

Appendix 2
Drought and Water Shortage Risk Scoring:
California's Small Water Supplier and
Self-Supplied Communities

Prepared for
County Drought Advisory Group process
as partial fulfillment of Assembly Bill 1668

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1.0 Purpose

Water Code Division 6 Part 2.55 Section 8 Chapter 10 (Assembly Bill 1668) effectively requires California Department of Water Resources, in consultation with other agencies and an advisory group, to create a list of small water suppliers and "rural communities" that are at risk of drought and water shortage. This list must be shared with counties, Groundwater Sustainability Agencies (GSAs), other regional groups, and the public. This document describes the indicators, datasets, and methods used to construct this deliverable.

This is the first effort to systematically and holistically consider water shortage risk statewide of small water suppliers and self-supplied communities. The indicators and scoring methodology should be revised as better data become available and stakeholders evaluate the performance of the indicators, datasets used, and aggregation and ranking method used to aggregate and rank risk scores. Additionally, the scoring system should be adaptive, meaning that our understanding of what contributes to risk of drought and water shortage may evolve. This understanding may especially be informed by experiences gained while navigating responses to future droughts.

Coordination

DWR recognizes and is in communication with other state agencies and experts working on related efforts. These include the State Water Resources Control Board's (SWRCB) Needs Assessment, the California Office of Environmental Health Hazard Assessment's (OEHHA) metrics being developed to track the Human Right to Water, and Water Equity Science Shop at UC Berkeley in their development of geospatial datasets applicable to this project. Our effort creates a model of risk that is consistent with concepts, datasets, and metrics with these other efforts whenever possible. (The State Water Board received [funding authorization](#) to perform a Needs Analysis regarding the state of drinking water in California. The analysis must be completed by June 2021. See https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/needs.html. Three workshops will cover the main aspects of this assessment: public water systems, domestic wells, and cost analysis.)

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2.0 Roadmap for Risk Scoring

The overall goal is to produce a list of what small water suppliers and 'rural communities' are at risk of drought and water shortage. To achieve this goal, we set four objectives to take us stepwise to achieving this goal.

- Objective 1. Identify factors that indicate a small water supplier and/or self-supplied community is at risk of drought and/or water shortage vulnerability.
- Objective 2. Develop measurable indicators for evaluating risk of water shortage and drought for small water suppliers and self-supplied households.
- Objective 3. Develop a scoring method to combine measurable indicators
- Objective 4. Calculate risk scores and generate profiles of risk and vulnerability for each county, GSA, and statewide.

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3.0 Key Concepts and Approach

This section presents key concepts and definitions.

3.1 Units of Analysis

The final lists required by legislation must be in the form of listing small water suppliers and rural communities (referred to here as 'self-supplied communities'). Because the risk factors differ between these groups, we conducted an analysis of these separately and therefore construct separate lists.

- The unit of analysis used for small water suppliers is the service area boundary polygons available through the Water Boundary Tool.
- The unit of analysis for the self-supplied households is Census Block Groups (ACS 2012-2016 Tiger Shapefile). The Census Block Groups do not represent individual communities, but they do cover areas where population resides. Using this spatial unit for this analysis allows us to access demographic information that is otherwise not available.

3.2 Small Water Suppliers

'Small water suppliers' for this analysis are those publicly-regulated systems with fewer than 3,000 service connections and using fewer than 3,000 acre feet (AF). Those suppliers with 3,000 connections and/or use over 3,000AF are required to develop an Urban Water Management Plan, which includes a section on drought and water shortage contingency planning. Those small suppliers that are listed as participating in an Urban Water Management Plan were also excluded because they are expected to be covered by their Urban Water Management Plan.

The analysis includes those suppliers that have spatial boundaries of their service areas recorded in the Water Boundary Tool, as of May 23, 2019 (<https://trackingcalifornia.org>). The "State Small Systems" (SWRCB) with fewer than 15 service connections are considered under the self-supplied communities' analysis.

3.3 Self-Supplied Communities

This category of *self-supplied communities* intends to cover what is regarded as the "rural communities" in the legislation. This is intended to cover those households and others with domestically used water (dish washing, showering, drinking, etc.) on their own wells and surface water supplies. The unit of analysis for these communities is the US Census Block group, omitting those with zero population (according to ACS 2012-2016) and/or those that have no domestic wells recorded between 1970-2019 (based on data from the DWR Well Report Database, queried September 2019).

For the purpose of this risk and vulnerability assessment, this category also addresses communities served by water suppliers with fewer than 15 service connections, which are either local small (serving between 2–4 connections) state smalls (serving between 5–14 connections) or domestic wells (serving one connection).

3.4 Risk

Consistent with the IPCC's 2012 Special Report (Cardona et al. 2012) and its upcoming Sixth Assessment Report, *risk* is the combination of vulnerability and the extent of exposure to a hazardous event or conditions, including projected future hazards (IPCC 2017). Vulnerability, as described below, is the combination of sociological and structure factors that make it more or less likely for people to be harmed when they are exposed to a hazard. The treatment of risk as manifested both from environmental, natural conditions and human dimensions is consistent with scholarly work of disaster risk management as articulated by Wisner and colleagues: "The crucial point about understanding why disasters happen is that it is not only natural events that cause them. They are also the product of social, political, and economic environments... These two aspects – the natural and the social – cannot be separated from each other: to do so invites a failure to understand the additional burden of natural hazards, and it is unhelpful in both understanding disasters and doing something to prevent or mitigate them." (Wisner et al. 2003, p.4-5). The stakeholders in CDAG meetings agreed that risk is driven by both environmental events and conditions and social, political and economic factors, and supplier vulnerability, all of which is consistent with scientific literature on water shortage and scarcity (see Kummu et al. 2016; Mekonnen and Hoekstra 2016).

3.5 Exposure to Hazard

Exposure in this risk framework represents the degree to which a water supplier's service area and/or a community is exposed to various hazardous environmental conditions and events that could lead to drought and/or water shortage.

3.6 Vulnerability

Vulnerability is the propensity or predisposition to be adversely affected. Such predisposition constitutes an internal characteristic of the affected element, whereas exposure to a hazard is a condition or event to which the affected element (i.e., supplier) is subjected. In the field of disaster risk management, this includes the characteristics of a person or group and their situation that influences their capacity to anticipate, cope with, resist, and recover from the adverse effects of physical events (Wisner et al., 2004). For further reading on vulnerability, see "Key Concepts and Methods in Social Vulnerability and Adaptive Capacity." (https://www.fs.fed.us/rm/pubs/rmrs_gtr328.pdf) and Chapter 1 in Intergovernmental Panel on Climate Change Special Report on Extreme Events (Lavell et al. 2012). Vulnerability is commonly estimated by combining *sensitivity* and *capacity* of the supplier or community or other grouping of population or assets.

Sensitivity

Sensitivity is one of the two core sub-components to understand vulnerability. This is the likelihood of susceptibility of harm in an extreme event relating to drought and/or water shortage. This is often measured using characteristics of a population or a system. For this analysis, we represent sensitivity in Component 3 of the framework and it covers mostly physical vulnerability indicators.

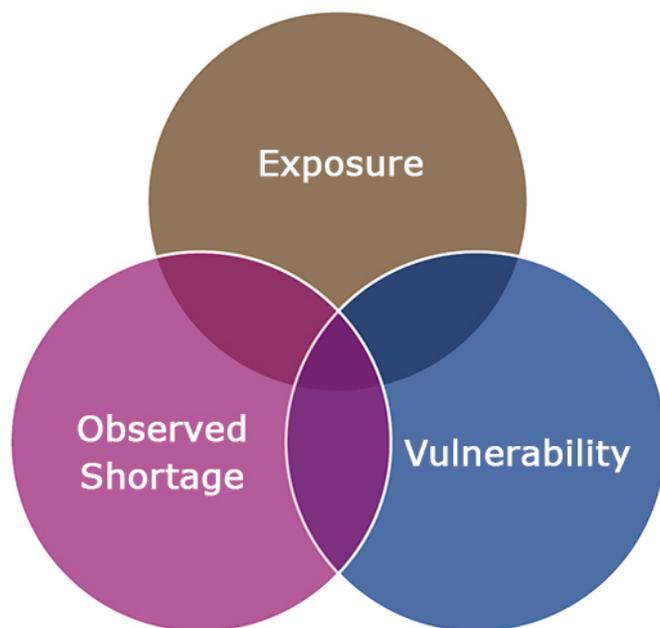
Adaptive Capacity

The *capacity* to adapt or cope is one of the two core sub-components necessary to understand vulnerability. This is the ability or potential of a system (or supplier, household, etc.) to respond successfully to climate variability and change and includes adjustments in both behavior and in resources and technologies. For this analysis, we represent capacity in *Component 4: Organizational Vulnerability* of the framework, which covers social and economic vulnerability indicators.

