FROM THE GROUND DOWN

Understanding Local Groundwater Data Collection and Sharing Practices in California

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Stanford | Water in the West

Stanford Law School
Martin Daniel Gould Center for Conflict Resolution

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About Water in the West

Water in the West is a partnership of the faculty, staff and students of the Stanford Woods Institute for the Environment and the Bill Lane Center for the American West. The mission of Water in the West is to design, articulate, and advance sustainable water management for the people and environment of the American West. Linking ideas to action, we accomplish our mission through cutting-edge research, creative problem solving, collaboration with decision-makers and opinion leaders, effective public communications and hands-on education of students. To learn more visit waterinthewest.stanford.edu.

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The Martin Daniel Gould Center for Conflict Resolution is located at Stanford Law School. The Center is the home for both the Gould Negotiation & Mediation Program and a series of research projects on a range of negotiation, public policy, and system design applications including sustainable groundwater management, online dispute resolution, and international comparative dispute resolution.

Cover photo and inside front cover photo courtesy of Chris Austin. Inside back cover image courtesy of the Bureau of Reclamation.

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LIST OF ACRONYMS

C2VSim	California Central Valley Groundwater-Surface Water Simulation Model
CVHM	Central Valley Hydrologic Model
DWR	California Department of Water Resources
GD	Groundwater-Dependent
GDE	Groundwater-Dependent Ecosystems
GSA	Groundwater Sustainability Agency
GSFLOW	Coupled Groundwater Surface Water Flow Model
GSP	Groundwater Sustainability Plan
GW	Groundwater
GW-SW	Groundwater-Surface Water
IGSM	Integrated Groundwater and Surface Water Model
InSAR	Interferometric Synthetic Aperture Radar
IWFM	Integrated Water Flow Model
MODFLOW	Modular Groundwater Flow Model
NGO	Nongovernmental Organization
SGMA	Sustainable Groundwater Management Act
SW	Surface water

1 EXECUTIVE SUMMARY

Groundwater provides up to 60 percent of California's water supply, contributes to stream flow, and supports many ecosystems. Despite its importance, groundwater went unregulated until passage of the Sustainable Groundwater Management Act (SGMA) in 2014. This legacy resulted in fragmented management, inconsistent data and a broad range of management outcomes, which will make meeting the new legislation's requirements a long and arduous task for many groundwater basins.

In the fall of 2015, Stanford University's Water in the West Program and The Gould Center for Conflict Resolution conducted a groundwater data survey to (1) learn more about the current groundwater data collection, use and sharing practices across the state, and (2) identify some of the common data-related challenges that local groundwater agencies are likely to face during SGMA implementation.

The results of our survey suggest that a variety of regulatory and policy actions could substantially improve the quality of data collected by local agencies for sustainable groundwater management.

Examples of our recommendations for local agencies include:

1. **Expand or develop groundwater monitoring well networks.** One-third of survey respondents with wells in their management area did not have a dedicated groundwater monitoring well network.
2. **Use the authority given under SGMA to monitor private production wells.** Only slightly more than half of respondents consider the geographic coverage (54 percent) of groundwater level data to be adequate for decision-making purposes. Using more private wells for monitoring purposes would improve spatial coverage.
3. **Use the authority given under SGMA to implement groundwater extraction metering.** Nearly 30 percent of survey respondents to an open-ended question indicated the need for groundwater extraction data. Groundwater extraction information is a critical component of water budget and groundwater model development.

Examples of our recommendations for state and federal agencies include:

1. **Require local groundwater management agencies to use consistent, state-developed data collection and monitoring standards and a common data-sharing platform to enable data integration across regions.** Nearly 60 percent of survey respondents to an open-ended survey question indicated the need for standardized data collection methods and a common data sharing platform.
2. **Develop a statewide advisory committee to provide guidance on data collection technologies and other data-related topics.** Some 40 percent of survey respondents plan to use geophysical methods or satellite-based methods for groundwater management in the next three to five years. This committee would advise the state and groundwater management agencies on geophysical methods, technologies and other data-related topics.
3. **Require the use and reporting of geophysical borehole logs in new wells.** Some 63 percent of survey respondents have used geophysical borehole logs for groundwater management. These logs provide objective information about subsurface conditions that can be used for improved basin characterization.

Results from this survey suggest that many local agencies across California already have a strong foundation on which to build their groundwater monitoring networks for sustainable groundwater management, albeit with significant gaps. As agencies move toward the basin-scale coordination requirements under SGMA, it will be increasingly important that agencies focus on acquiring data using consistent collection and monitoring protocols to ensure that data can be readily integrated and shared.

2 OVERVIEW

Groundwater provides up to 60 percent of California's water supply, contributes to stream flow and supports many ecosystems. Despite its importance, groundwater went unregulated until passage of the Sustainable Groundwater Management Act (SGMA) in 2014. This legacy resulted in fragmented management, inconsistent data and a broad range of management outcomes (Nelson, 2012), which will make meeting the new legislation's requirements a long and arduous task for many groundwater basins.[1]

Improving "data collection and understanding about groundwater" is an explicit goal of SGMA (Cal. Water Code § 10720.1(f)). Groundwater data and the development of robust groundwater monitoring and management are key components of the groundwater sustainability plans (GSPs) that are at the heart of the legislation (Cal. Water Code § 10727.2). SGMA requires GSPs to include data on recharge areas, groundwater levels, groundwater quality, subsidence and groundwater–surface water interaction (Cal. Water Code § 10727.2). Agencies must also develop monitoring protocols designed to generate information that promotes efficient and effective groundwater management (Cal. Water Code § 10727.2(f)). These monitoring protocols must focus specifically on detecting changes in groundwater levels, water quality, land surface subsidence, and flow and quality of interconnected surface waters. In basins where these issues apply, the statute requires additional plan elements on saline water intrusion, wellhead protection areas, contaminant transport and remediation efforts, well construction and/or destruction policies, conservation efforts, conjunctive use or underground storage, and impacts on groundwater-dependent ecosystems.

Given the existing inconsistency in groundwater data collection and monitoring protocols, meeting the legislated monitoring and management requirements will be a slow and contentious process in many basins. In some cases, groundwater sustainability agencies (GSAs), the agencies tasked with GSP development and implementation, will need to plan and build groundwater monitoring networks largely from the ground up, often with limited existing information about their basin's subsurface geology or groundwater conditions. Many basins will have to do so facing limited resources and the looming threat of groundwater adjudication if local groundwater pumpers object to management actions.

There are additional concerns about how to coordinate and integrate datasets at the scales necessary for sustainable groundwater management. SGMA attempts to overcome the fragmented nature of groundwater management by requiring basins to develop GSPs that use the "same data and methodologies" for core plan elements including monitoring networks and the monitoring objectives, water budget and the basin's sustainable yield (Cal. Code of Regulations, Title 23 § 357.4(b)(3)). Emergency regulations adopted on June 1, 2016, also require multiple GSAs within the same groundwater basin to develop a "coordinated data management system" (Cal. Code of Regulations, Title 23 § 357.4(e)).

The legislative mandates of basin-scale coordination required under SGMA are a significant step forward for integrated water management. However, integration of existing water and ecological datasets at the state-level, as intended in Assembly Bill 1755 ("The Open and Transparent Water Data Act") — currently before the California legislature, will require water management agencies at all levels to develop and use consistent, transparent water monitoring protocols that enable data integration across all regions. Additionally, it will require agencies to develop the financial, technical and human capacity to support consistent, ongoing groundwater monitoring and management efforts.

1 This report uses the term basin to refer to a basin or subbasin identified in the California Department of Water Resources' Bulletin 118 report.

2.1 Survey Motivation

The survey was developed by Stanford University's Water in the West Program and The Gould Center for Conflict Resolution and was conducted in the fall of 2015 with two main goals. Firstly, we wanted to gain a more comprehensive understanding of current groundwater data collection, use and sharing practices across different regions and groundwater management types within California. Secondly, we sought to identify some of the common data-related challenges that local groundwater agencies are likely to face during SGMA implementation. Our goal was to use this information to inform the state's development of regulations and best management practices[2] for sustainable groundwater management, and to provide guidance for GSAs during GSP development.

This report presents preliminary survey results and findings. More detailed survey analysis will be released in a series of reports and academic publications that combine survey results with key findings from a four-part groundwater data workshop series developed with the California State University Sacramento's Center for Collaborative Policy and hosted at Stanford University between November 2015 and October 2016.

2 Under SGMA, DWR must publish best management practices for sustainable groundwater management of groundwater by January 1, 2017.

