


## Monitoring the human right to water in California: development and implementation of a framework and data tool

C. Balazs <sup>a,\*</sup>, J. J. Goddard<sup>a,b</sup>, C. Chang<sup>a,c</sup>, L. Zeise<sup>a</sup> and J. Faust<sup>a</sup>

<sup>a</sup> Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, 1515 Clay St, Oakland, CA 94612, USA

<sup>b</sup> Energy & Resources Group, University of California, 310 Barrows Hall, Berkeley, CA 94720, USA

<sup>c</sup> School of Public Health, University of California, 2121 Berkeley Way, Berkeley, CA 94704, USA

\*Corresponding author. E-mail: carolinabalazs@gmail.com

 CB, 0000-0002-1691-2077

### ABSTRACT

Ensuring the human right to water requires monitoring at national or subnational levels, but few comprehensive frameworks exist for industrialized contexts. This paper introduces a subnational-level framework – known as the California Human Right to Water Framework and Data Tool (CalHRTW) – developed by the authors at the California EPA's Office of Environmental Health Hazard Assessment. This paper has two objectives: (1) to present the theoretical foundations and methodology used to develop the first version of CalHRTW (CalHRTW 1.0) and (2) to showcase how results can be used. CalHRTW 1.0 measures three components of the human right to water: drinking water quality, accessibility and affordability for community water systems in California. Nine individual indicators grouped by component, and three indices that summarize component-level outcomes are used to quantify system-level results. CalHRTW allows users to: (1) summarize system-level conditions statewide and identify challenges, (2) explore social equity implications and (3) centralize information for planning. CalHRTW draws on approaches from existing international monitoring efforts and complements existing California efforts by being the first US effort to comprehensively and explicitly monitor the HRTW under one umbrella. This work offers other US states and countries a model to build monitoring efforts to realize the human right to water.

**Key words:** Access, Framework, Human right to water, Monitoring, Water quality, Water service delivery

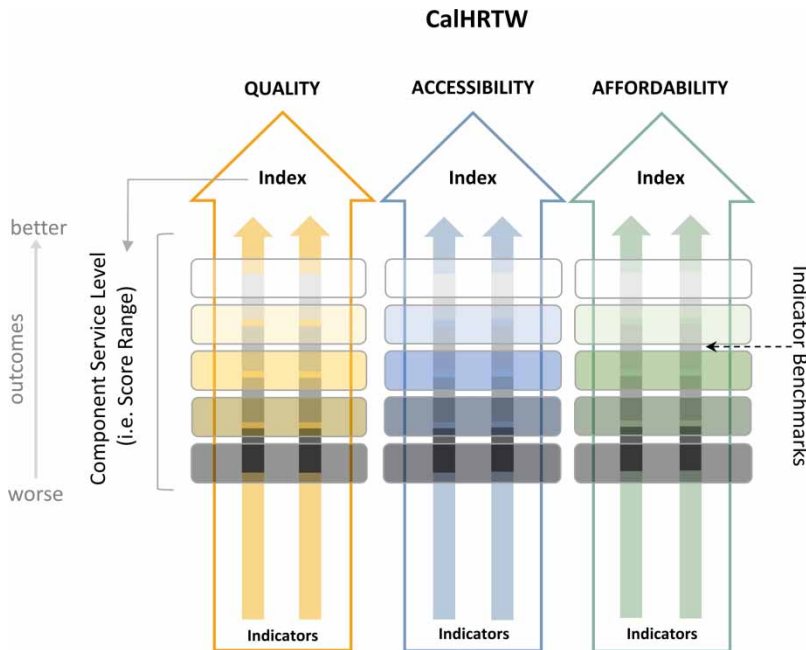
### HIGHLIGHTS

- CalHRTW is the first effort to comprehensively monitor the human right to water in California.
- We develop a monitoring framework and tool track the human right to water in California.
- Nine indicators and three component-level indices allow users to track water system-level conditions and screen for challenges, explore social equity implications and centralize information.
- The approach and application offers a model for other subnational locales.

---

This is an Open Access article distributed under the terms of the Creative Commons Attribution Licence (CC BY-NC-ND 4.0), which permits copying and redistribution for non-commercial purposes with no derivatives, provided the original work is properly cited (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## GRAPHICAL ABSTRACT



## 1. INTRODUCTION

California sits at a unique confluence of drinking water policy currents regarding the human right to water and sanitation (HRTW). Internationally, the United Nation (UN)'s adoption of the HRTW has underscored the criticality of this right and the need to monitor its progressive realization (UN CESCR, 2002; General Assembly, 2010; de Albuquerque, 2014; Meier *et al.*, 2017). While the United States (US) is not a formal signatory of the HRTW, since 2012, Massachusetts, Pennsylvania and California have adopted specific human right to water legislation (Assembly Bill No. 685, 2012; Massachusetts Const. art. XCVII, n.d.; Pennsylvania Const. art. I, n.d.), largely due to grassroots water justice advocacy. These legislative efforts complement the US Safe Drinking Water Act (SDWA) by explicitly focusing on three inter-related dimensions of drinking water: water quality, water accessibility and water affordability. In doing so, such legislation addresses the persistent, worsening and multi-faceted water access challenges for individuals and communities (Fedinick *et al.*, 2017; Allaire *et al.*, 2018; Teodoro, 2019). This paper presents the first US state effort to develop and implement an HRTW monitoring framework – the California Human Right to Water Framework and Data Tool (CalHRTW).

Despite a rich regulatory and institutional environment, challenges in drinking water quality, accessibility and affordability abound in the US. Large-scale agriculture that contaminates aquifers, wildfires that compromise distribution lines (Proctor *et al.*, 2020), saltwater intrusion from the overuse of coastal aquifers (Barlow & Reichard, 2010) and governance failures (Hanna-Attisha *et al.*, 2015) are but a few pressures affecting water quality. Widespread violations of the SDWA are well documented (Fedinick *et al.*, 2017), and emerging contaminants, such as pharmaceuticals and perfluoroalkyl substances present additional challenges, as these are neither systematically monitored nor regulated in the US (Bradley *et al.*, 2018; Domingo & Nadal, 2019).

Water access – or the physical acquisition of safe drinking water – can be a challenge at both the household and community levels. Between 2013 and 2017, over one million people in the US lacked piped running water (Meehan *et al.*, 2020a, 2020b). Some communities still rely on hauled water or purchase their water from local vendors or nearby markets (Roller *et al.*, 2019). Aging water infrastructure poses a fundamental concern for maintaining adequate water and sanitation for communities (Riggs *et al.*, 2017). Increases in water demand in both urban and rural settings burden smaller water systems that are particularly vulnerable to supply shortages caused by extreme events, such as drought (Ekstrom *et al.*, 2018; Mullin, 2020; Proctor *et al.*, 2020).

Water affordability is also a growing concern. The tripling of water and wastewater rates over the last three decades (Rubin, 2018) and stagnant income levels for most households mean that water affordability is a growing problem, worsened by the fact that many households purchase expensive bottled water when they lack safe tap water (Moore *et al.*, 2011; Allaire *et al.*, 2019; Deitz & Meehan, 2019). Customers risk having their water shut off for failing to pay water bills (Riggs *et al.*, 2017). And during environmental crises, such as droughts, communities face exacerbated utility costs due to additional charges (Feinstein *et al.*, 2017).

Social inequities in water access persist across the three aforementioned areas. Communities in the US that are lower-income, of color and rural tend to bear the burden of disproportionately worse water quality (Wescoat *et al.*, 2007; Olson & Fedinick, 2016; McFarlane & Harris, 2018; Schaider *et al.*, 2019), less accessible water (Meehan *et al.*, 2020a, 2020b) and less affordable water (Teodoro, 2019). Access to adequate sanitation poses similar concerns, especially in communities of color (Deitz & Meehan, 2019; Lakhani, 2020). Contaminated aquifers in Native American communities without access to adequate treatment are prevalent (Corlin *et al.*, 2016; Eggers *et al.*, 2018). Beyond driving disparities in exposures, these inequities add coping costs (Balazs & Ray, 2014) and impact the physical well-being and psychosocial stress levels of individuals and communities (Gaber *et al.*, 2020; Venkataramanan *et al.*, 2020). Uneven water governance further exacerbates these issues, creating regulatory and institutional inequalities among the communities with the poorest water access (Pannu, 2012).

These national trends are mirrored in California. Nearly one million Californians are served by public water systems that are out of compliance with primary drinking water standards (State Water Resources Control Board, 2019). Water sources contaminated with chemicals – including nitrate and arsenic – disproportionately burden low-income communities and communities of color (Balazs *et al.*, 2011, 2012; London *et al.*, 2018). In rural areas, especially, many low-income households are served by water systems with aging infrastructure, unreliable supplies and a cost structure that push water rates to unaffordable levels. Households served by small water systems have less affordable water compared with larger systems, though households in poverty may struggle to pay the bill regardless of system size (Goddard *et al.*, 2021). After her US visit, the UN Special Rapporteur on the right to water and sanitation summarized these challenges in a 2011 report (de Albuquerque, 2011), amplifying decades of advocacy work by water justice advocates.

Recognizing these challenges, in 2012, California became the first US state to legislatively recognize the HRTW through Assembly Bill (AB) 685 (Assembly Bill No. 685, 2012). However, AB 685 offered no guidance with respect to how this right should be monitored or tracked. In response, in 2015 the CalEPA and the State Water Resources Control Board (State Water Board) enlisted the Office of Environmental Health Hazard Assessment (OEHHA) to develop a framework and tool for evaluating the quality, accessibility and affordability of the state's drinking water supply. In 2021, the OEHHA published the final version of its Human Right to Water Framework and Data Tool (CalHRTW 1.0), marking a foundational step by the State of California in comprehensively monitoring and tracking water challenges (OEHHA, 2021a).

This paper presents the theoretical and methodological foundations for CalHRTW and showcases how results of such a subnational level monitoring framework and data tool can be used in California. CalHRTW draws on

approaches from existing international monitoring efforts and complements existing California drinking water efforts by being the first US (and state) effort to comprehensively and explicitly monitor the HRTW under one umbrella. Ultimately, while existing international, national and subnational frameworks influenced and shaped the development of CalHRTW, the basis for the framework's details – components and indicators – is grounded with attention to the historical context of the state's water challenges.

Below, we (1) contextualize CalHRTW in relation to international and US/California efforts (Section 2); (2) outline the theoretical foundations used to develop CalHRTW (Section 3); (3) introduce the methodology for how CalHRTW was developed (Section 4); (4) present key results and uses of the tool (Section 5); and (5) discuss the implications (Section 6).

## 2. BACKGROUND

CalHRTW responds to AB 685 and California's unique water context by developing a monitoring framework that draws on international efforts and augments federal and state-level approaches that monitor and address drinking water challenges.

