Orange County Water District: Adaptive Management – Operating Under Unknowns

SINCE 1933

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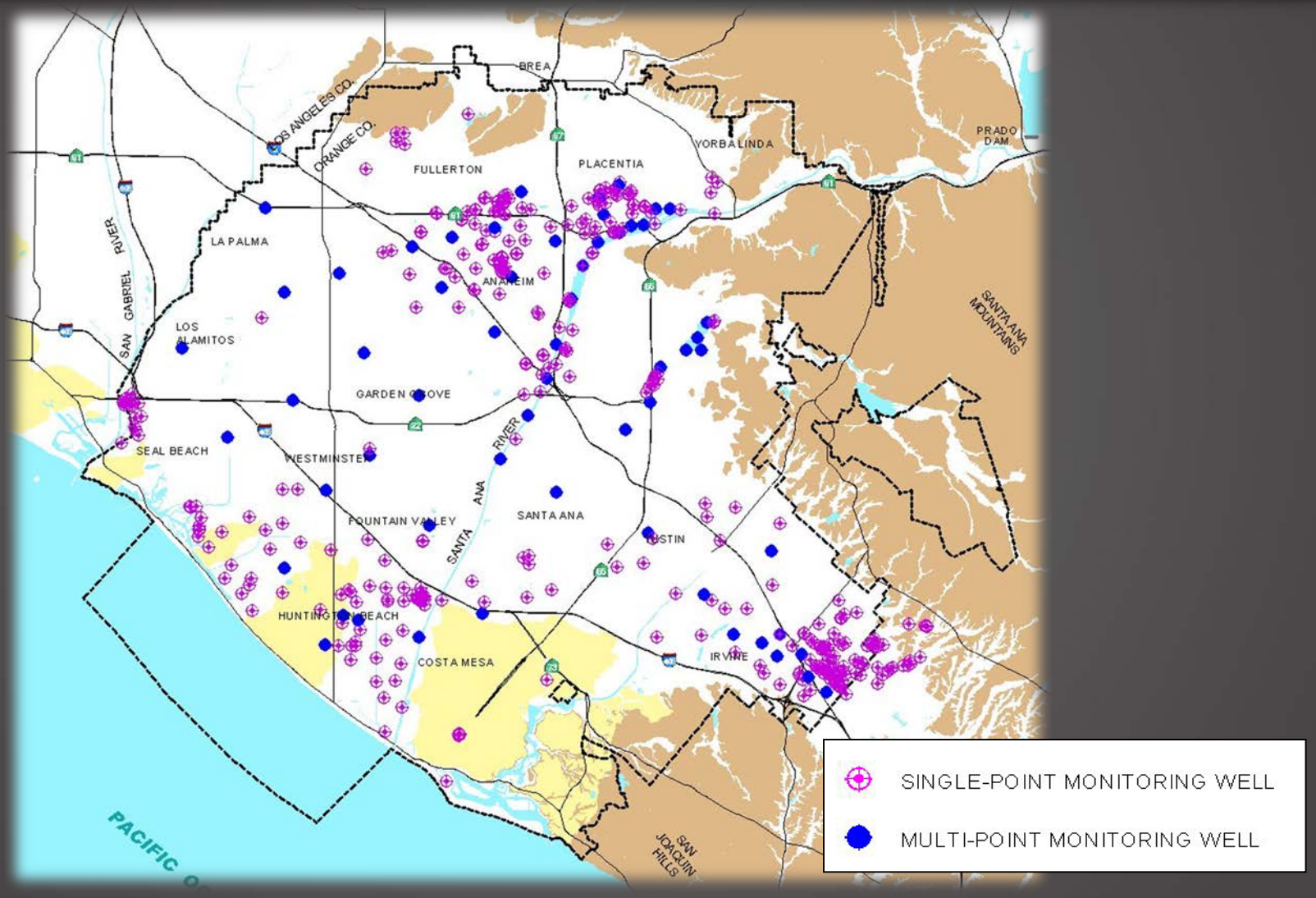
Recharge Planning Manager

1st Annual GSA Summit
June 6, 2018

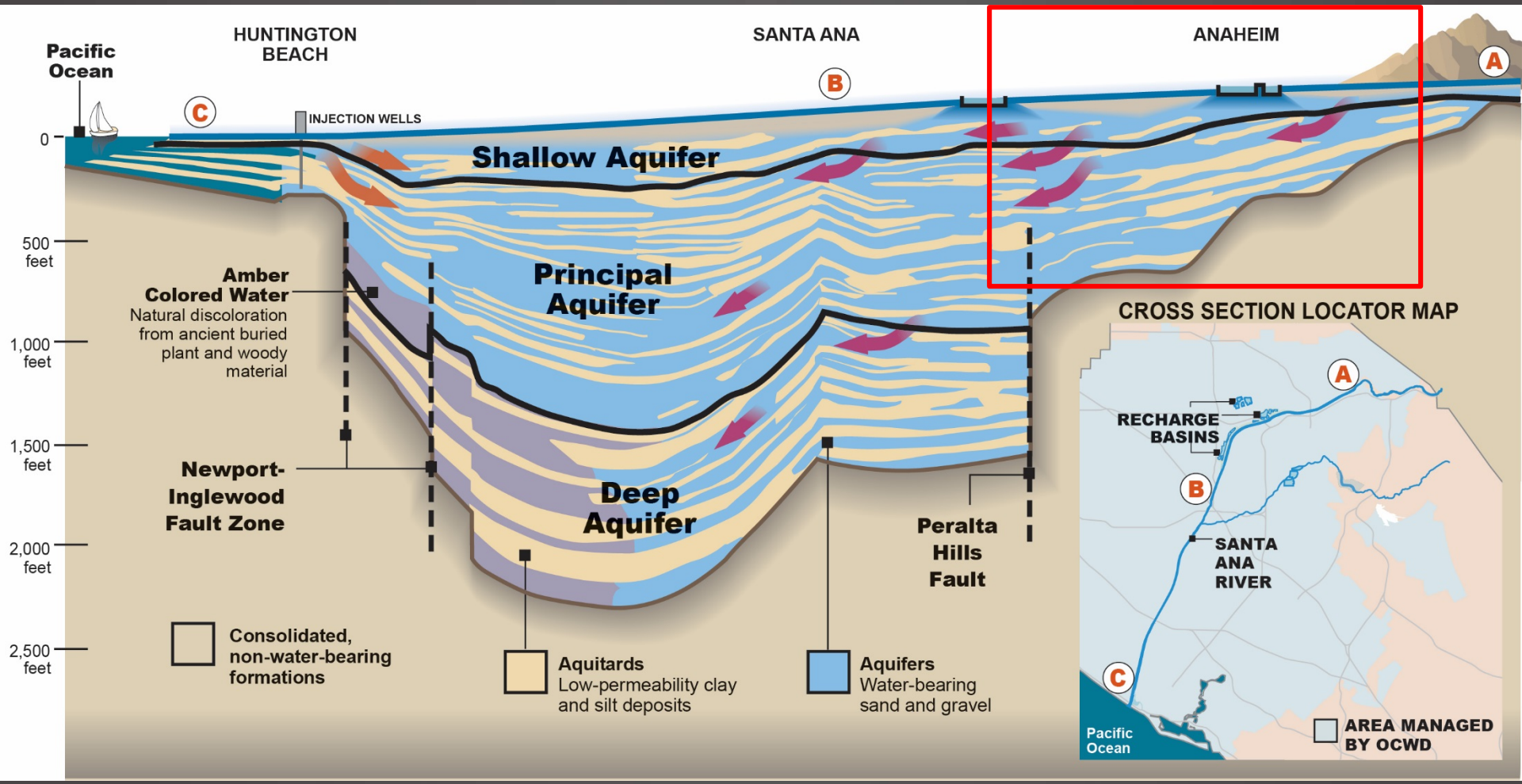
What unknowns?

- Hydrogeologic unknowns
- Hydrologic unknowns

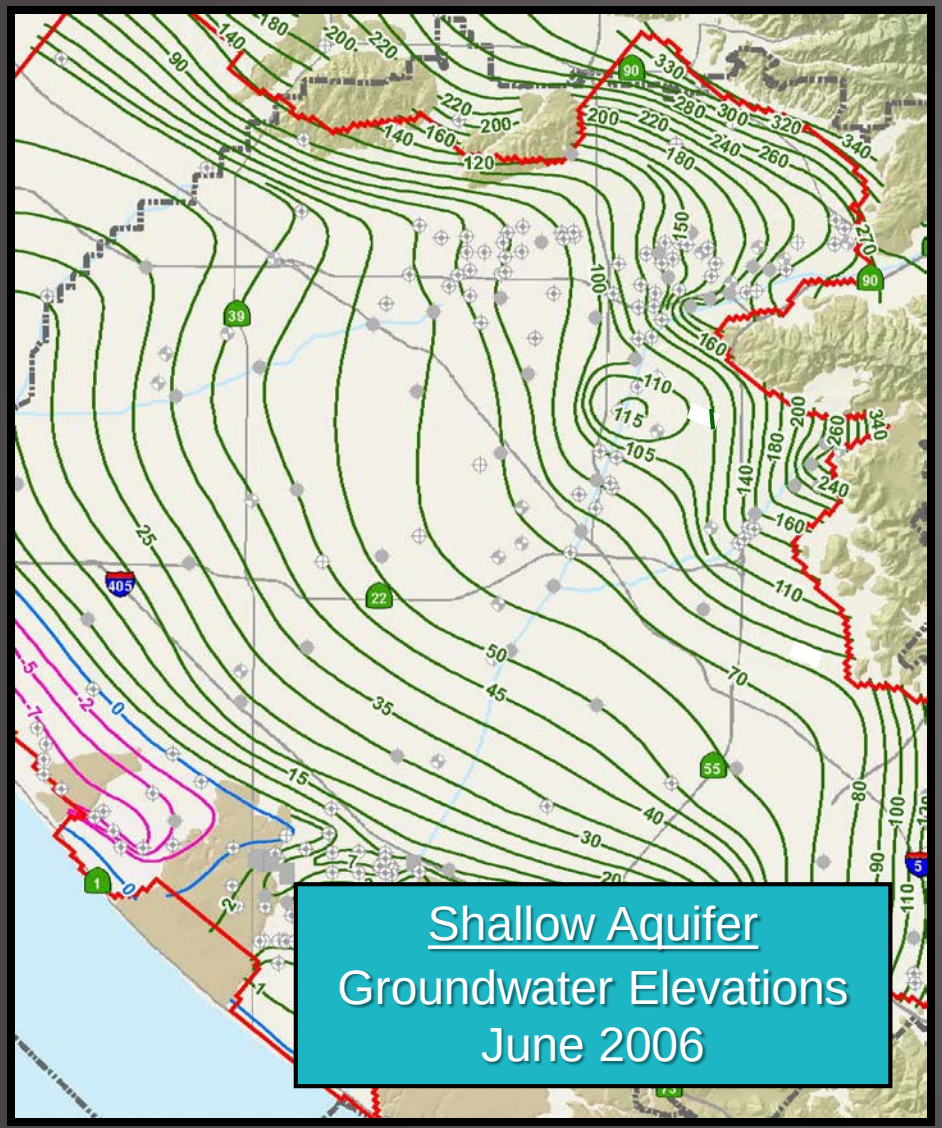
OCWD has constructed over 100 single- and multi-depth monitoring wells.

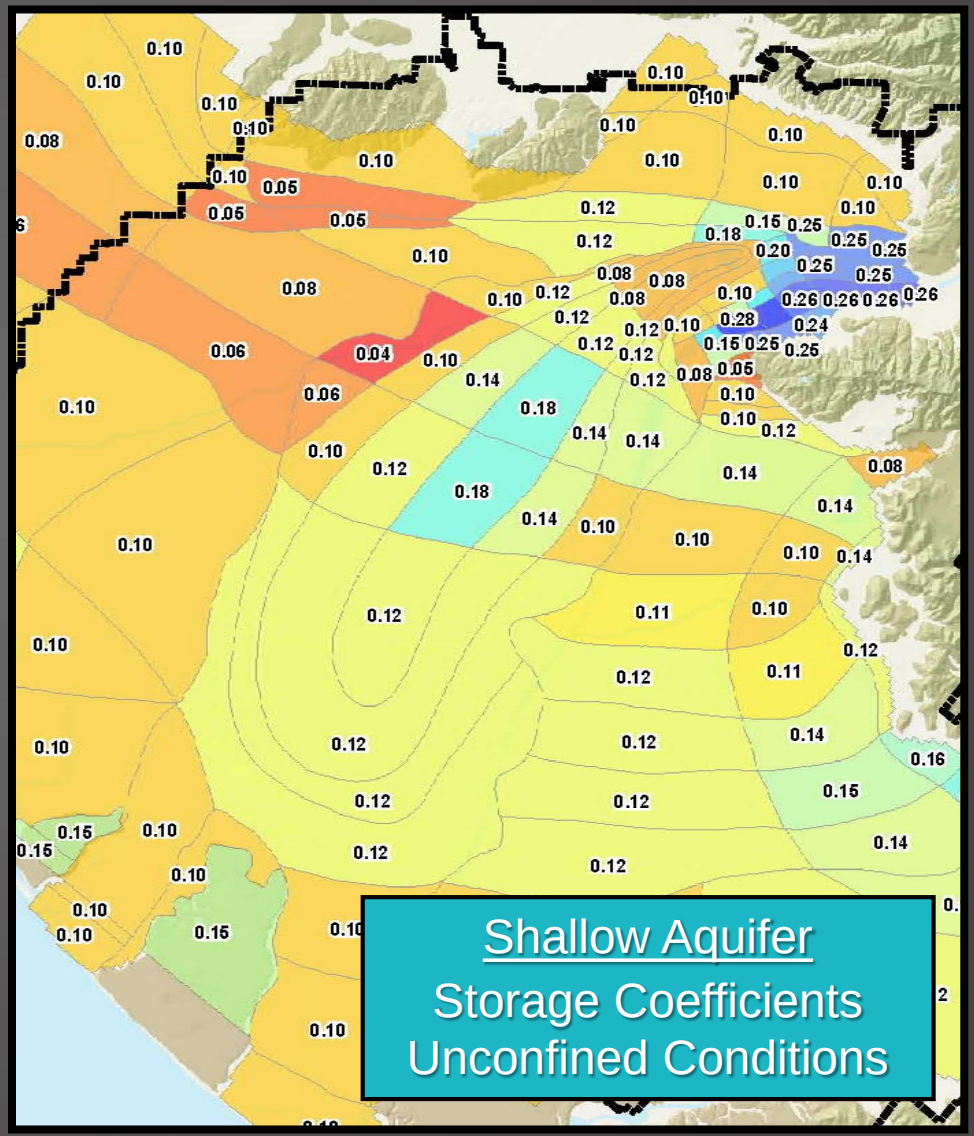


The basin is comprised of three major aquifer systems that are hydraulically interconnected.

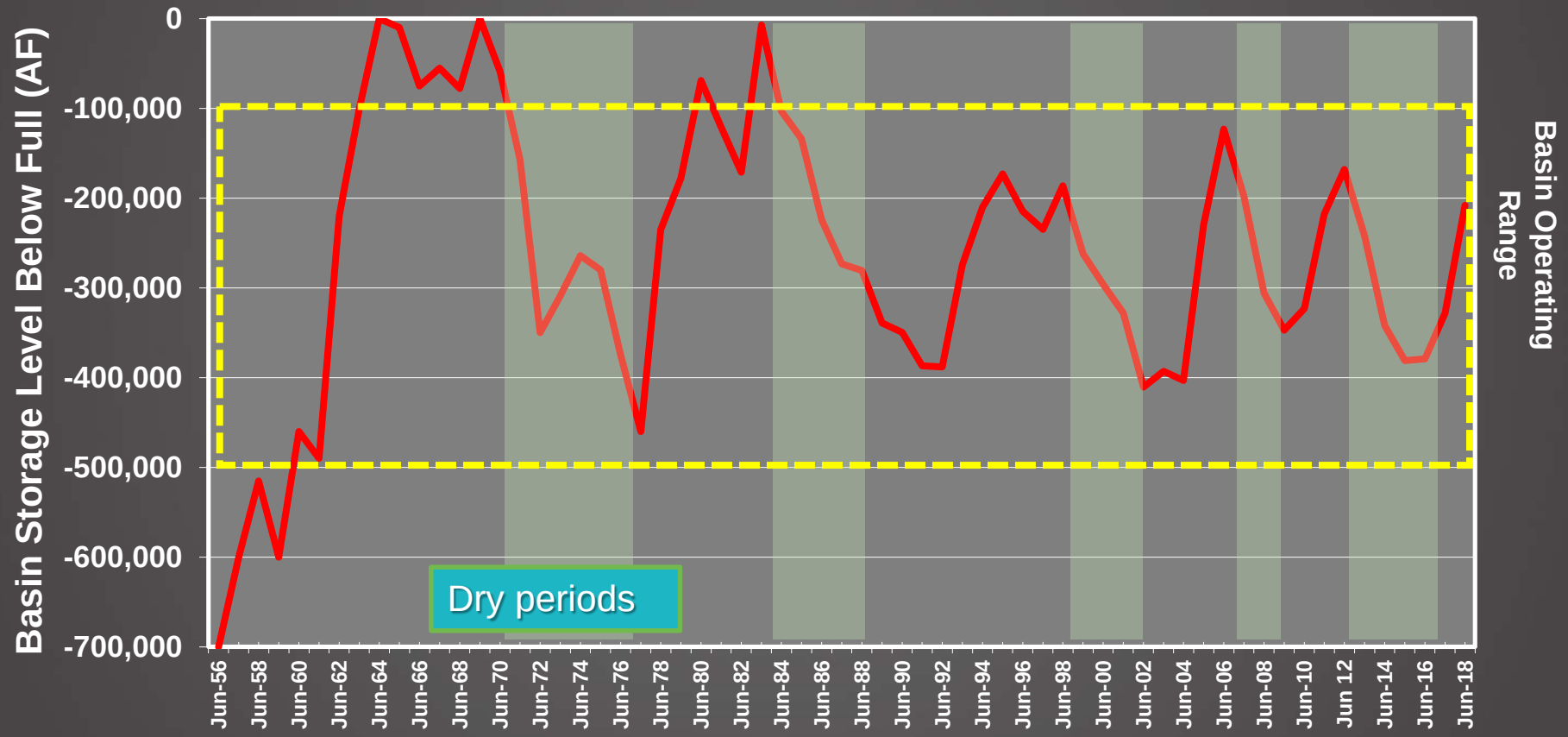


Accuracy of contoured water level data and storage coefficients is critical.



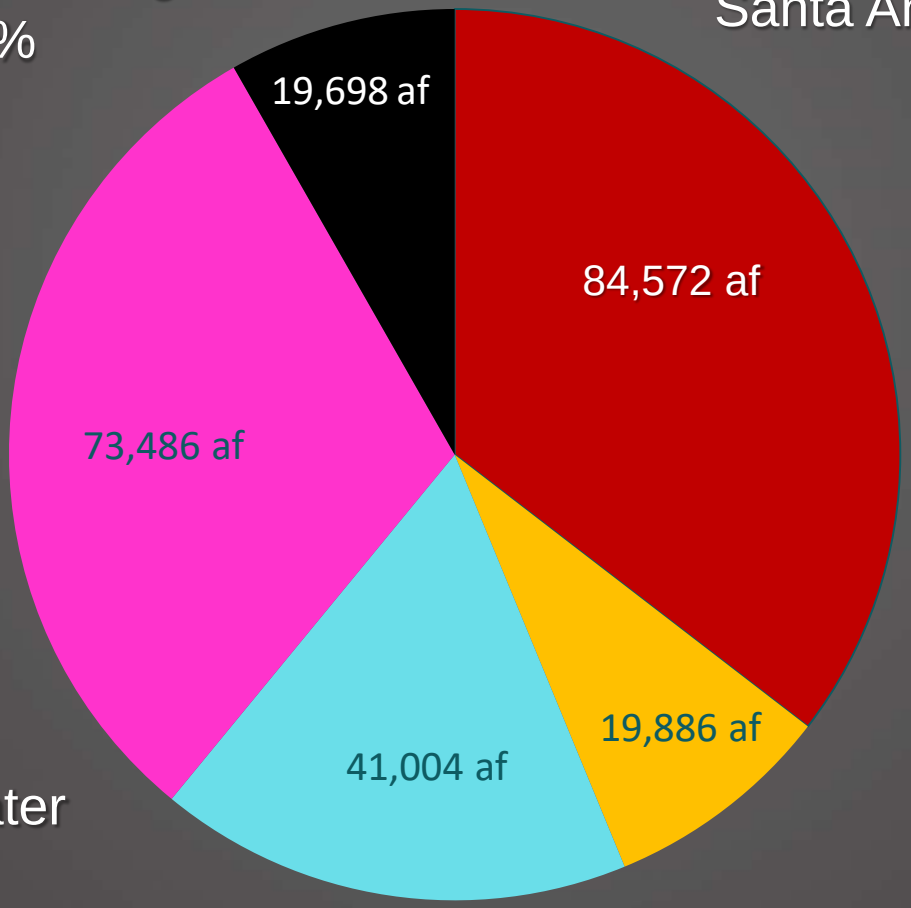


OCWD manages basin storage within a specific operating range.



Total basin storage is 66MAF. Operating storage is <1% of total storage.

OCWD invested in recycled water to reduce future supply uncertainties.



Total FY12-13 Recharge: 238,646 af

OCWD uses financial "disincentives" to control pumping.

- Non-adjudicated basin
- OCWD establishes percent of total demand that can be met with groundwater
  - Pay Replenishment Assessment (RA)
- Pumping above this percentage is allowed but a higher fee applies
  - Pay Basin Equity Assessment (BEA)
  - Additional fee makes cost of water equivalent to imported water (alternative supply)

OCWD continues to explore increasing reliable water supplies.

- Expand GWRS to 130 MGD
- Increased storm water capture at Prado Dam
- Increased storm water recharge
- Dry-year groundwater storage accounts in upper watershed
- Evaluating ocean desalination

Thank You!

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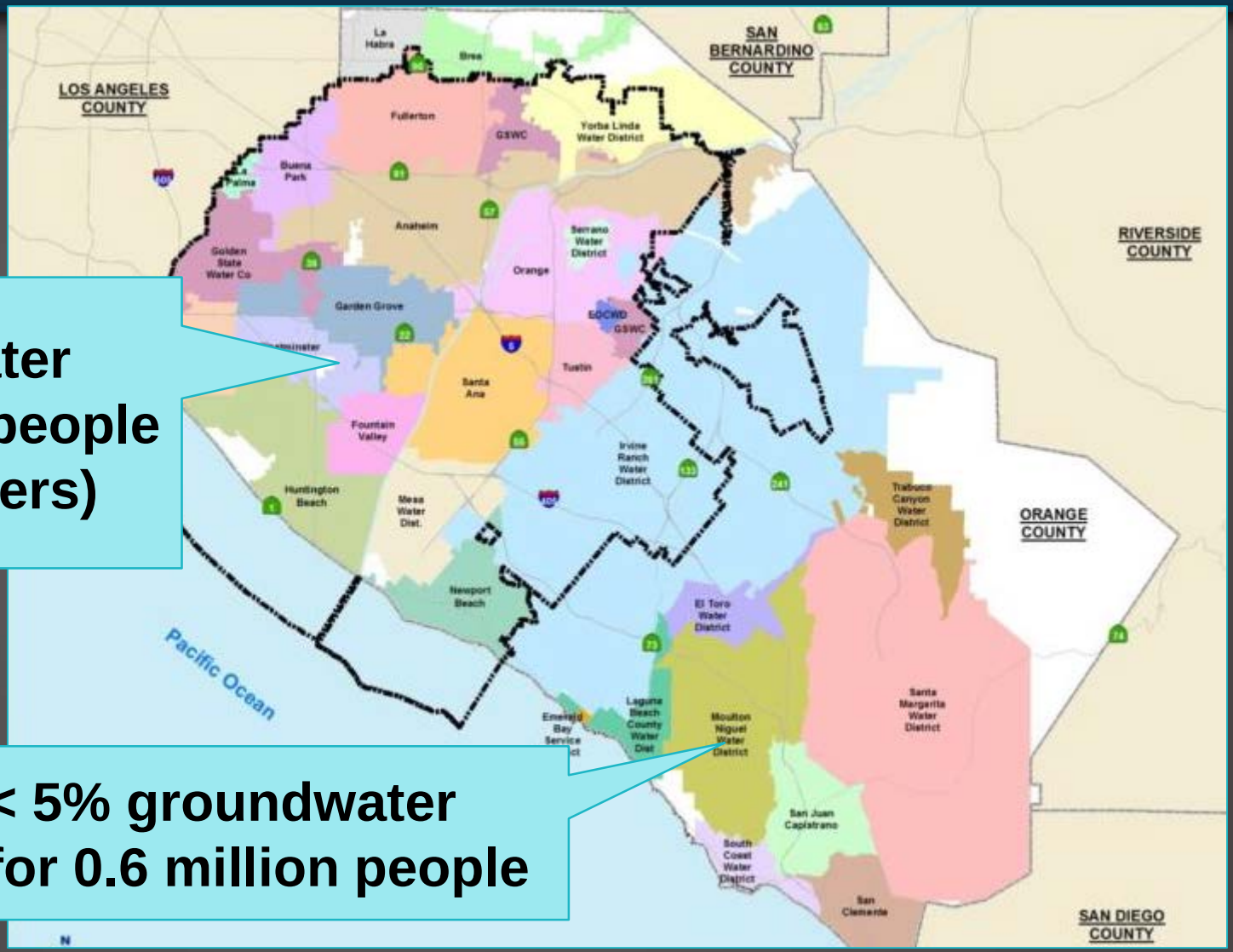
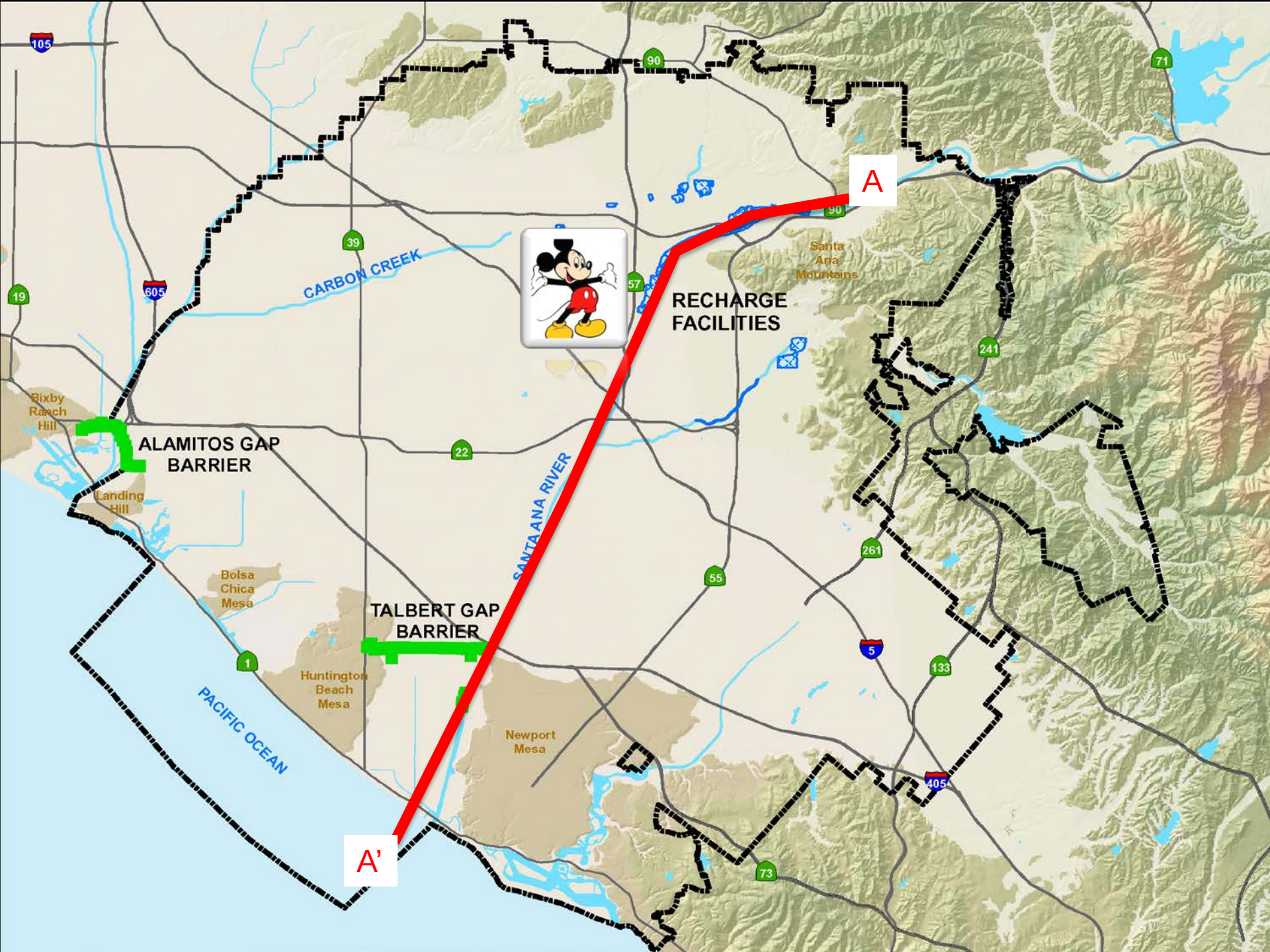
OCWD overlies the groundwater basin in the north and central portion of Orange County.

