Part 2: Appendix 1
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

By

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Water Use Efficiency Branch

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Abbreviations and Acronyms

AF	acre-feet
CDAG	County Drought Advisory Group
DWR	California Department of Water Resources
GCM	Global Climate Model
GSA	Groundwater Sustainability Agencies
km	kilometer
LMSL	local mean sea level
LOCA	Localized Constructed Analogue
MHHW	mean high high water
OEHHA	California Office of Environmental Health Hazard Assessment
SDWIS	Safe Drinking Water Information System
SLR	Sea Level Rise
State Water Board	State Water Resources Control Board
USGS	U.S Geological Survey

1.0 Purpose

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

This is the first statewide 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.

1.1 Coordination

DWR recognizes and is in communication with other state agencies and experts working on related efforts. These include but are not limited to 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, Climate Change and Health Equity of the California Department of Public Health, Governor's Office of Planning and Research, Community Water Center, Water Equity Science Shop at University of California, Berkeley. Our effort creates a model of risk that is consistent with concepts, datasets, and metrics with these other efforts whenever possible and as applicable.

2.0 Roadmap for Risk Scoring

The overall goal is to identify what small water suppliers and self-supplied 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.

3.0 Key Concepts and Approach

This section presents key concepts and definitions related to this report.

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 managed by the State Water Board.
- 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 or use over 3,000 AF are required to develop an Urban Water Management Plan, which is required to include sections on drought risk assessment and a structured water shortage contingency plan. When known, 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.

Much of the analysis relies on spatial data, therefore only those water systems that have spatial boundaries of their service areas recorded in California Drinking Water System Area Boundaries on the California State Geoportal, accessed July 1, 2020 (https://gis.data.ca.gov/datasets/fbba842bf134497c9d611ad506ec48cc_0).

The "State Small Systems" (as identified by SWRCB) are those non-public systems with 4 to 14 service connections that do not provide water regularly to more than an average of 25 people for more than 60 days. They are considered under the self-supplied communities' analysis until more data on this water system type is more readily available.

3.3 Self-Supplied Communities

The 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 (e.g., dish washing, showering, drinking) 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 to 4 connections) state smalls (serving between 5 to 14 connections) or domestic wells (serving one connection).

3.4 Risk

Consistent with the Intergovernmental Panel on Climate Change's (IPCC) 2012 Special Report on Extreme Events (Cardona et al. 2012) and the IPCC's 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 County Drought Advisory Group (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" (Murphy et al. 2015) 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 c*apacity* 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 (Cardona et al. 2012) and the World Risk Reports (Garschagen et al 2016; IFHV 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 1-1). Each also has a unique set of sensitivities and adaptive capacities that make it more or less vulnerable to this exposure (Vulnerability in Figure 1-1).

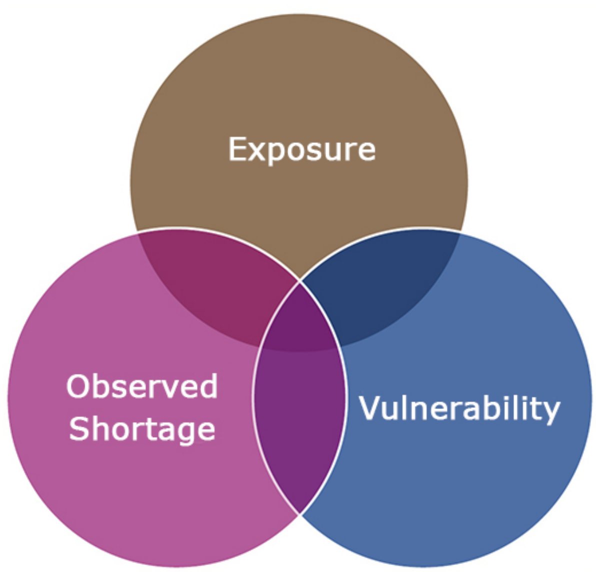


Figure 1-1. Groupings of Indicators (components) Used to Estimate Drought and Water Shortage Risk for Small Water Systems and Self-Supplied Communities (exposure, vulnerability, observed shortage)

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 following the workshop, the DWR staff matched the risk factors with potential statewide 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. This was done through breakout groups that focused on specific components for the target analysis (small water systems or self-supplied communities). The workshop gave time for participants to shift to different table's topic so they could contribute to discussions of indicators for multiple components. Breakout groups were concluded with a group representative summarizing the discussion and recommendations. Notes were also taken directly on the poster-sized indicator tables.

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 range from 0 to 1, where 0 is contributing to lower overall risk and 1 is contributing to higher overall risk. This scaling allows for multiple variables to be calculated together for a composite score. The 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.

4.0 Small Water Supplier Indicators and Scoring

4.1 Indicators

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, groundwater engineers and geologists, and climate scientists. The groupings of Components 1 and 2 represent the conditions and episodic events to which a water system could be exposed to, based on its geographic location. The groupings of Components 3 and 4 cover those attributes and characteristics of the water system that may make it more or less vulnerable to dry periods and other water shortage-related situations. Component 5 includes risk factors that indicate past record of impacts from the drought, which may indicate elevated risk of impact in future dry periods.

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 saltwater intrusion (via sea level rise). These represent mid-century projections, consistent with DWR's vulnerability assessment (though projections on wildfire and temperature are derived from the state's Fourth Climate Change Assessment 2018 and sea level rise impacts are from University of Arkansas and the U.S. Geological Survey (USGS). Future analysis should include projections of precipitation and drought, as these become readily available in a salient format for local water managers. Details of each indicator used are presented in Table 1-1 and described in more detail below.

Table 1-1. Indicators of Climate Change Impacts on Water Systems Relevant to Water Shortage and/or Drought (Component 1)

COMPONENT 1 –Climate Change Indicators (ID)	Metric	Data Source
Projected Temperature Shift (SC1a)	Projected change in temperature by mid-century	Pierce et al. 2018
SC1b - Projected Sea Level Rise	Presence of salt into coastal aquifers with projected 1-meter sea level rise	Befus et al. 2020
SC1c - Projected Wildfire Risk	Projected acres burned from wildfire for each system boundary or community	Westerling et al. 2018

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: Pierce et al. 2018

Location of data: Downloaded data from Cal-Adapt on 9/28/20, Raster called *tasmaxdiff_30yavg_ens10_rcp85_2035-2064.LOCA_2016-04-02.16th.CA_NV.tif*

What does it represent: The change in degrees Celsius of maximum temperature from historical range (1961-1990) to mid-century. From Cal-Adapt site's metadata description: Daily downscaled climate projections generated to support climate change impact studies for California's Fourth Climate Change Assessment by Scripps Institution of Oceanography. A total of 32 coarse-resolution (~100 kilometers [km]) Global Climate Models (GCM) from the CMIP5 archive were bias-corrected and downscaled to a resolution of 1/16° (about 6 km, or 3.7 miles) using the Localized Constructed Analogues (LOCA) statistical method.

What we want it to indicate: Increasing temperature as a pressure on water demand.

Metric generated: Change in degrees (Celsius) in maximum temperature by mid-century, attributed with spatial join (max) in ArcGIS to service areas. Rescale 0-1 using min/max/range equation.

Notes: This metric was updated from April 2020 public draft to use absolute temperature change instead of percent change; also updated the source to use Pierce et al. 2018 LOCA downscaled projections.

