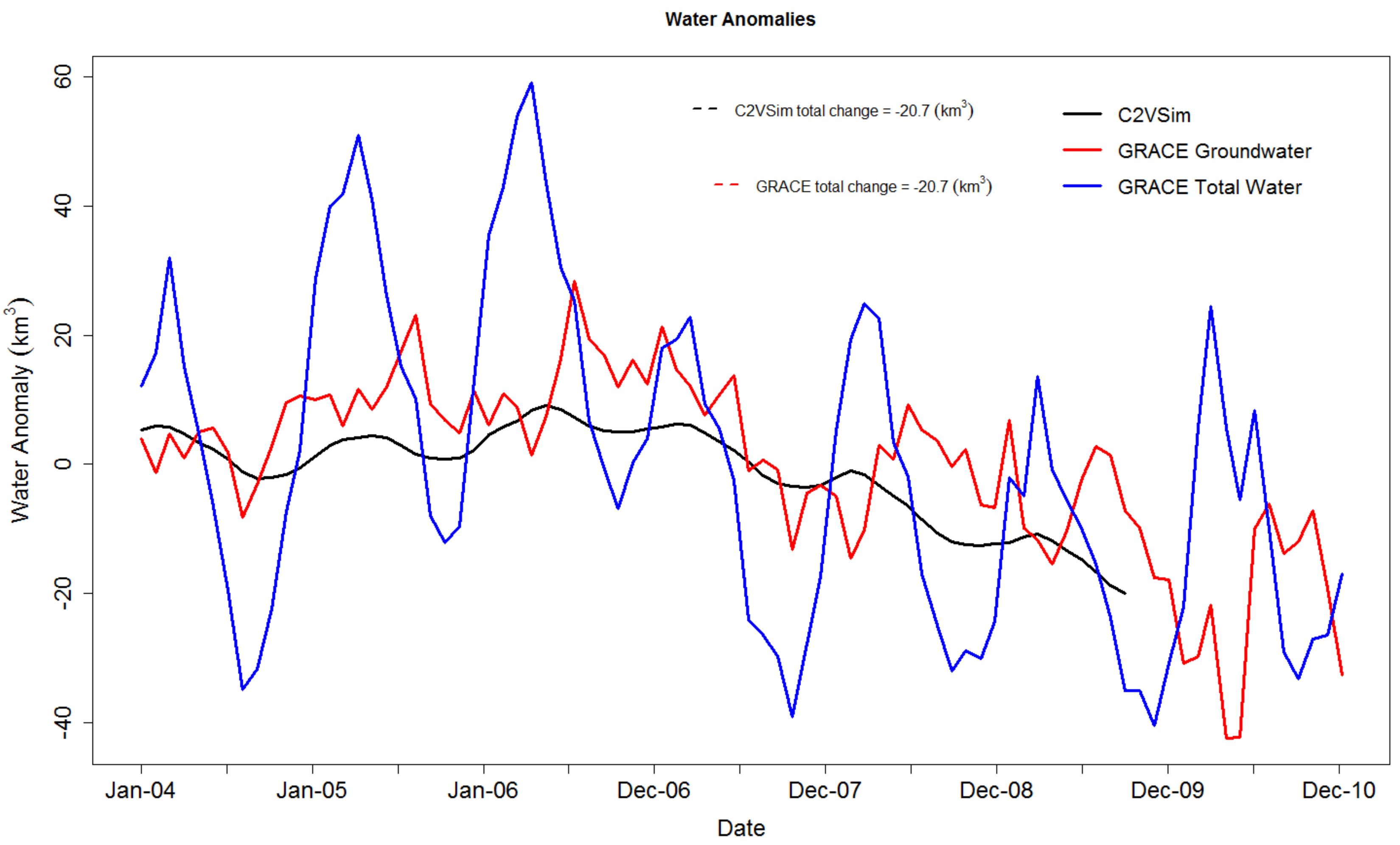
GRACE to Groundwater Storage

Change in Groundwater =

Total Change in Gravity
- Change in atmospheric moisture
- Change in snowpack
- Change in reservoir storage
- Change in soil moisture
- Change in petroleum reserves
- Change in tidal water