3.7 Risk and Vulnerability Framework

We developed a framework for examining risk using the risk and vulnerability concepts described in the Intergovernmental Panel on Climate Change IPCC (2012) and the World Risk Index (2018). Small suppliers and self-supplied households in California have varying degrees of exposure to hazardous events and conditions. We account for current and recent hazards as well as future hazards projected to occur with the changing climate (Exposure in Figure 1). Each also has a unique set of sensitivities and adaptive capacities that make it more or less vulnerable to this exposure (Vulnerability in Figure 1).

Figure 1 Indicators used to estimate each component of the risk framework (exposure, vulnerability, observed shortage)



3.8 Process for Development of Risk Indicators

Risk indicators were developed over several meetings with the CDAG and technical workgroups. Beginning in December 2018, the advisory group developed lists of factors that may affect the risk (via the exposure, sensitivity, and adaptive and coping capacity of a supplier or a household) of water shortage and drought. These lists were recorded and augmented with potential datasets that could be used to quantitatively indicate each factor. In the February 2019 CDAG meeting, participants and the project team staff collectively revised and prioritized the lists of factors and datasets for indicator development.

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Two April 2019 CDAG technical workgroup meetings were hosted to collect further insights regarding what datasets are available and useful for representing the listed risk factors. A third workgroup meeting was held in September 2019 to review the status of the supplier analysis and discuss further details. During this meeting we shared a visualization of the initial scoreboard to show significant data gaps, as well as how the indicators were being combined to create a risk index. For all of the technical workgroup meetings, stakeholders attended in person and by call-in/webcast. These discussions were instrumental in providing detailed feedback on scoring methods and data sources.

Working closely with the advisory group and project team, we developed a series of 29 metrics to quantitatively indicate multiple dimensions of risk of water shortage and drought for small suppliers and 20 metrics for examined risk and vulnerability of self-supplied communities. Each metric is described below.

Each variable is normalized and/or rescaled to add multiple variables together for a composite score. necessary. Data manipulation process is described for each indicator below. First, we present indicators and the aggregation method of these for the small suppliers. Second, we present indicators and aggregation method used for the analysis of self-supplied communities.

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4.0 Small Water Supplier Indicators and Scoring

4.1 Indicators

Exposure to Hazards

4.1.1 Climate Change

We use three indicators representing the spatial threats of climate change as it could impact water suppliers. These include temperature changes, wildfire, and salt-water intrusion (via sea level rise). These represent mid-century projections, consistent with DWR’s vulnerability assessment (though projections on wildfire and drought are derived from the State’s Fourth Assessment 2018 and sea level rise impacts are from University of Wyoming). Future analysis should include projections of precipitation and drought, as these become readily available. Details of each indicator used are presented in Table 1 and described in more detail below.

Table 1 Indicators of climate change impacts on water systems relevant to water shortage and/or drought (Component 1)

COMPONENT 1 – Climate Change	Metric	Data Source
SC1a – Projected Temperature Shift	Projected change in temperature by mid-century	<i>Pierce, Cayan Scripps UCSD, DWR</i>
SC1b - Projected Sea Level Rise	Presence of salt into coastal aquifers with projected 1 meter sea level rise	USGS, Befus Univ. Wyoming
SC1c - Projected Wildfire Risk	Projected acres burned from wildfire for each system boundary or community	Westerling UC Merced

Projected Future Hazard

SC1a. Projected Temperature Shift under Climate Change

Impact on risk: Increased temperatures could increase water supply demands from customers, evapotranspiration, and others thereby increasing the risk of drought and/or water shortage impacts on a supplier

Data source: Derived from the DWR Water Storage Investment Program climate change projections

What does it represent: The percentage of change in maximum temperature from historic range (1961-1990) to mid-century.

What do want it to indicate: Increased temperature as a pressure on demand

What does it represent: The percentage of change in maximum temperature from historic range (1961-1990) to mid-century.

What do want it to indicate: Increased temperature as a pressure on demand

Location of data: queried by DWR from the climate projections used in the Water Shortage Investment Program

Metric generated: Percent change in maximum temperature by mid-century

Notes: None.

SC1b. Projected Sea Level Rise Risk as Salt Water Intrusion in Coastal Groundwater

Impact on risk: Increases risk when exposed to current and future salt water intrusion

Data source: Kevin Befus, University of Wyoming – dataset in preparation for publication (as of August 2019)

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What does it represent: 0,1 binary (0= no modelled exposure of service area to salt water intrusion in groundwater current or with 1 meter sea level rise; 1= yes, exposed to current or future salt water intrusion in coastal groundwater aquifer with up to 1m sea level rise)

What do want it to indicate: Risk to coastal salt water intrusion into unconfined coastal aquifers under sea level rise of 1 meter, representing a mid-century projection.

Location of data: Kevin Befus, University of Wyoming

Link: <http://www.uwyo.edu/befushydro/>

Notes: The exposure data (of which service areas are at risk to this indicator) were calculated using a shapefile developed and provided directly by Dr. Kevin Befus at University of Wyoming. This shapefile represents the modelled output of saltwater intrusion into unconfined coastal groundwater aquifers with sea level rise up to 1 meter. The modelled area indicates those with a fresh-saline groundwater interface that is <50 m deep (as you move inland, the interface gets deeper). The shapefiles were merged (by Befus) from present-day up until a sea level of 1 m above present day (using a bathtub type assignment of sea level, though also uses the LMSL tidal datum from NOAA's vdatum that is variable along the CA coast). This calculation is based on a steady-state (or equilibrium) groundwater model.

Metric generated: Spatial join of small water suppliers' service areas and/or Block groups intersect with the spatial extent of projected salt water intrusion

Associate analysis units to hazard index: Generated presence/absence data per service area boundary

SC1c. Projected Wildfire Risk under Climate Change

What: Projected (future) wildfire risk with climate change

Data source: Leroy Westerling, UC Merced

What does it represent: Projected risk of wildfire as influenced by climate change, representing acreage burned annually averaged across 2035-2064 periods from the average across 10 global climate models.

What do we want it to indicate: Varying degrees of risk to wildfire in mid-century for areas in California

Location of data: Westerling, UC Merced

Link: <https://cal-adapt.org>

Metric generated: Average acreage burned within in period of 2035-2064, RCP 8.5, Original data ranges from 0 to 100, rescaled to 0-1 for analysis.

4.1.2 Exposure to Current Environmental Conditions and Events

Current hazard is composed of three groups of risk factors: episodic stressors, source vulnerabilities, and source quality risks. Each group is composed of several indicators, and the two latter groups measured using data related to groundwater basins. These data are available for Bulletin 118 Basins (DWR 2019), which do not cover the entire state.

Table 2 Indicators of current or recent hazardous conditions and events (System -- Component 2, SC2)

COMPONENT 2 –Recent Conditions and Events	Metric	Data Source
SC2a – Current Wildfire Risk	Modelled current risk for each system (based on vegetation)	CalFire
SC2b - Drought Early Warning Forecast Water Year 2019	Annual Risk of Local Drought (precipitation)	PRISM OSU
SC2c - Fractured Rock Area	Fractured rock	DWR
SC2h - Projected population growth	Near term projected population growth rate	DWR
SC2i – Water Quality in Surrounding Basin	Water quality problems in surrounding basin	USGS GAMA

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COMPONENT 2 –Recent Conditions and Events	Metric	Data Source
SC2d - Basin- Subsidence	Susceptibility to subsidence	DWR
SC2e - Basin- Salt	Salts documented in basin	DWR
SC2f - Critically Overdrafted	Critically overdrafted basin	DWR
SC2g - Chronic declining water levels	Declining groundwater levels	DWR
SC2j -Surrounding agricultural land use	Presence of irrigated agricultural in basin	DWR

Episodic Stressors

SC2a. Drought Early Warning Forecast Water Year 2019

What: Current Year's Early Warning for Risk of Local Drought (must be updated annually)

Data source: Oregon State University PRISM Climate Group

What does it represent: Current drought risk based on percent of average precipitation already received for first part of Water Year.

What do want it to indicate: Annual Forecasted Risk of Local Drought

Location of data: <http://www.prism.oregonstate.edu>

Metric to generate: Score those areas under 70% =1 (high risk); Score those areas over 70% = 0.

Notes: The level of precipitation received by the end of January is a good indication of how well the water year will be for a local supply. Those suppliers in areas that have received less than 70% of average precipitation by January 31st each year are considered 'at risk of drought' for that water year (Anderson DWR in prep). The metric used to indicate annual drought risk is percent of average precipitation received by January 31st in that water year. This needs to be updated annually. Because legislation requires this risk list be produced by January 2020, we use Water Year 2019 data.

