Integration of C2VSim and SWAP for a Groundwater Sustainability Pilot Study in the Kings-Tulare Lake Region

IWFM/IDC Users Group Meeting

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CALIFORNIA WATER FOUNDATION

Project Overview

Goal:

Evaluate hydrologic and economic implications of attaining a sustainable groundwater condition in the Kings and Tulare Lake Groundwater Subbasin.

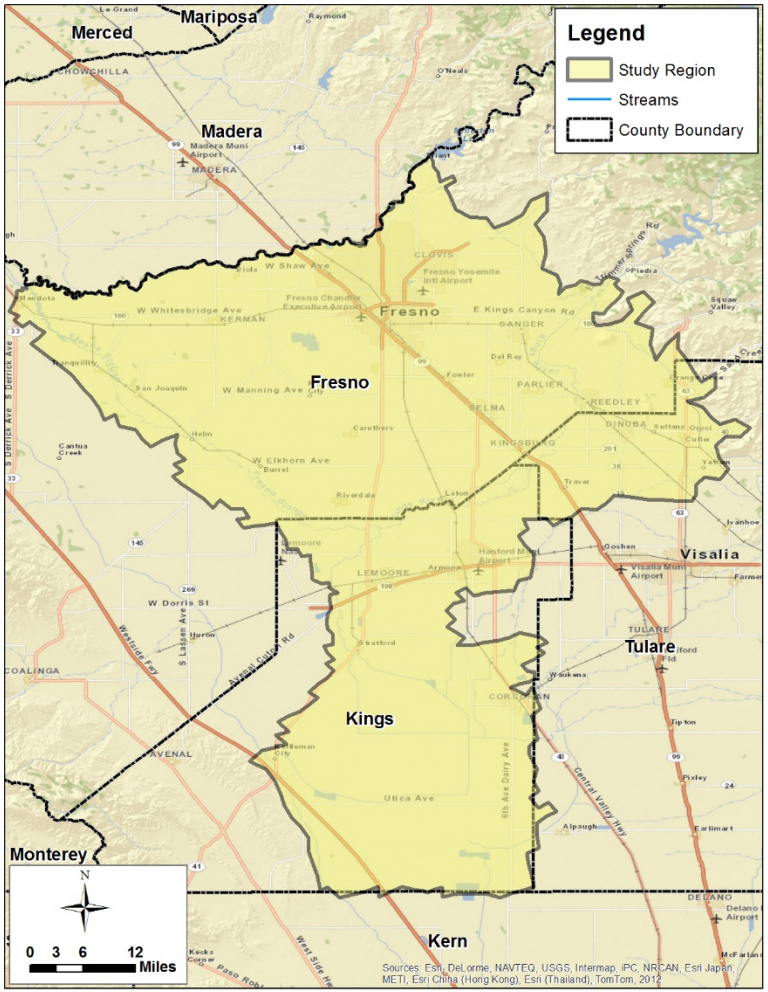
Objectives:

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

Methodology:

- Parameterize C2VSim model,
- Use econometrics to fit GW level response functions,
- Embed response functions in SWAP,
- Evaluate sustainable groundwater management

Study Region



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**

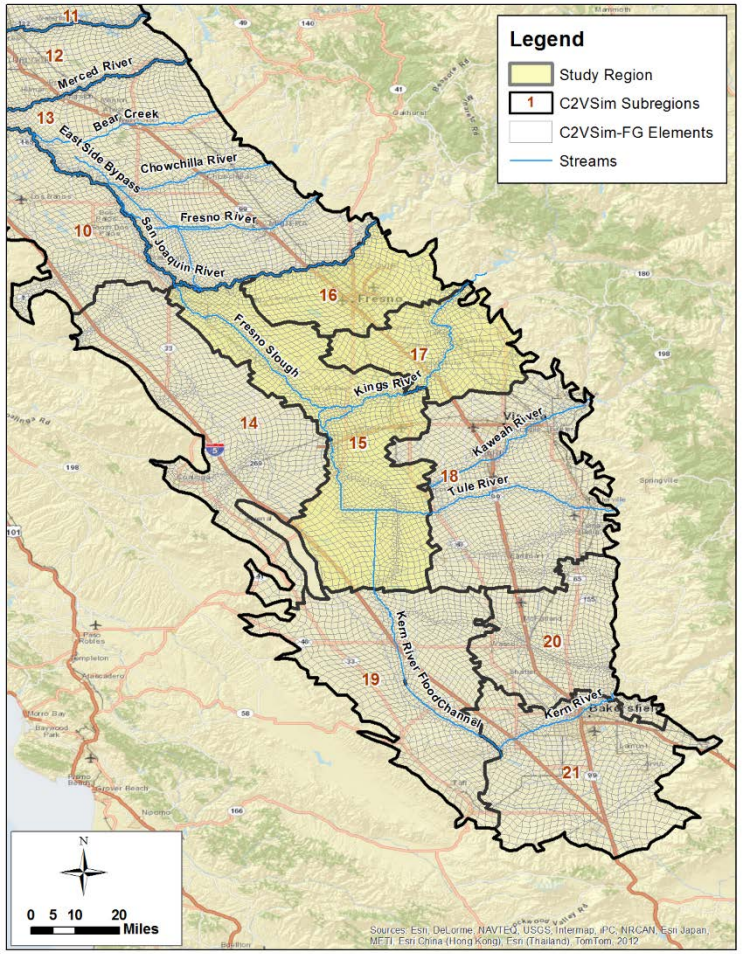
  Statewide Agricultural Production (SWAP) model is a multi-region, multi-input and output economic optimization model of the agricultural economy in California

