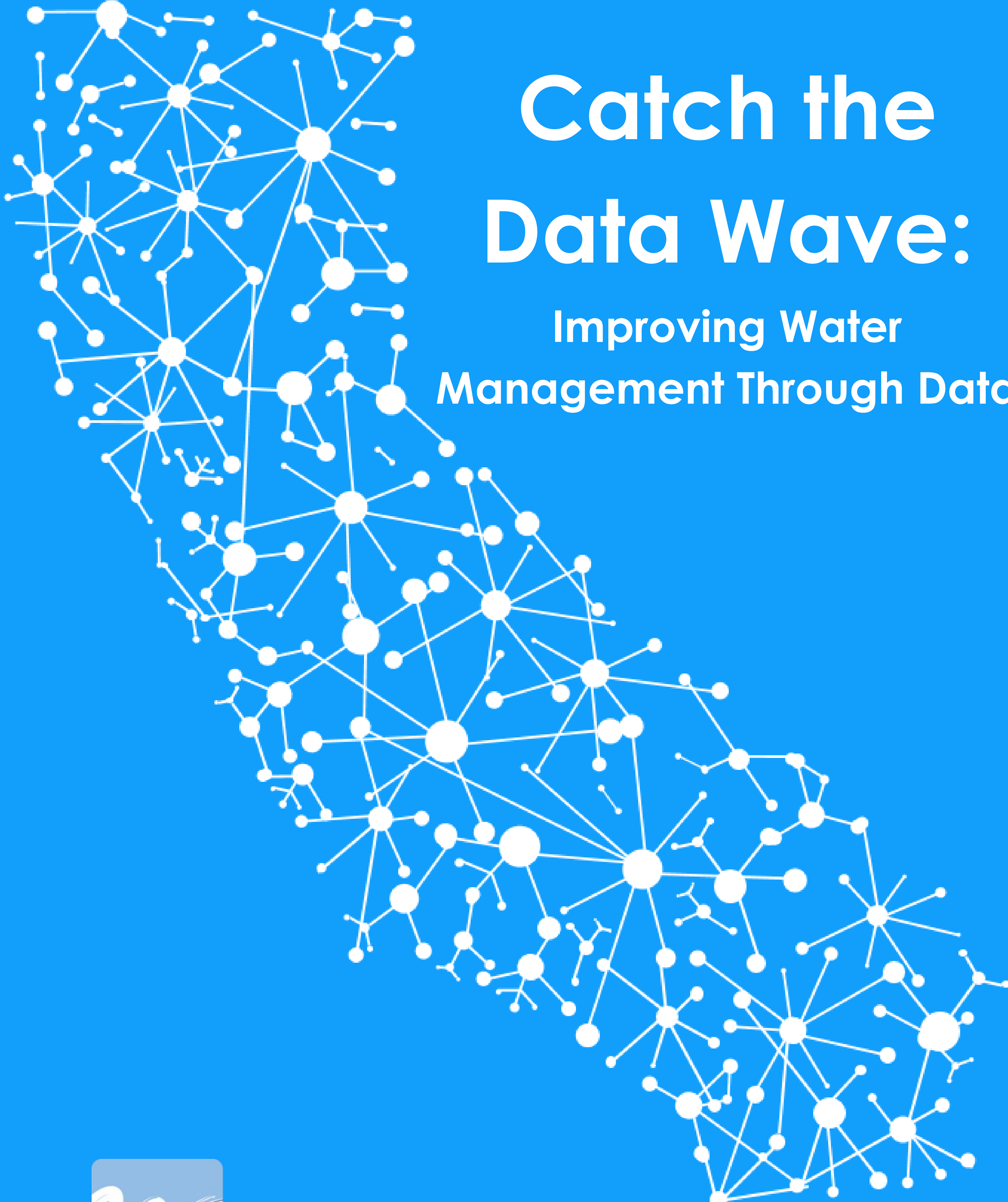


Catch the Data Wave:

Improving Water Management Through Data

A Report by the

2018 Water Education Foundation Water Leaders

WATER EDUCATION FOUNDATION

Acknowledgement and Thanks

The 2018 Water Leaders Class would like to express our sincere appreciation to the Water Education Foundation for providing us with this unique opportunity and to our employers for their support and encouragement throughout this past year. We would also like to express our gratitude to the individual mentors for sharing their invaluable time and insights. Finally, we would like to thank the supporters of the Water Education Foundation and the William R. Gianelli Water Leaders program. Without your generosity, this program would not be possible.

Disclaimer

The opinions expressed in this report are not endorsed by all Water Leaders, their employers or the Water Education Foundation.

Table of Contents

Forward

The Water Education Foundation's 2018 Water Leaders Class was charged with exploring the topic of, and providing policy recommendations on, how to improve water management through data. In the course of that task, the group evaluated the current efforts underway on water data in California, including the implementation of the Open and Transparent Water Data Act (AB 1755). To better understand the key considerations and policy concerns regarding the use of data in water management, the 2018 Water Leaders deployed a comprehensive strategy that included analysis of the research currently available and the efforts underway to implement the Open and Transparent Water Data Act, interviews and knowledge sharing with experts in the water industry, and internal discussions among the 2018 Water Leaders on key policy themes and considerations. The policy recommendations in this report are intended to inform future decision-making.

Jennifer Bowles, executive director of the Water Education Foundation (WEF), paired each member of the 2018 Water Leaders Class with an experienced water professional for an exchange of ideas on the topic of water data for water management. The assigned mentors are all leaders in their respective water fields and come from diverse backgrounds, including federal and state agencies; the Legislature; water agencies; urban, agricultural and environmental stakeholders; universities and think tanks; and the technology sector. The 2018 Water Leaders "shadowed" their mentors for a day, gaining insight into their workday and the responsibilities and perspectives of these mentors. Through a collaborative process, the 2018 Water Leaders identified 10 core questions related to data and water management to present to the mentor group. Responses were analyzed and synthesized, and together with other research, these insights informed the development of the 2018 Water Leaders' policy recommendations.

Over the course of their year-long fellowship, the 2018 Water Leaders heard from water experts with diverse experiences and perspectives, including from state and federal agencies, local governments, environmental and agricultural organizations and researchers/scientists. Bowles arranged for lectures by speakers from multiple disciplines who spoke about the need for water data and the state's current efforts underway to implement the Open and

Transparent Water Data Act. The 2018 Water Leaders Class also attended WEF's annual Water 101 Workshop to gain a solid grounding on the history, legal and regulatory aspects of California water; WEF's annual Water Summit to hear discussions about pressing issues across California and the West; a three-day water tour of the Sacramento-San Joaquin Delta (Delta) and San Francisco Bay; and a second WEF water tour of their choosing.

Each of these experiences, and the insights gained from them, informed the development of the policy recommendations contained in this report. The 22 members of the 2018 Water Leaders Class are grateful to offer the following report to their colleagues in the water community.

Mentor and Water Leader List

Mentor	Water Leader
Brent Hastey President, Association of California Water Agencies Board Member, Yuba Water Agency	**Kate Anderson** Senior Environmental Planner Delta Stewardship Council kate.anderson@deltacouncil.ca.gov
Mike Kiparsky Director, Wheeler Water Institute Center for Law, Energy and the Environment UC Berkeley School of Law	**Julia Barfield** Project Manager, Dynamic Water Management The Nature Conservancy jbarfield@tnc.org
Bart Fisher Trustee, Palo Verde Irrigation District Owner, Fisher Farms	**Michael Bernardo Jr.** Special Assistant U.S. Bureau of Reclamation, Lower Colorado Region mbernardo@usbr.gov
David Mooney Bay-Delta Office Area Manager U.S. Bureau of Reclamation	**Ashlee Casey** Water Resources Engineer, Grade 4 GEI Consultants ashleekaitlin@gmail.com
Martha Guzman Commissioner California Public Utilities Commission	**Lisa Cuellar** Sustainable Landscaping Program Manager California Water Efficiency Partnership lisa@calwep.org
Joshua Haggmark Water Resources Manager City of Santa Barbara	**Jessica Diaz** Attorney Brownstein Hyatt Farber Schreck jdiaz@bhfs.com
Fiona Sanchez Director of Water Resources Irvine Ranch Water District	**Christine Frey** Government & Regional Affairs Representative Metropolitan Water District of Southern California cfrey@mwdh2o.com
Cannon Michael President Bowles Farming Company	**Chelsea Haines** Regulatory Advocate II ACWA chelseah@acwa.com

Mentor	Water Leader
Joaquin Esquivel Board Member State Water Resources Control Board	**Rebecca Harms** Attorney Kronick Moskovitz Tiedemann & Girard rharms@kmtg.com
Joone Lopez General Manager Moulton Niguel Water District	**Wesley Henson** Research Hydrologist U.S. Geological Survey whenson@usgs.gov
Newsha Ajami Director of Urban Water Policy, Water in the West Stanford University	**Yuan Liu** Associate Water Resource Specialist Contra Costa Water District yliu@ccwater.com
Yung-Hsin Sun Chief Water Resources Engineer Stantec	**Ryan Ojakian** Regional Water Authority Legislative and Regulatory Affairs Manager rojakian@rwah2o.org
Greg Gearheart Deputy Director, Office of Information Management and Analysis State Water Resources Control Board/CalEPA	**Evan Perez** Water Resources Engineer Stantec evan.perez@stantec.com
Kamyar Guivetchi Manager, Statewide Integrated Water Management California Department of Water Resources	**Karli Quinn** Associate Director Ag Association Management Services, Inc. karli@agamsi.com
Peter Yolles Founder WaterSmart Software	**Adam W. Robin** Legislative Affairs Director Northern California Water Association arobin@norcalwater.org
Dennis O’Connor Principal Consultant Senate Committee on Natural Resources and Water	**Rebecca Smith** Attorney Downey Brand LLP rsmith@downeybrand.com
Patrick Atwater Project Manager California Data Collaborative	**Sarah Spano** Managing Associate Environmental Science Associates sspano@esassoc.com
Denise Kruger Senior Vice President, Regulated Utilities Golden State Water Company	**Jenn Swart** Communication and Education Services Rep Water Replenishment District of SoCal jswart@wrd.org

Mentor	Water Leader
Kim Delfino California Program Director Defenders of Wildlife	**Emily Thor** Attorney California Department of Water Resources emily.thor@water.ca.gov
State Sen. Bill Dodd California State Senator 3rd Senate District	**Willie Whittlesey Jr.** Project Manager Yuba Water Agency wwhittlesey@ycwa.com
Eric Reichard Director, California Water Science Center U.S. Geological Survey	**Chad Williams** Engineering Services Supervisor Olivenhain Municipal Water District cwilliams@olivenhain.com
Wade Crowfoot Chief Executive Officer Water Foundation	**Kat Wuelfing** Senior Water Resources Planner EKI Environment & Water, Inc. kwuelfing@ekiconsult.com

Acronyms & Abbreviations

AB 1755: The Open and Transparent Water Data Act

AF: Acre-feet

ASO: Airborne Snow Observatory

BIOS: Biogeographic Information and Observation System

CASGEM: California Statewide Groundwater Elevation Monitoring

CCST: California Council on Science and Technology

CDEC: California Data Exchange Center

CDFW: California Department of Fish and Wildlife

CEDEN: California Environmental Data Exchange Network

CIMIS: California Irrigation Management Information System

CNRA: California Natural Resources Agency

CNRFC: California-Nevada River Forecasting Center

CWQMC: California Water Quality Monitoring Council

DAUs: Detailed analysis units

Delta: Sacramento-San Joaquin Delta

DSC: Delta Stewardship Council

DWR: California Department of Water Resources

EOW: EyeOnWater

ETAW: Evapotranspiration of Applied Water

eWRIMS: Electronic Water Rights Information Management System

GDEs: Groundwater dependent ecosystems

GSAs: Groundwater Sustainability Agencies

GSPs: Groundwater Sustainability Plans

IRWM: Integrated Regional Water Management

JPL: Jet Propulsion Laboratory

NASA: National Aeronautics and Space Administration

NOAA: National Oceanic and Atmospheric Administration

NRDC: Natural Resources Defense Council

NWIS: National Water Information System

PPIC: Public Policy Institute of California

RWIS: Reclamation Water Information System

SAWPA: Santa Ana Watershed Project Authority

SGMA: Sustainable Groundwater Management Act

SWAMP: Surface Water Ambient Monitoring Program

SWRCB: State Water Resources Control Board

TDS: Total dissolved solids

TNC: The Nature Conservancy

USBR: United States Bureau of Reclamation

USDA-ARS: United States Department of Agriculture - Agricultural Research Service

USFWS: United States Fish and Wildlife Service

USFS: United States Forest Service

USGS: United States Geological Survey

WEF: Water Education Foundation

WUEdata: Water Use Efficiency Data

Executive Summary

California is the most populous state in the United States and the fifth largest economy in the world (United States Census, 2017; Associated Press, 2018; Cooper, 2018). The most densely populated areas of the state are along its coast, most notably, its southwest coast. Interestingly, this is not where most of California's water supply is located (Xiao, 2018). Water has to be delivered throughout the state, which is approximately 770 miles long and 250 miles wide with varied terrain and complex water management demands. These management considerations are further stressed in times of drought and flood — phenomena with which Californians are intimately acquainted. As one can imagine, California requires a highly engineered water supply system (Bartholomay, Carter, Qi, Squillace & Rowe, 2007). While precipitation has always been highly variable, with decreasing snowpack and more frequent and prolonged droughts, better coordination and collaboration on data gathering and use across government levels and by stakeholders is critical to ensure human and ecological needs are met (Xiao, 2018).

Information about water resources — and in particular, open, transparent and accessible data — is an important tool in the successful management of California's water resources. To successfully apply that tool toward improved water management, consistent with the goals of the 2016 Open and Transparent Water Data Act, California's water sector should incorporate the following policy recommendations in its planning.

Develop a Privacy Protocol to Guide Public Distribution of Data

Privacy concerns arising from the dissemination of data are a significant barrier to the creation of a broad scale, open data framework. Individuals, organizations and businesses are concerned that the dissemination of data could, for example, reveal personal habits, lead to further regulation of water use, cause a loss in competitive advantage and render it difficult or impossible to monetize data services that offer expertise in collecting and interpreting data for paying clients. The creation of a broad scale, open data framework will be impossible without addressing these concerns. This report recommends that the water sector explicitly incorporate existing legal standards regarding the dissemination and protection of personal information to provide more certainty and guidance in situations in which privacy concerns arise from the potential dissemination of data.

Water Accounting & Data Integrity

Water data collection efforts in California have been diverse and disaggregated. The result has been fragmented, incomplete, incompatible or asynchronous data, which has prevented water managers from making decisions with full confidence. This report recommends certain steps toward data collection standardization that, if pursued, would improve the quality, integrity, and utility of data collected for water management. Specifically, the water sector should standardize and expand California's stream gauge data collection and distribution to improve the quantity and quality of water supply data. Second, policies should be implemented that support, encourage and incentivize the collection, analysis and summary of data related to less understood impacts and benefits of water transfers. Factors that could be better understood through data include: reservoir fill criteria, surface water depletion caused by groundwater use, evapotranspiration of applied water rates applicable to specific crops and watering practices, benefits of conservation practices and carriage water requirements.

