California

DRIP Collaborative

Drought Indicators & Metrics Workshop #1

Drought Resilience Interagency & Partners (DRIP) Collaborative

Wednesday, April 1, 2026
9:00AM – 12:30PM PT
Remote Participation (via Zoom)

Meeting Information

1. This meeting is being recorded for note taking purposes only.
2. This is a working meeting:
   - Your participation is important for our successful collaboration
   - This meeting does not require following BKA rules, but we are adhering to best practices
3. All participants are encouraged to keep their cameras on during the meeting to promote collaboration and discussion.
4. Please practice electronics courtesy and mute when not speaking.

Setting Commitment for Our Joint Work

Opening Comments from Paul Gosselin
Chair of the DRIP Collaborative



→ Why is it important for you to be part of this effort?
→ What is one thing YOU want to discuss today?

April 1 Meeting
Purpose and Agenda

Meeting Objectives:

✓ Co-create an aligned vision for advancing drought indicators and metrics, based on a shared understanding of the current situation, perceived gaps, and an opportunities assessment.

Meeting Topics:

- Review the history of drought indicators and data collection to ensure a collective vision and path forward can be identified
- Hear from drought indicator experts on what already exists in California
- Discuss the possible dimensions and considerations for future drought indicators and how that might drive drought resilience
- Brainstorm a proposed approach for 2026 DRIP activities, including the DI&M white paper

DROUGHT INDICATORS & METRICS DEVELOPMENT PROCESS

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Drought Indicators & Metrics

Problem Statement: As California faces a hotter, drier future, the absence of clearly defined, actionable drought metrics and indicators poses a significant challenge to prioritize drought actions effectively and understand their full impacts. To ensure adaptive and localized strategies through all phases of the water lifecycle, it is crucial to bridge data gaps, ensure data accessibility and interoperability, and support modeling for climate-ready decision making across the state.

2024 DRIP Collaborative Recommendation: Develop a practical drought early warning system to improve information to inform local and state drought management actions and increase overall drought resilience.

This analysis should include:

- **Implementation Considerations**: Need to develop a partnership between state agencies and other interested parties, possibly via steering workgroup and advisory committee. Conduct research activities and set-up hosting/maintenance
- **Equity Considerations**: Address limited resources and data to small communities, domestic well owners, tribal nations, and those most vulnerable to droughts
- **Alignment with Other Initiatives**: Ensure complementarity and value add with other existing efforts, including SB 552 (Water Shortage Vulnerability Tool), SAFER, NIDIS, US Drought Monitor and CWDC (Consortium) efforts

A few words from Alvar (who was the recommendation lead)...
Does this 2024 problem statement and recommendation resonate with you?



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DRIP White Paper Development Process 2026

PREPLANNING	• Identify individuals, organizations, and information resources to support topic development. • Develop a draft vision and white paper outline to guide workshops discussions.
I. VISION FOR THE FUTURE	• Define the desired end state and the key questions to be addressed in the white paper. Framing the Vision - Key Questions to Explore - White Paper Scope and Outline
II. UNDERSTANDING WHERE WE'RE AT	Establish a shared understanding of the current situation, experience, and capacity. Current Conditions - Experience and Capacity
III. GAP ANALYSIS	Identify discrepancies between the current situation and the desired future vision. Comparing Vision and Reality - Underlying Causes of Identified Gaps - Prioritizing Gaps
IV. LOOKING AHEAD	Identify practical pathways to move from current conditions toward the desired vision. Opportunities for Progress - Barriers and Challenges - Proposed Next Steps
V. PUTTING IT ALL TOGETHER	Draft the white paper to document discussions, findings, and suggested next steps.

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PROCESS GUIDING PRINCIPLES

Aligning on current conditions: Taking time to work together to understand where we're at is a crucial step to making a meaningful progress. This means a commitment to

- ✓ Examining the knowledge, expertise, experiences, and perspectives that each participant brings.
- ✓ Intentionally leveraging these diverse viewpoints to refine our collective understanding.
- ✓ Developing a shared understanding before moving forward in the problem-solving process.
- ✓ Fully engaging with the urgency of the problem while ensuring solutions are informed, durable, and broadly supported.

Framing the Vision for DI&M

Proposed vision statement:

All California **audiences** (farmers, people, local water agencies, State, NGOs, researchers) have access to the **current, historical, and upcoming risks and impacts** of drought.

This includes knowledge at a **sector-specific level** via a Drought Early Warning System (**DEWS**), that can help inform what **actions** are required to most effectively achieve drought resilience.

Concepts to consider and define:



1. Audiences
2. Current, historical and upcoming
3. Risks and impacts
4. Sector-specific level DEWS
5. Actions required

→ What else should be called out in the vision statement?

DI&M WHITE PAPER: KEY QUESTIONS TO ANSWER

1. **Vision**. What is the appropriate DI&M vision for California?

2. **Current Conditions (and Audience)**. What is the current landscape of drought tools and portals? Who are the various intended end users and what are their needs?

3. **Inventory**. What are the existing indicators? Can we create a master inventory list of indicators, identify key gaps, and plan out the path forward to ensure sufficient (spatial / temporal) coverage?

4. **Datasets**. What datasets are needed to achieve those indicators? Which ones exist already? What additional data needs to be gathered?

5. **Roadmap**. What defines success in 1 year (immediate)? 3 years (short-term)? Next 5 years (medium-term)?

6. **Funding/Resources**. What type of investment is needed to achieve the roadmap? What types of resources and expertise is needed?

7. **Organizations and Hosting**. What organizations needs to be involved? Who should lead the effort? Who will play what role in hosting and being authoritative sources for indicators? Will there always be many tools/efforts?

DEMYSTIFY DROUGHT INDICATORS AND METRICS
CA SPECIFIC CONTEXT

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KEY AUDIENCES: DROUGHT INDICATORS & METRICS



Agriculture/Farmers



Water Agencies

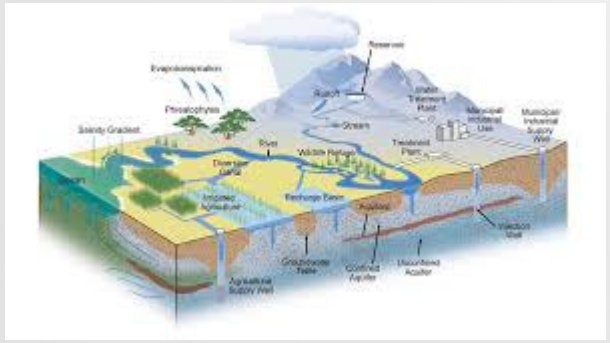


Cities



Vulnerable Communities

State Agencies



Academics/Researchers



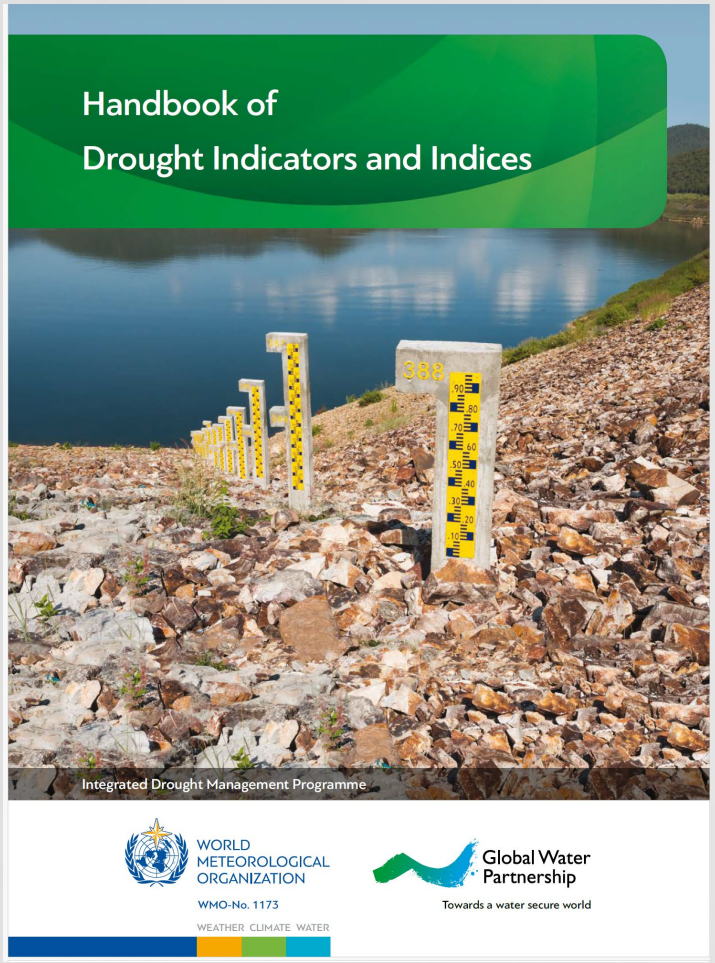
Counties



NGOs/Environment

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DROUGHT EARLY WARNING SYSTEM = ?



2016

Drought early warning systems

Drought early warning systems typically aim to track, assess and deliver relevant information concerning climatic, hydrologic and water supply conditions and trends. Ideally, they have both a monitoring (including impacts) component and a forecasting component. The objective is to provide timely information in advance of, or during, the early onset of drought to prompt action (via threshold triggers) within a drought risk management plan as a means of reducing potential impacts. A diligent, integrated, approach is vital for monitoring such a slow-onset hazard.

hazard, thresholds, action, impacts…

4. SELECTING INDICATORS AND INDICES

Just as there is no 'one-size-fits-all' definition of drought, there is no single index or indicator that can account for and be applied to all types of droughts, climate regimes and sectors affected by droughts. This handbook is not intended to be prescriptive by telling readers which indices and indicators are best to use and when; in fact, many factors feed in to determining which indicator, index or trigger (or combination thereof) is the best to use for a particular need or application.

The simplest indicator/index to use is typically one that is already being produced operationally and freely available, but this does not necessarily mean that it is the best or most applicable. Ultimately, the choice has to be determined by users at the regional, national or local levels. The

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KEY DROUGHT QUESTIONS (INDICATOR RELATED)

1. Are we in a drought? How severe? What type? What sector? Where? When?	→ **Hazard**	**Risk**
2. Am I (or my assets) at risk?	→ **Exposure**	
3. Level of susceptibility, given the broader situation (physical, institutional, economic)?	→ **Vulnerability**	
4. At what point will action be taken? By whom?	→ **Thresholds**	
5. What are the possible actions/response?	→ **Actions**	
6. How effective/efficient was the response?	→ **Effectiveness**	
7. What was (or will be) the impact (hydrologic, economic, societal, environmental)?	→ **Impacts**	
8. What is the resulting drought resilience?	→ **Resilience**	

DI&M: SAMPLE INDICATORS (FOUR CATEGORIES)

Risk

Hazard Indicators
- US Drought Monitor, including DSCI
- Palmer Drought Severity Index (PDSI)
- Standardized Precipitation Index (SPI)
- Normalized Difference Vegetation Index (NDVI)
- Standardized Soil Moisture Index (SSI)

+many, many others…

Thresholds

SWP allocations
- Snow water equivalent (SWE) and reservoir levels
- Availability modeling that inform SW curtailments

County, NGO, Individuals
- GW levels and dry well reporting

Delta
- Saltwater intrusion

Water Agencies
- Water shortage contingency stages
- GSP minimum thresholds

Actions

State Agency
- # of Executive Orders and drought proclamations
- $B in emergency drought response
- $/well to restore access

Surface water
- # of curtailments
- % water deliveries (SWP, CWP, etc.)

Water systems
- % water conservation
- # of PWS consolidation orders

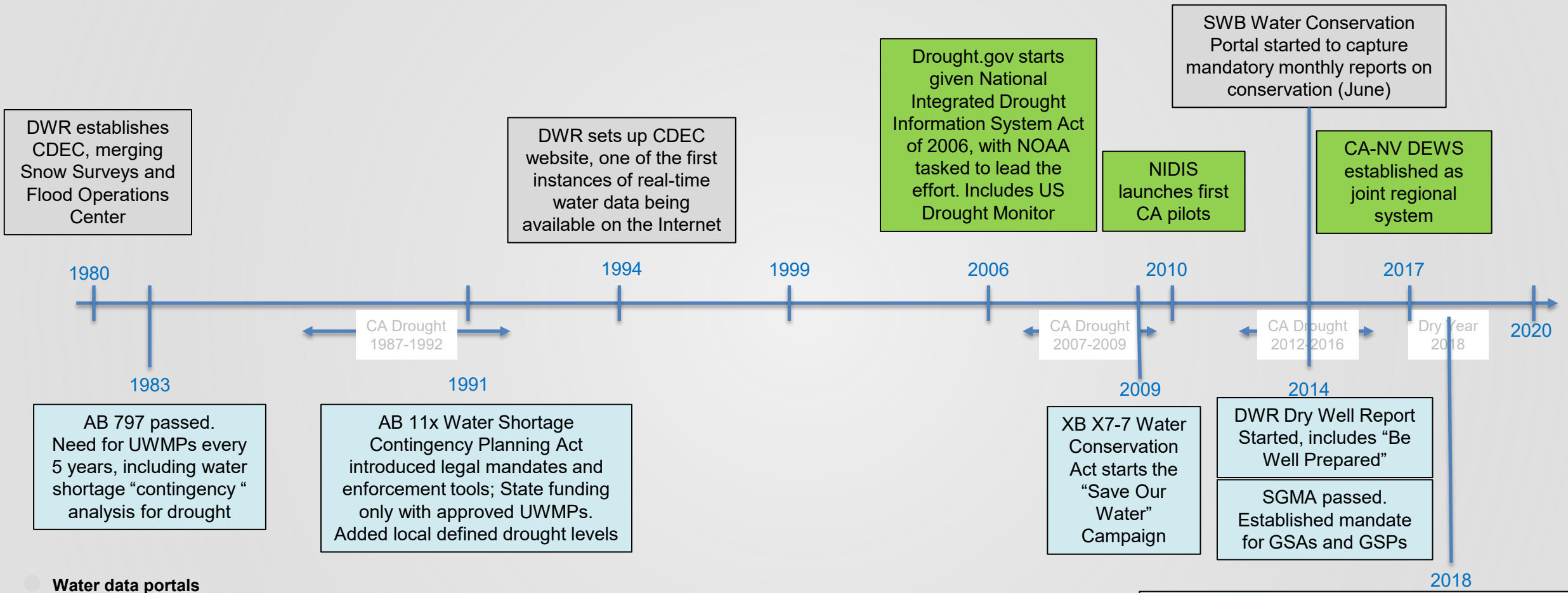
Impacts

Community
- # of dewatered wells
- # of people without sustainable access
- # of DACs affected

Agriculture
- % decrease in yields
- # of acres repurposed
- # of jobs lost
- $ of lost ag revenue

Environment
- % decrease in fish species
- % change in subsidence
- Impact on forests, fires

DI&M: HISTORICAL CONTEXT 1980-2020 (1OF2)

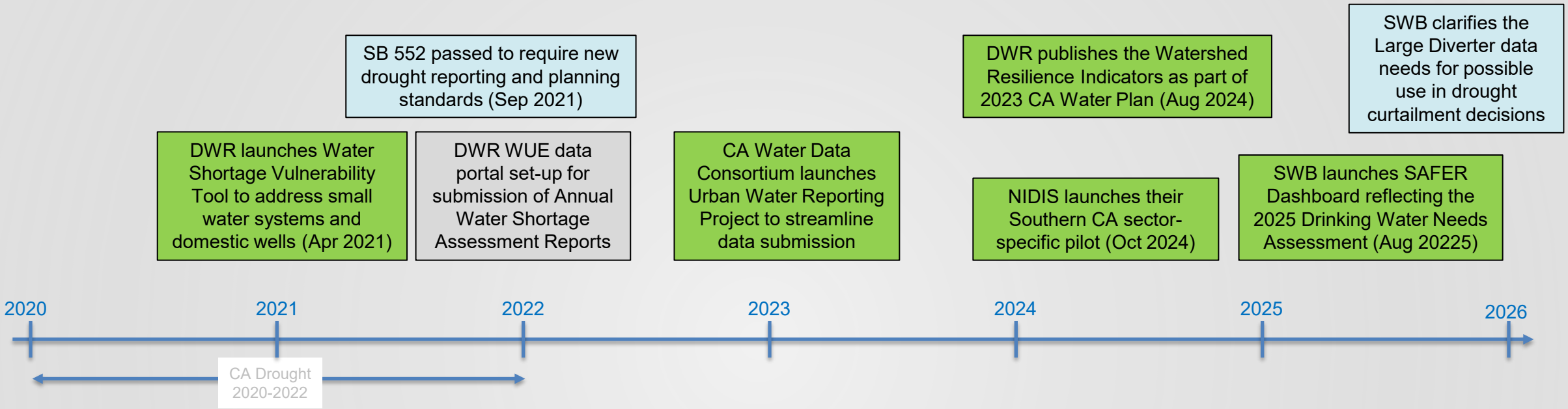


- **Water data portals**
- **Regulatory and policy**
- **Drought efforts, tools and communication**
- **DRIP Collaborative activities**

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Additional historical context can be found here (by Erik Porse):
[Evolution of Drought Response and Resilience in California's Cities - California WaterBlog]

DI&M: HISTORICAL CONTEXT 2020-2025 (2OF2)

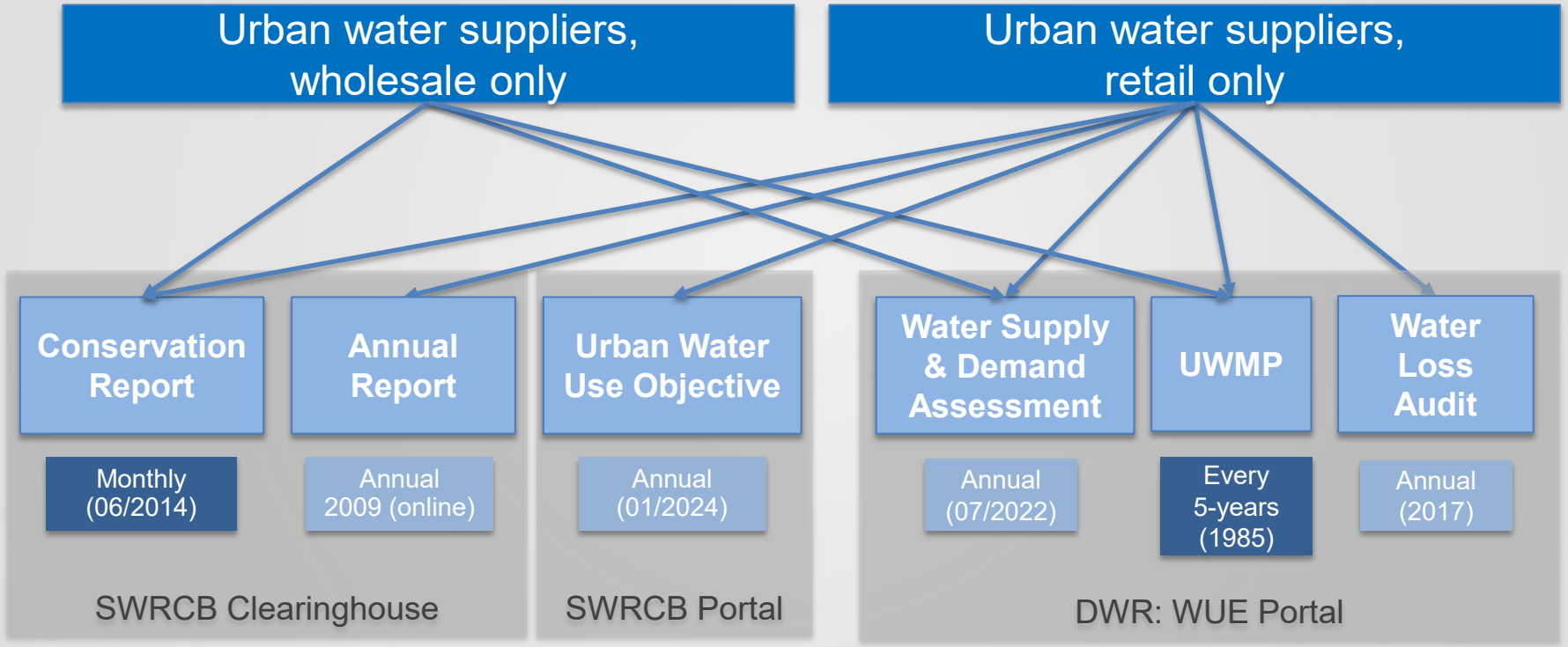


- **Water data portals**
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- **DRIP Collaborative activities**

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DI&M: CURRENT SIX URBAN WATER REPORTS

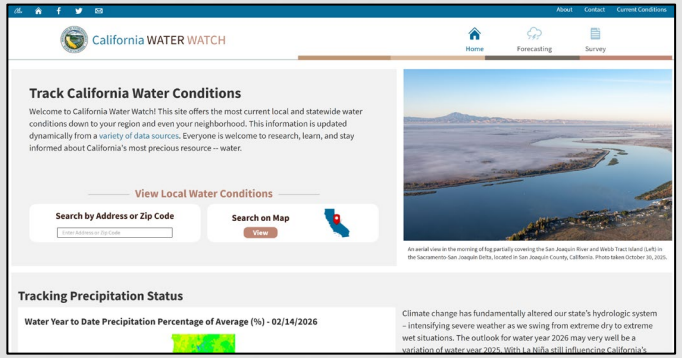
Today, urban water suppliers submit monthly, annual, and 5-year legal/regulatory reports to various agencies and data portals



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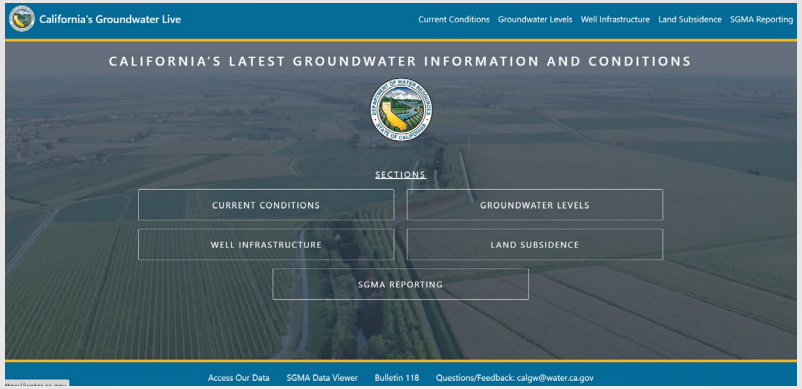
KEY WEBSITES FOR DROUGHT COMMUNICATION

California Water Watch



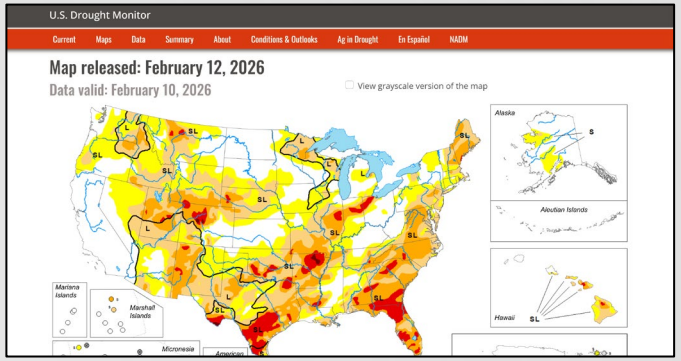
https://cww.water.ca.gov/

CA Groundwater Live



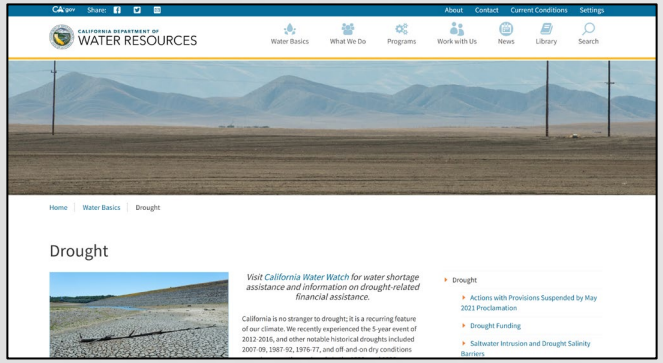
https://calgwlive.water.ca.gov/

US Drought Monitor



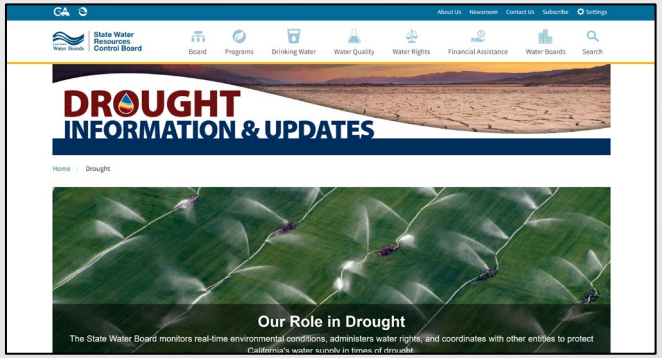
https://droughtmonitor.unl.edu/

DWR Drought Homepage



https://water.ca.gov/drought

SWB Drought Homepage



https://www.waterboards.ca.gov/drought/

Drought.gov



https://www.drought.gov/

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*Websites shown above are not exhaustive. Many other websites are available (but not shown)

