

CALIFORNIA DEPARTMENT OF WATER RESOURCES

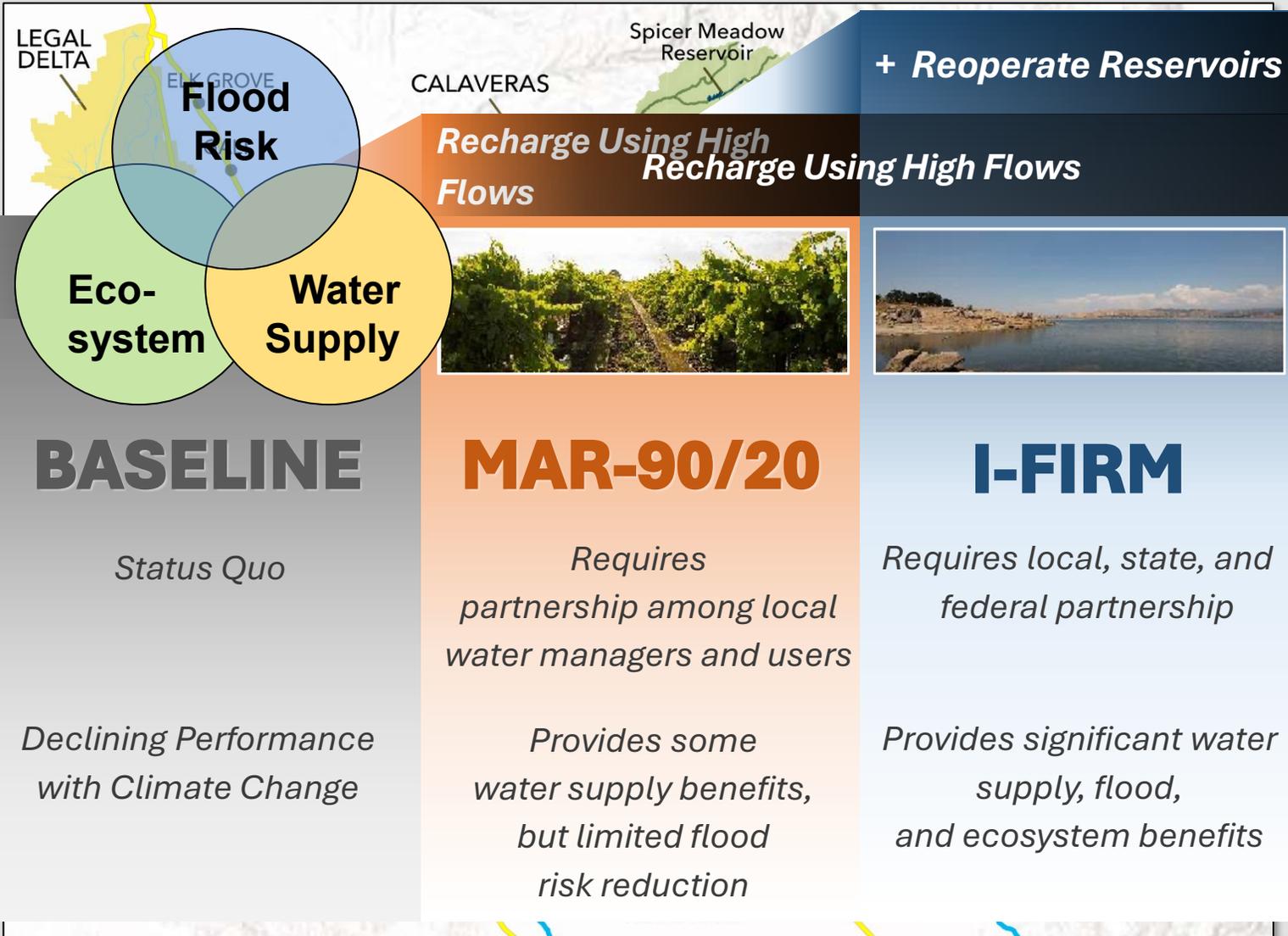
San Joaquin Flood-MAR Watershed Studies

ENHANCING CLIMATE RESILIENCE THROUGH ADAPTIVE FLOOD-MAR STRATEGIES

MAY 14, 2025

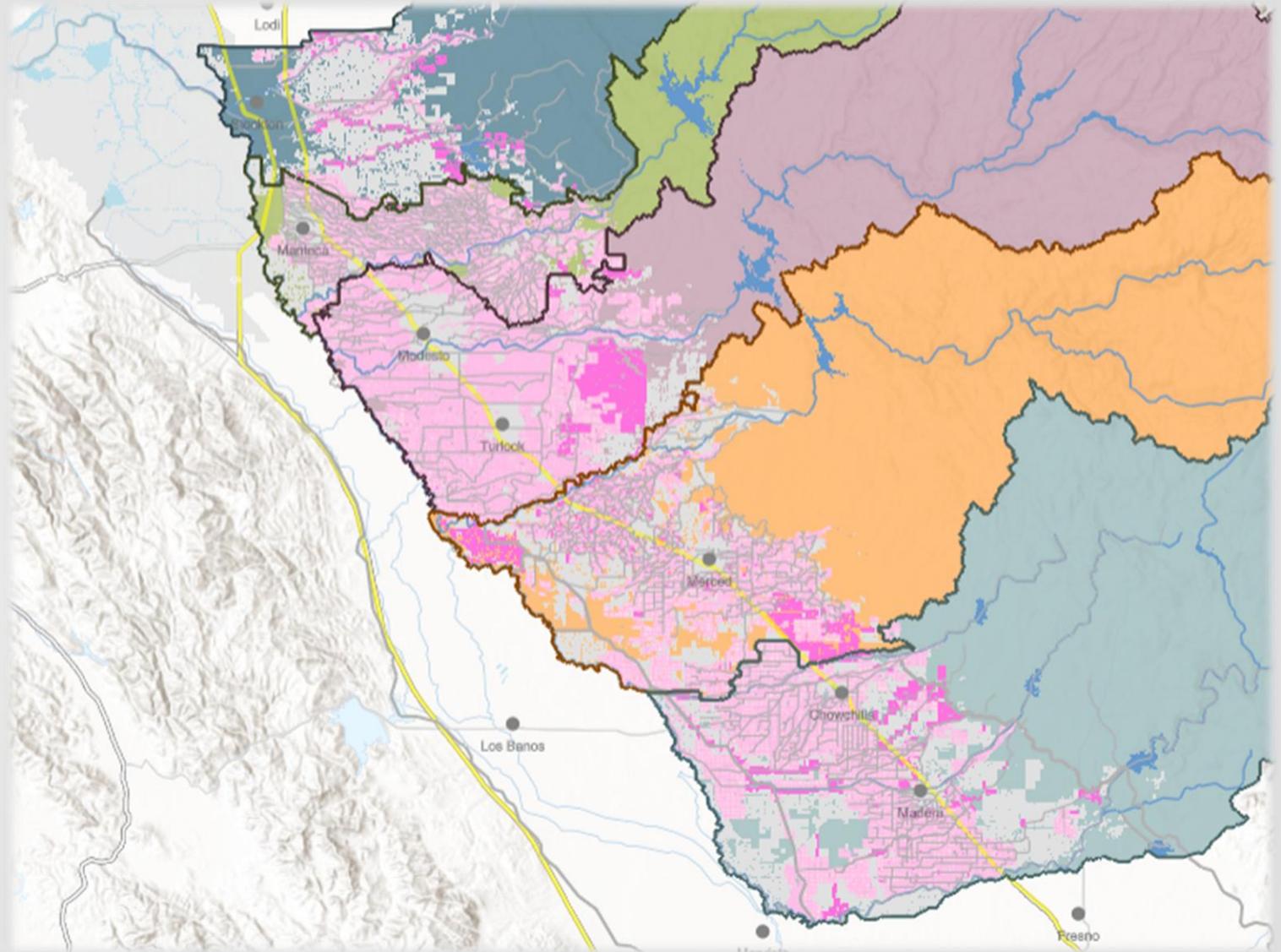


Adaptation Strategies



- Five watersheds on the eastern side of the San Joaquin Basin
- 16 climate conditions
- 100-year hydrologic sequence
- Three recharge actions
 1. **Baseline** – status quo, maintain baseline operations
 2. **MAR 90/20** – opportunistically recharge high flows
 3. **I-FIRM** – integrate recharge and forecast-informed reservoir operations
- Demonstrate the potential for local-State-federal partnerships to create multi-sector benefits

APPLIED RECHARGE



Takeaways – Applied Recharge

- Applied recharge depends on availability of excess flows (**supply**) and the recharge potential (**demand**).
- Each watershed has a unique recharge profile.
- Rivers are the main source of recharge supplies whereas creeks are the reliable source.
- Majority of the recharge is applied within the districts' boundaries using irrigable fields and where available, unlined canals.
- Investment in increased recharge efficiency reduces reliance on irrigable fields to achieve at-scale recharge.

Drivers of applied recharge

← Seasonal Average (November – March) →

Watershed (Primary Reservoir)	Reservoir Inflow above Required Minimum Flow	Conservation Pool Capacity		Local Runoff	Available Fields (thousand acres; MAR 90/20 – I-FIRM)
Calaveras (New Hogan)	105 taf	152 taf	1.5x	41 taf	14 – 29
Stanislaus (New Melones)	467 taf	1,970 taf	4.2x	16 taf	98 – 102
Tuolumne (New Don Pedro)	782 taf	1,690 taf	2.2x	18 taf	144 – 173
Merced (Lake McClure)	464 taf	658 taf	1.4x	137 taf	109 – 130
Upper San Joaquin (Lake Millerton)	414 taf	435 taf	1.1x	120 taf	185 – 212

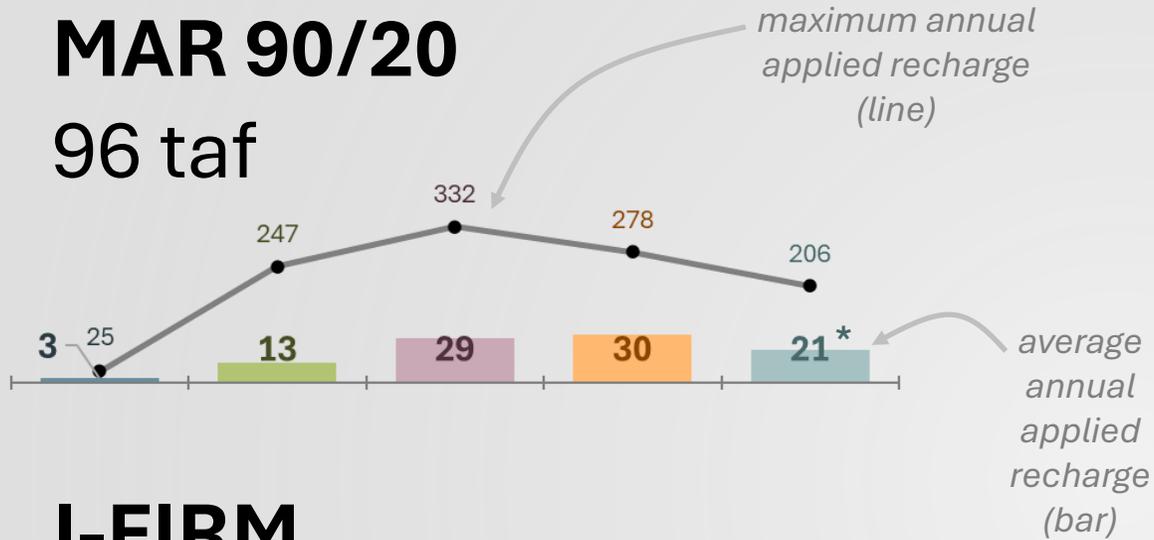
Available Supply of Excess Flows –
Quantity & Frequency

Recharge
Potential

Annual applied recharge volume (taf)