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The original PRISM precipitation is in raster (grid) format in GIS. We calculated the original PRISM data for the months of interest (Oct 1 2018 - Jan 31 2019, <http://www.prism.oregonstate.edu/recent/>) and divided by the average precipitation (reference to as '30-year normal' on website) between years 1981-2010 (provided by PRISM website, <http://www.prism.oregonstate.edu/normals/>). We used ArcGIS raster calculator for summing the months and then the division for the calculations. Then to associate the values in the grid to the service area polygons, we used the Spatial Analyst Tool Zonal Statistics (where the input zones were service area polygons).

SC2b. Wildfire as present threat to water shortage

What: Current Risk of Wildfire

Data source: CalFire

What does it represent: Fire Hazard Severity Zone maps for State Responsibility Areas in November 2007, as recognized by CalFire

What do want it to indicate: Severity of current wildfire risk

Location of data: <https://osfm.fire.ca.gov/divisions/wildfire-prevention-planning-engineering/wildland-hazards-building-codes/fire-hazard-severity-zones-maps/>

Metric to generate: rescaled to 0-1 scale with extreme severity as 1 (High=0.7; Moderate=0.3; Low=0)

Notes: Recoded, Done in SPSS

Source Vulnerabilities

Aquifer Characteristics

Fractured Rock – SC2c

- Indicated by areas not in alluvial groundwater basins as marked by Bulletin 118, developed by DWR North Regional Office as part of upcoming Bulletin 118.
- Scoring = 0/1 binary scale so that all areas outside of these basins are scored as 1 (high risk)
- Completed

SC2R. Groundwater Basin Vulnerability

What: Presence of one or more risks observed in the groundwater basin

Data source: Aggregated multiple risk factors from the SGMA basin prioritization dataset, including presence of subsidence in basin (SC2d), presence of salt in basin (SC2e), record of critically overdrafted basin (SC2f), record of chronic declining water levels (SC2g), and presence of irrigated agriculture (SC2j)

What does it represent: Groundwater basin vulnerability based on multiple risk factors.

What do we want it to indicate: A single score to represent one or more of the issues that commonly make a groundwater basin more vulnerable during a dry period.

Location of data: DWR

Metric to generate: Took the maximum score (0-1) of the recoded scores of the five combined factors that were associated to each small water supplier. Max score was used as the score to represent this aggregate indicator.

Notes: Complete.

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SC2d. Presence of Subsidence in Basin

Impact on risk: Higher susceptibility = higher risk

Data source: SGMA 2019 Basin Prioritization

What does it represent: "Documented Impacts #7.b Subsidence Points"

What do want it to indicate: subsidence problems and risk

Location of data: DWR GIS server (source data)

Metric to generate: Recoded to 0,.5,1 from original points of 0,3,10, then associated to supplier boundaries with spatial join in ArcGIS

Notes: Completed. Incorporated as part of SC2R indicator.

SC2e. Presence of Salt in Basin

Impact on risk: Suppliers in basins with documented salt intrusion issues may have increased challenges of dealing with challenges of saline groundwater

Data source: SGMA 2019 Basin Prioritization

What does it represent: "Documented Impacts #7.c Salt Intrusion Points"

What do want it to indicate: Areas that have been documented to have problems with salt intrusion

Location of data: DWR

Metric to generate: Rescale SGMA points of 0 and 5 to our risk indicator scoring of 0 and 1.

Notes: Technical workgroup (SGMA) suggested alternative scaling, but don't see any other options besides binary. Completed. Incorporated as part of SC2R indicator.

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SCf. Critically Overdrafted Basin

Impact on risk: If your local groundwater is in decline, this would increase your risk to water shortage and drought.

Datasource: B118 (Roy Hull, DWR)

What does it represent: Determinations of critically over drafted groundwater basin or not

What do want it to indicate: Local groundwater vulnerability

Location of data: DWR

Metric generated: Yes (1)/no (0) of whether area is in critical overdraft

Notes: Technical workgroup (SGMA) suggested alternative scaling, but only have binary for this so there is not other optional scaling. Completed. Incorporated as part of SC2R indicator.

SC2g. Chronic Declining Water Levels

Impact on risk: Declining level indicates surrounding increased risk

Data source: Documented Impacts #7.a - Declining GW levels Points

What does it represent: Groundwater level change in elevation 2011-2015

What do want it to indicate: Declining water levels in aquifer

Location of data: DWR

Metric to generate: Associate score of sub-basin to the supplier service boundaries.

Notes: This is included in addition to the overdraft indicator above because it is assumed that having this as more specific location data could be helpful to indicate more specific risk to water shortage during a drought. Incorporated as part of SC2R indicator.

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SC2j. Presence of Irrigated Agriculture in Surrounding Basin

Impact on risk: May indicate competing demand on groundwater supplies, which could create higher risk for small suppliers during a drought or water shortage event.

What does it represent: Presence of irrigated agriculture in surrounding basin

What do want it to indicate: Competing demand on water use

Location of data: DWR

Metric generated: Associated rescaled score of sub-basin to the service areas of small water suppliers examined.

Notes: Complete. Incorporated as part of SC2R indicator.

SC2h. Population Growth Rate

Impact on risk: Increasing population growth rates in surrounding region could increase risk of water shortage

Data source: Vendor-derived US Census-based estimates

What does it represent: Population growth projected in service area

What do want it to indicate: Near future increasing water demands

Location of data: DWR

Metric generated: Rescaled population growth rate from vendor estimates by service area

Notes: None.

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SC2i. Water Quality in Surrounding Basin

Impact on risk: Increased contamination = increased risk

Data source: GAMA USGS Priority Basin Project-derived (Deep Aquifer Assessment)

What does it represent: Potential risk of contaminants in surrounding groundwater (from deep aquifer of region)

What do want it to indicate: Potential risk of contaminants in groundwater

Location of data: DWR (USGS derived)

Metric generated: Calculated weighted percent of constituents past regulatory thresholds (1) or near thresholds (0.5)

Notes: Applies to deeper groundwater in established alluvial basins typically accessed by municipal supply wells.

4.2 Small Water Supplier Vulnerability

Several factors contribute to and indicate that a small supplier is more or less vulnerable to being affected by a water shortage and dry period. These are commonly divided and described using the concepts of "sensitivity" and "adaptive capacity", and in some instances including "coping capacity" (Füssel 2007; Fussel and Klein 2006; Wolf et al. 2013; McDowell et al. 2016). Vulnerability, as defined above in the introduction is a supplier's sensitivity to a dry period or water shortage and its ability to proactively adapt to make changes that would decrease or avoid the impacts. Additionally, vulnerability also represents its ability to cope when a dry period or shortage occurs. These factors naturally fell into physical infrastructure factors (sensitivity of a supplier) and organization factors (adaptive capacity of a supplier).

**Infrastructure Vulnerability + Organizational Vulnerability =
Vulnerability of Small System**

4.2.1 Infrastructure Vulnerability Factors

Infrastructure Vulnerability factors associated with small water suppliers included five categories of variables: connectivity, supplier’s infrastructure, portfolio redundancy, physical coping capacity, and historical source water conditions.

Table 3 List of indicators representing infrastructure vulnerability of small water suppliers, including metrics and datasets (Component 3)

COMPONENT 3 – Infrastructure Vulnerability	Metric	Data Source
SC3a - Interties	Presence of interties	SDWIS
SC3b – Emergency interties	Presence of emergency interties	SDWIS
SC3c - Baseline monitoring	Level of monitoring reported	eAR
SC3d – Customers metered	% system connections that have meters	eAR
SC3e - # Water Sources	Count of water sources	SDWIS derived
SC3f - # Source Types	Count of water source types	SDWIS derived
SC3g – Supplier Size	Service connections count	eAR
SC3i – Distribution Outage Record	Count of distribution problems of water outage	eAR
SC3j – Water Level Status	Levels of water source-recovering, steady, declining, blank	eAR

Connectivity

SC3a. Interties

Impact on risk: The more interties, the assumed lower risk of outage because they can potentially switch sources if needed

Data source: SDWIS

What does it represent: # interties

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What do want it to indicate: Available water transfers

Location of data: SWRCB SDWIS

Metric to generate: Rescaled to binary for those with one or more intertie (0, low risk) and those with zero (1, high risk)

Notes: requested from SWRCB 6/13/19 SDWIS; received and processed. Completed

SC3b. Emergency Interties

Impact on risk: The more emergency interties, the assumed lower risk of outage because they can potentially switch sources if needed

Data source: SDWIS

What does it represent: # emergency interties

What do want it to indicate: Availability of emergency water

Location of data: SWRCB SDWIS

Metric generated: Recoded to binary, so that zero emergency interties is 1, and more than zero reported is marked as '0'. Those with no data are marked "null".