In particular, CalHRTW draws on a rich foundation of water service and HRTW frameworks that organize indicators along a gradient in order to determine water service levels and fold in cross-cutting themes, such as equity. Following decades of prior efforts (United Nations, 1977; UNEP & GEMS/Water, 2007; WHO & UNICEF, 2010; Kayser *et al.*, 2013; Meier *et al.*, 2017; UNECE, 2019), the UN's General Comment No. 15 (GC 15) introduced a unified set of components to consider when assessing the HRTW: quality, accessibility and availability/quantity (UN CESCR, 2002). These components were formally recognized in 2010 (UN General Assembly, 2010). Within accessibility, physical accessibility, affordability ('economic accessibility'), nondiscrimination and information accessibility are included (UN CESCR, 2002).

Since then, several key international efforts have sought to monitor drinking water. The UN's monitoring of water quality and its health impacts (UNEP, 2007) and the global tracking of drinking water sources (UNEP & GEMS/Water, 2007) are two well-developed efforts focused largely on water quality and supply issues. Other efforts monitor participation and cooperation (e.g., UN GLAAS). The UN's Joint Monitoring Program (JMP) Sustainable Development Goal 6.1 is by far the most notable present-day effort to monitor the HRTW, though elements of affordability are still being developed (WHO & UNICEF, 2021). The JMP draws on earlier work that measures quantitative indicators of 'water service' – defined as the provision of water in relation to quality, accessibility and availability/quantity (e.g., Lloyd & Bartram, 1991; WHO, 1997; Howard & Bartram, 2003; Gawel & Bretschneider, 2016; WHO & UNICEF, 2017). With the exception of the JMP, these monitoring efforts do not integrate and monitor all elements of the HRTW under one umbrella. Moreover, international frameworks provide limited utility to local (e.g., state-level) monitoring or policy needs that require more fine-grained outcomes.

At a national or subnational level, countries such as India, Ghana, Burkina Faso and Mozambique have measured basic levels of service based on quantity, quality, accessibility and reliability (Burr & Fonseca, 2013). Countries within the pan-European region measure equitable water access using a self-assessing analytical tool (an 'Equitable Access Scorecard') structured around four themes to assess a country's progress toward the human right to water: governance, geographical disparities, vulnerable and marginalized groups, and affordability (UNECE, 2019).

In the US, a variety of efforts monitor drinking water. The SDWA requires public water systems to meet basic water quality guidelines through ongoing regulation of maximum contaminant levels (MCLs) for over 90 drinking water contaminants. All states must meet these guidelines or implement more stringent ones. In California, numerous state agencies track metrics that relate to the HRTW. Most notably, the State Water Board (2015) summarizes the status of compliance of public water systems every 5 years. Furthermore, the State Water

Board (2020a) maintains a human right to water portal that lists water systems in and out of compliance with the SDWA. An array of policy efforts fund drinking water solutions in California (e.g., Proposition 1, 2014; Senate Bill No. 200, 2019; State Revolving Fund, 2021b). Some states have created summary metrics of water quality issues, combining multiple drinking water contaminants into one index, as done in California's CalEnviroScreen 4.0 (OEHHA, 2021b), or creating a groundwater quality index whose quantitative results are binned and assigned a qualitative description (from 'very poor' to 'excellent') (e.g., Cude, 2001). At least one, nongovernmental organization has offered a conceptual approach for measuring the HRTW (Feinstein, 2018), though it has not been implemented.

Despite these inter-related efforts, in the US, no federal or state entity had created a monitoring framework that would explicitly monitor progress in achieving HRTW goals. Such subnational (or national)-level frameworks (e.g., Flores *et al.*, 2013; Young *et al.*, 2019) are necessary to meaningfully inform local policies, improve water service and improve health outcomes. Indeed, the UN reiterates that national governments bear the 'primary responsibility' for safe drinking water and sanitation (UN Human Rights Council, 2010; Staddon *et al.*, 2012).

### 3. THEORETICAL FOUNDATIONS: TOWARD A CONCEPTUAL FRAMEWORK

To develop CalHRTW's conceptual framework, we: (1) reviewed concepts related to monitoring the HRTW in the aforementioned approaches and frameworks and (2) typologized existing frameworks in order to develop the architecture of CalHRTW.

#### 3.1. Monitoring the HRTW

CalHRTW is based on the recognition that monitoring the HRTW is essential to both establish the accountability of duty bearers (i.e., states) and measure the adequacy of water access (de Albuquerque, 2014). GC15 recommends that states implement 'independent monitoring' that 'includes methods such as right to water indicators and benchmarks' (UN CESCR, 2002). Monitoring typically assesses three categories of indicators: outcome indicators that measure individual or collective attainments of a right (e.g., compliance with regulations), structural indicators that measure the commitment of the state (e.g., existence of legislation) and process indicators that measure state efforts (e.g., funding programs) toward achieving outcomes (UN Human Rights, 2008; de Albuquerque, 2014). Monitoring evaluates the degree to which progressive realization of a right is occurring over time and space (Meier *et al.*, 2017). CalHRTW focuses on outcome indicators in order to develop a baseline assessment of the state of the HRTW (OEHHA, 2021a).

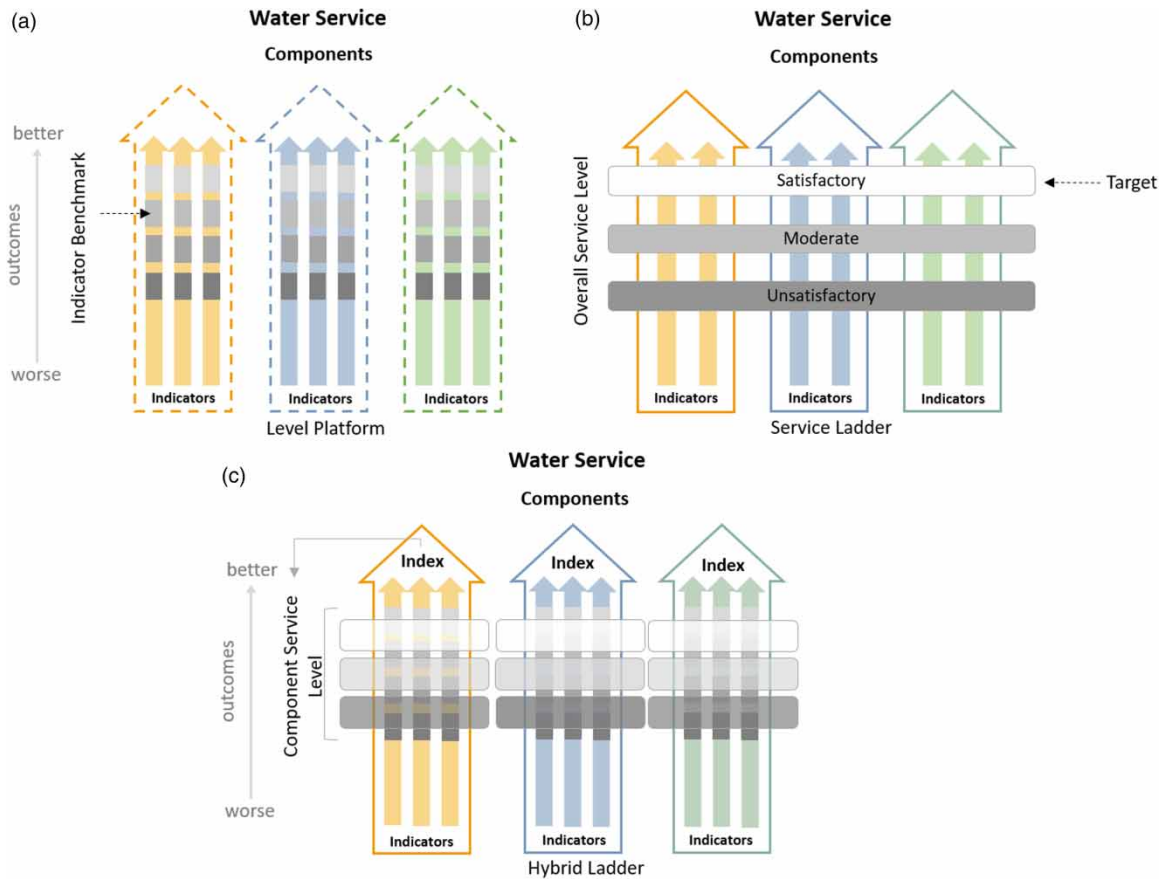
#### 3.2. A typology of HRTW and water service frameworks

##### 3.2.1. Key concepts

Several key concepts of HRTW monitoring frameworks emerge from the aforementioned lineage and are depicted in Figure 1, which summarizes a typology of HRTW/Water Service frameworks. The first concept is *water service*, which describes the provision of water in relation to common *components*, or obligations, for example, quality, availability/quantity and accessibility. In some frameworks, the metaphor of a *water service ladder* is used to identify where on the spectrum of outcomes water service falls.

*Indicators* describe specific characteristics of water service (e.g., water costs for households). Indicators can be measured on a quantitative scale. *Benchmarks* (i.e., predetermined values of an indicator) are usually set along this scale based on normative or empirical considerations. For example, in the US, drinking water contaminant concentrations are assessed in relation to MCLs which are based on health, technical and economic considerations. In the HRTW literature, a qualitative *target* or threshold (Roaf *et al.*, 2005) often centers around 'recommended' water service levels (UN CESCR, 2002; UN-OHCHR, 2012; Jensen *et al.*, 2014; Meier *et al.*,





**Fig. 1** | Typology of three HRTW monitoring frameworks. The Level Platform Framework (a) and the Service Ladder Framework (b) are distilled from the work of *Kayser et al. (2013)*. Large arrows represent a component (e.g., water quality). Narrow, color-filled arrows within the component arrows represent individual indicators. Indicator-level outcomes are represented by shaded gray squares, to which benchmarks can be associated. The core feature of the Level Platform is the inclusion of multiple indicators, where organization by component is optional or implicit (indicated by dotted lines), and all indicators are treated equally. In the Service Ladder and Hybrid Ladder frameworks, indicators are explicitly grouped by component (represented by a solid line). In the Service Ladder, indicators are primarily used to describe an overall water service level (represented by horizontal bars). The Hybrid Ladder Framework (c) combines the first two frameworks to include individual indicators and aggregates indicator results to estimate a component-level index which is then used to define a component service level. Examples of indicators grouped by component (named in parentheses) could include the presence of fecal contamination (water quality), the quantity of water available per capita per day (water access) and the cost of water relative to income (affordability). Please refer to the online version of this paper to see this figure in colour: <http://dx.doi.org/10.2166/wp.2021.069>.

2017). Indicator-level outcomes can be evaluated to determine the achievement of an overall service level target. From a human rights perspective, indicators should be measured at the individual level, as these rights are considered ‘individual’ (*Winkler, 2015*). However, where data is not available at the individual or household levels, the HRTW is assessed at aggregated units of analysis (e.g., water system) and understood as a proxy.

An *index* combines indicators into a single value by defining a condition, such as fitting a function (e.g., weighted average) that yields a final value. Usually, an index is a quantitative result that has combined individual indicators within, or across, components in a particular manner. The final value of a quantitative index may be further categorized into ranges or percentiles (e.g., *OEHHA, 2021b*) which are assigned a qualitative description.