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

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

Data source: Supplementary dataset of shapefiles of the saline groundwater wedge footprint for the twelve model scenarios for twelve sea levels outlined in: Befus, K.M., Barnard, P.L., Hoover, D.J., Finzi Hart, J.A., and Voss, C.I. (2020a), Increasing threat of coastal groundwater hazards from sea-level rise in California, Nature Climate Change, https://doi.org/10.1038/s41558-020-0874-1.

Location of data: Befus et al. 2020(b). California Saline Groundwater Wedge Footprint Model Results, *Hydroshare* (online data repository), https://www.hydroshare.org/resource/d369b76492a14a2ea5142b9826a61c41/

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

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

Notes: The exposure data (of which service areas are at risk to this indicator) were calculated using shapefiles downloaded from Hydrograph data repository (from Befus et al. 2020), compiling the mean high high water (MHHW) tidal level datasets. All county shapefiles were merged to create a single shapefile. 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 meters deep (as you move inland, the interface gets deeper). The shapefiles were merged (by DWR staff in October 2020) from present-day up until a sea level of 1 meter above present day (using a bathtub type assignment of sea level, though also uses the local mean sea level (LMSL) tidal datum from NOAA's vdatum that is variable along the California coast). This calculation is based on a steady-state (or equilibrium) groundwater model modelled under MHHW tidal conditions.

Metric generated: Spatial join of small water suppliers' service areas and/or Block groups intersect with the spatial extent of projected saltwater intrusion under 1 meter (SLR) and modelled as MHHW. Generated presence/absence data per block group polygon. Those block groups with any presence of saltwater intrusion are tagged as "1," signifying at risk of saltwater intrusion. Those service areas with no saltwater intrusion are tagged with "0."

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: Westerling et al. 2018.

Location of data: Cal-Adapt (https://cal-adapt.org)

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 for the entire state.

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

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

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 2020), which do not cover the entire state.

Table 1-2. Indicators of Current or Recent Hazardous Conditions and Events (Component 2)

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 2020	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
SC2d – Basin – Subsidence	Susceptibility to subsidence	DWR
SC2e - Saltwater Intrusion	Saltwater intrusion modelled in coastal aquifer under present conditions	DWR
SC2f – Critically Overdrafted	Critically overdrafted basin	DWR
SC2g – Chronic Declining Water Levels	Declining groundwater levels	DWR
SC2j – Surrounding agricultural land use	Amount of irrigated agriculture in service area	DWR

Episodic Stressors

SC2a. Drought Early Warning Forecast Water Year 2020

What: Current Water Year's Early Warning Forecast for risk of local drought (must be updated annually)

Data source: Oregon State University PRISM Climate Group

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

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

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

Metric generated: With raster files for months of October 2019, November 2019, December 2019 and January 2020, sum the precipitation received (using raster calculator in ArcGIS). Divided sum by normal historic precipitation. This product is the proportion of precipitation received as a proportion of the historic average precipitation. Block groups 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**.

The original PRISM precipitation data is in raster (grid) format. We calculated the original PRISM data for the months of interest (Oct 1 2019 -Jan 31 2020, 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). Adjusted the cell size in the raster calculator ("environment" menu in tool) to be 0.0001 so that all Block groups were captured.

.00 = Lower local drought risk – Local precipitation by January 31, 2020, was above 70 percent of average precipitation. 1.00 = Presence of local drought risk – Local precipitation was less than 70 percent of average precipitation

SC2b. Wildfire as present threat to water shortage

What: Current Risk of Wildfire

Data source: CalFire

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

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

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

Metric to generate: Rescaled to 0-1 ordinal scale with Extreme Severity = 1; High=0.7; Moderate=0.3; Low=0)

Notes: None.

Source Environmental Conditions and Stressors

SC2c. Fractured Rock

Impact on risk: Water availability in fractured rock areas is more difficult to monitor and therefore more uncertain for those relying on this as a source of water.

Data source: California's Groundwater Update 2020 (Bulletin 118)

Location of data: DWR

What does it represent: Areas that are outside alluvial basins in California

What we want it to indicate: Areas with fractured rock

Metric generated: Scoring = 0/1 binary scale so that all areas outside of basins are scored as 1 (high risk), those are inside of basins are scored as 0 (no risk for this indicator). Scores were weighted by multiplying by *weightSWforGWvar*, which reduces the risk contribution of this indicator for those water systems with one or more surface water supplies. The variable *weightSWforGWvar* is 0.5 for those systems that have one or more surface or purchased water sources, and 1 for those with only groundwater sources.

Notes: Block groups marked as presence of fractured rock may be entirely or only partially located in fractured rock area.

SC2R. Groundwater Basin Vulnerability

What: Presence and extent of one or more risks observed in the groundwater basin directly related to shortage risk. This is an aggregate indicator composed of the max value (0 to 1) for several risk factors relating to water shortage risk in groundwater basin. This indicator's score is weighted by whether or not the system has any surface water available as an active source or not. For those that do have an active surface water source, this indicator is down-weighted by half.

Data source: Several, see specific variables below. This is referred to as SC2defgj in the equation below for $Risk_{final}$.

Data source: Aggregated multiple risk factors that can play a role in increasing risk of water shortage, including presence of subsidence in basin (SC2d), presence of saltwater intrusion to coastal aquifers (SC2e), record of critically over drafted basin (SC2f), record of chronic declining water levels (SC2g), and presence and proportion of irrigated agriculture (SC2j).

Location of data: Various, see specific variables below.

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

What 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.

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. Scores were weighted by multiplying by *weightSWforGWvar*, which reduces the risk contribution of this indicator for those water systems with one or more surface water supplies. The variable *weightSWforGWvar* is 0.5 for those systems that have one or more surface or purchased water sources, and 1 for those with only groundwater sources.

Notes: Updated per public comments (June 2020) to use higher resolution data available (groundwater levels, subsidence, and irrigated agriculture presence). See details below for methods used to construct the individual indicators.

SC2d. Subsidence

Impact on risk: Higher susceptibility = higher risk

Data source: DWR 2020 https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence

Location of data: Raster Vertical_Displacement_TRE_ALTAMIRA_v2019_Total_Since_20150613_20190919 in geodatabase: \\cnrastore-gis\DWR_RIL_3\SAR\SGMA\2019_update\ImageServiceData\Vertical_Displacement_TRE_ALTAMIRA_v2019_Total_Since_20150613.gdb

What does it represent: Presence of subsidence in alluvial basin observed between June 2015 through September 2019.

What we want it to indicate: Subsidence problems and increased risk of shortage issues.

Metric to generate: Use ZonalStatistics on service area centroids to calculate the subsidence on record. Rescaled from 0-1 using the min-max rescaling technique.

Notes: Updated from public draft (April 2020) with higher resolution dataset than basin level.

SC2e. Saltwater Intrusion in Coastal Aquifers

Wells in areas where saltwater intrusion is present is increases water quality challenges. These challenges may worsen during a dry period.

Data source: Supplementary dataset of shapefiles of the saline groundwater wedge footprint for the twelve model scenarios for twelve sea levels outlined in: Befus, K.M., Barnard, P.L., Hoover, D.J., Finzi Hart, J.A., and Voss, C.I. (2020a), Increasing threat of coastal groundwater hazards from sea-level rise in California, Nature Climate Change, https://doi.org/10.1038/s41558-020-0874-1.

Location of data: Befus et al. 2020b, *California Saline Groundwater Wedge Footprint Model Results*, Hydrograph online data repository [https://www.hydroshare.org/resource/d369b76492a14a2ea5142b9826a61c41/]

What does it represent: Modelled saltwater intrusion into coastal aquifers in present day.

What we want it to indicate: Presence of saltwater intrusion in coastal aquifers that may add challenges to suppliers and households reliant on groundwater.