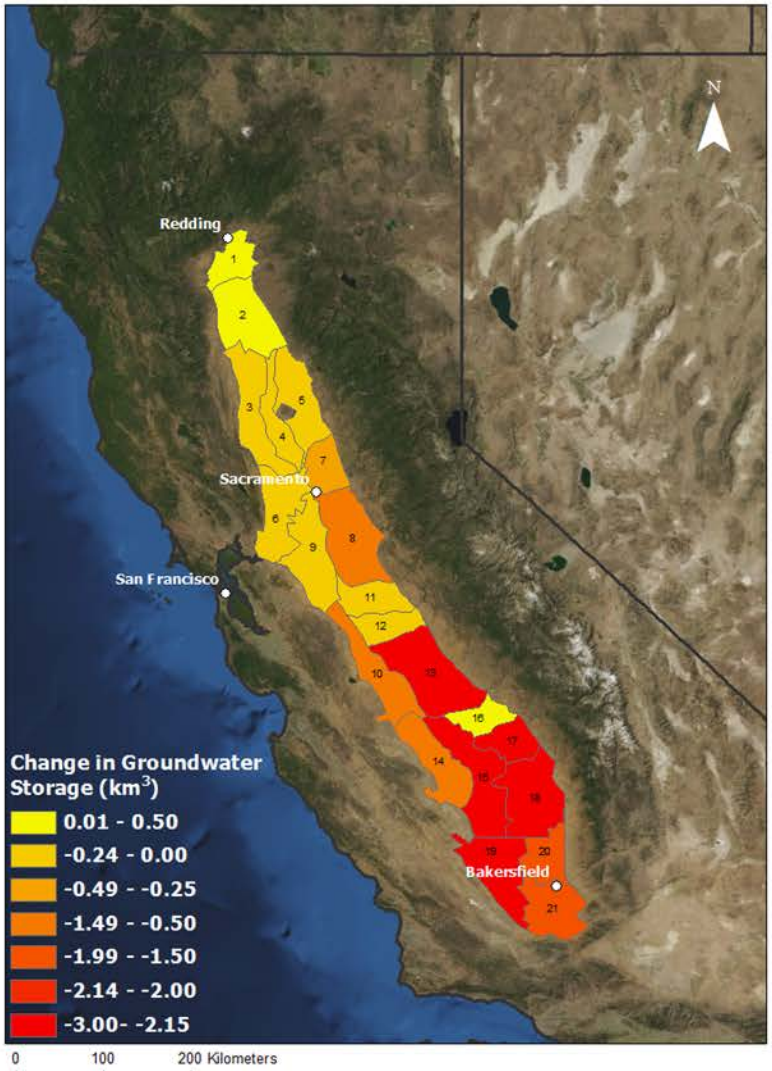


Compare GRACE and C2VSim