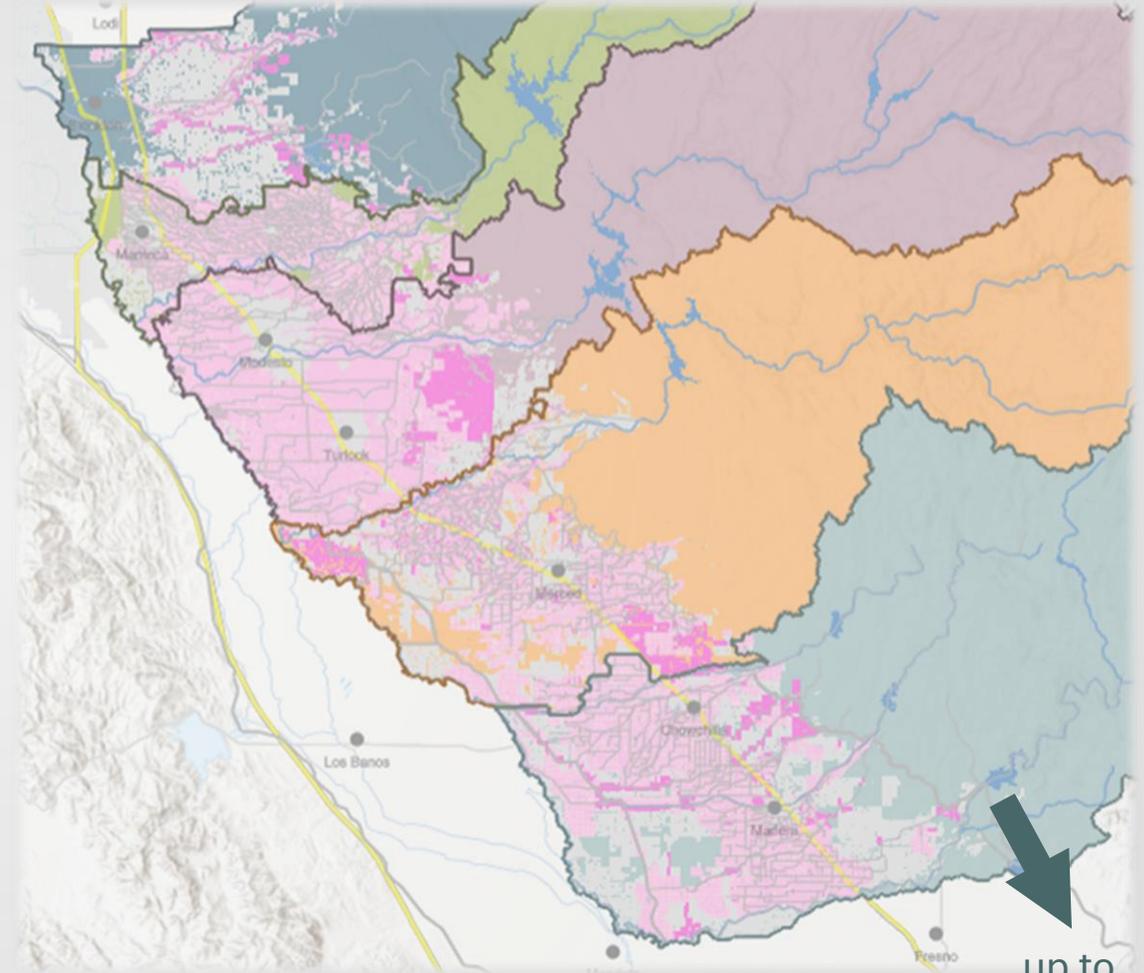
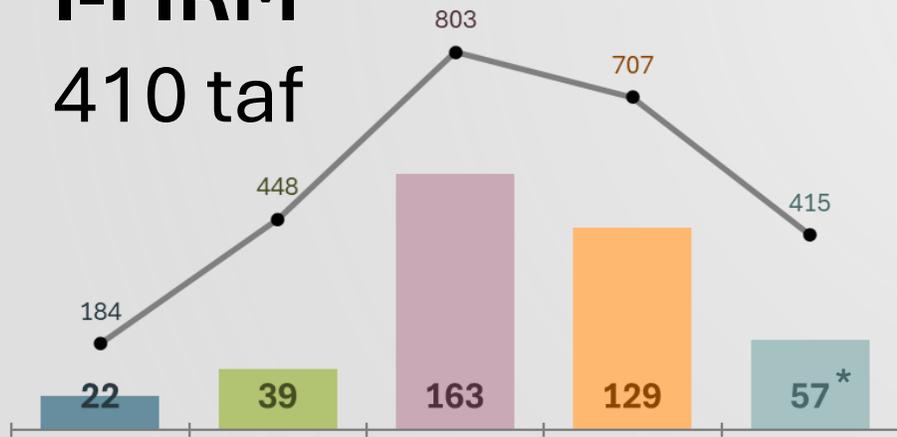
MAR 90/20

96 taf



I-FIRM

410 taf



up to
55 taf
under
I-FIRM

* Reported volume only includes the applied recharge available from Upper San Joaquin River/ Millerton lake diverted using Madera Canal. Additional recharge supplies are available and are diverted into the Tulare Lake region via Friant Kern Canal. However, since the Tulare Lake region is outside the San Joaquin Watershed Study Area, no further assessments were made if there is adequate recharge capacity available to apply the diverted recharge supplies.

Recharge Distribution Logic (one-to-many or many-to-many)

Existing Sharing Agreements

(Agreement 1988 Contractors in Stanislaus; Turlock and Modesto Irrigation Districts in Tuolumne; and Madera & Friant Kern Contractors in Upper San Joaquin)



Recognize District Seniority

(OID & SSJID before CVP Contractors – SEWD and CSJWCD – in Stanislaus)



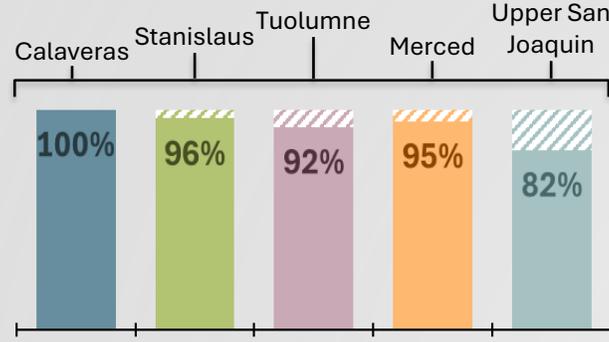
Distribute to Other Non-District White Areas or Watersheds*

Service areas that solely rely on a single source for their recharge supplies are prioritized over service areas with access to multiple sources of recharge supply to maximize application of recharge supplies (**sole reliance & sole place of use**). Service areas can be the whole district or a smaller footprint within the district.

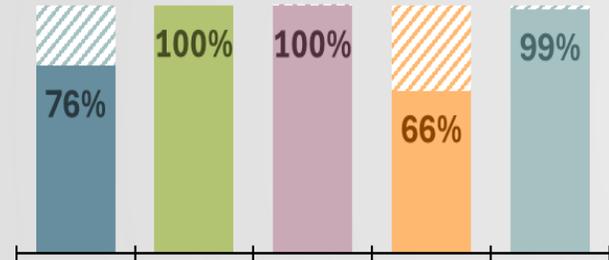
Limited to hydraulically connected watersheds that receive project supplies under the Baseline. No new inter-watershed infrastructure is included.

Application and sourcing of recharge supplies

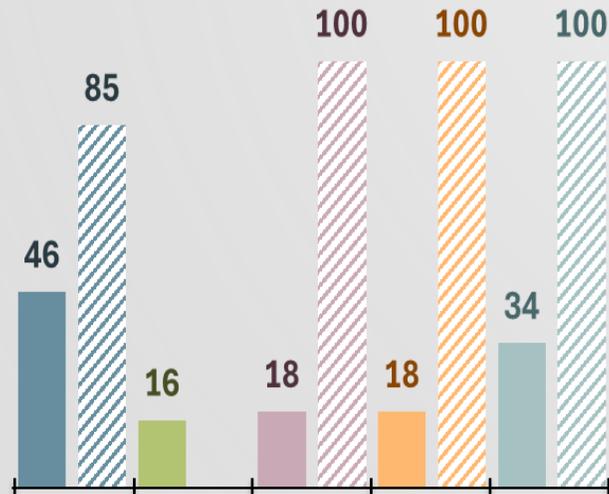
MAR 90/20



Percent total recharge applied in **Districts** (solid fill) vs. **Non-Districts and White Areas** (pattern fill)

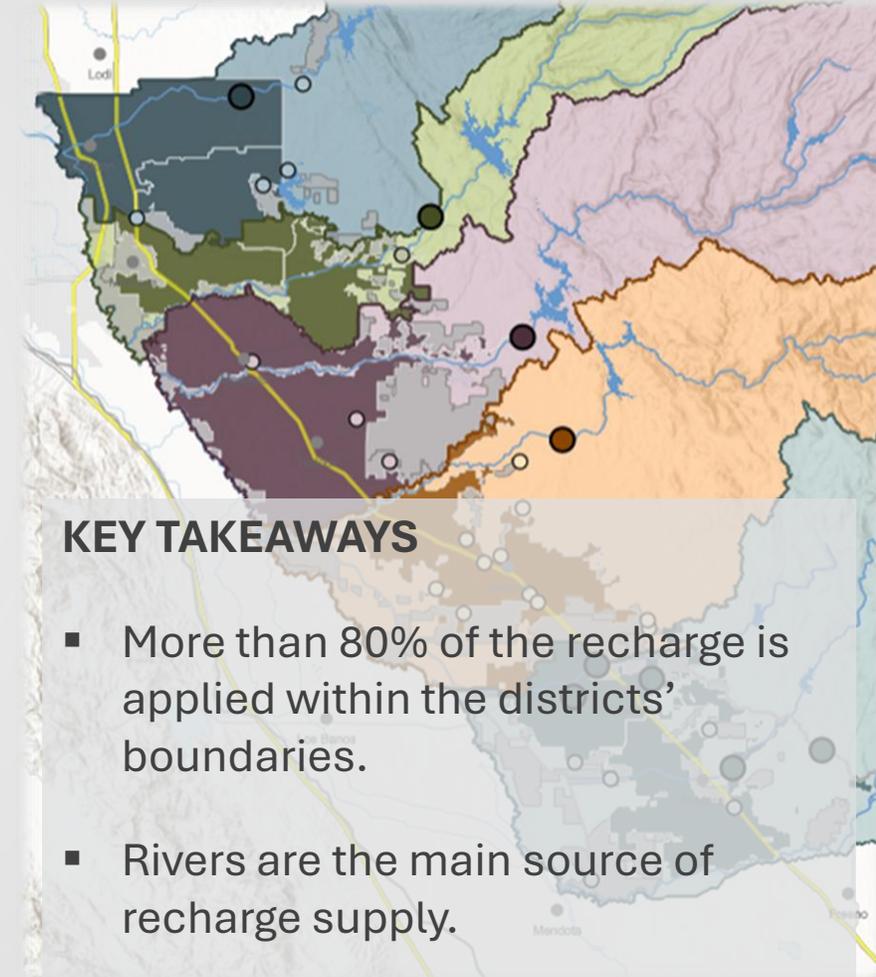
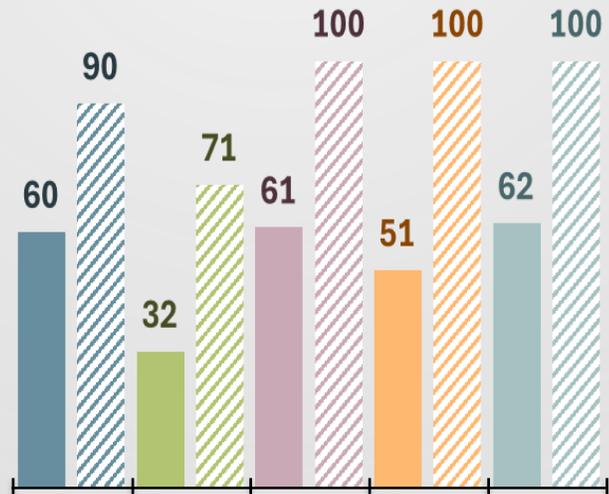
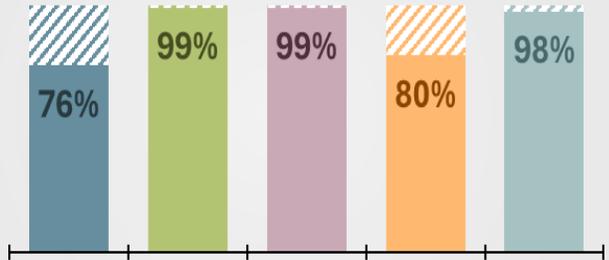
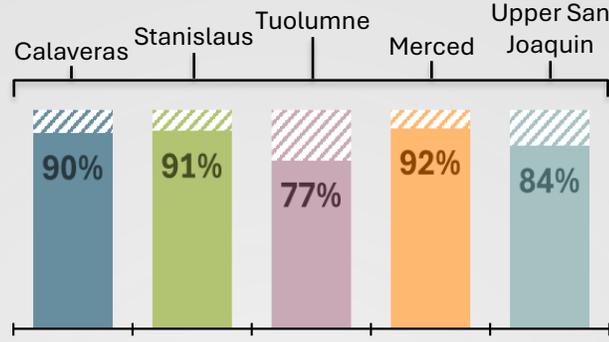


Percent total recharge sourced from **Rivers** (solid fill) vs. **Local Creeks** (pattern fill)



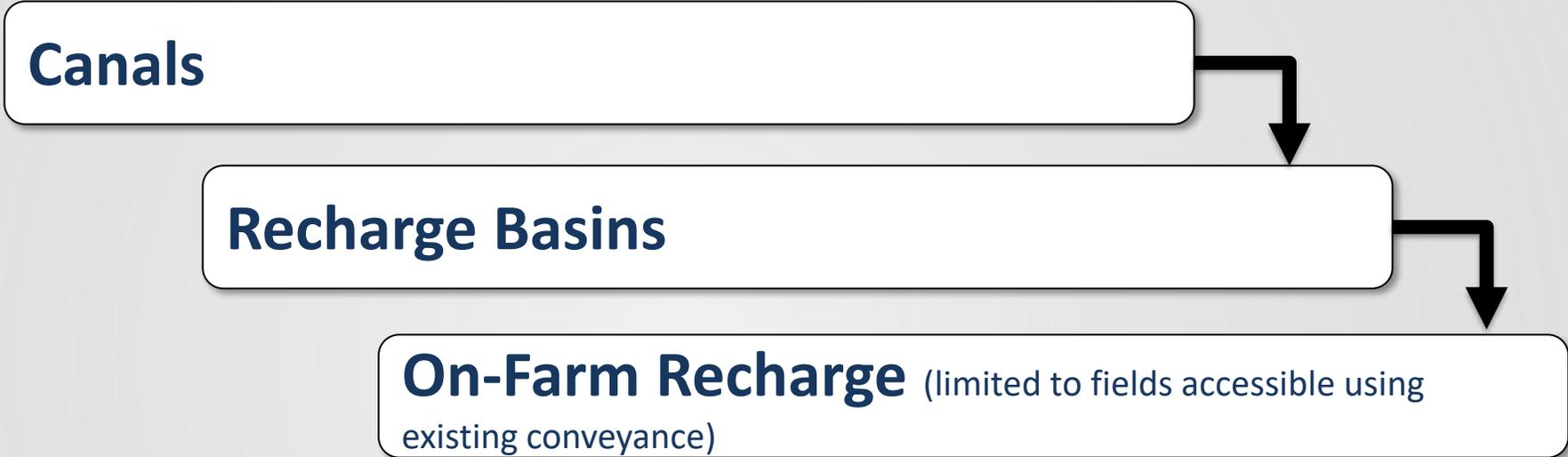
Number of years recharge supplies available from **Rivers** (solid fill) vs. **Local Creeks** (pattern fill)

