Merced River Watershed Study

In-depth Discussion of Ecosystem Effects

Karandev Singh (Karandev.Singh@water.ca.gov) | CWEMF Annual Meeting | 4/5/2022

Department of Water Resources · State of California

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theEARTH GENOME
REVEALING THE POSSIBLE

MID Merced Irrigation District
Water & Power

Session 16. Merced River Flood-MAR Study

1. Overview
2. Water Available for Recharge and Water Supply and Flood Risk Benefits
3. In-depth Discussion of Ecosystem Effects
4. Multi-sector Performance Using Risk-based Analytics

Results → Metrics → Sector Performance

Watershed Conditions	Upper Watershed Runoff
	Applied Demand
	Water Available For Recharge (WAFR)

Water Supply/ Groundwater (GW)	GW Pumping
	Δ GW Storage
	Δ GW Levels in Disadvantaged Communities

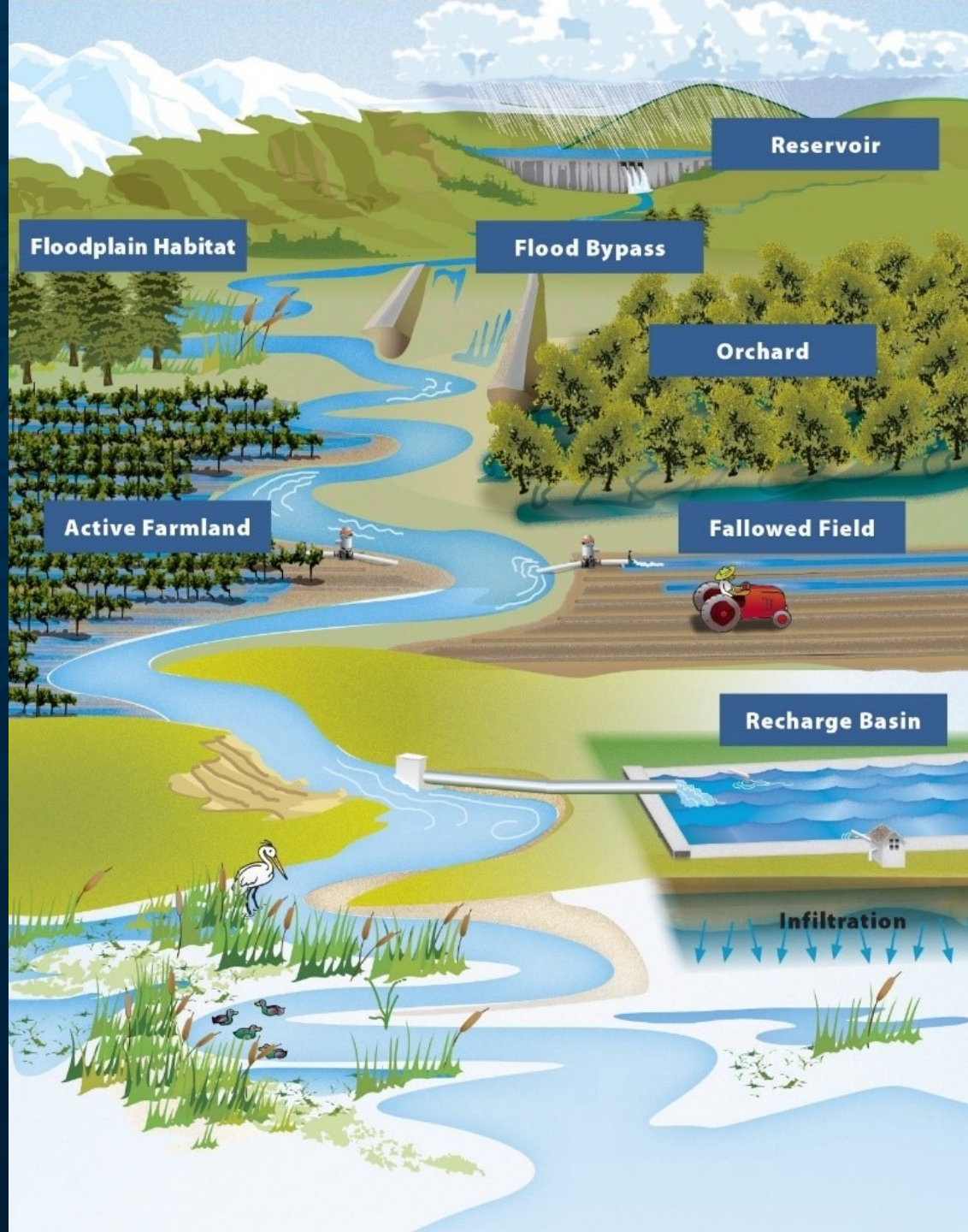
Water Supply/ Surface Water (SW)	Lake McClure Storage
	SW Deliveries

Flood Risk	Merced River Flood Conditions

Ecosystem	GDE Habitat
	Merced River Salmonid Habitat
	Shorebird Habitat

Ecosystem Sector

- Benefits of Flood-MAR to flood risk and water supply are clear.
- Benefits are expected for non-aquatic species (trees, shorebirds) that rely on groundwater and surface water affected by recharge actions.
- Aquatic species reliant on in-stream flow may see benefits and impacts



Ecosystem Objectives

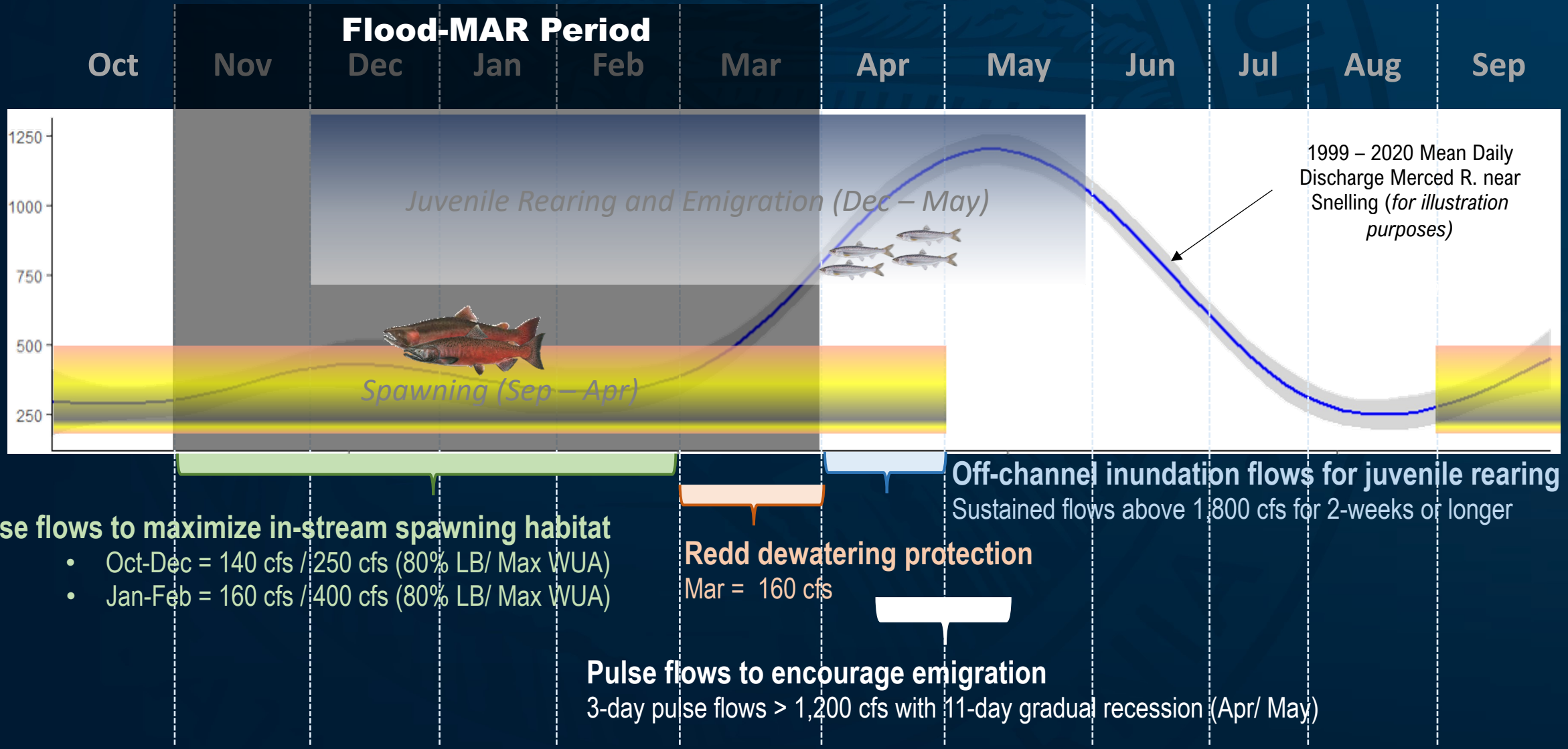
- Evaluate the potential effects of Flood-MAR on Groundwater Dependent Ecosystem species (GDEs), salmonids, shorebirds

- Provide recommendations for how reservoir re-operations and infrastructure enhancements can minimize impacts and provide potential benefits for salmonids

Scenario Overview

1. Baseline
2. Level 1 Intermediate “Recharge-only”
   - High flows using existing infrastructure
   - Passively managed ecosystem
3. Level 3 FIRO-MAR
   - High flows + Reservoir Reoperation + Infrastructure Improvement
   - Set higher winter base releases to maximize spawning habitat area
   - Repurposed winter and spring runoff for eco releases made in April-May (spring pulse flows, off-channel inundation flows etc.)
   - Improved off-channel habitat

Level 2/3 Eco-operations



Off-channel inundation flows for juvenile rearing

Sustained flows above 1,800 cfs for 2-weeks or longer

Base flows to maximize in-stream spawning habitat

- Oct-Dec = 140 cfs / 250 cfs (80% LB/ Max WUA)
- Jan-Feb = 160 cfs / 400 cfs (80% LB/ Max WUA)

Redd dewatering protection

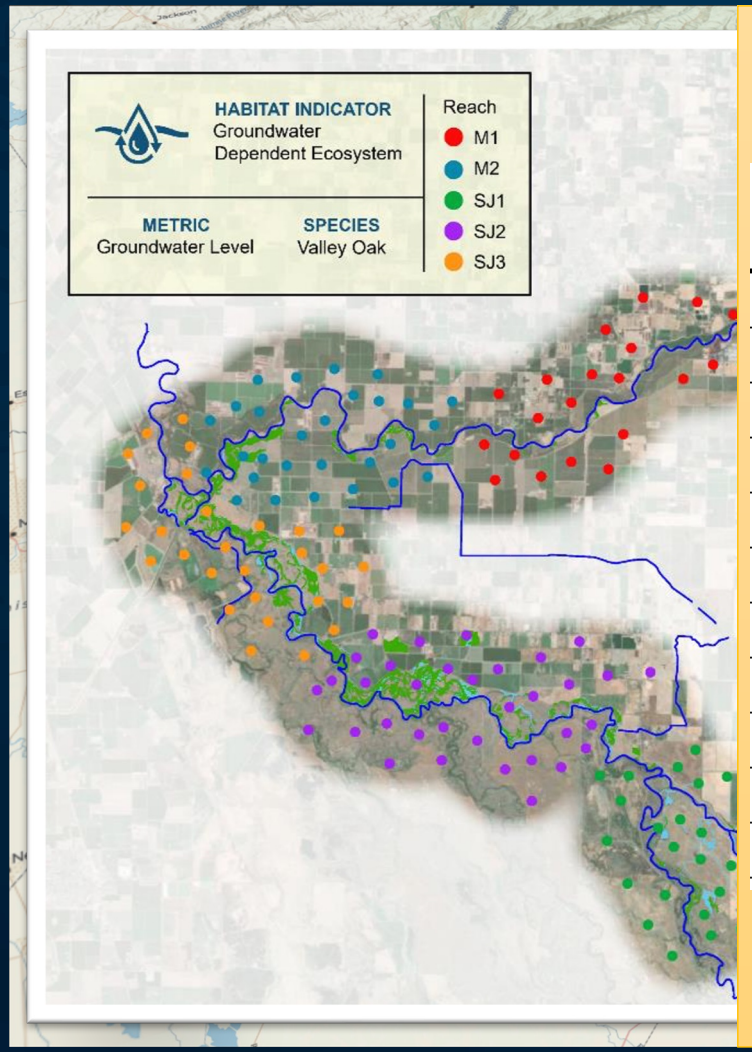
Mar = 160 cfs

Pulse flows to encourage emigration

3-day pulse flows > 1,200 cfs with 11-day gradual recession (Apr/ May)

Groundwater Dependent Ecosystems (GDEs)

- GDEs are plant and animal communities that require groundwater to meet some or all water needs
- Provide water purification, flood mitigation, base flow in rivers, and recreation opportunities
- We evaluated the effects of Flood-MAR actions relative to rooting depths of key tree species

