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Groundwater Monitoring Analysis and Management Recommendations in California: Cuyama and Santa Cruz Mid-County

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Groundwater Monitoring Analysis and Management Recommendations in California: Cuyama and Santa Cruz Mid-County Basin

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List of Acronyms

DWR – Department of Water Resources
GSA – Groundwater Sustainability Agency
GSP – Groundwater Sustainability Plan
SGMA – Sustainable Groundwater Management Act
MGA – Santa Cruz Mid-County Groundwater Agency
MG – Santa Cruz Mid-County Basin
CBGSA – Cuyama Basin Groundwater Sustainability Agency
CV – Cuyama Valley Basin
CASGEM - California Statewide Groundwater Elevation Monitoring Program
GWE – Groundwater Elevation

List of Terms

Sustainable Management Criteria - the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.
Interim Milestones – IMs are a target value representing measurable conditions, set in increments of five years. They are set by the CBGSA as part of the GSP; IMs will help the basin reach sustainability by 2040.
Measurable Objectives – MOs are specific, quantifiable goals for maintaining or improving specified groundwater conditions that are included in the adopted GSP to achieve the basin's sustainability goal.
Minimum Thresholds – MTs are a numeric value for each sustainability indicator, which are used to define when undesirable results occur if minimum thresholds are exceeded in a percentage of sites in the monitoring networks.
Sustainability Goals – Sustainability goals are the culmination of conditions in the absence of undesirable results within 20 years of the applicable statutory deadline.
Undesirable Results – Undesirable results are the significant and unreasonable occurrence of conditions that adversely affect groundwater use in the basin.

Abstract

Groundwater is an essential water resource, accounting for about 40 percent of supply in California and 80 percent in the Central Coast hydrologic region, but significant monitoring data gaps have limited sustainable management efforts. Twenty-four basins within the Central Coast hydrologic region were identified as critically over drafted in 2014. For this study, two basins were chosen based on differing sustainability concerns so that a comparative analysis could be performed on the groundwater monitoring methods. I obtained original groundwater elevation data reported (2000-2020) from the various groundwater monitoring organization wells to the California Department of Water Resources (DWR) within the Cuyama and Santa Cruz Mid-County groundwater basins. Groundwater sustainability plans (GSPs) from these two basins were evaluated to perform a comparative analysis on the management strategies implemented and the monitoring networks in place. Regulation of groundwater is a newly formed legislation in California (Sustainable Groundwater Management Act (SGMA)). It is expected that monitoring efforts will exhibit a quantitative increase following the enactment of SGMA in 2014, and that each basin will require separate local management provisions to reform data management concerns that affect estimated groundwater supply accuracy. A standard provision method guided by Saito et al. (2021) offers a universal standard protocol to monitoring groundwater resources that each management agency can follow. Results from the GSP and original data analysis highlight the need for a consistent groundwater elevation monitoring effort, which is an integral method in developing and maintaining a sustainable basin.

Introduction

It has been reported in recent years that about 33 percent of worldwide water withdrawal is sourced from groundwater and serves nearly half of the global population (Rodell et al. 2018, Famiglietti et al. 2011). Since groundwater acts as a primary supply to many humans throughout the world, groundwater management is a vital component of protecting water resources. In some countries (e.g., Denmark, Malta, Saudi Arabia, etc.) groundwater is the only source of water available (Zekster & Everett 2004). According to the USGS, groundwater accounts for ~30.1 percent of the total freshwater supply on Earth; a far greater supply than surface water, which is estimated at about 1.2 percent (USGS 2022). The remaining 68.7 percent of freshwater on Earth is stored in the unusable form of glaciers and ice caps, making groundwater the largest supply and often the sole source of water for communities lacking a nearby surface water body.

Although surface water is a limited and fluctuating resource, it has historically been the most recognized and straightforward source of sequestered global water supply (Richey et al. 2015) and is therefore more regulated than groundwater. This is largely due to the marked accessibility of observing and measuring surface water. However, this strategy has led to an imbalance in water management since surface water is most often integrated with the less regulated nearby groundwater basins on a spatial and temporal scale. Surface water is only one component of an entire hydrologic system and to properly manage water resources, management of all components in the system is necessary to be effective (Winter et al. 1998).

Aside from its vastly greater supply, using groundwater has some significant advantages over surface water. Groundwater is typically formed from a vast network of aquifers, generally higher quality, better protected from contaminants, and less effected by climate-based changes (Zekster & Everett 2004). Groundwater can also be easily sourced to smaller rural areas since it can be accessed from individual wells, requiring less logistical and utility infrastructure.

Despite the comparatively large supply, resilience, and quality of groundwater, there are ubiquitous problems with managing groundwater that permit immediate attention and action. These underground basins continue to be over drafted because of the growing need for more water, lack of knowledge in the community and general population regarding the amount of groundwater being extracted, and the absence of clearly defined regulatory policy in the water districts. Over-pumping groundwater has caused a depletion of groundwater supply in many basins at a rate which they cannot naturally replenish. Insufficient management and depletion of aquifers can lead to a variety of impacts including groundwater level decline, aquifer compaction and collapse, land subsidence, seawater intrusion, surface water level decline, and water quality degradation. If mismanaged, these impacts could lead to potential loss of an entire ecosystem and in some regions, the resource of water entirely.

There is significantly less rainfall in the mild and arid middle-latitude regions than other regions of the world, which are highly populated and withdraw a significant amount of groundwater. Groundwater is often the primary water resource extracted from these areas, and consequently unable to replenish the resource at the rate of its withdrawal. If managed this way for subsequent years, it will diminish the major supplying aquifers within decades (Famiglietti 2014, Famiglietti et al. 2011, Scanlon et al. 2012). Advancements in technology have offered some solutions to the difficulties faced in monitoring the freshwater supply on the surface and underground.

Comparatively, local surface water modeling is done *in situ* and has been a dependable method for collecting sufficient data. Because nearly all surface water bodies (creeks, rivers, lakes, reservoirs, etc.) interact with groundwater, surface water monitoring is an important aspect of groundwater monitoring. In some cases, surface water is fed by groundwater flow and alternatively groundwater is often recharged by surface water.

Global groundwater depletion has been confirmed, but the severity of the issue is evident at a regional scale, specifically in regions that have dense agricultural landscape and no nearby surface water (Aeschbach-Hertig and Gleeson2012). Many years of groundwater withdrawal went unmonitored and inaccurately measured in the state of California (Faunt et al. 2016). This is largely because pumping wells went relatively unmonitored and unrestricted, preventing any data collection or knowledge of consumption (Famiglietti et al. 2011). Because potential impacts on the drinking water supply in these middle latitude regions is so severe, the majority of the new groundwater management strategies meant to achieve sustainable yield tend to overlook the impacts on its surrounding ecosystem and wildlife (Saito et al. 2021), increasing the risk of harm to aquatic and riparian species that depend on the groundwater fed surface flow. Groundwater has been an integral water resource to animals and humans in regions within California that have agricultural yield and experience frequent drought (Mastrocicco et al. 2021).

The degree of reliance on direct groundwater withdrawal varies by region across the state. Some communities have nearby surface supply and withdraw very little, while others depend on groundwater as their primary source of freshwater. The state of California relies on approximately 30 percent surface water supply that originates in the snowpack of the Sierra Nevada and Shasta-Trinity Mountain ranges in the northeastern portion of the large state. The snowpack eventually melts to feed the San Joaquin and Sacramento rivers and subsequently the more accessible Sacramento-San Joaquin Delta in Northern California. Southern California has a notoriously dry and arid climate consisting of multiple deserts with much less surface water storage, and therefore gets most of its water imported from the Colorado River. Groundwater availability in California has been declining as the population and agricultural industry has grown. Groundwater accounts for ~40 percent of California's statewide water resources during average levels of annual rainfall, and ~60 percent of the state's water resources during drought years (Choy and McGhee 2014). Due to the limited supply and remote location of the state's main surface water supply (relative to the size of the state), groundwater use in California has been increasing significantly in response to the growing water demand (Faunt 2016).

Changes in our climate have been raising concerns for water management in California and across the globe, with warming temperatures and a rising sea level making previous strategies less effective. It has been predicted by the International Panel of Climate Change (IPCC) that the global temperature rise will increase evaporation of water from soil, surface reservoirs and snowpack. This increasing loss of glaciers and depleting surface water supply will contribute to a significant rise in the number of people experiencing water stress. This will be exacerbated in states like California that rely on snowpack as a main supply. In addition, the UN estimates that the world's population will increase by 2.3 billion once we reach the year 2050 (Diggle 2013). Groundwater storage banks may provide reasonable mitigation of impacts from climate change seen in California like extreme floods and longer periods of drought (Scanlon 2012).

As the global demand for water increases and the supply consecutively decreases, water managers are faced with a variety of sustainability concerns that require immediate action and modifications on infrastructure to resolve. To achieve a sustainable direction, new management methods should require a socio-economic development that will provide a sufficient amount of water that will supply the present demand without negatively impacting future generations from being able to achieve the same goal (Benson et al. 2019). The intensity and circumstances of these challenges varies based on geographic location and the current standing of socio-economic development within a country or hydrologic region (Proskuryakova et al 2017). Within this task of maintaining sustainable freshwater resources, regions around the world are struggling to manage their groundwater sources accurately and efficiently.

Groundwater monitoring is a significant concern in regions throughout the state of California because of its rapid per capita growth in population and decreasing groundwater supply (Hanak 2005). Impacts include land subsidence, saltwater intrusion, reduced groundwater levels, surface water decline, and water quality concerns (Famiglietti et al. 2011). Most importantly, these issues combined threaten to eliminate the ability to sustain groundwater supplies. These effects are worsened by the lack of data available from the various groundwater monitoring organizations in California. Without sufficient data, monitoring of a groundwater basins level does not provide an accurate representation of the changes occurring to its groundwater supply.

Although California consists of a large, interconnected water system, its management system is fragmented between hundreds of independent regional and local organizations. Until recently surface water and groundwater supply were managed and measured separately. The monitoring methods of California's surface water supplies is relatively strong, encompassing a snowpack monitoring system, USGS stream gauge networks, DWR, federal, state, and local data (Escriva-Bou et al. 2016). Monitoring groundwater is a relatively new management strategy to water regulation and administration that presents many challenges. These challenges are most apparent in areas of California like the Central Coast, that rely heavily on groundwater supply. Differences in a basins location, land use, agency establishment, and surface water sources will highlight the varying sustainable management concerns and the methods each agency faces to achieve sustainability.

Region of Study

The study area includes monitoring well data of two critically over drafted basins within the Central Coast Hydrologic Region (see Figure 1). This region of California is significantly vulnerable and unique in its disposition to overdraft due to the following: its municipalities rely more than 80 percent on groundwater for its water resource supply (Escriva-Bou et al. 2018), the proximity to the Pacific Ocean, and the remoteness from adequate surface water sources. The Central Coast contains numerous distinctly small aquifers that vary in their primary usage relative to the rest of the state. This combination of characteristics can create issues like chronic overdraft and groundwater storage depletion, water quality contamination via saltwater intrusion, and the inability to rely on imported surface water sources like the Sierra Nevada snowpack.

I have chosen two exemplary groundwater basins with distinct hydrogeologic differences to perform a comparative analysis for this study: Santa Cruz Mid-County Basin which lies adjacent to the Pacific Ocean and Cuyama Valley Basin which sits inland between two small mountain ranges (see Figure 1). I will be performing analysis of Groundwater Sustainability Plans (GSP) and analysis of original data groundwater elevation data obtained from the California Natural Resource Agency for both basins. These basins contain relatively small aquifers and are meant to be exemplary but not a complete representation of the Central Coast Hydrologic region. Both basins have unique geological positions and land use purposes within the region, and therefore experience their own individual set of issues related to groundwater management. This comparison is intended to show the differences that aquifers face despite being within the same hydrologic region, and the importance of locally managed groundwater policy and implementation (Hanak 2011).

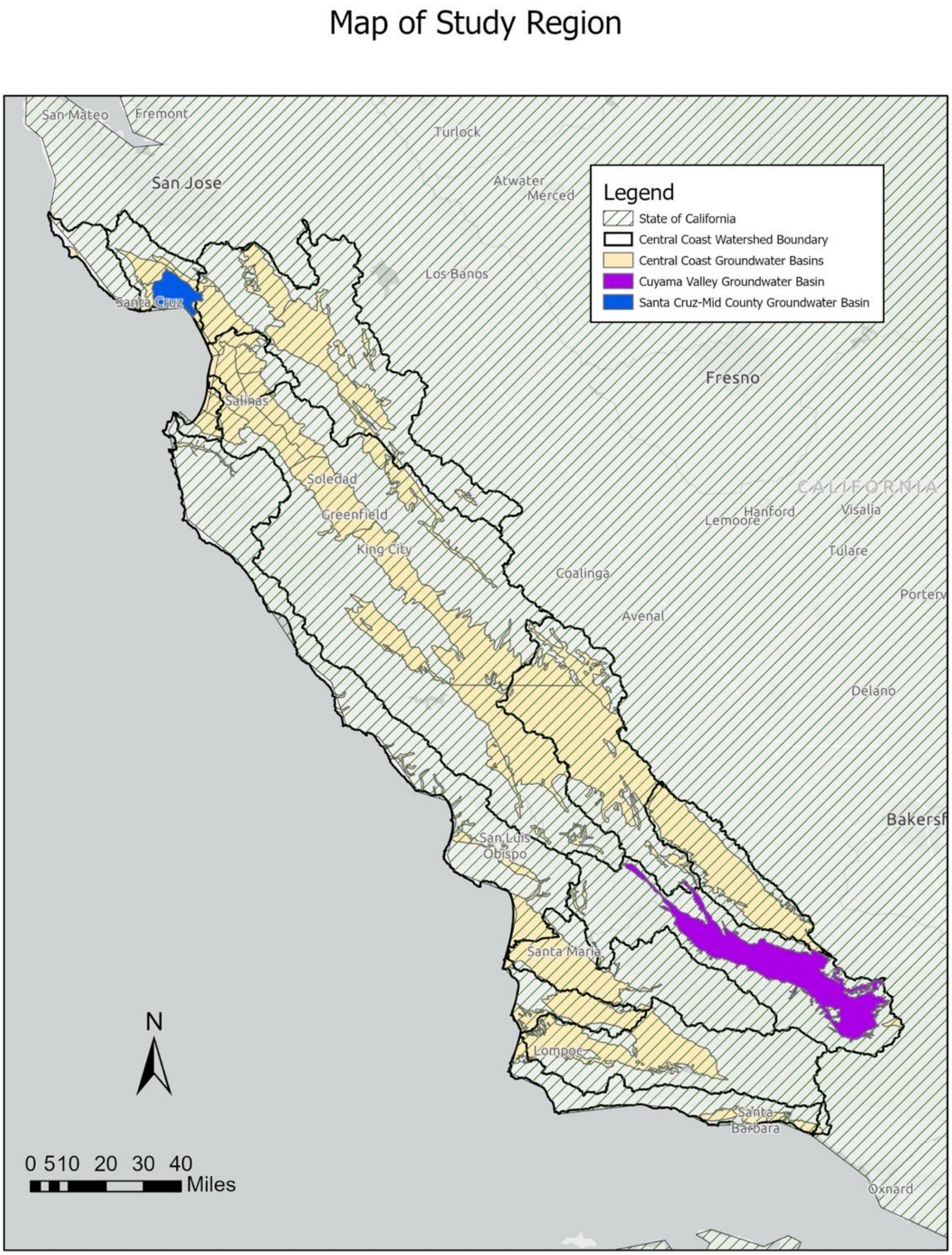

Figure 1: Map of study region within the Central Coast Hydrologic Region in California. Boundary data was accessed from CALFIRE and USGS March of 2021. https://gis.water.ca.gov/arcgis/rest/services/InlandWaters/WBD_HUC8_CA/FeatureServer and the EPA https://www.epa.gov

This study addresses how we can better identify data gaps in groundwater management and improve management strategies to reach sustainability goals. Firstly, I will discuss the current regulatory policies and provide an analysis of what they are lacking. Secondly, I will provide examples of the current methods groundwater monitoring in small-scale aquifers by analyzing Santa Cruz Mid-County and Cuyama Valley Groundwater Sustainability Plans (GSPs). The varying conditions of each basin that determine different management strategies will be discussed upon evaluation of each GSP. Thirdly, I will provide an original data analysis on groundwater elevation to highlight the data gaps in monitoring efforts within each basin. The final conclusions of this study will give insight on how various management strategies can be adapted to develop effective sustainable efforts. The regulatory policies will be discussed using a synthesis of peer-reviewed literature including several articles from the Public Policy Institute of California (PPIC). The methods of groundwater monitoring will be assessed using a comparative analysis of the GSPs submitted by Cuyama Valley and Santa Cruz Mid-County basins in 2019 in addition to an original data analysis of the past 20-years of the two basins groundwater elevation data.

Methods

The methods included secondary research, one interview, and an ArcGIS and Microsoft excel analysis of raw data. The paper presents a combination of recent and pre-SGMA (2014) literature reviews in addition to background of knowledge within the subject matter of groundwater regulation in California or primarily SGMA (above). The nature of water resource management and the interconnected relationship of surface water and groundwater and California climate and hydrology is briefly to discussed to introduce the importance of groundwater management, the study area, and need for management reform.

