RECHARGE ROUNDTABLE CALL TO ACTION:

Key Steps for Replenishing California Groundwater

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UC WATER
Security and Sustainability Research Initiative

Groundwater Resources Association of California

EXECUTIVE SUMMARY

On October 2, 2017 the Groundwater Resources Association of California (GRA) and the University of California Water Security and Sustainability Research Initiative (UC Water) convened a Recharge Roundtable Workshop to identify key actions needed to significantly increase recharge to California groundwater systems during the next five years. This document summarizes results of the workshop and of numerous follow-up discussions.

Six essential questions capture the essence of the Recharge Roundtable. This executive summary lists these questions and their underlying actions. The highest priority actions are highlighted in green, and further details can be found under the six sections that follow this summary.

1. How Much Water is Hydrologically Available for Recharge?

1.a Determine what fraction of the HMFs (high-magnitude flows) are available for recharge and not subject to water rights limitations.

1.b Determine instream flows associated with HMFs necessary to maintain stream functions and associated ecosystems

1.c Determine likely changes in streamflow due to climate change through integrated modeling of regional climate and regional hydrology.

2. How Much Recharge Can Be Accomplished in Different Hydrogeologic Environments?

2.a Update soils mapping for recharge.

2.b Characterize the subsurface geology with focus on mapping recharge locations that lack low-permeability impeding layers.

2.c Continue improving the maps of groundwater levels, including the water table to better determine available, and changes in, aquifer storage.

2.d Develop maps of recharge favorability based on a combination of soils, geologic, topographic, hydrologic and land use information.

2.e Measure recharge rates in controlled ponding experiments to develop better estimates of recharge volumes in full-scale recharge facilities. Additionally, measure and model regional benefits of recharge on confined and semi-confined aquifer water levels so that effects on both changes in groundwater storage and regional increases in semi-confined aquifer pressures or groundwater levels can be better tracked and predicted.

2.f Create recharge preserves on lands having high potential for recharge. Purpose would be to coordinate land uses such that full exploitation of those lands for recharge could occur.

3. What Are the Legal and Regulatory Bottlenecks, and How Can They Be Eliminated or Reduced?

3.a The current, temporary and standard permitting processes should be reviewed and evaluated to determine whether it is sufficiently effective to support large increases in future diversions. The legislature's AB 2649, as amended on April 25, 2018, was an important step in the right direction.

3.b Provide education and guidance, including case studies, to educate local districts on the process of applying for permits to capture HMFs and to ensure that applicants engage in the activity early and fully enough to succeed.

4. How Can Hundreds to Thousands of Recharge Projects Be Incentivized?

4.a Develop short- and long-term funding models for Groundwater Sustainability Agencies (GSAs). The funding models should satisfy four key objectives: support of GSA water management operations and infrastructure, establishment of economic incentives to control groundwater pumping, establishment of economic incentives that maximize recharge, and be compatible with Propositions 218 and 26.

4.b Set a statewide recharge goal based on statewide water availability, local and regional needs and include buffers for climate variability and long-term drought resiliency.

4.c Extend knowledge to water stakeholders on consequences of overdraft and benefits of carefully managing both pumping and recharge.

4.d Develop guidance for GSAs and other basin managers on strategies for satisfying the cost and benefit proportionality requirements of Propositions 218 and 26, as required by SGMA in Water Code Section § 10730.2(a),(c), thereby assisting proponents of recharge projects and avoiding inadvertent triggering of an election as a precondition of imposing a groundwater recharge fee or assessment.

There are only two ways to reduce groundwater overdraft – decrease pumping or increase recharge.

5. What Changes in Reservoir Reoperation and Conveyance Are Needed?

5.a Develop the means to jointly manage the water stores in both surface reservoirs and groundwater. This can be accomplished through data and models that include both the surface and subsurface reservoirs, as well as the streams and conveyance facilities that connect them.

5.b Develop optimized multi-objective operation polices with reformed objectives for the main reservoirs in the state.

5.c Develop rehabilitation plans for existing conveyance facilities and assess need for new conveyance capabilities to fulfill the integrated reoperation of surface and groundwater reservoirs, with particular attention to opportunities offered by high magnitude flows and high-capacity recharge areas.

5.d Consider the public benefit of recharge in the funding of a north-south conveyance facility through the Delta.

6. What Are the Water Quality Benefits and Concerns of Recharge?

6.a Continue the GAMA (California Ambient Monitoring and Assessment program), but examine whether it is adequate for providing a baseline of both shallow and deep groundwater quality information needed to ascertain water quality effects of recharge. Reconsider the GAMA program in light of planned or potential increases in recharge, and reinvest in or refocus the program if necessary.

6.b Estimate through the use of data and models the long-term future changes of groundwater

6.c Reexamine alignment of SGMA's recharge goals in light of California's water quality regulatory system, including the Porter-Cologne Act and the Antidegradation Policy, and adjust the system for mutual compatibility under increased recharge conditions.

CALIFORNIA WATER STORAGE CAPACITY AND OPPORTUNITY (MAF)

California has three main ways to store water: snowpack in the Sierra Nevada, surface reservoirs, and groundwater systems. Underground capacity for storing additional water in the Central Valley groundwater system is about 140 MAF, amounting to more than three times that of all the surface reservoirs in the state.

The Sierra Nevada accounts for 15 MAF of 17 MAF total snowpack storage which is available between November and April but increasingly jeopardized by climate change. Capacity of the State's extensive reservoir system is about 42 MAF. During the drought of record (2011-2016) the surface reservoirs stored 2-3 years of water supply. Past depletion of groundwater storage presents a massive opportunity for increasing total system storage through recharge.

INTRODUCTION

THE PROBLEM

California is commonly listed among the world's most severe regions of groundwater overdraft (e.g., Famiglietti 2014), due mainly to pumping in the Central Valley, one of the world's largest aquifer systems. The magnitude of annual overdraft in California has been estimated to be about 1.1 to 2.4 MAF (DWR 2013), but there is a range of estimates that suggest overdraft as high as 11.9 MAF and 5.1 MAF in dry and wet years, respectively (Beganskas and Fisher, 2017).

Passage of the Sustainable Groundwater Management Act (SGMA) in 2014 set California on a path toward stabilizing its groundwater resources. There are only two ways to reduce groundwater overdraft – decrease pumping or increase recharge. Eliminating California's overdraft will certainly require both actions, and likely more of the former than the latter. Nevertheless, it is increasingly obvious that tantalizing possibilities for increasing recharge to California's aquifers exist, yet state and local water agencies and stakeholders are not sufficiently prepared to capitalize on those possibilities. The stakes have been set even higher by the ongoing realities of climate change in which warmer temperatures, thinner snowpack, earlier snowmelt, more rain-on-snow events, fewer wet days with more rain, more severe drought and more intense atmospheric river flood events (Swain et al., 2018) create new challenges for stabilizing water security. Climate change is significantly compromising California's ability to store water in its extensive system of built reservoirs originally designed to capture snowmelt during April-July in time to meet summer peak water demands. Yet the timing of river flows is increasingly shifting to pre-April, when flood protection priorities are high and less reservoir inflow can be accommodated.