Focus on Regional Units to Develop Useful Data Frameworks for Water Management

To maximize the return on investment of water projects and programs that rely on both specific and general datasets, the water sector should implement a watershed approach for developing, publishing and accessing data. A regional (watershed or groundwater basin) approach allows complex and unique water data issues to be tackled at a size that is both manageable and simultaneously scalable. Empowering stakeholders within the watershed to use data from multiple sources for their water planning and management needs will likely improve collaboration and consensus building among users. To test the viability of this approach, an initial focus on watersheds with existing healthy partnerships should be used as first adopters.

Refine Data Reporting Metrics to Better Manage for Ecosystem Needs and Adapt to Climate Change Uncertainties

Uncertainty in data collection and analysis is inevitable, and California's policymakers, water managers and users must grapple with these uncertainties in managing water for the benefit of the state, its ecosystem and users. Some of these uncertainties arise from inconsistencies in how we categorize, define and track water use datasets while others stem from the changing data itself which is hard to effectively track and manage in order to inform management decisions. In either case, the state benefits from a robust data framework in which data can be shared and analyzed, and management choices readily informed to respond to these uncertainties.

Empower Water End-Users with Data and Tools

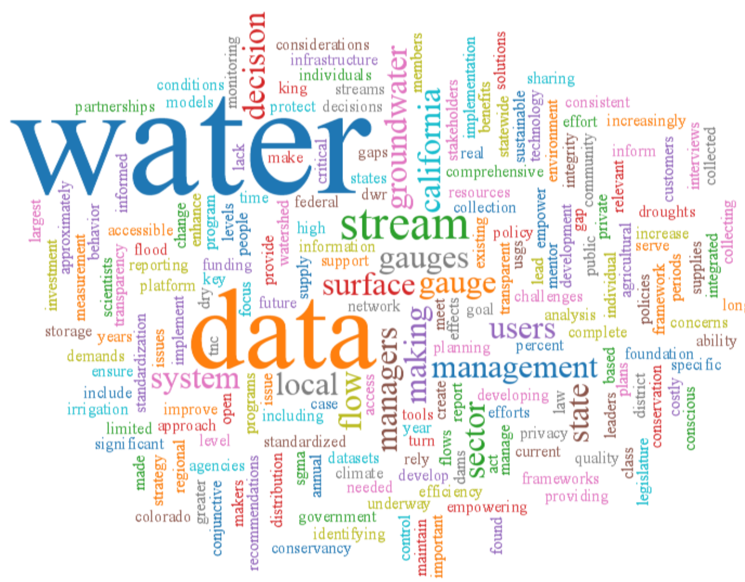
Data — when relevant, actionable and accessible — can help various end-users make better decisions about future water use and management. Data is actionable when it is organized in a format (rather than left unprocessed) that enables decisions to be made with greater efficacy. At the individual user level, water issues become relevant to people when they have a connection to the data. Therefore, the water sector should support policies and programs with the goal of making actionable data available to various end-users to increase engagement while simultaneously helping to guide the most relevant water use and management decisions.

I. Introduction

In 2016, the California Legislature, along with Gov. Edmund G. Brown Jr., recognized a need in California for "an authoritative open-access platform," intended to "help water managers operate California's water system more effectively and help water users make informed decisions" (Assembly Bill 1755*,* 2016). To meet that need, AB 1755, the Open and Transparent Water Data Act was passed into law.[1]

AB 1755 was introduced by then-Assemblyman Bill Dodd, D-Napa (*"AB-1755,"* 2016). Signed by the governor on Sept. 23, 2016, the Open and Transparent Water Data Act directs the California Department of Water Resources (DWR), in coordination with the California Water Quality Monitoring Council (CWQMC), State Water Resources Control Board (SWRCB), and California Department of Fish and Wildlife (CDFW), to develop and maintain a statewide integrated water data platform no later than Sept. 1, 2019 (Assembly Bill 1755, 2916; "*AB-1755*," n.d.; Cantor et al., 2018).

The Open and Transparent Water Data Act is intended to "seize upon" the opportunity provided by improvements in technology and open-source platforms "to integrate and increase access to existing water data" (Cal. Water Code § 12401(b)(Westlaw)).



The above word cloud reflects the top 200 most commonly used words within this report. The size of each word is scaled relative to its frequency of use.

The centerpiece of *AB 1755* is a statewide integrated data platform through which DWR, SWRCB and CDFW are directed to "coordinate and integrate existing water and ecological data" (Cal. Water Code §§ 12405, 12410 (Westlaw)). The purpose of that integration includes, but is not limited to, "providing adequate information to

[1] For the full text of AB 1755, including Legislative findings regarding the need for and animating principles behind the act, see Appendix A.

implement the Sustainable Groundwater Management Act (SGMA),[2] improving the management of the state's water resources, and bringing greater transparency to water transfers and the market" (Cal. Water Code § 12405 (Westlaw)). Such a platform is intended to increase access to and promote the utilization of high-quality data to spark innovation, promote research, encourage public participation, increase transparency and lead to more informed decision making (see Cal. Water Code § 12401 (Westlaw); Cantor et al., 2018). In pursuit of that end, DWR and its partners are directed to develop protocols for data sharing, documentation, quality control, public access and the promotion of open-source platforms and decision support tools related to water data (Cal. Water Code § 12406(a)(Westlaw)). Many in the water community mark the Open and Transparent Water Data Act as an important initial step to defragment water data among various stakeholders (*see generally* "*AB-1755*," 2016; Cantor et al., 2018).

In January 2018, UC Water, DWR and the California Council on Science and Technology (CCST) released a report to inform the implementation of AB 1755.[3] *Data for Water Decision Making* observed that "California faces many water management challenges, from balancing urban, environmental, and agricultural water needs to managing the impacts of drought and climate change. Addressing these challenges involves making decisions, and making sound, evidence-based decisions in turn requires reliable, usable data" (Cantor et al., 2018, p. 11). Effective water management is essential to the continued health of California's economy, ecosystems and public. Water managers are charged with making critical decisions that affect millions of people and rely on this data for their water management decisions. While data is crucial for effective decision-making, increasing the amount of raw data available to water managers alone is not enough to meaningfully assist in their day-to-day decision-making (Cantor et al., 2018). The data also needs to be in an accessible and usable format (Cantor et al., 2018).

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[2] "SGMA requires governments and water agencies of high and medium priority basins to halt overdraft and bring groundwater basins into balanced levels of pumping and recharge. Under SGMA, these basins should reach sustainability within 20 years of implementing their sustainability plans. For critically over-drafted basins, that will be 2040. For the remaining high and medium priority basins, 2042 is the deadline" (California Department of Water Resources [DWR], 2018e; Cal Water Code §10720 et seq. (Westlaw)).

[3] See *Data for Water Decision Making*, Cantor et al. (2018), available at https://www.law.berkeley.edu/wp-content/uploads/2018/01/DataForWaterDecisionMaking.pdf.

A tremendous volume of water data is collected by local, state and federal agencies, universities and nonprofits;[4] however, California, as a whole, has lacked a comprehensive approach in the collection and dissemination of this data, in part because of the lack of a collective statewide portal to host these data sets in a single location under a standard framework (Cantor et al., 2018). In addition to water data being housed by multiple entities, this data often has limited interoperability[5] (Cantor et al., 2018). Additional challenges include data gaps, lack of standardization and accessibility (Cantor et al., 2018). "The net result is less-informed decisions on how to best manage a foundational resource for California's environment and economy" (Cantor et al., 2018, p. 11).

Recognizing that "no one website or database could reasonably contain all of California's water-related data," DWR and its Partner Agency Team (comprised of the SWRCB, CDFW, CWQMC, the Governor's Office of Planning and Research, the California Natural Resources Agency (CNRA), the Government Operations Agency, and the Delta Stewardship Council (DSC) have proposed to use a federated network of data portals, resulting in a decentralized platform where no single host or database is responsible for housing all of the varied datasets included in the platform (California Department of Water Resources [DWR], 2018d; Cantor et al., 2018).[6]

II. Policy Recommendations

Overcoming many of the state's water challenges relies in part on the ability not only to access quality data, but to put that data to productive use in decision-making. As water management challenges continue to evolve, a relevant and sustainable data platform will need to be flexible and able to adapt to new technologies in order to effectively assist water managers in their decision-making. This data platform should be a living tool that can work over time to close data gaps and other shortcomings.

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[4] See Appendix B: Inventory of Existing California Water Data Platforms and Tools.

[5] Interoperability is "the ability of information technology systems to exchange meaningful information with each other in standard ways that allow for common comparison, aggregation, and analysis" (Cantor et al. 2018, p. 11).

[6] "The intended outcome for AB 1755 is a federated network of data portals…[E]ach open data platform will be accessible through a federated data catalog, analogous to the inter-library loan system. " (DWR, 2018d, p.1). Even though it is not without challenges, "because no one website or database could reasonably contain all of California's water-related data, federation offers a viable technical solution" (DWR, 2018dp.1; Cantor et al., 2018).

Just as there is an abundance of water data, there also is an abundance of research on the role of data for decision-making and the key components of a water data platform. The ability of stakeholders to coordinate and build solutions that ensure the trustworthiness and transparency of a data platform is paramount to the success of the Open and Transparent Water Data Act.

Consistent with these principles, the five policy recommendations listed below are intended to help empower and inform decision-makers for a more reliable and resilient water future.

- Develop a Privacy Protocol to Guide Public Distribution of Data
- Water Accounting & Data Integrity
- Focus on Regional Units to Develop Useful Data Frameworks for Water Management
- Refine Data Reporting Metrics to Better Manage for Ecosystem Needs and Adapt to Climate Change Uncertainties
- Empower Water End-Users with Data and Tools

Data, like California's water system, is complex and ever-evolving. To respond appropriately and effectively to that evolution, and to effectively apply data to improved management, the needs of water managers, policy-makers and end users must remain at the forefront.

A. Develop a Privacy Protocol to Guide Public Distribution of Data

AB 1755 is oriented around the principle that making water use data publicly available across multiple sectors (e.g., urban, commercial, industrial and agricultural) can result in a better understanding of overall water supply shortages and contribute to the development of strategies that can more equitably balance the needs of all communities, industries and the environment (see generally Cal. Water Code §12401 (Westlaw)). The law also recognizes that making "information accessible, discoverable, and usable by the public can foster entrepreneurship, innovation, and scientific discovery" (Cal. Water Code § 12401(d) (Westlaw)).

Open and transparent data (freely accessible by all users) can be used as a means to resolve conflict and engender trust. Accordingly, "water data and information technology tools and applications developed and gathered using state funds should be made publicly accessible" (Cal. Water Code § 12401(e) (Westlaw)). To aid in carrying out this legislative intent, AB 1755 directs DWR to "develop protocols for data sharing, documentation, quality control, public access, and promotion of open-source platforms and decision support tools related to water data" (Cal. Water Code § 12406(a) (Westlaw)).[7]

This transparency and increased access comes with limitations, however. One of the most significant barriers to a broad-scale open data framework is concerns raised by individuals and organizations regarding the ownership and privacy of water data collected, and later disseminated, by public agencies. [8] In some cases, users express reluctance to share or disseminate water-related data out of fear that disclosing it will result in losing a competitive edge or business advantage (either to the user or the aggregator of the data); in others, concern that revealing additional data may lead to regulatory action drives parties to keep this information private. In other settings, disclosure of water use data may serve as an analog for more personal information: the timing of showers or use of faucets in a residential setting, for example. These privacy concerns can limit voluntary participation in data sharing (for example, the inclusion of private wells in monitoring networks), and can incentivize less robust reporting in mandatory programs (for example, in providing only the regulatory minimum in granularity or timing of reporting, even where more detailed data is available).

In the open-source, high-accessibility environment contemplated by AB 1755, there is a need to develop specific privacy protocols governing the dissemination and treatment of that data. Whether on the AB 1755 integrated platform or through other data-sharing tools, data that could harm or jeopardize a private party's physical or financial well-being, for example, must be identified and handled appropriately.

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[7] AB 1755 goes so far as to condition the receipt of state grants or contracts for research or projects relating to the improvement of water or ecological data on the applicants' adherence to these protocols for data sharing, transparency, documentation and quality control (Cal. Water Code § 12406(b), (c) Westlaw).

[8] It is important to note that the statute speaks directly to data gathered by public agencies: It neither precludes nor requires integration of wholly privately-collected water data. See Cal. Water Code § 12401(c) (Westlaw) ("California is working to increase access to water data collected by state agencies"); Cal. Water Code § 12401(d) (Westlaw) ("State agencies should promote openness and interoperability of water data"); Cal. Water Code § 12401(e) (Westlaw) ("water data and information technology tools and applications developed and gathered using state funds should be made publicly accessible"). Nonetheless, the volume and diversity of data collected by state agencies is vast (see, e.g. Appendix B).

***Recommendation:** Develop standard policy protocols to guide the public distribution of data, relying on existing legal standards and mechanical tools to protect privacy while advancing knowledge.*

1. Identifying and Protecting "Private" Data

Water-related datasets may contain personal information for which there is a reasonable expectation of privacy. In those cases, making the raw data set publicly available presents privacy concerns. For example, some water system use data have a sufficient degree of granularity to identify when an individual's shower or toilet is running. There also is a lack of consensus about what kind of data present a privacy concern upon disclosure, and so a need to develop some universal standards and definitions regarding what data is protected for privacy reasons (outside of existing legal protections from disclosure, for example, as a trade secret or under security regulations). Agricultural and industrial water use data, for example, is the subject of some debate regarding whether disclosure of those water uses implicates personal privacy issues or could bestow an unfair competitive advantage.

Although the rise of a centrally located open and transparent data network under AB 1755 is new, concerns about the privacy implications of publicly shared information are certainly not. The California Constitution gives each citizen an "inalienable right" to "pursuing and obtaining safety, happiness and privacy" (Cal. Const. Art. I, § 1). This right is maintained through various, separate laws, each of which provides specific protections. Separately, California law limits the kinds of personal information that, if held by a public agency, must be publicly disclosed upon request (for example, pursuant to a Public Records Act request, the California equivalent of the Freedom of Information Act). So, for example, in other forums, data that implicates "autonomy privacy" (e.g., a person's privacy interest "in making intimate personal decisions or conducting personal activities without observation, intrusion, or interference") is not disclosed without a "compelling state interest" (*Hill v. National Collegiate Athletic Assn.*, 7 Cal.4th 1, 35-36 (Cal. 1994). Documents requested from a public agency under the California Public Records Act, likewise, are generally withheld where they are otherwise protected by California law, or if "on the facts of the particular case, the public interest served by nondisclosure clearly outweighs

the public interest served by disclosure of the record." (Cal. Gov. Code § 6255 (Westlaw); *see generally* California Attorney General's Office, 2004).

With that reality in mind, this report recommends that the data portal explicitly incorporate existing legal standards regarding the dissemination and protection of personal information. Application of this standard in the water context allows for a balancing between the level of protection necessary to protect individuals' privacy interests and the level of disclosure necessary to develop robust, meaningful and readily available water data sets.

In an increasingly data-centric world, the development of a privacy protocol and best management practices surrounding the public dissemination of water data is essential to the successful management and sharing of water data. An optimal privacy protocol would (1) serve as a reference point to incorporate existing legal standards (for example, the Public Records Act's limitations on the disclosure of personal addresses and phone numbers); (2) provide recommendations regarding the degree of anonymity required in the collection and dissemination of water data; and (3) set best practices for the degrees to which data should be anonymized, if necessary, before distribution.

