A FRAMEWORK AND TOOL FOR EVALUATING CALIFORNIA'S PROGRESS IN ACHIEVING THE HUMAN RIGHT TO WATER

JANUARY 2019

Office of Environmental Health Hazard Assessment

California Environmental Protection Agency

OEHHA

SCIENCE FOR A HEALTHY CALIFORNIA

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Acknowledgments
We acknowledge Robert Brownwood, Max Gomberg, Liz Haven, Wendy Killou, Karen Larsen, Betsy Lichti, Gilbert Penales, Darrin Polhemus, Dave Spath and Jim Stites at the State Water Resources Control Board for providing data and technical guidance, and for reviewing the report. We are grateful to Hongtai Huang for analysis which helped inform OEHHA's consideration of how to assess outcomes across components. We also thank Seigi Karasaki for research assistance. This document builds on early work conducted at University of California, Berkeley and the Community Water Center with funding from the University of California Center for Collaborative Research for an Equitable California. Some of the concepts in this report grew out of collaborations with Rachel Morello-Frosch of the University of California, Berkeley, Jim Sadd of Occidental College, and Manuel Pastor of the University of Southern California. Brandon Lee of Brandon Lee Design designed the report. We also acknowledge former OEHHA Director George Alexeeff for his support and review of earlier versions of this work.

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Abbreviations

AL	Action Level
AB 685	Assembly Bill No. 685
CPT	County Poverty Threshold
CWS	Community Water System
DBCP	1,3-Dibromo-3-chloropropane
DAC	Disadvantaged Communities
JMP	Joint Monitoring Program
LCR	Lead and Copper Rule
MCL	Maximum Contaminant Level
MHI	Median Household Income
MTBE	Methyl tertiary butyl ether
OEHHA	Office of Environmental Health Hazard Assessment
PCE	Perchloroethylene
PHG	Public Health Goal
SDAC	Severely Disadvantaged Community
TMF	Technical, managerial, and financial capacity
TCR	Total Coliform Rule
TTHM	Total Trihalomethanes
TCE	Trichloroethylene
1,2,3-TCP	1,2,3-Trichloropropane
UN	United Nations
UNICEF	United Nations Children's Fund
UN CESCR	United Nations Committee on Economic, Social, and Cultural Rights
US EPA	US Environmental Protection Agency
WHO	World Health Organization

Introduction

Reliable access to safe and affordable water is fundamental to human health and well-being. Yet many factors can limit people's access to this essential resource. These factors include groundwater and surface water source contamination, aging infrastructure, unaffordable rates, and, at times, unreliable water service. Drought and climate change also dramatically affect water quality, availability, and affordability.

In California, nearly 300 communities rely on water sources that contain elevated levels of arsenic, which can cause cancer, birth defects, and heart disease, among other health effects. Other Californians depend on small water systems and domestic wells impacted by contaminants like nitrate, which can likewise cause detrimental health outcomes.[1] Across the state, contaminated water sources disproportionately burden low-income communities and communities of color, further stressing some of the state's most vulnerable populations. Developing tools and policy solutions to address water quality problems, avoid water scarcity and shutoffs, and improve the technical, managerial, and financial capacity of our water systems is therefore increasingly critical.

In 2012, with the enactment of Assembly Bill (AB) 685 (Eng, Chapter 524, Statues of 2012), California became the first state to declare that every human being in our state has a right to clean, safe, affordable, and accessible water adequate for human consumption and sanitary purposes. The legislation instructed all relevant state agencies, including the State Water Resources Control Board (State Water Board, or Board), to consider the human right to water when revising, adopting, or establishing policies, regulations, and grant criteria pertinent to water uses. The State Water Board strives to protect the quality, accessibility, and affordability of California's water by developing and enforcing environmental and drinking water standards, tracking comprehensive water quality data, and administering water conservation programs, among various other efforts. In 2016, the Board adopted a Human Right to Water Resolution[2] making the human right to water, as defined in AB 685, a primary consideration and priority

[1] Harter, et al. (2012), "Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater: Report for the State Water Board Report to the Legislature," University of California, Davis, July 2012.
[2] State Water Board. Human Right to Water Resolution. Available at URL: http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2016/rs2016_0010.pdf.

across all of the state and regional boards' programs (State Water Resources Control Board Resolution No. 2016-0010).

Recently, the Board enlisted the expertise of the Office of Environmental Health Hazard Assessment (OEHHA) to develop a framework for evaluating the quality, accessibility, and affordability of the state's domestic water supply. Once populated with data, the framework described in this report can be used as a tool to track changes and needs across the state's community water systems and across the framework's three principal analytic components – water quality, accessibility, and affordability. This marks the first state-led effort to develop a conceptual framework and method for assessing the status of the state's water systems in the context of AB 685 and tracking progress in achieving the statute's broad policy goals. Other related efforts focus on one aspect of water service, or present results at a single point in time. This framework and tool will uniquely offer information that can be viewed over time, at the state or system-level, across all three principal components of the State's human right to water.

With input and additional data, the framework and tool will be further developed and refined. For example, the current framework and tool would specifically analyze water quality, accessibility, and affordability, at the community water system level, over time. At this stage, it does not include state small water systems, or private wells. However, with additional information, the tool's indicators and the framework can include these systems, and, coupled with data from the State Water Board's existing databases, the tool can provide critical data points to inform a variety of policy decisions.

While OEHHA's proposed framework and tool looks at three components of domestic water supply across the State's public water systems, the State Water Board also is developing a separate report that focuses on affordability challenges and potential solutions for low-income households, pursuant to AB 401 (Dodd, Chapter 662, Statutes of 2015). The report will consider concepts such as low-income rate assistance and rate design changes. The Board's draft AB 401 report therefore covers some of the same ground as OEHHA's framework, but begins a more detailed discussion of what a low-income rate assistance program could look like, and what factors the state should consider in developing a successful program model. OEHHA encourages all stakeholders and members of the public to review and provide comments on the State Board's draft report.

In the long term, ensuring that California's human right to water is realized will require funding, technical assistance, and policy changes, and basic information on the availability of water, including a method to monitor, track, and assess the adequacy of water access, quality, and affordability across the state, as proposed in this report. OEHHA's draft framework outlines a systematic approach for developing and applying a set of indicators to characterize progress toward achieving this right, and it complements the State Water Board's more specific

evaluation of policy options to address the burden that rising water rates place on low-income families.

This draft report first presents an overview of the framework and tool. Next, it introduces each of the three components—water quality, water accessibility and water affordability—along with the indicators that comprise each component. The report then explains how the tool might work, walking readers through a series of hypothetical cases with supporting visual information. Finally, following a brief conclusion, the draft report includes a number of appendices that review various technical aspects of the discussion. OEHHA welcomes, and looks forward to receiving the public's input on this draft document.

Framework and Tool: Approach and Overview

Approach to Building a Framework

In developing this framework and tool, OEHHA drew on existing international approaches to tracking the human right to water, most importantly those of the World Health Organization and the United Nations' Joint Monitoring Program (WHO and UNICEF 2017b). OEHHA adapted these approaches to develop a framework and specific indicators that address the conditions and needs of California.[3] These efforts are also intended to complement and build upon the work of the State Water Board and other agencies to ensure the quality, accessibility, and affordability of California's domestic water supply.[4]

The goals are to:

1) Reflect core, California-specific objectives for safe, clean, affordable, and accessible water that is adequate for human consumption, cooking, and sanitary purposes for all state residents.
2) Create a system of indicators of water quality, accessibility and affordability that can be examined individually or in groups to allow for a nuanced understanding of key domestic water issues.
3) Develop a working data set and analytic framework to which indicators can be added, or in which indicators can be refined, based on public input, policy needs and data availability.
4) Outline an approach to evaluate trends in the provision of clean, safe, accessible and affordable drinking water to all Californians, and assess progress over time.

Framework Overview

Assessing the overall adequacy of the provision of water means taking into account the following three objectives:

Water Quality: The water supplied to California residents should be safe to use. This means that it should be free from harmful bacteria and other pathogens, and that the

[3] OEHHA followed Holst Jensen et al.'s (2014) methodology for developing the framework for the screening tool, while drawing on international tracking efforts such as the United Nations' Joint Monitoring Program (UNICEF 2017).

[4] Domestic water supply refers to water that is used for indoor and outdoor household purposes such as drinking, cooking, bathing, etc.

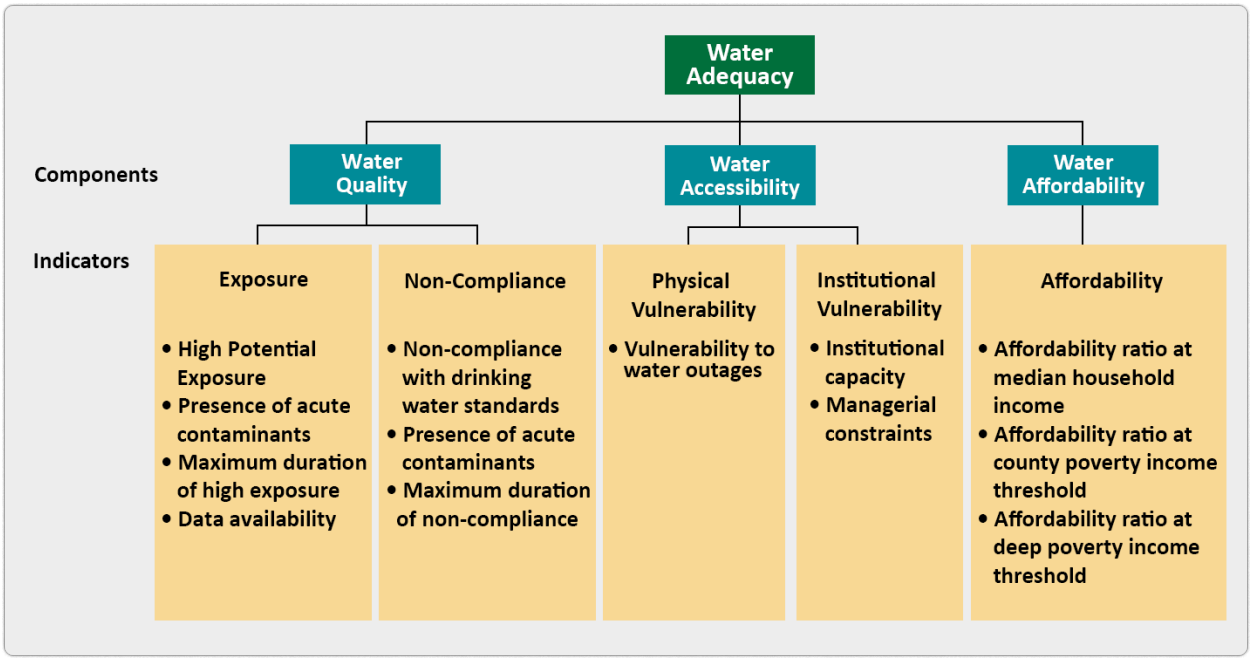
levels of chemical contaminants such as solvents and pesticides, heavy metals, and radioactivity should not pose significant public health risks.

