**Public Interest Energy Research (PIER) Program**
**White Paper**

# CLIMATE CHANGE AND WATER SUPPLY SECURITY:

## Reconfiguring Groundwater Management to Reduce Drought Vulnerability

**A White Paper from the California Energy Commission's California Climate Change Center**


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# PREFACE

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California. The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

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In 2003, the California Energy Commission's PIER Program established the California Climate Change Center to document climate change research relevant to the states. This center is a virtual organization with core research activities at Scripps Institution of Oceanography and the University of California, Berkeley, complemented by efforts at other research institutions.

For more information on the PIER Program, please visit the Energy Commission's website http://www.energy.ca.gov/research/index.html or contract the Energy Commission at (916) 327-1551.

# ABSTRACT

Periodic droughts, projected to become more frequent and severe with climate change, present a significant planning challenge for California's water agencies. This research examined approaches to reducing drought vulnerability, focusing on five water agencies on California's north and central coast that rely on local and regional sources of water. Curtailing water use is the principal response to drought. In contrast, this project highlights an important but underutilized proactive adaptation to improve water supply security during drought: the development of *locally based* groundwater drought reserves. While this approach represents an obvious solution in principle, it is uncommon to find it in practice, and this research provides insight into (1) motivating factors, (2) legal barriers and opportunities, (3) tools, and (4) policy options to support increased drought resilience and the development of drought reserves.

***Motivating Factors:*** The hydro-geophysical elements, water management policies, and socio-legal characteristics that motivate an agency to initiate *proactive* adaptation strategies to increase drought resilience and establish drought reserves. This research points to the following as significant:

- Severely limited access to water during a drought
- Regulatory constraints, e.g., under the Endangered Species Act or a growth moratorium
- Strong leadership and stakeholder commitment to sustainable water management

***Legal Opportunities and Constraints:*** The legal rules and institutional structures affecting groundwater management in California, and the opportunities and constraints they provide to establish drought reserves.

***Tools***

- Decision support mechanisms that can assist water agencies in the calculation of metrics to establish a local groundwater drought reserve: estimation of a basin's storage capacity and calculation of groundwater levels to bring a basin into hydrologic balance and to sustain a reserve
- Determination of criteria to access a drought reserve

***Policy Options:*** Policy options to support the establishment of proactive drought adaptation strategies, including drought reserves.

**Keywords:** drought, water supply, groundwater, reserve, resilience

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# Section 1: Introduction

## 1.1 The Problem

Droughts are a natural occurrence in California (Cal. Climate Action Team 2006; (California Department of Water Resources (DWR) 2005), and climate change is predicted to increase their number and intensity (Hayhoe et al. 2004). Although precise localized impacts of climate change on water resources remain less certain, even in the absence of changes in precipitation patterns, higher temperatures resulting from increased greenhouse gas concentrations are expected to lead to higher evaporation rates, reductions in stream flow, and more frequent droughts (Nash and Gleick 1991a,b, 1993; DWR (2008a).

Many communities in the state already experience water shortages during a drought (Hanak 2005; Cal. Climate Action Team 2006; California Legislative Analysts Office (LAO) 2009), and climate change is likely to exacerbate this vulnerability. For example, general circulation models suggest that climate change could result in large-scale soil drying in some regions in the summer owing to higher temperatures, with potentially significant impacts on the supply of and demand for water (Vinnikov et al. 1996; Brumbelow et. al. 2000). The state recently experienced a multi-year drought, intensifying concerns over reduced water supplies for many communities and ecosystems (Hotakainen 2009).

A drought affects all sectors of society, impacting basic water needs for consumption, agriculture, and public heath including sanitation and firefighting (Governor's Advisory Drought Planning Panel 2000). During the 1988–92 drought in California, urban users paid more for water, lost jobs, saw electricity costs rise, and experienced adverse affects on water-based recreation and major fisheries. By year three of the drought, statewide reservoir storage had decreased by 60 percent, and did not return to average conditions until 1994 (Gray 1994). Water districts did utilize price incentives, conservation, water reallocation, and water transfers to cope with the diminished supply, but there was also a 25 percent annual increase in the sale of pumps during the drought, and groundwater pumping accounted for a significant portion of the water substitution resulting from a lack of surface water supplies (Zilberman et al. 1995). This resulted in groundwater overdraft, causing land subsidence in some aquifers, and saltwater intrusion in aquifers along the coast.

***The key issue that this research addresses is how to proactively adapt to drought.***[1] The project provides insights into the conditions that generate different levels of vulnerability to drought and strategies that can increase resilience to ensuing water shortages.

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[1] "Drought" is a complex term, generally defined as being meteorological, hydrological, or agricultural. But the definition and consequences of a drought must be placed in the context of the social and economic activities of a given region. The National Drought Monitor defines drought as a moisture deficit bad enough to have social, environmental, or economic effects. Their drought intensity categories are based on five key and additional supplementary indicators, and include: abnormally dry, moderate drought, severe drought, extreme drought, and exceptional drought (*http://droughtmonitor.unl.edu/classify.htm).* We note that in California, even events classified as mild can have an effect on local communities, as discussed in Section 5.

A significant problem is that with few exceptions, state guidelines and traditional drought adaptation strategies are reactive. They include generating surface and groundwater data and preparing and implementing water shortage contingency plans *after* a drought occurs DWR 2008c). The problem with this approach is that it does not provide for long-term proactive measures to reduce vulnerability to water shortages (Wolfe and Brooks 2003; Langridge 2009). Additionally, while strategies such as surface storage, recycling, desalination, and conservation may be effective in some circumstances, and are often commended for providing additional water during a drought, they may also lead to a pernicious unintended consequence: expanded supplies and reduced usage can prompt growth in water-stressed regions during wet periods, causing an eventual increase in future water requirements. Along with a hardening of demand-side conservation strategies, and without setting aside reserves, this can actually *increase* a region's vulnerability to water shortages during a future drought (Langridge 2009).

## 1.2 Our Proposition

***We propose that the development and maintenance of locally based groundwater drought reserves, an underutilized and proactive adaptation, can improve water supply security during extreme droughts***. The emphasis is on groundwater recharge, storage, and the establishment of high-quality buffers to reduce drought vulnerability. Recovery of water for short-term demand can occur so long as the reserve is maintained. Moreover, given the decreasing reliability of imported water, our project focuses on the use of regional and local water sources to enable a community to develop its drought reserve supply.

Coastal communities that are not connected to the major water projects in the state, and that typically rely on groundwater and small capacity storage systems fed by annual rainfall, are particularly at risk for water shortages (DWR 2008b), and their needs have not been fully addressed within California's institutional framework for drought planning (Governor's Task Force Discussion Paper on Drought 2003). Yet, during critically dry years, groundwater is the lifeline for many of these communities when water districts and individual users greatly increase groundwater pumping to offset surface water shortfalls (DWR 2000, 2003; California Energy Commission [CEC] 2005; Sandino 2005). In their drought simulation, Miller et al. (2008) found that groundwater pumping in the Central Valley would increase by 74 percent in a severe drought and 51 percent in a moderate drought scenario. This shows that even basins with access to imported water tend to rely heavily on groundwater during droughts. Additionally, given the current economic, political and environmental costs of substantially expanding surface-storage capabilities in California, enhanced underground storage is likely to appear comparatively attractive for many communities.

The problem is that many of California's groundwater basins are in overdraft, with groundwater levels that are declining over the long term (United States Geological Survey (USGS) 2009). Groundwater overdraft contributes to numerous problems, including subsidence and permanent loss of storage, reduced surface flows, and associated damage to aquatic ecosystems. Saltwater intrusion is already occurring along California's coast from San Diego to Humboldt County (Ashley and Smith 1999).

While the state recently provided funding for the development of more sustainable groundwater management, and many water agencies currently manage groundwater basins in an effort to reduce overdraft and seasonal and short-term water shortages, ***no program has yet been established and implemented to proactively address drought through the establishment of local groundwater drought reserves.*** Rather, during the last 150 years, when California experienced a slightly above average wet regime with a small number of short-duration dry periods, agriculture, for example, utilized the relative abundance of water to expand production rather than meaningfully recharge aquifers and develop long-term reserves (Ingram et al. 1996; Cook et al. 2004). This is unfortunate, as aquifer conditions at the beginning of a drought are critical to maintaining the quality and quantity of water supplies throughout and after the drought. Moreover, an over-drafted basin can reduce future opportunities to utilize groundwater for consumption, agriculture, and public health and safety. The California Department of Water Resources (DWR 2008b) notes that utilizing aquifers as storage facilities will be particularly useful in the face of climate change impacts.

Importantly, establishing drought reserves is a "no-regrets" strategy, which is defined by the Intergovernmental Panel on Climate Change (IPCC) as a policy that would have net social benefits whether or not there is anthropogenic climate change (McCarthy et al. 2001; Kiparsky and Gleick 2003). Additional storage is also a recommendation in several state agency reports (DWR 2008c). Moreover, researchers emphasize the need for buffers as a proactive strategy to cope with drought events (Blomquist et al. 2004) and government guidelines indicate that all water suppliers should maintain a multi-year drought water supply buffer whenever possible, such as in local groundwater basins (DWR 2008b), **but so far there is little guidance on establishing and maintaining a locally based long-term reserve.** Our research addresses this gap.

We emphasize that by conserving groundwater in normal **and** wet years, reducing overdraft, and developing reserve supplies, communities can increase their resilience to drought.

## 1.3 Project Goal

Our project utilized multidisciplinary tools to illuminate the physical, legal and institutional conditions that generate differential levels of vulnerability to drought and to elucidate opportunities, incentives, and tools to enhance the development of strategic groundwater drought reserves as an important adaptation strategy that can increase the resilience of coastal regions to drought.

## 1.4 Project Objectives

- Detail drought adaptation processes utilized by coastal communities and their water agencies in California, with a focus on basins that operate largely independently of large-scale conveyance systems.
- Illuminate motivations to reduce drought vulnerability and strategies to increase resilience to anticipated water shortages.
- Investigate physical and legal-institutional characteristics that affect opportunities and constraints to establish groundwater reserves.
- Investigate robust approaches to replenish aquifers and develop groundwater reserves.
- Develop tools to assist water agencies in calculating targets for storage and when to withdraw from a reserve.

- Explore feasible institutional incentives and develop a legal roadmap to support reserve development and more sustainable groundwater management.

Communities not connected to the major water projects in the state are particularly vulnerable to water shortages, including many rural and coastal areas. Our project therefore focuses on water supply planning in several regions in north and central coastal California. These may serve as examples to develop metrics, methods and incentives that can subsequently be applied more broadly across the state.

Our project addresses topics of primary importance to the California Energy Commission:

1. Institutional adaptations to climate change and more frequent and severe droughts.
2. Options to enhance the long-term sustainability and reliability of water supplies.
3. Management strategies to preserve or enhance groundwater availability under drought conditions.
4. Energy use reduction through an emphasis on developing more sustainable local sources of water.

We use an underutilized interdisciplinary approach to addressing water supply security that incorporates physical, legal, social, and institutional dimensions to illuminate a more proactive strategy to cope with drought.

## 1.5 Paper Roadmap

Section 1 introduces the problem and our proposition. Section 2 discusses the physical dynamics of groundwater recharge and storage in the context of establishing a drought reserve, potential sources of water for a reserve, and general considerations in establishing a reserve. Section 3 examines legal-institutional factors including broad legal requirements for groundwater storage and withdrawal, and unsettled areas of the law. Section 4 introduces the groundwater basins and districts that serve as examples for this study. We discuss the physical dynamics, legal and institutional background, and current status of each site, including: hydro-geophysical characteristics of each groundwater basin; goals and strategies of local water agencies and other stakeholders; and the history of groundwater management, existing legal and institutional requirements to use, store and extract water, and cooperative projects and conflicts. Section 5 addresses general considerations in assessing both the amount of water needed for a reserve and when to withdraw water from a reserve. It also examines how three water agencies could approach the calculation of a drought reserve, including development of guidelines for when reserves should be withdrawn. Section 6 discusses findings from these studies and highlights key characteristics and policy options that could make efforts to establish drought reserves more or less successful.

# Section 2: Study Elements: Physical Dynamics

The physical characteristics of groundwater basins, the history of local water management and use, and the legal and institutional regime in which management is embedded all play a significant role in creating the vulnerability of an area to drought. This section discusses the physical dynamics of groundwater recharge and storage in the context of establishing a groundwater drought reserve, and a discussion of potential local and regional sources of water for a reserve. Section 3 provides a general discussion of the legal-institutional factors involved in creating a groundwater drought reserve along with areas of unsettled law.

## 2.1 Hydro-geologic Characteristics

The physical characteristics of aquifers vary greatly; therefore, the suitability of a particular aquifer to serve as an area for immediate storage and later extraction depends on the geologic and hydrologic variability in the character, thickness, and conductivity of geologic materials both within and overlying the aquifer; the porosity of the basin material; and the depth of the basin (Foley-Gannon 2008). The geometry of an aquifer is usually poorly defined, and subsurface water can interact with surface flows (Sheng 2005; Zektser et al. 2005). Extractions from a groundwater basin can result in the lowering of the water table and cause water from a connected surface water system to percolate into the basin. Similarly, pumping from the same or adjacent aquifer units can redirect the natural flow of water and result in overdraft conditions for some communities, while upstream pumping can result in less groundwater available to downstream users.

The quality of the water stored within the basin is also important. Pollution concerns arise when chemically and microbiologically different waters mix, so the source of water is significant. The fluctuation in water levels in a basin can alter the rate or direction of groundwater flow, which could force contaminated water in the basin to flow towards wells. In this way, recharged aquifers can exacerbate pollution problems within a basin by hastening the dispersal rate of pollutants throughout the aquifer. Land uses overlying the basin can also affect groundwater quality. Thus, prior to recharge, an assessment of the level and location of contaminants within a basin is important (Helperin et al. 2001). When a basin is adjacent to the ocean or a saline aquifer, the withdrawal of water can allow for intrusion of saltwater into the freshwater aquifer, potentially rendering the water stored within the basin unusable without treatment (Foley-Gannon 2008). Additionally, groundwater quality depends on water temperatures, flows, runoff rates and timing, and the ability of watersheds to assimilate wastes and pollutants.

Climate change could alter all of these variables. Studies suggest that changes in precipitation will affect water quantity, flow rates, and flow timing. Large increases in precipitation will probably lead to increases in runoff: such increases can either worsen or lessen water management problems, depending on the region and the nature of the problem. Higher winter flows of water for example, could increase erosion of land surfaces and stream channels, leading to higher sediment, chemical, and nutrient loads in rivers. Increases in water flows can also amplify loadings from non-point source pollutants, increase export of pollutants to coastal wetlands and deltas (Mulholland et al. 1997; Schindler 1997), and boost turbidity in lakes, reducing ultraviolet-B (UV-B) penetration. Changes in storm flows will also affect urban runoff, with attendant water-quality impacts. Decreased flows in summer and fall can exacerbate temperature increases, intensify the concentration of pollutants, boost flushing times, and increase salinity (Schindler 1997; Mulholland et al. 1997). Lower summer flows could also reduce dissolved oxygen concentrations and increase zones with high temperatures. Decreased surface-water volumes can increase sedimentation, concentrate pollutants, and reduce non-point source runoff (Mulholland et al. 1997). Less directly, changes in land use resulting from climatic changes, together with technical and regulatory actions to protect water quality, can be critical to future water conditions.

## 2.2 Potential Sources of Water to Reduce Overdraft and Build a Reserve

Most agencies cope with seasonal and short-term water shortages through demand curtailment policies, and are not focused on creating long-term drought reserves. Creating these reserves requires the identification of water sources that can be used not only to balance a region's water budget, but also to establish an additional drought buffer. This can be especially challenging in regions where groundwater is already being overexploited and a basin is in overdraft.

Much of the state relies primarily on importing water to recharge aquifers and balance a region's water budget. As imported water has become less reliable, water agencies are exploring alternative sources to improve water supply security, including the ones identified in this section. Currently, the sources discussed below are mainly being used to balance a region's water budget, but they could be utilized for developing reserves. Importantly, many coastal regions never relied on imported water, so these water sources are especially relevant to reducing their drought vulnerability.

### Stormwater Capture

Stormwater capture could be used to enhance local supplies and reduce reliance on imported sources (Atwater 2011). One goal is to maximize infiltration by slowing runoff and reducing flooding and erosion. Another goal is to enhance recharge in order to reduce aquifer overdraft and develop drought reserves. Approaches include the reduction of impervious surfaces to support the natural treatment of stormwater through soil filtration and plant uptake of pollutants and nutrients, and the storage of stormwater in a retention facility such as a rain-barrel or cistern (Pitzer 2011).

The direct capture and storage of precipitation in a rain barrel or cistern is one of the oldest, simplest ways to increase the amount of water available for domestic use. Used by people around the world for many hundreds of years, this is one "local" solution to water supply on a household-by-household basis. One disadvantage is its small scale; many cisterns would be required to significantly affect an entire region's water budget. The initial capital outlay for a major system could be high, and individual water users would likely be the ones bearing the cost and/or dealing with maintenance issues. Moreover, with the state's Mediterranean climate, a cistern might fill early during the winter and remain full throughout the wet season, but be fully depleted by late spring and sit empty through most of summer and fall. Nevertheless, in groundwater-dependent regions of California, a rainwater catchment system could be used to reduce groundwater pumping during the early spring, especially during wet years, and could potentially serve to slowly replenish existing overdraft and eventually develop local reserves, if that is a goal.

Rainwater harvesting policies vary from state to state, and many western states actually prohibit rainwater catchment systems as they are seen as intercepting recharge to which somebody else already has a preexisting groundwater right (Friederici 2008). In California, there are no known local laws restricting rainwater harvesting at this time, but neither has the state officially approved the process, and the law is silent on rights to rainwater that has not reached a stream. In 2007, two bills were passed in the California State Legislature that require local water districts to create water conservation programs and building standards: AB 1420[2] and AB 1560;[3] however neither bill discusses rainwater harvesting as a water conservation option (City of San Diego 2012).

The capture of storm runoff, either directly from streets and storm sewers, or from the excess flushing flows of swollen creeks and streams, is somewhat akin to the direct capture of precipitation, but on a larger, more-efficient scale. Nonetheless, this method of increasing the amount of water available for groundwater recharge also presents a series of potential problems. Water quality now becomes an issue, as rainwater flowing across lawns, streets, and fields can pick up a contaminants that would make it unfit for direct consumption or direct injection into an uncontaminated aquifer.

Temporary storage of large sporadic storm flows might also prove a problem. Whereas 100,000 cisterns might be individually costly and difficult to maintain, their benefit is that their surface footprint is widely disbursed; i.e., everyone has room in their yard for one. Conversely, whereas a larger scale stormwater capture system addresses cost and maintenance issues more efficiently, finding large areas of land suitable for the construction of temporary storage facilities might prove more challenging, and transmission systems to convey water to or from such facilities would also bear a cost.