2. Practical Solutions to Privacy Concerns

Much if not all of these sensitive data sets could be managed in a way that could protect individuals' privacy, but still be made available to the public. For example, household or agricultural water use data could be aggregated and averaged across larger subpopulations or geographic areas to obtain useful information without unduly intruding on the personal or business activities of water users.

Privacy concerns can cause individuals or smaller water users to have reservations about sharing their data due to who may have access to it, and what they may do with the knowledge they may gain from it. Over time, a well-crafted and generally accepted set of privacy and data handling principles has the potential to yield a higher quantity of accurate data. Removing the personal aspects of data being submitted can inspire confidence on the part of data generators that may result in higher rates of participation. The protection of having a third party reviewing and resubmitting the information would raise the probability of receiving the most accurate numbers and data submitted. This approach will ensure accountability and transparency to the citizens of the state who share the public water resource while providing a means to aggregate important data without violating private information.

B. Water Accounting & Data Integrity

Historically, water data collection efforts in California have been diverse and disaggregated. Indeed, lack of a uniform system of water measurement and accounting is often cited as a significant limiting factor in improving water management. Data has been collected and used by water managers for specific and meaningful purposes, but this data may not have been collected using standardized methods or been fully considered on a large scale. The resulting data gaps present challenges as water managers and stakeholders work to make informed water management decisions about the management and allocation of water and operation of water infrastructure; the development, planning and execution of water transfers; and their own water and land use decisions, including irrigation and development choices.

Recognizing that a full standardization of data collection methods, intervals and units of measurement across datasets is not feasible or economically viable in the near-term, this report recommends certain steps toward data collection standardization in key areas that, if pursued, would have beneficial impacts on the quality, integrity and utility of data collected for water management.

1. Making Data Work for California

It is often said that there is no normal water year in California – only dry years and wet years, which presents a significant challenge for both water supply planning and optimization of conjunctive use. As water management needs intensify, the challenges presented by fragmented, incomplete, incompatible or asynchronous data intensify as well. In response to this challenge, the statewide integrated platform under AB 1755 is required to "integrate existing water and ecological data" from local, state, federal and academically-maintained databases "using consistent and standardized formats" (Cal. Water Code § 12415 (Westlaw). That integration effort is specifically required to include:

- DWR-held datasets related to State Water Project reservoir operations, groundwater use, groundwater levels, urban water use and land use;
- SWRCB-held data on water rights, water diversions and water quality through the California Environmental Data Exchange Network (CEDEN);
- CDFW data on fish abundance and distribution;
- United States Geological Survey (USGS) streamflow conditions through National Water Information System (NWIS);
- Central Valley Project operations information maintained by the U.S. Bureau of Reclamation (USBR); and
- USFWS, USFS, and NOAA fish abundance information

Integration of these diverse datasets statewide, however, does not resolve the more immediate challenge for water managers: Where gaps in the quality or quantity of data collected create uncertainty about local conditions, aggregation and integration alone may not be enough to optimize water resources management.

Integrating Groundwater and Surface Water Data. Groundwater and surface water are often used in concert to meet water demands (i.e., conjunctive water use), and enhanced streamflow data can inform and improve conjunctive water use. Groundwater provides approximately 38 percent of the state's water supply in normal years and at least 46 percent in dry years.

Aquifers are important reservoirs that store water from wet years for use during dry periods. Water managers and users can effectively manage their water supplies to have greater water supply reliability if these reservoirs are managed to preserve their storage.

When surface water supplies are uncertain, groundwater is often used because it is readily available and easily accessible. Real-time information about both surface and groundwater availability will empower water users with information they need to meet their water demands and reserve groundwater for periods when surface water is unavailable. To truly optimize this strategy, real-time information is needed so that communities can plan and adapt to changing water demands and supplies throughout the year. This allows water managers and users to take full advantage of surface water resources and preserve their groundwater resources for when they are needed. These open data frameworks can facilitate optimized conjunctive water use and uncover opportunities for surface water capture, storage and groundwater recharge. Optimizing conjunctive water use throughout the year will allow water users to have more sustainable beneficial use and enhance their water supply reliability during dry periods or droughts.

Accounting for and Promoting Water Transfers. Water transfers also are an important tool to meet the demand for water throughout California and vary significantly in complexity and physical operation. Because of these complexities, the successful integration of water transfers into a water accounting or management regime can be data-intensive. Understanding transfers' relationship to, and impact on, related water management questions requires thoughtful integration of data across time and hydrogeological conditions.

The AB 1755 integrated water data platform is explicitly required to include data on completed water transfers and exchanges, including data on volume, price and delivery method; identity of buyers and sellers, and the water right associated with the transfer or exchange (Cal. Water Code § 12415(c) Westlaw). It must, likewise, include DWR-held datasets related to land and groundwater use. As a management tool, however, transfers and conjunctive use programs require a sophisticated understanding of diverse datasets that is not confined to volume and price of water used.

So, for example: A *groundwater substitution* water transfer occurs when a water user foregoes the use of surface water and instead pumps groundwater to meet normal demand. The surface water that goes unused is then made available for transfer to the buyer. In basins where groundwater substitution transfers are carried out, optimal water management decision making requires an integrated understanding of groundwater levels, surface-groundwater interaction, expected demand and cropping patterns and percolation rates, among other datasets.

In contrast, transfers facilitated through *reservoir reoperation* involve the increase in outflows above the rate at which water would normally be released from storage. To mitigate potential impacts on other water users reliant on the same stored water supply, reservoir refill criteria have been developed that dictate the conditions under which the reservoir that was drawn down to supply water for the transfer can be refilled. Data managers, in turn, must process and integrate not only information on flows and demand, but also on reservoir conditions, downstream water quality, water temperature and end-of-season carry-over projections (State Water Resources Control Board [SWRCB], 1999, p. 6-8) in order to optimize their management and planning efforts under this system.

Intra-watershed transfers (regardless of the water's source) add another data wrinkle: Water managers must plan for regulatory restrictions, capacity in pumps and conveyance facilities, carriage water and potential losses through the water's transportation from seller to buyer.

Recommendation. *In recognition of the potential value of water transfers and conjunctive use as management tools, focus on identifying and resolving gaps in key transfer-relevant datasets (i.e., percolation rates in areas of groundwater substitution transfers), and integrating those datasets according to the transfer demands of the watershed.*

Many hurdles exist in the process of developing, planning and executing a successful water transfer and many of these pressures are exacerbated during drought conditions when transfers are needed most. While water transfers are very common and necessary to

California's water supply, data related to these transfers is lacking and could be improved to provide decision-makers with enhanced knowledge necessary to manage for the full benefit of all water transfer mechanisms described above.

Accounting for Water Use Choices and Trends. An accurate accounting of demand and use within a watershed is essential to developing a useful water accounting system, and in planning for water transfers and conjunctive use programs. Gaps in that accounting can leave water managers without the information they need to make informed decisions. So, for example, many watersheds lack a complete understanding of how much water is used for irrigating crops. Similarly, while the California Water Plan Updates provide information on agricultural water use statewide, the reports are only issued every five years – a time interval that is less useful for a water manager making day-to-day delivery and operations decisions. In May 2018, DWR launched an online platform, WUEdata, which hosts monthly water delivery data collected from agricultural water suppliers through the Aggregated Farm-Gate Delivery Report, required by AB 1404 (DWR, 2018b). However, significant challenges remain as suppliers provide reports on paper and it appears that about 28 percent of the irrigation districts have never submitted their reports (West, 2018). Through Agricultural Water Management Plans, agricultural water suppliers must provide information on efficient water management practices – but because these plans also are submitted on a five-year basis, do not include total use, and are not machine readable or accessible, they are difficult to integrate into any real-time water management planning systems.[9]

In many areas, agricultural use patterns are an important part of the overall water management picture. Changes to those patterns have real implications for water managers and stakeholders. So, for example*, crop idling* (fallowing) or *crop shifting* (growing crops with lighter water demand) occurs when a farmer chooses to forego growing a crop for an entire season, or to grow a less water-intensive crop. The water that goes unused due to these decisions may then

[9] AB 1668 (Friedman, Chapter 15, Statutes of 2018) addresses many of the limitations in Agricultural Water Management Plans, including the submission in a standardized electronic format. Significantly, AB 1668 requires the submission of an annual water budget based on the quantification of all inflow and outflow. However, reporting under AB 1668 will not begin until the spring of 2021.

be made available for transfer, conservation or other uses. Quantifying the amount available because of this agricultural management decision is itself challenging.

There are a variety of efforts to model agricultural water use. One helpful platform, DWR's Land Use Viewer, provides spatially specific crop types throughout the state for 2014 and 2015 that is useful for starting to understand crop-specific water uses. Collection of data on the evapotranspiration of applied water (ETAW) also is helpful, though those datasets are incomplete. ETAW is the portion of applied water that is evaporated from the soil and plant surfaces and actually used by the crop, not including water that is lost to deep percolation, to groundwater or conveyance losses (California Department of Water Resources & State Water Resources Control Board [DWR & SWRCB], 2015, p. 4). To determine the baseline water use, a history of the crops planted is used, and average ETAW values are used to calculate the water available for transfer. Water conservation measures that result in a reduction in the consumptive use of water or prevent water from discharging to an unusable water supply make water available for transfer (DWR & SWRCB, 2015, p. 5). Documenting the historic conditions and demonstrating the real quantity of water conserved or made available, however, is challenging.

Recommendation. *Enhance local understanding of water demands and use to gain greater specificity in planning. Investigate automation of irrigation canal measurements.*

2. Strategic Steps for Plugging Data Gaps

Whether in the case of potential water transfer, conjunctive use projects, or simply understanding available supply and demand, limited streamflow data limits local management capabilities. Local, state and federal water managers rely on streamflow data to make informed, safe short-term decisions and to effectively plan for the future of water in California to protect public health and safety and the environment.[10] The need for effective monitoring

[10] For details on how streamflow information is critical to decision-making by water managers at local, state and federal levels, see the issue brief on streamflow monitoring from UC Berkeley's Center for Law, Energy, & the Environment (Miller et al., 2018.).

and real-time information about streamflow is more critical than ever with California's extremely dynamic weather systems and the effects of climate change increasing the risk of floods, droughts and catastrophic weather events. While there are multiple platforms and databases focused on collecting and publishing stream gauge data, there are still significant gaps in the spatial resolution and the data collection and quality control methods of those platforms.[11] Data on streamflows are collected primarily by utilizing stream gauges measuring stage and then calculating an associated flow. There are several sources for stream data in California including: USGS, California Data Exchange Center (CDEC), and the California-Nevada River Forecast Center (CNRFC). The USGS currently operates a system of stream gauges in cooperation with federal, state, tribal and local agencies as part of its National Streamflow Information Program (Olson & Norris, 2007), which provides streamflow information for various purposes

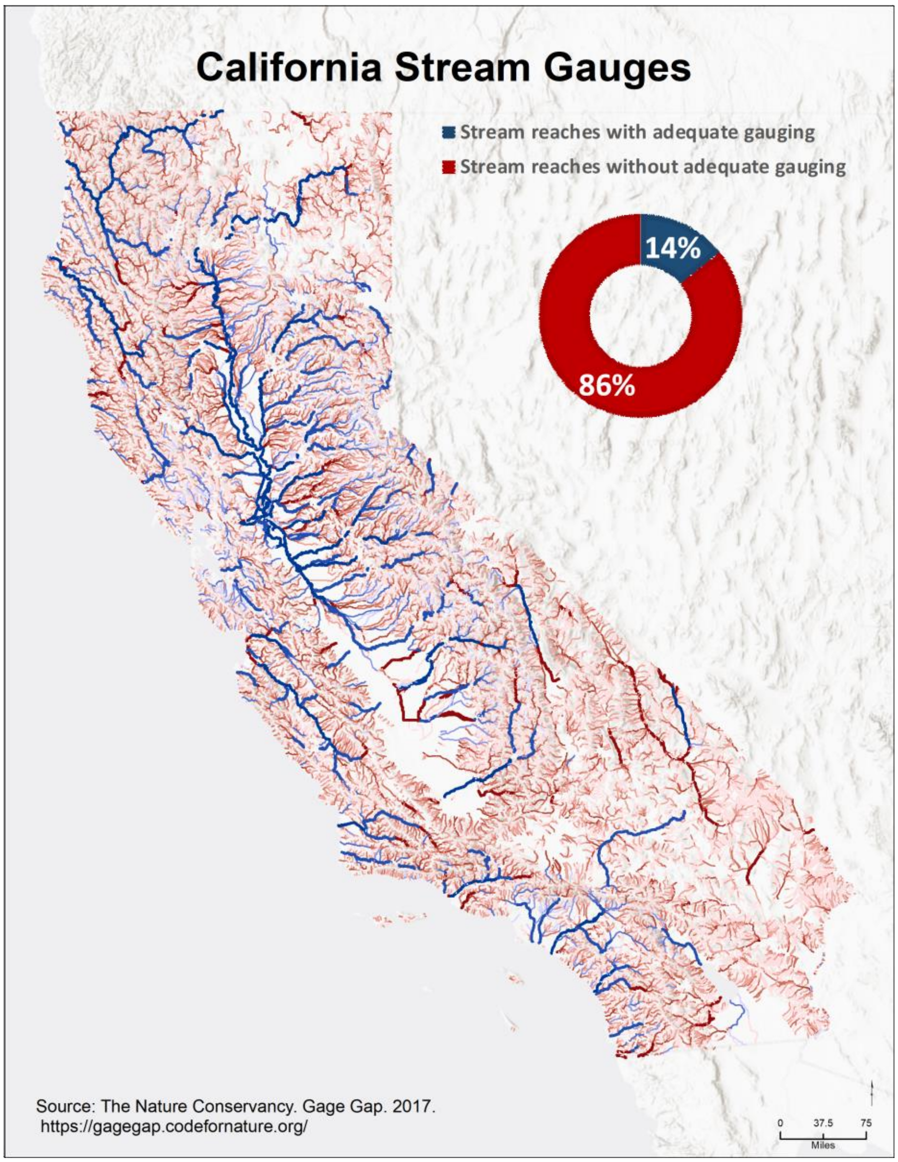

Figure 1, California Stream Gauges (TNC, 2018)

[11] An inventory of publicly available sources for water flow and quality may be found in Appendix B: Inventory of Existing California Water Data Platforms and Tools.

including flood prediction, water management and allocation, dam operation and recreational safety and enjoyment. USGS gauges measure streamflow and sometimes other conditions including turbidity, temperature, pH, flow rate, total dissolved solids (TDS) and salinity. Monitoring data from the USGS gauge network data are available through the USGS website in real time, and also are a subset of the gauges available on the CDEC. The CDEC also relies on partnering agencies to maintain and operate many of the more than 600 river gauges included on their data portal, more than 400 of which provide streamflow. CDEC data also are available in real time and are collected every hour, or in some cases every 15 minutes. The CNRFC focuses on real-time stage and precipitation data as they relate specifically to flood risks at around 100 locations within California. These three databases and related platforms provide fairly extensive geographic coverage for stream data within California, though there are areas and rivers where data is sparse or not available. Though each of these datasets is expected to be integrated into the AB 1755 statewide platform, the resulting dataset is not geographically