The first section of the paper introduces the brief history of local groundwater monitoring in comparison with global efforts drawn from a synthesis of peer-reviewed literature. This is followed with a comparative analysis of the Cuyama Valley and Santa Cruz Mid-County GSPs and how the various concerns in each plan effect the monitoring efforts. In addition to the GSPs, an interview with the Water Resources Manager of the Santa Cruz County Environmental Health Department is also incorporated. The section will compare the various concerns regarding hydrogeologic factors and water usage for each of the two basins.

Table 1: Sources of data collected for mapping and geospatial analysis discussed in the Groundwater Elevation Data section.

Data Variable	**Type**	**Source**
Groundwater levels	Point Feature	https://nwis.waterdata.usgs.gov/ca/nwis/gwlevels
NHD v2 Plus	Water boundaries	https://www.epa.gov/waterdata/get-nhdplus-national-hydrography-dataset-plus-data
Groundwater Wells	Locations	https://data.cnra.ca.gov/dataset/periodic-groundwater-level-measurements
Watershed Boundaries (HUC8)	Feature Layer	https://gis.water.ca.gov/arcgis/rest/services/InlandWaters/WBD_HUC8_CA/FeatureServer

The second section will discuss the issue of groundwater elevation data collection and interpretation. I have accessed groundwater level, water boundary, groundwater well locations, and watershed boundary data from the sources listed in Table 2. Spatial data acquired was water boundaries for California, aquifer boundaries for California and groundwater monitoring well locations in California. The watershed boundaries were subset to aquifers within the Central Coast and then used to select wells within those boundaries. I chose Cuyama and Santa Cruz-Mid County Basins based on the significant amount of data available compared to other basins in the Central Coast. This data was used for both groundwater basin study areas and sorted them through ArcGIS and Microsoft Excel for a simple interpretation without the use of models in the dry season when levels have reached their lowest from lack of recharge. This original data analysis of groundwater elevation will be compared with the most recent annual report provided by both GSAs.

The third and final section will use a combination of the GSP analysis and literature review to identify data gaps or weaknesses that can be improved upon both GSPs. This will follow with a sustainable GSP framework from Saito et al. (2021) to encourage a synchronous and eco-conscience approach to groundwater monitoring and elevation data collection. These various recommendations and provisions will be analyzed and then applied to each basin to discuss strengths and weaknesses. This analysis is meant to support the SGMA legislative initiative that groundwater management should factor in the local constituents of a region. Management recommendations will follow based on information provided by the GSPs in the first section, and analysis of raw data in the second section.

Review of Groundwater Monitoring

Groundwater elevation levels and groundwater supply have been observed in consistent decline for the past 50 years (Zhou et al. 2012). This is largely because unlike surface water, groundwater withdrawal went unregulated until recent years (Wilson et al. 2020). Monitoring groundwater elevation levels and withdrawal are fundamental in groundwater management and need to be accurately and consistently measured and shared across political and organizational boundaries (Famiglietti 2014). Frequent collection of groundwater level data is necessary to build management techniques, physical models, and general hydrologic analysis. The lack of a standardized measures to collect groundwater level data creates sampling with alternating times and dates, making it more difficult to analyze and input into useful tools such as models that estimate total water supply (Jung et al. 2021). Oikinomu et al. (2018) states that regional physically based groundwater models are becoming the better tool estimating groundwater supply in a basin for those agencies that can afford the technology, but still don’t offer a completely accurate assessment. A framework for filling data gaps will be discussed later in the management recommendations section of this paper.

Large-Scale vs. Small Scale

Global water supply monitoring is achieved via multiple satellite missions that retrieve data in conjunction with hydrologic models. The Gravity Recovery and Climate Experiments (GRACE) is a satellite mission that was initially launched in 2002 and is used to obtain data and estimate total water storage (TWS) changes around the world. GRACE works as a gravitational anomaly that measures the change in mass(water) on earth by the change in gravity. These satellites' measure changes in the Earth's gravitational field and can be directly correlated to changes in the TWS (Jakeman et al. 2016). This satellite mission evaluates all components of total water storage including seawater, groundwater, surface water, snowpack, soil moisture and glaciers at all depths on Earth. Seawater TWS is measured separately using surface mass signal reflections over the bottom of the ocean. The data is combined with other hydrological datasets to give an approximation of the overall changes in water levels. The following equation is a general model used to calculate changes in groundwater and other individual components of TWS within a region. Groundwater flow models must be used in conjunction with the GRACE data in order to isolate the groundwater variable without other variables in the equation. GRACE data combined with model data can be inclusive but may not provide the most accurate results (Aeschebach-hertig & Gleeson 2012).

$$TWS = Snowpack + Surfacewater + SoilMoisture + Groundwater$$

Using this straight-forward model, GRACE data can aid in the measure of separate components contributing to the entire water supply. GRACE has proven to be an efficient tool in the estimation of large basins such as the High Plains Aquifer (area of 450,000 km^2) in the middle of North America. Although GRACE is a valuable tool in global water supply and can be invaluable when looking at larger basins, accuracy diminishes in creating estimates of water bodies with an area less than 250,000 km^2 (Longuevergne et al 2010). This is due to the spatial scale resolution and increased noise contamination. This is not helpful in estimating smaller-scale aquifers that do not meet the criteria of spatial resolution and make up the majority of aquifers around the world. Cuyama Basin extends an area approximately 378 square miles (~979 km^2) and Santa Cruz Mid-County Basin is an area of approximately 56 square miles (~145 km^2). California's total land mass is approximately 163,696 square miles (423,970 km^2), and the 515 alluvial aquifers cover about 38 percent (62,204 square miles or 161,108 km^2) of that land mass (DWR 2013). This makes the average area of an aquifer in California approximately 121 square miles (312 km^2).

This spatial resolution limitation makes the state of California is challenged in its ability to incorporate GRACE data for groundwater monitoring because all 515 alluvial basins and subbasins are too small to be properly observed by the effective spatial resolution of the current orbiting satellites. For example, the Central Valley aquifer system is the largest in the state of California and spans around ~52,000 km^2(USGS Groundwater Atlas of the US) which is well below the limits of 250,000 km^2 previously stated.

Monitoring wells are sometimes referred to as "observation wells" and as defined by DWR (California Department of Water Resources), designed to monitor water in the saturated zone at or above atmospheric pressure (groundwater). Monitoring wells are strategically placed in areas of the water table that have a greater chance of exposure to contaminants and pollutants. These wells can be used for the combined purpose of tracking groundwater level in addition to groundwater quality. Conversely some of these wells are used for the sole purpose of measuring either groundwater level supply, water quality, or irrigated agricultural use.

However, simply collecting groundwater elevation and withdrawal data is not enough to understand the groundwater supply of a basin. Due to limitations in this data from the number of wells and measurements available, groundwater-flow models (as mentioned above) were developed to create a basins water budget. The most commonly used model us the USGS-MODFLOW, a computer program that simulates features in aquifer systems that include features such as rivers, streams, reservoirs, wells, evapotranspiration, and precipitation recharge (USGS 2005). These flow models are capable of estimating flow and aquifer characteristic when measurements aren't available and can simulate results of a hypothetical condition, e.g., chronic lowering of groundwater elevation causing nearby surface water depletion. Therefore, groundwater measurements are recorded by their affiliated management agencies and cumulative storage is estimated by *in-situ* monitoring and almost entirely influenced by the incorporation of this data into computer program models.

Groundwater Regulatory Policy

California Water Law

Current water law is known for its inability to properly manage the relationship between groundwater and surface water users. Much of the water resource rules and regulations were written to regulate surface water without consideration of groundwater supply and its interconnected relationship with surface water. There are two water rights recognized in the state of California: riparian and appropriative rights. Appropriative rights are obtained via permits given by the state of California Water Resources Board when the use of surface water is deemed for a reasonable and beneficial use. This right includes the maximum amount a user can divert, and how much must remain in the source. Riparian rights exist when a landowner owns a parcel adjacent to a lake, stream, or pond etc. Riparian rights do not need to go through the California permit system, but usage can be limited and regulated by a court.

Groundwater rights are more complicated as indicated by Hastings Law Journal in Douglas (Kari 1984) starting with groundwater first being regulated by a court decision in the early 1900s and differentiated from land ownership rights in Katz (1903). Permit regulation for water use was established in 1914 by the Water Commission Act, which did not include groundwater. Groundwater is recognized as water that is flowing into an underground stream or as water percolating underground. Groundwater in the form of a flowing stream underground is subject to California's permit system, but water percolating underground is not, and most groundwater is presumed to be percolating. Each landowner that is overlying a groundwater basin has the right to reasonable and beneficial use of that groundwater. These rights are classified as appropriative or overlying. Overlying rights are obtained when groundwater is being used to be put back into the overlying land e.g., irrigation. Appropriative rights are obtained by simply drilling a well into the ground and using the groundwater for reasonable and beneficial use, a federal water right enacted in 1928. No water right permit is required to pump percolating groundwater and any conflicts regarding whether groundwater withdrawal is for beneficial use must be settled in court. Only when a groundwater supply is notably insufficient to its users, is the water apportioned by court ruling with no priority given to length of time in land ownership. Rights to pump groundwater in California are not quantified aside from the 24 basins that were adjudicated based on their overdraft status (Escriva-Bou 2016).

SGMA

California water regulation began in 1914 with the creation of the State Water Board.

This administration issues water rights to users and portions out the supply based on beneficial use and seniority. However, since its establishment, the State Water Board has allocated water rights totaling five times greater than California's annual supply (Grantham & Viers 2014). Individuals and private well owners water usage is uncertain based on the legislative structure that protects the permit and license holders, and diversion volumes are not reported for individual points of diversion. Therefore, accurate water use information has been difficult to acquire. Before the year 2014, groundwater had no standing regulatory policy. If a landowner had access to an aquifer, they had the right to drill and withdraw the water without limits.

Regulatory policy that would enforce local government management of groundwater basins was created in 2014, when the state of California passed the Sustainable Groundwater Management Act (SGMA) signed by Governor Jerry Brown (see Table 1). This legislation consists of three bills(Senate Bill SB 1168 (Pavley), Assembly Bill AB 1739 (Dickinson), and Senate Bill SB 1319 (Pavley)) that collectively require local agencies throughout California to develop and oversee their own groundwater sustainability plans. SB 118 fundamentally establishes sustainable yield as a priority in groundwater resource management and requires the California Department of Water Resources (DWR) to prioritize basins need for immediate action based on the overdraft status. AB 1739 sets provisions for Groundwater Sustainability Agencies (GSAs) and Groundwater Sustainability Plans (GSPs) authorizing fiscal and legislative control of its groundwater basins---also removing any financial responsibility from the state. SB 139 allows for removal of power from any affiliated local agency if necessary and deemed appropriate by the state. This last bill allows the state of California to overrule any GSA management based on inadequacy and develop an interim GSP for the associated region being overruled. The enactment of SGMA in California legitimized the issue of water being a diminishing resource at a state level, while allowing management at the necessary local level. Sustainable management of water in California requires the development of an economically feasible water budget following in-depth analysis at each individual basin on their current demands of water.

Table 2: The legislative intent of the Sustainable Groundwater Management Act (SGMA) passed in 2014. The general purpose of SGMA is clearly stated and bullet pointed throughout this table. (SGMA 2014)

SGMA's Legislative Intent

(a) To provide for the sustainable management of groundwater basins.

(b) To enhance local management of groundwater consistent with rights to use or store groundwater and Section 2 of Article X of the California Constitution. It is the intent of the Legislature to preserve the Sustainable Groundwater Management Act, and related provisions Effective January 1, 2019, security of water rights in the state to the greatest extent possible consistent with the sustainable management of groundwater.

(c) To establish minimum standards for sustainable groundwater management.

(d) To provide local groundwater agencies with the authority and the technical and financial assistance necessary to sustainably manage groundwater.

(e) To avoid or minimize subsidence.

(f) To improve data collection and understanding about groundwater.

(g) To increase groundwater storage and remove impediments to recharge.

(h) To manage groundwater basins through the actions of local governmental agencies to the greatest extent feasible, while minimizing state intervention to only when necessary to ensure that local agencies manage groundwater in a sustainable manner.

(i) To provide a more efficient and cost-effective groundwater adjudication process that protects water rights, ensures due process, prevents unnecessary delay, and furthers the objectives of this part.

SGMA reinforces the need for local government to develop and implement management stratgies to sustain local groundwater supplies. It also reinforces the rights of users by requiring GSA's to consider the interests of all uses, including disadvantges communities. This is intended to prevent potential biases in the management plans, and creates a regulation to increase diversity in stakeholders and reinforce the right to beneficial use of water resources for all.

Although this regulation is intended to represent all water users, it may not succeed in creating an adequately sorted mixture of representatives and potentially fail to meet the needs of everyone. Cuyama Valley has a large percentage of land use in the agricultural sector, but does not have any agricultural representatives in their GSA. SGMA regulates groundwater contained in medium and high priority alluvial aquifers[1]. Also, this legislation does not account for brackish groundwater, low priority basins, or other types of aquifers where groundwater resides in volcanic rock or fractured hard rock. California has a 35 billion acre-feet capacity for groundwater storage and only 1 billion acre-feet of that is freshwater (about 2 percent). The majority of California's groundwater supply is stored as 24 billion acre-feet of deep brackish groundwater within alluvial aquifers and 11 billion acre-feet within hard-rock aquifers. Most volcanic or hard fractured rock is found in the mountain ranges of California, while the brackish groundwater is seen primarily in the Central Valley (Thompson et al. 2021).

When SGMA was first passed, basins that were deemed high and medium priority by the DWR were required to establish a GSA and develop their own GSP if one was not already in place. Basins that were identified critically overdrafted at the time SGMA passed are required to achieve a sustainable yield by 2040/2042. California had identified that 94 out of the total 515 basins and subbasins were not being managed adequately as a sustainable resource. Of those 94 basins identified, 24 were located along the Central Coast of California.

Today, there are 19 basins in the Central Coast Hydrologic region labeled high or medium priority and 5 of those (i.e., Cuyama, Salinas Valley-Paso Robles, Salinas Valley-180/400 Foot, Corralitos-Pajaro Valley and Santa Cruz Mid-County) are also labeled by the DWR as critically overdrafted. SGMA requires each GSA to submit an evaluation GSP every 5 years to analyze progress toward sustainability. This 5-year evaluation is submitted to the DWR, who then determines whether the progress is sufficient. SGMA created a standard that all GSAs/GSPs must have designated representative monitoring wells (RMW), and those wells must have minimum threshold values based on historical and present data of groundwater elevation within that basin. Each representative monitoring well will also have a measurable objective value (in feet) that will indicate successful progress toward the sustainability of that location. These values create a way to avoid undesirable results in a basin and are based on each well locations geological conditions and primary land use.

DWR is the highest authority in groundwater management. They can approve or deny decisions and plans made by any GSA. Members of a GSA and their associated stakeholder committees are intended to be a carefully sorted mixture of local water user representatives whose interests vary at a level regulated by SGMA and the DWR. However, this regulation may

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[1] Alluvial aquifers store groundwater between layers of sediment e.g., clay, silt, gravel, and sand.

sometimes fail to adequately represent all water users and their needs. Areas where water use is primarily in the ranching and agricultural sector such as the Salinas Valley Basin and Cuyama Valley Basin differ significantly in GSA member associations. Salinas Valley has extensive agricultural sector representatives while the Cuyama Valley has none. This potential misrepresentation in water users may lead to imbalances and bias when sustainability plans are designed and implemented.

Since the legal and political tools necessary for linking surface water rights and groundwater pumping are created in a case-by case basis in California, many groundwater basins in California have experienced significant impacts from over-withdrawal and lack of regulatory policy. Each local agency or GSA has a responsibility to their community to uphold the sustainability and quality of groundwater access and SGMA is a large step towards California's groundwater sustainability goals and climate crisis. To maintain these groundwater basins, rules and regulations must be implemented by these appointed GSAs at the local level. This begins with accounting for the most current status of each basin and the level of dependence for each region it provides.

Groundwater Sustainability Plan (GSP) Analysis

The analysis in this section is meant to identify data gaps in each basin and search for areas that require improved management strategies in order to reach sustainability goals. Each Groundwater Sustainability Agency (GSA) is required by SGMA to create and submit a Groundwater Sustainability Plan (GSP). Critically overdrafted basins were required to have a GSA and GSP by January 31st, 2020, and all other basins are required to have a GSA and GSP by January 31st, 2022. Basins identified critically overdrafted at the time SGMA passed are required to achieve sustainability by 2040/2042. The primary goal of each GSA is to reach sustainable use of groundwater resources provided by their GSP. The following is a brief analysis on the GSP's submitted by the affiliated agencies in the study region. Santa Cruz Mid-County Groundwater Basin submitted their GSP in November 2019 and Cuyama Valley Groundwater Basin submitted their GSP in December of 2019, both just before the SGMA deadline for critically overdrafted basins (mentioned above).

Each GSP is evaluated by its primary use, various monitoring organizations/network, sustainability concerns, ethical management, indicators of undesirable results, and total water storage or budget analysis. The primary use and climate of each basin is a determining factor on how the groundwater should be managed. The density of a basins' monitoring network is evaluated to reflect the potential data gaps and determine whether there is sufficient data capture occurring. The complexity of modeling software is briefly mentioned to inform the reader of where models are accessed and how there are uniquely modified to the managing agency and their basin. The six sustainability indicators are lowering groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, land subsidence, and depletion of interconnected surface water. These indicators are identified by SGMA as effects of groundwater conditions that cause undesirable results. Monitoring Objectives (MOs) and Monitoring Thresholds (MTs) are not required at all wells, only at specified representative monitoring wells in a basin.