The California Water Resources Control Board (SWRCB), deriving its authority from the federal Water Pollution Control Act (Clean Water Act), the U.S. Environmental Protection Agency, and the California Porter Cologne Act, regulates the runoff and treatment of stormwater in industrial, municipal, and residential areas in California. Stormwater is potentially a non-point pollution source, and while its diffuse nature makes it difficult to control, the Board recently adopted two statewide National Pollutant Discharge Elimination System (NPDES) general permits addressing stormwater discharges associated with industrial activities and from construction activities (Construction General Permit and Small LUP General Permit). Dischargers are required to develop a stormwater pollution prevention plan (SWPPP) to identify and implement control measures, and monitor their discharges. In March 2011, the U.S. Court of Appeals for the Ninth Circuit held that liability for stormwater pollution can be applied to an agency. This could also encourage municipalities to spend more money in controlling pollution from stormwater discharges (Pitzer 2011)

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[2] Assembly Bill 1420 (Laird), Chapter 628, Statutes of 2007

[3] Assembly Bill 1560 (Huffman), Chapter 532, Statutes of 2007

Today, the goal is to use stormwater runoff as a water source for landscape watering and groundwater replenishment. Thus, the capture and infiltration of excess storm flows into local aquifers is a potentially feasible source for aquifer recharge and drought reserve creation, and it could be enhanced by smaller-scale measures such as the use of permeable pavements, constructed wetlands, and landscaping that spreads and slows the rate of stormwater runoff. Several agencies in our study are offering programs to enhance the capture of stormwater runoff.

## Recycled Water

Urban wastewater recycling is a proven method to extend a region's water supply, and is currently being employed successfully in many areas of California, including to various extents in the Pajaro Valley, Scotts Valley, Soquel Creek, and Sonoma County. The use of recycled water might seem like an obvious choice, as it utilizes water that agencies already own and have in their physical possession, and might otherwise waste by discharging downstream or out to sea. However, as with previous water sources discussed, recycled water has its limitations. In order to be reused, recycled water must undergo a tertiary treatment and disinfection process, the energy and infrastructure costs of which are significant, but not necessarily prohibitive. The larger financial burden for a water district often comes with the construction and maintenance of a conveyance system that transports recycled water from the treatment plant to users completely separately from potable municipal water. For example, of the $48 million the Pajaro Valley Water Management Agency spent for its recycled water facility, nearly half was used for the construction of the initial phase of a Coastal Distribution System to deliver this water to coastal growers. Future expansions of this system will require even more funding.

While many uses are currently approved for tertiary treated recycled water (irrigation of fields, crops and lawns, car washing, laundry, and flushing toilets, just to name a few), direct injection or infiltration of recycled water into drinking water aquifers requires a special permit from the Regional Water Quality Control Board (California Department of Public Health (CDPH) 2008). Therefore, any benefit to aquifers as a result of wastewater recycling comes as in lieu recharge from groundwater not pumped, because recycled water is being used in its place.

Despite its many approved uses, finding enough customers to consume recycled water can be a challenge for water agencies. The problem is not so much the "yuck" factor as it is a cost factor. Water agencies must bear the cost of developing the infrastructure to produce and deliver recycled water, so it seems logical and fair that they charge a market price for it. Rates for deliveries of recycled water are therefore not typically discounted relative to those for primary potable water, and users have little incentive to make the switch. If landowners have the even cheaper third option of pumping and using groundwater from beneath their own property, then the prospect of paying a premium for recycled water deliveries can seem particularly unappealing.

### Desalination

Desalination also utilizes a water source that is free, legally available, and for coastal basins such as Santa Cruz or Soquel Creek, readily on hand: the ocean. Desalination is appealing because unlike recycled water, the water produced is considered to be of drinking water quality or better, and can therefore be distributed through a city's existing plumbing infrastructure. Relative to tertiary treatment and disinfection of urban wastewater, however, the infrastructure, materials and energy costs of physically removing dissolved salts from ocean water is much more expensive, as well as very energy intensive. Safe disposal of the residual highly concentrated salt brine is also a concern (Cooley et. al. 2006). Assuming desalinated seawater is produced and used directly, any benefit to groundwater reserves would come in the form of in lieu recharge from groundwater not pumped. Santa Cruz and Soquel Creek are in the planning stages for a desalination plant that would yield water for a drought reserve for both communities.

### Conservation

Over the past several decades, conservation has been the foremost tool water agencies have used to decrease per capita, and in some cases overall, water demand. Conservation measures are relatively easy for water districts to implement by using various financial "carrots" and "sticks," and the combined savings from among thousands of individual water users can be quite significant. Ironically, the amazing success of conservation in the past might inhibit its continued application in the future, as any individual water user cannot reduce the amount of water he uses beyond a certain practical limit. Gains can still be made however, particularly in the agricultural sector where water users who pump local groundwater are not necessarily subjected to the same restrictions and incentives as municipal water customers (Cooley et. al. 2008). All the agencies in our study have implemented some water conservation measures to address both seasonal and short-term demand and reduce groundwater overdraft. Simply leaving more groundwater in regional aquifers is the simplest, cheapest, and surest way to begin creating a strategic groundwater drought reserve.

## 2.3 General Considerations in Establishing a Drought Reserve

There are several methods by which water could be stored as a reserve against future drought. Reservoirs, both on-stream and off-stream, are widely used and one goal for their construction and operation could be their ability to serve as such a drought reserve. Lake water can also be drained to provide emergency drought supplies, but it often has no excess capacity that can be filled to serve as a reserve. As already mentioned, water tanks or other structures can be too expensive to serve as a reserve against more than just a few days of water shortage in Mediterranean climate regions such as California. This study is only considering the use of groundwater storage as a drought reserve.

It is critical to know the precise size of reserve needed. Creating a drought reserve might entail all sorts of economic costs, practical difficulties, environmental impacts, and community stresses. So it is important to not overbuild a drought reserve. There is a delicate balancing of the costs versus the benefits that must be carried out.

Withdrawal from a large reserve store of water that is just sitting there doing nothing is all too easy. The natural tendency is to go to the storage and take some water whenever the natural supplies are even slightly below normal or slightly below demands. The alternative is having an agency require its customers to reduce water use, a much less popular approach, particularly for a future risk such as drought. Moreover, frequent repeated requests for customer curtailment when no one can believe that there is a real drought emergency might be taken as an embarrassing indictment of the agency's failure to provide a reliable water supply. However, this tendency to “borrow” from the drought reserves should be resisted.

The purpose of a reserve is for protection against drought. Therefore it should only be used against real drought conditions, which might be defined as “A long period of abnormally low rainfall.” Real drought represents an extreme situation outside of normal climatic variability. Dealing with a precipitation amount that is slightly less that its long-term mean value should be considered part of normal risk management, and not a drought emergency.

There are real practical reasons to be stingy and strict on the use of a drought reserve. A year that is just slightly below its mean, or even two or more such years, could be the start of a real severe and long-term drought. Having dipped into the reserves for the early, slightly dry years could mean the reserves are now insufficient to actually protect against the real drought for which the reserve was designed and created. The terrible impact and hardships of not having enough water to survive the real drought could be much more severe and tragic than the inconveniences of not quite enough supply during the earlier slightly dry year(s). A much more blatant case of unwarranted dipping into reserves would be using reserve supplies to service some increasing demands from new development year after year until the reserves are completely exhausted.

# Section 3: Study Elements: Legal-Institutional Dynamics

The net effect of climate change on future water supplies depends not just on changing climatic conditions or the physical attributes of a region, but also on a wide range of human actions and decisions (Kirparsky and Gleick 2003). Legal and institutional structures and processes are major influences on why agencies adopt particular drought adaptation strategies, including the establishment of groundwater drought reserves.

It is important to note that while water is regulated and managed in the United States at the federal, state, and local levels, the many laws affecting water use and management were designed without considering how climate change impacts, including more frequent and severe droughts, would be affected (Kiparsky and Gleick 2003). Even without climate change, providing legal options to reduce vulnerability to water shortages is a no-risk approach, and efforts are needed to update and improve legal tools for managing and allocating water resources during drought.

This section considers the legal rules and institutional structures that affect groundwater in California and the opportunities and constraints they provide to support the establishment and maintenance of groundwater drought reserves.

## 3.1 Legal Authority to Manage Groundwater

Although surface and underground water are hydro-geologically interconnected, the State of California manages them under different legal regimes based on their specific classification. Surface waters and "underground streams flowing in known and definite channels" are subject to the statutory water rights system, and the SWRCB administers a water right permit and license system for appropriations initiated after December 19, 1914. The permit process does not apply to riparian rights, pre-1914 appropriative rights, or percolating groundwater (California Water Code, § 1200 et seq.). Owners overlying a groundwater basin follow a correlative doctrine, which gives all parties equal rights to a reasonable amount of the groundwater in the basin (*Katz v. Walkinshaw* 1903).

A key issue is that, with no state permit requirement for groundwater extraction, each owner can pump as much groundwater as is reasonable with respect to the reasonable rights of other overlying groundwater users, so long as use is beneficial and not wasteful. The lack of a permit system to allocate groundwater, the historical resistance of the California legislature to implement a permit-based process, and the correlative rights rule, has limited the ability of the state to address groundwater declines in many areas of the state. ***Reducing these declines is critical to establishing drought reserves.***

### Local Regulation

In lieu of state regulation through a permit system, more than 20 types of local agencies have authority to manage some aspect of groundwater, including, for example, water replenishment districts and water conservation districts. Depending on their enabling legislation, these districts can, but do not have to, limit or regulate extraction, levy groundwater extraction fees, and collect fees to establish recharge programs that address overdraft (California Water Code §§ 60221, 60230, 74508). Special groundwater management districts, created by the legislature in only a few areas, can manage groundwater to control in-basin pumping upon evidence or threat of overdraft, limit exports out of the district, regulate well spacing to minimize well interference, and levy fees for groundwater management activities and for water supply replenishment (California Water Code §§ 119–709). Conflicts over groundwater are primarily settled in court and have sometimes resulted in a groundwater basin adjudication where everyone's rights are spelled out and a water master oversees management of the aquifer. In theory, an adjudicated basin could require a drought reserve as a management condition, but this has not occurred so far.

### County Regulation

Along with local districts, almost 30 percent of California's counties have groundwater management ordinances. These may include for example, that a county will only issue a permit if an export of groundwater will not cause overdraft, affect safe yield, reduce water quality, cause subsidence, or injure water users within the county (Sandino 2005). County authority to regulate groundwater was upheld in *Baldwin v. County of Tehama* (1994), with the court stating that because state law does not occupy the field of groundwater management, cities and counties may adopt ordinances to manage their groundwater resources under their police powers. Counties can also assert jurisdiction over water that is temporarily banked in their local aquifers, for example, through ordinances creating groundwater planning and permitting authority (SWRCB 2002). These ordinances could be models for more sustainable groundwater management in the public interest and require the development of county drought reserves.[4] But most were adopted by groundwater-rich counties out of concern that their groundwater resources could be exported to meet the growing demands of the Bay Area and Southern California, and to protect against someone purchasing land within a county with groundwater resources for purposes of obtaining groundwater rights, and then transferring water outside of the county for a fee, to the detriment of users within the county.

### State Statutory Requirements

Several regulations address water supply planning and drought adaptation, albeit under relatively narrow circumstances. The California Environmental Quality Act, or CEQA (California Code of Regulations Title 14 § 15000 et seq.), passed in 1970, requires state and local agencies within California to follow a protocol of analysis and public disclosure of environmental impacts of proposed projects and adopt all feasible measures to mitigate those impacts. The California Environmental Quality Act requires a realistic discussion of a development's water supply in its Environmental Impact Report, including groundwater usage and the condition of the groundwater aquifer (*Save Our Peninsula Committee v. Monterey Board of Supervisors* 2001). A project's potential cumulative impact to groundwater resources (including

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[4] There may be constitutional limitations on ordinances that ban export outright or discriminate with respect to the export of water based on arbitrary definitions of place of use, such as beyond county boundaries. This could violate the Constitution's Equal Protection or Commerce Clause (SWRCB 2002).

overdraft) must be identified and analyzed. Regarding new proposed projects, CEQA requires an inquiry be made with respect to whether the project would substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of preexisting nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted).

Legislation also addresses groundwater overdraft in urban areas by requiring water suppliers with 3,000 or more connections, or supplying more than 3,000 acre feet per annum (afa), to evaluate water reliability over the next twenty years in an Urban Water Management Plan (UWMP), including scenarios with normal, single, and multi-year dry periods (California Water Code § 10631, 10635). If groundwater is an available source of water, the evaluation must include groundwater management, and if the basin is in overdraft, the plan must detail efforts to eliminate any long-term overdraft (California Water Code § 10631(b)(1)–(2)). The DWR is not required to review the plan's quality (California Water Code § 10631(a)–(b)).

In 1992, Assembly Bill 3030 (California Water Code § 10750–10756) expanded the ability of agencies to address the problem of critical overdraft by increasing the number of public agencies authorized to develop a groundwater management plan (GMP). A very significant issue is that agency participation in AB 3030 GMP creation is entirely voluntary and plans do not have to be filed with the DWR, limiting both their reach and an understanding of their effectiveness. AB 3030 instructs, but does not require, participating agencies to monitor for change in groundwater levels, quality, land subsidence, and surface flow and quality affecting groundwater basins (California Water Code § 10753.7.a.4). Agencies can then use the information to plan to meet basin management objectives that could address saltwater intrusion, recharge, and overdraft mitigation (California Water Code § 10753.8 et seq.). Drought planning utilizing drought reserves is not explicitly mentioned in the AB 3030 guidelines.

For new developments, in 2001 the state added a requirement for verification of water supply sufficiency as a precondition of final subdivision map approval for more than 500 dwelling units (SB 221[5] and SB 610[6] 2001). The law also defines criteria for determining "sufficient water supply," including using normal, single-dry, and multiple-dry year hydrology (SB 221 2001). Moreover, if groundwater is a source available to a water supplier in a non-adjudicated basin, and if the basin is in overdraft, the plan must include current efforts to eliminate any long-term overdraft. But enforcement of these requirements relies largely on citizen challenges for non-compliance (California Water Code § 10850).

Financial incentives for more sustainable local management of groundwater include that any public agency seeking state funds for groundwater projects prepare and implement a groundwater management plan that includes specific basin management objectives and monitoring protocols. Funding for water supply planning has included Proposition 204 (The Safe, Clean, Reliable Water Supply Act of 1996), the $1.97 billion Proposition 13 (The Safe

[5] Senate Bill 221 (Kuehl), Chapter 642, Statutes of 2001.

[6] Senate Bill 610 (Costa), Chapter 643, Statutes of 2001.

Drinking Water, Clean Water, Watershed Protection, and Flood Protection Act) in 2000, the $3.44 billion Proposition 50 (The Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002), and the $5.4 billion Proposition 84 (The Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006).

In 2009, Senate Bill 6 (SBX7 6,[7] Steinberg) authorized local water management entities to assume responsibility for monitoring groundwater elevations in all groundwater basins in California, and requires that monitoring and reporting to DWR commence by January 1, 2012 (California Water Code § 10920 et seq.). Local agencies are required to conduct the monitoring, which will then be reported to DWR, who is required to report periodically to the public on the status of groundwater across the state. Local agencies that do not conduct required monitoring are barred from receiving state grants and loans (LAO 2010). But this information does not quantify overdraft or provide for an accounting of inputs and extractions (Sawyer 2010), all of which are needed to reduce declining levels and establish a groundwater drought reserve.

### California Water Code

Several additional sections of the Water Code are also relevant to reducing groundwater overdraft and establishing groundwater drought reserves. Sections 1005.1–1013 provide a means for owners of rights to pump groundwater to protect these rights when they conserve water or substitute water from an alternate non-tributary source for water previously appropriated or for pumped groundwater. California Water Code, § 1253 enables the SWRCB, to require, as a condition of a post-1914 surface water permit, that water appropriated and then imported and stored in a groundwater basin be developed, conserved, and utilized in the public interest. California Water Code Sections 1240–1242 state that storing water underground, including necessary diversion and spreading operations, is a beneficial use of water if the water stored is later put to the beneficial use for which the appropriation for storage was made. Where surface water is appropriated and then transferred to storage underground, the transfer also requires the approval of the SWRCB that it would not injure legal users or unreasonably effect fish, wildlife or other in-stream beneficial uses (California Water Code, Sections 1020, 1435, 1700, 1707 (for in-stream uses), 1725 or 1735.

Section 12922 states that the people of the state have a primary interest in preventing impaired use or irreparable damage to groundwater basins caused by overdraft and depletion. However, overdraft remains a significant problem in many areas. Finally, section 104 states that, "...the people of the State have a paramount interest in the use of all the water of the State and…the State shall determine what water of the State, surface and underground, can be converted to public use or controlled for public protection."

### State Public Interest Doctrines

Along with doctrines that specify the rules for private rights to water, there are several very important principles that oversee all water use in the state. Water rights are usufructory, conferring only a right to use water (*People v. Shirokow* 1980). The Public Trust Doctrine and the

[7] Senate Bill X7 6 (Steinberg), Chapter 1, Statutes of 2009-10 Seventh Extraordinary Session.

Doctrine of Reasonable and Beneficial Use articulate public-interest principles, and these are currently at the forefront of efforts to affirm the state's authority to manage a public resource, including establishing stronger requirements for more sustainable groundwater management.

The Public Trust Doctrine holds that the state, as an attribute of its sovereignty, has the right to regulate navigable waters, and lands underlying the waters for the benefit of the public (*Nat'l Audubon Soc'y v. Superior Court of Alpine County* 1983). While the public trust applies directly only to navigable surface water, the California Supreme Court held in Audubon that it may be used to limit diversions from non-navigable tributaries to a navigable body of water. The question of whether the state can impose conditions on the management of groundwater that hydrologically linked to a surface waterbody under the Public Trust Doctrine is an unsettled area of the law discussed later in this section.

The Doctrine of Reasonable and Beneficial Use, as specified by Article X, Section 2 of the California Constitution, requires that the use of all water in the state, surface and groundwater, be exercised reasonably. The court has held that Article X, Section 2 applies to both surface and groundwater rights (*Peabody v. City of Vallejo* 1935). ), stating that: "The right to the use of water ...does not extend to unreasonable use or unreasonable method of use or unreasonable method of diversion of water . . . . The foregoing mandates ... apply to the use of all water...." But whether the doctrine provides the state with authority to regulate groundwater overdraft or depletion of a groundwater drought reserve is unsettled and discussed later in this section.

### Federal Legal Authority

States generally assume primary responsibility for managing the nation's groundwater, but the U. S. Supreme Court's 1982 decision in *Sporhase v. Nebraska* made clear that the federal government, through the Commerce Clause, has "affirmative power ... to implement its own policies concerning [groundwater] regulation "... . Groundwater overdraft is a national problem and Congress has the power to deal with it on that scale." Examples where the federal government could be implicated include reserved rights to water on federal reservations and statutory authority under the Endangered Species Act. These are also discussed in the next section.

### Water Quality and Public Health Regulation

Water quality is regulated by the state and by the federal government. In California, the 1969 California Porter-Cologne Water Quality Control Act and the 1985 Pesticide Contamination Prevention Act mandate protection of water quality. The Regional Water Quality Control Boards (RWQCB) for example, have the authority to order the abatement of discharges, including nonpoint source discharges, that create or threaten to create pollution.
With respect to groundwater, NPDES permit requirements apply to discharges of groundwater containing pollutants that may affect receiving water quality (*Northern Plains Resource Council v. Fidelity Exploration and Development Co.* 2003).

The California Department of Pesticide Regulation regulates pesticide pollution. In 2004, the department designated about 2.4 million acres as Ground Water Protection Areas where soil conditions make shallow groundwater most vulnerable to pesticide contamination from leaching and runoff. New regulations for these areas prescribe actions to prevent pesticides from reaching groundwater before contamination actually occurs (California Department of Pesticide Regulation 2012).