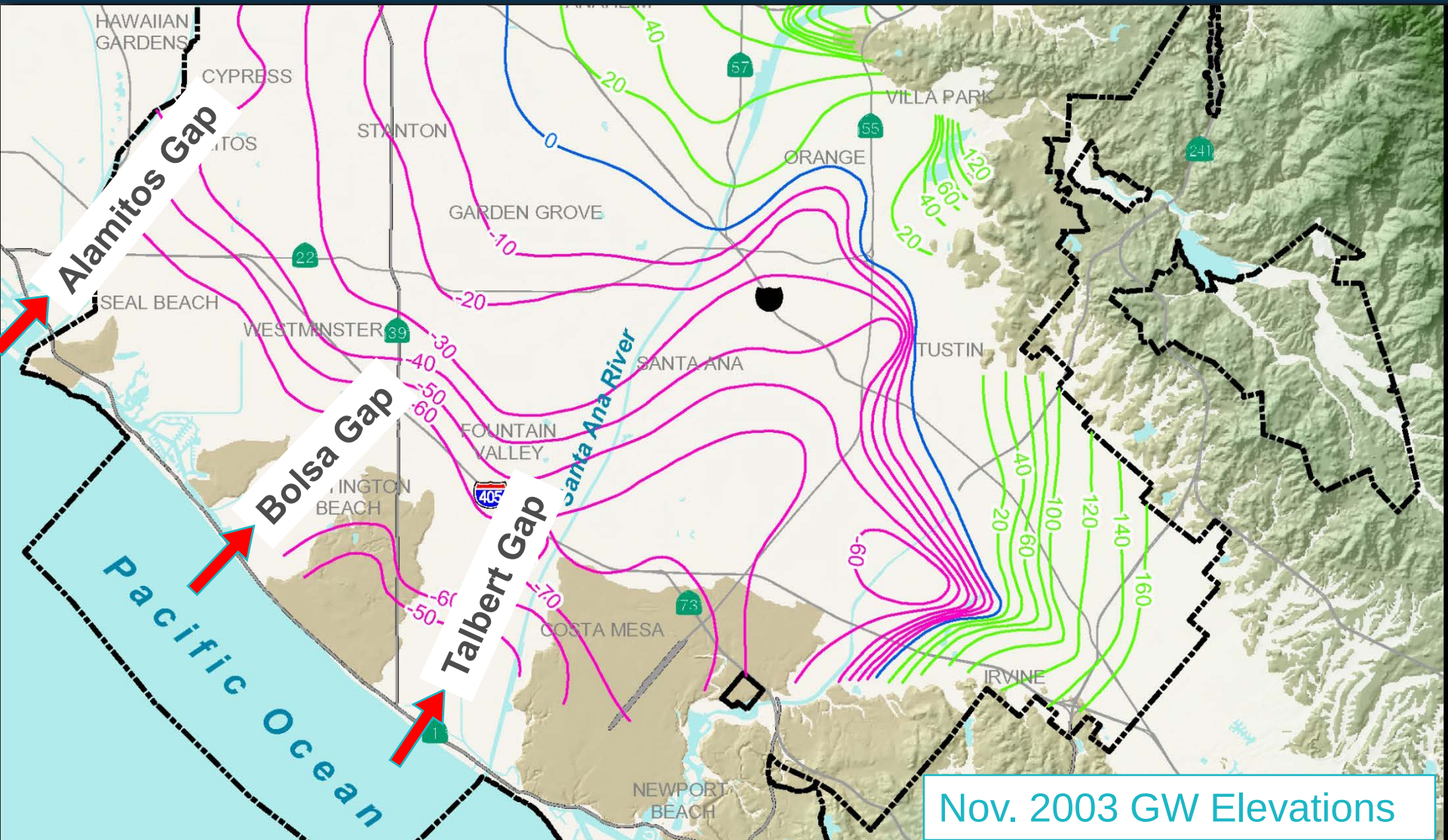


75% groundwater for 2.4 million people (19 water retailers)

< 5% groundwater for 0.6 million people


A
A'
RECHARGE FACILITIES
ALAMITOS GAP BARRIER
TALBERT GAP BARRIER
CARBON CREEK
SANTA ANA RIVER
PACIFIC OCEAN
Bixby Ranch Hill
Landing Hill
Bolsa Chica Mesa
Huntington Beach Mesa
Newport Mesa
Santa Ana Mountains
105
90
71
39
605
19
57
241
22
261
55
5
133
1
405
73

Seawater intrusion along the coast presents a continuing basin management challenge.

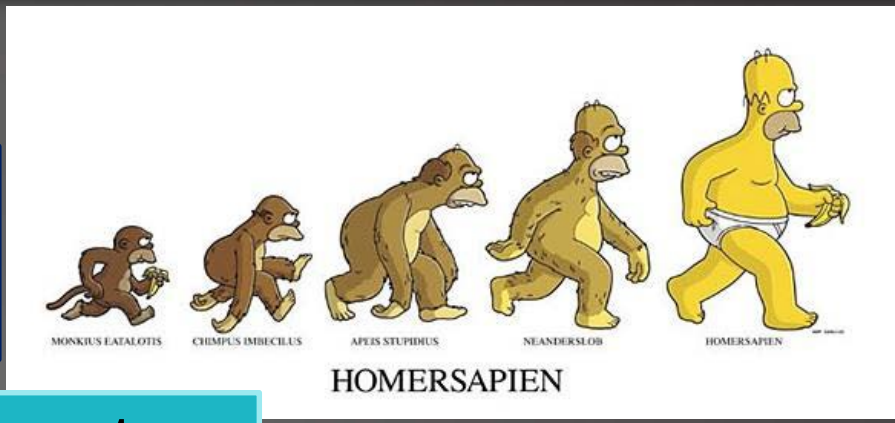


Nov. 2003 GW Elevations

OCWD's approach to basin management has evolved over time.

Capture/Recharge Native Water

- Refill basin with Imported Water
- Replenishment Assessment
- Meter pumping



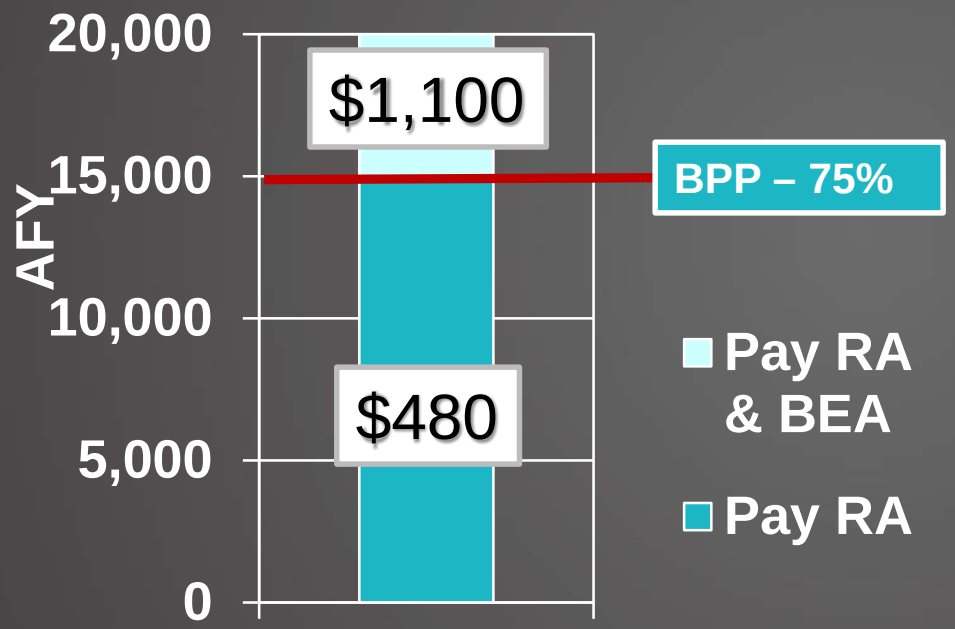
- Establish basin production percentage
- Basin Equity Assessment
- Seawater Barrier

- In-lieu recharge with imported water
- Expand capture/recharge of SAR Base/Storm Flow

Groundwater Replenishment System (Recycled Water)
Multi-Basin Conjunctive Use

OCWD uses economic incentives to manage pumping.

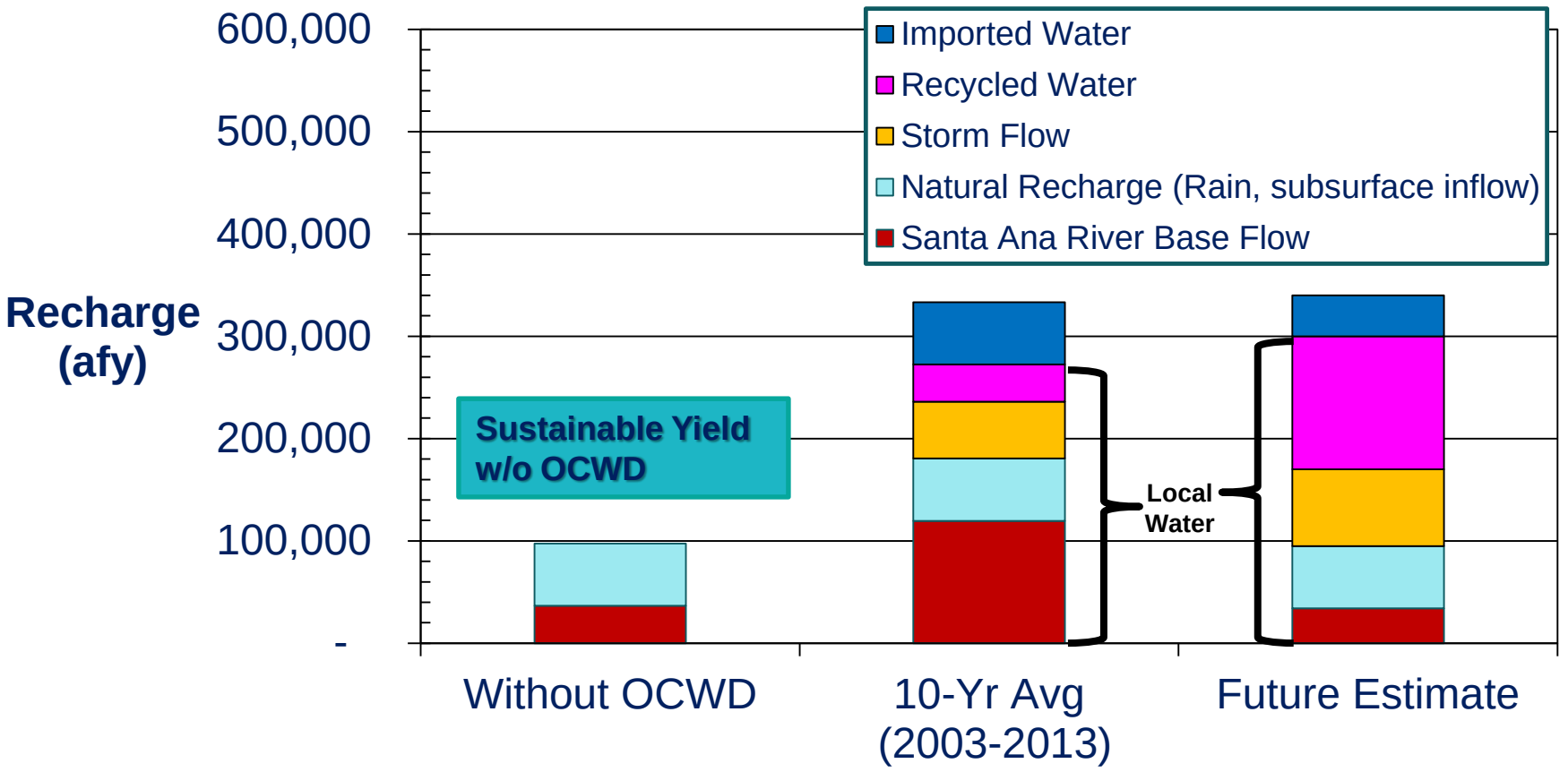
Example Water Utility with 20,000 afy of Total Water Demands

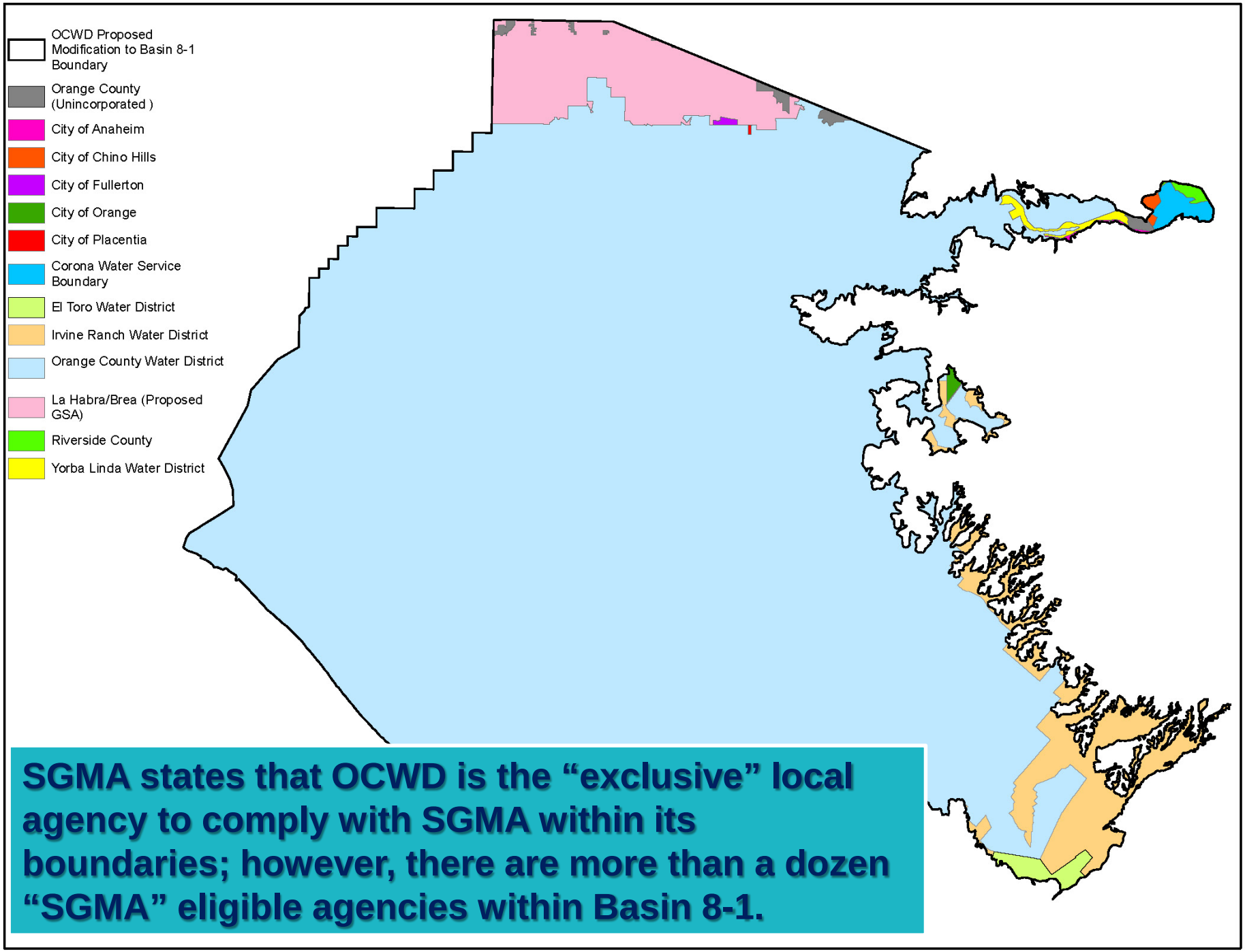


RA+BEA = Imported water cost

- **Basin production percentage (BPP)** = amount of total demand that can be met with groundwater
- **Replenishment assessment (RA)** = charge for groundwater below BPP
- **Basin equity assessment (BEA)** = additional charge for water pumped above BPP

The recharge of local water sources has more than doubled the yield of the basin.

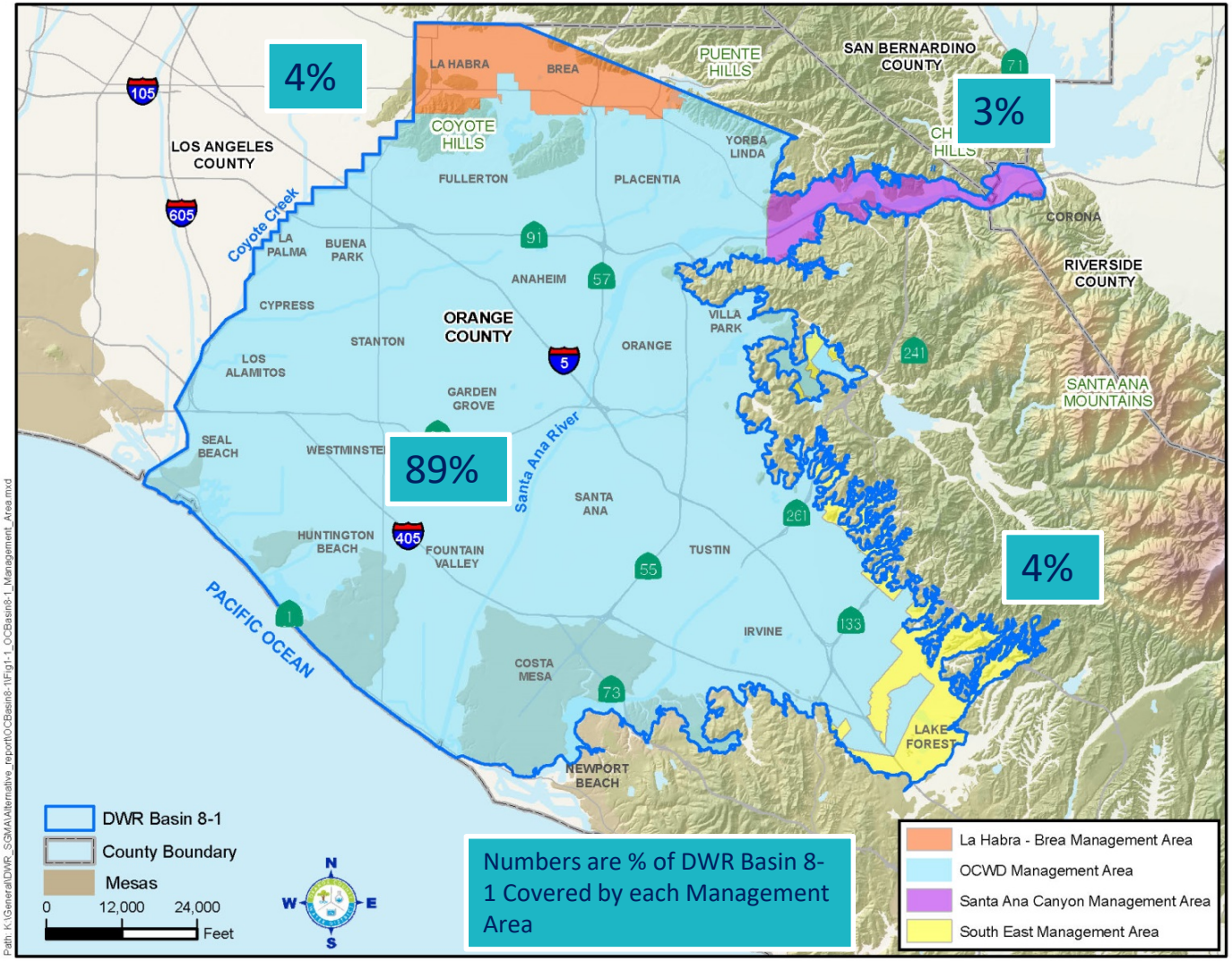




SGMA states that OCWD is the "exclusive" local agency to comply with SGMA within its boundaries; however, there are more than a dozen "SGMA" eligible agencies within Basin 8-1.

OCWD collaborated with multiple agencies to define four Management Areas in its "Alternative Plan".

Alterative Plan is currently under review by DWR.



The OC Basin has been operated sustainably since the mid-1970s.

Lowering GW Levels

No

Degraded Quality

No. OCWD is cleaning up contamination.

Reduction of Storage

Storage maintained in operating range.