Notes: Completed

Supplier's Information Infrastructure

SC3c. Baseline monitoring

Impact on risk: Having baseline monitoring could decrease your risk because it indicates the capacity to observe declining levels

Data source: eAR 2017, columns "CONSERVATION Monitor Static" + "CONSERVATION Levels"

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What does it represent: 0,1,2 scale (none, monitor static level, monitor pumping) reported in EAR

What do want it to indicate: Presence of baseline monitoring of source supply levels

Location of data: SWRCB, updated annually

Metric generated: -99= no data; 1 = no reported monitoring; 0.5= static monitoring only; 0= static and level monitoring in place.

Notes: Completed

SC3d. Customers Metered

Impact on risk: Absence of metering would increase risk to water shortage and drought because it makes it difficult to implement and monitor conservation measures than may be triggered to reduce customer demand.

Data source: eAR 2017 "T Potable UM"/"T Potable Total"

What does it represent: Proportion of system potable customers that have meters or not

What do want it to indicate: Whether customers and utility have ability to monitor consumption

Location of data: SWRCB SDWIS, updated annually

Metric generated: Proportion of potable connections unmetered (eAR 2017) (0-1 scalar)

Notes: Completed

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SC3e. # Water Sources

Impact on risk: The fewer sources, the assumed higher risk

Data source: SDWIS

What does it represent: Number of water sources (Note: volume per source is not captured)

What do want it to indicate: Flexibility and diversity of supply

Location of data: SDWIS

Metric generated: Count of (sw intakes + wells + imported water sources); More than one water source =0 risk and single source type =1 (high risk).

Notes: Combined from SDWIS data. Recoded binary in SPSS.

SC3f. # Source Types

Impact on risk: Fewer source types is higher risk.

Data source: SDWIS

What does it represent: Count of source types (GW, SW, purchased)

What do want it to indicate: Number of source types as one indicator of supply portfolio diversity

Location of data: SDWIS

Metric generated: Count of total types of sources; More than one water source type =0 risk and single source type =1 (high risk).

Notes: Counts from SDWIS data by SWRCB DDW. Recoded binary in SPSS.

Physical Coping Capacity

SC3g. Supplier Size

Impact on risk: The number of service connections is used as a proxy for size of the water supplier. The larger the supplier's size, the assumed higher capacity in terms of the staff and budget of the supplier. Smaller size is higher risk.

Data source: SDWIS

What does it represent: service connections count

What do want it to indicate: The number of service connections is used as a proxy for size of the water supplier. The larger the supplier's size, the assumed higher capacity in terms of the staff and budget of the supplier.

Location of data: SDWIS

Metric generated: $\log_{10}(\text{service connections})$; normalized 0-1 using min as 0/max as 2999/range, then flipped scale so that lower number of service connections is higher risk, (i.e., closer to 1).

Notes: Complete.

SC3i. Distribution Outage Record

Impact on risk: Potentially increases risk

Data source: eAR 2017

What does it represent: Count of distribution problems of water outage

What do want it to indicate: Recent record of outages, may indicate infrastructure needs

Location of data: SWRCB

Metric generated: Rescaled min-max-range to 0-1, maintain NULL for no data

Notes: Complete.

SC3j. Water Level Status

Impact on risk: Declining levels of water supply indicate an elevated risk to drought and water shortage

Data source: eAR 2017

What does it represent: Self-reported levels of water sources (optional survey question) for water systems. Options for this survey question were 'declining', 'in recovery', or 'steady' and 'not applicable'.

What do want it to indicate: This seeks to indicate whether the water supply is at risk

Location of data: eAR 2017

Metric generated: Scored survey responses to Steady or not applicable as "0" (no risk), recovering as "0.5", declining as "1" (high risk) and no response as "null"

Notes: This is self-reported by the supplier themselves. This was an optional question and therefore will be underpopulated.

4.2.2 Organizational Vulnerability

Organizational vulnerability factors that can affect a supplier's risk to water shortage and drought covers three categories of variables: financial, organizational, and customer base (Table 4).

Table 4 Risk factors and datasets proposed to represent indicators of each factor of social vulnerability related to small water suppliers (Suppliers Component 4)

COMPONENT 4 – Organization Vulnerability	Metric	Data Source
SC4a – Rate Updated	Year rate structure was last updated	SWRCB
SC4b – Rate Type	Type of rate structured used by supplier. Survey question in eAR 2017 (flat base rate =1; other =0)	SWRCB
SC4d – Drought Preparedness Plan	Have drought plan or WSCP; year written or updated	SWRCB
SC4e - Customer Base Socio-Economics	Multiple population characteristics combined score	Private vendor data

Financial

SC4a. Rate Structure Update

This indicator serves to gauge the financial capacity of the supplier. The dataset available is from the electronic Annual Report (eAR), reporting the year the supplier last upgraded their rate structure.

Impact on risk: The more recent rate restructuring would be considering to lower financial risk of a supplier

Data source: eAR 2017

What does it represent: How many years it has been since the supplier last updated their rate structure

What do want it to indicate: Financial capacity to cope through drought

Location of data: SWRCB

Metric to generate: (Rate updated 2015-2019=0; Rate updated 2010-2014=0.25; Rate updated between 2003-2009=0.5; Rate updated prior to 2003=1)

Notes: Completed

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SC4b. Rate Structure Type

Impact on risk: Those with rate structure other than flat base rates are considered to have higher capacity to cope financially during a dry period.

Data source: eAR 2017

What does it represent: Type of rate structure

What do want it to indicate: Financial capacity to cope through drought

Location of data: SWRCB

Metric to generate: Scored so that flat base rate =1; other =0

Notes: Completed

SC4c- eliminated via Advisory Group agreement (10/1/2019)

SC4d. Drought Preparedness Plan

Impact on risk: Having a drought or water shortage contingency plan reduces risk to drought and/or water shortage events.

Data source: eAR 2017, "CONSERVATION DPP Date"

What does it represent: Supplier reported to have a Drought Plan and what year it was written or updated: Drought Preparedness Plan, recoded years since DPP (eAR 2017) note we don't have record of who does not have a plan and cannot assume that no EAR response means no plan. Therefore, we use prior to 2004 to be high risk.

What do want it to indicate: having a recently updated drought preparedness plan indicates higher coping capacity.

Location of data: SWRCB, updated annually.

Metric to generate: Drought Preparedness Plan (DPP) developed before 2003; DPP developed between 2004-2014=0.5; DPP developed since 2015=1.

SC4e. Customer Base Socio-Economics

Impact on risk: Suppliers with customer bases that is considered socially vulnerable are considered to be at higher risk to drought and water shortage for two reasons: (1) the supplier may be especially restricted in making necessary rate structure changes (that would prevent financial impacts during droughts) if they could have major impacts on their customer base (ie., customer base cannot afford any increase in water bills); and (2) demographic and socioeconomic characteristics selected are known to be more impacted during emergencies and disasters, following Cutter et al. (2011) and Flanagan et al. 2011.

Data source: US Census, American Community Survey 2012-2016

What does it represent: Social vulnerability of estimated customer base, from a composite score of % poverty, mean household income (inverse), per capita income (inverse), % renter population, % education with high school degree or less only, %unemployed, %mobile homes, %group quarters, % of 5 or younger; %65yrs and older

What do want it to indicate: Social vulnerability of customer base

Location of data: US Census ACS/DWR Demographer by block groups, associated to service area polygons

Metric to generate: Social vulnerability score for each small water supplier aggregating estimates of each of the following measures listed in Table 5.

Notes: Completed. Other suggestion for improving this indicating in the future. Further delineation of Customer Base information into more specific factors (e.g., % State-wide MHI and Rate Affordability) will be considered for inclusion in future risk model updates. MHI data is available for water systems and rate affordability calculation would require knowledge of current water rates on an annual basis, all available information. % MHI could be an indicator of future rate increase tolerance and capacity for a specific water system.

Rate Affordability = indicator of how high current rates are indexed to EPA affordability criteria, and ability to fund future water system improvements to improve water system reliability in the future.

Table 5 Demographic and socioeconomic characteristics estimated to represent the customer base on the small supplier. Spatial analysis used to associate Census data to service area boundaries

Variable	Variable Names	Brief description of what variable is	Data Source
Per capita income 2016	PERCAP	Average per capita income for the all Block groups (BG) that intersected with the service areas	ACS 2012-2016
Mean household income	AvgMHI	Average Median Household Income (MHI) for the all BGs that intersected with the service areas	ACS 2012-2016
Percent persons 65 year of age or older	Q65yr	Percentage of population of 65 and older of all BGs that intersected with the service areas	ACS 2012-2016
Percent persons 5 year of age or younger	Q5y	Percentage of population of under 5 years age of all BGs that intersected with the service areas	ACS 2012-2016
Percent mobile homes	Qmobile	Percentage of mobile households of all BGs that intersected with the service areas	ACS 2012-2016
No vehicle available	NoVeh	Percentage of households with no vehicles of all BGs that intersected with the service areas	ACS 2012-2016
Percent persons with no high school diploma	Qedu	Percentage of population over 25 years age with no high school diploma of all BGs that intersected with the service areas	ACS 2012-2016
Percent population with single parent	Qparent	Percentage of population with single parent with children under 18 of all BGs that intersected with service areas	ACS 2012-2016
Percent population unemployed	Qunempl	Percentage of population of civilian unemployed of all BGs that intersected with the service areas	ACS 2012-2016

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Variable	Variable Names	Brief description of what variable is	Data Source
Percent of population in group quarters	Qgroup	Percentage of all census Block population with Group Quarters (GQ) that intersected with the service areas	Census 2010

4.2.3 Record of Water Shortage

The final component seeks to capture those suppliers that have recently experienced shortage. The assumption is that without sufficient changes to the water sources or supplier, the supplier is likely to experience shortage again. We use three indicators to estimate the shortage record, though recognize each comes with substantial caveats. The State does not have complete record of what suppliers experienced shortage during the drought or otherwise, especially for suppliers that did not report occurrences. We therefore combine information from supplier-reports of shortage (an optional survey question), documented drought assistance provided, and suppliers that received compliance orders during the drought.

