HydroEconomic Modeling of Groundwater Sustainability, A Pilot Study

California Water and Environmental Modeling Forum

2016 Annual Meeting
April 11-13, 2016

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Acknowledgments

- **California Water Foundation**
- **Project Team:**
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  - Ali Taghavi (RMC)
  - David Mitchell (M.Cubed)
  - Steve Hatchett (CH2MHill)

Project Overview

Goal:

Evaluate hydrologic and economic implications of attaining a sustainable groundwater condition in a pilot study area in Central Valley.

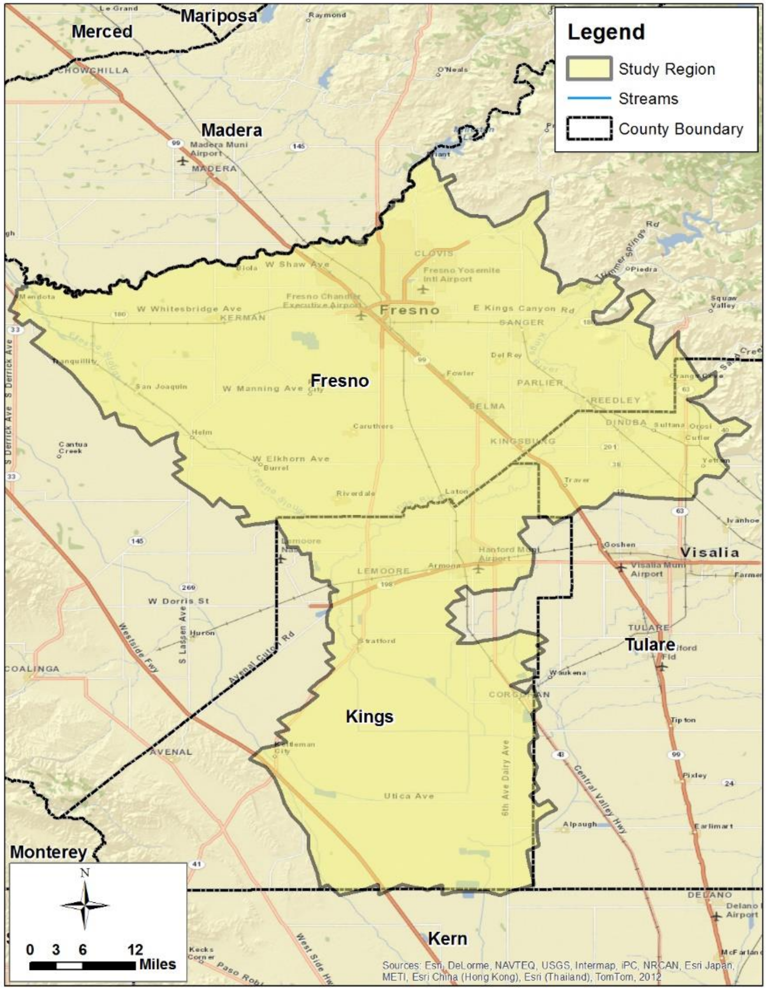
Objectives:

Integrate C2VSim and SWAP models and use the integrated model to define and evaluate sustainable groundwater management in the project area

Sustainable GW Management

- Stable groundwater levels and storage over a 20-year planning horizon
- Other undesirable effects such as GW quality and land subsidence are considered as an indirect benefit of stable GW levels
- This study only considers demand side measures to achieve sustainable conditions. Supply side measures, such as conjunctive use, direct or indirect recharge, or other measures will need to be considered as well.

Pilot Study Region



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Models

- **C2VSIM**

  An integrated numerical model that simulates water movement through the linked land surface, groundwater and surface water flow systems in California's Central Valley

- **SWAP**

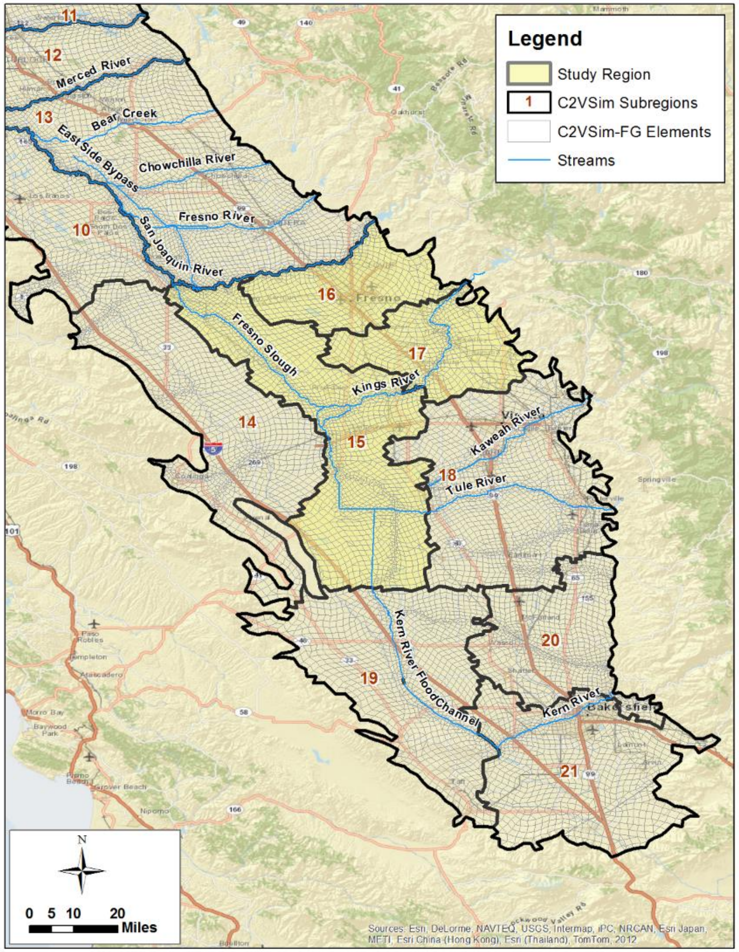
  Statewide Agricultural Production (SWAP) model is a multi-region, multi-input and output economic optimization model of the agricultural economy in California

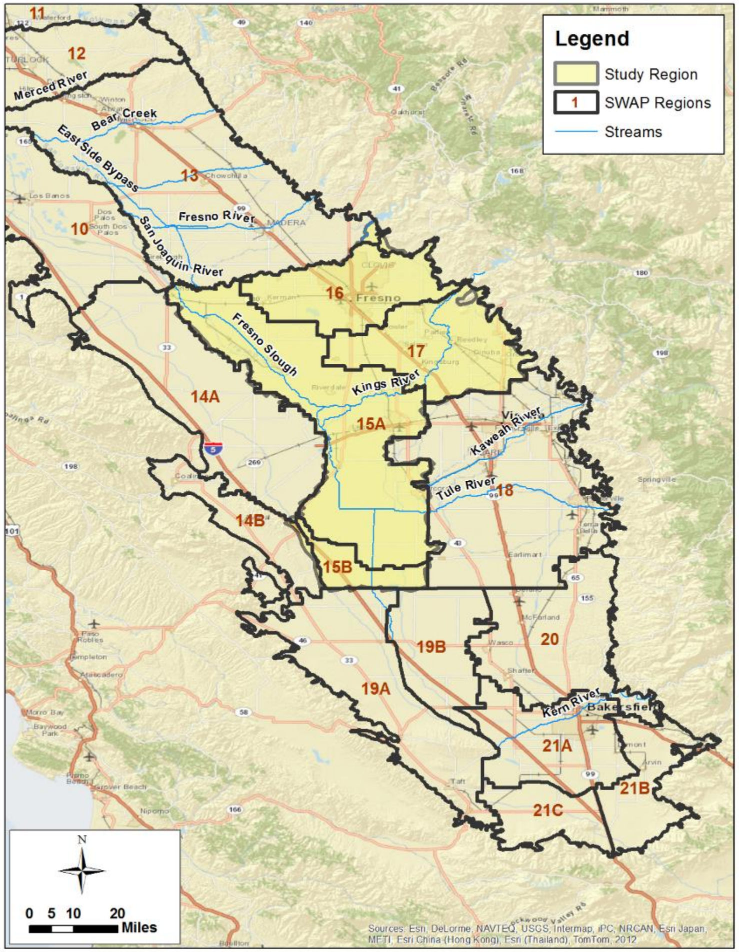
- **IMPLAN**

  A regionalized input-output model widely used to assess regional economic impacts stemming from changes in one or more industries in a region