UP NEXT: PRESENTATIONS (HIGH-LEVEL VIEW)

Project	Presenter	Innovation	Audience
UC Davis DEW	Alvar	• Sub-sector, sub-regional, supply mix portfolio • CA complexity, including infrastructure	State/regional/local Researchers
NOAA NIDIS SoCal Pilot	Amanda/Andy	• Sector specific (ag, utilities, public health) • Co-developed, sector engagement	Local health officials, farmers, water utilities
CWDC Drought Data	Robyn	• Link urban water data reporting and drought • User engagement (CA Water Data Summit)	Water data stakeholders, including water agencies
UC ANR / CIWR	Erik P	• Focus on financial impacts • Multi-benefit outcomes (and impacts)	State/regional/local Researchers
CA Water Watch & DWR Water Shortage Vulnerability Explorer	Julie	• Standardized, statewide for state smalls/DWs • Physical and social vulnerability. Informs CDRPs	Small Water Systems, DWs, State Small WS, Counties
SWB Outage Forecast Predictor	Eric Z	• Predictive (AI/ML), dynamic indicators • Automated data collection, open source	Div of Drinking Water, CalOES, Water System staff
LCI Drought and VCP	Ben	• Uses US Drought Monitor DSCI, Climate • VCP integrates drought with other factors	VCP: NGOs, locals, and policy makers

- **UC Davis (UCLA/PPIC)**. CA Drought Early Warning System research funded by NIDIS – Alvar
- **NIDIS**. NOAA work on the SoCal DEWS Pilot – Amanda/Andy
- **CWDC**. Consortium work on drought indicators and data, with linkage to urban water reporting – Robyn
- **UC ANR (CIWR)**. Research on financial impacts of drought – Erik P

SPOTLIGHT ON EXISTING PROGRAMS – LIGHTNING TALKS (RESEARCH)

Developing Drought Early Warning Systems for California



DRIP Drought Indicators Workshop

April 1, 2026

Alvar Escriva-Bou, PhD

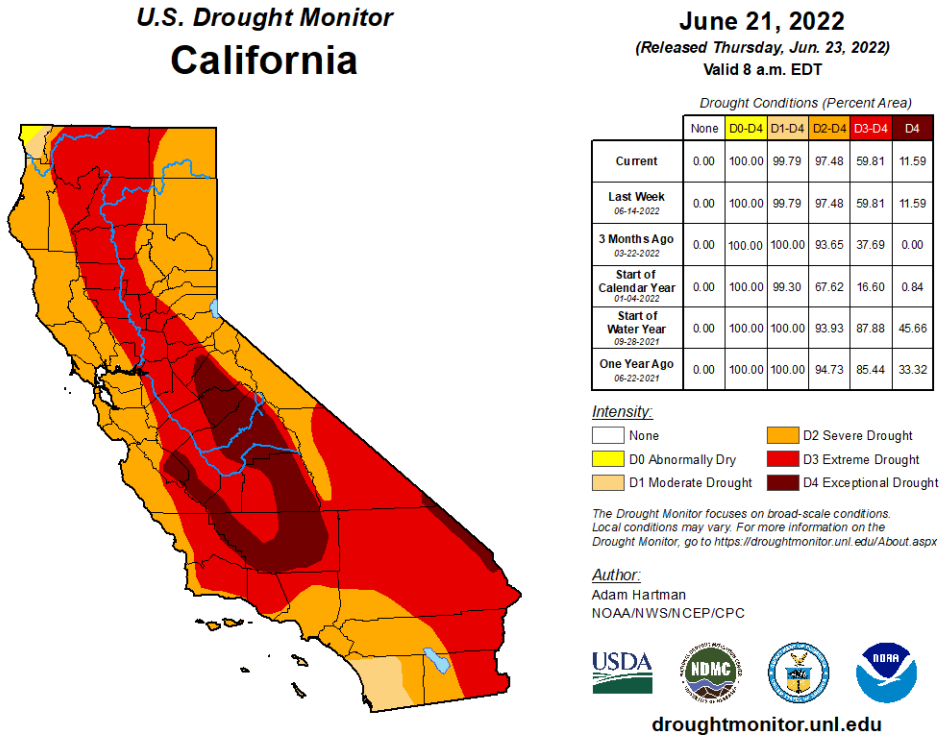
Assistant Professor
University of California, Davis

Supported by funding from National Oceanic Atmospheric Administration's (NOAA) National Integrated Drought Information System (NIDIS)

UCDAVIS
CIVIL AND ENVIRONMENTAL ENGINEERING

NOAA NIDIS

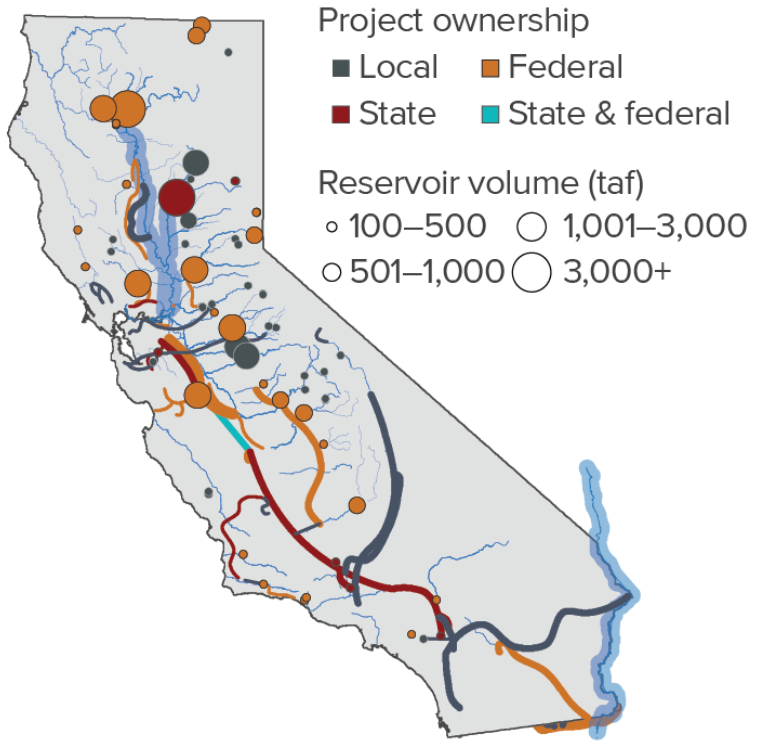
Current drought indicators focus on local hydrometeorological conditions



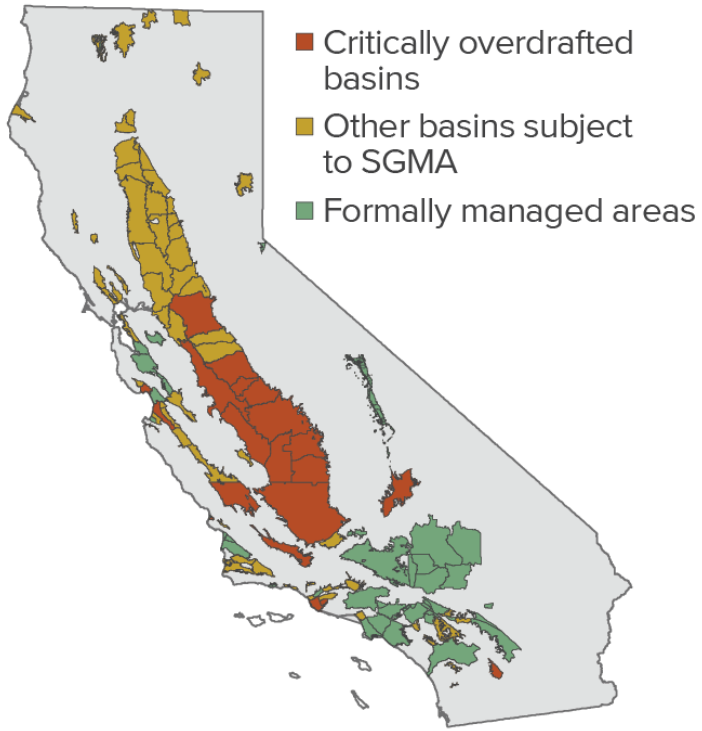
- Drought indicators fail to represent the complexity of California's water system
- Our NIDIS-funded projects are trying to fill these gaps

California has a complex water system, and characterizing drought is not a simple task

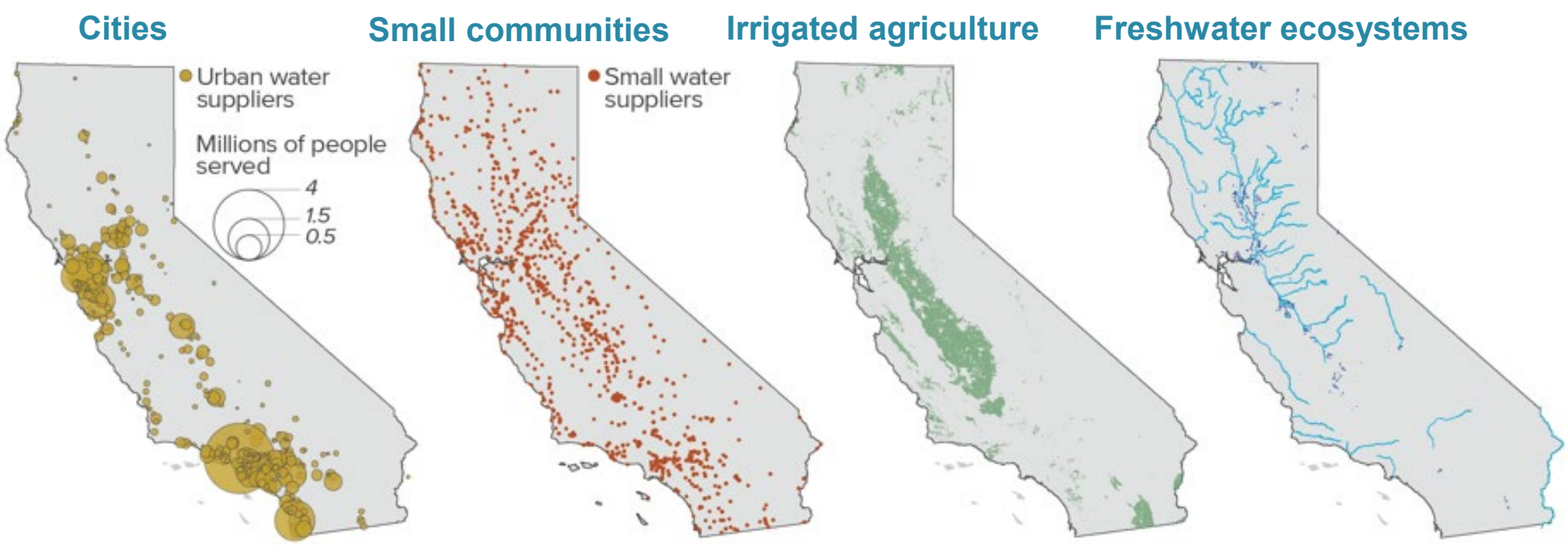
Above-ground storage and conveyance



Groundwater basins

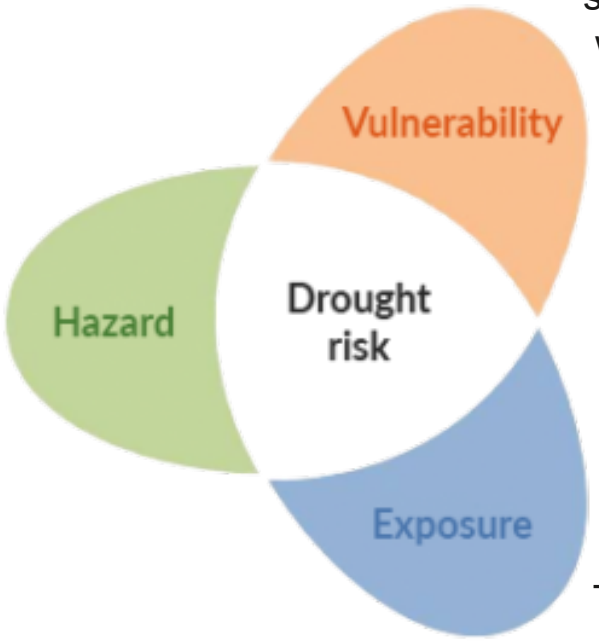


Different users have different supply portfolios, adaptation options, and potential impacts



Drought impacts can be characterized by a combination of hazard, exposure and vulnerability

The propensity of exposed elements to suffer adverse effects when impacted by a drought event



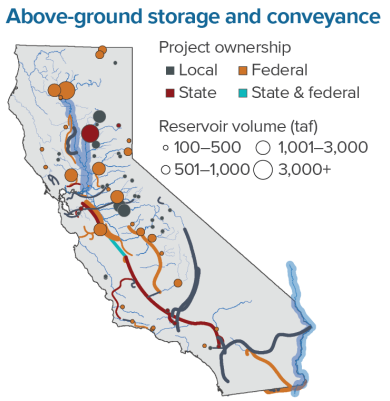
The possible occurrence of natural or human-induced physical events

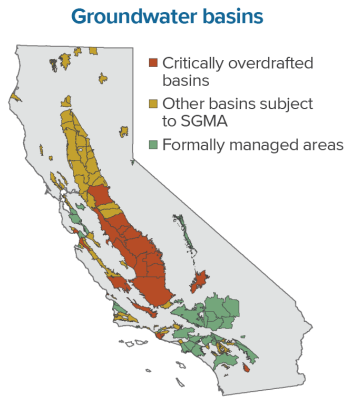
The total population, its livelihoods and assets in an area in which drought hazard events may occur

To improve drought management is key to better define drought conditions and impacts in California

1 A more nuanced view of drought conditions (drought hazard)

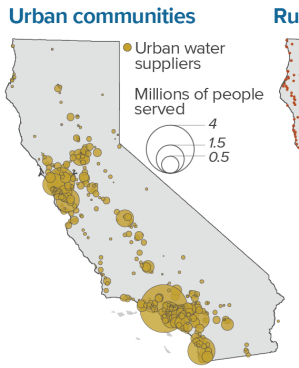
- Incorporate water infrastructure and management
- Integrate users' supply portfolios

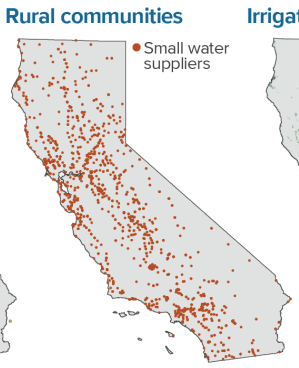


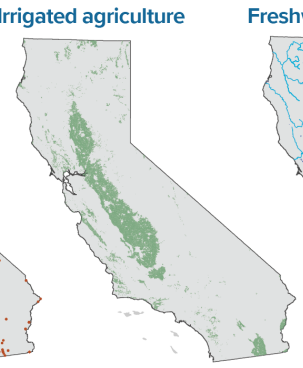


2 A better understanding of the link between drought conditions and impacts

- Understand users' <u>exposure</u> and <u>vulnerability</u> to drought





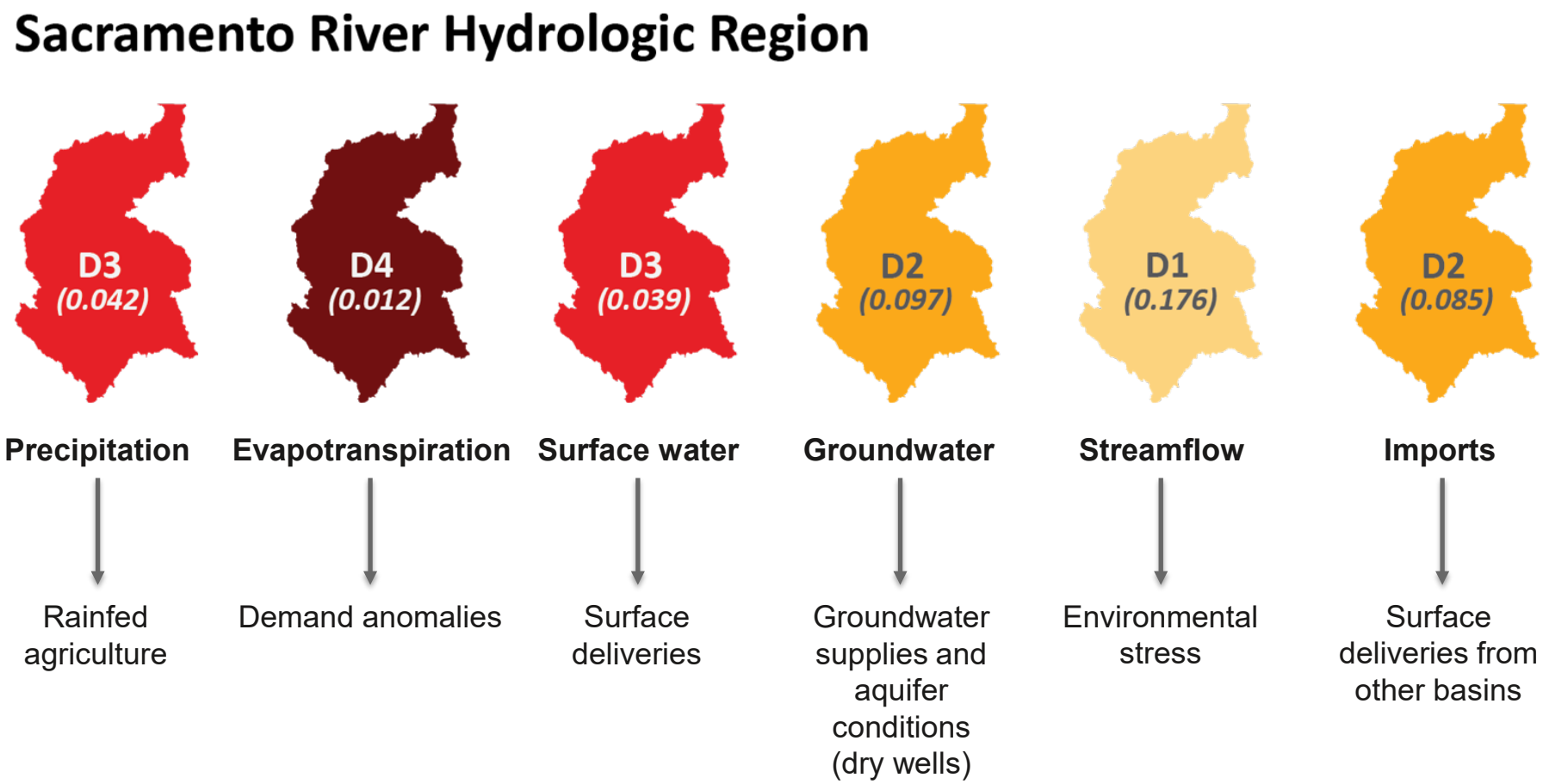




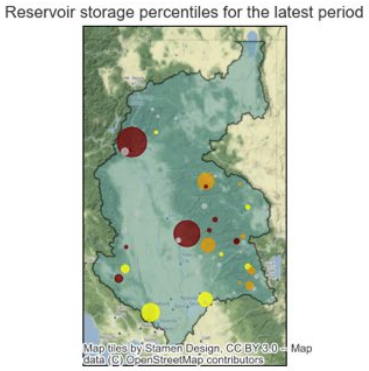
Some results so far:

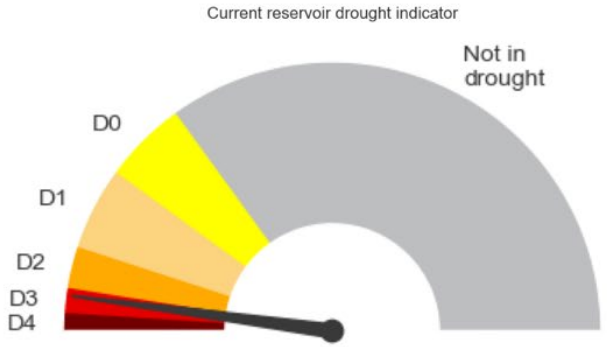
1. We have developed user-oriented drought hazard indicators for California
    a. For different supply sources
    b. For users with complex water portfolios
2. We are exploring quasi real-time monitoring of drought hazard and drought impacts
3. We are going to develop a Drought Early Warning Dashboard for California

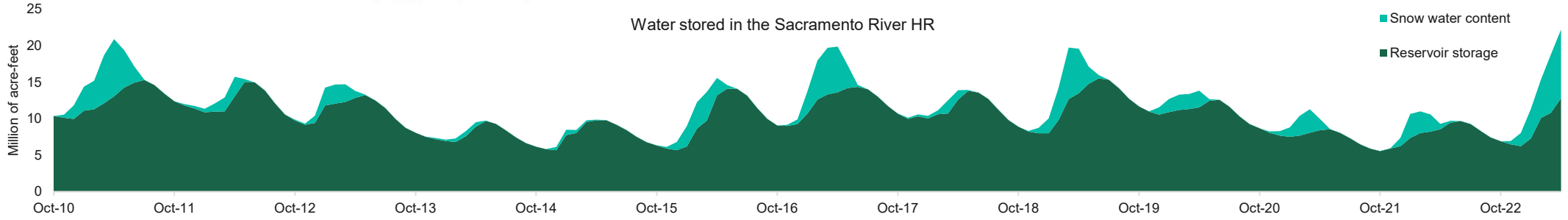
1a. Defining drought indicators for different water sources, or users' needs