Cuyama Basin

Introduction

The Cuyama Valley Basin (CV) is located between the Sierra Madre and Caliente Mountain ranges. CV consists of one principal aquifer and is referred to as Cuyama Valley Aquifer, therefore the term "basin" and "aquifer" can be used interchangeably. The Cuyama River essentially runs actively through the entire length of the Cuyama Valley Groundwater Sustainability Agency boundary. This basin encompasses portions of Santa Barbara, San Luis Obispo, and Ventura Counties. CV was chosen to be part of this study because it is a relatively large and critically overdrafted basin within the Central Coast Hydrologic Region susceptible to water supply shortages and land subsidence. This basin also relies 100 percent on groundwater for its water resources and the average annual precipitation in this watershed ranges from 7 to 30 inches.

The Cuyama Valley Basin recently developed a monitoring network and water resource availability study in 2010, although it has been withdrawing groundwater for agricultural irrigation since 1939 (Faunt 2019). Before SGMA was enacted in 2014, this basin did not have a groundwater management plan. Cuyama Basin Groundwater Sustainability Agency (CBGSA) submitted their GSP in 2019 with a detailed overview of the current groundwater elevation monitoring programs operated by regional, state, and federal organizations (see Table 1). Because the CBGSA incorporates multiple counties with various needs, their GSA is formed under a joint power's agreement[2] (SGMA section 10723.6) and the GSP contains a plan and priority for each county as sub-plans. The primary goals shared in all three participating counties (Santa Barbara, San Luis Obispo, and Ventura) include: protect and conserve water supplies, ecosystem restoration, and protect and improve water quality. Each county addresses concerns regarding the increasing demand of groundwater with expected population growth, agricultural elements and land use planning that may affect conservation efforts. The GSP states that the largest groundwater use in the Cuyama Basin is used for irrigating agricultural lands. The following subsections contain a summary of key information found in Cuyama's most recently submitted GSP.

Monitoring Programs

Groundwater level monitoring in the CBGSA is achieved by directly acquiring all data from the DWR and verified via the CASGEM online system to track seasonal and long-term trends in the groundwater data.[3] Three monitoring entities work within the CASGEM program for CV; Santa Barbara County Flood Control and Water Conservation District (SBCWA), Ventura County Watershed Protection District (VCWPD), and San Luis Obispo Flood Control & Water Conservation District (SLOFC&WCD). There is a total of six CASGEM Program wells and 107 voluntary wells, and 109 DWR Program wells. The first measurement was taken in 1946 and the average number of 19 records for one well and an average period of record per well

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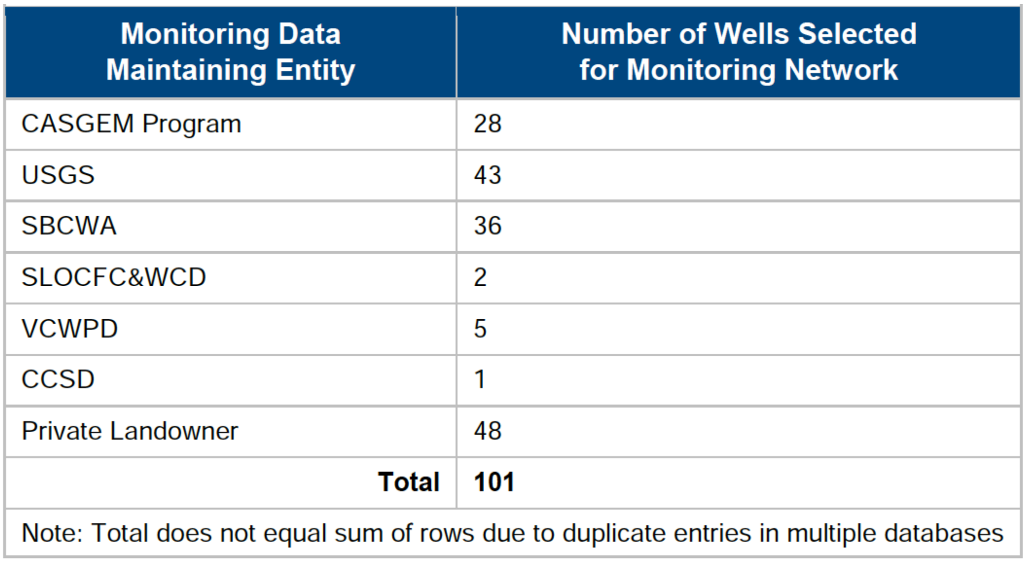
[2] Joint powers agreement is a contract between two or more public agencies which allows agencies to exercise authority outside of their normal jurisdiction.

[3] In 2009, Senate Bill Senate Bill x7-6 establish collaboration between local monitoring parties and DWR, enabling DWR to collect groundwater elevation data, and ultimately establishing the CASGEM Program.

lasting 12 years. The USGS as of 2019 has approximately 476 wells in Cuyama Basin with the earliest measurement occurring in 1946. The average number of records for a single well is 2 years with an average period of record per well lasting 2 years. Many of the USGS wells have been retired since a large groundwater study performed in 1966. Despite the total amount of groundwater wells available and at their disposal, the number selected for representing the monitoring network for the Cuyama Basin totals at 101 (see Table 3). This is because many of the wells excluded from the monitoring network had an unknown depth, infrequent measurement schedule, and outdated measurements. Monitoring wells were selected based on those that had the most metadata and the highest frequency of monitoring. Many of the USGS monitoring wells were excluded because they had not seen measurements in 20 or more years. These criteria are important when combining with surface water data since it is plugged into models that determine the estimated water budget and total water storage. The more data a basin has, the more accurate the water supply and use estimates can be.

Table 3: Cuyama Valley Basin wells selected for monitoring network. Accessed on April 25th, 2022, from 2019 Cuyama Valley GSP.



Monitoring Data Maintaining Entity	Number of Wells Selected for Monitoring Network
CASGEM Program	28
USGS	43
SBCWA	36
SLOCFC&WCD	2
VCWPD	5
CCSD	1
Private Landowner	48
Total	**101**

Note: Total does not equal sum of rows due to duplicate entries in multiple databases

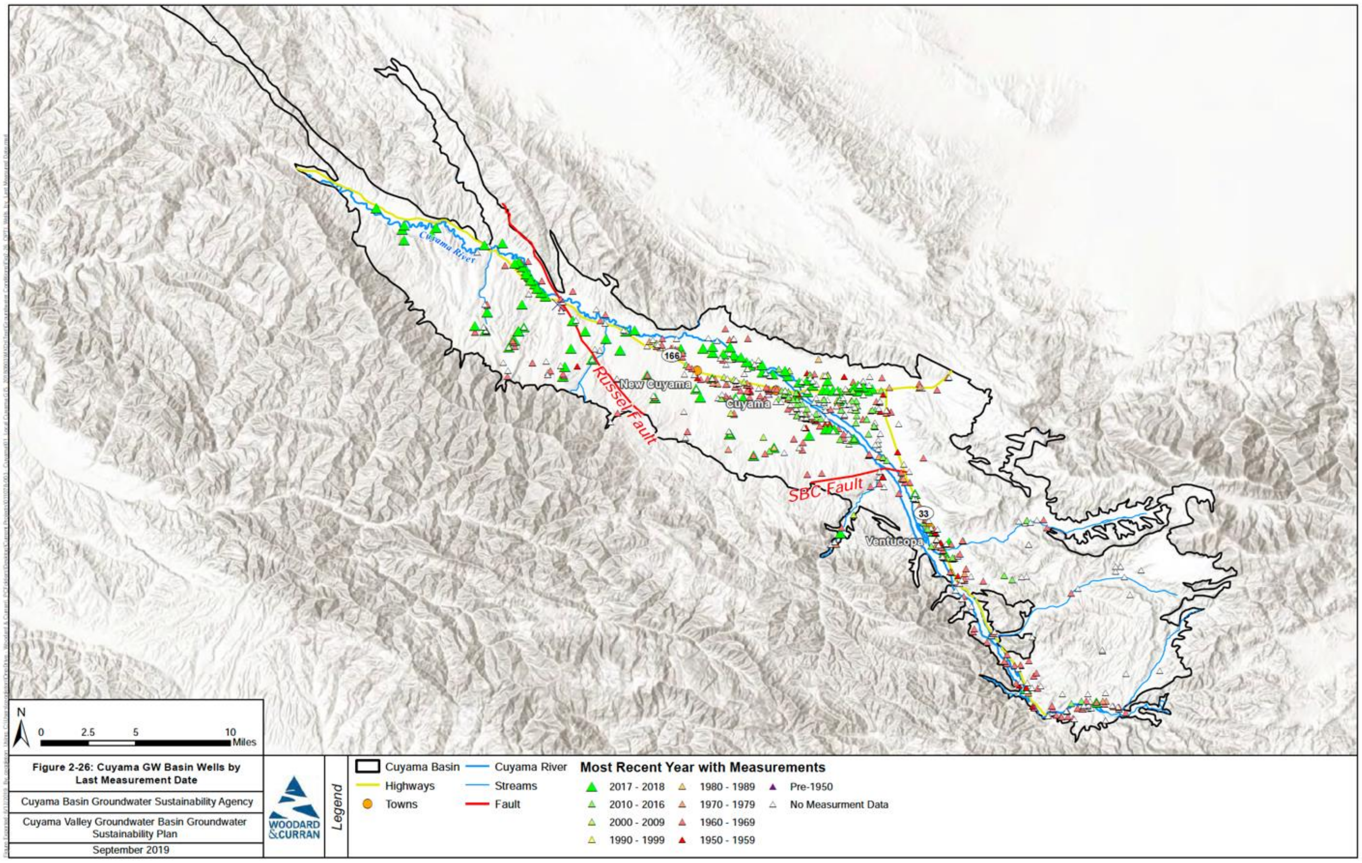


Figure 2: Cuyama GW Basin Wells by last measurement date. Accessed from 2019 GSP on April 25, 2022. All green triangles have been measured in the last 20 years. All large green triangles were measured between the 2017-2018 water year.

Areas of Concern

Agricultural land use only covers about 14 percent of the basin consisting of 53 square miles out of the entire 378 square mile area of the basin (Cuyama Basin GSP 2019). Groundwater elevation levels have declined in this portion of the basin by more than 400 feet. This decline has been evident since the 1940s and has continued to present day. The GSP notes that this significant and consistent decline is seen primarily in the central region of the basin where agricultural land use is prominent but absent from the western and eastern portions of the basin. Figure 2 shows that there are fewer monitoring wells placed in the eastern and western portions of the basin and the majority of recently measured wells are along the Cuyama River. The wells are placed strategically near areas of greater withdrawal with the intent to avoid inaccurate measurements. The western portion of the basin has recently increased development of agricultural lands, and the GSP calls out it may require additional monitoring to prevent the trend in declining levels.

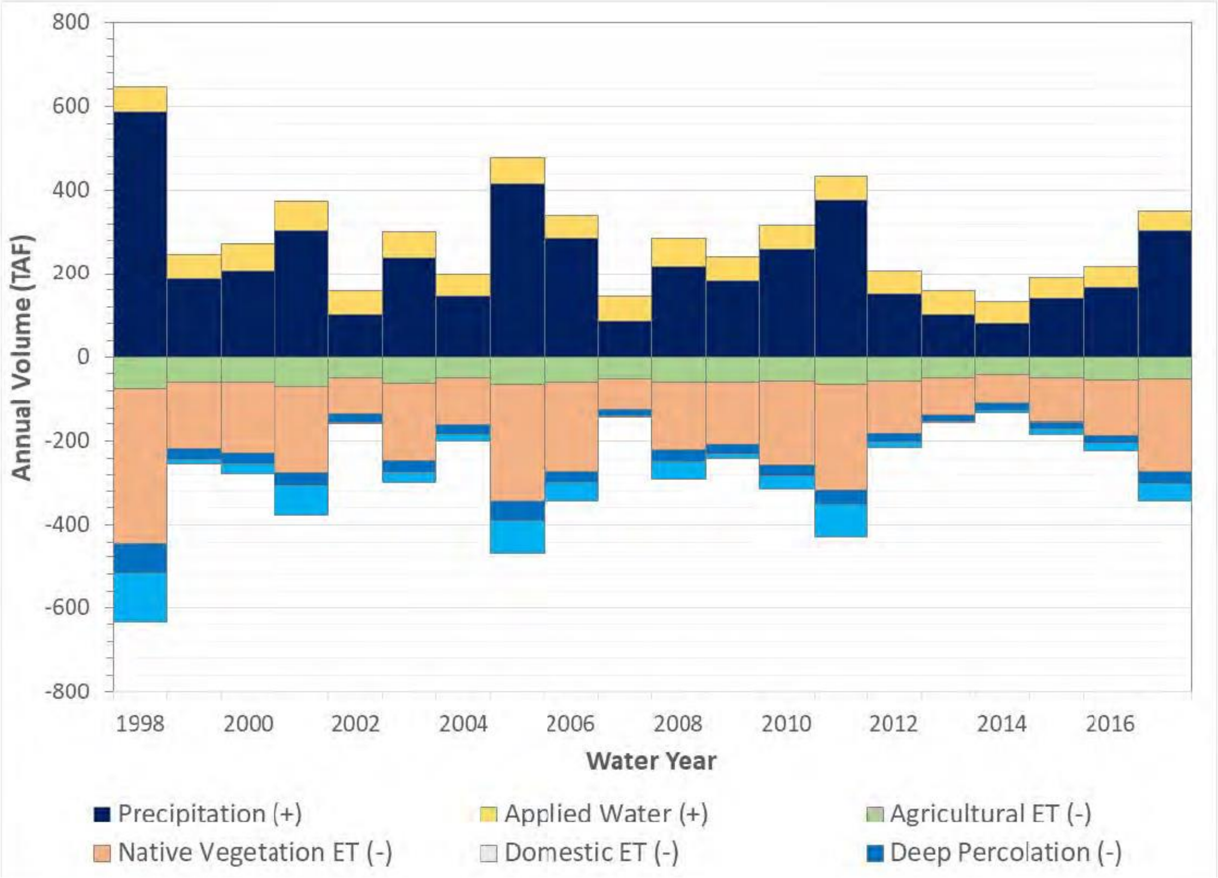


Figure 3: 20-Year Historical Precipitation and Apportionment in Cuyama Valley Basin. Accessed on 04/08/2022 from Cuyama Valley GSP 2019. Negative values indicate outflow and positive values inflow. Applied water is via an irrigation system to aid in the growth and production of agricultural lands.

Land subsidence in Cuyama is measured at two different stations: Cuyama Valley High School and Ventucopa Station. The Ventucopa Station exhibits a 0-inch change subsidence, while the Cuyama Valley High School station measured a 1.3-inch annual subsidence rate between the year 2017-2018. The minimum threshold for subsidence was set for 2.0 inches, and therefore does not qualify as an undesirable result. This subsidence monitoring network equates to an average of 0.5 subsidence stations per 100 square miles. There are currently no guidelines on the spatial density of subsidence monitoring set forth by the DWR, although the GSP does acknowledge that the current monitoring network resources do not adequately measure the variations in subsidence throughout the basin. Because of this oversight, no management changes are seen as required but the basin does call out the need for six new subsidence monitoring sites near areas of large volume groundwater withdrawal.

The Cuyama Valley Basin currently receives an average of 230,000 acre-feet a year from precipitation and 238,000 acre-feet per year is consumed for domestic use or by evapotranspiration (see Figure 3). An additional 60,000 acre-feet is received from applied water land surface inflow[4]. These estimates are calculated with the use of limited monitoring well data and USGS models. The results from Figure 3 do not give the basin much leeway for recharge, especially in an event when the basin experiences a very dry year as seen in 2014. Very little of the precipitation is qualified as deep percolation, and therefore the majority of outflow is seen as ET or evapotranspiration with very little to reach aquifers and create recharge. Although the basin receives fluctuation in annual precipitation, the projected annual groundwater overdraft ranges from 23,000 to 27,000 acre-feet per year. These conditions projected with climate change predict the overdraft average to be closer to 27,000 acre-feet per year.

The mean annual precipitation in the Cuyama Valley Basin for water years 1968 through 2017 is 13.1 inches. Paired with the rate of withdrawal from the basin, the precipitation average is not able to recharge the aquifers at a sustainable rate. This also leads to significant land subsidence occurring within the basin. Figure 3 shows the inflow matching almost precisely with the estimated outflow of surface waters in Cuyama Valley Basin. Because there is overdraft in this basin, breaking even in the surface water budget will not create a sustainable yield of water resources. This is seen by the small amount of deep percolation apportionment in Figure 3, arguably negated by the applied water used for irrigation but accounted for as inflow.

In addition to declining groundwater elevation levels, Cuyama Basin has historically high levels of total dissolved solids (TDS) and some localized areas containing high concentrations of arsenic and nitrate. Water quality is a continued concern in the basin due to recent measurements between the years 2011-2018. This period of record showed over 50 percent of groundwater measurements with TDS concentrations ranging from 1,500 to 6,000 mg/L along the southern portion of the basin. These TDS levels are well over the recommended secondary maximum contaminant level (MCL) of 500 mg/L set by the state of California. Water quality data is collected by USGS, DWR, County of Ventura, and private landowners.

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[4] Volume of land surface water applied by an irrigation system to aid in growth of crops and pasture.

There is mention in the CBGSP that the DWR well data overlaps data found on USGS monitoring records with approximately 106 wells downloaded in both datasets. Local and region well monitoring programs have significantly smaller networks that started much later (~1970s) but measurements are taken more frequently. Due to the numerous management organizations and monitoring networks (see Table 4 below), there is significant overlapping and duplicate data within the CV groundwater elevation monitoring program.