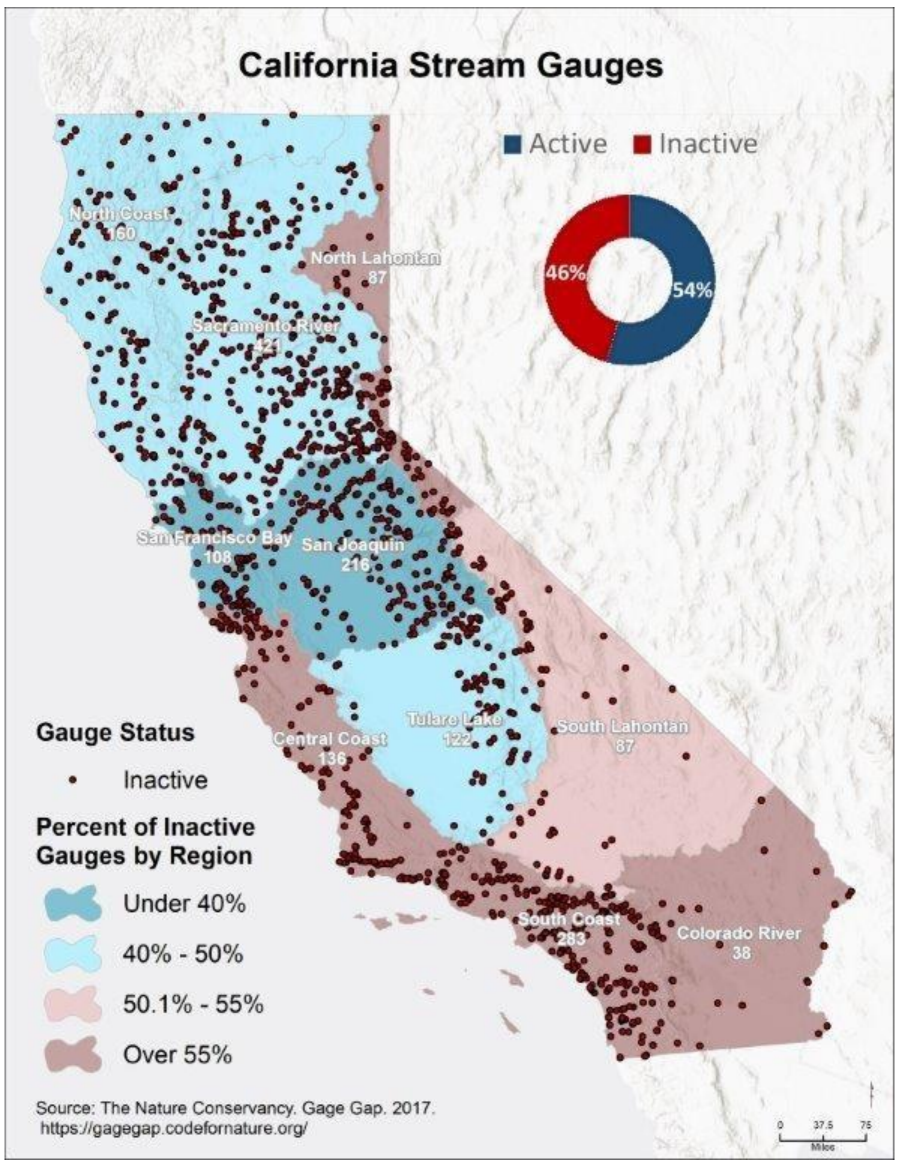

Figure 2, California Stream Gauges (TNC, 2018) uniform: For example, the Colorado River hydrologic region in the southeastern part of the state has considerably fewer gauges, as does much of the Sierra Nevada mountain range. Although many of California's largest waterways are currently monitored, data on how much water is moving through California's smaller waterways is insufficient for some purposes (The Nature Conservancy, 2018; Miller et al., 2018). Mapping by The Nature Conservancy (TNC) indicates that nearly half the stream gauges in California are now inactive and 86 percent of waterways are poorly gauged (The Nature Conservancy, 2018), and this proportion is increasing largely because of a lack of funding. A meager 14 percent of significant streams are considered "well-gaged" (The Nature Conservancy, "GageGap," 2017), and only a subset of gauges provide data in real time. Most USGS gauges only record stage, and regular field visits by qualified technicians are necessary for on-the-ground measurements to develop rating curves for accurate assessment of streamflow. Some private landowners install and maintain gauges, though they are not required to record and report data. Additionally, data type, quality and measurement standards vary depending on the private gauge operators.

This lack of uniformity presents management challenges. Understanding flows near diversion points on streams and rivers is critical in terms of managing water allocations and water accounting purposes. Expanding and standardizing streamflow data collection at diversion points would ensure consistency along a given basin or watershed and also would greatly increase the integrity of streamflow data when reviewed by diverters and others, facilitate efficient information sharing, reduce confusion and avoid costly duplication. This is especially important for developing consistent water balances across different management levels, ranging from local systems to larger river basins (Escriva-Bou, McCann, Hanak, Lund, & Gray, 2016). As individual data points, stream gauge utility may be limited; as a network, however, standardization at all points of diversion would help identify trends geographically.

Recommendation: *Improve the quantity and quality of water supply data by expanding and standardizing California's stream gauge data collection and distribution.*

As in any infrastructure program, identifying adequate funding remains a significant hurdle to the development of a standardized stream gauge system. A lack of funding is likely the greatest barrier because an effective, comprehensive network will be costly, and communicating its value to individual growers, smaller water districts and the public could be challenging. Additionally, without government mandates or incentive programs, it would be hard to require gauge installation.

Much of the cost associated with real-time stream gauging is the infrastructure to retrieve the data from the gauge. However, new technologies are being developed that could significantly lower the costs of real-time stream gauging. The USGS and Carnegie Mellon University are developing a new low-power, long-range wireless data transmission technology (LoRa). This new technology requires less infrastructure and power. In addition, each transmitter can cover more area, ranging up to five kilometers in urban areas, and up to 15 kilometers in rural areas. This can lower the barrier to entry cost, allowing many more projects and studies to add real-time capabilities. More importantly, low-cost, real-time deployments of large sensor networks can greatly enhance our understanding of water availability and ecosystem needs and provide situational awareness during floods, hurricanes and other disasters to prevent loss of life and property.

The majority of streamflow gauges within California watersheds are funded by cooperative agreements between local agencies and the USGS (Olson & Norris, 2007; The Nature Conservancy, 2017), which relies on annual funding appropriations made by Congress.[12] On average, each streamflow gauge costs approximately $16,300 and up to $26,500 for the USGS to manage annually (Weiser, 2017; Henson, Personal Communication). Political inertia also can pose barriers to the funding and implementation of gauge programs. In light of these challenges, local and regional agencies are increasingly managing installation and annual maintenance of stream gauges within their own watersheds.

[12] Federal budget control measures in 2013 significantly reduced funding for streamflow gauges. Federal budget appropriations for gauges are likely to be dependent on variable political dynamics and should not be relied upon as a funding source.

Investment in stream gauges has potential payoffs. For instance, expansion and standardization of gauges at diversion points would provide granularity and a specificity of information that could dramatically improve users' and stakeholders' understanding of (and ability to respond to) the supply and demand conditions of the system. A more expansive and standardized system of stream gauges also has the potential to enhance existing programs, adding layers of value to existing datasets and regulatory efforts. For example, to support SGMA implementation, additional data about surface water will be needed to assess the localized interactions between surface water and groundwater, such as diversion of surface water flows, surface water depletion from groundwater use, effects on groundwater dependent ecosystems and recharge of groundwater from streamflows. Additionally, the expanded stream gauge network has the potential to improve the transparency of the state's water balance sheet and help regulators identify and reduce unauthorized diversions. With that data both accessible and transparent, it could be used to (1) eliminate false reporting, (2) establish credibility for quantifying risks, benefits and tradeoffs of management decisions, (3) provide a framework for consensus building for water governance and (4) contribute to adaptive management strategies.

C. Focus on Regional Units to Develop Useful Data Frameworks for Water Management

A significant challenge water managers face related to water data is not a lack of data, but rather disparate sources, formats, quality and spatial scale or resolution. While various datasets related to water supply input and output exist, they are not always well organized for determining overall need and water availability at either a local or statewide scale. These datasets are diverse and varied: Water managers must rely on a panoply of platforms to analyze data related to issues such as water rights, water transfers, conservation, water leaks, urban water use, imports and diversions, consumptive use, etc. (Cantor et al., 2018, p. 28). Because of differences in the way that each responsible agency collects, stores, transmits and handles the information collected, many of these datasets provide a limited and incomplete view of the overall water budget for the system from which they are collected (Barrett & Green, 2015).

Recommendation: *To improve water management, focus on improving the collection, analysis, distribution and integration of data at the watershed level.*

In short, water managers need support when working to "connect the dots" between existing datasets, where units, intervals and standards of measurement may vary wildly across a single stream or watershed. Much of the initial work necessary to support decision-making at the watershed level will involve making those individualized datasets accessible and interoperable. With this challenge in mind, a key recommendation of this report is that dataset integration should be focused at a watershed level. For this particular task, the individual watershed presents a significant yet manageable scale for characterizing total surface and groundwater supplies and total urban, agricultural and environmental demands, with maximum utility for real-time integrated management decisions. As variable datasets are integrated across the watershed, these collectively maintained datasets have the ability to provide a more refined view of the water supply and demand picture and to enhance management on a watershed-by-watershed basis.

1. Watershed-Level Data Integration and Collection

A watershed-level approach to data collection and organization can focus data needs where they will provide the greatest return on investment, reduce uncertainty and foster greater stakeholder collaboration. This report recommends a three-pronged strategy:

- Enhance existing, agency-specific datasets or portals by ensuring their interoperability within the forthcoming federated network;
- Leverage emerging technology that offers spatially-complete, watershed-encompassing datasets; and
- Establish and incentivize partnerships within the watershed to improve data sharing and analysis.

Focusing data framework development at the watershed level has the added benefit of maximizing returns on investments in existing water projects and programs, while allowing for agility in planning as new management challenges arise. California's watersheds are diverse: Tailoring data collection and management at the watershed level allows managers and users to adapt quickly to the particular needs of that watershed. Moreover, by empowering stakeholders within the watershed to use data from multiple sources for their water planning and management needs, the sensitive balancing of competing demands within a watershed will be improved.

2. Paving the Way to Regional Success: Challenges in the Watershed Approach

The biggest challenges with implementing a watershed-based approach to data frameworks can be summarized simply as participation, leadership and funding. First, finding stakeholders within a particular basin who are willing to participate, share and enhance their data for interoperability may present challenges, particularly in basins where data collection is siloed among diverse groups or across incompatible technology platforms. Finding an entity that is able and willing to act as the leader or facilitator throughout the process of integrating watershed data will add an additional layer of complexity and constraints. The position of watershed leader will require a certain level of neutrality and trust amongst other stakeholders, and agencies that have already built this standing should be considered. In order to test the viability of this approach, an initial focus on watersheds with existing healthy partnerships should be used as first adopters. Finally, securing funding for a geospatially organized, open and interoperable data portal may require considerable coordination in the form of a cost share and/or grant applications which may be prohibitive in some instances. However, as with programs such as the Integrated Regional Water Management (IRWM) planning, or urban and agricultural water management planning, there may be options for state funding to serve as either a resource in the form of grants or an incentive in the form of eligibility for future grants once the process is complete. Furthermore, in-kind support from private corporations or foundations, such as Google Earth Engine (see Appendix B) and the Water Funder Initiative is already helping to bring open data platforms to fruition in certain arenas ("OpenET", n.d.).

3. Developments on the Horizon

Efforts to make datasets more accessible and interoperable are already underway, and it is anticipated that there will be a significant uptick in the amount and quality of data available to water managers over the course of the next five to 10 years. For example, the enactment of SB 88 in 2016 (which implemented an expanded monitoring and reporting program for surface water diversion in excess of 10 acre-feet (AF) annually) and SGMA will drive the generation of data not previously available in many watersheds.

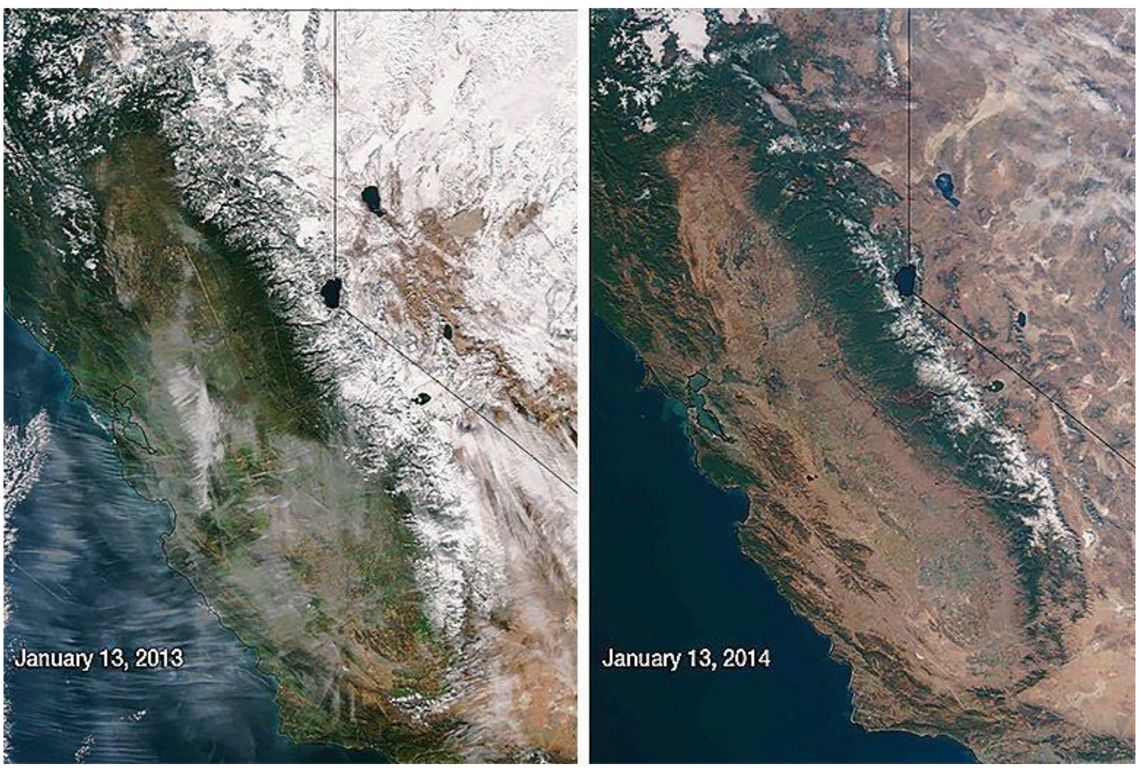

Figure 3, NASA Satellite Imagery of the Melting Sierra Snowpack (generated from ASO data; ASO, n.d.)

New technologies also afford an opportunity for improved understanding of a watershed's particular management concerns. Recent collaboration between DWR, regional water managers and the National Aeronautics and Space Administration (NASA) in the various applications of NASA's remote sensing technologies provides an excellent example for getting multiple stakeholders to coordinate at the regional level to improve data quality and availability. NASA's sophisticated data collection and processing tools are employed to create spatially-dense datasets that can describe an entire watershed with regard to variables such as snow water equivalent, snowmelt runoff, evapotranspiration and land subsidence. The enhancements to snowmelt data are particularly significant for water management in California as snowmelt accounts for a third of the state's water supply, and in some areas is critical to the management of the state's reservoirs (Serna, 2017). NASA's airborne techniques are working to support and expand traditional in-situ ground measurements that were previously extrapolated across vast swaths of land. The resulting datasets include geospatially referenced variables for existing and projected conditions and can be presented in a user-friendly interface on a regional scale. As spatially continuous, near real-time datasets are made available for mass consumption, decision-makers from throughout the watershed will have the ability to collaborate using widely accepted information. The highly applicable and available data makes watershed collaboration more convenient and valuable for all stakeholders and therefore more likely.