Water Accessibility: Water should be easily accessible in sufficient and continuous amounts to meet everyday household needs. For example, it should be available for drinking, preparing food, bathing, clothes washing, household cleaning, and toilet use.

Water Affordability: Water to meet household needs should be affordable, taking into consideration the amount of the household water bill, after accounting for other demands on income, and the direct and indirect costs associated with obtaining access to the water.

The framework uses indicators to characterize the three components. A total of 13 indicators are used to measure water quality, accessibility, and affordability for community water systems. These are represented in Figure 1. Each indicator has been chosen based on current data availability, data coverage and data quality. Other indicators that have not been included due to data limitations may be added or refined in future versions, as improvements in data collection permit (see Appendix, Table A1).

Figure 1. Proposed framework. Components are indicated in blue boxes. In each yellow box, subcomponent names are indicated at the top, followed by individual bulleted indicators.



Unit of Analysis

This first version of this framework and tool analyzes community water systems. These are defined as public water systems that serve at least 15 year-round service connections, or regularly serve at least 25 yearlong residents (Health and Safety Code Section 116275). Future versions of this framework and the associated tool may include other entities such as schools, and communities served by non-public water systems (e.g., those that have private domestic wells).

Time Period

This framework focuses on data from the most recent time period available across each dataset. However, it also offers a long-term view of water quality indicators, from 2008 to 2016 (for more information on this point, see the section of this report entitled Time Period, under Component 1: Water Quality). Data for all other indicators is intended to be from 2016, or as close to 2016 as possible.

Indicator Selection and Scoring

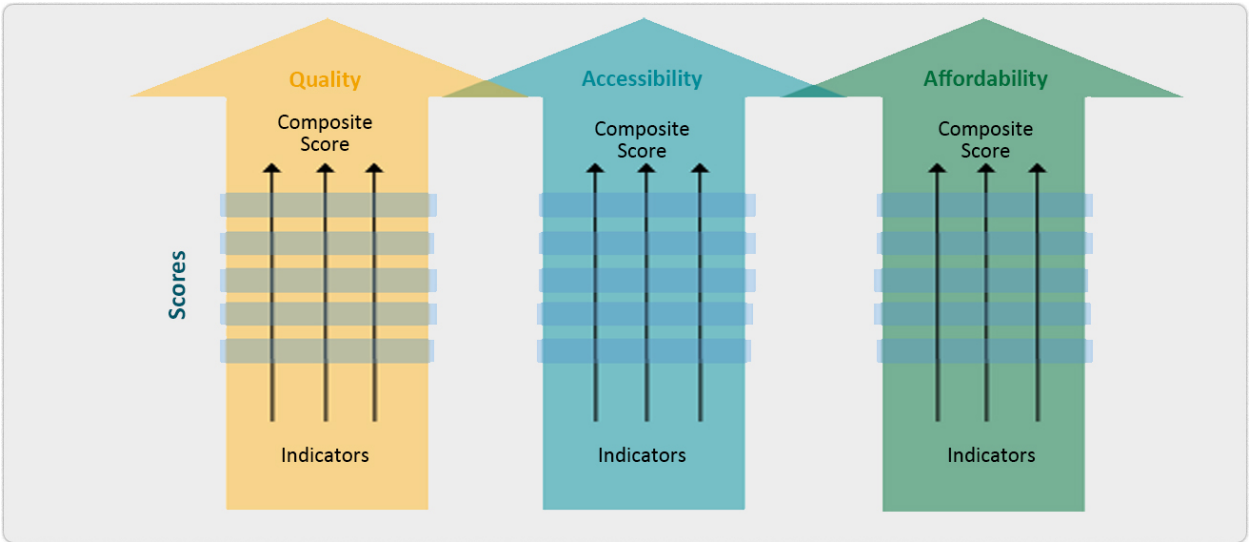
To create indicators for each component, we:

- Assess sources of data for quality, coverage, and availability.
- Select data for the relevant time period that is high quality, provides broad coverage, and is publicly available.

As shown conceptually in Figure 2, we then:

- Calculate each indicator value.
- Assign scores to each indicator, with higher values given to systems that perform favorably in the area that the indicator represents, and lower values given to systems that perform less favorably. This results, for example, in a higher score for better water quality, and a lower score for poorer water quality.
- Develop a composite scoring approach for each component, so that individual water systems have an overall score for water quality, accessibility and affordability based on the indicators that comprise each component.

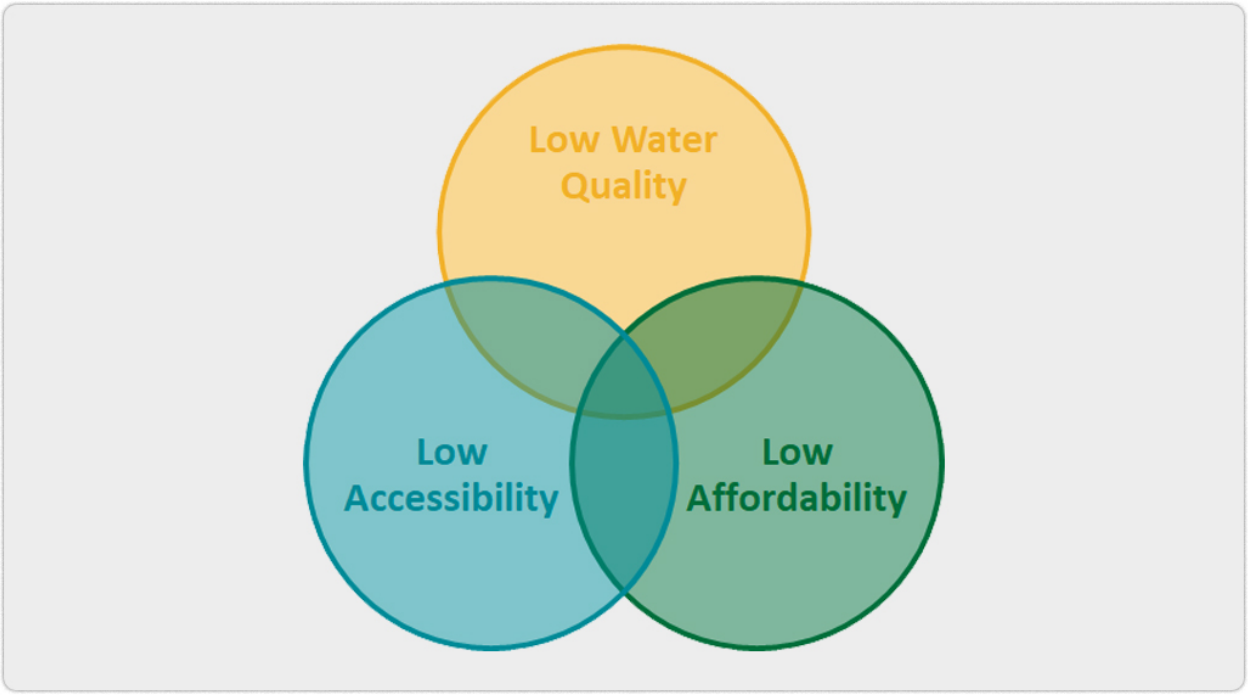
Figure 2. Conceptual view of the proposed framework and tool. The framework is composed of three core components, with indicators assigned to each component. Higher indicator scores reflect better water quality, accessibility or affordability.



A Holistic View of Water Systems

While individual indicators associated with each the framework's three components provide useful information, decision-makers may wish to assess water systems across components, to better understand the relationship between various water delivery and service characteristics. For this purpose, it is valuable to use the three composite component scores for a given system, to illustrate a system's overall status. Such a cross-component view can allow users to understand how a system's water quality, accessibility and affordability might relate to each other, as demonstrated conceptually in Figure 3, which is further elaborated upon later in the report (see Figure 9). The cross-component view offered by this framework can help identify water systems and regions that may need a more in-depth evaluation of water challenges. Periodic updating of the indicators will also illuminate broad trends and progress over time.

Figure 3. Conceptual view of how multiple challenges can affect individual water systems. The proposed framework and tool allow users to view overall trends for each human right to water component—quality, accessibility, affordability—while also comparing the overall status of a water system across these three components.



Finally, while a cross-component view yields valuable information, it is important to also recognize that each of the three components alone, and their associated indicators, offer important data and scores that are useful for planning and shaping policy solutions to local water system challenges. A holistic view of an individual or set of water systems should not replace a more specifically tailored view that might facilitate the development of an appropriate solution to a particular system-level challenge. For example, a system with unsafe drinking water needs an immediate remedy to address water quality, regardless of whether the supply is plentiful, and the rates are low. In other words, a system's deficiencies in any given single component should not be outweighed or downplayed by more favorable performance in the other components.

Component 1: Water Quality

Water Quality and Its Subcomponents

Clean water that is safe to drink is essential to human health. Although domestic water supplies in California are some of the safest by international standards, not everyone in the state enjoys the same level of water quality.

In this framework, water quality is evaluated in two basic ways, using two subcomponents:

- A "contaminant exposure" subcomponent measures the extent of exposure to chemical and microbiological contaminants in the drinking water.
- A "non-compliance" subcomponent measures the extent to which a water system fails to comply with primary drinking water standards.[5]

Each of the water quality subcomponents provides different kinds of critical information in evaluating the quality of the water provided by the system. Non-compliance status is determined by whether a water system adheres to drinking water regulatory standards (as determined by Maximum Contaminant Levels [MCL]). These standards are based on a combination of public health, technical feasibility, and economic considerations.

Compliance status offers important information about how successfully water systems are meeting established goals. However, measuring compliance alone may not capture the precise public health implications of exposure to drinking water contaminants because compliance with most regulatory standards is determined by whether a system's individual water sources meet these standards at the well or the site of a surface water intake.[6] Exposure levels, on the other hand, are determined by water quality at the tap. Exposure levels therefore differ from compliance status, and it is important to quantify them separately.