For example, Cude classified index results into a series of ranges that define water quality outcomes from very poor to excellent (Cude, 2001).

### 3.2.2. Typology of frameworks

Kayser *et al.* (2013) summarize four main types of HRTW and water service frameworks. We distill these into two general types based on what the indicators measure, how the indicators are categorized and what type of information the monitoring focuses on.

In a first type, the ‘Level Platform’ Framework (Kayser *et al.*, 2013) or ‘Human Rights Obligations Framework’ (Roaf *et al.*, 2005), any and all relevant indicators of water service components are measured, including indicators of quality, accessibility and availability/quantity. This framework focuses on outcome indicators (but could include structural and process indicators) that are weighted equally and measured, often in relation to a particular benchmark or set of thresholds (thus a ‘level platform’) (see Figure 1(a)). This approach does not evaluate interdependencies among indicators or components, nor does it focus on the creation of an index. Related indicators can, presumably, be grouped by component (as indicated by larger dotted arrows in Figure 1(a)), though this is not required. Figure 1(a) represents a generic schematic of this framework, which is exemplified by Lloyd & Bartram’s (1991) early work developing the quality of service indicators that include: coverage (e.g., percent of population served by what means), continuity (hours/day water is supplied), quantity (e.g., volume/capita/day), quality (fecal contamination), cost (monthly tariff) and sanitary risk. These indicators are given equal weight and optionally grouped by component (Figure 1(a)). Although in a second example, Lloyd & Bartram (1991) also provide a way to combine indicator information into an index (e.g., evaluating contamination and sanitary risk); this element of their work is not a Level Platform. A sub-type of the Level Platform Framework (which Kayser *et al.* (2013) consider as a stand-alone type) accounts for interdependencies among indicators and selects key representative indicators.

In a second type, the ‘Service Ladder Framework’, a select group of indicators, is used to summarize *overall service levels* – from low to high – for a specific user (e.g., an individual or country) (Figure 1(b)) (Kayser *et al.*, 2013). The overall service level is defined by using a conditional function that identifies a series of conditions to be met across certain indicators within components. For example, the JMP defines water as ‘safely managed’ when it is located on premise, available when needed and free from contamination. A key characteristic of this type of framework is the focus on the overall service level, rather than results for individual indicators, or even component-level results. A subtype of this type selects the worst-performing indicator across all indicators to represent the overall water service (see Moriarty *et al.*, 2011; Kayser *et al.*, 2013).

Both the Level Platform and Service Ladder frameworks would benefit from merging of approaches in order to explicitly provide information on individual indicators and component service levels, and if desired, overall service levels. Therefore, we developed a hybrid model, which we call the ‘Hybrid Ladder’ Framework (Figure 1(c)). For our purposes, this framework highlights both individual indicator outcomes and component service levels. The component service levels are derived by calculating an index or identifying a set of conditions that jointly define the level. For example, within each component, specific weights can be applied to different indicators to calculate an index. These index results can then be binned into ranges, which are used to identify component service levels. In theory, an overall service level can also be determined, as in the Service Level Framework. The benefit of the Hybrid Ladder framework is that it provides both indicator-level results as well as results aggregated at the component or overall service level, depending on the context of an application.

## 4. METHODS: APPROACH TO FRAMEWORK DEVELOPMENT

We implemented Jensen *et al.*’s (2014) methodology to develop a context-specific HRTW framework and a set of indicators for California. Jensen *et al.*’s proposed workflow includes a review of authoritative sources on the

HRTW (e.g., international treaties and resolutions), as well as key national/subnational legislation on the HRTW (e.g., AB 685), and secondary sources (e.g., guidelines and reports from international agencies and/or academia). Following, indicators and relevant benchmarks to evaluate outcomes are identified before data is gathered and analyzed to create indicators.

We followed these steps, with five modifications. First, we included framework selection as an explicit step (Step 1). Second, we selected benchmarks for all indicators but did not explicitly set targets for component or overall service levels (Step 5 below). Third, we applied three criteria – on data quality, coverage and availability – to select indicators. Fourth, we explicitly engaged the public and stakeholders (e.g., water utilities, water advocacy NGOs, impacted community members and academics) on two drafts of CalHRTW through public webinars, workshops and one panel of academic experts after the release of CalHRTW's draft 2019 report. Fifth, we include the development of an interactive geographic information system web tool. The resulting framework and indicators (Figure 2) are based on these context-specific considerations and public engagement.

#### 4.1. Step 1: framework selection

We developed the Hybrid Ladder framework (Figure 1(c)) for CalHRTW in order to quantify and summarize results for individual indicators and three components. The first version, CalHRTW 1.0, includes nine outcome indicators and a component-level index for each component. The component-level index results are binned into five ranges which can be used to describe a component service level. In this manner, CalHRTW draws on the water service ladder approach exemplified by the JMP, even though water service levels across all three components are not used for CalHRTW.

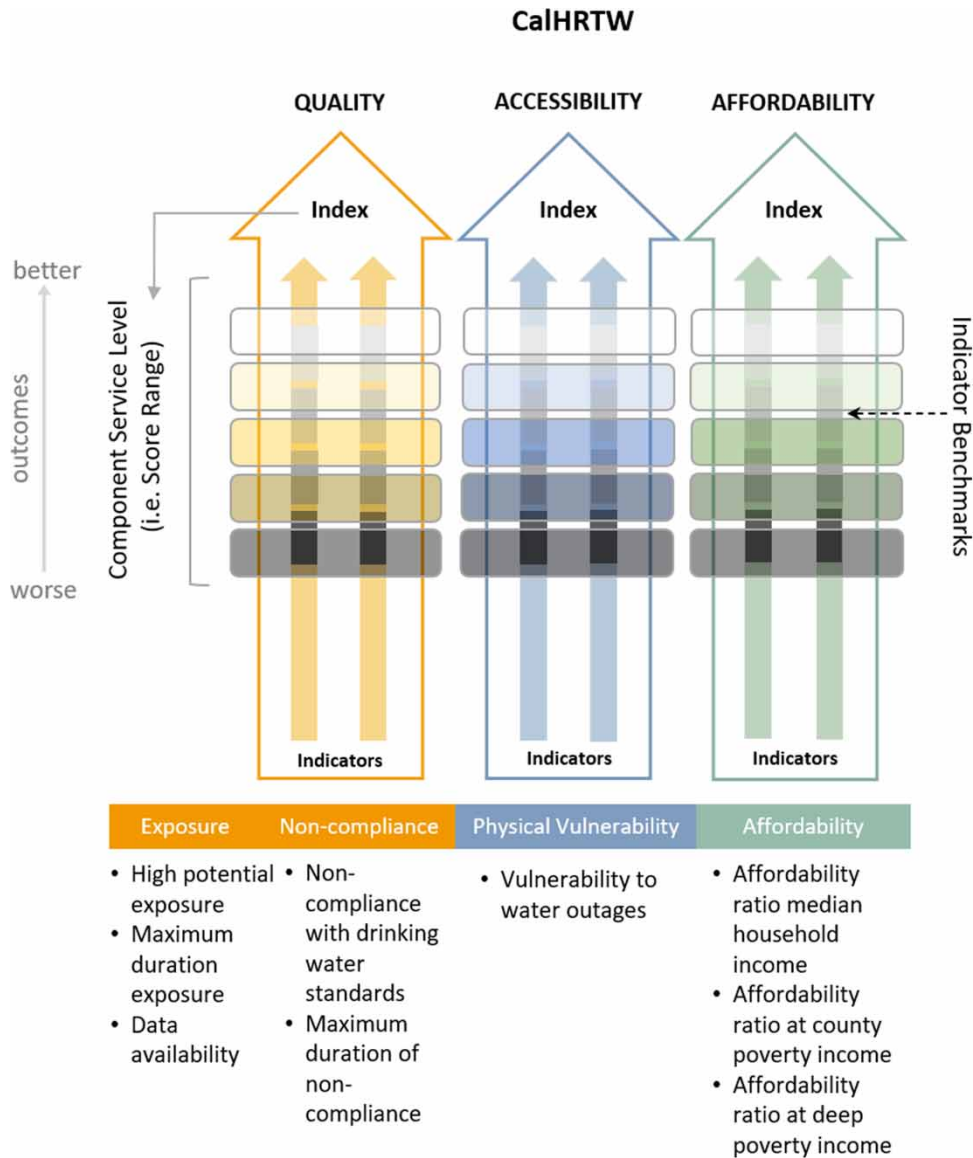
#### 4.2. Step 2: review of authoritative sources and key HRTW legislation

We focused on two sources to outline CalHRTW's basic architecture: GC15 – an international standard – and California AB 685 – the key HRTW legislation in California (Assembly Bill No. 685, 2012). The core components of AB 685 overlap with those in GC15, with some modifications (see Supplementary Material, Table S1). In particular, while internationally authoritative sources on the HRTW identify the three core components as: *quality*, *accessibility* and *quantity/availability*, AB 685 diverges slightly to highlight: *quality*, *accessibility (physical)* and *affordability*. The OEHHA interpreted AB 685's language on accessibility as referring to physical accessibility and subsumes the concept of water 'availability' (i.e., continuous and sufficient) within this component. Similarly, while affordability is formally a part of (economic) accessibility in GC15, OEHHA selected to keep it as its own component. These decisions reflect an intention to follow AB 685 as the guiding architecture for CalHRTW. We consider GC15's principles of equity, nondiscrimination and information accessibility to be 'cross-cutting' in that they are relevant to all three components in AB 685.

#### 4.3. Step 3: review of secondary sources

We reviewed and summarized relevant US/California legislative efforts and key academic and gray literature for each of the three components outlined in AB 685. The goal of this review was to identify relevant existing indicators and to identify new indicators to create that may not traditionally be measured in HRTW efforts, but which represent key issues relevant to California. In this manner, CalHRTW balances international aspirations and existing approaches, with a California-relevant context that accounts for its unique data and regulatory environment. The sections below summarize key aspects of our review, with a focus on California-relevant sources. Supplementary Material, Table S1 summarizes key indicators and benchmarks, organized by components identified in GC15 and AB 685.





**Fig. 2** | CalHRTW 1.0 conceptual framework. Each large colored arrow represents one component of water service – quality, accessibility and affordability. Individual indicators, represented as color-filled arrows, are located within each component. Indicator scores are combined to create a component-level score (i.e., index). Component-level scores, grouped into ranges, define the component service level. Component service levels are represented by five horizontal ladder rungs moving from worse (dark shaded) to better (light shaded) outcomes. Below the conceptual figure, a summary of CalHRTW 1.0 indicators is listed. For details on the definition of and approach for each indicator, see Supplementary Material, Table S2. Please refer to the online version of this paper to see this figure in colour: <http://dx.doi.org/10.2166/wp.2021.069>.

