Managing Groundwater Storage - Managed Aquifer Recharge in California

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California's 2014 Sustainable Groundwater Management Act

Requires

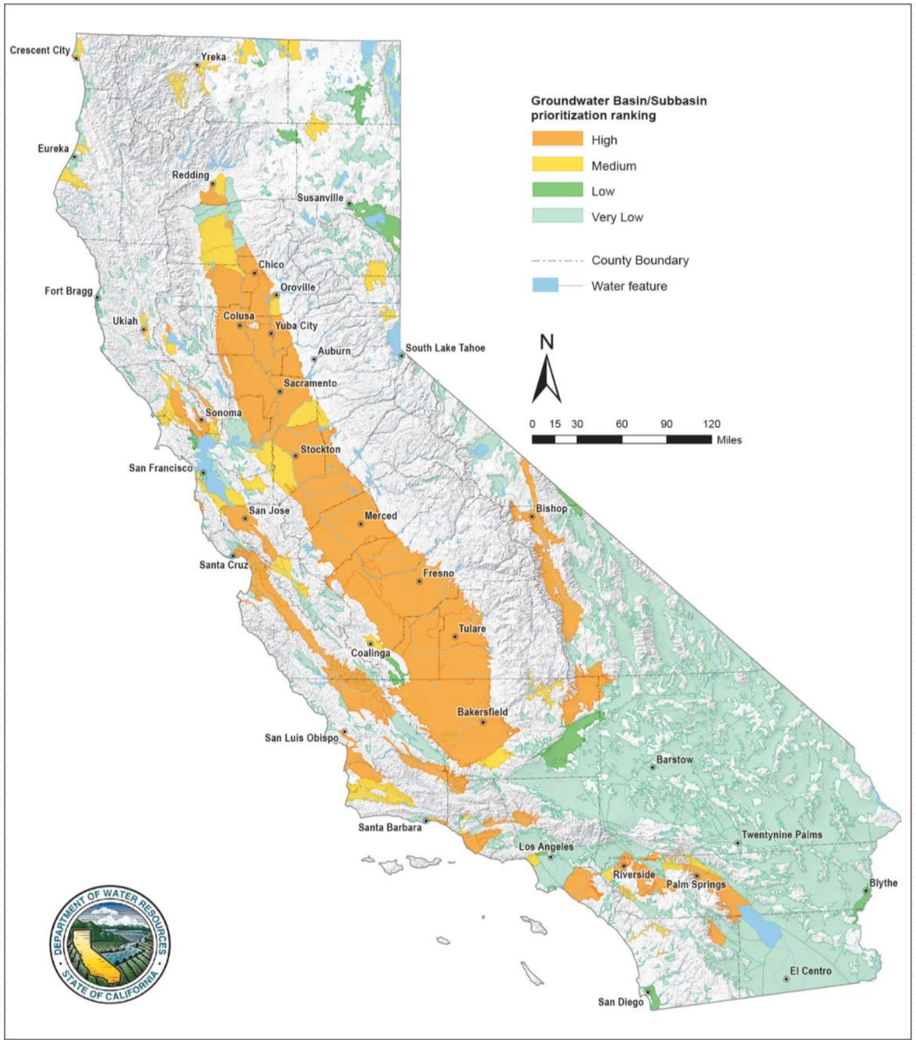
- Formation of Groundwater Sustainability Agencies in High and Medium Priority Basins by June 2017
- Development of Groundwater Sustainability Plans by January 2020 Critically Overdrafted Basins and January 2022 Others
- Become Sustainable within 20 years of GSP Adoption
- State may intervene if these mandates not met by locals

Perfect Hydrologic Storm

- Five years of drought
- Less surface water being delivered by state and federal systems due to drought and environmental constraints
- More groundwater being pumped due to above
- Increasing land subsidence
- Impacts to water conveyance
- Disadvantaged communities nitrate impacted groundwater

California SGMA and COD Basins

SGMA Basins are High and Medium Priority



Critically Overdrafted Basins

Basin/Subbasin Number*	Basin/Subbasin Name
3-001	Santa Cruz Mid-County
3-002.01	Pajaro Valley
3-004.01	180/400-Foot Aquifer
3-004.06	Paso Robles Area
3-008	Los Osos Valley
3-013	Cuyama Valley
4-004.02	Oxnard
4-006	Pleasant Valley
5-022.01	Eastern San Joaquin
5-022.04	Merced
5-022.05	Chowchilla
5-022.06	Madera
5-022.07	Delta-Mendota
5-022.08	Kings
5-022.09	Westside
5-022.11	Kaweah
5-022.12	Tulare Lake
5-022.13	Tule
5-022.14	Kern County
6-054	Indian Wells Valley
7-024.01	Borrego Springs

*See Appendix B, Figure B-2 for an explanation of the California groundwater basin/subbasin numbering system.