> *We need to motivate focused actions that effect large quantities of recharge and produce regional benefits.*

The security of water in general is integrally related to civilization's ability to store water for use by humans and ecosystems. This is especially true in a Mediterranean climate such as California's where adequate storage is essential for weathering both our annual April-October dry spell and multi-year droughts. This fact has produced calls to increase water storage through more construction of dams, especially during the recent 2012-16 drought. In reality, however, by far the largest 'reservoir' for augmenting storage lies beneath the surface of California, where underground capacity for storing additional water amounts to three times more than what all the surface reservoirs in the state can hold (The Nature Conservancy, 2016[1]). Clearly then, if we agree that water storage is paramount for water security and that groundwater overdraft must be eliminated, we must envision and implement an entirely new groundwater management strategy and put at least as much effort into replenishing groundwater as we do into extracting it. The age of tacitly treating groundwater as primarily an extractive resource is over, both for California and the rest of the world. This will require vastly more managed aquifer recharge than ever previously imagined.

THE RECHARGE ROUNDTABLE

It was in this spirit of profound concern for the future of not only groundwater resources, but also for water security and sustainability in general, that on October 2, 2017 the Groundwater Resources Association of California (GRA) and the University of California Water Security and Sustainability Research Initiative (UC Water) convened the Recharge Roundtable in Sacramento. The Recharge Roundtable consisted of 50 attendees with a diverse cross-section of disciplines and professions, including water managers, consultants, academics, hydrologists, and social scientists (See Appendix A for attendees). The strong experience and expertise assembled in this group, together with the sincere interest in solving a daunting water challenge, made the meeting very productive and led to the proposed actions included in this document.

At the time of the meeting, California seemingly had emerged from a punishing 5-year drought. Water Year 2017 was touted as one of the wettest years on record, and the state declared the drought officially over. Nevertheless, every member of this Roundtable knew that with respect to groundwater, the drought was not over and that immediate action would be needed to prepare for the next wet or average winter in which opportunities to recharge arise.

The goal of the Recharge Roundtable was to identify changes in infrastructure, knowledge, and institutions that are needed to substantially increase recharge in California within approximately the next 5 years. Concomitant with the Recharge Roundtable initiative, many organizations have been leading work on how to bring recharge and flood waters more prominently into the water supply portfolio. For example, the California Department of Water Resources has recently examined what infrastructural and institutional designs can be put into action to capture and recharge flood waters (Flood-MAR; DWR 2017b). University of California Agriculture and Natural Resources organized a Symposium on October 5, 2017 on Maximizing Groundwater Recharge: Land Use, Groundwater and Flood Management. The California Department of Food and Agriculture hosted a November 8, 2017 Public Forum on Managed Groundwater Recharge to Support Sustainable Water Management.

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[1] Based on difference in modeled groundwater storage in the Central Valley between pre-development and modern times.

Simultaneously, the California Water Commission has been searching for storage programs that meet strict criteria for public benefits. The Association of California Water Agencies has adopted groundwater replenishment as one of their key policy directives and published a report on water storage integration (ACWA 2017). Moreover, the greatest incentive for participation, the Sustainable Groundwater Management Act, looms large with an upcoming deadline of 2020 for Groundwater Sustainability Agencies (GSAs) in critically overdrafted basins to produce integrative plans founded on balanced groundwater budgets lest the State Water Resources Control Board intervene.

> ***With respect to groundwater, the drought was not over.***

Facilitated by the Center for Collaborative Policy, the October 2 Recharge Roundtable workshop included focused presentations on the scientific, institutional, and legal aspects of the recharge challenge, followed by three breakout sessions in the afternoon concerning legal and institutional aspects; technical resources and challenges; and feasible scope, scale and economics to increase conjunctive use and recharge. Each breakout session developed lists of needed actions, which were presented in a closing plenary session (See Appendix B for agenda).

> ***Water hydrologically available for recharge in the Central Valley is sizeable.***

The Recharge Roundtable planning committee recorded all attendee comments throughout morning presentations, breakout and reporting sessions: these comments, together with post meeting discussions are the basis for this paper. Relying on qualitative analysis (NVivo10) to code notes, we developed *a priori* categories to sort the comments. Due to the nature of the broader discussion that continued beyond the workshop, we also added emergent categories. To write the call to action, we employed an iterative process to ensure roundtable comments were fully integrated into the structure. In addition to expert reviews from within UC Water and GRA, roundtable attendees were invited to review the document.

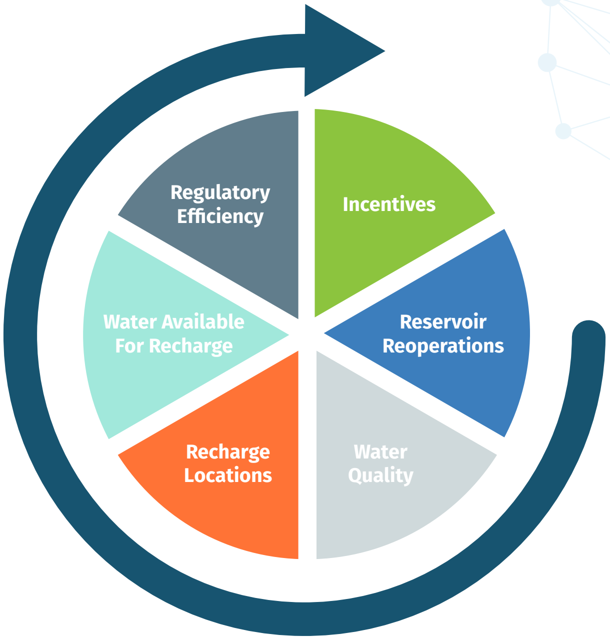
ACTION PLAN

This Recharge Roundtable report is an action plan that is organized around six key questions that were posed in the workshop and are considered essential to the recharge challenge:

1. How much water is hydrologically available for recharge?
2. How much water can be recharged in different hydrogeologic environments?
3. What are the legal and regulatory bottlenecks, and how can they be eliminated or reduced?
4. How can hundreds to thousands of recharge projects be incentivized?
5. What changes in reservoir reoperation and conveyance are needed?
6. What are the water quality benefits and concerns for recharge?

Within each of these six major questions, we have identified more specific questions and recommended actions that cogently convey the objectives of the underlying actions.

Recharge and its broader role within water resources management are issues much too broad to fully address in a short, call-to-action document. Accordingly, and in light of the urgent need for solutions that address the large overdraft numbers within years rather than decades, we focused primarily on actions that would potentially produce substantial increases in recharge within the next 5 years. The goal of this document is not to provide encyclopedic details about all the various recharge methods and obstacles, but rather to motivate focused actions that effect large quantities of recharge and produce regional benefits.



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HOW MUCH WATER IS HYDROLOGICALLY AVAILABLE FOR RECHARGE?

Adam Hutchinson, Graham Fogg, Helen Dahlke and Sam Sandoval Solis

1.

