

# Napa Valley Hydrologic Model Introduction

July 25, 2019



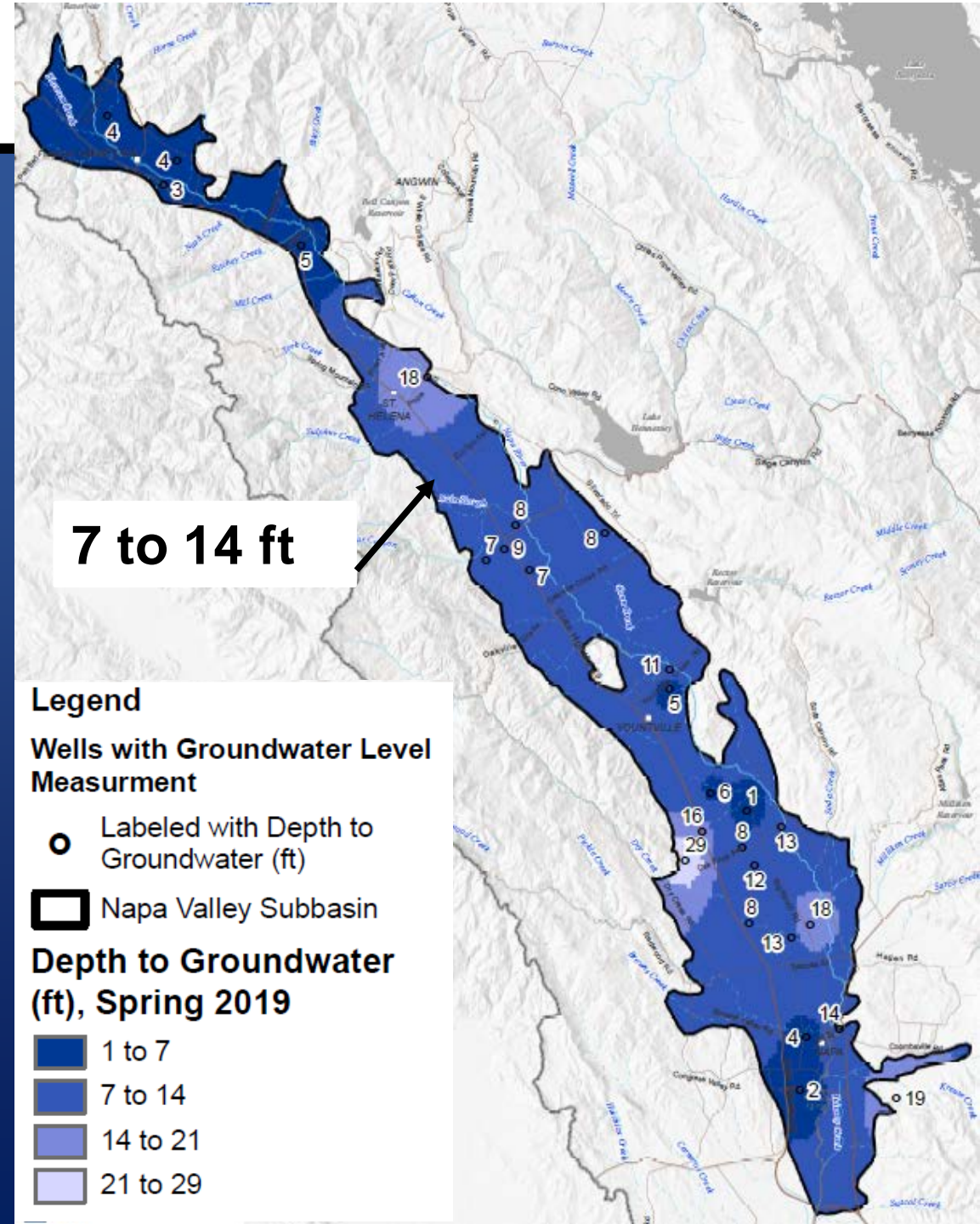
**Luhdorff &  
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Consulting Engineers



One Water

# Spring 2019 Groundwater Levels

- Network of 25 wells completed in the upper aquifer zones (out of total network of 107 wells)
- Depths to water less than 14 feet below ground surface in most areas



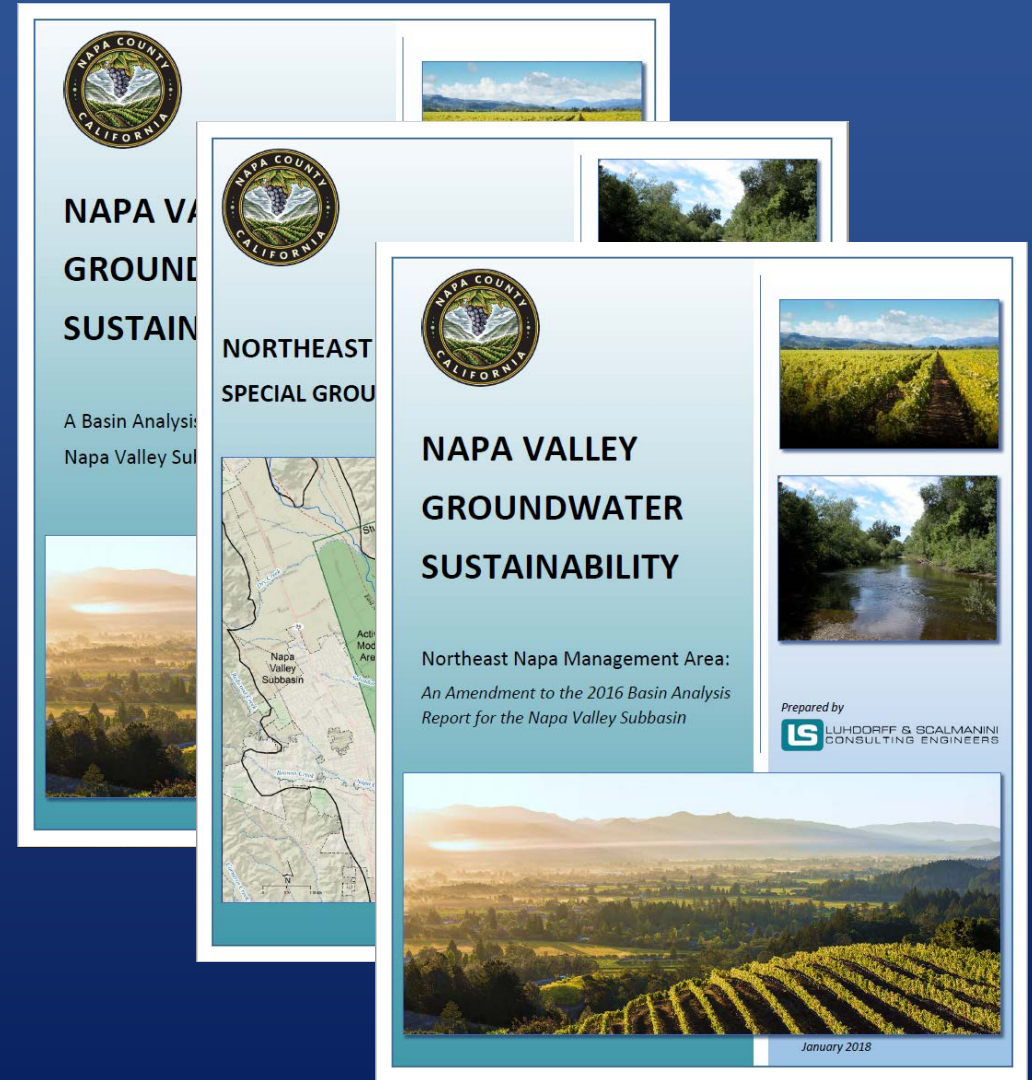
# Background

## Building on efforts underway since 1990s

- 1991 – Water Availability Analysis
- 1999 – County Groundwater Ordinance
- 2008 – General Plan Update, conservation goals and action items
- 2013 – Updated Hydrogeologic Conceptualization
- 2014 – Groundwater Resources Advisory Committee/Sustainability Goal
- 2015 – Revised Water Availability Analysis Guidance
- 2016 – Basin Analysis Report
- 2018 – Basin Analysis Report Amendment

# 2016 GSP Alternative & 2018 Amendment

- I. Subbasin-scale Water Budget and Sustainable Yield Analyses
- II. Establishing sustainability criteria – identification of SW-GW interactions as most sensitive sustainability indicator for the Napa Valley Subbasin
- III. County intent to develop a hydrologic model as part of a 5-year update of the GSP Alternative (or new GSP)

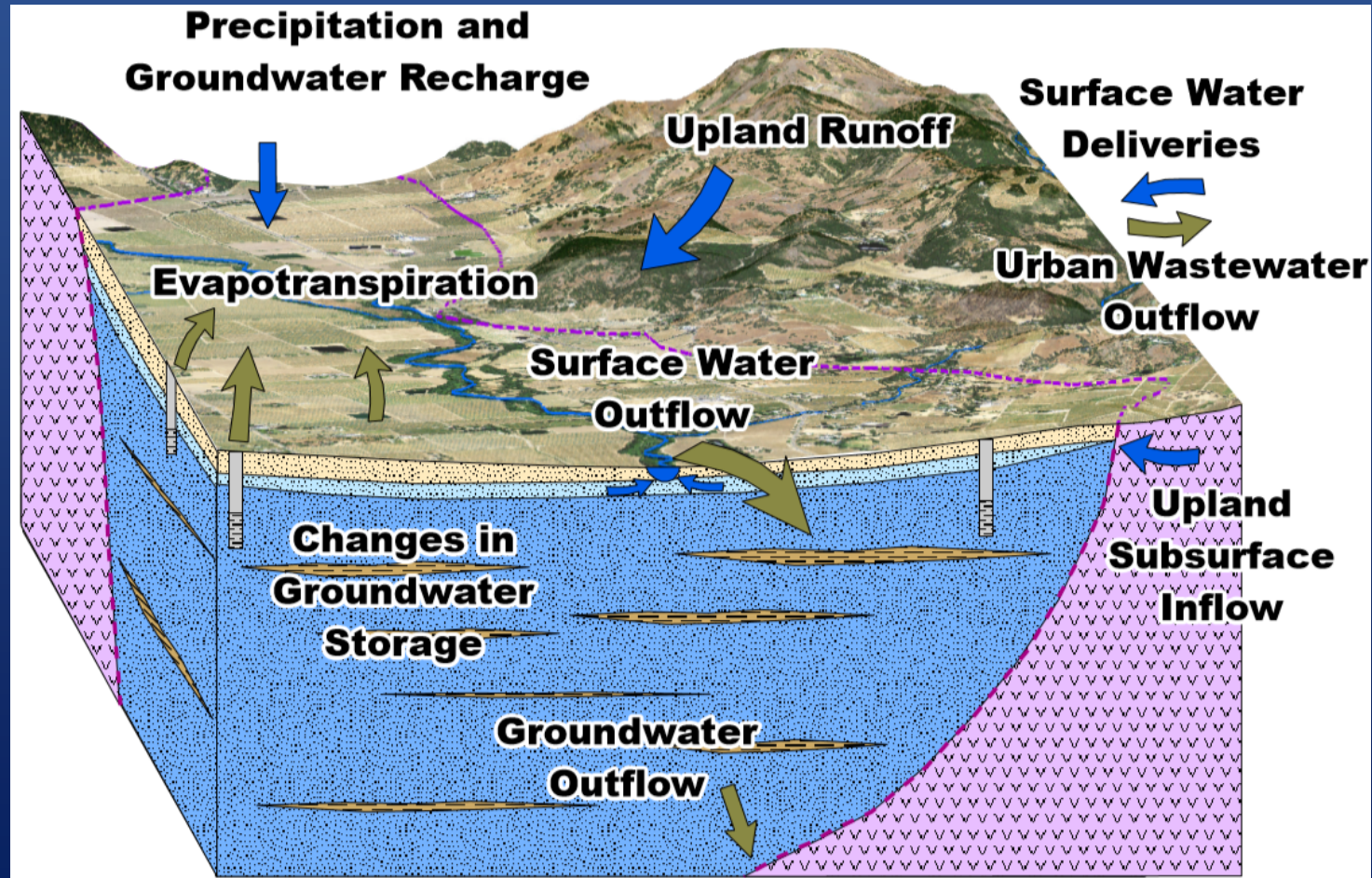




# 2016 GSP Alternative & 2018 Amendment

## I. Subbasin-scale Water Budget and Sustainable Yield Analyses

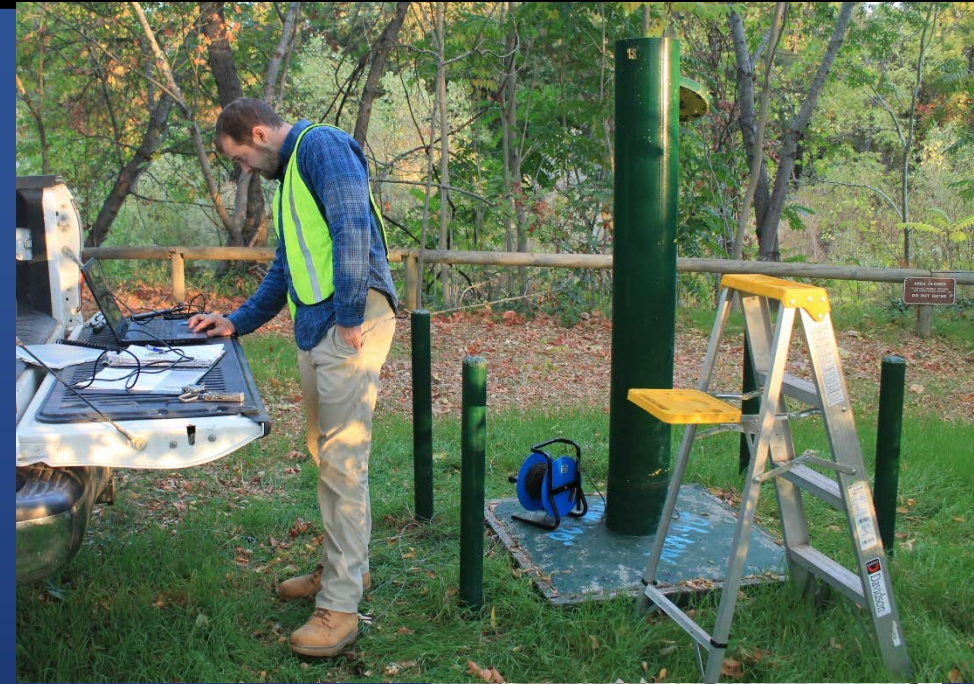
- 1988-2015 base period shows stable to slightly increasing groundwater storage
- Subbasin has operated within sustainable yield for >10 years
- Sustainable Yield between 17,000 to 20,000 acre-feet per year