Land Subsidence

No

Seawater Intrusion

Halted in 1975 with Talbert Barrier

Surface Water Depletion

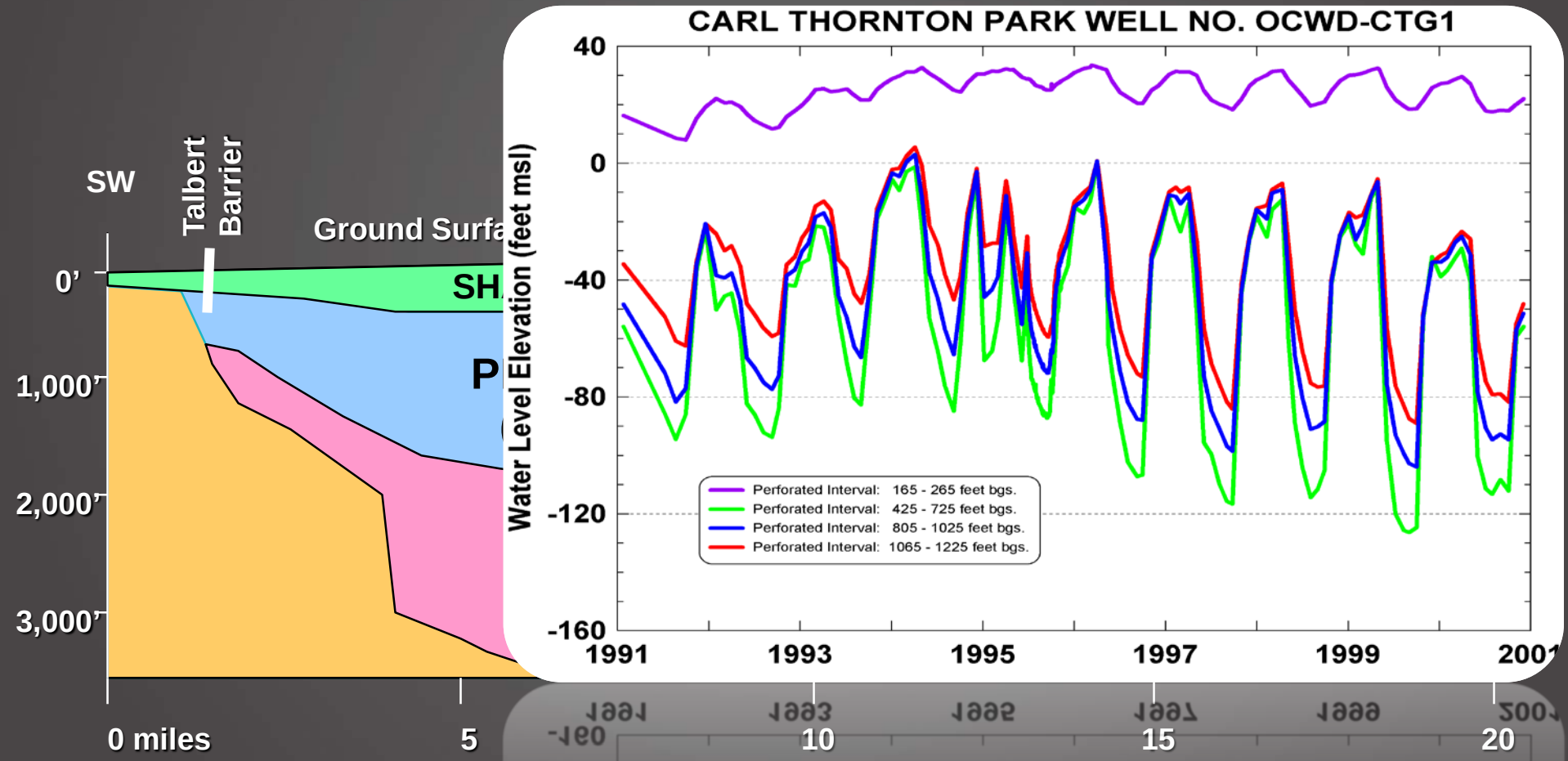
Not applicable

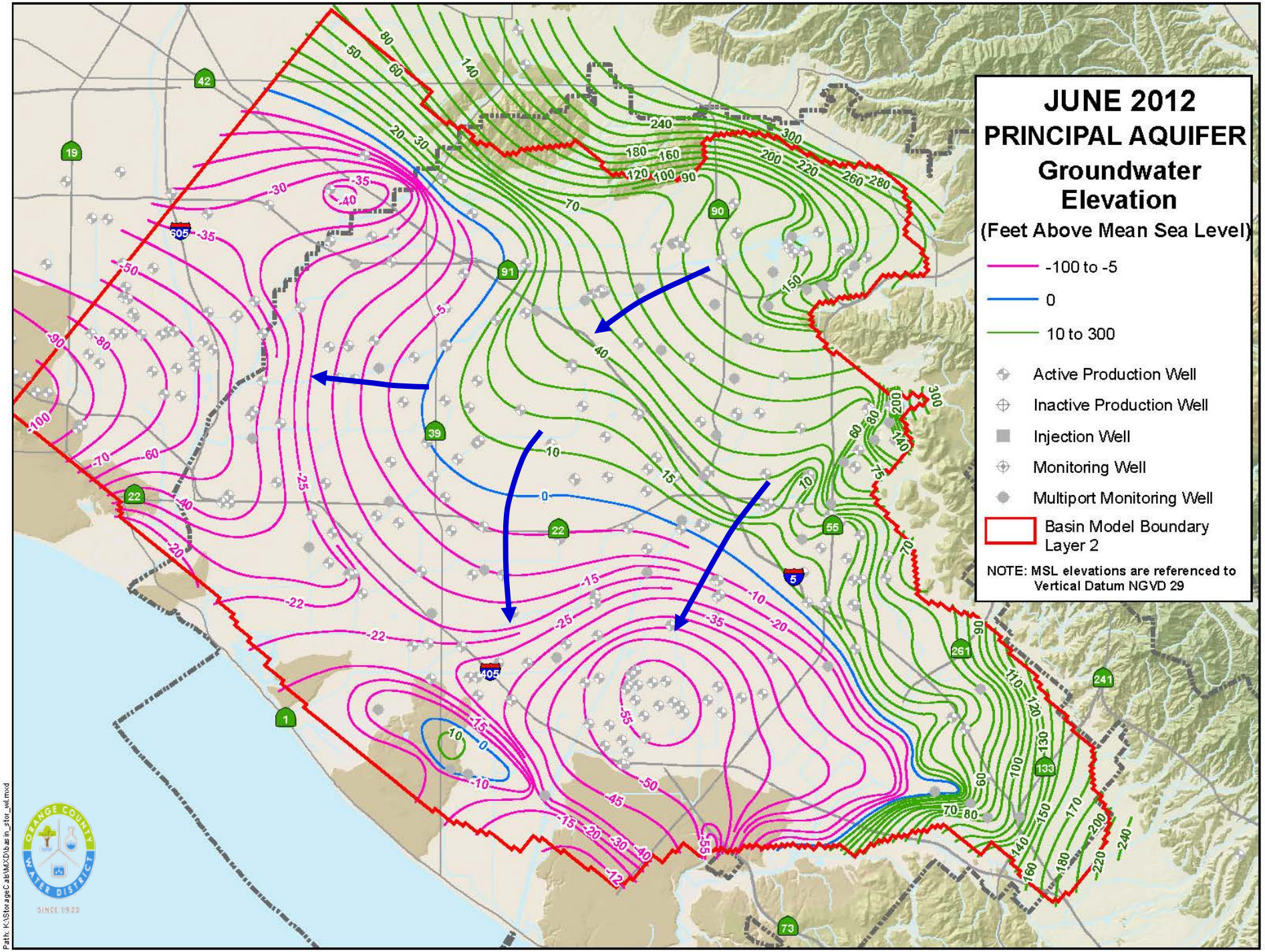
Managing GW Levels

- Extensive monitoring well network
  - 1,000 measuring points monitored monthly to bi-monthly
- Basin-wide water levels obtained every June (end of fiscal year)
  - Includes production wells
  - Contour maps of 3 aquifers generated annually
- Shift groundwater production away from coast as needed
  - Assists with Seawater Intrusion Barrier

Multi-depth wells were crucial to defining the three aquifer systems in the basin.

- Multi-level monitoring wells




JUNE 2012
PRINCIPAL AQUIFER
Groundwater Elevation
(Feet Above Mean Sea Level)
-100 to -5
0
10 to 300
Active Production Well
Inactive Production Well
Injection Well
Monitoring Well
Multiport Monitoring Well
Basin Model Boundary Layer 2
NOTE: MSL elevations are referenced to Vertical Datum NGVD 29
ORANGE COUNTY WATER DISTRICT
SINCE 1933
Path: K:\StorageCalcs\MXD\basin_stor_wl.mxd

What is significant and unreasonable?

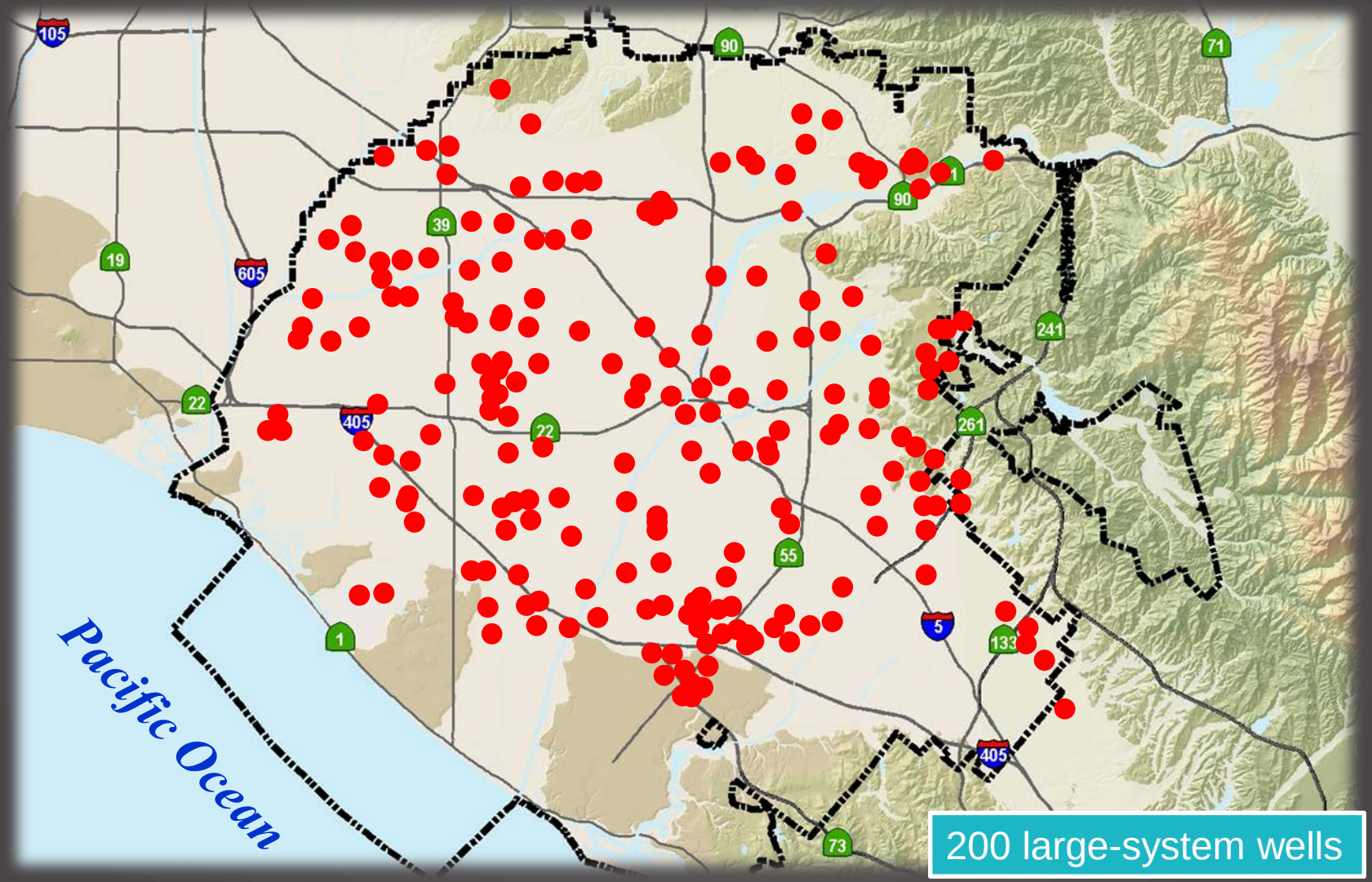
- Lowering of groundwater levels is significant and unreasonable if it results in basin storage to fall below the operating range for an extended period of time.
- Minimum Threshold: When basin storage falls below the operating range for an extended period of time.

Reduction of Storage

Managing GW Storage

- Calculate storage monthly using water budget approach
- Calculate storage annually for all 3 aquifers
  - Use June contour maps
  - Allows estimate of “unknown” or “incidental” recharge
- Two approaches generally agree
- Increase recharge or reduce pumping to maintain storage within operating range

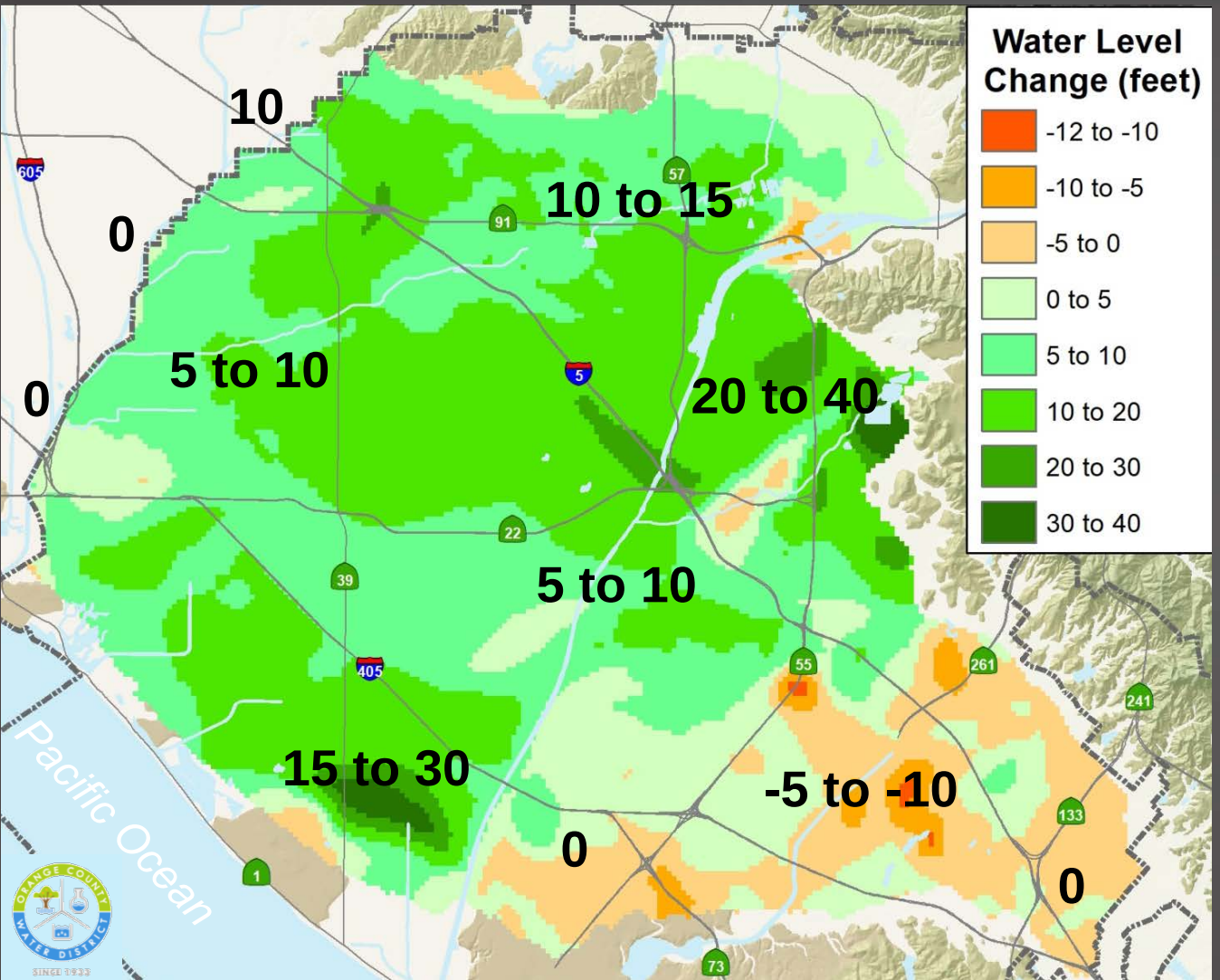
Groundwater production from 407 wells is metered and reported.



WY2012-13 Groundwater Budget

Inflows & Outflows (acre-feet)	Projected Avg Rain 13.66”	Actual Rain 5.85”
SAR Base Flow Recharge	105,000	93,200
SAR Storm Flow Recharge	50,000	19,100
Incidental Recharge	60,000	19,700
GWR System (Forebay & Barrier)	72,000	72,600
MWD Supplies	13,000	40,000
Other (Alamitos Barrier)	3,000	1,700
Total Water Into Basin	301,000	246,300
Basin Pumping @ 68% BPP	-300,000	-309,300
Storage Change	+1,000	-63,000
Basin Storage (af below full)	178,000	242,000

The difference in water levels in each aquifer is calculated annually.



Principal Aquifer Water Level Change

June 2016 to June 2017

Rise throughout most of basin: 10-15 ft

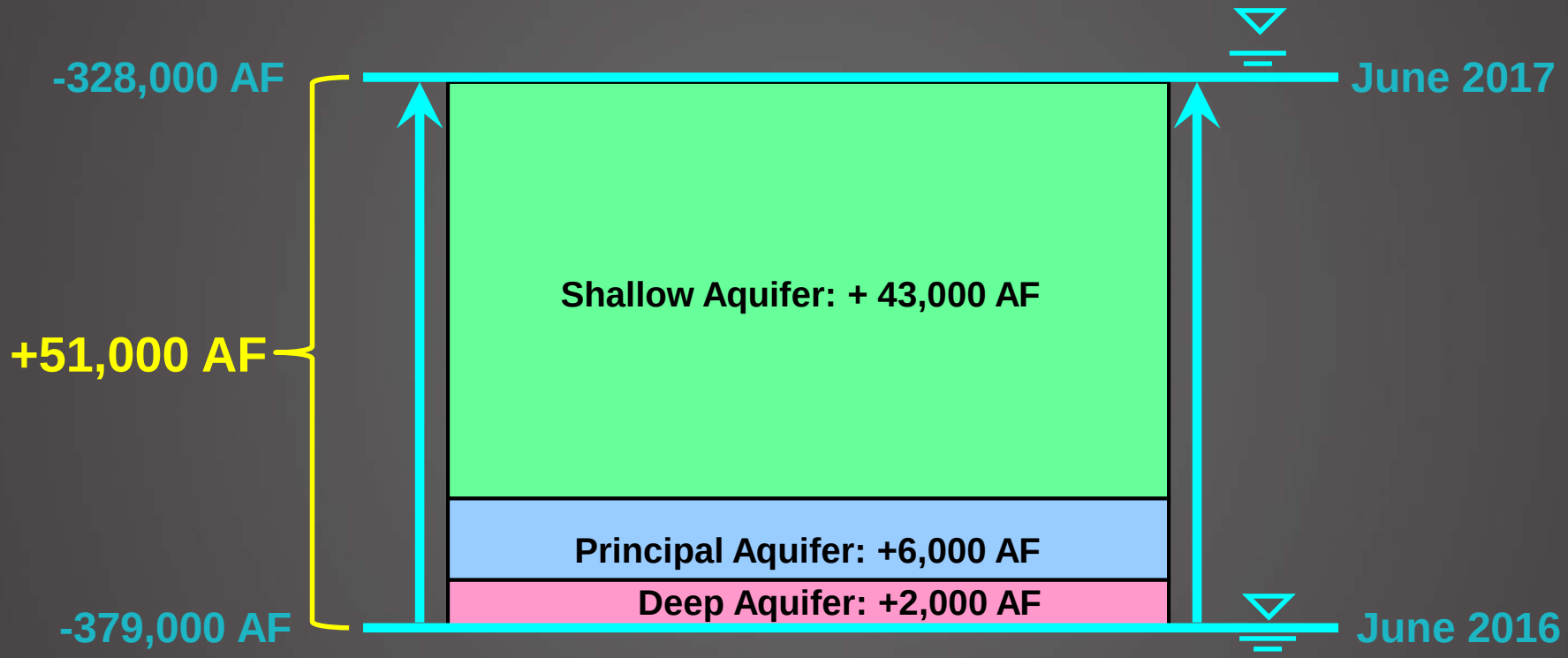
Max rise near Santiago Basins: 40 ft

Decline in most of Irvine area: 5-10 ft

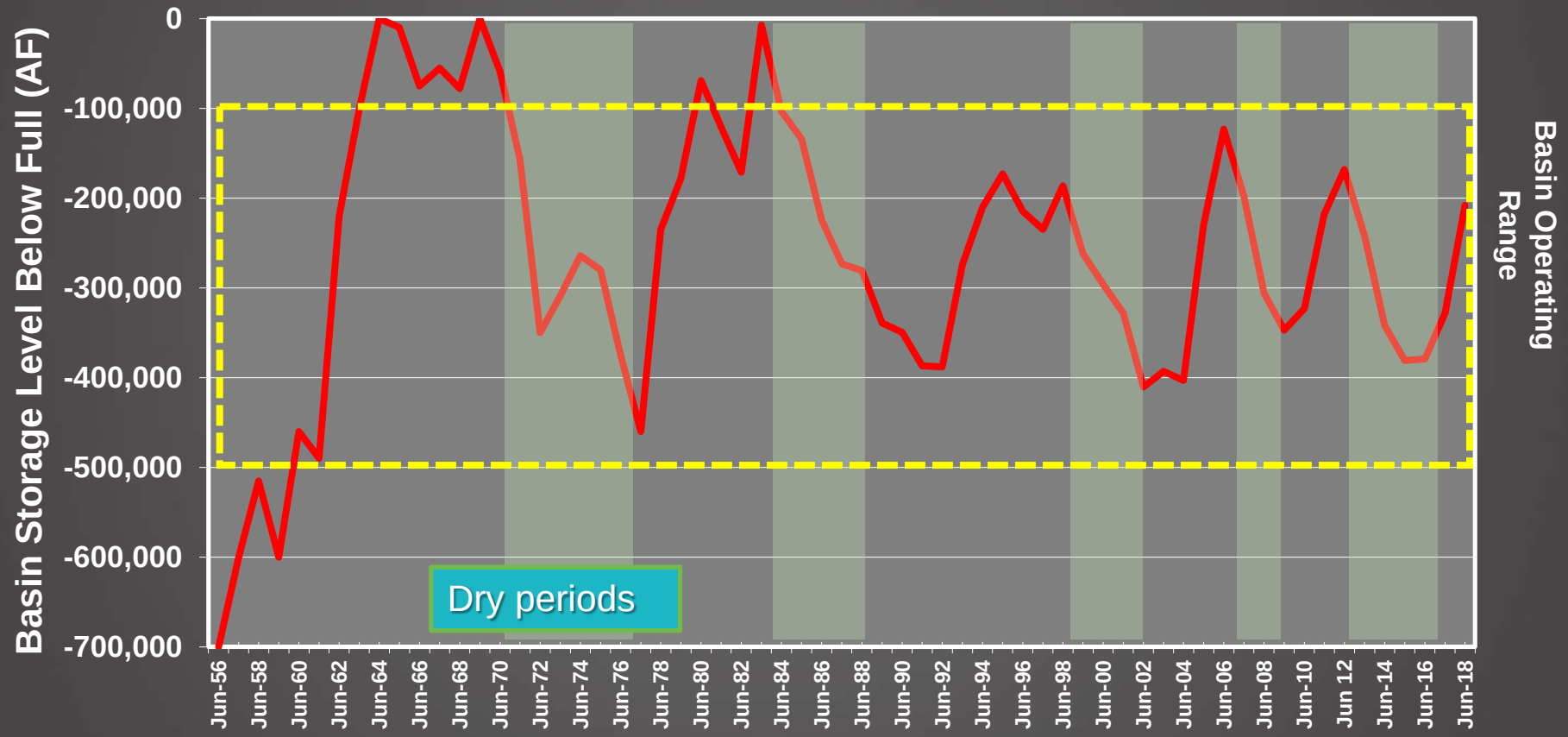
Smaller rise in west OC and LA County

Steeper gradient towards Long Beach

In WY 2016-17, there was in increase in 51,000 af of storage in the basin.



OCWD manages basin storage within a specific operating range.



Total basin storage is 66MAF. Operating storage is <1% of total storage.

OCWD has basin management triggers tied to basin storage conditions.

Basin Storage Conditions (acre-feet below full)	Basin Management Actions to Consider
Less than 100,000 af	Raise BPP
100,000 to 300,000 af	Maintain and/or raise BPP
300,000 to 350,000 af	Seek additional supplies to refill the basin and/or lower the BPP
Greater than 350,000 af	Seek additional supplies to refill the basin and lower the BPP

What is significant and unreasonable?

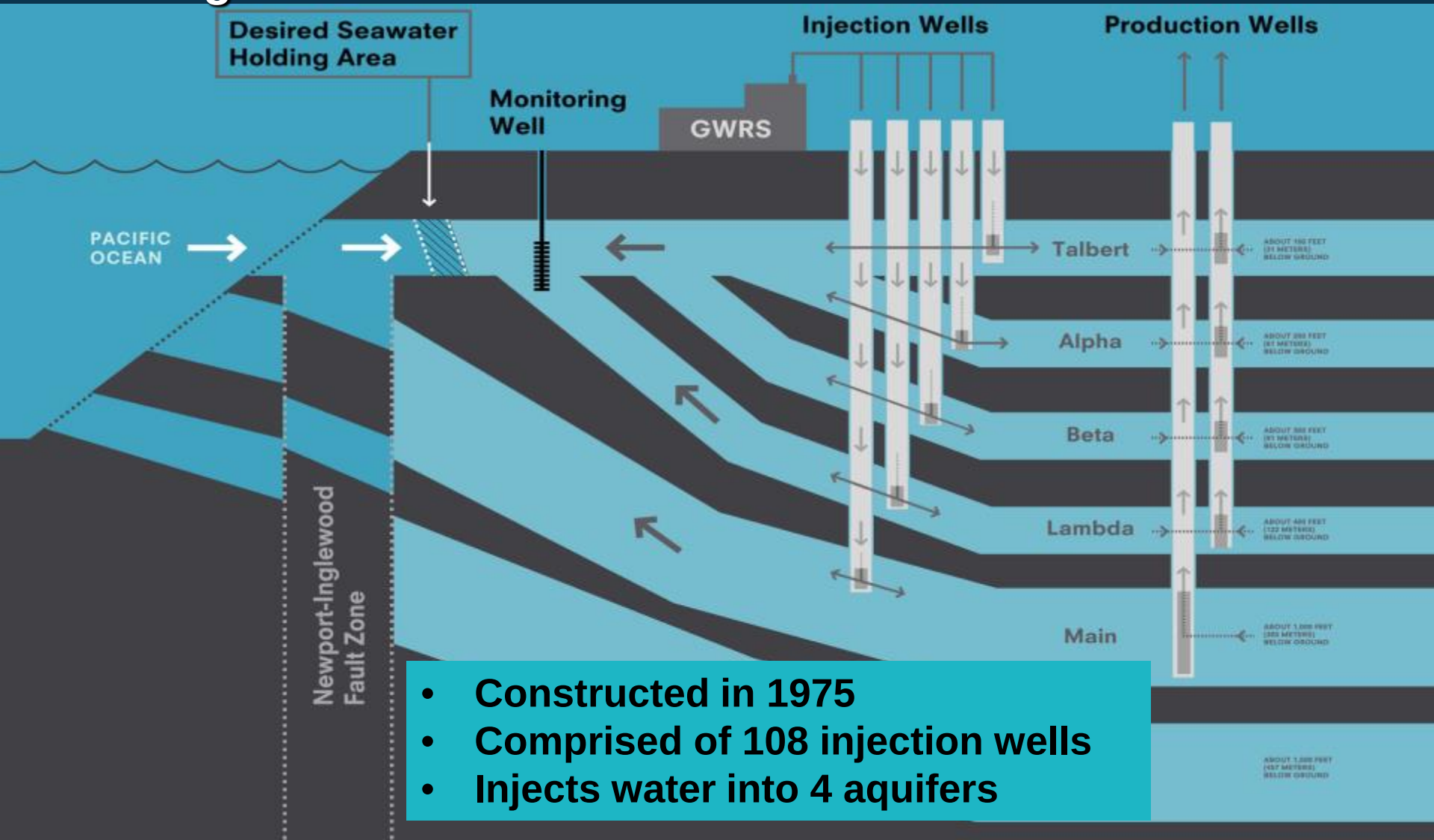
- A significant and unreasonable reduction in groundwater storage would occur if storage fell below 500,000 acre-feet for an extended period of time.
- Minimum Threshold: When the storage volume of the groundwater basin falls below 500,000 acre-feet for an extended period of time.