The federal Environmental Protection Agency also regulates injection wells under the authority of the Underground Injection Control (UIC) program, as provided for by Part C of the Safe Drinking Water Act (Federal Code of Regulations 40: 144–147). These wells, which carry and permanently place fluids underground, are a potential groundwater contamination source if not properly sited, constructed, and maintained. However, groundwater quality is not protected under state regulation to the same extent as surface water quality. This is in part because it is more difficult to systematically monitor groundwater than surface water, and the state cannot conduct monitoring on private property without permission. The most comprehensive groundwater quality monitoring required by the state is done by the Department of Public Health (DPH) through its drinking water monitoring programs, and DPH can impose terms and conditions on permits for public water systems to assure that sufficient water is available during a drought (LAO 2010).

## 3.2 Unsettled Legal Issues

Several unsettled questions are currently under review that would affect groundwater management and reserve development. These include (1) whether the recent re-articulation of the test for a "subterranean stream" can include water previously not under the jurisdiction of the SWRCB in the determination of surface water rights, (2) whether the SWRCB has the authority to manage, monitor, limit, or regulate groundwater extractions from new or existing wells, under the Public Trust Doctrine to ensure protection of public trust values, and/or under the Doctrine of Reasonable and Beneficial Use to prevent the unreasonable use of groundwater that results in declining groundwater levels, (3) what is the federal government's role in groundwater regulation, and (4) will groundwater regulation result in successful Fifth Amendment Takings challenges? The resolution of each of these questions could potentially affect the ability to reduce overdraft and develop drought reserves in many areas of the state, as well as the capability to promote more sustainable groundwater management.

### Definition of Groundwater

Although surface and underground waters are a single and interconnected resource, California manages water under different legal regimes based on their classification. Importantly, percolating groundwater is not subject to the state's statutory water rights system, and overlying landowners can pump as much as is reasonable with respect to other overlying owners, so long as use is not wasteful. Permits or licenses to appropriate water are required for surface waters and "underground streams flowing through known and definite channels" (California Water Code, § 1200). The problem is that groundwater systems rarely, if ever, fit within the rubric of subterranean streams flowing through known and definite channels, yet pumping from groundwater wells can, in some situations, have a direct and material impact on stream flow (O'Brien 2006). The question is whether the courts or the legislature will acknowledge that link, thereby providing the state with the authority to require permits to use water previously classified as percolating groundwater. This could potentially address reducing overdraft and developing a drought reserve.

In 1987, the SWRCB issued a decision holding that it must consider impacts on interconnected groundwater when reviewing applications to appropriate surface water and when conducting statutory adjudications (SWRCB 1614 1987). To determine the conditions under which groundwater falls within its permitting authority, in 1999 the SWRCB established a four-part test (known as the Garrapata test): (1) a subsurface channel must be present, (2) the channel must have a relatively impermeable bed and banks, (3) the course of the channel must be known or capable of being determined by reasonable inference, and (4) groundwater must be flowing in the channel (SWRCB Decision 1639 1999). The SWRCB based the Garrapata test on its reading of an 1899 California Supreme Court case, *City of Los Angeles v. Pomeroy*, and the Board utilized the test again in 2002 in a case involving the Pauma Valley Water Company (SWRCB Decision 1645 2002).

Following administrative proceedings in the Pauma as well as the Pala basins in Southern California, the SWRCB contracted with Professor Joseph Sax to examine the history of Water Code § 1200. In his report (Sax 2002), he recommended an impacts test as one approach to reconcile the code with the current scientific understanding of the interrelationships between groundwater and surface water systems. His proposal was to read Water Code § 1200 as granting the SWRCB authority over groundwater when the extraction of that groundwater would have an "appreciable and direct impact" on a surface stream. Furthermore, he stated:

> "If the Board were to take the view that a channel must fit the definition of being 'like a trench, furrow, or groove' or 'a tubular passage' [the standard definition of the term from the American Heritage Dictionary]—that is, something essentially long and narrow—it would doubtless be drawn toward the more restricted view of its jurisdiction that some urge, sticking to the immediate confines of the channels of surface streams. On the other hand, if a channel can be quite broad and un-furrow like, so long as it is enclosed by relatively impermeable beds and banks, subterranean stream jurisdiction could be quite extensive (Sax 2002:49–50)."

In a subsequent case, *North Gualala Water Co. v. State Water Resources Control Bd*, (2006) the Court of Appeals examined the controversy over the definition of "subterranean stream," and whether the Board had jurisdiction over groundwater pumping not just in the vicinity of a surface stream, but also in a broad alluvial valley where it had not ordinarily exercised its jurisdiction in the past. The court rejected arguments that a proper interpretation of Water Code § 1200 requires that (1) for a channel to be "defined" its width must be narrowing as the groundwater flows through it; (2) the bed and banks of a subterranean channel must be a "significant boundary" rather than "relatively impermeable"; and (3) the groundwater flow direction must closely follow the course of a surface stream's channel. But at the same time, it disclaimed any intent to extend SWRCB jurisdiction to wide alluvial valleys, and rejected the trial court's suggestion that once the operation of a well is shown to have an impact on surface flows (the Sax impacts test), the SWRCB's jurisdiction follows automatically.

Looking to the future, the question is whether the courts in other contexts will take the position that a channel must be long and narrow, or support an interpretation where the SWRCB's subterranean stream jurisdiction would apply if a channel is enclosed by relatively impermeable beds and banks. Sawyer (2010) argues that the State Water Board will likely stick with a narrow interpretation of the Pomeroy/Garrapata bed and banks test. However, if the

SWRCB does take a more expansive view of the definition of "subterranean streams," the state could have greater authority to address overdraft and support the development of drought reserves.

## The Public Trust Doctrine and Groundwater Regulation

The Public Trust Doctrine in California confers the authority on the State to protect and manage public trust resources for the benefit of the people of the State (*National Audubon Society v. Superior Court* 1983). The question is whether that authority can be extended to manage, monitor, limit, or regulate groundwater extractions from new or existing wells that contribute to and help regulate the flow and quantity of a surface waterbody to ensure protection of public trust values. Additionally, does interconnected groundwater need to be considered in any determination of surface water rights? This issue is the subject of a two pending actions.

The first involves the Scott River in Siskiyou County, where the California legislature authorized the SWRCB to conduct a statutory adjudication of the basin that includes both surface and groundwater rights (Cal. Water Code § 2500.5). This is the only basin for which such integrated authority exists. The lawsuit is being brought by Oakland non-profit, Environmental Law Foundation (ELF) against the State Water Resources Control Board and Siskiyou County. The Environmental Law Foundation alleges that the Board and County are harming fish by failing to control groundwater pumping nearby, and they are requesting a judicial determination of the SWRCB's authority under the Public Trust Doctrine of California to protect groundwater that is hydrologically connected to navigable public trust waterways (Wheaton 2010).

Walston, the attorney for Siskiyou County, points to several potential obstacles for the protection of groundwater under the doctrine; (1) groundwater is not navigable, (2) conservation is not included among the traditional list of protected purposes; and (3) the scope of the doctrine's retroactive powers are uncertain (Walston 2011). However, in the National Audubon case, the court did explicitly recognize ecological conservation as an additional trust purpose, and even though the contested water diversions were from non-navigable tributaries of Mono Lake, the court held that the public trust doctrine protects navigable waters from harm caused by the diversion of non-navigable tributaries. Walston (2011) nevertheless argues that it justified this move only on the grounds that these waterways affected the navigability of other waters.

The National Audubon decision also held that the state had an affirmative duty to consider the public trust "where feasible" in deciding how to allocate water resources. This established a balancing test, e.g., and the SWRCB can determine what is "feasible," including weighing and balancing competing water uses to determine what level of protection is consistent with the public interest. Additionally, no vested right precluded the State from reconsidering the allocation of existing water rights in the Mono Basin. In the *Environmental Law Foundation* case, the petitioners argue that where groundwater is hydrologically connected to nearby rivers and streams, the groundwater extractions can have huge negative impacts on those water bodies. They hope that the outcome of their case will establish the State's continuing duty under the Public Trust doctrine to manage groundwater resources that affect public trust waters and resources (*Environmental Law Foundation (ELF) et. al. v. SWRCB* 2010).

The second pending action with respect to the Public Trust Doctrine may be even more significant, and this also applies to groundwater and surface water that are hydraulically connected. The SWRCB's recently adopted a regulation that extends its jurisdiction to surface water and hydraulically connected groundwater withdrawals that deplete surface flows in the Russian River during the frost protection season. This will be a more noteworthy test because the Board did this without explicit legislative authorization, as exists in the Scott River situation (23 California Code of Regulations § 862).

## The Reasonable and Beneficial Use Doctrine and the Regulation of Groundwater

The use of the Reasonable and Beneficial Use Doctrine to address groundwater overdraft is another unsettled area of the law, and the full scope of this doctrine has not yet been defined through the courts. What is established is that in defining a right to use groundwater, a court must consider the reasonableness of the use, and that the water use must be reasonable for both the needs of water rights holders and in light of competing public uses of the resource. In *Joslin v. Marin Municipal Water District* (1967), the court stated that "what is a reasonable use of water depends on the circumstances of each case, such an inquiry cannot be resolved in vacuo isolated from statewide considerations of transcendent importance." Moreover, the courts have held that the law must keep pace with the needs and transformations constantly taking place in a rapidly changing society. As declared in *Environmental Defense Fund v. East Bay Municipal Utility District* (1980): "What constitutes reasonable water use is dependent upon not only the entire circumstances presented but varies as the current situation changes." In *Barstow v. Mojave Water Agency* (2000), the leading case on the issue, the court made it clear that the constitutional amendment dictates the basic principles defining water rights "that no one can have a protectable interest in the unreasonable use of water, and that holders of water rights must use water reasonably and beneficially."

Sax (2003) points to how, despite the SWRCB's lack of permitting authority, it can issue remedial orders against water users not abiding by the reasonable use mandate, and it could potentially institute litigation through the California Attorney General to control groundwater use that constitutes waste, unreasonable use, or method of use within the meaning of Article X, Section 2 of the California Constitution, and Section 100 of the California Water Code. Additionally, even though the SWRCB does not have permit and license jurisdiction over groundwater pumping, Section 275 of the California Water Code provides the Board and the DWR with its own authority to define and prevent waste, unreasonable use, unreasonable method of use or unreasonable method of diversion of water in the state. Thus the Board could potentially assert its own jurisdiction to adjudicate and remedy complaints about unreasonable groundwater use, (California Water Code 275 at 309). While the California Supreme Court has not expressly addressed whether Section 275 provides an independent source of jurisdiction over groundwater pumpers, the lower courts did establish that the Board could assert jurisdiction over the pumping of percolating groundwater to adjudicate and remedy claims that come within the scope of Section 275 of the Water Code (Sax 2003). This suggests that the Board has authority to remedy claims of pumping that cause overdraft of a basin and potentially to remedy unreasonable withdrawals that deplete a reserve. Sawyer (2010) points to the state's authority to prevent waste and unreasonable use as a potential tool to also address impacts of groundwater diversions on surface waters.

## Federal Issues in the Regulation of Groundwater

Regarding federal reserved lands, where groundwater is needed for in situ use, state law may provide some protection, even against pumping initiated by others prior to the reservation creation. Leshy (2008) proposes that if an aquifer lies under both federal and non-federal lands, state law might allow the United States to protect the waters associated with its lands against export schemes. Groundwater extraction, storage, and recovery projects sometimes require rights-of-way across federal lands, and the federal government could also condition such permits on steps being taken to protect federal interests such as the limiting of groundwater pumping that is otherwise lawful under state law (Leshy 2008).

The federal government does not directly administer programs to regulate the quality of groundwater as it does with surface water under the U.S. Clean Water Act. But the U.S. Environmental Protection Agency (U.S. EPA) works with California Department of Public Health to ensure that groundwater drinking water supply sources comply with mandated federal drinking water programs and standards, and it administers grant and loan programs for water treatment and cleanup (LAO 2010). Additionally, if there is a direct hydrologic connection to surface water where groundwater pollution will affect receiving surface water quality, a NPDES permit, which regulates point-source discharges of pollutants to navigable waters of the United States, is required (*Northern Plains Resource Council v. Fidelity Exploration and Development* 2003).

A common rationale and powerful stick for more recent federal intervention in state groundwater management has been to prevent jeopardy to listed species under the Endangered Species Act (ESA). The ESA is already the trigger for several major disputes involving groundwater pumping. It has driven better management of the Platte River and its associated aquifers in Colorado, Nebraska, and Wyoming (Echeverria 2000). It has been a key factor motivating several of the agencies in this study to undertake more sustainable water supply planning for drought.

## Fifth Amendment Takings and the Regulation of Groundwater

An unsettled question is whether the Takings Clause of the Fifth Amendment, which requires the government to pay just compensation when it takes private property for public use, applies to groundwater regulation. Requiring the government to compensate for any restrictions on groundwater pumping would be excessively expensive and could have the effect of eviscerating rules to limit overdraft.

In *Allegretti v. County of Imperial* (2006), the court held that the County of Imperial did not "take" a landowner's overlying water rights when the county issued a conditional use permit to the landowner limiting the amount of water the landowner could extract from the aquifers under its land. The court rejected the argument by the landowner, Allegretti, that the county's requirement amounted to a total regulatory taking because he had been deprived of all "economically beneficial or productive use" of its property. The court dismissed this argument, stating that "Allegretti has not demonstrated any economic impact from county's 12,000 acre-feet per year limitation other than unspecific lay testimony regarding reduced profits via a below market rental rate or diminution in value as a result of its inability to use the entirety of its 2,400-acre property for farming….and a mere diminution in value of property, however serious, does not constitute a taking." Moreover, although Allegretti has superior groundwater rights as an overlying user, those rights are restricted to reasonable beneficial use consistent with Article X, §2 of the state constitution, and the California Supreme Court has consistently held that no one has a compensable property right in an unreasonable use of water, including groundwater. (*Peabody v. City of Vallejo* 1935, *Joslin v. Marin Municipal Water District* 1967, *Environmental Defense Fund v. East Bay Municipal Utilities District* 1980, and *Barstow v. Mojave Water Agency* 2000.

The ELF case discussed earlier also addresses takings issues. In that case, Siskiyou County officials are arguing that the Scott River is “real property,” which consists of land or things attached to land. The Environmental Law Foundation’s argument is that a court has never held that water in its natural state is real property. If the river is declared to be real property, the government could be subject to Fifth Amendment takings claims, and potentially any limitation or control on the use of water for the public good would become a compensible taking where the government would be required to make substantial payments to water users if it cut their supplies.

### Discussion

Establishing locally based groundwater drought reserves could increase resilience to drought for many regions. While many local jurisdictions are working towards more sustainable groundwater management, the laws governing groundwater in California have so far have not been effective in reducing the significant overdraft that exists in many basins. Additionally, there are no mandated requirements to encourage the establishment of local groundwater drought reserves as a key adaptation to reduce vulnerability to a future prolonged drought. Reshaping water law and policy to allow for effective, proactive adaptation to drought is essential, including strengthening the legal ability of local, regional, and state institutions to reduce overdraft, create locally based drought reserves, and provide incentives for implementation. This is discussed further in Section 6.

# Section 4: Study Sites

A central question of our project is: *What physical, social, and institutional conditions reduce vulnerability to drought and support the creation of groundwater drought reserves?* Coastal communities in north and central California are ideal sites for a comparative examination of this question. The regions encompass diverse physical and social environments, and many communities rely on groundwater to satisfy water demand.

Our project focused on five water districts that are mapped in Figure 1: Scotts Valley Water District (SVWD), Pajaro Valley Water Management Agency (PVWMA), Santa Cruz Water Department (SCWD), Soquel Creek Water District (SqCWD), and Sonoma County Water Agency (SCWA). We also examined the Sonoma Valley groundwater basin region where SCWA recently conducted groundwater studies. The central coast communities rely exclusively on local sources. The north coast communities serviced by the SCWA receive water imported from the nearby Eel River. This section discusses the institutional history and physical characteristics of our study sites and their potential for reserve development.

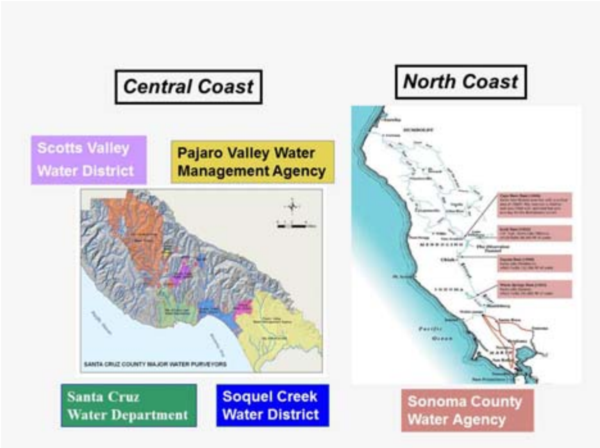
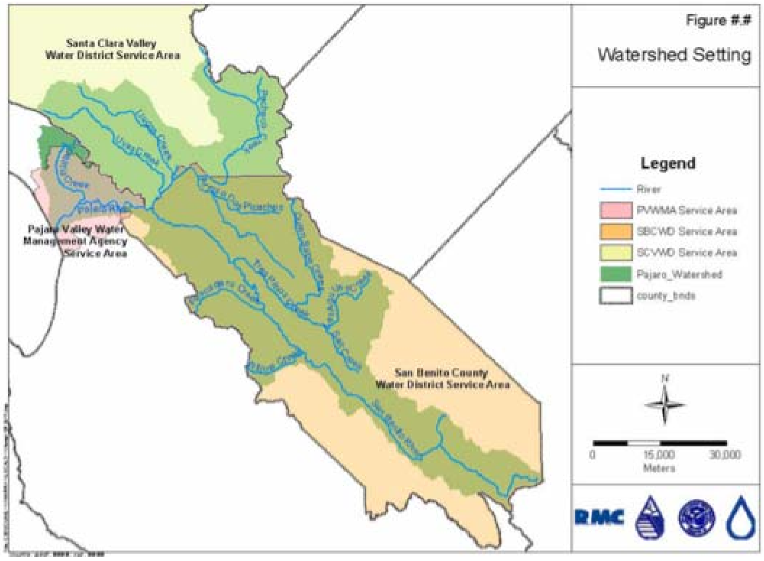



**Figure 1: Map of Study Sites**

## 4.1 Pajaro Valley Water Management Agency (PVWMA)

### Background

The Pajaro Valley groundwater basin, , mapped in Figure 2, encompasses an area of approximately 120 square miles adjacent to California's central coast. The region is bounded to the east by the San Andreas Fault Zone and to the west by Monterey Bay, and it overlaps four major political jurisdictions: the City of Watsonville, and Santa Cruz, Monterey, and San Benito Counties. Multiple water agencies tap groundwater from the same or different sub-units of the same aquifer for water supplies. The basin was overdrafted for many years, but no single agency had jurisdictional authority to manage groundwater in this area. To avoid future overdraft and to insure sufficient water supplies for present and anticipated future needs, the PVWMA was formed by a legislative act in 1984. Not all agencies that withdraw water from the basin are under the umbrella of PVWMA, but those that are manage their own potable water supplies, as well as flood control, stream restoration, and habitat management.




Source: http://www.pajarowatershed.org/

**Figure 2: Map of the PVWMA**

## Physical Setting

The primary aquifer in the region is the Aromas Red Sand. This layer of alluvial sand deposits is encountered at depths of 100–200 feet below the ground surface and often exceeds 500 feet in thickness. It is estimated that the Aromas Formation stores nearly 2,000,000 acre-feet (af) of groundwater. Below the Aromas Red Sands lies second water-bearing unit, the Purisima Formation. The upper portion of this aquifer, which consists of sandy marine terrace deposits, is estimated to store an additional 5,000,000 af of groundwater (Hanson 2003).