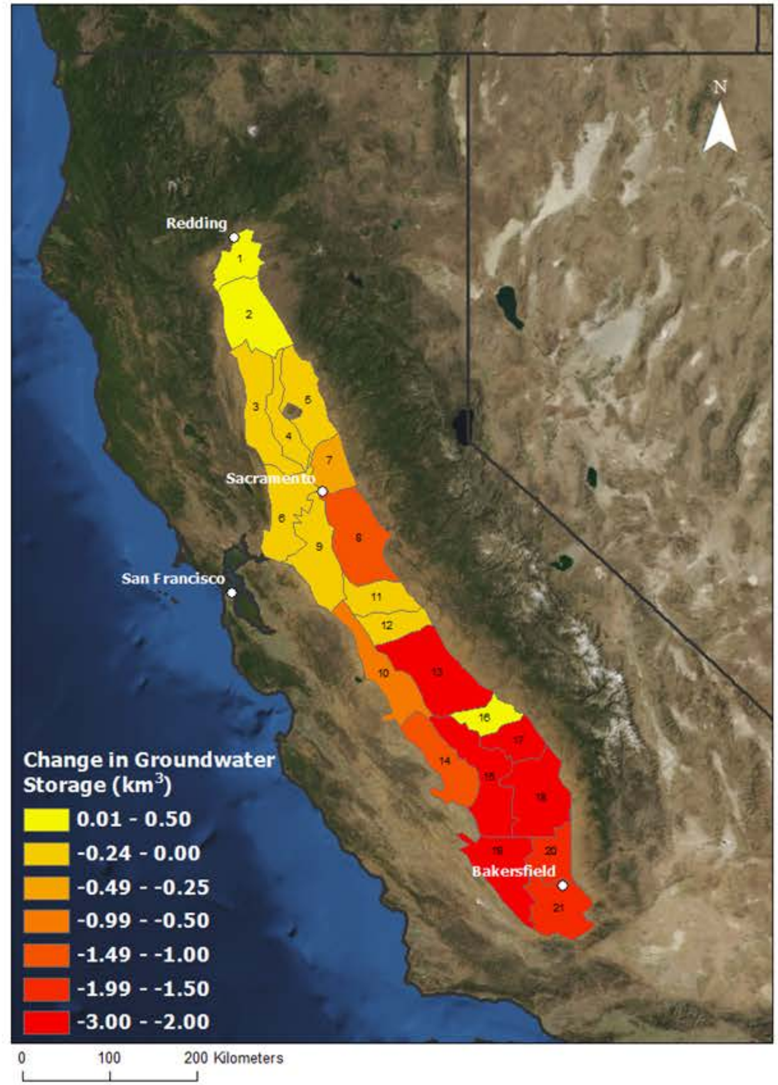


Groundwater Storage Estimates

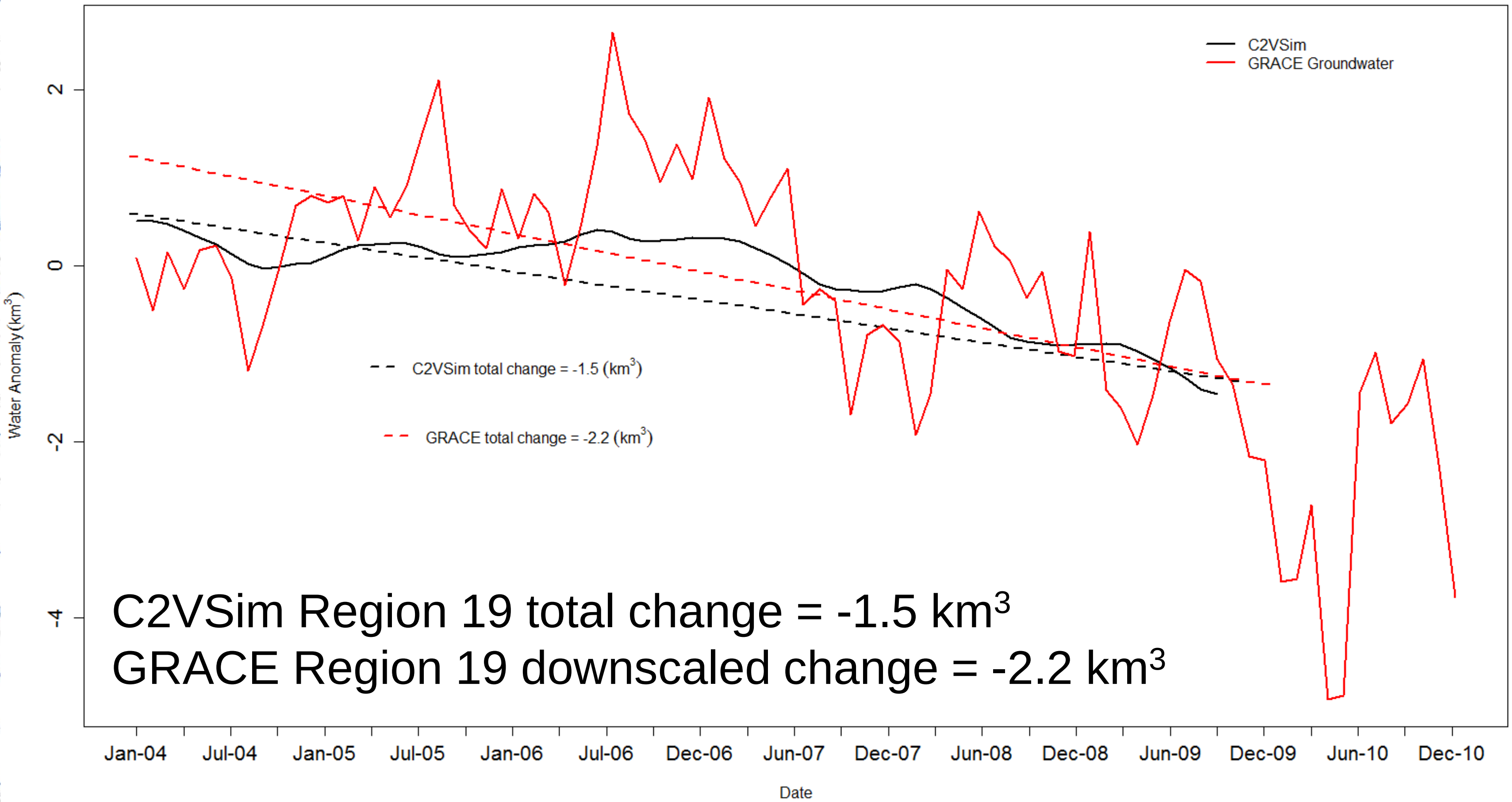
C2VSim Change in Groundwater Storage
October 2004 - September 2009