Despite improvements in data quality and availability, it will take time for new information to become adopted and incorporated and some data gaps will remain. Water managers can't afford to wait for perfect and all-encompassing information. If the water sector can connect the water budget dots at a regional level by enhancing existing datasets, leveraging new data collection efforts, and creating a geospatially searchable open data portal, water management decision making can move toward a data-driven approach that can reduce conflict, improve flexibility, increase transparency and maximize the use of limited investment in money and resources. Enhancing watershed-level understanding of datasets has real management payoffs for both surface water and groundwater systems. As SGMA is implemented and groundwater use becomes more regulated, the need for water management flexibility will increase, and having this watershed level data portal will improve the ability of Groundwater Sustainability Agencies (GSAs) to be successful. In addition, as many GSAs are already formed with multiple stakeholders and are working toward basin Groundwater Sustainability Plans (GSPs), including rigorous and detailed water accounting, there is an opportunity to utilize their framework and momentum to implement a regional data structure.

The availability of watershed-scale datasets also enhances water managers' ability to respond to and address "climate whiplash" (Swain, Langenbrunner, Neelin, & Hall, 2018), wherein water managers are asked to react to extremes of drought and then flooding from one year to the next. In line with this challenge, the Public Policy Institute of California (PPIC) recently recommended developing ecosystem drought plans at the watershed level in order to better prepare for and minimize the impacts of drought (Mount et al., 2018a, p. 16). There also were significant improvements in the water market exchanges in Victoria, Australia, when a regional planning approach was adopted (Mount et al., 2016). If an ecosystem drought plan were to be implemented at the watershed level and it were to produce similar results as those achieved in the Australian water market, there could be benefits not only for ecosystems but also for urban and agricultural water users. By inviting stakeholders within a common watershed to work with shared datasets, agencies will be better positioned to make swift yet calculated water management decisions that are tailored to their regions.

D. Refine Data Reporting Metrics to Better Manage for Ecosystem Needs and Adapt to Climate Change Uncertainties

Uncertainty in data collection and analysis is inevitable, and California's policymakers, water managers and users must grapple with these uncertainties in managing water for the benefit of the state, its ecosystem and future environmental challenges. Some of these uncertainties arise from variations in how water use datasets are categorized, defined and tracked, which can be challenging. The state will benefit from a robust data framework that will assist in more informed decision-making in response to these uncertainties. For instance, an improved understanding of environmental water uses and needs will allow better management of ecosystem needs and reduce uncertainties for other water users. While some of the use cases (Cantor et al, 2018) put forward by the AB 1755 Stakeholder Working Group touch on the following suggestions, opportunities remain to enhance and strengthen an improved understanding of environmental water uses and needs.

Recommendation: *Streamline data collection and reporting methods statewide to create a clearer understanding of water available for ecosystem needs.*

1. Define, Account for and Collect Water Data Related to Ecosystem Needs

Water needed for ecosystem function is poorly understood, and as a result, poorly or inconsistently accounted for throughout California. In many cases, the primary challenges are data availability, quality and consistency limitations. Lack of current, timely and transparent information on environmental and ecosystem water needs and uses complicates existing management efforts and confounds stakeholders' efforts to achieve certainty in their planning (Mount et al, 2018b).

The California Water Plan arises out of a statutory direction for "a plan for the orderly and coordinated control, protection, conservation, development, and utilization of the water resources" of California (Cal. Water Code § 10004 (Westlaw); California Department of Water Resources [DWR], 2018b). Updated on a five-year cycle by DWR, the plan contains (among other planning resources) portfolios and balances intended to "describe the distribution of water throughout the hydrologic cycle, water use by the urban and agricultural sectors, water in the environment, and water supply sources used to meet these uses" (California Department of Water Resources [DWR], 2017, p. 11; DWR, 2018b). These water portfolios and balances (which are generated across sub-units of counties and "detailed analysis units" (DAUs) and then aggregated to generate hydrologic region and statewide summaries) are intended "to estimate an accounting of all water that enters and leaves the state and how it is used in and exchanged between the regions" (DWR. 2017, p. 11). Those balances and planning assumptions provide an important foundation for other water-planning activities. The Water Plan Updates began to include environmental water use in these water balances in 2005. [13]

[13] In preparing the plan, DWR prepares estimates and assumptions related to (among other areas) environmental water needs, including regulatory instreamflow requirements, nonregulated instream uses and water needs by wetlands, preserves, refuges and other managed and unmanaged natural resource lands (Cal. Water Code § 10004.6 (Westlaw). For a detailed discussion of the assumptions and estimates upon which the 2018 update to the California Water Plan will be based, see https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/California-Water-Plan/Water-Plan-Updates/Files/Update-2018/Water-Plan-Update-2018-Draft-Assumptions-and-Estimates-Report.pdf.

Because of the California Water Plan's important role in water planning, this report focuses on some key improvements that, if implemented, would enhance the utility of the Water Plan and its included environmental water balances for purposes of water management and planning.

Case Study: Airborne Snow Observatory

The San Joaquin River Basin Airborne Snow Observatory (ASO) pilot program provides an example of a successful watershed level data collection effort. The pilot program was launched in 2017 and is overseen by NASA's Jet Propulsion Laboratory (JPL) in coordination with United States Department of Agriculture-Agricultural Research Service (USDA-ARS), regional water managers, DWR, and USBR. By using airplane-mounted LIDAR and imaging spectrometer technologies, depth of a snowpack and albedo measurements are calculated into volume and rate of snowmelt projections. The highly accurate, spatially contiguous data and information provided by the ASO program has improved the predictions of snowmelt runoff in the Sierra Mountains from margins of error that were sometimes greater than 40 percent — due to sparsely spaced weather stations, snow gauges and impassable terrain — to less than 2 percent (Osenga, 2017).

Environmental Water Categories. Managing streamflows for ecosystem objectives requires three basic sets of data: the characterization of the natural flow regime, the current (potentially altered) flow regime and an estimate of how much of a departure from the natural flow regime is acceptable for a set of ecological indicators (Zimmerman et al., 2018). The California Water Plan captures traditionally understood environmental water uses into four categories of applied water use:[14] Federal and state "wild and scenic" rivers, required Delta outflows, instreamflows and managed wetlands (California Department of Water Resources [DWR], 2014 Fig. 3-10; California Department of Water Resources, n.d.)[15]. These categories, however, do "not distinguish between outflow used to maintain water quality for diversions and outflow required to protect ecosystems" (Mount et al, 2018b, p. 2). Because a single acre-foot of water may, at various

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[14] Applied water use as described in the California Water Plan "represents the total amount of water diverted from any source to meet the demands of water users, without adjusting for water that is used up, returned to the developed supply, or irrecoverable. Applied water is the quantity of water delivered to the intake to a city water system, a factory, or a farm headgate, either directly or by incidental flows to a marsh or wetland for wildlife areas. For existing instream use, applied water demand is the portion of the streamflow dedicated to instream use or reserved under the federal or State Wild and Scenic Rivers acts or the flow needed to meet salinity standards in the Sacramento-San Joaquin Delta under State Water Resources Control Board standards." (California Department of Water Resources [DWR], 2013, p. 2).

[15] This accounting challenge has been recognized in multiple forums. Indeed, one goal of the 2013 Water Plan Update was to "Improve methods for representing consumptive and non-consumptive environmental water and where water reuse is occurring" (2013 Water Plan Update, p. 4-28).

points in its journey downstream, be used and re-used in multiple categories, these distinctions do not always adequately capture applied water use.[16]

Accounting. Environmental water needs also vary according to the ecosystem served, and this presents accounting and planning challenges as well. Mount et al. (2018b) and Gartrell, Mount, Hanak, and Gray (2017) have suggested four categories for Delta inflow to be utilized in water accounting: 1) Water Diversions: Water used for in-Delta diversions; 2) System Water: Outflow needed to meet salinity standards for in-Delta diversions and exports; 3) Ecosystem Water: Outflow to meet ecosystem regulations; and 4) Uncaptured Water: Water that results in outflow because of a lack of capacity for diversion. According to Mount et al. (2018b) and Gartrell et al. (2017), when these categories are used, it is possible to have a more accurate portrayal of ecosystem water use in the Delta ecosystem. For example, during the recent drought (water years 2012 through 2016), average ecosystem water accounted for less than

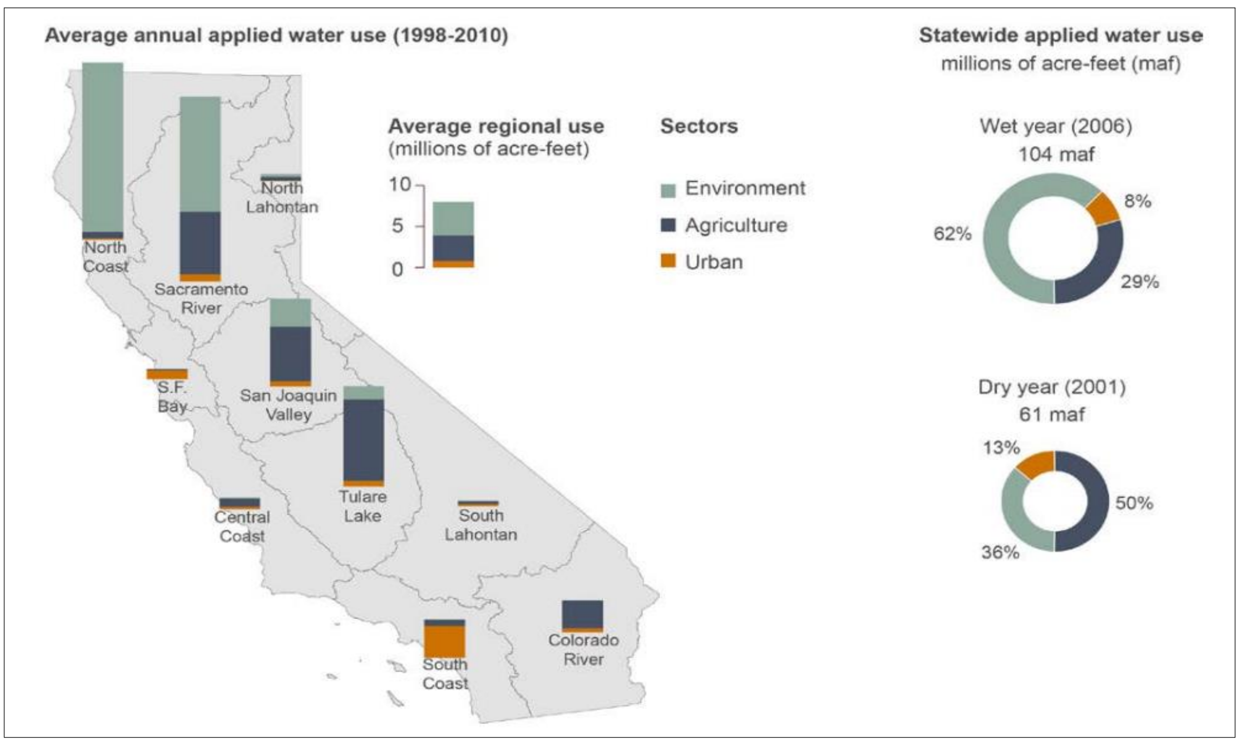


Figure 4, California Water Plan Water Use Categories (Gartrell et al., 2017)

[16] This accounting challenge has been recognized in multiple forums. Indeed, one goal of the 2013 Water Plan Update was to "Improve methods for representing consumptive and non-consumptive environmental water and where water reuse is occurring." (DWR, 2014, p. 4-28).

19 percent of Delta outflow — and in the driest year, 2015, it accounted for less than 7 percent of total outflow — versus 51 percent for system water (Mount et al., 2018b).

Water for environmental use from 1998 through 2010 averaged roughly 50 percent of total applied water use. (Gartrell et al., 2017; California Department of Water Resources [DWR], 2018f). "In public debates, the 50 percent share for the environment is sometimes used to illustrate how much water environmental regulations cost other water users" (Gartrell et al., 2017, p. 6). However, this 50 percent statistic does not demonstrate to the public that depending on the amount of runoff for a given year "the volume and share of environmental water" changes. [17](Gartrell et al., 2017, p. 6). For example, in wet years, environmental water represents a larger portion of water use (62 percent in 2006) and has limited effect on other uses. (Gartrell et al., 2017, p. 6). In addition, this statistic can be confusing to the public as it "does not distinguish among types of environmental water use, some of which do not conflict with other water uses." (Gartrell et al., 2017, p. 6). For example, wild and scenic rivers are mainly located along the North Coast, "where there are no alternative uses and little controversy exists over the rivers' protected status" (Gartrell et al, 2017, p. 6). Additionally, "a large portion of flows in upstream segments of Wild and Scenic Rivers in the San Joaquin Valley" are designated "as environmental water use, even though these river segments flow into reservoirs used for downstream water supply" (Mount et al., 2018b, p. 2).

There also are gaps in monitoring the smaller streams that are important for environmental flows (Escriva-Bou et al., 2016). Streamflow data is measured by gauges, and as discussed in an earlier section of this report, about 46 percent of stream gauges in California are currently inactive (The Nature Conservancy, 2017) and only about 14 percent of significant stream segments (drainage area of 5 km^2 or more) gauges remain well-gauged (TNC, "GageGap," 2017). Inactive gauges are problematic because a good understanding of historic trends (approximately 20 years or more) and real-time flow conditions are important for accurate monitoring, modeling, and prediction of flow conditions to inform decision making as extreme

[17]The regional reports from the 2013 Water Plan Update, containing annual water use and water supply balances for the various categories tracked by the California Water Plan, can be found here: https://water.ca.gov/Programs/California-Water-Plan/Water-Plan-Updates.

events become more frequent and catastrophic due to climate change (Miller et al., 2018; The Nature Conservancy, 2018). As a biodiversity hot spot, California should modernize by hosting a centralized, real-time environmental water monitoring system at a river basin scale. A first step could be to re-establish watershed-wide streamflow gauges (see more about management and funding challenges in Section A, above). Additionally, a well-gauged stream network is essential preparation for climate change and the expected resulting increase in extreme weather events, with longer droughts and more extreme floods.

Across the state, great work is underway in structuring a framework to organize in-stream functional flow targets by UC Davis, The Nature Conservancy, UC Berkeley, and the USGS (Zimmerman et al., 2018; Yarnell et al., 2015). Lane, Dahlke, Pasternack, and Sandoval-Solis (2017) characterized streamflow regimes by volume across the state and made the data available on eFLOWs, a website that allows users to explore and visualize unimpaired streamflow patterns, natural stream classes, and functional flow metrics. (See Figure 5.)