#### 4.3.1. Water quality (safe and clean)

Internationally and in the US, water quality is evaluated relative to health risk and aesthetic standards (i.e., taste, color and odor) (US EPA, 1974; WHO, 1997; UN CESCR, 2002; WHO & UNICEF, 2012). In California, the State Water Board implements the SDWA and enforces compliance with primary and secondary contaminants

through the use of MCLs.<sup>1</sup> In addition to regulatory compliance, contaminant exposure levels and the duration of exposure are core elements of safe drinking water from a public health perspective (Sexton & Hattis, 2007). For this, water quality monitoring data are used by state agencies and researchers to estimate average water quality served and potential exposure levels (e.g., Balazs, 2011) and as an indicator of potential exposure levels (e.g., OEHHA, 2021b). The roughly 5% of Californians using domestic wells do not have regulated water nor information about their water quality unless they voluntarily test their water quality.

Adequate monitoring and reporting of water quality and public accessibility to data is an essential part of information accessibility (de Albuquerque, 2014). In the US, this is acknowledged formally through the regulation of monitoring and reporting standards. However, audits of state and federal data indicate underreporting of violations of these standards (US GAO, 2011) and broader concerns about accuracy, reliability and consistency in data management (Josset *et al.*, 2019; Beecher *et al.*, 2020). Underreporting of regulatory violations underestimates water quality threats in the US (Fedinick *et al.*, 2017; Allaire *et al.*, 2018; Pauli, 2020).

### 4.3.2. Water accessibility (available and physically accessible)

**4.3.2.1. Availability.** Under GC15, water supply must be ‘sufficient and continuous for personal and domestic uses’ (UN CESC, 2002). In California, minimum quantities of water are established through norm-setting, which varies by policy context. Current policies aim for 50–55 gallons per person for indoor use (California Water Code, 2009; State Water Resources Control Board, 2014). The type and diversity of water infrastructure can shape availability and accessibility (Kayser *et al.*, 2013; Department of Water Resources, 2021).

**4.3.2.2. Physical accessibility.** Accessibility requires water resources and facilities to ‘be within safe physical reach for all sections of the population’ (UN CESC, 2002). Physical infrastructure used for water protection, treatment and transport can define water access (Stevenson, 2019). In California, where approximately 95% of residents obtain drinking water from public water systems via piped infrastructure (Bangia *et al.*, 2020), physical accessibility is determined less by distance to water source than by physical and socioeconomic aspects associated with water infrastructure and institutions (Meehan *et al.*, 2020a, 2020b). Physical accessibility – and community capacity to cope with related stressors – is largely influenced by water supply characteristics (e.g., infrastructure age) (National Research Council, 2007; Kayser *et al.*, 2013) and the water service type (e.g., water system or domestic well) (Moore *et al.*, 2011). In addition, in cases of drought, supply shortage, poor water quality, or perceived water quality threats, some residents are forced to haul water, or purchase water from vending machines. The number and type of water sources (e.g., groundwater vs. surface water) is a key factor shaping the vulnerability of water systems to current or future outages (Department of Water Resources, 2021).

### 4.3.3. Affordability

Under GC15, affordability is part of economic accessibility (UN CESC, 2002) and requires that ‘direct and indirect costs and charges associated with securing water must be affordable’ to all. GC15 also emphasizes the ‘right to be free from interference [of access], such as ... arbitrary disconnections’ (UN CESC, 2002). Most often, affordability is assessed as the fraction of household income (or an area’s median or lowest quintile income level) required to pay for water services (e.g., drinking, hygiene and/or sanitation) (UN CESC, 2002; Hutton, 2012). If the resultant ratio exceeds a designated threshold, households are considered to face unaffordable water costs.

<sup>1</sup> The US Safe Drinking Water Act requires that states meet or exceed the US EPA standard, justifying California’s more stringent enforcement of the non-legally binding federal standards. See: California Regulations Related to Drinking Water (Revisions). Titles 17 and 22 California Code of Regulations. July 1, 2013. The California Water Code requires regular monitoring and evaluation of secondary contaminants at the state level.

In California, affordability measures have largely followed US EPA's use of affordability criteria to support regulatory-induced water system upgrades (State Water Resources Control Board, 2020b; US EPA, 1998). Recent efforts focus on the impact of water costs on household incomes, alongside measures of community financial capability or poverty (Mack & Wrase, 2017; NAPA, 2017; Teodoro, 2018, 2019; Raucher *et al.*, 2019). Many advocate for the use of a basic needs amount of water to evaluate affordability ratios (Feinstein, 2018; Goddard *et al.*, 2021), though 'basic' varies by context and location (Vanhille *et al.*, 2018).

#### 4.3.4. Cross-cutting factors: equity and information accessibility

While not explicitly named in AB 685, cross-cutting principles of equity and nondiscrimination and information accessibility are critical themes in GC15 and California's water policy and environmental justice goals. In the US, economically and socially vulnerable groups include tribes (US Water Alliance, 2017), communities of color (Huang & London, 2012), low-income communities (Schneider *et al.*, 2019) and economically disadvantaged communities (DACs) (London *et al.*, 2018). Nondiscrimination of vulnerable or marginalized groups is part of environmental justice as defined by the US EPA as well as a necessary dimension of achieving the HRTW in California given findings from the water equity literature (e.g., Balazs *et al.*, 2011, 2012; Stillo & MacDonald, 2017; McDonald & Jones, 2018).

Information access includes the right to 'seek, receive and impart information concerning water issues' (UN CESCR, 2002). Beyond the SDWA's monitoring and reporting requirements, California's Assembly Bill 1755 supports transparency in water data and open source data platforms (Assembly Bill 1755, 2016). Information access is also essential to create indicators, thus becoming a cross-cutting theme of relevance to framework development.

#### 4.4. Step 4: indicator selection

We distilled a final list of indicators based on an iterative process of review from the literature (Supplementary Material, Table S1), interagency review and public comment (for a list of workshops, participants and public comments, see: <https://oehha.ca.gov/water/report/human-right-water-california>). In the process, we applied three selection criteria for indicators based on data requirements. These criteria were that data be of high quality and reliability, have statewide coverage for 80% of water systems and be publicly available. High quality was determined qualitatively in consultation with California water researchers and regulators familiar with each dataset over the course of several years. We defined reliable as data that is set to be continually collected and updated on some set time schedule, ensuring that future versions of CalHRTW can draw on the same sets of data. A fourth area of consideration was the importance of measuring an indicator in the absence of adequate coverage for statewide data. Indicators that did not meet these selection criteria were listed for future consideration (see Table 18 in OEHHA (2021a)).

#### 4.5. Step 5: benchmarks (and scoring)

CalHRTW evaluates individual indicators against benchmarks, and these results are given an indicator-level score. Our scoring process applied one of five scores to each indicator based on a combination of empirical analysis of raw data, public and expert input (e.g., from water utilities, NGOs, health experts and water engineers), and common benchmarks used by California agencies and/or relevant legislative or regulatory definitions. Scores for each indicator range from zero to four, with zero indicating a better outcome and four indicating a worse outcome (Figure 2). Indicator scores were then combined to create component-level indices (i.e., scores) (see Figure 2 for conceptual approach and Supplementary Material, Table S2 for specific formulas used).

We then used component-level indices (i.e., scores) to categorize scores into five ranges (i.e., component service levels) with lower values indicating better outcomes and higher values indicating worse outcomes. For example, for water quality, the ranges were 0, >0-1, >1-2, >2-3 and >3-4. CalHRTW 1.0 did not assign qualitative definitions to these levels (e.g., from very unsatisfactory to very good), as the state agencies involved determined that

doing so would ideally involve a deliberative process informed by stakeholders and experience applying the tool. For illustrative purposes, however, qualitative descriptions can be used to discuss these score ranges. For example, we consider low scores (e.g., a score of 0) to signify better outcomes, indicating water systems with few, if any, challenges. Alternatively, high scores (e.g., scores of 3 or more) signify worse outcomes, indicating systems that face more significant challenges. We did not calculate an overall score across all three components; in a pilot examination of a cross-component index, we found that this approach was inadequate to represent nuanced differences across components as supported in the literature (e.g., [Kayser et al., 2013](#)).

#### 4.6. Step 6: gather data, analyze and calculate indicator and component scores

For each indicator, we obtained publicly available datasets, assessed the raw data, determined how to measure the indicator, quantified the indicator in Stata 15.0 ([StataCorp, 2017](#)) or R Version 3.5.1 ([R Core Team, 2018](#)) and then scored the indicator based on the data distribution and/or empirical findings. For example, for exposure-related indicators, we used contaminant concentrations measured in water systems to calculate average annual concentrations for 19 relevant contaminants. This information was then combined to describe overall water quality relevant for each exposure indicator (e.g., number of contaminants with high potential exposure or maximum duration of high potential exposure). After each individual indicator was calculated and scored, we combined all indicators within one component into a final component-level score (i.e., index), in some cases weighting particular indicators. Indicator weights were determined through a combination of modeling different weighting options. Supplementary Material, Table S2 summarizes each indicator, how it is scored, its data source and the overall component-level score calculation. Further details are included in the OEHHA report ([OEHHA, 2021a](#)).

CalHRTW 1.0 calculated indicators for California's 2,839 active community water systems, defined as areas public water systems that serve at least 15 year-round service connections, or regularly serve at least 25 year-long residents ([Health and Safety Code Section 116275](#)). These water systems serve approximately 95% of the state's population (~35 million during the time period). Among these 2,839, 62% are very small, serving 1–200 service connections, 14% are small (201–999 service connections), 9.4% are medium (1,000–3,300 service connections) and 14.6% are large/very large (>3,300 service connections). Data covers 2011–2019 for water quality, 2019 for accessibility and 2015 for water affordability. All 2,839 water systems had data (and indicator values) for water quality and accessibility indicators. For affordability indicators, only 40% of systems had data to calculate indicators (for more information on this topic, see [Affordability Data Gaps](#) in [OEHHA \(2021a\)](#)).

#### 4.7. Framework summary

Following these steps, we finalized the CalHRTW 1.0 framework to include three main components and nine indicators. Indicators within each component are used to create three, component-level indices (e.g., scores). Whereas [Figure 2](#) summarizes the overall CalHRTW framework, Supplementary Material, Table S2 provides detailed explanation of each indicator and the calculation of component-level scores. As shown in [Figure 2](#), CalHRTW 1.0's water quality component includes six indicators, one of which (i.e., compliance with drinking water standards, or MCLs) incorporates common notions of water safety as used in WHO guidelines (and the JMP) and directly incorporates information regarding MCL violations as outlined in the SDWA. The other five use data collected from California's regulatory process to create a more nuanced understanding of health risks in California and respond to concerns expressed by water advocates throughout the state (e.g., that duration matters as does the extent of exposure and information availability). Thus, the additional indicators include the duration of noncompliance, the extent and duration of potential high exposure levels and the availability of water quality data as a first-order assessment of information availability. While the availability of data is relevant to all three components, as an order of priority, we included availability of water quality data as it is especially

important to address given that lack of such data can present direct threats to public health. Nineteen key contaminants are assessed as part of these indicators.