Seawater Intrusion

Managing Seawater Intrusion

- Monitor groundwater quality in “gaps” and other areas susceptible to intrusion
- Maintain groundwater levels in “gaps” at or above “protective” elevations
- Install additional monitoring and injection wells as needed
- Development of focused hydrogeologic models to optimize barrier performance

The Talbert Gap Seawater Intrusion Barrier was constructed to protect and maximize the use of basin storage.



- Constructed in 1975
- Comprised of 108 injection wells
- Injects water into 4 aquifers

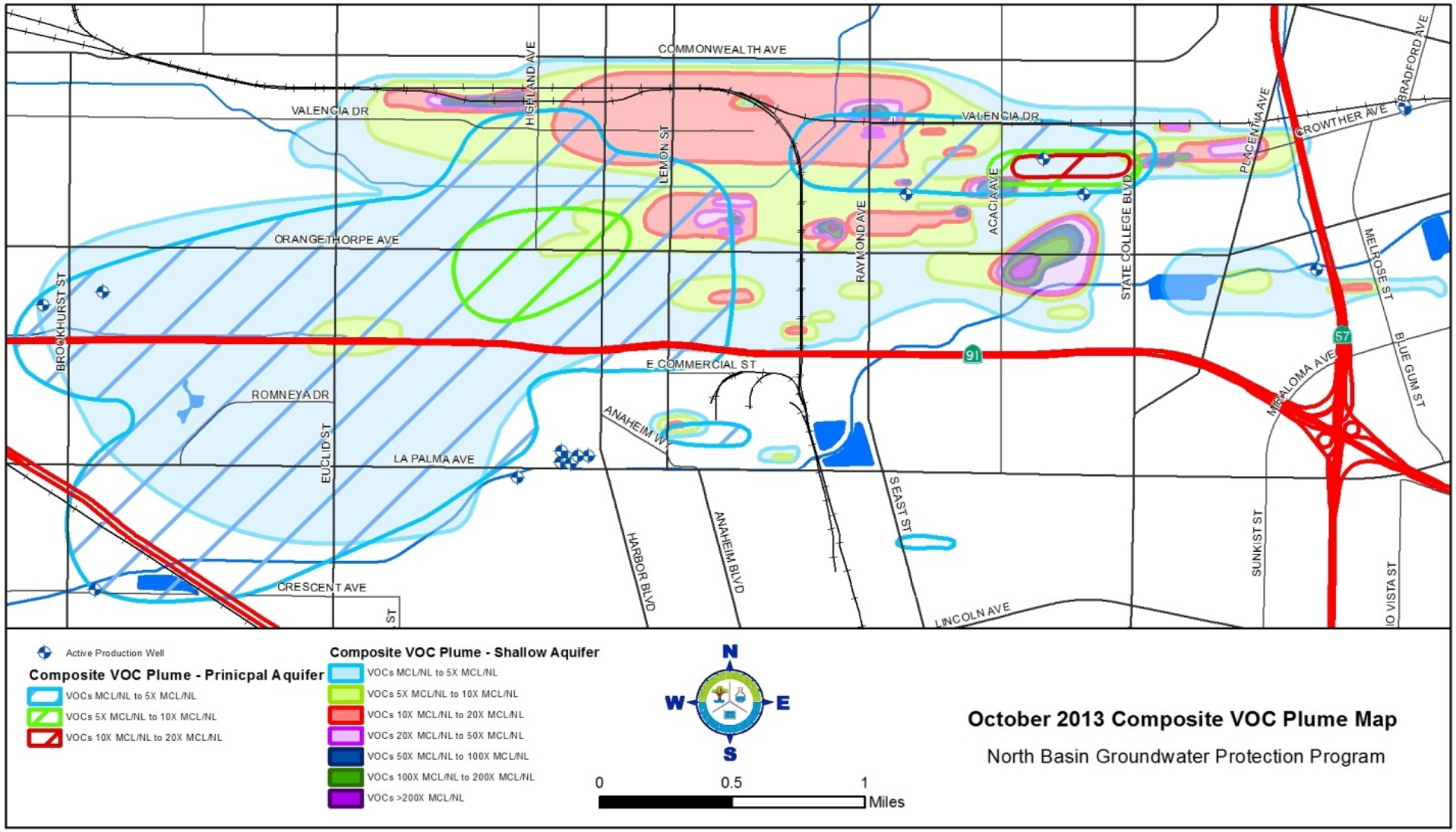
What is significant and unreasonable?

- A significant and continuing reduction in usable storage volume in the groundwater basin as a result of seawater intrusion.
- Minimum Threshold: When (1) active large system production wells are shutdown due to seawater-derived salinity and (2) continuing loss of a significant amount of basin storage due to seawater-derived salinity.

Managing Groundwater Quality

- Monitor groundwater quality
- Salinity management
- Work closely with and support existing agencies (e.g, DTSC, RWQCB)
- Groundwater quality improvement projects
  - TDS/Nitrate removal
  - VOC cleanup
- Provide financial incentives to producers

OCWD has been working to clean up a large, shallow VOC plume to protect deeper groundwater supplies.



What is significant and unreasonable?

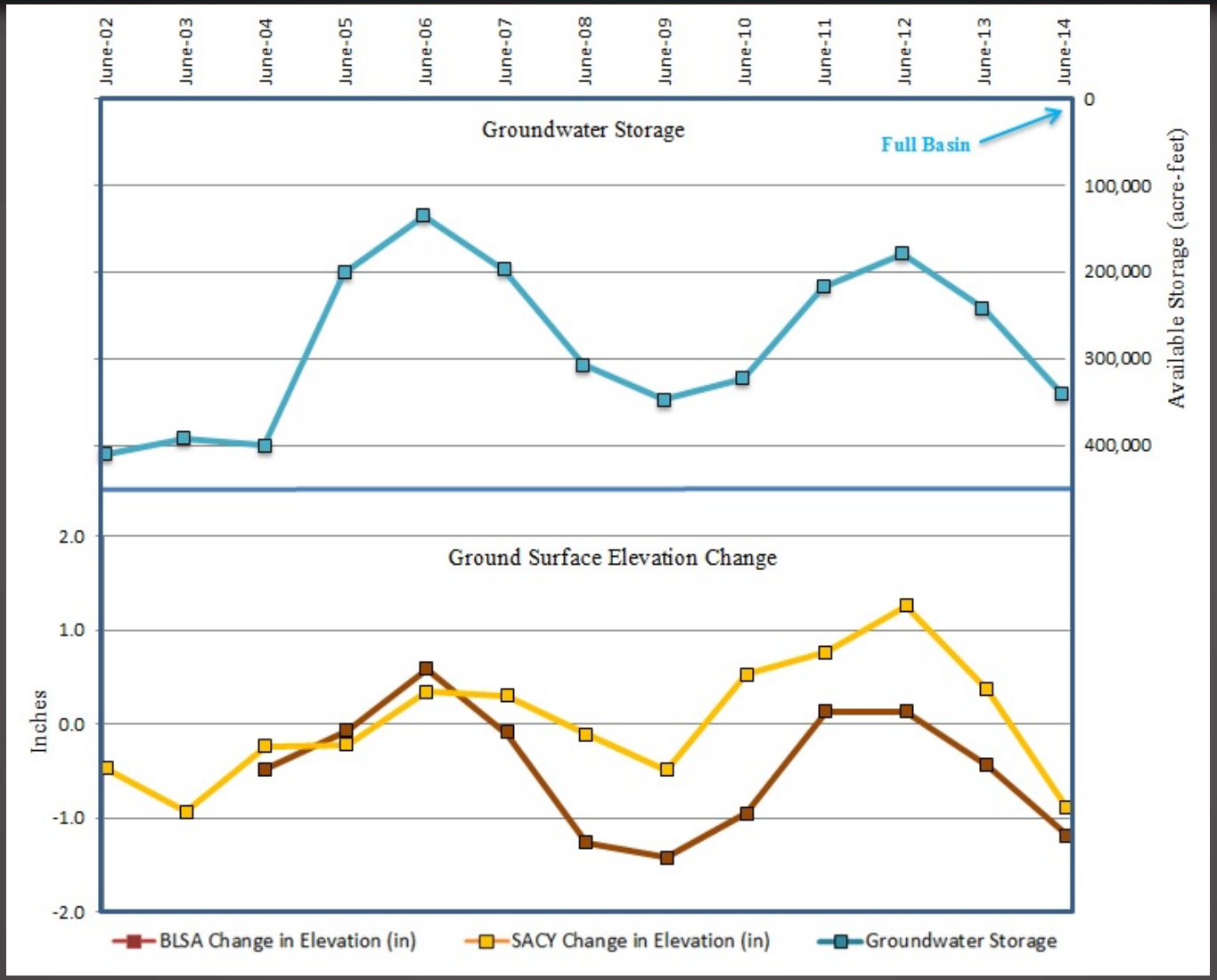
- Three key elements:
  - Causal nexus between groundwater management activities and groundwater quality
  - Beneficial uses and groundwater and water quality regulations (e.g., MCLs)
  - Volume of usable groundwater impacted
- Minimum Threshold: Exceedances of MCLs or other applicable regulatory limits that are directly attributable to groundwater management actions that prevents the use of groundwater for its designated beneficial uses.

Land Subsidence

Managing Subsidence

- Maintain groundwater storage within target operating range
- Monitor ground surface elevations
  - Orange County surveyor

Ground surface elevations rise and fall based on groundwater storage levels.



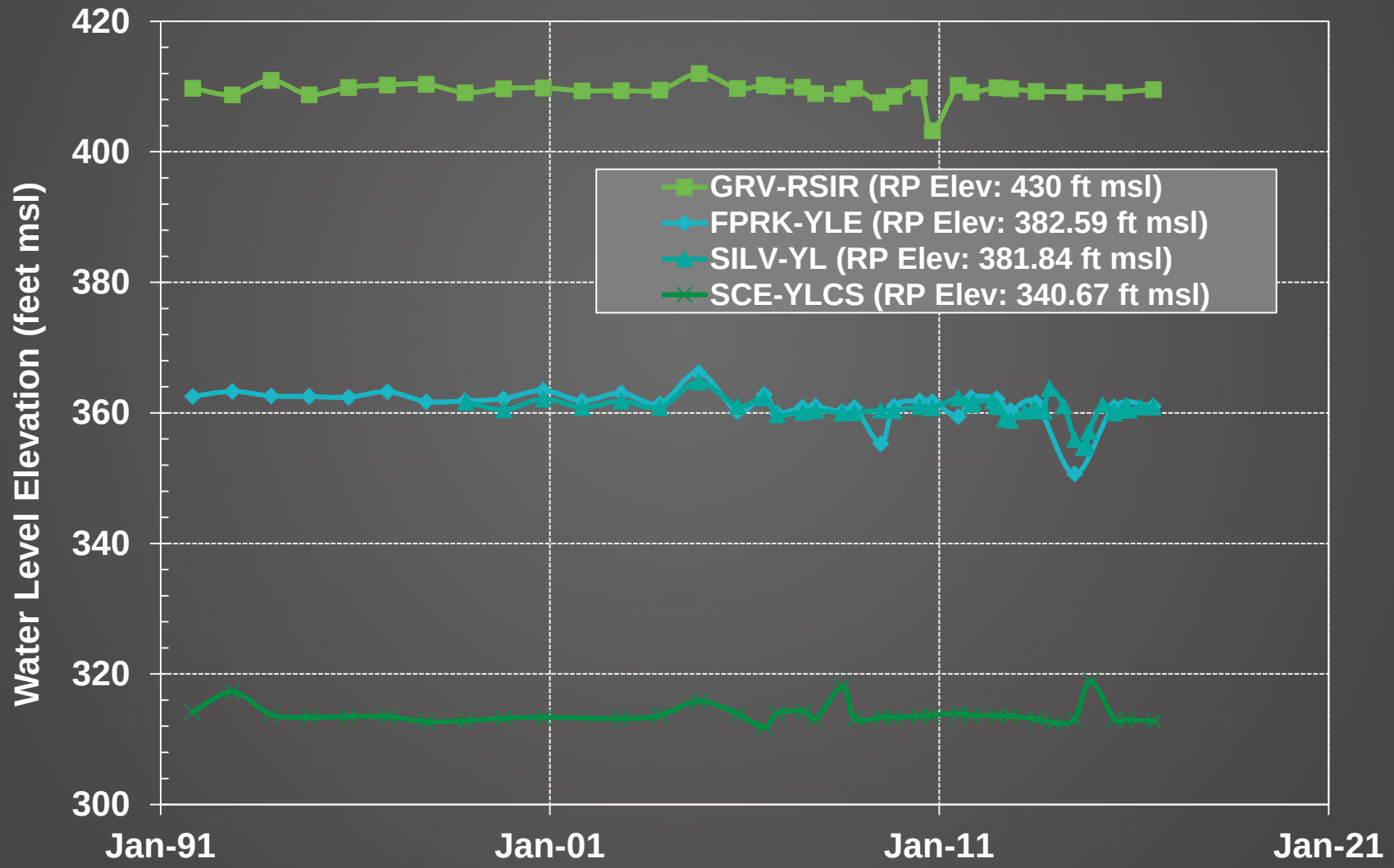
What is significant and unreasonable?

- Significant and unreasonable subsidence would be occur if ground surface elevation changes are determined to be inelastic over a significant period of time, caused by declines in groundwater storage and impact surface uses.
- Minimum Threshold: Sustained lowering of ground surface elevation that is attributable to lowering of groundwater storage and is likely to interfere with surface uses.

Managing Surface Water Depletion

- Only Santa Ana Canyon Management Area has surface water
- Santa Ana River flows in and over “full” alluvial canyon aquifer
  - Water levels are flat
  - Surface flow through canyon is orders of magnitude higher than groundwater pumping
- Once Santa Ana River exits canyon, it percolates into the river channel and becomes concrete lined to ocean

Groundwater in the Santa Ana Canyon is not affected by pumping/recharge in the main basin.



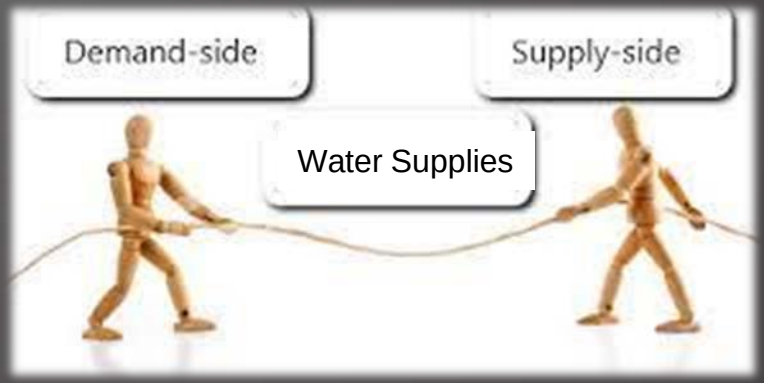
What is significant and unreasonable?

- No foreseeable significant and unreasonable impact to groundwater depletions impacting surface water.

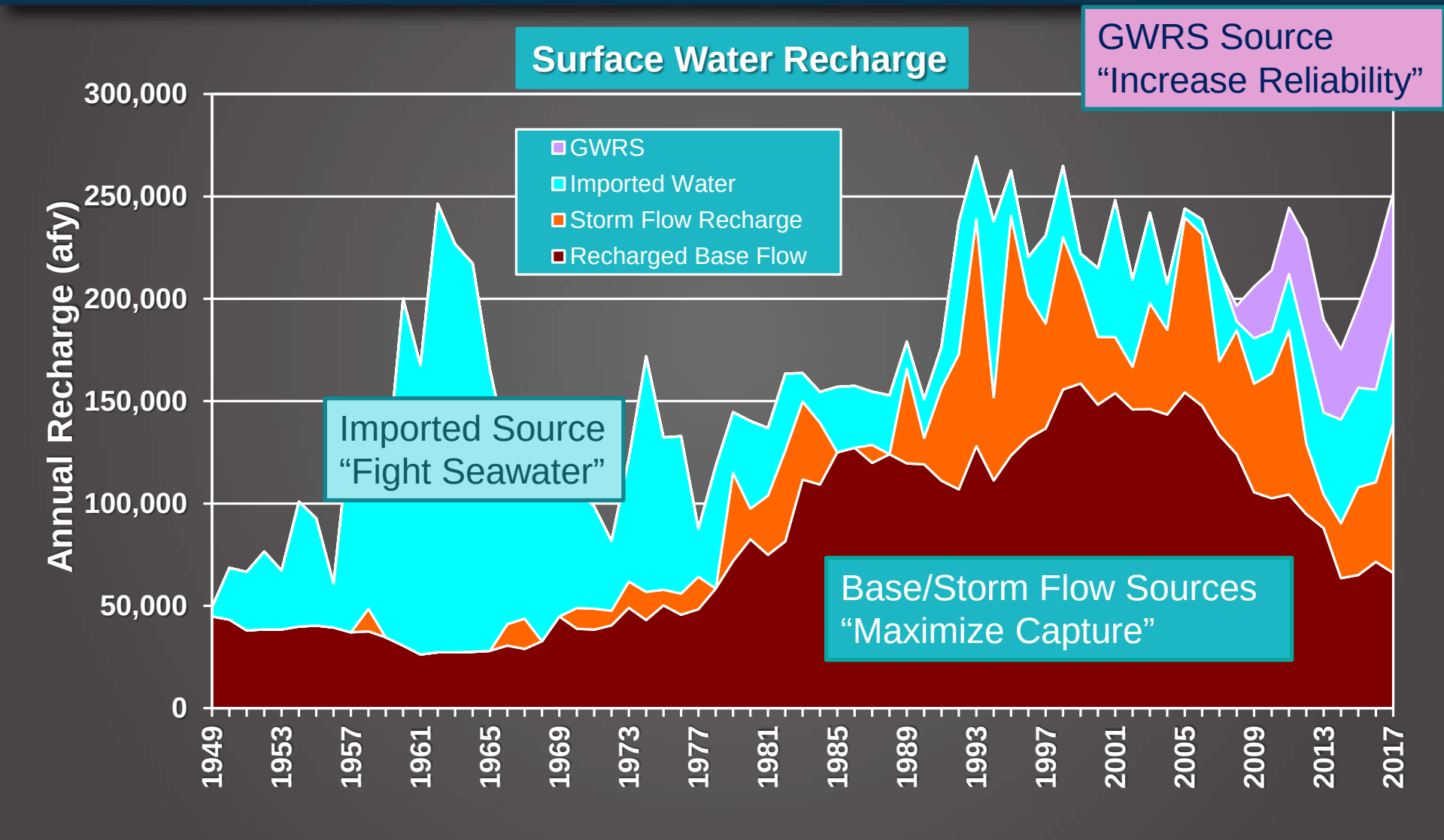
Exceeding our limits!

OCWD has always taken a “supply-side” approach to groundwater management.

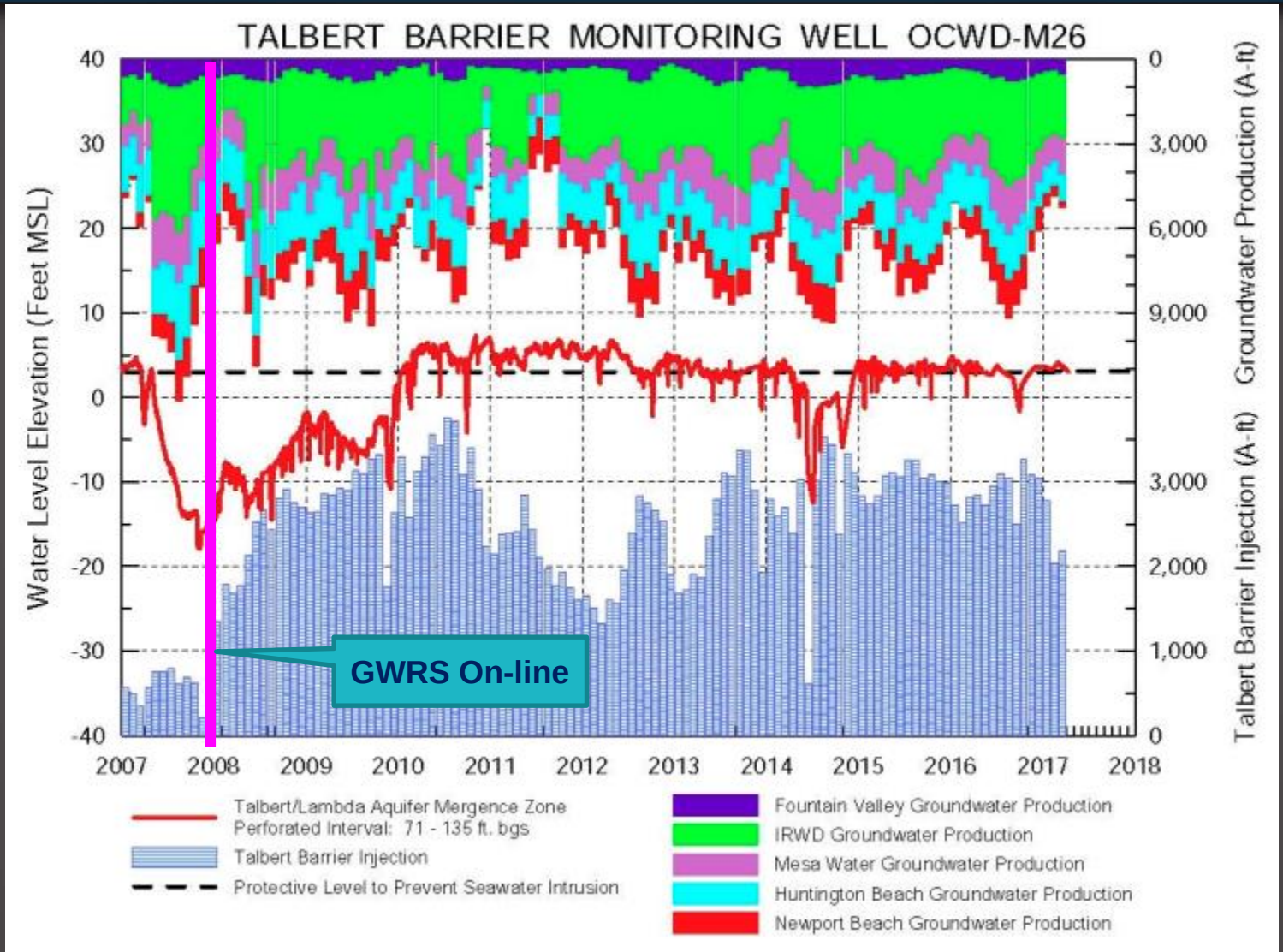
- Aggressively pursue opportunities to increase supply.
  - Early leaders were farmers and knew that land values were tied to abundant water supply
- Rejected adjudication as “philosophy of scarcity” and needless expense.



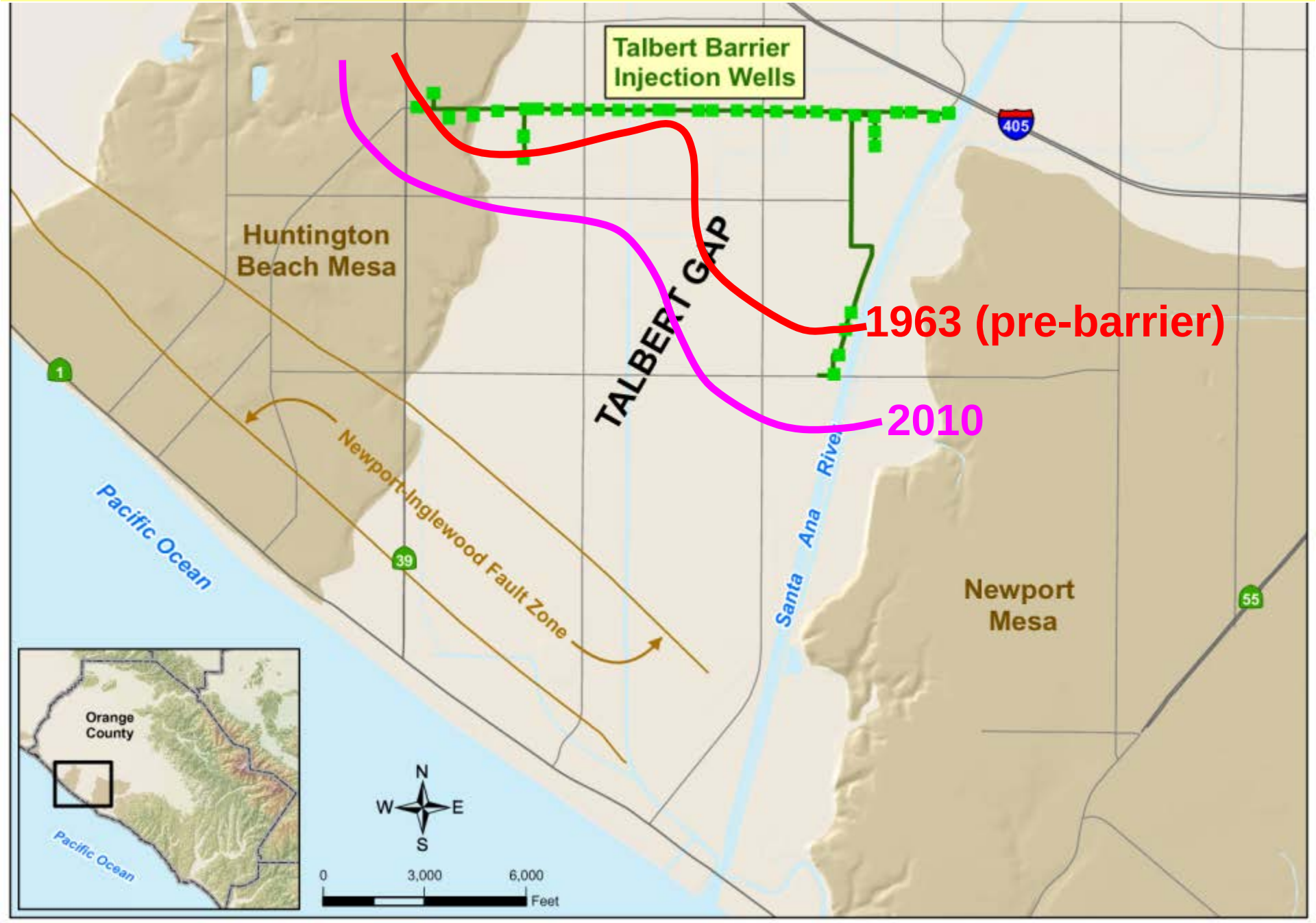
OCWD's managed aquifer recharge reflects changing approaches and opportunities in basin management.