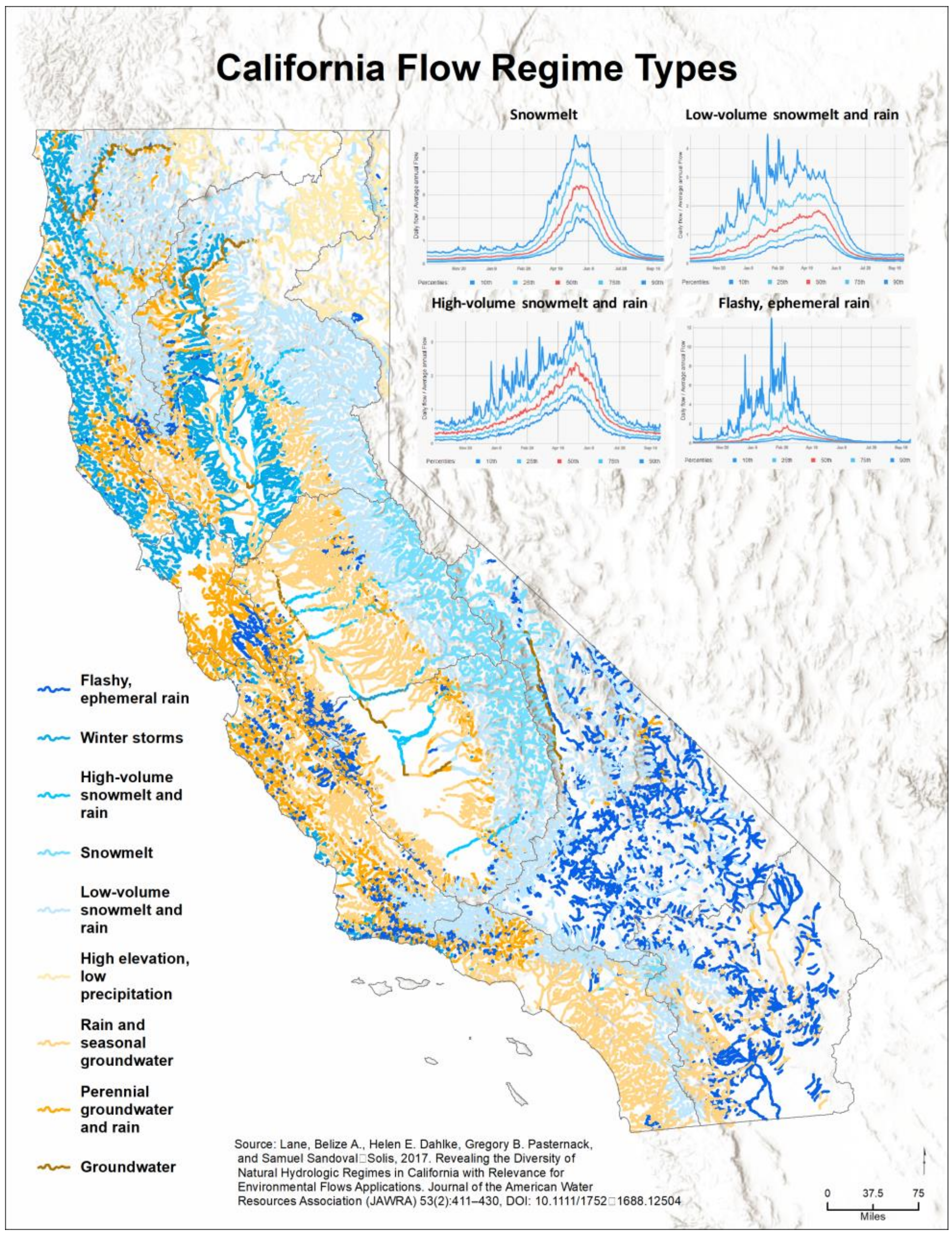


Figure 5, Hydrologic Regimes in California (generated from eFLOWS data; Lane et al., 2017)

Additionally, estimates of unimpaired flow in all Californian streams and rivers are available in the California Natural Flows Database. More recently, Zimmerman et al. (2018) evaluated the frequency and magnitude of streamflow alteration statewide, finding that 68 percent of gauges showed both depleted and inflated flows. (See Figure 6.) These efforts provide a hydrologic foundation to support decision-makers in developing strategies to understand and define ecosystem water budgets and quantifying environmental water needs within a watershed. A more robust data network could assist in being able to better track, and therefore provide greater clarity in water categorization and accounting, leading to more informed decision-making.

Timeliness. Water management, especially during droughts, requires accurate and timely data on water use and availability. Without comprehensive data on streamflow, for instance, there's no way of knowing how much water is available or whether environmental needs are being met as to a given stream or system (TNC, "GageGap," 2017). Though it serves important management functions in other ways, the most recent update to the California Water Plan was issued in 2013, and it evaluated water use from 1998 to 2010.[18] As a result, no real-time estimate of environmental water use was available during the recent five-year drought or during 2017, one of the wettest years on record. These long lags in water use estimates are especially challenging for water managers, who must make real-time decisions in the public arena.

Recommendation: *Modernize statewide environmental water use tracking systems for timely, up-to-date accounting.*

2. Manage for Uncertainty by Creating Innovative and Adaptive Approaches

Climate change is and will continue to introduce profound uncertainties to water management as changes in snowpack, sea level and river flows accelerate. In a 2016 article, Climate Change and the Delta, Dettinger et al. describe these uncertainties arising from how climate systems will respond to increases in greenhouse gas emissions, interactions with California's natural

[18] The 2018 Water Plan update is currently underway https://water.ca.gov/Programs/California-Water-Plan/Water-Plan-Updates.

hydroclimatic variability from climate phenomena like El Niño and the Pacific Decadal Oscillation, and the management choices that will need to be made. Adaptive management involves monitoring relevant variables, analyzing outcomes, and using feedback information to modify management decisions to better protect natural resources and is widely embraced as a framework to address uncertainty associated with climate change (Delta Stewardship Council [DSC], 2016). In order to function efficiently and accurately, adaptive management must be based on data from monitoring systems that will enable detection of ecological regime shifts and inform integrated modeling used to inform management actions. Cal-Adapt.org synthesizes downscaled climate change projections and climate impact research into visualization tools, data and resources that decision-makers can access. California's Fourth Climate Change Assessment also provides the latest data and tools, as well as technical reports on water (Governor's Office of Planning and Research, California Natural Resources Agency, & California Energy Commission, n.d.). See Appendix B for a list of current data management tools.

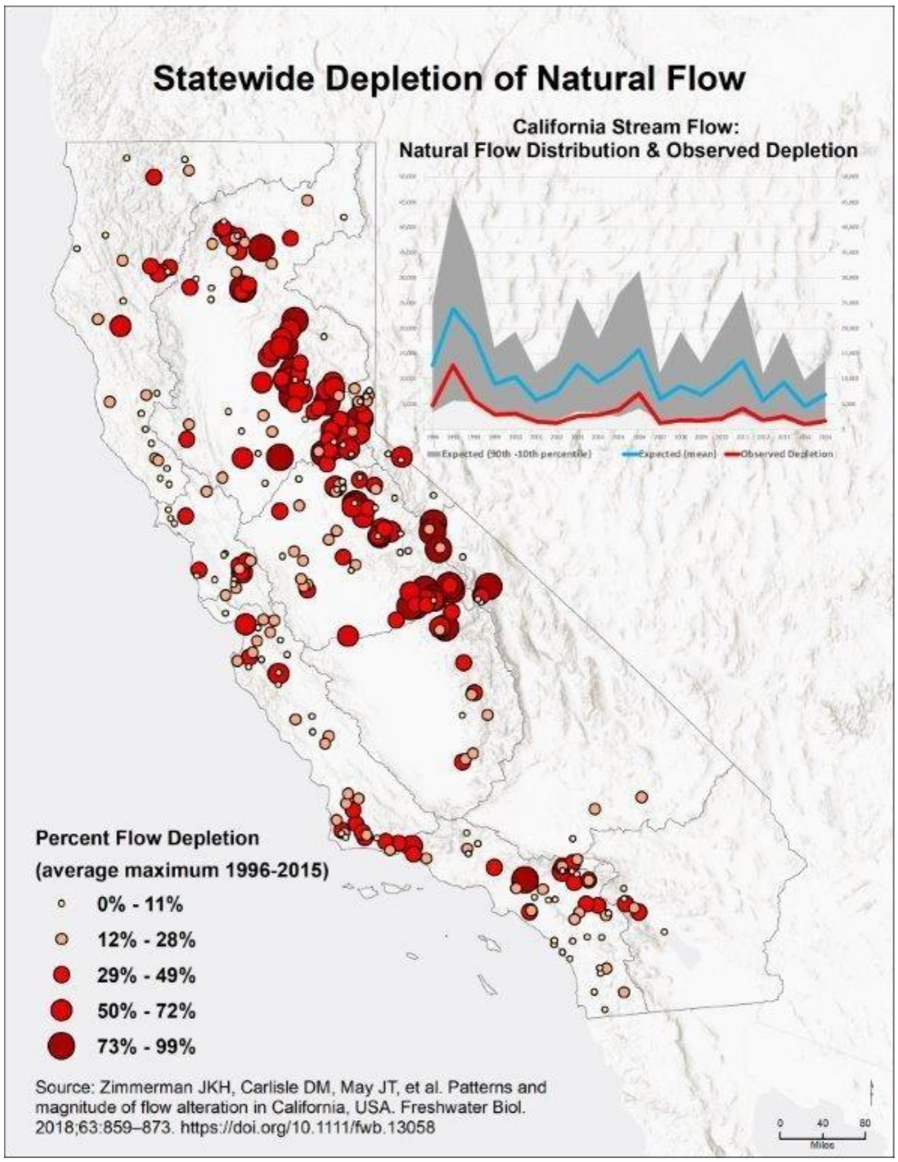


Figure 6, California Flow Depletion (generated from Tableau data; Zimmerman et al., 2018)

In the Delta region specifically, scientists and policymakers are using adaptive and flexible management tools that are responsive to the emergence of new models and trends related to climate change effects. A synthesis of more than 200 journal articles and technical reports on climate change as it relates to ecosystem restoration was conducted by the DSC in early 2018 to support the Delta Plan Ecosystem Amendment (Delta Stewardship Council [DSC], 2018). The synthesis paper acknowledged that data needs and uncertainties related to climate change are fundamental challenges for policy decisions. Adaptive management provides a way for natural resource managers to track changes in real time, allowing for quick modifications to management of our state's ecosystems and water systems, and should be considered more frequently by managers when adapting to a changing climate.

Data Success Stories: Reducing Subsidence & Improving Reliability

In the San Joaquin Valley, shared data allowed a community to respond and develop local scale solutions to mitigate the impact of subsidence and enhance water supply reliability at the same time. In 2016, the monitoring network for Triangle T Water District, based in Chowchilla, California, observed a change in ground elevation indicating land subsidence near an area of recent development, and notified the adjacent landowner. The landowner in turn was able to take quick action to arrest and prevent further subsidence. From this initial intervention, local stakeholders engaged to address the condition, and the water supply issues underlying it. The Eastside Bypass Conveyance Project, a flood-managed aquifer recharge project, also arose from this collaboration. This project facilitates groundwater recharge and mitigates the chronic lowering of groundwater levels that result in land subsidence, resulting in both increased reliability of supply and a reduction in land subsidence.

A good example of adaptive management in California is a dynamic conservation program called "BirdReturns" implemented by TNC to help address the shortage of waterbird habitat. The Central Valley is the linchpin of the Pacific Flyway, one of the last great migratory routes. With 95 percent of California's historic wetlands lost to agriculture and development, migrating waterbirds have very few places to stop to rest and refuel on their long migrations, which can stretch from Alaska to Patagonia. BirdReturns uses data-intensive models to predict habitat needs. Crowdsourced data from Cornell's eBird app, which provides information about bird migration patterns, are combined with water availability satellite data compiled by NASA to estimate the locations and timing of the greatest habitat need (Golet et al., 2017; Reynolds et al., 2018; Hallstein, 2014). Instead of purchasing land and/or water rights for ecosystem benefits that would cost billions of dollars, TNC uses a market-based approach that compensates private landowners, through a reverse-auction bid selection process, for creating "pop-up" or temporary wetlands on agricultural fields when and where birds need them most (Golet et al., 2017; Reynolds et al., 2018; Hallstein, 2014). The program is based on big data analytics and precision science that inform management actions. This integrated and flexible approach is providing solutions to an ecologically complex and ever-changing situation. BirdReturns demonstrates how collaboration and adaptation can create dynamic and flexible management that responds to some of the state's most pressing environmental uncertainties and can serve as a model for how water managers can adapt to a changing environment. Using data to understand nature's needs, and reallocating water to flexibly meet those needs, also has enormous potential to help meet critical freshwater conservation needs throughout the world.

E. Empower Water End-Users with Data and Tools

Data — when relevant, actionable and accessible — can help end-users and stakeholders make better decisions about future water use and management. Data is actionable when it is organized in a format that enables decisions to be made with greater efficacy. Different end-users require access to various forms of actionable data. For purposes of this policy recommendation, end-users represent a broad list of stakeholders and include residential and industrial water customers, farmers, segments of the general public and others. By collecting, analyzing, and providing information to end users, water professionals obtain

Data Success Stories: Improving Water Efficiency and Crop Yield

In lieu of visual field observations, soil moisture probes can inform farmers of field conditions in real time, right on their smartphones. Such data enables farmers to irrigate more efficiently, adapting their watering schedules to the conditions and needs of their crops. Fisher Ranch, for example, has been using remotely accessible probes in its fields near Blythe, Calif., for the past three years. Comparing past irrigation data to soil moisture probe information, the farmers were able to better identify crop needs, adjust irrigation accordingly and improve crop yield as a result.

information that can be integrated into decision-making tools and/or processes, potentially improving the quality of water management on both a regional and statewide level.

At the individual user level, water issues become relevant to people when they have a connection to the data. So, to enable better decision making, data must also be presented in a way that is relevant to the needs of decision-makers (Cantor et al., 2018). To evaluate some of these needs, Cantor et al. (2018) examined 20 use cases.[19] These use cases will be used in the development of the functional requirements needed for the implementation of AB 1755 and inform design and protocols to increase usability of the data portal (Cantor et al., 2018).[20]

Research illustrates how data can be used to educate people on water issues and even encourage behavior change. Therefore, the water sector should support policies and programs with the goal of making actionable data available to various end-users to increase engagement while simultaneously helping to guide the most relevant water use and management decisions.

> ***Recommendation:*** *The water sector should support policies and programs with the goal of making actionable data available to various end-users to increase engagement while simultaneously helping to guide the most relevant water use and management decisions.*

1. Focus on Creating Tools That Empower Users

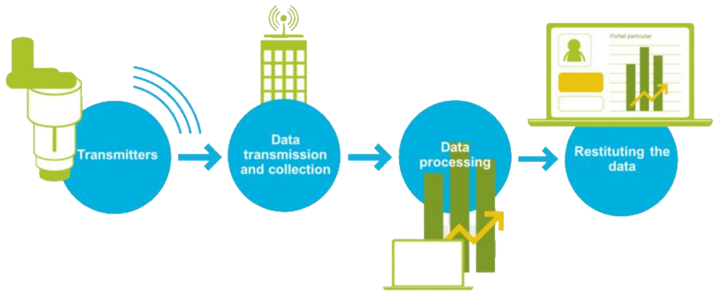
The following are recommendations and examples of how, based on existing case studies, the water sector can prioritize the development of tools, empower water users and improve water management.