San Joaquin River & Tulare Basins

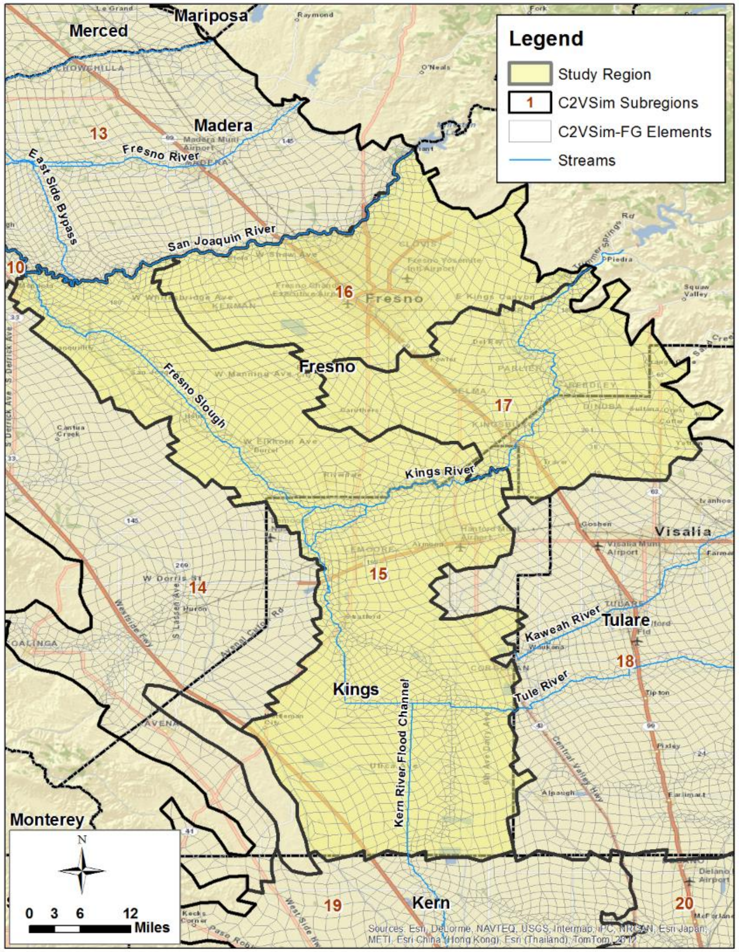
C2VSim & SWAP Subregions

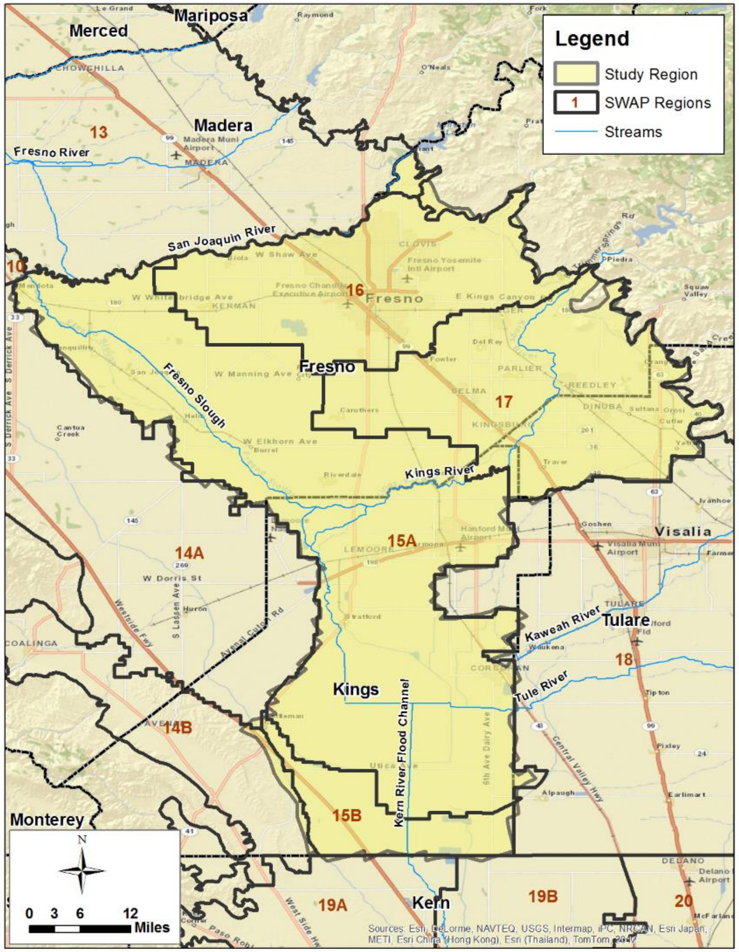




Pilot Study Region

C2VSim & SWAP Subregions





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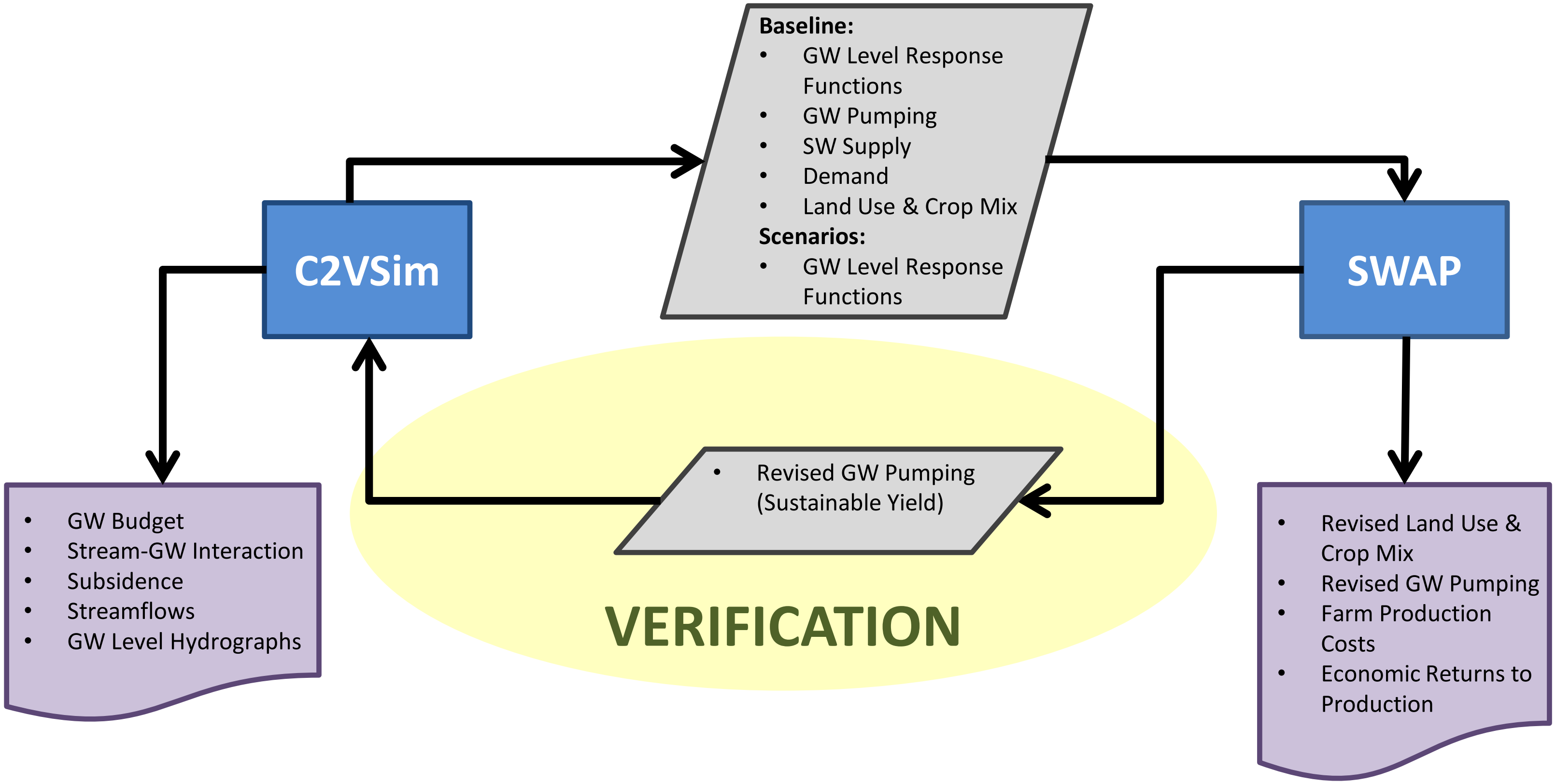
C2VSim – SWAP Integration



C2VSim – SWAP Integration

Step 1: Develop Future Condition Baseline & Data Benchmarking

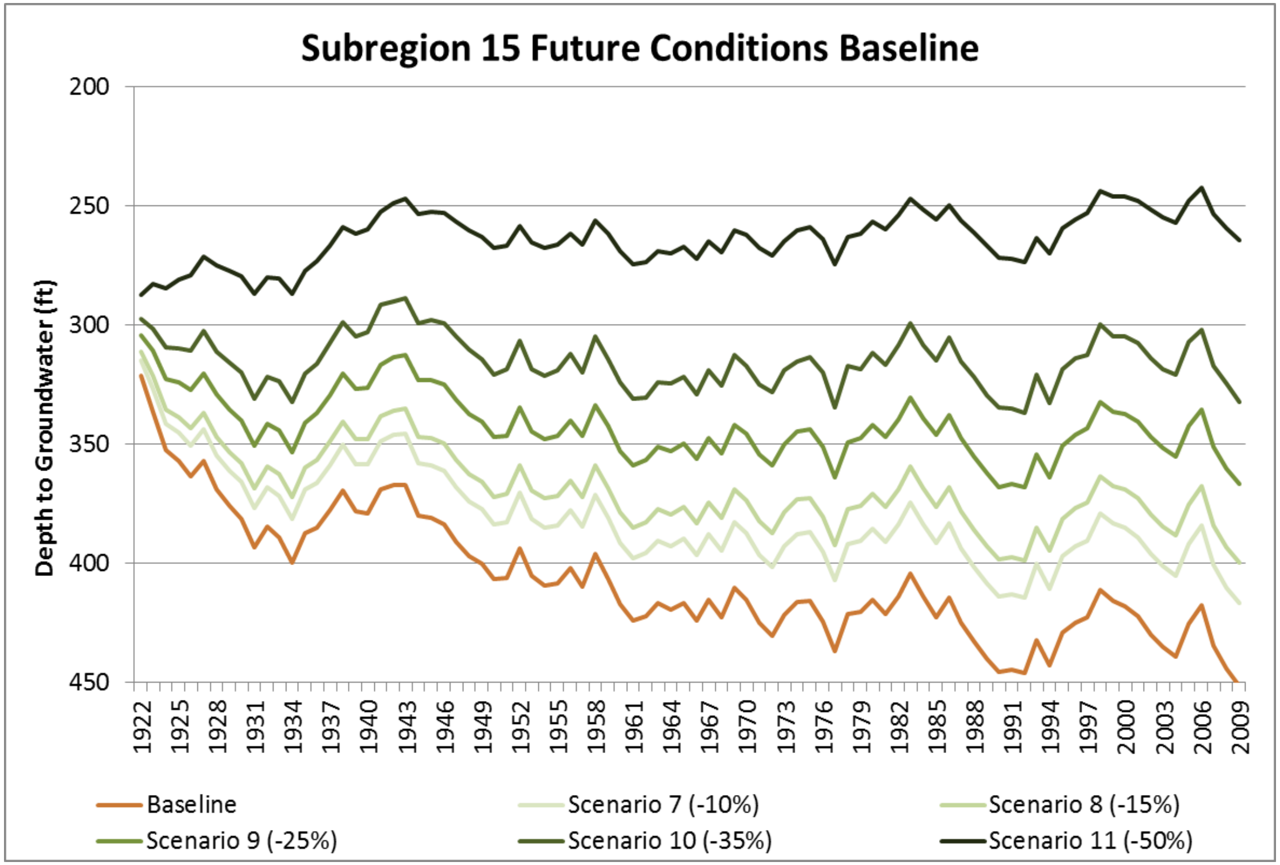
Agricultural water use and applied water rates are slightly different between the two models. In order to align the SWAP and C2VSim models the following steps were taken:

1. Calculate the groundwater applied to crops in the C2VSim model, averaged over 1922-2009 hydrology.
2. Proportionally adjust SWAP surface water supplies such that the baseline level of groundwater pumping in the SWAP model approximates the C2VSim average calculated in step 1.
3. Recalibrate the SWAP model to the surface water and groundwater quantities calculated in step 2 and verify that the models now report the same average baseline groundwater use

C2VSim – SWAP Integration

Step 2: Parametrize C2VSim

- Parameterize C2VSim over a range of groundwater pumping levels
  - 1922 – 2009, future conditions