Notes: Updated from public draft (April 2020) with higher resolution dataset than basin level.

SCf. Critically Overdrafted Basin

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

Data source: Phase 2 and 1 of SGMA Basin Prioritization (DWR 2020)

Location of data: DWR, https://data.cnra.ca.gov/dataset/sgma-basin-prioritization (SGMA Basin Prioritization [Dashboard Data] csv file)

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

What we want it to indicate: Local groundwater vulnerability

Metric generated: Yes (1)/no (0) of whether service area polygon is in any part pf critically overdrafted basin.

Notes: None.

SC2g. Groundwater Decline

Impact on risk: Declining level indicates surrounding increased risk

Data source: California's Groundwater Update 2020 (Bulletin 118)

Location of data: California's Groundwater Update 2020 (Bulletin 118)

What does it represent: Groundwater level change in elevation 2015-2019

What we want it to indicate: Declining water levels in aquifer that may put wells at higher risk of shortage.

Metric generated: Using point data of wells that are in decline from *California's Groundwater Update 2020 (Bulletin 118)* analysis, applied a spatial join in ArcGIS to associate service area polygons that have one or more wells in decline within the polygon.

Notes: The decline in well levels is included in addition to the critically overdrafted indicator (SCf) because it is higher resolution and it is assumed that having this as more specific location data could be helpful to indicate more specific risk to water shortage during a dry period. Incorporated as part of SC2R indicator. This indicator was updated from the April 2020 version using higher resolution dataset than the previously used basin level.

SC2j. Land Use

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 and proportion of irrigated agriculture in service area.

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

Data Source: Crop Map 2016 (DWR 2020)

Location of data: CNRA Open Data Portal
https://data.cnra.ca.gov/dataset/statewide-crop-mapping/resource/d5841996-ba8b-455c-819f-222006db7b85

Metric generated: Use crop mapping data on DWR GIS Atlas. Selected out only agricultural land use types using definition query for agricultural land use types (i.e. no urban, native vegetation, unclassified). Calculated farmed percent within service area. Classified results by low to high proportions of irrigated agriculture within service area: 0= none (0); .01-.25=low (.25); .26-.5=medium (.5); .51-1=high (1). Associated rescaled score of subbasin to the service areas of small water suppliers examined.

Notes: Updated from April 2020 public draft to use high resolution original land use data rather than basin level.

SC2h. Population Growth Rate

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

Data source: DWR vendor-derived US Census-based estimates (Nielsen Claritas 2016)

Location of data: DWR

What does it represent: Population growth projected in service area

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

Metric generated: Rescaled population growth rate from vendor estimates by service area from a proportion to 0-1 using min/max/range equation.

Notes: None.

SC2i. Source Water Quality Risk

Impact on risk: Increased contamination creates an increased risk during dry periods or other water shortages, especially in cases where systems have no other water source.

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

Location of data: Compiled from USGS data from factsheets on deep aquifers within each watershed study unit: https://ca.water.usgs.gov/projects/gama/includes/GAMA_publications.html)

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

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

Metric generated: Calculated weighted percent of constituents past regulatory thresholds (1) or near thresholds (0.5) for each watershed study unit (USGS). Applied spatial join to associate the service area polygons to the study unit score. Scores were weighted by multiplying by *weightSWforGWvar*, which reduces the risk contribution of this indicator for those water systems with one or more surface water supplies. The variable *weightSWforGWvar* is 0.5 for those systems that have one or more surface or purchased water sources, and 1 for those with only groundwater sources.

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; Füssel 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 it 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).

4.3 Infrastructure Vulnerability + Organizational Vulnerability = Vulnerability of Small System

Infrastructure Vulnerability Factors

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

Table 1-3. List of Indicators Representing Infrastructure Vulnerability of Small Water Suppliers, Including Metrics and Datasets (Component 3a – Connectivity Infrastructure Vulnerability)

COMPONENT 3a Connectivity – Infrastructure Vulnerability	Metric	Data Source
SC3a – Interties	Presence of one or more intertie	SDWIS 2020
SC3b – Emergency interties	Presence of one or more emergency intertie	SDWIS 2020
SC3e – Single Water Source	Water sources more than one	SDWIS 2020
SC3f – Single Source Types	Water source types more than one	SDWIS 2020

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: Safe Drinking Water Information System (SDWIS) (SWRCB)

Location of data: SWRCB SDWIS Query

What does it represent: Presence of more than one intertie

What we want it to indicate: Present capacity for water transfers

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

Notes: Received from SWRCB SAFER Program 10/26/2020 SDWIS query.

SC3b. Emergency Interties

Impact on risk: The availability of current emergency interties, the assumed lower risk of a water outage because the supplier can potentially switch sources if needed.

Data source: SDWIS 2020

Location of data: SWRCB SDWIS

What does it represent: Presence of emergency interties

What we want it to indicate: Availability of emergency water

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 left blank.

Notes: None.

SC3e. Single Water Source

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

Data source: SDWIS (SWRCB)

Location of data: SDWIS

What does it represent: Whether or not a system has more than one supply source for its water.

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

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

Notes: Received from SWRCB 10/26/2020 SDWIS query. Hauled water (code of NP is SDWIS) is not counted as a water source, therefore some systems have zero sources.

SC3f. Source Types Count

Impact on risk: Fewer source types is higher risk.

Data source: SDWIS

Location of data: SDWIS (SWRCB)

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

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

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 received from SWRCB 10/26/2020 SDWIS query. Hauled water not counted as a water source, therefore some systems have zero source types.

Component 3b – Other Infrastructure Vulnerability

Table 1-4. List of Indicators Representing Infrastructure Vulnerability of Small Water Suppliers, Including Metrics and Datasets (Component 3b – Other Infrastructure Vulnerability)

COMPONENT 3b – Other Infrastructure Vulnerability	Metric	Data Source
SC3c - Baseline monitoring	Level of monitoring reported	eAR 2018
SC3d – Customers metered	% system connections unmetered	eAR 2018
SC3i – Distribution Outage Record	Distribution problems related to water outage	eAR 2018
SC3j – Water Level Status	Levels of water source-recovering, steady, declining, blank	eAR 2018

Supplier's Information Infrastructure

SC3c. Source Monitoring

Impact on risk: Having baseline monitoring could decrease a supplier's risk because it indicates the capacity to observe declining levels.

Data source: eAR 2018, columns "CONSERVATION Monitor Static" + "CONSERVATION PWL"

Location of data: SWRCB
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/ear.html

What does it represent: Coded ordinal 0, 0.5, 1 scale (none, monitor static level, monitor pumping) reported in eAR 2018

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

Metric generated: -99= no data; 1 = no reported monitoring; 0.5= static monitoring only; 0= static and water 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 2018 "T Potable UM"/"T Potable Total"

Location of data: SWRCB
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/ear.html

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

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

Metric generated: Proportion of potable connections unmetered (eAR 2018) (0-1 scalar)

Notes: None.

Physical Coping Capacity

SC3i. Distribution Outage Record

Impact on risk: Potentially increases risk

Data source: eAR 2018

Location of data: SWRCB
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/ear.html

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

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

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

Notes: None.

SC3j. Water Level Status

Impact on risk: Self-reporting declining levels of water supply indicate an elevated risk to a dry period and/or water shortage.

Data source: eAR 2018 (fieldcode: *SourcesLevel*)

Location of data: SWRCB
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/ear.html

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 we want it to indicate: This seeks to indicate whether the water supply is at risk.

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 no data.

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

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 1-5).