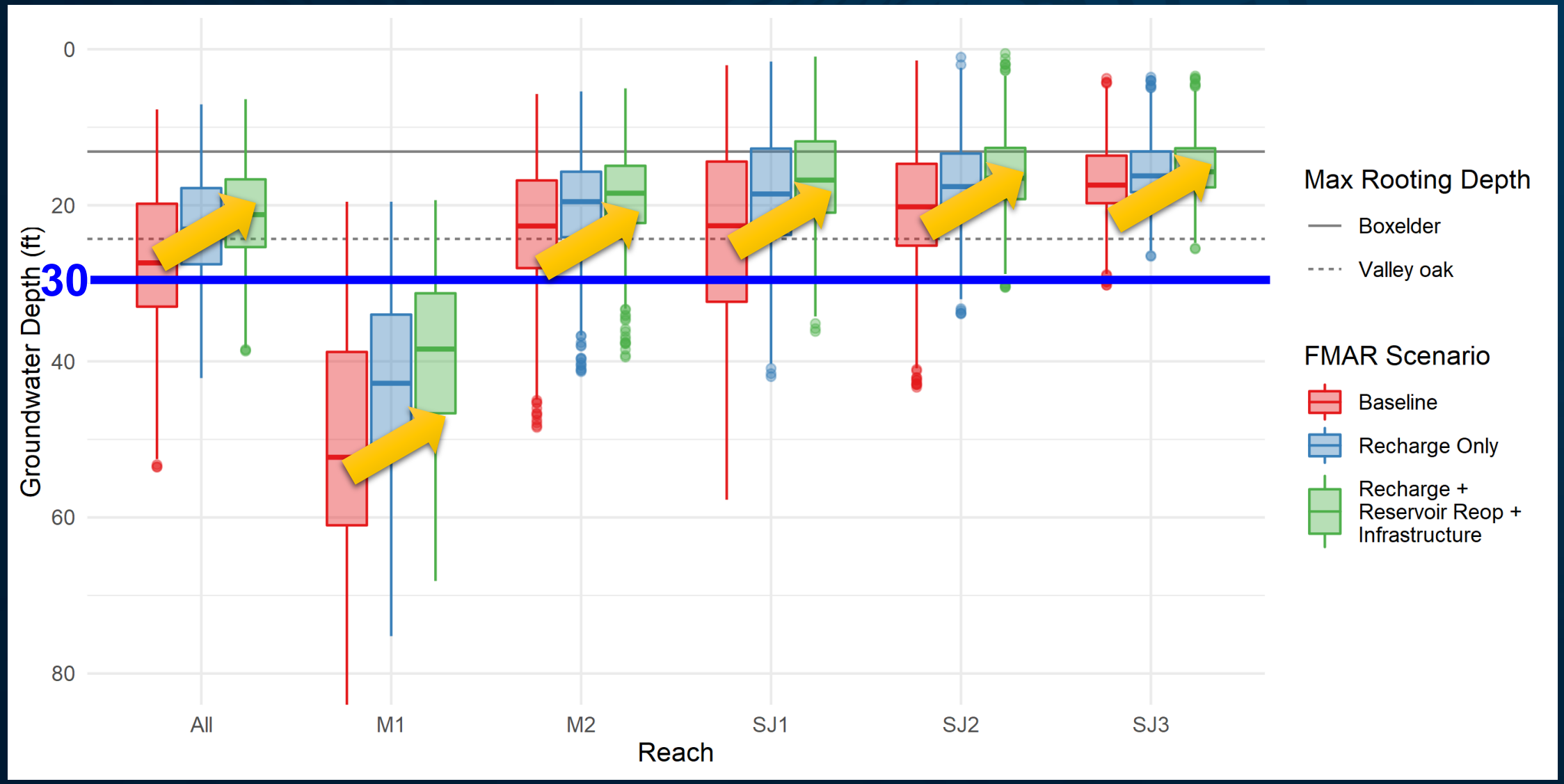


GDE Rooting Depth

Dominant Species Common Name	Rooting Depth (feet)
Valley oak	24.31
Boxelder	13.12
Goodding's black willow	6.89
Fremont cottonwood	6.89
Hinds' walnut	5.91
Narrow-leaved cattail	0.89
Narrow-leaved willow	NA
Common tule	NA
Mugwort	NA
Blackberry	NA
Arroyo willow	**NA**

Max rooting depth of 30 feet (Merced Sub-basin GSP, 2019)

Groundwater Dependent Ecosystems



System Performance

Performance Indicator: Decline | No significant change | Improvement

Preliminary Results – Subject to Change

Performance evaluated with respect to Baseline Current Conditions | *Performance evaluated with respect to Baseline DT3DP1.1 Scenario*





				VULNERABILITY		ADAPTATION PERFORMANCE	
				CURRENT BASELINE	DT3DP1.1	DT3DP1.1 L1 INTERM.	DT3DP1.1 L3 FIRO-MAR
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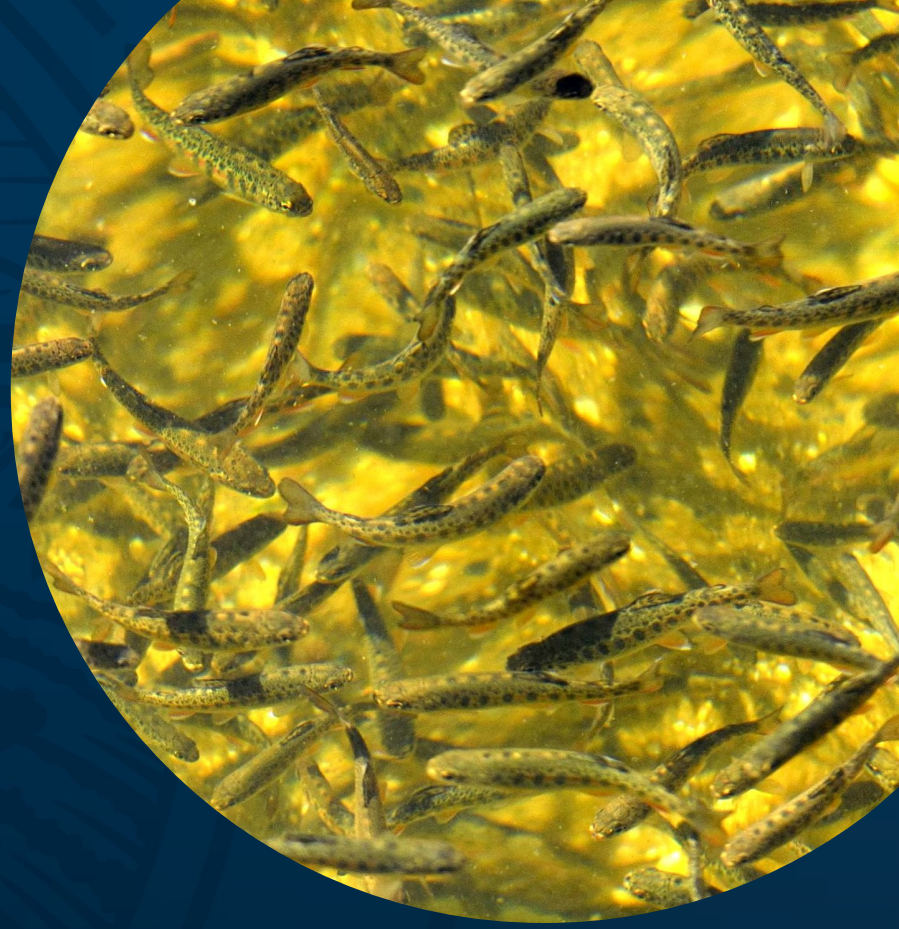
Ecosystem	GDE Habitat	% Months with GW Levels ≤ 30 feet	*Percent*	77	**70**	**79**	**83**

Salmonid Habitat

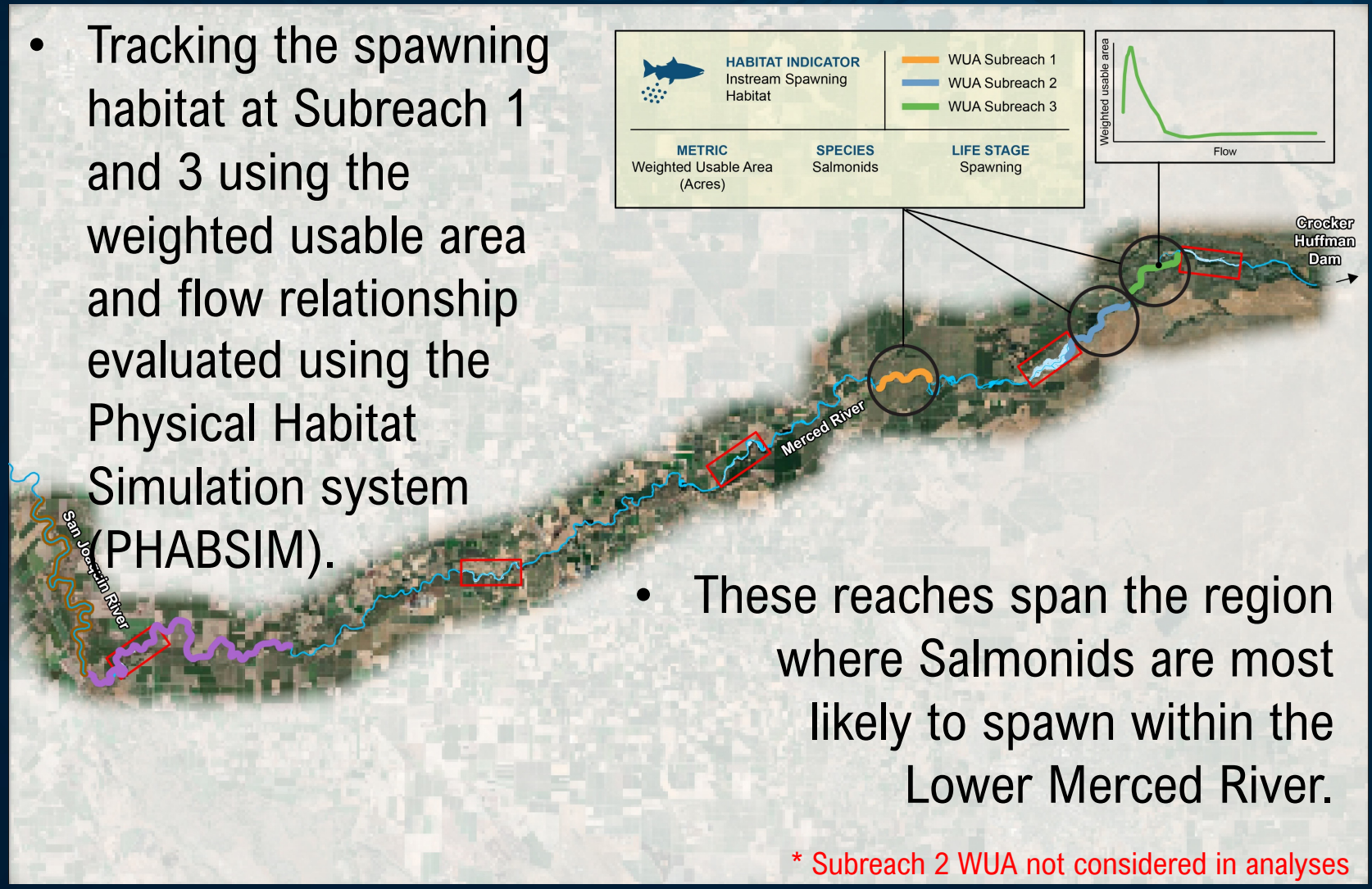


- Require freshwater for spawning and rearing
- Dependent on adequate depths, velocities, substrates, and cool temps
- Life stages evaluated: spawning, rearing, juvenile emigration
  - In-stream spawning habitat
  - Potential* seasonally inundated off-channel juvenile rearing habitat

**Without improvement, off-channel habitat very limited in Merced River currently.*

Instream Salmonid Spawning Habitat

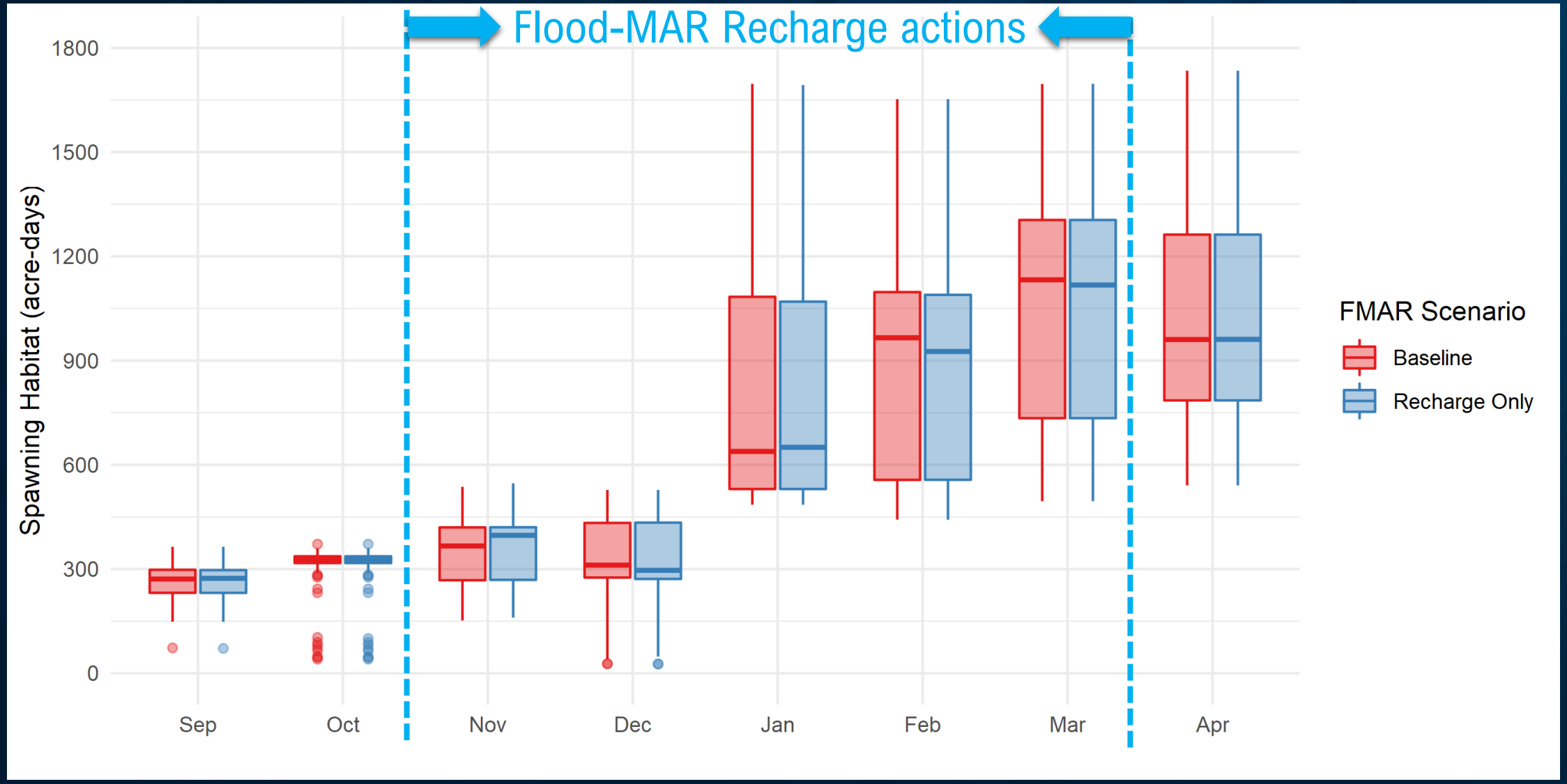
- Tracking the spawning habitat at Subreach 1 and 3 using the weighted usable area and flow relationship evaluated using the Physical Habitat Simulation system (PHABSIM).



- These reaches span the region where Salmonids are most likely to spawn within the Lower Merced River.