Water available for recharge depends on hydrology, storage (surface and subsurface), conveyance, legal and regulatory aspects, environmental instream flow needs, and water quality. Here we focus largely on the hydrology, or what nature is capable of delivering, and discuss the other factors in subsequent sections.

As stated in a recent report by the California Department of Water Resources (DWR, 2018) on water available for replenishment (WAFR), sources of replenishment water include surface water (including storm water), recycled water, desalination, water transfers, and conservation. DWR further points out that mitigation or correction of groundwater overdraft through replenishment will typically require a portfolio of sources and solutions and provides guidance on how GSAs or other, local water management entities can take steps to identify and quantify these sources.

The water available from recycled water, desalination and conservation will depend largely on local conditions and decisions within GSAs. Water available from water transfers will depend largely on existence of sources outside the GSAs. A remaining, considerable source of uncertainty is the amount of surface water available, whether internal or external to the GSA boundaries. Accordingly, DWR (2018) estimated amounts of surface water available for replenishment (WAFR). They produced a range of WAFR estimates in which the low-end numbers reflect infrastructure limitations and the high-end numbers do not. DWR (2018) estimated WAFR in the Sacramento Basin to range between 670 TAF/yr and 4,270 TAF/yr, and in the San Joaquin-Tulare Basins to range between 220 and 690 TAF/yr, with the higher numbers in both ranges roughly representing the amount of water hydrologically available for recharge (i.e., free of infrastructure limitations).

An analysis by Kocis and Dahlke (2017) of high-magnitude flows (HMF) in 93 Central Valley streams indicates that years with HMFs have produced, on average, 2,675 TAF and 1,297 TAF of additional water available for recharge in the Sacramento and San-Joaquin-Tulare Basins, respectively. Such HMFs occur during 7 and 4.7 years out of 10 years in the Sacramento and San-Joaquin-Tulare Basins, respectively. The future timing and magnitudes of these flows will of course depend greatly on future patterns in weather and climate.

It is beyond the scope of this paper to reconcile differences between the numbers of DWR (2018) and Kocis and Dahlke (2017) (K&D); however, one reason for the differences is that DWR's numbers are averages over all years, while K&D's are averages only during the years that the HMFs occurred. This would seem to be consistent with the fact that DWR's 690 TAF/yr for the San-Joaquin-Tulare Basins is roughly half that of K&D's 1,297 TAF/yr; but it does not explain why DWR's 4,270 TAF/yr for the Sacramento Valley is so much larger than K&D's 2,675 TAF. Hanak et al. (2018, Appendix A) recently provided an excellent comparison of the DWR (2018) and Kocis and Dahlke (2017) approaches for the San Joaquin Valley and Tulare Lake Basin region for water year 2017.

An important upshot of the work of DWR (2018) and Kocis and Dahlke (2017) is that the amount of water hydrologically available for recharge in the Central Valley is sizeable and perhaps greater than the estimated overdraft. Unfortunately though, most of the WAFR arises in the Sacramento Valley, while most of the overdraft is in the San Joaquin-Tulare Basins. North-to-south conveyance will therefore be paramount, as discussed in Part 5. Nevertheless, it appears that additional work is needed to reconcile the differences between the WAFR estimates so that future plans can rest on a solid foundation of information about how much water nature can deliver. As reflected in the key questions and actions listed below, significant questions remain about how much of the HMFs are subject to limitations due to water rights and environmental instream flow considerations. Importantly, those environmental flows include consideration of how much water needs to flow through the Delta and how that may change in the future (Gartrell et al. 2017). Moreover, future effects of climate change on amounts and timing of water available for recharge will need to be better estimated.

KEY QUESTIONS

1.1 How much surface water is hydrologically available for recharge? Where and how frequently will the water likely be available?

1.2 What instream (environmental) flows are needed in various watersheds and the Delta, and how will these affect amounts of HMFs (high-magnitude flows) available for recharge?

1.3 How will climate change alter the amounts and timing of surface water flows as well as the needed instream flows?

RECOMMENDED ACTIONS (high priorities in green):

1.a Determine what fraction of the HMFs are available for recharge and not subject to water rights limitations. Kocis and Dahlke (2017) state that the HMFs above the 90th percentile are less subject to water rights constraints, but potential diverters in each river basin will need to know with greater specificity the flows at which water can be diverted. This determination could be accomplished by a state-wide task force including critical departments, such as State Water Board and DWR, to develop a consistent approach and set of assumptions to evaluate water available within watersheds and hydrologic regions. This determination would be most accurate if HMFs could be compared to reported water use and water rights face values at existing points of diversion, rather than conglomerated reporting of potentially multiple points of diversion covered under a single right available in RMS and eWRIMS for post-1914 water rights. Water right statements (pre-1914 appropriative, riparian, etc.) are already reported based on a single point of diversion in the State Water Board's RMS database.

1.b Determine instream flows associated with HMFs necessary to maintain stream functions and associated ecosystems, including the Delta (e.g., see Kocis and Dahlke, 2017, p. 9). This determination could be accomplished by a state-wide task force including critical departments, such as CDFW, DWR, and State Water Board along with non-profits focused on fisheries (e.g., The Nature Conservancy and Trout Unlimited) to develop a consistent approach and set of assumptions to evaluate water available within watersheds and hydrologic regions. A preliminary analysis can be done by estimating the volume of water in excess of ecological flows during the winter season (high winter flows) that is above the desired high winter flows required to sustain ecological functions for river ecosystems.

1.c Determine likely changes in streamflow due to climate change through integrated modeling of regional climate and regional hydrology.

ANTICIPATED CONSEQUENCES

A fundamental requirement before any investment in construction of a dam is knowledge of streamflow amounts in space and time. Similarly, the major investments in recharge operations, including everything from land acquisition and modifications to conveyance structures, will not happen until reliable estimates of the amounts of divertible surface water can be developed. These estimates are foundational to integrated water resources planning and management where groundwater storage, in concert with surface storage, are central elements. Clearly, reliable estimates of amounts of divertible surface water will spur growth and development of recharge initiatives. Although the above discussion refers substantially but not exclusively to the Central Valley as a prime example, similar analyses are needed in other watersheds as well.

2

HOW MUCH RECHARGE CAN BE ACCOMPLISHED IN DIFFERENT HYDROGEOLOGIC ENVIROMENTS?

Graham Fogg and Andrew Fisher

2.

Methods for recharging groundwater include surface spreading (including on floodplains and farm fields), injection wells, dry wells, and streambed infiltration. This section focuses mainly on surface spreading because it has the greatest potential for recharging large volumes of water from HMFs originating from California's largest headwater source, the Sierra Nevada, especially as climate change leads to higher winter river flows in non-drought years. Recharge site suitability for surface spreading depends on how much water can be infiltrated into the subsurface, and ultimately to the water table. This in turn depends on soil infiltration rates, sub-soil (geologic sediments) percolation rates, the degree of hydrogeologic connectivity between the surface and the aquifers, inundation area, ponded water depths, and available storage space between the land surface and the water table. There are also issues associated with water quality, both for surface water and groundwater, and what can happen when they are mixed. Water quality issues are discussed in Section 6.