- depth to groundwater, averaged over nodes within each region

C2VSim – SWAP Integration

Step 3: Develop and Evaluate Groundwater Response Functions

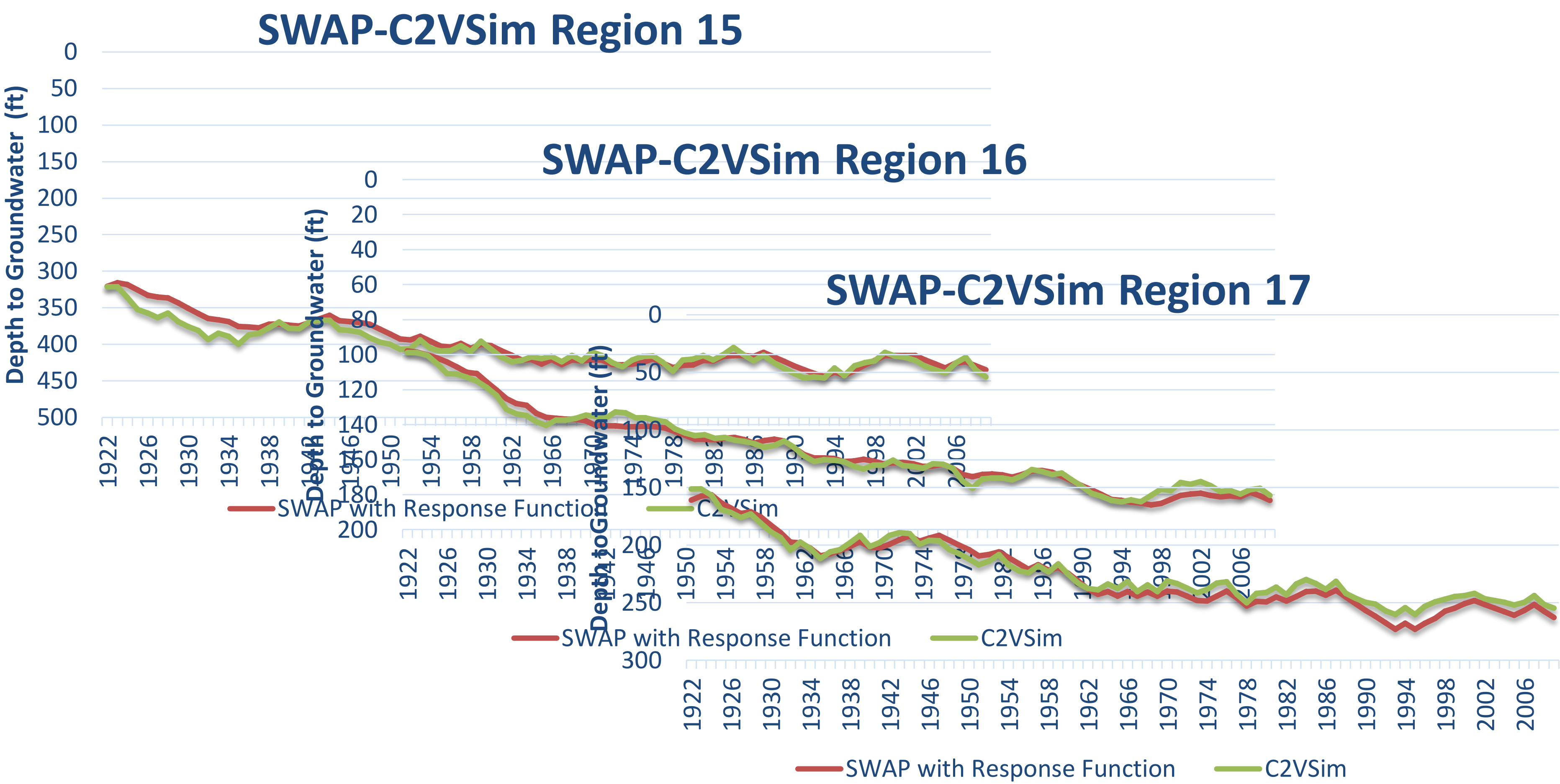
Multivariate regression analysis was used to fit groundwater response functions for each subregion.

The response function describes the change in groundwater elevation as a function of:

1. agricultural groundwater pumping (current and lagged)
2. water year type (current and lagged)
3. time trend
4. region and cross-region fixed effects to control for region-specific factors
5. interactions between these factors (current and lagged)
   - for example, we expect groundwater pumping to increase and recharge to be reduced in dry years, thus these terms are interacted in the econometric model.

C2VSim – SWAP Integration

Step 3: Develop and Evaluate Groundwater Response Functions



C2VSim – SWAP Integration

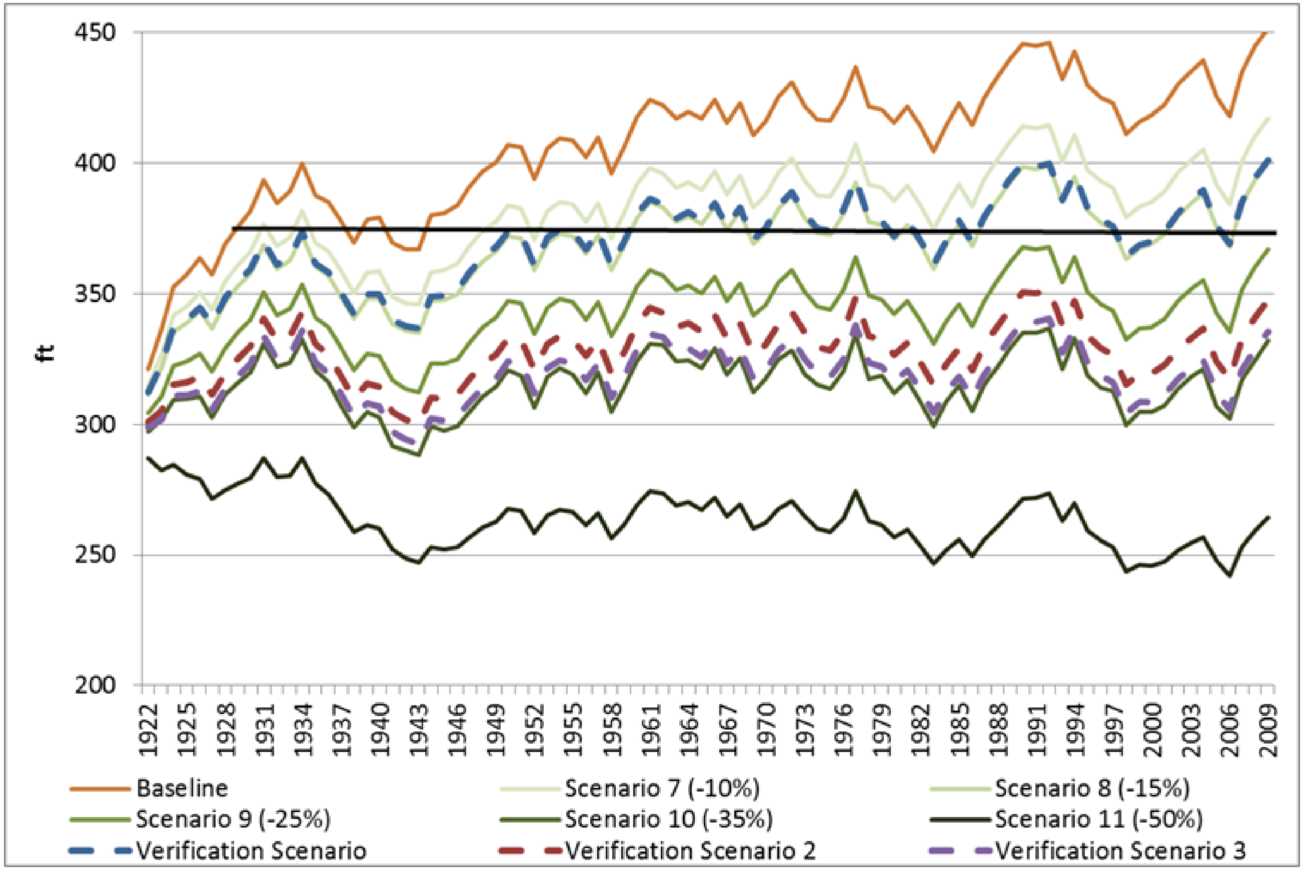
Step 4: Estimate Sustainable Yield

Definition Used for Sustainability for Modeling Purposes:

- Sustainable conditions are arrived when long-term change in depth to groundwater is near zero
- Sustainable yield for each region is the average pumping where change in depth to groundwater is 0 over simulation period after the first 20-25 years of planning horizon.
- Pumping allowed to vary year-to-year, e.g., more in dry years, less in wet years
- Calculated using the econometric response functions

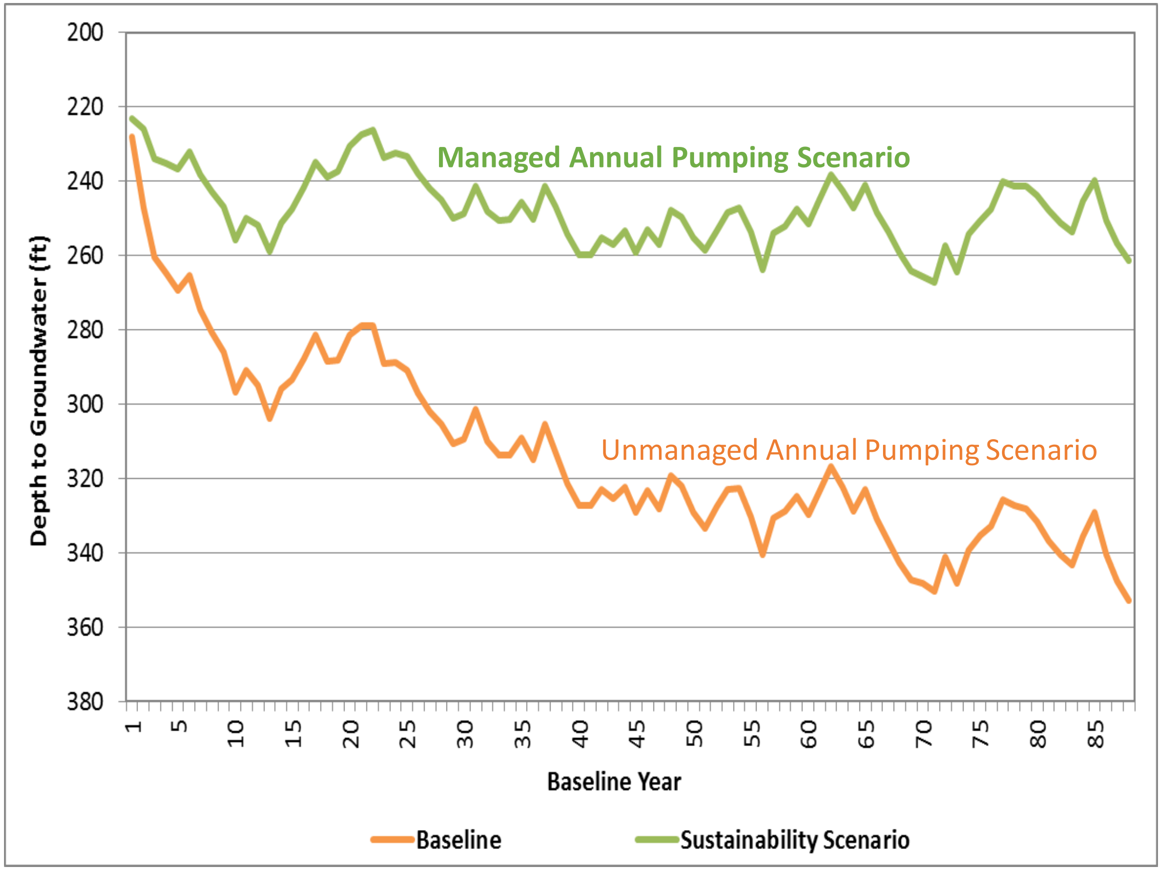
C2VSim – SWAP Integration

Step 5: Verify Sustainable Yield in C2VSim



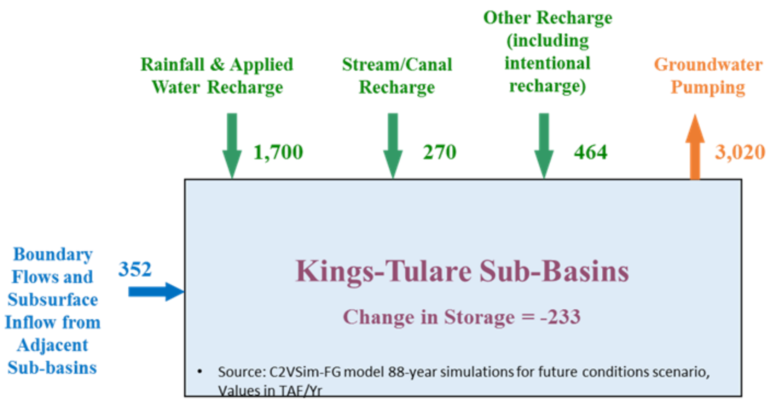
Modeling Results

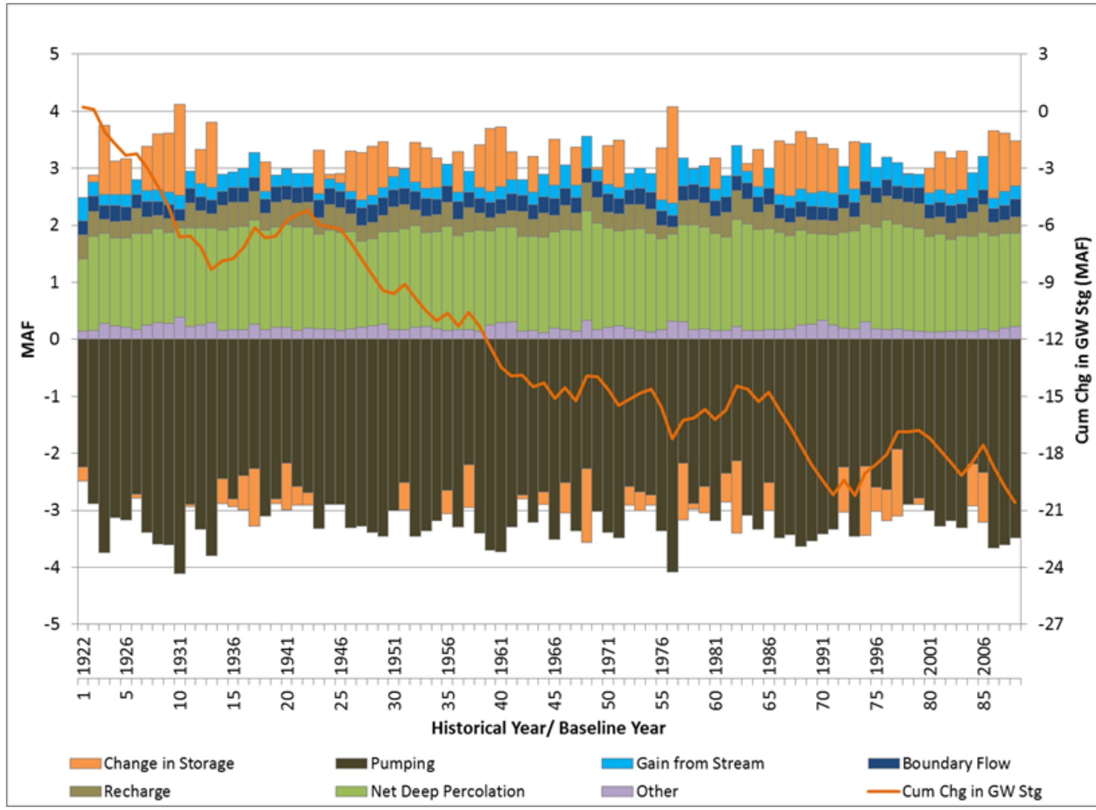
Average Depth to Groundwater in Pilot Study Region