3 GROUNDWATER DATA SURVEY RESULTS

The survey asked respondents questions on a broad range of groundwater data–related issues, including (1) perceptions of SGMA; (2) current data collection and monitoring practices, including the types of data collected, the number and types of monitoring wells, data needs and perceived data adequacy; (3) groundwater model use; (4) the current and anticipated use of geophysical methods in data acquisition; and (5) groundwater data communication. Survey responses declined slightly for later sections of the survey. As a result, survey statistics were calculated for each survey section. Details of respondent numbers by survey section are available in Appendix A of the companion document, Supplemental Appendices.[3] A complete list of survey questions can be found in Appendix B of the companion document, Supplemental Appendices.

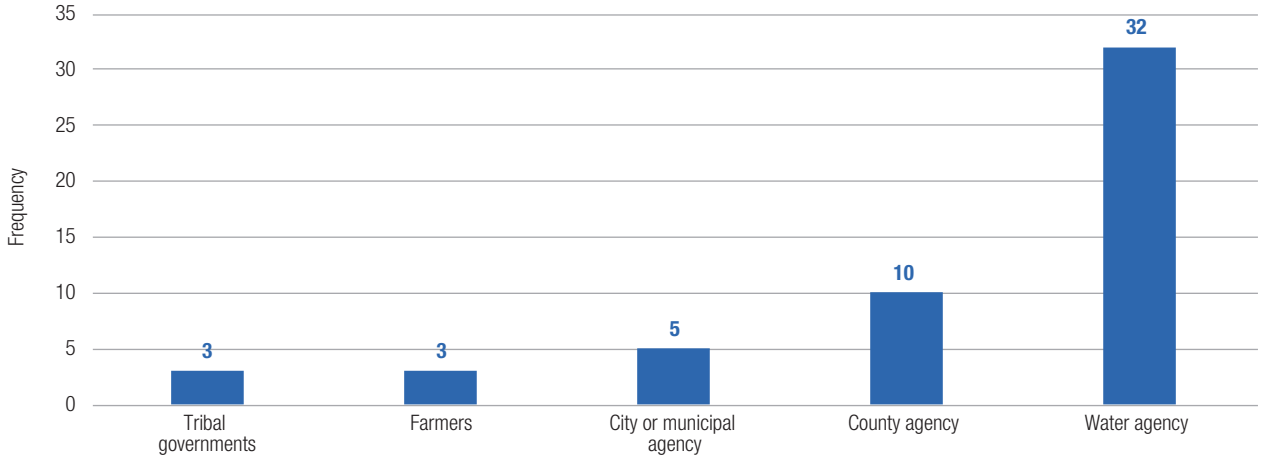
3.1 Survey Respondents

The survey was distributed via email through two listservs: the California Department of Water Resources (DWR) Sustainable Groundwater Management Program listserv and the Groundwater Resources Association of California listserv.

It reached a broad range of individuals involved in groundwater management, including state and federal employees, consultants, water agency employees, city or municipal agency employees, employees at NGOs and foundations, tribal governments and farmers. However, because this report focuses on developing recommendations to help local groundwater management agencies during GSP development and implementation, we have chosen to focus our analysis on survey respondents with management authority over a specific jurisdictional area. This includes (1) water agency employees (including irrigation districts, reclamation districts, water districts, water conservation districts, water replenishment districts, water storage districts, water works districts, special act districts and joint powers authorities); (2) city or municipal agency employees; (3) county agency employees; or (4) respondents who selected "Other" who indicated significant ties to water management (i.e., tribal governments and farmers) and provided groundwater basin and well information. Some 50 respondents fit the above criteria (Figure 1).

Figure 1. Survey Respondents by Role

Frequency of survey respondents by agency type or sector role (n=50). Responses are not mutually exclusive. Survey respondents self-selected their role in groundwater management.



3 Supplemental Appendices can be found at *http://waterinthewest.stanford.edu/sites/default/files/AppB_DataSurvey_Questions.pdf*

Individuals who did not have management authority over a specific jurisdictional area were not included in this analysis. As a result, the analysis does not include survey respondents who identified as consultants, state or federal agency employees, or foundation or NGO employees. Future analyses will present findings from these respondents.

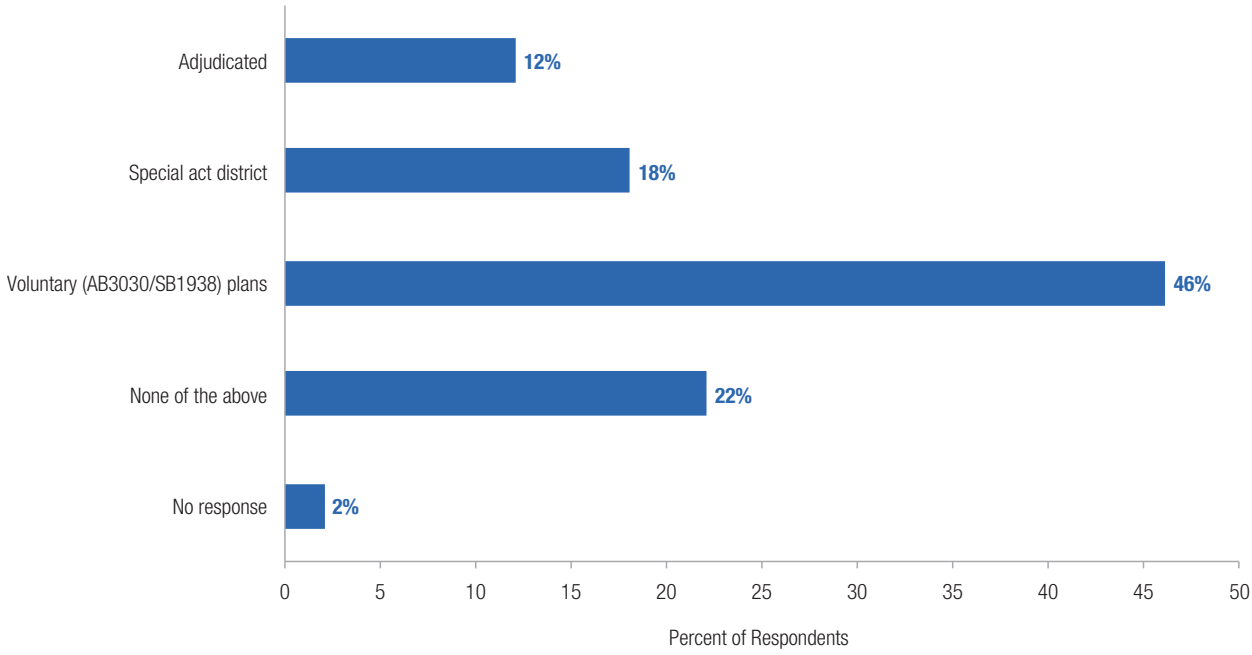
3.2 Groundwater Management Type and Jurisdictional Area

3.2.1 Groundwater Management Type

Survey respondents represented a range of groundwater management types (Figure 2). Some 76 percent of survey respondents represented areas managed under a formal groundwater management program (a special act district, an adjudicated basin or an AB3030 or SB1938 groundwater management plan). Some 22 percent of respondents did not manage under a formal groundwater management program. Only 2 percent of respondents did not answer this question.

Figure 2. Survey Respondents by Management Type

Percentage of survey respondents by management type (n=50). Management types are mutually exclusive.



Some 88 percent of survey respondents had jurisdictional areas that were located within or that included portions of a high- or medium-priority basin.[4] As a result, the majority of survey respondents will need to be managed under a GSP by Jan. 31, 2022, or before.[5,6]

Figure 3 shows survey responses by hydrologic region. Survey respondents came from all ten DWR hydrologic regions with five hydrologic regions (Sacramento River, San Francisco Bay, San Joaquin River, South Coast and Central Coast) representing nearly 80 percent of the survey responses. Nearly one-third of the total responses came from the Sacramento River hydrologic region. Collectively, these five regions represent 55 percent of groundwater use across the state (Figure 3). The Tulare Lake hydrologic region and San Joaquin River hydrologic region, which collectively account for 57 percent of the state's groundwater use, account for only 18 percent of survey responses. A low response rate from the North Lahontan, South Lahontan, Colorado River and North Coast regions was anticipated, as these regions account for only 8 percent of the groundwater use in the state (DWR, 2015).

Bias is inherent in any survey. Given the voluntary nature of this survey, respondents who are actively involved and engaged in groundwater management are more likely to respond to this survey. Of particular note, 30 percent of respondents came from adjudicated basins or special act districts—areas of the state with management regimes established through court or legislative actions. These numbers are not broadly representative of management numbers statewide (Table 1); groundwater adjudications and special act districts account for only 5 percent and 3 percent of all groundwater basins across the state, respectively. The survey results are more representative if the number of survey respondents from adjudicated basins and special act districts are calculated as a percentage of high- and medium-priority basins under SGMA (20 percent and 12 percent, respectively). However, results from this analysis are still likely to be biased toward more formal groundwater management regimes.