Table 4: Cuyama Valley Groundwater Agency: Groundwater Elevation Monitoring Programs from the 2019 GSP accessed from the California Department of Water Resources. Submitted in 2019 GSP to DWR.

DWR Water Data Library	Database that stores groundwater elevation measurements from wells in the Basin measured from 1946 through the present. Data contained in the WDL are from several different monitoring entities, including the Ventura County Watershed Protection District (VCWPD), SBCWA, Santa Barbara County Flood Control and Water Conservation District, and San Luis Obispo County Flood Control and Water Conservation District (SLOCFC&WCD).
USGS – National Water Information System	Contains extensive water data, including manual measurements of depth to water in wells throughout California. Wells are monitored by the USGS in the Santa Barbara County Flood Control and Water Conservation District's jurisdictional area. Most of the wells that were monitored in 2017 have been monitored since 2008, although a few have measurements dating back to 1983. Groundwater level measurements at these wells are taken approximately once per quarter.
CASGEM – California Statewide Groundwater Elevation Monitoring Program	Monitors seasonal and long-term groundwater elevation trends in dedicated groundwater basins throughout California. Monitoring entities establish CASGEM Program-dedicated monitoring wells and report seasonal groundwater levels to the CASGEM Program's database. The information below describes sources where CASGEM Program data can be retrieved.
DWR Groundwater Information Center Interactive Map	Database that collects and stores groundwater elevations and depth-to-water measurements. Groundwater elevations are measured biannually in the spring and fall by local monitoring agencies. Depth-to-water and groundwater elevation data are submitted to the Groundwater Information Center Interactive Map Application by the various monitoring entities including the SLOCFC&WCD, SBCWA, and VCWPD.
SBCWA CASGEM Program Monitoring Plan	Discusses the SBCWA's 19-well monitoring network, which includes 16 actively monitored wells and three inactive wells no longer monitored due to accessibility and permission issues. Initially, SBCWA was the sole monitoring entity for the entire Basin, but in 2014 SBCWA reapplied to the CASGEM Program as a partial monitoring entity to reduce their

	monitoring activities and grant permission for neighboring counties (San Luis Obispo and Ventura) to monitor their portions of the Basin.[5]
SLOCFC&WCD CASGEM Monitoring Plan	Identifies two wells in their CASGEM Program monitoring network. Upon recognition as a CASGEM monitoring entity in 2014, San Luis Obispo County Department of Public Works staff monitored these wells biannually. Static water level measurements are obtained biannually in April and October (corresponding to seasonal highs and low groundwater elevations).
VCWPD CASGEM Program Monitoring Plan	Identifies the two wells in their CASGEM Program monitoring network. Upon recognition as a CASGEM Program monitoring entity in 2014, VCWPD staff have monitored the two wells biannually. Static water level measurements are obtained biannually, due to the remoteness of the area, in April and October (corresponding to seasonal highs and low groundwater elevations). The two wells are in the southernmost portion of the Basin.[6]

Surface water monitoring is incredibly limited in the Cuyama Basin with only two active USGS stream gauges: one that has 58 years of streamflow record and the other having only 7 years of recorded streamflow. This limited monitoring network does not provide an accurate assessment of surface water flows and has been recognized as a data gap within the GSP. The agency has announced achievement of a SGMA grant from DWR Technical Support Services program that will allow them the funding necessary to identify and install new surface flow gages to accurately monitor the Cuyama Basin.

Sustainability Indicators and Undesirable Results

Identification of undesirable results during this GSP implementation is recognized when 30 percent of the representative monitoring wells fall below their minimum groundwater elevation threshold for two consecutive years. These minimum thresholds are divided into six regions within the Cuyama Basin and are measured as depth to water, making the minimum threshold a larger value than the measurable objective. The measurable objective is to decrease the space between the ground surface elevation of the well to the elevation at which water

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[5] Of the 16 active wells in SBCWA's monitoring network, three are CASGEM Program-dedicated monitoring wells and 13 are voluntary. Wells are monitored by either SBCWA staff or USGS staff. The three CASGEM Program-dedicated monitoring wells are measured biannually in April and October, whereas the 13 voluntary wells are measured annually. All wells are single completion. CASGEM Program-dedicated wells have known Well Completion Reports and perforated intervals.

[6] VCWPD does not have information beyond location and water elevation measurements for the two wells. There are no well completion reports for either well, and the perforation intervals are unknown. VCWPD identifies the southeastern portion of the Basin as a spatial data gap, given that the area contains no monitoring wells.

occurs. Therefore, the minimum threshold for this basin is determined by taking an average from the monitoring points and must read below the acceptable average elevation level over period of two years before management strategies are changed. The representative monitoring wells are selected based on several criteria: adequately spaced apart to provide better insight of the overall basin, higher amount of data over a long period of time to provide data insight regarding differing changes in climate (e.g. precipitation), areas of higher production to show where more significant changes occur, locations that are geographically complex and create uncertainty such as fault lines and steep topographic areas, wells of varying depths within an aquifer to better understand the area and extent of an aquifer, follows the best management practices provided by the DWR to ensure consistency, adequately constructed wells, professional judgement, and provides maximum coverage to increase spatial and vertical density of monitoring the area.

Water Budget

Total water storage and water budget development is done by use of the Cuyama Basin Water Resources Model (CBWRM) that predicts groundwater and surface water changes throughout the basin. The CBWRM is based off of MODFLOW-OWHM (One Water Hydrologic Model) provided by the USGS and intended to analyze integrated management systems. The term integrated includes a combination of groundwater flow, surface water flow, landscape, aquifer compaction(subsidence), conduit flow within pipes in an aquifer. The inclusion of the conduit process is a modification to the base MODFLOW, which is needed for basins that have agricultural irrigation systems. The MODFLOW-OWHM model was chosen and modified by members of the Technical Forum group. The CBWRM compares simulations of evapotranspiration, groundwater levels, and streamflow records with previously observed records. This model allows for the simulation of current, past, and future basin conditions to better estimate a water budget with the changing hydrologic conditions. The GSP states that the current water budget will be sufficient for the future water demand as it was determined that land and water use will not change. Figure 4 shows the historical groundwater water budget of Cuyama Valley, an additional requirement of SGMA, based on the previous 20 years of data.

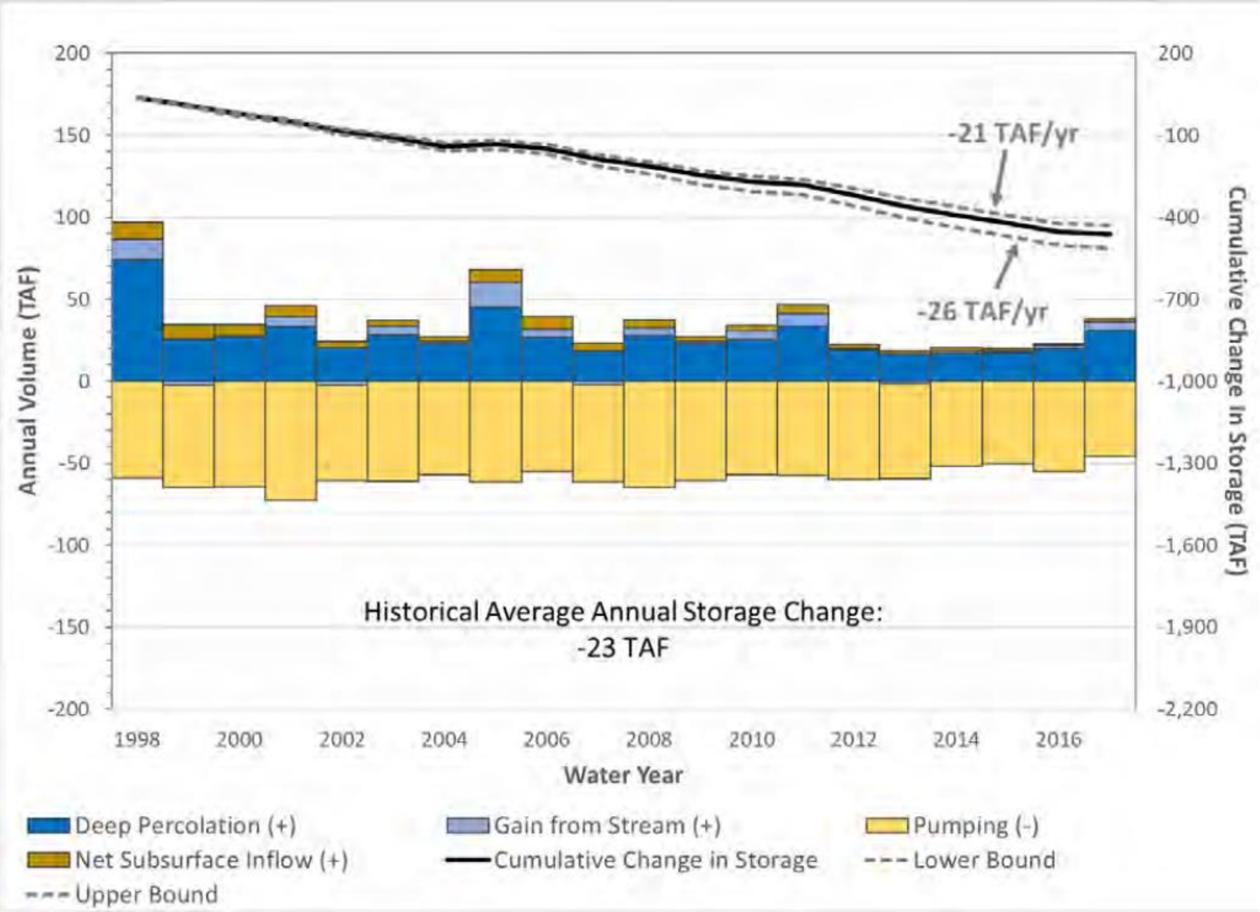


Figure 4: 20-Year Historical Groundwater Budget in Cuyama Valley Basin. Accessed on 04/08/2022 from Cuyama Valley GSP 2019. Values above zero indicate inflow and values below zero indicate outflow. Cumulative change in storage is shown in the solid line. Upper bound and lower bound indicated by the dashed line account for potential differences from inaccuracies in the numerical model used.

There is a steady trendline of decline in cumulative groundwater supply and this data has a variable range of 5,000 acre-feet per year because of the basins data gaps. These data gaps are identified as potential inaccuracies in monitoring methods due to limited number of well and stream gauge measurements. Figure 4 also clearly indicates a greater amount of pumping/outflow than inflow to the groundwater supply.

Santa Cruz Mid-County Basin

Introduction

The Santa Cruz Mid-County Groundwater Basin (MGA) lies on the northeast coast of Monterey Bay in Santa Cruz County, California. MGA consists of two primary aquifers: the Purisima Aquifer Formation and the Aromas Red Sands Aquifer. This study area was chosen because it is a small critically over drafted basin within the Central Coast Hydrologic Region susceptible to continued overdraft and saltwater intrusion. The average annual precipitation in this watershed is 32.5 inches. The Santa Cruz Mid-County Basin extends from the Santa Cruz Mountains to the Pacific Ocean including a portion of the City of Santa Cruz, all of Capitola and several unincorporated areas. The basin boundary was consolidated from four previously existing basins; the Soquel Valley, West Santa Cruz Terrace, Santa Cruz Purisima Formation, and the Pajaro Valley Basins. Each local water agency with access to water within the Santa Cruz Mid-County Basin is a member in the MGA.

Santa Cruz Mid-County Groundwater Agency (MGA) submitted their GSP to DWR in November of 2019. The main goal of this agency is to ensure safe and reliable groundwater supply to current and future users without causing undesirable results (MGA GSP 2019). Members either produce and provide drinking water or regulate the resource within their jurisdictional boundaries. These water agencies include City of Santa Cruz Water Department, Central Water District, and Soquel Creek Water District. Groundwater supply is used primarily for residential use in Santa Cruz County in both urban and rural spaces. Residential use is supplied in the form of municipal water service in the basin and generally occurs in urban areas supplying approximately 80,500 people.

Approximately 11,600 residents receive water from non-municipal wells and small or mutual water systems. Although 65 percent of basin residents get their water from agencies withdrawing from groundwater supply, the City of Santa Cruz Water Department serves the remaining 45 percent of residents with 95 percent surface water and 5 percent groundwater in average rainfall years. This surface water is imported outside of the basin boundary from San Lorenzo River, Majors Creek, Liddell Creek, Laguna Creek, Reggiardo Creek, and Loch Lomond Reservoir on Newell Creek. No water is imported from outside of the county. Santa

Cruz Water Department has recently agreed to supply Soquel Creek Water District (100 percent reliant on groundwater) with excess surface water supply when available to decrease its reliance on pumping from the basin and allow for aquifer recharge.

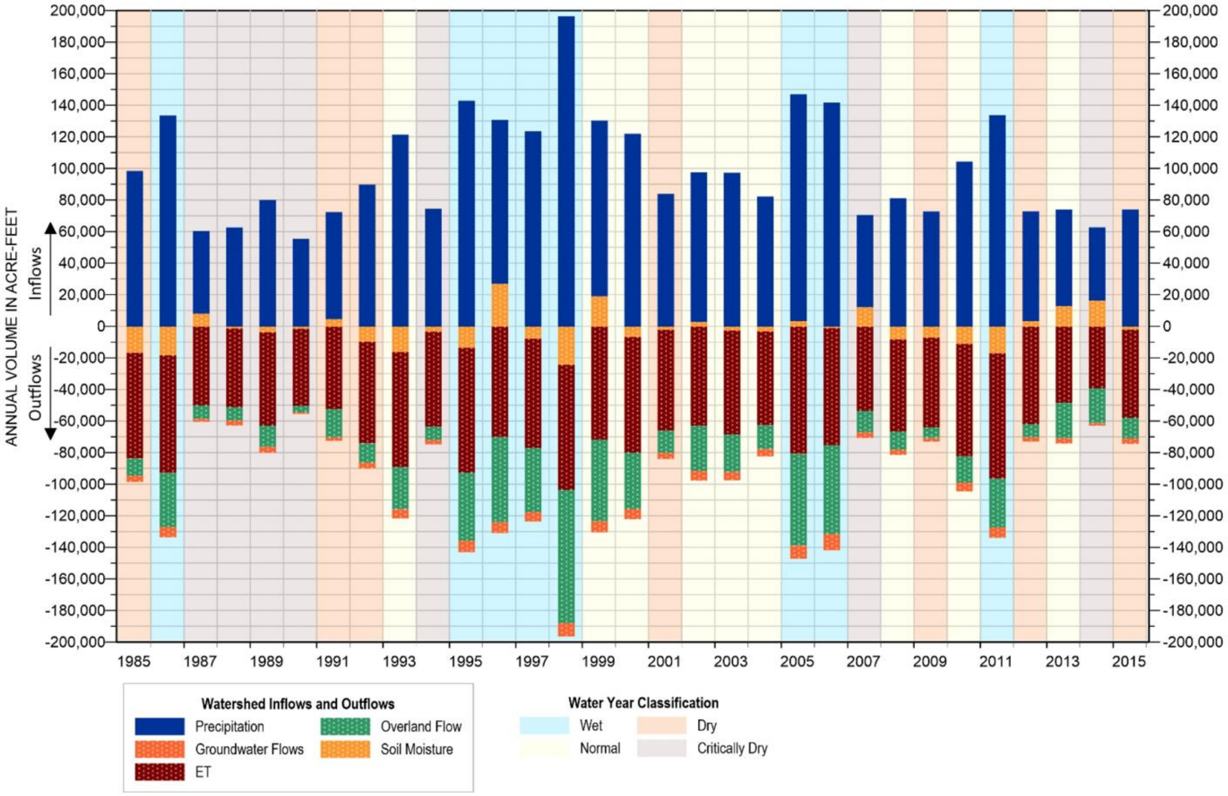


Figure 5: 31-Year Historical Surface Water Budget in Santa Cruz Mid-County Basin. Accessed on 04/08/2022 from Santa Cruz Mid-County GSP 2019. Positive values indicate inflow and negative values indicate outflow. There have been 8 wet years, 9 normal years, and 13 dry years within the 30-year period. Annual volume is indicated in acre-feet on the y-axis.

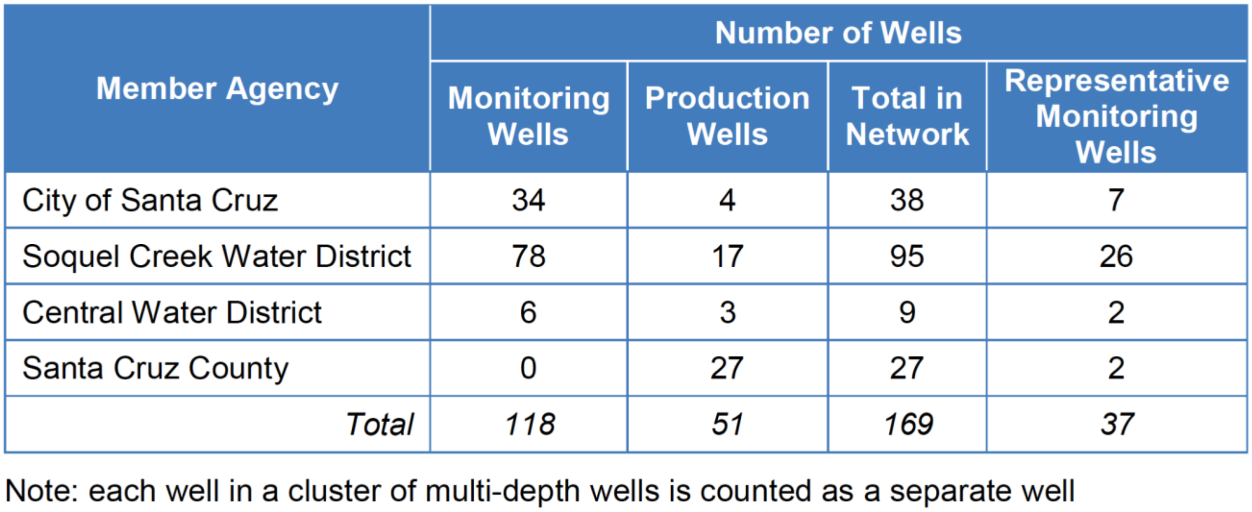
Annual precipitation values are shown through the 31-year historical period in Figure 5. This indicates that 66 percent of the average 96,200 acre-feet of precipitation, is either evaporated or transpired before reaching a water body. This also means that the majority of precipitation does not reach groundwater supply. The second largest outflow occurring in the basin is overland flow that leads to accumulation in surface water bodies. This surface water contribution accounts for 26 percent of the average annual precipitation. The rest of the precipitation is received for groundwater recharge (5 percent) and soil moisture (3 percent).