In the Central Valley and in most of California's other alluvial basins, most of the surficial soils and the geologic sediments consist of silts and clays rather than the sands and gravels that comprise the aquifer portions of the subsurface. Consequently, much of the landscape and deeper subsurface impedes the recharge process, making soil and geologic conditions especially important factors in site selection. This leaves two fundamental approaches for infiltration leading to recharge: target small areas with highly suitable properties, or inundate large areas accompanied by long inundation times to counteract low infiltration rates. A good example of benefits of large inundation area is provided in the irrigation history of the Central Valley, where the practice of irrigation over most of the landscape led to regional recharge rates exceeding pre-development recharge rates by a factor of two to three[2]. In other words, we know that applying water to large areas of the Central Valley dramatically increases recharge, even though the soils on much of that landscape are not highly permeable.

Most of these areas of enhanced, deep percolation potential are unknown and need to be determined.

Much progress on site suitability has already been accomplished in terms of soil characteristics (the upper 1-2 meters of the subsurface) via the work of O'Geen et al. (2015) on the Soil Agricultural Groundwater Banking Index (SAGBI). Much work remains to be done, however, on the deeper subsurface that is also essential to how and how fast water can penetrate in ways that benefit the vast aquifer systems. For example, Weissmann et al. (2004) determined that because of the glacial history of the Sierra Nevada, every major watershed draining from the Sierra Nevada onto the Central Valley floor has at least one, very coarse-grained channel deposit (called incised-valley-fill deposits) that would support much higher recharge rates at strategic locations in the Central Valley aquifer system. Most of these special channel deposits, however, have not been identified because of the general lack of progress in subsurface geologic mapping of California's major aquifer systems.

KEY QUESTIONS

2.1 Where are the most suitable soils (i.e., the upper 1 to 2 m of the subsurface)? Key attributes are texture (e.g., coarse- or fine-grained) and permeability.

2.2 Where are the most suitable geologic characteristics? Key attributes are texture, permeability and structure of the geologic sediments beneath the surficial soils. The sedimentary geology of the Central Valley is complex and inadequately mapped. Importantly, key portions of the aquifer system are anomalously coarse-grained and would afford relatively fast, deep percolation to the water table, as well as beneficial increases in groundwater levels in the deeper, semi-confined aquifers. Locations of most of these areas of enhanced, deep percolation potential (e.g., the incised-valley-fill deposits) are unknown and need to be determined.

2.3 What is the distribution of subsurface storage space for recharge? The key attribute is depth to the actual water table (not depth to the confined aquifer water levels recorded in most wells). If the water table is too shallow, the site cannot accommodate significant increases in groundwater storage. Moreover, if recharge brings the water table too close to land surface, there can be multiple adverse impacts, such as flooding of basements, increased potential for liquefaction, and direct evaporation from the soil, which can lead to soil salinization.

2.4 What recharge rates and volumes are achievable? The California water storage challenge requires that excess winter flood flows be diverted for recharge. Although answering the above questions will identify the best sites and strategies for recharge, the total volumes of water that can be recharged in a wet winter remain in question. Ultimately, this question will be best answered through field recharge experiments. A related, important question is: What are the benefits of recharge, which mainly fills in the pore spaces above the water table, to regional confined or semi-confined aquifer water levels. When the recharge area connects hydraulically to deeper, confined or semi-confined aquifer zones, benefits of the recharge spread regionally and relatively rapidly via groundwater pressure increases that boost groundwater levels in areas located far from the recharge site.

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[2] Based on difference in recharge between pre-development (1922-1932) and modern (1999-2009) conditions indicated by the C2VSim regional groundwater model and caused by extensive irrigation with both surface water and groundwater (Brush et al., 2013).

RECOMMENDED ACTIONS (high priorities in green):

2.a Update soils mapping for recharge. Because of the SAGBI product (Soil Agricultural Groundwater Banking Index; O'Geen et al., 2015) an excellent soils recharge index map is already available for California. SAGBI, however, can be improved by updating data on soil conditions, such as locations where the soils have been ripped to break up duripan layers that impede infiltration (O'Geen, personal comm., 2017).

2.b Characterize the subsurface geology with focus on mapping recharge locations that lack low-permeability impeding layers. This can be done through geologic analysis of available subsurface data from wells (e.g., borehole geophysical logs and drillers logs) and with newer technologies, such as airborne electromagnetics (Knight et al., 2018) implemented along with modern geologic knowledge (e.g., Weissmann et al. 2004). This would be best accomplished by a government agency tasked with a mission focused on characterizing the subsurface geology not only for identifying the best areas for recharge, but also for broad support of groundwater systems characterization to enable smarter integrated water resources management.

> ***Not doing a better job of mapping the subsurface in California would be like practicing medicine without adequate knowledge of human anatomy.***

2.c Continue improving maps of groundwater levels, including the water table to better determine available, and changes in, aquifer storage. Most of the wells in California alluvial basins are screened below one or more confining beds such that the groundwater occurs under confined or semi-confined conditions. As a result, well water levels can differ substantially (i.e., by 10 to 100 ft) from elevation of the actual water table. Extra effort is needed to map not only the groundwater levels found in the deeper wells, but also the groundwater levels in the shallowest wells that are most indicative of the true water table.

2.d Develop maps of recharge favorability based on a combination of soils, geologic, topographic, hydrologic and land use information. Examples of how to do this can be found in Russo et al. (2014) and Fisher et al. (2017). This action could be accomplished by the government agency mission identified in 2.b.

2.e Measure recharge rates in controlled ponding experiments to develop better estimates of recharge volumes in full-scale recharge facilities. Additionally, measure and model regional benefits of recharge on confined and semi-confined aquifer water levels so that effects on both changes in groundwater storage and regional increases in semi-confined aquifer pressures or groundwater levels can be better tracked and predicted.

2.f Create recharge preserves on lands having high potential for recharge. Purpose would be to coordinate land uses such that full exploitation of those lands for recharge could occur.

ANTICIPATED CONSEQUENCES

Just as the number of good dam sites are finite and require certain geographic and physiographic characteristics, there are a limited number of sites capable of supporting very high recharge rates in areas that can also benefit groundwater levels in the adjacent and subjacent semi-confined aquifers. Knowledge on the geographic locations of the best recharge locations, most of which are currently unknown, will lead to repurposing of land and water resources at high-potential recharge sites. Moreover, with better information on locations and characteristics of high-potential recharge sites, the necessary water allocation and conveyance planning can proceed to better estimate how much surface water can be transferred to groundwater storage as a function of available river flows and locations in the aquifer system. The necessary conveyance capabilities for many high-potential recharge locations will no doubt be lacking, but the sooner the locations of these sites are known, the sooner any necessary conveyance capabilities can be planned and built.