Table 1. Groundwater Management in California Prior to SGMA

The number of areas managed under each groundwater management type prior to SGMA implementation

Management type	Number statewide
Adjudications	26*
Special act districts	15*
County ordinances	27+
Voluntary management plans (AB3030, SB1938)	119**
No formal management	remainder

* Numbers from SGMA; + DWR, 2003; ** DWR, 2015.

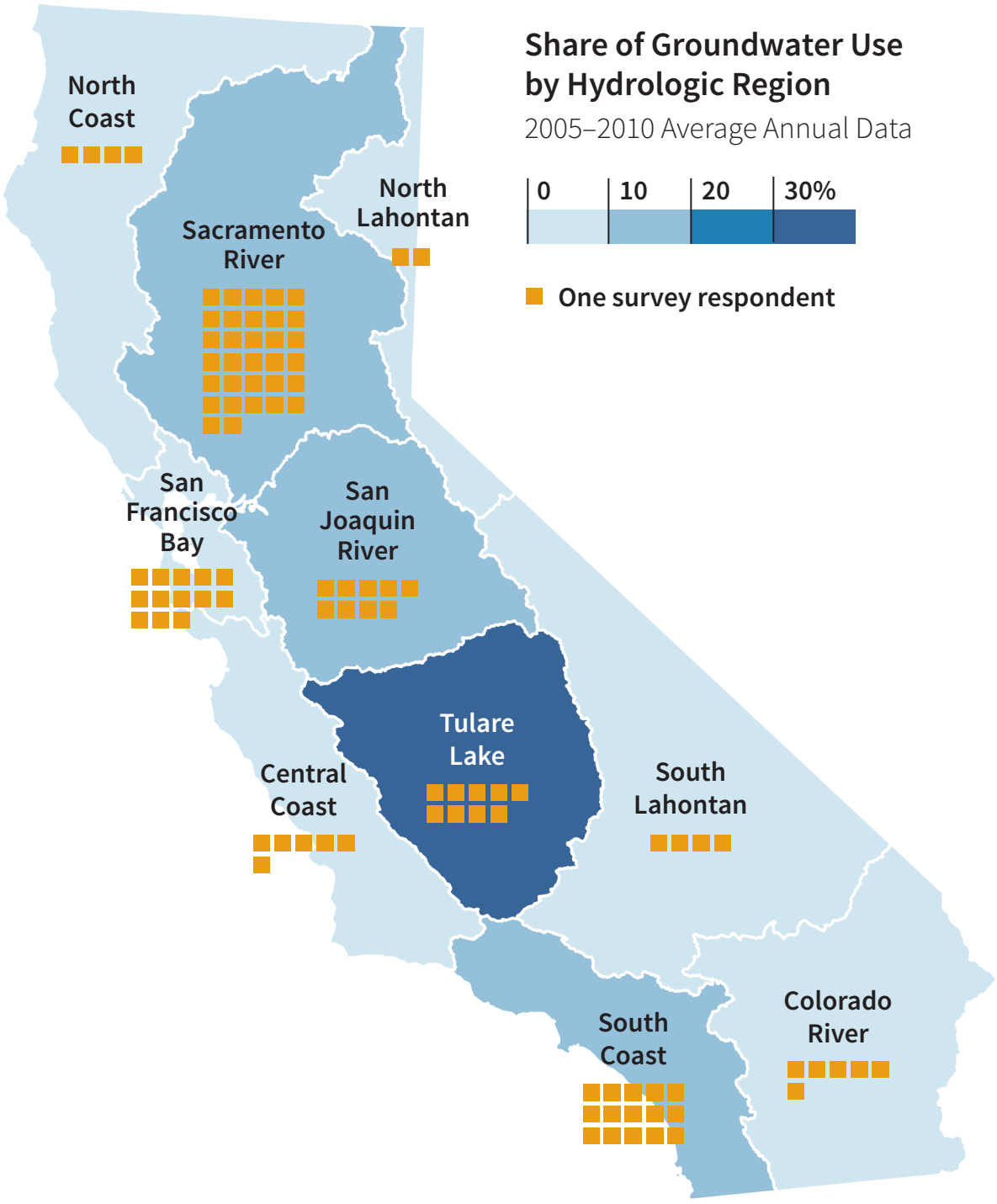
4 As required under SGMA, the California Department of Water Resources (DWR) prioritized all 515 alluvial groundwater basins in the state. Basins were placed into one of four categories—high, medium, low and very low—based on eight different criteria, including overlying population, projected overlying population growth, public supply wells, overlying irrigated acreage, reliance on groundwater, impacts on groundwater and any other relevant information. For more information on basin prioritization, see *http://www.water.ca.gov/groundwater/casgem/basin_prioritization.cfm.*

5 SGMA requires all high- and medium-priority basins to develop and implement a single or multiple GSPs. Basins subject to critical conditions of overdraft must be managed under a GSP by Jan. 31, 2020. All remaining high- and medium-priority basins must be managed under a GSP by Jan. 31, 2022 (Cal. Water Code § 10727(a)).

6 Note that existing groundwater adjudications are largely exempt from SGMA with exception to reporting criteria (Cal. Water Code § 10720.8). As a result, these basins will not need to form a GSA or develop a GSP. Additionally, existing special act districts have been named as the exclusive local agencies within their statutory boundaries (Cal. Water Code § 10723) and will not need to develop GSAs unless they elect to opt out of being the exclusive GSA.

Figure 3. Survey Respondents by Hydrologic Region

Survey responses by hydrologic region (each orange square represents one response). The blue shading indicates the percent of the state's total supply met by groundwater for each hydrologic region (2005–2010). Graphic by Geoff McGhee, Stanford University.



3.2.2 Jurisdictional Area

Survey respondents were asked to provide information on their jurisdictional area. Jurisdictional size varied greatly between survey respondents with a minimum, maximum and median jurisdictional area of <1 mi^2, 10,227 mi^2, and 313 mi^2, respectively. Some 60 percent of survey respondents worked in jurisdictional areas that did not span the entire basin, while 34 percent of respondents had jurisdictional areas that spanned multiple groundwater basins. Only 6 percent of survey respondents worked in jurisdictional areas that encompassed an entire groundwater basin. These findings suggest that a large percentage of the respondents will need to devote significant effort and resources to meet SGMA's basin-scale groundwater management coordination requirements (Cal. Code of Regulations, Title 23 § 357.4).

3.3 Knowledge and Perceptions of SGMA

Key Findings: Knowledge and Perceptions of SGMA

1. **The majority of groundwater management agencies are familiar with SGMA.** Some 91 percent of survey respondents had heard about SGMA. The remaining 9 percent did not respond to this question.
2. **The majority of respondents agree that SGMA will result in more sustainable groundwater management and more science-based decision-making.** Survey respondents generally agree that SGMA will result in more science-based planning and will lead to more sustainable groundwater management both in their jurisdictional area and in California as a whole.

Some 91 percent of survey respondents had heard about SGMA. The remaining 9 percent did not respond to this question. Respondents were asked to rank their level of agreement with the following four statements: (1) SGMA will help *my jurisdictional area* move toward sustainable groundwater management; (2) SGMA will help *California* move toward sustainable groundwater management; (3) SGMA will facilitate more science-based groundwater planning in my jurisdictional area; and (4) SGMA will facilitate more science-based groundwater planning in *California*. Table 2 provides normalized means of these responses. A normalized mean value greater than four indicates agreement with the statement.

Table 2. Perceptions of SGMA

Normalized mean values of responses to four statements about SGMA. Statements with a normalized mean value greater than four indicate general agreement with the statement (n=42).

Statement	Normalized Mean
SGMA will help my *jurisdictional area* move toward sustainable groundwater management.	4.6
SGMA will help *Californi*a move toward sustainable groundwater management.	5.5
SGMA will facilitate more science-based groundwater planning in my *jurisdictional area*.	4.6
SGMA will facilitate more science-based groundwater planning in *California.*	5.3

The majority of survey respondents agree that SGMA will result in more science-based planning and will lead to more sustainable groundwater management both in their jurisdictional area and in California as a whole. However, the lower mean values associated with responses pertaining to respondents' jurisdictional areas versus California more broadly indicate that survey respondents feel that SGMA will result in more sustainable groundwater management and better science-based planning in other jurisdictional areas than their own. These responses may be because survey respondents feel that groundwater conditions in their own jurisdictional area are better than elsewhere in the state or feel that the groundwater management being undertaken in their jurisdictional area is generally better than the management taking place in other areas of the state. Alternatively, survey respondents may be reluctant to criticize their own jurisdictional area when it comes to groundwater management.