Climate in the Pajaro Valley, and along the entire central coast, follows the typical California regime of dry summers punctuated by rainy winter months. Just over 20 inches of rain typically fall in the Pajaro Valley, although this amount may vary considerably from year to year. Precipitation helps recharge the region's aquifers, which supply water for intensive crop irrigation during the dry summer growing season, as well as for municipal and industrial use throughout the year. Natural recharge occurs primarily in the upland and hilly terrain along the eastern edge of the basin and in sandy aeolian soils located farther west. Agricultural irrigation returns contribute to aquifer recharge during the dry season, and there is also limited managed (artificial) recharge.

## Water Management and Use

Intensive development of groundwater in the Pajaro basin, the main source of water for the valley, began as early as the mid-twentieth century. In 1980, DWR identified the Pajaro Valley basin as one of eleven basins statewide experiencing critical conditions of overdraft and saltwater pollution. Significant development of rural and agricultural areas reliant primarily on groundwater, and the associated increase in population in southern Santa Cruz County contributed to the overdraft, as did a more recent shift in crop type over the past thirty years from low-water using deciduous crops (mostly apples) to high-water using strawberries, bushberries, and vineberries (PVWMA Revised BMP 2002:2-21). Today, irrigated agriculture uses about 85 percent of the water pumped from the groundwater basin, both along the coast and inland (PVWMA Revised BMP 2002:2-23).

As a result of intensive pumping, groundwater table elevations currently lie at or below sea level in large swaths of the Pajaro Valley, and the amount of fresh groundwater in storage has declined over the long term. In areas adjacent to the coast, this has resulted in the subsurface intrusion of salty ocean water causing a loss of effective (fresh groundwater) storage. Groundwater elevations at the coast remain below sea level all year. Currently, nearly half of the groundwater within the basin is below sea level for the entire year, and nearly two-thirds of the basin is below sea level during the fall. Further intrusion is expected until groundwater levels near the coast are restored. These conditions are occurring despite a long-term trend of higher than average rainfall. During the last 50 years, inland water levels have also fallen significantly in some locations despite slightly higher than average rainfall over that period. Inland water levels in much of the valley are only 10–20 feet above sea level. An analysis of a five-year drought (1987 to 1992) shows that the water levels fell significantly and did not fully recover. In 2002, the agency estimated more than 18,000 acre-feet of water would be needed to balance pumping and recharge. High concentrations of dissolved nitrates resulting from agricultural runoff and returns are also a concern in some locations. The data indicate that the basin remains vulnerable to the next drought cycle (PVWMA Annual Report 2010).

The PVWMA's activities typically focus on halting the saltwater intrusion. Recently the agency turned to recycled water, and in 2009 it completed the Watsonville Recycled Water Treatment Facility jointly with the City of Watsonville. The facility treats 8,000 afa of wastewater to create 4,000 afa of tertiary treated wastewater (~7 percent of total basin water use) to mix with other water supplies. At full capacity, the agency anticipates delivering 7,150 afa. Recycled and blended water that is delivered to coastal farmers using the Coastal Delivery System (CDS) pipeline contributes to reductions in groundwater pumping along the coast, helping to reduce overdraft and saltwater intrusion. The PVWMA is not currently permitted to use recycled wastewater for aquifer recharge because of health concerns related to the proximity of domestic and municipal water supply wells (PVWMA Recycled Water). The PVWMA is entitled to water from the Central Valley Project (CVP) but lacks a transmission pipeline. With reductions in CVP deliveries to established users, it seems unlikely that the PVWMA will ever receive CVP water, even if a means of conveyance were established (Local Agency Formation Commission [LAFCO] Santa Cruz County 2011).

### Legal-Institutional Issues

Ongoing conflict between Pajaro Valley stakeholders has made it difficult to significantly improve groundwater conditions. The main aquifer in the Pajaro Valley, the Aromas Sand, extends laterally across the basin from the foothills to the coast, and serves as an important water resource to both inland and coastal water users. As already indicated, because pumping exceeds natural recharge in this aquifer, the depletion of fresh groundwater has resulted in the intrusion of saltwater in portions of the coastal zone. Although saltwater intrusion is the result of net groundwater overdraft throughout the basin, its deleterious effects are borne mainly by water users along the coast. Meanwhile, inland users might not see saltwater affect their portion of the aquifer for many years, if ever.

Establishing the CDS, a water recycling plant, and a managed recharge project required significant costs for permitting, planning, and construction, and there are ongoing expenses for operations and maintenance. To fund these and other projects, the PVWMA levees augmentation fees on groundwater pumpage. Additional fees are charged for water deliveries by the agency and its partners (Bannister 2009). One might argue that if all users in the basin share a common groundwater resource, then all users should contribute to the cost of ensuring that they can all continue to enjoy this resource into the future. But there has been opposition from basin residents, growers, and landowners to payment of pumping augmentation fees, particularly those whose groundwater supply and quality are not already affected. Various groups and individuals have sued the PVWMA over augmentation fees, with varying degrees of success (PVWMA Annual Report 2010). In 2007, the Court of Appeal for the Sixth Appellate District ruled that an increase in the groundwater augmentation fee was invalid for failure to adhere to the requirements of Proposition 218 (requires a vote and two-thirds approval). A new groundwater augmentation charge by the agency is the result of its multi-year effort to create an assessment that would survive legal challenge. Property owners are again contesting the charge, claiming the fee required voter approval under Proposition 218.

Some PVWMA board members are also exploring changes to the governing rules contained in the 1984 state legislation that created the agency. Article 3 Section 316 will change the definition of "supplemental water" to include desalinated water. Article 7, section 710 will delete the current limit to using imported water solely for agriculture. The article 7, section 710 amendment may be seen as removing a restriction to urban growth, as agriculture currently uses ~85 percent of the pumped groundwater (Jones 2011).

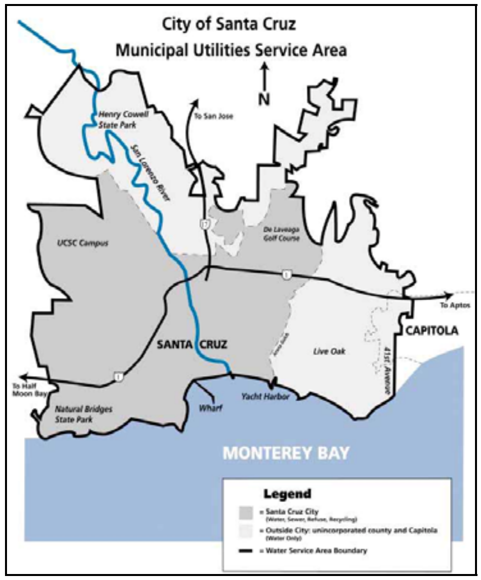
### Potential for Creating a Groundwater Reserve

The PVWMA, out of necessity, is focused primarily on reducing long-term overdraft, preventing further decline in groundwater levels, and halting saltwater intrusion. This is seen in the goals of the 2002 Basin Management Plan to balance water demand with sustainable water supplies, prevent salt water intrusion, and implement programs to protect water supply and quality in the basin (PVWMA Revised BMP 2002:1-1). The agency's first goal is to bring the basin into hydrologic balance. Moreover, chronic overdraft, along with the contentious legal and political issues in the region, create challenges to developing drought reserves in the near future despite coastal landowners being vulnerable to water shortages during future droughts.

## 4.2 Santa Cruz Water Department

### Background

The Santa Cruz Water Department, mapped in Figure 3, is the only agency in this study that obtains the majority of its water from surface sources.




Source: City of Santa Cruz

**Figure 3: Map of the City of Santa Cruz Municipal Service Area**

The agency manages water supplies for a population of about 90,000 in an area that includes the City of Santa Cruz. On average, 79 percent of the City's annual water supply needs are met by surface diversions from the coastal streams and the San Lorenzo River, and their yield in any given year is related mainly to the amount of rainfall received and runoff generated during the previous 6–12 months. Water stored in Loch Lomond Reservoir accounts for about 17 percent of use, and is used mainly in the summer and fall months when flows in coastal streams decline and additional supply is needed to meet higher summer demands. The remaining 4 percent is produced from the Live Oak groundwater wells (Goddard 2004).

The City of Santa Cruz is the only municipality around Monterey Bay that does not rely heavily on groundwater. It is completely isolated, with no facilities in place to transfer water to the system from adjacent water districts, nor is any water purchased or imported to the region from outside the Santa Cruz area. With limited surface supplies, the primary problem for the district is lack of long-term storage and dependence on recent precipitation and runoff.

## Physical Setting

The geology beneath the City of Santa Cruz consists primarily of crystalline metamorphic marbles and schists of the Salinian Block. The low primary porosity of these rock types makes them poor aquifers, resulting in Santa Cruz's evolving reliance on surface water to supply its water needs. Although providing only limited water, local groundwater resources play a minor but important role. In the southeastern Live Oak section of the city, where geology transitions to the sandy Purisima Formation, Santa Cruz owns and operates four groundwater production wells that average around 500 afa of water for the city. Generally only operated between 150 and 200 days per year, the wells are critical to help meet peak demand during dry summer months and during dry and critically dry years when lesser amounts of surface water are available.

Declining water levels in the Live Oak wells have been observed over the past 15 years, but monitoring wells located along the immediate coast have not yet detected any saltwater intrusion, and the interface between fresh and saline groundwater is believed to still be located well offshore (City of Santa Cruz 2011). However, the latter is a concern, as the wells are located less than a mile from the coast, and the Purisima formation is heavily utilized as a groundwater resource by water districts to the south and east, including neighboring Soquel Creek and others in Pajaro Valley. Although concentrations of naturally occurring minerals are high, water quality in the Live Oak wells is generally good.

## Water Management and Use

The SCWD is highly vulnerable to shortage in drought years when the San Lorenzo River and coast sources run low and water stored in Loch Lomond is depleted to satisfy demand. Under normal weather conditions, base flows in the coast and river sources are restored by winter rains, and storage in Loch Lomond is typically replenished to full capacity, allowing the system to meet the community's annual water requirements. In multi-year drought conditions, the combination of very low surface flows in the coast and river sources and depleted storage in Loch Lomond reservoir reduces available supply to a level that cannot support average dry season demands. Compounding the situation is the need, driven by prudent management, to reserve some storage in Loch Lomond for future dry conditions. Recent studies by SCWD of existing water supplies and demand projections conclude that water demands will continue to increase at a slow rate of growth and additional sources of supply will be required in the future, particularly to meet demand during drought (Goddard 2011).

Santa Cruz already experienced serious water supply deficiencies during the 1976–77 and 1988–92 droughts, when critical shortages of water led to severe water rationing. The 1976–77 event was established as the most severe drought of record, and is used by the SCWD as a benchmark for assessing system reliability. Modeling in 2003 demonstrated that the water supply system was inadequate to meet current demand under severe drought conditions. If a drought comparable to the 1976–77 one occurred today, SCWD would experience a 45 percent peak season shortage in the second year of drought.

Thus, most of the time there is sufficient water available to meet the existing needs of city water customers. Some of the time, there are shortages. Once a great while, the system is at risk of experiencing a severe water shortage generating extensive economic and social consequences. To reduce demand, the city implemented a variety of water-saving programs—including toilet, clothes washer, and rainwater cistern rebates and turf replacement—and enacted plumbing fixture retrofit ordinances. The SCWD recently revised requirements for installation of gray water systems in new construction. For drought management, SCWD employs a strategy that is typical of most California water districts: enforcing more stringent reductions in water use (Goddard 2011).

## Legal-Institutional Issues

A key motivator to reassess its supply and drought strategies is the agency's concern about potential restrictions on its water diversion rights to local streams as a result of listings of local species under the federal ESA. The SCWD estimates that federal requirements to protect fish habitat could reduce the city's water supply by 18 percent, or 800 million gallons per year (2,500 afa). As a result, SCWD is proactively developing a Habitat Conservation Plan (HCP) to comply with the ESA. If the HCP is approved by federal agencies, SCWD will receive an Incidental Take Permit, allowing it to continue to take water from the San Lorenzo River, Newell Creek, and north coast streams, but the timing and amount will be affected. As such, the proposed plan will result in less water being available for SCWD's drinking water system. Special status species being considered in the HCP include salmon and steelhead, the Pacific lamprey, Pacific pond turtle, tidewater goby, California red-legged frog, Mount Hermon june beetle, Zayante band-winged grasshopper, and the Ohlone tiger beetle. Studies for the HCP are evaluating the effects of the City's water operations and facilities on these species and developing conservation strategies and mitigations (City of Santa Cruz Water Department 2011, Brown 2011).

### Potential to Develop a Drought Reserve

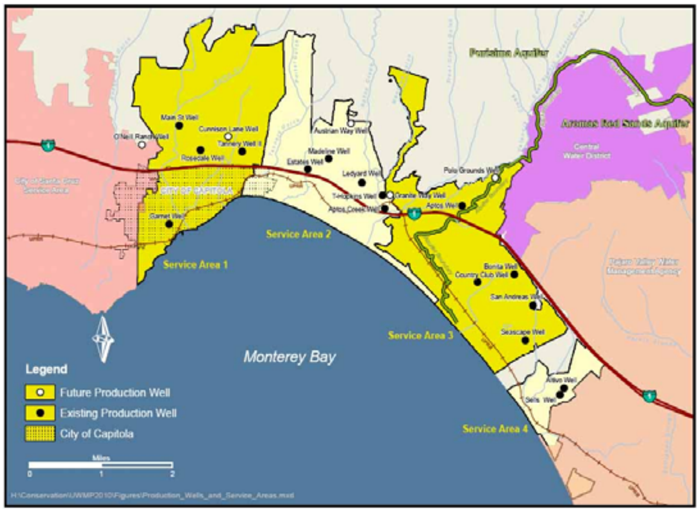
The city's limited surface supplies, along with the need to comply with the ESA, are the major factors influencing the city's desire to develop a drought reserve. However, there is virtually no groundwater storage opportunity in small coastal aquifers, because the available space is limited. Moreover, current California regulations do not allow recycled water (i.e., highly-treated wastewater) to be discharged directly into a potable/drinking water distribution system (otherwise known as direct potable use) and therefore would not meet SCWD's drought water supply needs. While recycled water could be used for indirect potable reuse, whereby highly treated wastewater is injected into the ground via percolation ponds or pumping and extracted later for use, this is not practical for SCWD because it requires blending recycled water with surface or groundwater prior to injection, and both surface and groundwater supplies are already limited. Recycled water could potentially provide irrigation water for parks, sports fields, and/or golf courses during a drought, but would require a new dedicated distribution system that would be prohibitively expensive compared with the relatively small volumes of water delivered (Kennedy/Jenks 2010a).

As a result, SCWD is developing plans for a new supply project, a 2,800 afa desalination plant to serve as a drought reserve supply. The desalination project, in partnership with the Soquel Creek Water District (SqCWD), is currently undergoing an environmental impact report (EIR) evaluation. The SqCWD would use the water during wet years as a means to reduce groundwater pumping, a form of in-lieu recharge. This would enable SqCWD's groundwater levels to increase and provide that district with a drought reserve. In dry years, SCWD would use the desalinated water as its drought reserve during drought years. The desalination plant thus serves as a reserve supply for two adjacent districts and avoids the conundrum of the plant sitting idly during wet years, or of excess wet year water encouraging further growth. An alternative to the desalination proposal by a citizen's group, Desal Alternatives, is to create a drought reserve through community commitment to increased conservation and a water-neutral growth policy, along with collaboration by the two water agencies to exchange water.

## 4.3 Soquel Creek Water District

### Physical Setting

Soquel Creek Water District (SqCWD), shown in Figure 4, is wholly dependent on groundwater.




Source: Soquel Creek Water District Draft Urban Water Management Plan (2010)

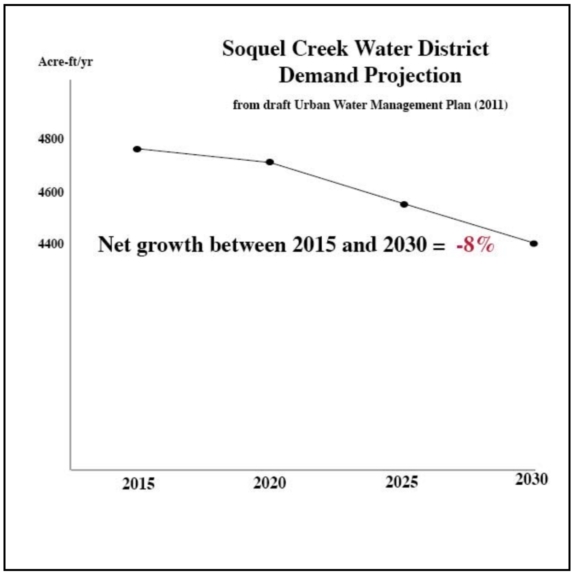
**Figure 4: Map of Soquel Creek Water District**

Seventeen wells in the Purisima Formation and Aromas Red Sands aquifer provide 5,500 afa to 49,000 people in the service area. Drought and above-average rain cycles do not appear to have short-term effects on SqCWD supplies, but there are longer-term impacts. For example, a recent District study showed that although the mean annual precipitation in the district is 31 inches, there is virtually no groundwater recharge when annual precipitation drops below ~20 inches/year. Most of the recharge occurs during the years with the heaviest rainfall (SqCWD UWMP 2005).

## Water Management and Use

Due to the 100 percent reliance on groundwater, SqCWD believes there would generally be plenty of water still in the ground that could be extracted to supply customers, and "it is not anticipated that any future *short-term* drought will affect its ability to provide water to its customers" (SqCWD UWMP 2005:17). But, a *long-term* drought could lower groundwater levels and potentially expose the aquifers to saltwater intrusion. Partly in response to the threat of a moratorium on new connections, the agency successfully promoted a range of conservation practices related to improving water supply security. To prevent cutting too deeply into groundwater supplies during a drought, SqCWD implements a 15 percent use reduction, a characteristic response to drought used by most water agencies in the state. This also allows the Board of Directors to carry out Water Emergency Response Plans of varying stringency that determine rationing, wasteful use fines, conservation programs, and prioritizing water uses (SqCWD UWMP 2005:53).

The SqCWD anticipates needing an additional 1,400 afa of supply by 2050 to account for growth after implementation of pumping reduction and conservation programs (SqCWD UWMP, 2005:30), and in 2003, the district implemented a water-neutral development policy requiring builders to offset 120 percent of new water demand. As the graph in Figure 5 below shows, Soquel Creek Water District is planning to more than offset growth in the next 20 years.



Source: Soquel Creek Urban Water Management Plan (2007)

**Figure 5: Soquel Creek Water District Demand Projection**

The district also needs to establish a safety buffer of 600 afa beyond the 1,400 afa to create a reserve, and auxiliary sources are required for this. Thus, once overdraft is eliminated and potential alternative supplies are developed, SqCWD will utilize in-lieu aquifer recharge to manage groundwater for future use and drought storage (SqCWD GMP 2007:70). One current strategy to address overdraft is to operate under a Well Master Plan to move pumping away from the coast and create equal spatial extraction from the basin. This will eliminate well redundancy and allow pumps to operate in different layers of the aquifer to reduce the potential for overdraft and saltwater intrusion (SqCWD WMP 2010: 2-18).