Downscaled GRACE Change in Groundwater Storage
October 2004 - September 2009

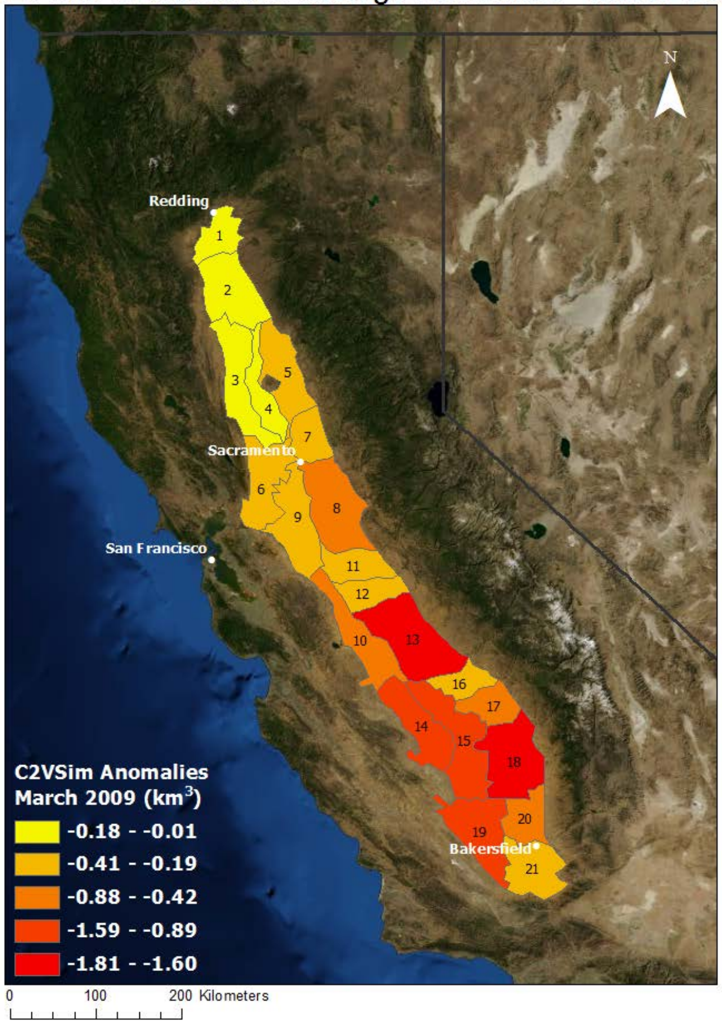


Downscale to Subregion 19