Table 1-5. 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 (ID)	Metric	Data Source
Rate Last Updated (SC4a)	Year rate structure was last updated	SWRCB
Rate Type (SC4b)	Type of rate structured used by supplier. Survey question in eAR 2018 (flat base rate =1; other =0)	SWRCB
Supplier Size (SC4c)	Service connections rescaled and inverted	SWRCB
Drought Preparedness Plan (SC4d)	Have drought plan or WSCP; year written or updated	SWRCB
Customer Base Socioeconomics (SC4e)	Multiple population characteristics combined score	DWR 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 2018

Location of data: SWRCB
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/ear.html

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

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

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: None.

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 2018

Location of data: SWRCB
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/ear.html

What does it represent: Use of flat base rate or no water rate, not based on volume of use.

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

Metric to generate: Scored so that flat base rate or no water rate =1; other =0

Notes: None.

SC4c. 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 SWRCB

Location of data: SDWIS

What does it represent: Inverted service connections count

What we 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.

Metric generated: Rescaled 0-1 using min/max/range equation and inverted so zero is the most service connections (thus contributing least to risk).

Notes: Received data from SWRCB 10/26/2020 SDWIS query.

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 2018 (field code: *CONSERVATION DPP Date*)

Location of data: SWRCB
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/ear.html

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 2018) 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 we want it to indicate: having a recently updated drought preparedness plan indicates higher coping capacity.

Metric to generate: Drought Preparedness Plan (DPP) developed in 2003 or before =1; DPP developed between 2004-2014=0.5; DPP developed since 2015=0.

SC4e. Customer Base Socioeconomics

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 (i.e.., 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. (2003) and Flanagan et al. (2011).

Data source: A private vendor software, Pcensus for Arcview based on Nielsen Claritas Pop-Facts database, was used to estimate population characteristics within service area boundaries. The Claritas Pop-Facts database uses various data sources, such as Census, American Community Survey, city, and county to estimate populations in custom geographies. Pcensus was used for estimating population socio-demographic variables for water system custom boundary data for two reasons:

(1) Estimating the Median Household Income (MHI) for the water system custom geographies: It is not mathematically correct to estimate MHI by using a proportion formula. In order to estimate MHI for an area, we need to determine the number of households in each income bracket and then find the median. That means when we have thousands of custom boundaries (such as the service areas of water systems) then there will be 30,000 to 40,000 intersected block groups. Therefore, due to time and money constraints, using the DWR owned private demographic software to estimate MHI is more efficient.

(2) Estimating socio-demographic variables for custom geographies: The software uses the block proration method as opposed to the area proportion formula described in method 1 above. If we use the area proportion formula, the assumption is that the numbers are evenly distributed throughout the study areas, which is rarely the case.
For details about Nielsen Claritas, please see
https://help.healthycities.org/hc/en-us/articles/225578908-Claritas-Pop-Facts-Demographics

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

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; and % 65yrs and older.

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

Metric to generate: Social vulnerability score for each small water supplier aggregating estimates of each of the following measures listed in Table 1-6.

Notes: The following is a 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. Percent MHI could be an indicator of future rate increase tolerance and capacity for a specific water system.

Additionally, Rate Affordability is an 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. This could be explored for future use as it is made readily available.

Table 1-6. Demographic and Socioeconomic Characteristics Estimated to Represent the Customer Base Served by the Small Supplier. Spatial Analysis used to Associate Census Data to Service Area Boundaries

Variable	Variable Label	Description	Data Source
Per capita income 2016	PERCAP	Average per capita income for Block groups (BG) that intersected with the service areas	ACS 2012-2016
Mean household income	AvgMHI	Average Median Household Income (MHI) for 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	Q5yr	Percentage of population of under 5 years of 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 of 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
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

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 which suppliers experienced shortage during the last drought or otherwise, especially for suppliers that did not report occurrences. We therefore combine information from supplier-reports of expected shortage (an optional survey question, eAR), documented drought assistance provided during the 2012-2016 drought, and suppliers that received compliance orders during the drought.

Table 1-7. Risk Factors Associated with Experienced Drought Impacts or Water Shortage Records

COMPONENT 5 – Recent Observed Shortage	Metric	Data Source
SC5a – Shortage: Self-reported projected	Supplier-reported projected shortage	eAR 2011-2018
SC5b – Shortage: Curtailment and Compliance Order	Systems under order of compliance for curtailment (2014) or building moratoriums	SWRCB
SC5c – Shortage: Drought Assistance Record	Systems that received drought assistance on record	SWRCB

SC5a. 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

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

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

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

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

SC5b. 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

Location of data: SWRCB https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/water_availability.html, accessed October 2019.

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

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

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

Notes: None.

SC5c. 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 Division of Financial Assistance

Location of data: SWRCB

What does it represent: Record of drought assistance to supplier

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

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

Notes: None.

4.4 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

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). The following equation represents how the indicators described above were combined to calculate a risk score.

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

$Risk_{raw}$ =

$$0.25 \times \mu(SC1a, b, c)$$

Exposure

$$+$$

$$0.75 \times \mu[(SC2a, b, c, i, h) + \max(SC2d, e, f, g, j)]$$

$$+$$

$$[0.67 \times \mu(SC3a, b, e, f)] + [0.33 \times \mu(SC3c, d, i, j)]$$

$$+$$

$$0.33 \times \mu(SC4a, b, c, d, e)$$

Vulnerability

$$+$$

$$0.33 \times max(SC5a, b, c)$$

Record of Water Shortage

Then, $Risk_{final} = Risk_{raw}\text{-}min(Risk_{raw})/(range(Risk_{raw}))$

Where all SC's value has been scaled from 0-1, ordinal between 0 and 1, or binary of 0 or 1. Zero represents not contributing to risk, and 1 represents presence of risk factor or high contribution to the overall risk score. 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 $Risk_{raw}$ score from each component are summed and rescaled from zero to 100 using the min-max scaling technique to calculate $Risk_{final}$.

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, groundwater engineers and geologists, 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.

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.

Table 1-8. Indicators of Climate Change Impacts on Water Systems Relevant to Water Shortage and/or Drought (Component 1)

Risk Factor	Measure	Data Source
RC1a - Temperature Shift	Projected change in max temperatures by mid-century (averaged across models, RCP 8.5, Celsius)	Pierce et al. 2018
RC1b -Saline intrusion risk	Spatial extent of projected SLR under RCP 8.5 by 2040 (1m) into coastal aquifers; spatial join with Block groups	*Befus et al. 2020*
RC1c -Wildfire risk	Projected area burned (averaged across all GCMs) by 2035-2064, RCP8.5; spatial join with block groups	Westerling et al. 2018

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: Downloaded data from Cal-Adapt on 9/28/20, Raster called *tasmaxdiff_30yavg_ens10_rcp85_2035-2064.LOCA_2016-04-02.16th.CA_NV.tif*

Location of data: Cal-Adapt (https://cal-adapt.org)

What does it represent: The change in degrees Celsius of maximum temperature from historic range (1961-1990) to mid-century. From Cal-Adapt site's metadata description: Daily downscaled climate projections generated to support climate change impact studies for California's Fourth Climate Change Assessment by Scripps Institution of Oceanography. 32 coarse-resolution (~100 km) Global Climate Models (GCM) from the CMIP5 archive were bias-corrected and downscaled to a resolution of 1/16° (about 6 km, or 3.7 miles) using the LOCAs statistical method.

What we want it to indicate: Increased temperature as an increased pressure on water demand.