Monitoring Programs

In 1995, a Groundwater Management Plan (GMP) was formed by the Soquel Creek and the Central Water District under a joint powers' agreement. In 2009 the GMP expanded to include the City of Santa Cruz and the County of Santa Cruz creating a larger groundwater monitoring agency network. The GMP was officially replaced by the 2019 GSP in compliance with SGMA policy.

MGA has a total of 118 monitoring wells, 51 production wells and 37 representative monitoring wells (see Table 4 below) that are used to determine GWE minimum threshold for chronic lowering of levels within the basin. Monitoring wells in the MGA are measured via data loggers, an electronic device that automatically records data in a specific location over time. The frequency of which the wells with data loggers are measured vary at each monitoring location. These electronic devices are scheduled to record quarterly, semi-annually, monthly, or annually.

Table 4 - Summary of MGA Member Agency Groundwater Level Monitoring Network. Divided into the four members of the Santa Cruz Mid-County Groundwater Agency. Submitted in 2019 GSP to DWR.



Member Agency	Number of Wells			
	Monitoring Wells	Production Wells	Total in Network	Representative Monitoring Wells
City of Santa Cruz	34	4	38	7
Soquel Creek Water District	78	17	95	26
Central Water District	6	3	9	2
Santa Cruz County	0	27	27	2
Total	*118*	*51*	*169*	*37*

Note: each well in a cluster of multi-depth wells is counted as a separate well

Sierra Ryan (personal communication, Santa Cruz County Environmental Health) speaks to the groundwater elevation level (GWE) sampling methods for MG Basin (see Appendix A). MG Basin samples through a vast network of monitoring wells. Some wells are running by municipal data loggers or automatic devices that measure depth of GWE and are uploaded in a frequency at the discretion of the groundwater agency. Water agencies within this basin have reduced water usage, but there is still a deficit between aquifer recharge and withdrawal, mainly from agricultural land use. Water agencies have their own wells and their own data loggers, and generally sample more often than groundwater agencies do. There are also sentinel wells [7]all along the coast that are meant to monitor water quality and more specifically saltwater intrusion.

Figure 6 shows the location of production wells, shallow wells, monitoring wells, and Santa Cruz County Groundwater Monitoring Program wells as of 2019. The Santa Cruz County wells represent the locations of private and domestic well users that are included in the total water storage models that MGA uses to create a water budget for the basin. These wells are well outside of the main municipal production area and have significantly less pumping than the active production wells indicated by blue triangles.

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[7] A sentinel well is a groundwater-monitoring well that is located near an area of known contamination and drinking water supplies. They are intended to give advanced warning before a contamination reaches drinking water supply.

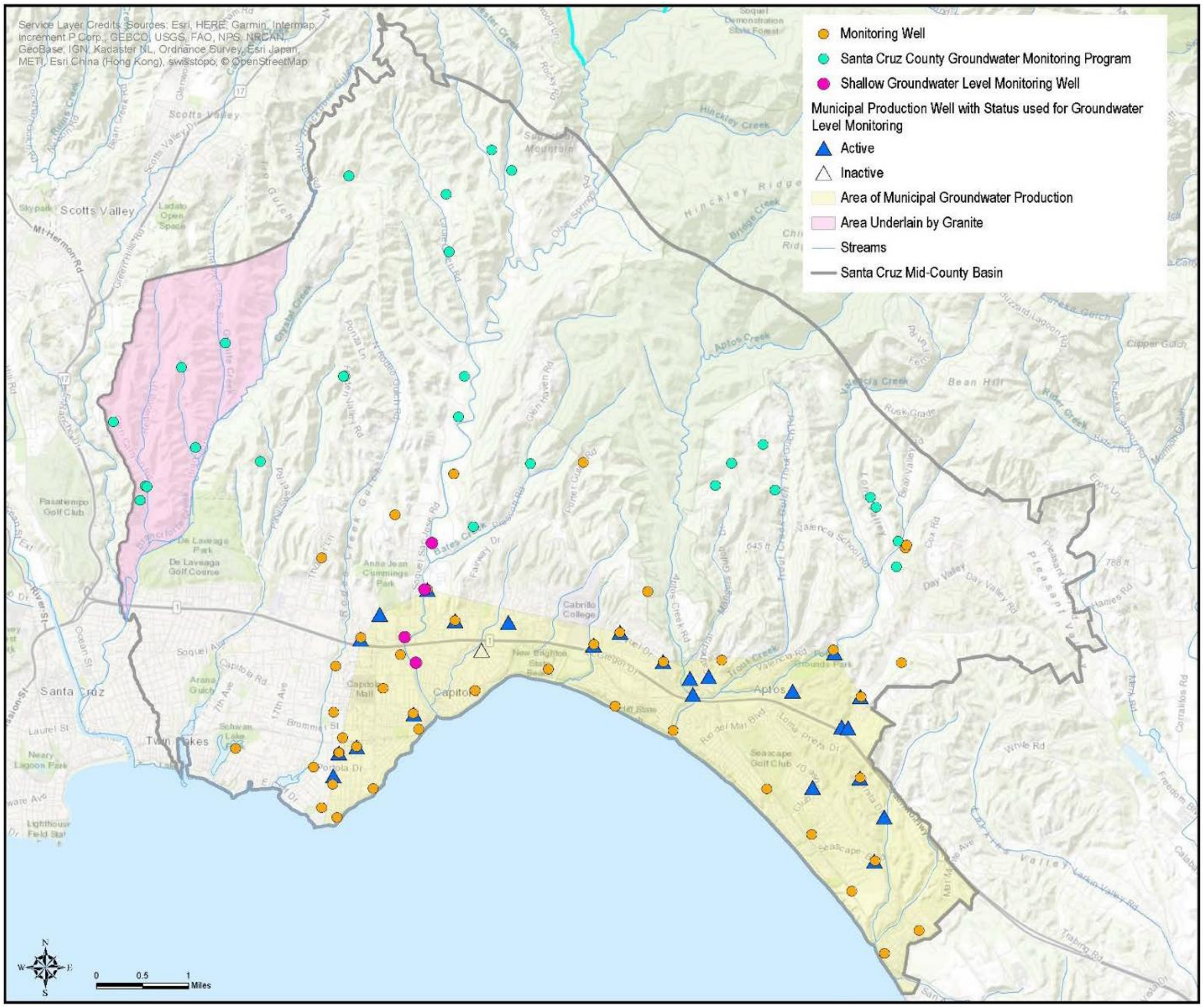

Figure 6: Location and classification of groundwater monitoring wells in MGA network. Accessed from MGA GSP 2019. The Santa Cruz County Groundwater Monitoring Program wells are regulated and permitted by the county. Active production wells are indicated as blue triangles and inactive wells are white triangles. There are several wells from the Santa Cruz County Monitoring Program that are well outside of the main municipal groundwater production area.

Areas of Concern

One of the largest concerns at MGA is to prevent saltwater intrusion from occurring as it did in the past during historical overdrafts. The basin was placed in critical overdraft because it was below the minimum threshold of its saltwater intrusion sustainability indicator as designated by DWR/SGMA. There are associated increases in TDS and chloride when saltwater is infiltrated into a freshwater basin, which lowers the water quality preventing the basin from providing water to its users. Exceeding TDS and chloride levels is the main water quality concern in the Santa Cruz Mid-County Basin—other than a few localized areas that have a naturally occurring exceedance in iron and manganese that is not acceptable for drinking water standards. The basin has 10 miles of exposure to coastline along the Pacific Ocean within the Monterey Bay, which creates a vast area where saltwater intrusion should be monitored. Both primary contributing aquifers (Aromas Sands and Purisima) have experienced some saltwater contamination to their underlying groundwater supply.

There are 13 sentinel wells used to monitor and alert groundwater managers of any potential contamination risks are located along the coast and contain data loggers that take measurements every 15 minutes. Although sentinel wells provide some advanced warning to monitoring potential saltwater intrusion, this type of contamination is made more difficult to regulate because there are many unmonitored private wells that continue to operate without any kind of limitations. The County estimates that 20-40 percent of water supply wells in use are not permitted and non-municipal wells that were drilled prior to the year 1971 when the County began to require permits to drill water wills. The actual number and location of these un-permitted wells is unknown and is approximated using the agencies' available data.

These existing unmonitored and unregulated wells also contribute to the difficult task of obtaining accurate groundwater elevation data. It is estimated that there are over 1,000 private wells that extract around 2 acre-feet per year for domestic purposes and remains unmetered. Small water systems that consist of between 5 and 199 connections or that serve more than 25 people for 60 days, are required to report their groundwater extraction data to Santa Cruz County monthly and annually. In addition to private wells, groundwater pumping for agricultural purposes is also identified as unmetered. Agricultural pumping is estimated based on type of crop and nearby evapotranspiration readings and factored in when calculating the total groundwater use in annual reports. The largest decline in groundwater elevation was 140 feet recorded in 1986 within the Purisima aquifer. The 2019 GSP proposes that groundwater monitoring efforts will increase at larger agricultural companies with significant use estimates. Therefore, groundwater extraction within this basin is based on metered municipal production wells, small water systems, and model estimates of private wells.

The MGA discusses groundwater monitoring data gaps occurring in section 3.3.4.1 in the GSP. Firstly, they suggest a lack of deep coastal monitoring wells to monitor seawater intrusion. In an effort to close this gap, the MGA has proposed installation of two deeper coastal monitoring wells because the existing nearby monitoring wells do not reach down far enough to the accurately measure the extent of the deepest and actively pumped aquifers. Further, each MGA water agency meters its own groundwater level and extraction data. This data is submitted by each contributing agency through Supervisory Control and Data Acquisition (SCADA).

The next data gap discussed is the existing eight shallow monitoring wells to monitor relationship of groundwater withdrawal to the depletion of surface water. There are 3 stream gauges along the reaches of Soquel Creek and 5 shallow wells that are strategically placed near these gauges to monitor the relationship between the two data. The basins data is limited by the location and quantity of the stream gauge and shallow well locations since all are along the single water body of Soquel Creek and there are many other small surface water sources in the watershed contributing to interconnected groundwater. More data points with adjacent well-gauge proximity are needed to better understand the interconnected relationship between groundwater extraction data and surface water. Where shallow groundwater elevation data is available, the inability to quantify the flow with the stream gauge data makes is difficult and less accurate to model the flow between stream and aquifer. The GSP proposes installation of 8 new shallow monitoring wells and 5 new streamflow gauges along Aptos Creek, Valencia creek, and some additional wells along Soquel Creek. These locations are chosen based on whether there is high groundwater extraction, streamflow gauges, and site access nearby.

Sustainability Indicators and Undesirable Results

The five sustainability indicators noted in the GSP are lowering groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, and depletion of interconnected surface water. To monitor elevation levels, groundwater monitoring wells are installed and measured in aquifers throughout the basin to establish accurate groundwater elevation contours. Undesirable results in the basins GSP are defined as any time an average monthly representative monitoring point experiences a decline in groundwater elevation below its minimum threshold. Therefore, each monitoring well location has a minimum threshold and a period of one month. Table 3 shows the minimum threshold values and objective values in the 17 wells that have been experiencing chronic lowering of groundwater elevation levels. Wells that are deep, like the Thurber Lane monitoring well in the Tu aquifer, exhibit negative elevation values for the minimum threshold because they are located far enough inland and do not pose a risk for seawater intrusion. It is noted within the GSP that there are two representative monitoring wells that do not have data loggers because they are privately-owned.

Water Budget

MGA uses USGS's Precipitation Runoff Modeling System (PRMS) combined with MODFLOW software (discussed above in Cuyama Water Budget) to create a USGS GSFLOW model to determine the total water storage relationship between surface and groundwater flow. The PRMS is a model system developed to simulate various hydrologic processes (evaporation, transpiration, runoff, infiltration, and interflow) and water budgets of a climates vegetative canopy, snowpack and soil that is based on records of temperature, precipitation, and solar radiation. These simulations are at the watershed scale and intended to model periods ranging from days to centuries (USGS website PRMS). The GSP exhibits results of this GSFLOW model with a historical period of 1985-2015 to analyze the groundwater budget summary and net increase in storage.

The 31-year historical groundwater budget is shown below in Figure 7.

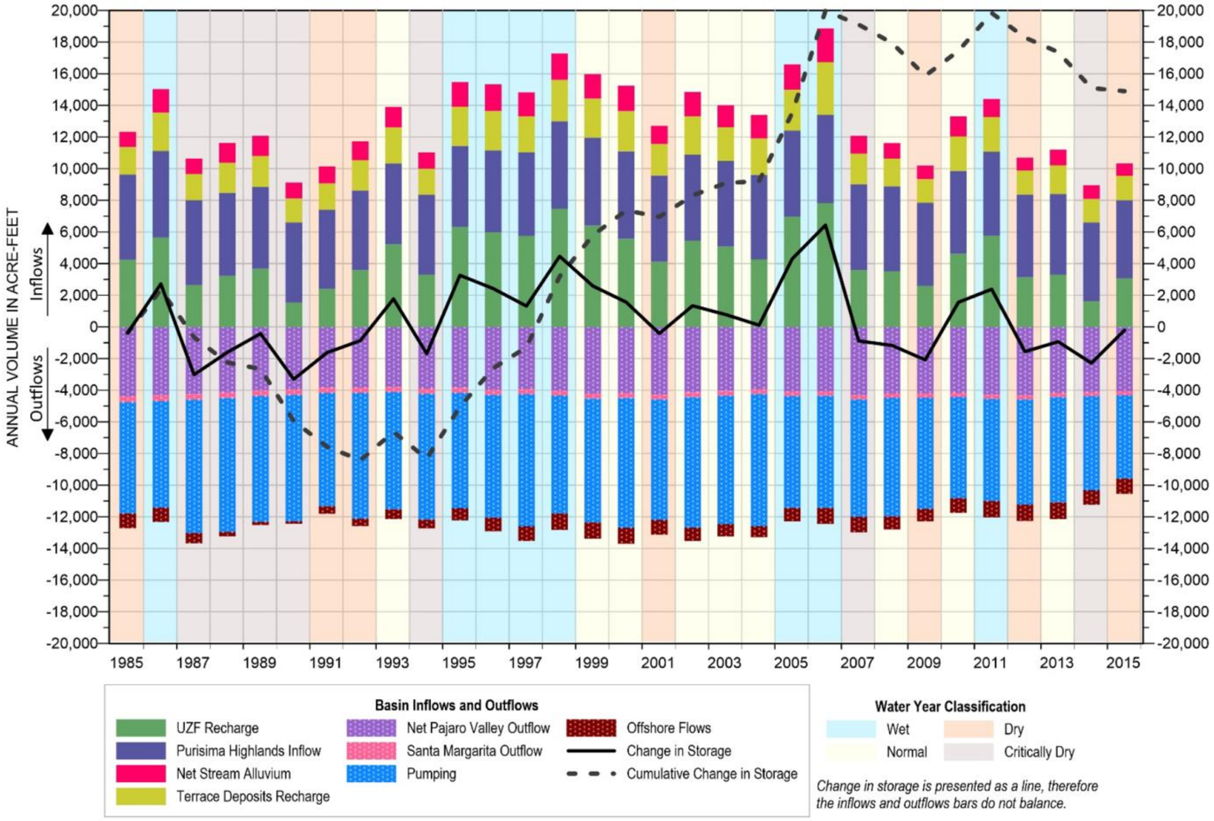

Figure 7: 31-Year Historical Groundwater Budget in Santa Cruz Mid-County Basin. Accessed on 04/08/2022 from Santa Cruz Mid-County GSP 2019. Positive values indicate inflow and negative values indicate outflow. Cumulative change in storage is shown in the dashed line. UZF Recharge is direct percolation of precipitation and return flows. Offshore flows indicate seawater intrusion risk.

The basin receives 60 percent of its inflow from surface water recharge of which about 34 percent occurs directly from precipitation. MGs groundwater supply has increased in storage by 14,910 acre-feet over the historical period equating to an average 480 acre-feet per year (see Figure 7). The dashed line in Figure 7 represents the cumulative change in groundwater storage over the 31-year historical period. Also note this figure considers the outflow of groundwater that is lost to the two adjacent groundwater basins (Pajaro Valley and Santa Margarita) as well as supply lost to offshore flows, which indicates risk of seawater intrusion. This historical period shows a 10-year decrease in storage from 1985-1995 that equated to approximately 8,000 acre-feet. This loss is storage was reflected by the declining groundwater levels in the municipal production wells. The increase in supply of 28,000 acre-feet between the years 1995-2006 is largely responsible for the cumulative increase in the historical period, likely because only one dry water year occurred during that time. Between 2007-2015, there were six dry water years which resulted in a cumulative loss of 4,000 acre-feet. This is much lower than the expected result based on past records of extended dry conditions in 1985-1995, but groundwater pumping had significantly decreased within the basin to sustainably manage the supply.