About 30,000 acre-feet per year of recharge is needed to maintain protective elevations.



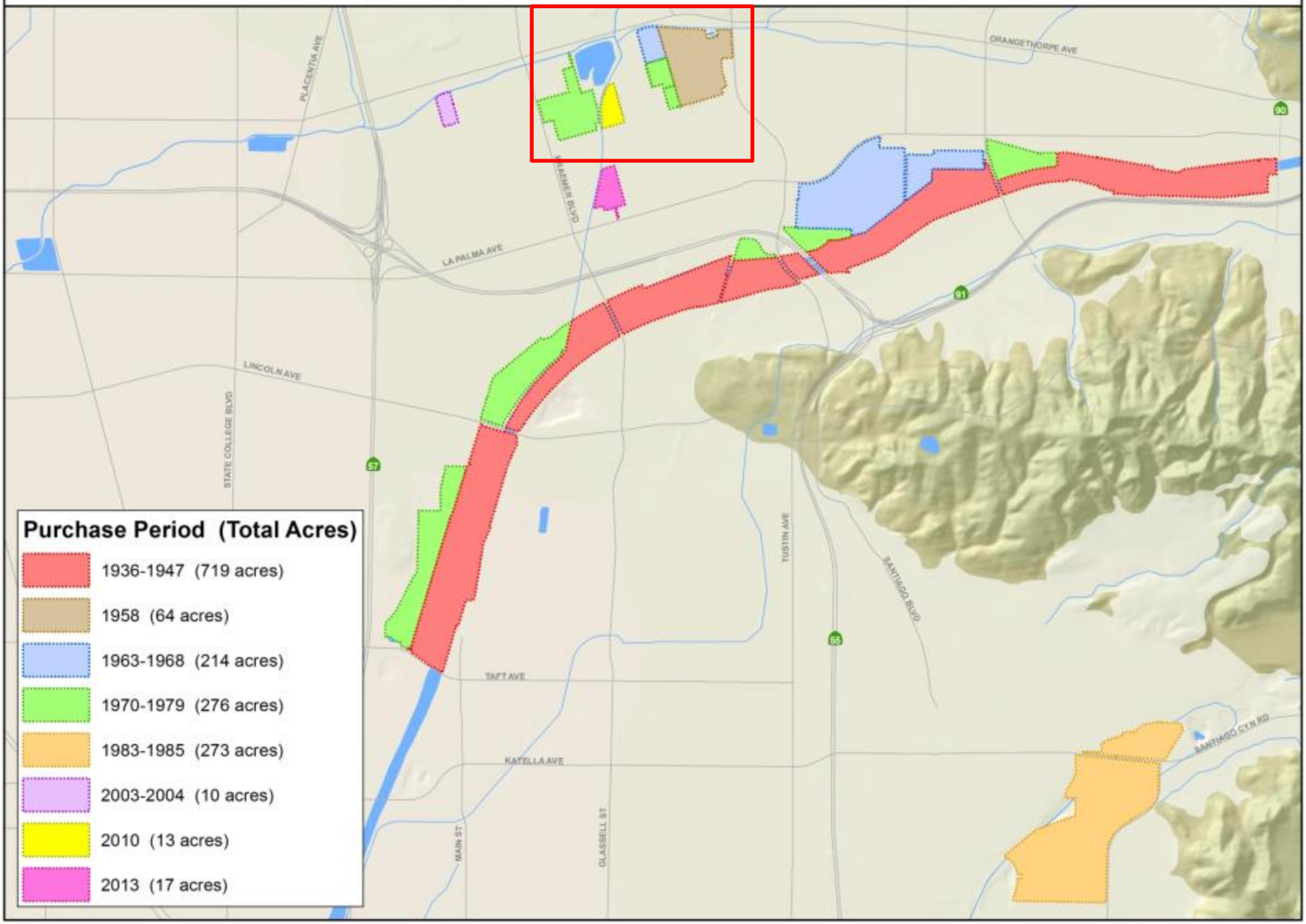
The 250 mg/L chloride line has been pushed further seaward.



What allowed OCWD to achieve sustainability.

- Agency created with narrow mission to manage groundwater.
- Supply-side orientation
  - Recharge all available supplies
  - Invest in local supplies (storm water, recycled)
- Non-adjudicated basin
  - Collaborative approach. All share in gains and pains.
- Reliable revenue stream based on pumping
- Economic incentives used to manage pumping

Over the course of 77 years, the District has purchased 1,590 acres for recharge.

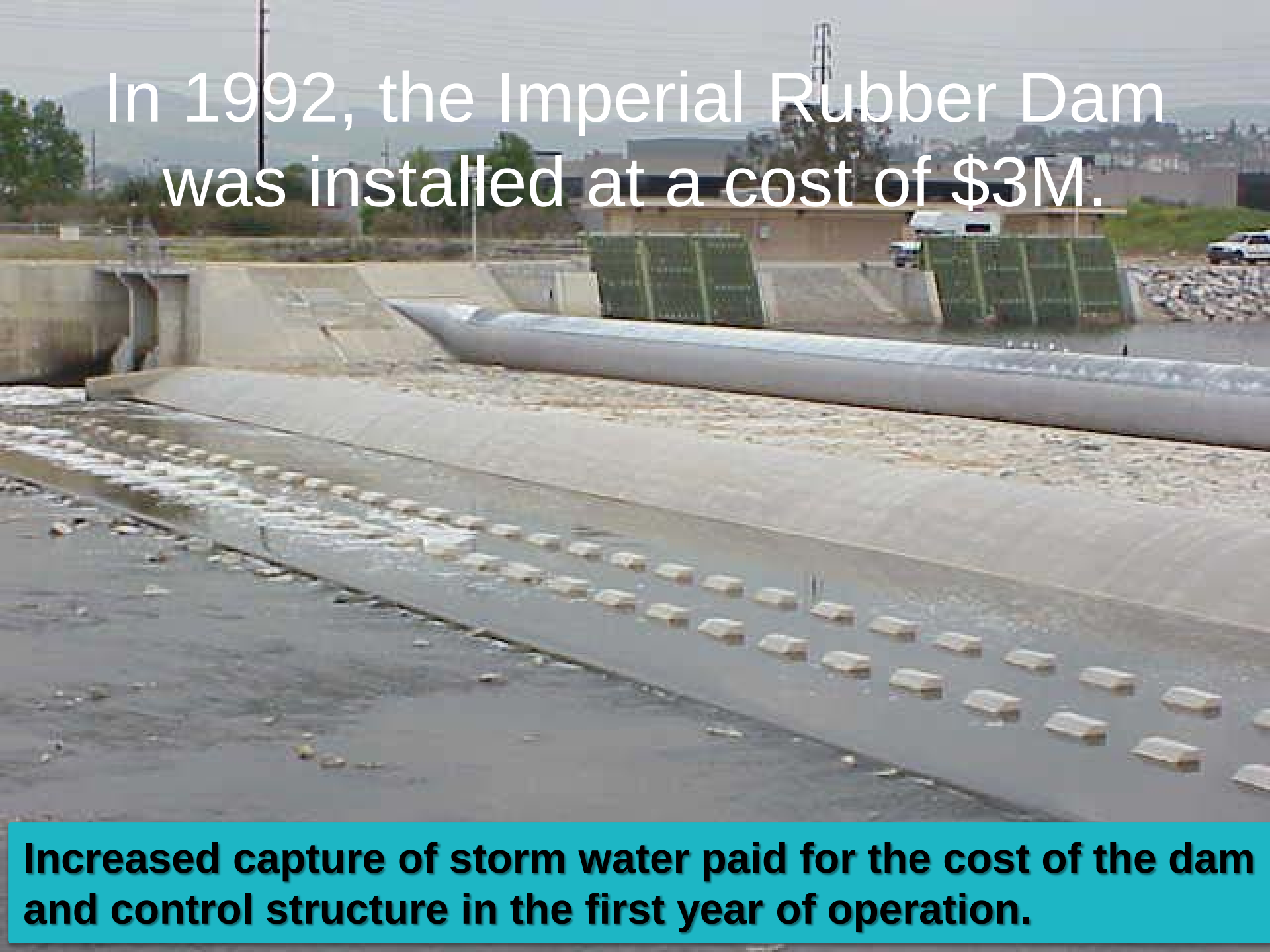


The deep basins are able to recharge up to 100,000 acre-feet per year.

Prior to the early 1990s, a large sand dike had to be constructed to divert water from the SAR.

Recharge operations to capture and recharge Santa Ana River flows started in the early 1930s.

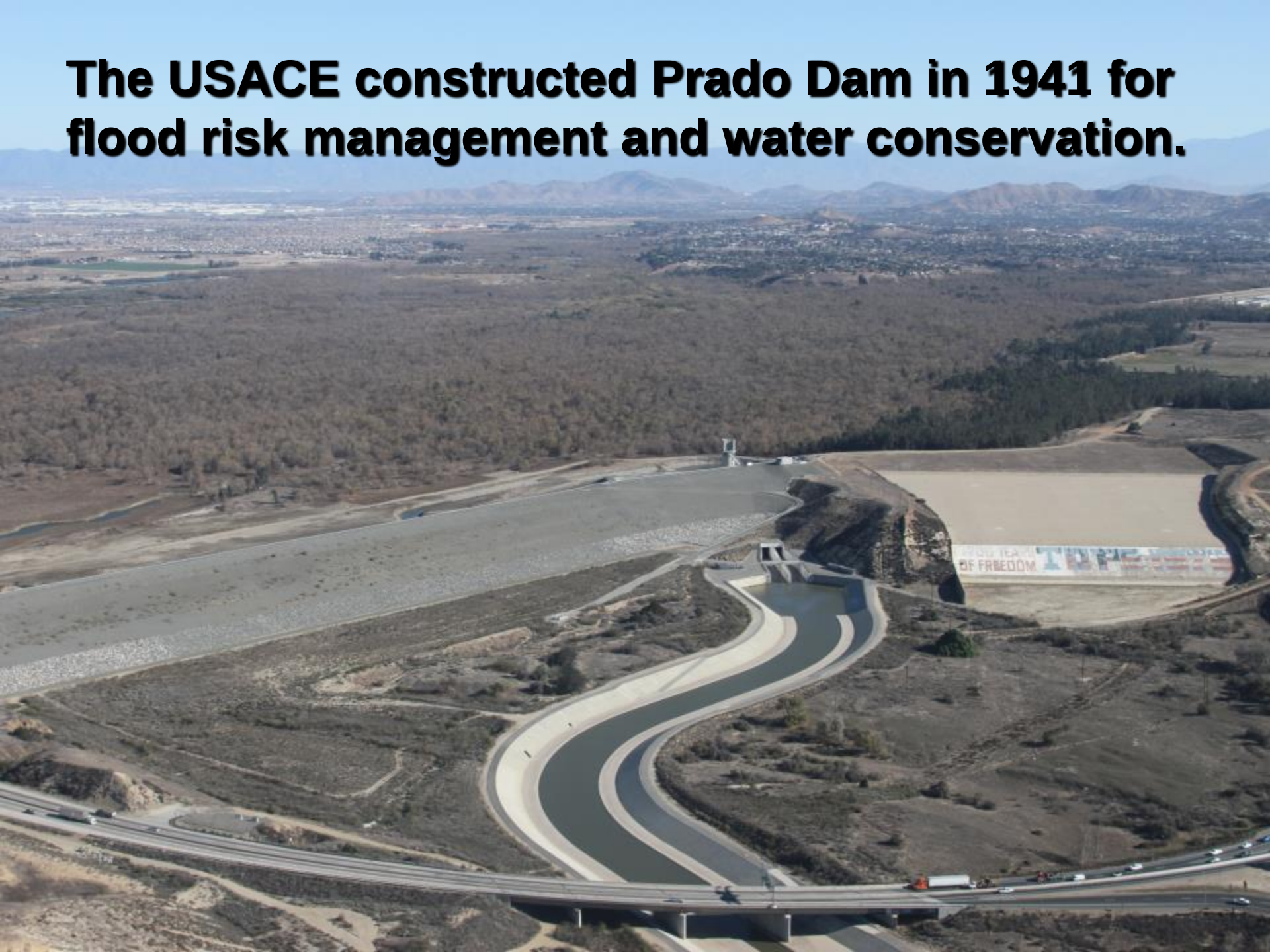
Santa Ana River, Anaheim



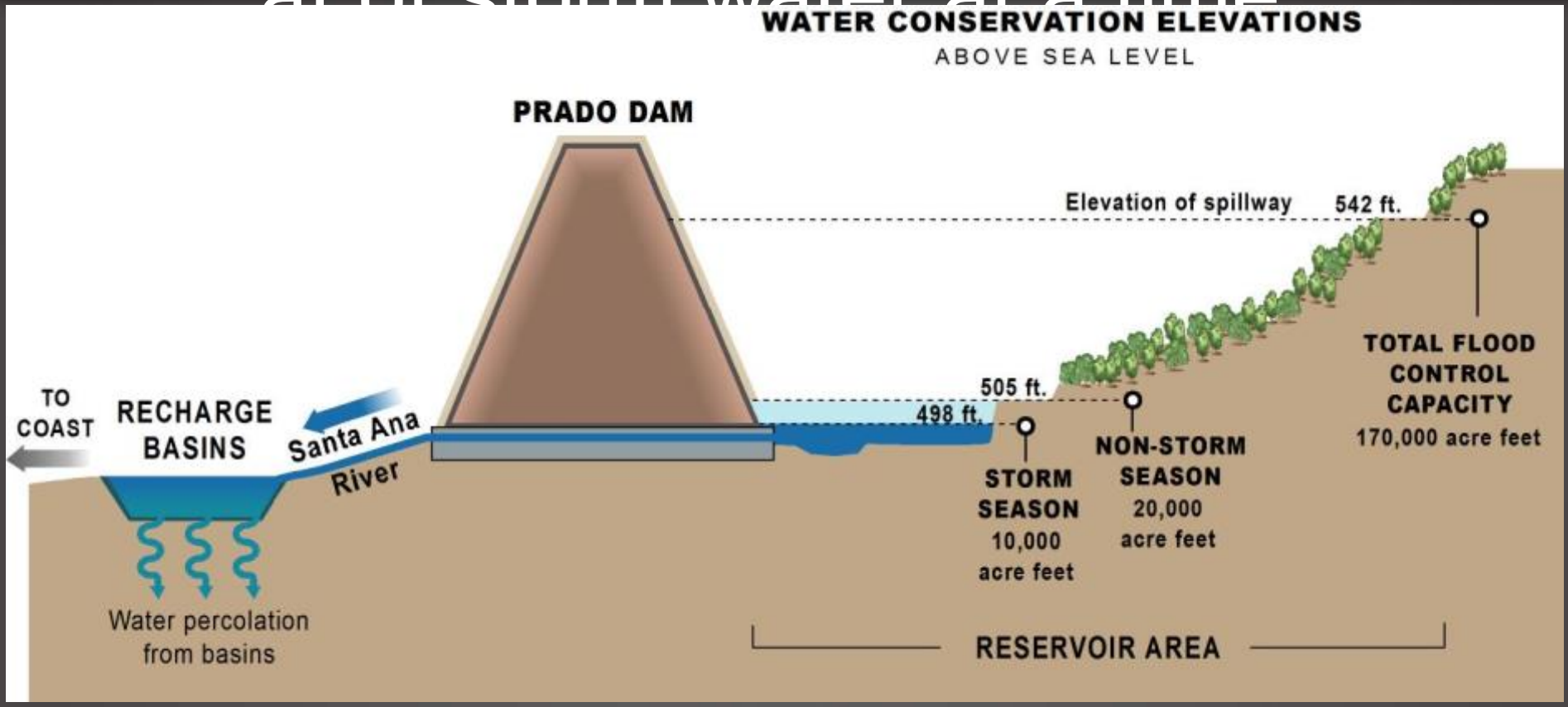
Increased capture of storm water paid for the cost of the dam and control structure in the first year of operation.

The Burris Basin pump station, with a capacity of 100,000 gpm, was installed in 1990 to move storm

The USACE constructed Prado Dam in 1941 for flood risk management and water conservation.

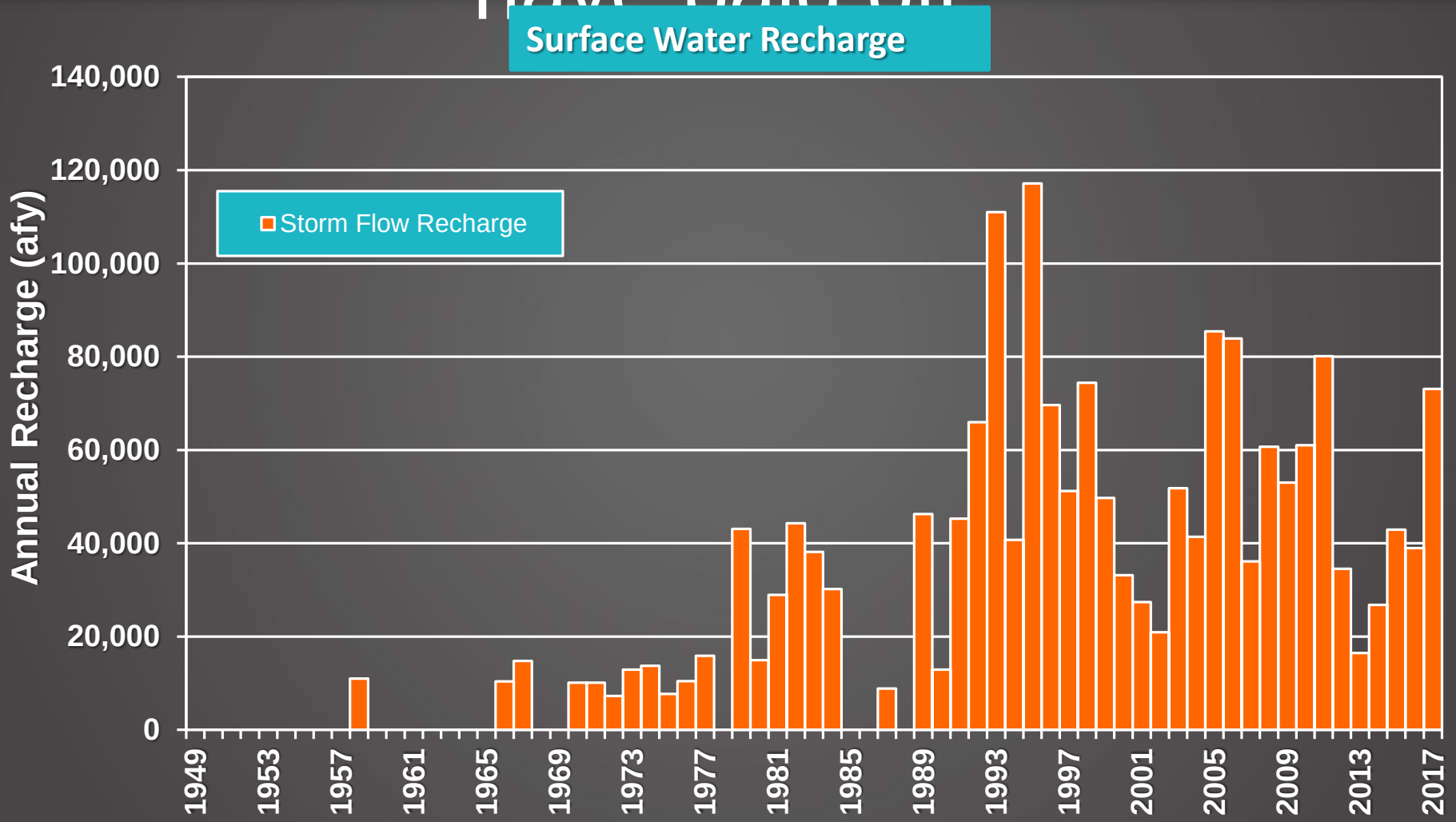


OCWD and the USACE cooperate to store and capture up to 20,000 af of storm water at a time



The ACOE coordinates the release rate with OCWD to match the capacity of the recharge system.

Investments in infrastructure and water conservation at Prado Dam have paid off



The District moved to control pumping and increase recharge.

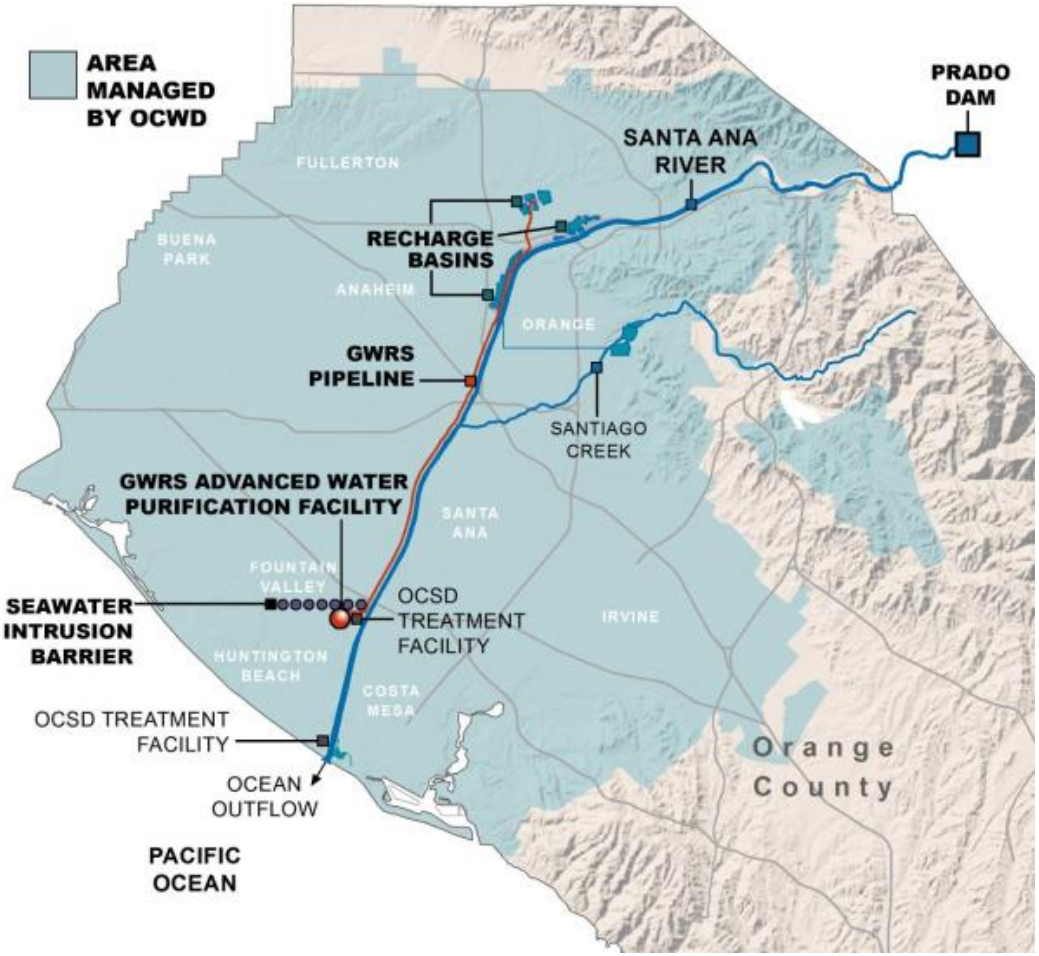
- Production wells registered
- Pumping tracked and reported 2 times per year
- Pumping assessment imposed to purchase imported surface water
- Expanded surface water recharge system


Sand “T and L” levees are constructed in the Santa Ana River channel to spread the water in the channel.
Santa Ana River
Burris Basin
The T and L levees also provide nesting and roosting habitat for numerous types of water fowl.

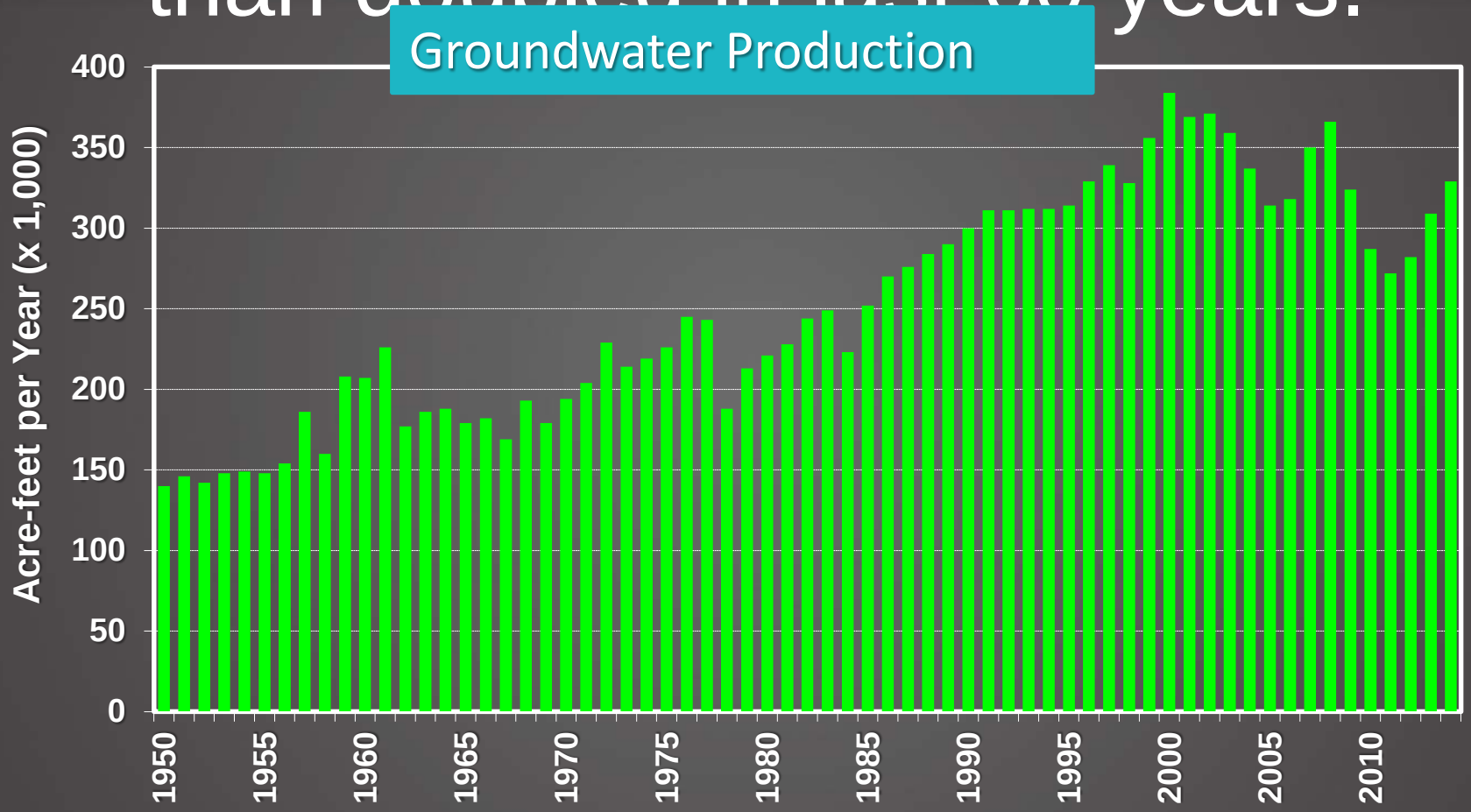
Water Factory 21 was constructed in 1975 to supply the barrier.