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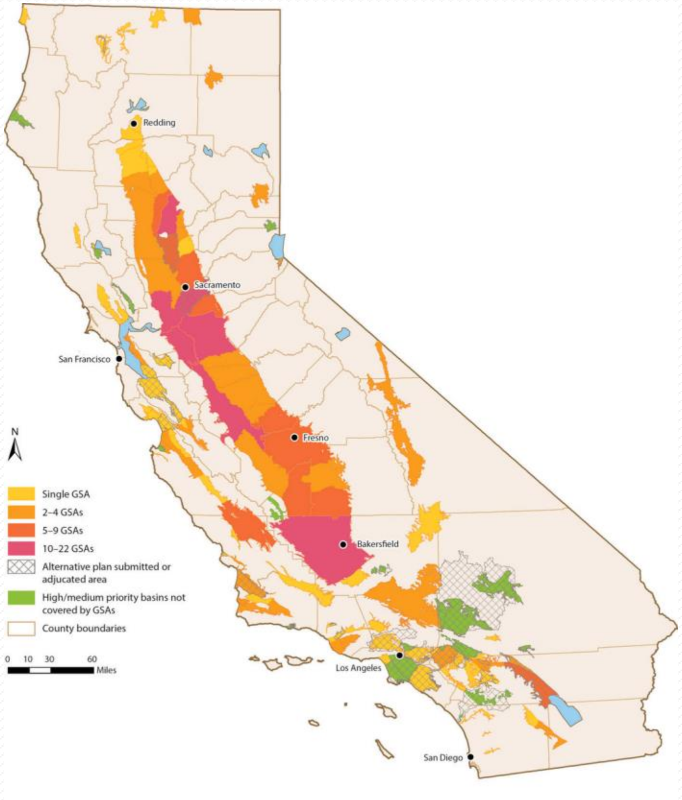
Status



Sustainability = increase supply, recharge or reduce demand

California Statewide Challenges

- 100's to 1,000's of recharge projects are needed statewide to stabilize groundwater declines and need for incentives to do so
- Determine the most suitable soil, geologic setting and aquifer space for recharge, and what rates can be achieved
- Need to know where, how much and how frequently surface water will be available for recharge, considering instream (environmental) flow needs and climate change
- Changes in reservoir reoperation and additional conveyance needed to maximize and optimize recharge opportunities
- Determine potential benefits and possible adverse impacts of increasing recharge to water quality based on different land and water management strategies and how compatible the existing regulatory system will be
- Regulatory permitting and legal water rights uncertainties need to be addressed with an emphasis of the public benefits of recharge and sustainability

Increasing Groundwater Recharge through Changing Management Practices is a Recognized Part of the Solution

Managing Groundwater Storage = Managed Aquifer Recharge (MAR)

- The purposeful recharge of an aquifer under controlled conditions to store the water for later extraction or to achieve environmental benefits.
- Requires:
  - Source of Water
  - Conveyance
  - Suitable receiving aquifer
  - Water rights
  - Satisfy regulations

WHY MAR?

- A tool to replenish aquifers and provide water supply security
- Generally the cheapest form of new water supply available
- Can be used to replenish depleted aquifers, protect and enhance groundwater-dependent ecosystems, and avoid saline intrusion and land subsidence
- Can help offset the costs of flood control and water reuse in urban areas where demand is out of balance with supply

Advantages & Challenges for MAR Compared to Surface Reservoirs

MAR Advantages

- Smaller impact on land use
- Protection against evaporative losses and algae bloom, fall out
- High natural attenuation
- Dampens quality and temperature
- Lower cost
- Can be scaled up over time to spread out capital investment

MAR Challenges

- Need suitable aquifer system
- Aquifers not water tight - losses
- Surrounding saline water may mix
- Reactions of source water with groundwater and aquifer matrix
- Infiltration/recovery rates van be limited by clogging
- Potentially higher operations and maintenance

Managing Groundwater Storage - Managed Aquifer Recharge

A Proven and Well Demonstrated Technology

- Economics good and typically costs less than alternative water sources, and staged implementation affordable
- Can be implemented as mutually beneficial projects for environmental and water quality improvements along with supply resiliency and security
- Adaptable to different settings, opportunities and constraints including fresh, brackish or saline receiving aquifers, using drinking water, recycled water, stormwater or groundwater as the source water