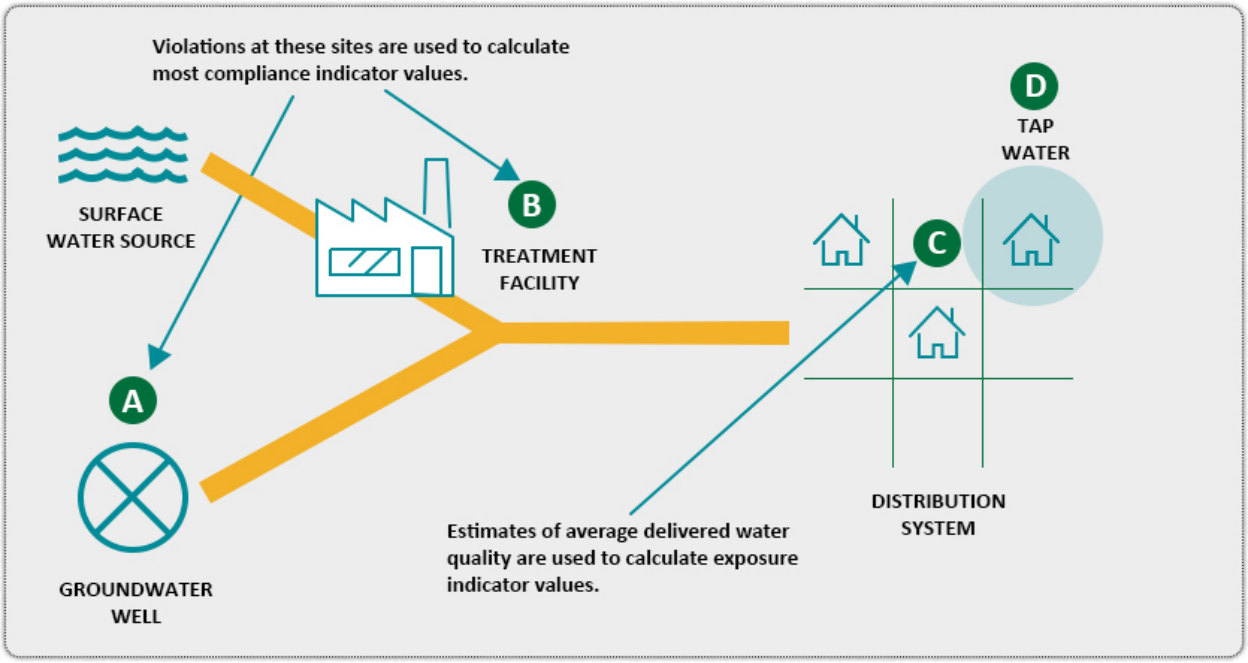
Figure 4 serves to make these various points. Here, a hypothetical community water system is shown to have a surface water source and a groundwater source. Generally, compliance with regulatory standards is assessed at the site of a groundwater well (A) and/or at the treatment facility (B). MCL violations issued at these locations are used to calculate the framework's compliance indicator values. Point C represents points in the system where average delivered water quality is calculated; this measurement is used to calculate the framework's exposure

[5] Most human right to water efforts, such as the United Nations' Joint Monitoring Program, only evaluate water quality in relation to compliance with regulatory standards.

[6] Exceptions include samples for the Total Coliform Rule (TCR), the Lead and Copper Rule (LCR) and the Disinfectants/Disinfection Byproducts Rule (DBPR). For example, compliance for TCR is determined using water samples taken from the distribution system.

indicators, and represents an estimate of tap water quality at Point D.[7]

Figure 4. Diagram of a hypothetical community water system. Generally, compliance with regulatory standards is assessed at the site of a groundwater well (A) and/or at the treatment facility (B). MCL violations issued at these locations are used to calculate the framework's compliance indicator values.* Point C represents points in the system where average delivered water quality is calculated; this measurement is used to calculate the framework's exposure indicators and represents an estimate of tap water quality at Point D.



* MCL violations for the Total Coliform Rule (TCR) and the Lead and Copper Rule (LCR) occur within the distribution system.

Methods

Time Period

Indicators related to water quality for the initial version of the tool will be drawn from a nine-year period from 2008 to 2016. This time period covers the most recent data available, while still including three consecutive compliance periods.[8] This is more effective than simply showing water quality for the most recent year, since not all systems may be required to report monitoring data within this shorter time frame. Using the nine-year compliance cycle also

[7] Data about water quality at the tap, and hence about exposure, are not widely available. To compensate for this, the average water quality of delivered water can represent potential exposure. This is the best way available to accurately capture information about water quality before water enters the household distribution system (Balazs et al. 2011; OEHHA 2017).

[8] US EPA guidelines govern the monitoring and reporting of drinking water quality over three-year compliance periods, within nine-year compliance cycles (US EPA 2004). In order to include the most recent data, our study period spans the second and third compliance periods of the 2002-2010 compliance cycle (i.e., 2005-2010), and the first compliance period of the 2011-2019 compliance cycle (i.e., 2011-2013).

provides a cumulative view of how water systems have performed with regard to water quality.

Contaminants Selected

The proposed water quality indicators are based on exposure levels and compliance for a set of drinking water contaminants. Each contaminant was selected based on whether there was significant coverage of water quality sampling data for the specified contaminant in the Water Quality Monitoring database across water systems in the 9-year time period between 2008 and 2016. Specifically, contaminants for which at least 80% of community water systems in the state reported at least one monitoring sample were included. These 14 contaminants are:

> Arsenic, barium, benzene, cadmium, carbon tetrachloride, lead, mercury, methyl tertiary butyl ether (MTBE), nitrate, perchloroethylene (PCE), perchlorate, trichloroethylene (TCE), toluene, and xylene (See Table 1).[9]

Contaminants associated with significant health effects but for which less than 80% of water systems had samples, or for which there are a significant number of MCL violations, were deemed to be "high priority" and were also selected. These four additional contaminants are:

> 1,2-dibromo-3-chloropropane (DBCP), 1,2,3-trichloropropane (1,2,3-TCP), total trihalomethanes (TTHM) and uranium (See Table 1).[10]

[9] While radium-226 and radium-228 (radioactive breakdown products of uranium) meet the criteria for inclusion, an assessment is underway regarding how best to include sampling data for these contaminants. Thus, the current framework does not currently include these contaminants.

[10] The presence of hexavalent chromium is a serious health concern, but this chemical is not currently in the framework because it does not have an MCL (State Water Board 2017).

Table 1. List of 19 contaminants currently included in the proposed framework and tool. The table indicates whether the contaminant was used for the water quality indicators, and the percentage of systems statewide that had samples for this contaminant. A water system is said to have coverage when there is at least one water quality monitoring sample for this system in the period from 2008 to 2016.

Contaminant	Measure Used in Water Quality Indicators		Percent of Systems with Water Quality Monitoring Data
	Exposure	Compliance	
Arsenic	Yes	Yes	95%
Barium	Yes	Yes	95%
Benzene	Yes	Yes	93%
Cadmium	Yes	Yes	95%
Carbon tetrachloride	Yes	Yes	93%
Dibromochloropropane (DBCP)	Yes	Yes	59%
Lead†	Yes	**No**	95%
Mercury	Yes	Yes	95%
Methyl tertiary butyl ether (MTBE)	Yes	Yes	93%
Nitrate	Yes	Yes	97%
Perchloroethylene (PCE)	Yes	Yes	92%
Perchlorate	Yes	Yes	96%
Trichloroethylene (TCE)	Yes	Yes	92%
1,2,3-Trichloropropane (1,2,3-TCP) †	Yes	**No**	63%
Toluene	Yes	Yes	92%
Total Coliform†	Yes	Yes	Not available
Total Trihalomethanes (TTHM)	Yes	Yes	74%
Uranium	Yes	Yes	45%
Xylene	Yes	Yes	92%

† Adjustments: For lead, the average of the 90th percentile sample results resulting from Lead and Copper Rule (LCR) monitoring is used. For 1,2,3-TCP, the 2017 MCL level is used as the threshold against which to assess potential exposure. For total coliform, MCL violations are used to approximate potential exposure.

Exposure Subcomponent

Approach

OEHHA developed four exposure indicators that measure:

1. The nature of contaminant concentrations ("high potential exposure").
2. Whether contaminants are acutely toxic.
3. The duration of high potential exposure.
4. The availability of monitoring data.

In generating these indicators, average delivered water quality for each contaminant is used to represent exposure to drinking water contaminants at the tap.[11] This draws on the approach used in CalEnviroScreen to calculate annual, time-weighted average concentrations per contaminant (OEHHA 2017). A contaminant's MCL is used as a benchmark against which to compare measured concentration levels. Potential exposure—measured as the annual average concentration of delivered water quality—is considered to be high if the annual average water concentration of a contaminant is at or above the MCL. Potential exposure is considered not to be high if it is below the MCL. Indicating that a potential exposure is not high under this approach is not intended to suggest that there is no health risk for a contaminant. OEHHA's Public Health Goals (PHG) for drinking water are the benchmark used to determine health risks from exposure to contaminants. However, it is not practical to use the PHGs as a threshold for this indicator, as the detection limit for many contaminants is well above the corresponding PHG.

Depending on the indicator, contaminant-specific adjustments are made:

- For 1,2,3-TCP, the 2017 MCL is used as a relevant threshold for *exposure-related* indicators, although the MCL was adopted after 2016, the last year of this study's time period.
- For lead, the data is used in two ways. First, tap water sampling results for the 90th percentile of samples (as per the Lead and Copper Rule [LCR]) are used to calculate the *exposure indicator*. This data is used instead of average delivered water quality estimates, as is done for other contaminants. Lead levels are then assessed against lead's Action Level (rather than an MCL). Therefore, we compare the average of these 90th percentile results to lead's Action Level.[12]
- Total coliform counts are monitored regularly. However, sample results for total coliform are not presently included in the state's public electronic water quality

[11] This approach was originally used in the CalEnviroScreen methodology developed by OEHHA (OEHHA 2017).
[12] Lead does not have a Maximum Contaminant Level. Instead, 90th percentile sampling results are compared to an Action Level (Lead and Copper Rule; Title 17, California Code of Regulations, section 64673).

monitoring databases.[13] Here, we propose using MCL violations of the Total Coliform Rule (TCR) to represent potential high exposure events, instead of the average contaminant concentration, as is done for other contaminants. Thus, MCL violations of the TCR are used to calculate both exposure and compliance indicators.[14]

Indicators

Water Quality Indicator 1: High Potential Exposure

This indicator evaluates the number of contaminants with high potential exposure levels. We define *high potential exposure* as a situation in which a system's average annual contaminant concentration is at or above the MCL for the contaminant at least once during the study period. This indicator then counts the number of contaminants whose average annual concentrations have been at or above the MCL during the study period. As shown in Table 1, this indicator assesses average annual contaminant concentrations relative to the MCL or relevant benchmark for 18 of the 19 contaminants of interest, and uses TCR MCL violations to represent high potential exposure for TCR.

As noted in the previous section, with the exception of lead and total coliform, we quantify *high potential exposure* by comparing the average annual concentrations of contaminants for the water system to the relevant MCL. For total coliform, given a lack of bacteriological sampling results, MCL violations serve to represent potential exposure. For lead, concentrations from samples representing the 90th percentile were compared against lead's Action Level. This results in a measure of potential high exposure for lead that is different than the measure for potential high exposure used for other contaminants (i.e., other contaminants use the average quality of delivered water across the system compared to the MCL). However, given lead's toxicity, and the fact that LCR sampling data is the best available lead concentration data, we include this measure.

Water Quality Indicator 2: Presence of Acute Contaminants

This indicator assesses if any of the contaminants for which there was high potential exposure are *acute contaminants* as defined by regulatory standards. Here, *acute risk* refers to a situation in which there is the potential for a contaminant or disinfectant residual to cause acute health effects (i.e., death or illness) as a result of a single period of exposure measured in seconds, minutes, hours, or days (Health and Safety Code section 64400). Among the

[13] TCR results are sent as hardcopies by laboratories directly to the State Water Board District Offices and Local Primacy Agencies. Compliance decisions are made manually, and any resulting information about violations is then entered into the Safe Drinking Water Information System database.