I-FIRM



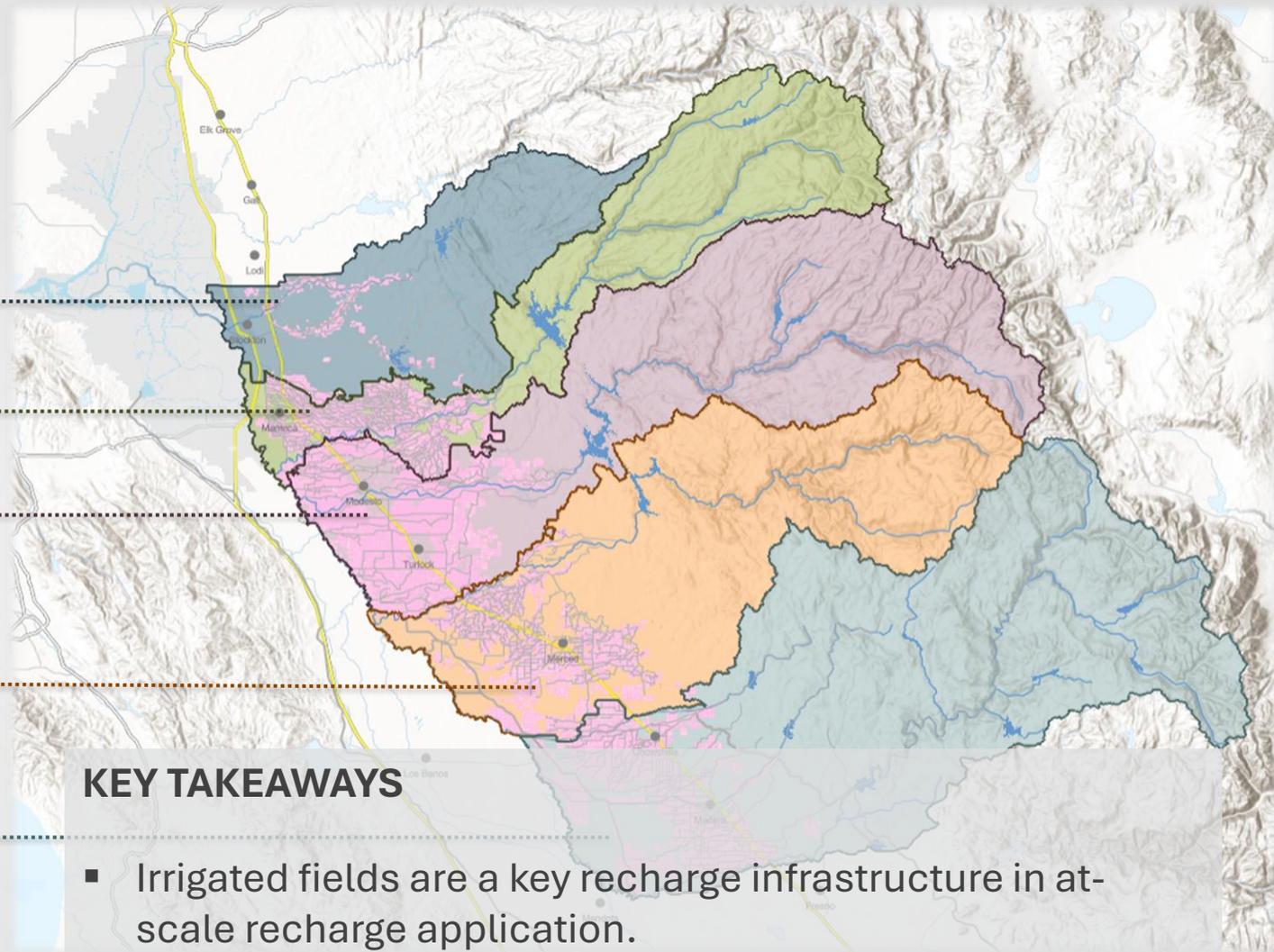
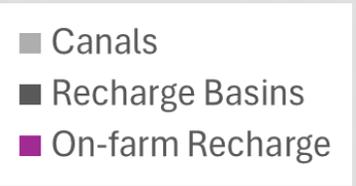
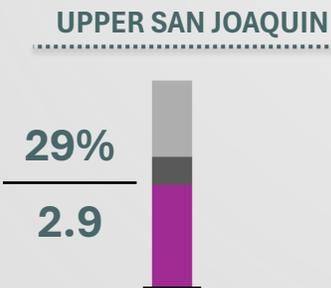
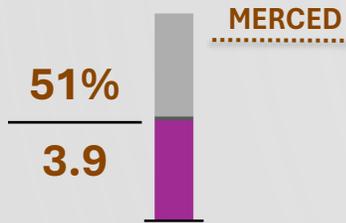
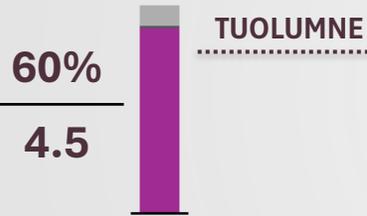
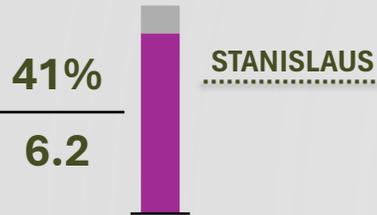
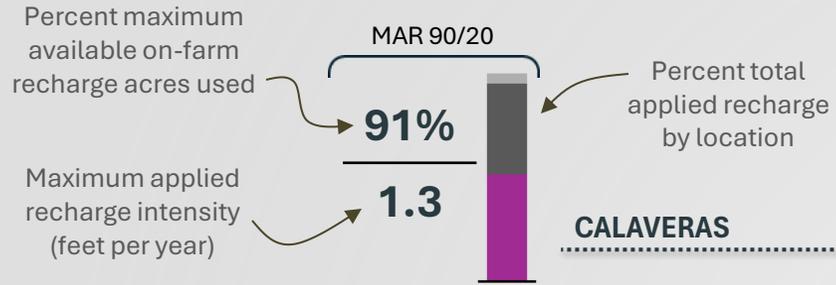
Recharge Placement Sequence – MAR 90/20

All recharge operations are constrained to December 1st – March 31st



	Calaveras	Stanislaus	Tuolumne	Merced	Upper San Joaquin
Canals	mainly rivers and streams; limited build canals (0.04 taf capacity)	mostly lined canals; 4.5 taf capacity	mostly lined canals; 4.5 taf capacity	mostly unlined canals; 12 taf capacity	mix of unlined canals, rivers, and streams; 5.5 taf capacity
Recharge Basin	five basins with combined capacity of 0.7 taf	no recharge basin	six basins with combined capacity of 0.8 taf	three basins with combined capacity of 0.4 taf	17 basins with combined capacity of 2.4 taf
On-Farm Recharge	14,176 acres available with recharge potential of 71 taf	98,175 acres available with recharge potential of 2,428 taf	144,047 acres available with recharge potential of 917 taf	109,147 acres available with recharge potential of 975 taf	185,077 acres available with recharge potential of 1,290 taf

Recharge Operations



KEY TAKEAWAYS

- Irrigated fields are a key recharge infrastructure in at-scale recharge application.
- Higher efficiency in recharge application and availability of unlined canal conveyance system reduces reliance on irrigated fields to achieve at-scale benefits.

Recharge Placement Sequence – I-FIRM

Recharge window extended to November 1st – June 15th unless otherwise noted

Added three new locations of recharge:
 (1) Flow Through Basins,
 (2) Regulating Reservoirs, and
 (3) In-Lieu Recharge

Expanded conveyance

Multi-benefit Flow Through Basins (creeks only)

Canals & Regulating Reservoirs (November 1st – March 31st; recharge-related seepage limited to outside the irrigation season)

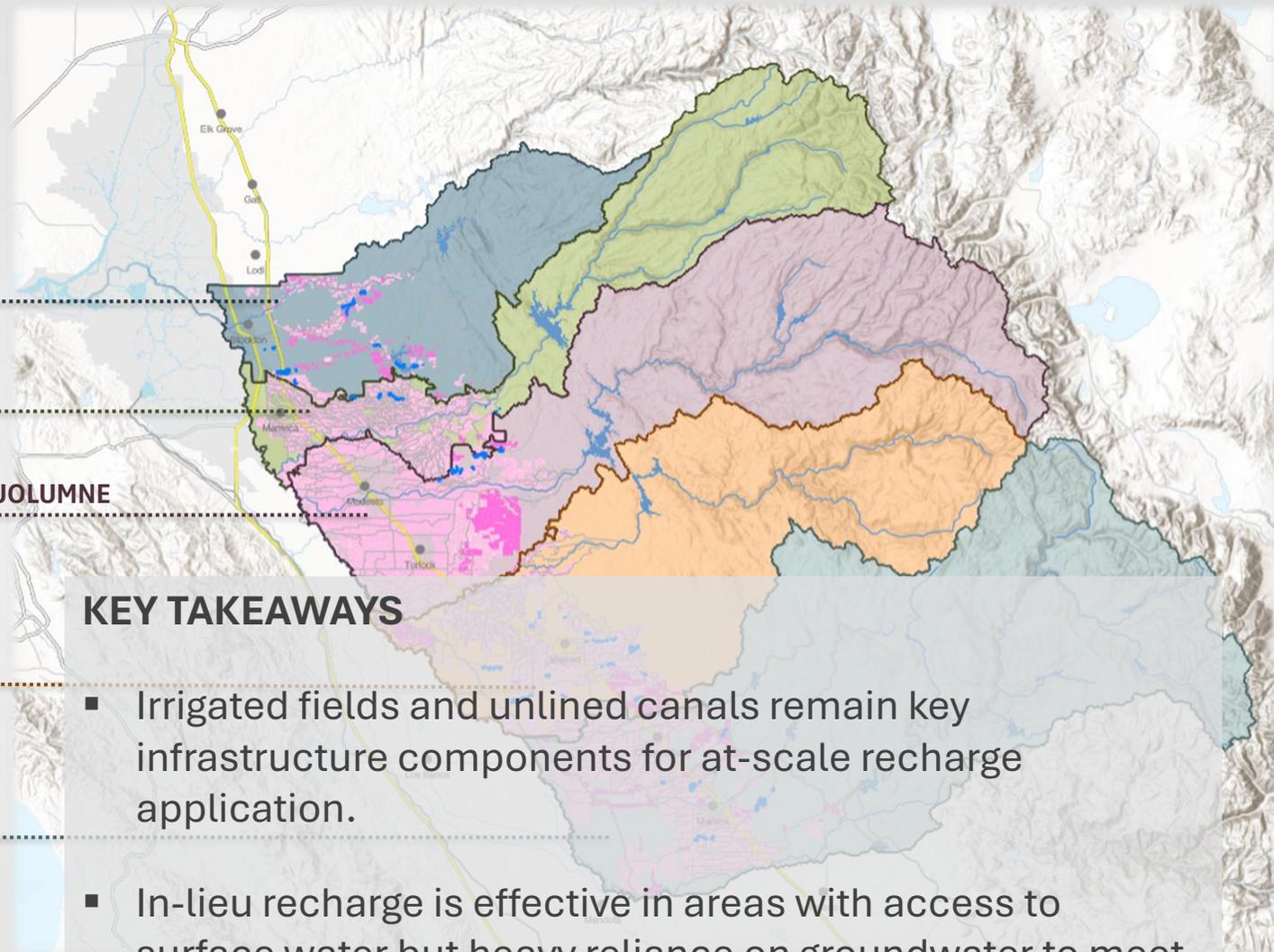
Recharge Basins

In-Lieu Recharge (April 1st – June 15th; limited to the irrigation season overlapping with the recharge period)

On-Farm Recharge (additional fields accessible with planned conveyance, expanded bottlenecks, and increased turnout capacity)