Water Factory 21 was replaced by GWRS in 2008 (being expanded to 130 MGD).

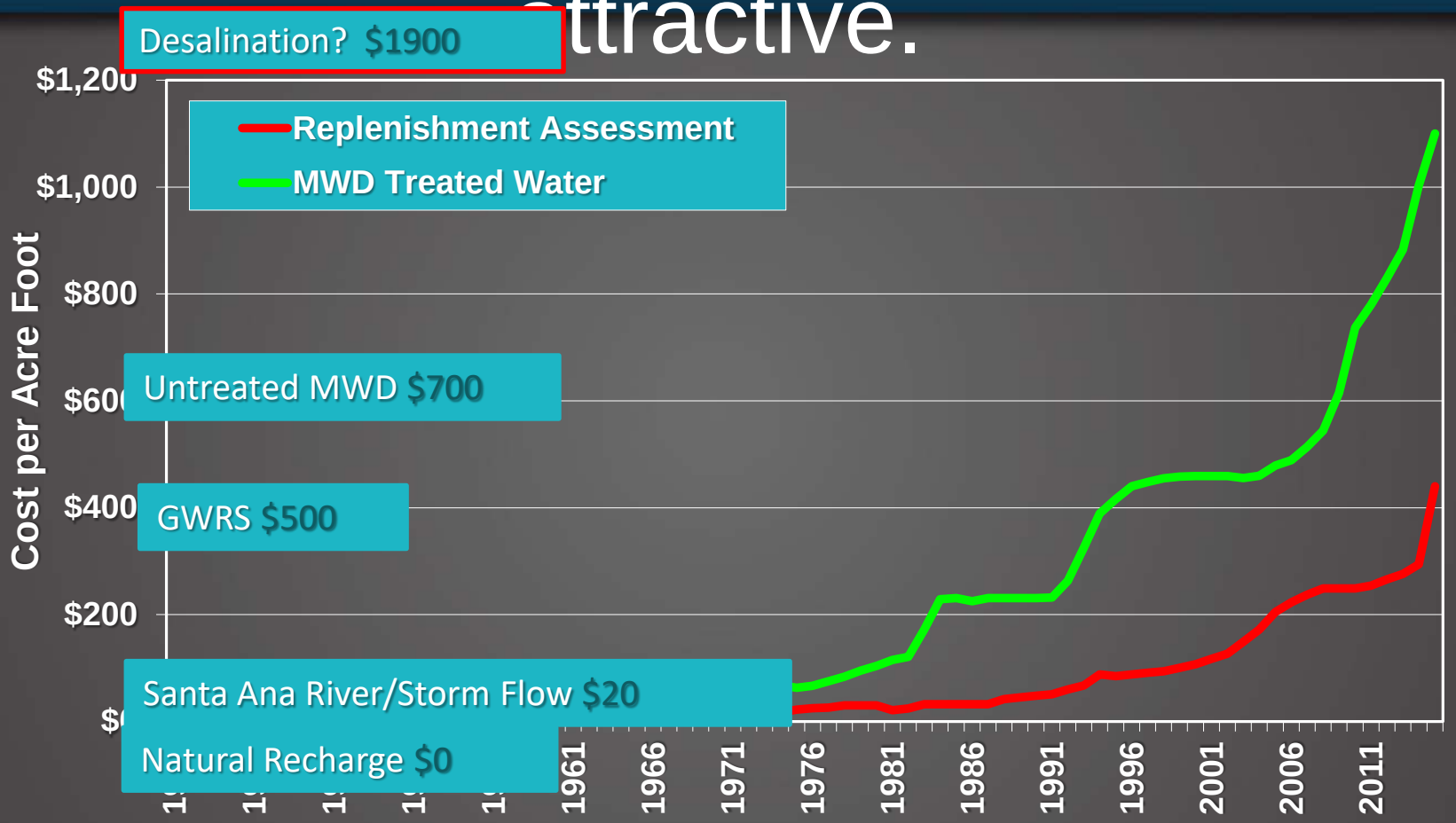
A 13-mile pipeline was constructed to link the treatment plant with the spreading basins



Demand for groundwater has more than doubled in last 60 years.



High imported water costs makes local resources development attractive.



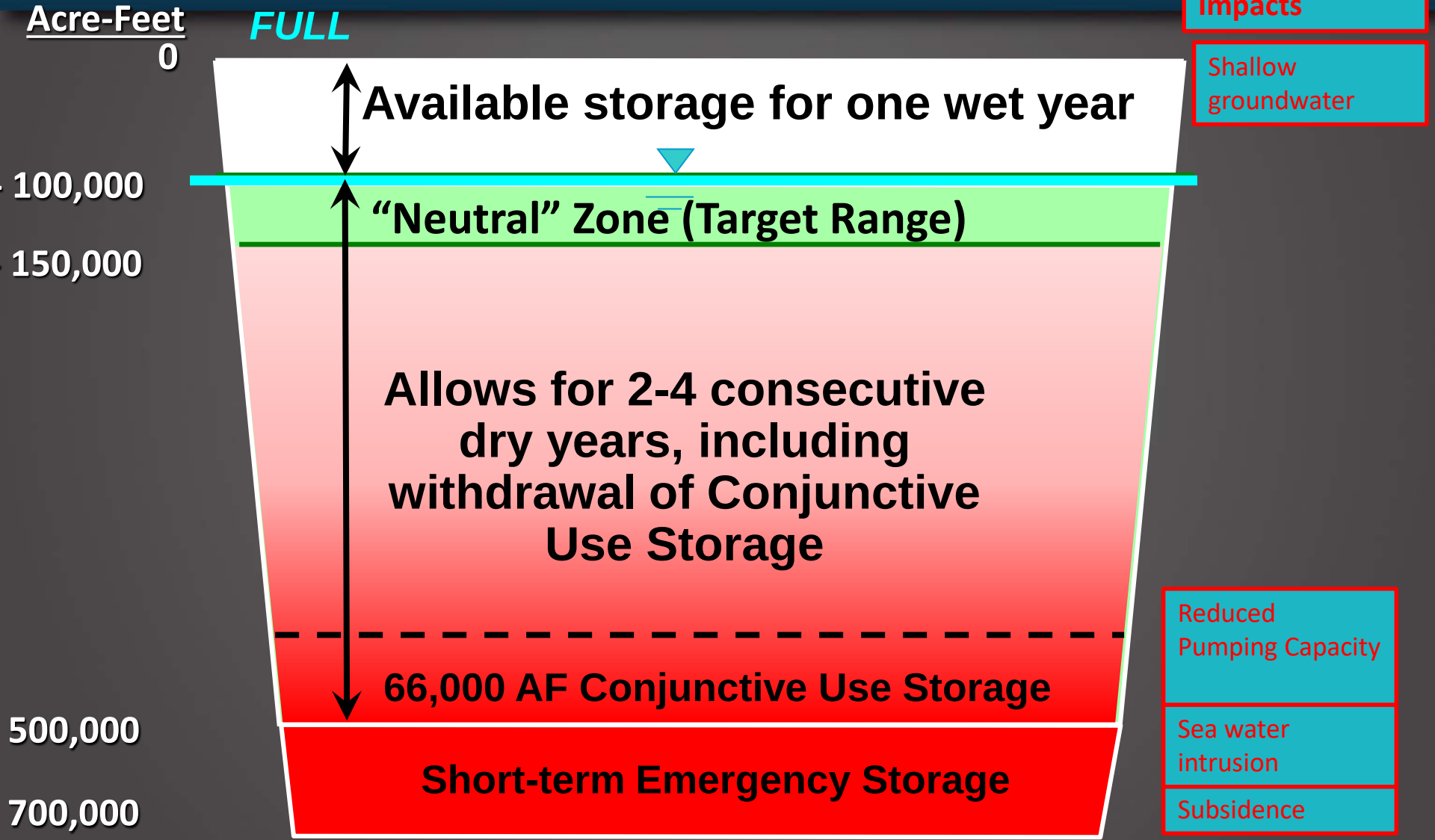
Closing thought.

- Two ways to bring a bring a basin into balance:
- 1. Reduce pumping
- 2. Increase supplies
- Both have a cost.
- In OCWD, if there is not enough groundwater, the cost of meeting demands is imported water ($1,000/af).
- What is the cost in your basin?

OCWD's statutory groundwater management authority is unique and effective

- 10-member Board of Directors (7 elected; 3 appointed)
- Basin not adjudicated (no court-assigned pumping limitations)
- Pumping determined each year based on basin supplies and storage level
- Over-pumping controlled by economic disincentives (penalty fees)
- Pumping fee charged to pay for OCWD programs and activities

Basin storage must be managed within limits or risk adverse impacts.



Fork in the Road (early 1970s): Import or Recycle?

- Seawater intrusion in Talbert Gap noted as far back as mid-1920s.
- Seawater barrier of multiple injection wells was needed.
- Imported water was inexpensive and readily available.
  - Legal issues created uncertainties with imported supplies (e.g., Az vs Ca, 1963)
- Recycled water was more expensive, but locally controlled.
  - Would take 30 yrs to perfect technology

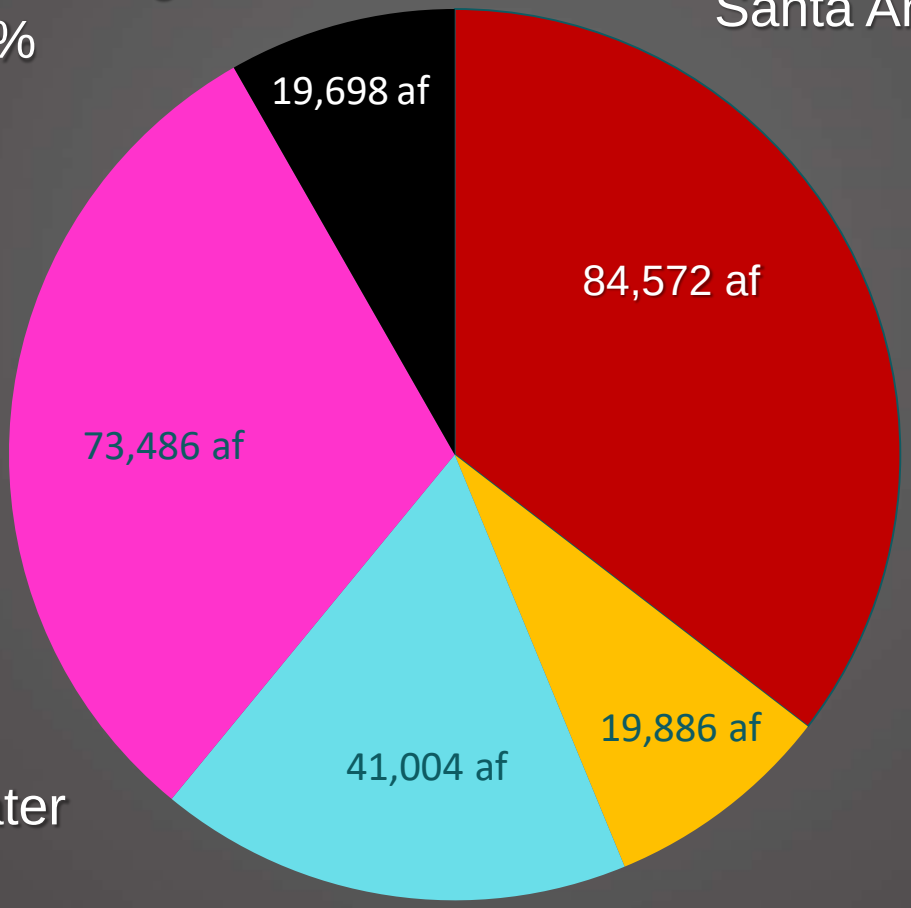
Account for the water ($).

- Meter pumping
- Measure surface flows
- Obtain water level data
- Estimate subsurface inflow/outflow
- Develop calibrated groundwater flow model

Wholistic: Develop integrated approach to water supply management.

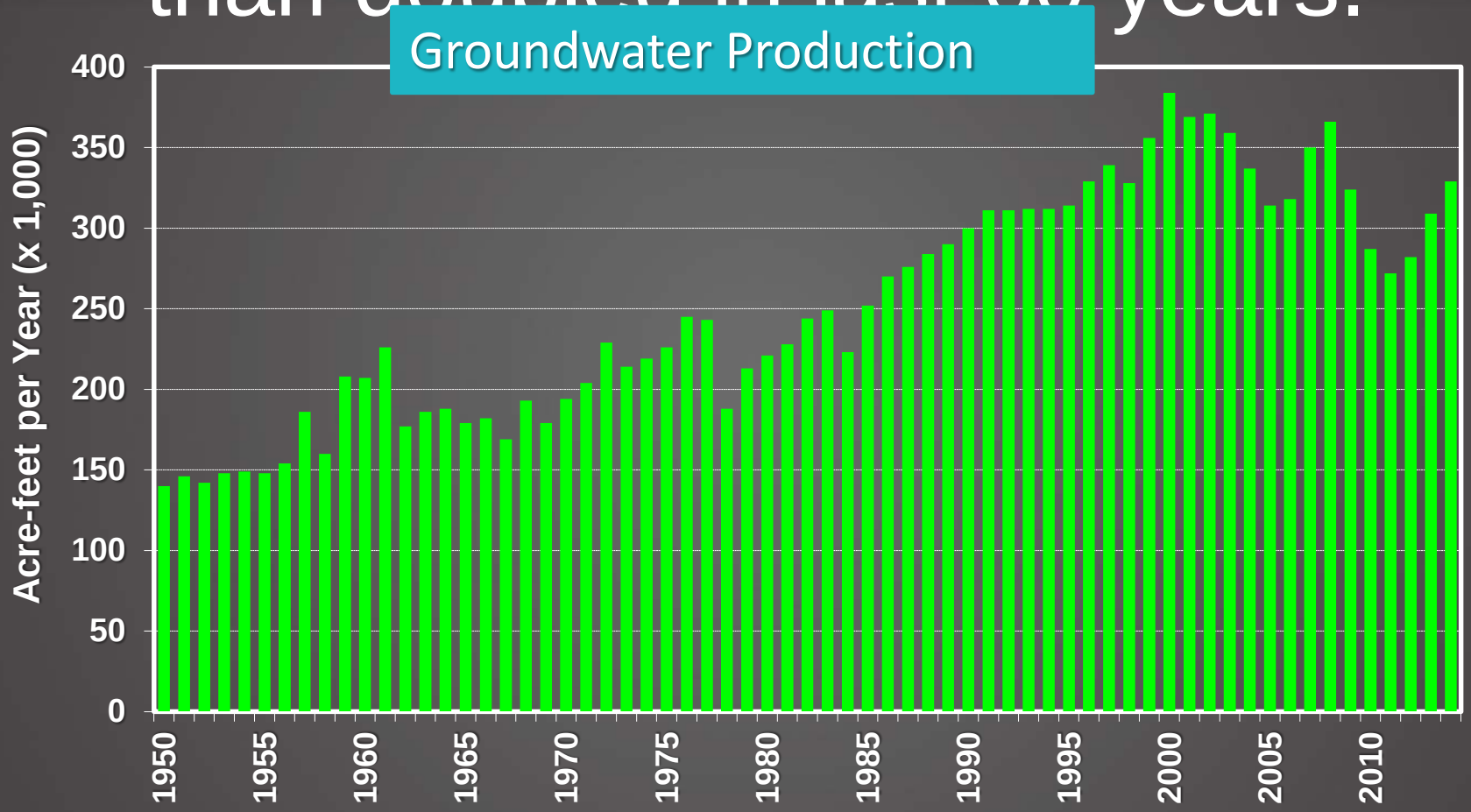
- Include entire watershed
- Conjunctively use surface water supplies/storage with groundwater supplies/storage
- Develop management structure that supports conjunctive use of surface/groundwater
- Include all users/beneficiaries
  - Environment is a key user/beneficiary

OCWD's recharge system has supported increased basin pumping.



Total FY12-13 Recharge: 238,646 af

Demand for groundwater has more than doubled in last 60 years.



What allowed OCWD to achieve sustainability.

- Agency created with narrow mission to manage groundwater.
- Supply-side orientation
  - Recharge all available supplies
  - Invest in local supplies (storm water, recycled)
- Non-adjudicated basin
  - Collaborative approach. All share in gains and pains.
- Reliable revenue stream based on pumping
- Economic incentives used to manage pumping

Closing thought.

- Two ways to bring a bring a basin into balance:
- 1. Reduce pumping
- 2. Increase supplies
- Both have a cost.
- In OCWD, if there is not enough groundwater, the cost of meeting demands is imported water ($1,000/af).
- What is the cost in your basin?

OCWD's statutory groundwater management authority is unique and effective

- 10-member Board of Directors (7 elected; 3 appointed)
- Basin not adjudicated (no court-assigned pumping limitations)
- Pumping determined each year based on basin supplies and storage level
- Over-pumping controlled by economic disincentives (penalty fees)
- Pumping fee charged to pay for OCWD programs and activities

Fork in the Road (early 1970s): Import or Recycle?

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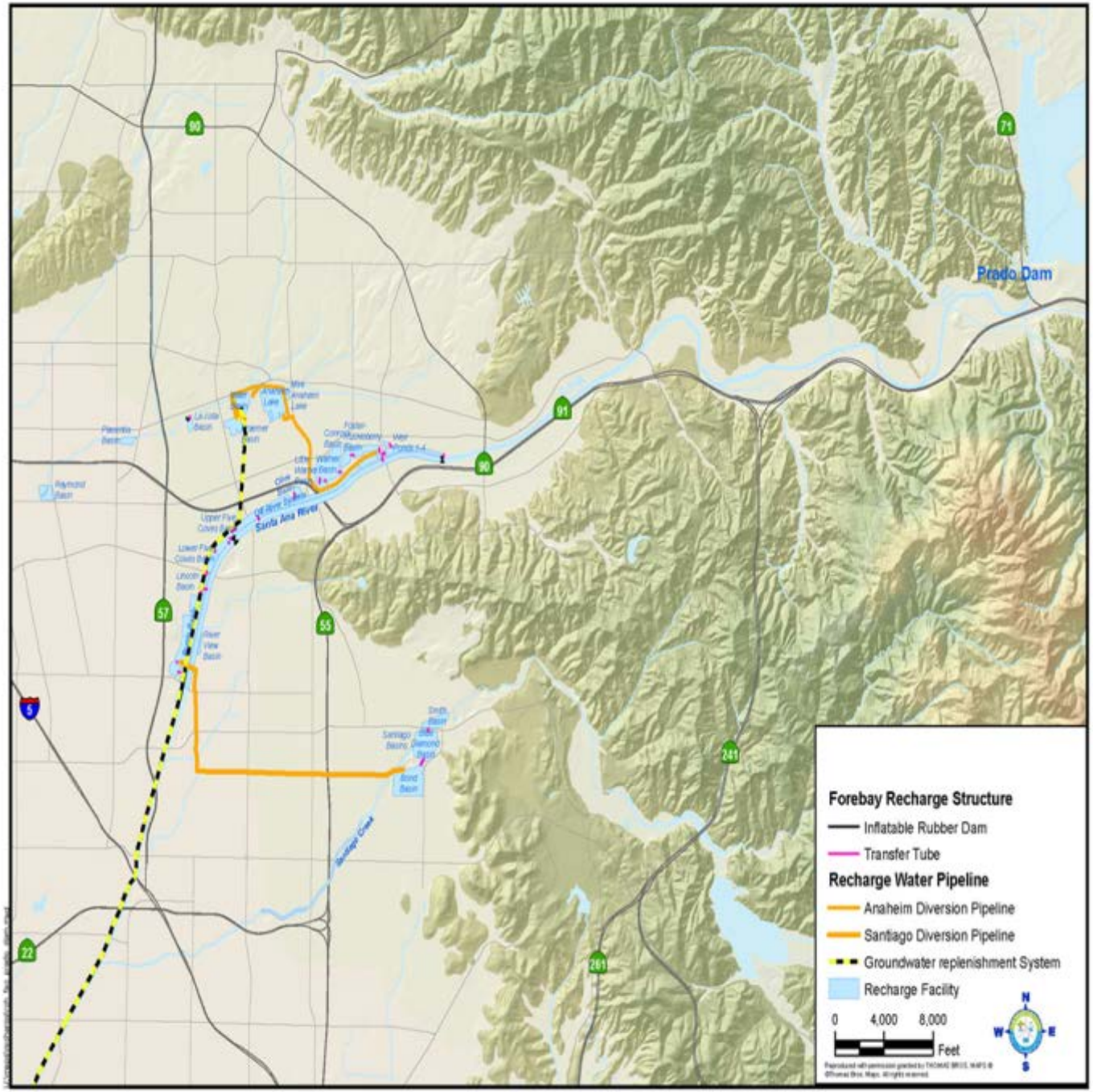
- Recycled water was more expensive, but locally controlled.
  - Would take 30 yrs to perfect technology

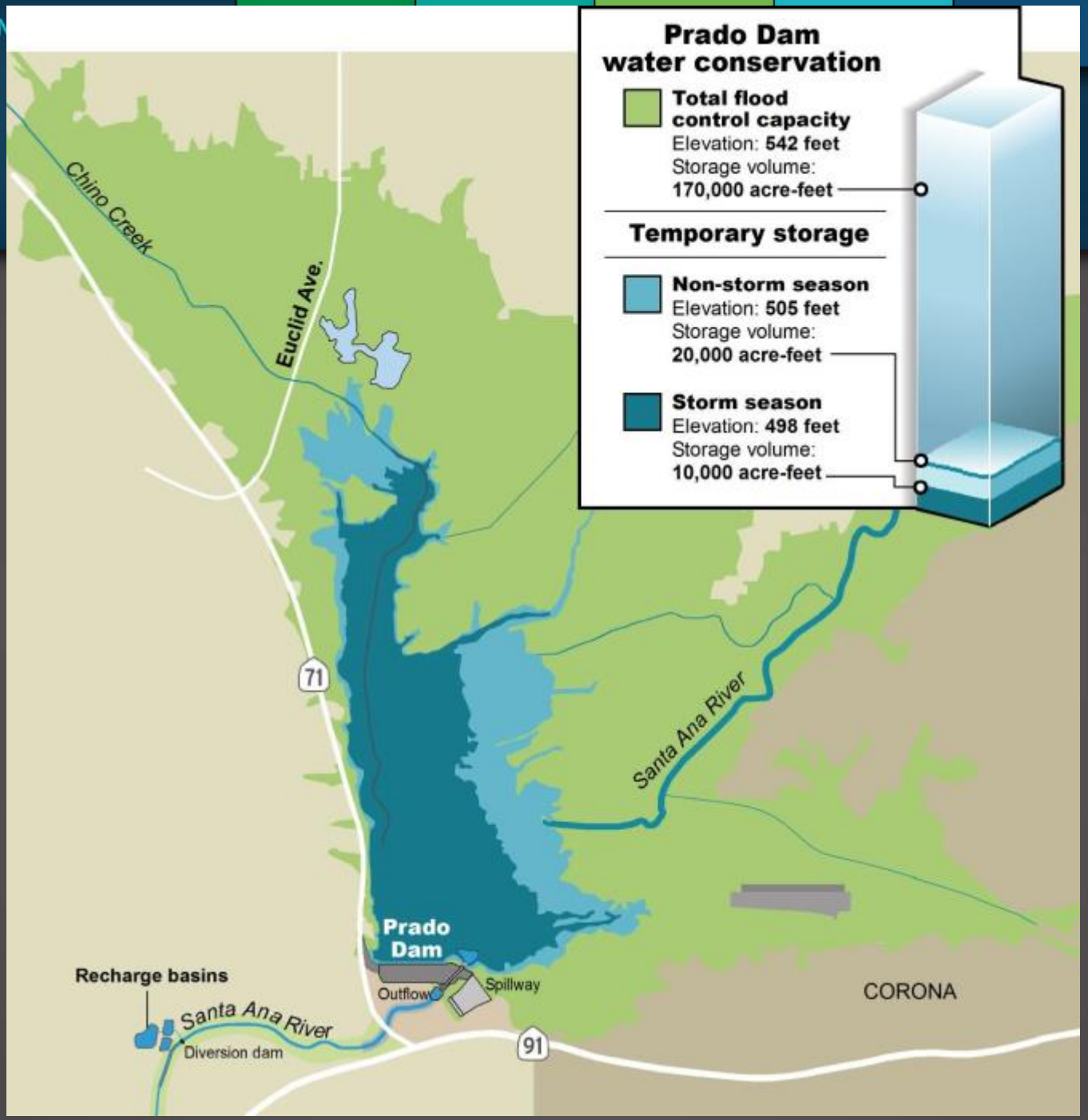

S.KELLEY
MOVE OVER...
DRINKING WATER FROM SEWAGE?