* Subreach 2 WUA not considered in analyses

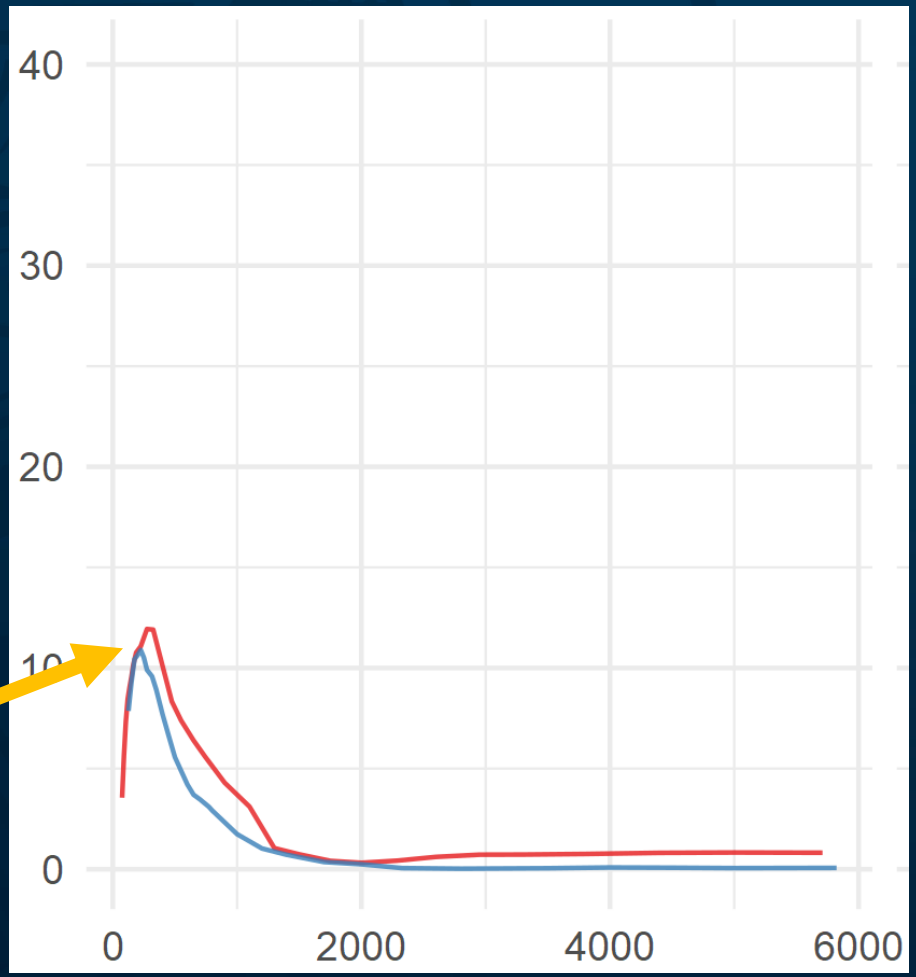
Instream Salmonid Spawning Habitat



Instream Spawning Habitat

Recommended Level 3 FIRO-MAR reservoir reoperation:

- Re-operate reservoir to maximize spawning habitat of salmonids by maintaining flows at the following levels
  - Oct-Dec = 140 - 400 cfs
  - Jan-Feb = 160 – 800 cfs
  - Mar = 160 cfs



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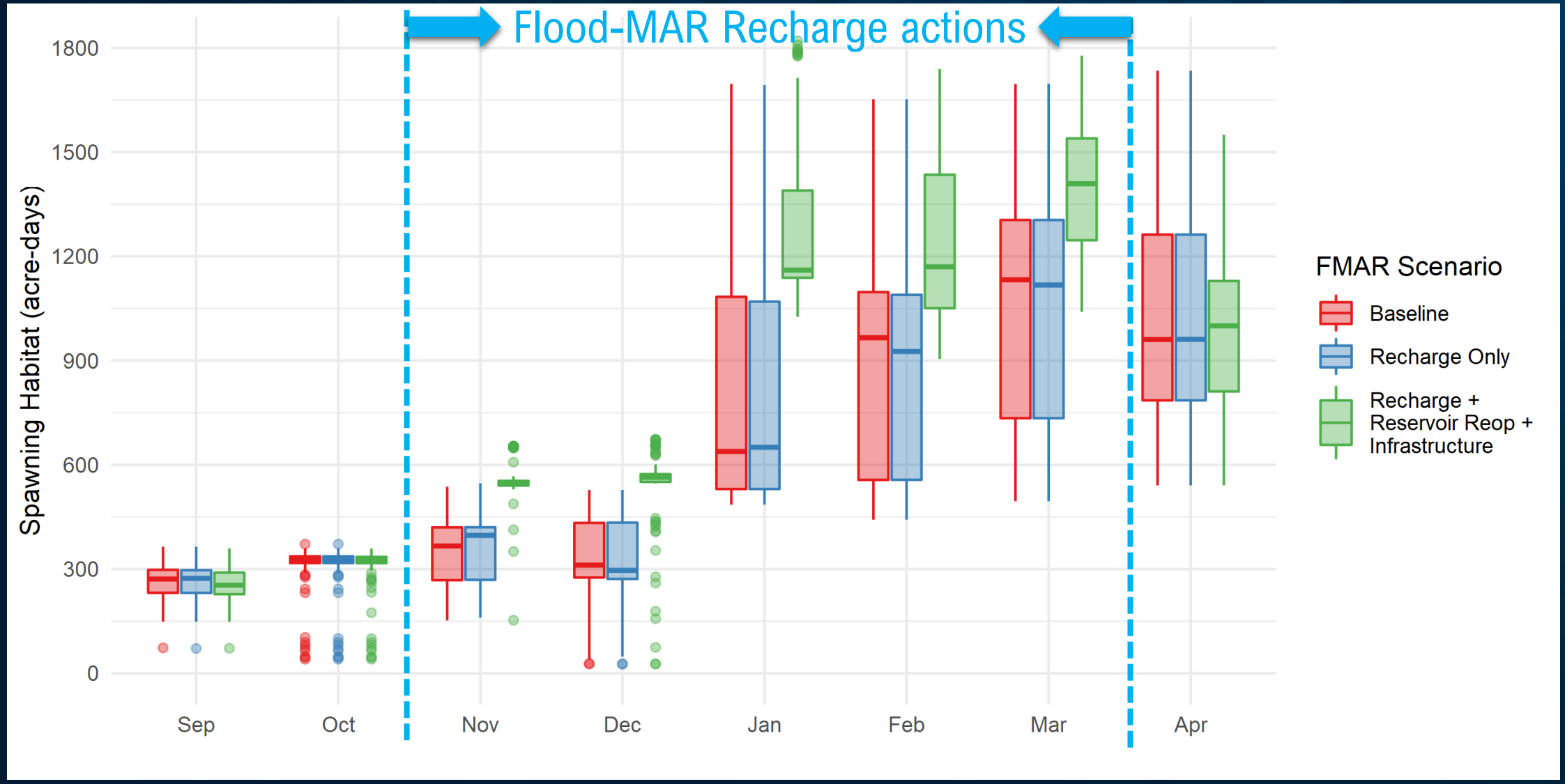

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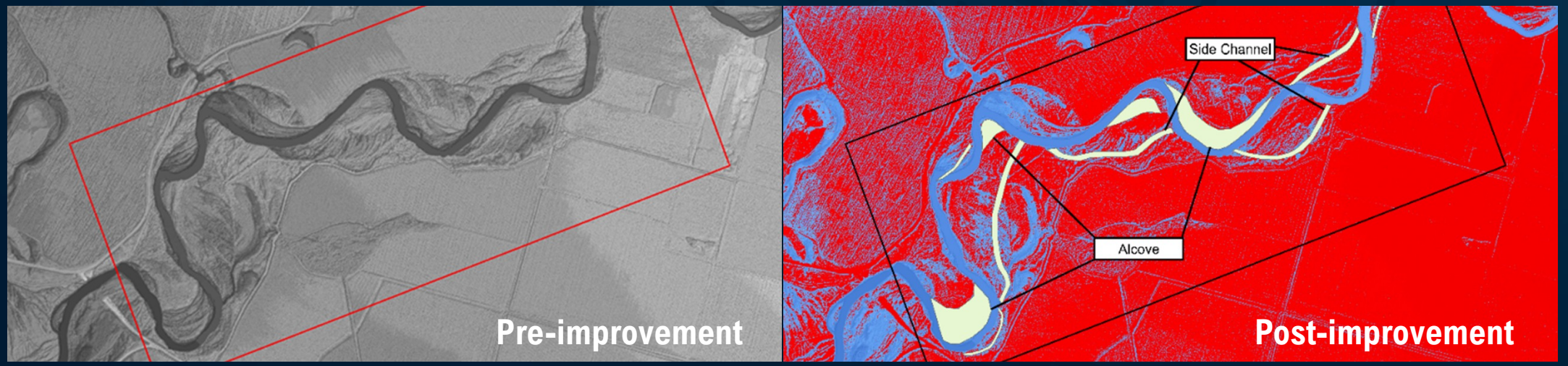
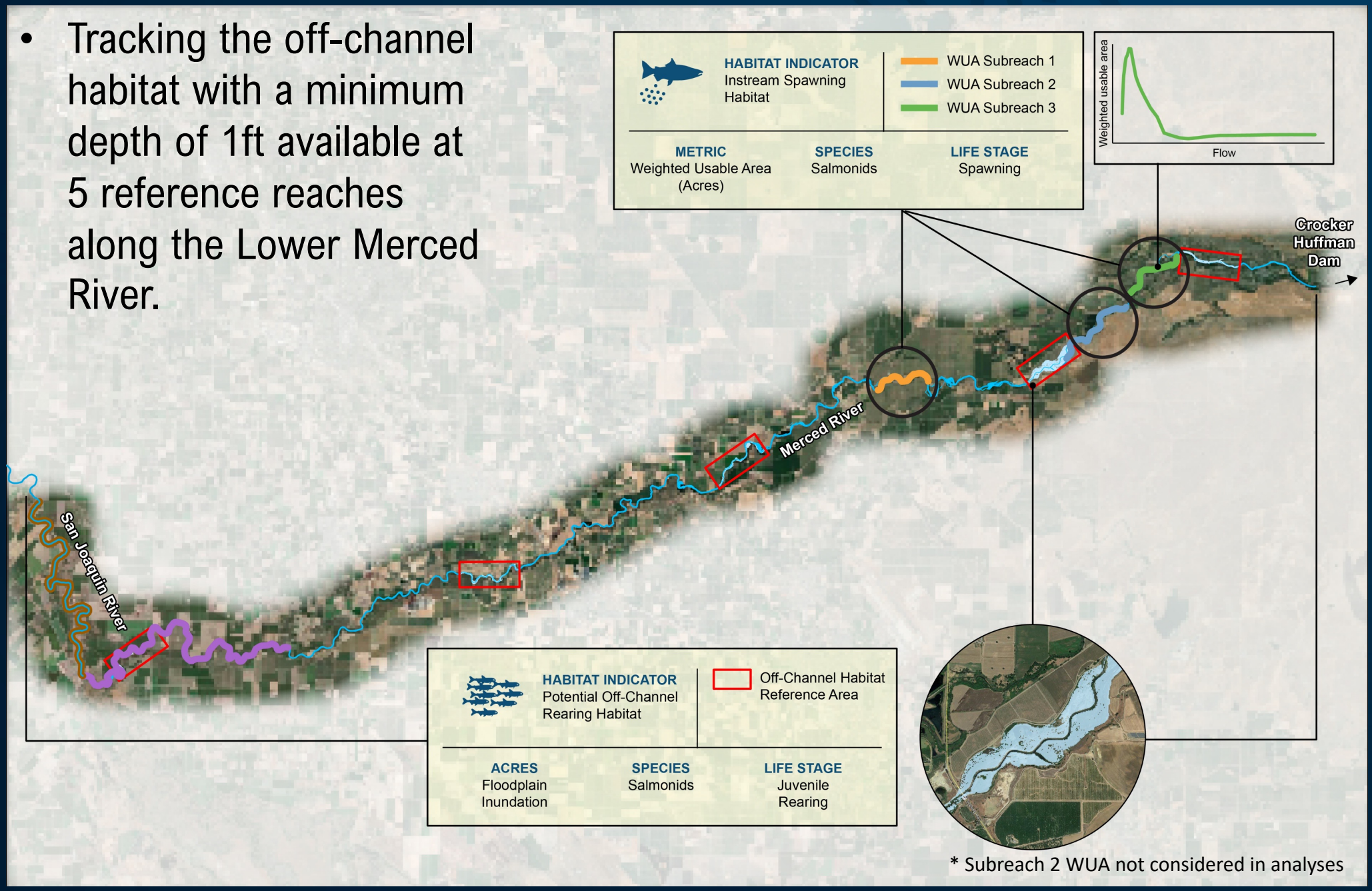
Ecosystem	GDE Habitat	% Months with GW Levels ≤ 30 feet	*Percent*	77	**70**	**79**	**83**
	Merced River Salmonid Habitat	In-stream spawning habitat (Sep – Apr)	*1000 Acre-Days*	530	**509**	509	**657**

Potential Off-channel Habitat

- Very limited in Merced River currently
- Recommended reservoir reoperation plus habitat improvement
  - Support a single off-channel habitat inundation event April
  - By maintaining sustained flow of 1,800 to create habitat with at least 1 foot of depth
  - For a minimum of 2-week period



- Tracking the off-channel habitat with a minimum depth of 1ft available at 5 reference reaches along the Lower Merced River.