# 2016 GSP Alternative & 2018 Amendment

## II. Establishing sustainability criteria

- Criteria established for all six sustainability indicators
- SW-GW interactions identified as most sensitive sustainability indicator for the Napa Valley Subbasin
- Thresholds determined by dedicated monitoring wells and historical stream gauge measurements





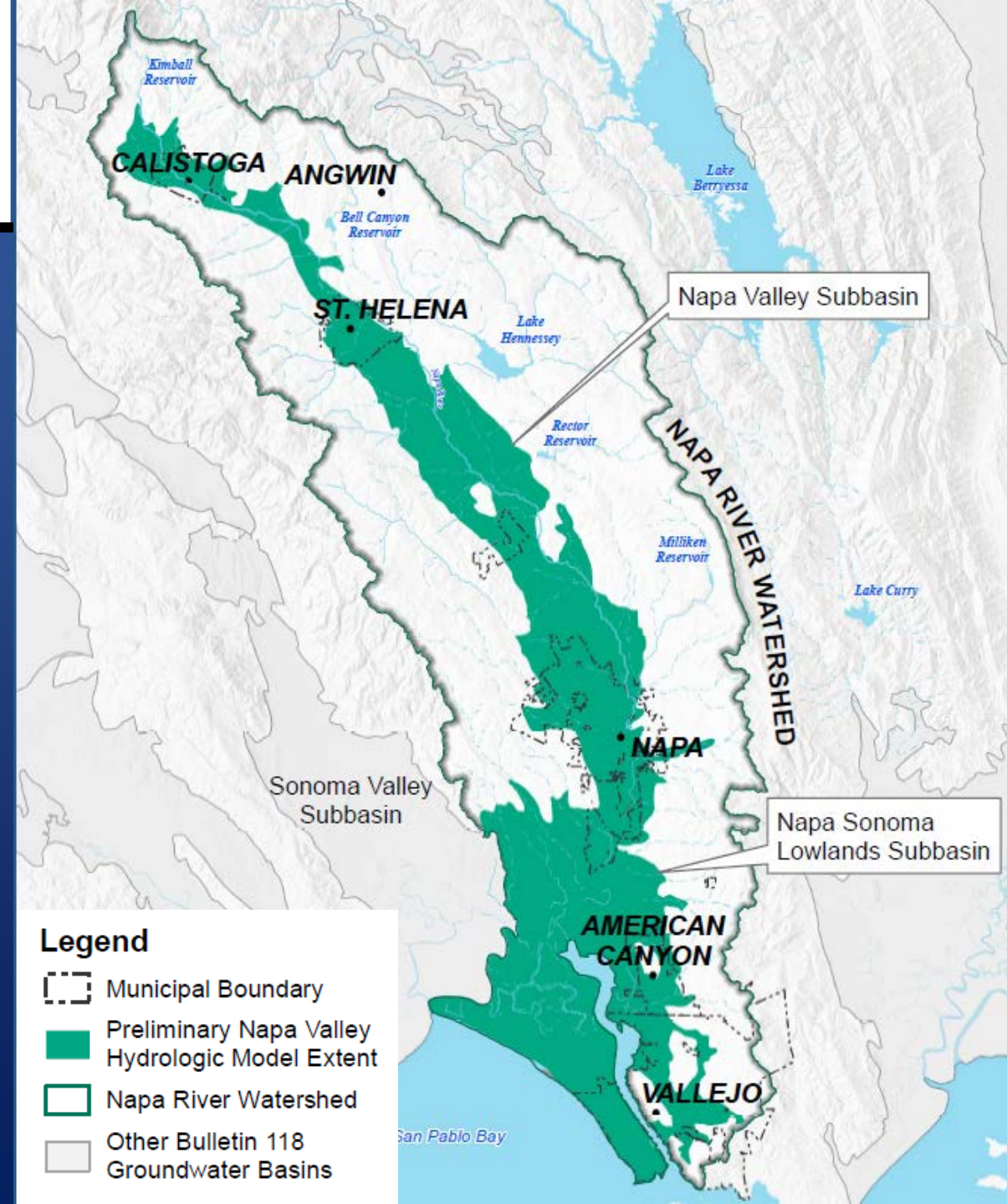
# 2016 GSP Alternative & 2018 Amendment

## III. Intent to develop a hydrologic model as part of a 5-year update of the GSP Alternative (or new GSP)

- Develop water budgets with biweekly time steps to reflect historical and modern hydrologic conditions
- Evaluate local scale conditions within the Subbasin and affects on six sustainability indicators
- Refine simulations of future conditions and evaluate options for maintaining sustainability

# Napa Valley Hydrologic Model Extent

- Preliminary Model Extent includes the Napa Valley Subbasin and Napa-Sonoma Lowlands Subbasin
- Model will account for hydrologic inputs from the larger Napa River Watershed





# Randy Hanson



## Hydrologist and President of One-Water Hydrologic, LLC

Formerly a Research Hydrologist with the USGS for 38 years

- Developed the open-source MODFLOW One-water Hydrologic Flow Model (MF-OWHM) known as “One-Water”
- Collaborated on projects across California (and beyond) on cooperative management of water resources
- Advocate for providing open-source water management software to foster sustainable resource management
- Currently assists consultants in analyzing conjunctive water use and related modeling projects





**ONE WATER**



# **NAPA's SGMA GSP with the New Integrated Hydrologic Model, "One-Water"**

**Randall T. Hanson**

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Napa County Groundwater Sustainability Planning

July 25, 2019



**Luhdorff &  
Scalmanini**  
Consulting Engineers



**NAPA COUNTY**  
CALIFORNIA

# Today's Update

- 1. What is the “One-Water” model?***
2. How Can One-Water Support NAPA- GSP for SGMA?
3. Water Budgets and Sustainability for SGMA
4. Undesirable Results and Thresholds
5. Reporting, Maintenance, & Updates





# Our Goal & Philosophy for Simulation and Analysis → ONE-WATER!

## All the water, All the time, Everywhere in the simulated Hydrosphere

**Conjunctive Use:** Combined use of All Waters (precipitation, surface water, recycled water, runoff, and groundwater) to optimize the use and quality for natural and human uses.

### **Conjunctive-Use Modeling**

- Build Integrated Hydrologic Model that connects climate, landscape, surface-water, & groundwater use and movement within a supply-constrained and demand-driven framework
- Train model with historical periods to address Future & Alternative conditions that require sustainability and adaptation analysis

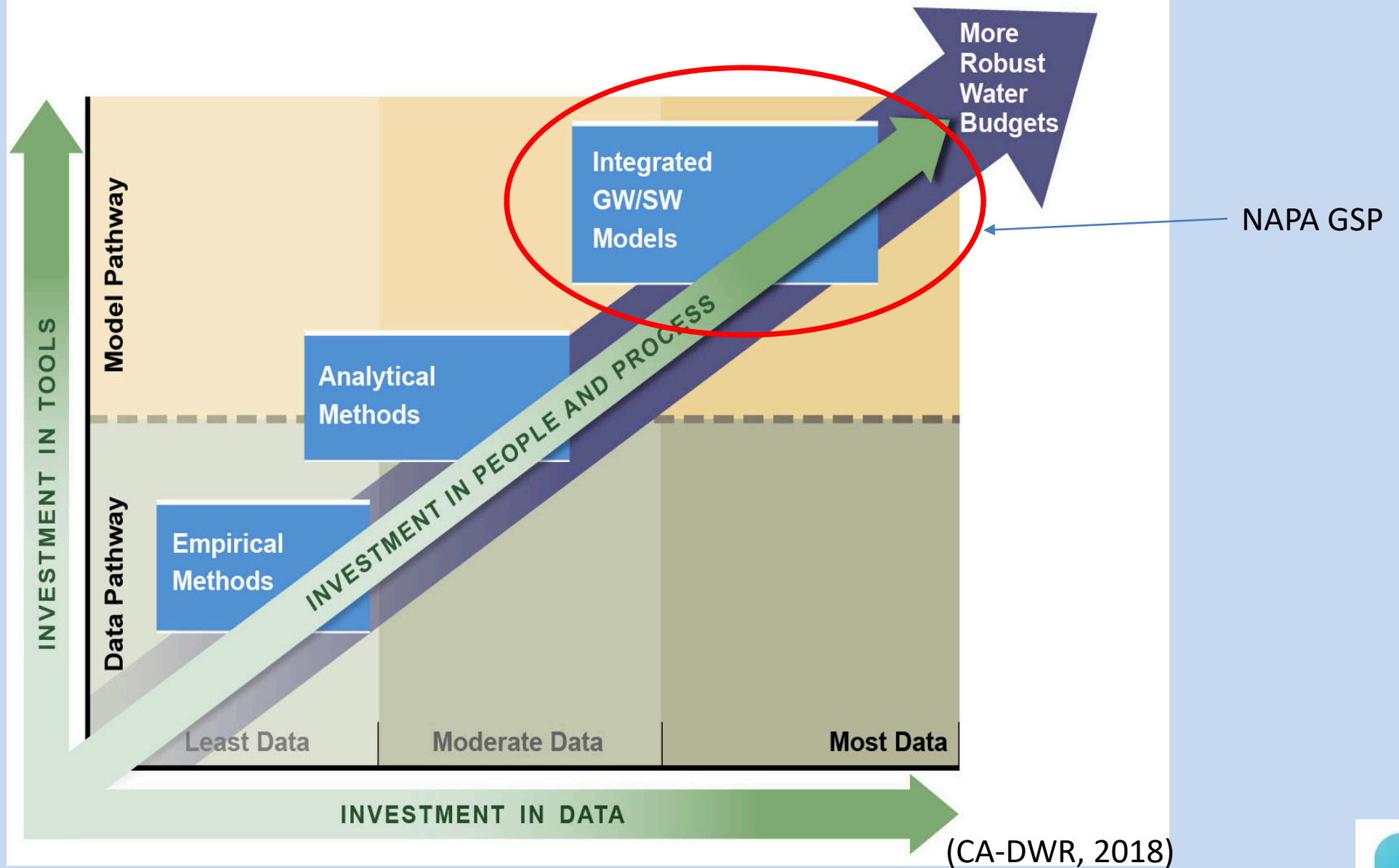
**Connectivity:** Connect within a model, to other models, & other types of models to extend linkages (ex. Agricultural Profit/Sustainability, water trades/markets, etc.)

**Sustainability:** Development and use of water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences.

### **Sustainable Yield:**

“Maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually without causing an undesirable result.” (Definition; Water Code Section 10721(v))

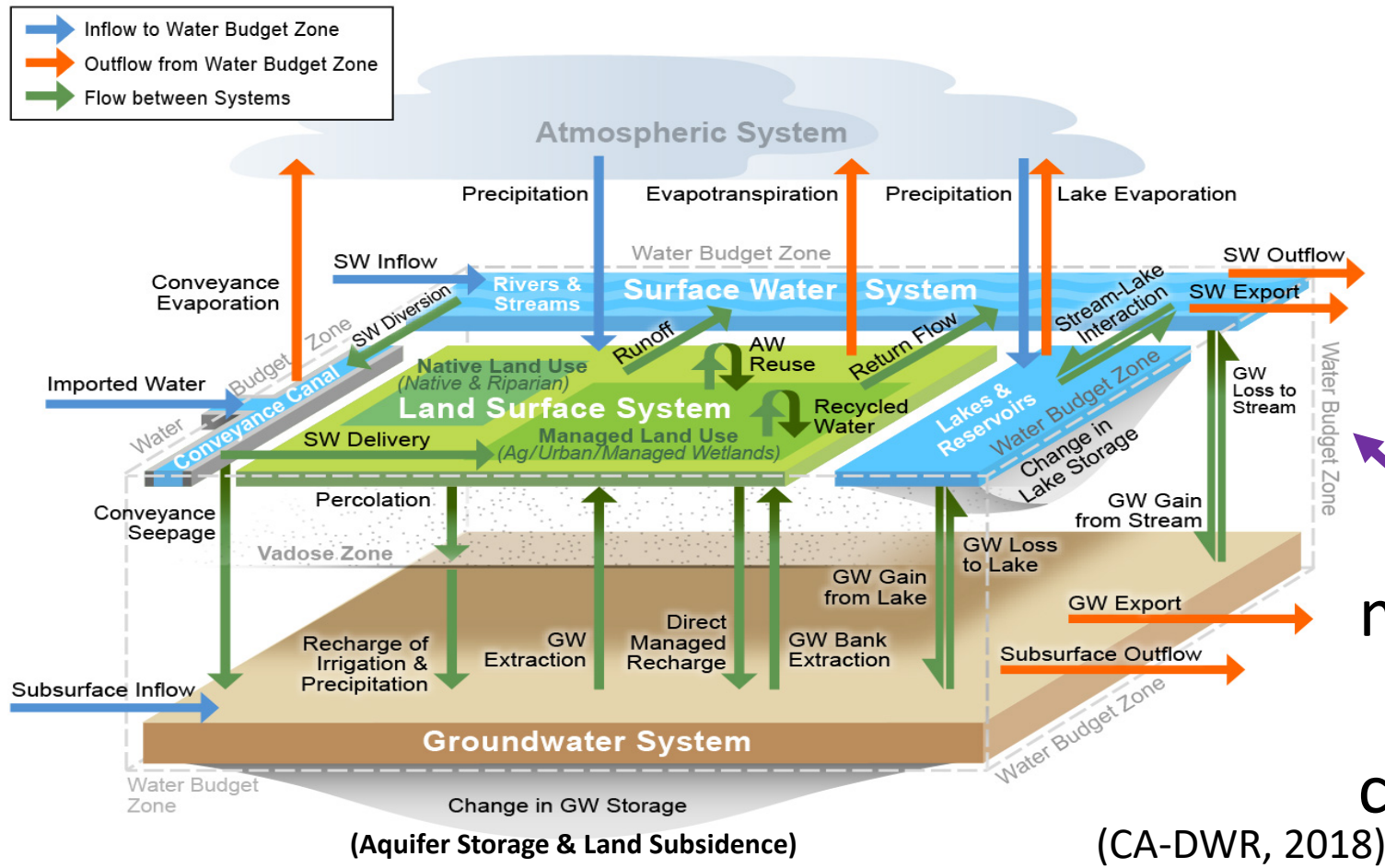
**Adaptation:** Modification of use, movement, and storage of water to promote sustainability of water, food, and energy security that is physically, economically, politically, legally, and socially feasible.



SGMA and CA-DWR have more water budget “expectations” with more data & data types and with better and more complete models. More expectations with more secondary effects to consider.



One Water



There are more water-budget components here than can be provided by a traditional Groundwater Model

Holistic data networks & model frameworks are required for CA-SGMA. Don't confuse complete with complex as complete frameworks are needed to address all the effects and linkages in the use and movement of water and linkages that drive the six "undesirable results" and related thresholds.