The creation of a subsurface characterization unit within a state agency, with the mission of characterizing subsurface geologic and soils conditions relevant to water resources, would provide long-term benefits to those who depend on groundwater. Most of the state's subsurface information, including drilling logs and geophysical logs, remains unanalyzed, and hence many relevant characteristics of our aquifer systems, including those that supply domestic and agricultural water in mountain and foothill areas, remain unmapped. An agency unit with the mission of collecting, curating and interpreting subsurface data in support of water management would greatly aid in the SGMA mission of GSAs by better defining our largest reservoirs in California, the subsurface reservoirs. Not doing a better job of mapping the subsurface in California would be like practicing medicine without adequate knowledge of human anatomy.

3

WHAT ARE THE LEGAL AND REGUALTORY BOTTLENECKS, AND HOW CAN THEY BE ELIMINATED OR REDUCED?

Thomas Harter, Graham Fogg and Helen Dahlke

3.

Any plan to divert surface water raises questions about water rights. Tackling the broad issue of California water rights is well beyond the scope of this recharge action plan. Given the potential articulated in part 1 for diversion of high-magnitude flows (HMFs) during the wet season and that such flows are less likely to be spoken for by existing diverters and instream needs (Kocis and Dahlke, 2017; DWR, 2017b), here we confine the scope mainly to diversion of HMFs. There is also the potential in many settings for limited collection of hillslope runoff before it reaches a stream course, but this section focuses on stream diversions. As pointed out by the State Water Board at the Recharge Roundtable Workshop and in subsequent discussions, the lack of basin-scale groundwater regulation has been an impediment to the regulatory approval of recharge; hence SGMA is expected to play an important role in both recharge implementation and helping clear the path toward regulatory approval.

Efforts to divert water during HMFs require the granting of both temporary water rights permits and "standard" water rights permits by the State Water Resources Control Board (State Water Board). Importantly, in November 2015 the Governor issued an executive order providing expedited process for temporary water rights permits, a process that may be extended by the legislature. But there is currently no guarantee that this executive order will be extended in the future (DWR, 2017b). In absence of the Order, the State Water Board has historically, and intends to continue, to prioritize any temporary urgency requests, including those for temporary permits. Only two diversions of HMFs were granted by the SWRCB during the following year (2016-17), partly because of the newness of this program and the lack of advance, local planning needed to also have the necessary diversions, conveyances, recharge facilities, etc. in place. Tips and more information on these temporary permits is available under water rights applications on waterboards.ca.gov[3].

Considerable discussion at the October 2, 2017 GRA-UCWater Recharge Roundtable Workshop, and at the November 8, 2017 CDFA and DWR Recharge Forum concerned the issue of beneficial use. Because recharge is not recognized as a beneficial use, some argued that it would be helpful to designate recharge a beneficial use in a water rights application for MAR, particularly in overdrafted basins, where some recharge will be needed for permanent storage, to reverse past overdraft, to address water quality degradation, or to stem seawater intrusion. On the other hand, at both meetings strong arguments were presented that indicated existing beneficial use classifications were sufficient to allow recharge and that adding a new beneficial use would expand the number of projects subject to permitting requirements. It was suggested at the Recharge Roundtable that recharge be considered a "public benefit," a term that is used frequently in DWR (2018) in order to support grant eligibility of projects. However, according to the State Water Board, merely changing the nomenclature will not resolve the underlying unintended consequences and imbalanced impacts to differing classes of existing water rights holders. Greater education and outreach is needed concerning the impacts to existing water rights holders, the potential creation of permitting burdens for flood management activities, and overall confusion that designations of "beneficial use" or "public benefit," could create.

Given that the expedited temporary permitting process specific to underground storage is not only new and relatively untested, it is also based on an executive order that may or may not be extended, the legal and regulatory foundations for supporting large increases in recharge are in need of careful review, strengthening, and educational outreach. It is worth noting that while only two temporary diversion permits were sought and granted in 2016-17, significant recharge occurred under existing water rights conditions in the San Joaquin Valley, and amounts recharged were more limited more by capacity constraints than by lack of water rights (Hanak et al. 2018). If California is to succeed in capturing and storing a significant amount of water during average and wet years, water managers and SWRCB will need to be prepared for processing and granting more such permits. Current efforts by the legislature to extend the temporary permit process, at affordable fees, and by waiving CEQA requirements for certain recharge projects (AB 2649, Arambula, as amended on April 25, 2018) were important steps in that direction.

Allowing a water-right permit for the diversion of "High Flow" could potentially bridge the gap between policy requirements (such as the need for a temporary or permanent water right for surface water diversions), legal requirements (stream reaches that are already legally over-appropriated), and physical surface water availability for groundwater recharge (in the form of flood flows during above normal or wet years). Such permits would have to agree on high flow thresholds at the point of diversion that ensure high flow diversions for groundwater recharge do not cause injury to existing water-right holders or environmental flow considerations. However, permits could be restricted to the winter period only (e.g., November –March) and define strict instream flow requirements (e.g., the passage of channel forming flows or fall flushing flows for sediment and nutrient transport). See Kocis and Dahlke 2017 for a more detailed discussion of these considerations. Clarification of the legal/regulatory challenges to groundwater recharge and solving those challenges will open new avenues to greater water security in California.

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[3] For more information on water rights and high magnitude flows, visit the State Water Resources Control Board site: https://www.waterboards.ca.gov/waterrights/water_issues/programs/applications/groundwater_recharge/

> *Just as the hydrologic uncertainties that were discussed above can serve as disincentives to the planning and investment needed to increase recharge, legal uncertainties will have the same effect.*

KEY QUESTIONS

3.1 What legal and regulatory framework, including laws, agency functions and interagency collaboration, are most helpful to minimize legal conflicts, bureaucratic hurdles, and to provide maximum operational flexibility in the handling of water rights applications for groundwater replenishment?

3.2 Is the current, expedited temporary permitting process adequate as a means of allowing for the needed multitude of HMF recharge diversions to effect substantial increases in groundwater storage? More specifically, is this process sufficiently nimble to handle potentially substantial increases in permit applications during the next wet period? Should projects be planned and permitted on an ad hoc basis in reaction to near-term hydrologic events or as part of longer-term efforts such as those required by SGMA?

3.3 If the expedited temporary permitting process is the appropriate regulatory framework for facilitating recharge of HMFs, what steps are needed to make it permanent? That is, does the Governor's executive order need to be extended or put into law? Will stakeholders be comfortable with a permanent suspension of CEQA for these types of projects?

3.4 What is the amount of HMF surface water legally available for aquifer replenishment? The answer depends partly on how much water must remain in the stream for downstream needs, which leads to the following question. (See question 1.1.)

3.5 What is the amount of surface water that must remain in the stream for downstream water rights holders and for environmental flows at any given location and time-of-year as well as under flood and flood-stage conditions? (See question 1.2.)

RECOMMENDED ACTIONS (high priorities in green):

3.a The current, temporary permitting process should be reviewed and evaluated to determine whether it is sufficiently effective to support large increases in future diversions. The legislature's AB 2649, as amended on April 25, 2018, was an important step in the right direction.

3.b Provide education and guidance, including case studies, to educate local districts on the process of applying for permits to capture HMFs, and to ensure that applicants engage in the activity early and fully enough to succeed.