For accessibility, our review underscored the relevance of stressors both internal and external to a water system. Due to data availability, the current framework focuses on one multi-dimensional system-level indicator that uses the number and type of sources available to a water system to represent internal, system-level factors that impede access to water.

The framework uses one basic type of affordability metric – the affordability ratio – measured at three income levels (i.e., median household income (MHI), county poverty levels and deep poverty levels) to address household burdens. Affordability ratios are supplemented with the portion of households earning these incomes within each water system and compared to a range of affordability thresholds identified through our literature review (see Supplementary Material, Table S2 for details). While affordability data was limited and did not meet our initial coverage criteria, due to its centrality in AB 685, the OEHHA included these indicators.

## 5. RESULTS

CalHRTW 1.0 measures baseline conditions (as of 2019) for the state's 2,839 active community water systems. CalHRTW 1.0 can be used in three main ways: (1) to summarize water system-level conditions statewide and screen for system-level challenges, (2) to explore social equity implications and (3) as an information and planning hub for community members, researchers and state entities. Below we present select results to highlight these uses.

### 5.1. Screening for system-level challenges

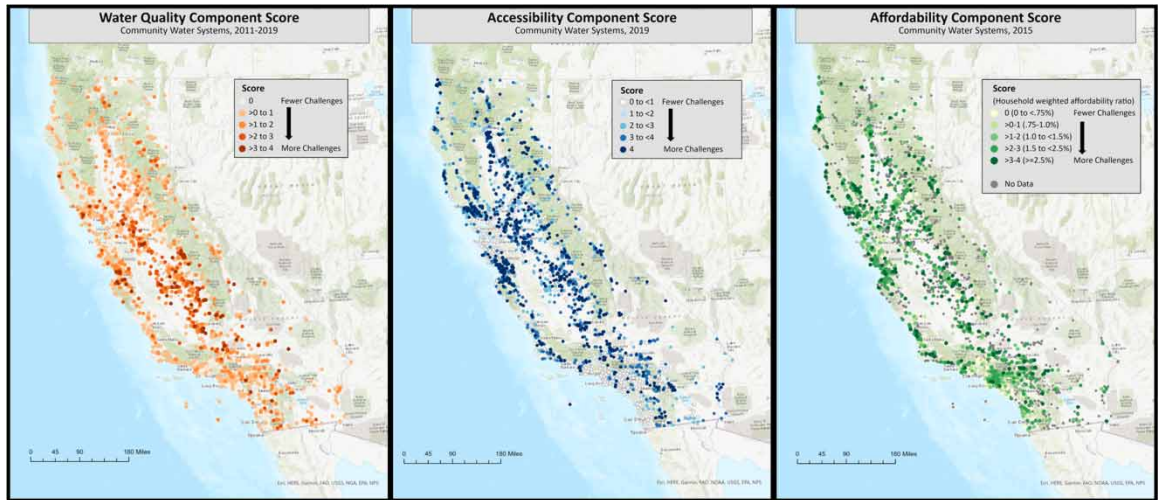
At its core, CalHRTW 1.0 characterizes baseline conditions for each component and helps screen (i.e., develop a first-pass, high-level evaluation) for drinking water challenges and successes. Using the component-level score for water quality as an example, we find that among California's 2,839 active water systems, the median component-level score for water quality was 0.08 (IQR 0–1). Overall, this indicates very good water quality across the state's community water systems. Nonetheless, 68 systems (3%) received a score greater than 3, highlighting systems with some of the worst outcomes, or more significant challenges. These results can be viewed geographically, with statewide maps highlighting component-level scores (Figure 3). Figure 3 also serves as a snapshot of the visualization element offered in the CalHRTW 1.0's web-based data tool that allows users to visualize results (see [Human Right to Water Data Tool \(CalHRTW 1.0\)](#)).

CalHRTW 1.0 also allows for a disaggregated view of indicator-level results that can be used in various ways. Indicator scores can highlight more detailed information on the challenges water systems face. For example, the maximum duration of noncompliance indicator shows that 209 systems received a score of 3 or higher due to having 4 or more years of noncompliance with primary drinking water standards during the 9-year study period. This indicates recurring contamination problems and the potential of longer exposure. Indicator scores can also be used to screen for challenges within a water system or to compare results across systems. For example, users may wish to highlight all systems where indicator results are 3 or higher to capture the more acute challenges.

### 5.2. Social equity

To address equity and nondiscrimination aspirations, CalHRTW 1.0 results can be used to explore relationships between HRTW outcomes and social equity. For example, component and indicator scores can be assessed in terms of key social and institutional vulnerability metrics, including the socioeconomic and racial/ethnic composition of communities, or the institutional and managerial capacity of water systems. Figure 4 presents a descriptive analysis of the relationship between component-level water quality and affordability scores and





**Fig. 3** | Maps of component-level scores (i.e., indices) in California, grouped by specific ranges for each component. Individual community water systems are shown as a colored dot. Higher scores (darker colored dots) indicate systems with greater challenges/worse outcomes, and lower scores (lighter colored dots) indicate systems with fewer challenges/better outcomes. These results can also be viewed interactively at [Human Right to Water Data Tool \(CalHRTW 1.0\)](#).



**Fig. 4** | Bar charts indicating larger proportions of water systems serving disadvantaged and smaller systems have higher scores (i.e., worse outcomes/greater challenges) for water quality and affordability. Disadvantaged status defined using state definitions for DACs and SDACs, as those whose Median Household Income (MHI) is below 80 or 60% of statewide MHI. System size is measured by the number of service connections, with the following cutoffs: very small (1–200), small (201–999), medium (1,000–3,000) and large/very large (>3,300). Percent of systems on x-axis, number of systems indicated within each bar.  $N = 2,839$  for water quality (i.e., 100% coverage) and  $n = 1,141$  for affordability.

institutional constraints, represented here by the socioeconomic conditions and size of a water system's customer base. Socioeconomic status is represented using state definitions for DACs and severely disadvantaged communities (SDACs), as those whose MHI is below 80 or 60% of statewide MHI, respectively (Proposition 84, Section 75021). System size is measured by the number of service connections, with the following cutoffs: very small (1–200), small (201–999), medium (1,000–3,000) and large/very large (>3,300).

Figure 4 indicates a larger percentage of DACs and SDACs have worse water quality and affordability scores (i.e., scores are higher and thus indicate greater challenges) compared to non-DACs. Figure 4 indicates the reverse is also true: among systems with better outcomes (i.e., low scores indicate better outcomes, or fewer challenges), there is a smaller percentage of DAC and SDACs compared to non-DACs. Similar results occur when looking at the relationship between water quality or affordability and system size. For example, Figure 4 indicates that among the 196 systems with the highest affordability scores (i.e., scores greater than 3, indicating greater affordability challenges), nearly 52% are very small and 26% are small, compared with 23 and 13% among the 121 systems with the lowest scores (i.e., better outcomes).

### 5.3. Mapping and information

A final use of CalHRTW 1.0 relates to its interactive web-based data tool (see [Human Right to Water Data Tool \(CalHRTW 1.0\)](#)). The tool allows users to visualize, download and explore the system and state-level results. Additionally, the tool serves as a platform to foster greater public participation and enhance information accessibility for California's HRTW moving forward. One snapshot of the tool's results is shown in Figure 3, highlighting the three component-level results for the entire state.

## 6. DISCUSSION

We present the theoretical foundations and practical uses of CalHRTW – the first US state effort to conceptualize the HRTW and measure the extent to which it is being met. CalHRTW 1.0's evaluation of indicators and components can characterize conditions and serve as a baseline from which to measure progress in the realization of the HRTW. CalHRTW 1.0 can screen for drinking water challenges at both component and indicator levels. For example, component-level scores show that while the vast majority of the state's community water systems have very good water quality outcomes (i.e., have low scores/better outcomes), a small, but significant number face significant challenges (i.e., have higher scores/worse outcomes). Indicator-level results highlight specific challenges, such as systems with recurring high potential exposure and noncompliance. Our preliminary exploration of social equity indicates that systems serving socioeconomically disadvantaged communities and those facing institutional constraints have some of the greatest water quality and affordability challenges (i.e., worse outcomes). These trends are corroborated by California studies in smaller geographic areas (e.g., Balazs *et al.*, 2011, 2012) and across the state (e.g., Bangia *et al.*, 2020), though follow-up statistical analyses are in order.

Building on past frameworks and papers outlining methodological options for measuring the HRTW (i.e., Kayser *et al.*, 2013; Jensen *et al.*, 2014), several key reflections emerge. First, the deliberative process of incorporating public and interagency engagement critically shaped both the framework and the tool, and reflects an explicit addition to the methodology presented by previous studies and aligns with HRTW calls for public participation. Second, the process of indicator selection included balancing the aspiration of incorporating all relevant indicators, with the reality of obtaining adequate data and addressing public input. The indicators conform to California's specific drinking water context and thus include metrics that augment those of many international HRTW frameworks. For example, while many HRTW frameworks (e.g., JMP) look at contaminant concentration levels in relation to drinking water guidelines or regulatory standards (i.e., 'compliance indicators'), CalHRTW includes compliance indicators as well as indicators that measure potential exposure to high levels of

contaminants and duration of this potential high exposure. Such indicators also reflect advances in public health about the relevance of exposure and cumulative impacts on health outcomes (Sexton & Hattis, 2007).

Third, data constraints on indicator development reflect both a limitation to comprehensive monitoring efforts and an actionable finding of CalHRTW 1.0. Nearly 60% of water systems (serving 5% of California's population) lacked adequate data to evaluate affordability. Without adequate data, systems lose representation in a monitoring process aimed to track and support progress toward the human right to water for all. California can leverage CalHRTW's missing data assessments to target areas for more robust data collection efforts, including survey development and targeted sampling (e.g., [State Water Resources Control Board 2021a](#)).

Fourth, CalHRTW is positioned to both monitor progress over time, across a common set of indicators, and be augmented with additional elements. Future versions may incorporate additional regulated and emergent contaminants, beyond the 19 contaminants included in CalHRTW 1.0. Existing indicators can improve, as underlying data sources improve (e.g., using more specific income levels for affordability ratios). Additional units of analysis such as tribal water systems and households reliant solely on domestic wells, as well as indicators that capture sanitation access will also be necessary to include for a full assessment of the HRTW. Future indicators, including water shutoffs, additional accessibility indicators that measure quantity available, and metrics to evaluate missing data need to be considered. Of course, the inclusion of additional indicators should be balanced with the principle of parsimony. Future efforts will aim to disaggregate results to the population or household level, which is ultimately the level at which the HRTW is to be met. Finally, continued exploration of how best to compare outcomes across components will benefit from ongoing public discussion, especially with regard to what service levels the state should target to realize the human right to water.