Most Common Types of MAR

MAR Type and Design Governed by Hydrogeologic Setting and Hydrology

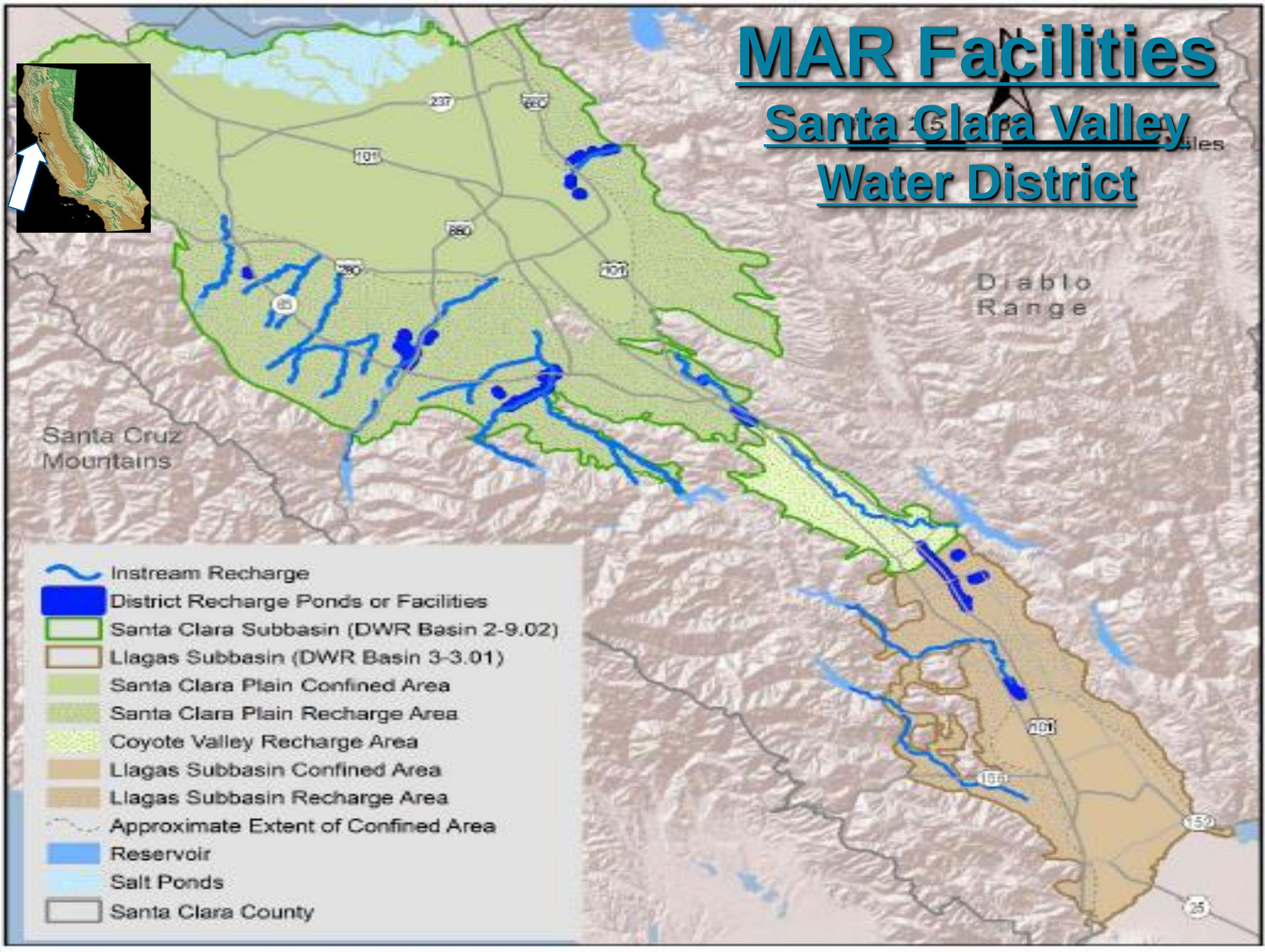
- Infiltration Basins
- Aquifer Storage & Recovery Wells (ASR)
- Aquifer Storage, Treatment & Recovery (ASTR)
- Dry Wells
- Bank Filtration
- Sand or Check Dams
- Distributed Projects
  - Flood MAR
  - Low Impact Development

Design Considerations

- Detailed hydrogeologic characterization
- Source and receiving water characterization
  - Source -Turbidity, pH, Total Organic Carbon, Metals
  - Receiving – Redox, Dissolved Oxygen, Salinity, Metals (Fe, Al, Mn), Red
- Clogging – very important because it will happen
  - Can be physical, chemical, mechanical, biological
  - Manage through engineering design, chemical intervention, performance monitoring and operational practices
  - Treatment options include strainers, filtration (sand and filters), microfiltration, disinfection, chemicals