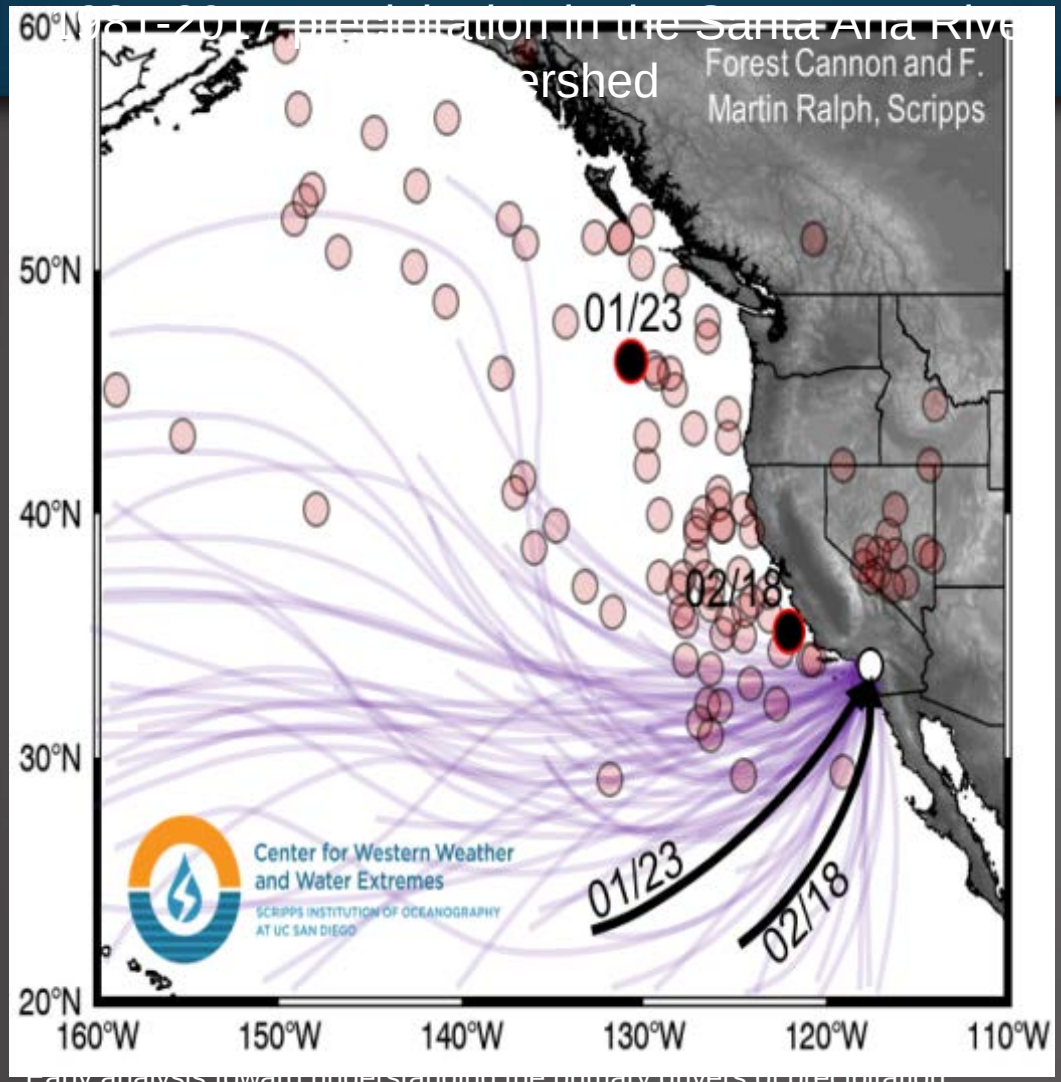
Starting about 11 miles downstream, OCWD recharges Santa Ana River water captured at Prado Dam

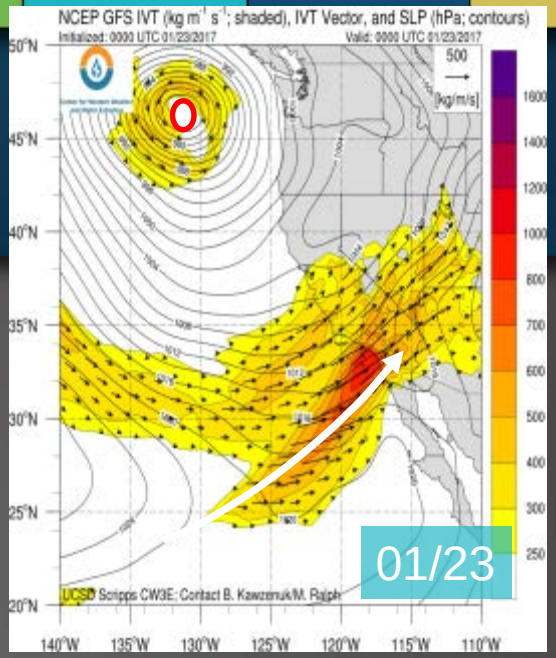
Ecosystem Restoration Planning Objectives

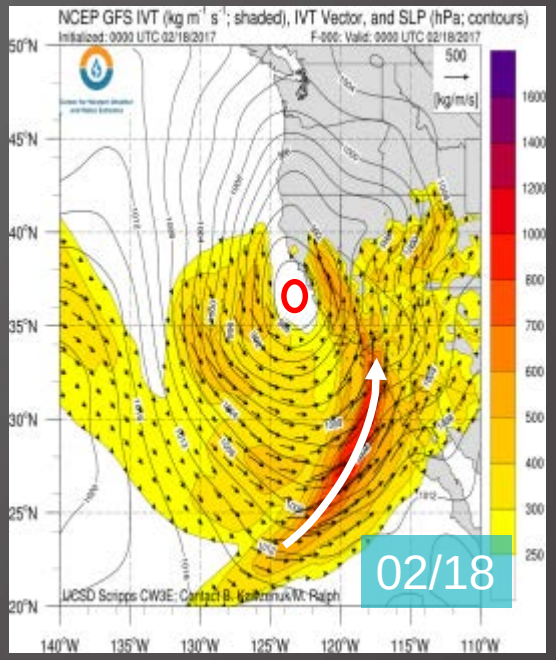
- Restore aquatic riverine habitat for native species within the project area Restore hydrology of fresh water marshes
- Provide vegetation, water access, stream channel connection and vegetation communities
- Provide water availability and diverse vegetation of transitional riparian buffer zones/edge habitats
- Facilitate wildlife movement between the project and adjacent wildlands, including the Santa Ana Mountains, Chino Hills State Park, and Cleveland National Forest


Prado Dam
water conservation
Total flood
control capacity
Elevation: 542 feet
Storage volume:
170,000 acre-feet
Temporary storage
Non-storm season
Elevation: 505 feet
Storage volume:
20,000 acre-feet
Storm season
Elevation: 498 feet
Storage volume:
10,000 acre-feet
Chino Creek
Euclid Ave.
71
Santa Ana River
Prado
Dam
Outflow
Spillway
Recharge basins
Santa Ana River
Diversion dam
91
CORONA

Preliminary schematic of the low pressure centers and moisture transport during 107 extreme events that accounted for ~50% of [illegible] precipitation in the Santa Ana River watershed







- Early analysis toward understanding the primary drivers of precipitation impacting Prado
- Event selection was based on PRISM precipitation within SARW boundaries, and schematic is based on GFS Analysis on the date of each event.

OCWD & OCSD: Turning wastewater to drinking water

ORANGE COUNTY WATER DISTRICT
SINCE 1933

G W R S
GROUNDWATER REPLENISHMENT SYSTEM

ORANGE COUNTY SANITATION DISTRICT
PROTECTING THE ENVIRONMENT

OCSD Secondary Effluent

Microfiltration (MF)

Backwash Sent to OCSD

Reverse Osmosis (RO)

Brine Treated in OCSD Outfall

Ultraviolet Light (UV) with Hydrogen Peroxide

Seawater Barrier (36 well sites)

Recharge Basins in Anaheim

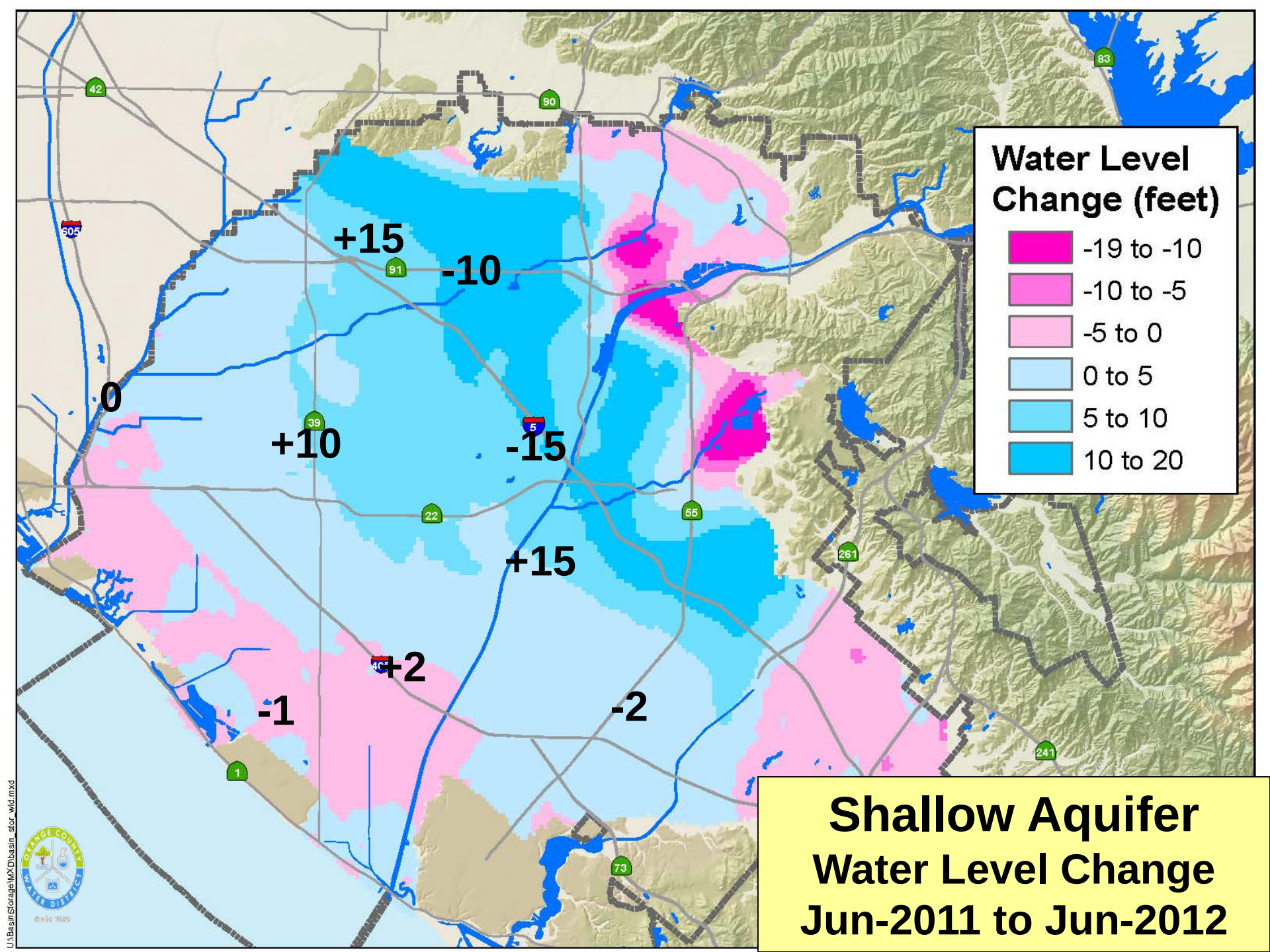
Redesigning the District: The Committee of 12

- Use of property taxes to purchase imported water seen as unfair
- Committed to increasing supply, not limiting demand
- Rejected centralized control over consumption, forced conservation, or adjudication
- A “pumping tax” was implemented
  - Those receiving benefits also paid for them
  - Incentive for conservation
  - Applied basin-wide

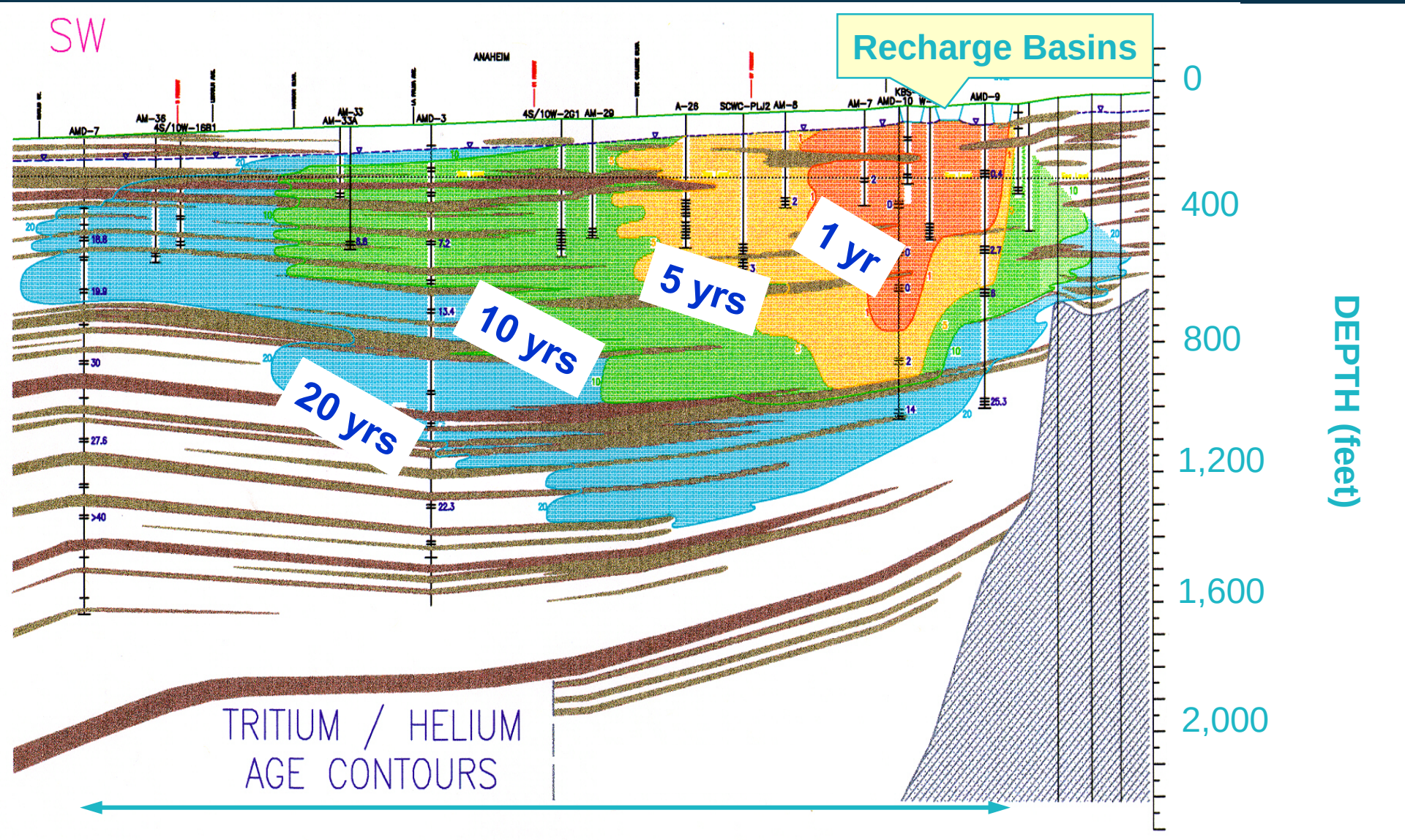
Moving from “Mine” to “Ours”

- **Adjudication (Mine)** **OCWD (Ours)**
  - Adversarial — **Supportive**
  - Individualistic — **Community**
  - Limited view of resource — **Expansive view of resource**

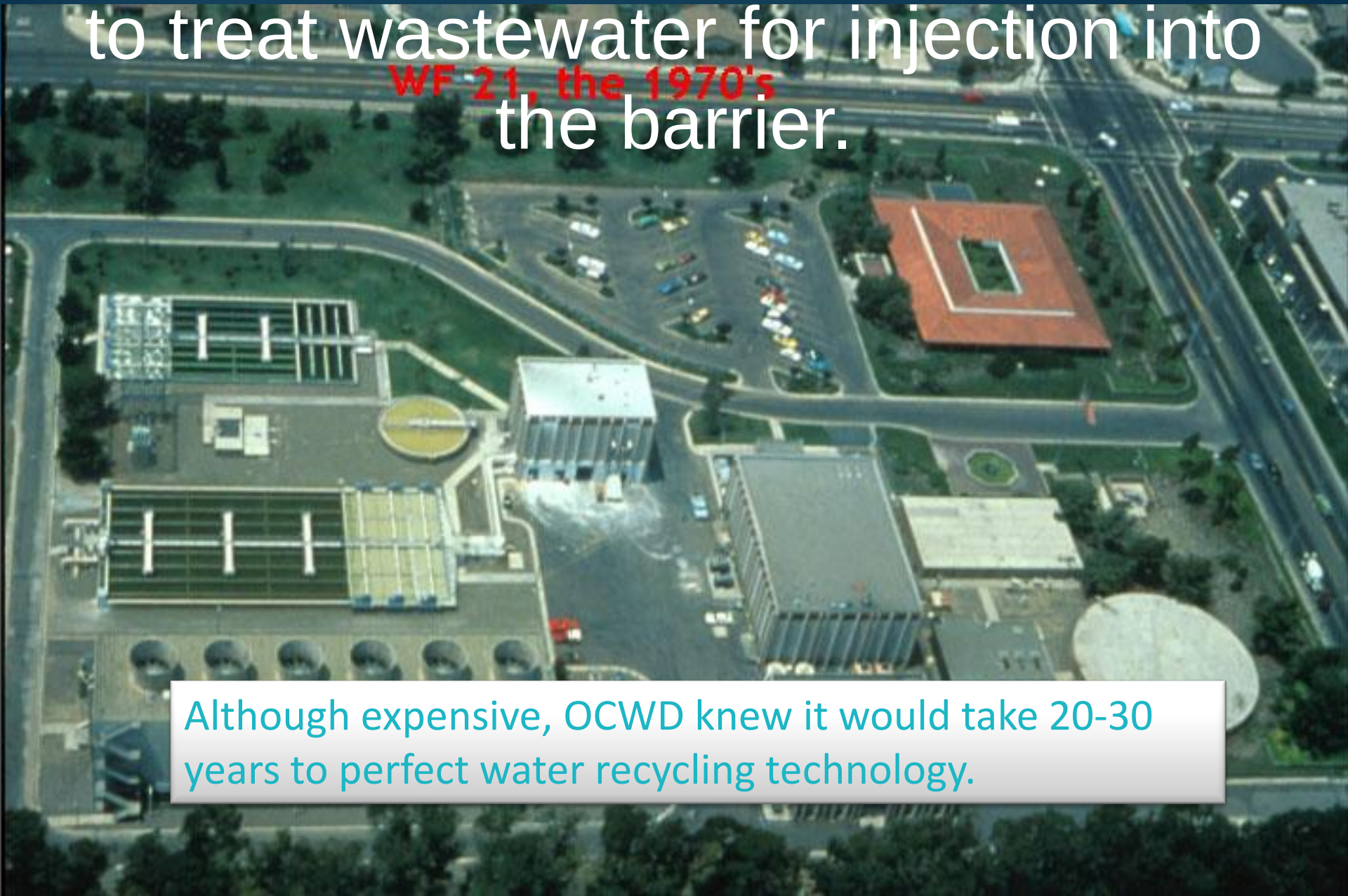
- **Key principles:**
  - Shared vision of resource
  - Adaptive management strategy
  - Courage to take political risks
- **Results: More water for everyone!**


Water Level Change (feet)
-19 to -10
-10 to -5
-5 to 0
0 to 5
5 to 10
10 to 20
+15
-10
0
+10
-15
+15
+2
-1
-2
Shallow Aquifer
Water Level Change
Jun-2011 to Jun-2012
U:\Basin\Storage\MXD\basin_stor_wld.mxd

Recharge water took 20 years to travel 6 miles and 1,200 feet deep.



In 1975, Water Factory 21 was built to treat wastewater for injection into the barrier.



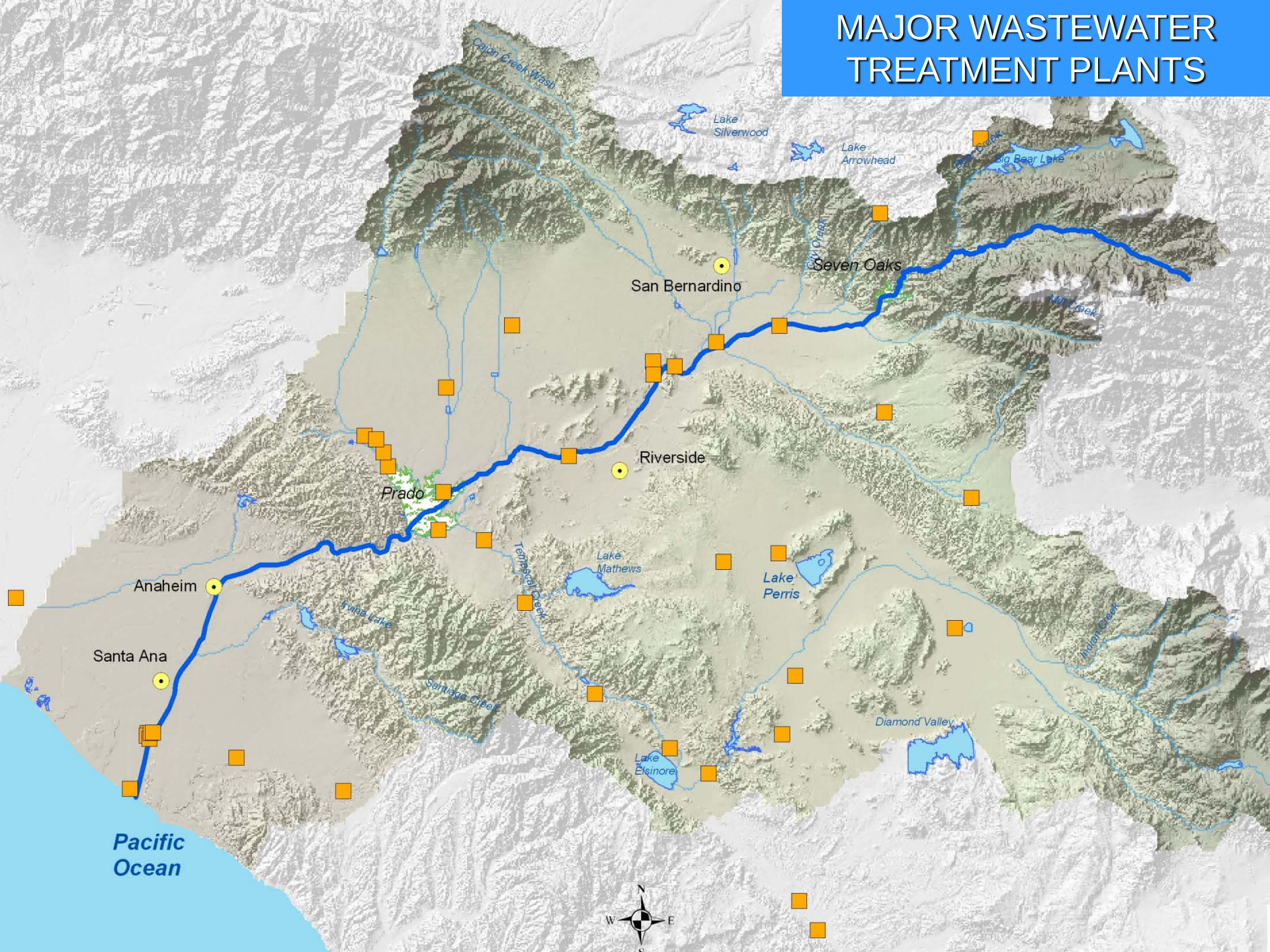
Although expensive, OCWD knew it would take 20-30 years to perfect water recycling technology.