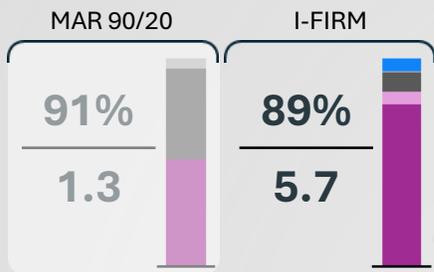
	Calaveras	Stanislaus	Tuolumne	Merced	Upper San Joaquin
Flow Through Basins	1,613 acres	506 acres	1,001 acres	3,027 acres	2,236 acres
Regulating Reservoirs	-n/a-	Woodward Reservoir	Tulloch Reservoir	Lake Yosemite	-n/a-
On-Farm Recharge	29,224 acres (+106%) available with recharge potential of 563 taf (8x)	101,730 acres (4%) available with recharge potential of 4,039 taf (1.7x)	173,475 acres (20%) available with recharge potential of 2,577 taf (2.8x)	129,667 acres (+19%) available with recharge potential of 3,202 taf (3.3x)	212,092 acres (+15%) available with recharge potential of 3,790 taf (2.9x)

Recharge Operations



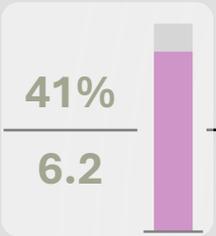
Percent applied demand met by groundwater pumping

81%



CALAVERAS

32%



50%



STANISLAUS

44%

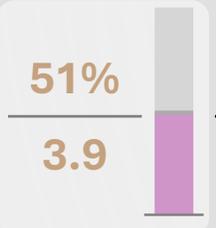


69%



TUOLUMNE

66%

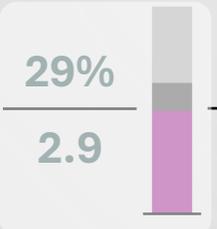


53%

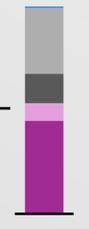


MERCED

78%



43%



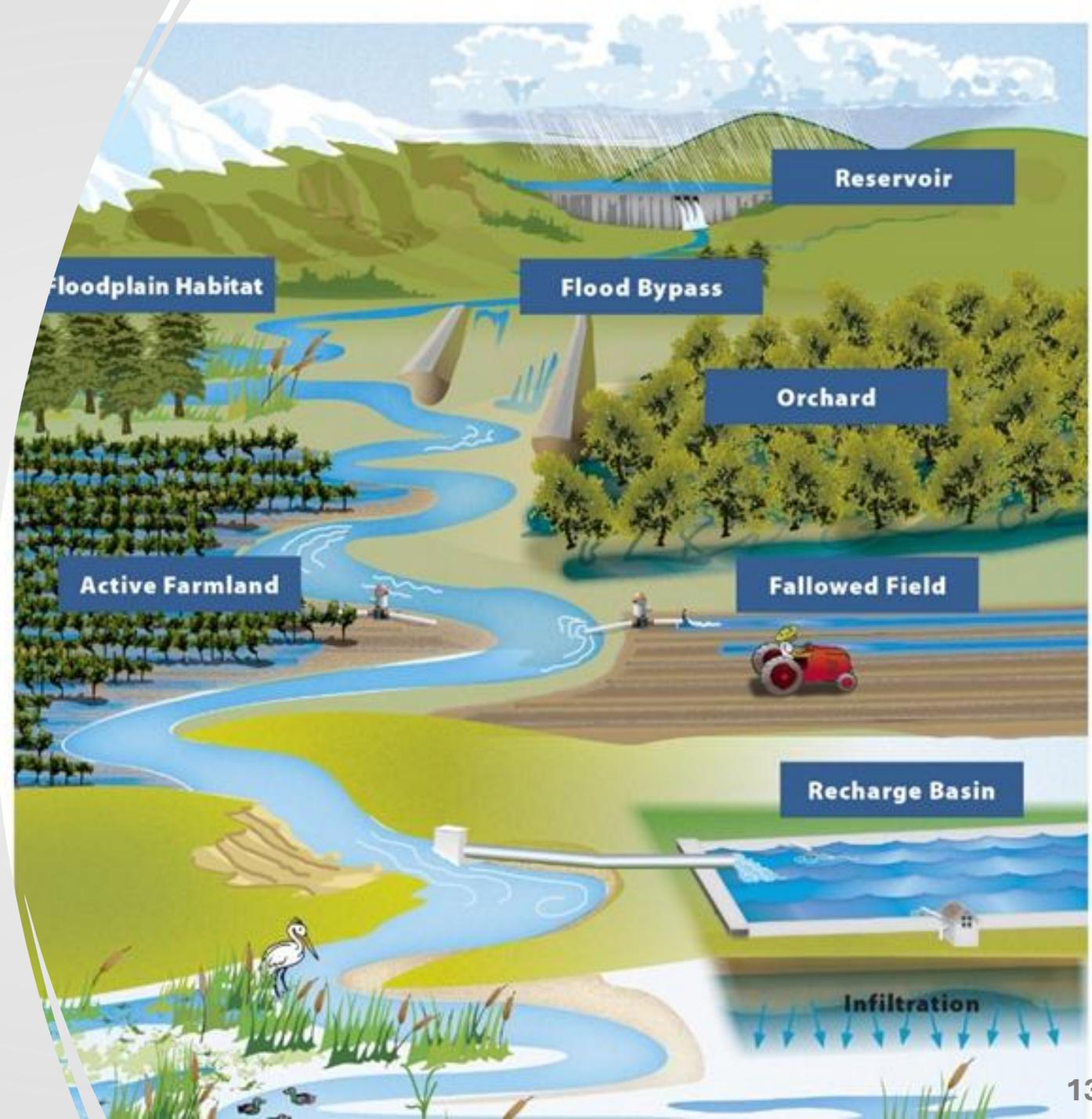
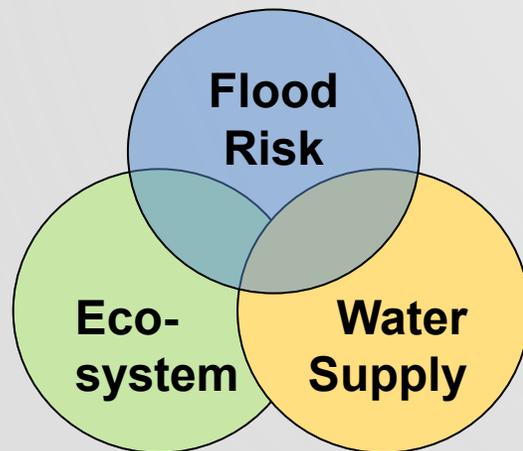
UPPER SAN JOAQUIN

KEY TAKEAWAYS

- Irrigated fields and unlined canals remain key infrastructure components for at-scale recharge application.
- In-lieu recharge is effective in areas with access to surface water but heavy reliance on groundwater to meet applied demands due to limited surface water supplies.
- Flow through basins are effective in watersheds with significant creek runoff.

- Flow Through Basins
- Canals and Regulating Reservoirs
- Recharge Basins
- In-lieu Recharge
- On-farm Recharge

MULTI-SECTOR PERFORMANCE



Performance Metrics



CALIFORNIA DEPARTMENT OF
WATER RESOURCES

METRICS DASHBOARD SAN JOAQUIN BASIN WATERSHED STUDIES

Start by selecting a page below.

Vulnerability with Respect to
Temperature

Vulnerability with Respect to
Precipitation

Average and Contingency
Performance

Adaptation Performance (Climate Condition)

Adaptation Performance (Time Horizon)

Total Risk

Sensitivity and Salience

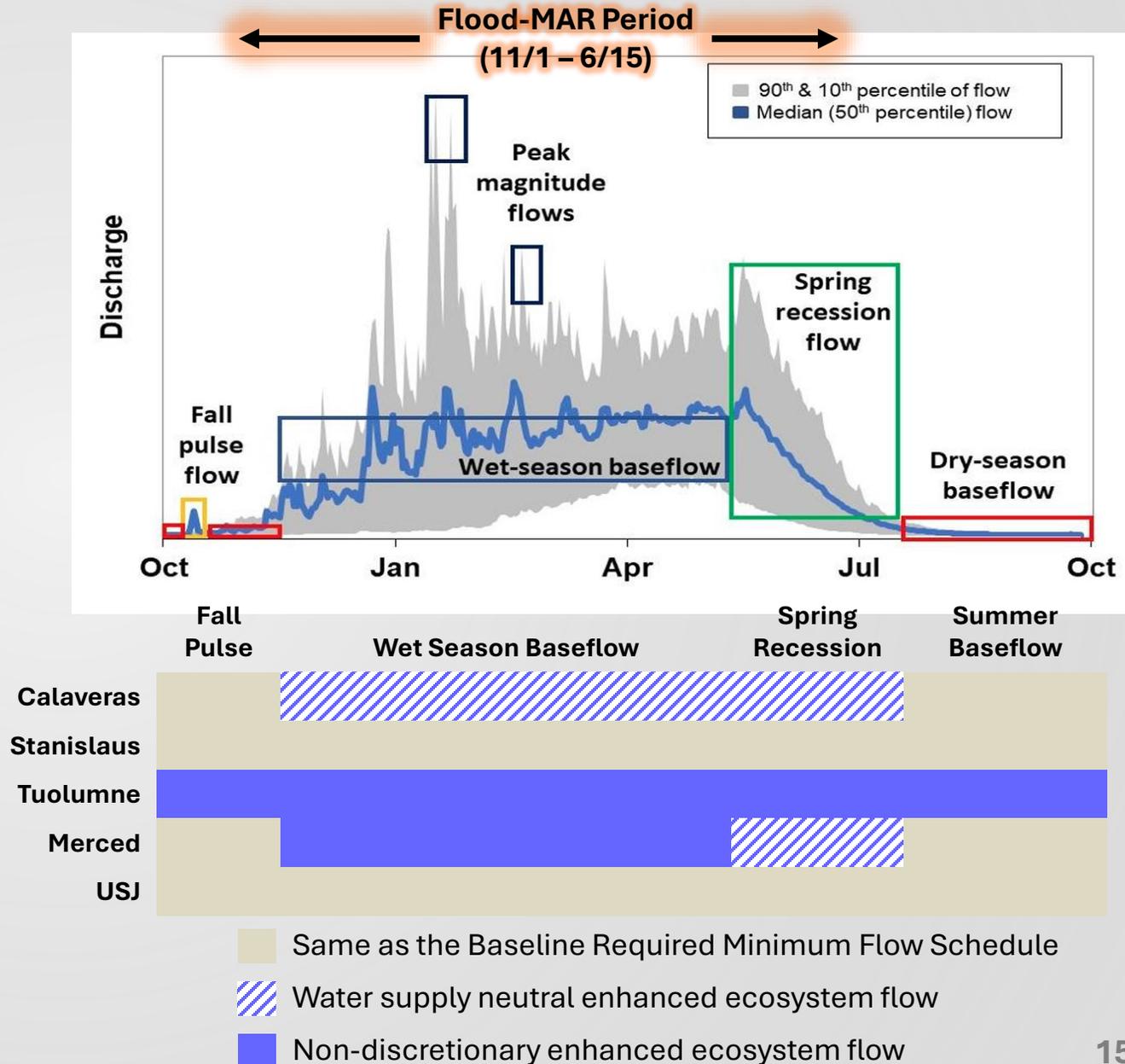
Explore Metrics by Location

Disclaimer:

The information presented on this dashboard is intended for **planning-level purposes only** and is provided as an **extension of the results documented in the Watershed Study Reports** available on the California Department of Water Resources' (DWR) website at <https://water.ca.gov/programs/all-programs/flood-mar>. The results displayed reflect the application of various models and analytical approaches based on a series of **specific study assumptions** regarding hydrology, infrastructure, operations, and other input parameters.

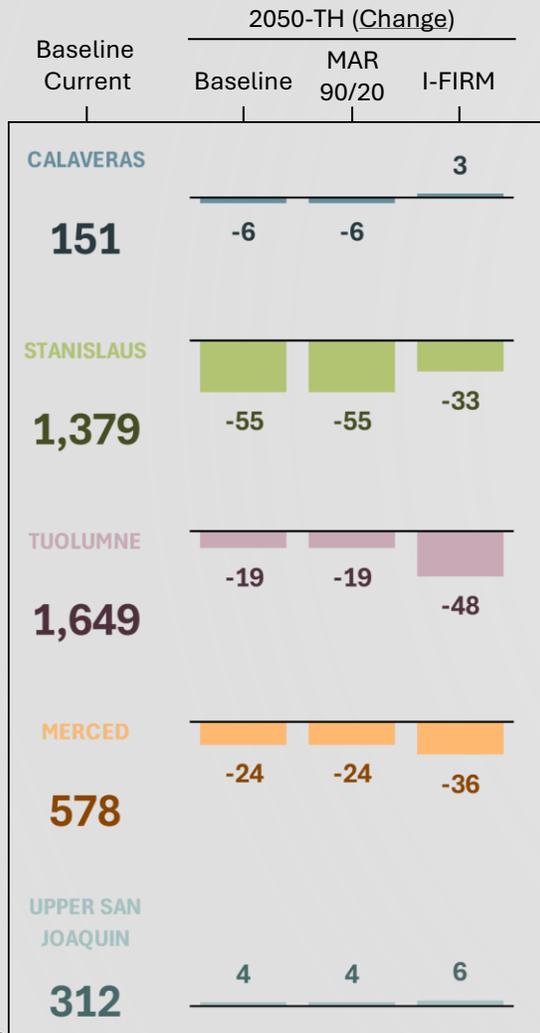
Takeaways – Water Supply (surface water)

- Reservoir operations are unchanged in **MAR-90/20** and therefore, the strategy has no effect on reservoir storage or applied surface water.
- **I-FIRM** includes changes to reservoir operations and incorporates enhanced ecosystem flows.
- Effect on surface supply depends on the design of the enhanced ecosystem flows.