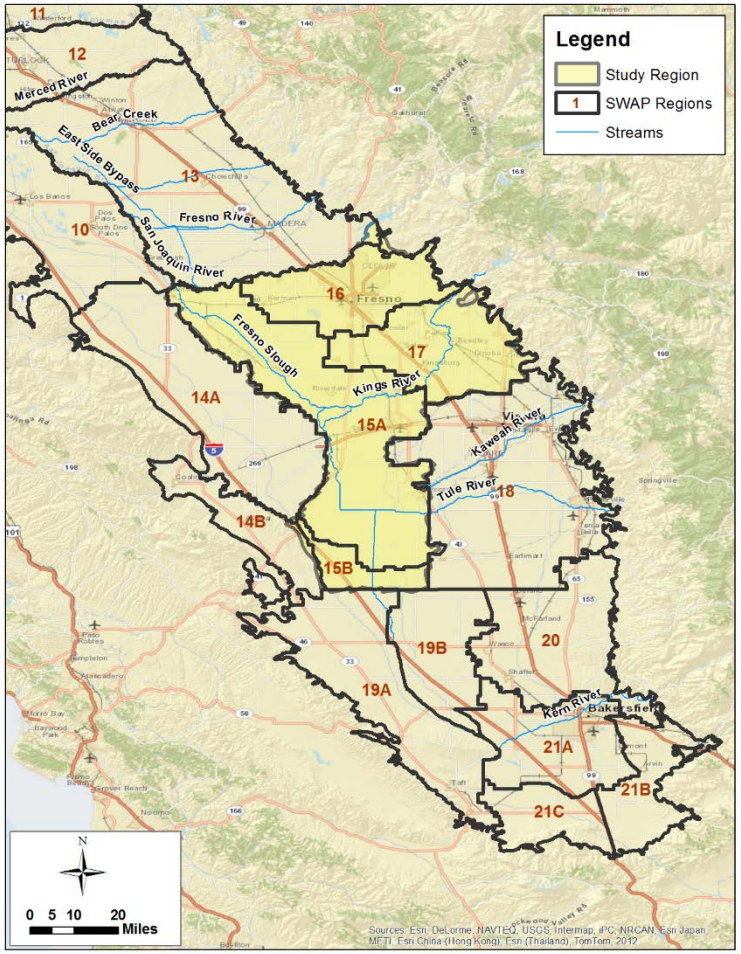
- **IMPLAN**

  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

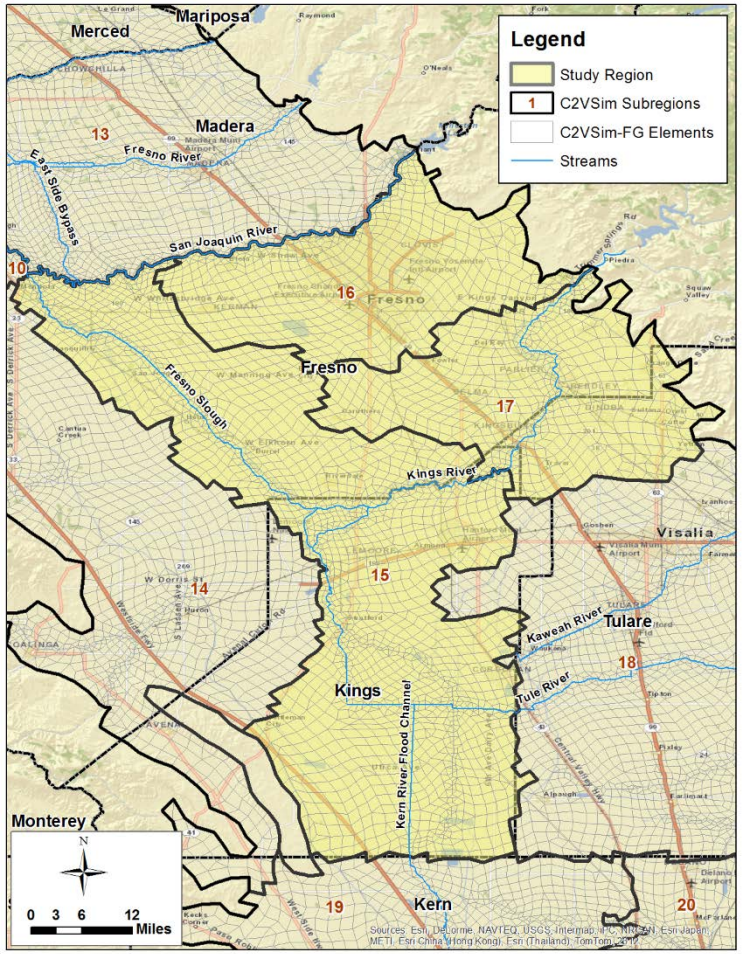
C2VSim & SWAP Subregions

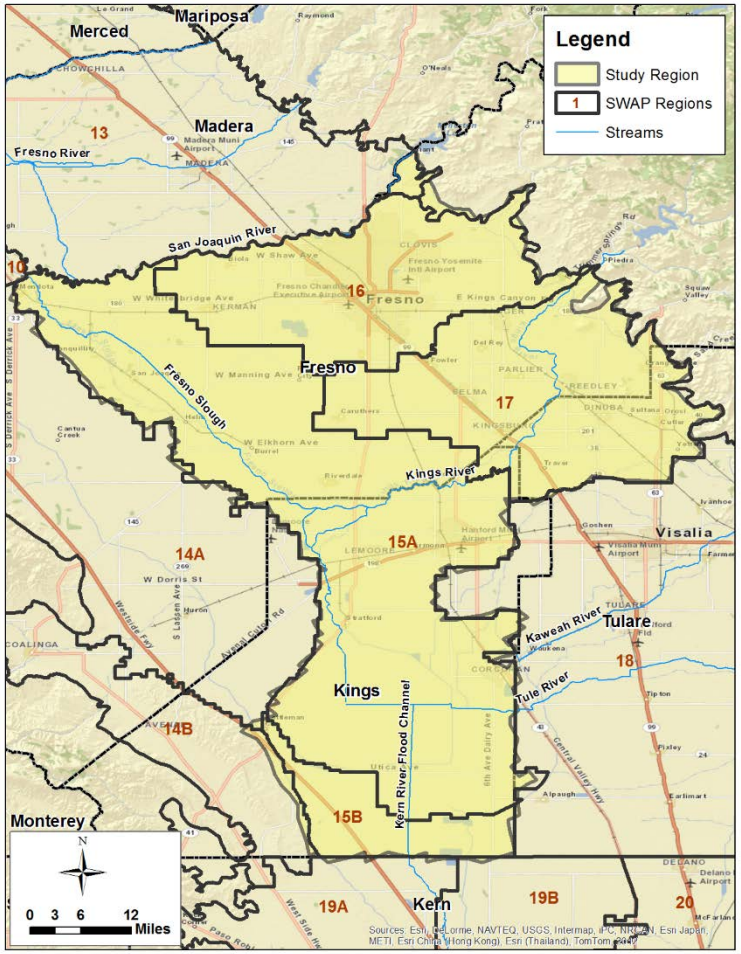




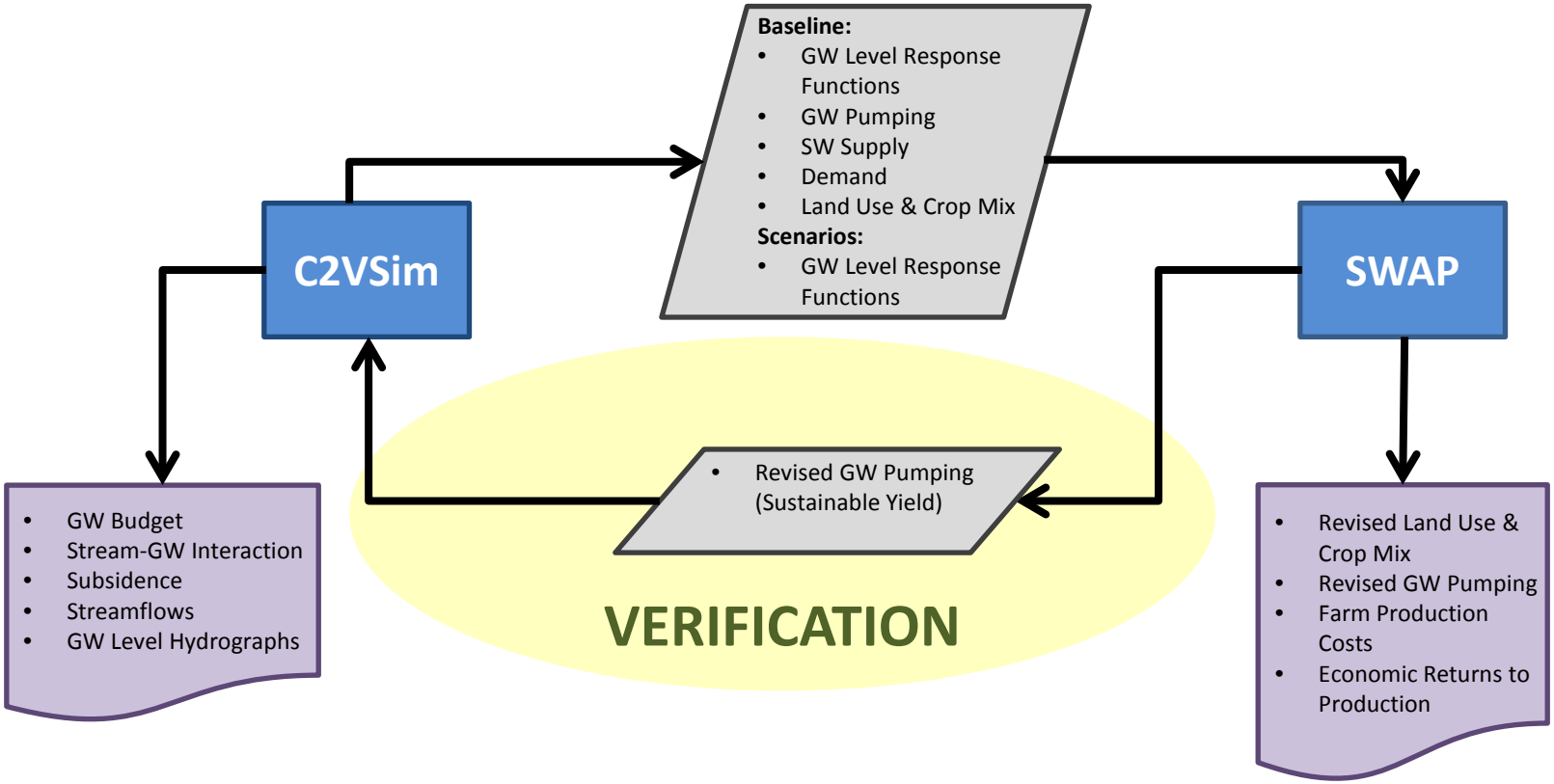
Study Region

C2VSim & SWAP Subregions





C2VSim – SWAP Integration



C2VSim – SWAP Integration

Step 1: Develop Future Condition Baseline & Data Benchmarking

Baseline Development Assumptions

Hydrology: 1922 -2009

Land Use : Current Level of Development

- Updated the urban land use to be consistent with 2060 level of development in the study region
- Crop mix is matched to the latest DWR agricultural land use estimates

Agricultural Demand: Calculated by C2VSim using the 1922-2009 hydrology and baseline land use data

Urban Demand : Urban Demand under Current Level of Development

- Updated the urban demand to be consistent with 2060 level of development in the study region

Ag SW Supply : Synthetic data developed from 1973-2009 historic data using water year type averaging

Urban SW Supply : Calsim-II Future Condition Baseline (if mapping between C2VSim and Calsim-II was available, otherwise water year type averaging method)

Pumping: Calculated by C2VSim (Demand-SW Supply)

Stream Inflows : Calsim-II Future Condition Baseline (if mapping between C2VSim and Calsim-II was available, otherwise water year type averaging method)