MAR Facilities

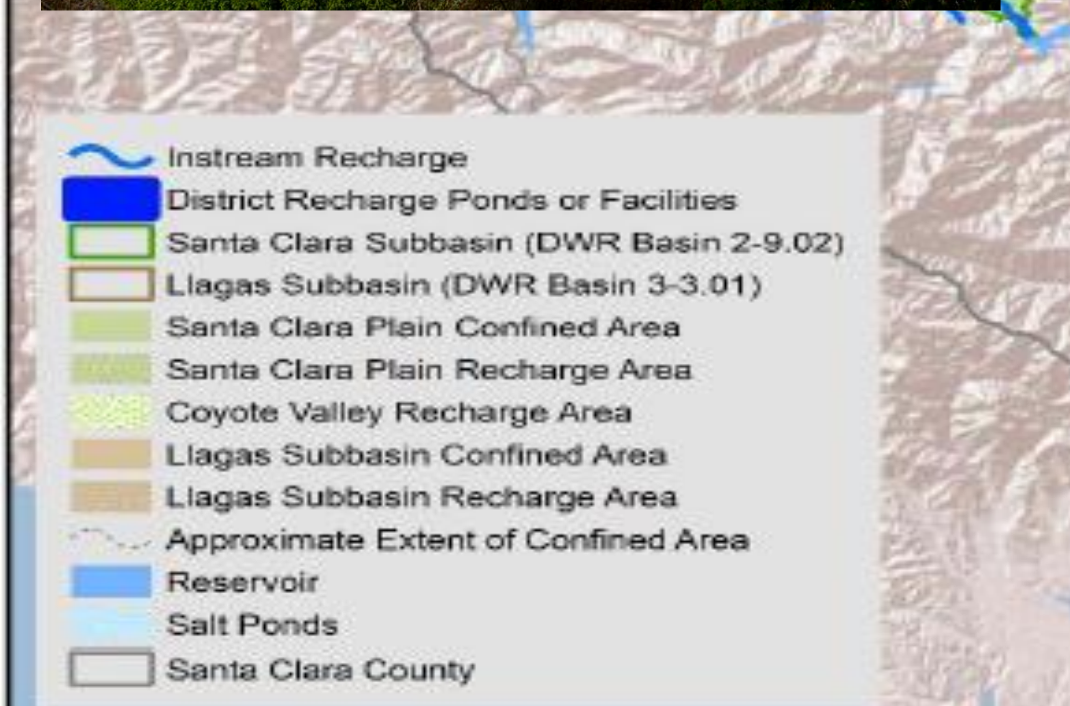
Santa Clara Valley Water District



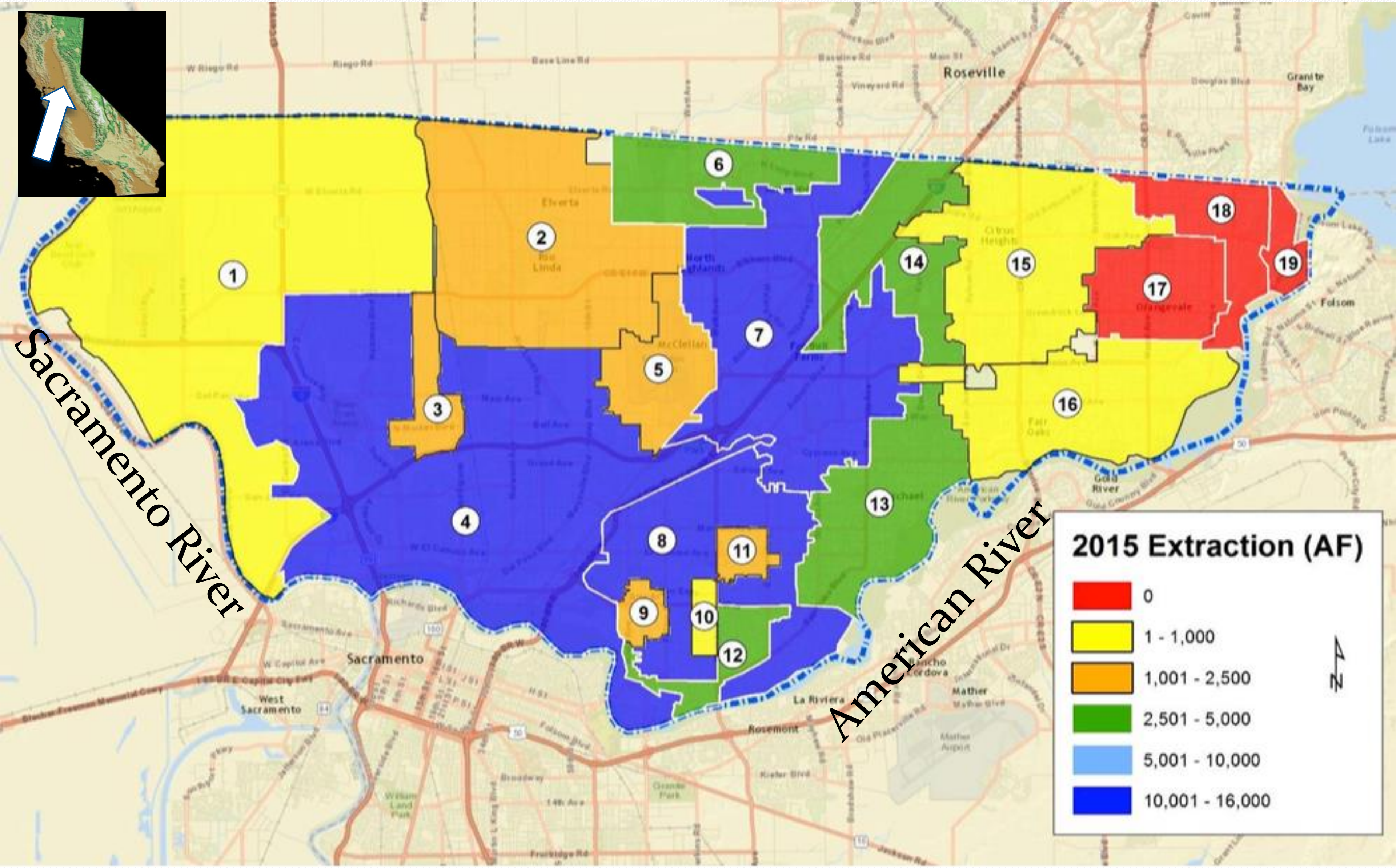
MAR Facilities

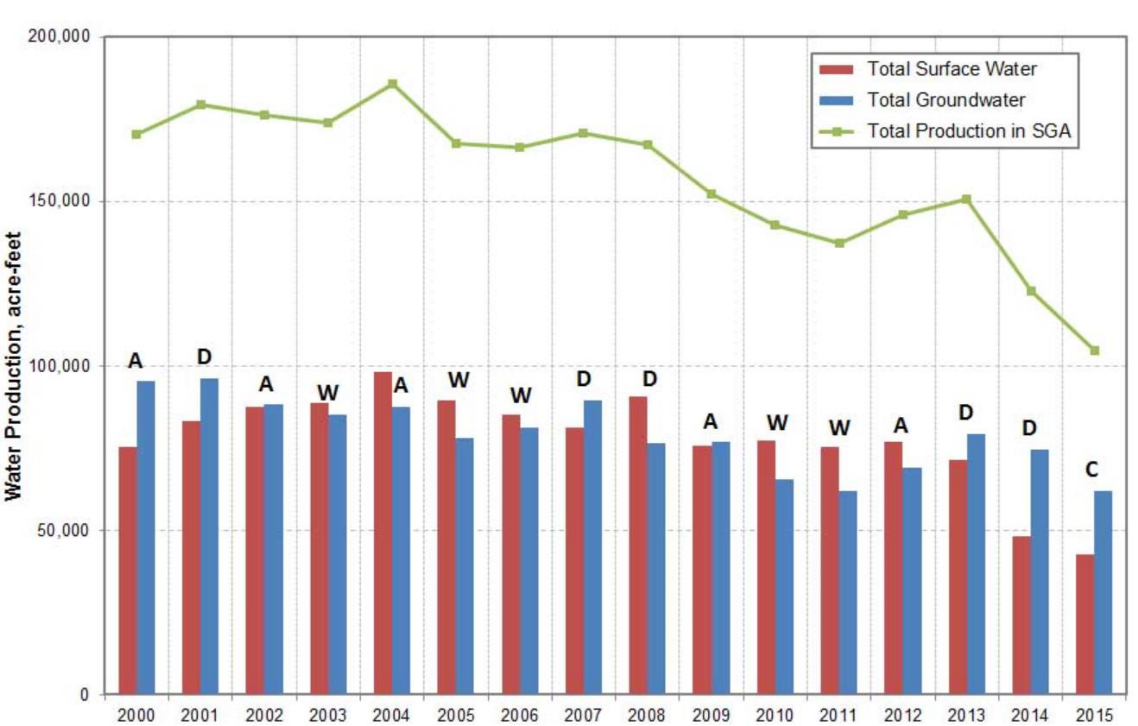
Santa Clara Valley Water District

- Land subsidence about 13 feet in San Jose between 1915-1970
- 393 acres of recharge ponds
- 91 miles of controlled in-stream recharge
- Recharge approximately 100,00 acre-feet per year