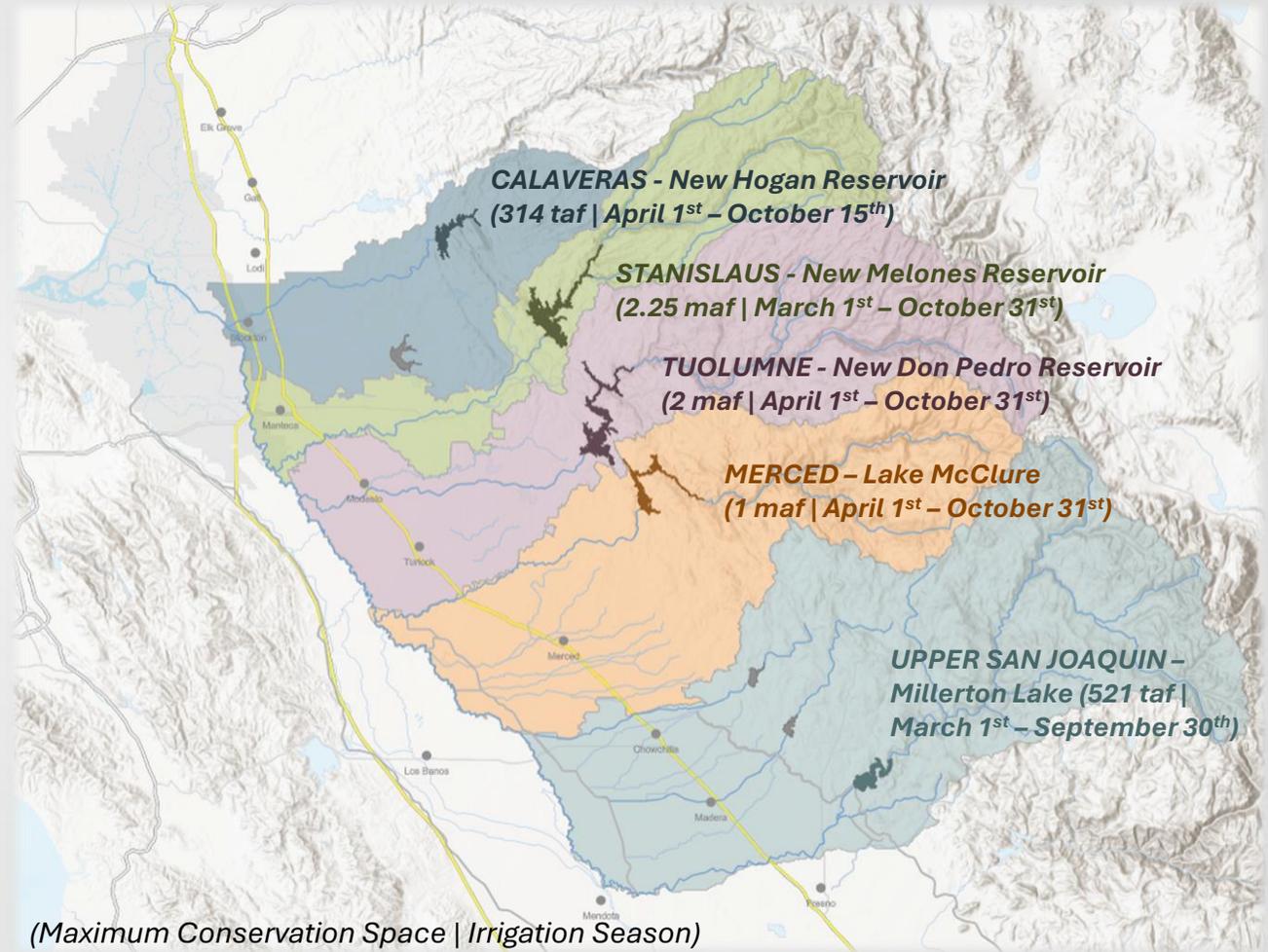
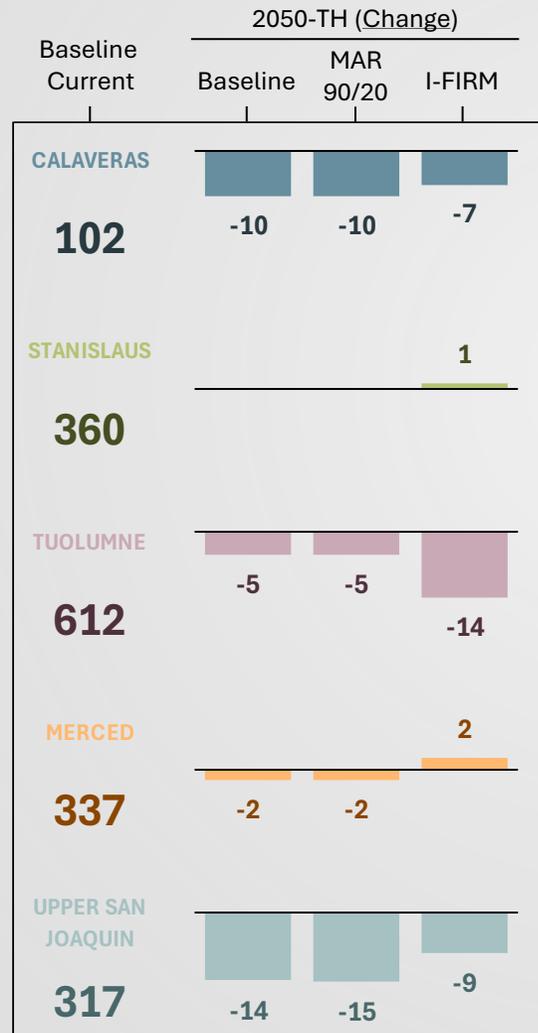


Adaptation Potential: Water Supply (surface water)

Average annual reservoir storage at the beginning of the irrigation season (taf)



Average annual applied surface water (taf)

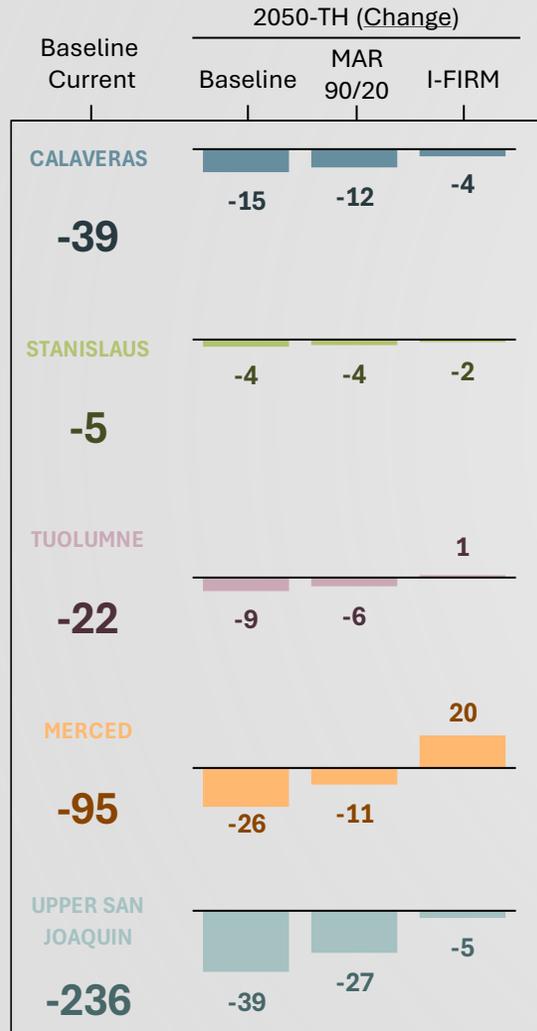


Takeaways – Water Supply (groundwater)

- Recharge contributes to increased groundwater storage over the long term.
- Benefits increase with higher recharge volumes.
- Flood-MAR alone does not completely alleviate groundwater overdraft.
- Applied recharge also affects stream-aquifer interactions and subsurface flows to neighboring subbasins.
- Fate of recharged water is highly dependent on the existing conditions of the watershed.
- Improved groundwater storage conditions are reflected in higher overall groundwater levels relative to the Baseline.

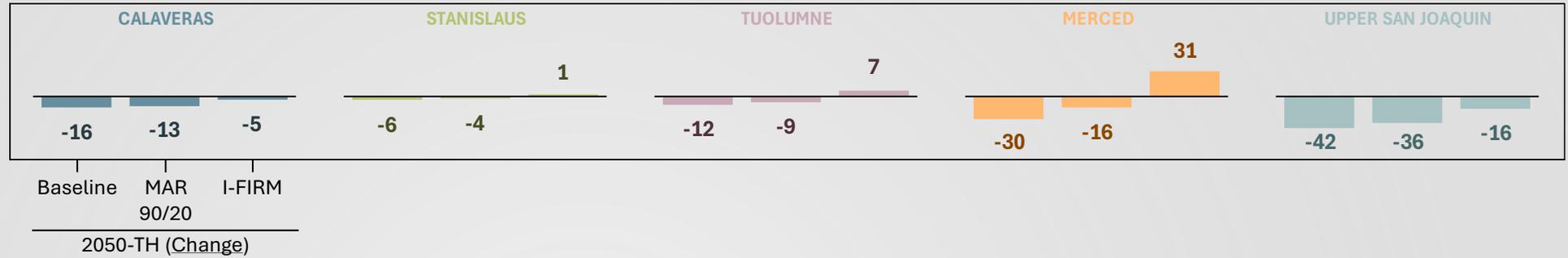
Adaptation Potential: Water Supply (groundwater)

Average annual change in subsurface storage (taf)

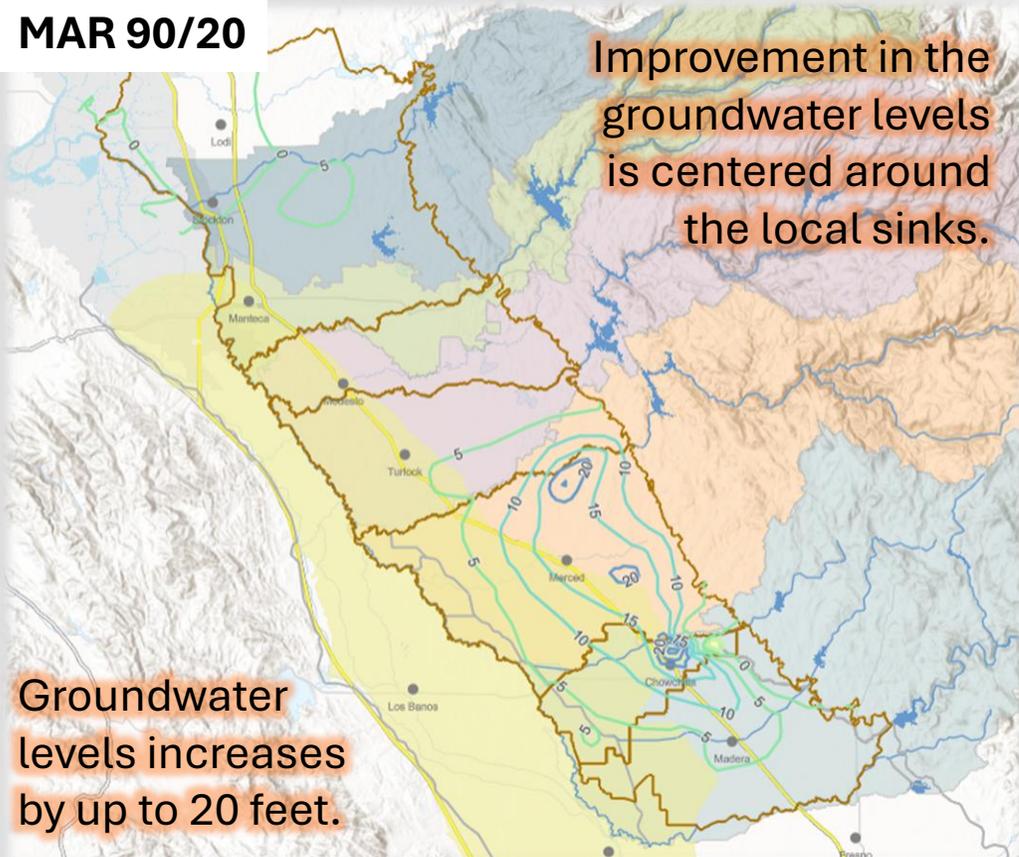


Adaptation Potential: Water Supply (groundwater)