[14] Future versions of this framework and tool may include new measures of bacteriological contamination to reflect the implementation of the recently revised TCR.

contaminants regulated in California, the following are considered acute or semi-acute for the purpose of Tier 1 Public Notice: nitrate, nitrite, or nitrate plus nitrite, perchlorate, and E. coli/fecal coliform (Health and Safety Code section 64463.1a).[15]

Water Quality Indicator 3: Maximum Duration of High Potential Exposure

This indicator measures the duration of high potential exposure for each of the 19 contaminants by summing the number of years for which a contaminant had high potential exposure (from 2008 to 2016). It then selects the maximum duration of high potential exposure, across all contaminants, during the nine-year study period (2008-2016). In contrast to Indicator 1, which captures how many systems have had any high-contaminant concentrations, this indicator focuses on the recurring nature of contamination. Accordingly, it is meant to highlight systems that show an ongoing contamination problem. Capturing this recurring exposure is important, especially when such exposure involves contaminants whose health effects are associated with chronic exposure. Furthermore, regardless of whether a contaminant is chronic or not, a long duration of potential high exposure can also signal that a system may need additional resources or support to remedy contamination.

Water Quality Indicator 4: Data Availability

Water quality monitoring is essential not only to ensure compliance with drinking water standards, but also to ensure that water systems and their customers have adequate information to develop appropriate responses. While Monitoring and Reporting violations capture instances of a water system not adhering to monitoring and reporting requirements (Title 22, California Code of Regulations. Section 60098), Indicator 4 measures how much data on water quality is available in current water sampling databases. It is used to estimate the adequacy of information with respect to a system's water quality.

In particular, this indicator evaluates the extent of system water quality sampling data for 14 contaminants for which a system must have conducted water quality monitoring. Depending on the contaminant, a system would need to sample at least once in the nine-year time period, in at least three separate years, or in all nine years, depending on the contaminant. According to the US EPA's Standardized Monitoring Framework (US EPA 2004), the following 11 contaminants should be sampled at least once, and should have at least one data sample for this nine-year time period: arsenic, barium, cadmium, mercury, benzene, MTBE, carbon tetrachloride, toluene, TCE, PCE, and xylene. Two contaminants—lead and perchlorate—should be sampled at least three times, and have at least three samples.[16] Nitrate and total coliform

[15] Chlorine dioxide is also an acute contaminant, but is not included in this framework.

[16] According to monitoring regulations, sampling for these contaminants must actually occur once in each compliance period. However, for the purposes of this report (and based on guidance we received from the State

must be sampled in each of the study period's nine years. However, because monitoring results for total coliform are not included in state water quality monitoring databases, total coliform is not included in this indicator. Thus, excluding total coliform, 14 contaminants are included in this indicator.

Non-Compliance Subcomponent

Approach

The framework's non-compliance indicators capture regulatory non-compliance with drinking water standards that can be associated with occasional (or ongoing) increases in contaminant concentrations *at the source level*.[17] As noted above, compliance with most regulatory standards is determined by whether a system's individual water sources meet regulatory standards (these measurements typically occur at the well or the site of a surface water intake). Here, we consider an instance of non-compliance to be based on whether an MCL violation is recorded for the primary drinking water contaminants listed in Table 1.

Indicators

Water Quality Indicator 5: Non-Compliance with Primary Drinking Water Standards

This indicator evaluates the number of contaminants that have been in non-compliance with the MCL during the study period for 17 of the 19 contaminants of interest (see Table 1). The two excluded contaminants are 1,2,3-TCP and lead. The chemical 1,2,3-TCP is excluded because its MCL was not effective until 2017, meaning that no MCL violations were issued during the study period. Lead is not included because there is no MCL for lead, only an Action Level. However, monitoring and reporting violations of the LCR are included in the count of Monitoring and Reporting violations, which is part of the accessibility component.

Water Quality Indicator 6: Presence of Acute Contaminants

A second, related compliance indicator assesses which, if any, of the non-compliance events have involved acute contaminants. Nitrate, perchlorate and E. coli/fecal coliform violations are considered, as they are for the exposure indicators.

Water Board), sampling results occurring during any three years of the entire time period of 2008 to 2016 are considered sufficient.

[17] Here, the term source refers to a facility that contributes water to a water distribution system, such as one associated with a well, surface water intake, or spring.

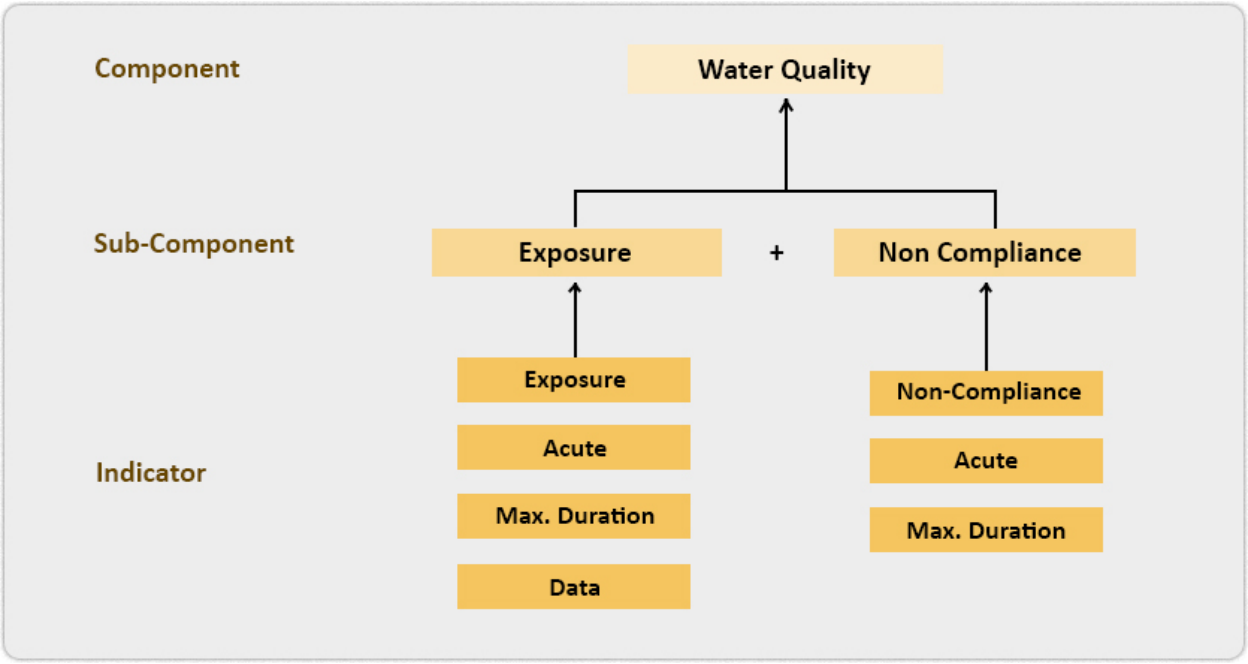
Water Quality Indicator 7: Maximum Duration of Non-Compliance

This indicator assesses the duration of non-compliance across all contaminants. To do so, for each system, the indicator sums the number of years (from 2008 to 2016) in which a given contaminant has been cited for at least one MCL violation. Importantly, the total number of violations per year *is not* counted, to control for various types of differences in monitoring and reporting across systems. Thus if one system experienced four nitrate violations in a given year, and another experienced only one, both systems would be considered to have had "at least one" nitrate MCL violation. The indicator then selects the maximum duration of non-compliance for each system, across all contaminants, during the time period.

A Composite View of Water Quality

Individual water quality indicators help highlight specific water quality problems. However, combining individual indicator scores to create a composite water quality score can highlight which systems have poor outcomes across several or all indicators, and which systems are therefore the most burdened in a cumulative sense. Figure 5 illustrates how individual indicator scores can be combined to yield a composite water-quality component score.

Figure 5. Creation of composite water quality score.



Component 2: Water Accessibility

Water Accessibility and Its Subcomponents

Easy, sufficient and continuous access to reliable water to meet basic household needs is not always assured. Some water systems in the state are particularly vulnerable. During the 2012-2016 drought, a number of water systems could not provide enough water to supply people's basic needs, and a large number of domestic wells went dry.

The water accessibility component of this framework addresses concerns of this kind. Its component measures both the physical and institutional vulnerability that can influence whether a water system can provide adequate supplies of water to meet household needs.

Water access is determined by a number of factors. These typically include:

1. The physical quantity of water that a water system can provide, or that a population can obtain.
2. The availability and reliability of the supply (i.e., whether the supply is sufficient and continuous, even in periods of drought).
3. How people or water systems access water (e.g., the source type and collection time).
4. The economic accessibility of the water obtained (i.e., the economic cost and its impact).[18]

There are many factors that interact with each other to either inhibit or promote access. For example, water access can be shaped by factors internal to a water system such as the number of wells, or by factors external to the system such as drought. The current framework focuses on system-related characteristics that may impede access to reliable and adequate water supplies, especially during times of severe stress. In this framework, the water accessibility component consists of two subcomponents: 1) the *physical* vulnerability of a water system to inadequate water supply and provision; and 2) the *institutional* vulnerability of a water system to inadequate water supply and provision.

Physical vulnerability refers to the factors that may interfere with the availability and reliability of an adequate water supply for a system's customers. For example, physical vulnerability may be shaped by how many wells a system has, and whether these wells offer an adequate supply

[18] Because water affordability is specifically addressed by AB 685, this framework treats economic accessibility (interpreted as affordability) as a separate component, rather than as a part of accessibility. This is different than General Comment No. 15 on the Right to Water, by the Office of the United Nations High Commissioner for Human Rights (UN CESCR 2002.

of water based on the number of customers served or the storage capacity of its wells. A system with only one well is more vulnerable to a water outage than a system with dozens of wells, as the former has no additional supplies to draw on.

Institutional vulnerability refers to the technical, managerial and financial capacity of a water system to conduct the operations and maintenance needed to provide adequate water to customers. Institutional vulnerability is shaped, in part, by a water system's capacity to meet its water supply challenges. For example, a system that has low institutional capacity may not be able to adequately address water contamination because of technical or financial limitations.

Physical Vulnerability Subcomponent

Overview

The physical vulnerability subcomponent currently contains one indicator that measures system-related characteristics that can impede access to an adequate water supply. This indicator represents the potential vulnerability of a water system to water shortages or outages. This vulnerability exists on a daily basis, and becomes more severe during times of stress, such as periods of drought. Data permitting, future versions of this framework could build in additional measures of physical accessibility related to sufficiency and continuity of supply (See Appendix, Table A1).

Indicators

Water Accessibility Indicator 1: Physical Vulnerability to Water Outages

This indicator assesses how vulnerable a water system is to a supply outage (or shortage). It identifies a system's main water source type (e.g., groundwater, surface water, or combined groundwater-surface water), and how many permanent and backup sources a system can use in case of emergency. The indicator assumes that groundwater-reliant systems with fewer wells are more vulnerable to supply-based outages than either surface water systems with multiple intake points, or combined systems (i.e., systems with surface water and groundwater sources).

