California Land Subsidence from Groundwater Extraction

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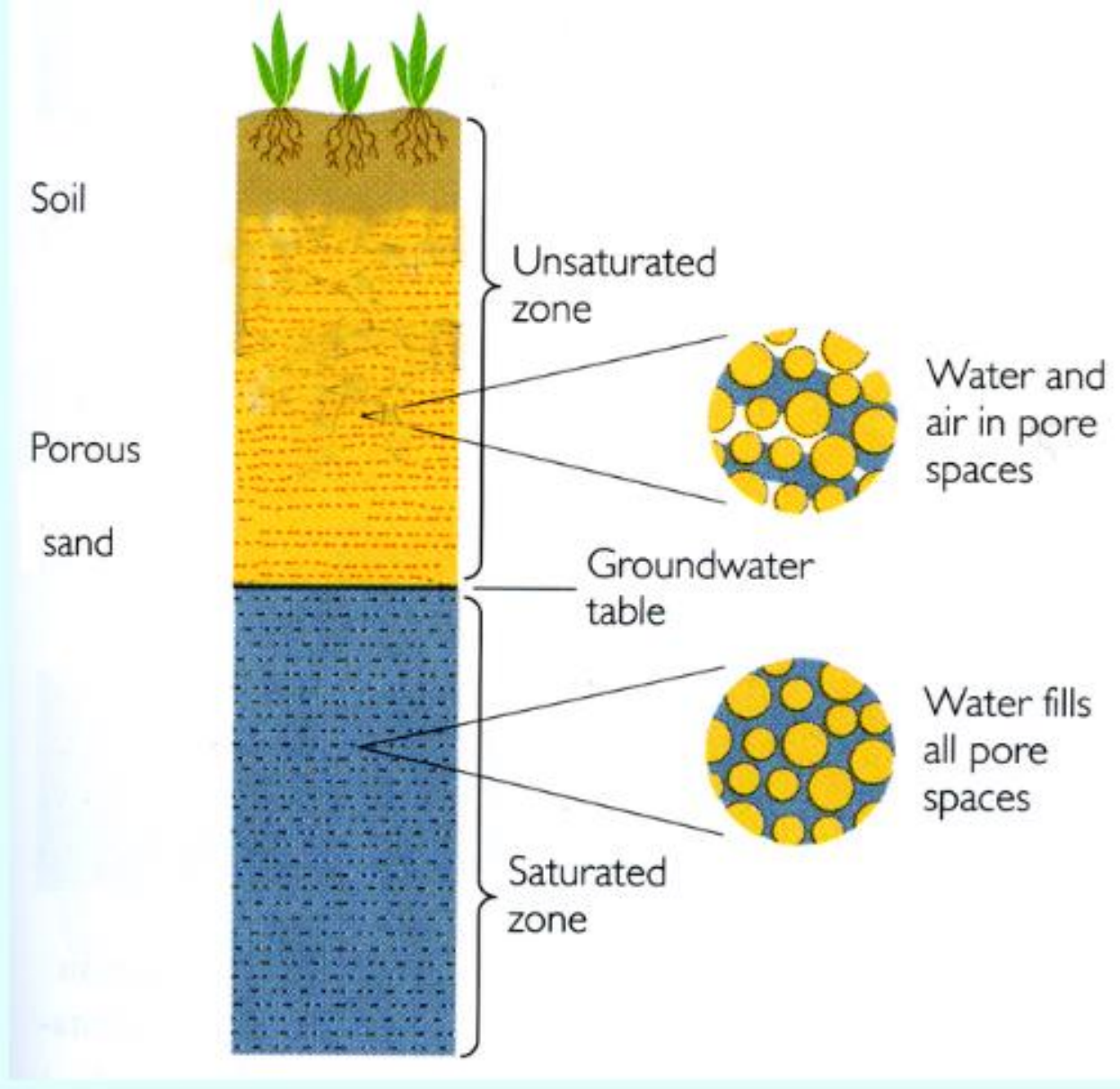
Land Subsidence Background

- Long California history of subsidence in unconsolidated sediments due to groundwater extraction (oil & gas extraction not covered in this presentation)
- San Joaquin Valley is most well-known area, Santa Clara Valley is another well-known historical area
- Subsidence risk depends on subsurface conditions
- Can damage infrastructure (above- and below-ground), change surface water flow patterns/drainage
- Often not visible if occurring over a wide area
- Historical in-situ monitoring by precise land levelling, only relatively recently by GPS