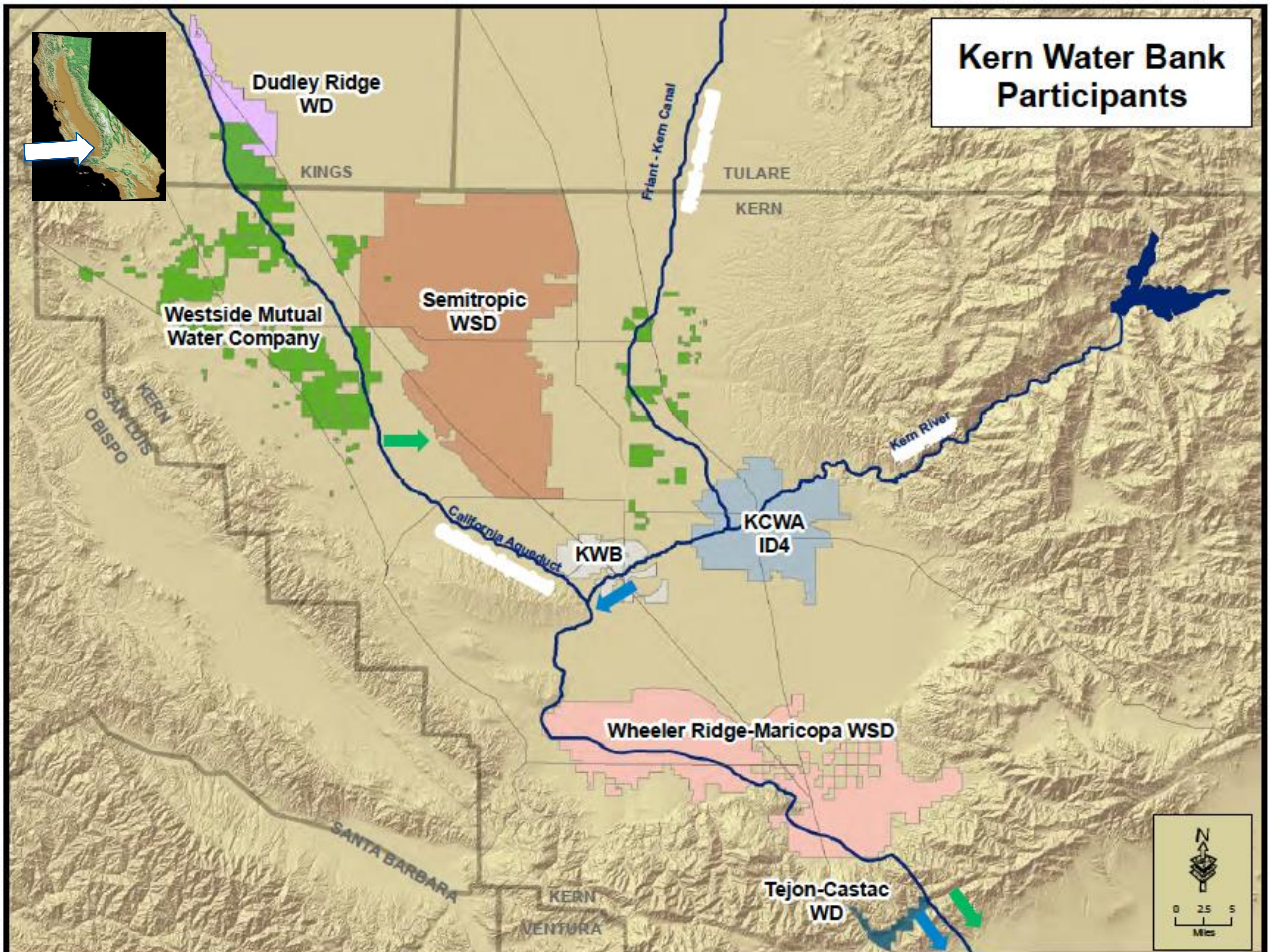


Regional Water Authority
Sacramento Groundwater Authority





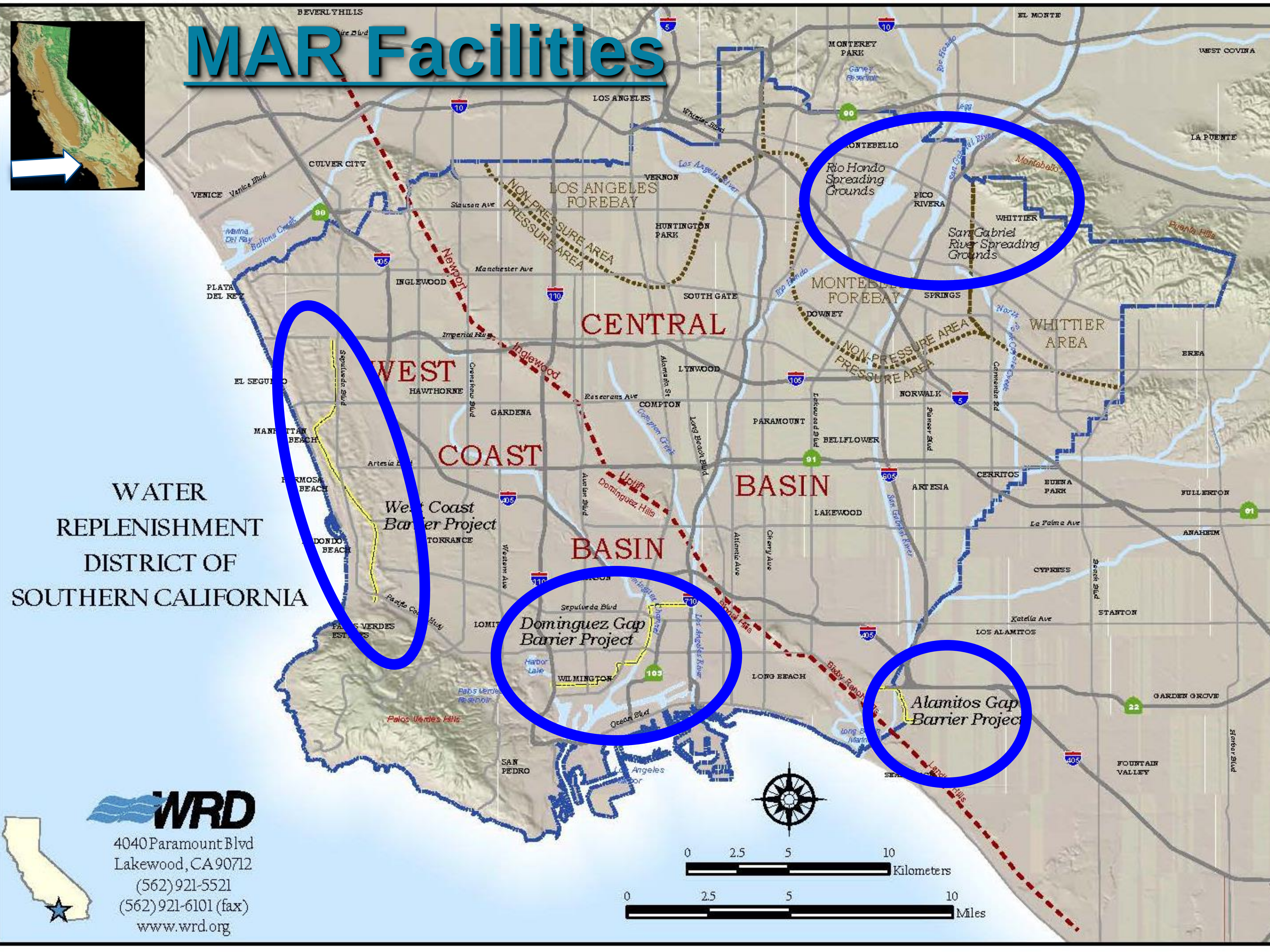
- Water Forum Agreement signed after 8 years of facilitated discussions
- Formed Regional Water Authority and Sacramento Groundwater Authority 1998
- Set in-streams flow for American River to avoid fisheries impacts
- Implemented a conjunctive use program cross connecting water distributions systems
- Successfully stored nearly 150,000 acre-feet of water in- lieu of pumping
- Water Accounting Framework in place for future potential exports