# MODFLOW And Its Children

- The MODFLOW-2005 (MF) diverged into multiple versions designed for specific needs. Model divergence created more options but also more limitations.
  - Selection of one version meant features of another were not available.
  - Most versions are not current and can't address agriculture supply and demand





# MODFLOW-OWHM



## One-Water Hydrologic Flow Model

- The One-Water Hydrologic Flow Model, MF-OWHM, is an enhanced fusion of multiple MODFLOW versions to serve as a new integrated hydrologic flow modeling software. Second version now available!!
- Provides historical and future water-flow budgets under different hydrologic and land use regimes as expected by DWR under SGMA
- Over 13 years of experience developing Integrated Hydrologic Models/Codes
- Public Domain free and open-source software as required by SGMA
- Used in biggest Agricultural Areas of CA → Central Valley, Salinas, Pajaro, Borrego, San Diego, Cuyama, Paso Robles, Sonoma,

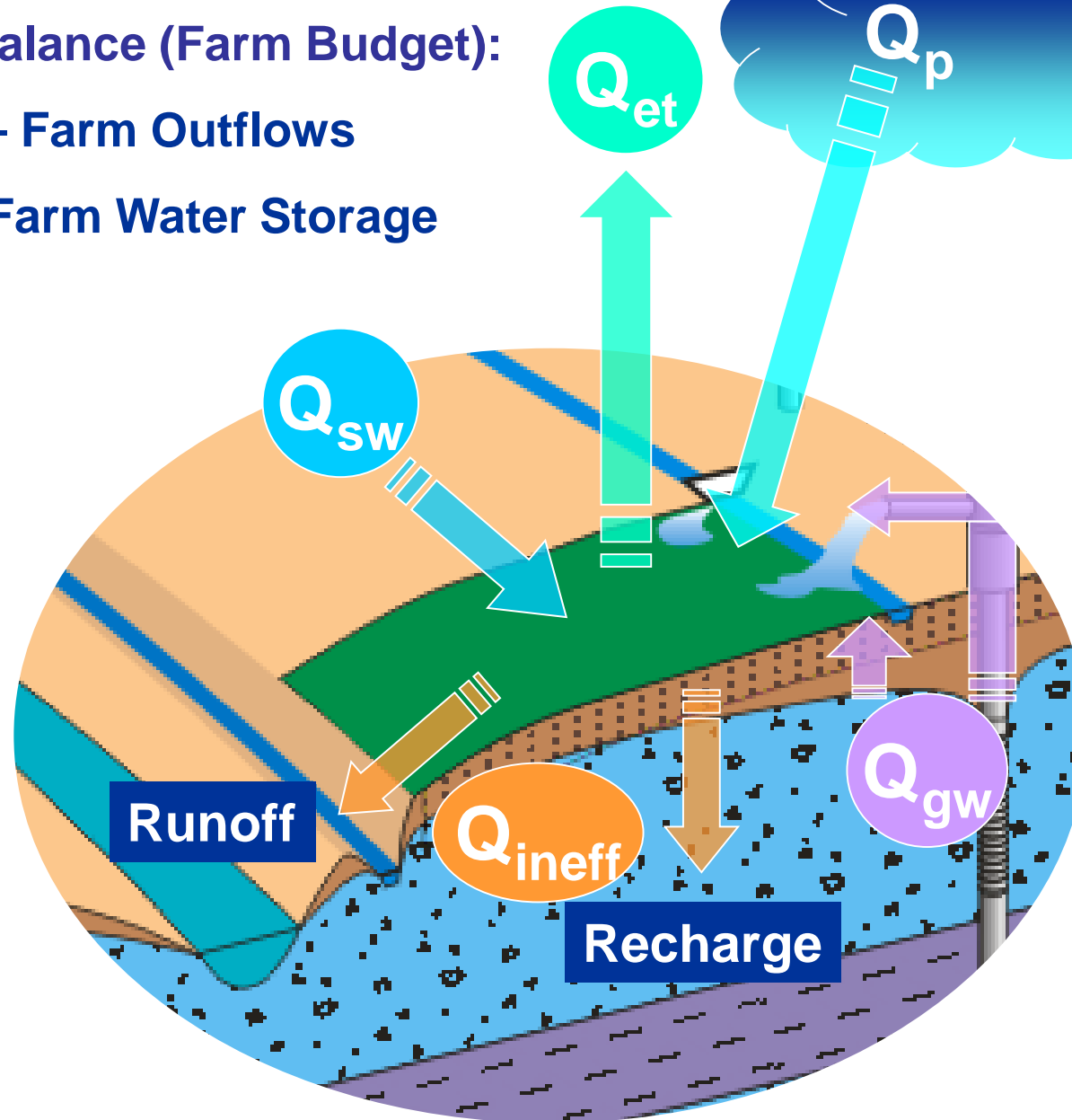
OWHM (version 2) → “One-Water”

## Supply & Demand features of Farm Process within One-Water Mass Balances

Farm Mass Balance (Farm Budget):

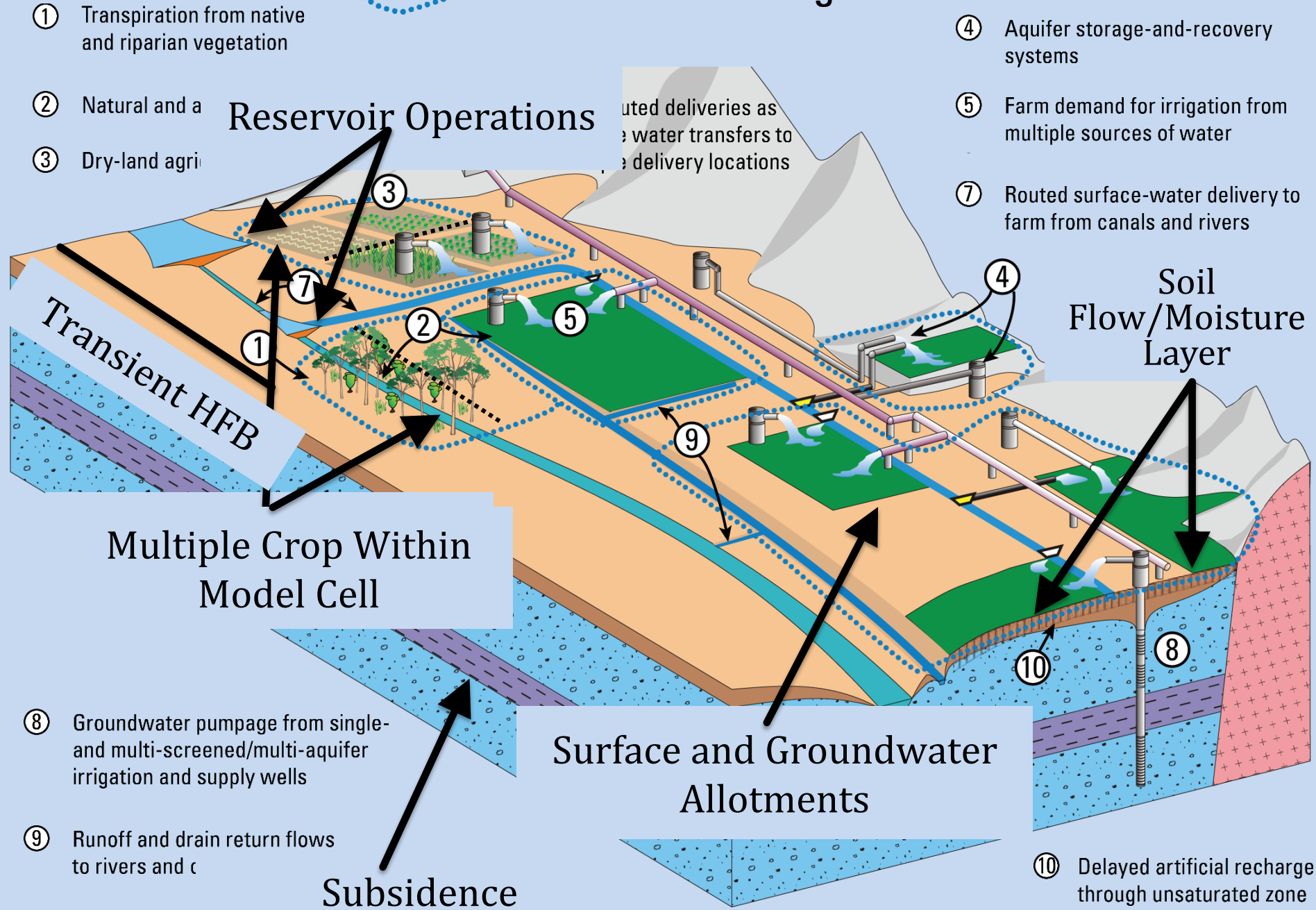
Inflow – Farm Outflows

= Change in Farm Water Storage





# Water-Balance Region



① Transpiration from native and riparian vegetation

② Natural and a

③ Dry-land agri

④ Aquifer storage-and-recovery systems

⑤ Farm demand for irrigation from multiple sources of water

⑦ Routed surface-water delivery to farm from canals and rivers

Multiple Crop Within Model Cell

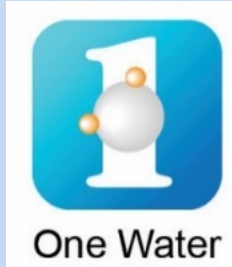
⑧ Groundwater pumpage from single- and multi-screened/multi-aquifer irrigation and supply wells

⑨ Runoff and drain return flows to rivers and c

Surface and Groundwater Allotments

Subsidence

⑩ Delayed artificial recharge through unsaturated zone



# One Water and the Farm Process

## SUMMARY OF FEATURES AND ADVANTAGES

### MODEL FEATURES MADE EASY

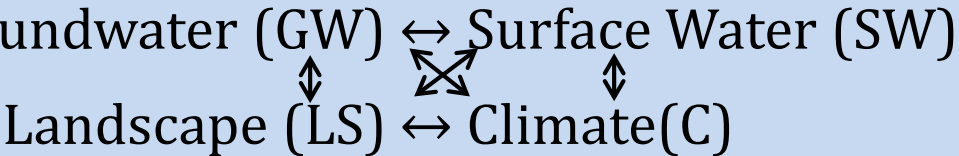
- Estimates Irrigation Demand & Supply (both SW and GW)
- Estimates Surface-Water Deliveries (Analyze Conveyance)
- Estimates Ground-water Pumpage (Train model with historical Ag pumpage/AET)
- Estimates Net Recharge (both natural and artificial)
- Estimates all Components for ET, Runoff, and Deep Percolation
- Complete Linkage between Landscape, Groundwater & Surface-water Flow

### ADVANTAGES FOR MODELERS

- No need for indirect estimates of Pumpage, Recharge, ET, Runoff, or Surface-water deliveries
- Uses Natural & Fundamental Data → Easier to Update Model & Interface with Data Networks
- Saves time and money for constructing, operating, and updating models
- Facilitates Operational and Forecasting Simulations → SGMA, Climate, etc.



# One Water Framework and Concepts

- Water should stay within the model for as long as possible
  - In traditional MODFLOW water disappears, ex. Drains, Wells, etc.
- Fully Coupled → Groundwater (GW) ↔ Surface Water (SW)  
Landscape (LS) ↔ Climate (C)  

- All water sources have a direct “relationship” between source & demand locations, and type of use (**Supply-and-Demand Framework**)
- Physically-based, supply-and-demand framework → seamless & meaningful analysis for conjunctive use, sustainability/adaptation, and climate change → SGMA
- Multiple Water Budgets: Groundwater, Surface Water, Landscape, & Climate → SGMA



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- 2. *How Can One-Water Support NAPA-GSP for SGMA?***
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# One-Water → SGMA Support

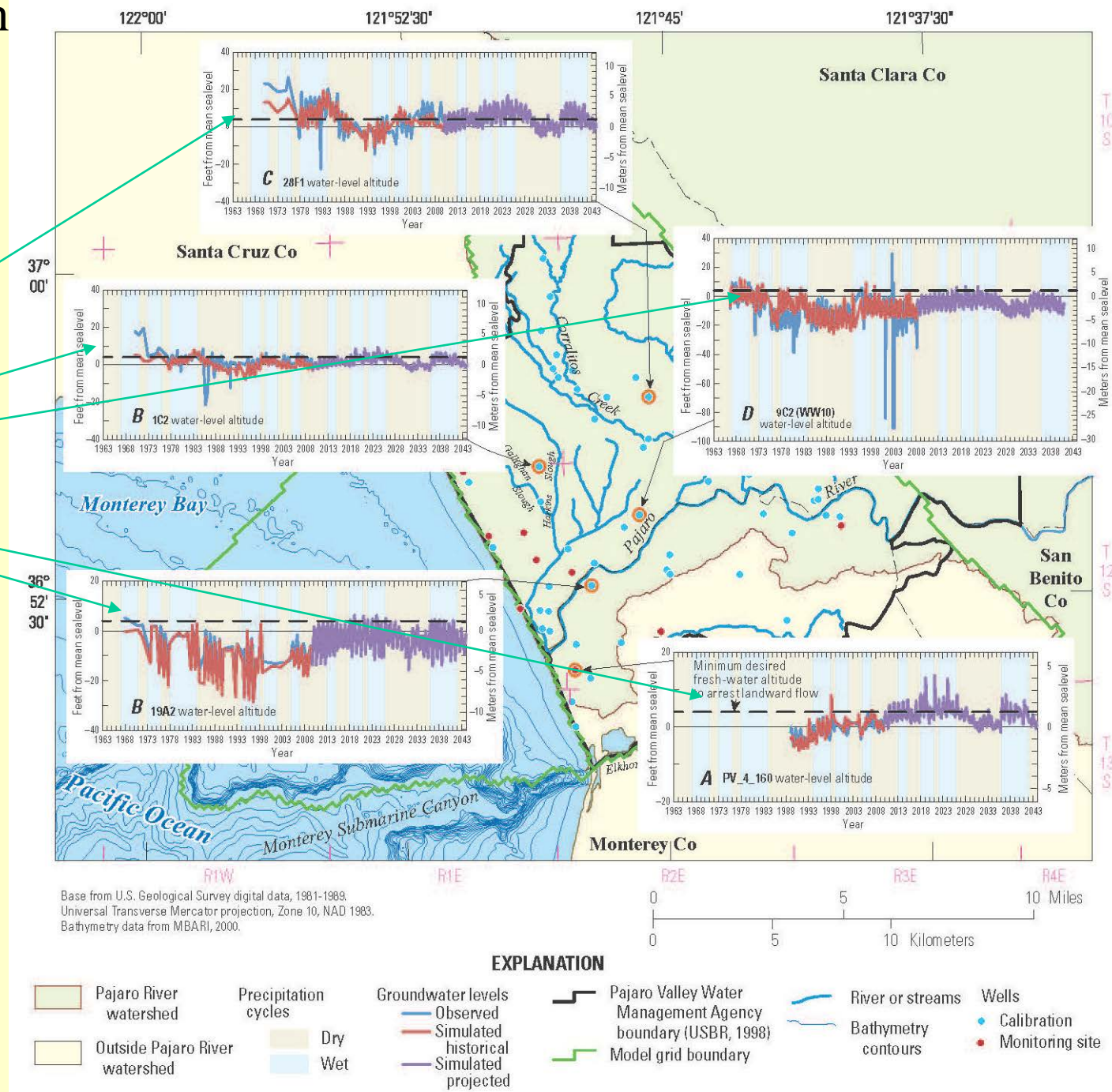
- Supply-and-Demand Framework and Water Balance subregion design (Pajaro Example – shown later)
- Water Budgets, undesirable results metrics, and thresholds (Pajaro Example)
- Projections of Sustainability and Adaptation (Cuyama Example – shown later)



One Water

# Projections of Sustainability and Adaptation

- Example of Future Analysis of Current Mitigation Projects using One-Water in Pajaro Valley
- Used to develop a new Basin Management Plan that includes additional projects to reduce overdraft & increase capture/use of local runoff, recycled water, ASR, & MAR
- Dashed Lines are Potential Thresholds Equivalent Fresh-water Head for that aquifer as an indicator of potential seawater intrusion.