Comparative Analysis

The GSP evaluations are meant to provide a thorough breakdown of how the location, size, primary land use and hydrogeologic factors influence the sustainability issues in a basin and subsequently, the management methods and priorities implemented by a GSA. Summaries for each study areas' GSP will be compared to evaluate key differences and similarities in management methods and concerns. Areas of concern in each basin include groundwater quality, groundwater elevation monitoring, and surface water monitoring. Each basin calls out the need for improvements and the observed data gaps as well as concerns for managing the water quality.

Firstly, Santa Cruz Mid-County Basin was categorized in critical overdraft due to the sustainability indicator exceedance of seawater intrusion. Cuyama Basin was categorized in critical overdraft due to the sustainability indicator of long-term groundwater elevation decline. Cuyama Basin does not have the same withdrawal limit concerns to their water quality as Santa Cruz Mid-County does, as saltwater intrusion is not a risk so far inland. Groundwater elevation level decline is more severe in the Cuyama basin decreasing by 400 feet recently recorded vs the Santa Cruz Mid-County which recorded a mere 35-foot decline in 2017. Although the groundwater elevation decline recorded in 2017 was significantly lower than Cuyama, it was recorded in a well adjacent to the Pacific Ocean and poses a risk for saltwater intrusion. The limited scope of land subsidence observed in Cuyama Basin is reflective in the greater magnitude of groundwater elevation decline seen at Cuyama Basin, where Santa Cruz Mid-County has no record of land subsidence.

Groundwater monitoring networks are an important part of this paper and are often the determining factor is sufficient and accurate data. This is discussed as a data gap in both GSPs, though they both focus heavily on their solution being to plan and install more monitoring wells in locations that will improve the accuracy of their measurements and models. However, this can be a confusing topic given how many different organizations, types and depths of wells are existing throughout each basin. After determining these aforementioned values of a well, there is also the matter of whether a well is active or inactive. It appears to be an ever-oscillating network that is more successful the more wells that exist, since locations of pumping continue to migrate as the decades of pumping continue to add up. The total number of monitoring wells identified in MGAs 2019 GSP is 188 and 37 of those wells are designated representative monitoring wells. Cuyama's 2019 GSP states they have a monitoring network of 101wells and 61 of those are designated as representative monitoring wells with an average density of 26.7 wells per 100 square-miles across the extent of the basin.

Surface water monitoring is mentioned in both GSPs because it plays an integral role in the amount of water that will provide an alternative water resource to the users within the extent of the basin and is indicative to the potential aquifer recharge observed throughout the basin. Two-thirds of the MGA precipitation is lost to evapotranspiration—unable to be distributed to the surface water supply and also unable to recharge any of the basin's aquifers. This indicates a need for aquifer recharge projects in the area. The GSP mentions multiple aquifer recharge projects that are due to be implemented upon the development of their infrastructure as adaptive management strategies to balance the existing evapotranspiration rate. Both basins have indicated there are data gaps in their surface water monitoring networks due to a lack of sufficient stream gauges. Both GSPs include installation of several stream gauges placed near areas of heavy groundwater pumping and significant water bodies.

Ethical management and stakeholder engagement is provided based on a SGMA list of regulations that each GSA must follow to communicate and engage with the public and various representatives of groundwater users. Cuyama does give a significant description of how this is included in their plan. MGA has a less descriptive and more of a placeholder section on how it plans to communicate and engage with disadvantaged groups of groundwater users within its basin. Since MGA has higher population of users falling into the disadvantaged groups category, they will likely need an effective solution to facilitate engagement of these users. To compare, the population of these groups under MGA is approximately 8,375 compared to 666 within the Cuyama Basin. MGA could benefit from a detailed agenda for how they will be engaging groundwater users from their disadvantaged groups community.

Although some of their concerns are similar, the effects vary when exceedances occur among sustainability indicators. Because of this, there most certainly is a need for local governance and regulation in groundwater management. One of the key elements in understanding groundwater issues in California is comprehending why there is no “catch-all” policy or management method available. Although SGMA has allotted a simple guideline that provides some setup for local governments to include in their planning, there are still limitations and some vague regulations effecting the monitoring and management that are subject to the review of the DWR. These limitations are seen in the need for policy reform, expansion of monitoring networks, and acquiring resources for the upkeep of infrastructure already in place.

Groundwater Elevation Data

This section of the paper is intended to show a raw data analysis that was not obtained from DWR annual reports or from either basins’ submitted GSP. A comparative analysis to the data reported in the DWR annual report and most recently submitted GSP (2019) will be used to infer the data and further highlight the complexity of groundwater data analysis. This is intended to uncover data gaps and provide direction in the management recommendations section of the paper.

Below I have developed a digestible 21-year snapshot of the groundwater elevation data that has been logged in two separate basins within one large study area. Interpretation of these two basins collective well measurement data will expose separately managed groundwater supply concerns and show the frequency of which the levels are measured. I chose 21 years as the period of record for the study to show a significant amount of time into the conditions of groundwater elevation data before a few extreme droughts, during droughts, and before SGMA (Sustainable Groundwater Management Act) was enacted in 2014. It is reasonable to assume that during years of critical overdraft there will be less data to infer and GWE will be lower. Conversely, we may find that available data will increase and show a trend of increasing GWE.

The time of year for which data was collected (July 1st through October 1st) is intended to show the dry season levels, which are congruent with lowest precipitation levels when groundwater elevation would also be at their lowest (Argus et al. 2017). This seasonal data extraction was chosen to create a more accurate representation of the deficit that withdrawal can cause within a basin. The groundwater level data was obtained from the Periodic Groundwater

Level Measurements dataset on the California Natural Resource Agency website. This dataset chosen to assess the mean over a 20-year period and because it includes measurements collected by DWR and all cooperating agencies in GW basins statewide. This will show all available well data collected by every monitoring organization in California, including some voluntary private well owners. The organizations that monitor these wells include SGMA, USGS, DWR, CASGEM (California Statewide Groundwater Elevation Monitoring) Program. Throughout the analysis, I will refer to results found in each GSAs recently submitted annual report to the DWR and provide a comparative analysis at the end of this section.

Santa Cruz Mid-County Basin

The following analysis for Santa Cruz Mid-County Basin includes original groundwater elevation data obtained from the California Natural Resource agency and is frequently compared to the 2020 MGA annual report submitted to DWR.

In the 2020 water year (October 2019 through September 2020), the DWR annual report for Santa Cruz Mid-County Groundwater Agency states the region used 5,171 acre-feet of groundwater and 3,598-acre feet of surface water imported from local sources.[8] Total change in groundwater storage at MG for the water year of 2020 reported to SGMA was -1,576 acre-feet. This total change is storage is calculated using a basin wide groundwater flow model (GSFLOW). This report shows that approximately 59 percent of MG water resources are provided from groundwater, making it a high-risk for continued overdraft and unsustainable conditions. The primary land use of this basin is residential and open space/parks with majority categorized as domestic municipal use. The various pumpers utilizing MG include Soquel Creek Water District, City of Santa Cruz, Central Water District, small water companies, and private domestic wells.

Once the data for MG was sorted in excel by year and basin using the methods discussed previously, the number of measurements taken for each year (see Figure 8) was plotted to show a trend in the number of groundwater monitoring wells being measured annually during the dry season. This representation is intended to show the changes in MG monitoring standards and whether it has had an overall increase or decrease in the past 20 years.

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[8] The local sources of imported water for MG Basin include creeks, springs, San Lorenzo River, and Loch Lomond Reservoir.

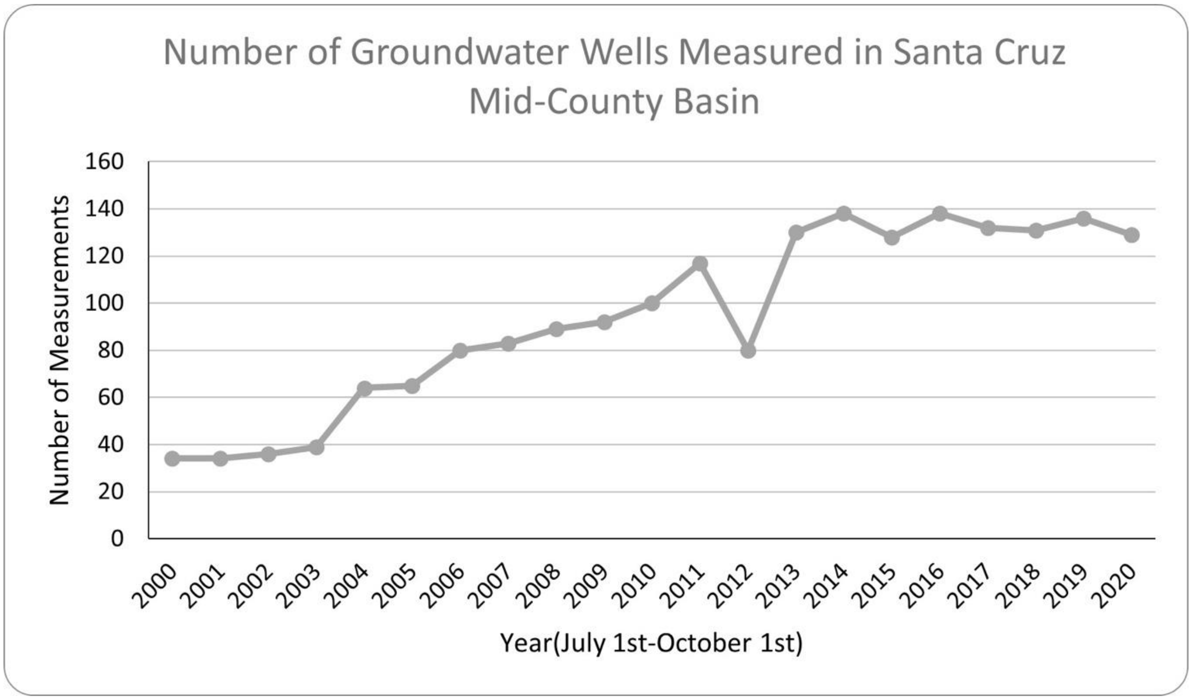

Figure 8: Number of groundwater monitoring wells measured annually in the Santa Cruz Mid-County Basin between July 1st and October 1st over a period of 20 years. Data accessed from the California Natural Resources Agency https://data.cnra.ca.gov/dataset/periodic-groundwater-level-measurements.

Figure 8 shows an overall trend increase in the number of wells being measured and monitored over the past 20 years. Between the years 2003 and 2006, the number of GWE measurements being taken doubled from ~40 locations to ~80 and has subtly increased to ~130 in 2020. Monitoring wells are being installed frequently throughout this time period and I therefore cannot infer to the utilization of historical well measuring, but the recent data shows that the majority of SGMA monitoring wells are being measured and utilized throughout the year.

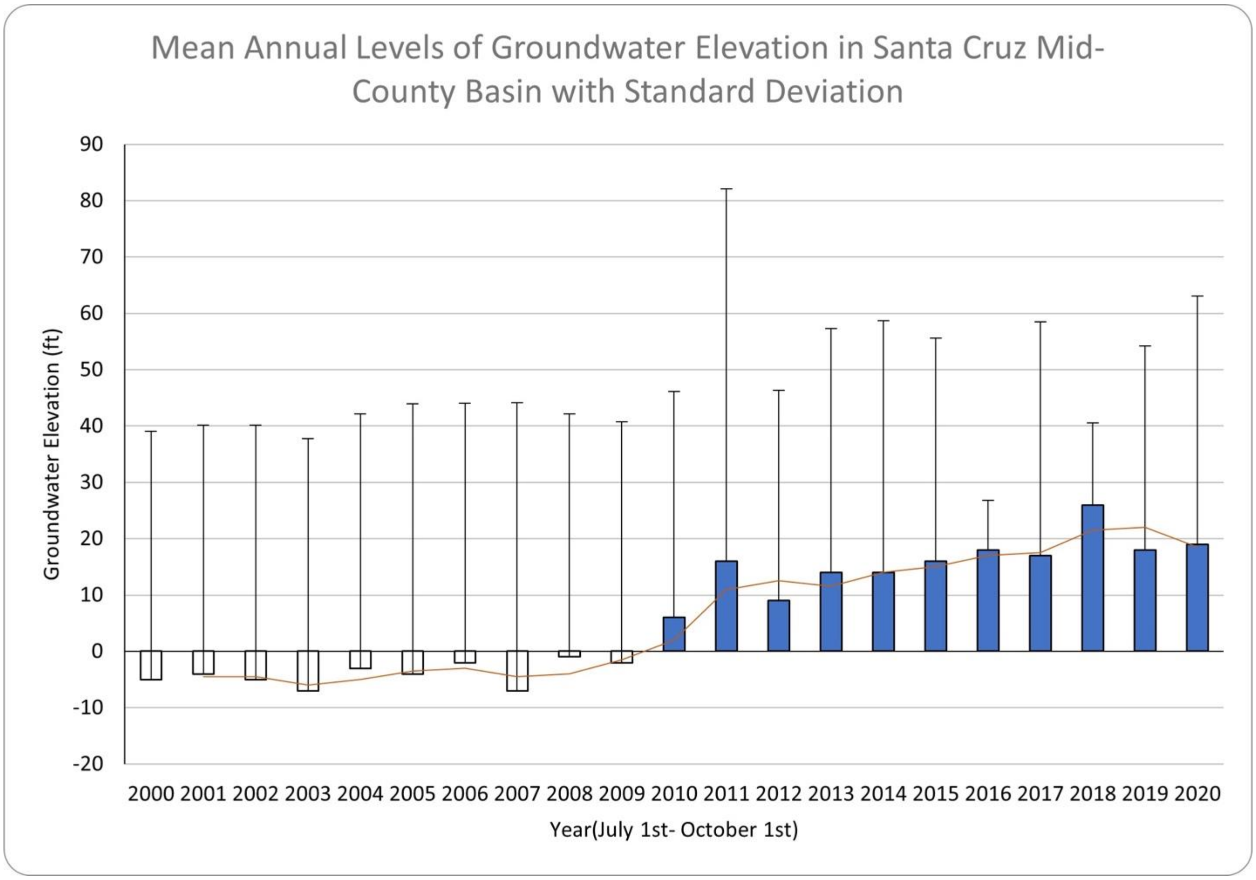

Figure 9: Annual means of groundwater elevation in Santa Cruz Mid-County Basin. Data collected between time period of July 1st and October 1st between the years 2000 and 2020. Error bars indicate standard deviation for each mean period. The curved orange line shows the moving average of annual means over a period of 20 years.

The mean annual GWE were also sorted in the period of record to show an average trend in elevation over time (see Figure 9). This representation is intended to show the changes in MG's GWE levels and whether it has had an overall increase or decrease in the past 20 years. Figure 9 portrays an overall increase from ~ -5 ft in 2000 to ~20 ft in 2020. The significant increase between the years 2009 and 2011 indicate a combination of an above average precipitation period and improvements in the management of groundwater resources in this region. The negative values shown through the years 2000-2009 are indicative of wells at sea level that are experiencing over withdrawal and likely experienced some seawater intrusion. This is supported by Figure 7 from the MGA 2019 GSP showing several production and monitoring wells along the coast having record of negative values so close to sea level.

Although seawater intrusion is correlated with negative values along the coastal wells, the negative elevation results in the raw data is impacted by deep wells that are located inland and do not pose risk of seawater intrusion. Deep wells located inland do not pose a risk to seawater intrusion and do not necessarily determine a well that is below desirable levels. However, the 21-year period was overlapping a period of significant overdraft that was experienced in MGA coastal aquifers. This is likely a strong factor in the calculated average negative values shown in the years 2000-2009 and shows that measurements were focused on the wells at risk of seawater intrusion. This is supported by MG's manager Sierra Ryan who states that significant overdraft occurred from the 1980s to the early 2000s and that MG Basin is still operating on a deficit because basins recharge rate cannot keep up with the withdrawal. The standard deviations in Figure 9 are meant to show how values deviate from the mean value of overall GWE.

Cuyama Valley Basin

In the 2020 water year (October 2019 through September 2020), the DWR annual report for CV Groundwater Agency states the region used 53,600 acre-feet of groundwater, with 53,300 acre-feet used for agricultural lands and a mere 300-acre feet for urban areas. Total change in groundwater storage at MG for the water year of 2020 reported to SGMA was -23,600 acre-feet. These estimates are made using a groundwater flow model referred to as Cuyama Basin Water Resources Model (CBWRM). The primary land use of this basin is irrigated agricultural, with lesser portions consisting of grazing and urban landscape. There are various organizations monitoring this basin including: CASGEM, USGS, Santa Barbara County Water Agency, San Luis Obispo Flood Control and Water Conservation District, Ventura County Watershed Protection District, Cuyama Community Services District, and one private landowner. There are a total of 207 monitoring wells in CV, 133 of which are SGMA monitoring wells and the remaining from other voluntary programs.