Metric to generate: Used the zonal statistics (used max) tool in ArcGIS on block groups with raster *tasmaxdiff_30yavg_ens10_rcp85_2035-2064.LOCA_2016-04-02.16th.CA_NV.tif* representing annual average values for mid-century 30-year period for 10 of the 32 LOCA downscaled GCMs under RCP 8.5. Filtered to block groups with presence of one or more domestic well and then rescaled to 0-1 using min/max/range, where higher temperature increase is closer to 1 and lower temperature increase is closer to zero.

Notes: Updated since April 2020 public draft replacing original data used to Pierce et al. (2018) and calculated change in degrees Celsius (instead of percent change in temperature).

RC1b. Projected Wildfire

What: Projected (future) wildfire risk with climate change

Data source: Westerling, UC Merced

Location of data: Cal-Adapt (https://cal-adapt.org)

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

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 Saltwater Intrusion in Coastal Groundwater

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

Data source: Befus et al. 2020a and Befus et al. 2020b

Location of data: Befus et al. 2020b. California Saline Groundwater Wedge Footprint Model Results, *Hydroshare* (online data repository), https://www.hydroshare.org/resource/d369b76492a14a2ea5142b9826a61c41/

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

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

Notes: The exposure data (of which block groups are at risk to this indicator) were calculated using shapefiles downloaded from Hydrograph data repository (from Befus et al. 2020), compiling the MHHW tidal level datasets. All county shapefiles were merged to create a single shapefile. 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 DWR staff) from present-day up until a sea level of 1m 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 California coast). This calculation is based on a steady-state (or equilibrium) groundwater model.

Metric generated: Spatial join in ArcGIS of Block groups intersect with the spatial extent of projected saltwater intrusion under 1m SLR and modelled as MHHW. Generated presence/absence data per block group polygon. Those block groups with any presence of saltwater intrusion are tagged as "1," signifying at risk of saltwater intrusion. Those block groups with no saltwater intrusion are tagged with "0."

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.

Table 1-9. Indicators of Current or Recent Hazardous Conditions and Events (Community – Component 2, SC2)

Risk Factor	Indicator	Data Source
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	PRISM Oregon State University
RC2b – Wildfire Risk	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 join in ArcGIS	CalFire
RC2c – Geology	Communities in Fractured Rock Areas (1) or not (0)	DWR
RC2h – Projected Population Growth	Projected population growth	DWR
RC2i – Water Quality in Shallow Aquifer	Domestic well water quality risk (includes areas outside of alluvial basins)	SWRCB
RC2d – Basin Subsidence	Record of subsidence	DWR, CNRA Open Data Portal
RC2e – Basin Salt	Presence of saltwater intrusion into coastal aquifer (based on model)	DWR, CNRA Open Data Portal
RC2f – Overdrafted Basin	Critically overdrafted groundwater basin	DWR
RC2g – Chronic Declining Water Levels	Declining groundwater levels	DWR
RC2j – Surrounding Land Use	Proportion of irrigated agriculture in block group	DWR CNRA Open Data Portal

Events and Environmental Conditions

RC2a. Drought Early Warning Forecast Water Year 2020

What: Current Water Year's Early Warning Forecast for risk of local drought (must be updated annually)

Data source: Oregon State University PRISM Climate Group (accessed October 5, 2020)

Location of data: Several files from http://www.prism.oregonstate.edu

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

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

Metric generated: With raster files for months of October 2019, November 2019, December 2019 and January 2020, sum the precipitation received (using raster calculator in ArcGIS). Divided sum by normal historic precipitation. This product is the proportion of precipitation received as a proportion of the historic average precipitation. Block groups under 70% =1 (high risk); Scored 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 January 31st in that water year. **This needs to be updated annually**.

The original PRISM precipitation data is in raster (grid) format. We calculated the original PRISM data for the months of interest (Oct 1 2019 -Jan 31 2020, 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 block group 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 = Lower local drought risk – Local precipitation by January 31, 2020, was above 70 percent of average precipitation.

1.00 = Presence of local drought risk – Local precipitation was less than 70 percent of average precipitation

RC2b. Wildfire as present threat to water shortage

What: Current Risk of Wildfire

Data source: CalFire

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

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

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

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 in coming years by CalFire.

Source: Environmental Conditions and Stressors

RC2c - Fractured Rock Area

Impact on risk: Water availability in fractured rock areas is more difficult to monitor and therefore more uncertain for those relying on this as a source of water. For more information, see California's Groundwater Update 2020 (Bulletin 118, DWR 2020)

Data Source: California's Groundwater Update 2020 (Bulletin 118)

Location of data: DWR

What does it represent: Areas that are outside alluvial basins in California

What we want it to indicate: Areas with fractured rock

Metric generated: Scoring = 0/1 binary scale so that all areas outside of these basins are scored as 1 (high risk)

Notes: Block groups marked as presence of fractured rock may be entirely or only partially located in fractured rock area.

RC2h - Population Growth in immediate region

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

Data source: Census

Location of data: DWR

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

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

Metric generated: Rescaled population growth rate from a proportion to 0-1 using min/max/range equation.

Notes: None.

RC2R. Groundwater Basin Vulnerability

What: Presence of one or more risks observed in the groundwater related to shortage risk.

Data source: Aggregated multiple risk factors that can play a role in increasing risk of water shortage, including presence of subsidence in basin (RC2d), presence of saltwater intrusion to coastal aquifers (RC2e), record of critically over drafted basin (RC2f), record of chronic declining water levels (RC2g), and presence and proportion of irrigated agriculture (RC2j).

Location of data: DWR

What does it represent: Groundwater basin vulnerability score is based on the maximum of any of the risk factors examined for this category (subsidence, saltwater, critically overdrafted basin, declining water levels, and presence of irrigated agriculture).

What 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.

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

Notes: Updated per public comments to use higher resolution data available (groundwater levels, subsidence, and irrigated agriculture presence). See details below for methods used to construct the individual sub-indicators.

RC2d. Presence of Subsidence in Basin

Impact on risk: Higher susceptibility = higher risk

Data source:

Location of data: CNRA Open Data Portal, https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence downloading file: Vertical_Displacement_TRE_ALTAMIRA_v2019_Total_Since_20150613_20190919

What does it represent: Presence of subsidence in alluvial basin observed between June 2015 through September 2019.

What we want it to indicate: Subsidence problems and increased risk of shortage issues.

Metric to generate: Presence and depth of subsidence (in feet) associated to block groups with Zonal Statistics in ArcGIS on centroids of block groups. Rescaled to 0-1 where 1 was the maximum feet of subsidence recorded that overlapped with a block group in this analysis.

Notes: Updated from public draft (April 2020) with higher resolution dataset than basin level.

RC2e. Saltwater Intrusion (Present Day)

Impact on risk: Wells in areas where saltwater intrusion is present in coastal aquifers is increases water quality challenges. These challenges may worsen during a dry period.

Data source: Supplementary dataset of shapefiles of the saline groundwater wedge footprint for the twelve model scenarios for twelve sea levels outlined in: Befus, K.M., Barnard, P.L., Hoover, D.J., Finzi Hart, J.A., and Voss, C.I. (2020a), Increasing threat of coastal groundwater hazards from sea-level rise in California, Nature Climate Change, https://doi.org/10.1038/s41558-020-0874-1.

Location of data: Befus et al. 2020b, *California Saline Groundwater Wedge Footprint Model Results*, Hydrograph online data repository [https://www.hydroshare.org/resource/d369b76492a14a2ea5142b9826a61c41/]

What does it represent: Modelled saltwater intrusion into coastal aquifers in present day.

What we want it to indicate: Presence of saltwater intrusion in coastal aquifers that may add challenges to suppliers and households reliant on groundwater.