Embrace creative partnerships. The water sector should collaborate with entities from other industries (such as tech companies) to utilize their advanced data analysis technologies and expertise. Moulton Niguel Water District, for instance, partnered with Netflix to better

[19]Use cases "describe water decision-making processes and the data needs associated with those processes" and cover a diverse range of water management topics, from groundwater recharge to urban water management plans and management of flows to protect salmon habitat (Cantor et al., 2018, p. 21).

[20] "The 20 draft use cases are a starting point for the kinds of decisions to which the evolving federated, interoperable open data portals of AB 1755 must respond" (California Department of Water Resources [DWR], 2018, p. 5.).

understand customer water usage. The water district was planning to construct a seasonal storage facility (at great expense to the district and its customers) to meet customer demands during peak periods. It worked with Netflix to build algorithms to evaluate real-time water usage and found that peaks in usage were driven by a small set of customers.



The water district then reached out to those customers and encouraged them to change the timing of their water usage. Water users complied, and as a result of their behavior change, Moulton Niguel avoided the cost of building the new water tank – a savings of $20 million. This unique partnership was brought about through DataKind, an organization that connects volunteer data scientists with organizations in need of help for projects that serve the greater good (Lohan, 2017). The success of this partnership highlights the opportunity for the water sector to pursue similar collaborations that bring unique perspectives to water data analysis and provide a greater level of insight on water consumption to both water agencies and water users.

Embrace civic technology. The water sector should focus on the

Data Success Stories: Reducing Residential Water Waste

The City of Sacramento Department of Utilities partnered with Badger Meter to employ a network of digital smart meters to motivate residential end-users to curb their water waste. For 19 months, a sample group of more than 8,000 households received a "Water Focus Report" detailing the household's monthly water use in comparison to similar homes within the city. The greatest water savings were achieved within the first three months following receipt of the reports, and were between 8-11 percent less per month than the control group. Further, above average water users reduced their consumption by 15 percent. In parallel, a second study was conducted, where the city granted access to more than 1,200 customers to the EyeOnWater (EOW) web-based portal. The portal dashboard, accessible via smart phone, not only displayed real-time water use but also included leak alerts and a bill-pay option. In the three months following sign-ups, the average duration of leaks was reduced from 29 to 19 days.

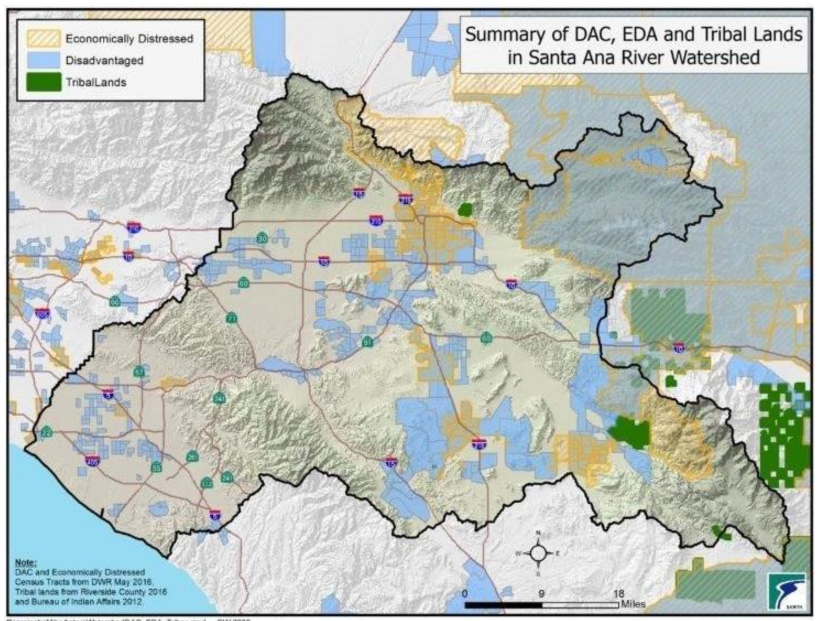
development of easy-to-use apps that engage water users. Increasingly, technology is being used to connect people to their government and to improve the efficiency of government programs. The CalFresh food stamp program, for example, found that many people started but failed to complete its lengthy online application. Code for America developed an app that enables users to apply for CalFresh benefits on their mobile phones in just minutes, resulting in increased participation in the program (Code for America, n.d.). Water-related apps could show water users their consumption in real time or help them find and apply for water efficiency rebates.

Some technologies in the water industry currently exist to educate consumers about their usage. For instance, many water agencies already use WaterSmart and Dropcountr software platforms, which provide customers with metrics on how their water use compares to neighbors and other similar households. Similar innovative applications of data could be developed and expanded through partnerships with groups like Code for America or by hosting hack-athons and data challenges focusing on how the general public can use water data.

Engage citizen scientists. Much like the Cornell Lab of Ornithology has been doing for years with the Great Backyard Bird Count and eBird, the water sector should foster citizen science programs in which members of the general public assist in the collection of scientific data, thereby engaging more people in water issues and expanding resources for data collection. For example, "Catch the King" GPS data collection effort focused on mapping the Virginia King Tide's maximum inundation extents in places like Virginia Beach and the Chesapeake Bay. An online map directed volunteers to public places that were forecast to flood; during the actual king tide, volunteers provided GPS data points while tracing the high-water line. This citizen science effort became the largest flood-related crowdsourcing data event in the world (Virginia Institute of Marine Science, n.d.).

Account for bottom-up, community-based data development. The water sector should support policies and programs that approach water management from the bottom-up to increase community engagement in decision making. Specifically, the water sector should invest in emerging water-management, decision making frameworks that integrate community-based qualitative data. This is particularly true from a water conservation perspective. While conservation initiatives – in the form of rebates, incentives and services – often are prioritized according to water-use patterns and monetary return-on-investment, they can overlook equitable solutions that account for diversity of end-users. A first-of-its-kind effort currently underway and led by a team of researchers from UC Irvine is seeking to bridge this gap by demonstrating the value of integrating qualitative data into the water planning process. The three-year, $6.3 million project supported by the Santa Ana Watershed Project Authority's (SAWPA) Disadvantaged Community Involvement Program and DWR Proposition 1 grant funding are aimed at generating a community water ethnography for underserved segments within the Santa Ana Watershed (Kearns, 2018).

This entails engaging citizens to assess their collective qualitative strengths and needs around water management, and in turn incorporate their feedback into decision-making models. This bottom-up framework has the potential to arrive at more locally relevant water management solutions that make benefits more equitable.

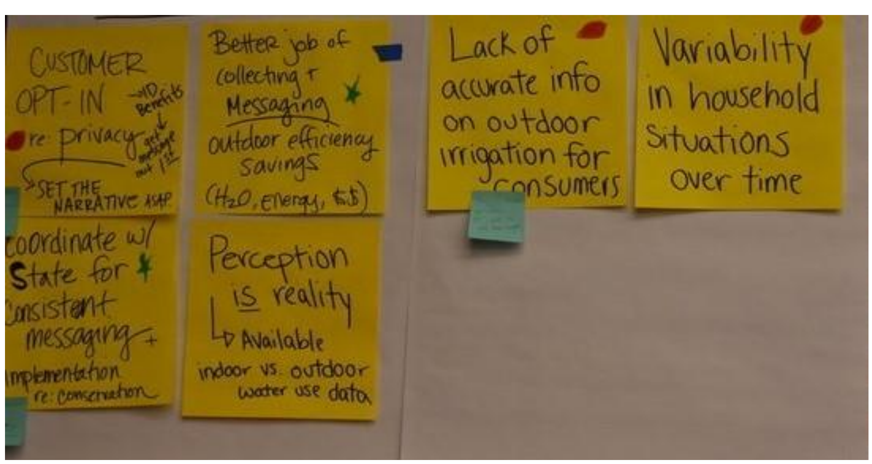


Support the development of open-source software. The water sector should support the development of model software that is open sourced and released for use by an open-source license, which provides the terms, definitions and uses for the software. Open-source software encourages wide adoption and use of developed products that support community sharing of enhancements and derivative works (Morin et al., 2012). Proceedings from the Science Enterprise Workshop support this recommendation by acknowledging that both the use of open-source software and promotion of data standards are necessary for the usefulness and "longevity of integrated modeling" (DSC, 2018). Numerous iterations of computer-based water management tools can be released within a relatively short time-frame. This rapid technological evolutionary time-scale, so to speak, necessitates the need for open-source software platforms. The complexity of watersheds and aquifers, as well as the diversity of stakeholder interests, calls for flexible and adaptable modeling tools that can be viewed, modified, changed and expanded to encompass new or evolving fields of interest (such as new climate change and sea level rise analysis techniques, hydrodynamic impacts of levee improvements or failures and restoration). In addition, by supporting open-source software, the water sector can leverage advancements in technological tools and datasets.

2. Barriers and Challenges to User Engagement

While improved technology and resources for obtaining and distributing water data are available, there are still a number of barriers and challenges to broad adoption of such resources.

Technological Limitations. Many of the technologies discussed in this report are new and emerging, and without a proven track record, many users are reluctant to adopt them. With many new technologies, early versions are often expensive and not highly accurate. This barrier can be overcome through the development of policies that support early adoption of beneficial technologies and support the development and testing of these technologies through pilot studies.



Data Interpretation and Analysis. Many types of water data have an inherent level of nuance and technical knowledge required to fully under-stand their meaning. As already indicated in the report, providing raw data may be easy to do, but doing so may not result in actionable information. Additionally, to provide processed and analyzed data can require an amount of specialized expertise and is consequently expensive and potentially time-consuming. These barriers can be overcome by developing standardized protocols for analysis and visualization of data focused on the specific end use/decision it is intended to support.

Funding and Implementation. Implementation of these technologies on a broad, statewide scale can be tremendously expensive and questions of funding sources can be very complex. In general, users are willing to adopt and share data when they see a direct benefit to themselves or they are required to by regulation. Even when one or both of these drivers exist, it may not be feasible to implement. Similarly, even when funding is available for the initial implementation of a new technology in the field, for the data to be available and reliable, consideration also should be made for funding its continued operation, maintenance and replacement as equipment ages over time. Therefore, for any and all such policies, funding and partnerships with an eye to the future are essential to successful implementation.

III. Conclusion

California faces many water management challenges. As discussed throughout this report, reliable, accessible and usable data is integral to the effective management of California's water resources. Under the Open and Transparent Water Data Act, DWR has been given the monumental task of creating and implementing a centralized, integrated data platform, in which data is openly and actively shared with stakeholders. This data platform, in turn, is an opportunity to assist stakeholders in making more informed water management decisions. The policy recommendations discussed in this report are intended to guide data management and the ultimate shaping of this data portal, with the end goal of improving water management through this valuable tool. The time is now for water users at all levels, environmental advocates, regulatory agencies and all other stakeholders to come together to address the challenges data presents in California water management.

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Appendix A: Assembly Bill No. 1755, The Open and Transparent Water Data Act

An act to add Part 4.9 (commencing with Section 12400) to Division 6 of the Water Code, relating to water data.

Approved by Governor September 23, 2016.

Filed with Secretary of State September 23, 2016.

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS: SECTION 1. Part 4.9 (commencing with Section 12400) is added to Division 6 of the Water Code, to read:

PART 4.9. The Open and Transparent Water Data Act

CHAPTER 1. General Provisions

12400. This part shall be known, and may be cited, as the Open and Transparent Water Data Act.

12401. The Legislature finds and declares all of the following:

(a) The recent drought reveals that California needs to integrate existing water and ecological data into an authoritative open-access platform to help water managers operate California's water system more effectively and help water users make informed decisions based on water availability and allocation.

(b) State and federal leadership, increased awareness by business, governmental, and nongovernmental organizations through open and transparent access to data, and improved technology and availability of open-source platforms create a unique opportunity that California should seize upon to integrate and increase access to existing water data.

(c) California is working to increase access to water data collected by state agencies. The state board is piloting a project to make water quality datasets available online through an open data portal. The portal creates an opportunity to foster collaboration among state agencies, share and integrate existing datasets, improve state agency operations through data-driven decisionmaking, and improve transparency and accountability.

(d) State agencies should promote openness and interoperability of water data. Making information accessible, discoverable, and usable by the public can foster entrepreneurship, innovation, and scientific discovery.

(e) Water data and information technology tools and applications developed and gathered using state funds should be made publicly accessible. State delegation of data management to contractors should not result in the public losing access to its own information.

(f) The availability of open-source tools makes it easier to access and explore water and ecological data and could facilitate the creation of an online integrated water data platform without the need to create an expensive new centralized database.

12402. Unless the context otherwise requires, the following definitions govern the construction of this part:

(a) “Department” means the Department of Water Resources.

(b) “Metadata” means data that describes data.

(c) “Platform” means the statewide integrated water data platform described in Section 12415.

(d) “State board” means the State Water Resources Control Board.

CHAPTER 2. Statewide Water Data Integration
Article 1. General Provisions

12405. The department, the state board, and the Department of Fish and Wildlife shall coordinate and integrate existing water and ecological data from local, state, and federal agencies. The purposes for integrating water and ecological data include, but are not limited to, providing adequate information to implement the Sustainable Groundwater Management Act (Part 2.74 (commencing with Section 10720)), improving the management of the state’s water resources, and bringing greater transparency to water transfers and the market.

12406. (a) The department, in consultation with the California Water Quality Monitoring Council, the state board, and the Department of Fish and Wildlife, shall develop protocols for data sharing, documentation, quality control, public access, and promotion of open-source platforms and decision support tools related to water data. The department shall develop and submit to the Legislature, in compliance with Section 9795 of the Government Code and by January 1, 2018, a report describing these protocols. The report shall be developed in collaboration with the California Water Quality Monitoring Council, the state board, the Department of Fish and Wildlife, relevant federal agencies, and interested stakeholders, including, but not limited to, technology and open data experts and water data users.

(b) Recipients of state funds through grants or contracts for research or projects relating to the improvement of water or ecological data shall, as a condition of the receipt of a grant or contract, adhere to the protocols developed pursuant to subdivision (a) for data sharing, transparency, documentation, and quality control.

(c) A grant or contract recipient that does not comply with subdivision (b) is not eligible for state funding until the grant or contract recipient complies with those requirements.

Article 2. Statewide Integrated Water Data Platform Creation

12410. (a) The department, in consultation with the California Water Quality Monitoring Council, the state board, and the Department of Fish and Wildlife, shall create, operate, and maintain a statewide integrated water data platform in accordance with Section 12415 and the following schedule:

(1) By January 1, 2018, the department shall do both of the following:

(A) Make public the protocols developed pursuant to Section 12406.

(B) Publish a strategic plan for data management to guide the implementation of this part.

(2) By April 1, 2018, the department shall release any request for proposals necessary for the development of a statewide integrated water data platform.

(3) (A) By September 1, 2019, the department shall make available existing water and ecological data held by state agencies on the platform.

(B) The department shall quarterly add the information described in subparagraph (A) not available as of September 1, 2019, that becomes available at a later date.

(4) (A) By August 1, 2020, the department shall make available on the platform available water and ecological data related to California water supply and management that is held by the following agencies:

(i) The United States Bureau of Reclamation.

(ii) The United States Fish and Wildlife Service.

(iii) The National Oceanic and Atmospheric Administration.

(iv) The United States Geological Survey.

(v) The United States Forest Service.

(B) The department shall quarterly add the information described in subparagraph (A) not available as of August 1, 2020, that becomes available at a later date.

(5) By August 1, 2020, the department shall make available on the platform any other existing information listed in Section 12415.