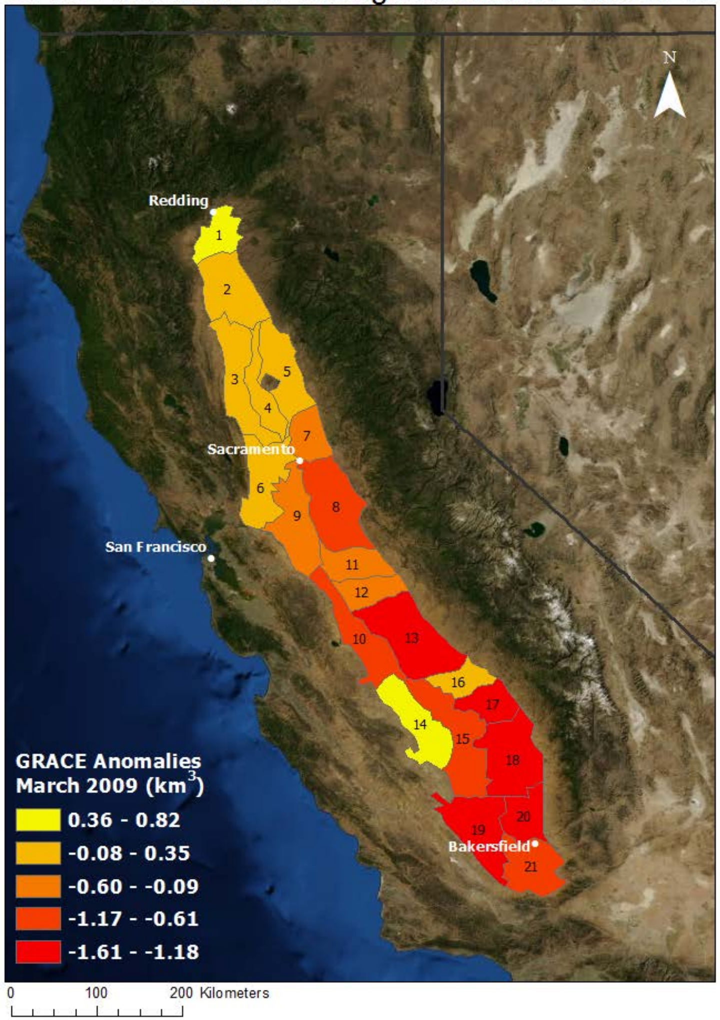


Downscaled Estimates

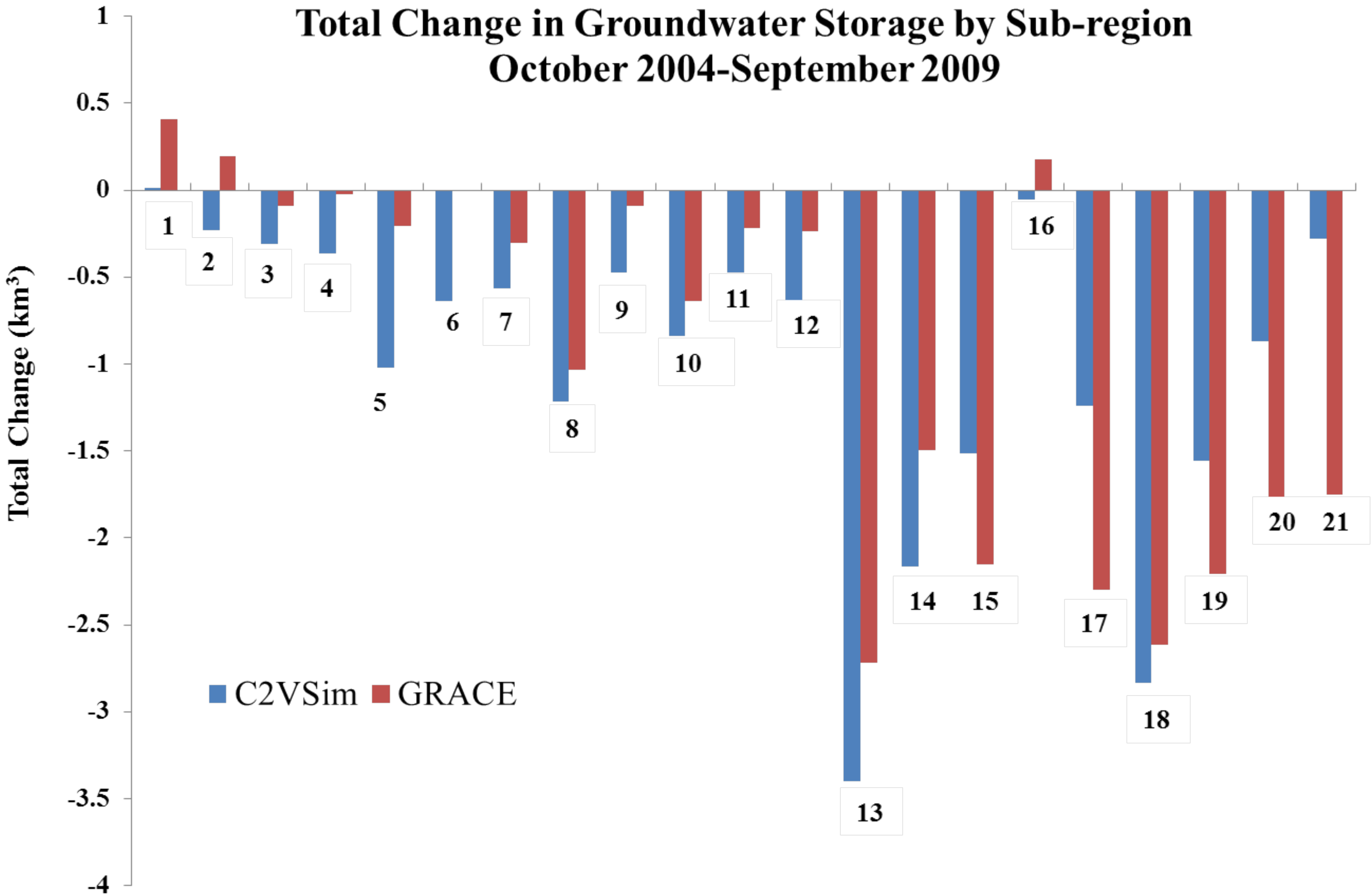
C2VSim Groundwater Storage Anomalies - March 2009