Initial Conditions: C2VSim Historic Calibration 2009 Results

C2VSim – SWAP Integration

Step 1: Develop Future Condition Baseline & Data Benchmarking

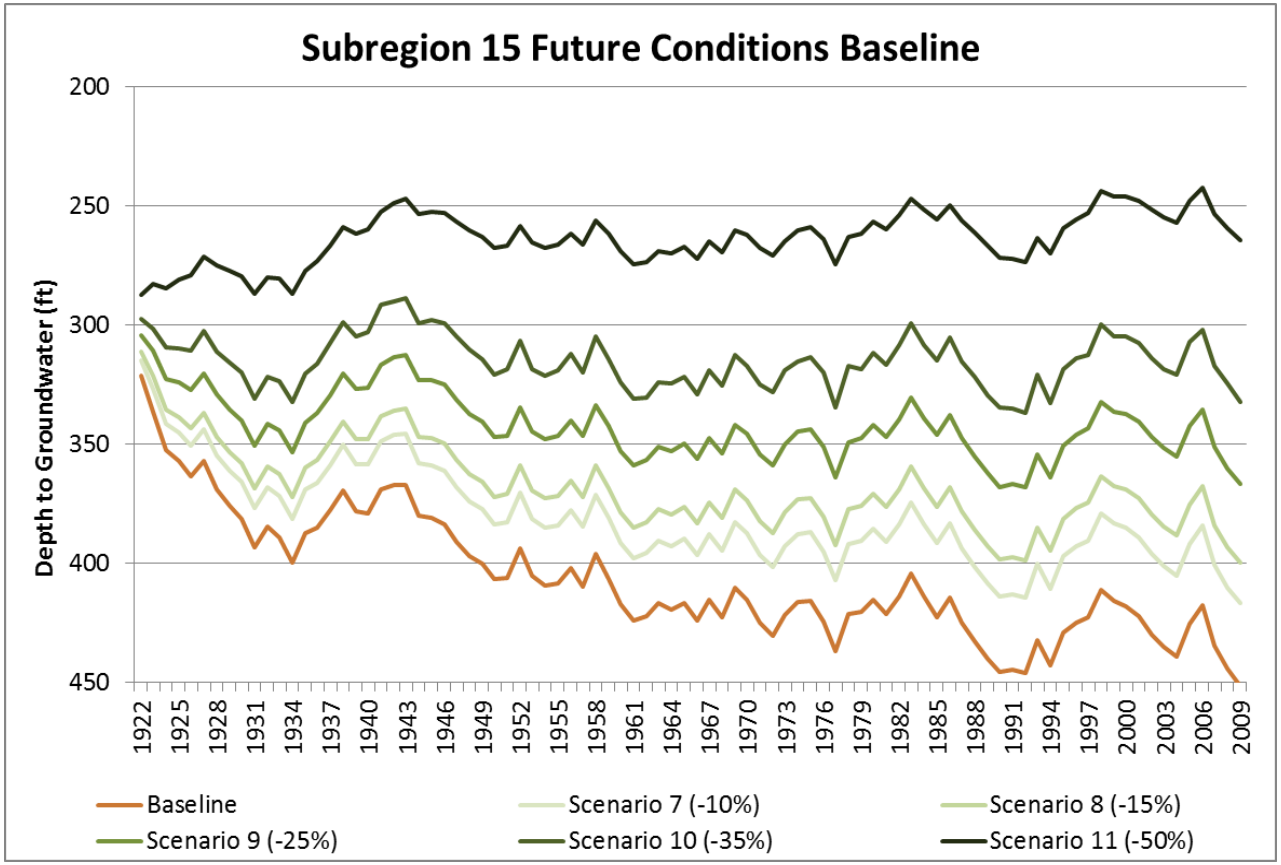
Agricultural water use and applied water rates are slightly different between the two models. In order to align the SWAP and C2VSim models the following steps were taken:

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

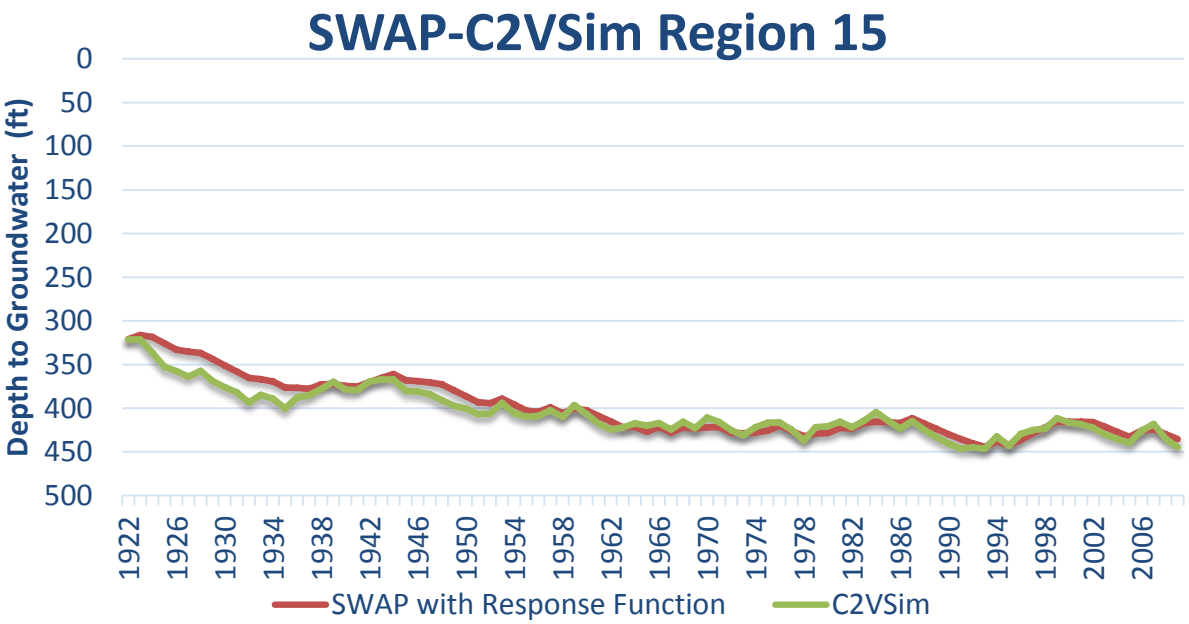
Step 3: Develop and Evaluate Groundwater Response Functions