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COMPONENT 5 – Recent Observed Shortage	Metric	Data Source
SC3h – Shortage: Self-reported projected	Supplier-reported projected shortage	eAR 2011-2018
SC3k – Shortage: Curtailment and Compliance Order	Systems under order of compliance for curtailment (2014) or building moratoriums	SWRCB
SC3L – Shortage: Drought Assistance Record	Systems that received drought assistance on record	SWRCB

SC3h. Shortage: Supplier-Reported Projected Shortage

Impact on risk: Assumed higher risk if a system has previously and recently self-reported a projected water shortage.

Data source: eAR 2011-2018

What does it represent: Presence of any reported projected shortage between 2011 and 2018.

What do want it to indicate: Water suppliers that experienced recent past shortages may indicate those that may have additional shortage problems in the future.

Location of data: eAR 2011-2018 projected water shortage (Conservation section in survey)

Metric generated: Binary score of “1” (at risk) if the supplier reported a projected shortage in any of the eAR 2011-2018 surveys. If they responded to that question with a “no” for any of the survey years, that system is marked as a ‘0’ (no risk). If they did not respond to that question for any of the survey years, they are marked as “null”.

Notes: Complete (JE 9/6/19). This is self-reported by the supplier themselves. This was an optional question and therefore will be underpopulated.

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SC3k. Shortage: Curtailment and Compliance Order

Impact on risk: Suppliers with past record of curtailment order may be at risk of future curtailment

Data source: SWRCB

What does it represent: Water suppliers whose water sources during the last drought were impacted severely and were eligible for drought funds

What do want it to indicate: Water suppliers that experienced major impacts from the drought

Location of data: website

Metric generated: Binary score of "1" (at risk) if the supplier is listed as having received a compliance order from the SWRCB.

Notes: Complete

SC3L. Shortage: Drought Assistance Record

Impact on risk: Suppliers with record of severe impacts from drought may be at relatively higher risk in future droughts

Data source: SWRCB DFA

What does it represent: Record of drought assistance to supplier

What do want it to indicate: Water suppliers that experienced major impacts from the drought

Location of data: SWRCB DDW

Metric generated: Binary score of "1" (at risk) if the supplier is listed as receiving drought assistance funds.

Notes: Complete

4.3 Method of Aggregation for Scoring Small Suppliers

To aggregate the risk factor variables described above, all variables were rescaled 0-1, and then were combined with the variables in their respective component. We use a simple calculation that weights each variable within its given component of the framework. Then we aggregate the weighted component scores together. Weightings were developed based on feedback from CDAG, Division of Drinking Water District Engineers (SWRCB) and several others. This offers a transparent, repeatable and communicable method for calculating risk based on the many variables identified.

Equation for Small Water System Risk:

Supplier's Risk of Drought and Water Shortage for Small Water System Risk =

$$\begin{aligned}
 &0.25 \times \mu(\text{SC1a, b, c}) \\
 &+ \\
 &0.75 \times \mu((\text{SC2a,b,c,i,h}) + \text{Max}(\text{SC2d,e,f,g,j})) \\
 &+ \\
 &0.67 \times \mu(\text{SC3a,b,c,d,e,f,i,j}) \\
 &+ \\
 &0.33 \times \mu(\text{SC4ab, d, e, g}) \\
 &+ \\
 &0.33 \times \text{Max}(\text{SC3h, k, l})
 \end{aligned}$$

Where, all SC's value is scaled from 0 to 1, ordinal between 0 and 1, or binary 0 or 1.

Each group of variables is to be combined with the other groups' scores for that component (components are Exposure, Vulnerability, and Observed Shortage). Finally, the scores for each component will be added to create a risk score.

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5.0 Self-Supplied Communities Risk Indicators and Scoring

All indicators were developed based on input we received and facilitated at advisory group in-person meetings and smaller web-based technical work group meeting. Development of metrics was taken directly from verbatim input we received during these meetings, as well as additional feedback received from the data stewards and groundwater engineers and climate scientists.

5.1 Indicators

Exposure to Hazard

Hazard risk factors seek to indicate the likelihood of the intensity, severity, duration, and frequency for water shortage and drought in a given area. For the purpose of this project, this includes risks based on modeled future projections with climate change (Component 1) and based on recent conditions and events (Component 2). These are then spatially analyzed to determine the extent to which each community is exposed to these hazards, as described below.

5.1.1 Climate Change

Also note, at this time, sufficient data does not exist to estimate numbers and locations of households on self-supplied *surface* water intakes, but this is recognized as a major data gap for future consideration.

Similar to following the method of attribution for the indicators used in the Small Water Supplier risk scoring, each indicator for the Self-Supplied Communities was attributed to the Block groups with one or more domestic well outside of service areas.

Table 6 Indicators of climate change impacts on water systems relevant to water shortage and/or drought (Component 1)

Risk Factor	Influence on Risk	Proposed Variable	Proposed metric (measure)	Dataset	Data Source	Data Availability
RC1a - Temperature Shift	Increases risk	Projected change in heat by mid-century	Projected change in max temperatures by mid-century (averaged across models)	Water Storage Investment Program	DWR	DWR WSIP
RC1b - Saline intrusion risk	Increases risk	Susceptibility to seawater intrusion --1 meter sea level rise into coastal aquifers	Spatial extent of projected SLR under RCP 8.5 by 2040 (1m) into coastal aquifers; spatial join with Block groups	University Wyoming, Kevin Befus saltwater intrusion into coastal aquifers from 1m SLR	<i>University of Wyoming (coordinated with USGS)</i>	<i>Can't post statewide original data until published</i>
RC1c - Wildfire risk	Increases risk	Projected severe or high severe risk for each system boundary or community	Projected area burned (averaged across all GCMs) by 2035-2064, RCP8.5; spatial join with Block groups	Westerling's wildfire projections from 4 th Assessment, he queried dataset directly per our request	UC Merced	Posting to DWR portal when Westerling is ready

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RC1a. Projected Heat Risk

Impact on risk: Increased temperatures could increase water supply demands from customers, evapotranspiration, and others thereby increasing the risk of drought and/or water shortage impacts on a supplier

Data source: Derived from the DWR Water Storage Investment Program climate change projections; see <https://cwc.ca.gov/-/media/CWC-Website/Files/Documents/2017/WSIP/TechnicalReference.pdf>

What does it represent: The percentage of change in maximum temperature from historic range (1961-1990) to mid-century

What do want it to indicate: Increased temperature as a pressure on demand

Location of data: WSIP DWR

Metric to generate:

Notes:

RC1b. Projected Wildfire

What: Projected (future) wildfire risk with climate change

Data source: Leroy Westerling, UC Merced

What does it represent: Projected risk of wildfire as influenced by climate change, representing acreage burned in 2035-2064 periods of the average across all global climate models for the entire state.

What do we want it to indicate: varying degrees of risk to wildfire in mid-century for areas in California

Location of data: Westerling, UC Merced

Link: <https://cal-adapt.org>

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Metric to generate: Average acreage burned within in period of 2035-2064, RCP 8.5, Original data ranges from 0 to 100, rescaled using min/max to 0-1 for analysis.

Notes: Used Zonal Statistics as Table tool in ArcGIS to calculate mean acreage burned per Block Group (from Westerling's raster data). Adjusted the cell size in the raster calculator ('environment' menu in tool) to be 0.001 so that 13K Block groups were captured.

RC1c. Projected Salt Water Intrusion in Coastal Groundwater

Impact on risk: Increases risk when exposed to current and future salt water intrusion

Data source: Kevin Befus, University of Wyoming – dataset in preparation for publication (as of August 2019)

What does it represent: 0,1 binary (0= no modelled exposure of service area to salt water intrusion in groundwater current or with 1 meter sea level rise; 1= yes, exposed to current or future salt water intrusion in coastal groundwater aquifer with up to 1m sea level rise)

What do want it to indicate: Risk to coastal salt water intrusion into unconfined coastal aquifers under sea level rise of 1 meter, representing a mid-century projection.