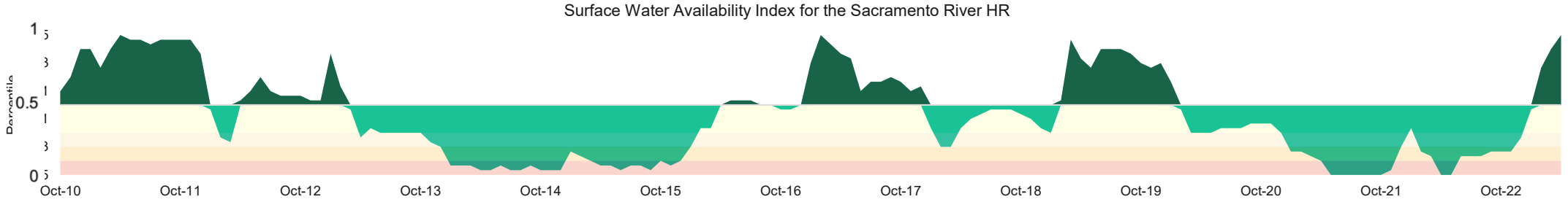


Drought index for surface supplies is based on reservoir storage and snowpack

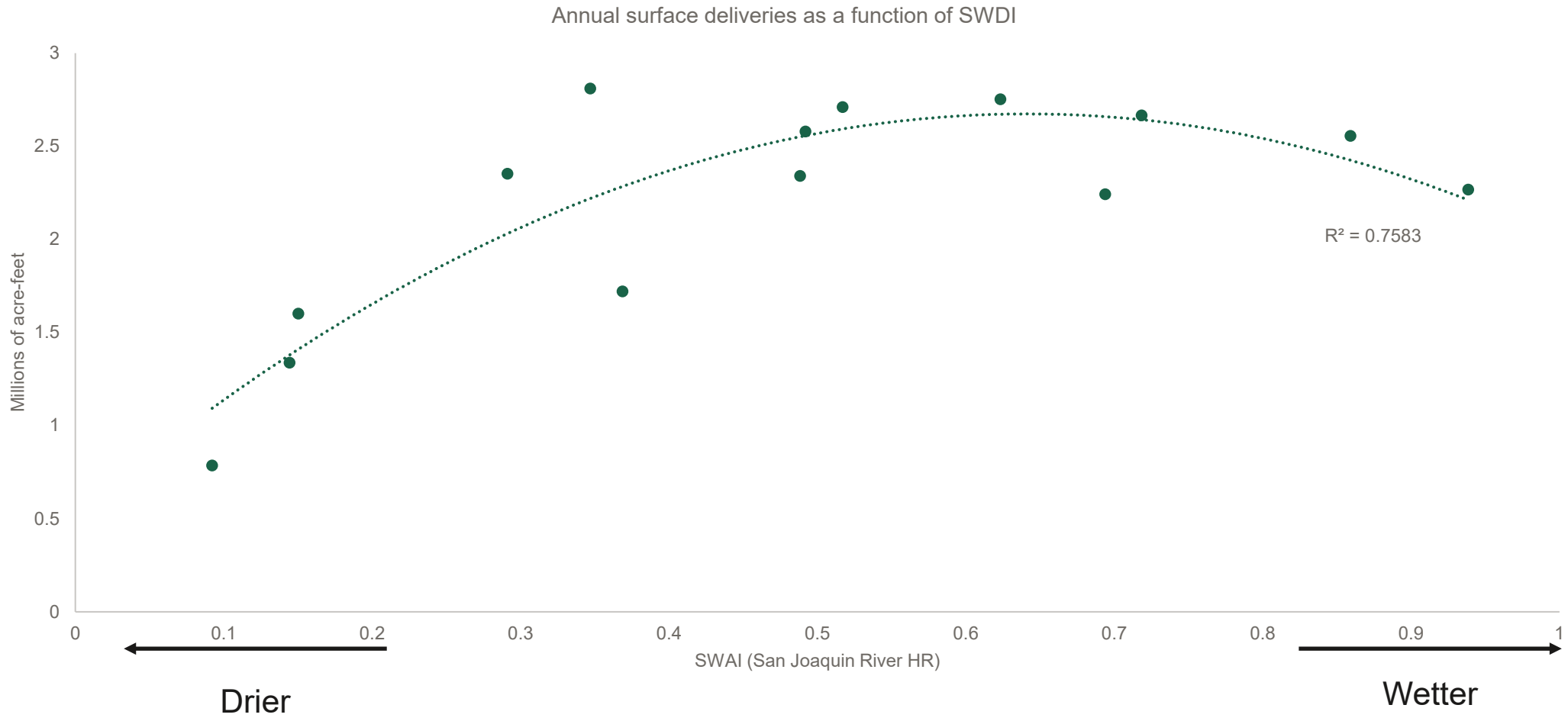




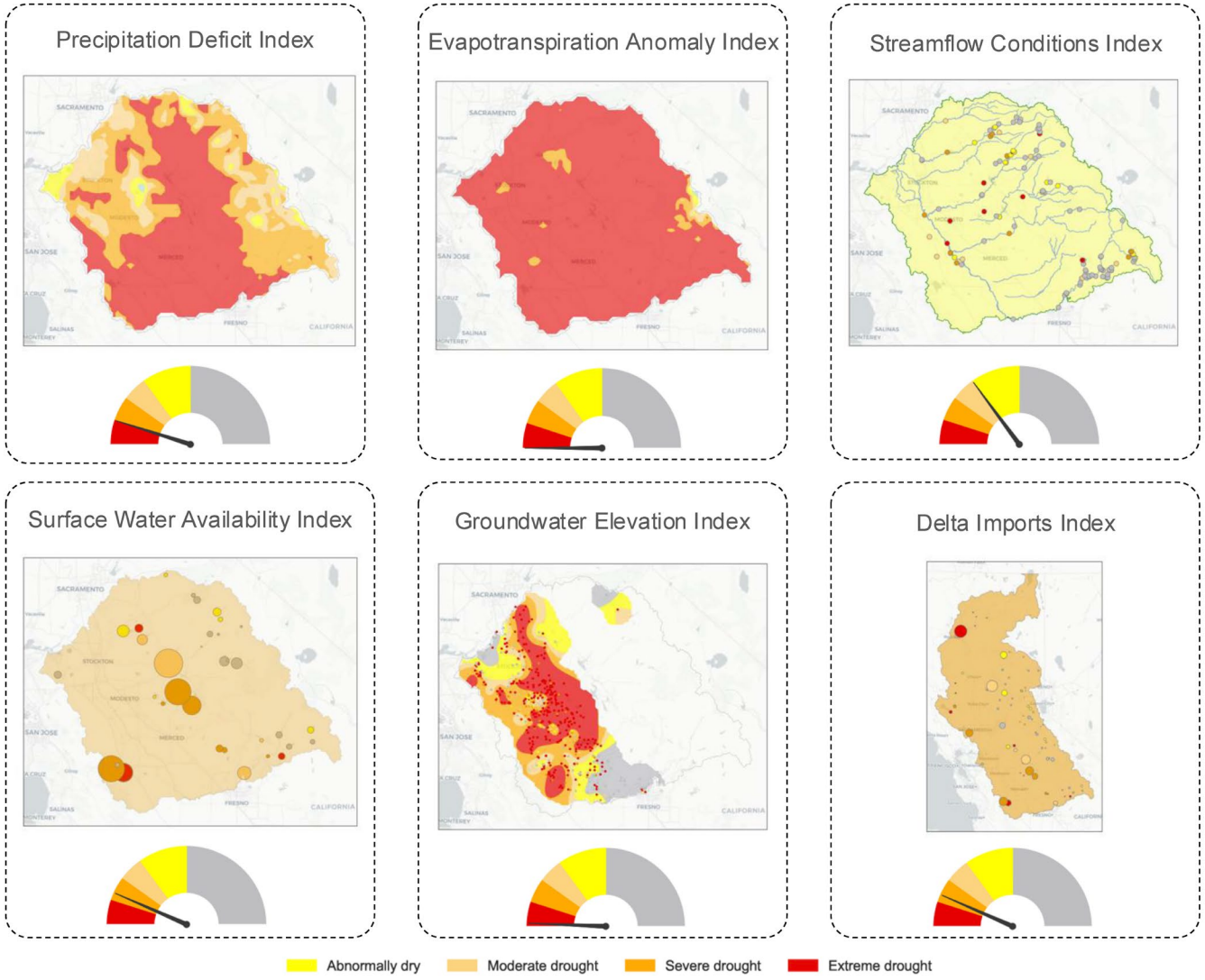


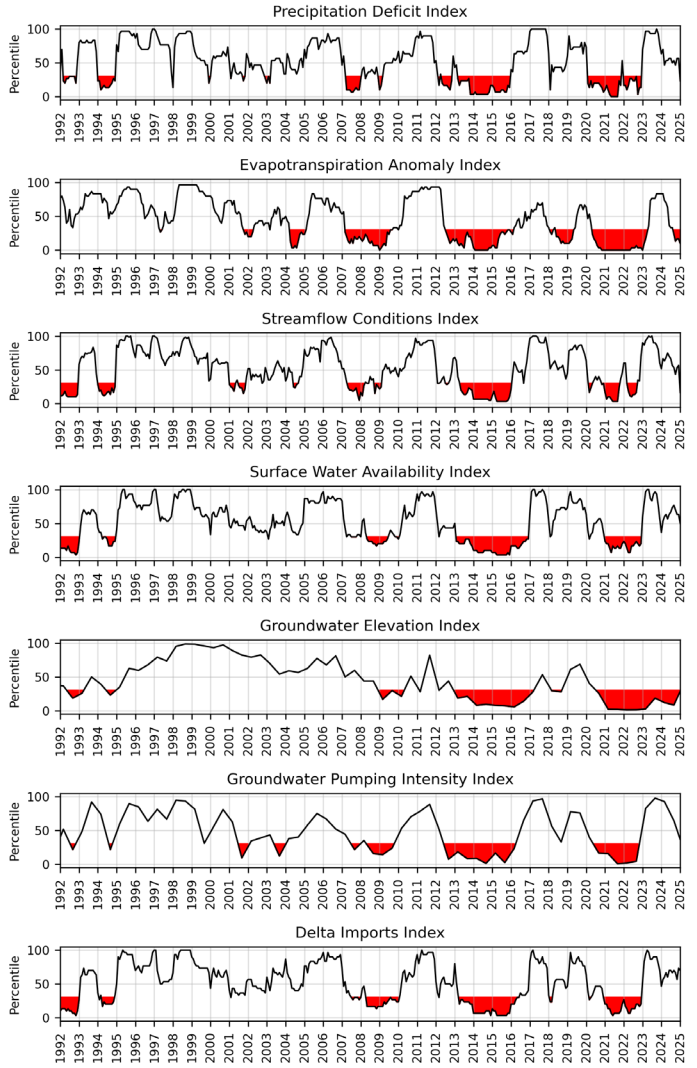


Surface deliveries are highly correlated with the Surface Water Availability Index (SWAI)



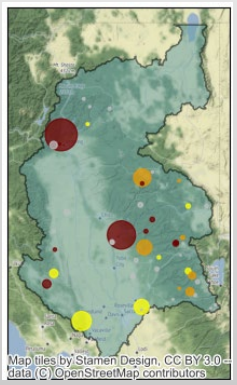
Supply-oriented indices for each hydrologic region

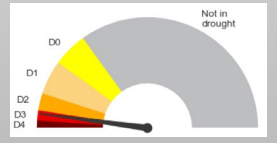




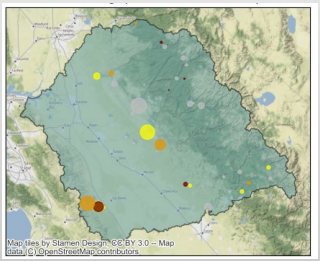
1b. Drought indices for users with complex supply portfolios: System Drought Hazard Index

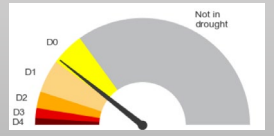
CVP imports
(Sac River Drought)



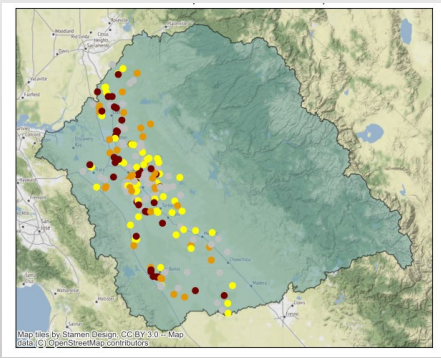


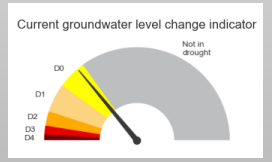
Local surface supplies
(Local Drought)



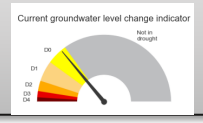


GW Supplies
(GW Drought)

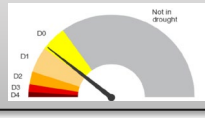




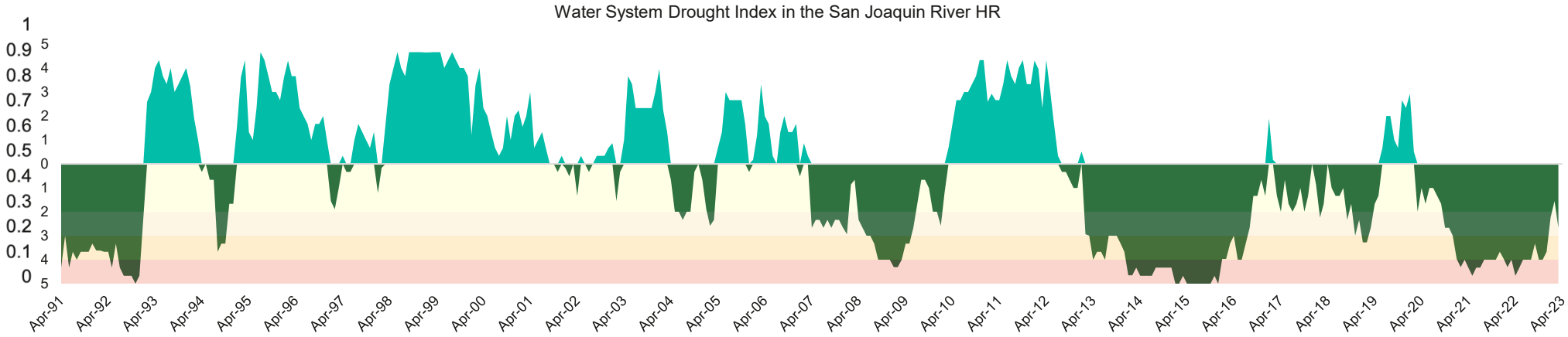
Evapotranspiration
(demand anomalies)

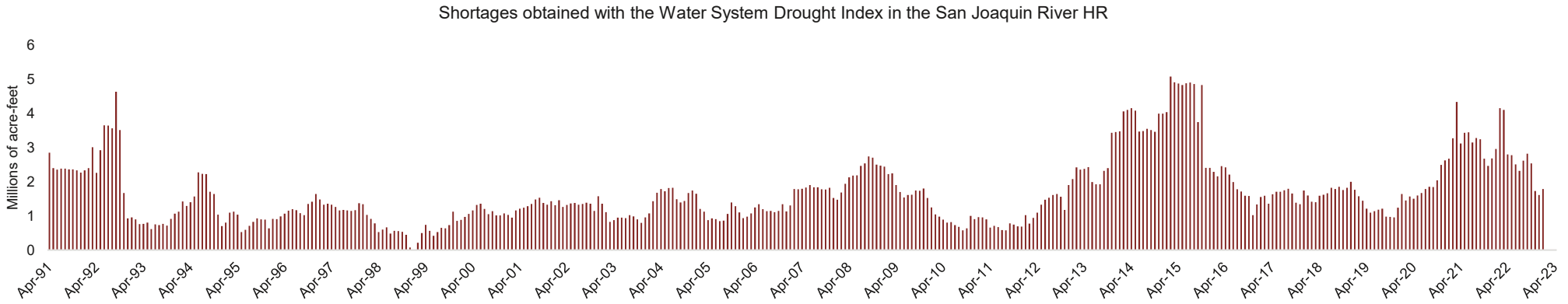


Groundwater overdraft

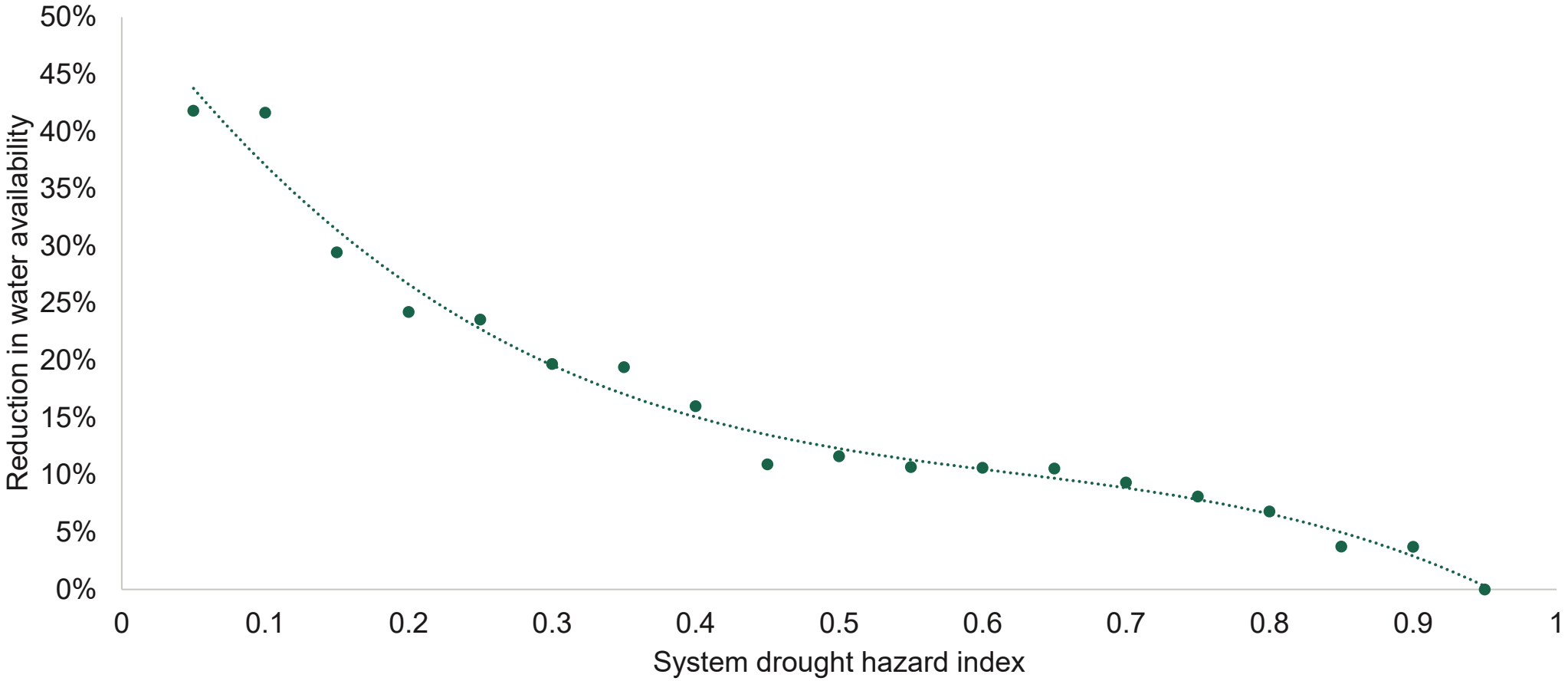


System drought indicator is related directly with water shortages…

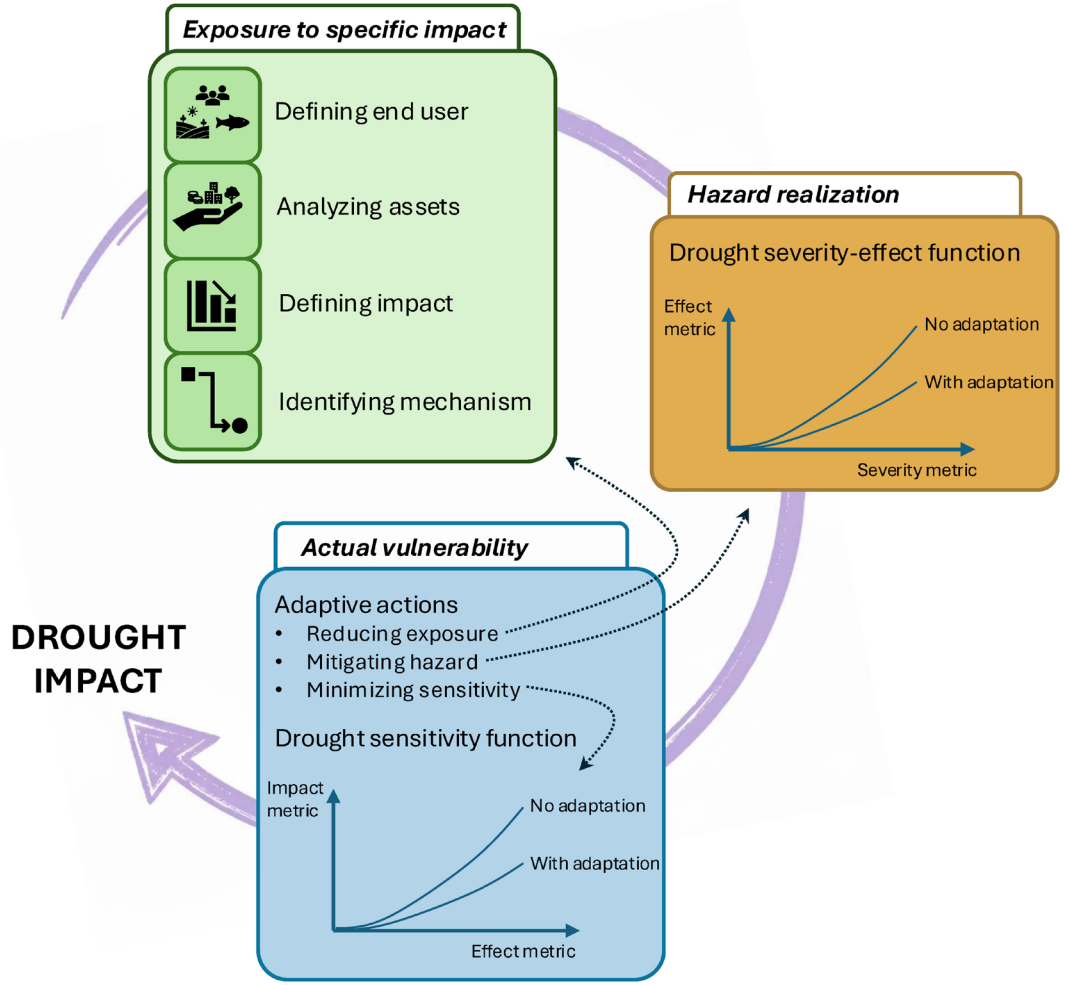




And can be translated to reduced water availability



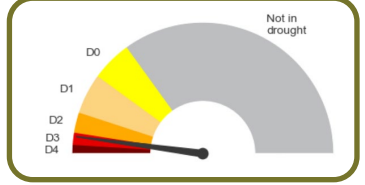
2. Quasi-real time estimation of drought hazard and drought impact



Example of quasi real-time estimation of drought impacts

Drought indicators

Current drought severity

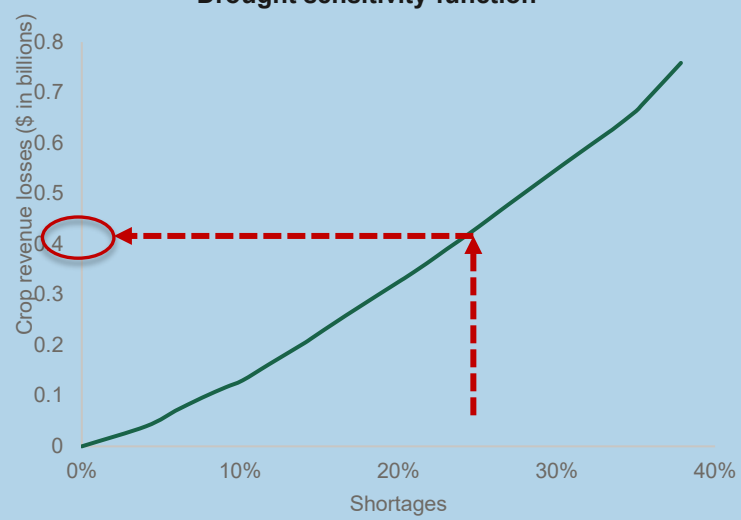


Exposure to specific impact

400,000 acres of irrigated ag with $3 billion in revenues

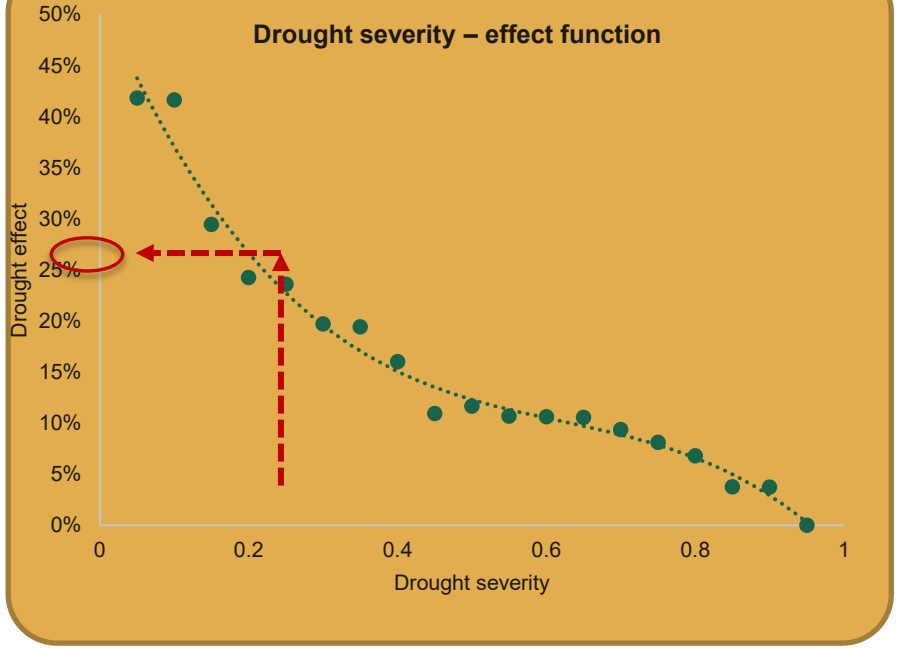
Reduced water deliveries impact agricultural output