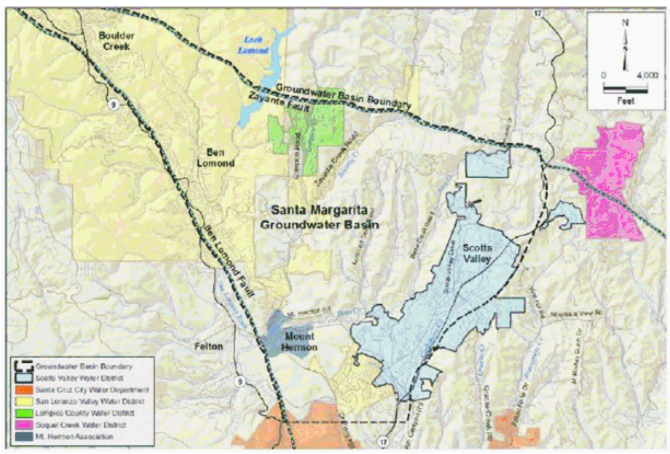
## Potential for Creating a Groundwater Reserve

As already indicated, a regional desalination plant run in cooperation with the Santa Cruz Water Department (SCWD) is the alternative supply choice preferred by both agencies to meet the projected need and potentially create a groundwater drought reserve for the community. During normal years 2,800 afa would go to SqCWD to replace groundwater, allowing aquifers to recover from historic overdraft and push back the spectre of saltwater intrusion (SqCWD UWMP 2005:33). With recharged aquifers, SqCWD could temporarily increase pumping to meet demands after water restrictions during a drought. During drought years the desalinated water would be fully utilized by Santa Cruz. It is currently estimated that it will take ten years of in-lieu recharge action to restore aquifers to their original non-overdrafted state, when they would then be ready to establish a drought reserve The offshore extensions of the Purisima Formation aquifer are the most likely storage units for excess groundwater (SqCWD GMP 2007:70). The agency is actively working towards developing a sustainable future water supply, and there are currently no pending legal-institutional issues.

## 4.4 Scotts Valley Water District

### Background

The Scotts Valley Water District (SVWD), shown in Figure 6, was established in 1961, before the City of Scotts Valley became independent. It relies solely on groundwater sources from the regional Santa Margarita Groundwater Basin, a roughly triangular area that is bounded by two regional faults and covering approximately 30 square miles. The U.S. EPA designated the Santa Margarita Sandstone Aquifer of Scotts Valley as a "Sole Source Aquifer" in 1985 (one of four areas with this designation in California). This designation means that at least fifty percent of the area's drinking water comes from the aquifer beneath it, and indicates the importance of maintaining its quantity and quality in that there is no water supply alternative (Kennedy/Jenks 2010b).




Source: Kennedy/Jenks (2010b)

**Figure 6: Map of Scotts Valley Water District**

### Physical Setting

The Santa Margarita Groundwater Basin encompasses approximately 30 square miles in the Santa Cruz Mountains. The basin is bounded on two sides by regional faults and is comprised of a geologically complex series of layered, folded sedimentary units, underlain by granite. From youngest to oldest, these are: the Purisima Formation, the Santa Cruz Mudstone, the Santa Margarita Sandstone, the Monterey Formation, the Lompico Sandstone, the Butano Formation, and the Locatelli Formation. Of the above, the Santa Margarita, Lompico, and Butano formations are the primary water-bearing units (Kennedy/Jenks 2010b).

The Santa Margarita is a thickly bedded, fine to medium grained sandstone unit, exposed at the surface throughout much of the central and southern portions of Scotts Valley. This large degree of aerial exposure, combined with a relatively high infiltration capacity, make the Santa Margarita Sandstone an important area for groundwater recharge. In several locations, subsequent discharge from the formation contributes to surface flow in springs and streams.

The Lompico Sandstone underlies the Santa Margarita Sandstone and supplies the majority (~60 percent) of the groundwater pumped by the SVWD. This unit ranges from 200–300 feet in thickness, and like the Santa Margarita, is composed primarily of fine- to medium-grained sand. The Lompico Sandstone is only exposed at the land surface at a few locations along the northern margin of the groundwater basin; otherwise, it is encountered at depths up to 1,000 feet below ground. The Lompico and Santa Margarita sandstones are separated from one another by the more finely grained Monterey Formation, but in certain areas, the Monterey is absent, and the Lompico and Santa Margarita are in direct contact. These are the most important areas for groundwater recharge to the Lompico Sandstone, as recharging groundwater can be transmitted directly downward through the Santa Margarita. Likewise, pumping from the Lompico in these locations may contribute to drawdown observed in the Santa Margarita (Kennedy/Jenks 2010b).

The Butano Formation directly underlies the Lompico Sandstone and, along with the Lompico, is the other principal source of groundwater used by the SVWD. Water from the Butano Formation comprises ~40 percent of total production. The Butano Formation consists primarily of sandstone, but contains interbeds of siltstone, mudstone, and shale. It is located at depths >1000 feet beneath Scotts Valley, but exhibits significant outcrops on the ridges along the groundwater basin's northern edge. These serve as the formation's primary recharge areas.

Natural recharge to the aquifers of the Santa Margarita Groundwater Basin occurs both as direct infiltration at the land surface and through streambeds. In both cases, the amount of recharge that occurs in any given year is highly dependent on that year's precipitation. Scotts Valley averages ~42 inches of rainfall annually, although amounts can be highly variable, ranging from more than double to less than half of this amount. Periods of multiple dry years coincide with steep declines in groundwater levels in wells. For example, from 1986–1992, Scotts Valley accumulated a rainfall deficit of nearly 100 inches. This coincided with a water table decline in excess of 100 feet in several wells screened in the Santa Margarita and Lompico formations. Likewise, a series of wet years lead to elevated water levels in primary aquifers. Because the majority of annual rainfall occurs during the winter months, and peak groundwater use occurs during summer, groundwater levels in wells also vary on a seasonal basis. Several wells in the Butano Formation show seasonal fluctuations in excess of 100 feet (Kennedy/Jenks 2010b).

Several designated environmental compliance sites are located within the Santa Margarita Groundwater Basin. These include former gas stations, dry cleaners, and auto repair shops, as well as one federally designated Superfund site. Groundwater at each site is monitored on a site-specific basis in accordance with past or ongoing remediation activities. The SVWD monitors groundwater quality at each of its production wells for both naturally occurring and industrial pollutants. In all wells, concentrations are found to be either below the detection limit or below state maximum contaminant levels. The SVWD also monitors levels of nitrate, total dissolved solids, and salts in wells and surface water bodies. Salinization of the aquifer as a result of seawater intrusion is not a concern in Scotts Valley (Kennedy/Jenks 2010b).

### Water Management and Use

Groundwater levels in the Santa Margarita Sandstone were historically within several tens of feet of the land surface. However, the amount of water produced increased fourfold from approximately 500 afa (acre feet per year) in the mid 1970s to 2,000 afa by the year 2000. The concentrated pumping in south Scotts Valley coincided with an extended period of industrial and urban growth, and eventually produced significant declines in water levels in municipal production wells. Less than 1 percent of the total groundwater pumped by the Scotts Valley

Water District (SVWD) is now derived from the Santa Margarita Sandstone, and in many locations, the formation has been completely dewatered. Additionally, groundwater levels in the Butano formation dropped by as much as 200 feet between the 1980s and mid-1990s.

By the late 1990s, the groundwater storage declines resulted in significant community concern. The District's Board of Directors adopted a water policy statement that acknowledged the groundwater declines, and in 2000 they initiated a moratorium on the issuance of meters until a new recycled water treatment plant began operation in 2002. The recycling program provides additional water for District customers. New housing developments are now required to use recycled water for front-yard landscaping needs, if feasible, and the District has pursued an aggressive program of retrofitting its largest existing landscape customers from potable water supply to recycled water. Approximately 166 af of tertiary-treated urban wastewater from Scotts Valley water users is for landscaping and irrigation, and serves as an in lieu recharge to the Santa Margarita basin, particularly during the summer months. Since its inception, recycled water has steadily attracted additional customers and now accounts for approximately 10 percent of SVWD water use. Proposed extensions to the recycled water distribution pipelines should allow for further expansion of recycled water deliveries. The District also increased water conservation efforts, including a 10 percent voluntarily reduction in use by customers per the District's request during significantly dry years. This voluntary reduction proved to be effective in reducing consumption.

The SVWD is also operating a pilot study for enhanced groundwater recharge and is investigating opportunities for conjunctive use. Additional conservation activities include a new tiered water rate structure, leak repairs, water use audits, retrofit rebates, free low-flow devices, and public educational outreach programs. These programs have contributed to stabilizing groundwater levels, and pumping may now be roughly in balance with natural recharge (Kennedy/Jenks 2010b).

Today, the SVWD serves a population of about 11,195 through 3,773 active water service connections. There is no longer any commercial agriculture in the area, and Scotts Valley's largest industry is now computer software development and disk drive assembly. Water pumped directly from SVWD's seven production wells accounts for the majority of groundwater use in the Santa Margarita Groundwater basin. Smaller amounts are pumped by other water districts, private residential or industrial wells, or for environmental remediation. The agency works actively to encourage public participation at meetings, to coordinate with other local agencies, and to maintain a groundwater monitoring and evaluation program (SVWD 2011).

### Potential for Creating a Groundwater Reserve

In terms of the physical parameters discussed, SVWD appears to be in relatively good position to begin considering the creation of a strategic groundwater drought reserve. The geology of the Santa Margarita Groundwater Basin is well mapped and well understood, and the formations are conducive to the infiltration, transmission, and storage of groundwater for future use. Although the Santa Margarita Groundwater Basin experienced significant depletion of groundwater storage in decades past, this trend has since stabilized, as indicated both by monitoring well water level records as well as data outputs of model-based analyses. By both of these measures, it appears that the basin is now in or near a state of hydrologic balance. Thus any additional water added to the basin, either through continued reductions in pumping and/or through enhanced natural or artificial recharge, might contribute to developing a reserve, as groundwater levels would be expected to increase as a result.

Ample physical space (over 10,000 af since 1985) for such a reserve exists in the previously depleted portions of the Santa Margarita, Lompico, and Butano sandstones. In theory, much of this volume could be refilled during the process of creating a reserve. Intentionally building water levels back up would buffer the effects of drawdown during the next multi-year drought. In the meantime, higher groundwater levels would likely reduce pumping costs and might provide the added benefit of increased environmental flows to springs and streams.

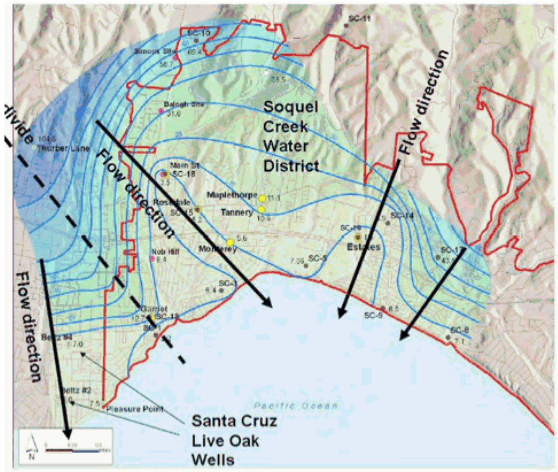
The SVWD has the accumulated knowledge, infrastructure, and good community relations to make implementing a strategic groundwater reserve plan a viable drought planning option. The greatest challenges are in locating a suitable supply of water to be used for establishing a reserve, securing water rights and permits, and raising funds needed to plan, build, and operate associated facilities.

## Central Coast Agencies - Discussion

Three of the central coast agencies—Santa Cruz, Soquel, and Pajaro—rely to some extent on groundwater from the Purisima Formation. The degree to which groundwater pumping by any one of these agencies affects the other is nevertheless limited because groundwater generally recharges in upland areas and discharges underwater where the aquifer outcrops offshore. Moreover, the natural flowpaths, from the hills to the bay, are generally parallel in each of the three regions that are utilized by these agencies, and none lies directly upstream or downstream of the other. It is important to note that this could be subject to change if one agency suddenly started pumping much more water, which it could, given the state's groundwater laws. The result could turn the natural flow gradient away from the coast and toward the pumping site. This is illustrated in the Figure 7 with Santa Cruz and Soquel Creek.

Additionally, although some people in the Pajaro pump from the Purisima, the shallower Aromas is the more widely drawn-upon aquifer. The depth of the Purisima increases the energy costs of pumping, potentially making it a less attractive option.

Even though the SVWD is geographically close by, it is inland and not linked hydrogeologically with the Purisima Formation. The aquifer units that SVWD draws from (Santa Margarita, Lompico, Butano) are likely not present beneath the three coastal areas (or present at some very great depth). Again, given California's groundwater laws, SVWD's concerns regarding pumping would lie with other Santa Cruz Mountain water users who draw on the same aquifers.




Source: Modified from HydroMetrics WRI, 2010

**Figure 7: Santa Cruz and Soquel Creek Water Flow Gradient**

## 4.5 Sonoma County Water Agency

### Background

The Sonoma County Water Agency's (SCWA)'s jurisdiction, mapped in Figure 8, includes areas of Sonoma County and neighboring Marin County. It is a special district whose duties are defined by enabling statutes, and the agency is a water wholesaler who supplies water to about 570,000 people, including the cities of Santa Rosa, Windsor, Rohnert Park, Cotati, Petaluma, and Sonoma; as well as the Valley of the Moon, North Marin, Marin Municipal, and Forestville water districts, and several water companies. All buy water from the SCWA in addition to utilizing local surface or native groundwater sources. The rest of Sonoma County—including Sebastopol, Healdsburg, and Cloverdale and most of the area outside city limits, including most farms, dairies, and vineyards—obtain their water from local wells (Sonoma Valley Groundwater Management Plan 2000).

### Physical Setting

The area of northern California in which the agency operates is geologically complex and variable across sub-regions. Overall, the region is characterized by northwest-southeast trending ranges of mountains and hills that are composed of volcanic and highly metamorphosed marine sedimentary rocks, interspersed with deeply filled valleys of more recent sedimentary deposits. Creeks and rivers draining the valleys generally flow toward the south and west. The largest of these, the Russian River, has an average annual discharge of 1.6 million afa. Other valleys, including the Sonoma Valley, the Alexander Valley, and the Santa Rosa Plain, are key groundwater resource areas in the region.

The region experiences the same Mediterranean climate regime of cool wet winters and hot dry summers as study areas farther to the south. However, as a result of its higher latitude and rugged terrain, it generally receives greater amounts of winter precipitation. Annual rainfall averaging over 70 inches on the mountainous north coast feeds rivers and streams and recharges local groundwater. Lesser amounts of precipitation, averaging near 25 inches per year, fall on drier valley locations.


Source: Sonoma County Water Agency

**Figure 8: Map of the Sonoma County Water Agency**

## Water Management and Use

The SCWA gets its water primarily from six wells plunging up to 60 feet into deep gravel beds and extending laterally beneath the Russian River near Forestville. Massive pumps with a combined 14,750-horsepower rating pull water from the gravel aquifer and propel it into a distribution system that contains about 79 miles of underground pipeline and 18 steel water storage tanks. While technically this is Russian River water, it is part of a system that stretches nearly 100 miles to the north and collects rainfall from 235 square miles in hilly, rural reaches of Sonoma and Mendocino counties. Two reservoirs—Lake Sonoma near Healdsburg and Lake Mendocino near Ukiah—hold 282,000 af of water behind dams and also serve as Russian River flood control facilities.

Lake Mendocino, on the East Fork of the Russian River, provides water to Ukiah and Mendocino County farms and holds about half of Sonoma County's supply. But it is primarily Eel River water that feeds Lake Mendocino. In 1908, the demand for water and electrical power led to the construction of Van Arsdale Reservoir on the Eel River where, taking advantage of a natural mountain divide between the Eel and the Russian River, a tunnel was drilled through the mountain to drop the Eel River water into a power plant, the Potter Valley Hydropower Project, located in the Russian River watershed. The imported Eel River water was then released after use into the East Fork of the Russian River. A second and larger reservoir on the Eel River, Lake Pillsbury, constructed in 1920, increased the diversion. Lake Mendocino, which depends on spring rains and its Eel River diversion for annual refilling, is also solely responsible for the river flow between Ukiah and Healdsburg (Langridge 2002).

Northwest of Healdsburg, the federally funded Warm Springs Dam and Lake Sonoma were constructed in 1983 after a prolonged political battle. The dam is a 319-foot compacted earthen barrier at the confluence of two small creeks, Warm Springs and Dry Creek. Lake Sonoma holds 212,000 acre-feet of water for human consumption, which is considered a two-year supply for the region. This abundance of water facilitated rapid population growth and accelerated urbanization in Sonoma County, and in the 1980s, Santa Rosa was the twenty-eighth fastest growing city in the United States. Today, however, the region's water dynamics are more complicated.

## Legal-Institutional Issues

In 1990, Eel River salmonids were listed as threatened under the federal Endangered Species Act. This necessitated reducing the flow of water from the Eel River to the Russian River under the Biological Opinion to avoid jeopardy to the fish. Salmonids were also listed on the Russian River, based on findings that too much water in the Russian River during certain times of the year is bad for the young fish maturing in the creek. This resulted in limits on the amount of water that could be released from Lake Sonoma down a 14-mile stretch of Dry Creek to the Russian River. If a proposed reconfiguration of Dry Creek fails to protect the fish against higher flows, the county may have to build an expensive pipeline from the dam to the Wohler pumps.

With respect to overall planning for drought, using a United States Geological Survey (USGS) modeling program, the agency is projecting minimum reservoir levels in Lakes Mendocino and Sonoma for normal, single-dry, and multiple-dry years (SCWA UWMP 2011:4-6). Assuming past curtailment efforts would be as successful in future droughts, as they were in the past, the model shows the lakes holding adequate water supply to withstand a single-year or multi-year drought through 2035 (SCWA UWMP 2011:6-3). The SCWA notes that their pumps could have pumped a higher volume of water during the dry year of 2008 without causing significant overdraft or mechanical stress to the pumps (UWMP 2011:4-16).

The listings under the Endangered Species Act on both the Eel and Russian Rivers were a major factor in the agency evaluating a full range of options to diversify its water sources to both increase its water supply security and build resilience to future droughts. One of these options is recycled water for seasonal use. The agency supplies tertiary treated urban wastewater for irrigation and large landscaped areas, along with wildlife habitat restoration and residential landscapes. The agency also proposes to construct storage areas for the unused wintertime recycled water, as well as additional distribution structures, and then use it in the summer when there is maximum demand. To offset groundwater pumping, the agency operates wastewater treatment under the Sonoma Valley County Sanitation District, and future potential wastewater treatment projects would aim to do the same (SCWA UWMP 2011:4-21).

To comply with ESA, the agency is also focusing on better use of groundwater to accommodate projected growth in demand along with reduced surface water supplies as a result of ESA compliance. Groundwater conditions in Sonoma have changed significantly over the past three decades, and there is current concern regarding saltwater pollution, high nitrate concentrations, and mixing with waters high in mineral content in some areas. Additionally, curtailment of the imported supply from the Eel River, a main source of recharge to the groundwater system in the Russian River, makes it critical to manage local groundwater resources sustainably. The Agency recently partnered with the USGS to evaluate groundwater resources in several groundwater basins and also began a Groundwater Banking Feasibility Study. The goal is to conjunctively manage surface and groundwater supplies with member retail agencies to provide groundwater banking using excess water from the Russian River during wet years for banking in the Santa Rosa Plain and/or Sonoma Valley aquifers for groundwater recovery in drought years and emergencies (SCWA UWMP 2010:4-16).