Institutional Vulnerability Subcomponent

Overview

The subcomponent of institutional vulnerability includes two indicators that measure the institutional characteristics of a system that can impede access to an adequate water supply. The first represents overall institutional capacity. The second represents managerial constraints. Broadly speaking, a system's overall institutional capacity is composed of its technical, managerial, and financial (TMF) capacity. TMF capacity plays a key role in a system's ability to undertake the operations and maintenance required to provide adequate water service. The state collects information on TMF capacity for a limited number of systems. Therefore, OEHHA is using the two indicators described below.

Indicators

Water Accessibility Indicator 2: Institutional Capacity

This indicator represents the overall institutional capacity of the water system. It uses a combination of information about a system's size and available economic resources to jointly define a system's TMF capacity. For example, larger systems have greater economies of scale that allow them to finance capital improvements. Systems with greater proportions of socioeconomically disadvantaged residents face additional financial constraints, as their customer base may be generally less financially able to contribute to necessary system upgrades.

Challenges and benefits due to size and socioeconomic status can mutually reinforce each other. For example, a small system that serves a more socioeconomically disadvantaged population is assumed to have less institutional capacity than a small system that serves an affluent population. In the same vein, a system that is large and serves a disadvantaged population presumably benefits from economies of scale to overcome some of the population's economic disadvantages. Thus, a population's disadvantaged status can amplify the limitations faced by small systems with smaller customer bases.

To characterize system size, this indicator draws on data on the number of service connections. To characterize socioeconomic status, it uses state definitions of disadvantaged and severely disadvantaged communities. The term disadvantaged community (DAC) has multiple definitions. For drinking water applications, it is defined by the State of California as a community with an annual Median Household Income (MHI) that is less than 80 percent of the statewide MHI (Public Resources Code section 75005[g]). A severely disadvantaged community (SDAC) is a community with less than 60 percent the statewide MHI. According to US Census

American Community Survey (ACS) 5-Year Data for 2011-2015, the statewide MHI was $61,818; hence, the calculated income threshold is $49,454 for DACs, and $37,091 for SDACs.

Water Accessibility Indicator 3: Managerial Constraints

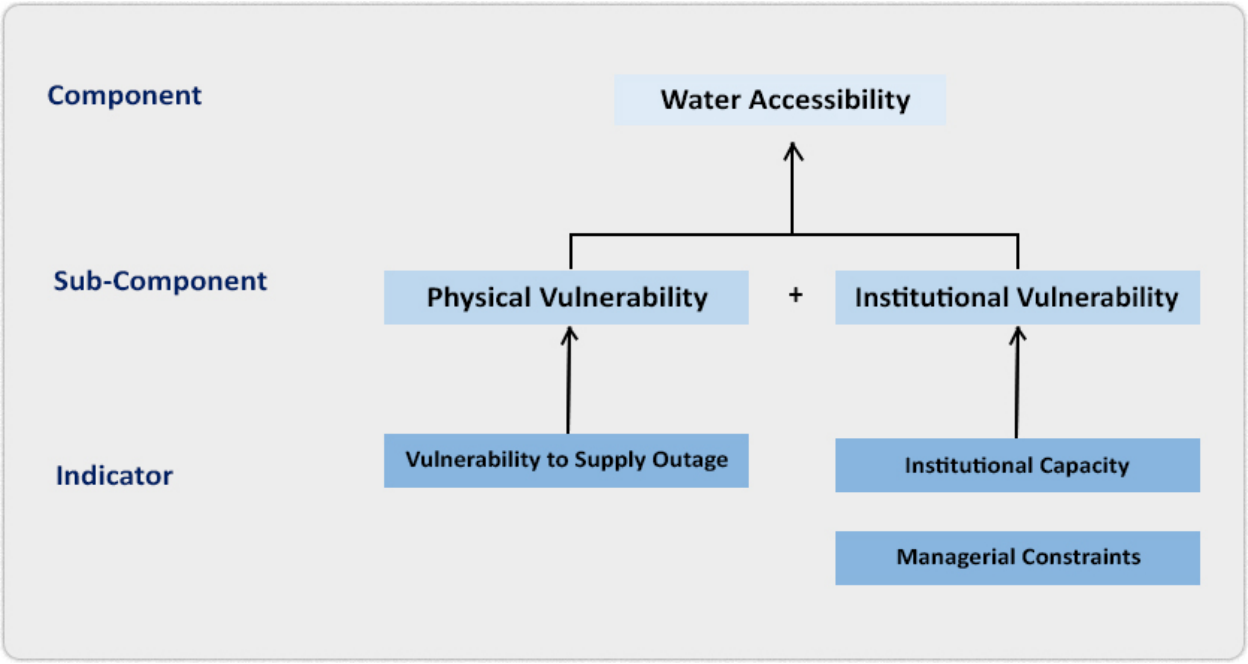
The third accessibility indicator represents potential managerial constraints. The managerial capacity of a water system depends on various factors, such as a water system's number and type of staff, and the training level of its staff. Because this data is not readily available for all water systems, OEHHA worked with the State Water Board's Division of Drinking Water to identify an indicator that could show managerial constraints in addressing contamination and/or maintaining adequate water supply. This represents is a tally of the total monitoring and reporting violations that a water system receives. These violations assess the degree to which a water system complies with monitoring and reporting requirements for particular contaminants and treatment techniques.[19]

A Composite View of Water Accessibility

Individual water accessibility indicator scores can be combined to create a composite water accessibility score. This composite score can serve to highlight systems that have some of the lowest scores across all accessibility indicators, and are therefore the most burdened in the area of accessibility. Figure 6 is a conceptual representation showing how individual indicator scores could be combined to yield a composite water accessibility component score.

[19] See Health and Safety Code section 60098 for more information.

Figure 6. **Creation of composite water accessibility score.**



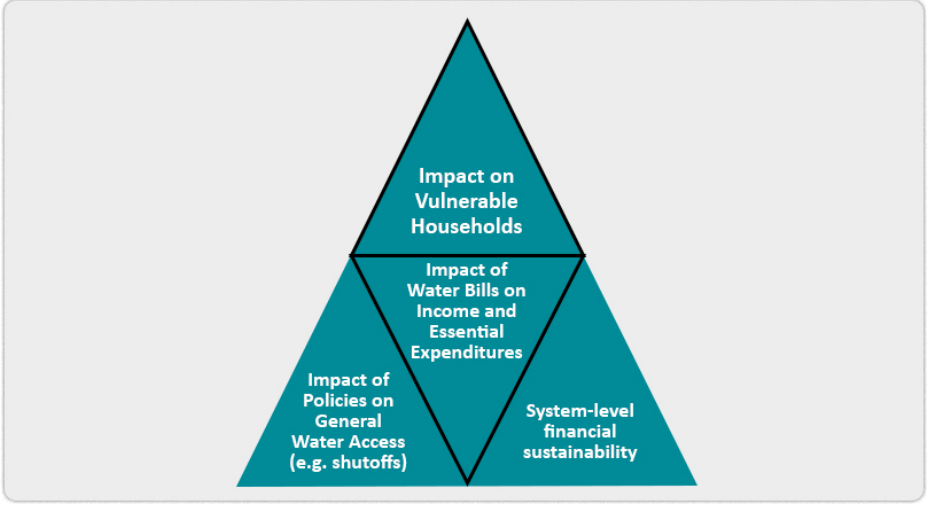
Component 3: Water Affordability

Water affordability typically refers to the direct and indirect costs of water charged to a household, relative to the household's income level. Measuring water affordability can also help inform how these costs affect the attainment of households' other basic needs (e.g., housing or food). To address issues of non-discrimination and equity, most approaches to evaluating water affordability emphasize that water should be affordable to the most vulnerable populations, and that users should be free from unnecessary disconnections (UN CESCR 2002).

Figure 7 summarizes the concepts that commonly comprise affordability considerations, and highlight the two areas of affordability that form the main focus of this framework.[20] In particular, the current framework focuses on the impact of water bills on income and essential expenditures, as well as the impact of water bills on vulnerable households. While financial sustainability is a key aspect of affordability, and is indirectly considered in the first of the framework's three affordability indicators (see Appendix B1), the framework does not speak directly to a system's financial sustainability. Similarly, assessing the impact of water system policies on water access (e.g., shutoffs) is related to affordability. However, the framework does not currently measure such factors (see Appendix A for future potential indicators).

[20] Water customers' ability to pay for water is a central consideration in achieving the human right to water. Yet part of keeping water affordable means ensuring that the financial capacity of water systems is sustainable. This can ensure that revenue streams and their management are adequate to cover ongoing infrastructure maintenance and capital costs, and can prevent sudden and even catastrophic loss of drinking water when critical infrastructures fail. See, for example Davis and Teodoro (2014), OECD (2010), and US EPA (1998: 12-18). These aspects are currently captured by the institutional capacity indicator of the accessibility section.

Figure 7. Core aspects of affordability. Triangles highlighted in black indicate areas that this framework focuses on.



Historically, the US EPA has used conventional affordability ratios to measure the impact of a water system's average water bill on a household earning the median household income (US EPA 1998). The conventional affordability ratio is an indicator used primarily to screen water systems for affordability challenges. Water is understood to be unaffordable if water bills exceed a pre-established percentage of median household income (see Box 1: What is an affordability ratio?). Concerns about the adequacy of this approach have resulted in extensive discussions about best practices, and about the limitations of the conventional affordability ratio approach (see Appendix B1 for a more detailed discussion).

Building on this rich discussion, this framework uses three affordability indicators to measure affordability at the water system level (Goddard et al. 2019).[21] Unlike the Water Quality and Water Accessibility components outlined above, the Affordability Component has no subcomponents.

Box 1: What is an affordability ratio?

An affordability ratio captures the impact of a water bill on a household's income. In its most generic form, this ratio typically consists of a water bill at a specified volume of water divided by an income level. The resulting ratio is meant to capture the fraction of a household's income that is spent on water bills. Typically, the affordability ratio is reviewed against a threshold to determine whether water bills are or are not affordable.

Conventional affordability ratios may simply use average water costs divided by a region's median household income level. However, these ratios have limitations. Ideally, the figure used for household income should represent total household income minus other essential expenditures (such as housing and food), so that basic expenditures are not in conflict with one another.

Indeed, improved affordability ratios specify the water cost for a particular volume of water, and aim to measure disposable income minus other essential expenditures.

[21] Data limitations often make it hard to generate fine-scale data about affordability at the household level (including, for example, information about a specific household's water bills and income level). Therefore, indicators that screen for potential household concerns are often developed at larger geographic scales (for example, at the water system or census-tract scale).