GRACE Groundwater Storage Anomalies - March 2009



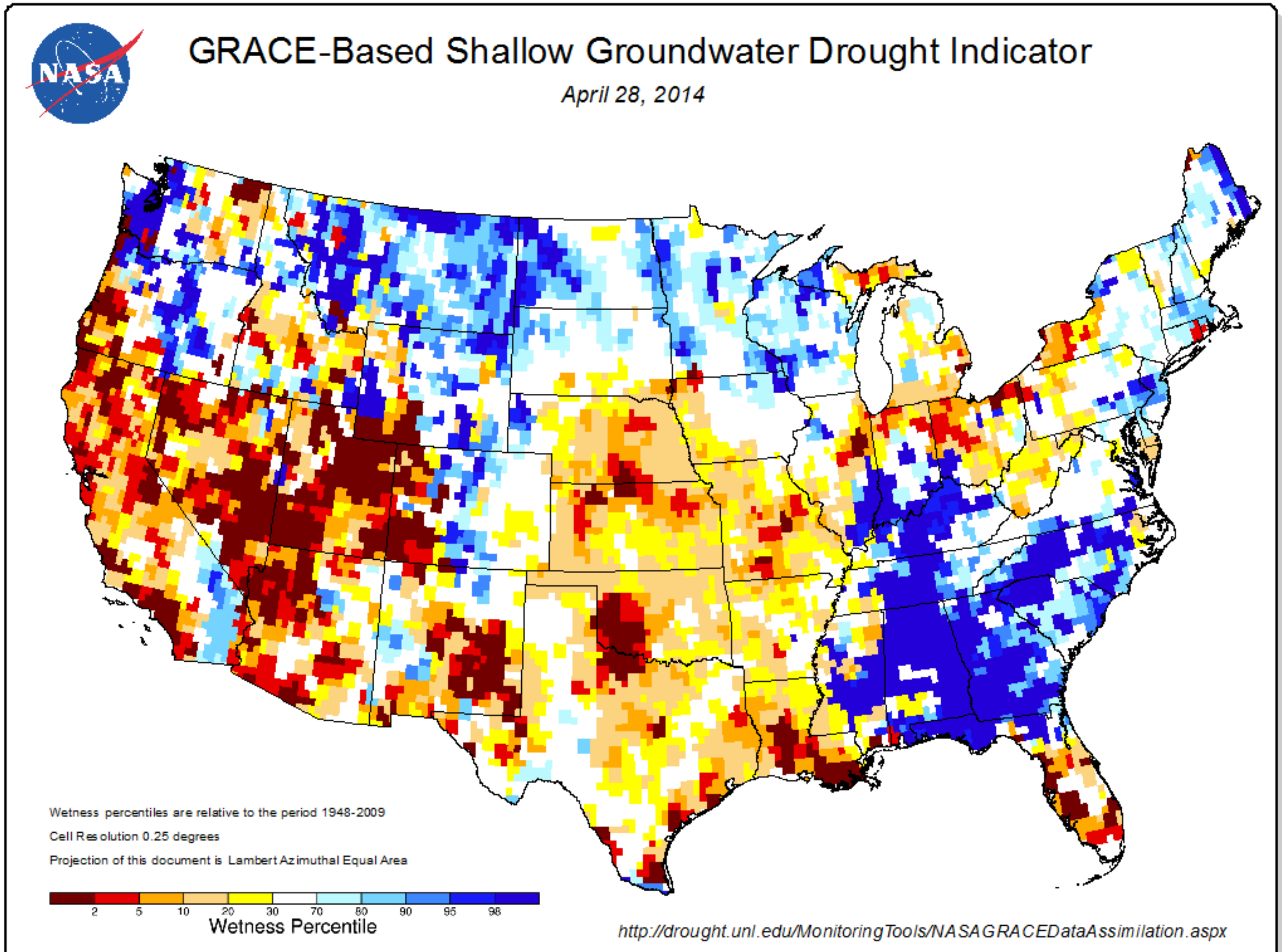
Subregional Change in Storage



Preliminary Findings

- GRACE provides reasonably accurate estimates of the change in groundwater storage in near-real time for large areas (Central Valley) and long time frames (1 year)
- GRACE loses accuracy as the time and/or area are reduced
- GRACE results can be downscaled using C2VSim

Change in Groundwater Storage



National Drought Mitigation Center.
http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx

Tomorrow

- Running C2VSim
- Using the C2VSim ArcGIS GUI
- Groundwater Pumping Case Study
  - Add some pumps to the model
  - See the changes in heads and river flows
- Aquifer Storage and Recovery Case Study
  - Modify a diversion and add a pump
  - See the changes in heads and river flows

END