### Potential for Creating a Groundwater Reserve

The SCWA is relatively well prepared to respond to drought conditions through reduced usage, its significant storage capacity in Lake Mendocino and Lake Sonoma, and groundwater, and it anticipates few drought impacts once curtailment is enforced. As a result of the agency's ample water supplies and the current diversity of its water sources, the agency is well positioned to build a sustainable groundwater resource. The agency is not currently focused on developing a drought reserve, but this remains an option as part of enhancing ongoing management plans.

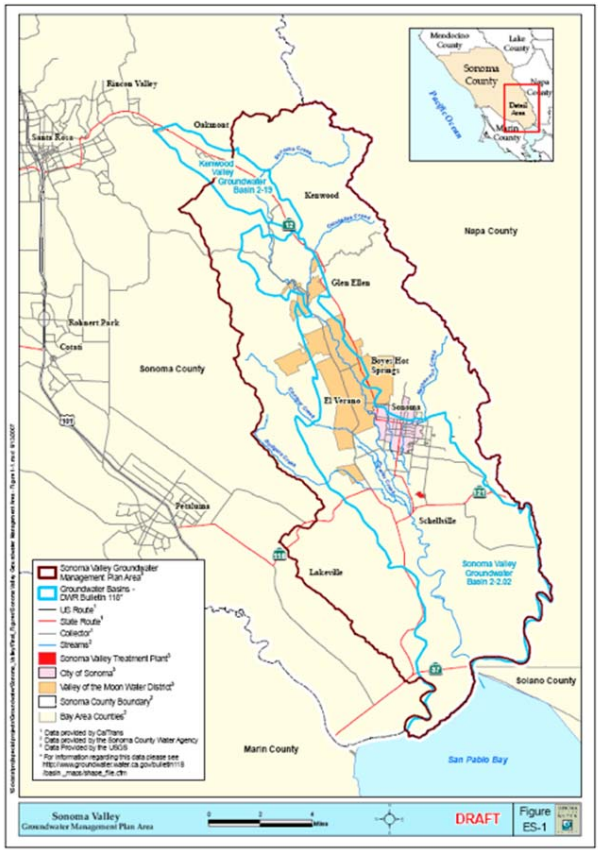
## 4.6 Sonoma Valley

### Background

Our project focused on Sonoma Valley, mapped in Figure 9, as one region where groundwater studies were being conducted by the SCWA, and where groundwater resources have long played a significant role in the development, growth, and sustainability of the region. Groundwater meets more than half of Sonoma Valley's annual water demand, and irrigation is the largest consumer of this resource. The basin occupies an area of approximately 160 square miles bounded to the east and west by the Mayacamas and Sonoma Mountains, respectively, and extends from the City of Kenwood in the north to San Pablo Bay on its southern end. Its boundaries roughly coincide with those of the Sonoma Creek watershed. The dominant land use type is native vegetation followed by agriculture, primarily vineyards. The basin encompasses the City of Sonoma and the Valley of the Moon Water District, both of which rely on water from the Sonoma County Water Agency as well as groundwater.

### Physical Setting

The Sonoma Valley is a well-defined hydrologic basin with some areas of declining ground-water levels, potential water-quality problems from saltwater intrusion and upwelling of geothermal waters, and ground-water/surface-water interaction. The geology of the Sonoma Valley groundwater basin can be divided into two general rock types. Sedimentary units of the Glen Ellen and Huichicha Formations occupy the valley floor, while the igneous Sonoma Volcanics form the surface geology of the mountains and underlie valley deposits at depth. Both rock types are considered aquifers, as productive wells have been developed in each to depths of 1,600 feet below ground (Farrar et al. 2006).




Source: Sonoma Valley Groundwater Management Plan (2007)

**Figure 9: Map of Sonoma Valley**

The sedimentary Huichicha and Glen Ellen Formations underlie the central part of Sonoma Valley and range in thickness from a few hundred to >1,000 feet, with thickness generally increasing toward the valley's southern end. The units are composed of Pliocene to Pleistocene aged alluvial and fluvial deposits of material eroded from the Sonoma and Mayacamas mountains and deposited on the valley floor. The Huichicha and Glen Ellen formations exhibit highly variable stratigraphy, with grains ranging in size from silt and clay to sand, gravel, and large cobbles, and grain sorting is often very poor. The aquifer properties of these formations are thus also highly variable, with well yields ranging from <1 to >100 gallons per minute (Farrar et al. 2006). The Sonoma Volcanics that comprise the mountainous areas and deeper valley geology of the Sonoma Valley groundwater basin erupted and deposited sediment between 8 and 2.5 million years ago. The Sonoma Volcanics are highly variable in composition, with interbedded layers of basaltic to rhyolitic lava flows, tuffs, lahar deposits, and debris and avalanche deposits. The rocks of this unit are strongly folded and broken by faults, and it is this secondary porosity that allows the Sonoma Volcanics to be exploited as a groundwater resource. Successful wells that intercept water-bearing fractures in the subsurface may produce on average between 10 and 50 gallons of water per minute (Farrar et al. 2006).

Groundwater elevations are highly variable across Sonoma Valley, ranging from approximately 500 feet above mean sea level near Kenwood, to slightly below sea level near the coast and in portions of the southern valley. Groundwater elevations in the central and southern portions of the groundwater basin, particularly near the City of Sonoma and in the Valley of the Moon, have decreased by several tens of feet between the 1970s and present. This is likely due to increased groundwater development in these areas. Conversely, areas of the northern valley have observed apparent increases in groundwater levels during this period, but such changes are likely due to the time of year during which measurements were made (autumn versus spring), as well as changes in multi-year drought conditions (Farrar et al. 2006).

Precipitation is also highly variable across the Sonoma Valley groundwater basin, with average annual amounts ranging from approximately 20 inches at the valley's southern end to 40 inches in the northern Mayacamas Mountains, and it varies greatly from year to year. Natural recharge to the aquifers of the Sonoma Valley groundwater basin occurs both as direct infiltration at the land surface at higher elevations and at the valley floor, as well as through streambeds. Streambed infiltration appears to be particularly important in upland and foothill areas. In its lower reaches, Sonoma Creek is observed to be a gaining stream, receiving flow from naturally discharging groundwater (Farrar et al. 2006).

Several chemical constituents of potential concern are observed in wells in the Sonoma Valley groundwater basin. Elevated levels of nitrate, a common agricultural pollutant, are present in about a half dozen wells to the immediate south and west of the City of Sonoma. Boron, a naturally occurring element commonly associated with igneous bedrock geology, is present at high concentrations at a few scattered locations throughout the basin.

Brackish to saline groundwater occurs in the southern portion of the basin adjacent to San Pablo Bay. Although some modern seawater intrusion to the aquifer may be occurring, the majority of this saline portion of the aquifer is classified as "historical," associated with the naturally occurring bay mud deposits overlying the southern portion of the groundwater basin. Isolated areas of higher salinity further inland may be associated with the upwelling of deep groundwater from marine sedimentary deposits in areas of high geothermal activity (Farrar et al. 2006).

## Water Management and Use

The valley experienced rapid population growth from 14,000 in 1970 to 32,400 in 2000. Over that same time period the irrigated acreage land use expanded from 3,000 acres to 11,000. The percentage of the land used for vineyards was about 50 percent in 1974. The remaining irrigated acreage was primarily higher water-consuming crops and pasture. By 2,000, vineyard cultivation had climbed to 95 percent of the total irrigated land.

As of 2000, total groundwater use in the Sonoma Valley groundwater basin was estimated to be 8,400 afa. This represents a >30 percent increase in groundwater pumping since the 1970s, and demand is projected to increase an additional 20 percent above 2000 levels by 2030. Most groundwater pumped from the Sonoma Valley groundwater basin (~6,100 afa) is destined for agricultural use. While urban water demand (~5,800 afa) is also a significant component of total water use in the basin, the majority of this is supplied by surface water delivered via pipeline to the valley by the SCWA. The City of Sonoma owns and operates six local groundwater production wells, but less than 1,000 afa of local groundwater is currently used by the City of Sonoma and Valley of the Moon Water District combined. Whether or not this quantity increases or decreases in the future will depend on the ability of these urban areas to acquire additional imports from SCWA. If additional imports cannot be obtained, local groundwater pumping for urban use is projected to nearly double by 2030 in order to meet increased demand.

### Potential for Creating a Groundwater Reserve

Sonoma Valley has great potential for creating a drought reserve. The basin is not in a state of significant overdraft, but is quite close to being in balance. The SCWA is already engaged in an impressive groundwater sustainability program. They brought stakeholders together to work on a groundwater management program including agriculture-dairy/grape growers, the County of Sonoma, domestic well owners, business owners, environmental groups, the Resource Conservation District, Valley of the Moon Water District, and the City of Sonoma. They prepared a guide for property owners to implement stormwater management projects to reduce runoff and promote groundwater recharge, with the slogan “Slow It, Spread It, Sink It.” In addition, the Agency is performing groundwater recharge mapping in coordination with the Sonoma Ecology Center using California DWR grant funds to identify natural groundwater recharge areas and locations suitable for groundwater recharge enhancement projects, including integrating and ranking recharge components such as geology, soil, slope, and vegetation (Trotta 2011). This program could reasonably lead to the supplemental water supply needed to create the groundwater reserve.

# Section 5: Establishing a Drought Reserve

## 5.1 General Elements to Establishing a Drought Reserve

Establishing a groundwater drought reserve involves specific requirements at each step of a process that includes: establishment of the source of water for the reserve, transmission to the storage site, recharge at the storage site, withdrawal of stored water, and transmission to users. These steps entail hydro-geologic considerations and legal requirements, and involve multiple interests who may control aspects of essential elements.

### Source of Water for a Reserve

Two types of water are available for a reserve: native and non-native. Native groundwater is defined in this analysis as water that comes from local precipitation and in-basin hydrologically connected surface flows that percolate into the aquifer where the storage site is located. Native water remains in the aquifer via two methods: (1) reduced demand utilizing conservation, or (2) in-lieu recharge, where pumpers forgo withdrawing groundwater and utilize surface water to satisfy demand. Neither process requires permits until the withdrawal stage.

Non-native water is defined in this paper as water that comes from an in-basin source (e.g., recycled water) but that is not hydrologically connected with the storage site, from a local or regional desalination facility, or from water imported from a different watershed. Most current California groundwater storage programs use Central Valley Project (CVP) or State Water Project (SWP) non-native water imported from significant distances outside the basin for recharge, and this water is then primarily transmitted to users that are also located significant distances from the storage site. Today, water imported via the CVP and SWP is less reliable and many water agencies throughout the state are exploring alternative approaches to establishing water supply security. Importantly, many smaller coastal water agencies have never relied on water from outside their watershed, and our discussion is particularly relevant to their drought strategies.

The focus of this paper is therefore on native sources and local or regional non-native sources of water that are then used to establish a locally based drought reserve to serve communities in the local watershed or region during drought. With respect to our agencies, SCWA does not receive water from the big projects, but it does import some of its water from a regional source, the adjacent Eel River, and uses that water to supply its customers in Sonoma County and adjacent Marin County, including the cities in Sonoma Valley. The cooperative desalination project between the adjacent communities served by the SCWD and SqCWD will involve SqCWD receiving non-native desalination water transmitted from a local plant in Santa Cruz.

As discussed earlier in the paper, the water sources we considered include flood control releases, desalinated water, captured rainwater, stormwater, and recycled water. Each source is subject to a range of requirements. Regulations for rainwater collected for storage are not fully developed at this time, but no permit is needed from the state if water is designated for non-potable uses such as landscaping. For all permittees and licensees, rights to utilize their surface water sources for recharge will require a permit from the State Water Resources Control Board that specifies changes in the amount, point of diversion, place of use, and purpose of use (California Water Code §§ 1243, 1253). Such orders must generally comply with CEQA, which requires that potential environmental impacts be disclosed, assessed, and mitigated. These orders will also require a finding of "no injury" to legal users of water (SWRCB 2002).

## Transmission to the Storage Site

Water that is retained in the basin through reduced demand does not require any transmission. In-stream flushing flows and floodwater releases below a dam that can be routed down a stream channel to an area of percolation in-stream may not need any other transmission facility. This water can also be channeled via a transmission facility to off-stream spreading ponds. All other sources of water, whether utilized for "in-lieu" or managed recharge and storage, generally require transmission to a recharge site or a distribution facility. A local water agency or a private party may own the transmission facility, and a contract may need to be arranged (Kidman 2004). Again, for all permittees and licensees, both in-stream conveyance and re-diversion rights need to be verified, and the SWRCB must approve any changes in existing rights regarding water flows, point of diversion, water use, and place of use (California Water Code §§ 1243, 1253).

## Underground Storage

The question of who "owns" the storage space needs to be clarified, separately from rights to recovery of the stored water. In the case of non-native water, the groundwater basin managing agency or a permitting authority created by a local government ordinance must be consulted to verify the existence of storage capacity and to determine whether the water can be stored without interfering with any vested rights to pump native water. Additionally, the parties involved may need to negotiate who has responsibility for water losses that may occur.

In *Central and West Basin Water Replenishment District v. Southern California Water Co.* (2003) the issue was who has the right to utilize unused storage space in the Central Basin, a groundwater basin, and who has the right to manage the subsurface storage space. The court held that the unused storage space is a public resource and as such, the Water Replenishment District of Southern California was authorized to manage it as against private groundwater pumpers.

The question of who can use a storage space where there is no shortage of available space in relation to demand remains unanswered. In addition, it is unclear whether, in such circumstances, any entity, including overlying landowners, can exclude others from using the aquifer storage space or exact a "rental" fee for such use. The court holdings in *City of Los Angeles v. City of Glendale* and *City of Los Angeles v. City of San Fernando* make no provision for compensation for use of aquifer storage space. Also unsettled is whether the right of groundwater appropriators to utilize aquifer storage space is subordinate to the right of overlying landowners, and the extent to which coordination with existing rights holders is a prerequisite to a public agency's use of storage space (SWRCB 2002).

In *Niles Sand and Gravel Co. v. Alameda County Water District* (1974), the company was prohibited from draining groundwater from its quarry because it violated a condition of its operating permit that prohibited interference with a statute that created a county groundwater replenishment program to prevent saltwater intrusion. The court cited the need for water conservation and salinity management in the area, and stated that the law imposes a "public servitude" on overlying users that prohibits uses to the contrary (SWRCB 2002), and that the district had the authority to store water in a groundwater basin pursuant to its police powers.

### Recharge

First, a groundwater basin, or areas of a groundwater basin, must be capable of physical recharge. Three basic processes can replenish aquifers: (1) natural recharge, (2) active recharge (also referred to as enhanced, direct, or artificial recharge), and (3) in-lieu recharge. Natural recharge can occur as part of the hydrologic cycle or as the result of water seeping or percolating into the aquifer from various surface water sources: streams, rivers, lakes; surface water conveyance facilities; and return flows from irrigated agriculture and rainfall that infiltrates the land surface and percolates into the underlying aquifers (California Department of Water Resources 2009). Natural recharge rates differ both spatially and temporally due to variations such as soil type, plant cover, land slope, and rainfall timing and intensity (Sophocleous 2004).

Active recharge occurs when water is pumped or injected into wells or spread over a land surface to allow it to seep into the aquifer. This method generally uses imported water in several different scenarios. A storage-and-release regime can modify an existing reservoir to allow it to capture a larger fraction of peak flow events and move a substantial portion of this imported water into groundwater basins with unutilized aquifer storage capacity. Similarly, users can extract native groundwater from full aquifers for local use, creating storage space, and subsequently fill the space with the non-native water through active recharge, including injection or spreading. In-lieu recharge involves a reduction in groundwater extraction so that a depleted aquifer can recharge through natural or active processes. Parties generally substitute more available surface water supplies for consumption.

Recharge processes depend upon factors such as the area available for recharge, surface, and subsurface geology and recharge rate, and these processes are influenced by the source of recharge water. Depending on the water source for active or in-lieu arrangements, different permitting requirements and rules can apply to water quality issues. The party who wishes to recharge water into a groundwater basin must own or contract for the use of recharge facilities. In some basins artificial groundwater recharge is conducted by a management agency. In other cases, a flood control agency or local public works department can conduct recharge operations, and must be consulted.

In general, a party who wishes to recharge and recover groundwater bears the burden of establishing that this will not adversely affect, or "injure" other "legal users" of the groundwater basin (Cal. Water Code § 1702 - applicable when a change order from the SWRCB is required). The scope of this protection is not certain because of significant disagreement over who comprises the "legal user[s] of the water," and because determining injury is difficult due to the different standards governing surface water and groundwater (SWRCB 2002). With respect to water quality, the rule, applying to both surface and groundwater, is that a right holder is entitled to protection against acts that deteriorate the quality of water for the uses to which the right holder wishes to apply it. At a minimum, the entity recharging groundwater must avoid raising the groundwater table to a level that invades the root zones of neighboring crops or neighboring structures, or cause risk of liquefaction. It must avoid unreasonably lowering the groundwater table below the level that would result in the dewatering of neighboring wells or increasing the power requirements for pumping, and/or causing subsidence or seawater intrusion, and it must also avoid degrading the quality of the in situ groundwater. Additionally, a storage project cannot alter existing groundwater rights or harm surface infrastructure, and existing water right holders may be legally entitled to prevent a water storage project from reducing the natural infiltration capacity of their aquifer that captures and stores naturally occurring percolating groundwater.

Water in aquifers is not static. Artificial recharge alters the hydrostatic pressures within the groundwater basin, and may cause some of the native groundwater to become unrecoverable to overlying landowners (by migrating to a salt sink or a surface waterbody, for example). Thus, there is no guarantee that water deposited in a groundwater bank in one year will be physically available to extract in a future year, and some percentage of the banked water generally cannot be recovered without adverse impacts on other users of groundwater in the same basin. This potential for injury to other groundwater users may be mitigated or avoided by adjusting the rates, volumes, and location of the extraction wells and the residence time of the banked water (SWRCB 2002).

A recharge and recovery project may also have to comply with regulatory requirements imposed by a local groundwater management authority—such as an AB 3030 groundwater management authority or a permitting authority created by local government ordinance. County authority to regulate groundwater was upheld in *Baldwin v. County of Tehama* (1994). Local entities may potentially assert jurisdiction at both the importation/storage and extraction stages, and generally impose their own version of a "no injury" rule. Case law is not yet settled regarding how to apportion unsaturated aquifer storage space among parties that may be competing to store non-native water (SWRCB 2002).

### Recovery

Parties that store water in a groundwater basin require assurances that they can recover the stored water. With respect to native groundwater, as already indicated, overlying landowners enjoy correlative rights and groundwater appropriators enjoy appropriative groundwater rights. In the case of non-native water imported into the storage site, the law states that a party who causes a quantity of non-native water to be placed into a groundwater basin has a priority right to recover like quantity of water from the basin less whatever losses may be entailed (*City of Los Angeles v. City of San Fernando* 1975), unless abandoned (*Stevens v. Oakdale Irrigation District* 1939). This is subject to the requirement of avoiding injury to legal users of the native groundwater with which the imported groundwater may commingle. Injury could arise where extraction wells are located proximate to those of pre-existing groundwater users and where the rate of extraction creates a cone of depression that increases the neighbor's pumping power requirements compared to pre-existing conditions. Most important, as already mentioned, enforcing one's rights to imported water against unauthorized withdrawals by other users of the aquifer is challenging, as is calculating the amount of water to which an importer is entitled.