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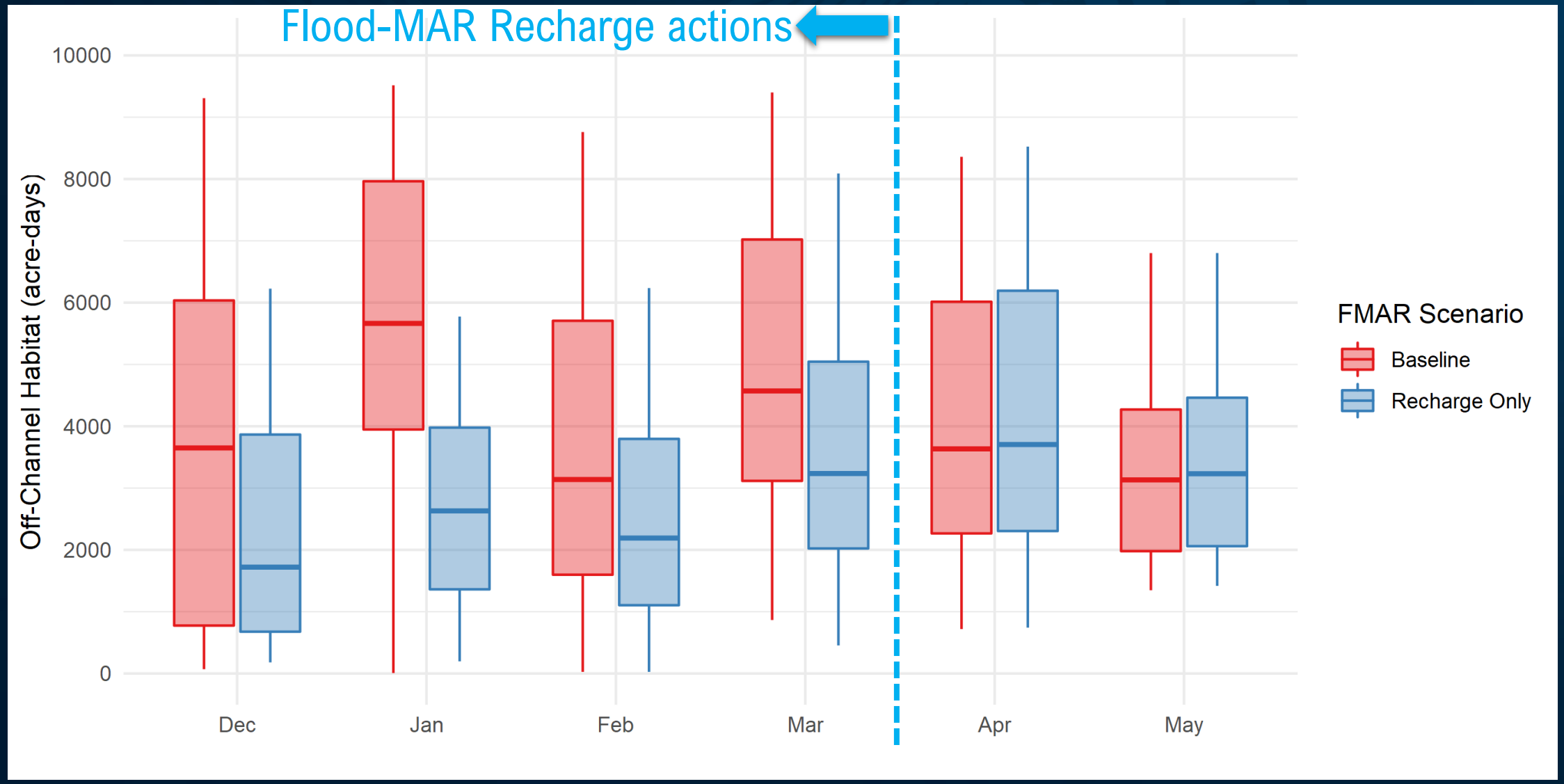

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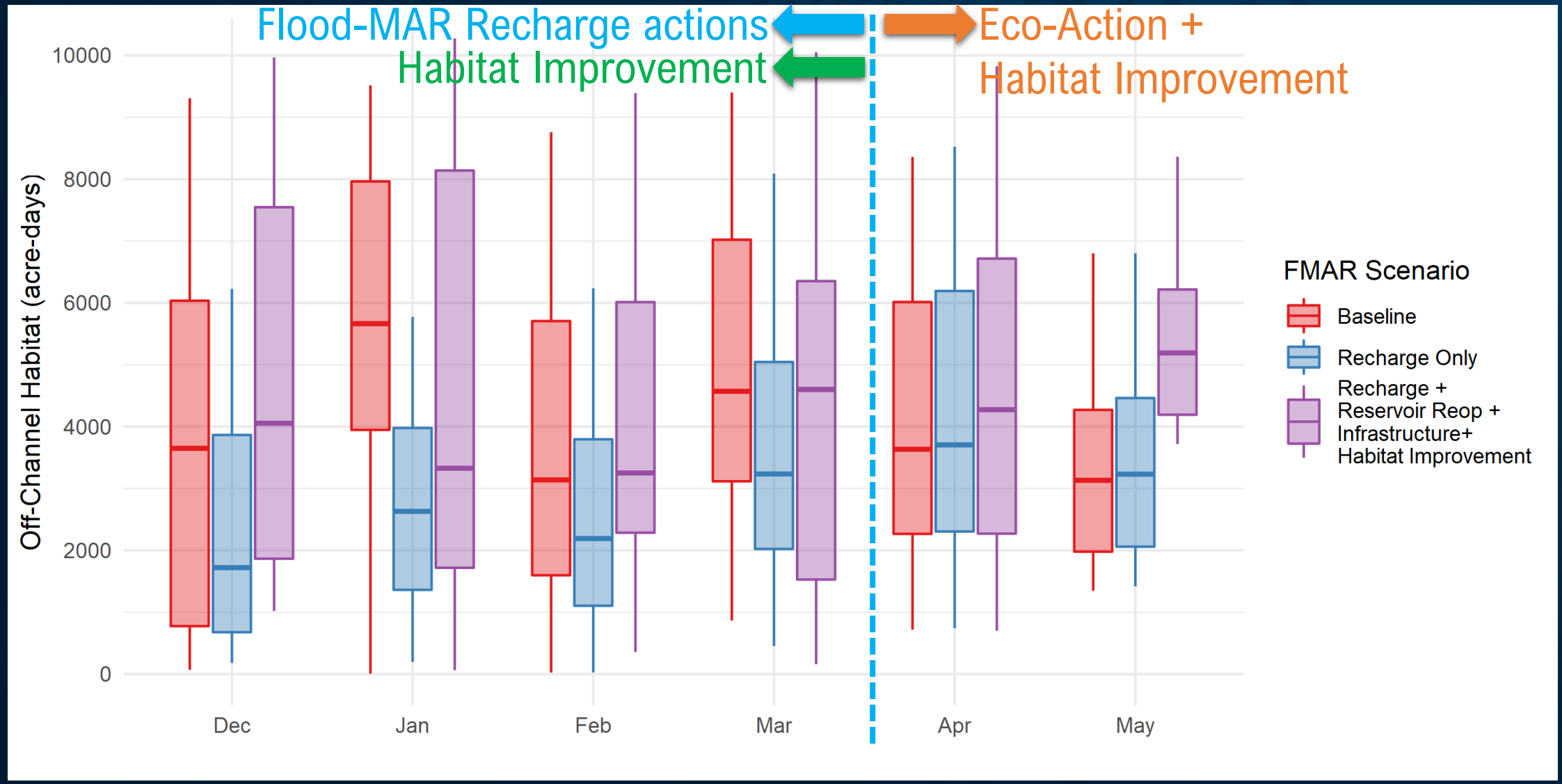

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		Potential off-channel seasonally inundated habitat	[illegible]	[illegible]	[illegible]	[illegible]	427

Without improvement, very limited off-channel habitat in Merced River.
L3 FIRO-MAR scenario includes habitat improvement in addition to providing inundation flows.

Shorebirds

- Recommendations from The Nature Conservancy
  - 2” – 4” inundation for a minimum of 2 weeks
  - Two distinct migratory periods:
    - March 15 – April 30
    - July 15 – October 15
  - Habitat created within 6 miles from a managed wetland preferred

Shorebirds

- 521 acres of habitat created*
- at 2” inundated depth
- during March
  - 2-days of ramp up period
  - 28-days of constant inundation depth
  - 1-day of ramp-down period

Land-Use	SAGBI Soil Type	Within 6 miles of Merced NWR (acres)	Outside 6 miles of Merced NWR (acres)	TOTAL (acres)
Idle	Poor	121	360	**481**
Idle	Very Poor	0	40	**40**
TOTAL (acres)		**121**	**400**	**521**

**Level 2 and 3 FIRO-MAR & Hybrid-MAR scenarios only*

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		Potential* off-channel seasonally inundated habitat [1]	*1000 Acre-Days*	212	**633**	**441**	**427**
			Years	30	**45**	45	**46**
	Shorebird Habitat	Inundated ag fields (521 acres x 28-days x # Events)	*1000 Acre-Days*	--	--	--	**963**

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In summary…

1. Flood-MAR actions are expected to benefit GDEs and shorebirds
2. Aquifer recharge alone, without careful consideration of aquatic species, may have net negative impacts
3. Reservoir reops can minimize impacts and create benefits by:
    - Fine-tuning releases to maximize habitat for key life stages (e.g., spawning)
    - Providing pulse flows in key months to encourage juvenile emigration
4. Off-channel habitat improvement can provide beneficial rearing habitat for salmonids

QUESTIONS?

KARANDEV SINGH (KARANDEV.SINGH@WATER.CA.GOV) | CWEMF ANNUAL MEETING | 4/5/2022

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300 Runs

30 Climate Scenarios x [Baseline + 9 Project Alternatives]

Why the 30 climate scenarios?

9 Models

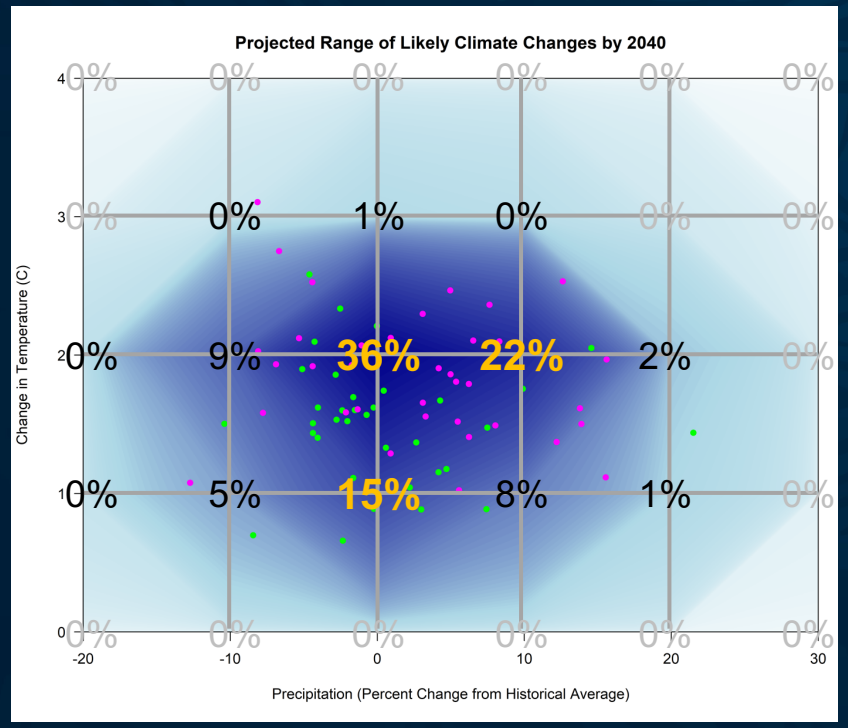
simulating integrated "headwater-to-groundwater" physical processes and operations at a sub-daily to monthly timestep over a 100-year continuous period representing hydrologic conditions between WY 1900 and WY 1999.

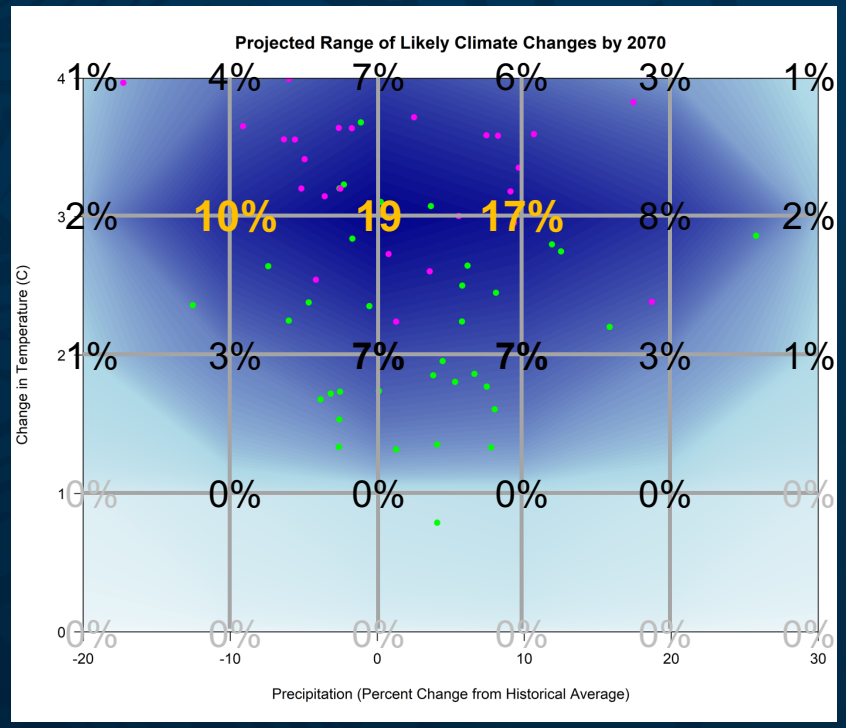
CHALLENGE: How to meaningfully present and understand climate vulnerability and adaptation potential?

Scenario-based vs. risk-based analytics

Decision scaling: what and why?

The dots represent the shift in average annual precipitation and temperature for the ensemble of Fifth Coupled Model Intercomparison Project (CMIP5) general circulation models (GCMs) driven with Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (RCP) scenarios 4.5 and 8.5 in the region contributing flow to the Central Valley Water System for the 30-year period centered at 2040 and 2070 relative to the 1971–2000 period.

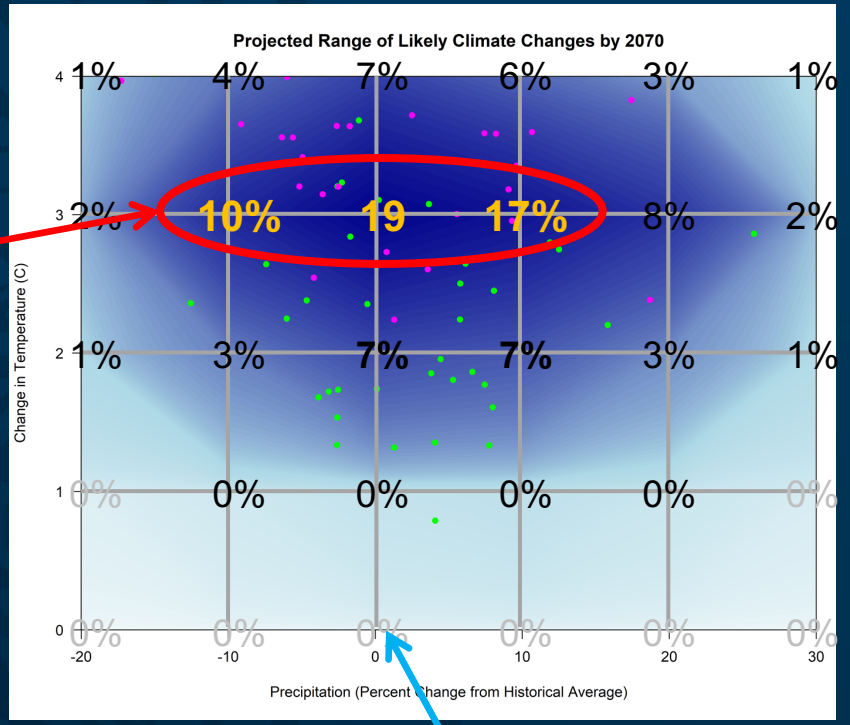




CURRENT CONDITION → 2040 → 2070 → FUTURE CONDITION

Instead of selecting handful "representative" climate scenarios, evaluated across a full spectrum of probable climate futures.