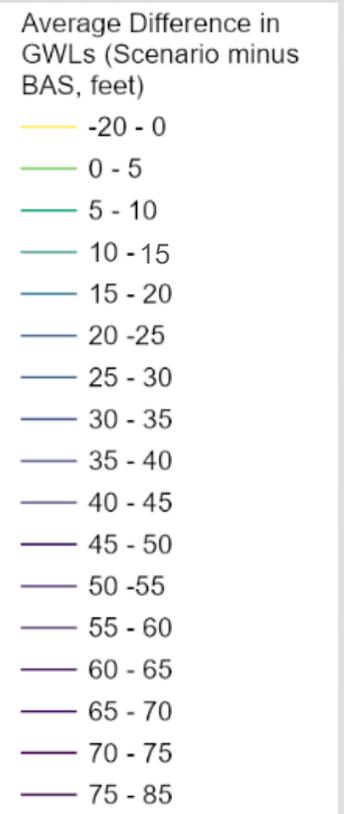
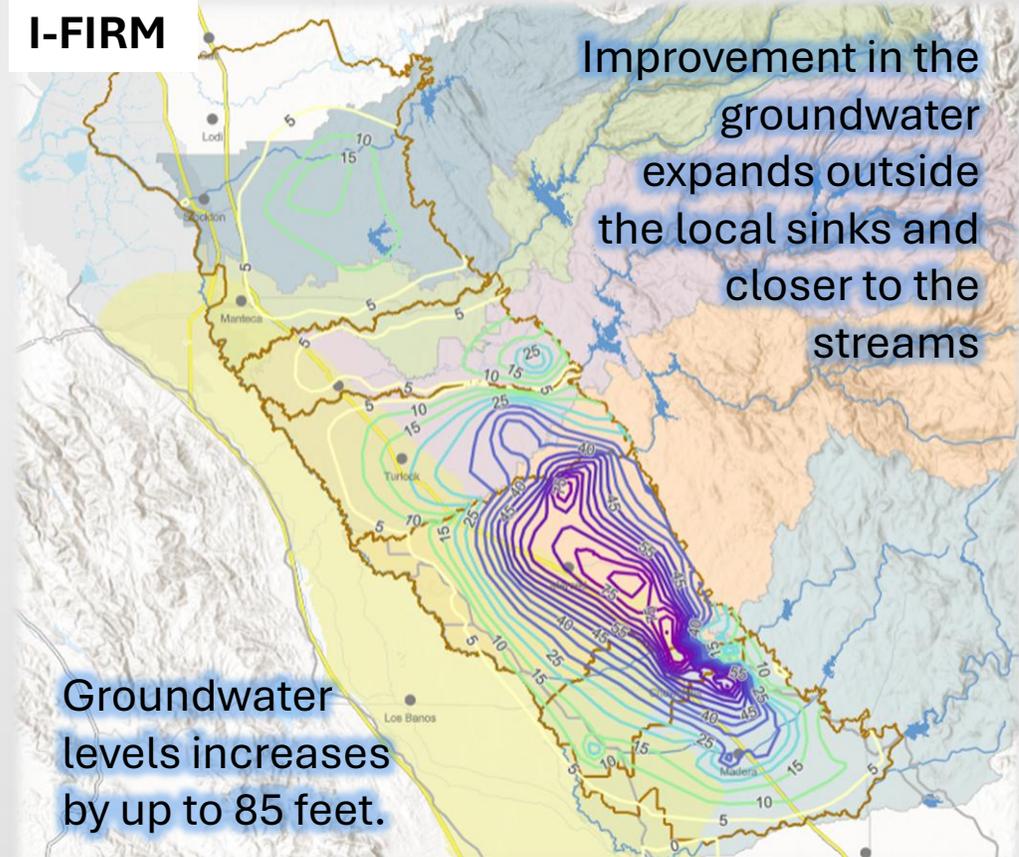
Difference in groundwater levels east of Corcoran Clay relative to baseline current conditions (feet)



MAR 90/20



I-FIRM



(Contours = change in groundwater levels relative to the Baseline under the +2°C climate condition)

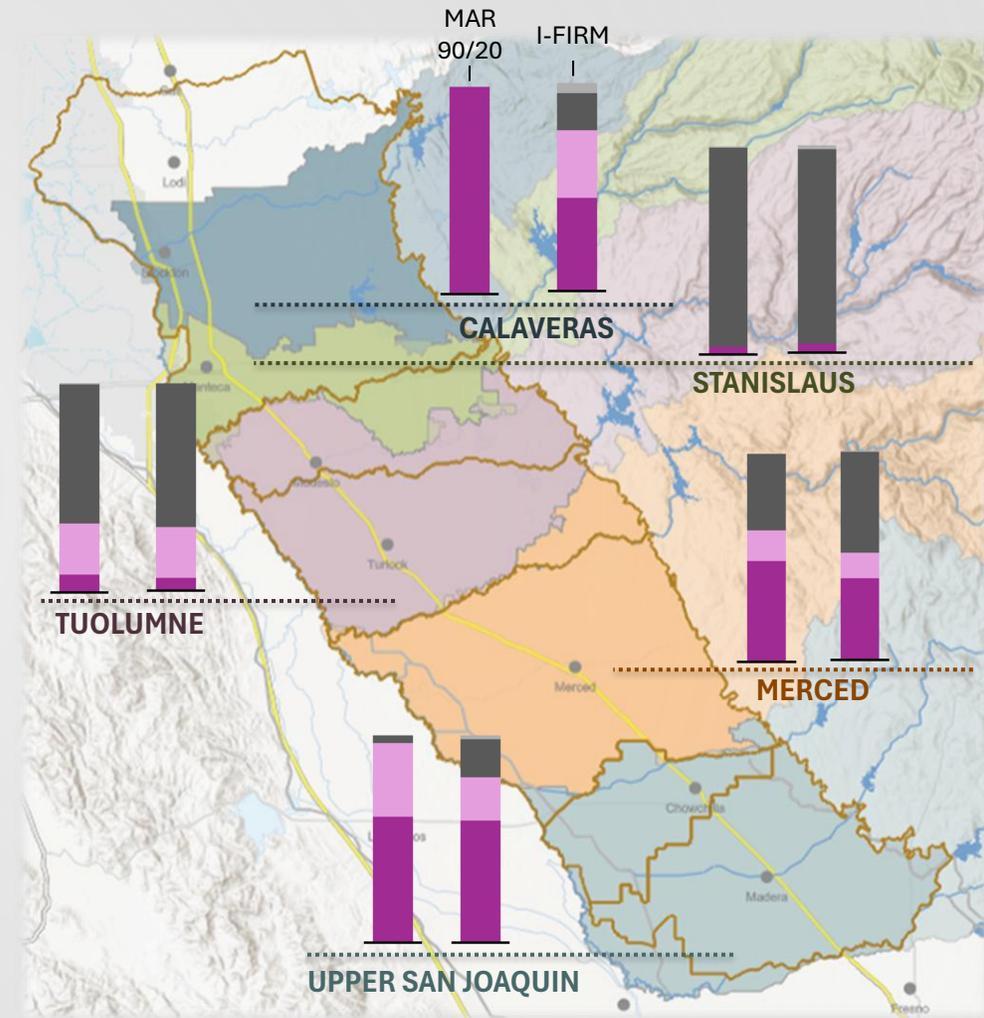
Fate of the Recharged Water

- low water table and higher depth to groundwater offers greater groundwater storage potential
- higher groundwater levels results in higher groundwater discharge to stream

MAR 90/20 – 2050 TH

I-FIRM – 2050 TH

	Applied recharge (taf)	Change in groundwater storage (taf)	Change in watershed outflow (taf)	Applied recharge (taf)	Change in groundwater storage (taf)	Change in watershed outflow (taf)
Calaveras	3	3 (100%)	-1 (-35%)	22	11 (50%)	-11 (-49%)
Stanislaus	13	1 (4%)	2 (+14%)	39	2 (6%)	2 (+6%)
Tuolumne	29	2 (8%)	-15 (-52%)	163	9 (6%)	-100 (-61%)
Merced	30	15 (48%)	-12 (-40%)	129	46 (36%)	-63 (-49%)
Upper San Joaquin	21	12 (58%)	0* (0%)	57 (+55 via FKC)*	34 (60%)	-63 (-56%)*
	96	33 (34%)	-26 (-27%)	410 (+55 via FKC)	103 (25%)	-235 (-57%)

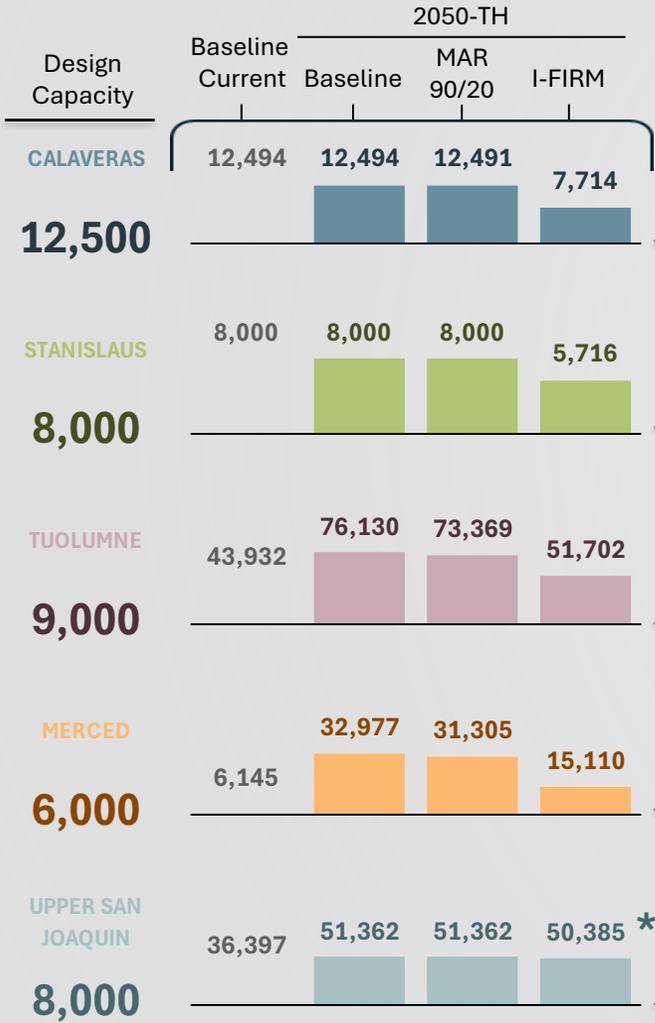


Takeaways – Flood Risk

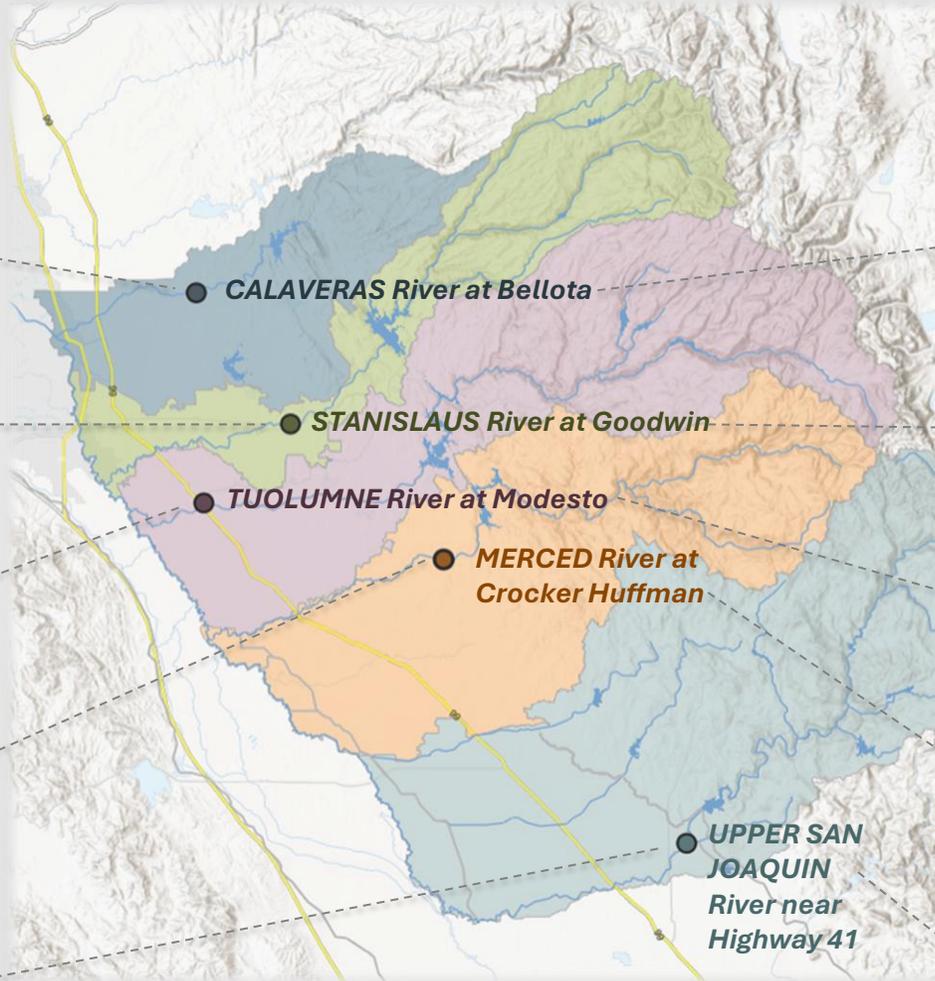
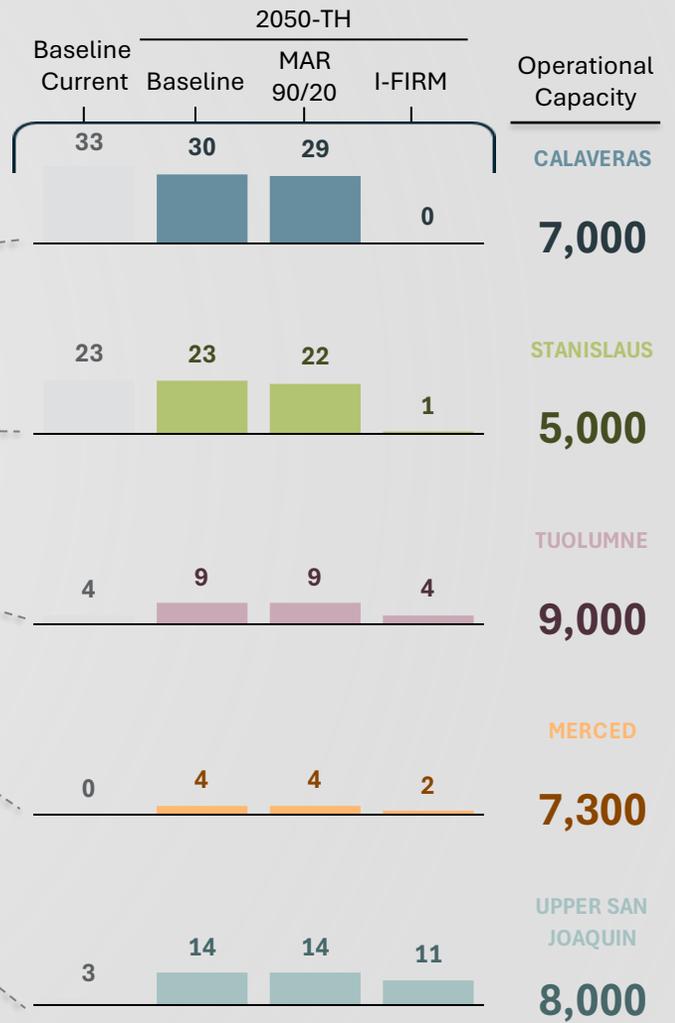
- Flood risk reduction potential in **MAR-90/20** is limited to daily maximum MAR diversion rate.
- Coordinated use of flood space for recharge and flood management under **I-FIRM** is more effective in managing flood risk – magnitude, frequency, and duration.
- Pairing FIRO with MAR increases flood release capacity to design channel capacity *plus* daily maximum MAR diversion rate.