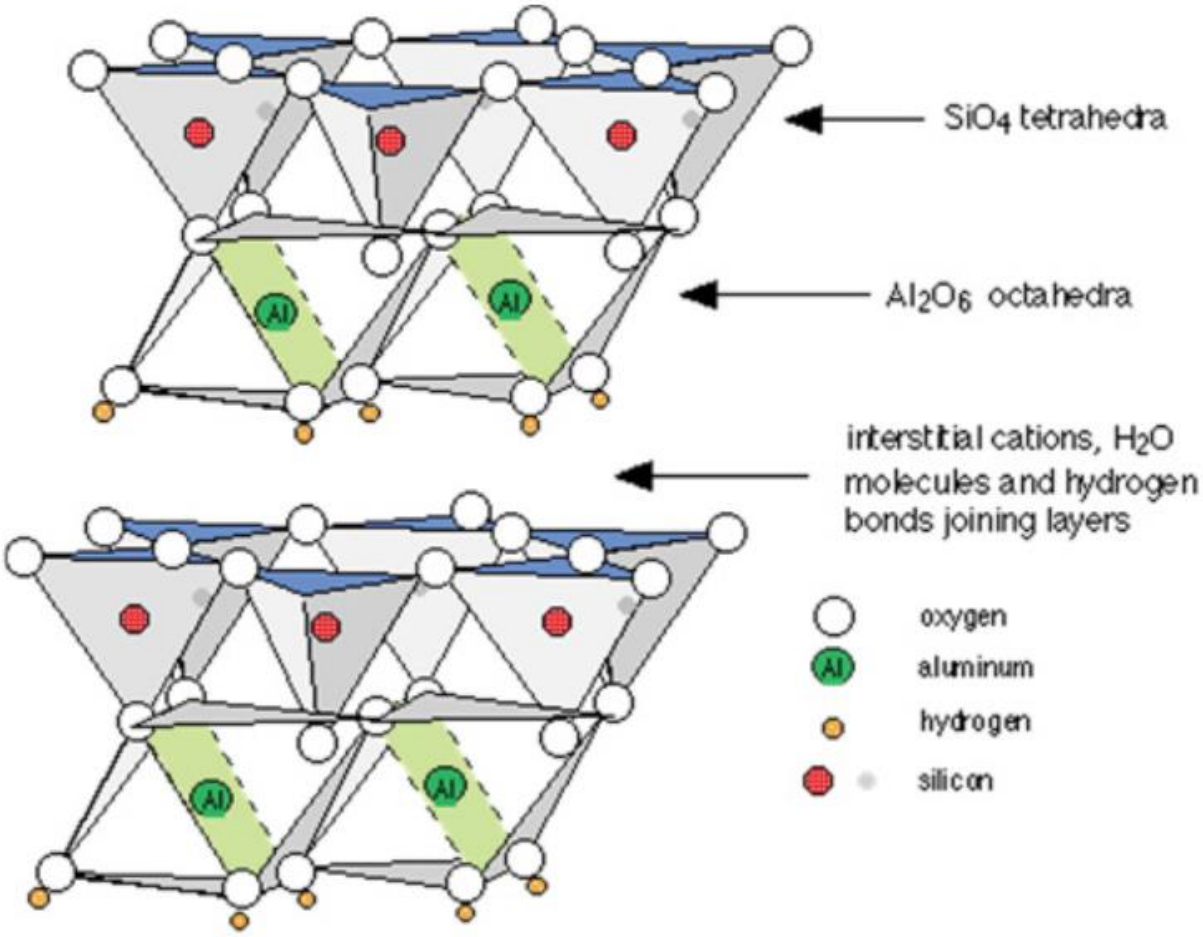
San Joaquin Valley Subsidence

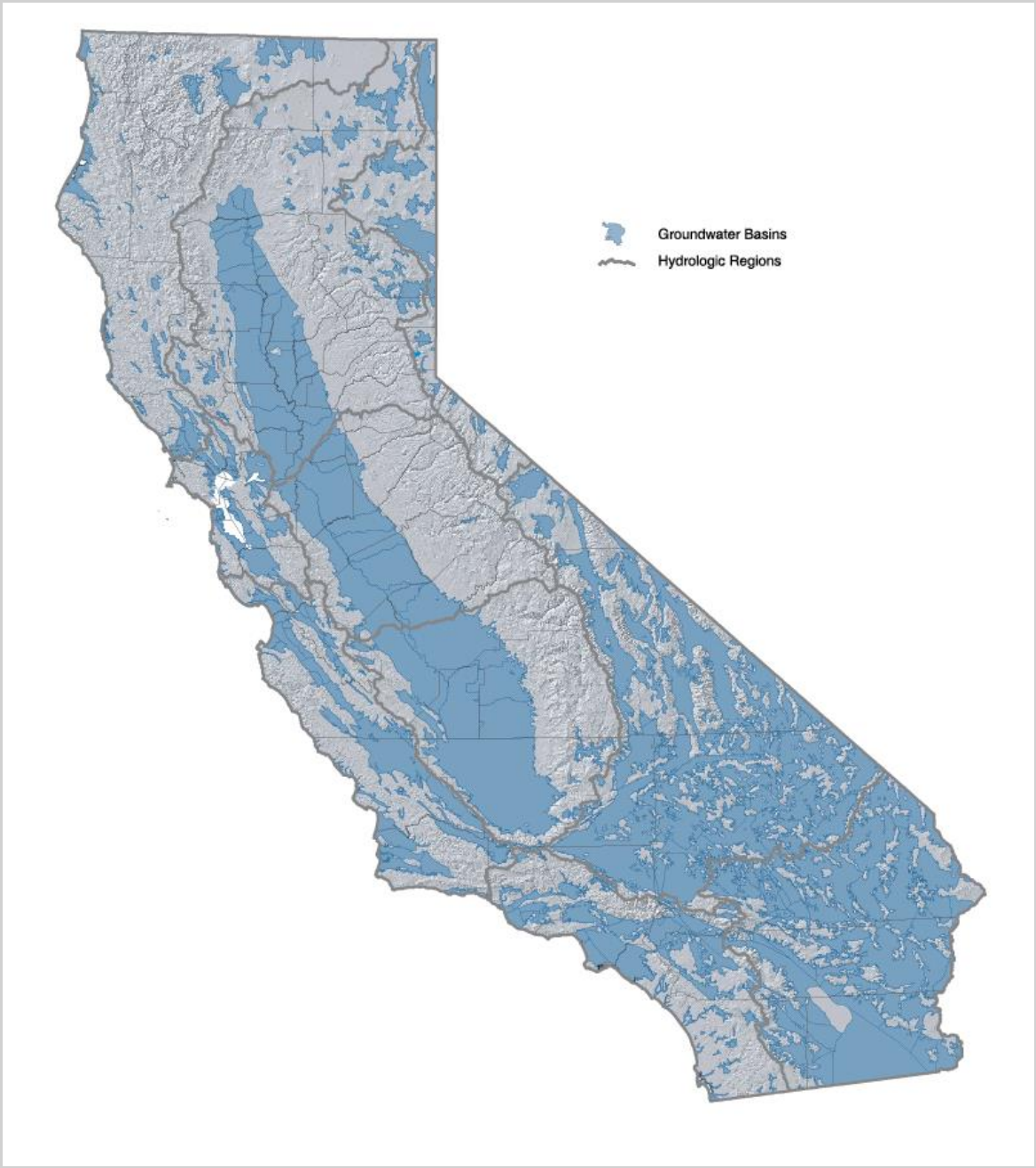
- Observed in San Joaquin Valley since 1920s; was considered in design of CVP & SWP. Historical SJV groundwater overdraft of 1 – 2 MAF annually, over many decades
- Subsidence initially decreased after water project construction provided new imported water