3.4 Groundwater Data

Improved basin characterization and the development of data collection and monitoring protocols to support effective groundwater management are key goals of SGMA (Cal. Water Code § 10727.2). Understanding current groundwater data collection and sharing practices provides insight into the data-related challenges local agencies are likely to face during SGMA implementation and potential regulatory or policy solutions to address them. This section of the report focuses on the current groundwater data collection and sharing practices of local groundwater management agencies, as well as their perceptions on data adequacy for decision-making.

Key Findings: Groundwater Data

1. **Groundwater data is often inadequate for decision-making purposes.** Despite the fact that more than 80 percent of survey respondents collect groundwater levels data, only slightly more than half consider the geographic coverage (54 percent) and monitoring frequency (56 percent) of these data to be adequate for decision-making purposes. Similar results are observed with water quality data. In this case, 76 percent of survey respondents collected water quality data in their jurisdictional area, but less than half of survey respondents considered the geographic (44 percent) and monitoring frequency (40 percent) of these data to be adequate for decision-making purposes.
2. **Many data necessary for effective groundwater management are missing or highly uncertain.** Survey respondents indicated that missing or highly uncertain datasets hinder their ability to manage effectively. Missing or uncertain datasets included groundwater recharge potential (38 percent), the location of groundwater recharge areas (28 percent), sustainable yield (36 percent), groundwater-dependent ecosystems (26 percent), groundwater extractions (24 percent) and groundwater levels (22 percent).
3. **Many local agencies do not have dedicated groundwater monitoring wells.** Some 12 percent of respondents with dedicated groundwater monitoring networks did not have a single dedicated monitoring well in their network. Production wells accounted for 54 percent of the wells in dedicated groundwater monitoring networks.
4. **Groundwater management agencies need more data that can be readily shared at a variety of scales.** Nearly 60 percent of survey respondents to an open-ended survey question indicated the need for standardized data collection methods and a common data-sharing platform.
5. **Local agencies rely on data from other agencies (local, state and federal) to supplement data collected in their jurisdictional area.** Groundwater level, water quality, land use data and geology are the data most commonly shared between local agencies. Some 62 percent of survey respondents report using groundwater level and water quality data from other local agencies. Local agencies also rely on state and federal agencies for a breadth of data, including groundwater level and water quality data, climate data and geology.

3.4.1 Groundwater Data Collection and Sources

Table 3 summarizes survey responses to the question, "Does the jurisdictional area in which you work collect (or hire consultants to collect) the following types of data?" Data types included groundwater levels, water quality, stream gauge, subsidence, groundwater–surface water (GW-SW) interactions, land use change, groundwater-dependent ecosystems (GDEs) and groundwater extraction. Responses are summarized into three categories as they apply to SGMA: (1) required; (2) required where applicable; and (3) coordination of data and/or methodologies are required within a groundwater basin.

Table 3. Groundwater Data Collection

Percent of survey respondents who collect (or hire consultants to collect) the following types of data in the jurisdictional area in which they work (n = 50). Responses are summarized into three categories as they apply to data requirements under SGMA: (1) required; (2) required where applicable; and (3) data and/or methodologies pertaining to these data must be coordinated within a groundwater basin. GW is groundwater; GW-SW is groundwater–surface water; GD is groundwater-dependent.

Data requirement under SGMA	Data type	Yes (%)	No (%)	Not sure (%)	No response (%)
Required	GW levels	84	10	2	4
	Water quality	76	14	2	9
	Land use changes	64	22	4	10
	Stream gauge	52	32	6	10
	Subsidence	38	44	6	12
	GW-SW interactions	38	42	12	8
Required where applicable	GD ecosystems	20	42	28	10
Data must be coordinated within (sub)basins	GW extraction	62	28	2	8

The amount of groundwater data that local agencies collect varies widely (Table 3). The majority of agencies collect basic information about their groundwater basin, such as groundwater levels (84 percent) and water quality data (76 percent). More than 60 percent of respondents collect some form of groundwater extraction data. However, these percentages decline dramatically for groundwater datasets that are more complicated or labor-intensive to collect, such as data about GDEs (20 percent), subsidence (38 percent) and GW-SW interactions (38 percent).

Our analysis did not assess the reasons for the low collection rates of certain data types. It is possible that some data are too difficult or expensive to collect, that they are not considered necessary for the successful groundwater management in the respondent's jurisdictional area (e.g., areas without a surface water body would not need to collect information about GW-SW interactions) or that collection rates were low for other reasons.

3.4.2 Groundwater Monitoring Networks

More than three-quarters of survey respondents had groundwater wells within their jurisdictional area.[7] One-third of respondents with groundwater wells in their jurisdictional area did not have a dedicated groundwater monitoring well network.

Table 4 shows the well composition of dedicated monitoring well networks. Production wells (54 percent) and dedicated monitoring wells (28 percent) make up the majority of wells used in the monitoring well networks of survey respondents. Some 12 percent of respondents with established groundwater monitoring well networks did not have a single dedicated monitoring well. Groundwater monitoring from groundwater production wells alone can result in lower data accuracy (DWR, 2010) and may limit an agency's understanding of aquifer-specific groundwater levels and water quality data, particularly in multi-aquifer systems.

Table 4. Well Composition of Dedicated Groundwater Monitoring Networks

The percent of different well types used in the dedicated groundwater monitoring well networks of survey respondents (n=25). Minimum and maximum values in each row represent the single highest and lowest percentage of well type reported in each well category by a single respondent.

	Production wells (%)	Dedicated monitoring wells (%)	Retired production wells (%)	Other wells* (%)
Mean	54	28	10	8
Median	47	20	3	0
Minimum	10	0	0	0
Maximum	100	82	50	80

* The survey did not define the "other wells" category. This category was intended to capture wells not used for groundwater extraction (production wells) or groundwater monitoring (monitoring wells) (e.g., wells installed for environmental remediation). Thus, this category was expected to have low total percentages. In some instances, this was not the case. This may be due to interpretation of the "other well" designation, because of additional well activity not foreseen by the authors or for other reasons.

3.4.3 Data Adequacy

More than 80 percent of survey respondents collect groundwater levels data in their jurisdictional area (Table 3). However, only slightly more than half consider the geographic coverage (54 percent) and monitoring frequency (56 percent) of these data to be adequate for decision-making purposes.

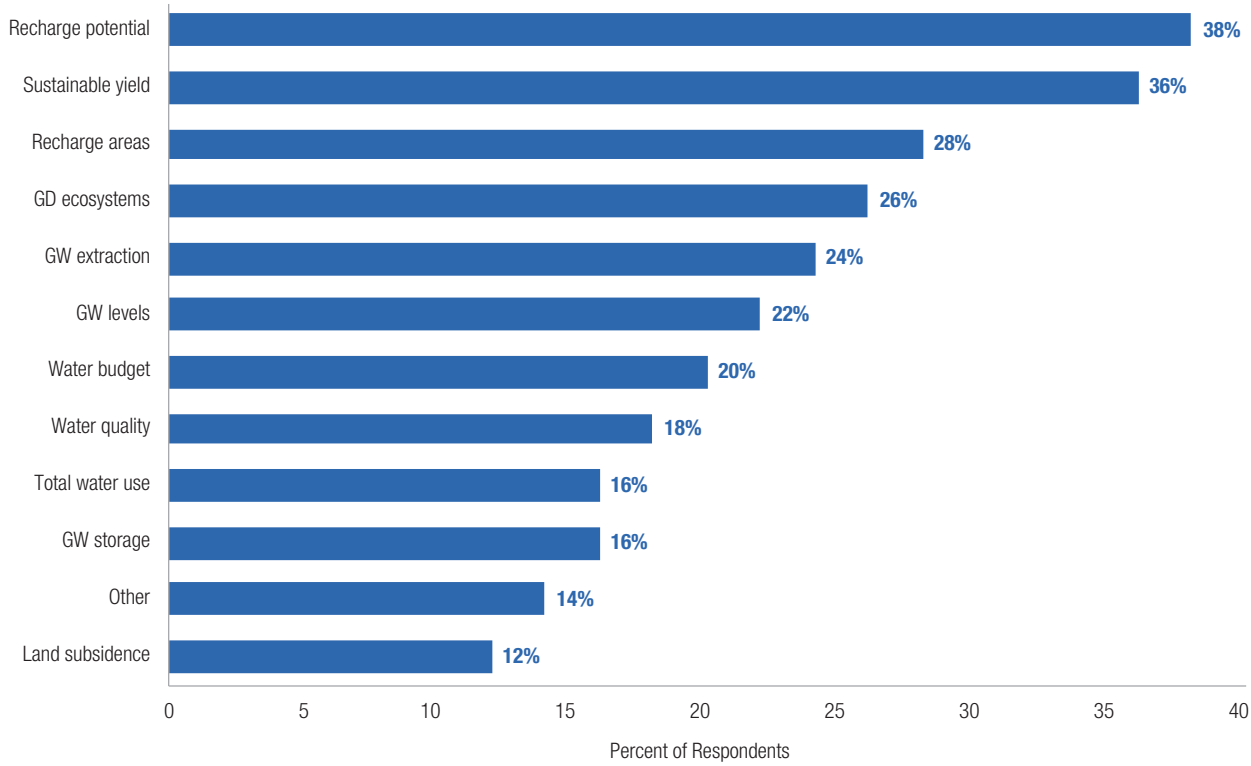
Similar results are observed with water quality data, where 74 percent of survey respondents collected water quality data in their jurisdictional area, but less than half of survey respondents consider the geographic coverage (44 percent) and monitoring frequency (40 percent) of these data to be adequate for decision-making purposes.