## 7. CONCLUSION

The main purpose of CalHRTW 1.0 is to provide a comprehensive, stand-alone, quantitative assessment of the human right to water in California that can assess conditions and changes over time. With periodic measurements of its indicators (e.g., every 3 years), CalHRTW can help the change in the overall status of the HRTW in the state, with results from CalHRTW 1.0 establishing the initial baseline. In doing this, CalHRTW will allow California to monitor progress in achieving the HRTW and assess what percent of systems (or of population served) face drinking water challenges, and which systems have (or have not) improved their scores over time. More specifically, CalHRTW can capture acute contamination events of regulated contaminants in specific systems or demonstrate the increase in unaffordability of water over time. As monitoring occurs over time, CalHRTW may also indirectly capture the impact of rapidly changing environmental conditions (e.g., climate change or drought) on drinking water conditions, though this is not the current focus. While the main focus is on statewide monitoring, individual water systems and the residents of these systems can use these system level results and compare their outcomes to nearby systems.

CalHRTW's framework and results offer a platform for informing California drinking water planning efforts, as well as supporting other HRTW monitoring efforts that may develop in the US. For example, CalHRTW 1.0 has a foundational role in developing a statewide response for the HRTW by providing accessible information and influencing related policy efforts. Following the 2019 passage of Senate Bill 200 which aimed to support the acquisition of safe and affordable water for drinking water systems across the state (especially economically DACs), the State Water Board began to develop a needs assessment to identify how to fund at-risk systems. This needs assessment approach drew directly on CalHRTW's conceptual framework to include indicators on quality, accessibility and affordability, and adopted a similar methodological approach.

CalHRTW draws on existing HRTW monitoring efforts but is unique in several key ways. First, CalHRTW is state-led with commitments to improve monitoring over time. Second, and relatedly, CalHRTW was developed

in response to state-level legislation that reflected the state's commitment to the HRTW. As such, CalHRTW is both an important indicator of the state's efforts to monitor and work toward the progressive realization of the HRTW, as well as a framework that builds on policy momentum focused on rectifying historical water challenges in the state. Third, CalHRTW was built with the flexibility to measure all key components of the HRTW, including drinking water quality and accessibility indicators (including affordability). Finally, CalHRTW and its theoretical foundations were guided not only by the international, top-down monitoring aspirations of GC15, or the state-level goals of AB 685, but also by grassroots water justice efforts that center water quality, access and affordability as a state priority. Thus, while it draws on international approaches, it is specifically meant to reflect a California context.

In presenting the theoretical foundations and practical uses of CalHRTW, the goal of this paper was to showcase how California is monitoring the HRTW and to provide a model for how other US states may wish to adopt a similar approach. While monitoring efforts and data availability may vary in other subnational settings, subnational administrative areas in other countries may be interested in developing similar efforts. Assuming adequate data availability for each indicator, this approach could also be applied at a federal level, using a similar technique. The approach to developing CalHRTW is particularly well suited to regions where the regulatory environment provides an ongoing source of high quality, publicly available data, and where HRTW legislation exists, or HRTW tracking efforts are desired. Ultimately, state-level leadership on monitoring the HRTW came out of a unique confluence of California's historical grassroots water justice activism, heightened policy and legislative focus on the HRTW, technological capacity to collect and maintain a diverse set of drinking water datasets and the state's desire to monitor progress. Continued implementation of CalHRTW will support, through monitoring, the progressive realization of this important right and should facilitate the development of related tools elsewhere.

## ACKNOWLEDGEMENTS

We thank Komal Bangia for the production of Figure 3. We thank Yana Garcia, Arsenio Mataka, Laurel Firestone and the late George Alexeef for supporting the development of this work. We thank Komal Bangia, Allan Hirsch, Laura August, Walker Wieland, Andrew Slocombe, Hongtai Huang, Ella Belfer and Anushka Thakkar for their collaboration on analytical elements that informed this work. We thank Emilie Fons and Molly Starke for earlier literature reviews that supported this work. We thank Professor Isha Ray for the review of an earlier draft of this manuscript and the four anonymous reviewers who reviewed this manuscript.

## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information. Readers can also view OEHHA 2021a for a full description of CalHRTW 1.0 and its results.

## REFERENCES

- Allaire, M., Wu, H. & Lall, U. (2018). National trends in drinking water quality violations. *Proceedings of the National Academy of Sciences* 115(9), 2078–2083. <https://doi.org/10.1073/pnas.1719805115>.
- Allaire, M., Mackay, T., Zheng, S. & Lall, U. (2019). Detecting community response to water quality violations using bottled water sales. *Proceedings of the National Academy of Sciences* 116(42), 20917–20922. <https://doi.org/10.1073/pnas.1905385116>.
- Assembly Bill No. 685 (2012). Eng. Chapter 524. State Water Policy. Available at: [http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill\\_id=201120120AB685](http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120AB685).



- Assembly Bill 1755 (2016). The Open and Transparent Water Data Act. Available at: [https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill\\_id=201520160AB1755](https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB1755).
- Balazs, C. (2011). *Just Water? Social Disparities and Drinking Water Quality in California's San Joaquin Valley*. University of California, Berkeley.
- Balazs, C. & Ray, I. (2014). The drinking water disparities framework: on the origins and persistence of inequities in exposure. *American Journal of Public Health* 104(4), 603–611. <https://doi.org/10.2105/AJPH.2013.301664>.
- Balazs, C., Morello-Frosch, R., Hubbard, A. & Ray, I. (2011). Social disparities in nitrate-contaminated drinking water in California's San Joaquin Valley. *Environmental Health Perspectives* 119(9), 1272–1278. <https://doi.org/10.1289/ehp.1002878>.
- Balazs, C., Morello-Frosch, R., Hubbard, A. & Ray, I. (2012). Environmental justice implications of arsenic contamination in California's San Joaquin Valley: a cross-sectional, cluster-design examining exposure and compliance in community drinking water systems. *Environmental Health* 11, 84. <https://doi.org/10.1186/1476-069X-11-84>.
- Bangia, K., August, L., Slocombe, A. & Faust, J. (2020). Assessment of contaminants in California drinking water by region and system size. *AWWA Water Science* 2(5), e1194. <https://doi.org/10.1002/aws2.1194>.
- Barlow, P. M. & Reichard, E. G. (2010). Saltwater intrusion in coastal regions of North America. *Hydrogeology Journal* 18, 247–260. <https://doi.org/10.1007/s10040-009-0514-3>.
- Beecher, J., Redican, K. & Koliouopoulos, M. (2020). (Mis)Classification of water systems in the United States. *SSRN Electronic Journal*, 1–38. <https://doi.org/10.2139/ssrn.3627915>.
- Bradley, P. M., Kolpin, D. W., Romanok, K. M., Smalling, K. L., Focazio, M. J., Brown, J. B., Cardon, M. C., Carpenter, K. D., Corsi, S. R. & DeCicco, L. A. (2018). Reconnaissance of mixed organic and inorganic chemicals in private and public supply tapwaters at selected residential and workplace sites in the United States. *Environmental Science & Technology* 52(23), 13972–13985.
- Burr, P. & Fonseca, C. (2013). Applying a life-cycle costs approach to water. WASHCost Working Paper 94.
- California Water Code (2009). *Division 6: Conservation, Development, and Utilization of State Water Resources (Chapter 3 added by Stats. 2009, 7th Ex. Sess., Ch. 4, Sec. 1) Chapter 3. Urban Retail Water Suppliers. Sections 10608.20*. Available at: [http://leginfo.legislature.ca.gov/faces/codes\\_displaySection.xhtml?lawCode=WAT&sectionNum=10608.20](http://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=WAT&sectionNum=10608.20).
- Corlin, L., Rock, T., Cordova, J., Woodin, M., Durant, J. L., Gute, D. M., Ingram, J. & Brugge, D. (2016). Health effects and environmental justice concerns of exposure to uranium in drinking water. *Current Environmental Health Reports* 3, 434–442. <https://doi.org/10.1007/s40572-016-0114-z>.
- Cude, C. G. (2001). Oregon water quality index a tool for evaluating water quality management effectiveness. *JAWRA Journal of the American Water Resources Association* 37(1), 125–137.
- de Albuquerque, C. (2011). *Report of the Special Rapporteur on the Human Right to Safe Drinking Water and Sanitation*. Mission to the United States of America.
- de Albuquerque, C. (2014). *Realising the Human Rights to Water and Sanitation: A Handbook by the UN Special Rapporteur: Monitoring*.
- Deitz, S. & Meehan, K. (2019). Plumbing poverty: mapping hot spots of racial and geographic inequality in U.S. household water insecurity. *Annals of the American Association of Geographers*. 1–18. <https://doi.org/10.1080/24694452.2018.1530587>.
- Department of Water Resources (2021). *Small Water Systems and Rural Communities Drought and Water Shortage Contingency Planning and Risk Assessment: Part II – Drought and Water Shortage Vulnerability Assessment and Risk Scoring Report Pursuant to Section 10609.42 of the California Water Code*. Available at: <https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Water-Use-And-Efficiency/County-Drought-Advisory-Group/Files/Draft-CDAG-Report-March-2020.pdf>.
- Domingo, J. L. & Nadal, M. (2019). Human exposure to per- and polyfluoroalkyl substances (PFAS) through drinking water: a review of the recent scientific literature. *Environmental Research* 177, 108648. <https://doi.org/10.1016/j.envres.2019.108648>.
- Eggers, M. J., Doyle, J. T., Lefthand, M. J., Young, S. L., Moore-Nall, A. L., Kindness, L., Other Medicine, R., Ford, T. E., Dietrich, E., Parker, A. E., Hoover, J. H. & Camper, A. K. (2018). Community engaged cumulative risk assessment of exposure to inorganic well water contaminants, crow reservation, Montana. *International Journal of Environmental Research and Public Health* 15(1). <https://doi.org/10.3390/ijerph15010076>.
- Ekstrom, J. A., Klasic, M. R., Fencil, A., Lubell, M., Baker, E. & Einterz, F. (2018). *Drought Management and Climate Adaptation of Small, Self-Sufficient Drinking Water Systems in California*.
- Fedinick, K. P., Wu, M. & Mekela Panditharatne, J. D. (2017). *Threats on Tap: Widespread Violations Highlight*.