- But increased post-1990, as CVP & SWP imported supplies become increasingly unreliable
- Increased subsidence rates observed in 2007-09 drought, then 2012-16 drought, and 2020-22 drought because of surface water shortages

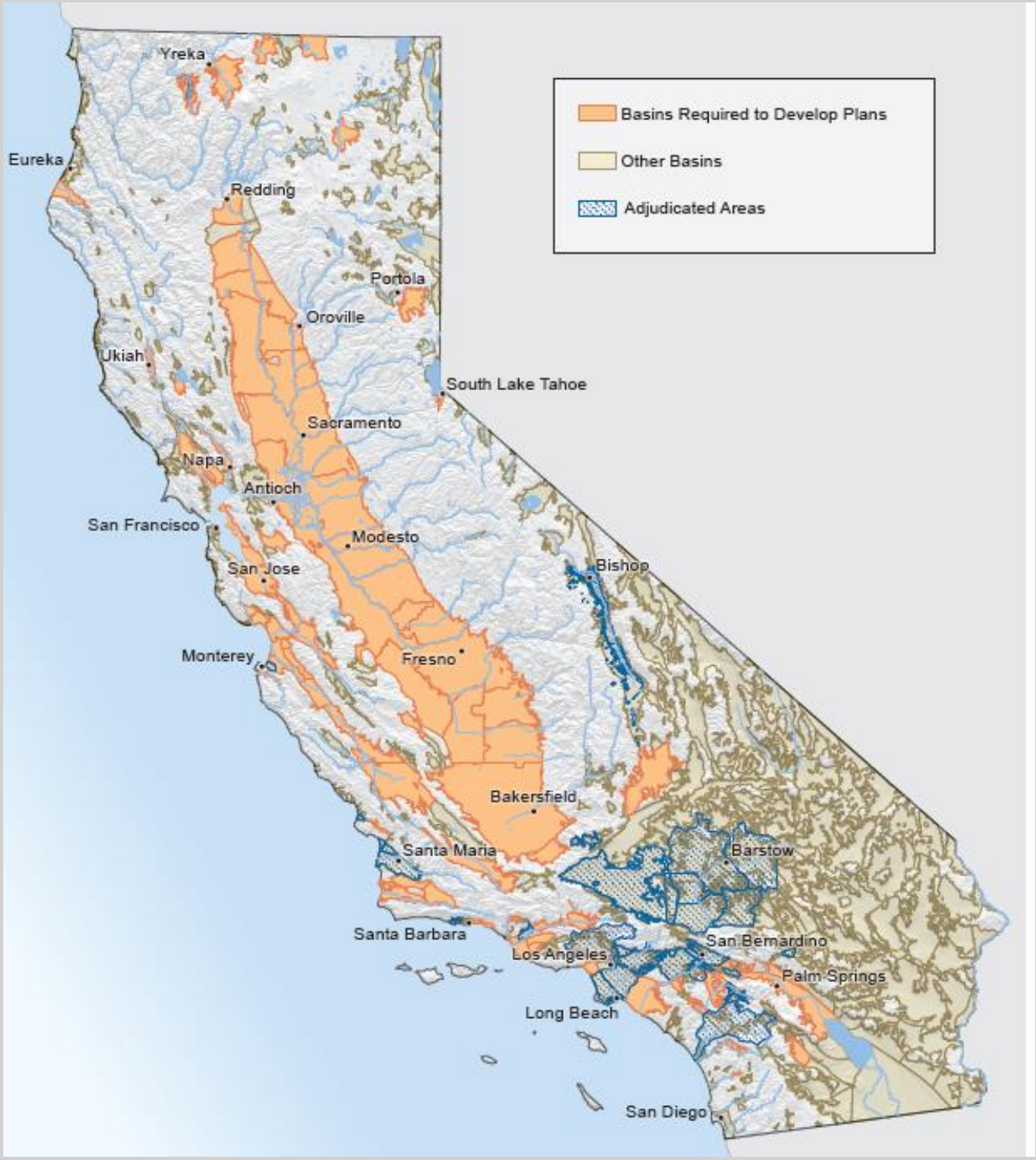
Subsurface Characteristics & Subsidence Risk