Most probable 2070 climate futures (+3°C and ±10%)



Current Climate (0°C and 0%)

SYSTEM PERFORMANCE

Scenario Comparison

Results – Future Conditions (+3°C, +10%)

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						L1 INTERM.	L3 FIRO-MAR	L3 RP-MAR
Watershed Conditions	Upper Watershed Runoff	Oct – Sep	*TAF/ year*	1,123	1,277	1,277	1,277	1,277
		Nov – Mar	*TAF/ season*	434	688	688	688	688
		Apr – Oct	*TAF/ season*	689	589	589	589	589
	Applied Demand	Agricultural Demand (Oct – Sep)	*TAF/ year*	800	854	854	854	854
	Water Available For Recharge	Available (Nov – Mar)	*TAF/ season*	--	--	90	119	151
		Applied (Nov – Mar)	*TAF/ season*	--	--	79	111	145
Water Supply/ Groundwater (GW)	GW Pumping	Oct – Sep	*TAF/ year*	466	499	499	501	506
	Δ GW Storage	Change in basinwide GW storage	*TAF/ year*	-50	-60	-35	-32	-15
	Δ GW Levels	Aquifer east of Corcoran Clay layer	*Feet/ year*	-0.6	-0.8	-0.2	-0.1	0.3
Water Supply/ Surface Water (SW)	Lake McClure Storage	End of October Storage	*Avg. TAF*	518	474	474	472	435
		# Years allocation ≤ 80%	*Years*	7	7	7	8	9
	SW Deliveries	Oct – Sep	*TAF/ year*	355	372	372	369	367
Flood Risk	Merced River Flood Conditions	100-year max simulated flow	*cfs*	6,004	42,412	40,552	15,660	8,774
		# Years with flows > 7300 cfs	*Years*	0	9	9	1	2
Ecosystem	GDE Habitat	% Months with GW Levels ≤ 30 feet	*Percent*	77	70	79	83	79
	Merced River Salmonid Habitat [1] Dec – May [2] Sep – Apr	In-stream spawning habitat [2]	*1000 Acre-Days*	530	509	509	657	628
		Potential* off-channel seasonally inundated habitat [1]	*1000 Acre-Days*	212	633	441	427	354
			Years	30	45	45	46	37
	Shorebird Habitat	Inundated ag fields (521 acres x 28-days x # Events)	*1000 Acre-Days*	0	0	0	963	0

Results – Future Conditions (+3°C, 0%)

Performance evaluated with respect to Baseline Current Conditions | *Performance evaluated with respect to Baseline DT3DP1.1 Scenario*

Performance Indicator: Decline | No significant change | Improvement

Preliminary Results – Subject to Change

***Without improvement, very limited off-channel habitat in Merced River.**

				VULNERABILITY		ADAPTATION PERFORMANCE		
				CURRENT BASELINE	DT3DP1.0	DT3DP1.0		
						L1 INTERM.	L3 FIRO-MAR	L3 RP-MAR
Watershed Conditions	Upper Watershed Runoff	Oct – Sep	*TAF/ year*	1,123	1,074	1,074	1,074	1,074
		Nov – Mar	*TAF/ season*	434	569	569	569	569
		Apr – Oct	*TAF/ season*	689	505	505	505	505
	Applied Demand	Agricultural Demand (Oct – Sep)	*TAF/ year*	800	864	864	864	864
	Water Available For Recharge	Available (Nov – Mar)	*TAF/ season*	--	--	60	79	103
		Applied (Nov – Mar)	*TAF/ season*	--	--	54	73	100
Water Supply/ Groundwater (GW)	GW Pumping	Oct – Sep	*TAF/ year*	466	520	520	524	528
	Δ GW Storage	Change in basinwide GW storage	*TAF/ year*	-50	-115	-93	-91	-77
	Δ GW Levels	Aquifer east of Corcoran Clay layer	*Feet/ year*	-0.6	-1.6	-1.1	-1.0	-0.8
Water Supply/ Surface Water (SW)	Lake McClure Storage	End of October Storage	*Avg. TAF*	518	417	417	414	374
		# Years allocation ≤ 80%	*Years*	7	14	14	15	18
	SW Deliveries	Oct – Sep	*TAF/ year*	355	359	359	354	350
Flood Risk	Merced River Flood Conditions	100-year max simulated flow	*cfs*	6,004	6,077	6,077	6,047	6,553
		# Years with flows > 7300 cfs	*Years*	0	0	0	0	0
Ecosystem	GDE Habitat	% Months with GW Levels ≤ 30 feet	*Percent*	77	34	39	42	40
	Merced River Salmonid Habitat [1] Dec – May [2] Sep – Apr	In-stream spawning habitat [2]	*1000 Acre-Days*	530	481	481	645	610
		Potential* off-channel seasonally inundated habitat [1]	*1000 Acre-Days*	212	374	245	230	182
			Years	30	33	34	34	28
	Shorebird Habitat	Inundated ag fields (521 acres x 28-days x # Events)	*1000 Acre-Days*	--	--	--	773	--

Results – Future Conditions (+3°C, -10%)

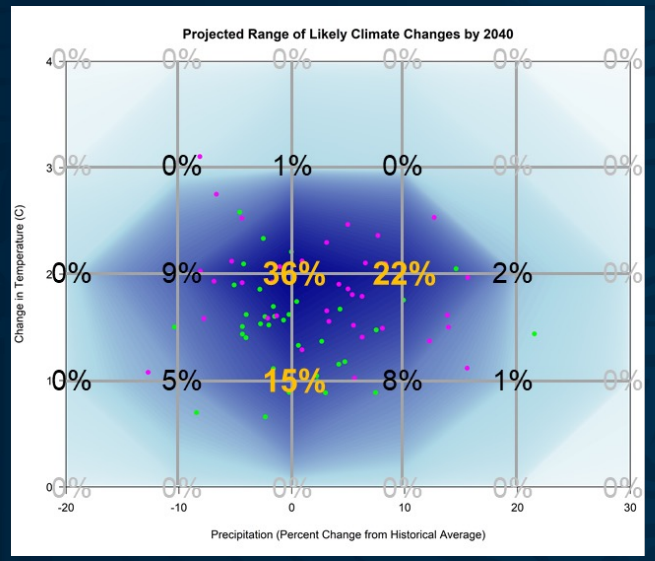
Performance evaluated with respect to Baseline Current Conditions | *Performance evaluated with respect to Baseline DT3DP1.1 Scenario*

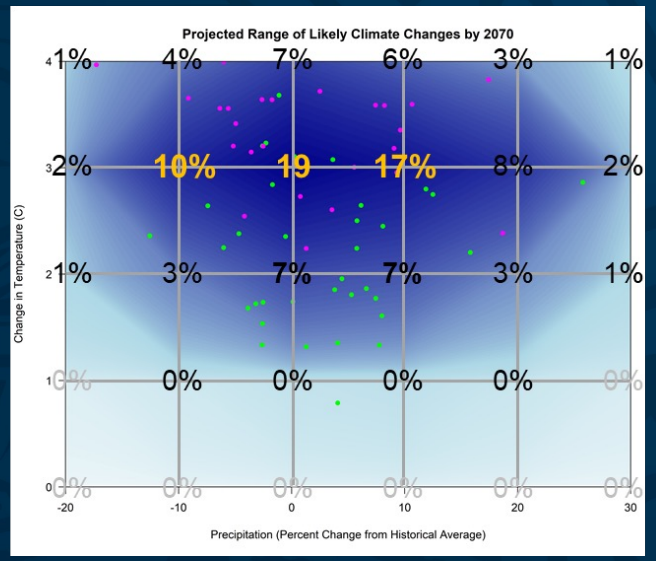
Performance Indicator: Decline | No significant change | Improvement

Preliminary Results – Subject to Change

***Without improvement, very limited off-channel habitat in Merced River.**

				VULNERABILITY		ADAPTATION PERFORMANCE		
				CURRENT BASELINE	DT3DP0.9	DT3DP0.9 L1 INTERM.	DT3DP0.9 L3 FIRO-MAR	DT3DP0.9 L3 RP-MAR
Watershed Conditions	Upper Watershed Runoff	Oct – Sep	*TAF/ year*	1,123	879	879	879	879
		Nov – Mar	*TAF/ season*	434	456	456	456	456
		Apr – Oct	*TAF/ season*	689	423	423	423	423
	Applied Demand	Agricultural Demand (Oct – Sep)	*TAF/ year*	800	875	875	875	875
	Water Available For Recharge	Available (Nov – Mar)	*TAF/ season*	--	--	33	49	65
		Applied (Nov – Mar)	*TAF/ season*	--	--	30	45	63
Water Supply/ Groundwater (GW)	GW Pumping	Oct – Sep	*TAF/ year*	466	547	548	553	558
	Δ GW Storage	Change in basinwide GW storage	*TAF/ year*	-50	-185	-172	-170	-161
	Δ GW Levels	Aquifer east of Corcoran Clay layer	*Feet/ year*	-0.6	-2.5	-2.2	-2.2	-2.0
Water Supply/ Surface Water (SW)	Lake McClure Storage	End of October Storage	*Avg. TAF*	518	359	358	354	316
		# Years allocation ≤ 80%	*Years*	7	22	22	25	28
	SW Deliveries	Oct – Sep	*TAF/ year*	355	338	338	332	328
Flood Risk	Merced River Flood Conditions	100-year max simulated flow	*cfs*	6,004	6,004	6,004	6,021	6,021
		# Years with flows > 7300 cfs	*Years*	0	0	0	0	0
Ecosystem	GDE Habitat	% Months with GW Levels ≤ 30 feet	*Percent*	77	20	21	21	21
	Merced River Salmonid Habitat [1] Dec – May [2] Sep – Apr	In-stream spawning habitat [2]	*1000 Acre-Days*	530	451	452	629	590
		Potential* off-channel seasonally inundated habitat [1]	*1000 Acre-Days*	212	177	118	100	87
			Years	30	24	24	21	17
	Shorebird Habitat	Inundated ag fields (521 acres x 28-days x # Events)	*1000 Acre-Days*	--	--	--	598	--





CURRENT CONDITION

2040

2070

FUTURE CONDITION

SYSTEM PERFORMANCE

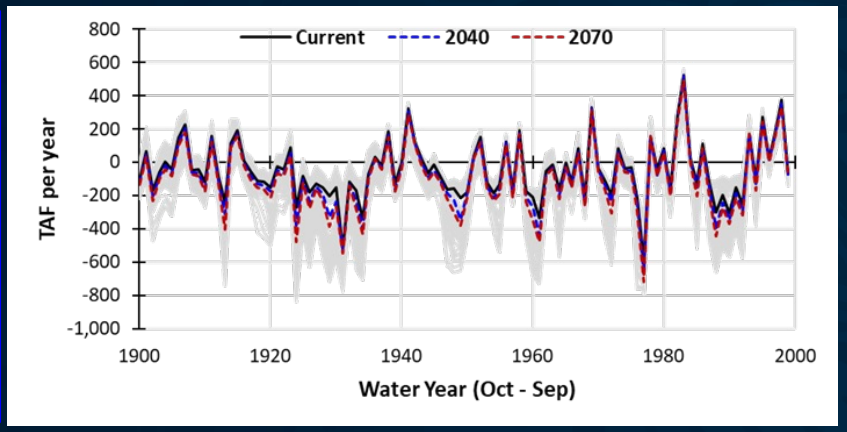
Planning Horizon

AVERAGE = assign equal weight which assumes that all scenarios have same likelihood (probability) of occurrence

WEIGHTED AVERAGE = assign weight based on the likelihood of occurrence

Planning Horizon/ Expected Value

Baseline



Change in Temperature	Change in Precipitation 0.8	0.9	1	1.1	1.2	1.3
0	-184	-109	-50	-13	7	20
1	-211	-133	-70	-26	-2	12
2	-238	-158	-92	-42	-14	4
3	-267	-185	-115	-60	-26	-5
4	-295	-210	-139	-81	-41	-16

Planning Horizon 2040

Change in Temperature	Change in Precipitation 0.8	0.9	1	1.1	1.2	1.3
0	0%	0%	0%	0%	0%	0%
1	0%	5%	15%	8%	1%	0%
2	0%	9%	36%	22%	2%	0%
3	0%	0%	1%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%

Planning Horizon 2070

Change in Temperature	Change in Precipitation 0.8	0.9	1	1.1	1.2	1.3
0	0%	0%	0%	0%	0%	0%
1	0%	0%	0%	0%	0%	0%
2	1%	3%	7%	7%	3%	1%
3	2%	10%	19%	17%	8%	2%
4	1%	4%	7%	6%	3%	1%

	LT
Current	-50
2040	-79
2070	-101

Preliminary Results – Subject to Change

Results – 2040 Planning Horizon

Performance evaluated with respect to Baseline Current Conditions | *Performance evaluated with respect to Baseline DT3DP1.1 Scenario*

Performance Indicator: Decline | No significant change | Improvement

Preliminary Results – Subject to Change

***Without improvement, very limited off-channel habitat in Merced River.**

				VULNERABILITY		ADAPTATION PERFORMANCE		
				CURRENT	PH 2040	PH 2040		
				BASELINE		L1 INTERM.	L3 FIRO-MAR	L3 RP-MAR
Watershed Conditions	Upper Watershed Runoff	Oct – Sep	*TAF/ year*	1,123	1,138	1,138	1,138	1,138
		Nov – Mar	*TAF/ season*	434	528	528	528	528
		Apr – Oct	*TAF/ season*	689	610	610	610	610
	Applied Demand	Agricultural Demand (Oct – Sep)	*TAF/ year*	800	835	835	835	835
	Water Available For Recharge	Available (Nov – Mar)	*TAF/ season*	--	--	59	81	108
		Applied (Nov – Mar)	*TAF/ season*	--	--	54	75	105
Water Supply/ Groundwater (GW)	GW Pumping	Oct – Sep	*TAF/ year*	466	494	494	497	501
	Δ GW Storage	Change in basinwide GW storage	*TAF/ year*	-50	-79	-62	-59	-46
	Δ GW Levels	Aquifer east of Corcoran Clay layer	*Feet/ year*	-0.6	-1.0	-0.6	-0.6	-0.3
Water Supply/ Surface Water (SW)	Lake McClure Storage	End of October Storage	*Avg. TAF*	518	479	478	474	425
		# Years allocation ≤ 80%	*Years*	7	10	10	11	13
	SW Deliveries	Oct – Sep	*TAF/ year*	355	359	359	356	352
Flood Risk	Merced River Flood Conditions	100-year max simulated flow	*cfs*	6,004	15,677	14,919	9,084	8,384
		# Years with flows > 7300 cfs	*Years*	0	3	2	1	1
Ecosystem	GDE Habitat	% Months with GW Levels ≤ 30 feet	*Percent*	77	57	63	66	63
	Merced River Salmonid Habitat [1] Dec – May [2] Sep – Apr	In-stream spawning habitat [2]	*1000 Acre-Days*	530	509	509	657	625
		Potential* off-channel seasonally inundated habitat [1]	*1000 Acre-Days*	212	367	249	264	198
			Years	30	36	35	39	31
	Shorebird Habitat	Inundated ag fields (521 acres x 28-days x # Events)	*1000 Acre-Days*	--	--	--	865	--