# Potential Conjunctive-Use Questions

- (1) How does increased irrigation efficiency affect recharge, reuse, surface-water conveyance, GDEs?**
- (2) How will water reuse affect gw storage depletion & surface-water conveyance?**
- (3) How do unpumped multi-aquifer wells contribute to conjunctive use and deep-aquifer recharge?**
- (4) How can captured Recharge/Discharge affect sustainability of gw storage, springs/streamflows, fish migration, stabilizing GDEs?**
- (5) How can changes in land use affect sustainability or facilitate water markets?**
- (6) How does climate affect different response in subregions?**



# Today's Update

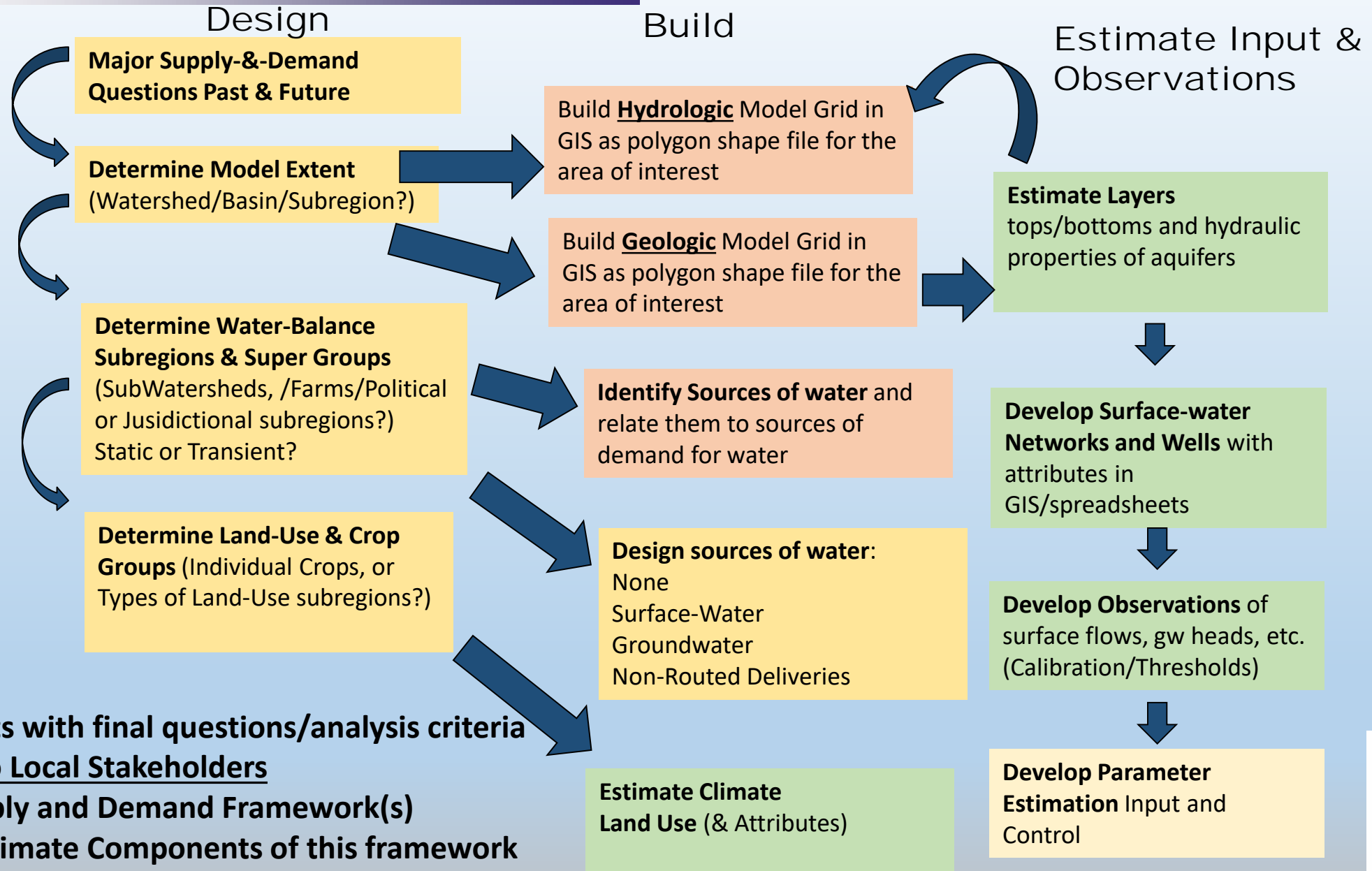
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# Model Design/Build

## Workflow Process



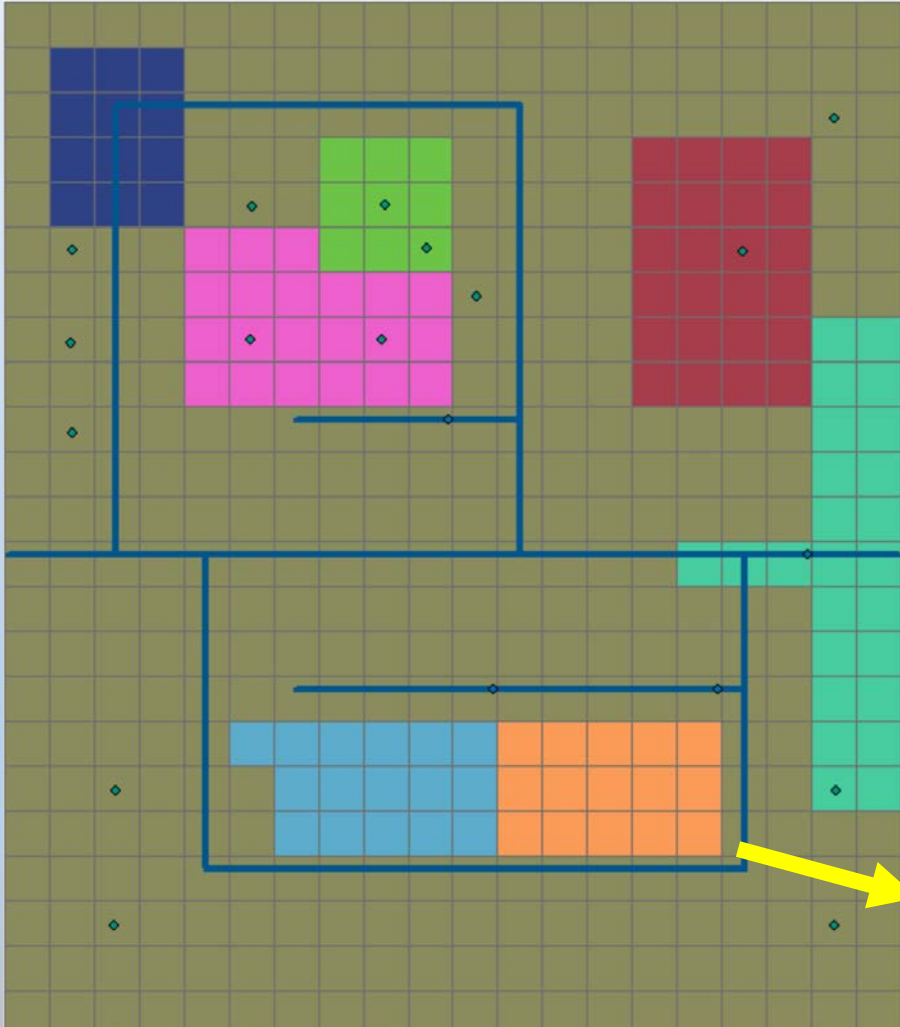
- 1) Design starts with final questions/analysis criteria
- 2) Outreach to Local Stakeholders
- 3) Define Supply and Demand Framework(s)
- 4) Identify/Estimate Components of this framework (MODEL Development: Top → Down & Outside → In)





One Water

Water Budgets for Agriculture start on the Landscape with the Farm Process → Establishes a supply-and-demand framework for a group of land uses and governance



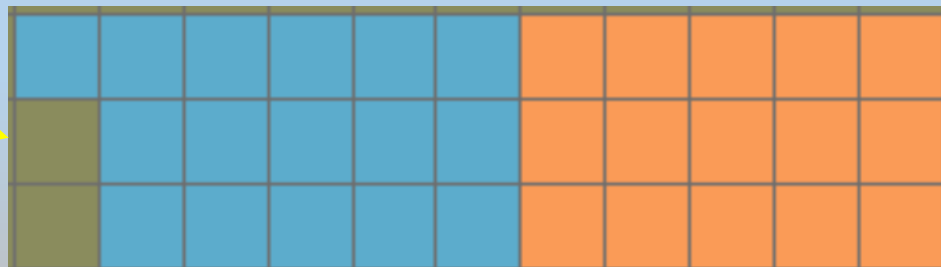
A water demand is calculated for each Land Use in each cell

A Water-Balance Subregion (WBS) defines a group of land uses (source of demand) with common water supply

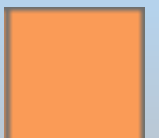
Precipitation, Wells, stream diversions, reservoir releases, non-routed deliveries (pipelines, reuse, ASRs), and groundwater are potential sources to meet demands

Supply and demand are accounted for cell-by-cell in each WBS

WBS (Farm)

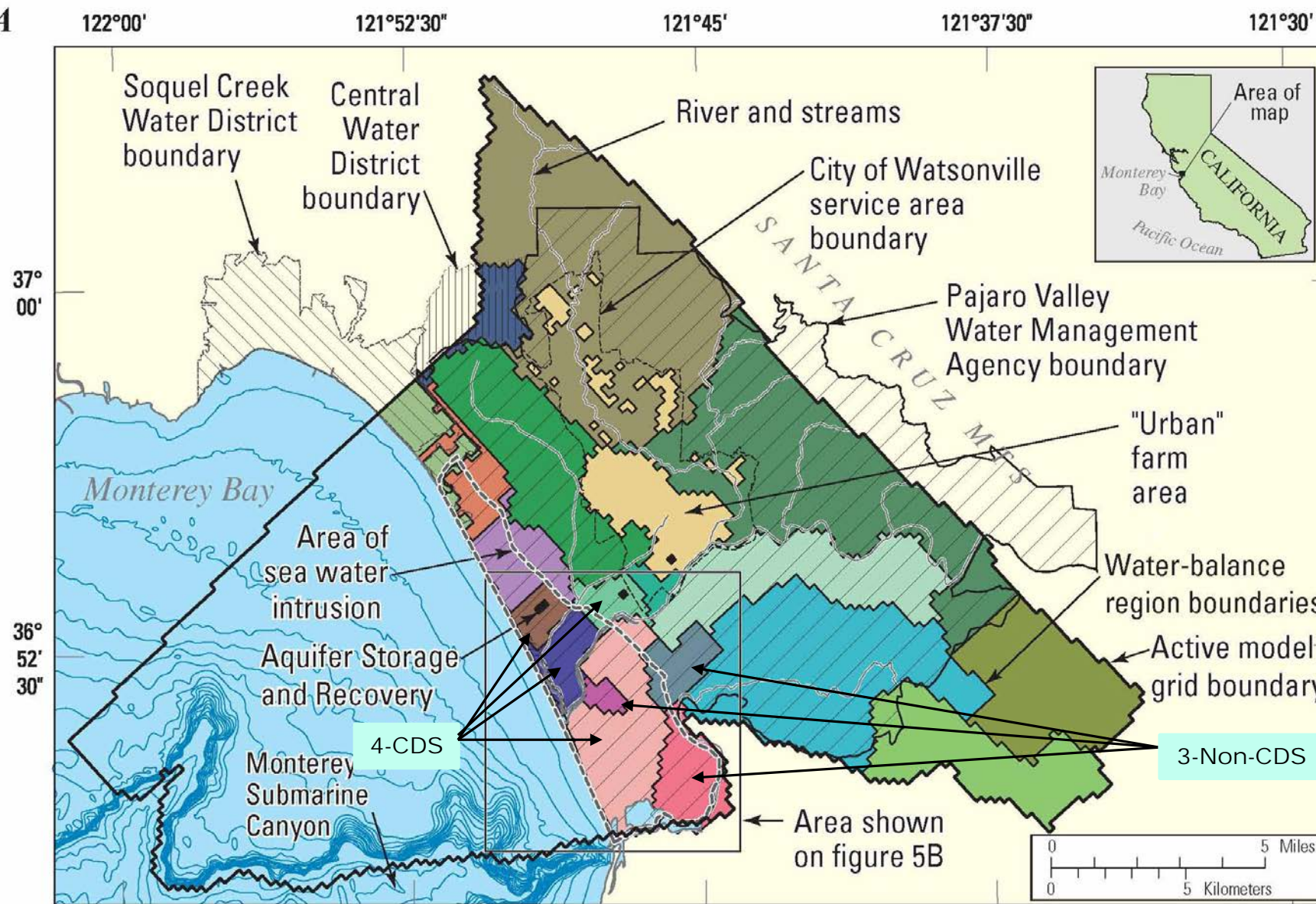


Land Use (crop)





A



## Supply-and-Demand Framework

### WBS Categories (24 Onshore-Static)

- 2-Districts (GW driven) (2)
- 1 Urban (GW +SW) (1)
- 1 ASR (Diversion for AG) + supplemental & blend wells (4)
- Subwatershed regions (10)
- 4 NRD's for Recycled Water for AG  
→ Coastal Delivery System (CDS) (NRD's Variable in time) (4)
- Non-NRD's (3)