ANTICIPATED CONSEQUENCES

Just as the hydrologic uncertainties that were discussed above can serve as disincentives to the planning and investment needed to increase recharge, legal uncertainties will have the same effect. The recommended actions will help prepare California to capitalize on average and wet winter streamflow, while also improving the foundations of water law as related to management of both surface water and groundwater.

4

HOW CAN HUNDREDS TO THOUSANDS OF RECHARGE PROJECTS BE INCENTIVIZED?

Tim Parker, Graham Fogg, Andrew Fisher

4.

Because of the distributed nature of groundwater, substantially increasing groundwater storage will require not a few projects, but 100s to 1000s of projects across landscapes overlying groundwater basins. This has been scientifically demonstrated throughout the irrigation history of the Central Valley, where the practice of irrigation on thousands of farms led to regional recharge rates exceeding pre-development recharge rates by a factor of two to three[4]. In other words, applying water to large swaths of the land dramatically increases recharge. To this day, crop irrigation remains the largest source of recharge in most of California's irrigated groundwater basins, though still falling well short of current amounts of pumping in some areas. While recharge is accomplished locally on a specific plot of land, the benefits typically spread regionally and can strongly benefit many neighboring areas. Hence, a person who recharges on their land, also benefits other landowners. This raises the question: What would motivate individuals to recharge if they are not compensated for benefiting the larger water community?

Crop irrigation remains the largest source of recharge in most of California's irrigated groundwater basins.

Most of the existing examples of managed recharge are not at the landscape scale, but rather, at specific sites operated by water districts that put up the capital to accomplish large-scale surface infiltration, at aquifer storage and recovery well facilities, and at detention dams to slow and control surface water flows and increase recharge in upper canyons (e.g., Kern Water Bank, Coachella Valley Whitewater Spreading Basin, Orange County Water District). For such capital projects, the incentives arise largely from: (1) a need to store more water to, for example, eliminate groundwater overdraft and provide a buffer against droughts, (2) capture and recharge low cost water (e.g., storm water) to reduce the need to obtain more expensive sources of water (e.g., imported water), (3) a need to install seawater intrusion barriers along the coast and (4) availability of water and appropriate sites to infiltrate or inject water. These incentives for the larger capital projects will likely increase due to SGMA, and will mainly hinge on the topics discussed in the other sections in this recharge action plan, especially those that deal with amounts of water available for recharge, suitable recharge sites, legal and regulatory considerations (including compliance with Propositions 218 and 26), financial considerations, and water quality.

Where specific action is needed, however, is in the incentivization of hundreds to thousands of land owners, including farmers, as well as irrigation districts and GSAs to initiate recharge projects on their lands. In addition to farms, many other lands, including parks and airports could potentially be used for recharge. These incentives will arise from knowledge and economics. The knowledge includes not only all the other topics in this report, especially the hydrologic and legal-regulatory availability of water for recharge, but also the suitability of various croplands for winter fallow irrigation without harming the crop. For example, Dahlke et al. (2018) concluded that alfalfa is an excellent candidate for recharge, partly because of low fertilizer application rates and deep, well-drained soils, and that 2.6 million ac-ft of recharge would be possible on California alfalfa crop lands.

Considerable action also needs to be devoted to the economic incentives. While a farmer or other individual is paying for the energy and possibly GSA fees to pump groundwater, they will have little incentive to recharge outside the growing season unless they are compensated for that recharge. A promising approach for incentivizing recharge by individuals such as farmers is the same financial model used in net-metering in the domestic solar power market (Kiparsky et al. 2018), where homeowners with solar panels sell power back to the electric utility when they are producing more power than needed, offsetting costs of power that they buy from the utility when their demand exceeds their solar-generated supply. Similarly, A. Fisher (Kiparsky et al. 2018) has proposed and helped implement with the Pajaro Water Management Agency a groundwater net metering system where the landowner pays fees to the GSA in accordance with pumping amounts, but gets reimbursed for any recharge that they accomplish on their land during the wet season.

Groundwater net metering as part of an overall financial system for operation of a GSA has great potential to not only control groundwater demand, but also to maximize recharge regionally in the groundwater basin. The net metering approach, however, is an economic model predicated on a water community where the water users are already being charged on the basis of their water use. Importantly, because of Propositions 218 and 26 there is now considerable uncertainty concerning a GSA's ability to charge fees without first getting voter approval.

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[4] Based on difference in recharge between pre-development (1922-1932) and modern (1999-2009) conditions indicated by the C2VSim regional groundwater model and caused by extensive irrigation with both surface water and groundwater (Brush et al., 2013).

KEY QUESTIONS

4.1 What water management strategies or systems will lead to incentivizing 100s to 1000s of recharge projects?

4.2 Where is groundwater net metering a sufficiently viable, scalable model that could be applied in the Central Valley?

4.3 Besides the net metering approach, what are other funding models for supporting operations' costs of GSAs while also incentivizing recharge? In severely overdrafted areas, will infusion of State funding be necessary?

4.4 What funding models will be compatible with Propositions 218 and 26 that will allow for incentivizing recharge?

RECOMMENDED ACTIONS (high priorities in green):

4.a Develop short- and long-term funding models for Groundwater Sustainability Agencies (GSAs). The funding models should satisfy four key objectives: support of GSA water management operations and infrastructure, establishment of economic incentives to control groundwater pumping, establishment of economic incentives that maximize recharge, and be compatible with Propositions 218 and 26. The groundwater net-metering approach as well as other approaches should be considered.

4.b Set a statewide recharge goal based on statewide water availability, local and regional needs, and include buffers for climate variability and long-term drought resiliency.

4.c Extend knowledge to water stakeholders on consequences of overdraft and benefits of carefully managing both pumping and recharge.

4.d Develop guidance for GSAs and other basin managers on strategies for satisfying the cost and benefit proportionality requirements of Propositions 218 and 26, as required by SGMA in Water Code Section § 10730.2(a),(c), thereby assisting proponents of recharge projects and avoiding inadvertent triggering of an election as a precondition of imposing a groundwater recharge fee or assessment.

ANTICIPATED CONSEQUENCES

California's groundwater overdraft is sufficiently massive that it will not be significantly mitigated with just a few, large recharge projects. Economic incentivization of 100s to 1000s of recharge initiatives will make possible the broad distribution of the coming, large wet season high-magnitude flows (HMFs) over enough of the landscape to accomplish the significant increases in recharge. Furthermore, the demonstration of economic-based incentives for managing both pumping and recharge will help GSAs produce economically sustainable water management plans eliminating overdraft, and any needed curtailments in pumping can be accomplished with economic incentives rather than top-down control.

5

WHAT CHANGES IN RESERVOIR REOPERATION AND CONVEYANCE ARE NEEDED?

Erfan Goharian and Graham Fogg

5.

Most of the water for MAR ultimately comes from headwaters and surface reservoirs. Water available for recharge must be routed to lowland recharge locations via conveyance structures such as canals, ditches and pipelines. California's hard infrastructure for water storage and conveyance was designed, developed, and operated by assuming stationarity in climate and hydrology. Moreover, the system was designed under the tacit assumption that conventional management of the surface reservoir water stores would provide adequate flood protection and drought supplies. Because of climate warming there is a need to reconsider reservoir and conveyance operations to account not only for different timing and amounts of reservoir inflows, but also for changes in reservoir outflows needed to manage the greater flood flows while also allowing for groundwater recharge. That recharge would, in turn, augment groundwater storage to offset the loss of surface reservoir storage, reduce flood management risks and augment environmental flows.