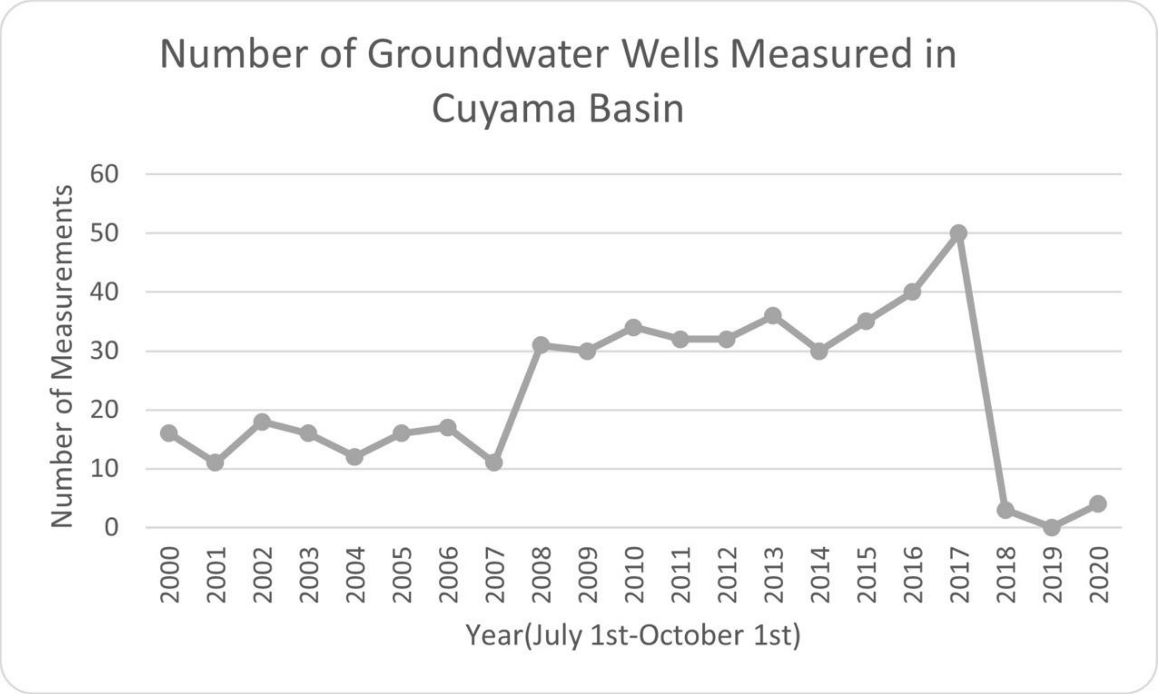

Figure 10: Number of groundwater monitoring wells measured annually in the Cuyama Basin between July 1st and October 1st over a period of 20 years. Data accessed from the California Natural Resources Agency https://data.cnra.ca.gov/dataset/periodic-groundwater-level-measurements.

Methods used for CV are the same as explained above in Santa Cruz Mid-County.[9] Figure 10 shows the quantified trend of measurements taken at different monitoring wells during the period of study. The trend shows that the number of wells being measured is increasing apart from the last three years in 2018, 2019, and 2020. It is possible that the measurements were not uploaded or recorded during the 3-month period of dry season for these years. Figure 10 shows that the number of measurements increases significantly in 2008 and again after SGMA is enacted in 2014. Despite the lack of measurements found in the past three years, it appears that CV is also trending in the installment and utilization of more monitoring wells throughout the basin.

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[9] Once the data was sorted in excel by year and basin using the methods discussed previously in this paper, the number of measurements taken for each year (see Figure 10) was plotted to show a trend in the number of groundwater monitoring wells being measured annually during the dry season. This representation is intended to show the changes in monitoring standards and whether it has had an overall increase or decrease in the past 20 years.

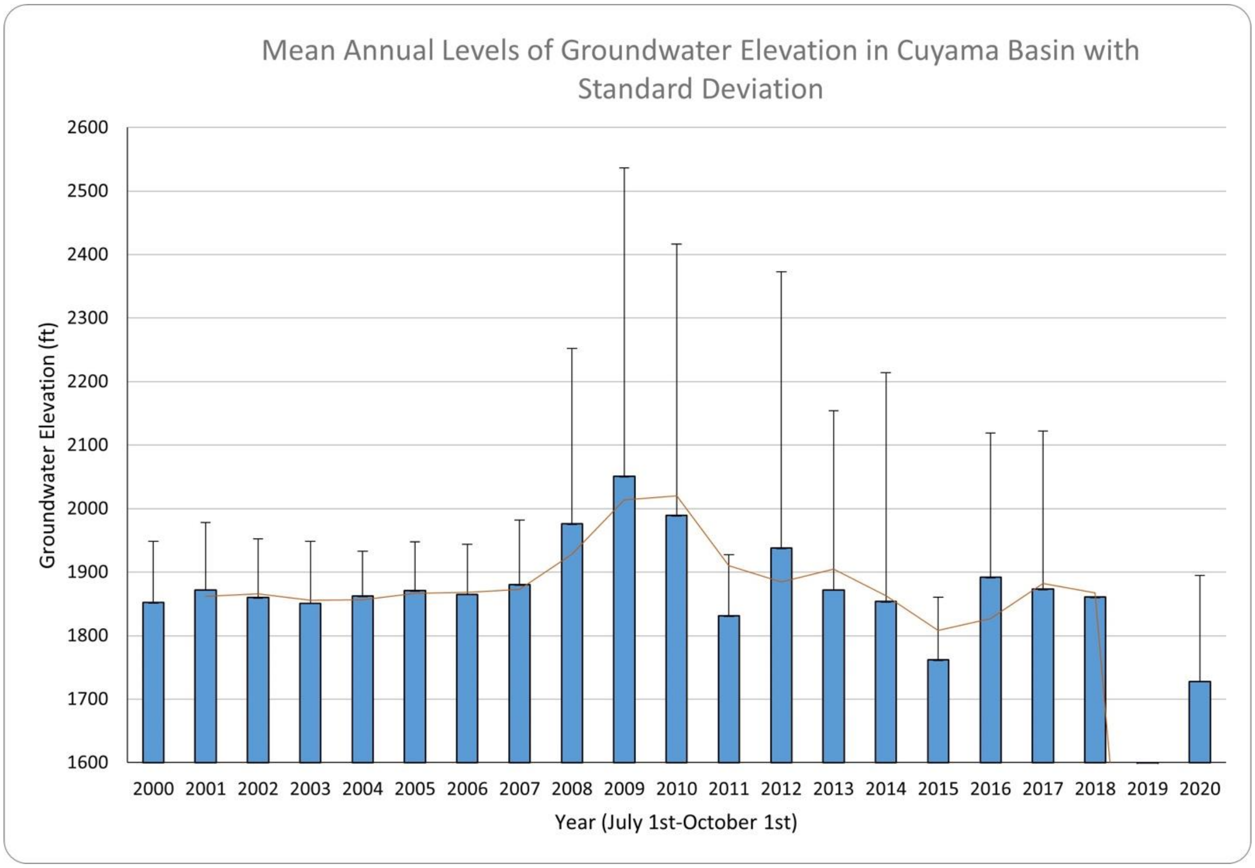

Figure 11: Annual means of groundwater elevation data collected in the Cuyama Basin between July 1st and October 1st. Error bars indicate standard deviation for each mean period. The curved orange line shows the moving average of annual means over a period of 20 years. Data was accessed from the California Natural Resource Agency https://data.cnra.ca.gov/dataset/periodic-groundwater-level-measurements.

GWE data collected for CV is depicted in Figure 11. The elevation data appears to be trending down (decreasing) except for years 2008, 2009 and 2010. These three years that trend upward have an extended standard deviation indicating that they greatly differ from the annual mean. California experienced heavy drought from 2007 through 2009, so CV may have used imported surface water resources during these years and allowed for groundwater supply to recharge adequately. Despite this uptick in the data, the GWE levels in CV have lowered overall through the 20-year period of record and indicate the basin is still in critical overdraft.

One problem observed during data analysis is the inability to monitor all private wells regularly—these are measured at most twice a year. In addition, the method of limiting data to the dry season doesn't account for all measurements taken outside of the 3-month range of the study. Lastly, a data gap that is seen often by Sierra Ryan (Water Resources Manager at Santa

Cruz County Environmental Health) is that most shallow aquifers are often not measured because of the difficulty and lack of resources.

Comparative Analysis

After analysis of both basin datasets, there are numerous differences I see in the monitoring methods of each basin. Firstly, the number of measurements in the Santa Cruz Mid-County Basin is significantly greater than those seen in the Cuyama Basin. For example, there are less than ~20 monitoring well measurements occurring in Cuyama between the years 2000-2007, while Santa Cruz Mid-County has about double that is the same time period. The growth of monitoring wells being measured steadily increases in the Santa Cruz Mid-County Basin other than the drop seen in 2012. Cuyama's small number of measurements are likely due to the lack of a groundwater management plan before 2014 when it became mandatory for GSAs and GSP to be established. Cuyama Basin also has little to no measurements recorded for the last 3 years of data between 2018-2020. It is unclear why this has occurred, but it does point to the conclusion that there was either error in downloading and processing the data, or more likely no groundwater elevation measurements were taken during the study period and range, specifically July 1st through October 1st of these years. This may have been due to the infrastructure changes occurring within the Cuyama Basin following the establishment of their newly formed GSA.

There are significant differences in the elevation levels that were extracted for each Basin. Most notable is Santa Cruz Mid-County's negative values between the years 2000-2009. This is likely due to a few factors after evaluation of their GSP. Because of their proximity to the Pacific Ocean, they can withdraw negative values and create seawater intrusion. Also, some aquifers drawn from inland areas are deep water aquifers that have water elevations significantly below the sea level of the wells surface elevation. In MG, 17 of the 37 representative monitoring wells (shown in Table 4 above) are designated for monitoring groundwater elevation as indicated by this Basins 2020 GSP annual report submitted to the DWR. 33 of these 37 representative monitoring wells are used for water quality or seawater intrusion monitoring. It is also worth noting that cumulative change is storage of groundwater supply seen in Figure 7 is reflected by the original data output of groundwater elevation increase in Figure 9.

The original data analysis was conducted before the GSP evaluations, and therefore the hypothesis that more wells would be measured subsequent to overdraft and drought is more complicated than anticipated. After reading the GSP and annual reports for each basin, it is clear that the location and history of the well is significantly more important than the number of wells being measured. The location of monitoring wells and the number of those being measured fluctuates based on the locations of production wells that pump the largest amount of groundwater volume. This is why local management and implementation are important in groundwater management, considering each basin is utilized differently based on the fluctuating demands and resources relative to each region.

Management Recommendations

This section of the paper is intended to provide management recommendations based on the comparative analysis of the two basins GSPs and the framework of Saito et al. (2021). These recommendations are directed toward groundwater management within state of California and specifically toward my area of study. The first subsection is an overview of recommendations deemed significant based on the analysis of the Santa Cruz Mid-County and Cuyama Valley GSPs. A final subsection with literature-based minimum provision guidelines for groundwater management that provides a standard all GSAs can follow. The Saito et al. (2021) framework is based on the sustainability of the resource along with considerations of the ecosystems impacted by the area of withdrawal. The frameworks emphasis on maintaining a high-functioning ecosystem in regions of withdrawal takes on adaptive management strategies that preserve all species need for water resources, not only humans. The key take-away of adaptive management is the conservation approach. The approach involves the establishment of an agency that monitors, manages, and adjusts the natural system on the basis of trends observed (Saito et al. 2021, Nie and Schultz 2012, Thomann et al. 2020).

Monitoring Recommendations

Upon the analysis of the Santa Cruz Mid-County and Cuyama Valley GSPs, the following are recommendations meant for those GSAs that created each GSP, in addition to some state level water regulation recommendations. These recommendations focus on improvements of groundwater monitoring, arguably the most fundamental method in managing a groundwater basin.

Firstly, creating a monitoring schedule with regular frequencies of measurement should be adopted. Regular day and time intervals of groundwater elevation and quality measurement will offer consistent data and allow for more accurate analysis. Data loggers should be scheduled to record at the same time intervals as other monitoring wells in the basin to have a sufficient amount of empirical data. Further, implementing data loggers in each representative monitoring well will allow the GSAs to create a regular scheduling of data record and establish consistent long-term data acquisition. MGA has all but two representative wells equipped with data loggers, allowing for sufficient data collection for a more accurate model and better insight into the status of each well location. Implementing data loggers can be costly however, at around $700 per device.

Secondly, spatial variability of monitoring well locations should be quantified based on the hydrogeology of each basin or aquifer. Each of the agencies GSPs expresses the need for more monitoring wells throughout areas that are more difficult to access but would be scientifically important for better understanding of groundwater flow. Installation in areas that are recommended by technical groups including geologists and hydrologist will allow for a better understanding of how the changes in groundwater levels are affecting the entirety of the basin. In Cuyama Valley, there are more existing USGS wells than any other organization but because they were not measured regularly or recently, these wells were unable to be incorporated into their associated representative monitoring networks.

Thirdly, installation of monitoring wells with varying depths should be prioritized. As stated earlier in this paper, varying depths of monitoring wells provides thorough analysis of the various areas in aquifers that are being withdrawn. Varying depths also aid in water quality assessments, connections to surface water, and when applicable, insight to seawater intrusion.

Fourth, there should be an increase the number of streamflow gauges to improve surface water monitoring and the understanding of its interconnected relationship with groundwater. This is largely related to USGS, as they are the main distributor and operator in charge of streamflow gauges. This increase in streamflow gauges aids in SGMA's requirement for developing sustainable management criteria on the depleting interconnected surface water supplies (DWR and SGMA 2017). This interconnected relationship is also better understood by an increased number of shallow monitoring wells.

Fifth, federal water regulations should be amended for state and local agencies to regularly monitor private wells. This may be one of the most complicated recommendations due to water rights in California. Currently, groundwater regulation is settled in court on a case-by-case basis. This can be a long and arduous process if trying to regulate numerous private well owners. Regulation of groundwater is only permitted and ruled in court when the user is accused of unreasonable, illegal, or wasteful use. Local groundwater agencies do not have to time or money to attempt the legal processes necessary to investigate and pursue regulation of these private wells. In addition, there would likely be a significant political response to landowners' privacy regarding the use of their water right. This is usually adjudicated[10] in settlement when one or more landowners has a conflict with neighboring users of the same water right.

Sixth, SGMA should include best management practices that require delineation of the bottom extent of each basin. The BMPs for the Sustainable Management of Groundwater states "the definable bottom of the basin should be at least as deep as the deepest groundwater extractions." Yet approximately 60 percent of the GSAs in critically overdrafted basins have ignored this recommendation and used the outdated US Geologic Survey maps in their mandated Groundwater Sustainability Plans (GSPs) (Thompson et al 2021).

The Santa Cruz Mid-County GSP/ GSA exhibits strengths in its monitoring and minimum threshold protocols. Unlike the Cuyama Basin that indicates undesirable results that must be ongoing for a period of two years before any restrictions or modifications to production be implemented, this GSP acts when a location exhibits a month of values below the minimum threshold. This management effort defined in the GSP supports the data that I collected in my original analysis, indicating more frequent measurements with some data loggers recording as

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[10] Make a formal judgment or decision about a problem or disputed matter.

often as 15-minute intervals. Although the current models developed with USGS provide useful insight for groundwater management of each basin, their results are limited by the amount of elevation data available for input. These groundwater models are also made less accurate for water budget predictions because climate change has become a growing factor creating significant changes in annual precipitation and warming temperatures.

Current resources for implementation of the above management recommendations are limited by availability of state and federal grants as well as a local government budget that historically did not allot for groundwater monitoring methods and infrastructure. SGMA has given these local agencies a chance to thoroughly assess and recommend their need for new developments to sustainably manage each basin.

GSP Minimum Provisions

Much of this analysis was inspired by the lack of a universal standardized protocol of measuring groundwater elevation data. This is likely due to the structure of monitoring rapidly changing over recent years and the different monitoring organizations involved in data retrieval. Because the elevation data is collected by multiple organizations, inconsistencies in quantitative methods such as how often a well is measured creates a dataset that is difficult to capture collectively. Implementing a standard may prevent future data gaps and provide a baseline for the resources needed at each governing agency to properly manage their groundwater supply.

Although the aim of this paper is on groundwater elevation monitoring, Saito et al 2021 provides a framework that specifically seeks to protect all species in groundwater dependent ecosystems (see Table 5). The ethical and political issues arise when potential regulations or policy changes are discussed regarding the curtailment of water resources. The focus of the recommended provisions is sustainable yield in arid regions, like the Central Coast of California.

Provision 1: Clearly define management goals and objectives. This is certainly discussed in SGMA and both GSPs evaluated. The sustainable goals, minimum thresholds (MT), and measurable objectives (MO) are the specific goals for each basin to increase sustainability. The longer history of data accumulated, the more accurate and obtainable these goals and objectives will be.

Provision 2: Define science-based protective triggers for action. This is overlooked in the GSPs and would be a useful tool in reversing a trend toward minimum threshold, e.g., Cuyama Basin land subsidence occurs annually but no measures are taken to stop the subsidence because the overall subsidence is above the minimum threshold. This keeps the regulatory agency (DWR) from corrective action and allows the basin to continue in the negative trend.

Provision 3: Use predictive groundwater and ecological models to prioritize the most effective management strategies. This provision is currently used successfully with USGS models modified to fit the characteristics of each basin. These models allow GSAs to develop future water budgets based on historical water data and ecological assessments to account for future management needs.