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

1. 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.
2. Use the response functions to calculate the steady-state safe-yield for each subregion

C2VSim – SWAP Integration

Step 3: Develop and Evaluate Groundwater Response Functions



C2VSim – SWAP Integration

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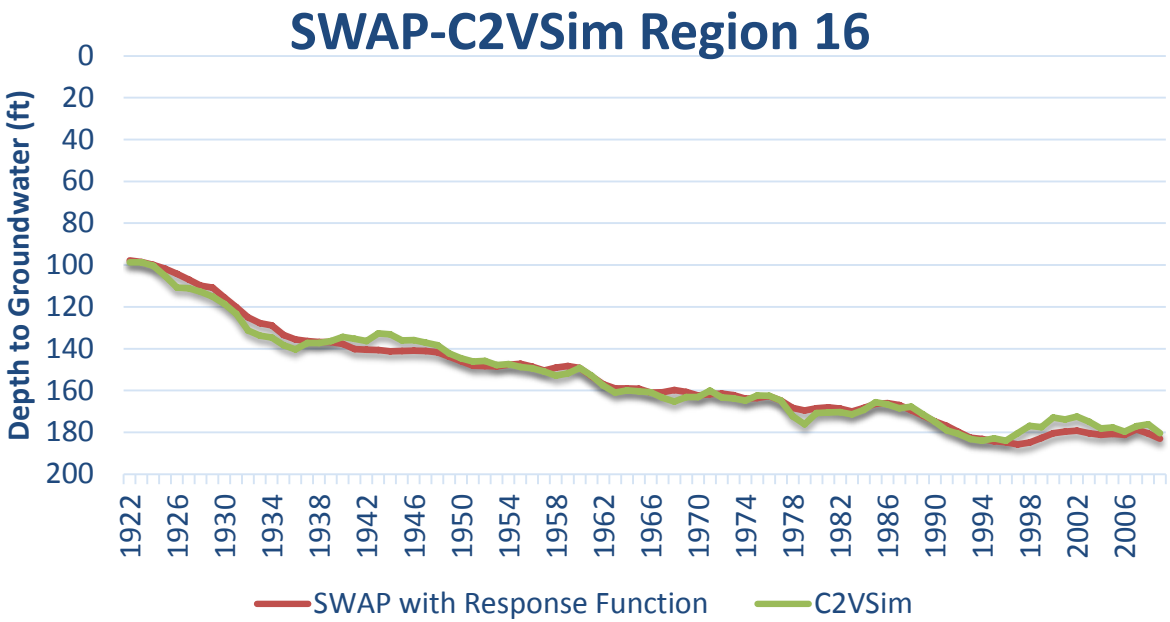
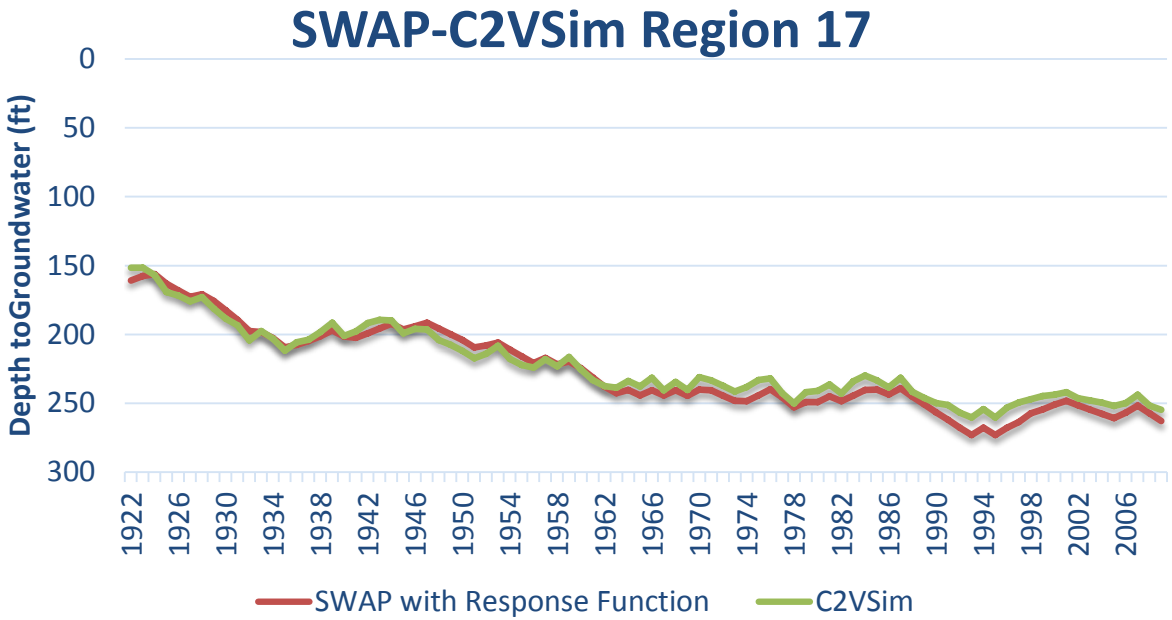