(b) The department may partner with an existing nonprofit organization, with a new nonprofit organization that the department creates, organized under paragraph (3) of subsection (c) of Section 501 of Title 26 of the United States Code, or with another state agency to create, operate, or maintain, or any combination thereof, the platform.

(c) Notwithstanding subdivision (a), the department may enter into an agreement with an existing nonprofit organization, with a new nonprofit organization that the department creates, organized under paragraph (3) of subsection (c) of Section 501 of Title 26 of the United States Code, or with another state agency for that nonprofit organization or state agency to create, operate, or maintain, or any combination thereof, the platform.

(d) The Department of Technology is deemed to have delegated to the department any authority over the implementation of this part granted to it pursuant to Section 11546 of the Government Code.

(e) Nothing in subdivision (a) shall prevent a state agency from disseminating, managing, or publishing data separately from the platform.

Article 3. Statewide Integrated Water Data Platform Features

12415. The statewide integrated water data platform created pursuant to Section 12410 shall, at a minimum, do all of the following:

(a) Integrate existing water and ecological data information from multiple autonomous databases managed by federal, state, and local agencies and academia using consistent and standardized formats.

(b) Integrate the following datasets, as available:

(1) The department’s information on State Water Project reservoir operations, groundwater use, groundwater levels, urban water use, and land use.

(2) The state board's data on water rights, water diversions, and water quality through California Environmental Data Exchange Network (CEDEN).

(3) The Department of Fish and Wildlife's information on fish abundance and distribution.

(4) The United States Geological Survey's streamflow conditions information through the National Water Information System.

(5) The United States Bureau of Reclamation's federal Central Valley Project operations information.

(6) The United States Fish and Wildlife Service's, United States Forest Service's, and National Oceanic and Atmospheric Administration Fisheries' fish abundance information.

(c) Provide data on completed water transfers and exchanges, including publicly available or voluntarily provided data on the volume, price, and delivery method, identity of the buyers and sellers, and the water right associated with the transfer or exchange.

(d) Provide documentation of data quality and data formats through metadata.

(e) Adhere to data protocols developed by state agencies pursuant to Section 12406.

(f) Be able to receive both spatial and time series data from various sources.

CHAPTER 3. Water Data Administration Fund

12420. (a) The Water Data Administration Fund is hereby created. All moneys in the fund are available, upon appropriation, to the department, the state board, or the Department of Fish and Wildlife for the collection, management, and improvement of water and ecological data for the purposes of this part.

(b) The Department of Finance shall develop a standardized agreement to allow for the voluntary donation to the fund by any person, educational institution, government entity, corporation or other business entity, or organization.

Appendix B: Inventory of Existing California Water Data Platforms and Tools

Airborne Snow Observatory (ASO)

https://aso.jpl.nasa.gov/

Developed by NASA and JPL, in partnership with DWR, the ASO provides "an imaging spectrometer and scanning lidar system, to quantify [snow water equivalent] and snow albedo, generate unprecedented knowledge of snow properties for cutting edge cryospheric science, and provide complete, robust inputs to water management models and systems of the future." (NASA. *About Us*. Retrieved from https://aso.jpl.nasa.gov/.)

Bay Delta Live

https://www.baydeltalive.com

Bay Delta Live is a collaboration aimed at "expanding open and transparent sharing of information essential in understanding the complex and dynamic ecosystem of the Sacramento-San Joaquin Bay Delta." It provides information from multiple sources using enhanced visual interfaces, and is supported through contributions from federal, state, and local agencies. (Bay Delta Live. *About BDL*. Retrieved from https://dev.baydeltalive.com/wiki/16804.)

Biogeographic Information and Observation System (BIOS)

https://www.wildlife.ca.gov/data/bios

BIOS is designed to enable the management, visualization, and analysis of biogeographic data collected by CDFW and its partners. BIOS also facilitates data sharing and "GIS, relational database management, and ESRI's ArcGIS Server technology to create a statewide, integrated information management tool that can be used on any computer with access to the Internet." (CDFW. *Biogeographic Information and Observation System (BIOS)*. Retrieved from https://www.wildlife.ca.gov/data/bios.)

Cal-Adapt

https://cal-adapt.org/

Cal-Adapt is designed to provide access to the voluminous climate change data produced by California's scientific and research community, and offers insight into how climate change may impact the state at the local level. Cal-Adapt provides visualization tools, data, and avenues for community participation. Cal-Adapt's creation originated from a recommendation of the 2009 California Climate Adaptation Strategy. (Cal-Adapt. *About Cal-Adapt*. Retrieved from https://cal-adapt.org/about/.)

California's Fourth Climate Change Assessment

http://www.climateassessment.ca.gov/

California's Climate Change Assessments bolster the scientific foundation for analyzing climate-related vulnerability at the local scale and inform state and local resilience actions, policies, plans, programs and guidance. The website also provides the latest data and tools, as well as technical reports on water. (California's Fourth Climate Change Assessment. *What is the Climate Assessment?* Retrieved from http://www.climateassessment.ca.gov/.)

California Data Exchange Center (CDEC)

https://cdec.water.ca.gov/

CDEC is managed by DWR and serves as a centralized database to "store, process, and exchange real-time hydrologic information," including data from automatic snow reporting gauges and precipitation and river stage sensors. (DWR. *Welcome to the California Data Exchange Center.* Retrieved from https://cdec.water.ca.gov.) According to DWR, "[t]he data collected by CDEC enable forecasters to prepare flood forecasts and water supply forecasts; reservoir and hydroelectric operators to schedule reservoir releases; and water suppliers to anticipate water availability." (DWR. *CDEC Brochure.* Retrieved from https://cdec.water.ca.gov.)

California Department of Water Resources Land Use Viewer

https://gis.water.ca.gov/app/CADWRLandUseViewer/

DWR developed this tool to provide technical assistance to GSAs and other water managers throughout California. It allows GSAs and the public to easily access both statewide and existing county land use datasets that have been collected over the last 30 years. There are also a variety of tools that will allow users to download and analyze land use data. (DWR. *Launch of the California DWR Land Use Viewer*. Retrieved from https://gis.water.ca.gov/app/CADWRLandUseViewer/.)

California Environmental Data Exchange Network (CEDEN)

http://ceden.org/

Managed by the SWRCB, CEDEN provides "a central location to find and share information about California's water bodies, including streams, lakes, rivers, and the coastal ocean." A party collecting water quality data in California is able to submit such data to CEDEN via four regional data centers, with guidance on data templates and detailed documentation. CEDEN then provides an aggregated clearinghouse for environmental managers and the public to access this data.

(SWRCB. (March 2016.) *California Environmental Data Exchange Network Fact Sheet*.)

California Estuaries Portal

http://californiaestuaryportal.com/

The California Estuaries Portal is a collaboration among numerous federal and state agencies, as well as non-governmental organizations. In addition to providing background information on various estuary topics, the centralized portal is used to host management tools, data dashboards and visualization capabilities aimed at helping resource managers make informed environmental decisions. (California Estuaries Portal Workgroup. *California Estuary Portal*. Retrieved from http://californiaestuaryportal.com/.)

CalFish and Other Fish Data Sets

http://www.calfish.org/ProgramsData/Species/CDFWAnadromousResourceAssessment.aspx

CalFish is "a multi-agency cooperative program designed to gather, maintain and disseminate anadromous fish and aquatic habitat data, and data standards." The CalFish website includes links to a variety of information including "life history and species accounts, population trends, habitat data, barrier data, distribution information, and hydrography data," as well as enabling "visualization of the spatial distribution of these datasets." (CalFish. *CalFish FAQ*. Retrieved from http://www.calfish.org/AboutCalFish/FAQ.aspx.)

Other sources of fisheries data are available as follows:

http://www.calfish.org/ProgramsData/Species/CDFWAnadromousResourceAssessment.aspx

https://flowwest.github.io/cvpiaHabitat/reference/index.html
http://oceanview.pfeg.noaa.gov/shiny/FED/CalFishTrack/
https://flowwest.shinyapps.io/sac-valley-dashboard/
http://www.spk-wc.usace.army.mil/plots/california.html
https://fishsciences.shinyapps.io/dsm2-velocity-map/
https://calfishtrack.github.io/real-time/pageLSWR.html
http://oceanview.pfeg.noaa.gov/CVTEMP/

California Irrigation Management Information System (CIMIS)

https://cimis.water.ca.gov/

Aimed at helping irrigators better manage water resources, CIMIS is a DWR-managed network of over 145 automated weather stations. These stations collect weather data on a minute-by-minute basis. (DWR. *CIMIS Overview, Introduction.* Retrieved from https://cdec.water.ca.gov.)

California Nevada River Forecast Center (CNRFC)

https://www.cnrfc.noaa.gov/

Located in Sacramento, the CNRFC is a field office of the National Weather Service (NWS), which is an agency of the National Oceanic Atmospheric and Administration under the U.S. Department of Commerce. The mission of NWS field offices is to provide flood forecasting and basic hydrologic forecasting information aimed at improving the nation's environmental and economic well-being. This mission is accomplished through continuous hydrometeorological data assimilation, river basin modeling and hydrologic forecast preparation. (NWS. *Forecasts and Service*. Retrieved from https://www.weather.gov/about/forecastsandservice.)

California Open Data Portal

https://data.ca.gov/

The Government Operations Agency sponsors data.ca.gov, a statewide open data portal created to improve collaboration, expand transparency and lead to innovation and increased effectiveness. The Agency's open data efforts support data analysis and using existing data to improve state operations. While several state agencies host their own open data portals, data.ca.gov was designed specifically to host open data from more than one agency. The Government Operations Agency is in the process of linking each of the existing state portals, so that all of the state's open data sets can be searched from https://data.ca.gov.

California Statewide Groundwater Elevation Monitoring (CASGEM)

https://water.ca.gov/Programs/Groundwater-Management/Groundwater-Elevation-Monitoring--CASGEM

CASGEM is a publicly available portal with water surface elevation and depth to groundwater data from thousands of wells statewide. It was a critical precursor to SGMA and continues to serve as a tool to achieve SGMA's mandates. (DWR. *Groundwater Monitoring – CASGEM*. Retrieved from https://water.ca.gov/Programs/Groundwater-Management/Groundwater-Elevation-Monitoring--CASGEM.)

Dreamflows

http://www.dreamflows.com/index.php

This privately maintained website aggregates publicly available stream and reservoir data and uses this data to estimate streamflow at particular locations. Dreamflows maintains a database with real-time flow information for select rivers in California and Nevada, as well as a database called "Fantasy Flows" which offers future flow predictions.

EcoAtlas

https://www.ecoatlas.org/

Hosted by the San Francisco Estuary Institute, EcoAtlas is a collaboration among numerous federal, state and local agencies, as well as non-governmental organizations. EcoAtlas is comprised of maps and other tools aimed at facilitating effective wetlands management by "integrating stream and wetland maps, restoration information, and monitoring results with land use, transportation, and other information." (San Francisco Estuary Institute. *EcoAtlas*. Retrieved from https://www.ecoatlas.org/.)

eFLOWS

https://eflows.ucdavis.edu/

Hosted by a group of University of California, Davis scientists, academics and researchers, eFLOWS "is designed to enable the management, visualization, and analysis of biogeographic data collected by CDFW and its partners." (eFLOWS. *eFLOWS.* Retrieved Nov. 2, 2018 from https://eflows.ucdavis.edu/.)

Electronic Water Rights Information Management System (eWRIMS)

https://www.waterboards.ca.gov/waterrights/water_issues/programs/ewrims/

Developed and managed by the SWRCB, eWRIMS is a public online portal used to track and disseminate information on state water rights. eWRIMS can be used to access information provided by surface water users through various state-mandated filings such as Statements of Diversion and Use, Permit Progress Reports, License Reports and certificates/registrations for small irrigation, small domestic and stockpond use. (SWRCB. *eWRIMS – Electronic Water Rights Information Management System.* Retrieved from https://www.waterboards.ca.gov/waterrights/water_issues/programs/ewrims/.)

Natural Communities Commonly Associated with Groundwater Dataset

https://gis.water.ca.gov/app/NCDatasetViewer/#

SGMA and its implementing regulations require the identification of groundwater dependent ecosystems (GDEs) and, in certain cases, mitigation of impacts to GDEs. GDEs are defined as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." DWR created this dataset to assist GSAs in the preparation and implementation of groundwater sustainability plans pursuant to SGMA. (DWR. *Natural Communities Commonly Associated with Groundwater Dataset*. Retrieved from https://gis.water.ca.gov/app/NCDatasetViewer/#.)

OpenET

https://etdata.org/

Currently under development, the OpenET platform and web application will provide low-cost, automated and widely accessible evapotranspiration (ET) data available at user-defined scales and timeframes. The platform uses data from multiple satellites and employs an ensemble of trusted methods to calculate ET. The project team includes NASA, Environmental Defense Fund, Google, the Global Water Security and Sanitation Partnership and the Desert Research Institute. (OpenET. *OpenET,* Retrieved Nov. 2, 2018 from https://etdata.org/.)

Reclamation Water Information System (RWIS)

https://water.usbr.gov/RWISmap.php

RWIS is a pilot version of a system for disseminating United States Bureau of Reclamation (USBR) data through a centralized online portal. As of publication, the RWIS site includes a map, a query tool that can be narrowed by parameter or site, and an API that can be used to automate retrieval of datasets for use in models or applications. (USBR. *What is RWIS?* Retrieved from https://water.usbr.gov/aboutrwis.php.)

SacPAS

http://www.cbr.washington.edu/sacramento/

This online portal is maintained by the Columbia Basin Research program at the University of Washington's School of Aquatic and Fishery Science. It provides "a publicly accessible, web-based query and reporting system of historical and current fish, environmental, and hydrologic information, vital to year-round planning and adaptive management of the Central Valley Project and State Water Project." (Columbia Basin Research. *Data Queries and Alerts*. Retrieved from http://www.cbr.washington.edu/sacramento/data/.)

Surface Water Ambient Monitoring Program (SWAMP)

https://www.waterboards.ca.gov/water_issues/programs/swamp/

Managed by the SWRCB, SWAMP's mission is "to provide resource managers, decision-makers, and the public with timely, high-quality information to evaluate the condition of all waters throughout California." (SWRCB. *SWAMP – Mission*. Retrieved from https://www.waterboards.ca.gov/water_issues/programs/swamp/mission.html.) SWAMP was created in response to 1999 legislation requiring a comprehensive monitoring program covering all California surface waters. In particular, SWAMP is aimed at proving ambient data that fills gaps left by compliance-based data collection narrowly aimed at fulfilling regulatory requirements. (SWRCB. (Dec. 2014.) *Review of the Surface Water Ambient Monitoring Program (SWAMP) SWAMP RR-SB-2014-0001*.)

USBR Central Valley Operations Office

https://www.usbr.gov/mp/cvo/

USBR's Central Valley Operations Office maintains a website that offers current daily and historic information on CVP Reservoir Operations, Water Quality Reporting, Flow Schedules and Project Deliveries. (USBR. *Central Valley Operations*. Retrieved from https://www.usbr.gov/mp/cvo/.)

Water Use Efficiency Data (WUEdata)

https://wuedata.water.ca.gov/

Administered by DWR, this is an online submittal tool for water managers as well as a means for the public to access urban water management plans, water loss audit reports, and agricultural water management plans. (DWR. Water Use Efficiency Data. Retrieved from https://wuedata.water.ca.gov/.)