Clays


SiO_4 tetrahedra
Al_2O_6 octahedra
interstitial cations, H_2O molecules and hydrogen bonds joining layers
oxygen
aluminum
hydrogen
silicon
Al
Al
Al
Al


Groundwater Basins
Hydrologic Regions


Basins Required to Develop Plans
Other Basins
Adjudicated Areas
Yreka
Eureka
Redding
Portola
Oroville
Ukiah
South Lake Tahoe
Sacramento
Napa
Antioch
San Francisco
Modesto
San Jose
Bishop
Monterey
Fresno
Bakersfield
Santa Maria
Barstow
Santa Barbara
San Bernardino
Los Angeles
Palm Springs
Long Beach
San Diego


Tule Lake
Clear Lake
Trinity Lake
Shasta Lake
Whiskeytown Lake
Red Bluff Diversion Dam
Lake Almanor
Corning Canal
Tehama-Colusa Canal
Black Butte Reservoir
Glenn Colusa Canal
Stony Gorge Reservoir
Lake Oroville
East Park Reservoir
New Bullards Bar Reservoir
Lake Mendocino
Englebright Reservoir
Clear Lake
Indian Valley Reservoir
Lake Tahoe
Folsom Lake
Lake Sonoma
Lake Berryessa
Folsom South Canal
North Bay Aqueduct
Cosumne River Reservoir
Mokelumne Aqueduct
Hetch Hetchy Aqueduct
New Melones Lake
Contra Costa Canal
New Don Pedro Lake
Grass Lake
Lake McClure
Lake Crowley
South Bay Aqueduct
Delta-Mendota Canal
Madera Canal
Millerton Lake
Santa Clara Conduit
Pine Flat Lake
Hollister Conduit
San Luis Reservoir
San Luis Canal
Friant-Kern Canal
Lake Kaweah
Coalinga Canal
Success Lake
San Antonio Reservoir
California Aqueduct
Isabella Lake
Nacimiento Reservoir
Los Angeles Aqueduct
Cross Valley Canal
Twitchell Reservoir
Cachuma Reservoir
California Aqueduct
Castaic Lake
Lake Casitas
Silverwood Lake
Colorado River Aqueduct
Lake Matthews
Lake Perris
Coachella Canal
Henshaw Reservoir
San Diego Aqueducts
San Vicente Reservoir
All American Canal
Lower Otay Reservoir