A lack of data and/or data uncertainty can limit local agencies' ability to effectively manage groundwater in their jurisdictional area. Figure 4 shows the top 12 responses to the question, "Are there key data or information missing or highly uncertain in the jurisdictional area in which you work that interfere with your ability to manage groundwater effectively?"

7 Respondents without wells fell into a variety of categories, including county agencies with well-permitting authorities, water districts without groundwater wells, farmers and a joint powers authority.

Figure 4. Missing or Highly Uncertain Groundwater Data

Percentage of survey respondents who indicated having missing or highly uncertain data in each category (n=50). Responses are not mutually exclusive. GD is groundwater-dependent; GW is groundwater.



All of the datasets shown in Figure 4 are either required under SGMA or have methodologies that require coordination in basins developing multiple GSPs under SGMA, with exception of the "Other" category. These results indicate that many datasets necessary for sustainable groundwater management under SGMA are missing or are currently considered highly uncertain.

Survey respondents indicated a high degree of uncertainty associated with groundwater recharge potential (38 percent) and the locations of groundwater recharge areas (28 percent) in their jurisdictional area. Agencies will increasingly be looking to recharge their groundwater aquifers during years of excess in order to meet their basin's sustainability goal. Identifying potential groundwater recharge areas to protect those from development and to prevent groundwater contamination is one cost-effective way of maximizing natural recharge to groundwater basins. Additionally, improving recharge potential estimates through improved soil and subsurface mapping will likely be an important part of successful SGMA implementation.

Some 36 percent of survey respondents were lacking key information or data necessary for determining sustainable yield in their jurisdictional area. The identification of GDEs was another area of significant uncertainty for survey respondents, with more than a quarter of respondents indicating a lack of information or data. Agencies and consultants alike should seek to develop the technical capacity to identify areas of uncertainty in sustainable yield estimates in order to prioritize further data collection.

Surprisingly, survey respondents indicated more uncertainty around recharge data than around groundwater extraction data. These results may be as much an indication of basin management priorities as they are of data uncertainty.

3.4.4 Data Needs

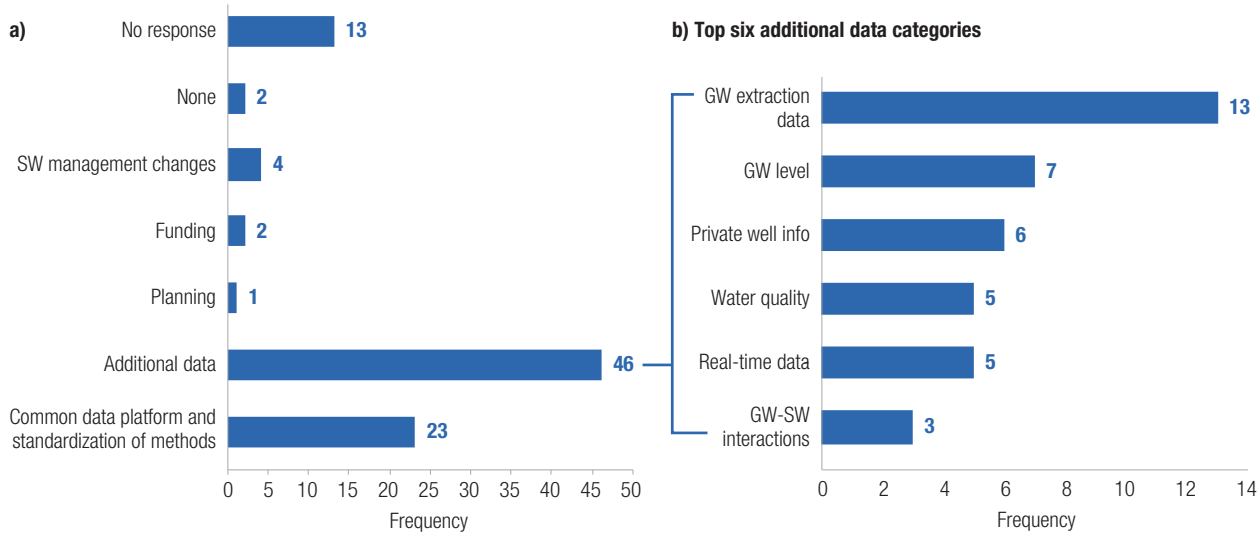
Figure 5 shows the groundwater data collection opportunities identified by survey respondents when asked the open-ended question, "In your opinion, what one improvement related to data collection and/or monitoring would make the biggest difference to groundwater management in the jurisdictional area in which you work?" Responses were grouped into the following seven categories: (1) a common data platform and/or standardization of data collection methods; (2) additional data; (3) better planning tools; (4) more funding; (5) changes to surface water management; (6) no changes needed; and (7) no response. Responses were not mutually exclusive. If a respondent listed more than one improvement in his or her response, all responses were categorized.

Survey respondents overwhelmingly identified two areas for improvement: the need for additional data (46 responses, 90 percent) and the need for standardization of methods and a common data-sharing platform (23 responses, 58 percent) (Figure 5a).

Figure 5b shows the top six data responses reported in the additional data category. Nearly 30 percent of survey respondents who listed a data request in response to this survey question indicated the need for groundwater extraction data. Surprisingly, the majority of additional data requests focused on basic groundwater information, including groundwater level data, access to private well information and water quality data.

Figure 5. Data Collection Improvements for Groundwater Management

Responses to the open-ended question, "In your opinion, what one improvement related to data collection and/or monitoring would make the biggest difference to groundwater management in the jurisdictional area in which you work?" (a) The frequency of groundwater data–related improvements identified by survey respondents (n=50). (b) The top six data needs identified by survey respondents in the "additional data" category. Responses are not mutually exclusive. SW is surface water; GW-SW is groundwater–surface water.



3.4.5 Data Sharing and Sources

In many cases, local groundwater management agencies rely on data from other agencies (local, state and federal) to supplement their own data. Table 5 shows responses to the question, "Does the jurisdictional area in which you work use groundwater data from other agencies? Local agencies? State agencies? Federal agencies?" Table 5 displays the types of data and the agencies from whom they are acquired. Data are summarized into three categories as they apply to data requirements under SGMA.

Table 5. Data Use from Local, State and Federal Agencies

Percent of survey respondents who use groundwater data from other agencies categorized by data type (n = 50). Responses are summarized into three categories as they apply to data requirements under SGMA: (1) required; (2) required where applicable; and (3) not required. The four most referenced datasets from each agency are shown in bold. Responses are not mutually exclusive. GW is groundwater.

Data requirement under SGMA	Data type	Local agencies (%)	State agencies (%)	Federal agencies (%)	None of the above (%)	No response (%)
Required	GW levels	**62**	**40**	24	14	12
	Water quality	**62**	**28**	**26**	14	16
	Stream gauge	28	24	**42**	16	26
	Subsidence	24	18	12	32	28
	Land use data	**54**	20	10	14	24
	Geology	**30**	**36**	**40**	16	20
Required where applicable	Climate data	24	**40**	**32**	10	26
Not required	Geophysics	24	16	18	32	32

Groundwater level, water quality, land use, and geology are the datasets most commonly shared between local agencies. Some 42 percent of survey respondents use stream gauge data from federal agencies. Additionally, 40 percent of survey respondents report using groundwater level data from state agencies and geology from federal agencies, respectively. These results highlight the need for continued maintenance and development of publicly available datasets from both state and federal agencies.