22 Adaptation Potential: Flood Risk

Maximum flow over 100 years (cfs)



Number of years above operational capacity (years)



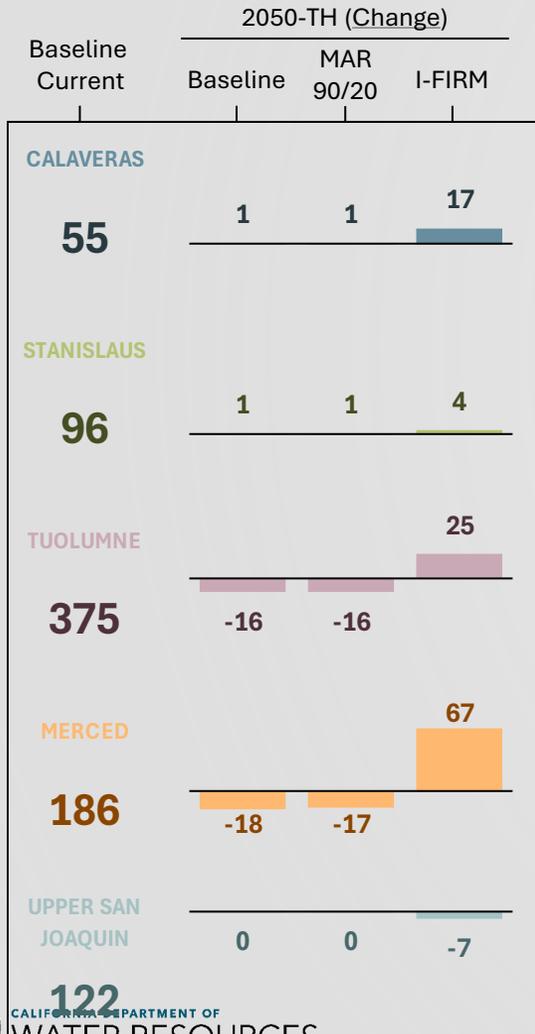
* Peak flow occurs in April, outside the FIRO-MAR period and during the irrigation season; therefore, limited opportunity for FIRO-MAR to provide any flood risk reduction benefit.

Takeaways – Ecosystems

- **MAR 90/20** recharge diversion criteria is considered protective of the baseline ecological functions. No enhanced ecosystem actions are considered.
- Reservoir re-operations under **I-FIRM** is expected to have a greater impact salmonid habitat from recharge diversions.
- Enhanced ecosystem management actions included in I-FIRM to: (1) limit impact to the salmonids, and (2) provide diversified benefits where possible to salmonids and other indicator species.
- Possible to co-manage for recharge and ecosystem benefits.

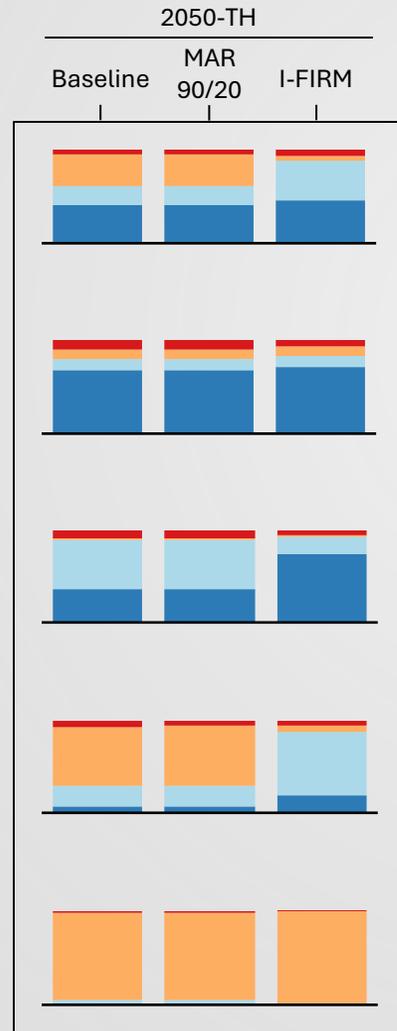
Adaptation Potential: Ecosystems – Salmonid Habitat

Average annual instream spawning (acre-days per linear mile; Nov – Feb)

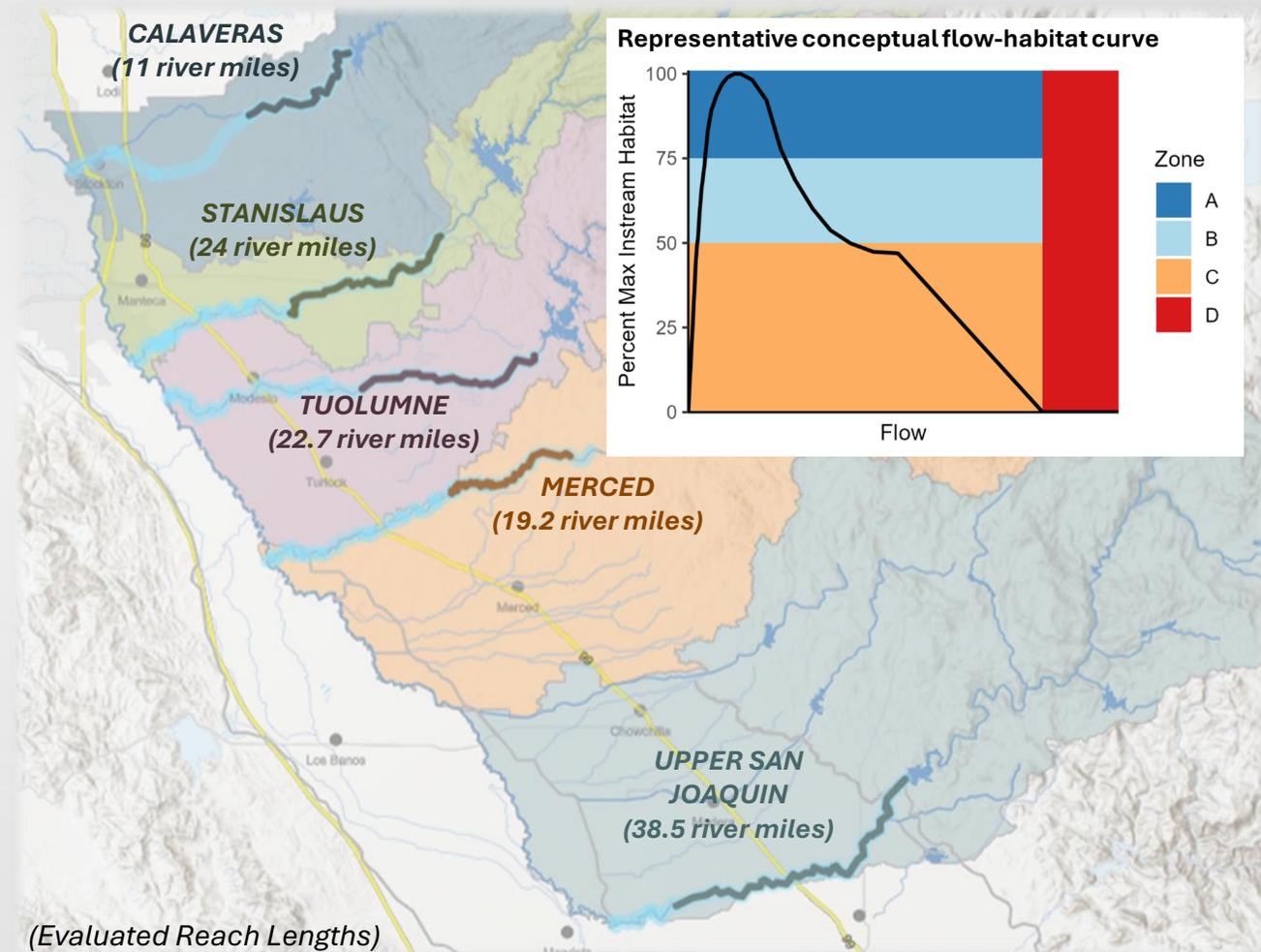


Percent days by habitat zone

■ Zone A (75 - 100%)
 ■ Zone B (50 - 75%)
 ■ Zone C (0 - 50%)
 ■ Unsuitable



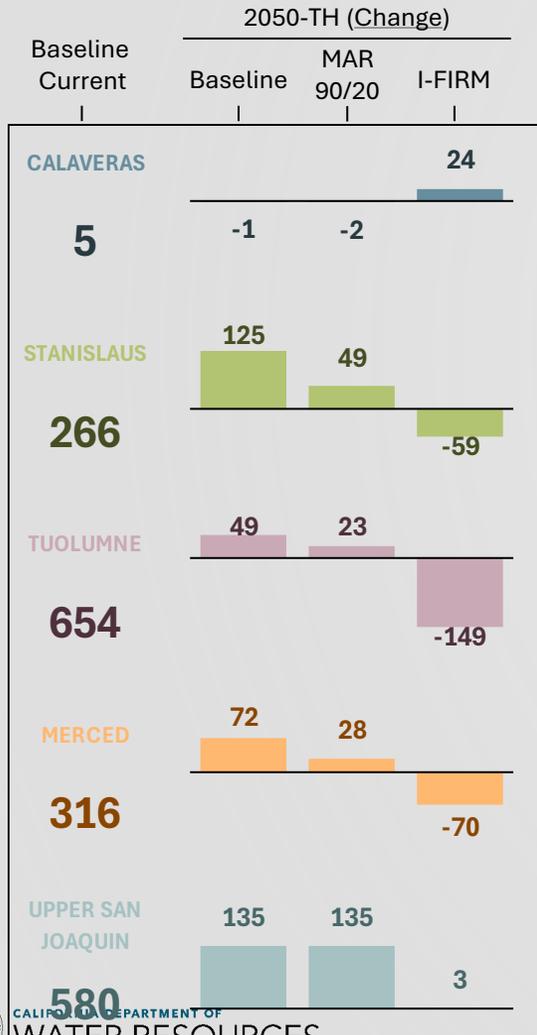
Instream spawning benefits are derived from flows with lower velocities and shallower depths, which in the narrow, incised channels common in the Central Valley, correspond to low-flow conditions.