Location of data: Kevin Befus, University of Wyoming

Link: <http://www.uwyo.edu/befushydro/>

Notes: The exposure data (of which service areas are at risk to this indicator) were calculated using a shapefile developed and provided directly by Dr. Kevin Befus at University of Wyoming. This shapefile represents the modelled output of saltwater intrusion into unconfined coastal groundwater aquifers with sea level rise up to 1 meter. The modelled area indicates those with a fresh-saline groundwater interface that is <50 m deep (as you move inland, the interface gets deeper). The shapefiles were merged (by Befus) from present-day up until a sea level of 1 m above present day (using a

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bathtub type assignment of sea level, though also uses the LMSL tidal datum from NOAA’s vdatum that is variable along the CA coast). This calculation is based on a steady-state (or equilibrium) groundwater model.

Metric generated: Spatial join of Block groups intersect with the spatial extent of projected salt water intrusion

Associate analysis units to hazard index: Generated presence/absence data per Block group polygon.

5.1.2 Exposure to Current Environmental Conditions and Events

Current hazard is composed of three groups of risk factors: episodic stressors, source vulnerabilities, and source quality risks. Each group is composed of several indicators, and the two latter groups measured using data related to groundwater basins. These data are available for Bulletin 118 Basins (DWR 2019), which do not cover the entire state.

Table 7 Indicators of current or recent hazardous conditions and events (Community – Component 2, SC2)

Group	Risk Factor	Indicator	Metric (measure)	Dataset	Data Source
Episodic	RC2a - Drought early warning	Annual Updated Early Drought Risk Warning	Less than 70% of average precipitation by January 31st for that water year = high risk of drought	Calculated percent of normal precipitation received by January 31st for that Water Year	PRISM OSU
	RC2b - Wildfire risk	Modelled current risk maximum for each Census Block Group	Use CalFire Scoring HAZ_CODE: Moderate (1)= .33; High (2)= .67; Very High (3) =1; no score =0 (no or low risk); Took max for each Census BG with spatial	CalFire Wildfire risk	CalFire

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Group	Risk Factor	Indicator	Metric (measure)	Dataset	Data Source
			join in ArcGIS		
Environmental Conditions and Stressors	RC2c - Geology	Fractured Rock Area	Communities in Fractured Rock Areas (1) or not (0)	DWR per B118 upcoming 2020 update	DWR
	RC2h – Increasing water demand	Projected population growth	Census data estimates of growth rate between 2016 to 2021, estimated by service area	DWR/Private Vendor Census data estimates	DWR
	RC2i- Water quality in shallow aquifer	Domestic well water quality risk (includes areas outside of alluvial basins)	Indication of likelihood that groundwater likely accessed by domestic wells may contain concentrations of constituents above regulatory levels.	Division of Water Quality GAMA Groundwater Information System	SWRC B
Alluvial Basin Conditions	RC2d – Basin subsidence	Record of subsidence	Documented Impacts #7.b Subsidence Points; recoded to 0,.5,1 from original points of 0,3,10, then associated to Block groups	SGMA 2019 Basin Prioritization	DWR
	RC2e – Basin salt	Record of salts	Documented Impacts #7.c Salt Intrusion Points	SGMA 2019 Basin Prioritization	DWR

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Group	Risk Factor	Indicator	Metric (measure)	Dataset	Data Source
Alluvial Basin Conditions	RC2f – Overdrafted basin	Critically overdrafted groundwater basin	Yes (1)/no (0) of whether area is in critical overdraft	SGMA 2019 Basin Prioritization	DWR
	RC2g - Chronic declining water levels	Declining groundwater levels	Documented Impacts #7.a - Declining GW levels Points	SGMA 2019 Basin Prioritization	DWR
	RC2j - Surrounding land use	Presence of irrigated agriculture in surrounding basin	Irrigated Acres Priority Points	SGMA 2019 Basin Prioritization	DWR

Events and Environmental Conditions

RC2a. Drought Risk

What: Current Year’s Early Warning for Risk of Local Drought (must be updated annually)

Data source: Oregon State University PRISM Climate Group

What does it represent: Current drought risk based on percent of average precipitation already received for first part of the current Water Year.

What do want it to indicate: Annual Forecasted Risk of Local Drought

Location of data: <http://www.prism.oregonstate.edu>

Metric to generate: Score those areas under 70% =1 (high risk);
Score those areas over 70% = 0.

Notes: The level of precipitation received by the end of January is a good indication of how well the water year will be for a local supply. Domestic wells can be sensitive to levels of annual precipitation in their region. Those with under 70% of average for their area by January 31st each year are considered ‘at risk of drought’ for that water year. The metric used to indicate annual drought risk is percent of average precipitation received by

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January 31st in that water year. **This needs to be updated annually.** Because legislation requires this risk list be produced by January 2020, we will use Water Year 2019.

The original PRISM precipitation is in raster (grid) format in GIS. We calculated the original PRISM data for the months of interest (Oct 1 2018 - Jan 31 2019, <http://www.prism.oregonstate.edu/recent/>) and divided by the average precipitation (reference to as "30-year normal" on website) between years 1981-2010 (provided by PRISM website, <http://www.prism.oregonstate.edu/normals/>). We used ArcGIS raster calculator for summing the months and then the division for the calculations. Then to associate the values in the grid to the Census BG polygons, we used the Spatial Analyst Tool Zonal Statistics (where the input zones were service area polygons). Adjusted the cell size in the raster calculator ('environment' menu in tool) to be 0.0001 so that all Block groups were captured.

.00 = "Drought risk absence – Local precipitation by January, 31, 2019, was above 70 percent of average precipitation."

1.00 = "Drought risk presence – Local precipitation was less than 70 percent average (of a water year)."

RC2b. Wildfire as present threat to water shortage

What: Current Risk of Wildfire

Data source: CalFire

What does it represent: Fire Hazard Severity Zone maps for State Responsibility Areas in November 2007, as recognized by CalFire

What do want it to indicate: Severity of current wildfire risk

Location of data: <https://osfm.fire.ca.gov/divisions/wildfire-prevention-planning-engineering/wildland-hazards-building-codes/fire-hazard-severity-zones-maps/>

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Metric to generate: rescaled to 0-1 scale with extreme severity as 1.
Category scores rescaled as follows: Moderate (1) = .33; High (2) = .67;
Very High (3) =1; no score =0 (no or low risk).

Notes: This may be updated soon by CalFire

Source Environmental Conditions and Stressors

RC2c - Fractured rock area

- Indicated by areas not in alluvial groundwater basins as marked by Bulletin 118, developed by DWR North Regional Office as part of upcoming Bulletin 118.
- Scoring = 0/1 binary scale so that all areas outside of these basins are scored as 1 (high risk)
- Completed

RC2h - Population Growth in immediate region

Impact on risk: Increasing population growth rates in surrounding region could lead to increased demand and thereby increasing risk of water shortage

Data source: Census, private vendor for demographic data

What does it represent: Population growth projected between 2016-2021

What do want it to indicate: Near future increasing water demands

Location of data: DWR

Metric generated: Rescaled population growth rate from a proportion to 0-1

Notes:

Alluvial Basin Characteristics

RC2R. Groundwater Basin Vulnerability

What: Presence of one or more risks observed in the groundwater basin

Data source: Aggregated multiple risk factors from the SGMA basin prioritization dataset, including presence of subsidence in basin (RC2d), presence of salt in basin (RC2e), record of critically over drafted basin (RC2f), record of chronic declining water levels (RC2g), and presence of irrigated agriculture (RC2j)

What does it represent: Groundwater basin vulnerability based on multiple risk factors.

What do we want it to indicate: A single score to represent one or more of the issues that commonly make a groundwater basin more vulnerable during a dry period.

Location of data: DWR

Metric to generate: Took the maximum score (0-1) of the recoded scores of the five combined factors that were associated to each small water supplier. Max score was used as the score to represent this aggregate indicator.

Notes: Complete.

RC2d. Presence of Subsidence in Basin

Impact on risk: Higher susceptibility = higher risk

Data source: SGMA 2019 Basin Prioritization

What does it represent: "Documented Impacts #7.b Subsidence Points"

What do want it to indicate: subsidence problems and risk

Location of data: DWR GIS server

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Metric to generate: recoded to 0,.5,1 from original points of 0,3,10, then associated to Block group

Notes: Completed. Incorporated as part of Alluvial Basin Conditions score.

RC2e. Presence of Salt in Basin

Impact on risk: Block Groups in basins with documented salt issues may have increased challenges of dealing with challenges of saline groundwater

Data source: SGMA 2019 Basin Prioritization

What does it represent: "Documented Impacts #7.c Salt Intrusion Points"

What do want it to indicate: areas that have been documented to have problems with salt in basin

Location of data: DWR

Metric to generate: rescale SGMA points of 0 and 5 to our risk indicator scoring of 0 and 1.