Kern Water Bank Participants
Dudley Ridge WD
KINGS
TULARE
KERN
Friant - Kern Canal
Semitropic WSD
Westside Mutual Water Company
KERN
SAN LUIS OBISPO
Kern River
California Aqueduct
KWB
KCWA ID4
Wheeler Ridge-Maricopa WSD
SANTA BARBARA
KERN
VENTURA
Tejon-Castac WD
N
0 2.5 5
Miles

Kern Water Bank

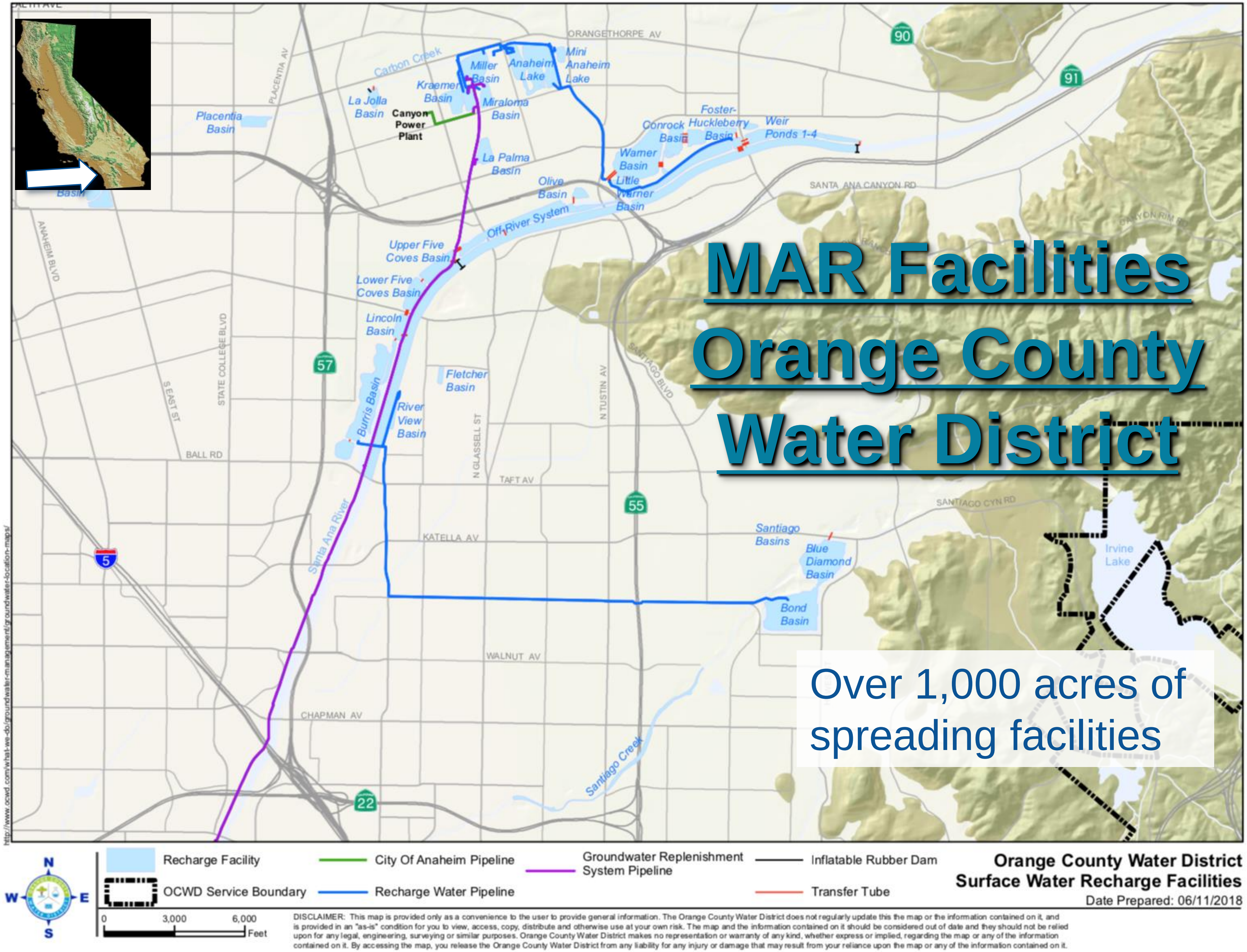
- Started operating in 1994
- Multi-benefit project for ecosystems – one of the top freshwater wetlands in state
- 70 shallow recharge ponds covering 7,000 acres situated on coarse grained Kern River alluvial fan deposits
- Average recharge rate about 1/3 foot per day
- Maximum annual recharge capacity about 500,000 acre-feet per year
- 84 recovery wells - average depth about 750 feet below ground surface
- Annual recovery capacity about 240,00 acre-feet at recovery program beginning