Results – 2070 Planning Horizon

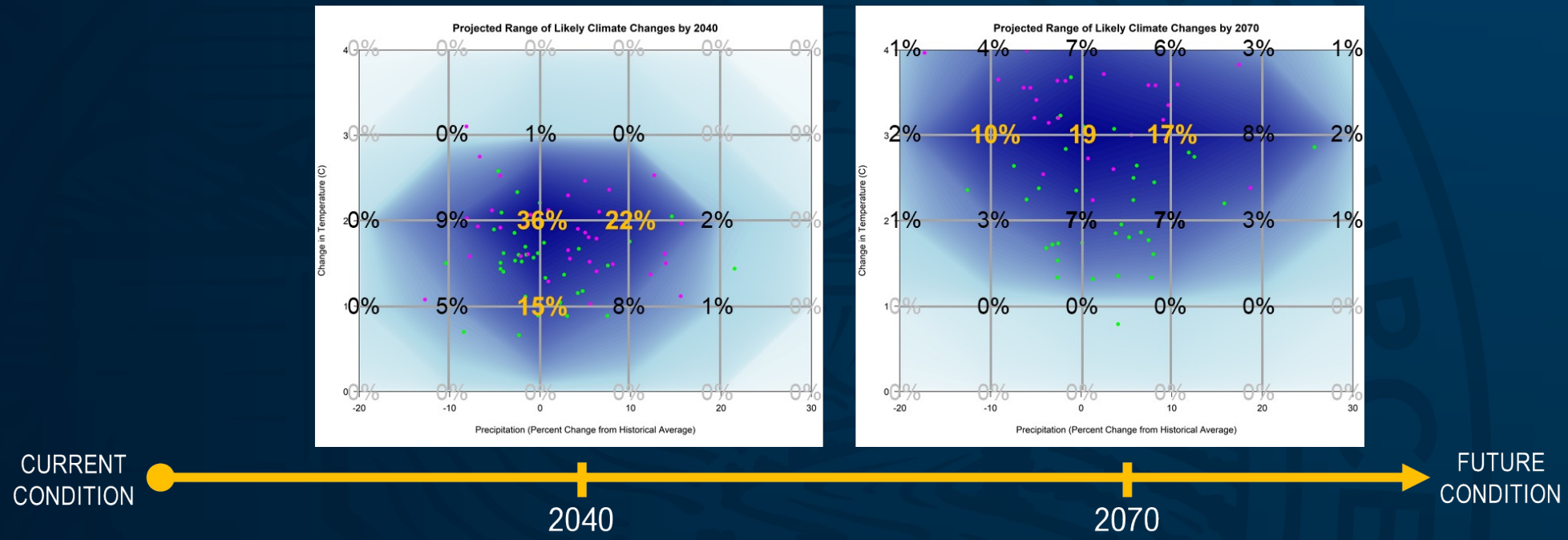
Performance evaluated with respect to Baseline Current Conditions | *Performance evaluated with respect to Baseline DT3DP1.1 Scenario*

Performance Indicator: Decline | No significant change | Improvement

Preliminary Results – Subject to Change

**Without improvement, very limited off-channel habitat in Merced River.*

				VULNERABILITY		ADAPTATION PERFORMANCE		
				CURRENT	PH 2070	PH 2070		
				BASELINE		L1 INTERM.	L3 FIRO-MAR	L3 RP-MAR
Watershed Conditions	Upper Watershed Runoff	Oct – Sep	*TAF/ year*	1,123	1,161	1,161	1,161	1,161
		Nov – Mar	*TAF/ season*	434	619	619	619	619
		Apr – Oct	*TAF/ season*	689	542	542	542	542
	Applied Demand	Agricultural Demand (Oct – Sep)	*TAF/ year*	800	860	860	860	860
	Water Available For Recharge	Available (Nov – Mar)	*TAF/ season*	--	--	73	96	123
		Applied (Nov – Mar)	*TAF/ season*	--	--	65	89	118
Water Supply/ Groundwater (GW)	GW Pumping	Oct – Sep	*TAF/ year*	466	515	516	519	523
	Δ GW Storage	Change in basinwide GW storage	*TAF/ year*	-50	-101	-80	-78	-66
	Δ GW Levels	Aquifer east of Corcoran Clay layer	*Feet/ year*	-0.6	-1.3	-0.9	-0.8	-0.5
Water Supply/ Surface Water (SW)	Lake McClure Storage	End of October Storage	*Avg. TAF*	518	436	436	433	395
		# Years allocation ≤ 80%	*Years*	7	12	12	14	16
	SW Deliveries	Oct – Sep	*TAF/ year*	355	359	359	356	352
Flood Risk	Merced River Flood Conditions	100-year max simulated flow	*cfs*	6,004	29,327	28,222	18,312	14,765
		# Years with flows > 7300 cfs	*Years*	0	5	5	2	2
Ecosystem	GDE Habitat	% Months with GW Levels ≤ 30 feet	*Percent*	77	50	55	58	56
	Merced River Salmonid Habitat [1] Dec – May [2] Sep – Apr	In-stream spawning habitat [2]	*1000 Acre-Days*	530	492	492	648	616
		Potential* off-channel seasonally inundated habitat [1]	*1000 Acre-Days*	212	501	349	339	287
			Years	30	38	38	39	32
	Shorebird Habitat	Inundated ag fields (521 acres x 28-days x # Events)	*1000 Acre-Days*	--	--	--	840	--



SYSTEM PERFORMANCE

Risk-based Results

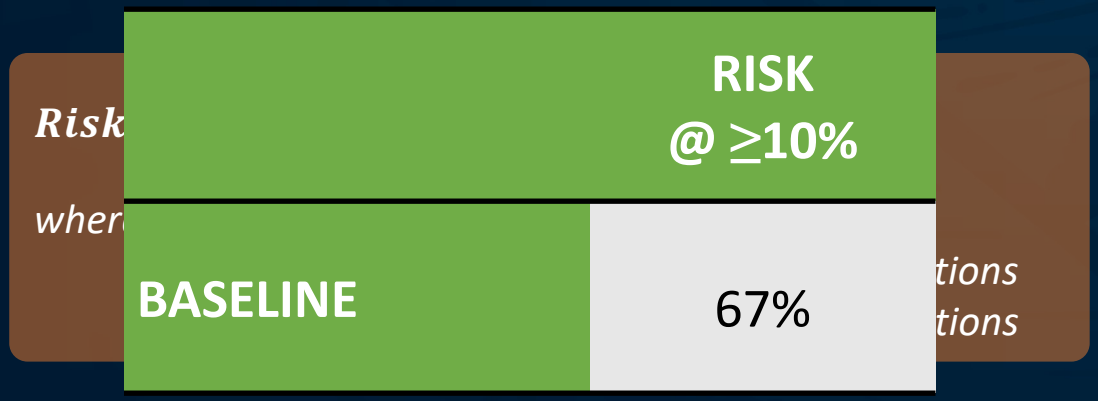
How to evaluate risk-based performance?

RISK – probability that future performance across all probable climate scenarios will **deteriorate** *by more than a specific threshold (e.g. 10%)* compared to the baseline current conditions.

RISK – What is the probability that long-term change in GW storage rate is will exceed beyond 55 TAF (50 TAF + 10%) by 2040?

BASE		Change in Precipitation					
		0.8	0.9	1	1.1	1.2	1.3
Change in Temperature	0	-184	-109	-50	-13	7	20
	1	-211	-133	-70	-26	-2	12
	2	-238	-158	-92	-42	-14	4
	3	-267	-185	-115	-60	-26	-5
	4	-295	-210	-139	-81	-41	-16

Trend relative to baseline current conditions	less than	Change in Precipitation					
		0.8	0.9	1	1.1	1.2	1.3
Change in Temperature	0	1	1	0	0	0	0
	1	1	1	1	0	0	0
	2	1	1	1	0	0	0
	3	1	1	1	1	0	0
	4	1	1	1	1	0	0



Planning Horizon 2040	EV	-79.02	Change in Precipitation					
	Risk	67%	0.8	0.9	1	1.1	1.2	1.3
Change in Temperature	0		0%	0%	0%	0%	0%	0%
	1		0%	5%	15%	8%	1%	0%
	2		0%	9%	36%	22%	2%	0%
	3		0%	0%	1%	0%	0%	0%
	4		0%	0%	0%	0%	0%	0%

There is 67% probability that long-term change GW storage rate will exceed by *more than 10%* beyond the baseline current conditions by 2040.

Preliminary Results – Subject to Change

How is vulnerability reduced with Flood-MAR?

BASELINE "DO NOTHING"

BASE — Change in Precipitation

Change in Temperature	0.8	0.9	1	1.1	1.2	1.3
0	-184	-109	-50	13	7	20
1	-211	-133	-70			
2	-238	-158	-92			
3	-267	-185	-115			
4	-295	-210	-139			

LEVEL 1 INTERMEDIATE

ALT — Change in Precipitation

Change in Temperature	0.8	0.9	1
0	-178	-100	-36
1	-204	-123	-54
2	-232	-147	-73
3	-258	-172	-93
4	-288	-194	-116

LEVEL 3 FIRO-MAR

ALT — Change in Precipitation

Change in Temperature	0.8	0.9	1	1.1	1.2	1.3
0	-181	-98	-33			
1	-206	-121	-51			
2	-235	-146	-71			
3	-260	-170	-91	-32	0	19
4	-291	-193	-114	-50	-10	11

Horizon — EV -79, Risk 67%

Change in Precipitation

Change in Temperature	0.8	0.9	1	1.1	1.2	1.3
0	0%	0%	0%	0%	0%	0%
1	5%	15%	8%	1%	0%	
2	9%	36%	22%	2%	0%	
3	0%	1%	0%	0%	0%	
4	0%	0%	0%	0%	0%	

Change in Precipitation

Change in Temperature	0.9	1	1.1	1.2	1.3
0	0%	0%	0%	0%	0%
1	5%	15%	8%	1%	0%
2	9%	36%	22%	2%	0%
3	0%	1%	0%	0%	0%
4	0%	0%	0%	0%	0%