Metric to generate: Merged coastal counties together to create a single statewide shapefile. Used a spatial join in ArcGIS to flag the block groups with presence of any saltwater intrusion (1 = presence; 0 = absence).

Notes: Updated from public draft (April 2020) with higher resolution dataset than basin level.

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

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

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

What we want it to indicate: Local groundwater vulnerability

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

Notes: None.

RC2g. Chronic Declining Water Levels

Impact on risk: Declining level indicates surrounding increased risk

Data source: California's Groundwater Update 2020 (Bulletin 118)

Location of data: California's Groundwater Update 2020 (Bulletin 118)

What does it represent: Groundwater level change in elevation 2015-2019

What we want it to indicate: Declining water levels in aquifer that may put wells at higher risk of shortage.

Metric generated: Using point data of wells that are in decline from *California's Groundwater Update 2020 (Bulletin 118)* analysis, applied a spatial join in ArcGIS to associate block groups that have one or more wells in decline within the block group.

Notes: The decline well levels is included in addition to the critically overdrafted indicator above because it is more high resolution and it is assumed that having this as more specific location data could be helpful to indicate more specific risk to water shortage during a dry period. Updated from the April 2020 version using higher resolution dataset than basin level.

RC2j. Presence and amount of irrigated agriculture in block group

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 and proportion of irrigated agriculture in block group.

What we want it to indicate: Competing demand on water use, especially during dry years.

Data source: DWR

Location of data: CNRA Open Data Portal, https://data.cnra.ca.gov/dataset/statewide-crop-mapping/resource/d5841996-ba8b-455c-819f-222006db7b85

Metric generated: Used crop mapping data on DWR GIS Atlas. Selected out only agricultural land use types using definition query for agricultural land use types (i.e. no urban, native vegetation, unclassified). Calculated farmed percent within service area. Classified results by low to high proportions of irrigated agriculture within service area: 0= none (0); .01-.25=low (.25); .26-.5=medium (.5); .51-1=high (1). Associated rescaled score of subbasin to the block groups.

Notes: This was updated with higher resolution than what was used in the April 2020 public draft.

RC2i. Source Water Quality Risk

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

Data source: State Water Board's Division of Water Quality GAMA Groundwater Information System

Location of data: SWRCB Division of Drinking Water GAMA Unit

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

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. Detailed methodology involved in generating these risk indices is posted to the Division of Drinking Water Needs Assessment website.

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.

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 1-10. Physical Vulnerability Indicators for Self-Supplied Communities (Component 3)

Factor	Metric	Dataset	Data Source
R3a - Well depth flag	Well-depth flag – if any portion of the groundwater unit(s) that intersect with the block group has relatively shallow 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

Data source: OSWCR DWR

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 block groups for this analysis (by 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 we want it to indicate: Higher risk when domestic wells are shallow.

Metric generated: DWR's OSWCR dataset of domestic well depths and locations processed by SWRCB DWQ GAMA Unit by Public Land Survey Section and then attributed to each groundwater unit. The processing included a comparison of domestic wells to public supplier wells by calculating a "bottom" for both (domesticmax, publicmax), which involved averaging the deepest wells per section within a groundwater unit, and then adding three standard deviations to that mean. The intention was to capture the deepest possible public/domestic depths. These deepest numbers for public and domestic, and also check if the depths are within 10% of each other. These were then recoded to 0/1/-999 (where -999 is no data) to calculate risk. A 0 means that public and domestic wells access the same aquifer, a 1 means they do not. A -999 means that there were either no public wells, no domestic wells, or no wells at all in the groundwater unit to make a comparison. This measure is the proportion of public land survey sections within the block group where the maximum depth of domestic wells is shallower than the maximum depth of public supply wells. These groundwater units were then associated to block groups for this analysis by DWR.

Notes: None.

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 with additional processing, see notes above for RC3a.

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

Metric generated: DWR's OSWCR dataset of domestic well depths and locations processed by SWRCB DWQ GAMA Unit by Public Land Survey Section and then attributed to each groundwater unit. These groundwater units were then associated to block groups for this analysis by DWR. See additional description of data for RC3a.

Notes: None.

Socioeconomic Vulnerability (RC4)

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, 2018), a report written by several scientists at the Center for Disease Control to document its commonly used set of socioeconomic 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.

The American Community Survey (ACS) of Census Bureau is the main source of data for estimating socio-demographic variables for the most recent data estimates in California and is collected every year. For ACS data, the Census Block Group (BG) is the smallest level of geography whereas block is the smallest level of geography in Census (collected every ten years). When the socio-demographic data is needed by standard geographic areas such as census counties, places, tracts and block groups, then we can extract directly from ACS, as we have done in this analysis.

Impact on risk: Demographic and socioeconomic characteristics examined are known to be more impacted during emergencies and disasters, following Cutter et al. (1996) and Flanagan et al. (2011).

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

Location of data: US Census/DWR

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

What we 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.

Metric to generate: Method following U.S. Center for Disease Control Social Vulnerability Index (CDC SVI) as described in Flanagan et al. (2011), Flanagan et al. (2018), Lehnert et al. (2020) and Wolkin et al. (2015). Described below.

Notes: See table of variables used and notes on methods following the table.

Table 1-11. Indicators and Datasets Chosen to Represent Social Factors (adaptive capacity, RC4) that Contribute to Increased Risk to Water Shortage and Drought for Self-Supplied Communities (Component 4)

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 of 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 of age with no high school diploma of all BGs	ACS 2012-2016

Table 1-11. Indicators and Datasets Chosen to Represent Social Factors (adaptive capacity, RC4) that Contribute to Increased Risk to Water Shortage and Drought for Self-Supplied Communities (Component 4) (contd.)

Variable	GIS Variable Names	Brief description of what variable is	Data Source
Percent Population with Single Parent	Qparent	Percentage of population with single parent with children under 18 of all BGs	ACS 2012-2016
Percent of Population Unemployed	Qunempl	Percentage of population of civilian unemployed of all BGs	ACS 2012-2016
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 a 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

The percentile rank was calculated for each variable. Then these ranks 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 (as a proportion from 0-1) to include as a variable (RC4) 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).

Record of Shortage

Stakeholder expressed the preference to incorporate recent past impacts from drought into the risk scoring. Record of outages was recorded by the state and continues to be managed by DWR.

Table 1-12. Record of Outages Indicators of Self-Supplied Communities (Component 5)

Component 5: Water Shortage Record	Indicator	Data Source
RC5a – Reported Household Outages on Domestic Well	Presence of one or more households with reported outages in Census Block Group	DWR
RC5b – Reported Household Outages on Private Well	Proportion of households with reported outages in Census BG (compared to total households in BG) (0-1 scalar)	DWR

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/

Location of data: DWR, My Dry Well Database (https://mydrywatersupply.water.ca.gov/report/), Accessed October 2019

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

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

Notes: None.

RC5b – Reported household outages on private well

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

Data source: DWR My Dry Well Database (https://mydrywatersupply.water.ca.gov/report/), Accessed October 2019

Location of data: DWR My Dry Well Database (https://mydrywatersupply.water.ca.gov/report/), Accessed October 2019

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

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

Notes: None.

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).