MAR Facilities

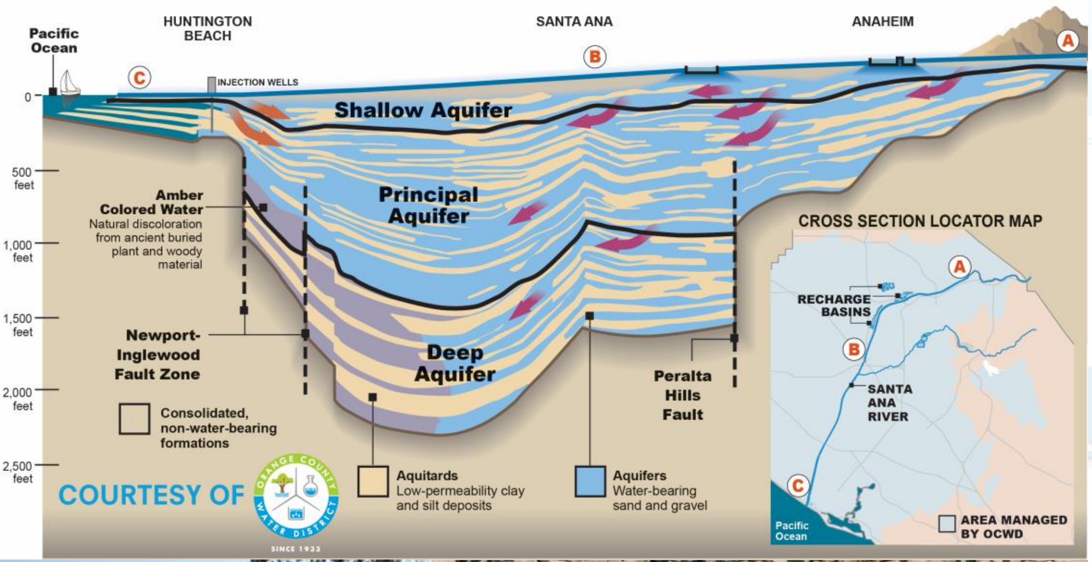


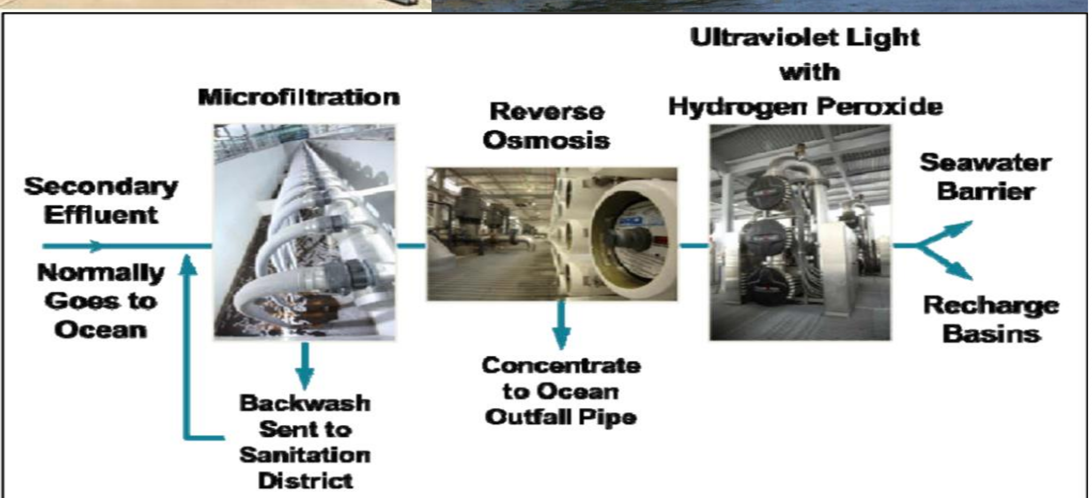
- Seawater intrusion was the catalyst in the 30’s and 40’s
- LA County started installing injection wells along coast in 1950’s
- WRD formed in 1959 to recharge groundwater
- Adjudications:
  - 1961 West Coast basin
  - 1965 Central basin
- Capped pumping above safe yield at 281,835 AFY
- WRD provides replenishment to meet safe yield annually
- Projects 2018 recharge 70,000 AF by spreading in basins and 30,000 AF by injection
- Use stormwater, recycled water and imported water
- Moving away from unreliable imported water

MAR Facilities Orange County Water District



Over 1,000 acres of spreading facilities





- 1933 OCWD established to manage groundwater and seawater intrusion
- 1950 OCWD first purchase of imported water
- 1954 establishes replenishment assessment
- Factory 21 Operational
- 2008 Groundwater Replenishment System operational 70 MGD
- 2015 GWRS 100 MGD (112,000 AFY)
  - 30 MGD to seawater intrusion barrier
  - 70 MGD to recharge basins
- 2023 GWRS 130 MGD
- Recharges approximately 250,000 – 300,000 AFY

References/Contacts

- International Association of Hydrogeologists - Managed Aquifer Recharge Commission https://recharge.iah.org/
  - ISMAR10 in Madrid, Spain 20-24 May 2019
- National Ground Water Association www.ngwa.org
- American Groundwater Trust www.agwt.org
- Groundwater Resources Association of California
  - www.grac.org BSMAR17 in Arizona in 2020
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  - Vanessa de la Piedra vdelapiedra@valleywater.org
- Regional Water Authority http://rwah2o.org/ John Woodling jwoodling@rwah2o.org
- Kern Water Bank http://www.kwb.org/ Jon Parker jparker@kwb.org
- Water Replenishment of Southern California http://www.wrd.org/
  - Ted Johnson tjohnson@wrd.org
- Orange County Water District www.ocwd.org Adam Hutchinson ahutchinson@ocwd.com

Questions and Comments