Actual vulnerability

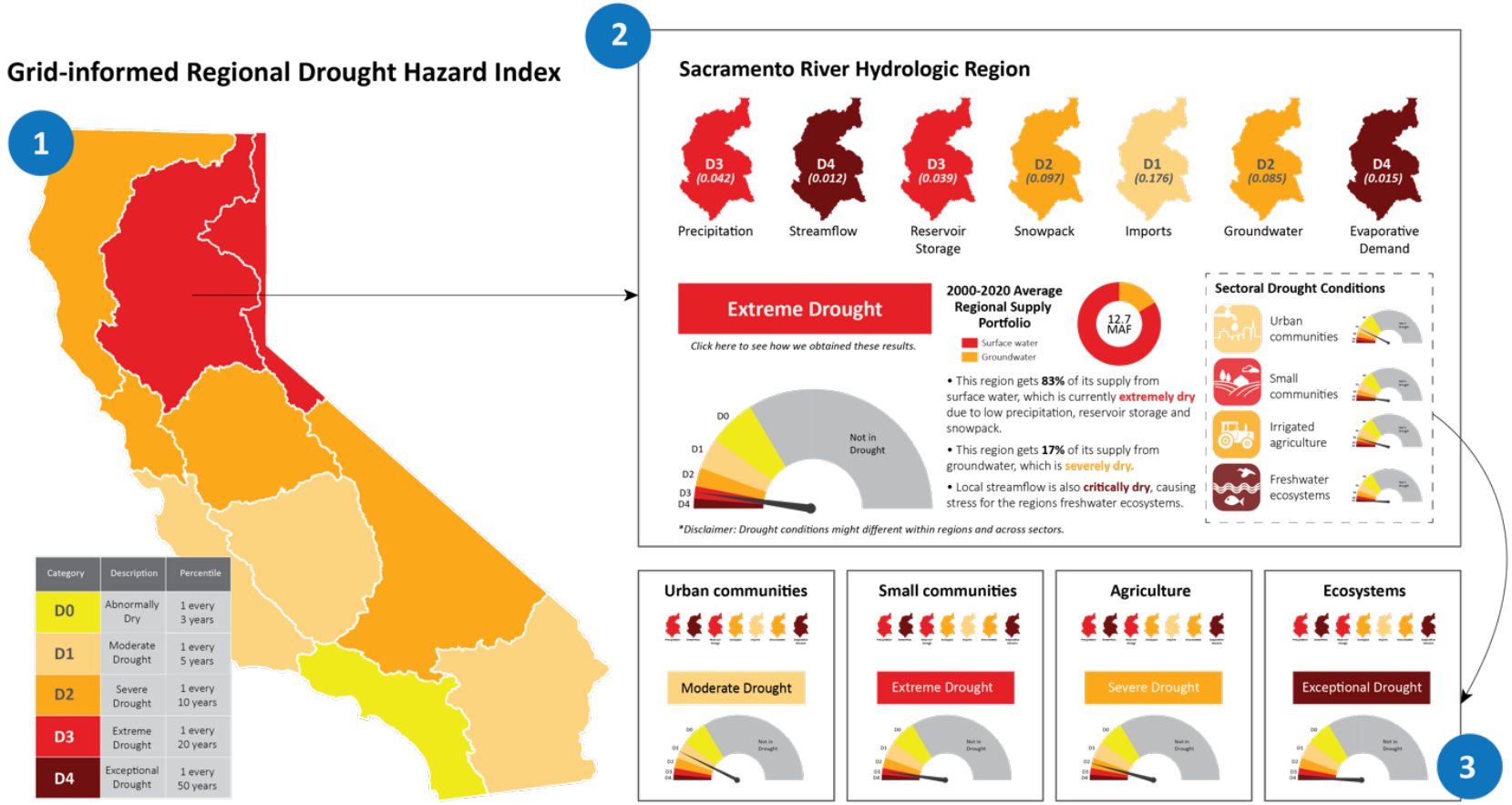


DROUGHT IMPACT: $400 million

Hazard realization



3. Developing a Sector-Specific Drought Early Warning Dashboard for California



Web mock-up developed to help understand the goal of our project

Next steps

- Start Drought Early Warning Dashboard:
  - Convene sectoral advisory groups to respond to data needs for meaningful actions
  - Complete drought hazard, exposure and vulnerability methodologies at finer scales
  - Develop useful dashboard
- Develop quasi-real time monitor of drought hazard and drought impacts
  - Pilot project in San Joaquin River

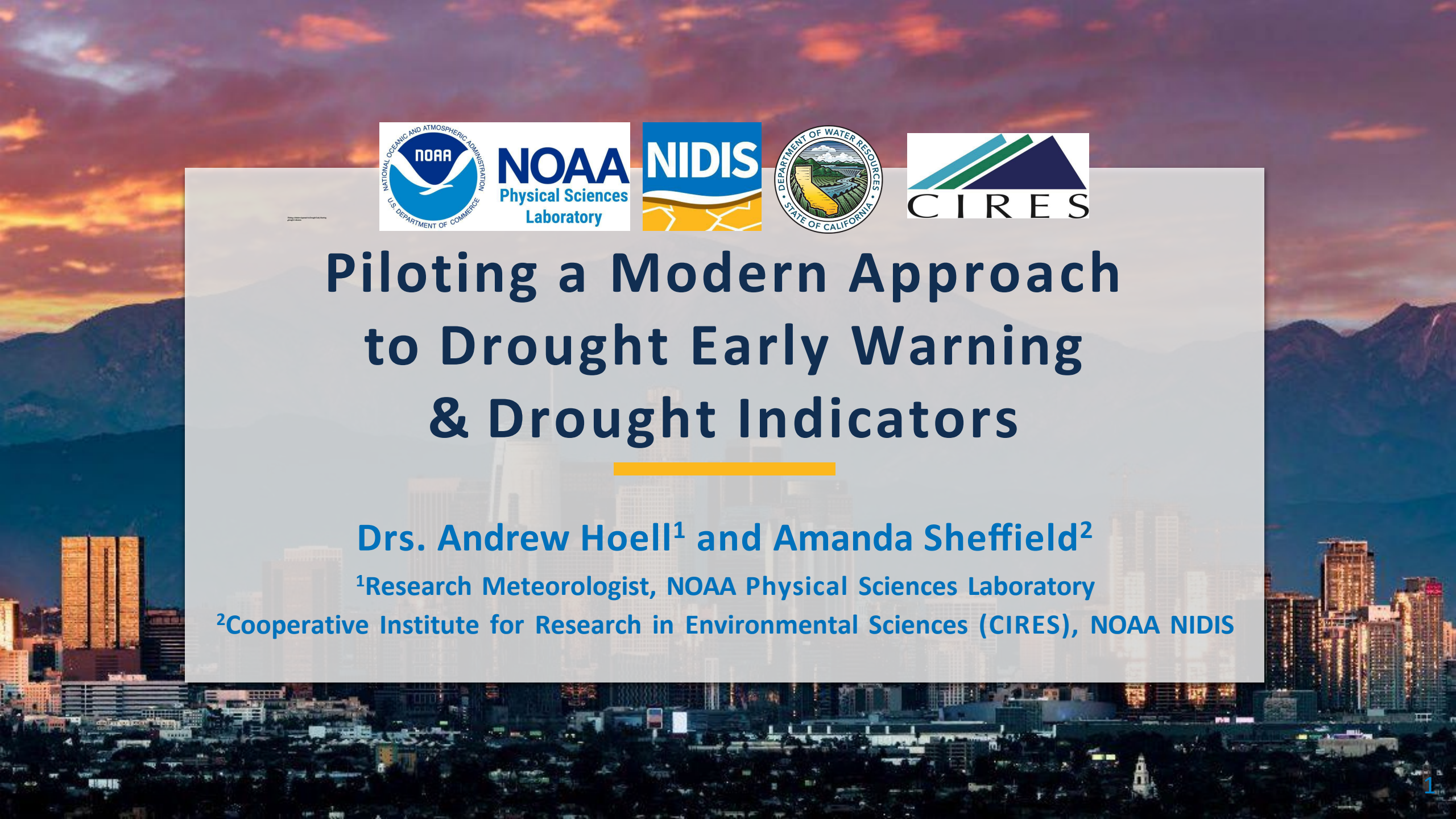
Thank you!

Don’t hesitate to send me an email if you have any questions, comments or suggestions

Alvar Escriva-Bou

aescriva@ucdavis.edu





Piloting a Modern Approach to Drought Early Warning & Drought Indicators

Drs. Andrew Hoell[1] and Amanda Sheffield[2]

[1]Research Meteorologist, NOAA Physical Sciences Laboratory

[2]Cooperative Institute for Research in Environmental Sciences (CIRES), NOAA NIDIS

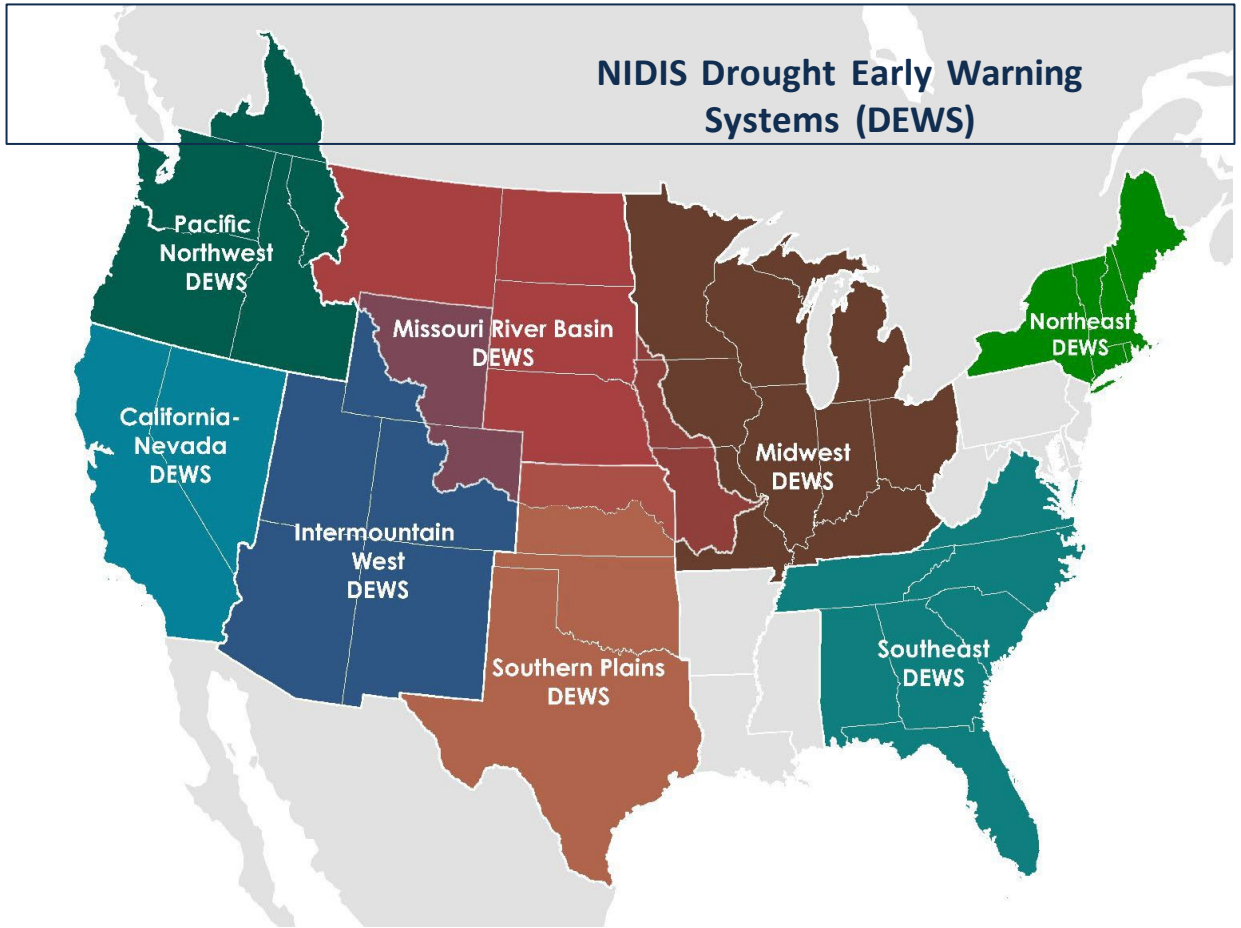
National Integrated Drought Information System (NIDIS)

NIDIS is a multi-agency partnership that coordinates drought monitoring, forecasting, planning, and information at federal, tribal, state, and local levels across the country.

How do we do this work?

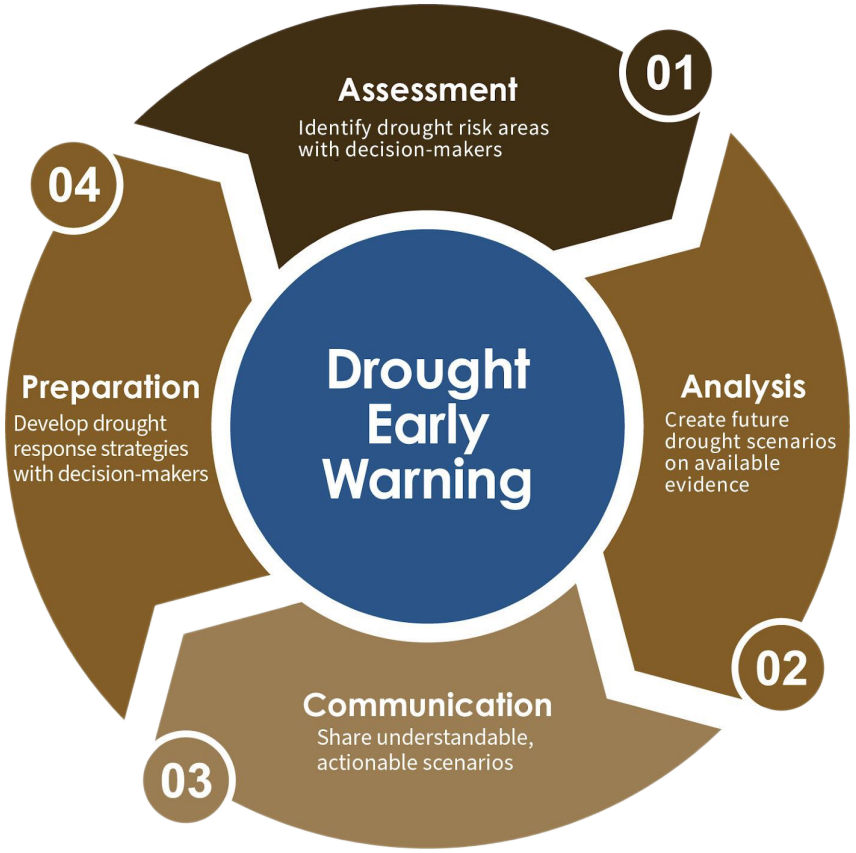
- Advancing Regional Drought Early Warning Systems
- Improving drought prediction and forecasting
- Supporting drought planning and preparedness
- Supporting drought impact assessments
- Strengthening collaboration
- Leading the U.S. Drought Portal: www.drought.gov

Enable the Nation to move **from a reactive to a more proactive** approach to managing drought risks and impacts



Modernizing Drought Early Warning

User centric, modern approach geared towards helping users make decisions and navigate drought impacts

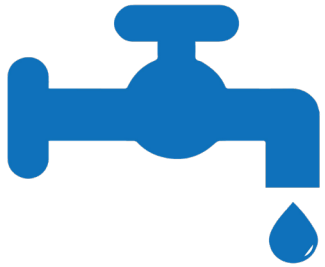


Improve sector-specific preparedness and shift users to a more proactive drought response.

Incorporate and evaluate new information, and improve upon the Outlooks in real time.

Educate users on available data and information through regular communication.

Water Utilities Scenario



Reservoir and groundwater storage is expected to be average California through 2026 (high confidence).

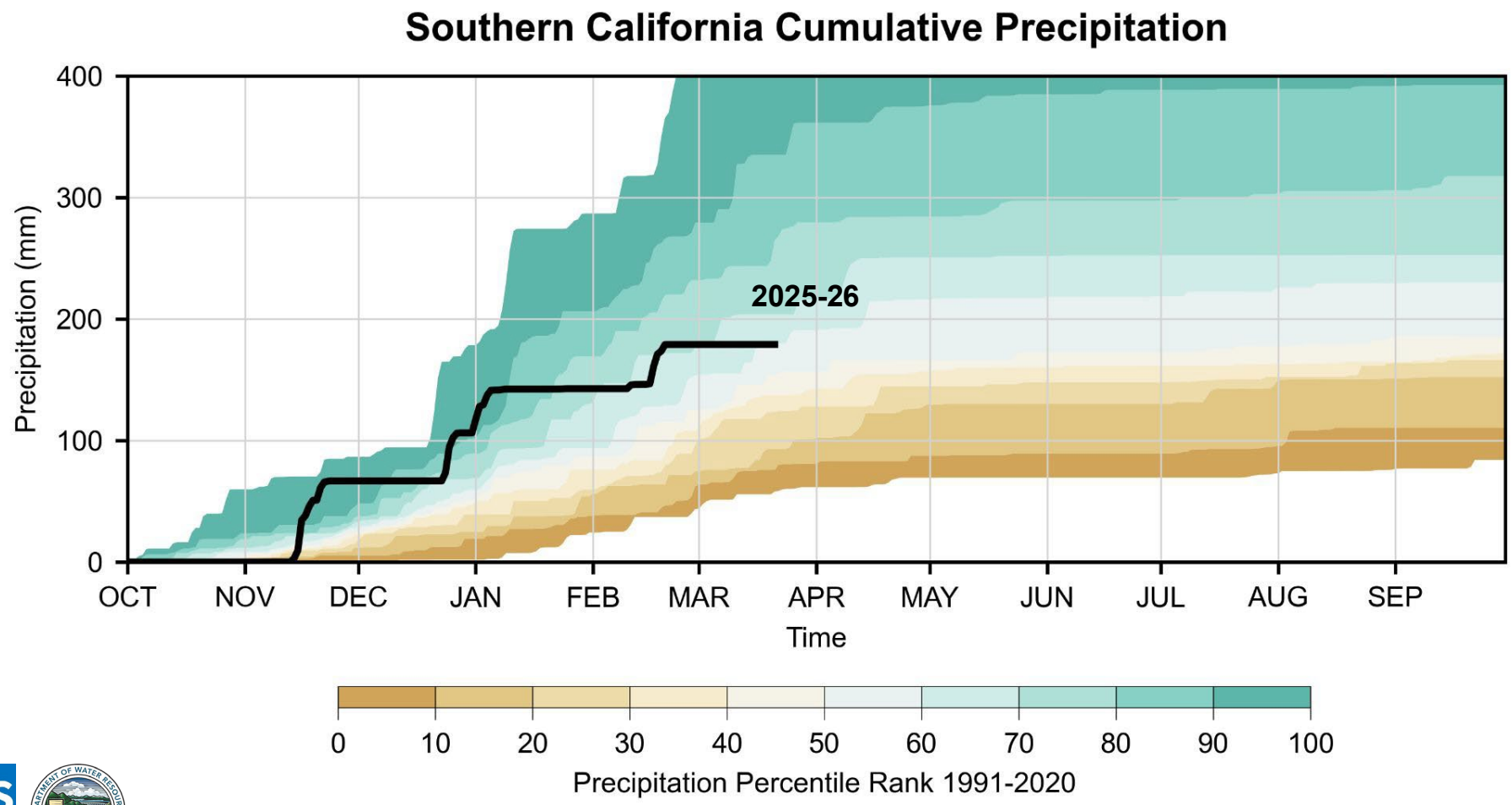
Low inflows into Lakes Powell and Mead from the Colorado Ri year, which could impact water supply (high confidence) and (high confidence) in late 2026 and 2027.

Supporting Evidence:

- Reservoir and groundwater levels increased to average and above-average in California after above-average precipitation since November 2025.
- The Southwest is experiencing low snowpack and snow water equivalent as of March 26, 2026. This includes key watersheds, such as the Central Sierra Mountains and the Upper Colorado River Basin, where record-low snow water equivalent is present.
- Below-average precipitation and above-average temperatures are forecast for the remainder of the current wet season in the Southwest U.S.
- Based on most probable outcomes, the Bureau of Reclamation projects lower inflows into Lake Powell in the next two years, and lake levels approach minimum power pool.