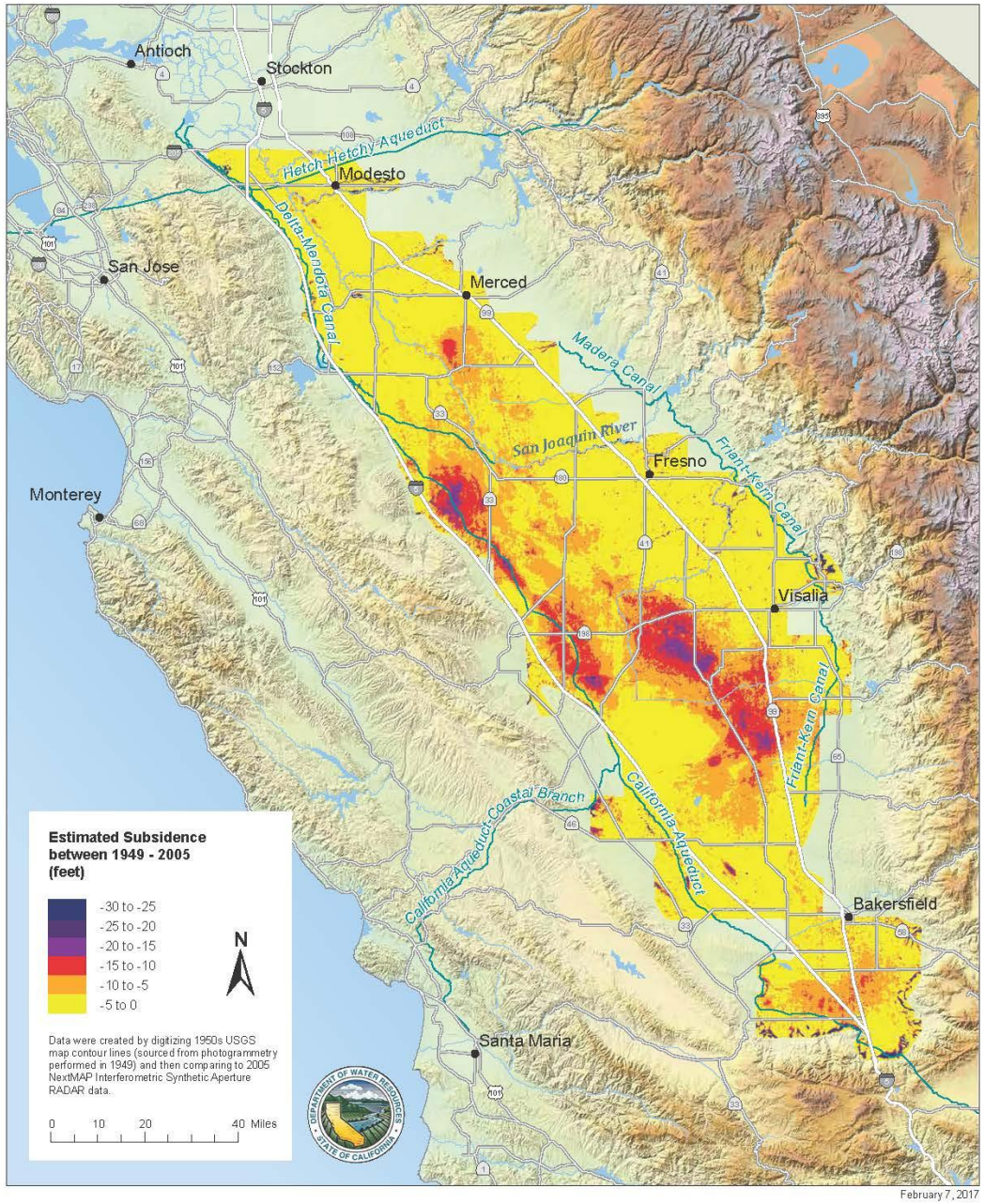
Risks to Critical Water Infrastructure

- Subsidence damages are cumulative over time, often not immediately apparent
- Reduces canal and floodway flow capacity (California Aqueduct, Delta-Mendota Canal, Friant-Kern Canal, Eastside & Chowchilla Bypasses), for example 60% capacity reduction in part of FKC
- Reduces levee freeboard & changes river gradients
- Destroys well casings