The right to recover water stored in a basin under an in-lieu arrangement is unsettled if actively recharged non-native water is also stored in the basin. Theoretically, water rights holders to the native supply have no claim to any non-native water placed into a groundwater basin. But as these waters are generally intermingled, a mechanism is needed to ensure the rights of different parties are maintained. With an in-lieu groundwater storage program, native groundwater turns in situ into stored non-native water, which must be reconciled with competing rights to that same native water. The recovery right for such water is yet to be tested in an appellate court decision (Kidman 2004). Additionally, the "return waters" of imported surface water supplies applied for irrigation and percolated into a groundwater basin do not become groundwater subject to use by overlying users or to appropriators (*City of Los Angeles v. City of Glendale* 1943).

### Diversion to User

Where a surface water diversion involves storage of water underground, the State Water Board's authority over the permittee includes authority to regulate the re-diversion and use of the stored water and the no-injury rule will apply (California Water Code §§ 1243, 1253; California Code of Regulations., tit. 23, § 722).

## 5.2 Calculating a Drought Reserve – General Elements

To determine the groundwater space available for water storage there are three groundwater aquifer quantities that must be determined: the aquifer extent or area, the extent of available vertical space, and the fraction of available volume that can be used to store recoverable water (storativity). The first two terms, the product of which comprises a rough estimate of aquifer volume available for storage, are often well known on the basis of basin investigations. However, there can be important practical issues about the definition of the aquifer top where the aquifer is unconfined.

Filling an aquifer to even just a little below the ground surface could lead to all kinds of problems such as soil saturation that could kill plants, flood basements or other subterranean structures, and crack or weaken building foundations. Because of the potential for exposure to such liability risks, it might not be advisable to attempt to store excessively large amounts of water by filling the aquifer to abnormal, artificially high top elevations. A safe value for the aquifer top value that would seem to be quite prudent and legally defensible would be to utilize some past observed elevation. Most aquifers today have been artificially lowered by significant extraction pumping and decreased recharge flows. It is thus highly likely that there is plenty of unused aquifer space in which to store a drought reserve.

An aquifer is almost never a simple, regular rectangular solid volume. The concept of a single value for its bottom, top, and area is a gross simplification. In practice, an aquifer would be subdivided into much smaller sub-units such that they have shapes that are more regular and uniform. Then the total quantity of storage space in the aquifer is found by summing the computed volumes of such aquifer sub-units.

For water storage, the primary concern is not the volume of aquifer space available as much as the quantity of water that can be stored. To calculate the quantity of water possible for storage, the aquifer storage space volume is multiplied by the effective aquifer porosity (that fraction of aquifer volume that is available for storage). Aquifer properties are not homogenous, but tend to vary over a wide range. Subdividing the aquifer into sub-units can be used to provide narrower ranges for porosity and other values.

Droughts need to be placed in the context of the social and economic activities of a region because it is in these contexts that water management is conducted (Walker et al. 1991). In calculating the amount needed for a drought reserve, the first issue is the degree of drought risk for which protection is desired. Our project draws on the U.S. Drought Monitor's classification of drought intensities as: Dry, Moderate, Severe, Extreme, or Exceptional. The length of a drought is not a completely independent variable, since dryness is partly cumulative. However, it can be important to consider the drought length separately since many water systems can withstand a short-intense drought much better than a longer-milder drought (National Drought Monitor 2011). Defining a target drought by combining an expected drought length in years together with their drought intensities gives a good metric for the expected risk.

A drought risk can be specified by the identification of a past historical drought and its record. For example, the most recent drought in California had a length of three years (2007–09). The statewide precipitation values expressed as a percentage of average for each year were 63 percent, 72 percent, and 76 percent. The corresponding surface streamflows were 53 percent, 60 percent, and 70 percent A more severe drought occurred in the 1970s, but it lasted only two years: 1976 and 1977. The precipitation values were 65 percent and 45 percent, with streamflows of 47 percent and 22 percent. This was the third most severe California drought in 120 years of records as identified by its reductions of statewide precipitation and surface water runoff, and it caused significant economic, environmental, and social challenges. Note that in identifying a historical drought to assess drought risk, the effect of future climate change on any increase in drought severity or frequency of a similar future drought needs to be considered.

Given the values for the target drought's projected precipitation and streamflows, an agency can then make an estimate of water supply shortfall. In estimating surface water supplies, consideration must be given to water rights terms and conditions. For example, any other rights that are senior to that of the agency must be completely satisfied before the agency rights can be addressed. Environmental streamflow allocations might well be an example of such a higher priority water right. Any other rights equivalent to that of the agency would be satisfied together with that of the agency on an equal footing. If groundwater is used from an adjudicated basin or has other constraints that apply, then this supply might also have some quantity limitations.

Drought water demands for an agency must also be estimated. Without any vigorous action, water demands often tend to increase during a drought. A water use such as irrigation might be increased to counteract increased soil and vegetation dryness by more frequent and heavier watering. However, if an agency makes extraordinary exhortations to its customers, mandates stringent usage policies, institutes draconian financial penalties, and other strict usage terms, then some drought usage curtailment below typical water demands might be expected. Subtracting the expected drought water demands from the expected supplies, the shortfall for each drought year is computed. The sum of these individual shortfalls across all the years of the target drought yields the total drought water shortfall. A drought reserve would need to contain this total shortfall quantity in order to successfully protect against this defined target drought. The next sections discuss approaches to calculating a drought reserve in three sites.

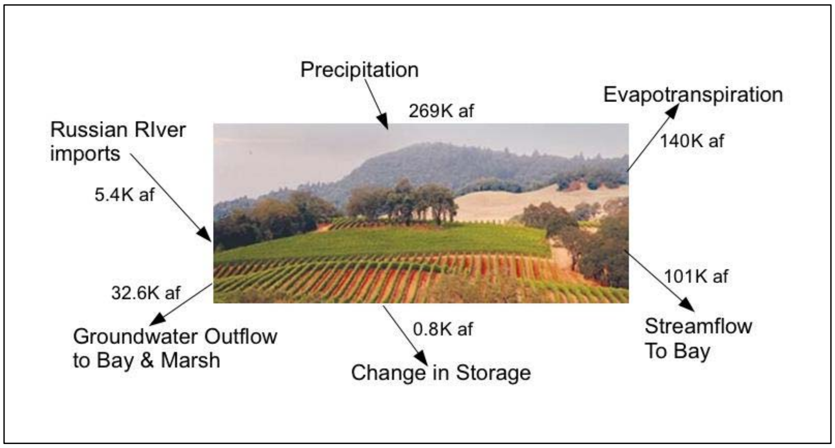
Groundwater basins are almost never completely closed and sealed off from their surroundings. Instead there are a number of methods by which groundwater can and does leak away. Groundwater will tend to flow from its basin down-gradient toward other basins or the ocean. Groundwater can also escape by discharging from the groundwater basin into local streams that then carry their streamflow out of the basin. Therefore, to create a drought reserve over a number of years of some volume "X," it cannot assumed that a recharge of only that volume "X" of groundwater is sufficient. Instead account must be taken of the expected basin loss each year to determine the actual net recharge.

Once the reserve has been completely filled to the desired volume, it cannot be ignored, but rather must be actively maintained and would require continuous recharge to be applied each year to restore the volume removed by potential basin loss. The creator of a reserve might find it legally challenging or technically impractical to extract water that has migrated off-site. An even more challenging situation could occur if adjoining neighbors or other agencies engaged in active pumping within the basin. This would tend to increase the groundwater gradient and could accelerate the off-site migration of the reserved groundwater.

## 5.3 Establishing a Drought Reserve – Sonoma Valley

Gravity data indicate the Sonoma Valley groundwater basin is as deep as 6,000 ft in the main part of Sonoma Valley, and as much as 10,000 ft in the Kenwood area and along the edge of San Pablo Bay. So there is a vacated underground space available of over 420,000 af. A storativity of 0.1 would yield water storage capability of 42,000 af, equivalent to about three years of storage. Basin studies indicate increased pumping between 1975–2000 (6,000 to 8,500 afa) with localized decline of groundwater levels and a 17,000 af decline in groundwater storage. At this time, the parts of the area up-valley from Sonoma do not show any clear trend of declining water levels over broad areas. But in recent years, pumping depressions developed in the central part of the valley southeast of Sonoma and southwest of El Verano. Water levels changed significantly between 1980 and 2003, and groundwater elevation maps show a lowering of about 20 feet over a central valley area that represents about 20 percent of the watershed. Groundwater levels were also below sea level in parts of the south end of the valley. As already indicated, there are also areas with potential water-quality problems from saltwater intrusion and upwelling of geothermal waters, and groundwater/surface-water interactions.

As indicated in Figure 10, the normal year water supply for Sonoma Valley consists of Russian River water imports of 5,400 af, and the groundwater pumping is 8,340 af, a total of 13,740 af.



Source: USGS 2006

**Figure 10: Overall Water Balance in Sonoma Valley**

Utilizing specific assumptions for this basin, one can provide a rough calculation of the amount required for a reserve (Table 1). First, assume a target drought for this agency to be the most recent California drought of the three years 2007–09. Assume that the resulting reduced streamflows are shared equally among all surface water diverters, giving all Russian River users proportionate reductions equal to 53 percent, 60 percent, and 70 percent. Then, Sonoma Valley imports would be reduced to 2,86; 3,240; and 3,780 af. These constitute a shortfall of the imported water received by the valley equal to 2,538; 2,160; and 1,620 af, for a total shortfall of 6,318 af. Assuming groundwater withdrawal is the same as in normal years, the only supply decrease will be this computed Russian River shortfall.

Second, assume the water agency can achieve water demand curtailment from their customers for those drought years of 15 percent, 12 percent, and 10 percent. That would represent demand savings of 810, 648, and 540 af for a total of 1998 af by their Sonoma Valley customers importing water. The difference of the total supply shortfall reduction of 6,318 af minus the curtailment demand savings of 1,998 af means the total drought shortfall equals 4,320 af. The groundwater drought reserves would need to be at least as large as 4,320 af in order to protect against the target drought.

**Table 1: Calculating a Drought Reserve**

| | 2007 | 2008 | 2009 | Totals |
|---|---|---|---|---|
| Reduced imports | 2,862 | 3,240 | 3,780 | |
| Shortfall | 2,538 | 2,160 | 1,620 | 6,318 |
| Curtailment | 810 | 648 | 540 | 1,998 |
| Amount needed for reserve | 1,728 | 1,512 | 1,080 | 4, 320 |

**Total Reserve Required for Three-Year Drought – 4,320 af**[8]

[8] Total imports (af) less percent reduction = Reduced imports (af)
Total imports (af) less reduced imports = Shortfall (af)
Total imports (af) less percent curtailment = Curtailment (af)
Shortfall (af) less curtailment (af) = Amount required for a reserve

Over the last 120 years, from 1890 to 2010, there were eleven multi-year statewide droughts (Table 2). These extended from two to six years in duration and caused a wide range of impacts to precipitation and to surface streamflow runoff relative to their mean values.

**Table 2: California Droughts**

| Period | Duration | Precipitation (%) | Runoff |
|---|---|---|---|
| 2007–09 | **3** | **69** | **61** |
| 2001–02 | **2** | **77** | **73** |
| 1987–92 | **6** | **74** | **50** |
| 1976–77 | **2** | **57** | **35** |
| 1959–62 | **4** | **76** | **69** |
| 1947–50 | **4** | **78** | **71** |
| 1929–34 | **6** | **77** | **56** |
| 1918–20 | **3** | **85** | **64** |
| 1912–13 | **2** | **88** | **65** |
| 1902–03 | **2** | **92** | **NA** |
| 1898–99 | **2** | **61** | **NA** |

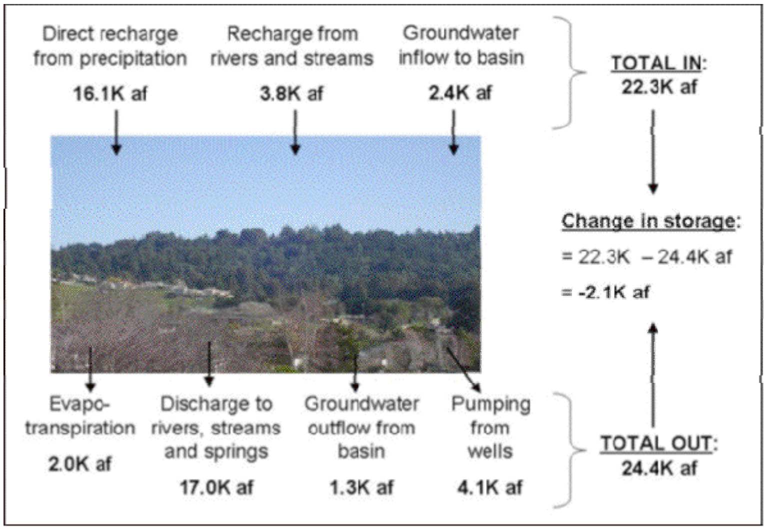
For the target drought considered for this calculation, 2007–2009, there was an intense 63 percent reduction from typical precipitation amounts during the first year, 2007. The following two years 2008 and 2009 experienced significantly less precipitation reductions of only 72 percent and 76 percent with 69 percent as the reported three-year average. The streamflow runoff values for each of these years were 53 percent, 60 percent, and 70 percent of typical amounts, with a three-year average of 61 percent. Thus the drought reserve might not have been tapped or might have been used somewhat less during the second or third drought years, if more stringent withdrawal requirements were applied.

Naturally an agency can use its own local metrics and definition of drought. In this case, one or all of the years 2007–09 might be considered to represent droughts. But still, every reasonable effort should probably be applied to eliminate or reduce reserve withdrawals. For example, Sonoma Valley might have been able to temporarily reduce demand by 20 percent through customer curtailment, aggressive conservation retrofits, and other programs. Such demand reduction of 20 percent would have saved 2,748 af, which is more than the supply reduction of 2,502 af in 2009 and most of the supply reduction of 3,336 af in 2008.

## 5.4 Establishing a Drought Reserve - Scotts Valley

The Scotts Valley Water District relies entirely on groundwater from the Santa Margarita Basin. In 2006, the district's completed analysis of the basin indicated that the sustainable yield for the *entire basin* was 3.320 acre-feet per year, and the sustainable yield of Scotts Valley to be 2,600 afa (ETIC 2006).

The figures shown in Figure 11 for the average annual groundwater deficit are large because the period of record used by the 2006 model included numerous dry years, and predates more recent gains in conservation, recycling, and other measures. Current pumping is approximately 1,500 afa.



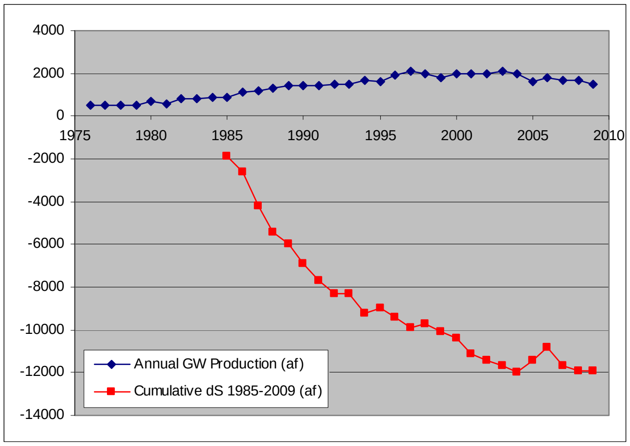

Source: ETIC Engineering, Inc., May 2006

**Figure 11: Water Balance for Scotts Valley**

The history of groundwater use in Scotts Valley can be divided into two distinct phases. The 1970s through the late 1990s was characterized by considerable growth in the valley, and annual groundwater production during this time increased fourfold, from 500 afa in 1976 to over 2000 afa by 1997. In any given year, total groundwater demands could not be balanced by natural recharge taking place. The removal of water from aquifer storage resulted in a nearly 200-foot decline in groundwater elevations in many SVWD wells. Though primarily a result of increased groundwater usage, this problem was exacerbated by the severe droughts of 1976–77 and 1987–92, which decreased the amount of natural recharge taking place.

By the time SWVD produced its first Groundwater Management Plan in 1994, the basin had accumulated a total groundwater deficit of nearly 10,000 af relative to pre-1985 conditions. Through the latter half of the 1990s, however, the situation slowly began to turn around. A reduction in the rate of growth, a shift in industry away from water-intensive quarrying operations, and new conservation measures implemented by the agency caused total groundwater pumping to begin to level off. The initiation of a tertiary-treated recycled water delivery in 2002, combined with continuing conservation efforts, actually caused overall pumping to begin decreasing starting in the early 2000s. These human factors, combined with a series of wetter precipitation years, resulted in a state of relative hydrologic balance since approximately 2002.

As shown in Figure 12, the basin's cumulative groundwater deficit peaked near 12,000 af in 2004 and has changed little in recent years.




Source: Kennedy/Jenks June (2010b)

**Figure 12: Annual Groundwater Production for the Scotts Valley Water District Area**

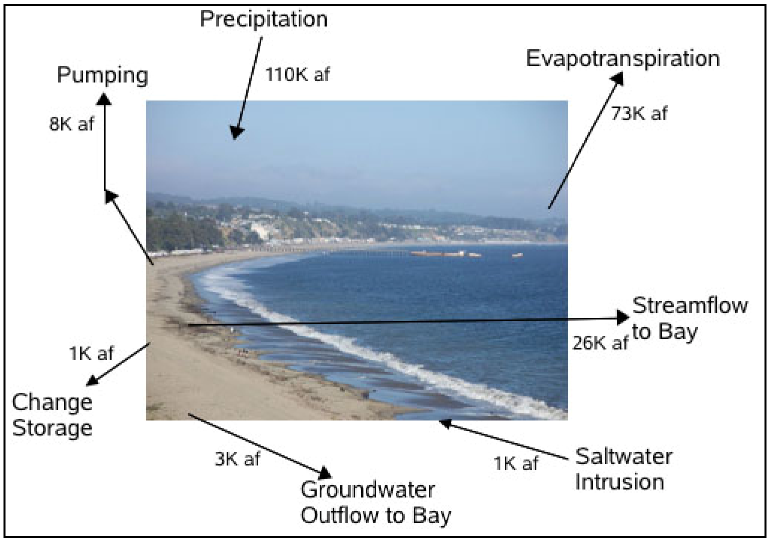
SVWD is now in the position to begin refilling the "hole" it has spent the last several decades creating. If the availability of future supplies continues to regularly exceed demands, the difference can be put back into storage in the aquifer. This can be done either actively (e.g., injection or percolation of a surface source) or passively (e.g., by increasing use of recycled wastewater in lieu of pumping). In either case, increasing the amount of groundwater in storage will in effect create a strategic reserve that could be drawn upon in the event of drought, increasing the valley's preparedness for and resilience to such an event.

In determining the amount the district would want for a reserve, the district could utilize specific assumptions to provide a rough calculation of the amount required for a reserve. Similar to Sonoma Valley, they would assume a target drought—e.g., the most recent California drought of the three years 2007–2009. They would incorporate precipitation values, determine related groundwater recharge values, and determine reductions in groundwater levels related to both precipitation and demand. They would also determine water demand curtailment that might be imposed on their customers for those drought years. The difference of the total supply reduction minus the curtailment demand savings would provide the total drought shortfall. The groundwater drought reserves would need to be at least as large as this in order to protect against such a target drought.