NOAA Physical Sciences Laboratory NIDIS

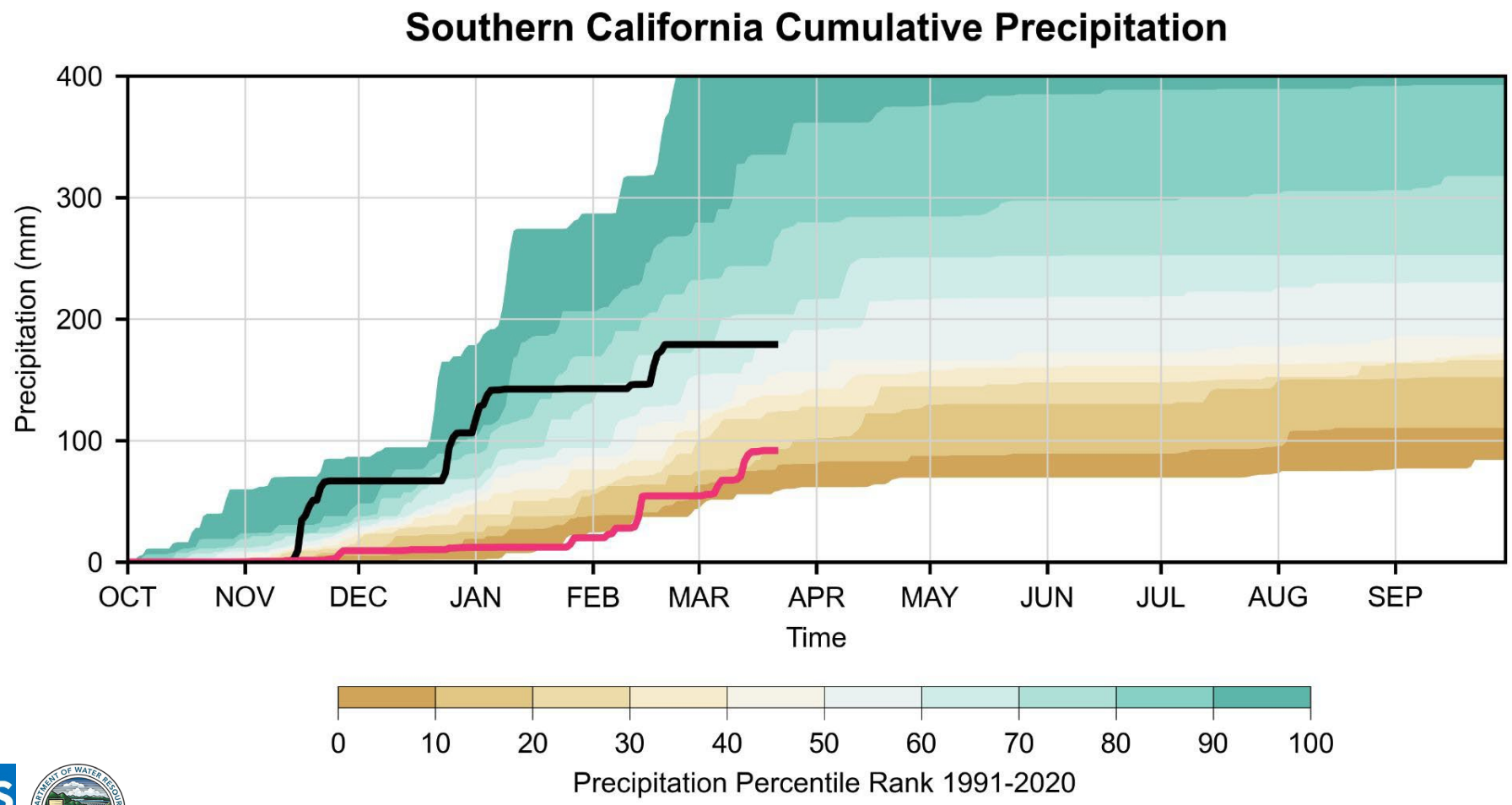
No Precipitation in Last Four Weeks in Southern California Pr
Oct 202



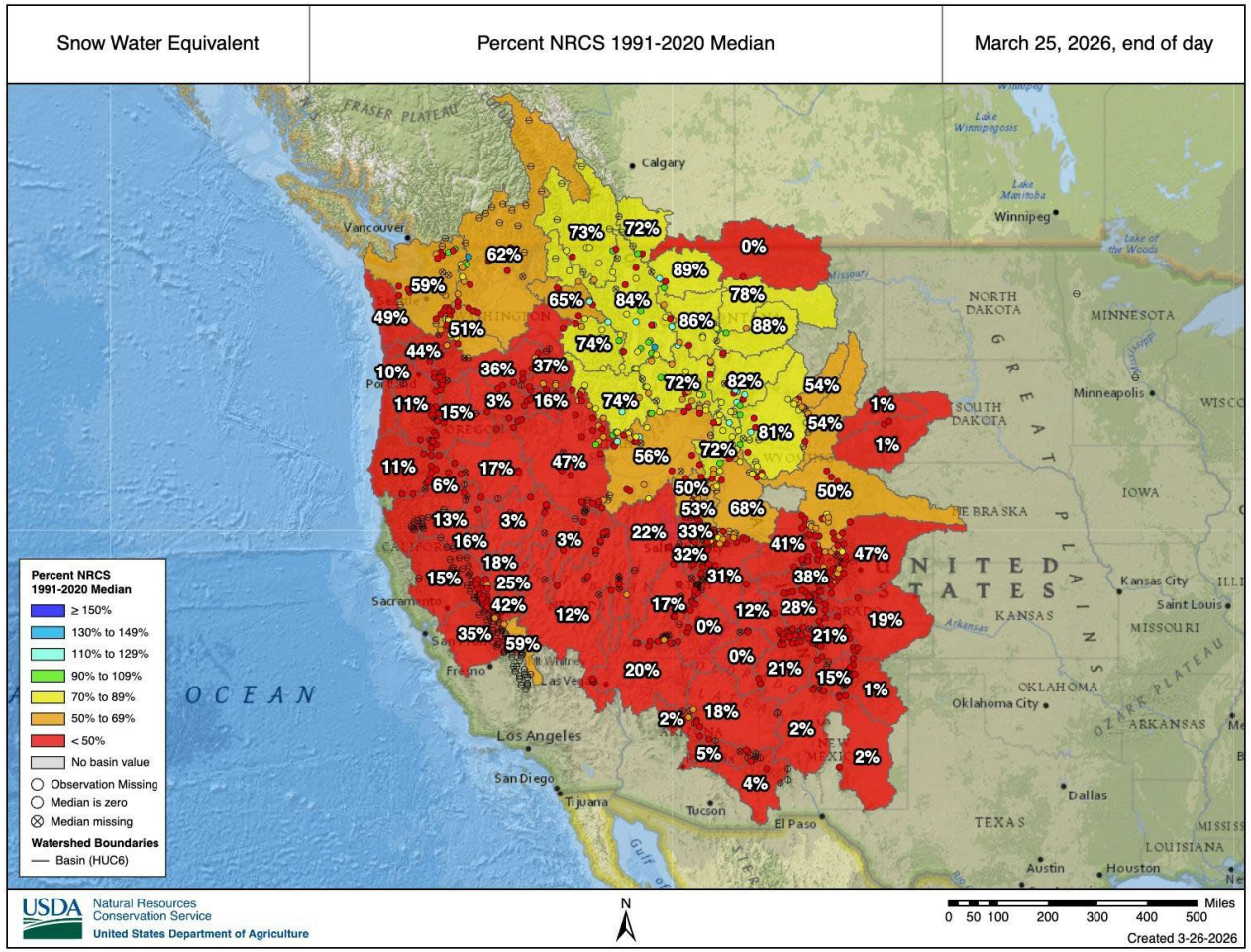
NOAA Physical Sciences Laboratory

NIDIS

Despite La Niña, Much More Precipitation in 2



Exceptionally Low Snow Water Equivalent Across Much of the Southwest United States



NOAA Physical Sciences Laboratory

NIDIS

DEW Pilot | *Lessons Learned*

- **Scenario Development - Learning more about the partners to create more meaningful scenarios for them.**
- **Capacity Development - Exposing users to drought information and forecasts so they can envision how this is useful to them.**
- **Communication - Meeting the users where they are.**

Stepping stone to dig deeper into drought with DRIP, California Department of Public Health, and local National Weather Service.

Drought Indicator Relevance by Region and Season

Molly Woloszyn, M.S.
Cooperative Institute for Research in Environmental Sciences (CIRES)
NOAA's National Integrated Drought Information System (NIDIS)

Research Overview

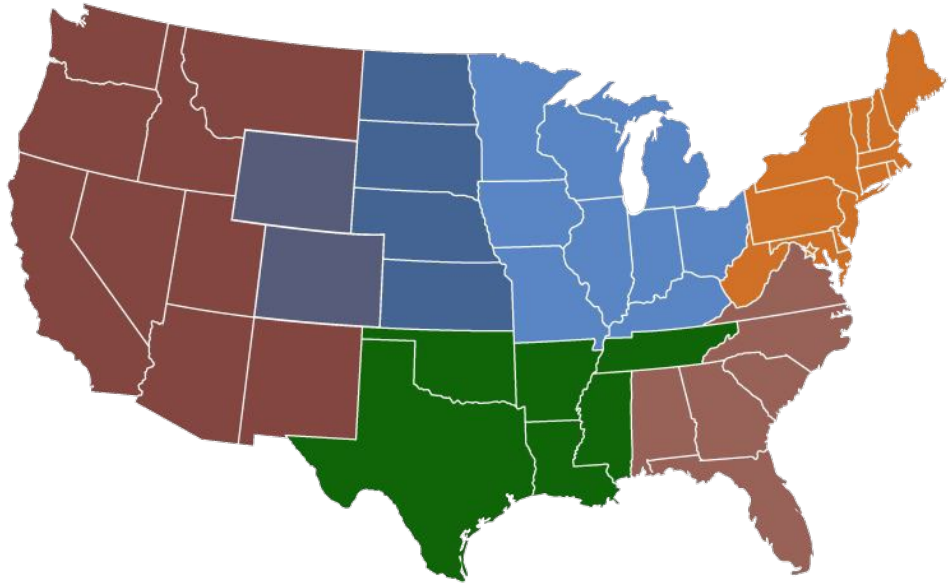
Thank you for joining

A team of NASA scientists conducted research to **quantify the relative importance—or "drought explainability"—of specific indicators with respect to the U.S. Drought Monitor (USDM)**.

The researchers looked at 113 indicators of drought, including in situ, modeled, and remote-sensing data.

They used an information theoretic measure, **mutual information (MI),** to compare these 113 indicators to U.S. Drought Monitor data from **2006-2019**. Produced **fractional information (FI)** values from normalizing MI.

The results show which indicators have highest FI values with respect to the USDM broken down **by geographic region and by season** (as well as annually).

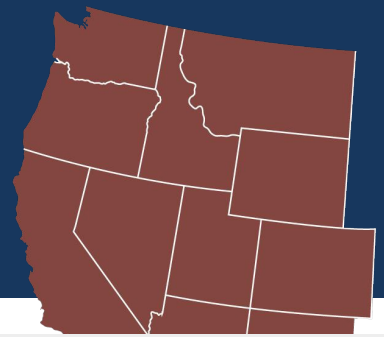


Read the article in the *Journal of Hydrometeorology*

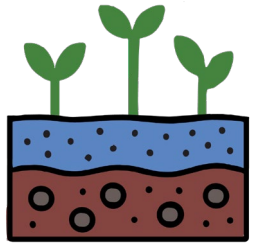
Key Takeaways from Research

1. Results show which **drought indicators are most representative** of the Drought Monitor (USDM)'s depiction of drought for a **given region and season**.
2. No individual indicator can define drought on its own and there are seasonal differences. **Higher "drought explainability" comes when combining multiple indicators.**
3. The **top 15** highest ranked drought indicators in each region can capture about **~55-75% of "explainability" for the USDM.**
4. Using only **model-based indicators** show promise for **drought prediction and forecasting**.
5. Using only **remotely-sensed indicators** show value for drought monitoring at in situ **data-scarce locations.**

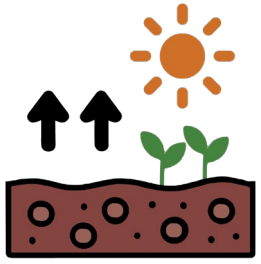
Key Takeaways for the West
All-Seasons Data



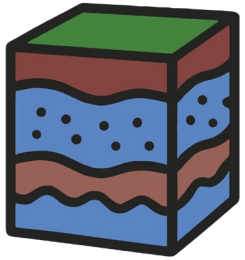
TOP INDICATORS



Soil Moisture
Total Column Soil Moisture



Evaporation-Based Indicator
Standardized Precipitation Evapotranspiration Index (SPEI)
Timescales: 6-month, 9-month, 12-month, 24-month



Groundwater



Palmer Indices
Palmer Modified Drought Index
Palmer Hydrological Drought Index



Precipitation-Based Indicators
Standardized Precipitation Index (SPI)
Timescales: 9-month, 12-month, 24-month

Precipitation
Timescales: 9-month, 12-month, 24-month

Key Takeaways for the West
Seasonal Data



The Standardized Precipitation Evapotranspiration Index (SPEI) dominated as a top indicator across all seasons.

Soil moisture has seasonal importance: it is a top indicator in the summer and spring, but not in the winter and fall.

Fall and winter favored even longer timescales for precipitation indices (24- and 36-month) than spring and summer.

The West, in general across all seasons and all-year combined, favor **longer timescales (9-months+)** compared to other regions.

Outreach & Translation of Results

Thank you for joining



January 2025

Listening Sessions

Engaged drought monitoring community to share the results of the research and asked how to make this information actionable for their work.

June 2025

National Weather Service Webinar

Shared the results of the research with NWS to build support for local drought monitoring capabilities.

Summer 2025

Translate Research

Developed public-friendly ways to convey research results in collaboration with NASA scientists.

Fall 2025

Develop Prototype Web Page with Research Findings

January 2026

User Testing

Hosted feedback sessions on communication of results with end users.

Feb/ March 2026

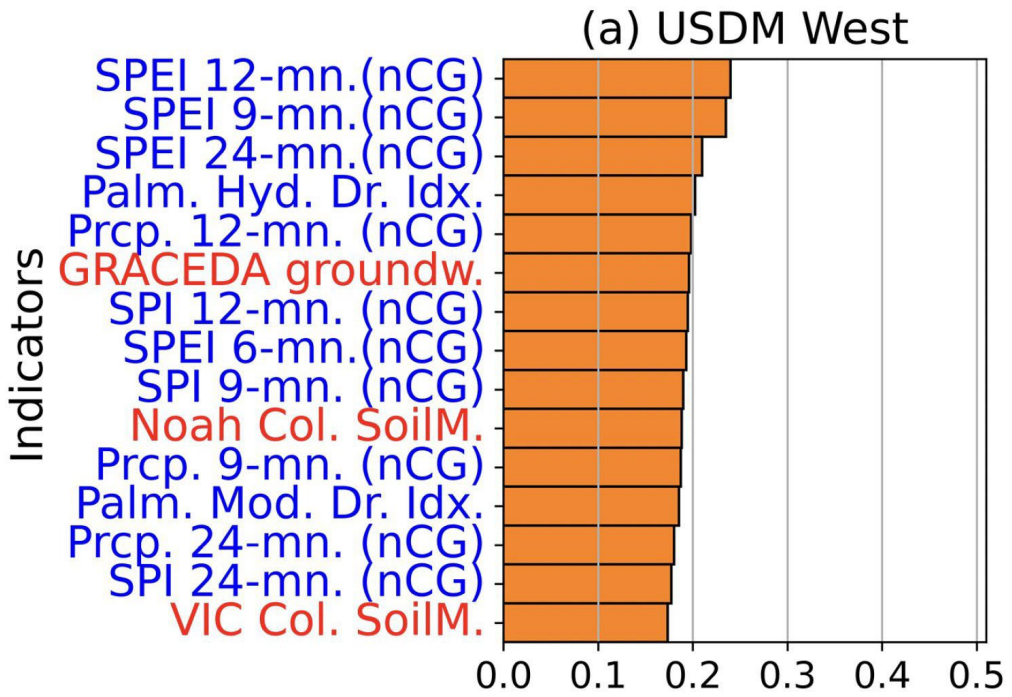
Finalize & Launch

Final adjustments on project results web page based on user feedback.

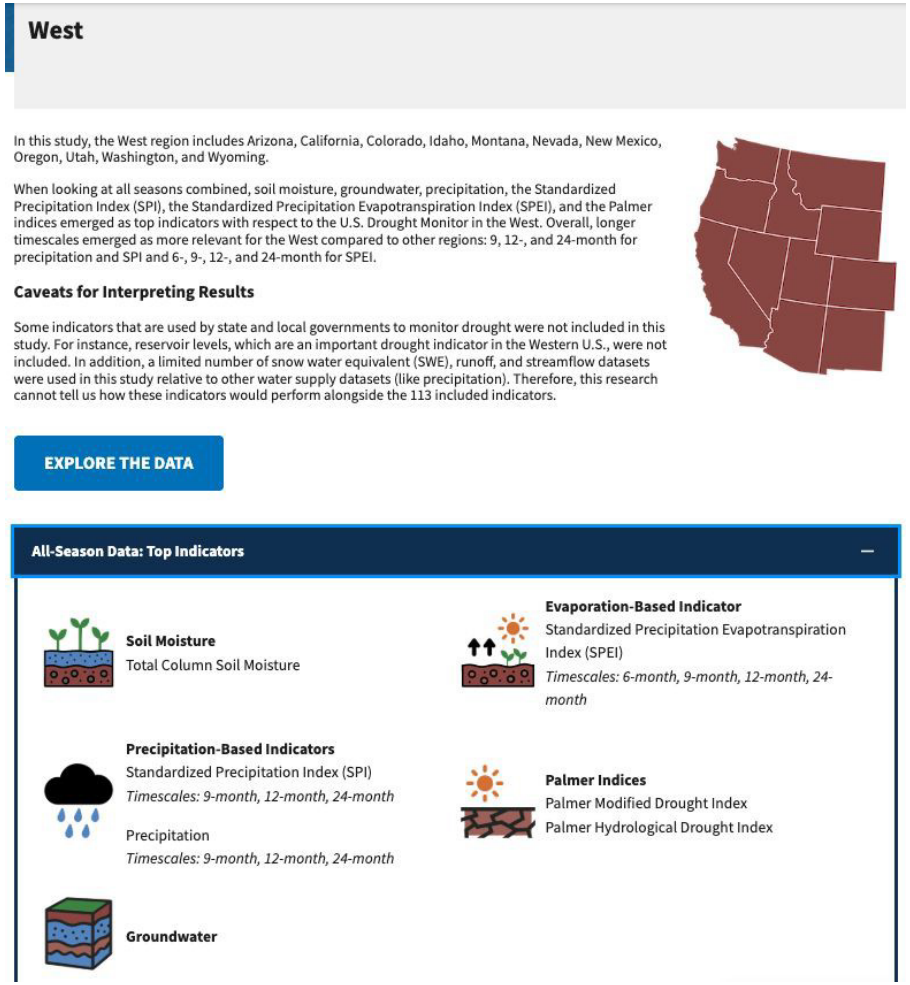
Outreach & Translation of Results

Original Results

Top 15 Indicators (All Season)



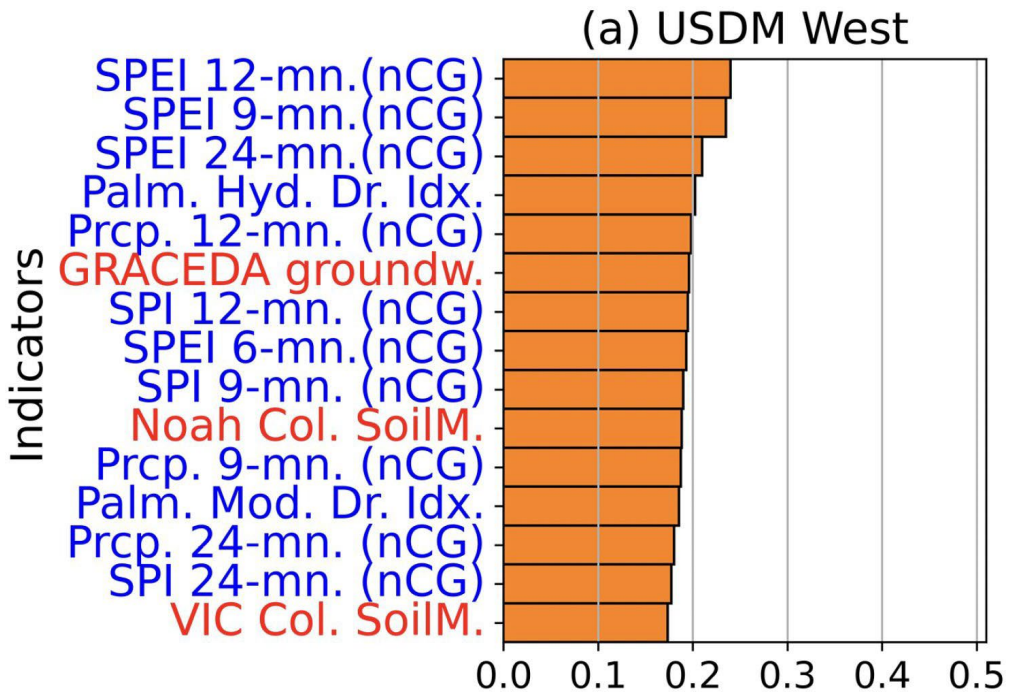
Drought.Gov Version



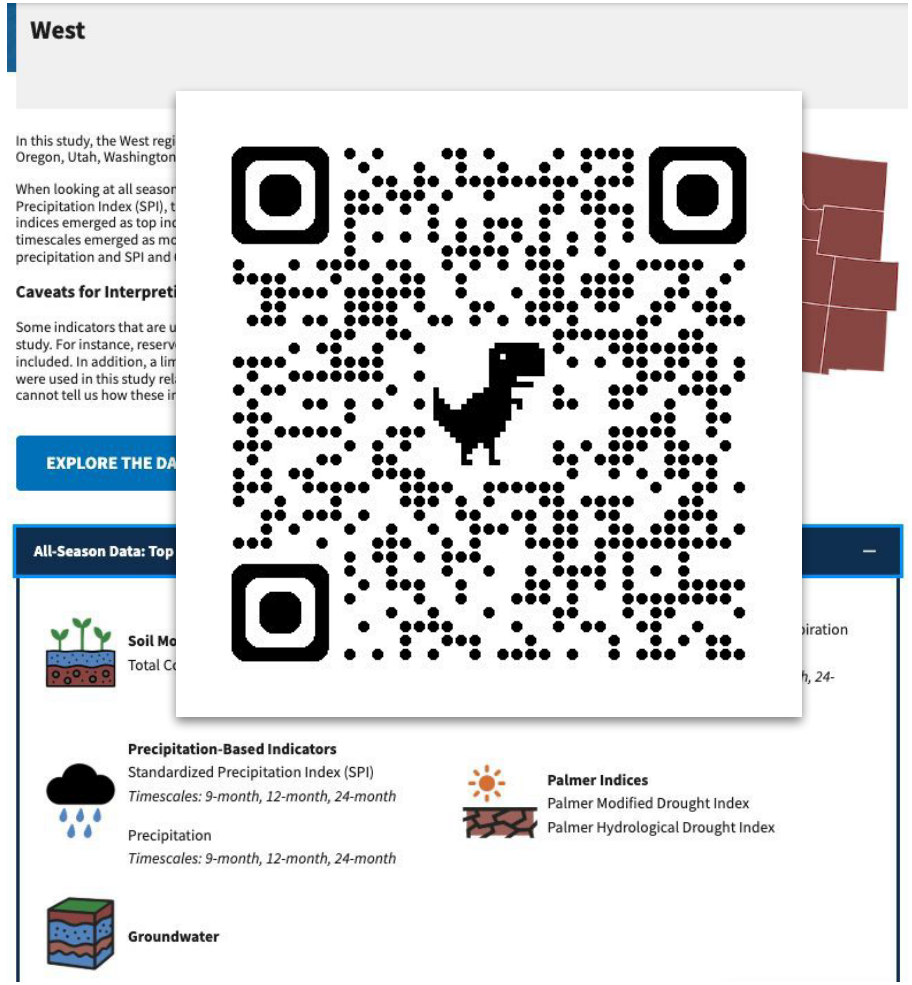
Outreach & Translation of Results

Original Results

Top 15 Indicators (All Season)



Drought.Gov Version



Thank You!

Amanda Sheffield
Regional Drought Information Coordinator
amanda.sheffield@noaa.gov

www.drought.gov

National Integrated Drought Information System

@NOAADrought



California Water Data CONSORTIUM

April 1, 2026

Drought Indicators & Metrics

Needs and Opportunities



High-Level Findings from August Data Summit Workshop



California Water Data CONSORTIUM

Key Ideas



01

1 Adaptation Capacity, Learned Behaviors and Response Capacity are Critical Metrics for Drought Resilience (& Impact)

1.1 Adaptation Capacity – how much conservation capacity is left within the local system? How diverse is the supply portfolio?

1.2 Behavioral Memory – how recent was the last drought (emergency memory "half life"), and how did the local population respond?

1.3 AMI data opens a new frontier for local drought impact predictors – can now observe real-time behavior and demand shifts, execute ET-demand coupling, and explore other demand and response signals

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2 The Right Spatial and Temporal Scale?

… It Depends

3

2.1 Local / Agency Scale: critical for indicators / metrics that impact decisions made by operators and individual water users; also important for highly groundwater-dependent systems

4

2.2 Regional and Watershed Scales: Most relevant for agencies dependent on wholesalers like MWD, and essential for collaborative State and regional efforts at long-term planning and targeted local assistance

2.3 Temporally, most indicators can be tracked at a monthly timestep, with weekly and/or daily measurements necessary only in very specific circumstances

3 Groundwater is Increasingly Taking Center Stage

4

3.1 Groundwater Levels act as drought reserves, and groundwater is both a risk and resilience indicator, depending on the context

3.2 Critical to understand the connection between surface supplies, groundwater levels and pumping

4 Economics and Water Quality are Important Drivers of Locally Felt Drought Impacts

3.1 Water quality issues can decrease effective available supply

3.2 A system can be in drought financially even when supplies are still available but too expensive → disproportionately affects smaller agencies. Indicators should reveal capacity gaps, not just exposure.

3.3 Source-locked agencies have fewer drought response options, putting them at a disadvantage as a “buyer”, and also increasing risk from any water quality-driven shortages.

The Audience



California Water Data CONSORTIUM

02

Who Benefits from Improved Metrics and Indicators?