Provision 4: Include appropriate monitoring at the right temporal and spatial scales. This provision alters the minimum threshold and sustainability indicator methods that SGMA recommends. Instead of waiting until these undesirable results occur in a basin, a thorough ecological assessment should be performed with sufficient climate and hydrological data to prevent negative results. Since undesirable results are often observed much later than their cause e.g., overdraft, it is best to implement guidelines that factor in the duration of time these negative effects might occur at the current rate of use.

Provision 5: Provide accessible and timely reporting of data. This provision is supported in SGMA’s stakeholder engagement requirement which encourages participation from community members and leaders in the GSAs plans for the basin. However, not all data is reported instantaneously, which could be a valuable platform for the public to access and understand the status of their water resources. Groundwater elevation data is not reported at the same transparent level as water quality levels and would be a useful tool for public outreach.

Provision 6: Implement effective management actions if triggers are reached. Each GSA should have an adaptive management strategy when undesirable results have been observed to stop the effects before, they are irreparable. This is achieved most effectively as a change in the regulation or increased limitation of water use. Other methods of change are mostly ineffective and may not reverse the negative impacts already incurred on the effected ecosystem.

Provision 7: Secure adequate funding and capacity for project planning, implementation, monitoring, and reporting. GSAs have limited funding options because previously implemented water resource plans and monitoring did not include groundwater to such an extent until recently. The cost of planning and implementation is often funded by grants but is restricted due to the vast majority of basins in California that are relatively just beginning to create a groundwater sustainability plan. Although necessary, the state cannot afford to completely redesign water resource management agencies across California simultaneously in such a short period of time.

Table 5: Framework for groundwater management provided by Saito et al. 2021.

Provision	**Description**
1	Clearly define management goals and objectives.
2	Define science-based protective triggers for action.
3	Use predictive groundwater and ecological models to prioritize the most effective management strategies
4	Include appropriate monitoring at the right temporal and spatial scales
5	Provide accessible and timely reporting of data
6	Implement effective management actions if triggers are reached
7	Secure adequate funding and capacity for project planning, implementation, monitoring, and reporting

Conclusions

Managing groundwater currently lacks much needed supportive laws and policies to protect and sustain the cumulative supply and its relationship to surface water supplies. Groundwater management at a regulatory level is a relatively new concept and work in progress for many water users. Current federal law states that any landowner or groundwater rights holder may withdraw an unregulated amount of water from their underlying basin with reason and beneficial cause. Private wells continue to lack any monitoring unless voluntary due to current federal water rights, and extraction is only estimated. This is a problem because it allows users to over withdraw from their underlying basin until there is indication of short supply occurring. Sustainable groundwater management methods are improving rapidly and the passing of SGMA in 2014 has kickstarted this process. As groundwater regulation becomes amended and approved, enforcing agencies will have to consider the growing population, changing climate, and existing federal water rights to account for future water use. With stricter regulation, groundwater resources can be managed to prevent shortages instead of focusing plans for when a shortage occurs.

On June 3rd, 2021, the DWR approved the 2019 Santa Cruz Mid-County GSP. The 18-month long evaluation resulted in one corrective action. The corrective action requires that GSA focus on further explanation of how groundwater level minimum threshold values are determined. The monitoring network of 17 multi-depth wells throughout the basin was approved to be a sufficient effort in observing groundwater levels. This result supports my GSP and original data analysis that MGA is collecting a sufficient amount of data and has a relatively developed monitoring network. This result is highlighted by the fact that MGA (formerly GMP enacted in 1995) was developed well before SGMA was enacted.

On June 3rd, 2021, the DWR warned the CBGSA of several deficiencies in their GSP to be corrected within 180 days. The corrective actions are numerous, but some important deficiencies found in their GSP relating to this analysis include: the lack of justification for minimum thresholds and undesirable results, does not address how overdraft will be mitigated, does not fully address degraded water quality with available public reports, and does not use adequate science to describe how groundwater levels will be used to monitor interconnected surface water depletion. Following consultation on these deficiencies, on January 21, 2022, the DWR determined the Cuyama GSP incomplete. If the CBGSA is unable to address deficiencies by July 20, 2022, the GSP will be deemed inadequate and require state intervention. This is supported in my analysis of the GSP and original data collected for the area. Figure and Figure show the current trend of Cuyama groundwater supply and elevation. The CBGSA does not have the same level of historical data as MGA because it was established shortly after SGMA was passed in 2017.

Collection of sufficient groundwater data is essential in creating sustainability plans because they are necessary for the current groundwater monitoring methods available. There cannot be an accurate minimum threshold established without scientific evidence to support a basins limitations and proven fluctuations. Management of the various groundwater basins in California vary not only in their hydrology and geology, but also in when their sustainability efforts begin.

The management recommendations directed toward GSAs mentioned previously are based on the needs of the two basins in the study region and are exemplary of the varying data gaps based on the current conditions and management practices in a region. The management recommendations based on Saito et al. (2021) framework can be used in conjunction with current SGMA guidelines and can be applied to all GSPs.

The results of these analyses show that successful management is seen the sooner an agency begins to collect groundwater data and the larger the effort on collecting at a sufficient quantity and frequency. The most valuable takeaway from this analysis is to identify data gaps and allocate funding to the areas where monitoring could be most improved based on scientific evidence. This process is time consuming as is the implementation of an approved GSP and its various measures. Developing ways to provide quicker access to these monitoring improvements is essential to solving the California groundwater supply crisis and the potential global water crisis we are facing.

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Appendix A

Interview with Sierra Ryan

Research question: How can you identify data gaps in groundwater monitoring and develop adaptive management strategies to reach sustainability goals?

Interviewee: Sierra Ryan, Santa Cruz County Environmental Health, Interim Water Resources Manager, sierra.ryan@santacruzcounty.us

Manages the water resources sections of Environmental Health Services Agency (HAS). Coordinates water resource management activities among the other county departments and works closely with other local, state, and federal water supply and resource management agencies in the County and the Central Coast. She is an excellent resource in discussing the methods of current groundwater measurement protocol in the Central Coast Hydrologic Region, more specifically within Santa Cruz County.

Introduction: My name is Kayla Souza, and I am researching groundwater sustainability management and methods of groundwater data collection. I would like to assess the main management concerns of small-scale aquifers and the gaps in data collection occurring at Cuyama and Santa Cruz Mid-County Basin. I currently work as an environmental consultant in the Central Coast with aspirations of becoming a water resource specialist in my region/department. I am speaking with Sierra Ryan who is the current Water Resources Manager at the County of Santa Cruz Health Services Agency (HAS).

Transcript:

Q: Sierra my first question for you is what do you like about your current role as the water resources manager? I know you used to be a planner, so what are some differences you're seeing there?

A: I just started this is actually my first week in this new position officially. I've been interning since January, but the difference in the role from my previous position is I'm really now doing a lot of the planning like the big picture planning and coordination and trying to figure out the role that the county as an entity can play in benefiting water resources throughout the county as a geographic region into the long-term future. So, our water resources here in the county are significant because we're hydrologically isolated from the rest of the state so we don't bring in water or send water outside our boundaries. Everything that we have is sourced locally. It all originates as rain and then we get it either as surface water diversions or groundwater coming through groundwater pumping. There's a small amount of recycled water but that's right now only being used for irrigation so there's a lot of need looking towards the future in the face of climate change to be kind of nimble and proactive in trying to kind of store up the resiliency of our water supplies so that there is enough through the face of potentially extended drought. There's enough water for people, for our consumption, for health and safety, for irrigation, as well as protecting the natural environment (making sure there still enough water in the stream to support healthy fisheries and ecosystems). In the past I was doing a lot of the work but now I get to do the work and also kind of decide what work needs to be done.

Q: Do you still hold a current role at the mid county groundwater agency?

A: I do, yeah. So, I'm now one of the executive staff members. So, there's four member agencies of the joint powers that form the mid county groundwater agency and the county is one of those member agencies and we have two county supervisors who sit on the board of directors. The person in this role (the water resources manager) sits on the executive staff team. We have a joint staffing model to the Mid-County Groundwater Agency, so it doesn't have its own director or its own staff. It's managed jointly through this kind of joint staffing model where the executive staff of all of the agencies create this executive team who act kind of as the executive director would. They're doing the planning and the long-term programmatic developments and making the decisions deciding what goes to the board and needs to be done, when we need to do outreach, and when we need to hire consultants to do studies. So, there is some talk of changing that model. Right now, it is pretty challenging for the staff to be doing their own jobs and then also managing this other agency and we definitely want to make sure that the agency is able to thrive and fulfill its mission, so we might in the long run start looking, or actually maybe even in the near term, start looking to kind of change that model a little bit.

Q: So, a big thing that I am trying to figure out when I'm looking at the data is, what are the sampling methods and techniques that are actually being implemented? When I look at the groundwater levels, I see a lot of negative values in the Santa Cruz basin. I’m curious about the sampling methods, if there's a protocol and if you know much about it. What's the relation of the negative and positive elevation values I am seeing?

A: So, if you have groundwater elevations that are below sea level that is just asking for trouble in a coastal aquifer because you invite seawater intrusion. That's what that those negative values are relative to I believe. Our sampling methods are through a vast network of monitoring wells in terms of groundwater elevation we have all of the water supply wells in the basin that are municipally run have data loggers that are measuring their depth. There's also monitoring wells that all of the water agencies already had in place throughout the basin adjacent to like near their production wells but not so close that they're being directly impacted by pumping on like a daily basis and that's been in place for a long time so that the water agencies who depend on the basin could keep an eye on things like seawater intrusion and depleted groundwater elevations that aren't increasing overtime. That basin in particular has suffered pretty significant overdraft over the last…really from the 80s to the early 2000s there was some pretty significant over pumping and groundwater elevations fell. They're still operating in a deficit where recharge is not keeping up with extraction overall, although the individual water agencies have really dramatically improved their water use some. Most water agencies now are using about the same amount of water they were in the 80s, but the population has increased pretty dramatically. There are still other pumpers in the basin that aren't municipal that are maybe not keeping up with that and aren't making those dramatic changes such as agricultural users. So, the water agencies have to keep a close eye on groundwater elevations so they've got their own logger, their own wells with their own loggers and they collect data as often as they need to, which is probably in general more often than the groundwater agency will need to. There's also a series of wells along the coast that are called the sentinel wells. The idea is that they act as sentinels or seawater intrusion, so they're looking more at water quality than elevation but there's such a strong relationship in a coastal basin between groundwater elevation and the risk of seawater intrusion that we need to make sure that we're tracking both of those things and then all of that information is put into our groundwater model which is the USGS MODFLOW base model. That kind of he creates the elevation maps. Topographic isn't the right term but the elevation maps that kind of smooth everything out. So, we have data points, and the model is kind of used to smooth that out to give us a sense of what's happening throughout the basin since we don't have points everywhere. So, there's times moving there and that's updated pretty frequently as part of the 3030 compliance and now will be wrapped into the groundwater annual groundwater update. So, you'll be able to see changes and there's always changes in groundwater elevation annually. You see higher groundwater elevations during and after the wet season and then during the summer and fall groundwater elevations that are lower there's no recharge happening and people are using more water for irrigation and things like that, and more evapotranspiration from plants because it's hotter in the days are longer. So, it's kind of a triple whammy that hits the basins during the summer where you have increased evapotranspiration essentially no recharge happening, at least naturally, and then increased pumping due to irrigation. So, if you're trying to figure out groundwater elevations, if you want to see worst case scenario, you kind of look at what's it look like in September/October and then best-case scenario is usually like March or April.

Some people have daily information coming from their data loggers and some people, usually what happens is that if it's data loggers (it's collecting data kind of constantly) and then we downloaded every month. Maybe not even every month, more like quarterly. We also had the county do twice a year-- we go out and do manual sounding so we take a sounder out to a network of I think about 40 wells throughout the county that are all private (individual people's private wells) because we don't have, you know I don't know if we're going to transition into data gaps but, the area that we have the least information is these aquifers that are not being used for municipal supply but are being used by individuals for their private wells. They tend to be much shallower, they tend to have less fluctuation, there further from the coast in general. We go out twice a year. So, we got in like April and October and do well soundings to measure elevation there. So, overtime that's valuable because you kind of get the high and the low and you can look for trends but it's certainly not anywhere near the level of data collection that we have at least municipal monitoring wells.

Q: Do you feel like the methods provide sufficient data currently?

A: No. We identified in the plan there are some areas of data gaps. So, currently we don't have a good network of shallow monitoring wells. In the areas of the most significant pumping, we have plenty of data for management purposes but then trying to define the impacts of groundwater pumping on surface water is the probably the most challenging component in SGMA and it's certainly the area that we have the least information. Frankly, Mid-County Basin has more data than probably any other basin in the state on surface water impacts because we have been looking at that already. We're installing 10 (now 77) or 8 monitoring new monitoring wells. We're in the process of identifying the best locations for those now and getting permission to install these new wells. These wells are going to be between 40 and 60 feet below ground surface to try to get out the impact of pumping on stream flow. They're going to be paired with nearby stream gauges to kind of see overtime if changes in groundwater elevation are impacting stream flow. Our model says that there is a correlation. We have not been able to detect it in the monitoring that we've done so far, and we have, like I said, there are some areas where we have pretty extensive monitoring where we have (data) loggers, and the department prefers loggers in the shallow aquifer and stream gauges near each other. We cannot detect the relationship between the elevations in the deposit before, where people are doing the pumping and the stream flow. But our model says that there is probably A 1.4 cubic square foot reduction overall throughout the basin, which is a little hard. It isn't particularly meaningful that the model thinks that there's a relationship, we just don't have enough data points to measure it yet though. That's probably our biggest data gap is these shallow aquifers. Also, to a lesser extent (just because we think it's less important), but some of the areas away from the coast (more in the in the hills) we have a lot less monitoring data. But we also don't expect that those areas have been badly impacted. We're not seeing groundwater levels in a way that we think will impact any beneficial uses there, so we don't feel the need to fill those gaps right now. But it is always great if private well owners allow us to go monitor their wells because maybe there are pockets of areas that are experiencing depressed groundwater elevations that we just don't know about. Mid-County Basin is considered coastally influenced (to into a groundwater elevation of 50 feet), so 0 feet is essentially sea level. 50 feet elevation is where we still think that it's kind of driven by the coast and then kind of from there inland is what we have been considering the inland areas. So, the geography of Santa Cruz is that we have all these coastal terraces that are flat and then we have mountains. So, it's like once you start getting into the mountains the influence of the coast is much less important and concerns end up being less about seawater intrusion and more about impacts the stream flow and potential impacts of lower groundwater levels on private wells.

Q: What aquifer recharge projects have you worked on and what type of result can we expect?
A: You know, the Mid-County Basin is not well suited to recharge unfortunately compared to the types of managed aquifer recharge, like Cuyama I'm sure it is very well suited to recharge projects. Corcoran clay is an issue impressed with the Central Valley I don't know if it is in Cuyama, but the recharge projects haven't been really successful in Mid-County. We've done a few now but there's a number of reasons why it just isn't penciling out to be a very big component of the project. So, if I if you're talking about like stormwater recharge projects, the

problem is mainly that we have a stacked aquifer system here. It's really complicated, so if you're recharging through stormwater, essentially, you're likely only recharging the top one or two aquifer levels which is not where most of [water is stored]. So, to do a stormwater recharge project where you're getting into the area of pumping, you’re drilling down and you're doing dry wells. That's kind of the only way to do it and then there's this issue if you're using dry wells of ensuring that the water is clean enough to be recharged into the aquifer you have to deal with the fact that you do have these other aquifer levels above it that make it almost impossible to get to the area that you want to recharge because you can't put a dry well through other areas of water. You just end up getting the water coming in from the top layers, so that's been a real challenge for identifying sites. Another component is the very high value of land here. Like in parts of the Central Valley they have these recharge areas, and even in Pajaro, there are some areas of recharge projects that are multiple acres in size. But land here (Santa Cruz County) goes for the cost of installing a project. First you have to spend $300,000 on land and then you start doing the project. The area that the projects would probably actually have the most benefit would be projects up in the mountains because that's where the prime recharge happens. To get it to the areas of municipal pumping plays a part. There's not a lot of development out there so there really isn't much need for these recharge projects. That land is all sloped so you can't really do like a basin, and it recharges on its own pretty well. Anyway, I think it is clear what we're going to see is that the most effective way to recharge our basin is through projects like **** for storage and recovery or advanced purified recycled water which is the main plan in this basin. Both of those two together, where we're actively injecting directly into the aquifers what we're pulling out of it. So, it's less larger quantities of water. You're not dependent on storms to bring in water and you are treating the water before it gets in there. The one thing about depressed groundwater levels is it sort of creates this hole that you can put more water in. So yeah, the stormwater recharge, managed aquifer recharge, flood water recharge, those are all kind of I think really vital pieces of water management in like the Central Valley and Pajaro and of itself many other parts of the state. But it seems like here it's going to be a much smaller piece it's not going to solve anything. It might help, but there's a lot a lot of challenges. You know we did an extensive research process trying to identify the best places to do recharge and the best project was like 11-acre feet and it's going to cost $450,000. It's great to try to do things like that, it's great to try to do the research. That is something that maybe private developers could do as part of their development projects because maybe that's the way that we kind of at least offset some impacts that, yeah $450,000 for 11-acre feet of unreliable water because it depends on storms is just not a real viable solution. We have a clay layer here that kind of occupies the top 15 feet of soil, so bioswales on their own just sit there and become stagnant pools because there's no recharge happening through the place. So dry wells are really the most effective way to get water in and take up the least amount of space but they're expensive and still don't provide a huge amount of water.

Kayla: I really appreciate you meeting with me. This was so awesome and helpful. Thank you so much have a good week.

Sierra: You too, Kayla. Bye, bye.