Indicators

Affordability Indicator 1: Affordability ratio for the Median Household Income level (AR_{MHI})

The first affordability indicator is an affordability ratio based on the median household income level of the customers of each system (AR_{MHI}). AR_{MHI} improves upon the US EPA's CAR approach in several ways (see Appendix B1), and takes into account data availability issues. First, AR_{MHI} is evaluated using water bills for an essential minimum water volume of 600 cubic feet (or 6 Hundred Cubic Feet [HCF]). This amount of 6 HCF equates to approximately 150 gallons per household per day.[22] As such, the amount of 6 HCF falls within the range of basic needs water consumption for California, while aligning with the state's water conservation goals.[23] Even so, it is important to note that some households may require higher water use. For example, households with pregnant women or people with illnesses or disabilities may require more than 6 HCF per month. Similarly, households in different regions of the state may require more water due to climate and livelihood considerations.

An affordability ratio using the median income level indicates the water bill burden for households at the 50th percentile of the income distribution in a water system. Thus, if water bills are high for households at the median income level, affordability ratios for the median household income may indicate that: 1) water is unaffordable for at least 50 percent of households in a water system; and/or 2) the water system's financial capacity is at risk for being unsustainable, since household affordability and system financial capacity are interrelated.

AR_{MHI} is therefore calculated as:

$$ARmhi = \frac{Systemwide\ Average\ Bill\ for\ 6\ HCF/Month\ \times\ 12\ Months}{Annual\ Median\ Household\ Income\ of\ Water\ System}$$

[22] This is equivalent to 50 gallons per person per day in a three-person household, or 38 gallons per person per day in a four-person household. The average household size in California in 2015 was 2.9 persons per household.

[23] Gleick (1996) proposes a basic water requirement of 50 liters per capita per day (13 gallons). This is equivalent to 150 liters (39.6 gallons) for a three-person household and 200 liters (52.8 gallons) for a four-person household. Gleick's study presents a range of 57-165 liters per capita per day (15-45.6 gallons), depending on the region, technological efficiencies, and cultural norms. Feinstein (2018) recommends evaluating water affordability in California using a measure of 43 gallons per capita per day, equivalent to 129 gallons per three-person household and 172 gallons per four-person household. A provisional standard of 55 gallons per capita per day is identified in California Water Code section 10608.2 for indoor water use for urban water suppliers who are aiming to reduce water demand.

Affordability Indicator 2: Affordability ratio for the County Poverty Threshold (AR_{CPT})

The second affordability indicator used here is an affordability ratio based on the county poverty income level, which OEHHA refers to as the "county poverty threshold" (AR_{CPT}). AR_{MHI} provides a snapshot of affordability challenges at the median income level. However, the scholarly literature on affordability demonstrates that, when used alone, AR_{MHI} is insufficient to capture affordability challenges for the most vulnerable households.

Indeed, established human right to water frameworks make a point of emphasizing that assessing affordability also means considering issues of equity. This means that more vulnerable households and individuals should be expressly considered with regard to their ability to pay for water.[24] Using the median income level alone will not necessarily provide information on the affordability of water for lower-income households: thus, affordability analyses should explicitly consider lower-income levels. Following this logic, the second indicator used here measures the impact of water bills on households at a specified poverty level.

In developing this indicator, OEHHA evaluated several existing datasets and measures of poverty. OEHHA selected the county poverty income thresholds

Box 2: Affordability Considerations: What is in a Water Bill?

Water bills are most frequently used to represent total water costs, where data on indirect or replacement costs does not exist. However, water bills cannot fully capture the cost of water in cases where households pay for bottled water (costs referred to as replacement costs). They do not always include wastewater costs. Nor do they account for the water costs faced by persons experiencing homelessness. Furthermore, water bills do not always incorporate long-term infrastructure and maintenance costs.

The contractual relationship between renters and homeowners represents another challenge. Water bills are often received by homeowners, who pay their water bills directly, or pass them on to tenants. In theory, the cost transferred from the homeowner to the renter should be proportional to a renter's water use. As water bills are most often included in rent, however, the relationship between what renters should pay for water and what they actually pay is not generally metered or documented.

As a result, the use of water bills to gauge water affordability may underestimate or overestimate how much renters actually pay for water. The indicators in this report thus do not currently directly consider affordability for renters, who may or may not be paying utilities directly.

[24] General Comment No. 15 on the Right to Water, by the Office of the United Nations High Commissioner for Human Rights, notes that equity considerations regarding affordability "demand that poorer households should not be disproportionately burdened with water expenses as compared to richer households." (UN CESCR 2002: 9).

Box 3: High Cost of Living Considerations

A household's ability to pay for water largely hinges on its disposable income, or its total income minus taxes, and the cost of other non-water essential expenditures. Ideally, the disposable income value that is used to calculate an affordability ratio would reflect disposable income minus non-water essential expenditures. This would allow a household's water bill to be compared to its remaining disposable income (discretionary income) without infringing on other basic needs such as shelter.

In California, the high cost of living, along with regional variations in housing prices, substantially influences the amount of income available to households to pay for water. For example, two households may pay the same water bill and have the same income level. However, the household in a region with a high cost of living will have less discretionary income to allot to its water bill than the household in a region with a low cost of living, increasing the former's affordability challenges.

Measuring affordability challenges while taking into account these significant income/cost variations is critical. Thus, the denominator used for Affordability Indicators 2 and 3 reflects cost-of-living adjustments. However, the variation in housing costs may also occur intra-county, which this measure does not account for.

calculated by the Public Policy Institute of California (PPIC) for data on poverty income levels (Bohn et al. 2013).[25] In particular, the PPIC calculates county poverty income thresholds building on the approach of the US Census. These thresholds use data on the expenditures needed for a family of four to stay out of poverty within a given county (for more information, see Appendix B2).

The PPIC thresholds offer two important advantages over other approaches that were considered. First, the income levels identified by each PPIC county poverty income threshold represent *disposable* income (i.e., income after taxes)—rather than gross income—for poverty-level households (Sawkins and Dickie 2005; Teodoro 2018).[26] Second, the PPIC's thresholds explicitly account for differences in housing costs across counties in California, thus including a key driver of differential household expenditures across the state.[27] For the purposes of this framework, OEHHA adopts the term "county poverty threshold" (CPT) to refer to PPIC's county poverty income thresholds.

[25] The PPIC uses these county poverty thresholds to calculate its California Poverty Measure (CPM), and thus refers to these as CPM thresholds. OEHHA uses the actual county poverty thresholds in its affordability indicators, and thus refers to these as county poverty thresholds (CPT) (Bohn et al. 2013).

[26] Other studies have explored alternate metrics for poverty-level affordability ratios. For example, some evaluate affordability at the 20th percentile with discretionary income (Teodoro 2018) or evaluate affordability at every income decile (Sawkins and Dickie 2005). Alternative sources for poverty-level data include area income estimates produced by the Housing and Urban Development, as recommended in the recent Pacific Institute report (Feinstein 2018), for example. Using this data would be the equivalent of using low-income data from the Housing and Community Urban Development office in California.

This affordability ratio at the county poverty threshold (AR_{CPT}) is calculated as:

$$AR_{CPT} = \frac{Systemwide\ Average\ Bill\ for\ 6\ HCF/Month\ \times\ 12\ Months}{County\ Poverty\ Threshold\ for\ Water\ System's\ County}$$

It is important to note that the affordability ratio at the county poverty threshold represents the income of individual households within that county *only* if they are at or near the county poverty threshold level. For example, a particular system may have 1% of its households living at the poverty level. In this case, this ratio would only apply to 1% of households. Accordingly, this proposed framework and tool will consider AR_{CPT} in conjunction with information on the percentage of households within a water system that are at or below the California county poverty threshold.

Affordability Indicator 3: Affordability ratio for the deep poverty threshold (AR_{DP})

Analyzing affordability challenges for households living at the county poverty threshold offers information about one subset of vulnerable households. However, in many communities, an even deeper level of poverty exists, presenting an even greater vulnerability challenge. Thus, OEHHA uses a third indicator for some of the most vulnerable households: an affordability ratio for households in deep poverty (AR_{DP}).[28] Here, deep poverty is defined as being at half the county poverty-level income, based on the PPIC county poverty thresholds used in Affordability Indicator 2.

The affordability ratio at the Deep Poverty threshold (AR_{DP}) is calculated as:

$$AR_{DP} = \frac{Systemwide\ Average\ Bill\ for\ 6\ HCF/Month\ \times\ 12\ Months}{\frac{1}{2}\ x\ County\ Poverty\ Threshold\ for\ Water\ System's\ County}$$

As with AR_{CPT}, affordability ratios at the Deep Poverty level (AR_{DP}) do not reflect the *actual* affordability ratio for a water system's households, unless households are at or near the Deep Poverty level. As such, this ratio will be considered in conjunction with a measure of the percentage of households that live at or below the deep poverty level within a water system.[29]

[28] It is worth noting that even measuring deep poverty levels does not necessarily capture the poverty faced by people experiencing homelessness, or families facing seasonal, temporary, inconsistent work, or other conditions that result in extreme poverty levels.

[29] Households in deep poverty likely face affordability challenges across a range of essential needs. Research into trade-offs among water bills and other essential expenditures is scarce, but two recent studies suggests that households facing unaffordable water will forgo housing and health-related bills to pay for water (Cory and Taylor 2018; Rockowitz et al. 2018).

Threshold Selection

Research and information on the value of different thresholds is inadequate, making it hard to choose a specific threshold (NAPA 2017). Therefore, the present framework does not select a specific threshold against which affordability ratios are determined to be "unaffordable." As such, this framework will consider affordability/non-affordability along a spectrum rather than as a binary phenomenon tied to a specific threshold.

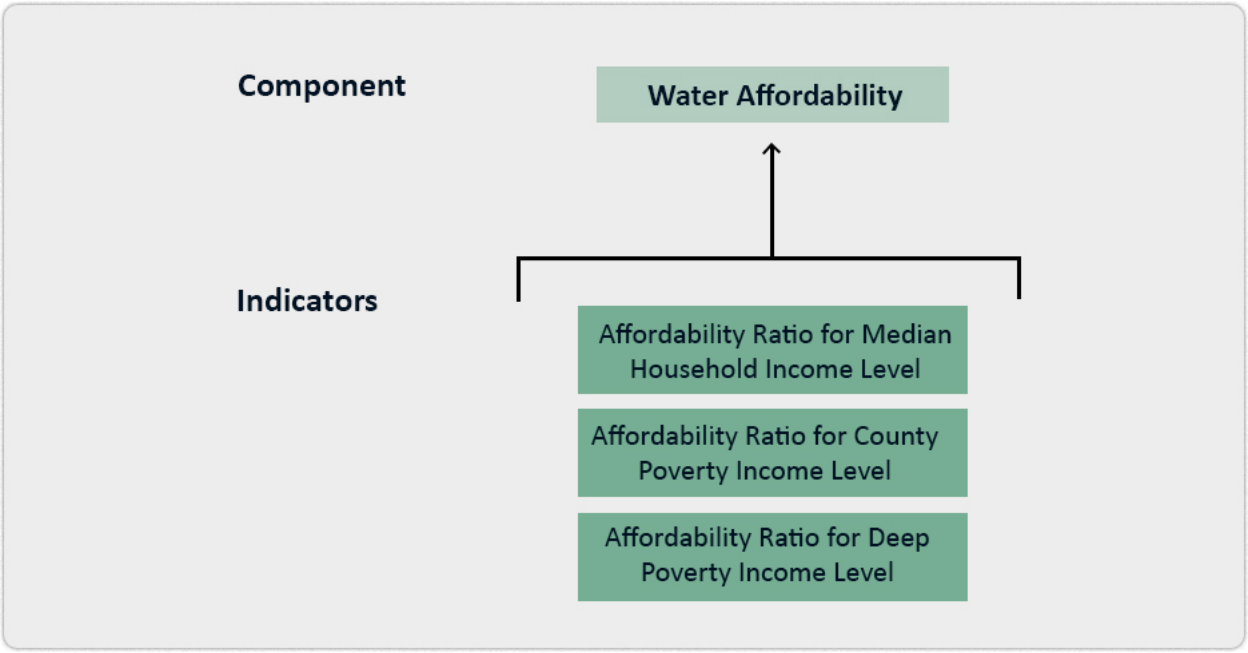
As new insights into affordability thresholds becomes available, OEHHA could update this approach for all or some of the indicators. For example, AR_{CPT} and AR_{DP} best approximate the affordability of water relative to disposable income for households at low-income levels. For these two indicators, for example, a higher range of thresholds may be more appropriate than the range of thresholds used for the affordability ratio at the median income level (Feinstein 2018; Teodoro 2018).