Land subsidence and geophysical data both had a much lower rate of data sharing than other data types included in our survey. Some 32 percent of survey respondents indicated that they did not use these data from other agencies—all other data types had an average "none of the above" rate of 14 percent. Our survey did not assess reasons for lower data use between agencies. However, in addition to lower collection rates for subsidence data (Table 3), these results may indicate that there is not a consistent, reliable source of land subsidence data or that agencies do not consider these data to be as high a priority as other data necessary for effective groundwater management.

Geophysical data are more difficult to assess. These technologies can be deployed at a range of scales, from local-scale analyses of soil properties to large-scale satellite images of subsidence or other variables. As result, local agencies may not see the value in sharing site-specific geophysical data with other water management agencies. This is despite the fact that the sharing of local-scale geophysical information can provide a more comprehensive understanding of basin conditions as a whole.

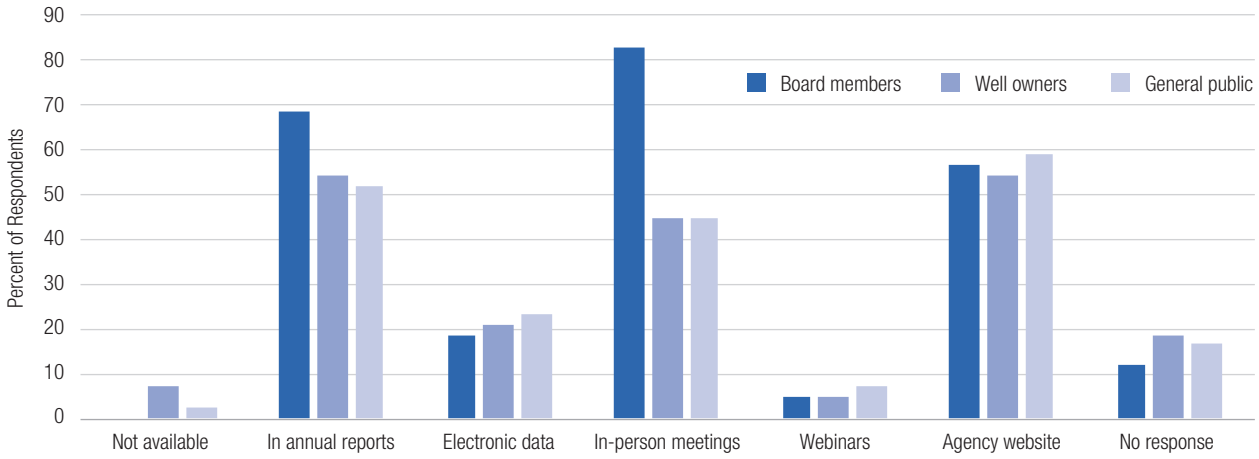
3.4.6 Data Communication

This portion of the survey asked how groundwater data and information were shared with (a) board members; (b) public and private well owners; and (c) the general public. Information-sharing methods between all groups were broadly similar, and sharing was done primarily through annual reports, through in-person meetings and via the agency website (Figure 6). Board members are more likely than well owners and the general public to receive groundwater data and information via in-person meetings.

Data and information were made available in electronic format by approximately 20 percent of respondents. Note that we did not ask respondents about important information pertaining to the dissemination of electronic data, such as the inclusion of metadata, data readability, data structure or other factors that may influence the access and functionality of electronic data files.

Figure 6. Communication of Groundwater Information

Different data communication methods used by survey respondents when reporting groundwater information to (a) board members; (b) public and private well owners; and (c) the general public (n=42). Responses are not mutually exclusive. Note: One survey response was eliminated because the respondent indicated that data were both available and not available on the agency's website.



3.5 Groundwater Models

Groundwater models[8] are representations of a physical system. Groundwater managers can use them to estimate a basin's water budget, sustainable yield, recharge rate or other variables. Additionally, depending on how groundwater models are developed, they can be used to make predictions about the impact of different management actions or scenarios over time. Given these functions, as well as the 50-year planning horizon designated under SGMA (Cal. Water Code § 10721(q)), groundwater models are likely to be used by local and state agencies to meet groundwater management requirements under the legislation for a variety of applications. This section of the report focuses on current groundwater model use at the local level.

Key Findings: Groundwater Models

1. **Groundwater models are a common groundwater management tool.** Some 75 percent of survey respondents use a groundwater model in their jurisdictional area. Groundwater models are used for a range of groundwater planning applications, including long-term water resource planning, recharge planning (72 percent), water budgets (56 percent), groundwater extraction planning (47 percent), recharge planning (42 percent), environmental impact assessment (25 percent), estimates of streamflow depletion (17 percent), land-use planning (17 percent), contaminant tracing (11 percent) and more.
2. **Groundwater models in California are developed using predominantly two model codes.** Of the respondents that reported model codes, the USGS's MODFLOW and DWR's IWFM model codes account for more than 95 percent of the reported groundwater models used across the state. The consistency in model codes used across the state may aid in groundwater model coordination efforts under SGMA.
3. **Inadequate funding is a barrier for groundwater model development.** Four out of seven survey respondents without a groundwater model in their jurisdictional area indicated that the cost of model development and/or the lack of resources for ongoing model maintenance and use were primary barriers for groundwater model development.
4. **Groundwater models may act as a catalyst for improved basin characterization.** While most survey respondents did not see the lack of groundwater data as a barrier to groundwater model development, 26 percent of respondents with a groundwater model indicated that additional data were acquired for model development. These data included historical records of climate, higher (temporal and spatial) resolution well data, more refined groundwater extraction estimates and information from adjacent areas.

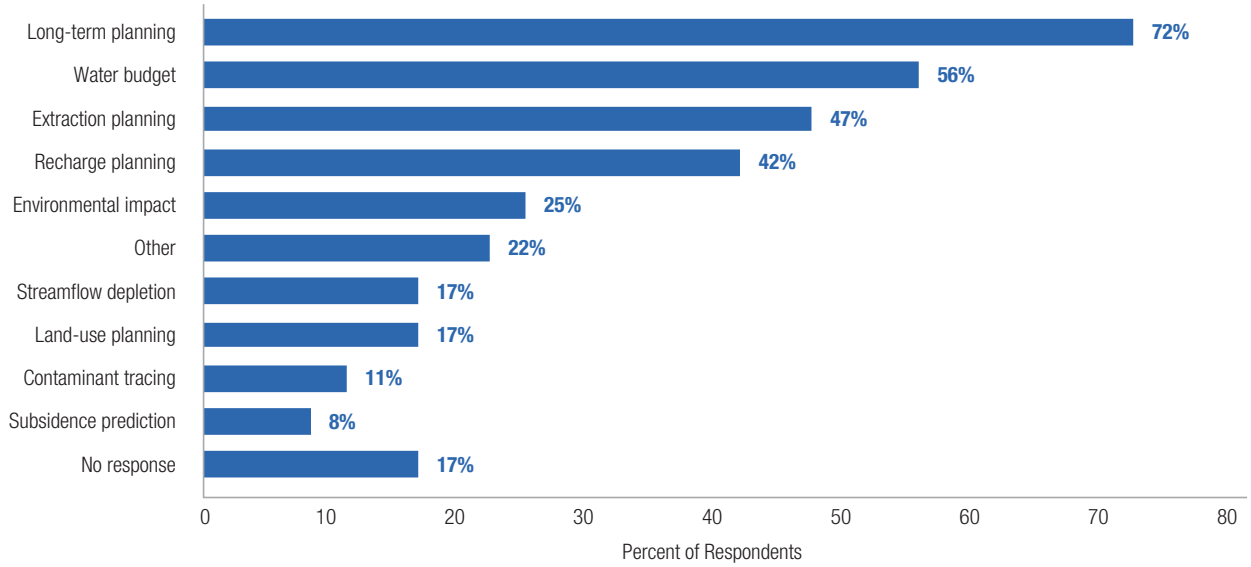
3.5.1 Groundwater Model Use

Three-quarters of survey respondents use a groundwater model in their jurisdictional area. Groundwater models are used for a variety of groundwater planning applications. Some 72 percent of survey respondents who use a groundwater model (n=36) use it for long-term water planning (Figure 7). Other common applications for groundwater models include water budgets (56 percent), groundwater extraction planning (47 percent) and recharge planning (42 percent).

8 This report uses the term groundwater models to refer to both groundwater models and integrated hydrologic models used for groundwater management.

Figure 7. Groundwater Model Use

Percentage of survey respondents who use groundwater models for each planning application (n=36). Responses are not mutually exclusive.