Russell Ave Bridge, Firebaugh

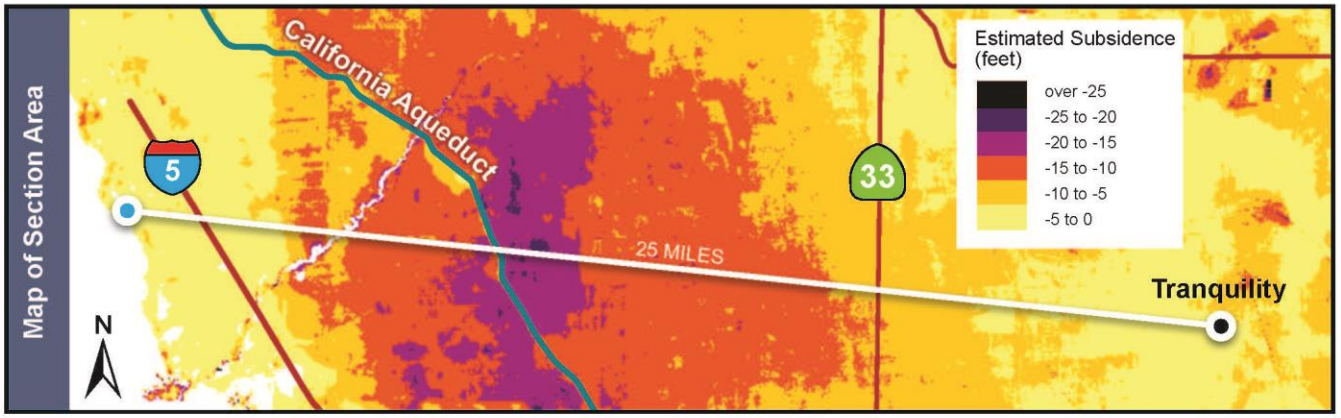
Friant-Kern Canal Subsidence Repair

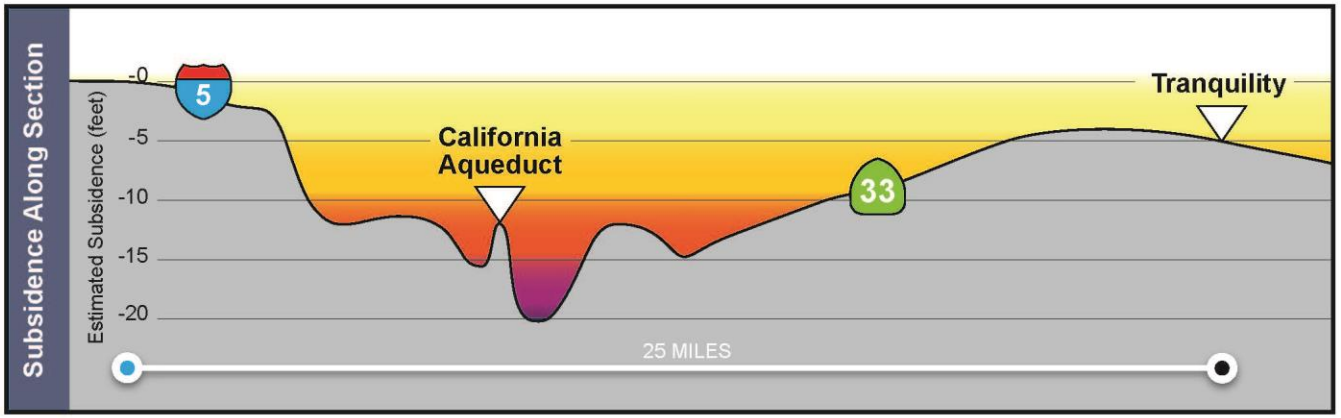
Estimated Subsidence in the San Joaquin Valley between 1949 – 2005



February 7, 2017

Estimated Historical Subsidence from 1949 - 2005, cross-section from I-5 to Tranquility





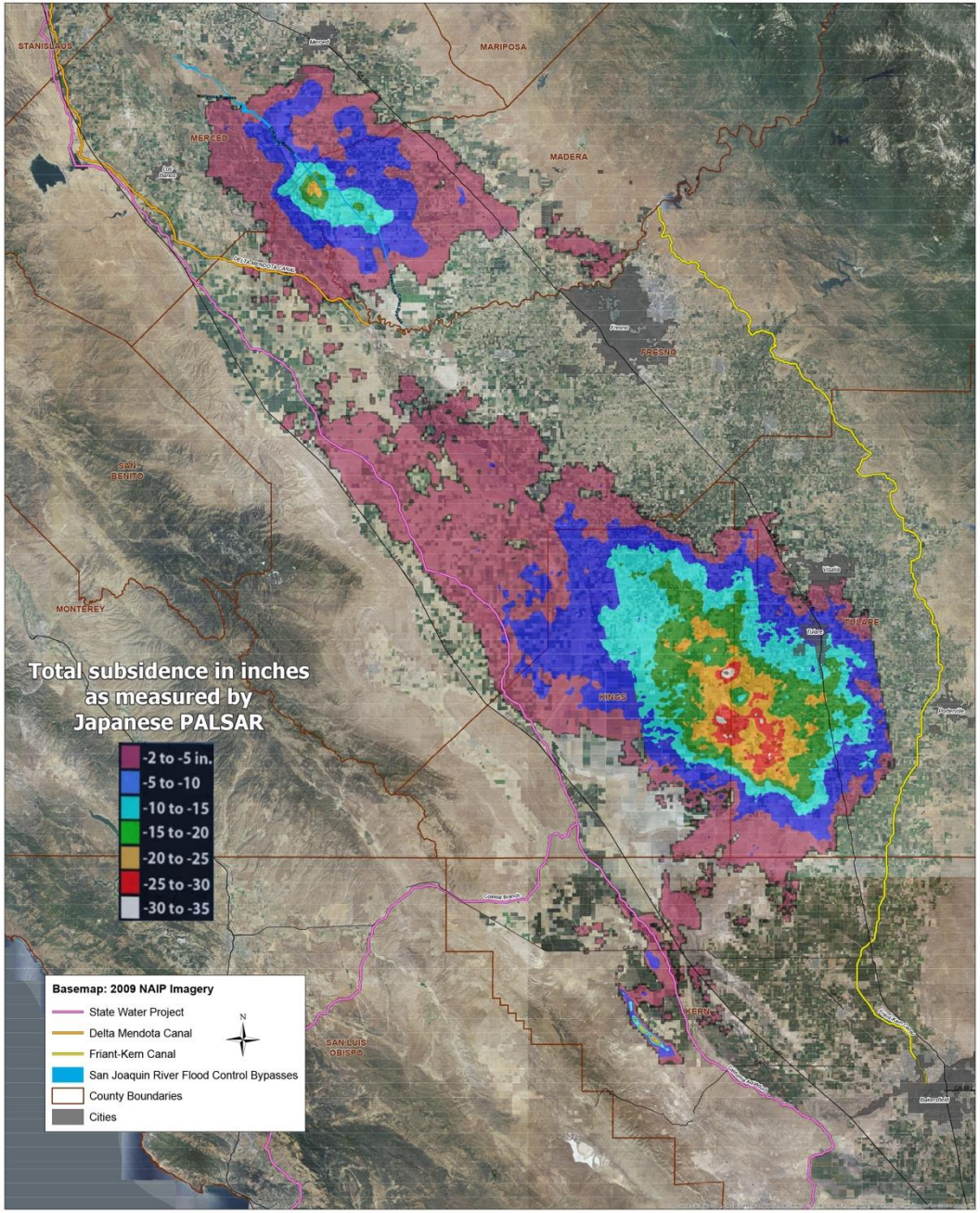
Note: Construction of these portions of the Aqueduct and of Interstate 5 was completed in 1967 and 1972, respectively.