### Grouped WBS - "Super Groups"

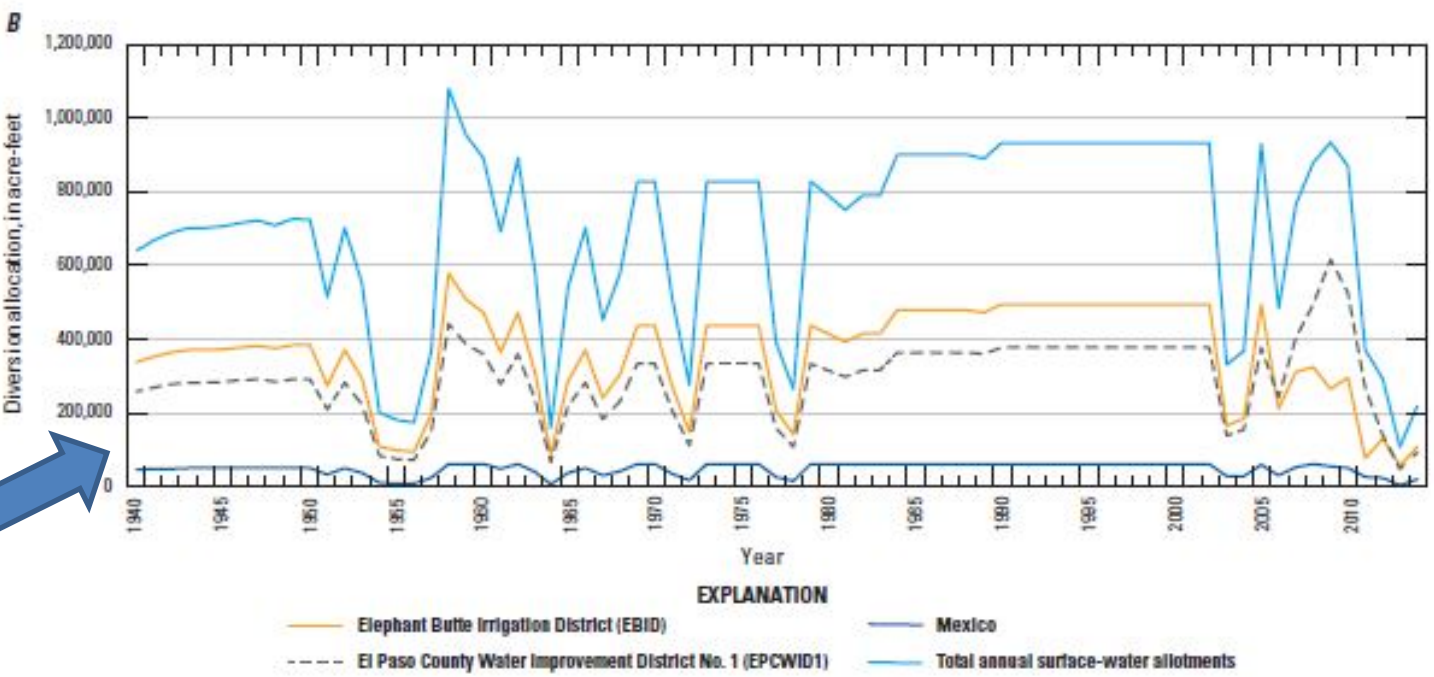
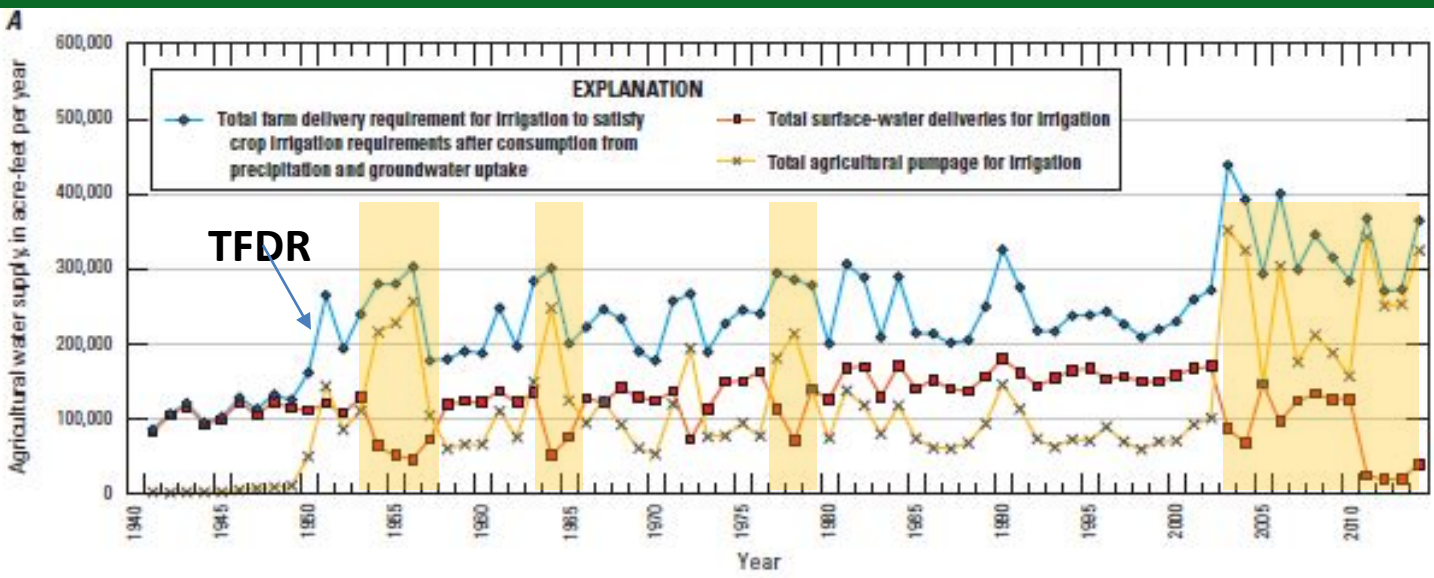
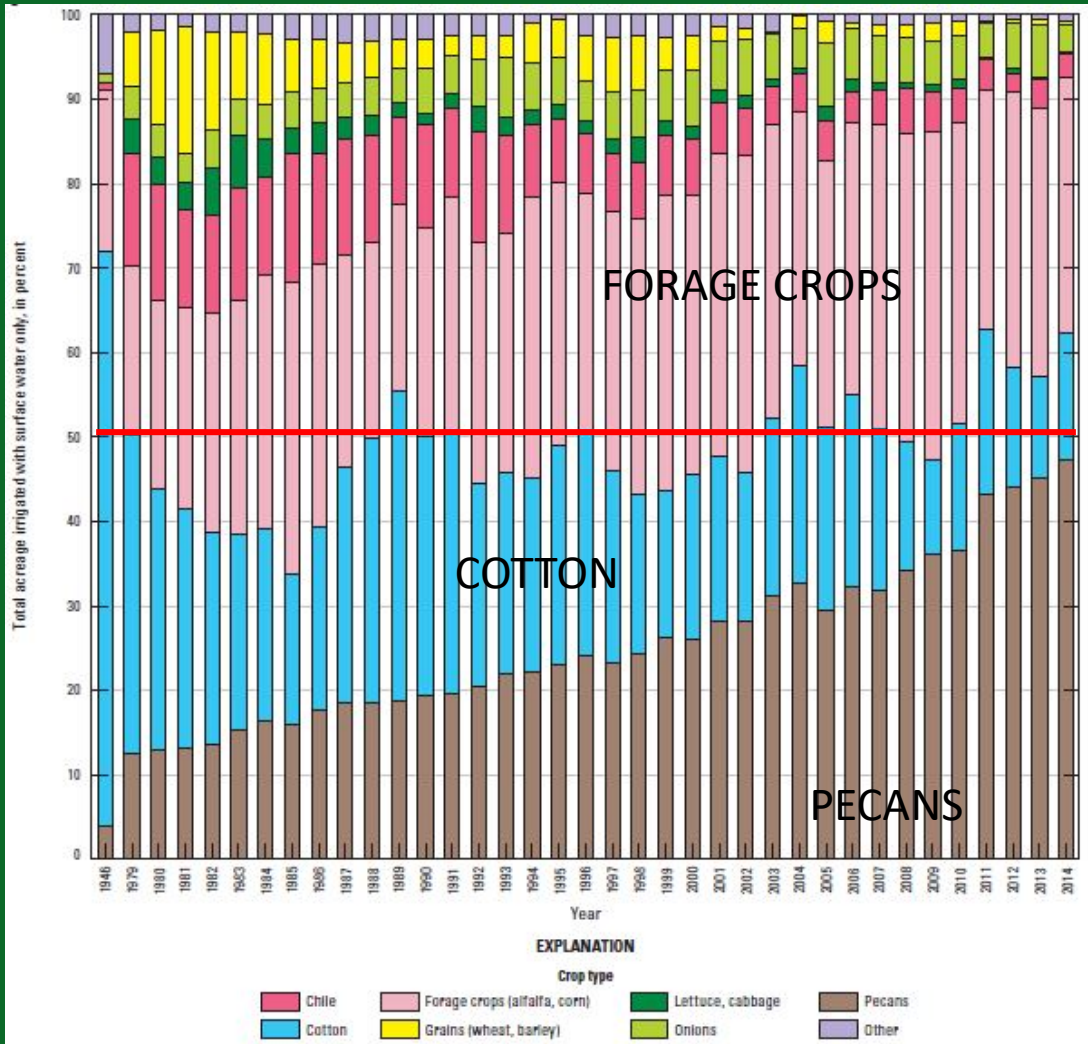
- (1) Santa Cruz County Inland (2)
- (2) Monterey County Inland (4)
- (3) Santa Cruz County Water Districts (3)
- (4) Santa Cruz County coast CDS (3)
- (5) Santa Cruz county coast non-CDS (4)
- (6) Monterey County coast CDS (1)
- (7) Monterey County coast non-CDS (3)
- (8) ASR system (4)

Pajaro Valley Hydrologic Model → Budget Groups and Basin-Wide Budget Modified from Hanson et al., 2008

Water-balance subregions (WBS) used in PVHM to assess conjunctive use, coastal pumpage, and related sea water intrusion in Pajaro Valley, California (modified from Hanson et al. 2008).



Increased Water Demand and "Hardening of Demand" with more Pecan Orchards (permanent crops)



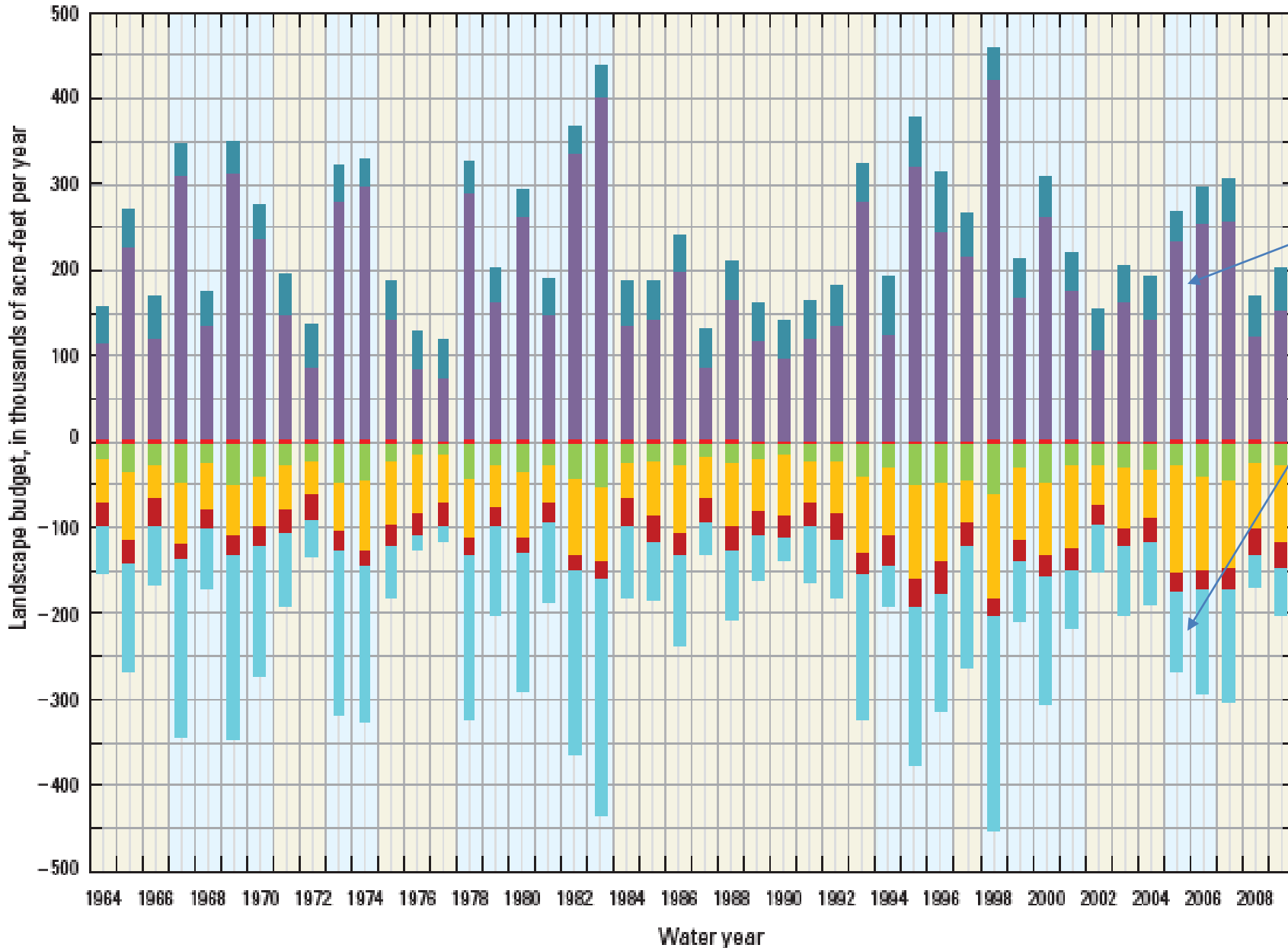
Lower Rio Grande Supply-and-Demand Budget: TFDR - TOTAL FARM DELIVERY REQUIREMENT (IRRIGATION DEMAND)

Increased TFDR and Groundwater use in dry years with less surface-water allocations





# Example Landscape Budget, Pajaro Valley, CA



Flows into & out of Landscape show large portions of Inflow → Precipitation  
Outflow → Runoff