Local Operators and Boards

Need defensible, granular indicators for decisions and public communication.

Small Systems and GSAs

Gain early warning and shared analytical capacity, and a more meaningful framing for collaboration with other local utilities and providers..

State Agencies

Avoid blunt, inequitable curtailments and provide more targeted and effective local assistance.

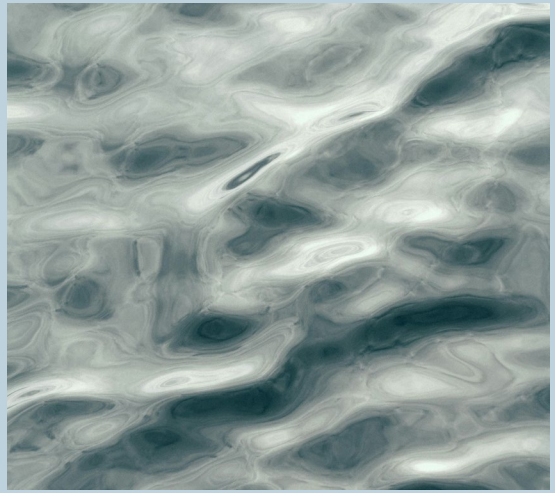
Media and the Public

More locally specific indicators are more informative for individual decisions about conservation efforts and investments.

Promising Indicator Categories



03



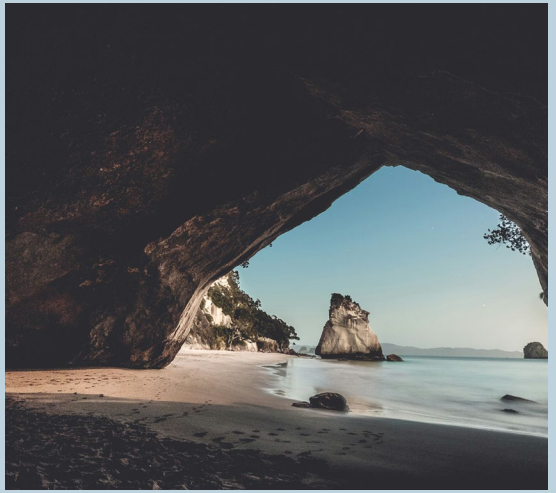
Risk

- Precipitation, snowpack, ET anomalies
- Climate forecasts (with back-testing)
- Interconnectedness / access to transfers or alternative supplies



Impact

- Storage and reserves (surface + groundwater)
- Water quality
- Affordability
- Sector-specific (ag, industrial, urban)



Resilience

- Remaining adaptation capacity
- Strength of regional collaboration
- Conservation experience / fatigue
- Historical drought memory
- AMI-based demand response
- Governance and staffing capacity

Data are Largely Available, but they are:

- Fragmented
- Inconsistently defined
- Inaccessible
- Poorly formatted

*Participants explicitly said **they do not use state-reported data for planning**, even when it contains similar information to their own internal databases.*



California Water Data Consortium

What’s Next?



04

Within the Next Year…



White Paper Contributions

Help scope the need and opportunity for more meaningful drought indicators and metrics to shape improved drought planning, assistance, response, and conservation in California.



Partnership Development*

Based in part on white paper recommendations, begin to build the collaborative muscle and partnership structure necessary to

- refine input datasets
- develop and pilot reliable metrics and indicators
- build the user interfaces and back-end APIs with which end user communities can access and integrate data, metrics and indicators.

**Dependent on funding*

California Water Data Consortium

Thank you!



Contact Us

cawaterdata.org

info@cawaterdata.org

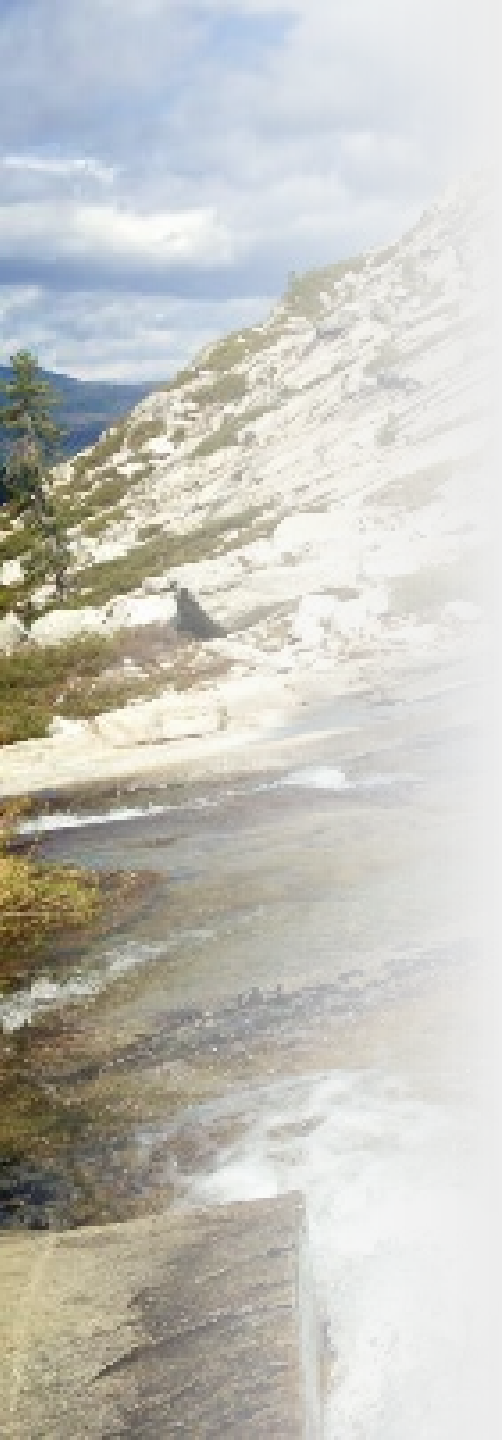
california-water-data-consortium

CAWaterData

cawaterdataconsortium

501(c)(3) nonprofit organization

An independent nonprofit formed in 2019 by state agencies and other partners.



Drought Impacts and Responses in California

Erik Porse, PhD
Hope Hauptman, PhD

California Institute for Water Resources
University of California Agriculture and Natural Resources

April 1, 2026

California Institute for Water Resources
University of California Agriculture & Natural Resources

California Institute for Water Resources (CIWR) Team



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Hope Zabronsky, Academic Coordinator, Program Manager



Divya Prakash, Research Specialist, Nitrogen and Irrigation



Erika Cassio Madrazo, Project Scientist



Sam Sandoval Solis, UC Davis Professor and UCANR Cooperative Extension Specialist, Faculty Affiliate



Erik Porse, Director, Cooperative Extension Specialist



Hope Hauptman, Project Scientist



Daniel Swain, Professional Researcher, Climate Science and Communications



Camilo Salcedo, Project Scientist



Jonathan Kaplan, Senior Economist, (Part-time) & Sacramento State Faculty



Darrene Hackler, Water and Workforce Initiatives Leader, (Part-time)

CIWR Programs

Climate Smart Agriculture Team

Community Education Specialists, located in 10 counties across California

Nitrogen and Irrigation Initiative Team

Staff Research Associates located in Central Coast and Central Valley

Students and Fellows

CIWR student employees and fellows support projects and programs in water resources

Drought Impacts

Agriculture (source: npr.org)





Ecosystems and aquatic habitat (source: CA CDFW)

Urban landscapes (source: grist.org)





Communities and Local governments (source: Water Education for Latino Leaders)

Direct

Indirect

Induced

Drought Impacts

Assessing state-funded drought relief from drought (2013-2016)

Source: California Legislative Analyst's Office

Figure 1

State Drought Response Appropriations

2013-14 Through 2016-17 (In Millions)

Activity	Amount
Water Supply	
Support groundwater management and cleanup	$843
Improve/increase water recycling, wastewater treatment, stormwater management, and desalination	609
Fund Integrated Regional Water Management projects	473
Improve drinking water infrastructure	311
Subtotal	**($2,235)**
Emergency Response	
Expand/enhance fire protection	$384
Address emergency drinking water needs	115
Provide food and other assistance to drought-affected communities and farmworkers	99
Conduct statewide drought assistance, monitoring, and response	55
Remove and dispose of dead trees	41
Monitor/enforce water rights and conservation regulations	20
Various other activities	21
Subtotal	**($734)**
Water Conservation	
Increase urban water efficiency and conservation	$126
Increase agricultural water efficiency and conservation	110
Fund innovative water efficiency technologies	30
Conduct conservation outreach and public messaging	23
Increase water efficiency at state facilities and wildlife refuges	28
Subtotal	**($287)**
Environmental Protection	
Emergency fish and stream activities	$70
Eradicate water hyacinth	4
Study and model flows	3
Subtotal	**($78)**
Total	**$3,334**

Research: How has drought affected water utility finances in California?

Regression modeling shows weak correlations of drought and water utility finances unless controlling for utility-specific factors

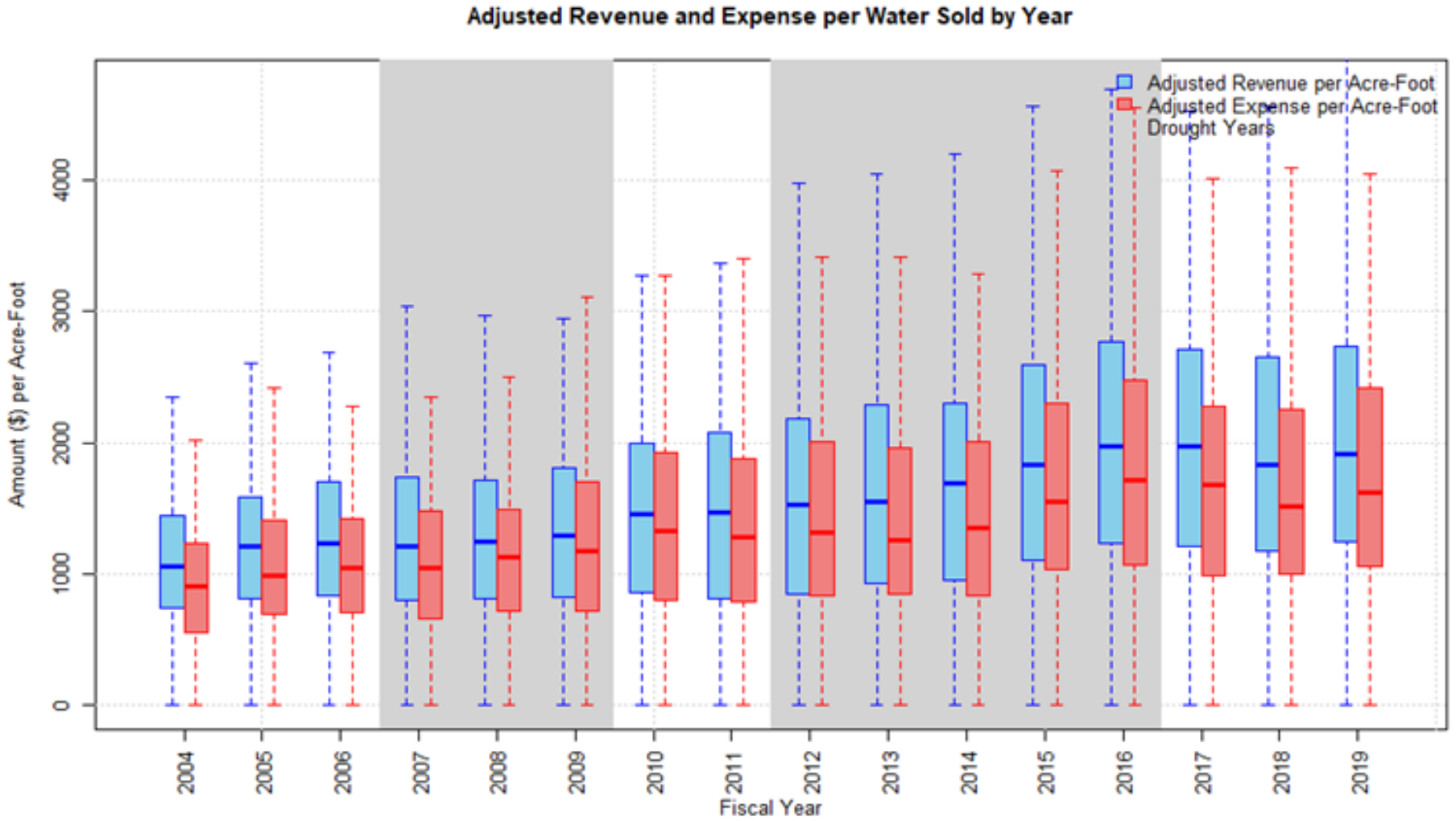
Adjusted Operating Ratio in a water system appears to decrease about 2% in drought years

$$\textbf{Adjusted Operating Ratio} = \frac{Operating\ Revenues}{Operating\ Expenses + Depreciation}$$

Where depreciation is the accrued reduction in the value of assets over time

Source: Hauptman et al (in preparation)

Research: How has drought affected water utility finances in California?



Source: Hauptman et al (in preparation)

Some Policy Insights

Drought impacts can be obvious, but are often long-term or hidden

Is there an expectation of drought relief tied to indicators?

California has methods to assess drought impacts on agriculture in CA, but methods are less consistent for cities/communities and ecosystems

Many California urban water agencies have seen increased costs from drought, but have incorporated this into planning & are recovering costs from ratepayers

Participatory methods during development lead to increased adoption



Thank You


Rio Hondo Spreading Grounds, Los Angeles, CA
Source: E. Porse

Contact

Erik Porse, eporse@ucanr.edu

Hope Hauptman, hhauptman@ucanr.edu

https://ciwr.ucanr.edu



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- **DWR**. CA Water Watch and Water Shortage Vulnerability Explorer Tool – Julie Ekstrom
- **SWB**. Div of Drinking Water forecasting community water system outages via machine learning – Eric Zuniga, Dan Wang
- **LCI**. How the State thinks about drought indicators and climate – Ben McMahan

SPOTLIGHT ON EXISTING PROGRAMS – LIGHTNING TALKS (STATE USE)

CA WATER WATCH &
WATER SHORTAGE VULNERABILITY EXPLORER TOOL

DRIP Collaborative Drought Indicators & Metrics Workshop
April 1, 2026

Julie Ekstrom
Water Justice Office
CA Dept of Water Resources

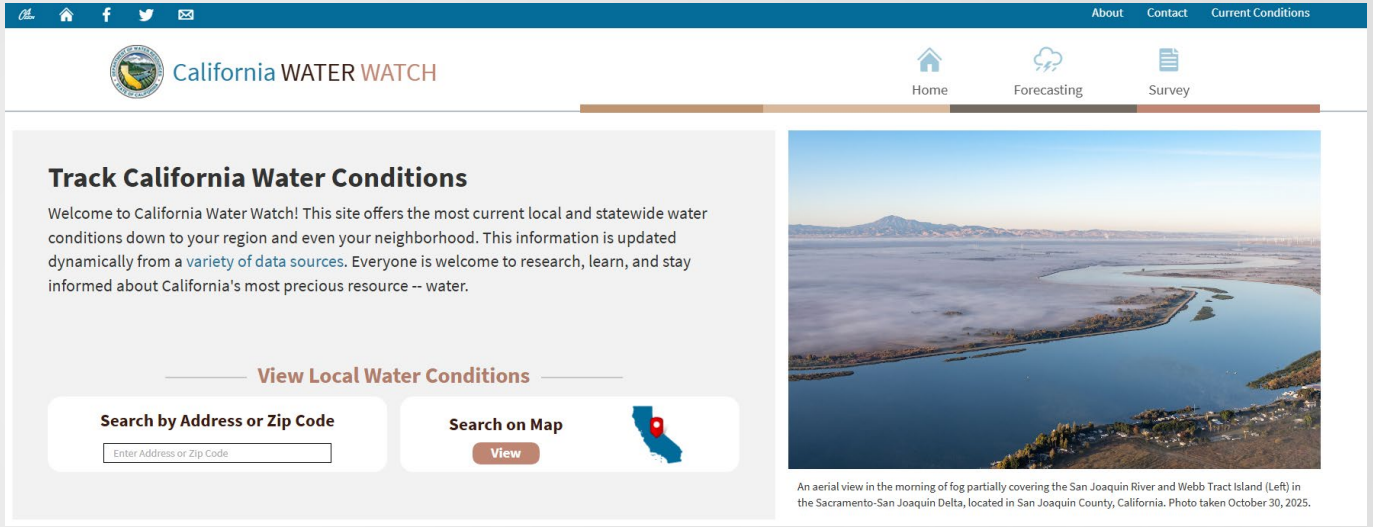
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California WATER WATCH

- 2012-2016 Drought
- Clear Gap: Publicly accessible water conditions data

- 2015: Built CA Water Watch interactive web dashboard, multiple datasets, real-time visualizations
- Hydrology real-time
- Individualized option
- Supports: Local and State decisions
- +Educational resource

- Let's take a quick tour



https://cww.water.ca.gov/

Screenshot of individual/local zoom in

California WATER WATCH

PRISM
Northwest Alliance for Computational Science and Engineering

CALIFORNIA DATA EXCHANGE CENTER
CALIFORNIA DEPARTMENT OF WATER RESOURCES

USGS
science for a changing world

NASA
National Aeronautics and Space Administration (NASA)

USDA
U.S. Department of Agriculture (USDA)

CALIFORNIA COOPERATIVE SNOW SURVEYS
CALIFORNIA DEPARTMENT OF WATER RESOURCES

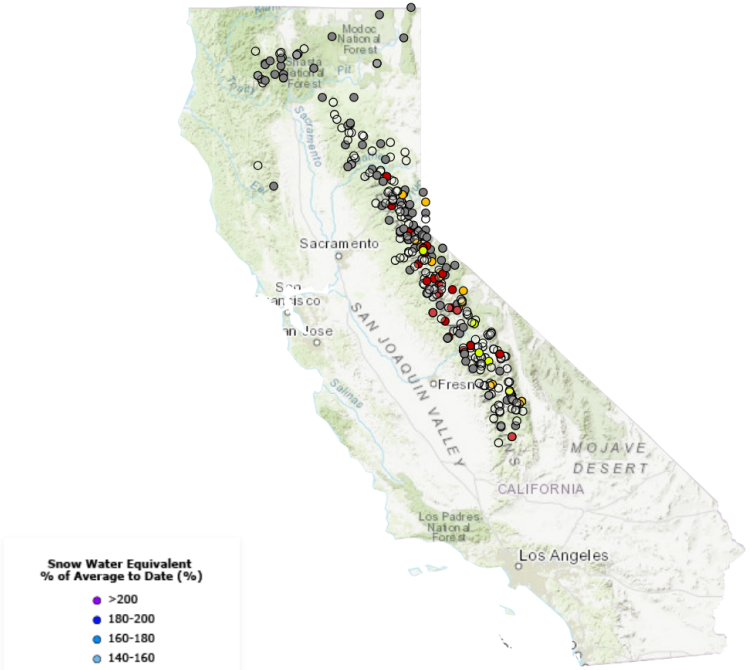
SGMA Data Viewer

NASA SPoRT

NOAA NIDIS Drought.gov
National Integrated Drought Information System

- Not drought specific
- Hydrologic-climate conditions, each as a tab
- Adds educational and contextual information (translate)
- Interactive dashboard+
- Refers user to full original indicator data source

PRECIPITATION | SNOWPACK | RESERVOIRS | GROUNDWATER | TEMPERATURE | STREAMFLOW | SOIL MOISTURE | VEGETATION

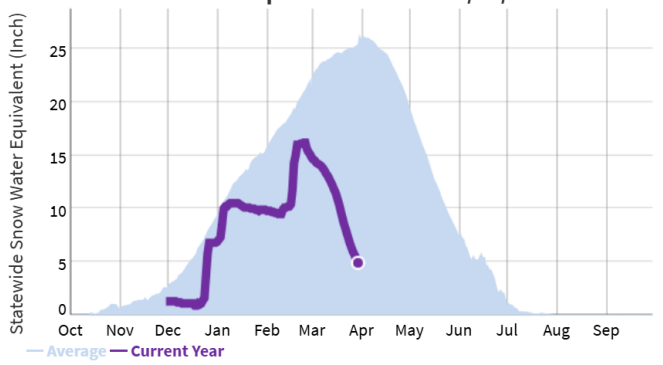


Snow Water Equivalent
% of Average to Date (%)
- >200
- 180-200
- 160-180
- 140-160
- 120-140
- 100-120
- 80-100
- 60-80
- 40-60
- 20-40
- 0-20
- No data found

Snowpack as of 03/29/2026

The map of California shows how snowpack conditions compare to the historical averages at various locations across the state. The plot below aggregates this same data to show how the cumulative statewide snowpack is tracking relative to the historical average. This allows us to see how well the snowpack is doing to date, as well as how much snow may still be needed to reach the average peak snowpack (i.e., April 1st snowpack)

Statewide Snowpack Chart as of 03/29/2026



Percent of normal to date: 18%

Percent of April 1st average: 18%

California's new Water Year began Oct. 1, 2025 and ends Sept. 30, 2026. Graphics on this site use data for WY 2025-26. To view WY 2024-25 data, visit the yearly summary page.

Track Snow Conditions >

Water Shortage Vulnerability
Indices & Explorer

Small Water Systems, Domestic Wells, and State Small Water Systems

Tool & Scoring Directive:

(1) Maintain and update continue to refine existing data and gather new data for the tool:

who

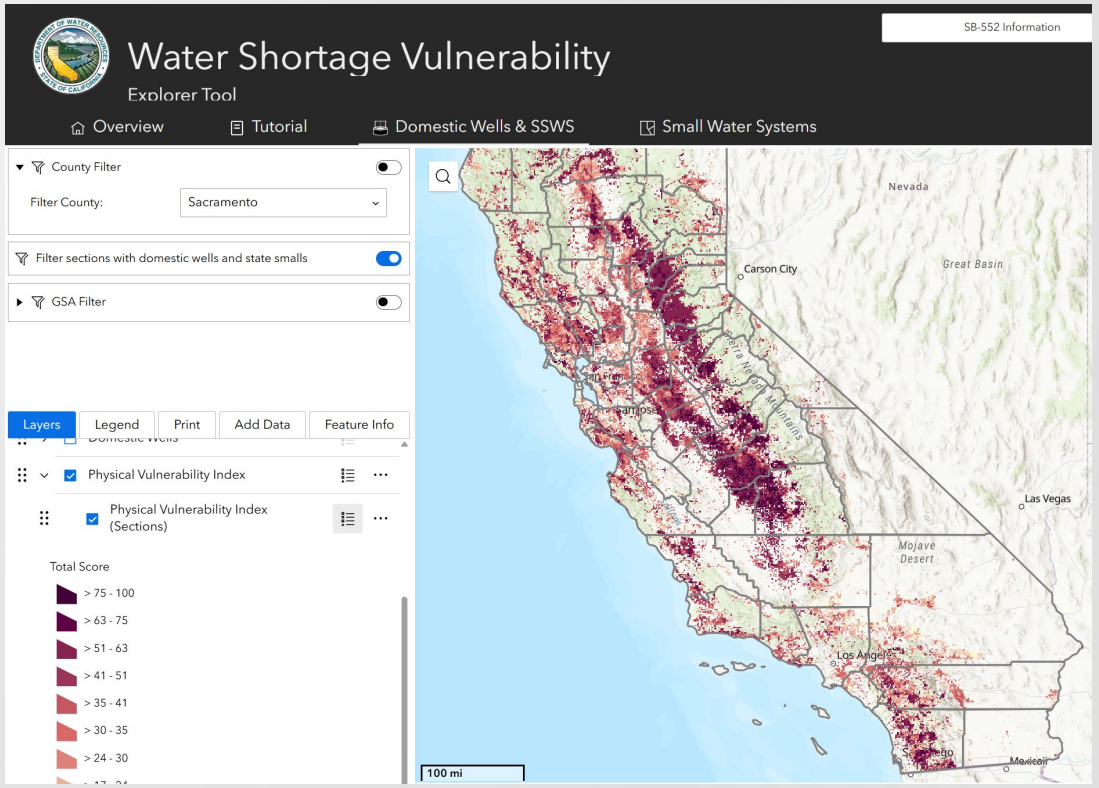
(A) Small water suppliers and nontransient noncommunity water systems serving a school.
(B) State small water systems and rural communities.
(C) Domestic wells and other self-supplied residents.