DWR's InSAR Monitoring Experience

- Pilot project with NASA during 2012-16 drought, motivated by increased subsidence observed during 2007-09 drought
- InSAR monitoring was a game-changer, cost-effective synoptic data over large spatial scales
- Identified subsidence hot spots outside canonical subsidence areas
- Success of drought project with NASA motivated DWR to adopt operational monitoring to support Sustainable Groundwater Management Act implementation
- DWR plans to process NISAR data, when available, in-house

San Joaquin Valley Subsidence

June 2007 to December 2010



1:350,000 1 in = 6 miles

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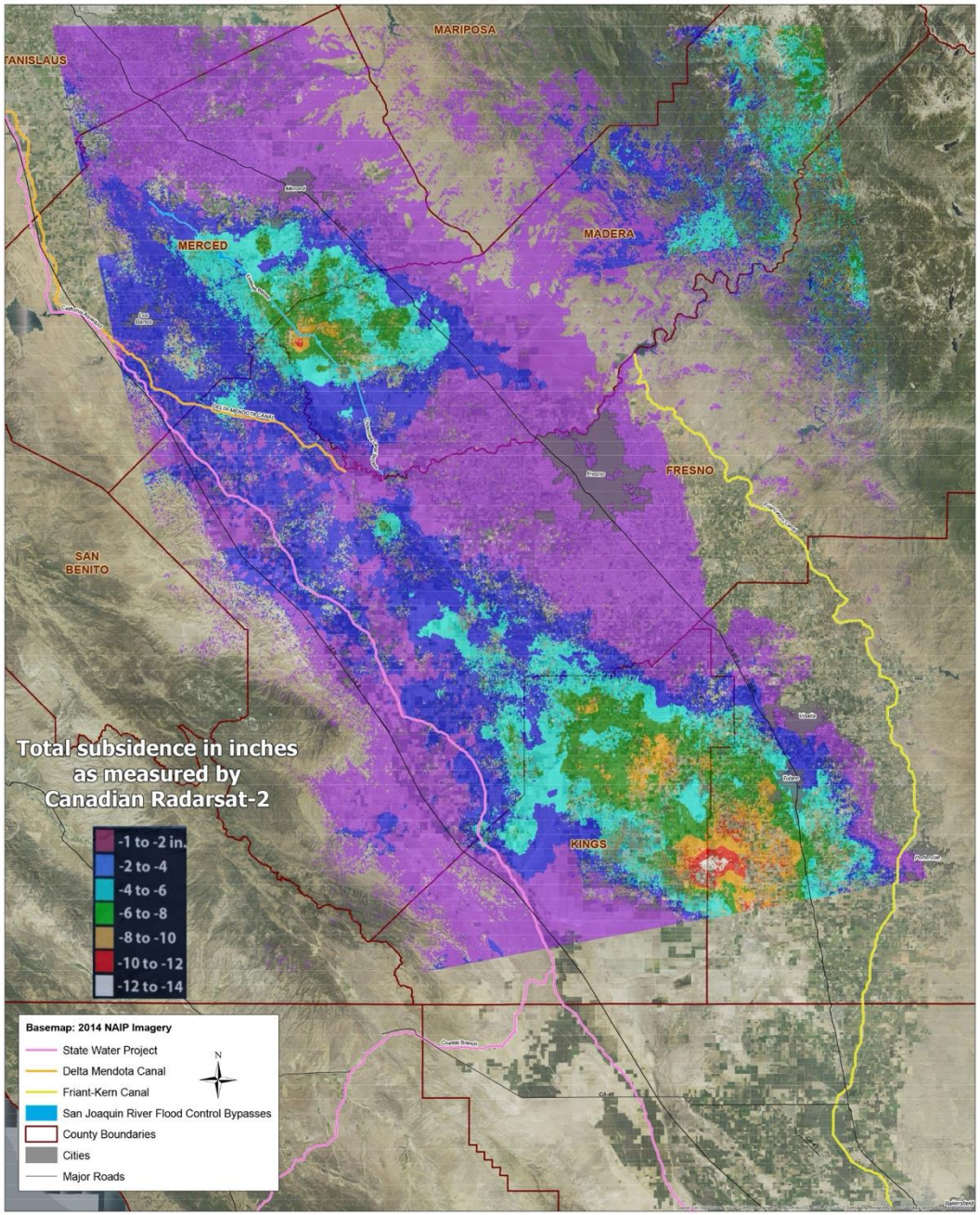
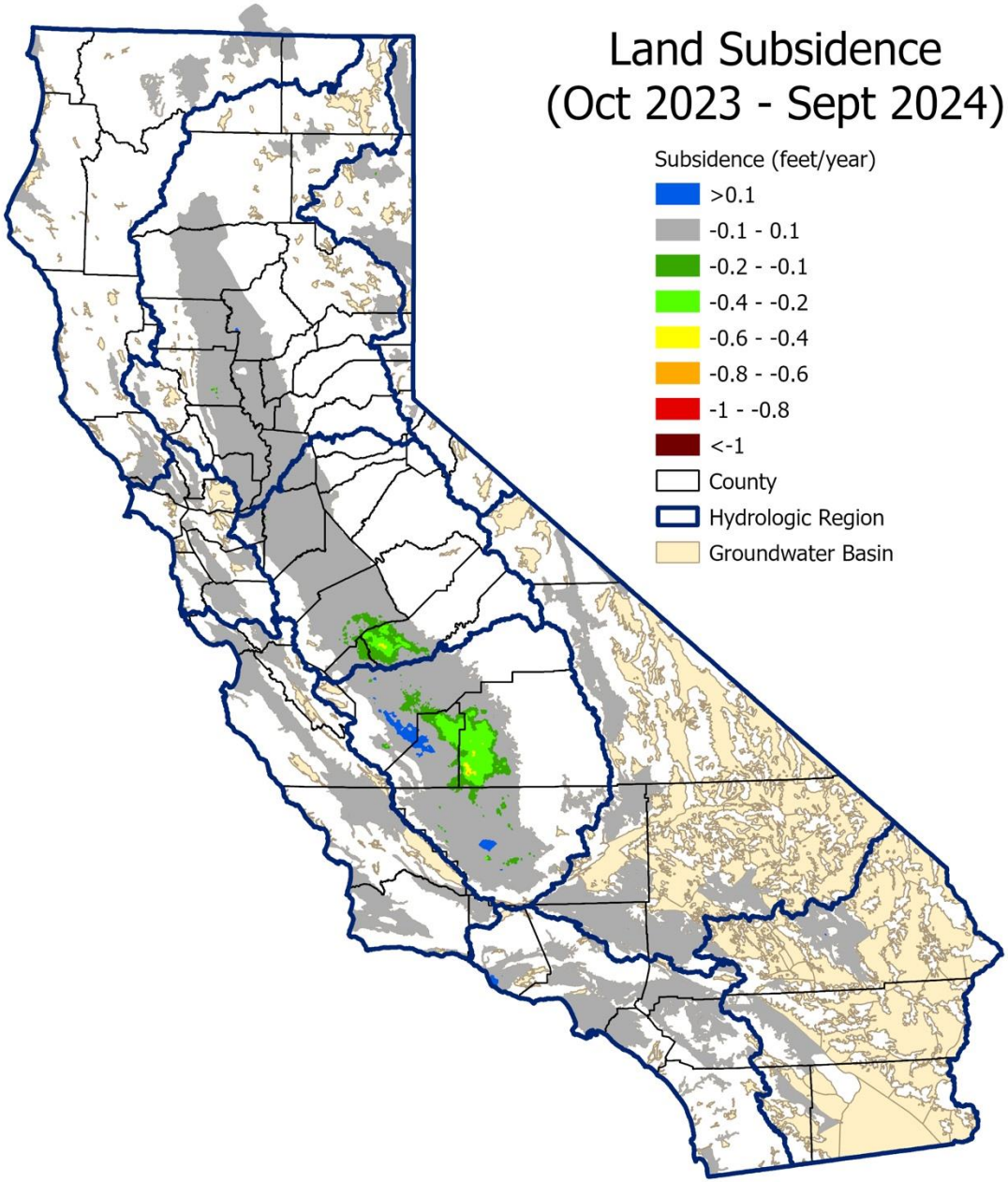
San Joaquin Valley Subsidence

May 2014 to January 2015



1:350,000 1 in = 6 miles


Land Subsidence
(Oct 2023 - Sept 2024)
Subsidence (feet/year)
>0.1
-0.1 - 0.1
-0.2 - -0.1
-0.4 - -0.2
-0.6 - -0.4
-0.8 - -0.6
-1 - -0.8
<-1
County
Hydrologic Region
Groundwater Basin