With large amounts of potential runoff (Precipitation, Tile Drain Capture, Excess NRD's) PVWMA has implemented a Recharge credit program separate from their pump augmentation fee

**EXPLANATION**

Landscape budget through time for Pajaro Valley, California

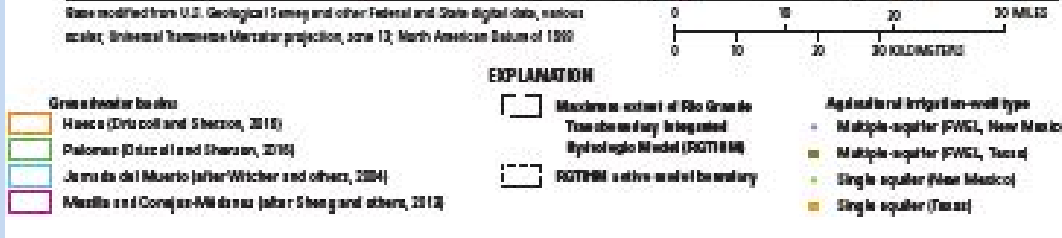
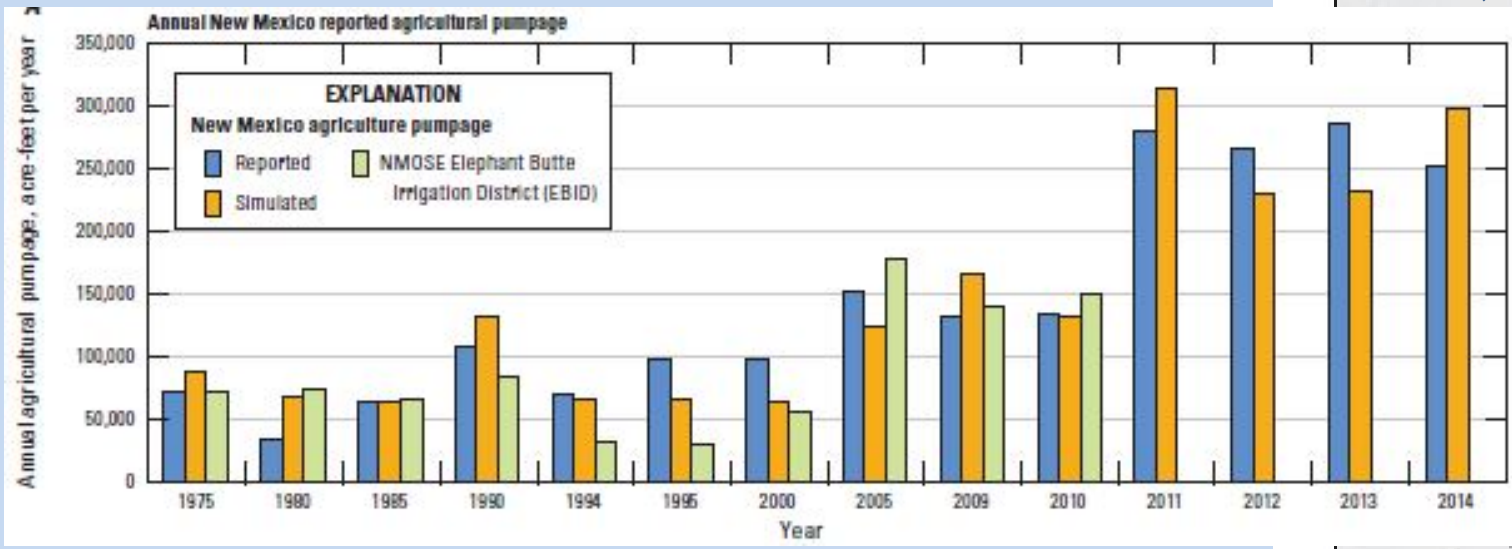
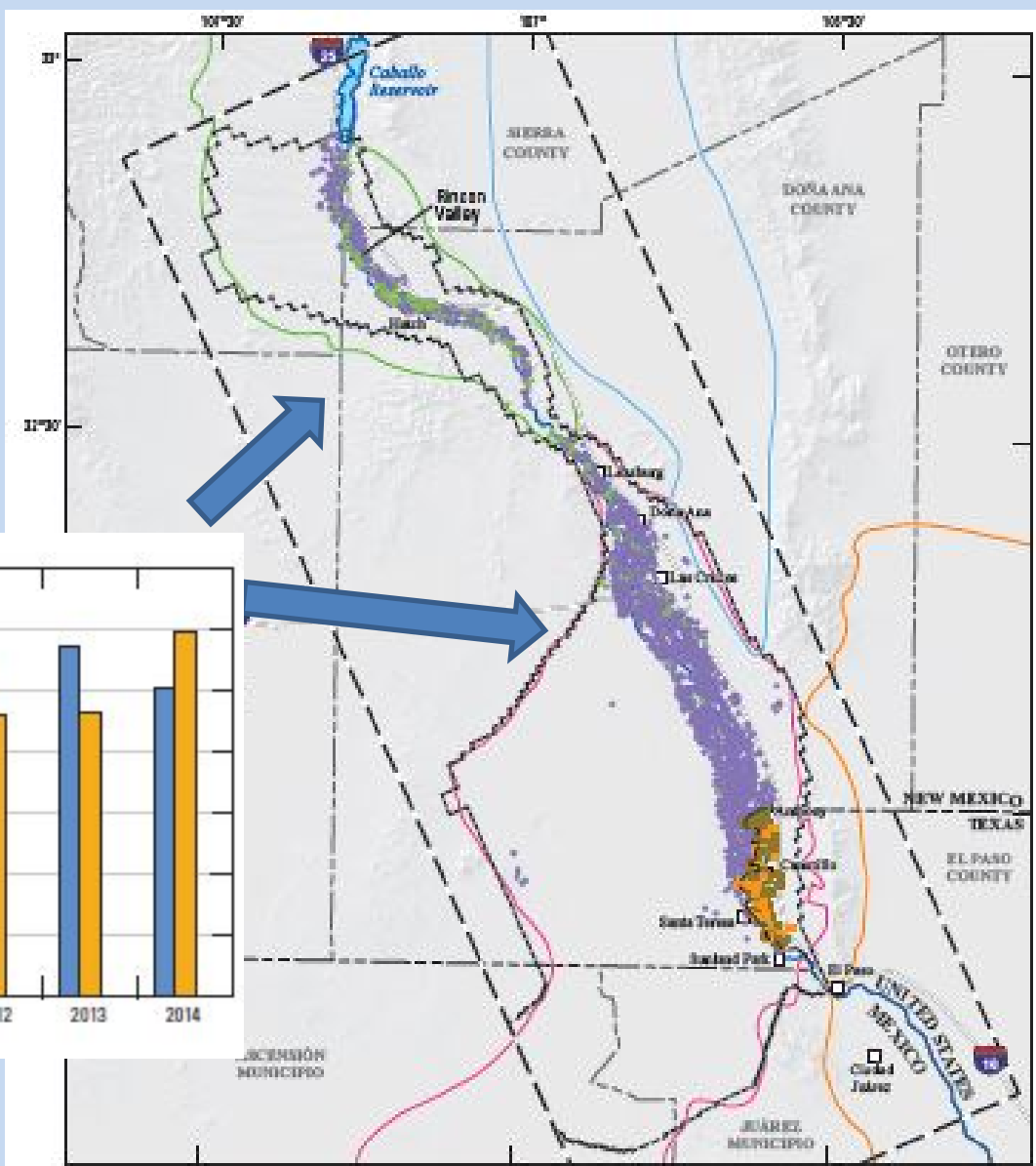
- Pumpage
- Precipitation
- Evapotranspiration from groundwater
- Deep percolation
- Evapotranspiration from precipitation
- Evapotranspiration from irrigation
- Runoff

Recent precipitation cycles

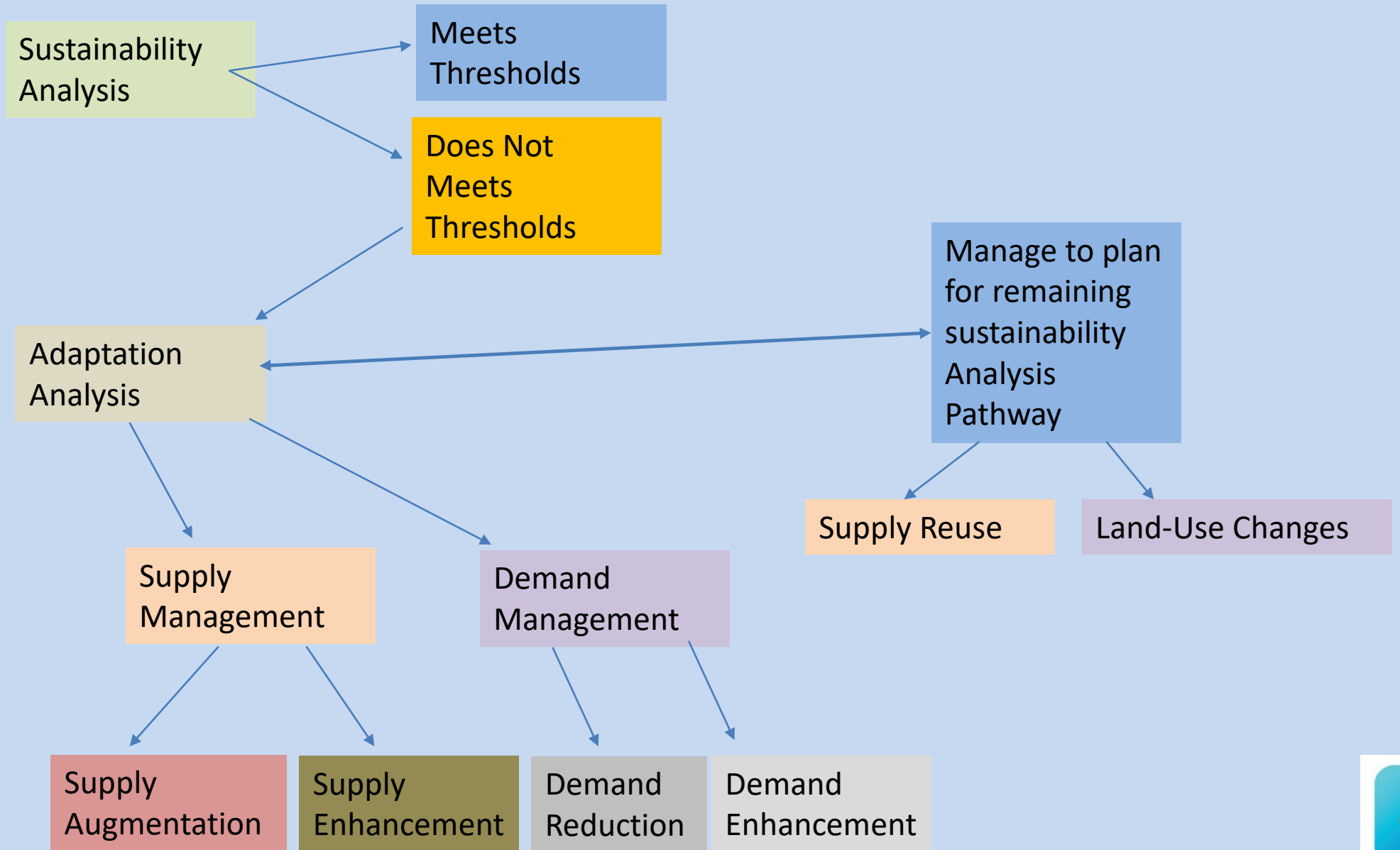
- Dry
- Wet

# Example of Pumpage Budget: Lower Rio Grande Annual Ag GW Pumpage, New Mexico from thousands of Agricultural wells

Matches Reported Annual Agricultural Pumpage for Irrigation:  
 (~6% Average Annual Percent Error)



# Sustainability Analysis Pathways

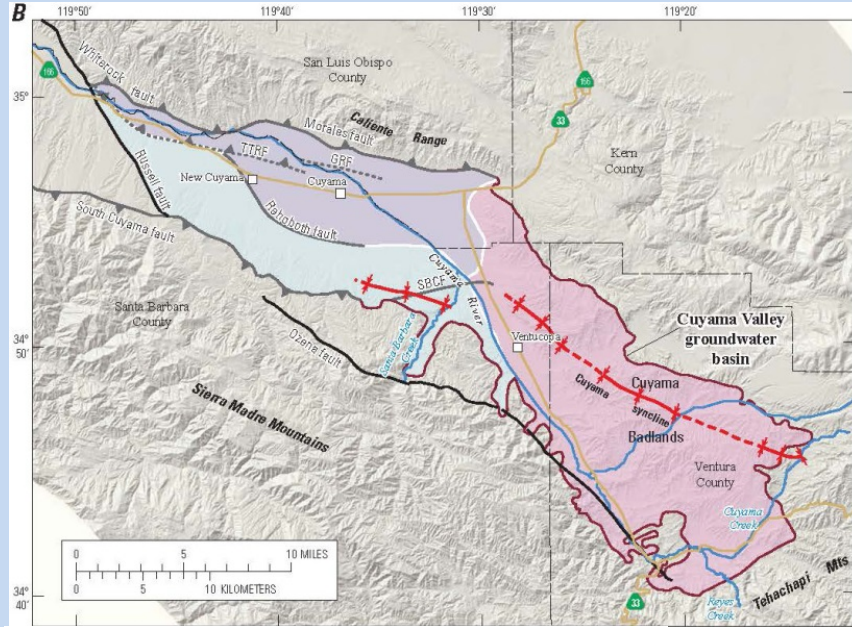
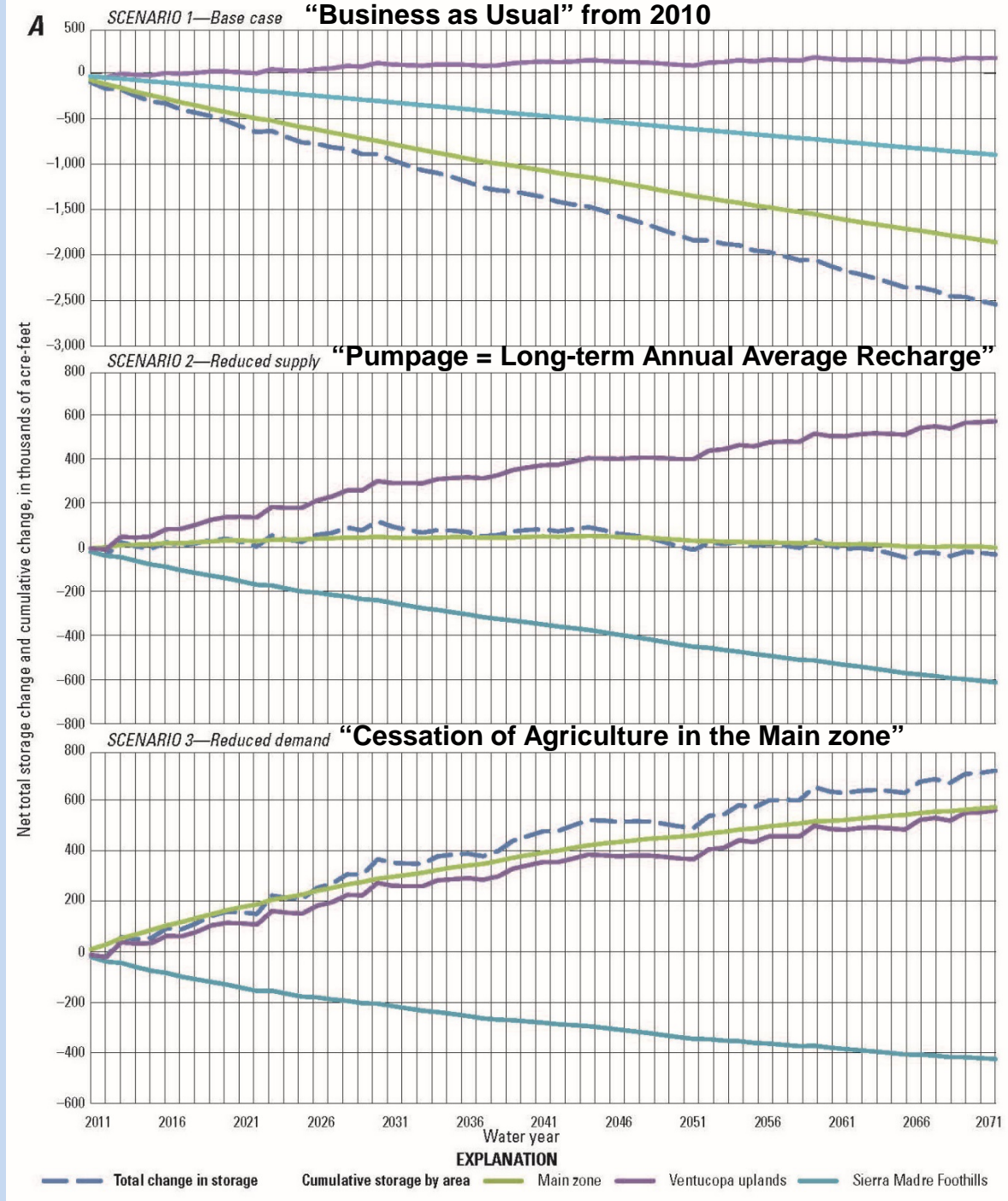