Notes: Technical workgroup (SGMA) suggested alternative scaling, but don't see any other options besides binary. Completed. Incorporated as part of Alluvial Basin Conditions score.

RC2f. Critically Overdrafted Basin

Impact on risk: If local groundwater is in decline, this would increase risk of water shortage and drought.

Data source: Phase 2 and 1 of SGMA Basin Prioritization

What does it represent: Determinations of critically over drafted groundwater basin or not

What do want it to indicate: Local groundwater vulnerability

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Location of data: DWR Phase 2 update, combined with Phase 1

Metric generated: Yes (1)/no (0) of whether area is in critical overdraft

Notes: Technical workgroup (SGMA) suggested alternative scaling, but only have binary for this so there is not other optional scaling. Incorporated as part of Alluvial Basin Conditions score.

RC2g. Chronic Declining Water Levels

Impact on risk: Declining level indicates surrounding increased risk

Data source: Documented Impacts #7.a - Declining GW levels Points

What does it represent: Groundwater level change in elevation 2011-2015

What do want it to indicate: Declining water levels

Location of data: DWR

Metric to generate: Associated rescaled score of sub-basin to the Census BGs.

Notes: This is included in addition to the overdraft indicator above because it is assumed that having this as more specific location data could be helpful to indicate more specific risk to water shortage during a drought. Incorporated as part of Alluvial Basin Conditions score.

RC2j. Presence of irrigated agriculture in surrounding basin

Impact on risk: May indicate competing demand on groundwater supplies, which could create higher risk for small suppliers during a drought or water shortage event.

What does it represent: Presence of irrigated agriculture in surrounding basin

What do want it to indicate: Competing demand on water use

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Location of data: DWR

Metric generated: Associated rescaled score of sub-basin to the Census BGs.

Notes: Complete. Incorporated as part of Alluvial Basin Conditions score.

RC2i. Source Water Quality Risk

Impact on risk: Presence of constituents at elevated concentration = increased risk

Data source: State Water Boards Division of Water Quality GAMA Groundwater Information System

What does it represent: Quality of groundwater likely accessed by domestic wells, based on the last 20 years of available data (from DDW, DWR, USGS, GAMA, and ILRP datasets) for each PLS section.

What do want it to indicate: Potential water quality problems in groundwater within the Census Block Group

Location of data: SWRCB

Metric generated: Five risk indices were developed for this metric: 1 (highest value) indicates an average historic or recent MCL exceedance for two or more constituents, 0.8 indicates an average historic or recent MCL exceedance for one constituent, 0.5 indicates historical average water quality between 0.5 and 1 times the MCL, and 0 indicates an historical average of less than 0.5 times the MCL for all constituents. -999 indicates where no data was available on water quality for that section.

Notes: Water quality data from Division of Water Quality at SWRCB. More detailed methodology involved in generating these risk indices will be posted to the Division of Drinking Water Needs Assessment website once complete.

5.2 Vulnerability of Self-Supplied Communities

We quantify vulnerability using a series of social and physical factors as they relate to groups of self-supplied residences. These groupings spatially are represented by US Census Block Groups. As done for the small water supplier vulnerability, self-supplied community vulnerability is quantified using three main components: (RC3) physical and (RC4) social vulnerability factors. Available data is sparse about households on their own supplies, so all information is estimated based on spatial associations to domestic wells within the Census Block Groups. No data was identified as readily available to represent those households that rely on private surface water intakes.

Note: As with the small water supplier assessment above, *vulnerability* is not a tangible, measurable concept; it is only relative as a comparison to others.

5.2.1 Physical Vulnerability

Physical vulnerability seeks to indicate the susceptibility of water shortage and drought for a self-supplied community. Two indicators developed using the depth of domestic wells compared to the depth of public wells are used to represent this component.

Table 8 Physical Vulnerability indicators for Self-Supplied Communities

Factor	Metric	Dataset	Data Source
RC3a - Well depth flag	Well-depth flag – if any portion of the groundwater unit(s) that intersect with the Census BG has relatively domestic wells, marked whole BG as ‘1’ (high risk) (0,1)	Well Completion Reports, processed by GAMA SWRCB	OSWCR-DWR
RC3b – Well depth proportion	Proportion of Public Land Survey Sections in Block Group where the max depth of domestic wells is shallower than max of public wells (0-1)	Well Completion Reports, processed by GAMA SWRCB	OSWCR-DWR

RC3a - Shallow Depth of Domestic Wells Part 1

Impact on risk: Increased risk when domestic wells in the area are shallower than public supply wells

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Data source: OSWCR DWR

What does it represent: Areas that could go out first, earlier than others during a dry year and are more shallow than public supplier wells in the surrounding area.

What do want it to indicate: higher risk when domestic wells are shallow

Location of data: DWR, processed by DWQ SWRCB group by Public Land Survey Section and then attributed to each groundwater unit. These groundwater units were then associated to Census Block groups for this analysis (by DWR).

Notes: Complete

RC3b - Shallow Depth of Domestic Wells Part 2

Impact on risk: Increased risk when wells are shallow, captures the proportion of area that is estimated as having shallower domestic wells (compared to public supply wells)

Data source: OSWCR DWR

What does it represent: Areas that could go out first, earlier than others during a dry year and are more shallow than public supplier wells in the surrounding area.

What do want it to indicate: Higher risk where domestic wells are shallower than public supplier wells, capturing extent of the risk

Location of data: DWR, processed by DWQ SWRCB group by PLS Section and then attributed to each groundwater unit. These groundwater units were then associated to Census BGs for this analysis (by DWR).

Notes: This is a proportion scale.

5.2.2 Socioeconomic Vulnerability

Social vulnerability factors associated with self-supplied communities includes 14 variables. The list of demographic variables selected to gauge social vulnerability of self-supplied communities is based on the CDAG input combined with Flanagan et al. (2011), a report written by several scientists at the Center for Disease Control to document its commonly used set of socio-economic population characteristics used to estimate social vulnerability. These population characteristics are the currently accessible factors they recommend using to calculate social vulnerability for disaster management, though we have omitted race and ethnicity factors given that these do not drive the population to be at higher risk. Race and ethnicity data can be offered as additional layer for post-scoring analysis given that they are characteristics of populations that often are exposed to higher risk.

Impact on risk: Demographic and socioeconomic characteristics examined are known to be more impacted during emergencies and disasters, following Cutter et al. (2003) and Flanagan et al. 2011.

Data source: US Census 2010 and American Community Survey 2012-2016

What does it represent: Social vulnerability of population within Census Block groups

What do want it to indicate: Social vulnerability of population within Census Block groups that may indicate households' varying capacity to manage their private water source when exposed to drought and shortage conditions.

Location of data: US Census/DWR Demographer

Metric to generate: Method of Center for Disease Control

Notes: Complete

Table 9 Indicators and datasets chosen to represent social factors (adaptive capacity) that contribute to increased risk to water shortage and drought for self-supplied communities

Variable	GIS Variable Names	Brief description of what variable is	Data Source
Per capita income 2016	PERCAP	Average per capita income for all block groups (BG)	ACS 2012-2016
Mean household income	AvgMHI	Average Median Household Income (MHI) for all BGs	ACS 2012-2016
Percent persons 65 year of age or older	Q65yr	Percentage of population of 65 and older of all BGs	ACS 2012-2016
Percent persons 17 year of age or younger	Q17yr	Percentage of population of under 17 years of all BGs	ACS 2012-2016
Percent persons 5 year of age or younger	Q5y	Percentage of population of under 5 years age of all BGs	ACS 2012-2016
Percent mobile homes	Qmobile	Percentage of mobile households of all BGs	ACS 2012-2016
No vehicle available	QnoVeh	Percentage of households with no vehicles of all BGs	ACS 2012-2016
Percent persons with no high school diploma	Qedu	Percentage of population over 25 years age with no high school diploma of all BGs	ACS 2012-2016
Percent population with single parent	Qparent	Percentage of population with single parent with children under 18 of all BGs	ACS 2012-2016
Percent population unemployed	Qunempl	Percentage of population of civilian unemployed of all BGs	ACS 2012-2016

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Variable	GIS Variable Names	Brief description of what variable is	Data Source
Percent of population who speak English less than well	Qlang	Percentage of population who speak English less than well of all BGs	ACS 2012-2016
Percent of population in group quarters	Qgroup	Percentage of all census block population with Group Quarters (GQ)	Census 2010

Following the Center for Disease Control's method of calculating social vulnerability index, we used the following groupings of the socioeconomic variables.