(2) Update the risk vulnerability tool for small water suppliers and rural communities periodically, by doing all of the following:

How, what

(A) Revise the indicators and construction of the scoring as more data becomes readily available.
(B) Make existing and new data publicly available on the California Open Data internet web portal.
(C) In consultation with other relevant state agencies, identify deficits in data quality and availability and develop recommendations to address these gaps..

(Water Code §10609.80. (a)



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Water Shortage Vulnerability Explorer: https://arcg.is/0jT94f2 - updated annually, designed for local planners

Water Shortage Vulnerability Explorer Timeline

2012-2016 Drought

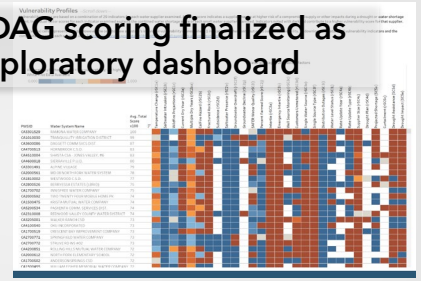
2018

AB 1668 passes, Making Conservation a Way of Life

CDAG directive to **identify rural communities & systems vulnerable** to water shortage and drought

2021 (Feb)

CDAG scoring finalized as exploratory dashboard



2021 (Sept)

SB 552 (rural-focused drought planning and preparedness) **passes with mandate** to continue updating and maintaining the tool

2023

Explorer Tool updated to directly support county planning processes and drought risk assessment development

2026

Counties completing plans now, **future development**

- Next: should it go beyond a big picture drought risk assessment planning tool?

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Ingredients

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CASGEM

CA Governor's Office of Land Use and Climate Innovation

PRISM Northwest Alliance for Computational Science and Engineering

Dry Well Reporting System

CAL FIRE SINCE 1885

USGS science for a changing world

CALIFORNIA Water Boards

SAFER DRINKING WATER

CDC U.S. CENTERS FOR DISEASE CONTROL AND PREVENTION

United States® Census Bureau

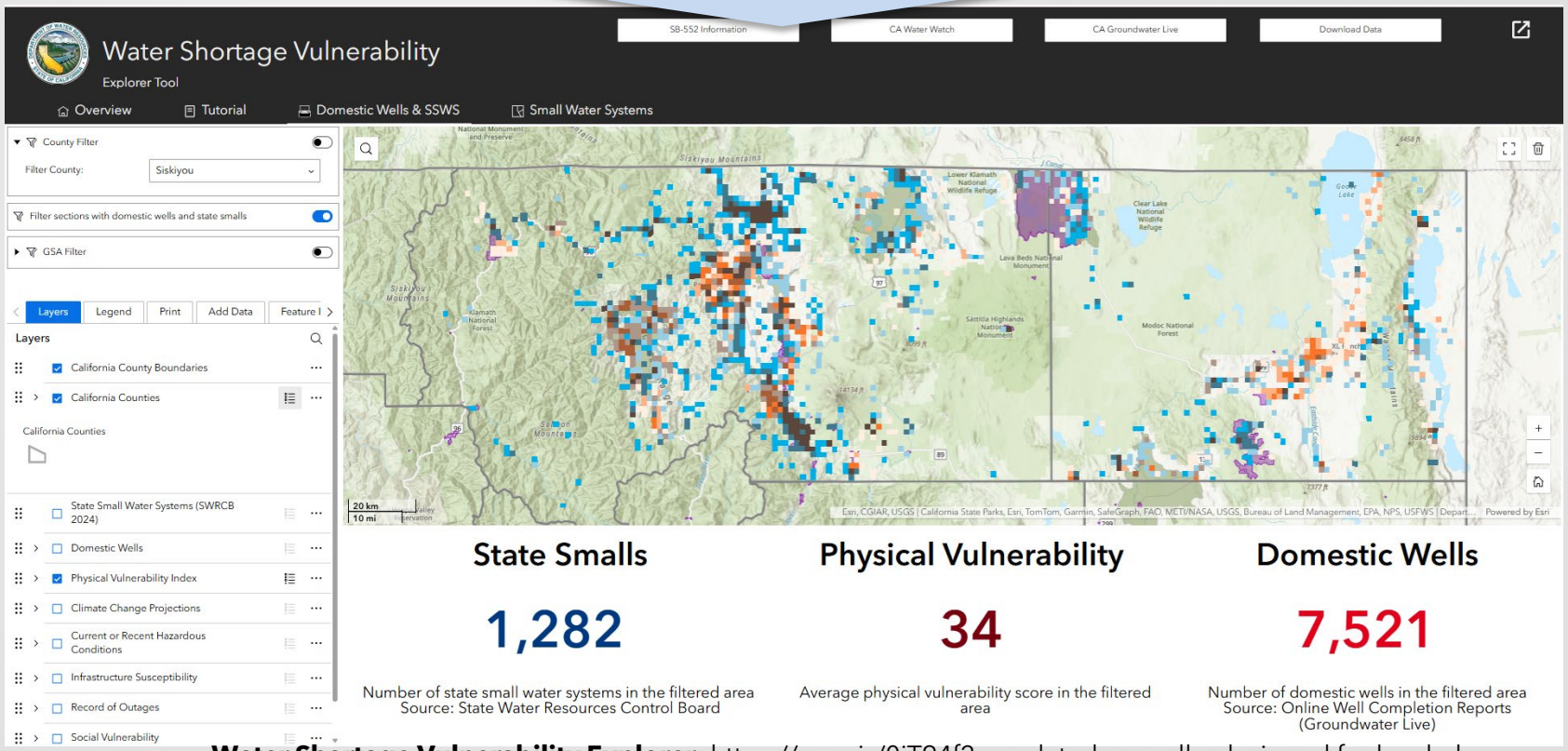
Scoring

Indicators-based composite metrics of water shortage vulnerability

- Domestic Wells & State Smalls
- Small Water Systems

Tool

The online shell to explore the scoring along with other information



Water Shortage Vulnerability Explorer: https://arcg.is/0jT94f2 - updated annually, designed for local planners

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Water Shortage Vulnerability Explorer

Small water systems, domestic wells, and state small water systems

- Helps to fill what was a gap to understand vulnerabilities across rural communities
- Largely a planning tool to date
- Static composite scoring
- Continues by mandate, next steps…



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Forecasting Community Water System Outages

The Evolution of Predictive Analytics at the State Water Board using drought indicies

ERIC ZÚÑIGA, P.E. & DAN WANG
Division of Drinking Water – State Water Resources Control Board
DRIP Collaborative Drought Indicators - 4/1/2026

The Definition of Success

Transitioning from reactive crisis management to proactive, predictive drought resilience using localized drought indicators.

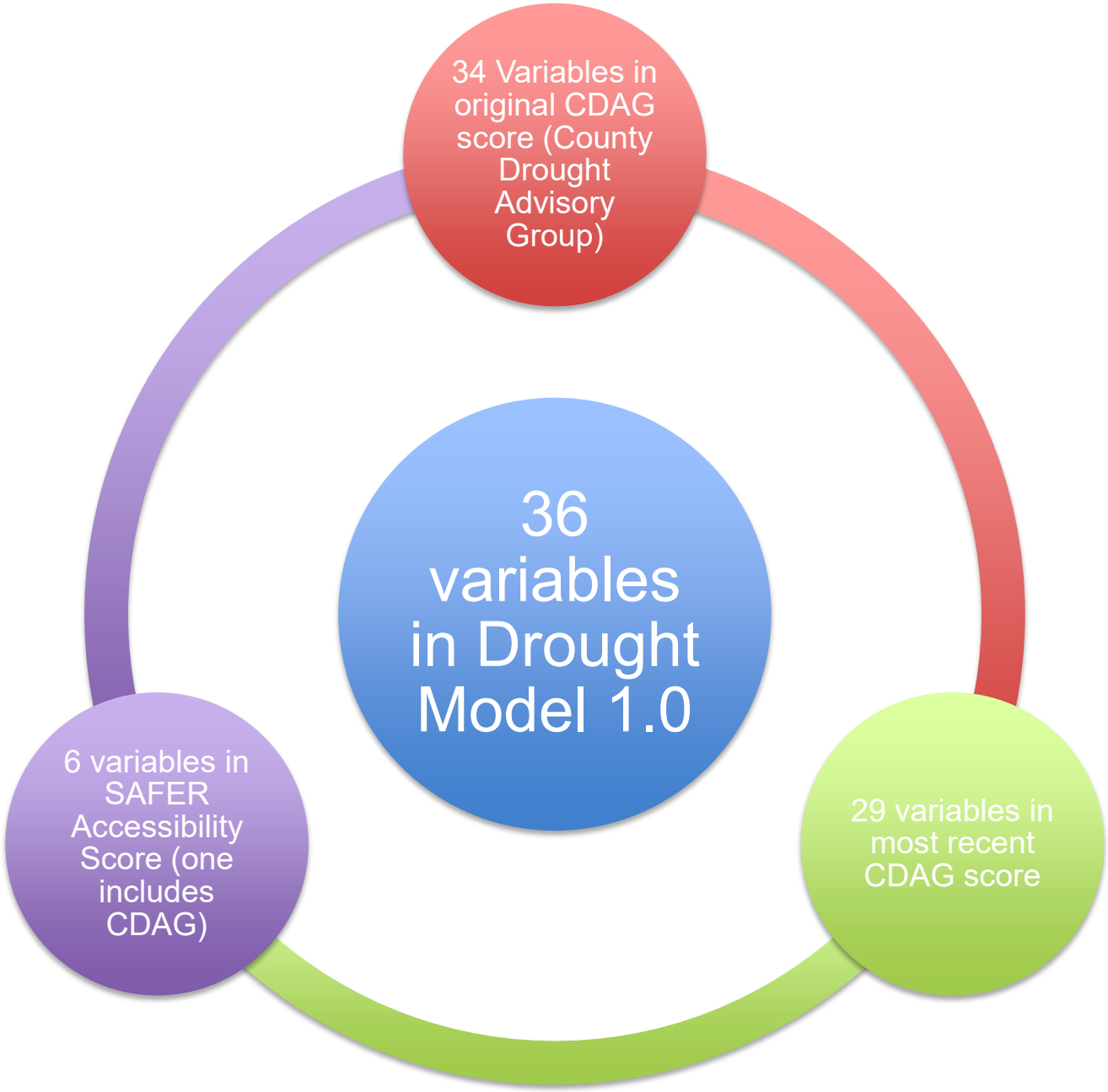
"Success is defined by our ability to proactively anticipate water system failures before they manifest as crises."

DROUGHT RESPONSE PROGRAM
OPERATIONAL OBJECTIVE

Version 1: The Paradigm Shift

- **The Limitation of Tradition:** Historically, we relied on manual risk scoring. While human intuition is valuable, this method was highly subjective and resource-intensive to execute at a statewide scale.
- **The Machine Learning Transition:** To overcome this, we adopted a supervised machine learning approach, specifically deploying a Random Forest model architecture.
- **The Objective:** Objectively evaluate nearly 2,900 community water systems against dozens of feature variables to predict drought impact vulnerability.




34 Variables in original CDAG score (County Drought Advisory Group)
36 variables in Drought Model 1.0
6 variables in SAFER Accessibility Score (one includes CDAG)
29 variables in most recent CDAG score

Version 1: The Reality Check (2022)

510

SYSTEMS FORECASTED IMPACTED

123

ACTUAL IMPACTED SYSTEMS

A Lesson in Statistical Conservatism

While our initial model successfully identified vulnerable systems, it was highly conservative. We incorrectly flagged hundreds of safe systems.

This was a natural, albeit inefficient, byproduct of attempting to minimize false negatives—ensuring absolutely no truly vulnerable community slipped through the cracks. We required a much more refined approach.

Version 2: The CalData Collaboration

Partnering with the Office of Data & Innovation (ODI) Data Science Accelerator to address operational hurdles.

Solving Efficiency & Integration

Challenge 1: Efficiency

We moved away from heavy reliance on static variables and single-use modeling. We built a sustainable, lightweight model focused on dynamic variables that can execute in seconds and run continuously throughout the year.

Challenge 2: New Data Integration

Many legacy datasets require intensive manual cleaning. Our new architecture is designed for a continuous feedback loop, allowing the model to independently learn and refine its predictions as new, disparate data sources are introduced.



Challenge 3: Solving Explainability



Fair

Implemented through an "Ethics Toolkit," we ensured the forecasts are fundamentally unbiased and do not inadvertently discriminate against underrepresented or under-resourced community groups.



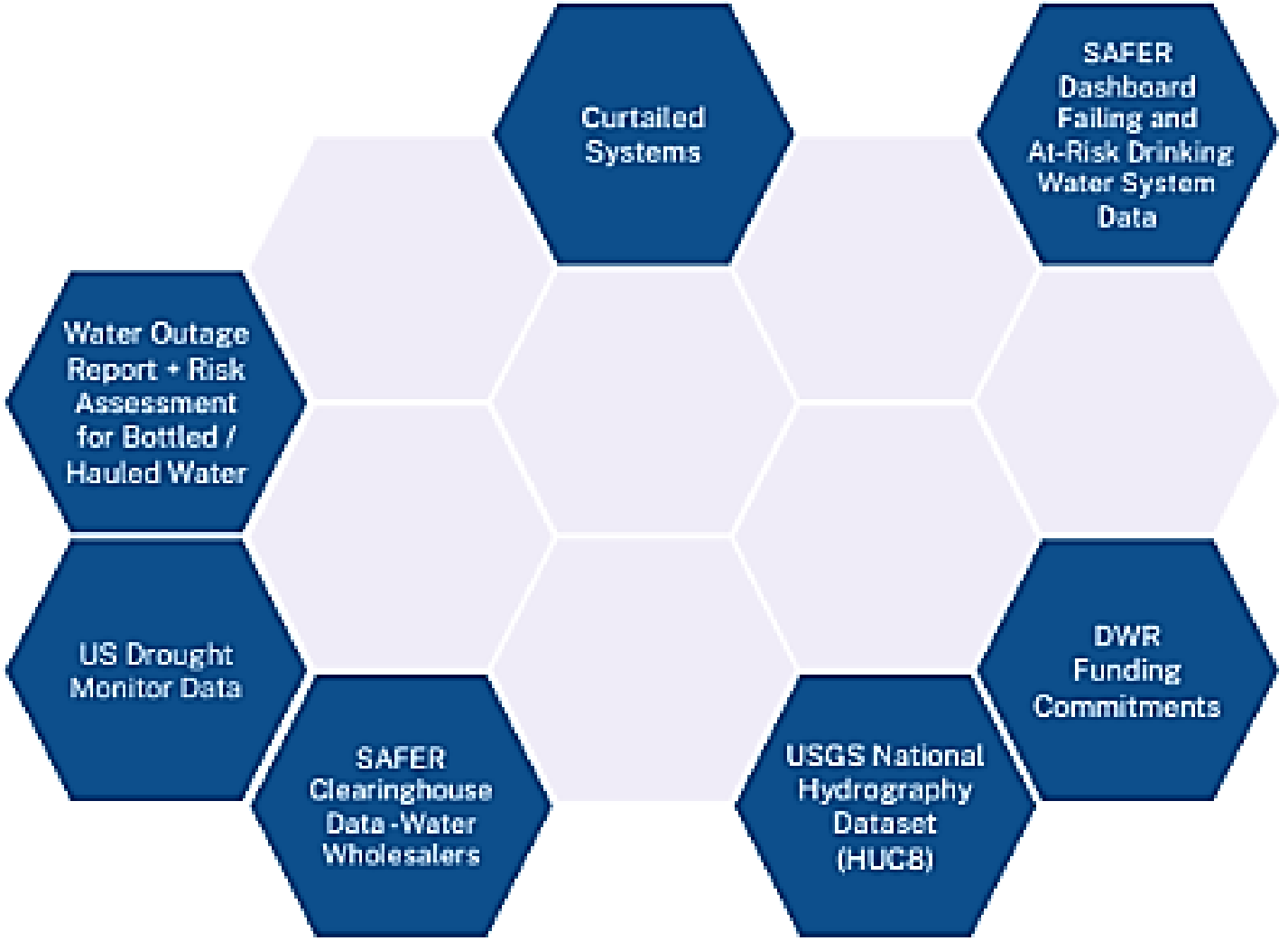
Useable

A prediction is useless without context. The model is designed to provide highly specific, helpful, and actionable information directly to qualified state and local reviewers.



Trustworthy

We developed a "Counterfactuals" tool. This explicitly shows a water system exactly which variables are driving their risk percentage, empowering them to craft individualized mitigation strategies.


Curtailed Systems
SAFER Dashboard Failing and At-Risk Drinking Water System Data
Water Outage Report + Risk Assessment for Bottled / Hauled Water
US Drought Monitor Data
SAFER Clearinghouse Data -Water Wholesalers
USGS National Hydrography Dataset (HUC8)
DWR Funding Commitments

Bridging the Gaps: Our Path Forward



Modern Data Platform

To support advanced modeling, we must develop a centralized database paired with automatic tools that rigorously check for data quality and errors.



Continuous Data

We cannot rely solely on crisis data. We must proactively and continually collect time-varying data on a frequent cadence, not just during defined drought years.



Granular Indicators

National, county-level indices are insufficient for local planning. We require a California-specific, highly granular hazard indicator to feed our system of experts.

Version 3: The System of Experts

Transitioning from a monolithic algorithm to an advanced, multi-tiered machine learning architecture.

Multi-Tiered Predictive Logic

Tier 1: Atmospheric

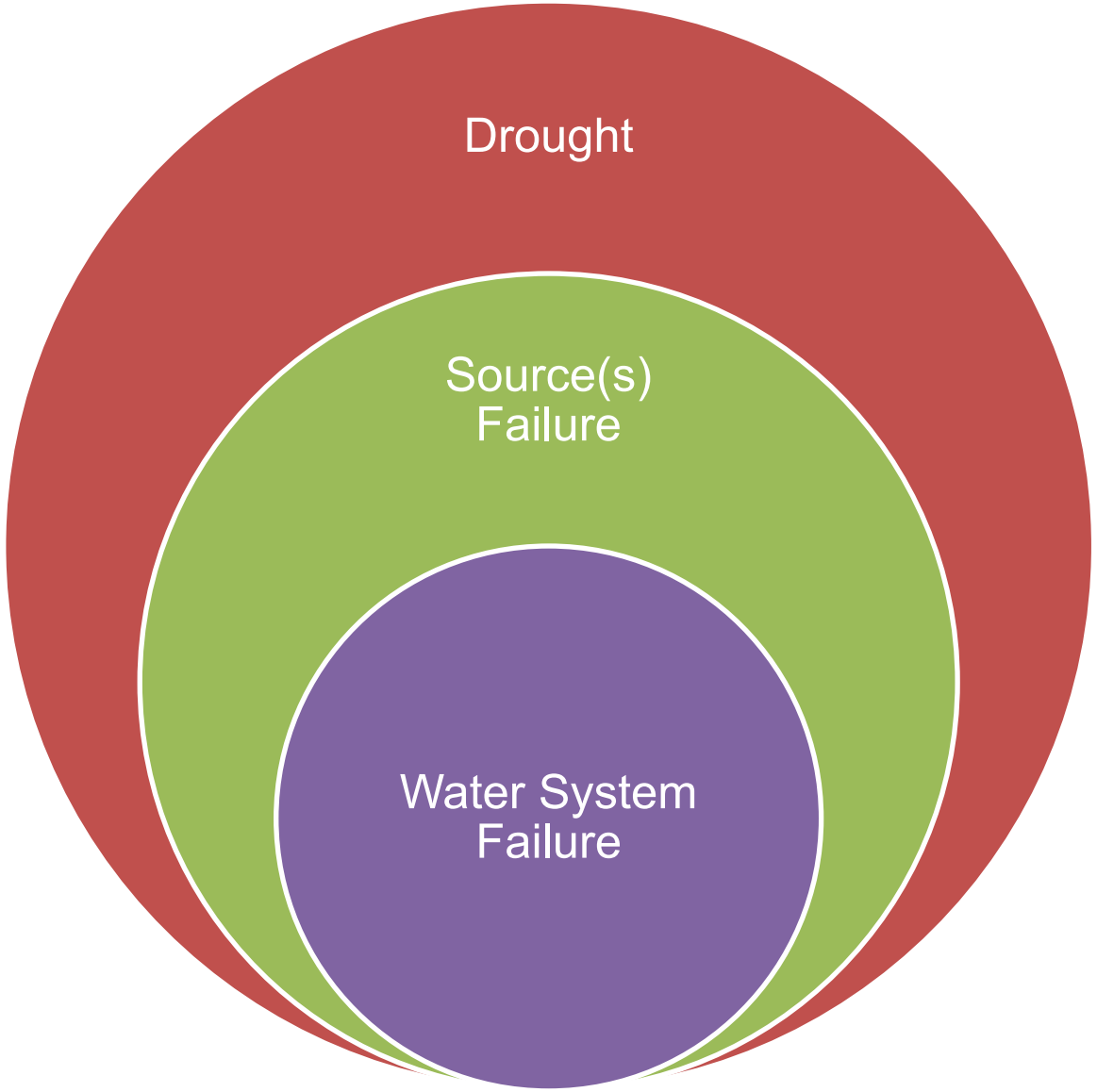
Predicts the specific meteorological and atmospheric changes induced by overarching drought conditions.

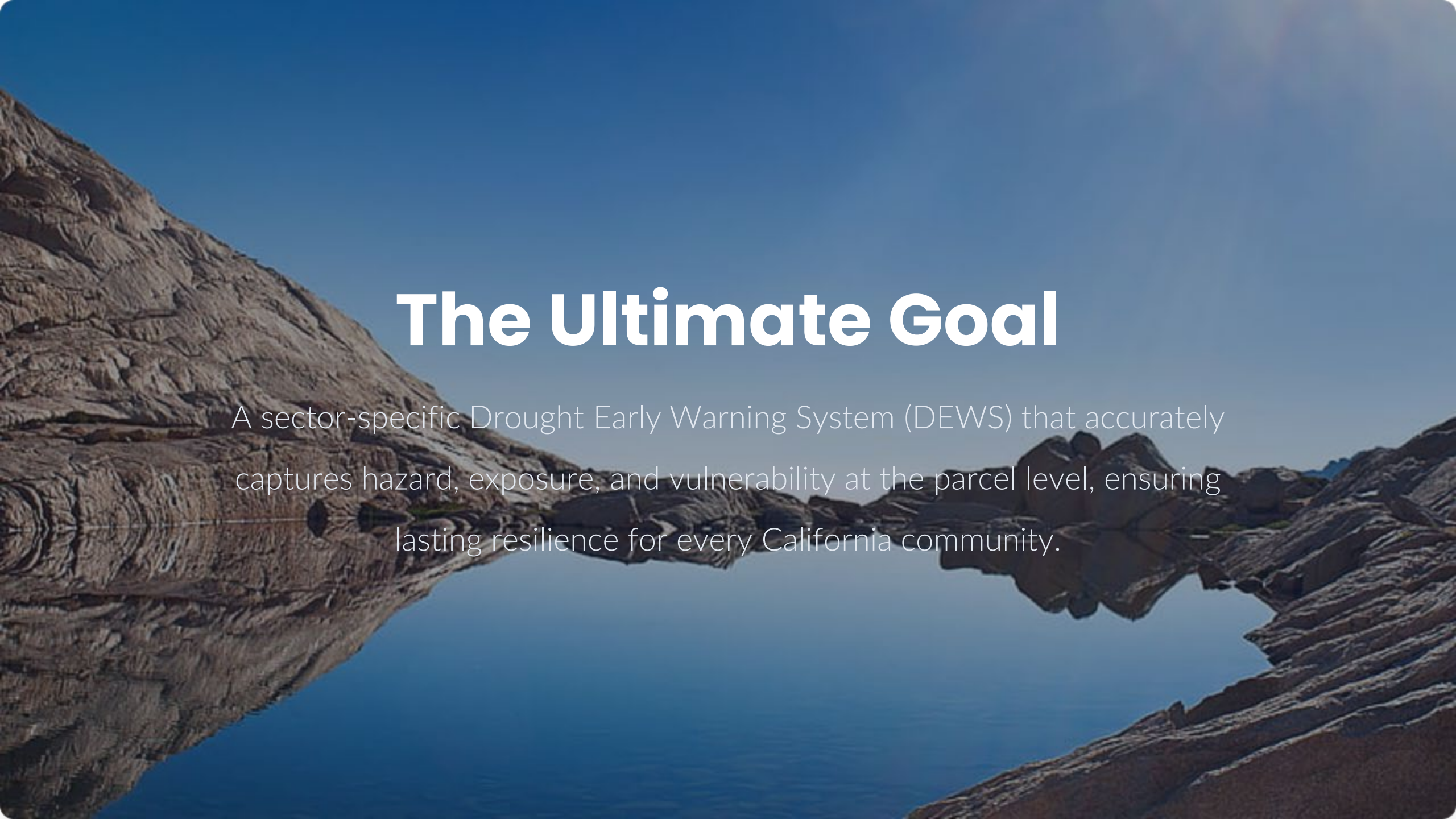
Tier 2: Source Failure

Analyzes Tier 1 outputs to determine the highly localized probability of failure for specific groundwater basins or surface water sources.