Modeling Results

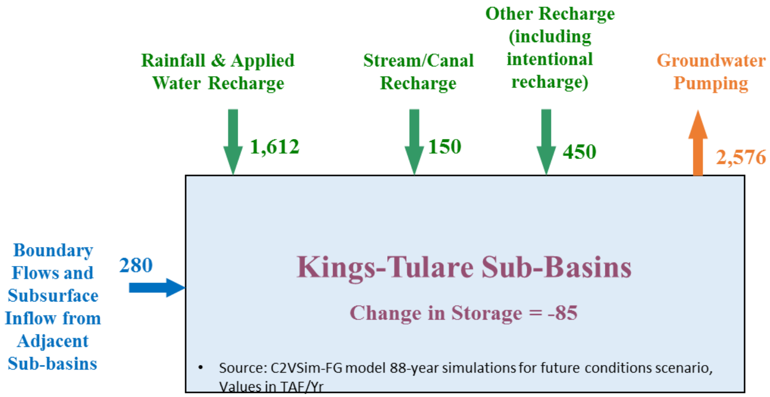
Groundwater Budget – Unmanaged Annual Pumping Scenario

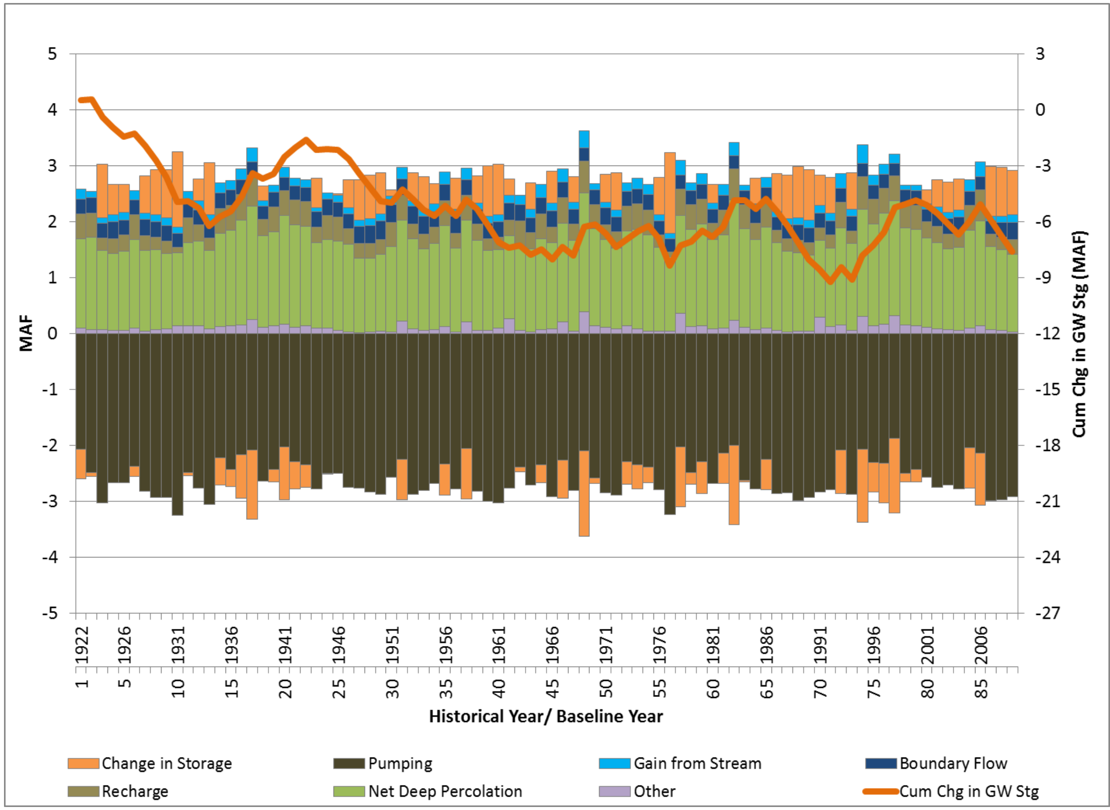




Modeling Results

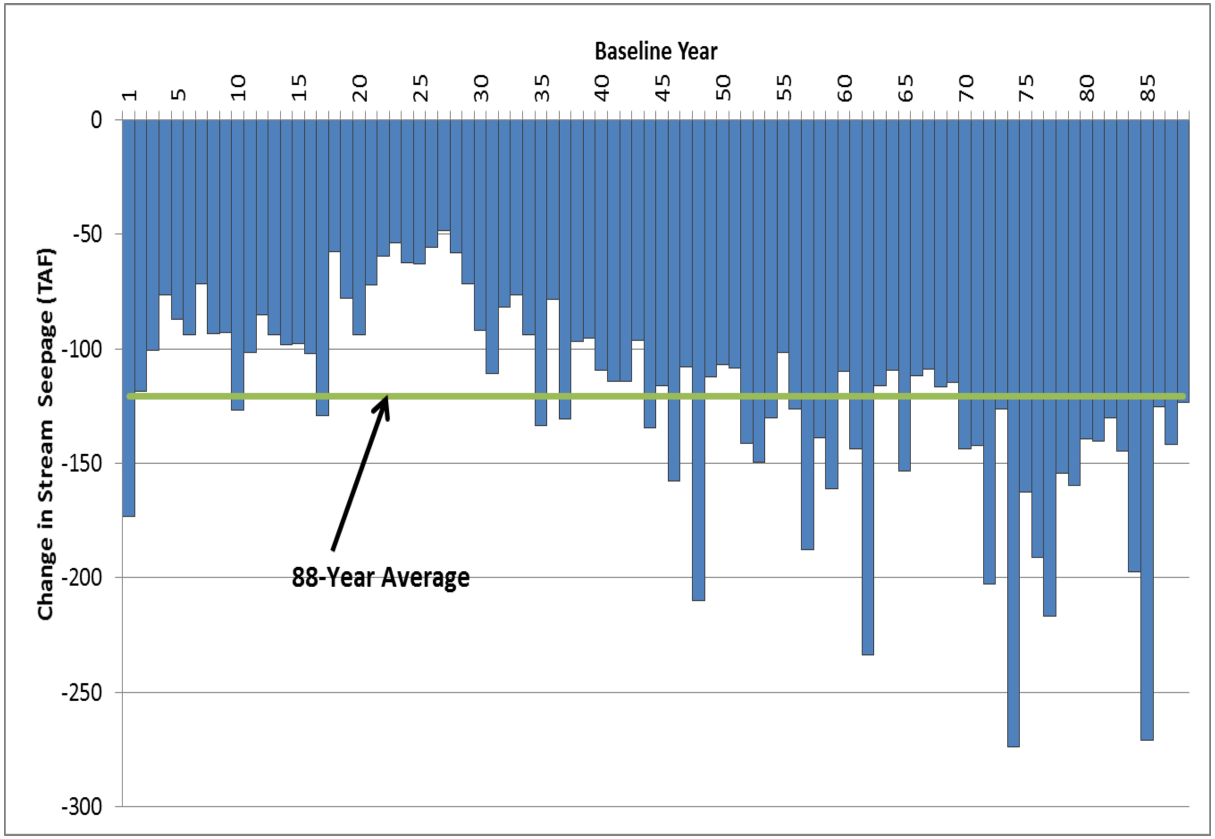
Groundwater Budget – Managed Annual Pumping Scenario