- Feinstein, L. (2018). *Measuring Progress Toward Universal Access to Water and Sanitation in California. Defining Goals, Indicators, and Performance Measures*. Pacific Institute. Available at: [http://pacinst.org/wp-content/uploads/2018/08/Measuring-Progress\\_Pacific-Institute\\_Sep-2018.pdf](http://pacinst.org/wp-content/uploads/2018/08/Measuring-Progress_Pacific-Institute_Sep-2018.pdf).
- Feinstein, L., Phurisamban, R., Ford, A., Tyler, C. & Crawford, A. (2017). *Drought and Equity in California*. Available at: [https://pacinst.org/wp-content/uploads/2017/01/PI\\_DroughtAndEquityInCA\\_Jan\\_2017.pdf](https://pacinst.org/wp-content/uploads/2017/01/PI_DroughtAndEquityInCA_Jan_2017.pdf).
- Flores, Ó., Jiménez, A. & Pérez-Foguet, A. (2013). Monitoring access to water in rural areas based on the human right to water framework: a local level case study in Nicaragua. *International Journal of Water Resources Development* 29(4), 605–621. <https://doi.org/10.1080/07900627.2012.757017>.
- Gaber, N., Silva, A., Lewis-Patrick, M., Kutil, E., Taylor, D. & Bouier, R. (2020). Water insecurity and psychosocial distress: case study of the Detroit water shutoffs. *Journal of Public Health*. <https://doi.org/10.1093/pubmed/fdaa157>.
- Gawel, E. & Bretschneider, W. (2016). Sustainable access to water for all: how to conceptualize and to implement the human right to water. *Journal for European Environmental & Planning Law* 13(2), 190–217.
- Goddard, J. J., Ray, I. & Balazs, C. (2021). Water affordability and human right to water implications in California. *PLOS One* 16(1), e0245237. <https://doi.org/10.1371/journal.pone.0245237>.
- Hanna-Attisha, M., LaChance, J., Sadler, R. C. & Champney Schnepf, A. (2015). Elevated blood lead levels in children associated with the flint drinking water crisis: a spatial analysis of risk and public health response. *American Journal of Public Health* 106(2), 283–290. <https://doi.org/10.2105/AJPH.2015.303003>.
- Health and Safety Code Section 116275 (n.d.). *Division 104. California Safe Drinking Water Act. (Article 1 added by Stats. 1995, Ch. 415, Sec. 6) Article 1. Pure and Safe Drinking Water. Section 116275*. Available at: [https://leginfo.ca.gov/faces/codes\\_displaySection.xhtml?lawCode = HSC&sectionNum = 116275](https://leginfo.ca.gov/faces/codes_displaySection.xhtml?lawCode = HSC&sectionNum = 116275).
- Howard, G. & Bartram, J. (2003). *Domestic Water Quantity, Service Level and Health*. World Health Organization. Available at: [https://www.who.int/water\\_sanitation\\_health/diseases/WSH03.02.pdf](https://www.who.int/water_sanitation_health/diseases/WSH03.02.pdf).
- Huang, G. & London, J. K. (2012). Cumulative environmental vulnerability and environmental justice in California's San Joaquin Valley. *International Journal of Environmental Research and Public Health* 9(5), 1593–1608.
- Human Right to Water Data Tool (CalHRTW 1.0), available from: <https://oehha.maps.arcgis.com/apps/MapSeries/index.html?appid=a09e31351744457d9b13072af8b68fa5>.
- Hutton, G. (2012). Monitoring 'affordability' of water and sanitation services after 2015: review of global indicator options. In: *A Paper Submitted to the UN Office of the High Commissioner for Human Rights*, p. 95.
- Jensen, M. H., Villumsen, M. & Petersen, T. D. (2014). *The AAAQ Framework and the Right to Water: International Indicators for Availability, Accessibility, Acceptability and Quality*. p. 42. Available at: [https://www.humanrights.dk/sites/humanrights.dk/files/media/migrated/aaaq\\_international\\_indicators\\_2014.pdf](https://www.humanrights.dk/sites/humanrights.dk/files/media/migrated/aaaq_international_indicators_2014.pdf).
- Josset, L., Allaire, M., Hayek, C., Rising, J., Thomas, C. & Lall, U. (2019). The U.S. water data gap – a survey of state-level water data platforms to inform the development of a national water portal. *Earth's Future* 7(4), 433–449. <https://doi.org/10.1029/2018EF001063>.
- Kayser, G. L., Moriarty, P., Fonseca, C. & Bartram, J. (2013). Domestic water service delivery indicators and frameworks for monitoring, evaluation, policy and planning: a review. *International Journal of Environmental Research and Public Health* 10(10), 4812–4835. <https://doi.org/10.3390/ijerph10104812>.
- Lakhani, N. (2020). *People of Color More Likely to Live Without Piped Water in Richest US Cities*. The Guardian (Using census data from 2013–2017, as compared to white households). Available at: <https://www.theguardian.com/environment/2020/nov/02/people-of-color-piped-water-us>.
- Lloyd, B. J. & Bartram, J. K. (1991). Surveillance solutions to microbiological problems in water quality control in developing countries. *Water Science and Technology* 24(2), 61–75.
- London, J., Fencl, A., Watterson, S., Jarin, J., Aranda, A., King, A., Pannu, C., Seaton, P., Firestone, L., Dawson, M. & Nguyen, P. (2018). *The Struggle for Water Justice in California's San Joaquin Valley: A Focus on Disadvantaged Unincorporated Communities*. Available at: [https://regionalchange.ucdavis.edu/sites/g/files/dgvnsk986/files/inline-files/The Struggle for Water Justice FULL REPORT.pdf](https://regionalchange.ucdavis.edu/sites/g/files/dgvnsk986/files/inline-files/The%20Struggle%20for%20Water%20Justice%20FULL%20REPORT.pdf).
- Mack, E. A. & Wrase, S. (2017). A burgeoning crisis? A nationwide assessment of the geography of water affordability in the United States. *PLOS One* 12(1), e0169488. <https://doi.org/10.1371/journal.pone.0169488>.
- Massachusetts Const. art. XCVII (n.d.). *Massachusetts Constitution Article XCVII*. Available at: <https://malegislature.gov/laws/constitution#amendmentArticleXCVII>.
- McDonald, Y. J. & Jones, N. E. (2018). Drinking water violations and environmental justice in the United States, 2011–2015. *American Journal of Public Health* 108(10), 1401–1407. <https://doi.org/10.2105/AJPH.2018.304621>.

- McFarlane, K. & Harris, L. M. (2018). Small systems, big challenges: review of small drinking water system governance. *Environmental Reviews* 26(4), 378–395. <https://doi.org/10.1139/er-2018-0033>.
- Meehan, K., Jepson, W., Harris, L. M., Wutich, A., Beresford, M., Fencil, A., London, J., Pierce, G., Radonic, L., Wells, C., Wilson, N. J., Adams, E. A., Arsenault, R., Brewis, A., Harrington, V., Lambrinidou, Y., McGregor, D., Patrick, R., Pauli, B., Pearson, A. L., Shah, S., Splichalova, D., Workman, C. & Young, S. (2020a). Exposing the myths of household water insecurity in the global north: a critical review. *WIREs Water*, e1486. <https://doi.org/10.1002/wat2.1486>.
- Meehan, K., Jurjevich, J. R., Chun, N. M. J. W. & Sherrill, J. (2020b). Geographies of insecure water access and the housing–water nexus in US cities. *Proceedings of the National Academy of Sciences*, 202007361. <https://doi.org/10.1073/pnas.2007361117>.
- Meier, B. M., Cronk, R., Luh, J., Bartram, J. & Albuquerque, C. d. (2017). Monitoring the progressive realization of the human rights to water and sanitation frontier analysis as a basis to enhance human rights accountability. In: *The Oxford Handbook of Water Politics and Policy*. Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780199335084.013.21>.
- Moore, E., Matalon, E., Balazs, C., Clary, C., Firestone, L., de Anda, S. & Guzman, M. (2011). *Human Costs of Nitrate-Contaminated Drinking Water in the San Joaquin Valley*. Pacific Institute, Fresno State. Community Water Center. Available at: <http://pacinst.org/publication/human-costs-of-nitrate-contaminated-drinking-water-in-the-san-joaquin-valley/>.
- Moriarty, P., Batchelor, C., Fonseca, C., Klutse, A., Naafs, A., Nyarko, K., Pezon, C., Potter, A., Reddy, R. & Snehathala, M. (2011). *Ladders for Assessing and Costing Water Service Delivery*. IRC International Water and Sanitation Centre. Available at: <https://pt.ircwash.org/sites/default/files/Moriarty-2011-Ladders.pdf>.
- Mullin, M. (2020). The effects of drinking water service fragmentation on drought-related water security. *Science* 368(6488), 274–277. <https://doi.org/10.1126/science.aba7353>.
- NAPA (2017). *National Academy of Public Administration. Developing a New Framework for Community Affordability of Clean Water Services*. Report by a Panel of the NAPA for the US Environmental Protection Agency. Available at: [https://www.napawash.org/uploads/Academy\\_Studies/NAPA\\_EPA\\_FINAL\\_REPORT\\_110117.pdf](https://www.napawash.org/uploads/Academy_Studies/NAPA_EPA_FINAL_REPORT_110117.pdf).
- National Research Council (2007). *Drinking Water Distribution Systems: Assessing and Reducing Risks*. National Academies Press, Washington DC.
- OEHHA (2021a). *Achieving the Human Right to Water in California – January 2021*. Office of Environmental Health Hazard Assessment. Available at: <https://oehha.ca.gov/media/downloads/water/report/hrtwachievinghrtw2021f.pdf>.
- OEHHA (2021b). *CalEnviroScreen 4.0*. Office of Health Hazard Assessment. Available at: <https://oehha.ca.gov/calenviroscreen>.
- Olson, E. & Fedinick, K. (2016). *What's in Your Water? Flint and Beyond Analysis of EPA Data Reveals Widespread Lead Crisis Potentially Affecting Millions of Americans*. National Resources Defense Council. Available at: <https://www.nrdc.org/sites/default/files/whats-in-your-water-flint-beyond-report.pdf>.
- Pannu, C. (2012). Drinking water and exclusion: a case study from California's Central Valley. *California Law Review* 100. <https://doi.org/10.15779/Z38B133>.
- Pauli, B. J. (2020). The flint water crisis. *WIREs Water* 7(3), e1420. <https://doi.org/10.1002/wat2.1420>.
- Pennsylvania Const. art. I Sec. 27 (n.d.). *Constitution of the Commonwealth of Pennsylvania, Art. 1, Sec. 27. § 27*. The people have a right, including generations yet to come. Available at: <https://www.legis.state.pa.us/WU01/LI/LI/CT/HTM/00/00.001..HTM>.
- Proctor, C. R., Lee, J., Yu, D., Shah, A. D. & Whelton, A. J. (2020). Wildfire caused widespread drinking water distribution network contamination. *AWWA Water Science* 2(4), e1183. <https://doi.org/10.1002/aws2.1183>.
- Proposition 1 (2014). *Proposition 1: Water Quality Supply, and Infrastructure Improvement Act of 2014*. Available at: [https://leginfo.ca.gov/faces/billNavClient.xhtml?bill\\_id=201320140AB1471](https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB1471).
- Proposition 84, Section 75021. Available at: [https://www.waterboards.ca.gov/drinking\\_water/services/funding/Prop84.html](https://www.waterboards.ca.gov/drinking_water/services/funding/Prop84.html).
- Raucher, R., Clements, J., Rothstein, E., Mastracchio, J., Green, Z. & Group, G. R. (2019). *Developing a New Framework for Household Affordability and Financial Capability Assessment in the Water Sector*. The American Water Works Association.
- R Core Team (2018). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna.
- Riggs, Hughes, J., Irvin, D. & Leopard, K. (2017). *An Overview of Clean Water Access Challenges in the United States*. Global Water Challenge and the Environmental Finance Center, School of Government, University of North Carolina.
- Roaf, V., Khalfan, A. & Langford, M. (2005). *Monitoring Implementation of the Right to Water: A Framework for Developing Indicators*. Heinrich Böll Stiftung, Berlin.