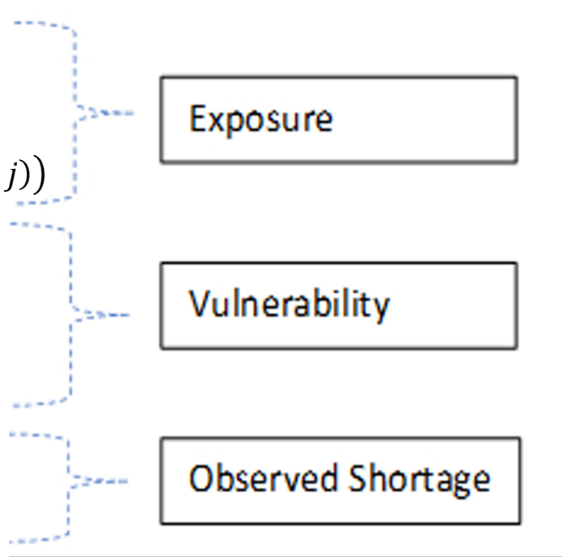
We examined 5,000 Census Block Groups, selecting those that had at least one domestic well drilled between 1970-2019 (from DWR Well Completion Reports) and had at least one household on record by the US Census.

Equation for Self-Supplied (Rural) Communities Risk:

Where: μ = mean; RC are indicators described above; and missing variables are treated as missing.

$CommRisk_{raw}$ =

$$0.25 \times \mu(RC1a, b, c)$$
$$+$$
$$1 \times \mu\big((RC2a, b, c, i, h) + Max(RC2d, e, f, g, j)\big)$$
$$+$$
$$0.25 \times \mu(RC3a, b)$$
$$+$$
$$0.75 \times RC4$$
$$+$$
$$0.5 \times (RC5a + b)/\max(RC5a + b)$$



Then, $CommRisk_{final} = CommRisk_{raw} - min(CommRisk_{raw})/(range(CommRisk_{raw}))$

Weighting

Two main weightings were considered to capture the CDAG's discussions. First, the scores were calculated for each component and then added together. This approach allows for communicating the level of risk by component and allows for weighting by grouping of risk factors. For example, based on the October 2019 CDAG meeting discussions and post-meeting written comments, the climate change indicators were weighted substantially lower than the current conditions indicators, decreasing the important of climate change factors on the final scores.

The second weighting considered, but rejected, involved the population's estimated use and reliance on domestic wells. The purpose of this method was to de-emphasize the weighting of those block groups with high exposure and high vulnerability that are mostly supplied by public water systems. In this case, block groups would be ranked low in the risk score in block groups where a water system may be present even if it were exposed to hazardous conditions and indicated high vulnerability. Experts agreed that such a weighting would create a potentially misleading message about risk of drought and water shortage. Therefore, the explorer tool offers the Domestic Well Count per block group and an estimated domestic well reliance with the final score, but not as part of it.

6.0 Variable Name and Description Table

The table below presents the ID, name and brief description of each variable provided in the downloadable table of results for the small water suppliers risk scoring and self-supplied communities risk scoring.

Table 1-13. Variable ID, Field Names and Descriptions for Small Water Systems Risk Scoring

ID	Field Name	Description
N/A	PWSID	Primary Key, Public Water System ID
N/A	RegAgency	Regulatory Agency (SDWIS 2020)
N/A	System_name	Name of Water System (SDWIS 2020)
N/A	County	County (SDWIS 2020)
SC1a	rSC1a_cctemp	Mid-century temp change under RCP 8.5 (Pierce et al. 2018)
SC1b	rSC1b_SLR	SLR_1m, compiled from Befus et al. 2020 of all counties stitched, (MHHW) includes present saltwater intrusion and conditions with 1m SLR
SC1c	rSC1cR_firecc	Projected wildfire risk by midcentury, recoded burned area
SC2a	rSC2a_precip	Recoded WY2020 drought early warning
SC2b	rSC2b_wildfire	Wildfire risk recoded to PWS (CalFire)
SC2c	rSC2c_fra_sw	FRA recoded to account for decreased weighting when on surface water as primary supply
N/A	SC2dR_subsid	Rescaled subsidence, COMPUTE rRC2d_subsid=SC2d_winzorized/(-2.75)
N/A	SC2eR_saltintrus	Saltwater intrusion present, modeled for coastal aquifer intrusion (Befus et al. 2020)
N/A	SC2fR_overdraft	Critically overdrafted basin points in surrounding basin
N/A	SC2gR_decline_2020b118	Wells in decline (B118, DWR 2020)
N/A	rSC2h_popgrowth	Rescaled 0-1 population growth within service area between 2016-2021, Nielsen Claritas (2016) query September 2019

Table 1-13. Variable ID, Field Names and Descriptions for Small Water Systems Risk Scoring (contd.)

ID	Field Name	Description
N/A	SC2defgj_noweight	COMPUTE newSC2defgj_noweight=max(SC2dR_subsid,SC2eR_saltintrus,SC2fR_overdraft,SC2gR_decline_2020b118,SC2jR_ag)
SC2defgj	SC2defgj_weight	Weighted down with surface water only to multiple times 0.5, groundwater vulnerability for SC2defgj (done Oct 2020); COMPUTE newSC2defgj_weight=weightSWforGWvar*SC2dR_subsid
SC2i	rSC2iR_gamawq_xwatertype	Water quality in basins based on GAMA data, multiplied by water type weighting (lower for surface water)
SC3a	rSC3a_intertie	Presence or absence of intertie (SDWIS 2020)
SC3b	rSC3b_emergintertie	Recoded emergency interties to binary (presence of >0 emergency interties=0 (lower risk); 0=1 (high risk) (SDWIS 2020)
SC3e	rSC3e_singlsrc	Binary of more than water source (those with fewer than two sources are high risk as 1; those with two or more sources are lower risk as 0)
SC3f	rSC3f_typesources	Binary of more than water source type (those with more than one source are lower risk as 0; those with one or zero sources of water are high risk, labelled 1)
SC3c	rSC3c_monitoring	Monitoring for wells in place. COMPUTE rSC3c_monitoring=(SC3c_PWL+SC3c_Static)/2
SC3d	rSC3d_Qunmetered	Proportion of unmetered service connections, rSC3d_Qunmetered=TPotableUM/TPotableTotal (eAR 2018)
SC3i	rSC3i_DISTprobWO	Rescaled reported water outage distribution problems (eAR 2018)
SC3j	rSC3j_level	Numeric code of reported level of groundwater sources (eAR 2018)
SC4a	rSC4a_Rateupdated	Numeric code representing year rate structure was last updated (eAR 2018)
SC4b	rSC4b_ratetype	Flat base rate or no rate (1) or other rate type (0) (eAR 2018)
SC4c	rSC4c_size	Size of system based on number of service connections (SDWIS 2020), rescaled 0-1; COMPUTE rSC4c_size=1-((ServCnxs-1)/2981)
SC4d	rSC4d_DPPdate	Recoded CONSERVATION DPP date, which is data of updated Drought Preparedness Plan (eAR 2018)

Table 1-13. Variable ID, Field Names and Descriptions for Small Water Systems Risk Scoring (contd.)