# Example of Agricultural Sustainability Projections: Modeled Changes in Projected Groundwater Storage in Cuyama Valley

No Supply or Demand Management: Not Sustainable Continued Storage Depletion into Future

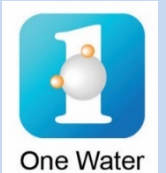
Demand Management (Adjudication Scenario): Overall Sustainable with Accretion and Depletion in Subregions into Future

Demand Management (Land-Use Change): Overall Storage Recovery of about 1/4 of Historical Depletion into Future



## Simplified Cuyama groundwater basin zones

- Main
- Sierra Madre Foothills
- Ventucopa Uplands





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# San Joaquin River Restoration Project

Unexpected Result → Seepage in vineyard on right bank of San Joaquin River during high flow releases (4/13/11)



One Water

# Groundwater Sustainability Indicators

**Not Causing Undesirable Results:  
Means Avoiding Significant and Unreasonable ...**

**Lowering of  
GW Levels**

**Reduction of  
GW Storage**

**Seawater  
Intrusion**

**Water Quality  
Degradation**

**Land  
Subsidence**

**Depletion of  
Surface Water**

**Napa Valley Hydrogeologically  
Sensitive to this Indicator**

# Minimum Thresholds and Measurable Objectives

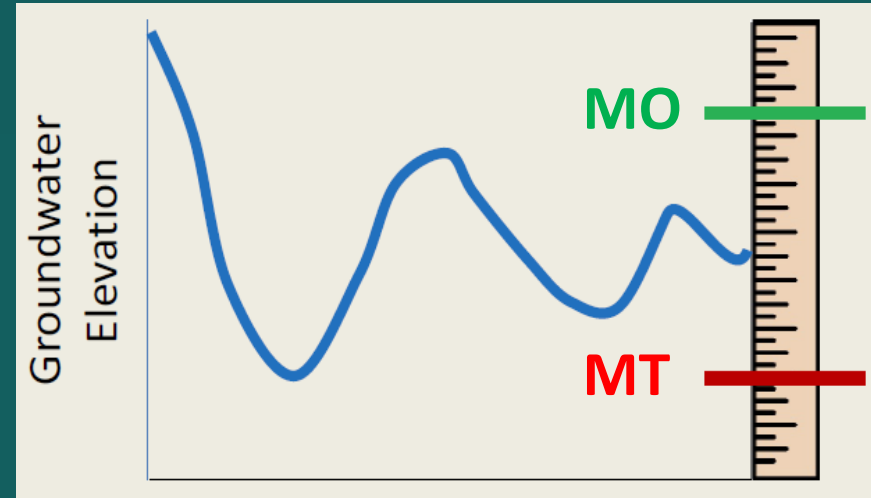
- **Minimum Threshold (MT)**

“a numeric value for each sustainability indicator used to define undesirable results” (Sec 351)

- **Measurable Objective (MO)**

“specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions” (Section 351)

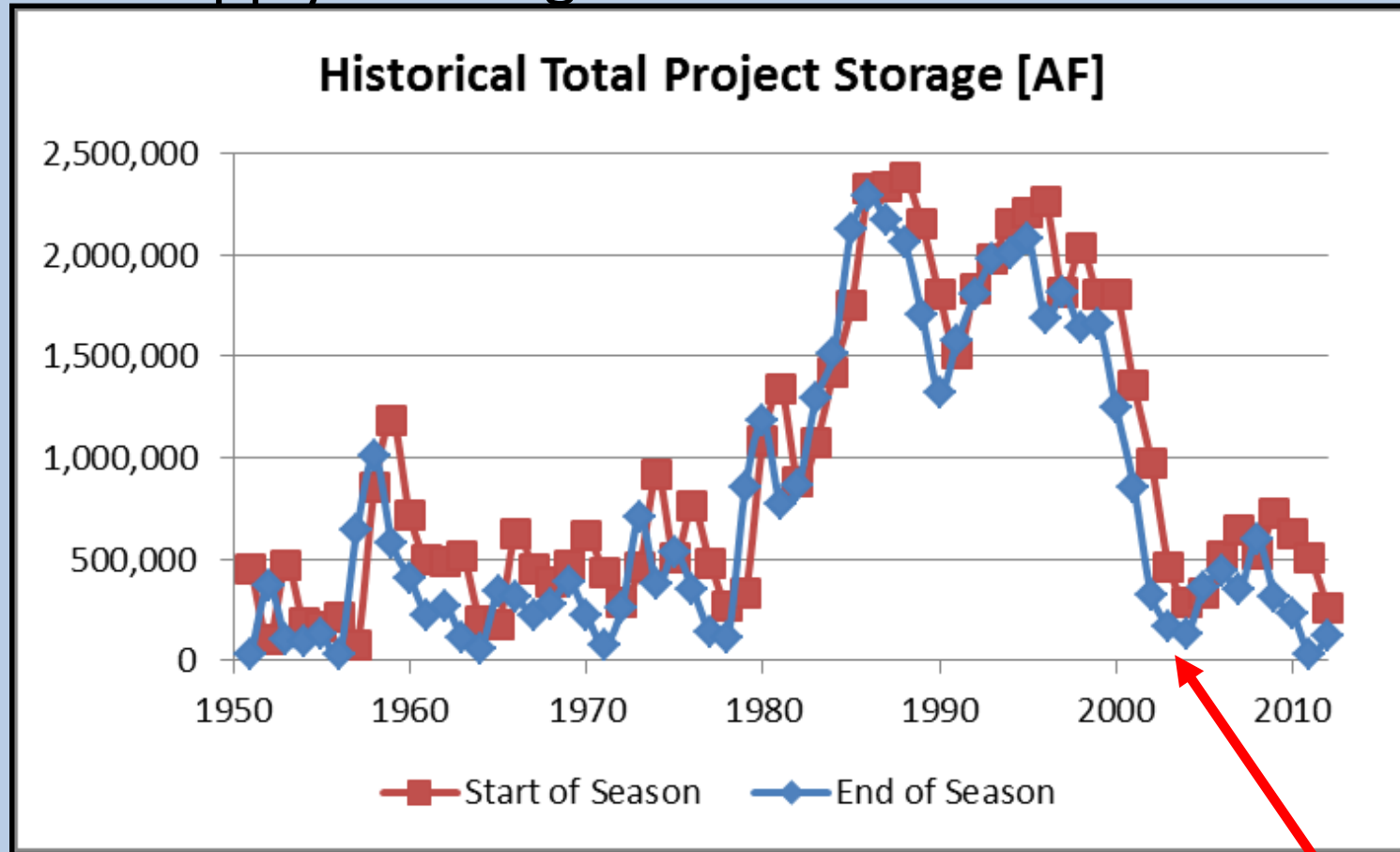
**Measurable objectives and minimum thresholds are established to ensure GW sustainability or improve GW conditions.**



(DWR, March 2016)

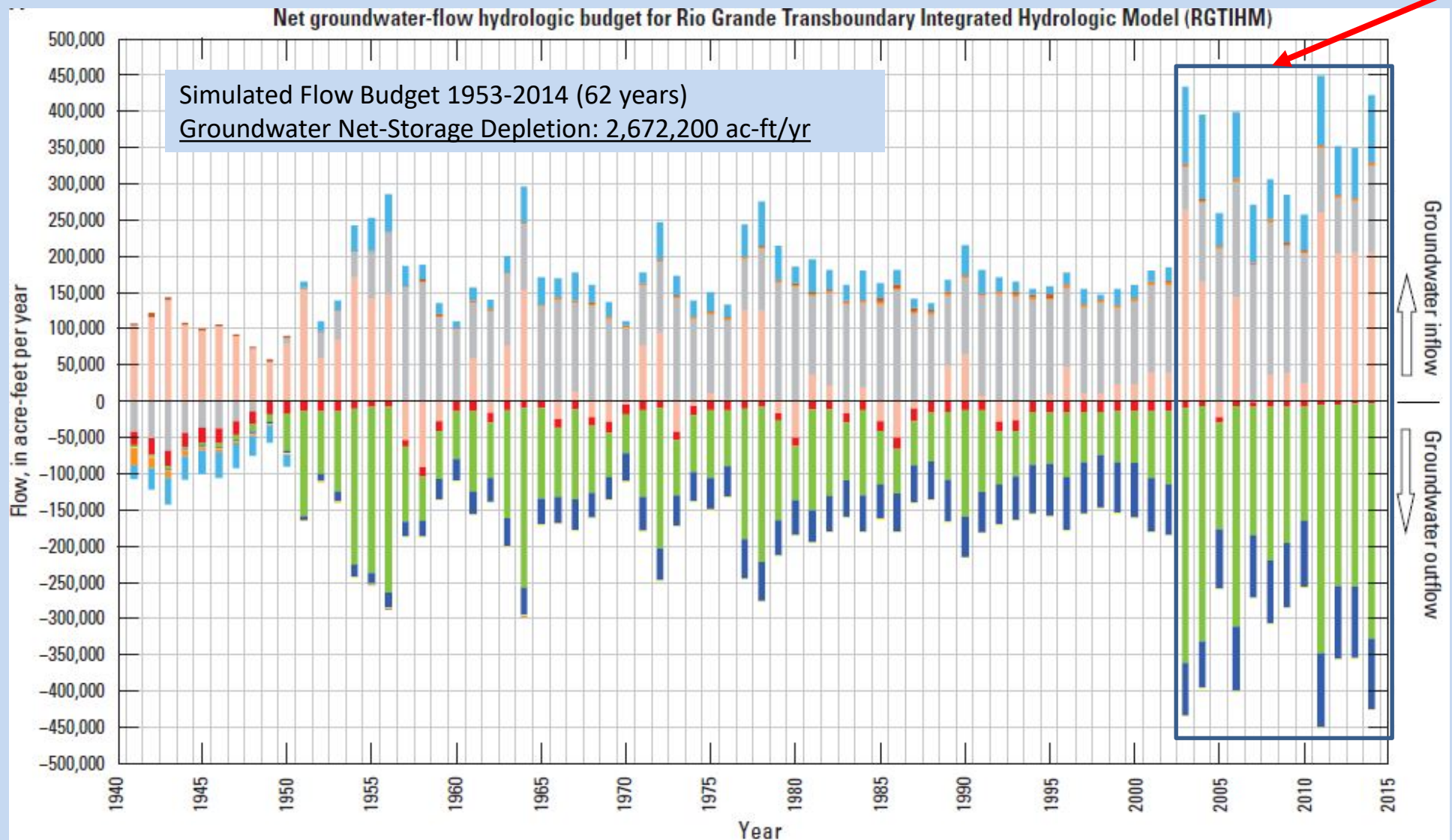


# Changes in Supply = Changes in Surface-Water Availability



Lower Rio Grande (NM, TX, MX) -- Beginning in 2003, surface-water shortages (Surface-water drought conditions) have also contributed to increases in supplemental groundwater use.