Two model codes — USGS's Modular Groundwater Flow Model (MODFLOW)[9] (65 percent) and DWR's Integrated Water Flow Model (IWFM)[10] (26 percent) — account for the majority of groundwater model use by survey respondents (Table 6).

Table 6. Groundwater Models Code Use

Model codes used by survey respondents (n=34). Responses are mutually exclusive.

	MODFLOW‡	IWFM**	Other	No response
Percent of respondents*	65	26	3	15

‡ Respondents who indicated the use of MODFLOW, CVHM or GSFLOW were categorized as using the MODFLOW model code.

**Respondents who indicated the use of IWFM, IGSM or C2VSim were categorized as using the IWFM model code.

3.5.2 Groundwater Model Coordination

The survey asked questions about groundwater model coordination both within basins and between hydrologically connected basins. Some 47 percent of survey respondents with a groundwater model indicated that at least one other agency within their groundwater basin utilizes the same groundwater model. Of these respondents, 72 percent indicated that they coordinated model runs with that agency.

9 The survey question asked, "Which model (or model code) is used?" Agencies that indicated the use of MODFLOW, CVHM or GSFLOW were categorized as using the MODFLOW model code.

10 The survey question asked, "Which model (or model code) is used?" Agencies that indicated the use of IWFM, IGSM or C2VSim were categorized as using the IWFM model code.

It is slightly less common for respondents to use or coordinate groundwater model use across groundwater flow boundaries. Some 33 percent of respondents with a groundwater model use the same groundwater model as other water agencies in hydrologically connected basins. Some 67 percent of these respondents indicated that they coordinated model runs with another agency.

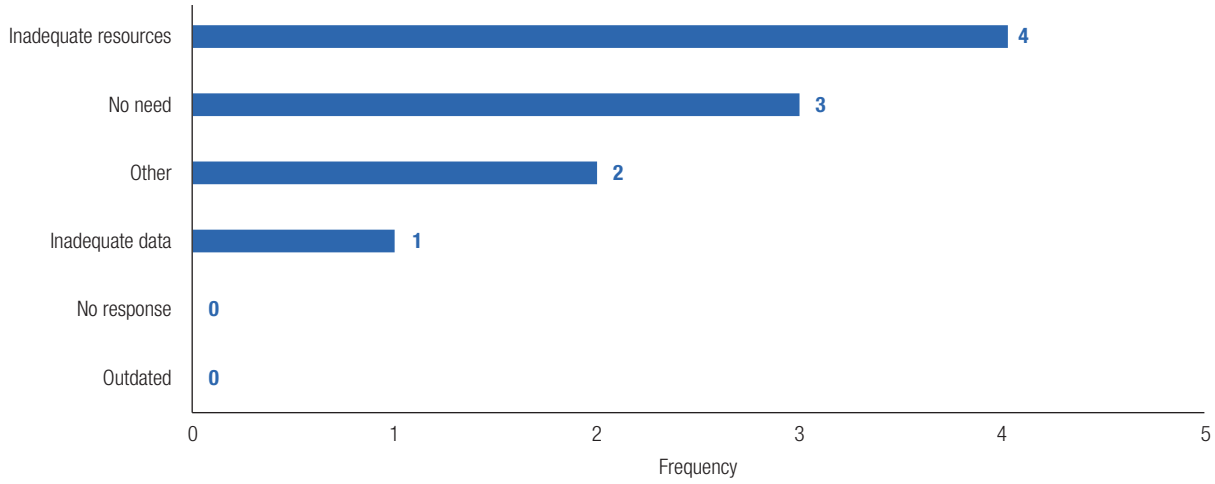
It is important to note that the survey did not define groundwater model coordination. However, these results suggest some degree of existing groundwater model coordination between agencies within groundwater basins and between groundwater basins that share a groundwater flow boundary.

3.5.3 Barriers to Groundwater Model Use

Seven survey respondents reported not using a groundwater model in their jurisdictional area. Of these seven respondents, four respondents indicated model development and/or maintenance costs as a primary barrier for groundwater model development (Figure 8). Three respondents indicated that a groundwater model was not necessary in their basin, with one of these respondents indicating that the basin was managed to maintain groundwater levels. Only one survey respondent without a groundwater model felt that the lack of data for model calibration was a barrier to model development.

Figure 8. Barriers to Groundwater Model Development

Percentage of survey respondents without a groundwater model who indicated the following barriers to groundwater model development or use in their jurisdictional area (n=7). Responses are not mutually exclusive.



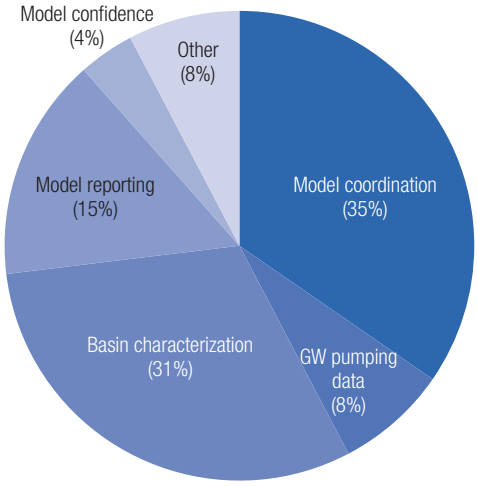
While most survey respondents did not see the lack of groundwater data as a barrier to groundwater model development, 26 percent of survey respondents with a groundwater model indicated that additional data were acquired for model development. These data included historical climate records, higher (temporal and spatial) resolution well data (i.e., agencies drilled more wells and/or increased monitoring frequency), refined groundwater pumping estimates and groundwater use estimates, and information from adjacent areas. These results may indicate that developing a model can serve as an impetus for improved basin characterization and targeted data collection.

Figure 9 shows responses to the open-ended question, "In your opinion, what one improvement related to groundwater model development or use would make the biggest difference to groundwater management in the area in which you work?" Responses were categorized into six mutually exclusive categories. These categories were improved (1) model coordination; (2) groundwater pumping estimates; (3) basin characterization; (4) transparency in groundwater model development and reporting; and (5) model certainty. The sixth category was Other.

More than one-third of the respondents who answered the question (35 percent) indicated the need for improved model coordination (Figure 9). Some 31 percent indicated the need for improved basin characterization (with an emphasis on meeting SGMA requirements). Additional improvements included increased transparency in groundwater model development and reporting (15 percent), improved groundwater pumping data (8 percent) and increased model confidence (4 percent).

Figure 9. Improvements for Groundwater Model Development

Survey responses to the open-ended question, "What one improvement in groundwater model development would most improve groundwater management in your jurisdictional area?" (n= 26). Responses are mutually exclusive.



3.6 Geophysical and Satellite-Based Methods

Groundwater managers are increasingly using geophysical and satellite-based methods to acquire information necessary for groundwater management. In many cases, these technologies can be used to complement existing information or to provide information about a system at higher spatial or temporal resolution than would be acquired using traditional data collection methods. This section of the report focuses on current and anticipated uses of geophysical and satellite-based methods at the local level.

Key Findings: Geophysical and Satellite-Based Methods

1. **Geophysical and satellite-based methods — particularly geophysical borehole logs — are commonly used in groundwater management.** Only 10 percent of survey respondents did not use geophysical methods or satellite-based data for groundwater management. Some 63 percent of respondents used borehole logs, 31 percent used satellite data, and 27 percent used electrical methods for groundwater management.
2. **There is a strong interest in using geophysical and satellite-based methods for groundwater management in the next three to five years**. Some 40 percent of survey respondents anticipate using geophysical or satellite-based methods for groundwater management in the next three to five years. Of these respondents, 69 percent anticipate using satellite data for subsidence monitoring and to estimate groundwater extractions.