Tier 3: Portfolio Risk

Evaluates a community water system's entire portfolio of sources to determine the conclusive probability of a total system outage.


Drought
Source(s)
Failure
Water System
Failure



The Ultimate Goal

A sector-specific Drought Early Warning System (DEWS) that accurately captures hazard, exposure, and vulnerability at the parcel level, ensuring lasting resilience for every California community.

RECAP: PRESENTATIONS (HIGH-LEVEL VIEW)

Project	Hazard	Exposure	Vulnerability	Thresholds	Actions	Impacts
UC Davis DEW	Yes	Yes	Yes	D-Scale	Via Decision Support Tools	Yes (in process)
NOAA NIDIS SoCal Pilot	Yes	Yes	Future Scenarios	Yes	Informs Response Strategies	Sectoral Impacts
CWDC Drought Data	Yes	Yes	Yes	Yes	Yes	No
UC ANR / CIWR						**Yes**
DWR Vulnerability Explorer	Yes	Yes	Physical/Social	Via County Drought Resilience Plans	Via County Drought Resilience Plans	No
SWB Outage Forecast Predictor	Yes	Yes	Physical/Process	Flag for "High Risk"	Yes	No
LCI Drought and VCP	Yes	Yes	Population/Health	No	No	No

WORKING SESSION
– GAP ANALYSIS AND POSSIBLE OPPORTUNITIES

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DI&M: QUOTES (GAPS/OPPORTUNITIES)

"We need to start with practitioner needs, not indicators. How do we link this to decisions, such as supply and demand assessments and curtailments. We need a framework to think through metric types." Robyn G and Alyssa S (CWDC)

"We're focused on anticipating water system failures. We would ideally have a drought hazard indicator akin to US Drought Monitor, but ***locally relevant and CA specific****. That and more funding."* Eric Z (SWRCB)

"Some of the biggest gaps today are in ***impacts*** *and links to* ***cascading hazards****, such as wildfire. We also need better predictions, such as snow and short-term, physics-based predictions."* Amir A and Phu N (UC Irvine)

"We need impact metrics mapped to ***unique end users****. How do we ensure the most relevant indicators are clear for each audience? Sort of like a guidebook for most key inputs (or recipe for key ingredients)."* Ben M (LCI)

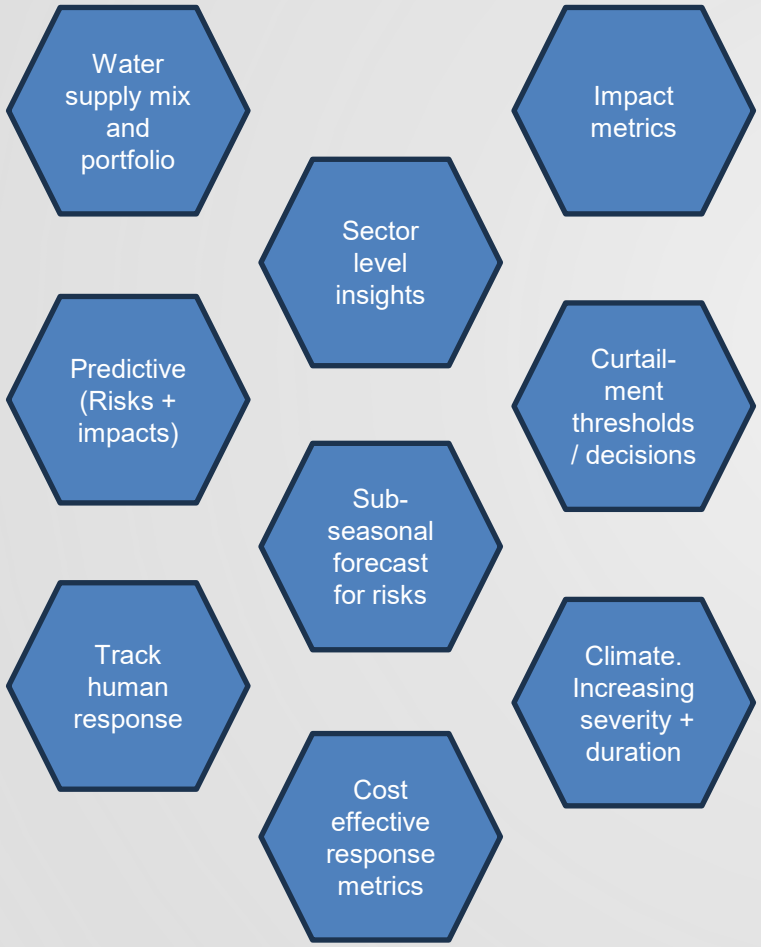
"A key opportunity is for us to really define what is great ***sector level engagement****. We know granular sector indicators are needed, but how do we create those so they are usable, useful and used?"* Amanda S and Andy N (NIDIS)

"We need more ***impact metrics****, especially on the agriculture side. Similar with cities and drinking water, including affordability. Financials and multi-benefit need a link as well."* Erik P (UN ANR)

DI&M: POSSIBLE GAPS, KEY CONSIDERATIONS

Sample Gaps

FOR DISCUSSION
(Many possible combinations possible, each aimed at different audiences)



Key Considerations

1. **Early warning**. Ideally a DEWS exist, but what exactly do you gain with "early" warning?

2. **Audience**. The critical dimension is "end user" (practitioner needs). Every indicator needs to create value for a particular decision maker or stakeholder. Trust and credibility is key

3. **Spatial/temporal**. There is no "single" spatial or temporal scale. Needs to be "fit for purpose". Answers will likely span from agency to full watershed (dynamic view of watersheds).

4. **Costs/effort**. What resources are required to produce that indicator?

5. **Equitable**. Will all stakeholders benefit? Who bears the cost of ensuring an indicator is possible? How does this affect smaller agencies or communities?

WORKING SESSION
– BRAINSTORM PRIORITIES FOR 2026

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DI&M WHITE PAPER: KEY QUESTIONS TO ANSWER

1. **Vision**. What is the appropriate DI&M vision for California?

2. **Current Conditions (and Audience)**. What is the current landscape of drought tools and portals? Who are the various intended end users and what are their needs?

3. **Inventory**. What are the existing indicators? Can we create a master inventory list of indicators, identify key gaps, and plan out the path forward to ensure sufficient (spatial / temporal) coverage?

4. **Datasets**. What datasets are needed to achieve those indicators? Which ones exist already? What additional data needs to be gathered?

5. **Roadmap**. What defines success in 3 years (short-term)? Next 5 years (medium-term)?

6. **Funding/Resources**. What type of investment is needed to achieve the roadmap? What types of resources and expertise is needed?

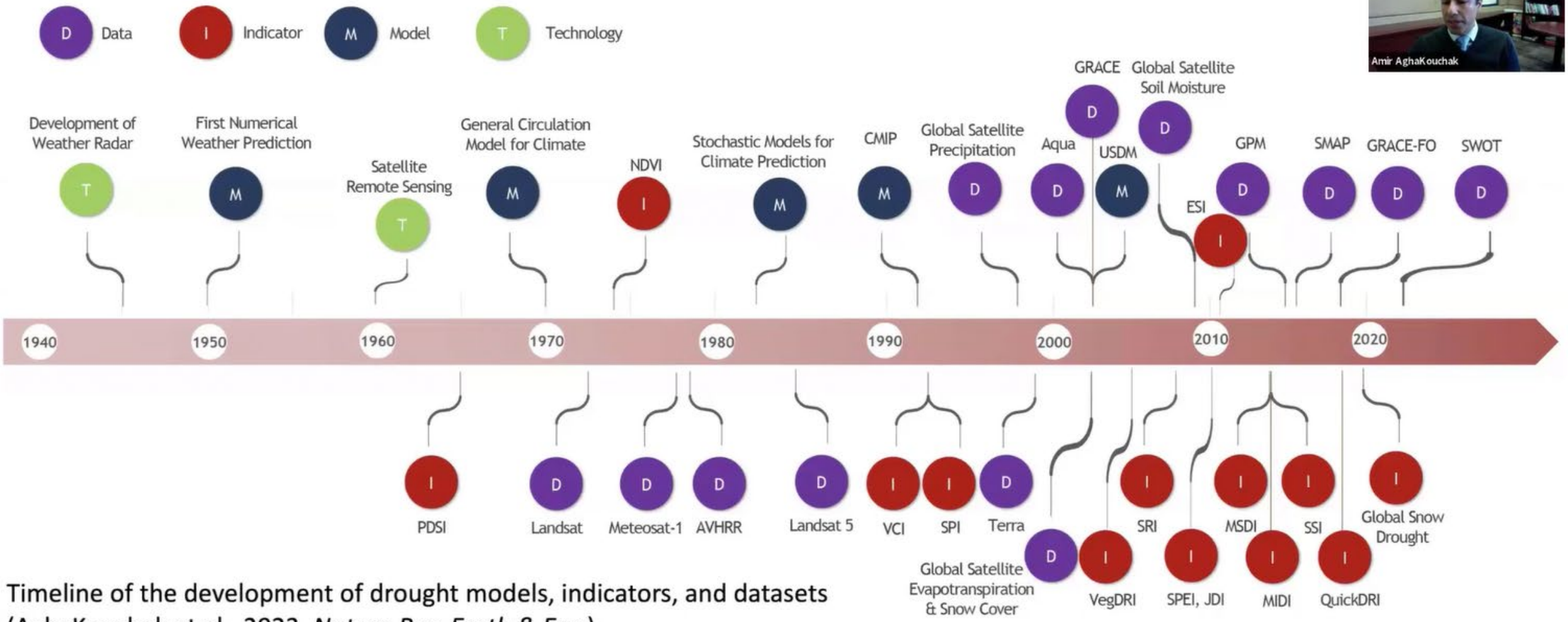
7. **Organizations and Hosting**. What organizations needs to be involved? Who should lead the effort? Who will play what role in hosting and being authoritative sources for indicators?

MASTER LIST OF METRICS/INDICATORS – GETTING READY FOR WORKSHOP 2

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DI&M: BROADER CONTEXT (NOT CA SPECIFIC)





Timeline of the development of drought models, indicators, and datasets (AghaKouchak et al., 2023, *Nature Rev. Earth & Env.*)

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Timeline is taken from this Webinar (with Professor Amir AghaKouchak, UC Irvine):
Beyond Drought Monitoring: Assessing Water-Resource Vulnerability

TOWARD IMPACT-BASED MONITORING

nature reviews earth & environment https://doi.org/10.1038/s43017-023-00457-2

Perspective Check for updates

Toward impact-based monitoring of drought and its cascading hazards

Drought indicator	Drought Type	Category	Use or Limitation
Palmer Drought Severity Index (PDSI[1])	Meteorological	S	PDSI information from different climate regions often cannot be compared as it is a non-standardized index.
Normalized Difference Vegetation Index (NDVI[2])	Ecological, Agricultural	C	It is a proxy that provides information on vegetation stress based on vegetation color. NDVI values from different environments cannot be easily compared.
Standardized Precipitation Index (SPI[3])	Meteorological	S	The most widely used standardized index that allows comparing droughts in different regions. Provides probabilistic drought severity information.
Vegetation Condition Index (VCI[4])	Ecological, Agricultural	C	It is a proxy that provides information on vegetation stress based on vegetation color. VCI values from different environments cannot be easily compared.
Percent of Normal Precipitation (PNP[5])	Meteorological	S	A simple index that shows deviation of precipitation from normal. Cannot be used to generate consistent probabilistic drought severity information in regions with very different climates.
Climatic Water Balance (CWB[6])	Meteorological, Hydrological	C	A water balance approach with multiple components. Cannot be used to generate consistent probabilistic drought severity information in regions with very different climates.
Vegetation Drought Response Index (VegDRI[7])	Ecological, Agricultural	C	A composite model-based indicator with operational applications. Cannot be used to generate consistent probabilistic drought severity information in regions with very different climates
Standardized Runoff Index (SRI[8])	Hydrological	S	The most widely used standardized index that allows comparing hydrologic drought based on runoff data. Provides probabilistic drought severity information. In places where runoff is heavily regulated, SRI may not be very informative.
Standardized Precipitation-Evapotranspiration Index (SPEI[9])	Meteorological	C	Widely used indicator that goes beyond precipitation for meteorological drought. Method of evapotranspiration estimation significantly affect SPEI estimation.
Joint Drought Index (JDI[10])	Multiple	C	Integrates precipitation and streamflow using a multivariate approach. In places where runoff is heavily regulated, SRI may not be very informative.
Evaporative Stress Index (ESI[11])	Agricultural, Meteorological	C	Widely used for describing flash drought and also stress on ecosystem and agriculture.
Multivariate Standardized Drought Index (MSDI[12])	Agricultural, Meteorological	C	Integrates precipitation and soil moisture for composite drought monitoring. Requires long-term records for reliable multivariate drought assessment.
Standardized Soil Moisture Index (SSI[12])	Agricultural	S	A standardized index that allows comparing droughts in different regions. Provides probabilistic drought severity information. Lack of reliable soil moisture information is a major limitation.
Microwave Integrated Drought Index (MIDI[13])	Multiple	C	Designed for integrating remotely sensed observations. It does not provide spatially consistent probabilistic drought severity information.
Rapid Change Index (RCI[14])	Ecological, Agricultural	C	Estimates accumulated magnitude of moisture stress changes and used as an indicator of flash drought.
Standardized Relative Humidity Index (SRHI[15])	Meteorological	S	A standardized index that allows comparing droughts in different regions. Provides probabilistic drought severity information. High SRHI values do not indicate lack of drought as high humidity does not necessarily translate to precipitation. SRHI may show the onset of meteorological drought before precipitation signal.
Multivariate Standardized Reliability and Resilience Index (MSRRI[16])	Anthropogenic, Socioeconomic	C	Combines climate information (top-down) with local water use and storage (bottom-up). It requires long-term records of water demand and storage that may not be available.
Evaporative Demand Drought Index (EDDI[17])	Meteorological, Ecological	C	It measures anomalies in the atmospheric evaporative demand across different scales. It can be used as an indicator of flash drought.
Quick Drought Response Index (QuickDRI[18])	Ecological, Agricultural	C	A composite model-based indicator with operational applications. Cannot be used to generate consistent probabilistic drought severity information in regions with very different climates.
Standardized Snow Water Equivalent Index (SWEI[19])	Hydrological	S	A standardized index that allows comparing droughts in different regions. Provides probabilistic drought severity information. Relies on SWE at a certain time (i.e., it does not track snow evolution during the entire snow season).

Supplementary table 1. A non-exhaustive selection of drought indices, their characteristics and limitations. Drought indicator category is represented with an S (a single drought indicator) or a C (a composite, multivariate or multi-variable indicator).

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HANDBOOK OF DROUGHT INDICATORS AND INDICES

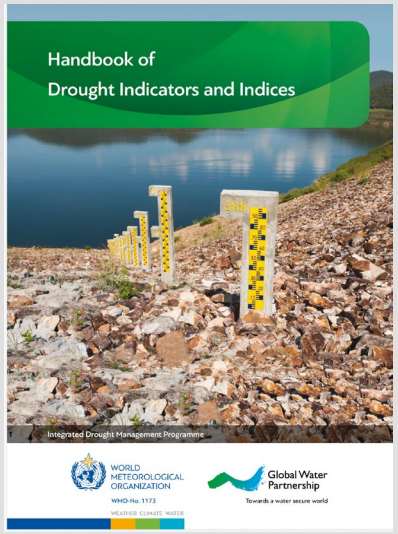


Table 1. Indicators and indices listed in this handbook

Meteorology	*Page*	*Ease of use*	*Input parameters*	*Additional information*
Aridity Anomaly Index (AAI)	11	Green	P, T, PET, ET	Operationally available for India
Deciles	11	Green	P	Easy to calculate; examples from Australia are useful
Keetch–Byram Drought Index (KBDI)	12	Green	P, T	Calculations are based upon the climate of the area of interest
Percent of Normal Precipitation	12	Green	P	Simple calculations
Standardized Precipitation Index (SPI)	13	Green	P	Highlighted by the World Meteorological Organization as a starting point for meteorological drought monitoring
Weighted Anomaly Standardized Precipitation (WASP)	15	Green	P, T	Uses gridded data for monitoring drought in tropical regions
Aridity Index (AI)	15	Yellow	P, T	Can also be used in climate classifications
China Z Index (CZI)	16	Yellow	P	Intended to improve upon SPI data
Crop Moisture Index (CMI)	16	Yellow	P, T	Weekly values are required
Drought Area Index (DAI)	17	Yellow	P	Gives an indication of monsoon season performance
Drought Reconnaissance Index (DRI)	17	Yellow	P, T	Monthly temperature and precipitation are required
Effective Drought Index (EDI)	18	Yellow	P	Program available through direct contact with originator
Hydro-thermal Coefficient of Selyaninov (HTC)	19	Yellow	P, T	Easy calculations and several examples in the Russian Federation
NOAA Drought Index (NDI)	19	Yellow	P	Best used in agricultural applications
Palmer Drought Severity Index (PDSI)	20	Yellow	P, T, AWC	Not green due to complexity of calculations and the need for serially complete data
Palmer Z Index	20	Yellow	P, T, AWC	One of the many outputs of PDSI calculations
Rainfall Anomaly Index (RAI)	21	Yellow	P	Serially complete data required
Self-Calibrated Palmer Drought Severity Index (sc-PDSI)	22	Yellow	P, T, AWC	Not green due to complexity of calculations and serially complete data required
Standardized Anomaly Index (SAI)	22	Yellow	P	Point data used to describe regional conditions
Standardized Precipitation Evapotranspiration Index (SPEI)	23	Yellow	P, T	Serially complete data required; output similar to SPI but with a temperature component
Agricultural Reference Index for Drought (ARID)	23	Red	P, T, Mod	Produced in south-eastern United States of America and not tested widely outside the region
Crop-specific Drought Index (CSDI)	24	Red	P, T, Td, W, Rad, AWC, Mod, CD	Quality data of many variables needed, making it challenging to use
Reclamation Drought Index (RDI)	25	Red	P, T, S, RD, SF	Similar to the Surface Water Supply Index, but contains a temperature component

Soil moisture	*Page*	*Ease of use*	*Input parameters*	*Additional information*
Soil Moisture Anomaly (SMA)	25	Yellow	P, T, AWC	Intended to improve upon the water balance of PDSI
Evapotranspiration Deficit Index (ETDI)	26	Red	Mod	Complex calculations with multiple inputs required
Soil Moisture Deficit Index (SMDI)	26	Red	Mod	Weekly calculations at different soil depths; complicated to calculate
Soil Water Storage (SWS)	27	Red	AWC, RD, ST, SWD	Owing to variations in both soil and crop types, interpolation over large areas is challenging

Hydrology	*Page*	*Ease of use*	*Input parameters*	*Additional information*
Palmer Hydrological Drought Severity Index (PHDI)	27	Yellow	P, T, AWC	Serially complete data required
Standardized Reservoir Supply Index (SRSI)	28	Yellow	RD	Similar calculations to SPI using reservoir data
Standardized Streamflow Index (SSFI)	29	Yellow	SF	Uses the SPI program along with streamflow data
Standardized Water-level Index (SWI)	29	Yellow	GW	Similar calculations to SPI, but using groundwater or well-level data instead of precipitation
Streamflow Drought Index (SDI)	30	Yellow	SF	Similar calculations to SPI, but using streamflow data instead of precipitation
Surface Water Supply Index (SWSI)	30	Yellow	P, RD, SF, S	Many methodologies and derivative products are available, but comparisons between basins are subject to the method chosen
Aggregate Dryness Index (ADI)	31	Red	P, ET, SF, RD, AWC, S	No code, but mathematics explained in the literature
Standardized Snowmelt and Rain Index (SMRI)	32	Red	P, T, SF, Mod	Can be used with or without snowpack information

Remote sensing	*Page*	*Ease of use*	*Input parameters*	*Additional information*
Enhanced Vegetation Index (EVI)	32	Green	Sat	Does not separate drought stress from other stress
Evaporative Stress Index (ESI)	33	Green	Sat, PET	Does not have a long history as an operational product
Normalized Difference Vegetation Index (NDVI)	33	Green	Sat	Calculated for most locations
Temperature Condition Index (TCI)	34	Green	Sat	Usually found along with NDVI calculations
Vegetation Condition Index (VCI)	34	Green	Sat	Usually found along with NDVI calculations
Vegetation Drought Response Index (VegDRI)	35	Green	Sat, P, T, AWC, LC, ER	Takes into account many variables to separate drought stress from other vegetation stress
Vegetation Health Index (VHI)	35	Green	Sat	One of the first attempts to monitor drought using remotely sensed data
Water Requirement Satisfaction Index (WRSI and Geo-spatial WRSI)	36	Green	Sat, Mod, CC	Operational for many locations
Normalized Difference Water Index (NDWI) and Land Surface Water Index (LSWI)	37	Green	Sat	Produced operationally using Moderate Resolution Imaging Spectroradiometer data
Soil Adjusted Vegetation Index (SAVI)	37	Red	Sat	Not produced operationally

Composite or modelled	*Page*	*Ease of use*	*Input parameters*	*Additional information*
Combined Drought Indicator (CDI)	38	Green	Mod, P, Sat	Uses both surface and remotely sensed data
Global Integrated Drought Monitoring and Prediction System (GIDMaPS)	38	Green	Multiple, Mod	An operational product with global output for three drought indices: Standardized Soil Moisture Index, SPI and Multivariate Standardized Drought Index
Global Land Data Assimilation System (GLDAS)	39	Green	Multiple, Mod, Sat	Useful in data-poor regions due to global extent
Multivariate Standardized Drought Index (MSDI)	40	Green	Multiple, Mod	Available but interpretation is needed
United States Drought Monitor (USDM)	41	Green	Multiple	Available but interpretation is needed

Note: Indicators and indices are sorted by 'ease of use' and then alphabetically within each 'ease of use' category.

Key to variables:
AWC = available water content,
CC = crop coefficient,
CD = crop data,
ER = ecoregion,
ET = evapotranspiration,
GW = groundwater,
LC = land cover,
Mod = modelled,
Multiple = multiple indicators used,
P = precipitation,
PET = potential evapotranspiration,
Rad = solar radiation,
RD = reservoir,
S = snowpack,
Sat = satellite,
SF = streamflow,
ST = soil type,
SWD = soil water deficit,
T = temperature,
Td = dewpoint temperature,
W = wind data.

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Next Steps

DRIP Collaborative meeting – Friday, April 17, 2026, 10 am – 5pm

- Report on key learnings from the workshop and inventory work
- Continue to hear diverse perspectives on both Roles & Responsibilities and DI&M

Next DI&M workshop – to be scheduled in May

- Continue discussion on specific indicators, aligned to prioritized gaps and opportunities

THANK YOU FOR YOUR CONTRIBUTION TODAY!

REFLECTIONS

Any closing thoughts?

TIME FOR Q&A



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THANK YOU!

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