It is important to note that other agencies operate within the basin. San Lorenzo Valley is a significant groundwater user (>1000 afa on average), but additional use is probably from individual well owners who do not receive city water. Groundwater flows northwest to southeast across the basin, so SVWD lies down gradient from the other use areas. As indicated earlier, if these other areas were to suddenly start using more groundwater, it is possible that SVWD's groundwater inflows could be reduced. Conversely, if SVWD were to suddenly start using more water, thereby "deepening its hole," it might receive *more* groundwater inflows because the flow gradient toward SV would now be steeper. Historically, this is what happened: in the 1980s, SV had more groundwater outflows than inflows, but as groundwater in the basin was developed, this gradient reversed so today SV has a net inflow of groundwater to the basin. When the district does its computer modeling, it takes into account already existing use by the other sub-areas.

## 5.5 Establishing a Drought Reserve – Soquel Creek Water District

Figure 13 shows Soquel Creek's estimated water balance.

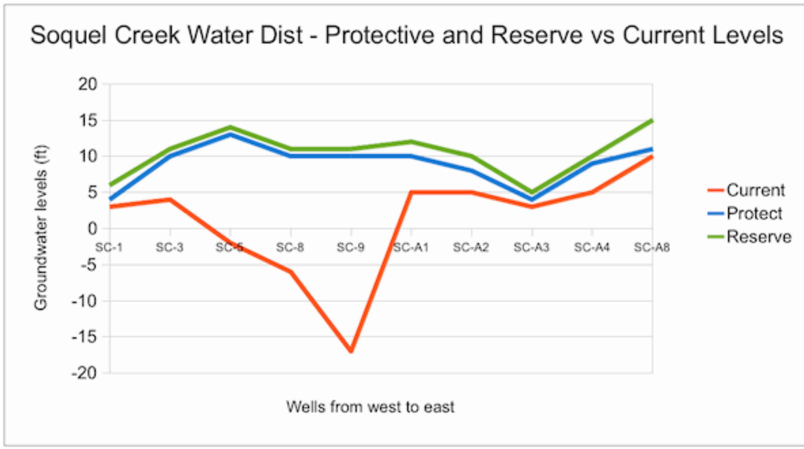



Source: Daniels (2011) Figures from: SqCWD 2004 and 2009

**Figure 13: Soquel Creek Water District Water Balance**

Soquel Creek Water District has already defined its assumptions regarding what they consider would be a reasonable drought groundwater reserve. The reserve quantity was specified as enough water for three years of drought, together with water demands sufficient for a future 2050 population growth level, also with an expectation of a 15 percent customer curtailment of that demand during the drought, and with just 4,800 af of the "sustainable" yield groundwater supply, but with no desalination alternate supply water.

The "safe storage" and the reserve storage are both specified in terms of the groundwater levels at the shoreline monitoring wells needed to block any further inland saltwater intrusion, as shown in Figure 14:




Source: Data from Soquel Creek Water District 2009
These groundwater level metrics can also be converted into values of acre-feet of storage in the aquifer.

**Figure 14: SqCWD Protective and Reserve vs. Current Levels**

As already indicated, the largest barrier to the establishment of a drought reserve for Soquel Creek is the need to first eliminate the conditions of overdraft in the aquifers. This naturally requires finding enough excess water to recharge and restore the depleted aquifer, through extreme conservation policies and also by obtaining a supplemental water supply such as desalination. Once this recharge water has been obtained, then it is estimated that it would take ten years of restoration activity before the aquifer would be restored and ready for the creation of a drought reserve.

There is a significant opportunity to implement a reserve here because the same supplemental water supply being used to restore the overdrafted aquifer would be already acquired and available. Therefore it would be the water that could and would continue to be used for recharge, thus enhancing the aquifer with additional water so as to make a drought reserve.

# Section 6: Discussion

*".....groundwater basins – when managed appropriately – can act as a buffer, providing a secure water supply in times of drought. Long-range climate forecasts suggest that California will see more seasonal droughts in this century, making groundwater buffers essential to California's water security."* (Enion 2011)

Periodic droughts, projected to become more frequent and severe with climate change, present a significant planning challenge for water management agencies in California. Coastal communities that are not connected to the major water projects in the state are particularly vulnerable to drought and ensuing water shortages. Our study examined five coastal water agencies to better understand their approaches to reducing vulnerability to drought. The primary strategy statewide, and the one utilized by most of our agencies, is to curtail water use after a drought occurs. In contrast, our project focused on an important and underutilized proactive adaptation to improve water supply security during drought for many regions: the development and maintenance of locally based groundwater drought reserves.

Groundwater is ideal for a decentralized supply buffer. During critically dry years, groundwater is an essential water supply source for many coastal areas when water districts and individual users greatly increase pumping to offset surface water shortfalls. Establishing locally based groundwater reserves can increase an area's resilience to drought and associated water shortages. Moreover, given the decreasing reliability of imported water, we highlight the use of regional and local water sources to enable a community to develop its own drought reserve supply. While this approach represents an obvious solution in principle, it is uncommon to find it in practice, and the key objective of our research is to understand and provide:

- **Motivating Factors**
  The physical characteristics, water use and management policies, and socio-legal attributes that motivate an agency to initiate proactive adaptation strategies to increase resilience to drought and establish drought reserves

- **Tools**
  Approaches and tools that can assist water practitioners in establishing more proactive drought management strategies, and, where feasible, the establishment and maintenance of drought reserves

- **Policy Options**
  Policy options to promote proactive drought planning, and specifically, the establishment of locally based groundwater drought reserves

## 6.1 Motivating Factors

An interdisciplinary approach is critical to understanding the motivations of our five agencies to adapt to climate change and more frequent and severe droughts. The physical characteristics of a region, the history of water use and management and the legal and institutional regime in which an agency is embedded, all contribute to its perception of, and responses to, future droughts (Table 3). Research illuminated several key factors as particularly significant (1) in motivating an agency to move proactively to reduce drought vulnerability, and (2) in the specific strategies selected by an agency to increase its resilience to drought. These include:

- Physical dimensions
    - Limited sources of water can motivate a community to plan proactively for a future drought

- Legal-Institutional-Socio-Political dimensions
    - Regulatory constraints, e.g., under the Endangered Species Act or a growth moratorium, can motivate a community to plan proactively for a future drought.
    - Stakeholder conflicts over groundwater management can constrain a community from establishing proactive strategies to reduce drought vulnerability.

These factors can be cumulative in influencing the direction an agency takes regarding adaptation to drought. This multi-variant approach is mapped below, alongside potential future options available to each of the agencies in our study to increase its region's drought resilience.

**Table 3: Mapping Potential Vulnerability to Drought**

| Context | Sonoma | Pajaro | Santa Cruz | Soquel Creek | Scotts Valley |
|---|---|---|---|---|---|
| Physical | Multiple GW & SW sources | GW overdraft & seawater intrusion | Limited SW storage & limited local GW | GW levels at sea level declining | GW levels declining – now stable |
| Socio-Political, Legal Drivers | ESA | Stakeholder conflicts | ESA | Initially- threat of a moratorium Currently – minimal | Initially – moratorium Currently – minimal |
| Vulnerability | LOW | **HIGH** | **HIGH** | MED | LOW |
| Adaptation Strategies | Diversify sources | Reduce overdraft | *Drought reserve* | *Drought reserve* | Conserve |
| Potential Resilience | **HIGH** | LOW | **HIGH** | **HIGH** | **HIGH** |

GW = groundwater; SW = surface water

## Sonoma County Water Agency

The agency has the advantage of multiple sources of water that can serve to buffer a typical California drought. Assuming that past curtailment efforts are as successful in future droughts as they were in the past, models indicate that their reservoirs will hold adequate water supply to withstand a single-year or multi-year drought through 2035 (SCWA UWMP 2010:6-3). Nevertheless, the listings under the Endangered Species Act on both the Eel River and Russian River were major factors in the agency evaluating a full range of options to diversify its water sources to both increase its water supply security and build resilience to future droughts. These options include use of recycled water and the better use of groundwater. The Agency recently partnered with the USGS to evaluate groundwater resources in several groundwater basins and also began a Groundwater Banking Feasibility Study. Because the agency has ample surface storage rights, the establishment of groundwater drought reserves is not as high a priority for

SCWA as for agencies with less-reliable surface water supplies (e.g., Santa Cruz). Therefore SCWA has approached groundwater management more systematically, including bringing together the diverse stakeholders in one groundwater basin, Sonoma Valley, to formulate a long-term plan for sustainable groundwater management. Given the correlative rights legal rule in California, where all landowners overlying a groundwater basin can pump as much as is reasonable with respect to other overlying owners, there is a clear advantage to bringing all users together. The agency's potential resilience is currently high and, while it is not yet working on establishing groundwater drought reserves, it is well positioned to consider this option in the future.

### Pajaro Valley Water Management Agency

The Pajaro Valley Water Management Agency experiences both socio-political tensions as well as severe long-term overdraft conditions. The multiple stakeholders under the agency's umbrella and the conflict between coastal and upland growers over groundwater management have restricted the agency's ability to significantly reduce overdraft. Nevertheless, the agency instituted several programs to reduce saltwater intrusion, including a coastal distribution project that provides recycled water to coastal growers in lieu of their pumping groundwater. While there presumably would be groundwater available during a short drought, a more severe drought would likely result in increased saltwater intrusion with significant impacts to coastal growers and to the valley overall.

### Santa Cruz Water Department and Soquel Creek Water District

The Santa Cruz Water Department has limited surface water supplies and very little local groundwater, and thus is particularly vulnerable to a multi-year drought. The city's limited surface supplies, along with the need to comply with the ESA, are the major influences on the city's desire to develop a drought reserve. Conversely, SqCWD relies solely on groundwater sources that it shares with other local water agencies, and it is experiencing declining groundwater levels in some areas. The threat of a growth moratorium prompted SqCWD to initiate a number of conservation activities to reduce groundwater withdrawals. But as a result of their close proximity to each other and complementary water needs, the two departments are working together to explore options to develop a drought reserve. The proposed construction of a shared desalination plant in Santa Cruz would allow Soquel Creek to utilize desalinated water during wet periods for in-lieu recharge of its groundwater. Replenishing its groundwater could eventually result in sufficient groundwater levels to sustain a drought reserve. Meanwhile, Santa Cruz will use the desalinated water only during some summer months and during droughts. The desalination plant not only serves as a drought reserve supply for two adjacent districts, it avoids the problem of the plant sitting idly during wet years, or of excess wet year water encouraging further growth. The Santa Cruz and SqCWD partnership is an example of one approach to cooperating regionally to establish local drought reserves.

### Scotts Valley Water Department

An actual growth moratorium prompted Scotts Valley to undertake conservation practices to reduce groundwater declines and stabilize its system. At this time, given a relatively stable aquifer and a good recycled water program, the department is not focused on a drought reserve, but it is well positioned to do so in the future.

## 6.2 Tools

This paper has outlined a number of approaches for water managers that can provide assistance and incentives to better adapt to climate change and more frequent and severe droughts. These include several decision-support mechanisms that can assist water agency managers in the calculation of metrics to establish a local groundwater drought reserve. These can also be developed further into web-based tools.

- Tool I
  - Estimation of the relationship between rainfall and deep groundwater recharge
  - Determination of drought curtailment criteria for groundwater dependent regions
  - Determination of criteria to access a drought reserve supply

- Tool II
  - Estimation of the storage capacity of a basin
  - Calculation of groundwater levels to bring basin into hydrologic balance
  - Determination of groundwater levels to sustain a reserve

## 6.3 Policy Options

Given the diverse variables that affect drought vulnerability, this study suggests that a number of policy options could contribute to increasing resilience to drought. Moreover, several agencies are already moving towards more sustainable groundwater management to conserve water, reduce overdraft, increase and stabilize groundwater levels, and establish locally based groundwater drought reserves. Examples of policies promoting that goal include:

- **Water Neutrality Program.** This program reduces the impact of increased growth and concomitant water demand. The program that Soquel Creek Water District implemented in 2003 utilized a water demand offset system for new development. Santa Cruz County is drafting an ordinance to require water neutral development in unincorporated areas of the county. The Santa Cruz County LAFCO also recently adopted a policy requiring new water service extensions to be water-negative: "In cases where the basin is overdrafted or existing services are not sustainable, a boundary change proposal may be approved if there will be a net decrease in impacts on water resources."

- **Rebates to Increase Supply or Reduce Demand.** Urban water agencies have instituted rebates for low-flow toilets, high-efficiency clothes washers, turf replacement, greywater use, rainwater catchment systems, and retrofit regulations for plumbing.

- **Awards to Agencies/Individuals for Demand Reduction Practices.** SCWA seeks annual nominations for special awards to recognize water users who have voluntarily implemented water conservation projects, and uses these examples as pilot studies.

- **Promotion of Recharge.** SCWA produced a guide for property owners to implement stormwater management projects to reduce runoff and promote groundwater recharge, with the slogan "Slow It, Spread It, Sink It." The Agency is also conducting groundwater

- **Cooperative Partnerships.** The cooperative approach being explored by Santa Cruz and Soquel Creek is a model for how to establish a locally based drought reserve, and has the potential to significantly increase resilience to a prolonged drought event for both areas. Additionally, the PVWMA, the County of Santa Cruz, and the City of Watsonville are currently working collaboratively on water resource issues in the region, albeit struggling with allocation of costs and a method of revenue collection.

These practices illuminate how local actions can be effective in stabilizing a region's water supply. But there is a caveat: no agency has yet actually established locally based drought reserves, and several are still focused solely on water curtailment after a drought is declared. The question remains as to the potential legal and institutional options that can be instituted, and reasonable options are those that will encourage more sustainable groundwater management and the establishment of reserves. The following are options that do not require significant changes to California's complicated and hydrologically unscientific legal system.

- **Incorporate the goal of establishing drought reserves into planning documents.** Stipulate that the specific *goal* of establishing drought reserves be incorporated into already existing planning documents and policies, including for example Urban Water Management Plans and AB 3030 Groundwater Management Plans. This is an important first step in moving towards the eventual creation of groundwater drought reserves, Funding is already available through these programs, and can be used to provide strong incentives to implement practices that reduce overdraft and begin the establishment of drought reserves Similarly, use already existing financial incentive programs to motivate inclusion of this goal and its implementation into Integrated Regional Water Management Plans.

- **Phase in more comprehensive groundwater monitoring.** Extend the groundwater monitoring system to provide information to local management to improve groundwater conditions and develop reserve supplies. Currently, monitoring does not quantify overdraft or provide for an accounting of inputs and extractions (Sawyer 2010). Including an identification of what needs to be done to improve groundwater conditions, or who should be responsible, would also enable the state to focus funding and technical assistance efforts in the areas of greatest need.

- **Increase incentives for counties to reduce groundwater overdraft and establish drought reserves.** Counties have the authority under their police power to regulate groundwater overdraft. Provide financial and other incentives to encourage counties to establish policies to reduce overdraft and establish regionally based drought reserves. Often several water management entities withdraw water from the same aquifer, and given the state's correlative groundwater law, coordination is critical to avoid overdraft. While some counties have enacted water neutrality rules and other policies for more sustainable management, financial incentives could increase county motivation to establish more proactive drought planning with the establishment of reserves.

- **Provide incentives for stakeholders to negotiate strategies to reduce drought vulnerability.** Where conflict is present, establish stronger incentives for stakeholders, including local, regional and county authorities, to negotiate long-term regionally based programs that will reduce overdraft and/or pollution. Examples are the establishment of active management areas where groundwater is particularly degraded, or basin-wide adjudications. These could clarify the sustainable yield of a basin and the amount needed for a reserve, and set firm parameters for withdrawal and management, including establishing drought reserves.

Enabling the state to move towards better groundwater management is a critical phase in developing locally based groundwater reserves. We note that most areas of California have no regulatory program in place to control groundwater pumping, and there is limited information about the resource and who's using it. Pajaro is a good example of where this has resulted in significant overdraft and salt water intrusion. While acknowledging the historical resistance in the state to alter groundwater law, we propose the following options as ways to control overdraft in many parts of the state. We maintain that reducing overdraft is critical for long-term sustainable use of the groundwater resource, and that the creation of locally based drought reserves is a key proactive approach to reducing vulnerability to drought:

- **Modernize groundwater law.** Establishing legal rules that accurately reflect the physical interconnection of surface water and groundwater—for example, developing a more realistic state classification scheme that acknowledges hydrologically linked groundwater and surface water—could enable the SWRCB to work with local entities to better address overdraft in some groundwater systems and create more favorable conditions for reserve development. The California Constitution, Article X, Section 2's Reasonable and Beneficial Use Doctrine is currently considered one of the best sources of existing legal authority for the state to address groundwater overdraft and groundwater-surface water problems. The SWRCB for example, can use its authority under Section 275 of the California Water Code to require compliance with the doctrine through the adoption of regulations to reduce overdraft, a critical first step in creating groundwater drought reserves. The Public Trust Doctrine also provides a potential tool for the SWRCB to address impacts of groundwater diversions on surface waters to the extent that GW withdrawals adversely affect public trust resources in surface bodies of water.

- **Provide incentives to establish clear standards for groundwater sustainability.** The cooperative federalism approaches of the Clean Water Act and the Coastal Zone Management Act (1972) could serve as models for a state-local cooperative framework for managing groundwater more sustainably. For example, under the Coastal Zone Management Act, grants are made to states with approved programs based on rules and regulations established by the federal government and where the state has developed and adopted a management program in accordance with these rules. Similarly, California could develop a state-local cooperative framework that would establish state-mandated standards for groundwater sustainability to be implemented locally. Such standards would: help to reduce groundwater overdraft and groundwater pollution; clarify legal rights for groundwater storage; encourage the development of drought reserves; and generally move the state towards greater water supply security.

Drought is an emergency situation, and concomitant water shortages are often accompanied by severe economic, environmental, and social impacts (U.S. Government Accounting Office [GAO] 2003). Nevertheless, most agencies in California are focused on reactive approaches to cope with drought. The state can no longer afford to ignore proactive drought management, including the establishment of local drought reserves.

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# Glossary

| | |
|---|---|
| af | acre feet |
| afa | acre feet per annum |
| CDPH | California Department of Public Health |
| CDS | Coastal Delivery System |
| CVP | Central Valley Project |
| DPH | Department of Public Health |
| DWR | California Department of Water Resources |
| EIR | environmental impact report |
| ELF | Environmental Law Foundation |
| ESA | Endangered Species Act |
| GAO | U.S. Government Accounting Office |
| GMP | groundwater management plan |
| GW | groundwater |
| IPCC | Intergovernmental Panel on Climate Change |
| LAFCO | Local Agency Formation Commission |
| LAO | California Legislative Analysts Office |
| NPDES | National Pollutant Discharge Elimination System |
| PVWMA | Pajaro Valley Water Management Agency |
| RWQCB | Regional Water Quality Control Boards |
| SCWA | Sonoma County Water Agency |
| SCWD | Santa Cruz Water Department |
| SqCWD | Soquel Creek Water District |
| SVWD | Scotts Valley Water District |
| SW | surface water |
| SWP | State Water Project |
| SWPPP | stormwater pollution prevention plan |
| SWRCB | California Water Resources Control Board |

| | |
|---|---|
| UIC | Underground Injection Control |
| U.S. EPA | U.S. Environmental Protection Agency |
| USGS | United States Geological Survey |
| UV-B | ultraviolet-B |
| UWMP | Urban Water Management Plan |