A Composite View of Water Affordability

Individual water affordability indicators can be combined to create a composite water affordability score. Unlike the AR_{MHI}, which is an affordability ratio estimated for the 50th percentile of the population, the affordability ratios for households living at the county poverty income level and/or the deep poverty income level do not capture what percentage of households live at or below the income threshold level.

The composite affordability ratio will account for the percentage of households at or below each income threshold level, alongside information on affordability ratios. Figure 8 is a conceptual representation showing how individual indicator scores could be combined to yield a composite water accessibility component score.

Figure 8. Creation of a composite water affordability score.



A Holistic View of Water Systems: Applications and Cases

Applications

This framework becomes a tool when it is populated with data, and once its indicators and components receive scores. Results can then be used in four main ways, at the water system or statewide level:

- To assess outcomes for particular indicators.
- To assess a particular component (e.g., water quality).
- To compare measures of water quality, accessibility, and affordability at the system level.
- To track and update progress in achieving the overall human right to water.

The tool offers a holistic view of a wide variety of information sources and community challenges. It can be useful to regulators, policy-makers, water system operators, and members of the public, who may approach water issues in different ways and with different concerns, effectively making our state more collectively equipped to understand and face its water challenges.

For example, regulators or water system operators may have information on the status of compliance for a particular water system. The tool can augment this understanding in several ways. First, the tool provides additional water quality information, such as exposure metrics. This can help decision-makers consider potential exposure threats *alongside* compliance challenges. Similarly, system operators and water planners can utilize previously unquantified metrics, such as those that measure affordability challenges, in order to weigh the needs and stresses of individual communities in their decision-making. Additionally, by viewing information across the three principal framework components, those who oversee water systems can consider disparate but interrelated characteristics of water delivery and water service that are not usually considered in tandem.

As for members of the public, including community groups and community members already deeply engaged in water issues, this tool can provide a useful, consolidated source for information across issues, regions, and time periods. For community members who may currently lack access to technical information, this tool offers a useful way to access, decipher and visualize the information they need to make decisions.

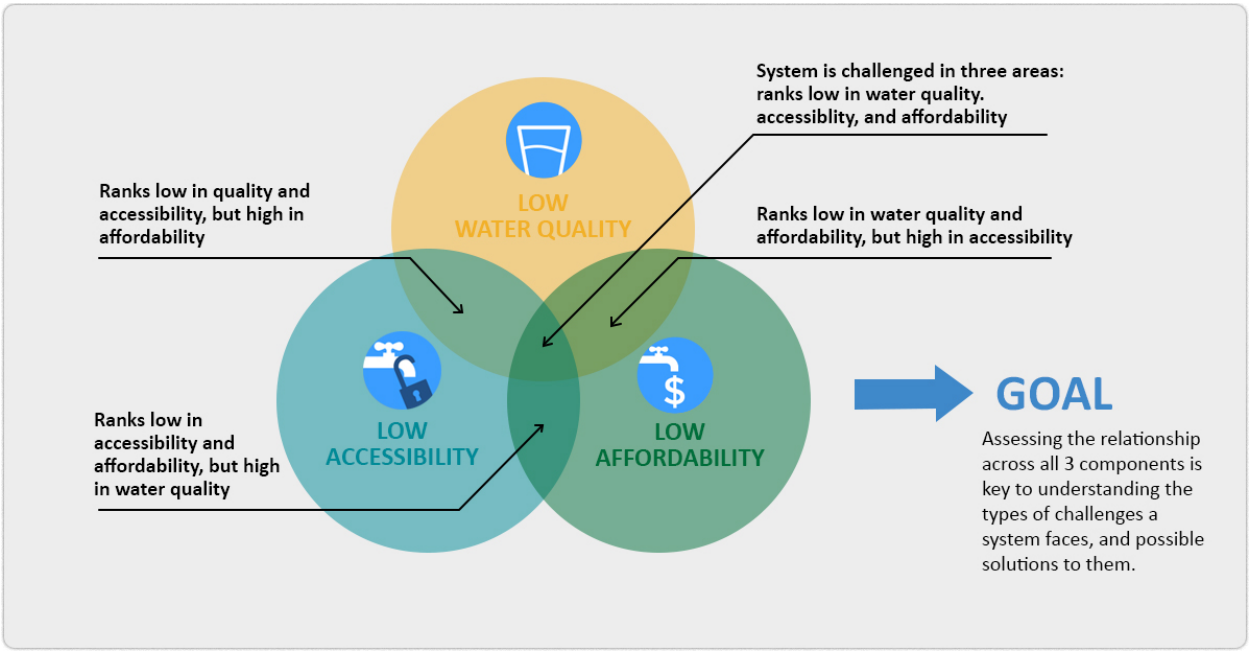
Finally, this tool allows for regional and statewide assessments of key trends across components. Previous initiatives have documented particular water challenges across the state, as well as a wide variety of challenges in particular regions. This tool, however, brings together information across water components, allowing the state and its residents to gain a holistic understanding of big-picture trends. In doing so, the tool may help Californians achieve the human right to water in a more consistent, equitable way.

The tool's usefulness is best underscored by Figure 9. Building on Figure 3, at page 8, the three framework components are shown in circles and are described as types of challenges: low water quality, low accessibility, and/or low affordability. Water systems may face one or more—or even all three—of these challenges, and these challenges may overlap with and even reinforce each other.

Figure 9 emphasizes the tool's ability to compare a water system's performance across several components. This can be particularly valuable in helping decision-makers or members of the public assess when there are combinations of quality, accessibility and affordability challenges. For example, a decision-maker or member of the public may start by asking: which systems show particular types of water quality challenges, or which systems face affordability challenges? Using this tool, they can now ask: which systems face *both* affordability challenges *and* water quality challenges; or which systems enjoy good water quality, but face threats to accessibility? It remains worth mentioning, as noted above, in the section *A Holistic View of Water Challenges*, that the information associated with each of the three components on its own, remains instructive and useful to inform local and state policies that can best address particular water challenges related to any single characteristic of water system service and delivery.

This section provides examples of the types of information the proposed framework and tool could help generate, and shows how multiple, overlapping challenges can be identified. Assessing and understanding these combined challenges is critical for devising relevant, sustainable and equitable solutions to the provision of water statewide.

Figure 9. Diagram of the three components in the proposed framework and tool, and the combinations of challenges a water system may face.



Hypothetical Case Studies

Water systems in the state operate under diverse sets of conditions, and face a range of water challenges. This section presents three hypothetical cases to show how the tool could function to understand these conditions. Ultimately, as these cases highlight, the framework allows for an assessment of crosscutting issues, at multiple levels (e.g., at the indicator, subcomponent or component level).[30]

Hypothetical System A: Here, a system faces challenges in all three components. Water quality, accessibility and affordability are all low.

This hypothetical small water system is located in a rural agricultural region, has fewer than 200 service connections, and serves 500 people. The median household income is $40,000. The system has one groundwater well and no backup sources. On average, water bills for 6 Hundred Cubic Feet (HCF) in this community are $65 per month, or $780 per year.

From 2008 to 2016, the system faced a number of **water quality** challenges. Exposure levels were high and the system faced a number of compliance hurdles. In particular, during the nine-year time period, the system had average concentration levels of nitrate between 45 and 65 mg/L in eight of the nine years. As the MCL for nitrate is 45 mg/L, this information indicates that potential exposure was high (i.e., concentration levels exceeded the MCL), and the duration of high potential exposure was long. During this time period, the system also received at least one nitrate MCL violation in eight of the nine years. Thus, the duration of the non-compliance period was also long. All data requirements were met.

Regarding **accessibility**, with only one groundwater well, the system is considered to be physically vulnerable to water outages. As a small system serving a predominantly economically disadvantaged community, it is estimated to have relatively low institutional capacity. It had ten monitoring and reporting violations, indicating potential challenges with managerial capacity.

With regard to **affordability**, residents served by the system also face a number of challenges. A household earning the median income level would be spending two percent of its income on water. This is nearly double what research has determined is the average spent on water in industrialized countries (Smets 2017) and 0.5 percent higher than the threshold used to guide financial assistance to DACs in the State Drinking Water Revolving Fund. Households living at the county poverty level of $24,151 would pay 3.2 percent of their income ($780/$24,151) on water. Those living in deep poverty ($12,075) would spend nearly 6.5% of their income on water. Because 20 percent of this water system's population lives at or below the county poverty threshold, a significant portion of economically vulnerable residents living in the community are particularly vulnerable to affordability challenges. Figure 10 depicts indicator

[30] In this report, we focus on the overall component outcome, rather than subcomponent outcomes.

results for each of the framework's indicators. Table 2 further serves to summarize the key information the tool can provide.

As described above, the results for nearly all indicators provided in the tool signal that this system faces serious challenges. However, how is one to use this information? To begin, the decision-maker may be interested in comparing this system to others to determine whether this is a system with relatively large or average challenges. Doing so could assist the decision-maker in determining what types of solutions might benefit the water system, whether to allocate resources (e.g., training and capacity building, technical decision-making support, or financial support), and what types of resources might be best suited to address the system's needs.

Second, the benefit of viewing information specific to each component, and across components, is that when the decision-maker devises solutions to these challenges, she or he may need to carefully assess trade-offs. For example, it could prove critical to address the fact that System A has had on-going water quality problems for an acute contaminant such as nitrate. The community served by the system may need to consider developing a new well, an intertie with a nearby system, or a treatment facility. However, such solutions could potentially increase the cost of delivering water. Since affordability is already a challenge for households served by this system, a sustainable and equitable solution would need to address the challenges described in all three component areas, including affordability.

Figure 10. Chart summarizing case study results. The rows show the results for each of the three hypothetical water systems. The columns represent the 13 indicators in the three components. The color of each box indicates the level of concern regarding a specific indicator. Dark blue boxes represent greater concern. Medium-blue boxes indicate a more moderate level of concern, and light blue boxes little to no concern.