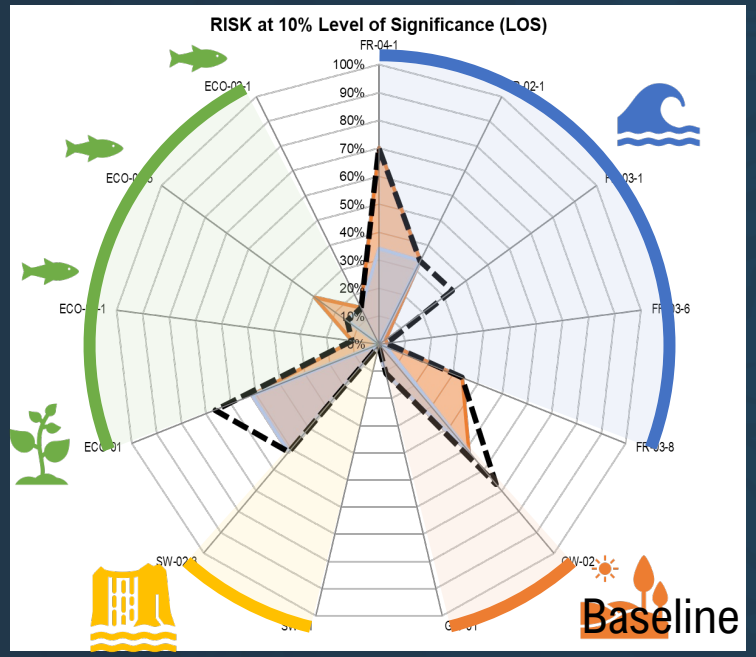
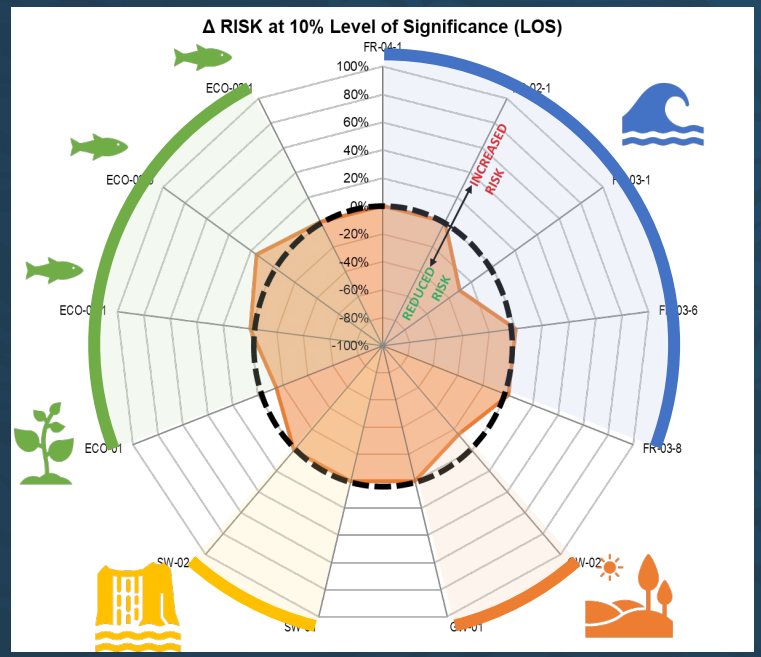
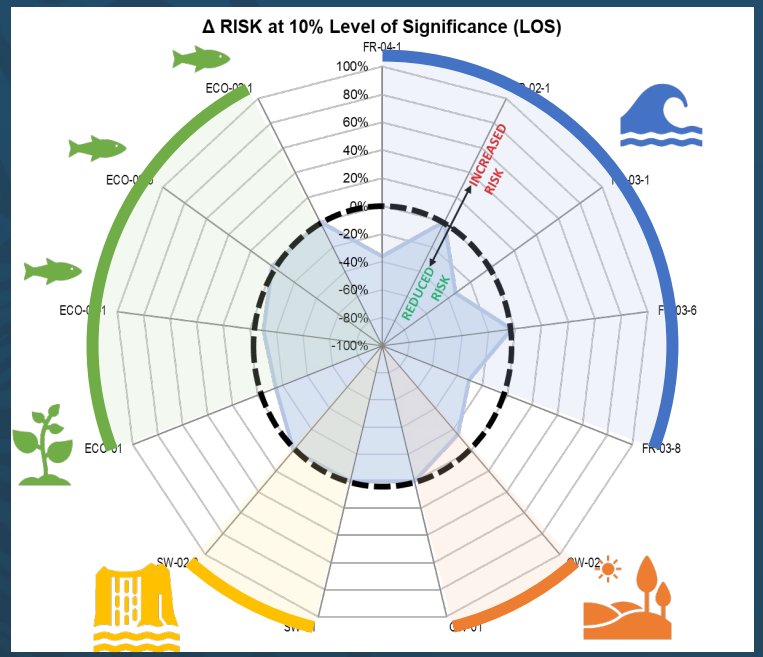
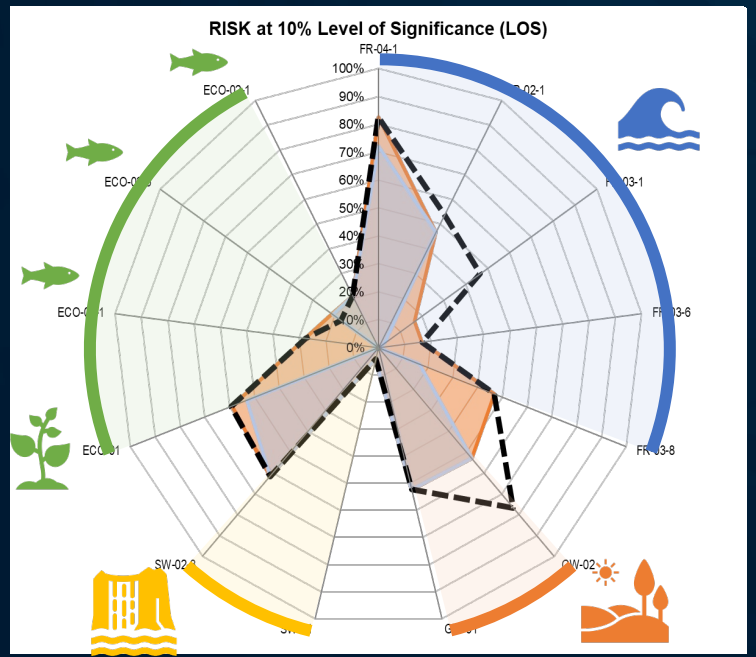
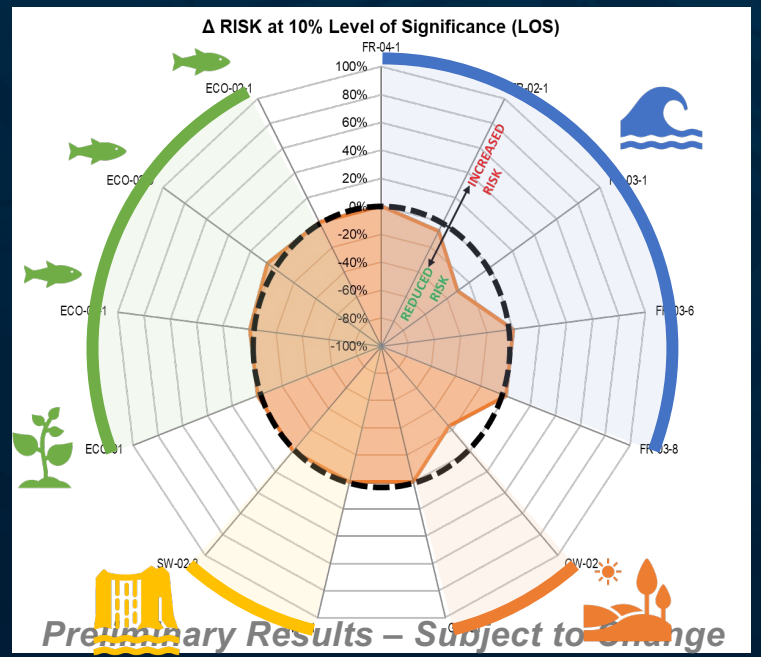
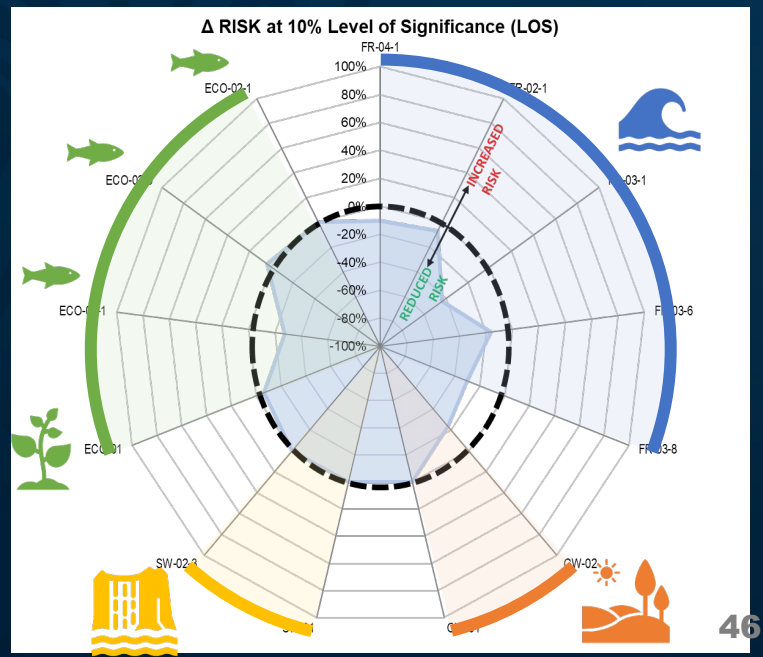
Change in Precipitation

Change in Temperature	0.9	1	1.1	1.2	1.3
0	0%	0%	0%	0%	0%
1	5%	15%	8%	1%	0%
2	9%	36%	22%	2%	0%
3	0%	1%	0%	0%	0%
4	0%	0%	0%	0%	0%

	RISK @ ≥10%
BASELINE	67%
RECHARGE ONLY (Level 1 Intermediate)	51% (-16%)
RECHARGE + RES REOP + INFRASTRUCTURE (Level 3 FIRO-MAR)	51% (-16%)

Results → Metrics → Sector Performance

Flood Risk	Lake McClure Flood Pool	Max Encroachment at Lake McClure (11/1 - 3/15)
	Merced River	Merced River 100-year maximum simulated flow (11/1 - 6/30)
	Local Creeks	Bear Creek 100-year maximum simulated outflow
		Mariposa Creek 100-year maximum simulated outflow
		Owens Creek 100-year maximum simulated outflow
Water Supply/ Groundwater (GW)	GW Storage	Basinwide average annual change in groundwater storage
	GW Pumping	Average annual total groundwater pumping to meet agricultural uses in the Merced watershed
Water Supply/ Surface Water (SW)	SW Deliveries	Average annual total surface water deliveries to agricultural users in the Merced watershed
	Lake McClure Storage	Average annual Lake McClure storage at the end of the irrigation season (Oct 31st)
Ecosystem	GDEs	Proportion of months with depth to groundwater less than 30 feet
	Instream Habitat	Merced River in-stream salmonid spawning habitat
	Potential Off-Channel Habitat	Potential Merced River off-channel juvenile rearing habitat during qualified events (Dec - May)
		Potential Merced River off-channel juvenile rearing habitat during qualified events (Dec - May)

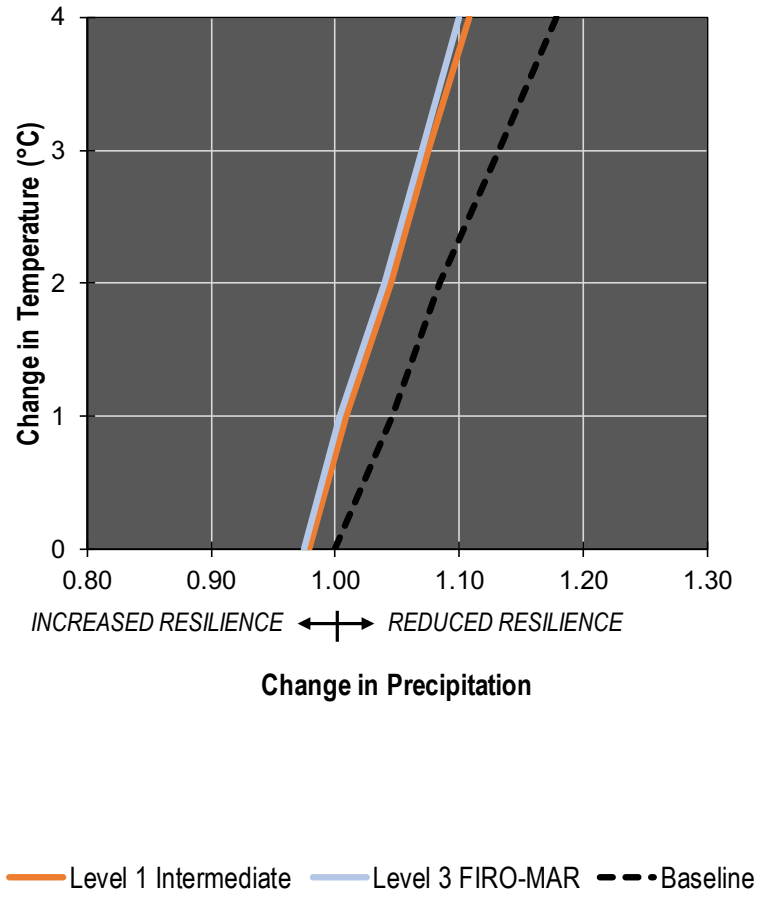
	RISK @ 10% LOS	Δ RISK – Level 1 Intermediate	Δ RISK – Level 3 FIRO-MAR
2040	 Baseline		
2070			

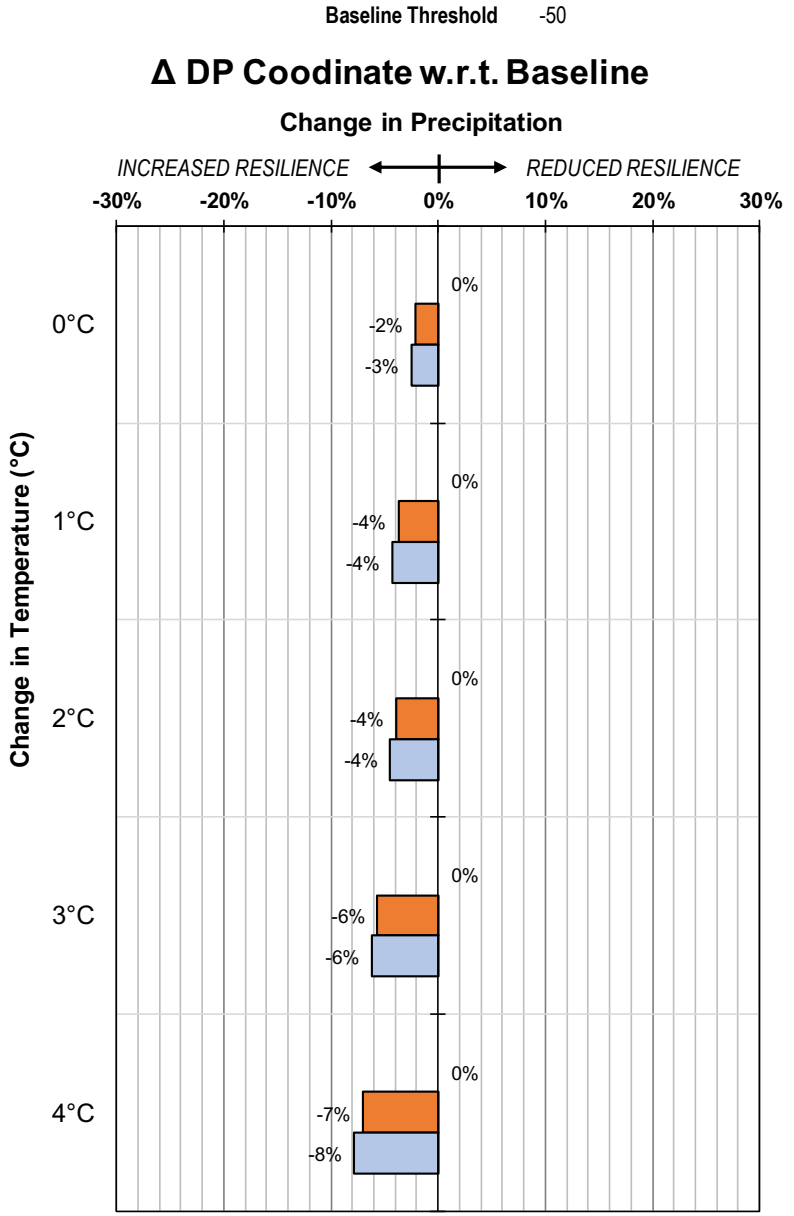
How to evaluate risk-based performance?

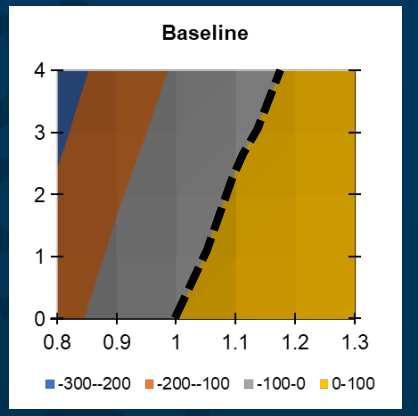
RISK – probability that future performance across all probable climate scenarios will **deteriorate** *by more than a specific level of significance (e.g. LOS = 10%)* compared to the baseline current conditions.