Modeling Results

Change in Regional Stream Seepage Losses for Managed Annual Pumping Scenario Relative to Unmanaged Annual Pumping Scenario



Summary of C2VSim Modeling Results

Qualitative Analysis

Change from UNMAP Scenario	Quantified Impact	Qualitative Impact
Groundwater Quality	Not quantified	(+) expected improvement in groundwater quality over time
Land Subsidence	Not quantified	(+) expected reduction in future subsidence risk

Modeling Results

Average Crop Mix over 88 Year Simulation Period (acres)

Scenario	Forage	Orchard and Vineyards	Other Field and Cotton	Grain	Vegetables	Total
UNMAP	102,460	452,820	309,680	135,390	63,530	1,063,880
MAP	63,440	449,890	294,730	100,260	62,780	971,100
Difference	-39,020	-2,930	-14,950	-35,130	-750	-92,780
% Difference	-38.1%	-0.6%	-4.9%	-25.9%	-1.2%	-8.7%

Summary of C2VSim Modeling Results

Economic

Change from UNMAP Scenario	Quantified Impact	Qualitative Impact
Agricultural Sector		
Avoided GW Pumping	+$2,016 million in present value	
Avoided GW Well Investment	+$981 million in present value	
Foregone Farm Gate Net Revenue	-$3,023 million in present value	
Urban Sector		
Avoided GW Pumping	Not quantified	(+) lower pumping costs incurred for municipal and domestic wells
Avoided GW Well Investment	Not quantified	(+) lower replacement costs incurred for municipal and domestic wells. Fewer domestic wells running dry during drought periods.

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Report Link

http://waterfoundation.net/wp-content/uploads/CWF-Transitioning-to-Sustainability-Final-Report_11_09_2015.pdf

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Questions ?

Back-up Slides

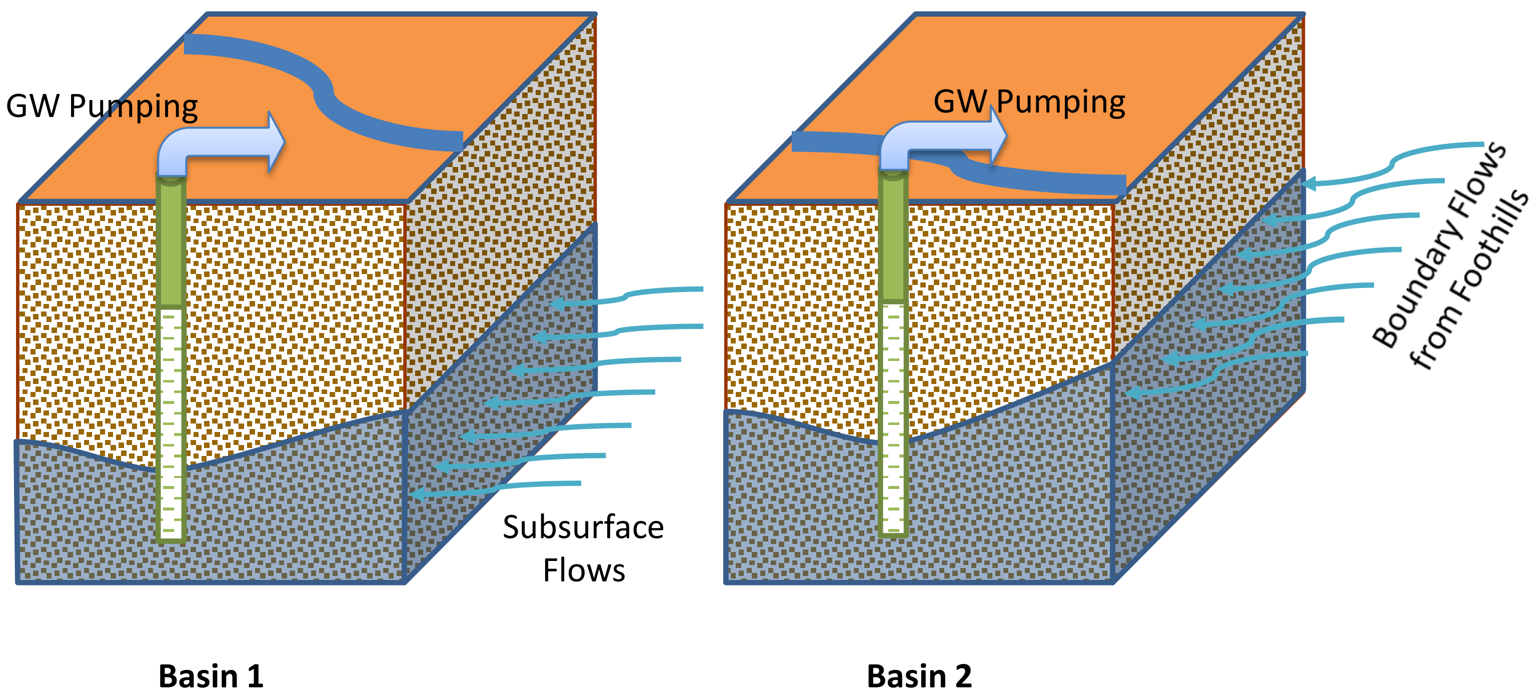
Summary of C2VSim Modeling Results

Physical/Environmental

Change from UNMAP Scenario	Quantified Impact	Qualitative Impact
GW Depth/Storage	+90 ft gain in elevation by end of simulation period +14 MAF by end of simulation period	(+) increased GW availability and reduced pumping depth/cost for future generations of GW users
Increased Stream Flow	+10% increase in average annual flow	(+) expected improvement in water quality and function of dependent ecosystems
Groundwater Quality	Not quantified	(+) expected improvement in groundwater quality over time
Land Subsidence	Not quantified	(+) expected reduction in future subsidence risk