DWR (2017) evaluated potential benefits of system reoperation to the reliability of water supply systems, ecosystems, and reduction in flood risk. Since the operation and management of surface reservoirs in California are already optimized for these objectives, they concluded that the reoperation offers potential benefits to water supply, flood risk and ecosystems, but that overall the benefits from reoperation were limited. However, new reservoir operation policies that take into account changes in hydroclimate conditions may be needed to accomplish joint and optimal operation of total storage in headwaters, surface reservoirs, and downstream groundwater reservoirs. The objective would be to maximize total water stored and provide flood protection under new flood hydrology regimes while also providing hydropower and needed instream flows.

Kocis and Dahlke (2017), ACWA (2017) and DWR (2018) concluded that due to variable hydrologic conditions in California, there are surplus flows in the system, especially during wet years, that can in theory be stored or diverted for MAR (see Section 1). Storing and diverting water is often limited by the physical constraints of conveyance structure capabilities and disconnection of water systems. The existing conveyance structures for getting water from the Sacramento Valley to points south of the Delta are based entirely on withdrawals from the south Delta via the federal and state water projects. It cannot be overemphasized that adequacy of this conveyance infrastructure for moving water to Central Valley recharge locations during the wet season needs to be evaluated. Furthermore, given that the HMFs will be occurring in every major stream draining the Sierra Nevada and Coast Ranges, investigation is needed into adequacy of diversion and conveyance structures on these streams, in relation to desired recharge locations. In particular, any changes in canal carrying capacity due to aging of structures, sediment deposition and effects of subsidence need to be fully ascertained and corrected if necessary. For instance, present capacities of the California Aqueduct, Delta-Mendota and Friant-Kern canals have been reduced by about 20 to 60 percent due to subsidence (Sneed et al. 2013; FWA 2017). Identification of the best recharge sites (Section 2) will help determine priorities for repair and expansion of conveyance structures.

KEY QUESTIONS

5.1 To what extent can reservoir reoperation lead to increase in potential use of water, especially HMFs, for MAR? Ongoing work by UC Water is showing that reoperation of Folsom Reservoir could yield hundreds of thousands of AF/year for MAR (Goharian et al., 2018) while increasing hydropower generation and satisfying Delta outflow requirements.

5.2 How much more water can be stored in the whole watershed by joint reoperation of both the surface and groundwater reservoirs?

5.3 What are the additional benefits of reservoir reoperation? To what extent will surface reservoir reoperation increase hydropower generation, reduce flood risk, restore ecosystem, and enhance aquatic habitats condition?

5.4 How will timings and magnitudes of HMFs into the surface reservoirs change as the mountain hydrology continues to adjust to a warmer climate marked by more wet and dry extremes?

5.5 Are the conveyance facilities adequate to support transfer of HMFs to the recharge areas, and what new projects and repairs are needed, especially for moving water from north to south of the Delta in winter? Although existing structures were not designed mainly for Flood-MAR, they may be appropriate in some places (e.g., Folsom South Canal, Goharian et al., 2018).

RECOMMENDED ACTIONS (high priorities in green):

5.a Develop the means to jointly manage the water stores in both surface reservoirs and groundwater. This can be accomplished through data and models that include both the surface and subsurface reservoirs, as well as the streams and conveyance facilities that connect them. The models should be capable of determining how various local and regional water resources management alternatives would affect total system water storage, hydropower generation and instream flows.

5.b Develop optimized multi-objective operation polices with reformed objectives for the main reservoirs in the state. Effectiveness of the new operation policies should be assessed based on improvements on flood protection, drought preparedness, groundwater sustainability, and ecosystem restoration. Reservoir reoperation studies should be included in areas where water for recharge is not necessarily available instream or water is already fully appropriated. In these cases, feasibility of providing excess/additional flood water by reforming the upstream management should be considered. Moreover, reoperation polices should consider future flood operating rules and water supply allocations under a changing hydrology.

5.c Develop rehabilitation plans for existing conveyance facilities and assess need for new conveyance capabilities to fulfill the integrated reoperation of surface and groundwater reservoirs, with particular attention to opportunities offered by high magnitude flows and high-capacity recharge areas.

5.d Consider the public benefit of recharge in the funding of a north-south conveyance facility through the Delta.

ANTICIPATED CONSEQUENCES

Fully integrated management of the surface water and groundwater stores will ensue from leveraging the full storage capacities of each with the high-magnitude stream flows and new and existing conveyance facilities. This will lead to improved overall water security, flood protection, groundwater sustainability, drought preparedness, and ecosystem function.

6

WHAT ARE THE WATER QUALITY BENEFITS AND CONCERNS OF RECHARGE?

John McHugh, Graham Fogg, Andrew Fisher, and Thomas Harter

6.

Key water quality challenges in irrigated agricultural lands are the management of nitrogen (Rosenstock et al., 2014; Tomich et al., 2016) and salts (CVsalinity.org). Groundwater basins receiving most of the recharge from irrigation rather than other sources and discharging much of that recharge back into irrigation are subject to long-term groundwater quality degradation on time scales of decades to centuries (e.g., Fogg and LaBolle, 2006, Zhang and Harter, 2006). In some localities, however, recharge will likely cause some significant but temporary declines in water quality owing to flushing of nitrate, salt or other contaminants out of the unsaturated zone that overlies the water table. Importantly, the HMFs (high-magnitude flows) of Flood-MAR, and most streamflow diversions, can be argued to be of much higher quality than irrigation recharge (Boyle et al., 2012; King et al., 2012).

Hence, there are two, key fundamentals concerning groundwater recharge in the agricultural landscape: First, in-season recharge due to over-irrigation is undesirable from a water quality perspective due to the high risk for nitrate and other agricultural chemical leaching. In particular the control of groundwater nitrate pollution is tied to significantly improving irrigation efficiency by reducing irrigation applications to plant water needs and, thus, reducing recharge. By minimizing water losses from the root zone during the growing season, more of the nutrients and other agricultural chemicals are appropriately consumed by plants and soils (Harter et al., 2012). Second, clean recharge during the off-growing season or outside of crop areas in active growth provides significant potential for dilution of salinity and residual nitrate. As agriculture continues progress towards addressing nitrate issues by improving irrigation and nutrient practices, underlying groundwater basins lose 20th century sources of recharge that must be compensated and enhanced by on-farm and flood managed aquifer recharge.

Water quality changes from MAR projects can be managed and predicted (Schmidt et al., 2011a, b), but better data are needed to characterize the present quality of both shallow and deeper groundwater. Moreover, there is a need for development of groundwater quality management models to complement our groundwater quantity management models (Fogg and LaBolle, 2006; Boyle et al., 2012; King et al., 2012).