Note: potential impacts on salmonids of changes in instream temperatures are not assessed in the study

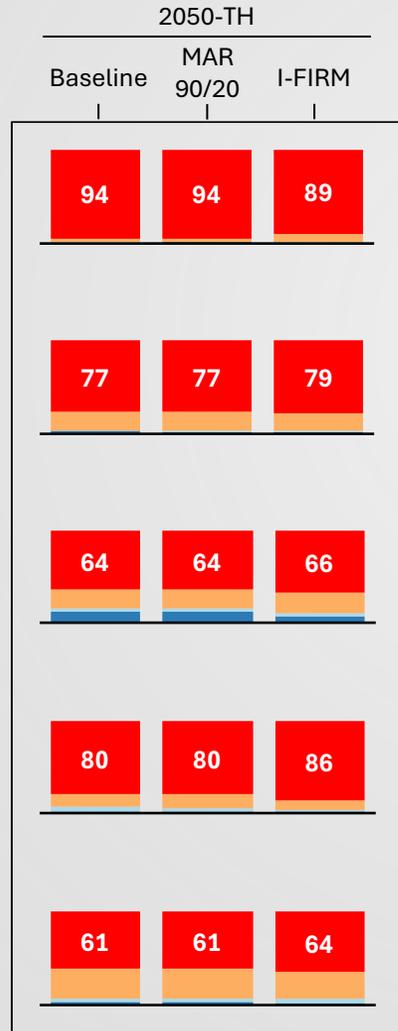
Adaptation Potential: Ecosystems – Salmonid Habitat

Average annual potential off-stream rearing (acre-days per linear mile; Dec – May)

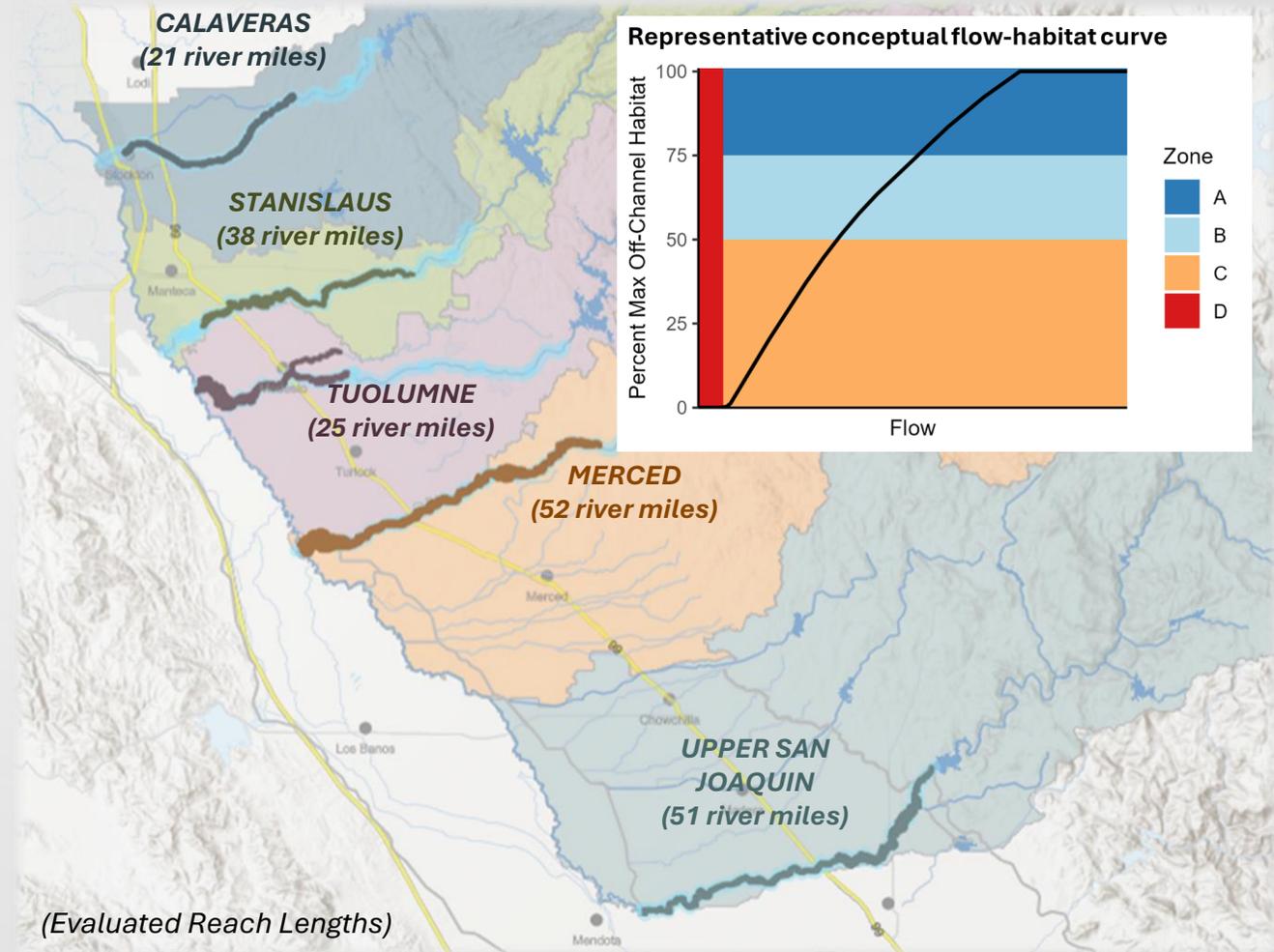


Percent days by habitat zone

■ Zone A (75 - 100%)
 ■ Zone B (50 - 75%)
 ■ Zone C (0 - 50%)
 ■ Unsuitable



Dependent on high-flow events that inundate off-channel sections to depths of 1–10 feet for 14 days or longer. This can conflict with recharge operations, designed to divert high flows and potentially limit the ability to inundate off-channel reaches to the desired depth.



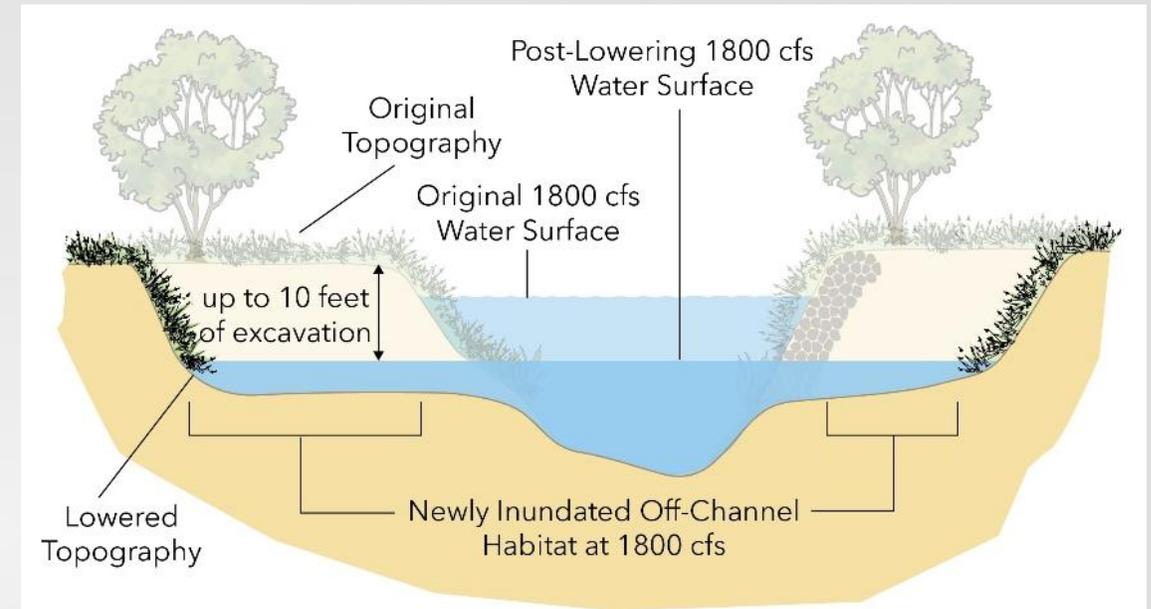
(Evaluated Reach Lengths)

Note: potential impacts on salmonids of changes in instream temperatures are not assessed in the study

Off-Channel Habitat Improvement (I-FIRM)

	I-FIRM – 2050 TH			Estimated additional restoration (acres)
	Acres Restored	Additional habitat (acre-day per year)	(acre-days per acre)	
Calaveras	5	22 (+4%)	4	--
Stanislaus	50	835 (+12%)	17	135 (3x)
Tuolumne	72	877 (+7%)	12	303 (4x)
Merced	85	704 (+6%)	8	437 (5x)
Upper San Joaquin	61	2,159 (+8%)	35	--

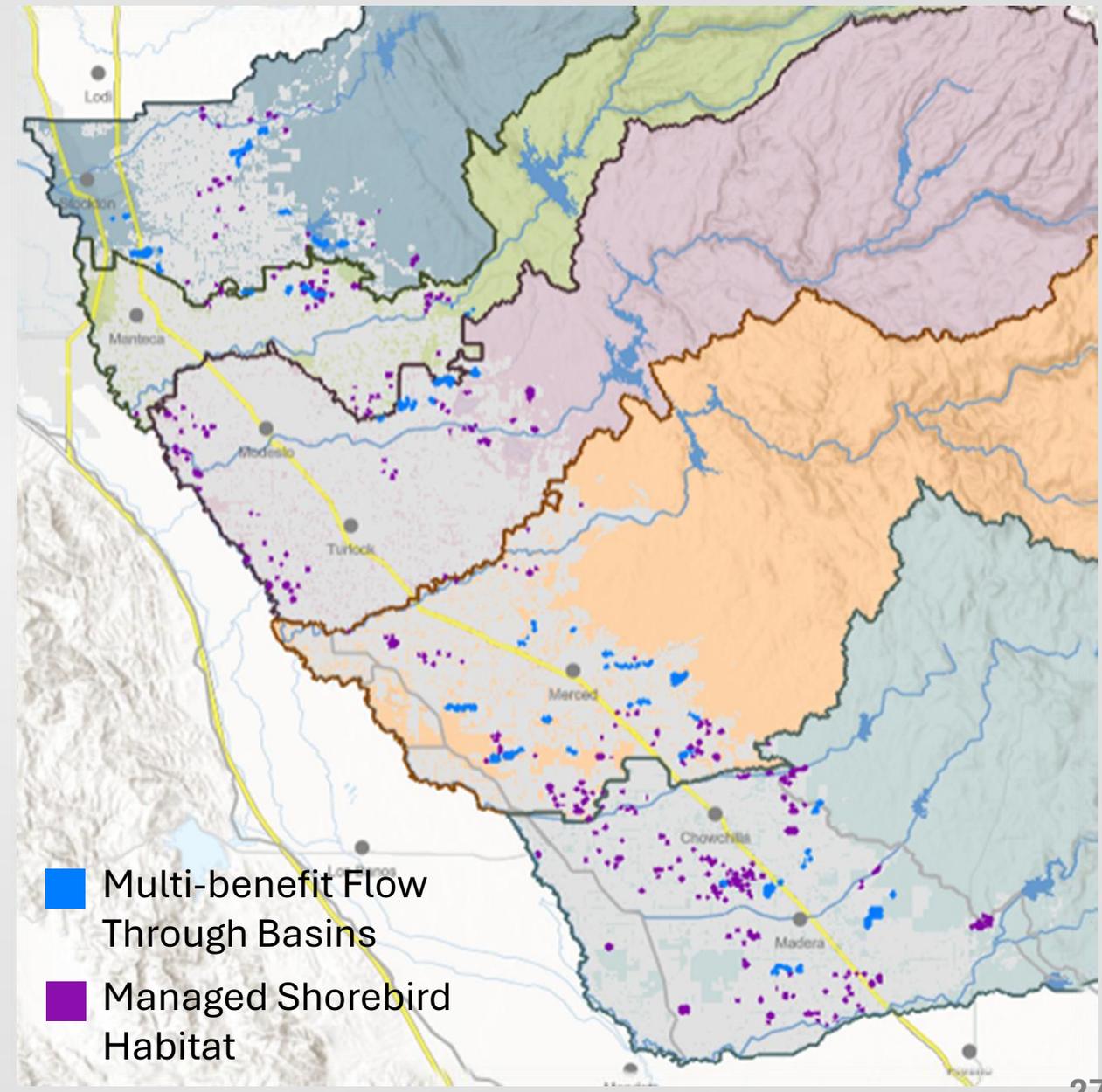
Or may be not? The analyses did not account for habitat quality. Restored reaches, designed adequately, are expected to provide greater habitat per acre than what currently exists.



- Non-flow enhanced ecosystem management action included in I-FIRM to compliment spring recessional flows by re-grading areas within the leveed reaches to inundate at the design flow.
- Targeted sites located within a single reach along the river providing the top 10 – 20th percentile uplift potential (benefit per unit excavated).
- Limited in size to be comparable to a planned large-scale restoration project.

Diversified benefits to other indicator species (I-FIRM)

	Multi-benefit Flow Through Basins 2050-TH		Managed Shorebird Habitat 2050-TH	
	Average annual habitat (acre-days per year)	Number of activation years	Average annual habitat (acre-days per year)	Number of habitat years
Calaveras	2,213	70	1,790	30
Stanislaus	286	72	984	17
Tuolumne	1,597	57	11,597	49
Merced	6,882	78	5,202	42
Upper San Joaquin	290	65	4,141	27
	11,268		23,714	



- Flood-MAR strategies can provide “win-win-win” solutions.
- **MAR 90/20** provides limited water supply and flood risk benefits.
- Climate change risk to water supply is more effectively mitigated through combining forecast-informed reservoir operations (FIRO) with groundwater recharge (**I-FIRM**).
- However, Flood-MAR alone does not completely alleviate groundwater overdraft.
- FIRO + MAR greatly reduces the magnitude, frequency and duration of high flows events.
- A comprehensive FIRO-MAR approach coordinates ecosystem management with the recharge operations to limit impact to habitat and diversify benefits.
- Strategies are not optimized for any single management objective and can be further refined to expand benefits.



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