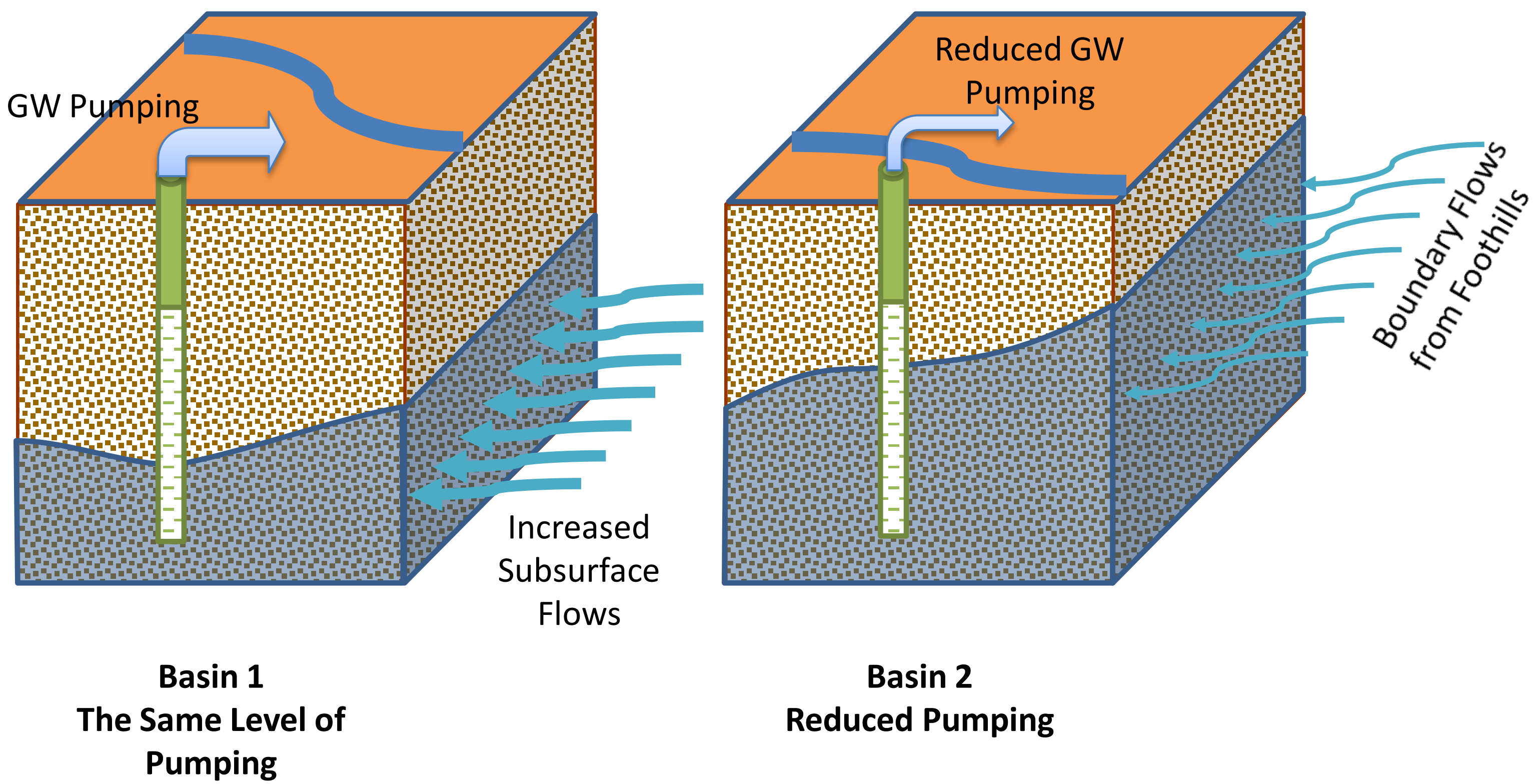
Issue of Subsurface flows between Subbasins

Baseline



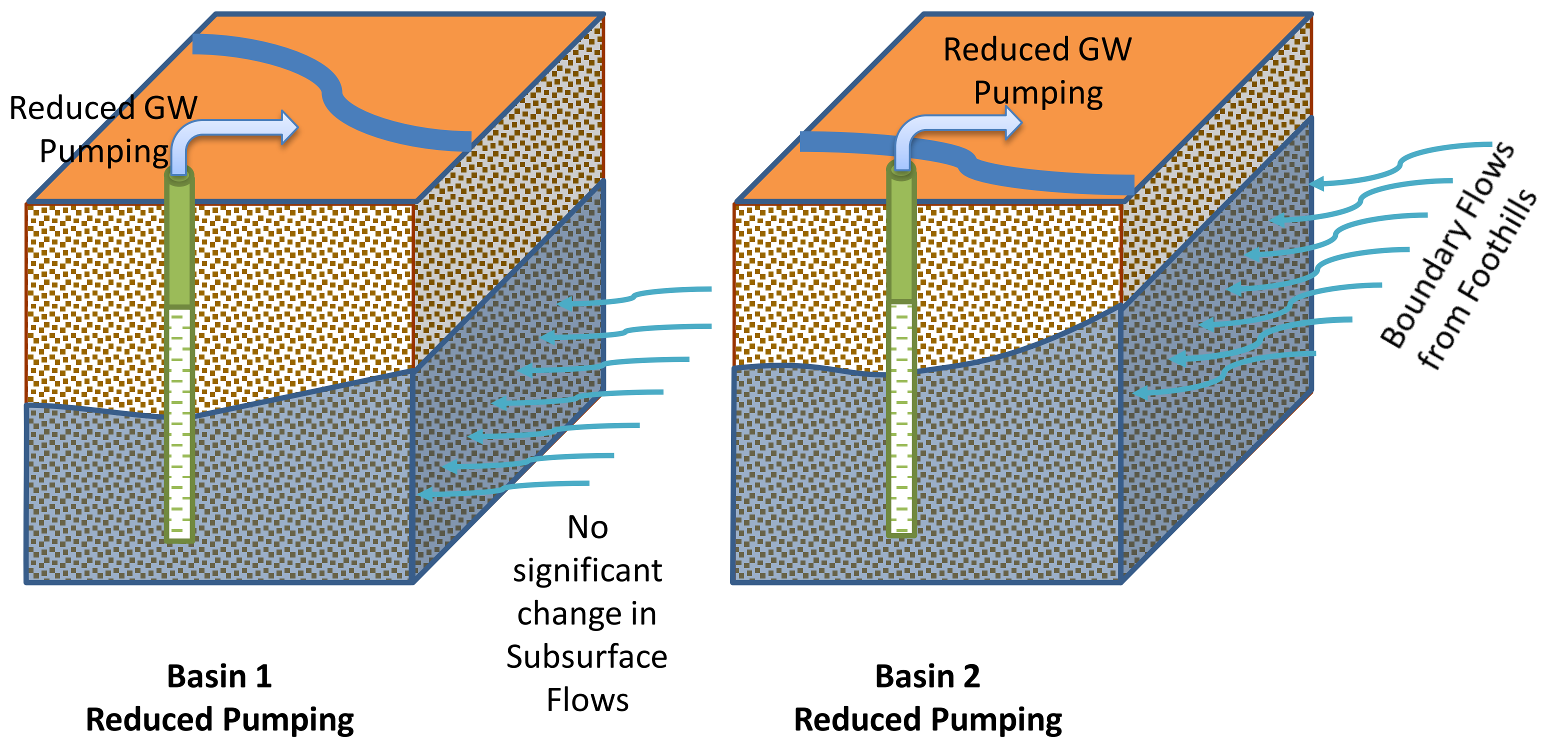
Issue of Subsurface flows between Subbasins

Case 1: Only one of the basin is reducing gw pumping to attain sustainability



Issue of Subsurface flows between Subbasins

Case 2: Both of the basin are reducing gw pumping to attain sustainability



Recommendations for Future Work

- Review land and water use data in SWAP and C2VSim to improve consistency of calibration data
- Extend this response function analysis to other basins -- this is a generalizable framework that can be used to evaluate California groundwater management.
  - Review response function approach to improve statistical fit of the C2VSim model in SWAP
- Dynamic Integration (Coupling) of the Models