KEY QUESTIONS:

6.1 What is the current quality of shallow, intermediate and deep groundwater in California, and how will it change under more widespread, aggressive recharge actions?

6.2 How can strategic recharge operations with relatively clean water, together with agricultural and urban land management practices be used to stabilize and improve groundwater quality?

6.3 What groundwater quality management data and tools will be needed in the future to jointly manage both the groundwater quality and quantity?

6.4 Is California's water quality regulatory system, including the Porter-Cologne Act and the Antidegradation Policy, compatible with significant increases in recharge that would potentially locally degrade groundwater quality even while improving regional groundwater quality over the long term?

RECOMMENDED ACTIONS: (high priorities in green):

6.a Continue the GAMA (California Ambient Monitoring and Assessment program), but examine whether it is adequate for providing a baseline of both shallow and deep groundwater quality information needed to ascertain water quality effects of recharge. Reconsider the GAMA program in light of planned or potential increases in recharge, and reinvest in or refocus the program if necessary.

6.b Estimate through the use of data and models the long-term future changes of groundwater quality under different land and water management strategies that include all the major sources of recharge, including irrigation, ongoing MAR operations, and Flood-MAR, among others. Develop groundwater quality management models to assist in this effort (Fogg and LaBolle, 2006; Boyle et al., 2012; King et al., 2012).

6.c Reexamine alignment of SGMA's recharge goals in light of California's water quality regulatory system, including the Porter-Cologne Act and the Antidegradation Policy, and adjust the system for mutual compatibility under increased recharge conditions.

ANTICIPATED CONSEQUENCES:

Actions that enhance our understanding of water quality changes due to recharge over time and at different scales will help make predictions more accurate and streamline the regulatory and project planning processes. Integration of knowledge on groundwater quality and quantity in the context of past, present and future recharge actions will lead to land and water management strategies that improve water security by both increasing stores of groundwater and improving or stabilizing the quality of groundwater.

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APPENDIX A: RECHARGE ROUNDTABLE ATTENDEES

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APPENDIX B: RECHARGE ROUNDTABLE PROGRAM

Call to Action to Recharge California's Depleted Aquifers
Groundwater Resources Association-UC Water Roundtable

October 2, 2017, 8:00 am – 5:00 pm
Hilton Arden West
2220 Harvard Street, Sacramento

General Theme: Share perspectives on successes and identify opportunities to significantly expand conjunctive use and recharge programs to support the Sustainable Groundwater Management Act (SGMA) and improve water supply resiliency in California.

Objectives:

- Discuss new goals and strategies for recharge and conjunctive use
- Produce potential activities and actions for a five-year strategy to significantly increase recharge and conjunctive use in California
- Highlight roundtable results thru the *California WaterBlog*, a workshop summary, white paper and other products to be determined
- Integrate results with other recharge events and conversations

8:00	**Check-in and Refreshments**
8:30	**Welcome and Introductions** • Chris Peterson, Tim Parker - Groundwater Resources Association (GRA) • Graham Fogg - UC Water
8:40	**Meeting Objectives and Agenda Review** • Dave Ceppos - Facilitator - Center for Collaborative Policy
8:45	**Roundtable Introductions** • All participants
9:20	**Framing the Conversation on Recharge Opportunities** • Graham Fogg, UC Water – California Setting for Recharge Opportunities
9:45	**BREAK**
10:00	• Jim Wieking, California Department of Water Resources – State Water Project Operations and Recharge Opportunities • Alicia Forsythe, Bureau of Reclamation – Central Valley Project Operations and Recharge Opportunities • Amrith Gunasekara, California Department of Food & Agriculture – Recharge Plans • Andy Fisher, UC Santa Cruz – Incentivizing Stormwater Capture and Recharge in Pajaro Valley • Amanda Montgomery & Erik Ekdahl, State Water Resources Control Board – Water Rights and Recharge Opportunities
11:00	**Panel Q&A, Roundtable discussion.**

APPENDIX B: RECHARGE ROUNDTABLE PROGRAM

11:50	**Overview of Afternoon Breakout Sessions** • Facilitator
12:00	**LUNCH**
12:45	**Afternoon Breakout Sessions** Each Session Theme will have three, 30-40 minutes rounds of discussion– participants may rotate between sessions or stay through all three rounds of discussion in one session **General Focus**: Expand conjunctive use and recharge opportunities to help meet SGMA mandates. **Sessions Themes**: *Institutions and legal framework needed to conjunctively manage and increase recharge* • Discuss approaches to organize around institutional, legal and regulatory frameworks to increase conjunctive use and recharge capacity • Identify elements of practical coordination among all conjunctive use and recharge programs and goals • Discuss priority actions to consider from 2018 thru 2022 *Technical resources and challenges to conjunctively manage and increase recharge* • Identify the existing tools available • Discuss assessment needs • Discuss factors for prioritizing actions • Identify components for attaining feasible goals • Identify investments needed in tools • Discuss priority actions to consider from 2018 thru 2022 *Feasible scope, scale and economics to increase conjunctive use and recharge* • Discuss increasing conjunctive use and recharge at appropriate scale for needs (subbasin to basin to regional to statewide) • Identify feasibility and economics considerations for rural versus urban area conjunctive management and recharge • Consider the cost benefit assessments for achieving recharge goals • Discuss priority actions to consider from 2018 thru 2022
3:00	**BREAK**
3:15	**Summary Plenary Session** • Break out groups report back • Discuss outstanding questions and resources needed • Group "pulse check" on breakout ideas and next steps to inform GRA and UC Water actions that support efforts
4:45	**Closing Remarks** • John McHugh – GRA • Graham Fogg – UC Water
5:00	**Meeting Adjourns**

TEAM

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PHOTOGRAPHY & FIGURE CREDIT

COVER ART

Delta-Mendota Canal buckling from subsidence, 2015, USGS.

Yolo Bypass in flood. The City of Sacramento sits safely above flood waters in the background, near Sacramento, CA, January 11, 2017. Photo by Graham E. Fogg.

View from Black Giant Peak into the Ionian Basin, Kings Canyon National Park, May 11, 2005. Photo by Graham E. Fogg.

Greenhouses and strawberry fields surround a Pajaro Valley managed aquifer recharge study site, near Watsonville, CA, June 2, 2016. Photo by Leigh Bernacchi.

Groundwater photo sourced from shutterstock.

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F.1 View from Black Giant Peak into the Ionian Basin, Kings Canyon National Park, May 11, 2005. Photo by Graham E. Fogg.

F.2 A view of Lake Shasta with 93 percent of total capacity, or 108 percent of historical capacity near Redding, California, May 11, 2016. Photo by Kelly M. Grow.

F.3 Groundwater basin depiction from Faunt, C.C. ed., 2009, Groundwater Availability of the Central Valley Aquifer: U.S. Geological Survey Professional Paper 1766, 225 p. Available at https://pubs.usgs.gov/pp/1766/

UC WATER
Security and Sustainability
Research Initiative

Groundwater
Resources
Association
of California

A collaboration between Groundwater Resources Association of California &
University of California Water Security and Sustainability Research Initiative