Socioeconomic status:

- MHI
- Per capita income
- Percent under poverty level

Household composition and language (this is revised from Center Disease Control's method to account for not having disability data and not using race data):

- Percent 65 years and over
- Percent under 5 years
- Percent single parent households
- Percent of unemployment among employable age
- Percent without a high school degree among those over 25 years
- Percent of population who speak less English less than very well

Housing and transportation:

- Percent of households with no vehicle
- Percent living in group quarters
- Percent renters
- Percent living in mobile homes

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The percentile ranking was calculated for each variable. Then these ranking were summed within each of their corresponding themes above. Then the percentile rank was calculated for each theme. Then the sum of the theme's percentile ranks was calculated to create an overall vulnerability score. This was rescaled using percentile rank to include as a variable in the Self-Supplied Communities Risk equation (see here for more information on this method (<https://svi.cdc.gov/publications.html>, and here: <https://www.youtube.com/watch?v=REKFHOryflA&feature=youtu.be>).

5.2.3 Record of Shortage

RC5a – Reported household outages on domestic well

Impact on risk: Increased risk in areas that have already experienced outages.

Data source: DWR <https://mydrywatersupply.water.ca.gov/report/>

What does it represent: Presence of one or more households with reported outages in Census BG (0,1)

What do want it to indicate: Areas that may experience outages again due to combinations of aquifer sensitivity/fluctuations and shallow wells.

Location of data: DWR, processed by DWQ SWRCB group by PLS Section and then attributed to each groundwater unit. These groundwater units were then associated to Census BGs for this analysis (by DWR).

Notes:

RC5b – Reported household outages on private well

Impact on risk: Increased risk in areas that have already experienced outages.

Data source: DWR <https://mydrywatersupply.water.ca.gov/report/>

What does it represent: Proportion of households with reported outages in Census BG (compared to total households in BG) (0-1 scalar)

What do want it to indicate: Areas that may proportionally experience outages again due to combinations of aquifer sensitivity/fluctuations and shallow wells.

Location of data: DWR Southern Regional Office

Notes: Complete

5.3 Method of Aggregation for Scoring Communities

To aggregate the risk factor variables described above, we use simple calculation that weights each variable within its given component of the framework. Then we aggregate the weighted component scores together. This offers a transparent, interpretable, and communicable method for calculating risk based on the many variables identified.

To combine variables, we use the method illustrated below. All variables are rescaled in 0-1 numbers, which then is combined with the variables in their respective component. Scales were adjusted when necessary so that all scales indicate higher risk on the higher end of the scale (1 is the highest, zero is the lowest). As described in Indicators Section above, each indicator has a different scoring done to make it applicable for this project.

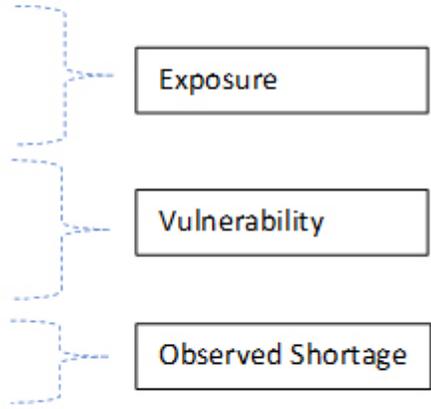
Each group of variables is combined with the other groups' scores for that component (components are Exposure, Vulnerability, and Observed Shortage).

We examined 5,000 Census Block Groups, selecting those that had at least one domestic well drilled between 1970-2019 (from DWR Well Completion Reports) and had at least one household on record by the US Census. The following map indicates the spatial coverage of the analysis.

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Equation for Self-Supplied (Rural) Community Risk:

Self-Supplied Community's Risk of Drought and Water Shortage =

$$\begin{aligned} &0.25 \times \mu(\text{RC1a, b, c}) \\ &+ \\ &0.75 \times \mu((\text{RC2a,b,c,i,h}) + \text{Max}(\text{RC2d,e,f,g,j})) \\ &+ \\ &(\widehat{\text{RC3a}} + b) \\ &+ \\ &\mu(\text{RC4a, b, c}) \\ &+ \\ &0.33 \times (\widehat{\text{RC5a}} + b) \end{aligned}$$


Exposure

Vulnerability

Observed Shortage

Where, all RC's value is scaled from 0 to 1, ordinal between 0 and 1, or binary 0 or 1.

Weighting

Two main weightings were considered to capture the CDAG's discussions. First, the scores were within each component. For example, based on the October 2019 CDAG meeting discussions and post-meeting written comments, the climate change indicators were weighted much lower than the current conditions indicators, decreasing the important of climate change factors on the final scores.

The second weighting considered involves the populations estimated use and assumed reliance on domestic wells. Preliminary exploratory analysis included that the sum of all three components were multiplied by a Domestic Well Reliance indicator. The purpose of this method was to de-emphasize the weighting of those Block groups with high exposure and high vulnerability, but that are almost entirely supplied by public water systems, are ranked low in the overall Self-Supplied Community Risk Score. However, such a weighting was determined to create a confusing and potentially misleading message about risk of drought and water shortage. Therefore, we offer the Domestic Well Count per Block Group with the final score, but not as part of it.

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6.0 Variable Name and Description Table

The table below presents the name and brief description of each variable provided in the downloadable table of results for the small water suppliers risk scoring.

Table 10 Variable Names and Descriptions

Variable Name	Variable Description
County	County on record in which water supplier is located
pwsid	Public water system identification number
owner_type	Ownership Type
PWS_TYPE	Type of public water system
RES_SDWIS	Estimated residential population served
SystemName	Public water system name
TotalPop	Total population served
WATER_TYPE	Type of primary water source
SC1a_abs_ch	SC1a - averaged absolute projected max temperature change by mid-century
SC1a_heatAvg_percen	SC1a - averaged percent of projected max temperature change by mid-century
SC1aR_Qheatcc	SC1a - Projected change in temperature rescaled 0-1
SC1bR_saltwatergwSLR	SC1b - Projected severe or high severe risk for each system boundary or community rescaled 0-1
SC1cR_firecc	SC1c - Presence salt with 1 meter sea level rise into coastal aquifers rescaled 0-1
SC2aR_wildfire	SC2a - Modelled current risk for each system (based on vegetation)
SC2bR_DroughtForecast2019	SC2b- Annual Risk of Local Drought (precipitation-based by January 31 of current year's analysis)
SC2c_fractured	SC2c - Fractured rock (presence 1, absence 0)
newSC2cR_fra_sw	Fractured rock presence, weighted by surface water reliance (0.5) or groundwater (1)

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Variable Name	Variable Description
SC2d_subsidence	SC2d - Susceptibility to subsidence
SC2e_salt	SC2e - Salts documented in basin
SC2f_overdraft	SC2f - Critically overdrafted basin
SC2g_gwlevel	SC2g - Declining groundwater levels
SC2h_Popgrowth_recodedpws2	SC2h - Near term projected population growth rate
rSC2Rbasindefgjxwatertype	Combined score with basin variables, weighted by primary water source type (SC2R – Groundwater Basin Vulnerability)
rSC2iR_gamawq_xwatertype	SC2i - Water quality flag weighted by primary water source type
rSC2jR_ag	SC2j - Presence of irrigated agricultural in basin
rSC3aR_intertie	SC3a - Available water transfers (presence of interties, rescaled 0-1)
rSC3bR_emergtie	SC3b - Availability of emergency water (presence of emergency interties, rescaled 0-1)
rSC3cR_monitor	SC3c - Baseline monitoring (level of monitoring reported, rescaled 0-1)
rSC3dR_qUnmeter	SC3d - Lack of metering (% system connections that have meters)
rSC3eR_singlesrc	SC3e - Number of sources
rSC3fR_srctype	SC3f - Number of source types
SC3_svc_connec	System size, number of service connections
rSC3g_servconn	SC3g - Supplier size rescaled 0-1
rSC3iR_distprob	SC3i - History of distribution problems
rSC3jR_watrSTATUS	SC3j - Current water supply levels
rSC3hR_short11to18	SC3h – Shortage: Self-reported projected shortage
rSC3kR_curtailorder2014	SC3L – Shortage: Systems under order of compliance for curtailment (2014) or building moratoriums
rSC3LR_droughtassist	SC3k – Shortage: Systems that received drought assistance
rSC4aR_yrssincerateupdate	SC4a - Upgraded rate structure, year updated
rSC4bR_ratetype	SC4b - Type of rate structure (Flat base rate or other)

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Variable Name	Variable Description
rSC4dR_yrDPP	SC4d - Have drought plan or water shortage contingency plan, year written or updated
rSC4eR_demogcustomers	SC4e - Customer base socio-economics
PERCMISSING_vulnerability	Percent of missing indicators from the vulnerability indicators (Components 3 and 4)
Prank_onethirdshortageRISKTOTAL	Final Risk Score, 1-100 with 100 as highest risk; for assessment conducted in 2019

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7.0 References

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