ID	Field Name	Description
SC4e	rSC4eR_demogcustomers	normalized demographic variables aggregated using their zscores, mean of zscores for single parents, mobile homes, mhi (inverse), percap (inverse), poverty, renters, no vehicles, group quarters
SC5a	rSC5a_short11to18	Recoded binary shortage projected from self-reported eAR survey between 2011 and 2018
SC5b	rSC5b_curtailorder2014	Presence of curtailment order in 2014
SC5c	rSC5c_droughtassist	Systems on record that received assistance from drought funds (SWRCB, with adding PWSID from DWR)
ScoreSC1	ScoreSC1_unweighted	Climate Change risk factors combined: COMPUTE ScoreSC1_unweighted=mean(rSC1a_cctemp,rSC1b_SLR, rSC1cR_firecc)
ScoreSC2	ScoreSC2_unweighted	Current Conditions risk factors combined: COMPUTE ScoreSC2_unw=mean(rSC2aR_wildfire,rSC2b_precip,rSC2cR_fra_sw,SC2defgj_weight,rSC2iR_gamawq_xwatertype)
ScoreSC3a	ScoreSC3abef_connectivity	COMPUTE SC3_connectivitytest=mean(rSC3a_intertie,rSC3b_emergintertie,rSC3e_singlsrc,rSC3f_typesources)
ScoreSC3b	Score3cdij_capacity	COMPUTE SC3_cdij=mean(rSC3c_monitoring,rSC3d_Qunmetered,rSC3i_DISTprobWO,rSC3j_level)
ScoreSC4	ScoreSC4_unweighted	Organizational vulnerability risk factors combined: COMPUTE ScoreSC4_unweighted=mean(rSC4a_Rateupdated,rSC4b_ratetype,rSC4c_size,rSC4d_DPPdate,rSC4eR_demogcustomers)
ScoreSC5	ScoreSC5_unweighted	Shortage record factors combined: COMPUTE ScoreSC5_unweighted=Max(rSC5a_short11to18,rSC5b_curtailorder2014,rSC5c_droughtassist)
Total (raw)	SRisksum	COMPUTE SRisksum=sum((.25*ScoreSC1_unweighted),(.75*(ScoreSC2_unweighted)),(.67*ScoreSC3abef_connectivity),(.33*SC3_cdij),(.33*(ScoreSC4_unweighted)),(.33*ScoreSC5_unweighted))
Risk	SRisk_0to100new	Final Risk Score: COMPUTE Risk_0to100new=100*((SRisksum-min(SRisksum)/(Range(SRisksum)))

The table below presents the name and brief description of each variable provided in the downloadable table of results for the self-supplied communities risk scoring.

Table 1-14. Variable Names and Description for Self-Supplied Communities Risk Scoring

ID	Field Name	Description
N/A	County	County
N/A	tractce	Census Tract ID
N/A	GEOID	GEOID (block group ID code for mapping) – Primary Key
N/A	PlaceName	Nearby city or town or other Census Designated Place name
N/A	TribalHomes	Number of tribal homes within block group
N/A	CountOfWCRNumber	Count of WCR domestic wells for 1970-2019
N/A	HH	Number of households in Census block group (from ACS 2012-2016)
N/A	DomWellReliance	Proportion of households to domestic wells
N/A	max_acres	Max acres burned in raster from zonal statistics for each block group
N/A	PerCapitaIncome	Per Capita Income
N/A	MHI	Mean Household Income
N/A	Q65yr	Proportion of population over 65 years
N/A	Q5yr	Proportion of population 5 years or younger
N/A	Qrenters	Proportion of households that are occupied by renters
N/A	Qmobile	Proportion of households that are mobile homes
N/A	QnoVeh	Proportion of households with no vehicle
N/A	Qedu	Proportion of population of age without high school degree (Nielsen Claritas, 2016)
N/A	Qparent	Proportion of households with single parent
N/A	Qunempl	Proportion of population unemployed
N/A	Qlang	Proportion of population speaking little to no English at home
N/A	Qpoverty	Proportion of families living at or under federal poverty level
N/A	Qgroup	Proportion of population residing group quarters
RC1a	rRC1a_cctemp	Rescaled RC1a absolute temp change, Pierce et al. 2018
RC1b	RC1b_slrsalt_Befus2020	Sea level rise impacts through saltwater intrusion into coastal aquifers, MHHW Befus et al. 2020
RC1c	rRC1c_ccfire	rescaled climate change projections of wildfire by mid-century

Table 1-14. Variable Names and Description for Self-Supplied Communities Risk Scoring (contd.)

ID	Field Name	Description
RC2a	rRC2a_drought	Early Drought Forecast (WY 2020)
R2b	rRC2b_calfire	Rescaled by range, max hazard code from CalFire risk map averaged within each block group with spatial join
R2c	rRC2c_FRA	Presence (1) or absence (0) of FRA in BG
N/A	rRC2d_subsidence	Rescaled raster value in feet, DWR 2020 of subsidence between 2015-2019, COMPUTE rRC2d_subsidence=RC2d_winsorized/-3.85; from Vertical_Displacement_TRE_ALTAMIRA_v2019_Total_Since_20150613_20190919
N/A	RC2e_salt_Befus2020	Presence of saltwater intrusion modelled of MHHW by Befus et al. 2020
N/A	rRC2f_overdraft	Located in overdrafted basin
N/A	rRC2g_gwdeclineB118	Degree of groundwater decline (B118 2020)
RC2h	rRC2h_popgrowth	Population growth rate by BG, normalized by dividing by the range (.23) so that scale is 0-1.
N/A	rRC2j_farmed	Proportion of irrigated agriculture in service area (increased risk as it is higher) (Crop Map 2016, LandIQ/DWR 2020)
RC2defgj	rRC2defgj_max	GW Vulnerability - combined from max of RC2defgj (subsidence, saltwater, overdraft, decline, and ag); COMPUTE newrRC2defgj_max=max(rRC2d_subsidence,RC2e_salt_Befus2020,rRC2f_overdraft,rRC2g_gwdeclineB118,rRC2j_farmed)
RC2i	rRC2i_wqswrcb	Water Quality Flag from SWRCB Needs Assessment (2019)
RC3a	rRC3a_depthbinary	Binary of whether max depth of domestic wells are shallower than max depth of public supply wells
RC3b	rRC3b_depthperc	Well depth score proportion
RC4	rRC4_QPsum_demog	Demographic variables score using CDC method of aggregation with percentile rankings
RC5a	rRC5a_hhOUTinBG	Presence of one or more households reported outage in Block Group
RC5b	RC5b_Qsumbyhh	Proportion of household in BG with reported outages

Table 1-14. Variable Names and Description for Self-Supplied Communities Risk Scoring (contd.)

ID	Field Name	Description
Score_RC1	Score_RC1abcmean	Climate Change risk factors combined: Mean of RC1abc rescaled indicators, updated Oct 2020
Score_RC2	Score_RC2mean	Current Conditions risk factors combined: COMPUTE Score_RC2mean=MEAN(rRC2a_drought,rRC2b_calfire,rRC2c_FRA,rRC2h_popgrowth,rRC2i_wqswrcb,rRC2defgj_max)
Score_RC3	Score_RC3mean	COMPUTE Score_RC3mean=MEAN(rRC3b_depthperc,rRC3a_depthbinary)
Score_RC4	Score_RC4	Social Vulnerability: sum of demographic variables, see CDC methods used above.
Score_RC5	Score_RC5absumrescaled	Shortage record factors combined: COMPUTE RC5absum=SUM(rRC5a_hhOUTinBG,RC5b_Qsumbyhh)/MAX(rRC5a_hhOUTinBG,RC5b_Qsumbyhh))
RCRiskraw	RCsum	Raw score of risk: COMPUTE RCsum=SUM((.25*Score_RC1abcmean),(Score_RC2mean),(.25*Score_RC3mean),(.75*Score_RC4),(.5*Score_RC5absumrescaled))
N/A	rDomWellReliance	recoded Domestic Well Reliance (winzorized so max is 100%)
N/A	RCsum_rescale	COMPUTE RCsum_rescale=((RCsum-min(RCsum)/range(RCsum)
RCRiskFinal	RCrisk_100	COMPUTE RCrisk_100=RCsum_rescale*100

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