C2VSim – SWAP Integration

Step 3: Develop and Evaluate Groundwater Response Functions



C2VSim – SWAP Integration

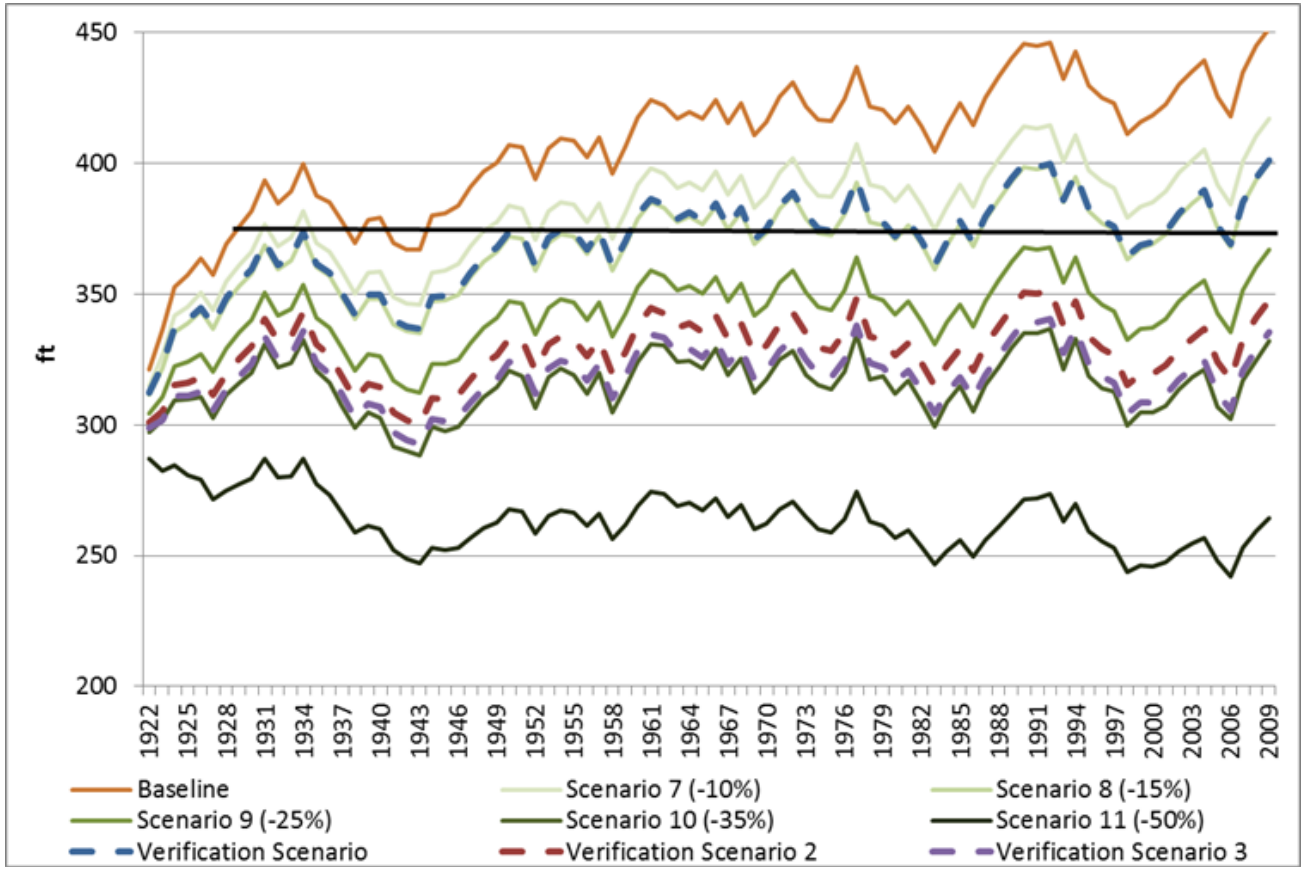
Step 4: Estimate Sustainable Yield

Definition Used for Sustainability for Modeling Purposes:

- Sustainable conditions are arrived when long-term change in depth to groundwater is near zero
  - Hydrologic Period of Record: 1922-2009
  - Economic Period of Record: 1979-2009
- Sustainable yield for each region is the average pumping where change in depth to groundwater is 0 over 1922-2009 (or some other sub-set of years)
- Pumping allowed to vary year-to-year, e.g., more in dry years, less in wet years
- Calculated using the econometric response functions

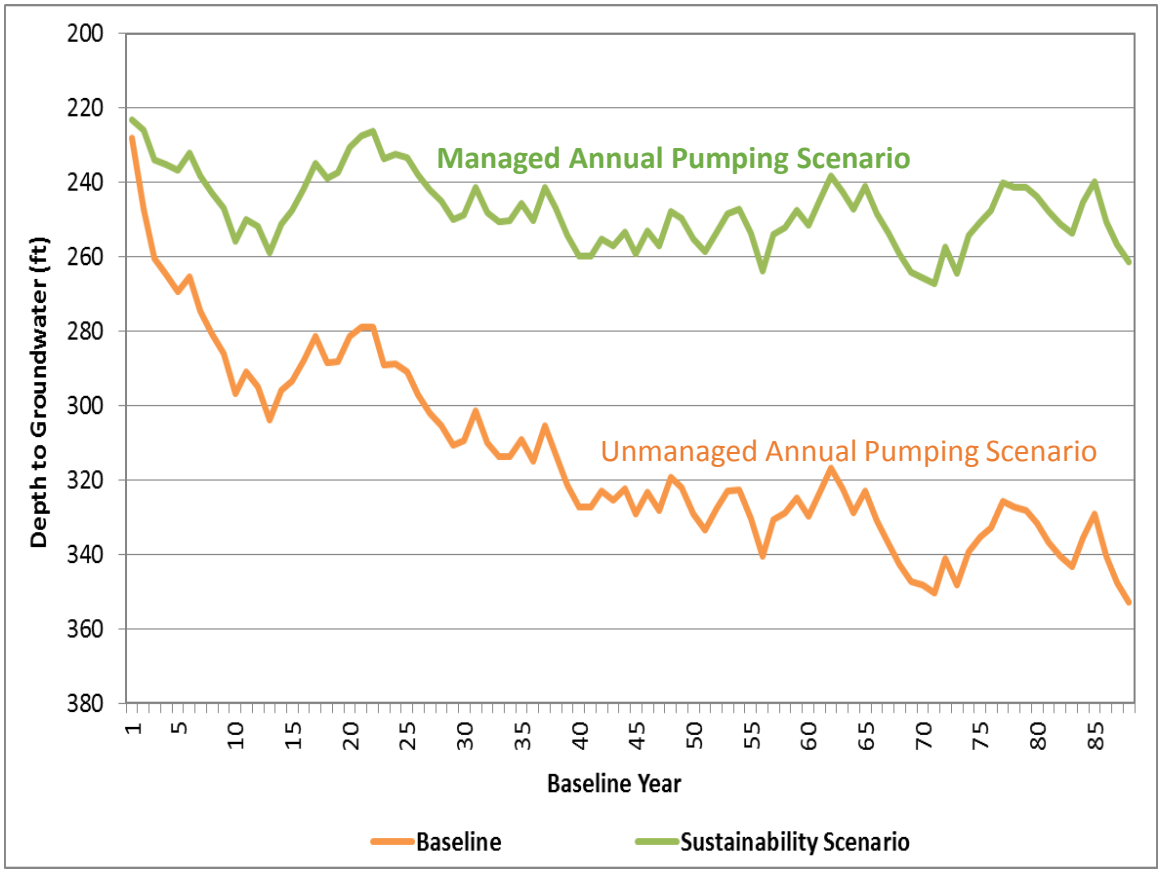
C2VSim – SWAP Integration

Step 5: Verify Sustainable Yield in CVSim



C2VSim – SWAP Integration

Average Depth to Groundwater in Study Region



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

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