- Roller, Z., Gasteyer, S., Nelson, N., Lai, W. & Shingne, M. (2019). *Closing the Water Access gap in the United States: A National Action Plan*. Dig Deep and US Water Alliance. Available at: <http://uswateralliance.org/sites>.
- Rubin, S. J. (2018). *Water costs and affordability in the United States: 1990 to 2015*. *Journal American Water Works Association* 110, 48–52. <https://doi.org/10.1002/awwa.1062>.
- Schaidt, L. A., Swetschinski, L., Campbell, C. & Rudel, R. A. (2019). *Environmental justice and drinking water quality: are there socioeconomic disparities in nitrate levels in U.S. drinking water?* *Environmental Health* 18(1), 3. <https://doi.org/10.1186/s12940-018-0442-6>.
- Senate Bill No. 200 (2019). *SB-200: Drinking Water*. Available at: [https://leginfo.ca.gov/faces/billTextClient.xhtml?bill\\_id=201920200SB200](https://leginfo.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB200).
- Sexton, K. & Hattis, D. (2007). *Assessing cumulative health risks from exposure to environmental mixtures – three fundamental questions*. *Environmental Health Perspectives* 115, 825–832. <https://doi.org/10.1289/ehp.9333>.
- Staddon, C., Appleby, T. & Grant, E. (2012). A right to water? In: F. Sultana & A. Loftus, eds. *The Right to Water: Politics, Governance and Social Struggles*, 62.
- StataCorp (2017). *Stata Statistical Software: Release 15*. StataCorp LLC, London.
- State Water Resources Control Board (2014). *Per Capita Daily Water Use Numbers*. Available at: [https://www.waterboards.ca.gov/press\\_room/press\\_releases/2014/pr110414\\_rgcpd.pdf](https://www.waterboards.ca.gov/press_room/press_releases/2014/pr110414_rgcpd.pdf).
- State Water Resources Control Board (2015). *Safe Drinking Water Plan for California*. Available at: [https://www.waterboards.ca.gov/publications\\_forms/publications/legislative/docs/2015/sdwp.pdf](https://www.waterboards.ca.gov/publications_forms/publications/legislative/docs/2015/sdwp.pdf).
- State Water Resources Control Board (2019). *2019 Annual Compliance Report*. Available at: [https://www.waterboards.ca.gov/drinking\\_water/certlic/drinkingwater/docs/acr\\_2019\\_final.pdf](https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/docs/acr_2019_final.pdf).
- State Water Resources Control Board (2020a). *Human Right to Water Portal*. Available at: [https://www.waterboards.ca.gov/water\\_issues/programs/hr2w/](https://www.waterboards.ca.gov/water_issues/programs/hr2w/).
- State Water Resources Control Board (2020b). *State of California Drinking Water State Revolving Fund Intended Use Plan 2020-2021*. Available at: [https://www.waterboards.ca.gov/water\\_issues/programs/grants\\_loans/docs/dwsrf\\_iup\\_sfy2020\\_21\\_final.pdf](https://www.waterboards.ca.gov/water_issues/programs/grants_loans/docs/dwsrf_iup_sfy2020_21_final.pdf).
- State Water Resources Control Board (2021a). *Drinking Water COVID-19 Financial Impacts Survey*. Available at: [https://www.waterboards.ca.gov/drinking\\_water/certlic/drinkingwater/covid-19watersystemsurvey.html](https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/covid-19watersystemsurvey.html).
- State Water Resources Control Board (2021b). *Drinking Water State Revolving Fund*. Available at: [https://www.waterboards.ca.gov/water\\_issues/programs/grants\\_loans/docs/dwsrf\\_iup\\_sfy2021\\_22\\_final.pdf](https://www.waterboards.ca.gov/water_issues/programs/grants_loans/docs/dwsrf_iup_sfy2021_22_final.pdf).
- Stevenson, E. G. J. (2019). *Water access transformations: metrics, infrastructure, and inequities*. *Water Security* 8. <https://doi.org/10.1016/j.wasec.2019.100047>.
- Stillo, F. & MacDonald Gibson, J. (2017). *Exposure to contaminated drinking water and health disparities in North Carolina*. *American Journal of Public Health* 107(1), 180–185. <https://doi.org/10.2105/AJPH.2016.303482>.
- Teodoro, M. (2018). *Measuring household affordability for water and sewer utilities*. *American Water Works Association* 110(1), 1–27. Available at: <http://mannyteodoro.com/wp-content/uploads/2014/03/Teodoro-JAWWA-2018-affordability-methology.pdf>.
- Teodoro, M. (2019). *Water and sewer affordability in the United States*. *AWWA Water Science* 1(2), e1129. <https://doi.org/10.1002/aws2.1129>.
- UN CESCR (2002). United Nations Committee on Economic Social and Cultural Rights. General Comment No. 15: The Right to Water. *UN Doc. E/C.12/2002/11*, 9. Available at: <https://www.refworld.org/pdfid/4538838d11.pdf>.
- UNECE (2019). *The Human Rights to Water and Sanitation in Practice: Findings and Lessons Learned from the Work on Equitable Access to Water and Sanitation under the Protocol on Water and Health in the pan-European Region* (World Health Organization Regional Office for Europe Protocol on Water and Health (ed.)). Available at: [https://www.unece.org/fileadmin/DAM/env/water/publications/WH\\_17\\_Human\\_Rights/ECE\\_MP.WH\\_17\\_ENG.pdf](https://www.unece.org/fileadmin/DAM/env/water/publications/WH_17_Human_Rights/ECE_MP.WH_17_ENG.pdf).
- UNEP (2007). *United Nations Environmental Programme 2007 Annual Report*.
- UNEP & GEMS/Water (2007). *Global Drinking Water Quality Index Development and Sensitivity Analysis Report*. Available at: <https://wedocs.unep.org/bitstream/handle/20.500.11822/12214/gwqi.pdf?sequence=1&isAllowed=y>.
- UN General Assembly (2010). *Resolution 64/292: The Human Right to Water and Sanitation*.
- UN Human Rights (2008). *International Human Rights Instruments. Report on Indicators for Promoting and Monitoring the Implementation of Human Rights*. Office of the United Nations High Commissioner for Human Rights. Available at: [https://www2.ohchr.org/english/issues/indicators/docs/hri.mc.2008.3\\_en.pdf](https://www2.ohchr.org/english/issues/indicators/docs/hri.mc.2008.3_en.pdf).

- UN Human Rights Council (2010). *Resolution on Human Rights and Access to Safe Drinking Water and Sanitation (A/HRC/15/L.14*, 24 September 2010).
- United Nations (1977). *Report of the United Nations Water Conference*. Available at: <https://www.ircwash.org/sites/default/files/71UN77-161.6.pdf>.
- UN-OHCHR (2012). *Human Rights Indicators: A Guide to Measurement and Implementation*. Available at: [https://www.ohchr.org/documents/publications/human\\_rights\\_indicators\\_en.pdf](https://www.ohchr.org/documents/publications/human_rights_indicators_en.pdf).
- US EPA (1974). *Safe Drinking Water Act*. Available at: [https://www.epa.gov/sites/production/files/2020-05/documents/safe\\_drinking\\_water\\_act-title\\_xiv\\_of\\_public\\_health\\_service\\_act.pdf](https://www.epa.gov/sites/production/files/2020-05/documents/safe_drinking_water_act-title_xiv_of_public_health_service_act.pdf).
- US EPA (1998). *US Environmental Protection Agency. Information for States on Developing Affordability Criteria for Drinking Water*. U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water, pp. 12–18. Available at: <https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=91022JSV.TXT>.
- US GAO (2011). *Government Auditing Standards: 2011 Revision*. Available at: <https://www.gao.gov/assets/590/587281.pdf>.
- US Water Alliance (2017). *An Equitable Water Future: A National Briefing Paper*. Available at: [http://uswateralliance.org/sites/uswateralliance.org/files/publications/uswa\\_waterequity\\_FINAL.pdf](http://uswateralliance.org/sites/uswateralliance.org/files/publications/uswa_waterequity_FINAL.pdf).
- Vanhille, J., Goedemé, T., Penne, T., Van Thielen, L. & Storms, B. (2018). *Measuring water affordability in developed economies. The added value of a needs-based approach*. *Journal of Environmental Management* 217, 611–620. <https://doi.org/10.1016/j.jenvman.2018.03.106>.
- Venkataramanan, V., Collins, S. M., Clark, K. A., Yeam, J., Nowakowski, V. G. & Young, S. L. (2020). *Coping strategies for individual and household-level water insecurity: a systematic review*. *Wiley Interdisciplinary Reviews: Water* 7(5), e1477.
- Wescoat, J. L., Headington, L. & Theobald, R. (2007). *Water and poverty in the United States*. *Geoforum* 38, 801–814. <https://doi.org/10.1016/j.geoforum.2006.08.007>.
- WHO (1997). *Guidelines for Drinking-Water Quality: Surveillance and Control of Community Supplies*, Vol. 3. World Health Organization, Geneva.
- WHO & UNICEF (2010). *The Drinking-Water and Sanitation Ladders*. Joint Monitoring Programme for Water Supply and Sanitation. <https://washdata.org/monitoring/drinking-water>.
- WHO & UNICEF (2012). *Rapid Assessment of Drinking-Water Quality: A Handbook for Implementation*. World Health Organization and UNICEF Joint Monitoring Program, Geneva, p. 8.
- WHO & UNICEF (2017). *Joint Monitoring Program for Water Supply, Sanitation and Hygiene (JMP) Methodology, 2017 Update & SDG Baselines*. World Health Organization and the United Nations International Children's Emergency Fund. Available at: <https://washdata.org/sites/default/files/documents/reports/2018-04/JMP-2017-update-methodology.pdf>.
- WHO & UNICEF (2021). *The Measurement and Monitoring of Water Supply, Sanitation and Hygiene (WASH) Affordability*. Available at: <https://washdata.org/sites/default/files/2021-05/unicef-who-2021-affordability-of-wash-services-full.pdf>.
- Winkler, I. T. (2015). *The human right to sanitation*. *University of Pennsylvania Journal of International Law* 37, 1331.
- Young, S. L., Boateng, G. O., Jamaluddine, Z., Miller, J. D., Frongillo, E. A., Neilands, T. B., Collins, S. M., Wutich, A., Jepson, W. E. & Stoler, J. (2019). *The Household Water InSecurity Experiences (HWISE) Scale: development and validation of a household water insecurity measure for low-income and middle-income countries*. *BMJ Global Health* 4(5), e001750. <https://doi.org/10.1136/bmjgh-2019-001750>.

First received 22 March 2021; accepted in revised form 13 August 2021. Available online 6 September 2021