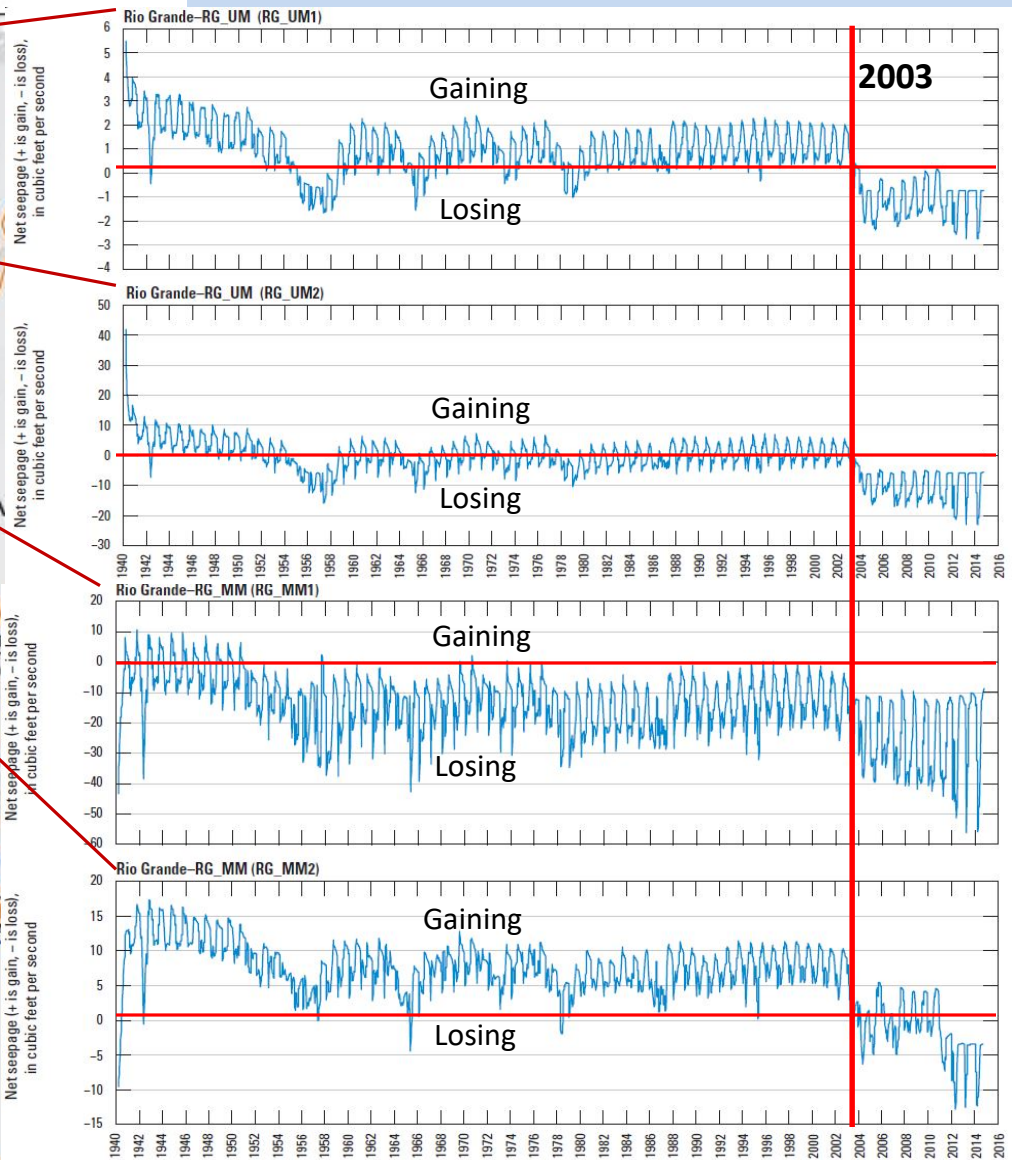
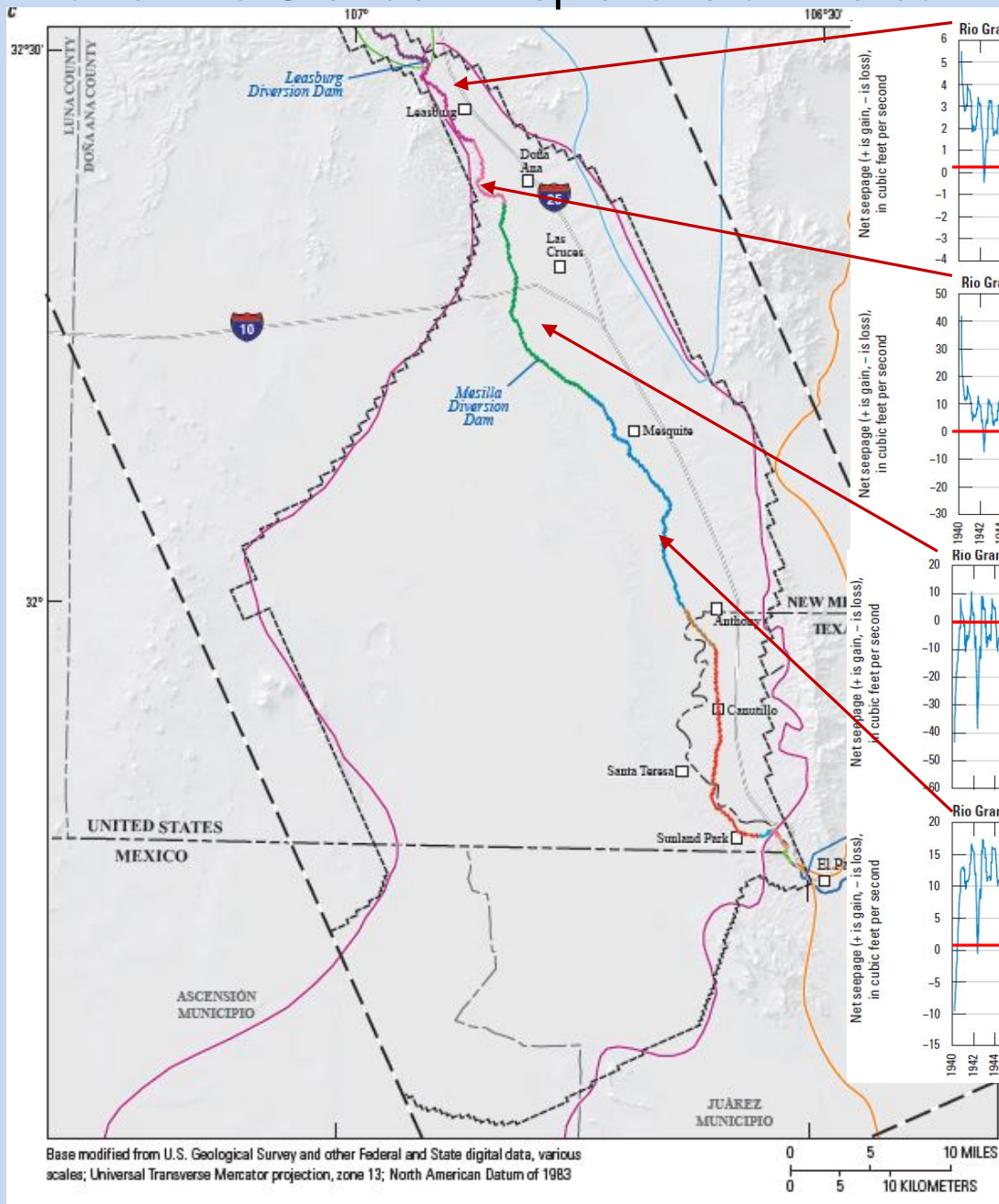
# Lower Rio Grande: Groundwater-Storage Depletion: cyclic and sustained after 2003



- EXPLANATION**
- Farm—net recharge
  - Net riparian (RIP) evapotranspiration
  - Domestic pumpage
  - Net head dependent bounds (underflow)
  - Net aquifer storage loss
  - Agricultural pumpage
  - Municipal and industrial pumpage
  - Net reservoir leakage
  - Net stream leakage from groundwater



# Lower Rio Grande -- Depletions of Interconnected surface-water (gw-sw):



Streamflow Capture → 7,411,480 Ac-Ft (1953-2014)

Changes with SW Availability & Location. Changes to losses after 2003 almost everywhere





# Questions about GW/SW in Napa?

- How do variations in the spatial distribution, timing, and amount of precipitation affect:
  - GW recharge?
  - GW discharge to the river system?
- How much annual land surface runoff and GW discharge to the river system leaves the Napa Valley Subbasin and flows to the San Pablo Bay?
- What benefits would occur with strategic stormwater capture:
  - With targeted recharge in suitable Subbasin areas?
  - With seasonal use of retained stormwater in lieu of pumping?
- What regions within the Napa Valley Subbasin are potentially more sensitive to streamflow depletion due to climate factors and/or pumping?
  - What strategies could be implemented to buffer or reduce such effects?
- What benefits may occur in response to stream restoration activities:
  - Related to streamflows?
  - Related to GW levels?
  - Related to habitat (GDEs) or fish passage?
- How can Reuse of Recycled Water or Captured Runoff supplant or supplement current GW



One Water

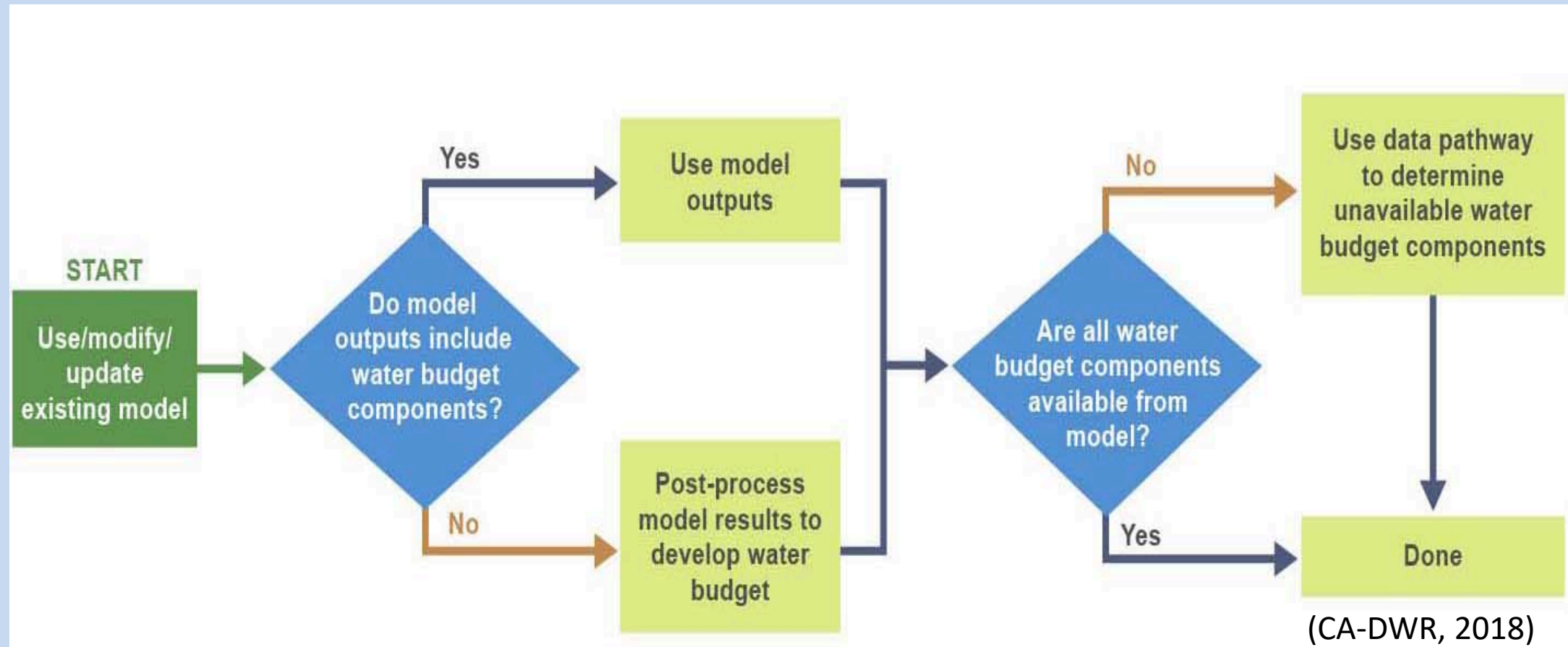


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## Develop & Maintain Data Networks and Model(s) for Hydrologic Budgets & Sustainability/Adaptation Analysis

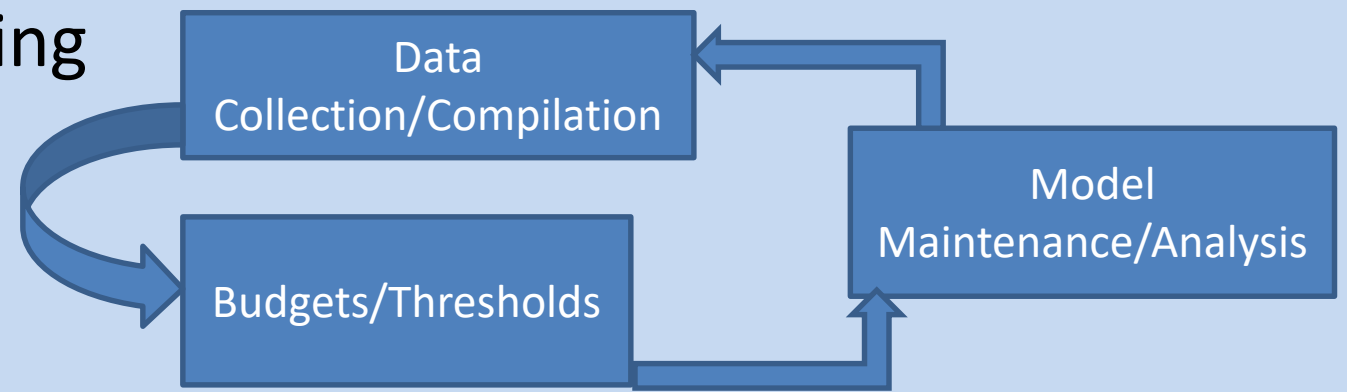


(1) Can your data represent & model simulate all of the features needed and provide a Hydrologic Budget regularly that is acceptable to the DWR criteria under CA-SGMA?

(2) Can your model and data streams from data networks help keep model, hydrologic budgets, and threshold analyses current?



# The Cycle of Data/Model/Reporting



- Updates

New Spatial Input → Land Use, Climate (Precipitation, Potential ET), Wells (?)

New Temporal Model Input →

- (a) Input:

- Streamflows, municipal and domestic pumpage, NRD's, Recycled Water, other sources

- (b) Observations:

- Groundwater Levels, streamflows, Actual ET, Agricultural Pumpage

- Budgets and Thresholds

- (a) Basinwide Analysis

- (b) Subregional Analysis

- Model Maintenance

- (a) New Features

- (b) New Analysis: Updates, Scenarios (Sustainability/Adaptation)



# GROUNDWATER SUSTAINABILITY = VINEYARDS FOREVER ?

Napa Valley, California

THE END - THANKS !

QUESTIONS & DISCUSSION ?



**Luhdorff &  
Scalmanini**  
Consulting Engineers



One Water



# Next Steps for the Napa Valley Hydrologic Model

## Updated Spatial Water Demand Datasets

Production well locations (known and inferred locations)

Merging SWRCB and CDFW diversion location info

Public water system production and delivery data

## Expanded Spatial Geologic Datasets

Alluvium thickness and geologic characteristics in southern Napa Valley

# Next Steps for the Napa Valley Hydrologic Model

## July 2019 – December 2019

- Receive stakeholder input on water demands and management practices
- Finalize model design (incl. water budget subregions)

## January 2020 – June 2020

- Develop initial condition and boundary condition time series datasets
- Initiate model and present results at public meeting
- Prepare for simulations of future hydrology and management actions to be included in the Nov/Dec 2021 SGMA submittal