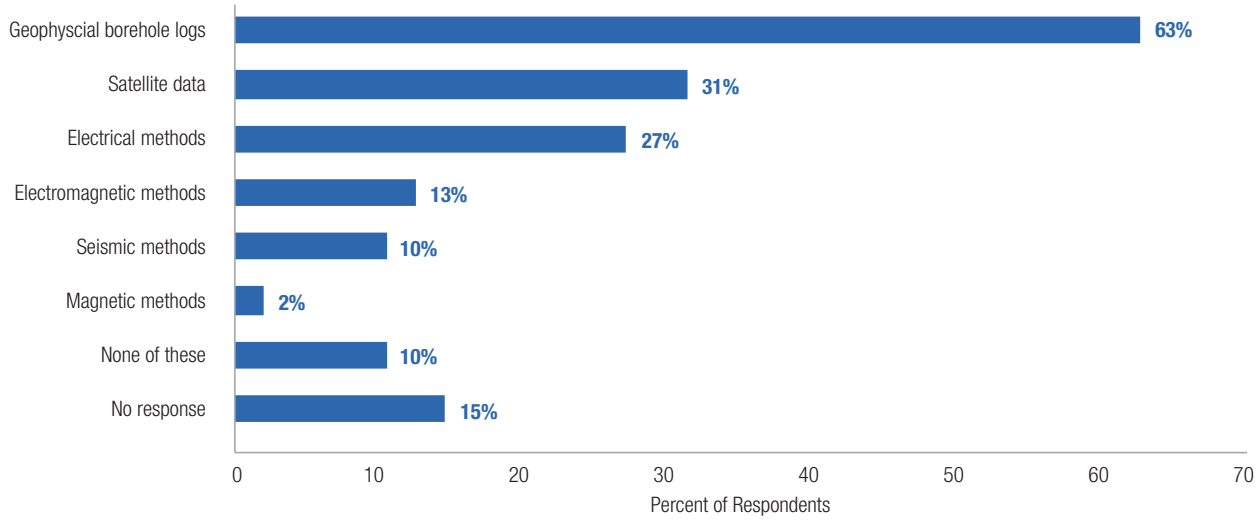
The survey asked questions about current and anticipated use of satellite-based data (e.g., Interferometric Synthetic Aperture Radar (InSAR), Landsat) for groundwater management, as well as about the current and anticipated use of surface-based geophysical methods for groundwater management. These methods include: geophysical borehole logs (e.g., electrical conductivity logs, gamma logs), electrical methods (e.g., electrical resistivity tomography), electromagnetic methods (e.g., ground penetrating radar, time domain electromagnetics), seismic methods (seismic tomography or reflection), and magnetic methods (e.g., nuclear magnetic resonance). For simplicity, we refer to surface-based geophysical methods as geophysical methods.

Only 10 percent of respondents reported no use of geophysical methods or satellite-based methods for groundwater management. Geophysical borehole logs were by far the most commonly used geophysical methods (63 percent). Satellite data and electrical methods were also commonly used methods, at 31 percent and 27 percent, respectively (Figure 10).

In addition to showing widespread use of geophysical methods, the survey revealed that respondents have a strong desire to integrate the use of geophysical and satellite-based methods into groundwater management in the next three to five years.

Figure 10. Geophysical and Satellite-Based Methods for Groundwater Management

Percentage of survey respondents who used geophysical or satellite-based methods for groundwater management (n=45). Responses are not mutually exclusive.



Some 40 percent of survey respondents plan to use geophysical methods or satellite-based methods for groundwater management in the next three to five years. Of these respondents, 69 percent anticipate using satellite data for subsidence monitoring and to estimate groundwater extractions, 38 percent anticipate using geophysical borehole logs, and 23 percent anticipate using electrical methods and electromagnetic methods, respectively.

4 RECOMMENDATIONS

The results from our survey suggest that a variety of regulatory and policy actions could substantially improve the quality of data collected by local agencies for sustainable groundwater management. Our recommendations include the following.

Groundwater management agencies should:

1. **Expand or develop dedicated groundwater monitoring well networks.** Some 33 percent of survey respondents with wells in their jurisdictional area did not have a dedicated groundwater monitoring well network. Given that these networks provide basic information about aquifers and serve as the basis for sustainable groundwater management, agencies should work to develop groundwater monitoring networks with consistent data collection and monitoring protocols that facilitate data integration at the basin scale.
2. **Invest in dedicated groundwater monitoring wells.** Some 12 percent of respondents with dedicated groundwater monitoring well networks did not have a single dedicated monitoring well. Whenever possible, agencies relying solely on production wells for their groundwater monitoring should invest in a dedicated monitoring wells that could be used to complement data from production wells.
3. **Use the authority given under SGMA to meter production wells.** Nearly 30 percent of survey responses to an open-ended survey question indicated the need for groundwater extraction data. Groundwater extraction information is a critical component of water budget and groundwater model development. Improving groundwater extraction estimates through metering or other methods would significantly improve basin characterization.
4. **Use the authority given under SGMA to monitor private production wells.** Only slightly more than half of respondents consider the geographic coverage (54 percent) of groundwater levels data to be adequate for decision-making purposes. An inability to access private wells for groundwater monitoring purposes may leave large portions of a basin unmonitored and may limit data collection necessary for sustainable groundwater management.
5. **Make local groundwater data publicly available in electronic format whenever possible.** Approximately 20 percent of respondents make groundwater data and information available in electronic format. Making these data available in readable formats, with appropriate metadata and necessary documentation, would help to ensure transparency and accountability and would enable independent assessment of basin conditions.
6. **Continue to leverage datasets from other local, state and federal agencies.** Groundwater level, water quality, land use and geology are the data most commonly shared between local agencies. Local agencies also rely on state and federal agencies for a breadth of data, including groundwater levels, stream gauge, climate, geology and water quality.
7. **Prioritize the collection of missing or highly uncertain datasets.** Survey respondents indicated a high degree of uncertainty associated with groundwater recharge potential (38 percent), estimates of sustainable yield (36 percent), the locations of groundwater recharge areas (28 percent) and groundwater-dependent ecosystems (26 percent). In areas where specific undesirable results are not considered applicable, agencies should be required to provide data demonstrating that this is the case.

The state and federal agencies should:

1. **Require local groundwater management agencies to use consistent, state-developed data collection and monitoring standards and a common data-sharing platform to enable data integration across regions.** Some 58 percent of survey respondents to an open-ended survey question indicated the need for standardized data collection methods and a common data-sharing platform.

2. **Develop a statewide data committee.** Some 40 percent of survey respondents plan to use geophysical methods or satellite-based methods for groundwater management in the next three to five years. The state should develop a data advisory committee composed of federal, state, and local agencies; private industry; and NGOs (for example, environmental, water) to advise the state and groundwater management agencies on geophysical methods, technologies and other data-related issues.
3. **Develop consistent, long-term technical and financial assistance to support sustainable groundwater management and model development**. Only slightly more than half of respondents consider the geographic coverage (54 percent) and monitoring frequency (56 percent) of groundwater levels data to be adequate for groundwater decision-making purposes. A lack of technical and financial resources may limit data collection necessary for sustainable groundwater management. Additionally, 57 percent of survey respondents without a groundwater model in their jurisdictional area indicated that the cost of model development and/or the lack of resources for ongoing model maintenance and use were primary barriers for groundwater model development.
4. **Require the use and reporting of geophysical borehole logs in new wells.** Some 63 percent of survey respondents have used geophysical borehole logs for groundwater management. These logs provide objective information about subsurface conditions that can be used for improved basin characterization.
5. **Maintain and develop state and federal datasets.** Some 42 percent of survey respondents report using stream gauge data from federal agencies; 40 percent of respondents use groundwater level data from state agencies. These results highlight the need for continued maintenance and development of publicly available datasets from state and federal agencies.
6. **Require agencies to use publicly available, open-source model codes.** The USGS's MODFLOW and DWR's IWFM model codes account for more than 95 percent of the reported groundwater models used by survey respondents. Both of these model codes are publicly available with supporting documentation available online. Requiring agencies to develop using these model codes will facilitate increased transparency in the model development process and enable third-party review of model construction and results.

Results from this survey suggest that many local agencies across California already have a strong foundation on which to build their groundwater monitoring networks for sustainable groundwater management, albeit with significant gaps. As agencies move toward the basin-scale coordination requirements under SGMA, it will be increasingly important for agencies to focus on acquiring data using consistent collection and monitoring protocols to ensure that data can be readily integrated and shared.

5 REFERENCES

California Department of Water Resources. (2003). *California's Groundwater: Bulletin 118, Update 2003*. Retrieved from *http://www.water.ca.gov/groundwater/bulletin118/index.cfm*

California Department of Water Resources. (2010). *Groundwater Elevation Monitoring Guidelines.* Retrieved from *http://www.water.ca.gov/groundwater/casgem/pdfs/CASGEM%20DWR%20GW%20Guidelines%20Final%20121510.pdf*

California Department of Water Resources. (2015). *California's Groundwater Update 2013: A Compilation of Enhanced Content for California Water Plan Update 2013. Volume 1 – The Strategic Plan: Chapter 3 California Water Today.* Retrieved from *http://www.waterplan.water.ca.gov/topics/groundwater/index.cfm*

Nelson, R.L. (2012). Assessing Local Planning to Control Groundwater Depletion: California as a Microcosm of Global Issues. *Water Resources Research, 48:* W01502. doi:10.1029/2011WR010927

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