Prado Dam was constructed in 1941 to protect Orange County

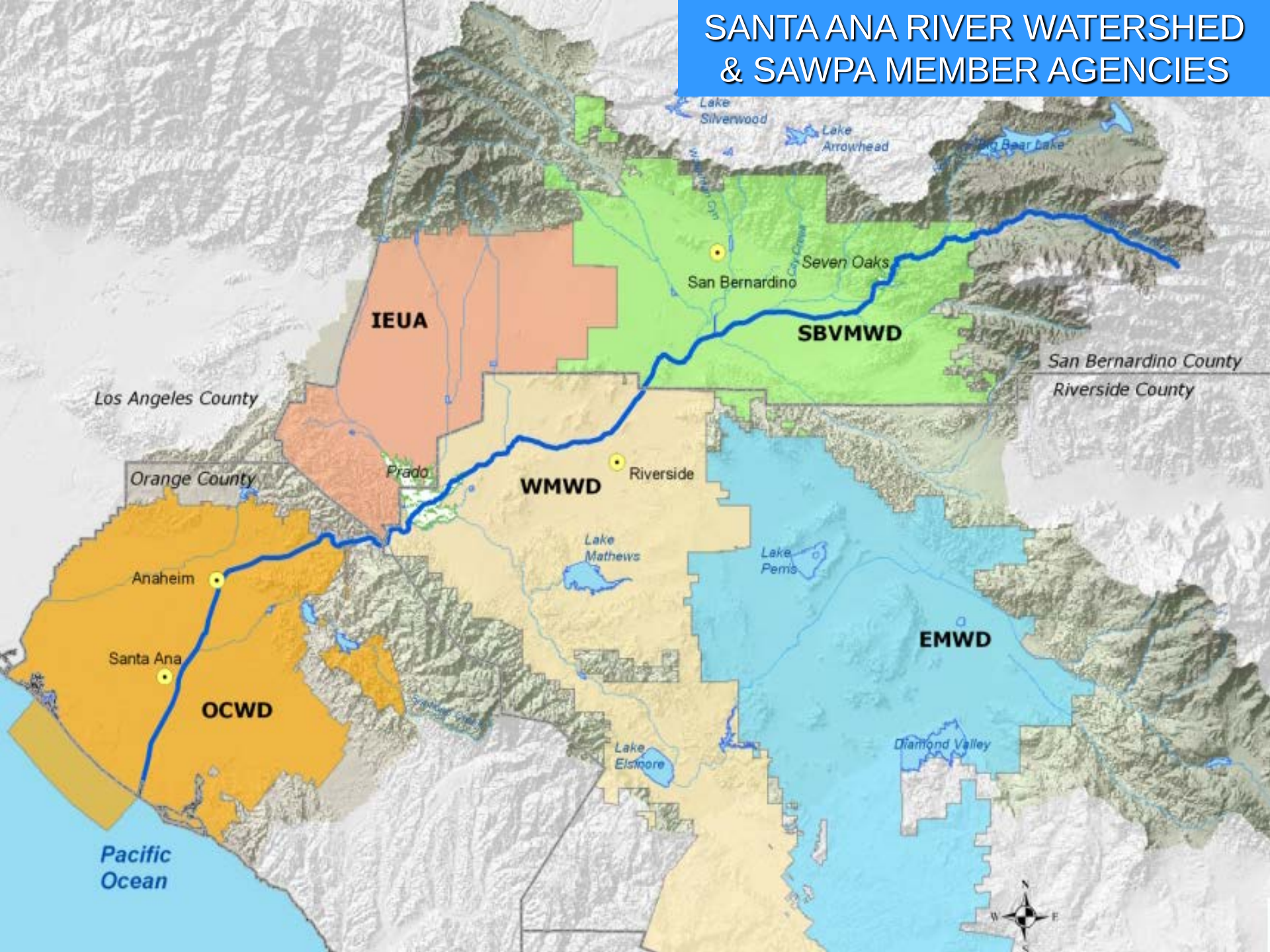
GW Management Tools

- Extensive monitoring well network
- Regular water level monitoring
- Frequent groundwater sampling/analysis
- Monthly reporting of MAR
- Monthly reporting of pumping
- GIS/Oracle database
- Groundwater flow model (MODFLOW)

MAJOR WASTEWATER TREATMENT PLANTS



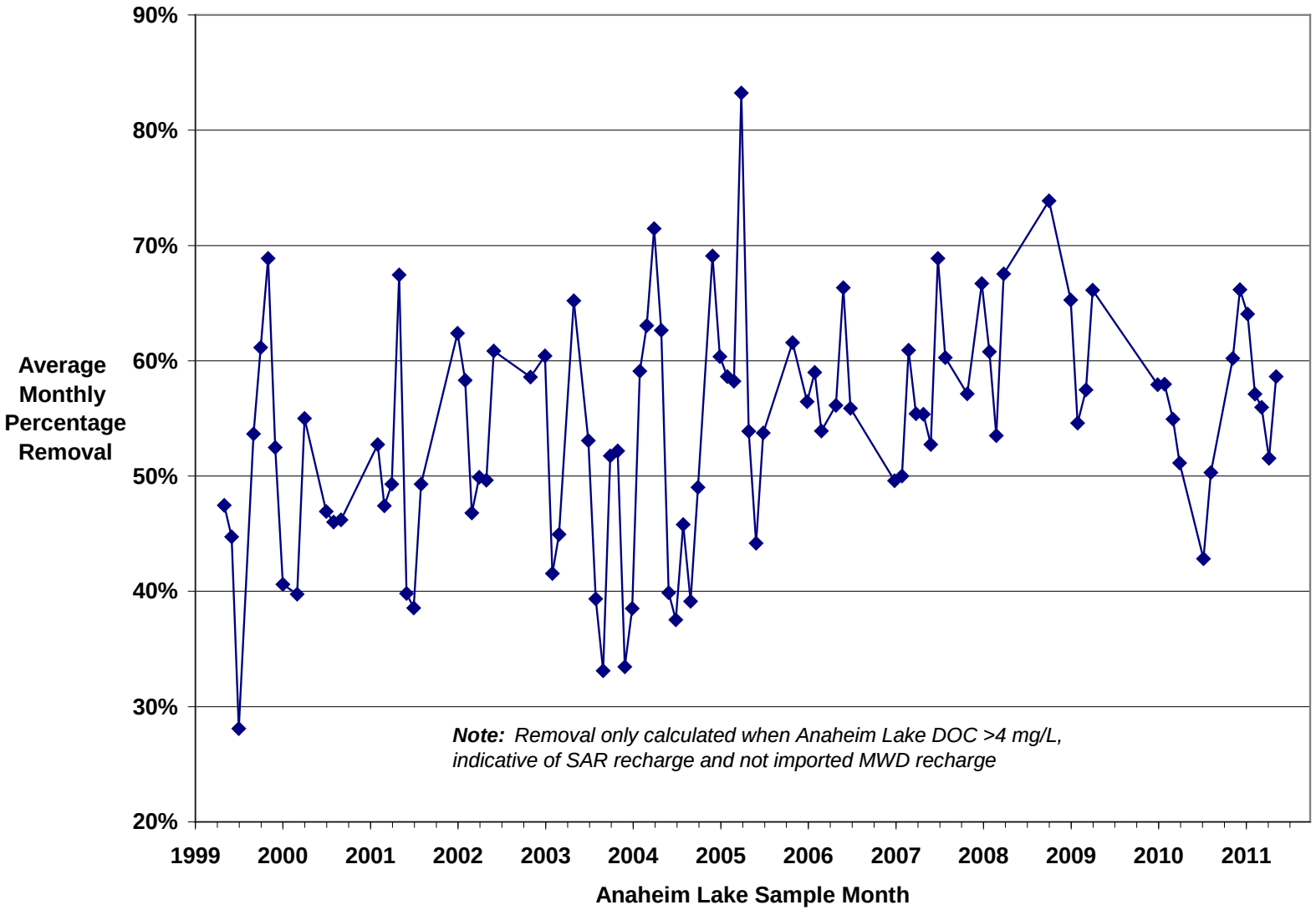
SANTA ANA RIVER WATERSHED & SAWPA MEMBER AGENCIES



Water quality is improved during recharge.

- Process is technically referred to as “Soil Aquifer Treatment” (SAT)
- Suspended sediment and other floating materials are filtered out.
- Bacteria and viruses are removed.
- The concentrations of nitrate, total organic carbon and other dissolved constituents are reduced.
- Even the concentrations of caffeine and ibuprofen are reduced during recharge!

From 40 to 70 percent of organic carbon is removed during recharge.



Removal seen at Anaheim Lake to AMD-9/MP1

ORANGE COUNTY WATER DISTRICT

Five sediment removal technologies were tested to assess if Santa Ana River water could be treated to reduce clogging.

Any method that used a chemical resulted in low percolation rates.

Flocculation-Sedimentation

Dissolved Air Flotation

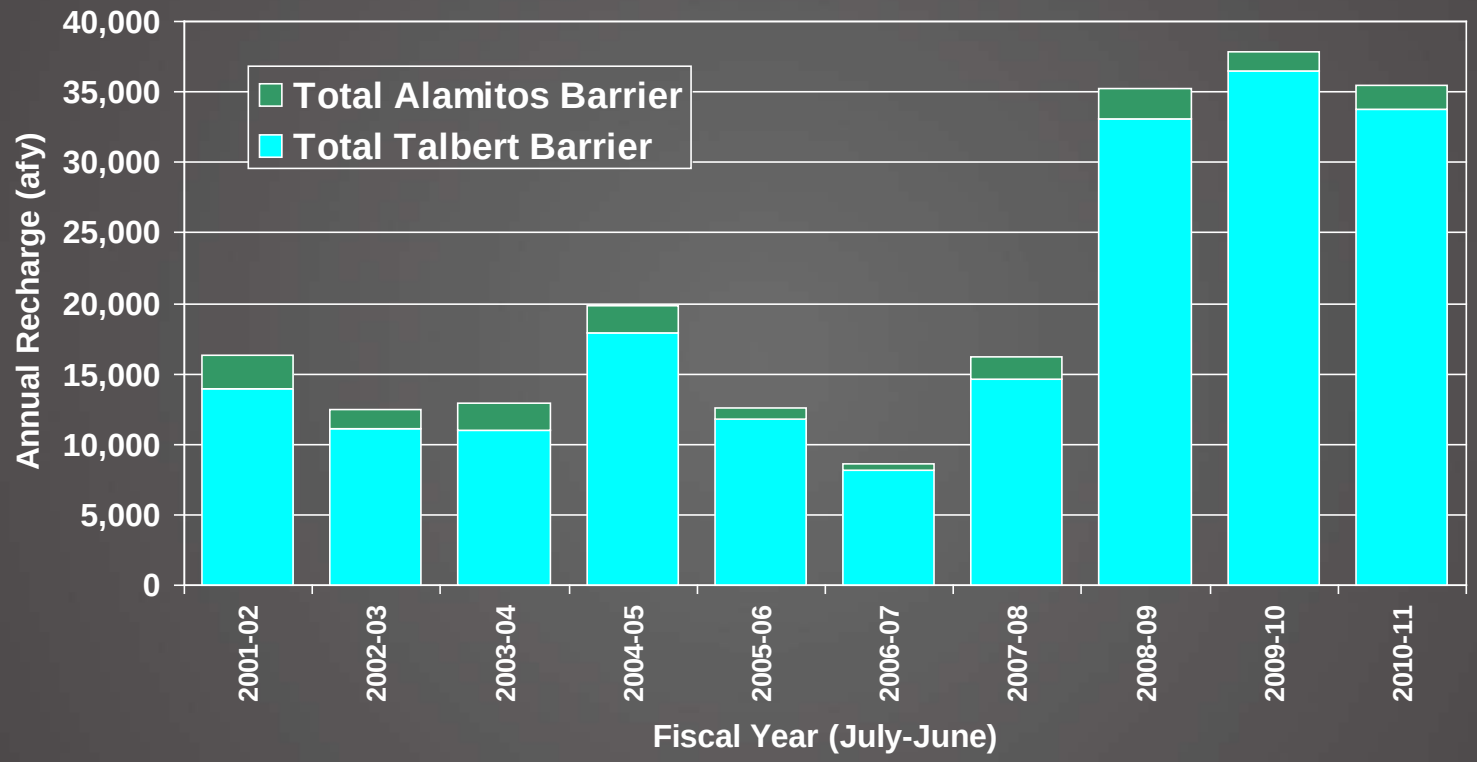
Ballasted Sedimentation

Cloth Filter

Riverbed Filtration

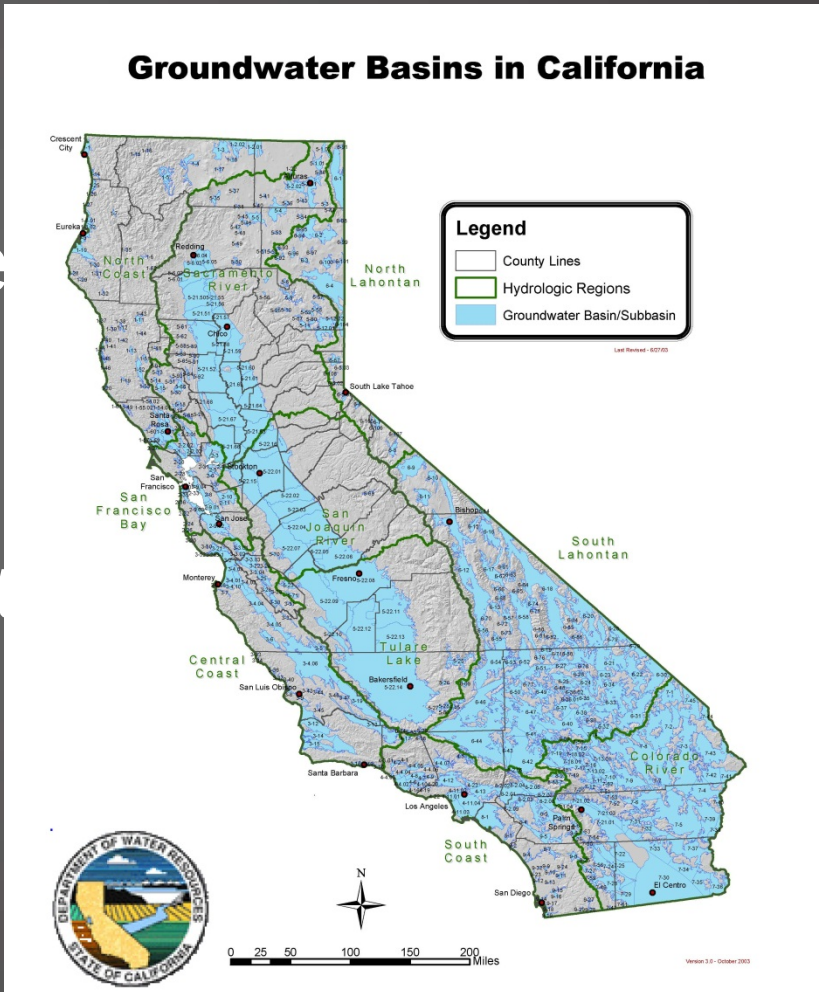
The Riverbed Filtration System takes advantage of natural filtration processes to remove suspended sediments in the water.

Seawater barrier recharge has dramatically increased since the GWRS came on-line in 2008.



One size does not fit all.

- 431 groundwater basins
- Cover 40% of state
- Diversity of GW Manage
  - Local GW Ordinances
  - Court Adjudications
  - Local Management via St
    - OCWD



Over the last 240 years, the Orange County groundwater basin has seen it all!

- Surface water supplies consumed
- Rapid agricultural growth
- Severe groundwater level declines, basin overdraft
- Seawater intrusion
- Rapid population growth
- Change from agricultural to industrial/suburban uses
- Massive storms and flood damage
- Salt imbalance
- Wastewater effluent dominating surface water supply
- Restricted imported water supplies

It’s mine!

- Twenty-two basins in California are adjudicated.
  - Safe Yield defines available supply
  - Court determines who gets how much
  - Must live within these limits
- Problems:
  - Adversarial
  - Individualistic
  - Limited view of resource

Committee of 12 formed to "Save the Basin" in 1952.

- Believed that common pool of water was more valuable than individually, adjudicated share of groundwater.
  - Said no to "philosophy of scarcity"
- Introduced innovative changes that had both socialistic and capitalistic elements
  - All pumpers treated equally
  - All pumpers have access to water
  - Prices established to control pumping, encourage conservation
- Took political courage to implement
  - Predominant model was adjudication

Even as OCWD expanded its aquifer recharge capacity, there was a need to regulate pumping.

- Amended District Act in 1969
  - Basin Production Percentage (BPP)
  - Basin Equity Assessment (BEA)
- Economic incentives used to manage groundwater withdrawals.
  - BPP used to discourage over-pumping.
  - BEA used to make water pumped over the BPP equivalent in cost to imported water.
    - Pumpers would rather turn off their wells to save energy and wear and tear on equipment.

BPP Calculation

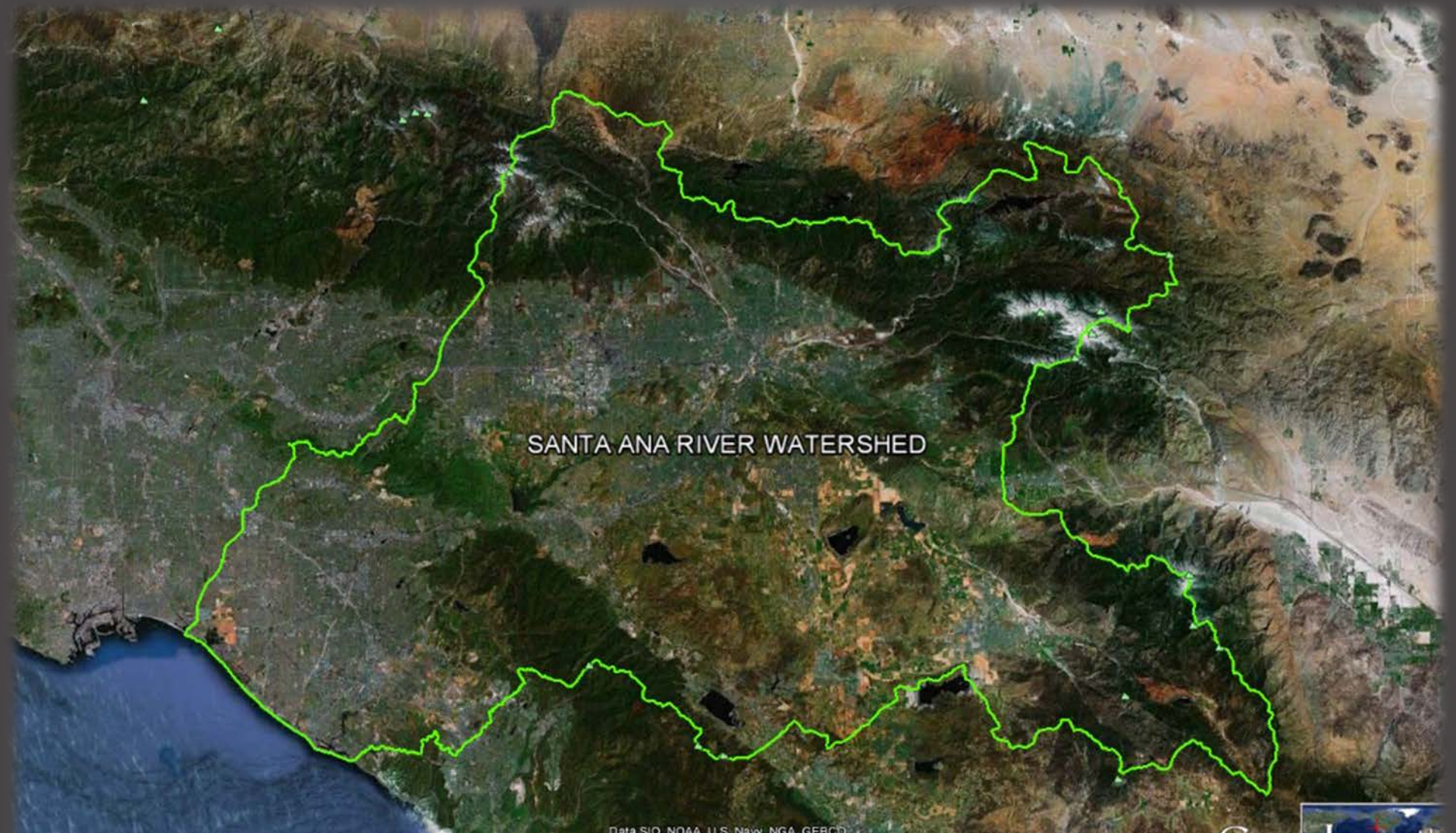
$$\frac{\text{Natural Incidental Recharge} + \text{SAR/Storm Water} + \text{Imported Water} + \text{Recycled Water} - \text{Planned Basin Refill}}{\text{Total Water Demands}} = \text{BPP}$$

Producers make up remainder of demand with imported water.

sustainability, but it takes a shared vision of the resource, an adaptive management approach, and political courage

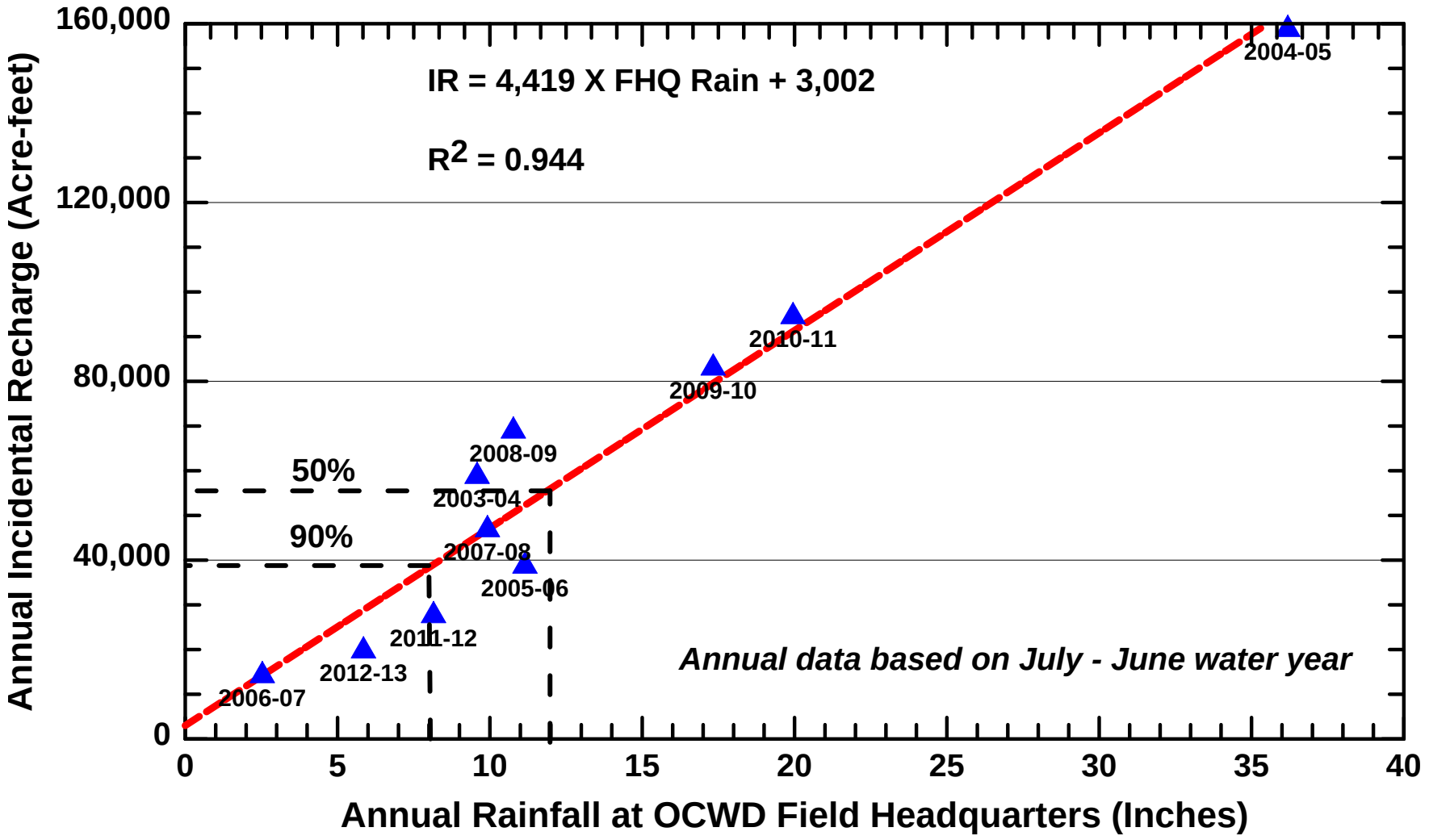
- Benefits:
  - More than doubled yield of groundwater basin
  - Provides low cost supply to producers
  - More local control of water supplies
  - A model that says “No to scarcity”
    - Socialistic/Capitalistic blend
    - Equitable treatment of stakeholders
    - Financial incentives used to control pumping
    - Model promotes efficient use of existing resources and development of new resources (e.g., recycled water)

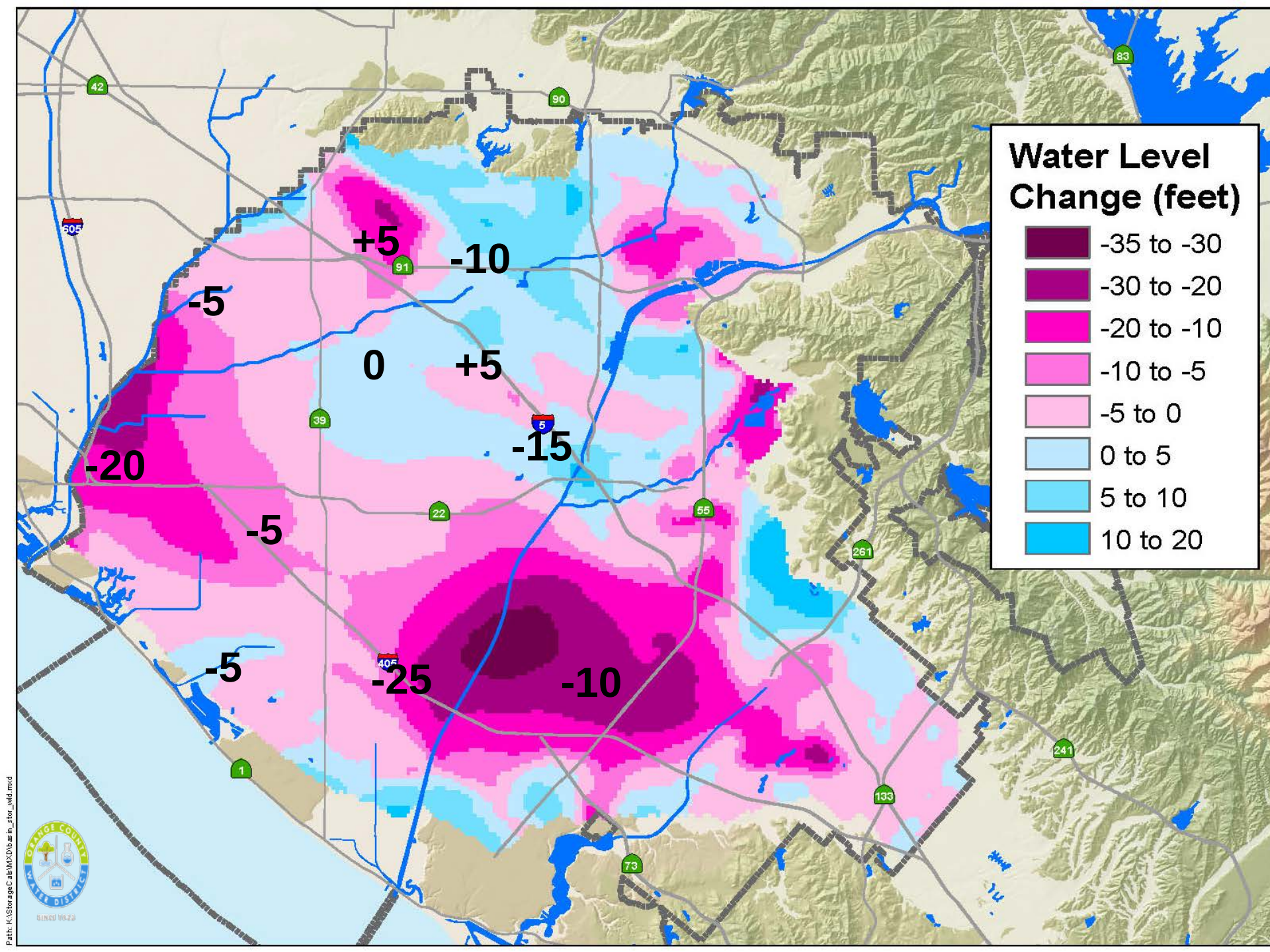
The OCWD overlies the groundwater basin at the base of the SAR watershed.



OCWD lies at the base of the Santa Ana River Watershed.

Incidental recharge correlates well with annual rainfall.




Water Level Change (feet)
-35 to -30
-30 to -20
-20 to -10
-10 to -5
-5 to 0
0 to 5
5 to 10
10 to 20
+5
-10
-5
0
+5
-15
-20
-5
-5
-25
-10
42
90
83
605
91
39
5
22
55
261
405
1
241
133
73