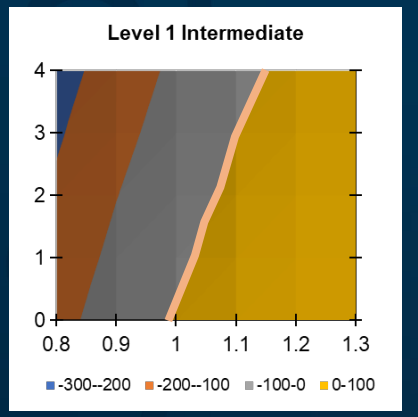
RESILIENCE – added buffer against change in precipitation to sustain the same level of future performance as the baseline current conditions for a given change in temperature threshold.

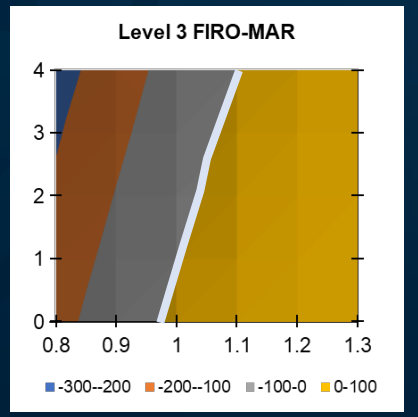
CLIMATIC RESILIENCE: *Added buffer against change in precipitation to sustain the baseline current conditions level of performance at 0, 1, 2, 3, and 4 °C change in temperature.*

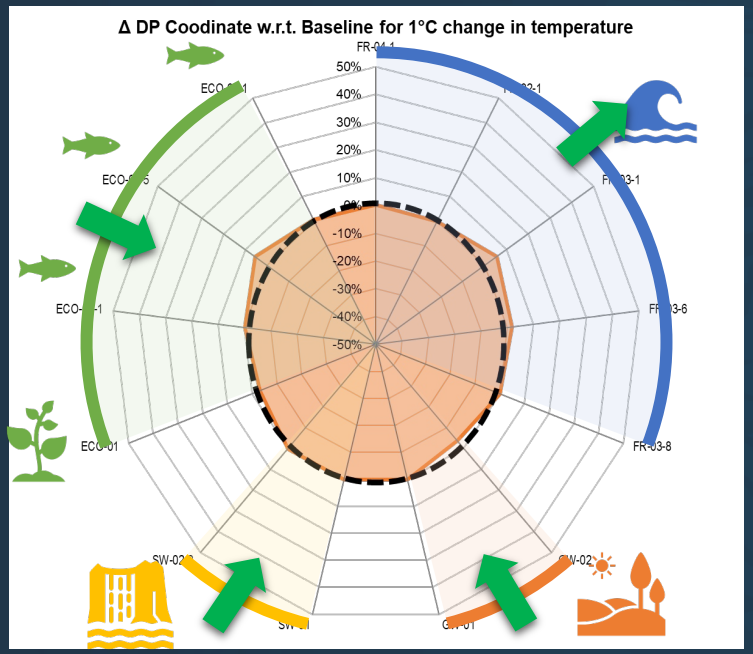
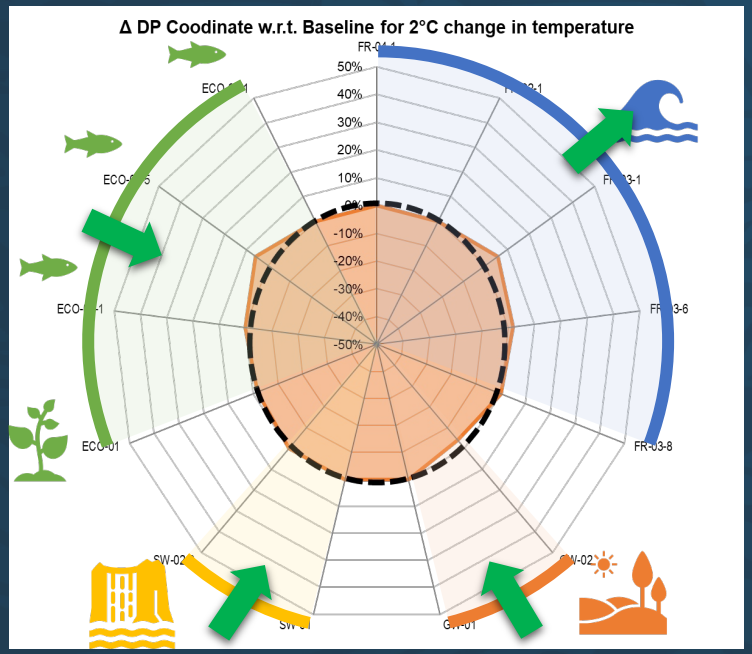
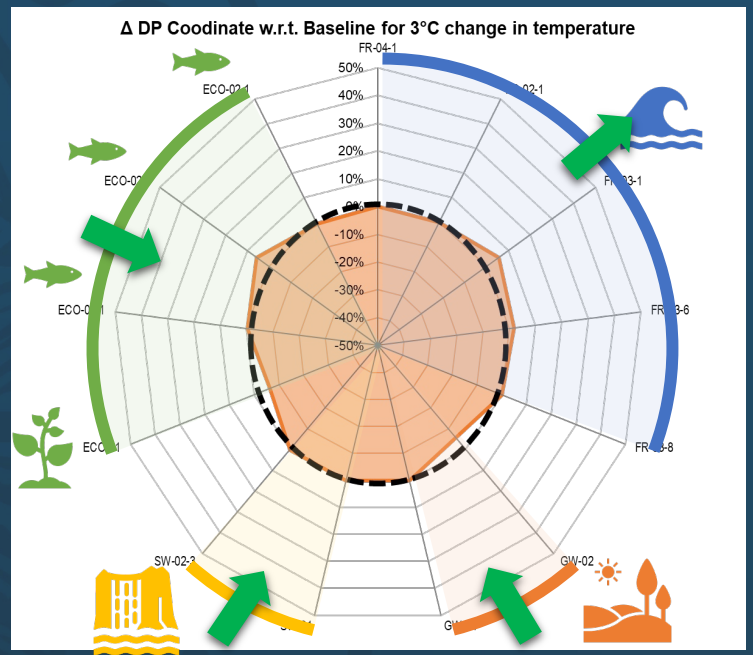
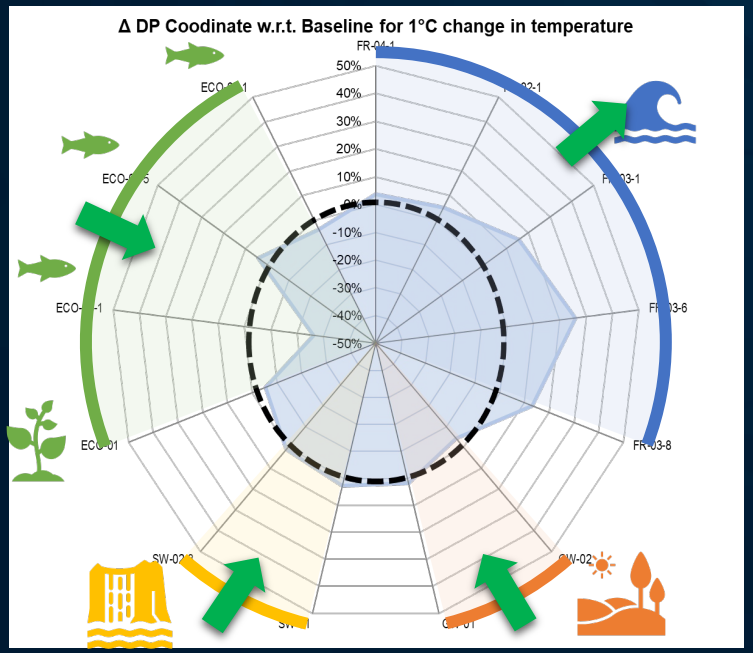
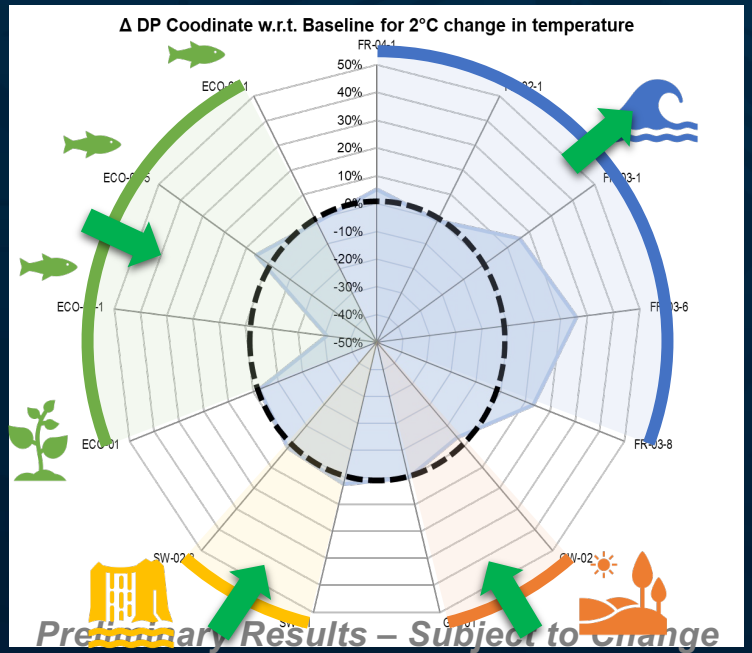
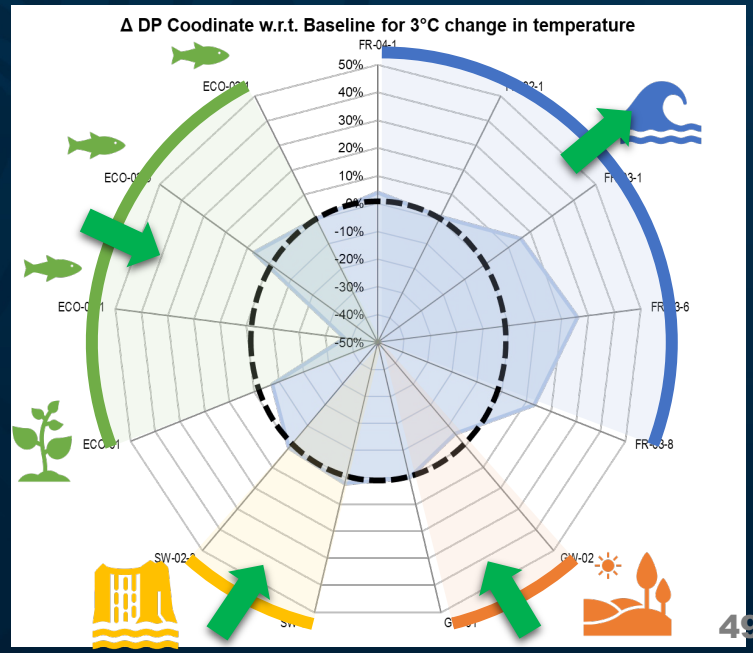




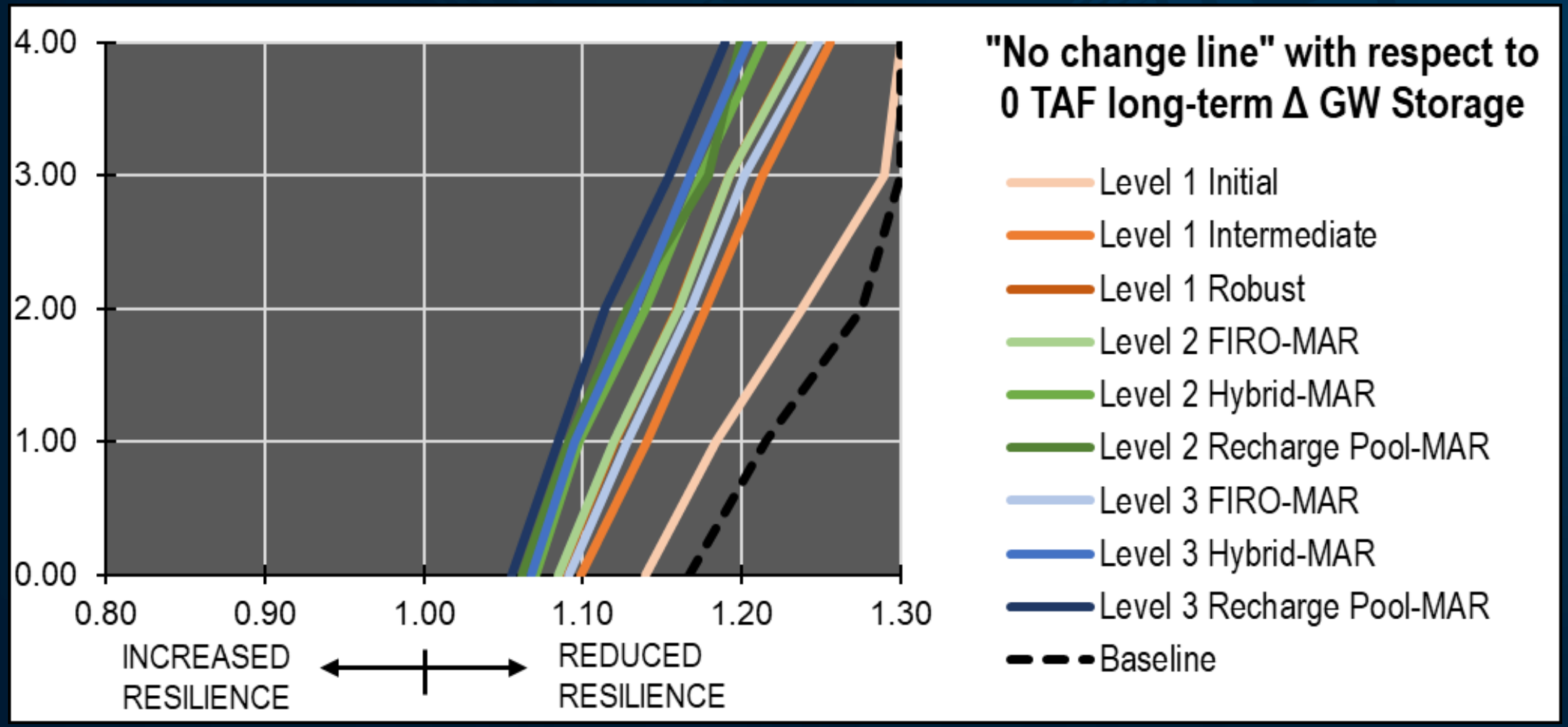






	Resilience @ +1°C	Resilience @ +2°C	Resilience @ +3°C
L1 Intermediate			
L3 FIRO-MAR			

Can Flood-MAR actions alone help reach GW sustainability in the Merced River watershed?



What's next: San Joaquin River Basin Watershed Studies

QUESTIONS?

KARANDEV SINGH (KARANDEV.SINGH@WATER.CA.GOV)