	Water Quality							Accessibility			Affordability		
Indicator	1	2	3	4	5	6	7	1	2	3	1	2	3
System A													
System B													
System C													

Table 2. Summary table for Hypothetical System A. This chart provides an example of how information can be translated into a clearly legible diagram, accessible to all kinds of stakeholders.

Water challenges in all three components.		
Water Quality	**Potential high exposure**	Eight years of potentially high exposure levels of nitrate, averaging between 45-65 mg/L.
	Presence of acute contaminants	Yes: nitrate.
	Maximum duration of potential high exposure	Eight years of high nitrate levels.
	Data availability	The system has monitoring data for all contaminants.
	Non-compliance with primary drinking water standards	During the nine-year study period, the system had one or more MCL violations in eight of the nine years.
	Presence of acute contaminants in non-compliance	Yes: nitrate.
	Maximum duration of non-compliance	Eight years of nitrate MCL violations.
Water Accessibility	**Physical vulnerability to water outages**	One groundwater well.
	Institutional capacity	Small, disadvantaged community.
	Managerial constraints	The system had no monitoring and reporting violations.
Water Affordability	**Affordability ratio at the median household income**	2%
	Affordability ratio at the county poverty threshold	3.2%. Here, 20% of the population lives at or below the county poverty income level.
	Affordability ratio at the deep poverty threshold	6.5%

Hypothetical System B: Here, a system faces some challenges in water quality and accessibility, but the key challenge lies in affordability.

This mid-sized hypothetical system, serving roughly 3,300 residents, is located in a rural, non-agricultural region of the state. The system has four groundwater sources and two surface water intakes. Median household income is $39,000. Average water bills for 6 HCF of water are $55 per month, or $660 per year. From 2008 to 2016, the water system received notification of on-going total coliform violations, with TCR MCL violations in six of the nine years. All data requirements were met.

With regard to ***accessibility***, the indicators do not signal major accessibility challenges, other than those stemming from the system's classification as one that serves a disadvantaged community.

However, with regard to ***affordability***, the residents who are served by the system face key challenges. The county poverty level is $25,361. Nearly 30 percent of the residents served by this water system live at or below this level. Nearly five percent of residents live at or below the deep poverty level of $12,680. Thus, while the affordability ratio for households at the median income level is 1.7 percent ($660/$39,000), the affordability ratio for households living at or below the county poverty level is significantly higher (2.6 percent), and is even higher for those living in deep poverty level (5.2 percent).

These affordability results highlight the usefulness of having multiple affordability indicators. In this case, while the affordability ratio at the median household income may not signal a major concern, the presence of a large proportion of residents who live at or below the poverty level indicates that there are pressing affordability challenges that might otherwise be missed.

As with System A, Figure 9 highlights the indicators that show key challenges in this system. A decision-maker assessing System B would likely want to address the ongoing TCR violations. However, the most urgent area of focus may be affordability challenges. At least 50 percent of households spend 1.7 percent or less of their income on water bills. Thirty percent or more of households face more acute affordability challenges, making them some of the most economically vulnerable residents served by the system.

Hypothetical System C: Here, a system has relatively high water quality and accessibility, but relatively low affordability.

The third hypothetical system, System C, is located in an urban county and serves nearly 30,000 people. The median household income in this community is $42,100. The system has over ten groundwater wells and one surface water intake. The average water bill for 6 HCF is $85 per month, or $1020 per year.

This system has had no **water quality** challenges in the time period, and has relatively strong **accessibility**, based on the framework's current indicators. The main challenge for this system is with regard to **affordability**.

At least 50 percent of the households served by this water system are paying approximately 2.4 percent of their income on water. Ten percent of the community's households earn income levels at or below the county poverty income level of $33,493. Thus, these households pay 3 percent of their income on water. While less than 0.5 percent of households in the community earn incomes at or below the deep poverty level of $16,746, these households pay 6.1 percent of their income on water.

These three affordability indicators highlight different affordability challenges. The affordability ratio for the median household income shows that the majority of the system's households (i.e. 50%) face considerable affordability challenges, given the typical affordability thresholds used. At least ten percent of the households served by the water system are economically vulnerable and face special hardship in paying their water bills. While only a small fraction of households pay 6.1 percent or more of their income for water, these are the most vulnerable households, whose cases need to be considered by planners and decision-makers.

Strategies to address the affordability challenges of this system should be explored with care. The fact that water quality and accessibility are high could be a function of the fact that water bills adequately cover the technical, managerial, and financial needs of the system. A simple decrease in rates could potentially compromise the system's high water quality. The tool helps highlight the need to balance decisions that impact one component, with potential consequences affecting other components.

Summary

In summary, these cases show how the framework—once populated with information—can become a tool that can be used by state agencies, water system operators and members of the public to understand the challenges that individual water systems may face, and help them move toward identifying technical solutions. These system-level results can also be used to provide state-level understanding of general progress in achieving the human right to water across water systems. For example, when users view the results in combination, they can assess overall trends across water systems in each of the three components. When these results are assessed over time (e.g., beyond the 2016 time period), users could gain a holistic picture of evolving patterns in any one component, or across all three.

In sum, this framework and tool allow users to:

- Evaluate California's progress toward ensuring accessible, safe, and affordable drinking water in community water systems.
- Identify which indicators and components pose significant challenges for a given water system.
- Access information that that can help lead to potential technical solutions to challenges or combinations of challenges in a particular system.

- Identify particular types of needs for support and assistance that water systems may have.
- Quantify overall trends across the state and/or regions to gain a picture of the overall level of challenge in one or more components.

Conclusions and Next Steps

The proposed framework and tool are intended to help shape efforts to assess the delivery of clean, safe, accessible and affordable water throughout the state. Together, they offer an additional way for the State Water Board and other agencies to identify communities that may face a variety of water burdens. Ultimately, this framework and tool enable a flexible, versatile, and adaptable approach to measuring how the human right to water is being realized in various contexts and time periods.

The strength of this tool lies precisely in its holistic and versatile approach. Indeed, the tool produces system-level or indicator-specific results for specific components. Thus, a user wishing to obtain an overall sense of water issues on a state or regional level can view the results across the tool's three components, while also exploring system-level specifics at the individual component or indicator level.

Depicting information in this way can enable decision-makers to ask new and probing questions about California communities and the water that sustains them. Which systems face water quality and affordability challenges? Which systems have low water quality, but perform well in other ways? What accounts for this unevenness, and how can it be addressed? How do these systems fare over time, and why? The ability to ask these questions will allow decision-makers to better tailor their approach to delivering clean, safe, affordable and accessible water to communities across the state. As a result, the tool can be used in conjunction with specific compliance information to help focus attention on water systems that are most in need.

Several next steps will be taken as part of this project. OEHHA will solicit public feedback on this framework report, and then release a draft tool with demonstration results, drawing on the framework. The results of this tool will inform our general understanding of water access across the state, and will provide valuable information for other state efforts, such as the State Water Board's assessment of needs for the state's water systems. With time, and data permitting, OEHHA will continue to refine this framework and tool to offer the most comprehensive view of water provision possible.

APPENDICES

Appendix A: Future indicators under consideration

The indicators in this framework were selected based on two main factors: the indicators' relevance for measuring the three water components of quality, accessibility and affordability; and the availability of high-quality statewide data that could be plausibly incorporated into OEHHA's first phase of work. Future versions could be adapted to include additional indicators for which high-quality statewide data may not be available currently. These are described in Table A1.

Appendix Table A1. Potential indicators or units of analysis for consideration in future versions of the proposed framework and tool.

Components or Units of Analysis	Potential Indicators
Water Quality	• Average potential contaminant exposure to secondary contaminants • Violations of Maximum Contaminant Levels (MCLs) for secondary contaminants • Relative toxicity of contaminants
Water Accessibility	• Amount of water available to customers • Average/median water use of water utility per customer • Total source capacity of system; total source capacity per capita • Vulnerability to climate change and/or drought • Drought-impacted systems • Applications for emergency interim solutions/drought funding • Reporting of supply shortages • Availability of alternative sources of water (e.g., proximity to vended water) • Service interruptions • Moratorium on service connections • Degree of reliance on purchased water sources

Components or Units of Analysis	Potential Indicators
Water Affordability	• Water affordability ratios disaggregated by demographic characteristics of people served by water systems • Water affordability including replacement costs (for bottled water) • Water affordability including sanitation costs • Water shutoffs
Additional Groups or Units of Analysis or Topics to Consider	• Sanitation • Private domestic wells • Schools • Populations experiencing homelessness

Appendix B: Affordability Considerations

B1. Critiques of Conventional Affordability Ratios

As noted in the main report, the proposed framework and tool go beyond conventional affordability ratios (CAR) to produce three improved affordability ratios (see Box 1 for a definition of an affordability ratio). This section provides additional background on the use of CARs, and on how and why they might be improved.

Historically, the US EPA has calculated affordability ratios (which it terms Residential Indicators) at the median income level to assess: 1) household affordability for the so-called average household; and 2) water system-level financial capacity, i.e., a water system's ability to access revenue for operations, maintenance, and new capital projects.

Four primary criticisms have emerged regarding the US EPA's Residential Indicator. First, measuring water affordability at the median income level does not capture the unaffordability challenges faced by households below the median income level. Second, using average water volumes to assess affordability may lead to erroneously characterizing over-consumption (e.g., landscaping with drinking water) as unaffordable, or labeling under-consumption (e.g., self-rationing) as affordable (Gawel et al. 2013; Kessides et al. 2009). Thirdly, some critics have noted that pre-existing thresholds that are used to determine what counts as affordable may be too high or not fully justified (NAPA 2017). Finally, without precise data on essential expenditures, data about gross income can lead one to overlook the trade-offs that many households may be forced to make among essential expenditures (Cory and Taylor 2018).

B2. The Public Policy Institute of California's County Poverty Measure

OEHHA uses the PPIC's poverty metric as the basis for two of its affordability indicators. This metric reflects a so-called basic needs budget. This is based on data on expenditures needed for a family for four to stay out of poverty within a given county. The metric builds on the approach of the US Census for tracking poverty by explicitly accounting for variations in California's cost of living across counties.[31] However, the PPIC poverty thresholds do not capture intra-county or intra-system variation in poverty levels and cost of living.[32]

[31] PPIC County Poverty Thresholds (CPT) are based on the average of 33rd and 36th percentile of national expenditures on food, clothing, shelter, and utilities, multiplied by 1.2 to account for 'key spending' for a family of four. These expenditures are then adjusted by county by multiplying the shelter and utilities portion of the threshold by the difference in housing costs between each county and national level costs. PPIC uses a dual index to adjust housing costs based on the proportion of renters and homeowners within each county. Of California's 58 counties, 38 have unique poverty thresholds, while the remaining 20 are grouped into three groups with equal thresholds due to census suppression criteria.

[32] As data with higher-scale resolution of in-county differences in cost of living becomes available, OEHHA will consider updating this indicator.

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