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The Sustainable Groundwater Management Act of 2014: A Comparative Analysis of Alternative Management Plans and Adjudications

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ABSTRACT

The confluence of an antiquated water rights system, unpredictable supply, and political intervention fostered legislation that became known as the Sustainable Groundwater Management Act of 2014. The trio of legislation signed into law on September 16, 2014, by Governor Jerry Brown revolutionized an entrenched and fiercely independent management of California's groundwater. The last western state to adopt comprehensive groundwater management, California was reeling from an epic drought that found many areas without water. Political pressure paved the way for overwhelming support for groundwater governance. Groundwater resources, typically 40% of the annual water supply swelled to 60% during the drought. Excessive pumping of the ungoverned resource in some areas caused wells to go dry, streams and habitats to suffer, and water quality to degrade. The legislation included AB 1739 (Dickinson), SB 1168 (Pavley), and SB 1319 (Pavley), which set forth the framework for groundwater governance highlighted by an historic drought beginning in 2012 and concluding in 2015, 1 year after the legislation was signed into law. The study evaluates the compliance of 2 groundwater groups: Adjudicated groundwater basins and users submitted an alternative management plan attesting to sustainable actions that comply with the new law.

Keywords: alternative management plans, adjudication, SGMA, Sustainable Groundwater Management Act

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My passion for water management is born out of the desire to be a good steward of the God-given resources we enjoy on this earth. My love for water resource management ignited the idea for this research of California's new groundwater governance. This study has only scratched the surface of an exploding topic in new groundwater governance.

My love for water resource management can best be summed up by borrowing the words of George McDonald (Scottish minister/author, 1824-1905):

> There is no water in oxygen, no water in hydrogen: it comes bubbling fresh from the imagination of the living God, rushing from under the great white throne of the glacier. The very thought of it makes one gasp with an elemental joy no physician can analyse. The water itself, that dances, and sings, and slakes the wonderful thirst—symbol and picture of that draught for which the woman of Samaria made her prayer to Jesus—this lovely thing itself, whose very wetness is a delight to every inch of the human body in its embrace—this live thing which, if

I might, I would have running through my room, yea, babbling along my table—this water is its own self its own truth, and is therein a truth of God.

DEDICATION

This research is dedicated to all the men and women with whom I have had the privilege of working during my career. The unseen dedication and expertise goes unacknowledged and unnoticed as you go about your daily tasks. Only you truly know what it takes to provide the vital health and safety services that are so often taken for granted.

To my colleagues at the regional and state boards who fiercely guard water quality to ensure its beneficial uses, thank you for the challenging work you do.

To the amazing staff at the Helendale Community Services District who comprise my work family. I am so proud of our team and the unbelievable things we have accomplished when others said we would fail. I so much appreciating experiencing life with all of you on a daily basis. You inspire me. I am so fortunate to be part of the CSD family.

Lastly, thank you to the amazing staff at Mojave Water Agency who ensure water for today and the future for the half million people in the High Desert area of the Mojave Desert.

I am proud to be one of you as we contribution to the greater narrative of water resource management on a daily basis.

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CHAPTER 1: INTRODUCTION TO THE STUDY

It is life, I think to watch the water. A man can learn so many things.

—Nicholas Sparks, *The Notebook*

Throughout California's history, water rights have been a source of contention, which has been further exacerbated by prolonged periods of drought impacting both surface and groundwater. A statewide drought emergency was declared during the 2012-2015 drought highlighting the insufficiency of above ground storage (Hanak, Mount, & Chappel, 2016), as surface water reservoirs were drawn down to historic lows (Mettler, 2016) shifting the burden of supply to already stressed groundwater reserves. Groundwater as defined in California Water Code section 10721 is "water beneath the surface of the earth within the zone below the water table in which the soil is completely saturated with water."

During the drought, more than 3,500 wells around the state went dry, substantiating the need for better management or regulatory oversight (Pitzer, 2017) of California's overutilized and underregulated resource (Perona, 2015). Previous efforts to collectively manage groundwater resources through voluntary compliance resulted in minimal participation and lack of desired coordination.

The most severe areas of groundwater overdraft are coincidentally within some of the richest and most fertile farmland in the nation representing over $43 billion in agricultural industries providing "one-third of the nation's vegetables and two-thirds of the nation's fruits and nuts" (Mettler, 2016, p. 242). Over the past decades, farmers in California's San Joaquin Valley have been facing reduced surface water allocation from the State Water Project and the Central Valley Project because of drought and mandated water supply reductions creating the need for farmers to utilize greater quantities of groundwater (Mettler, 2016). There is little coincidence that many of the high and medium priority basins are located within heavy agricultural areas. In many cases, there is not sufficient recharge to replace what is pumped, thereby exacerbating the overdrafted condition of the groundwater tables and resulting in undesirable negative impacts. Subsidence has been a widely noted problem in the Central Valley with some areas having lowered several feet in elevation (Romero & Berber, 2018).

Responding to the drought crisis, the convergence of environmental, political, and social pressures forged the path for comprehensive statewide management of California's fragile groundwater supply. The passage of the Sustainable Groundwater Management Act of 2014 (SGMA) established a framework for oversight and mandated criteria for groundwater sustainability.

To help contextualize the importance of the topic, groundwater accounts for approximately 38% of total annual water supply in California (Mettler, 2016), and many groundwater basins are in overdraft, a condition wherein more water is removed from the groundwater aquifer than is being recharged through rainfall or snowmelt. Overdraft puts the resource in peril from both a quantity and a water quality perspective. In many cases water in the deeper aquifers does not meet drinking water standards.

The SGMA defines groundwater basins in Title 23 of the California Code of Regulation as an "aquifer or stacked series of aquifers with reasonably well-defined boundaries in a lateral direction, based on features that significantly impede groundwater flow, and a definable bottom" (California Department of Water Resources [DWR], 2016a). Figure 1 helps to provide a visualization of the concepts of basin and subbasins by graphically illustrating the terms *groundwater basin* and multiple *subbasins* within a larger groundwater basin. As shown, basin boundaries have physical parameters such as subterranean bedrock and visible mountain peaks; subbasin boundaries within the larger watershed boundaries can be based upon other factors including geology, streams, rivers, and nonphysical boundaries such as jurisdictional boundaries as illustrated in Figure 1.

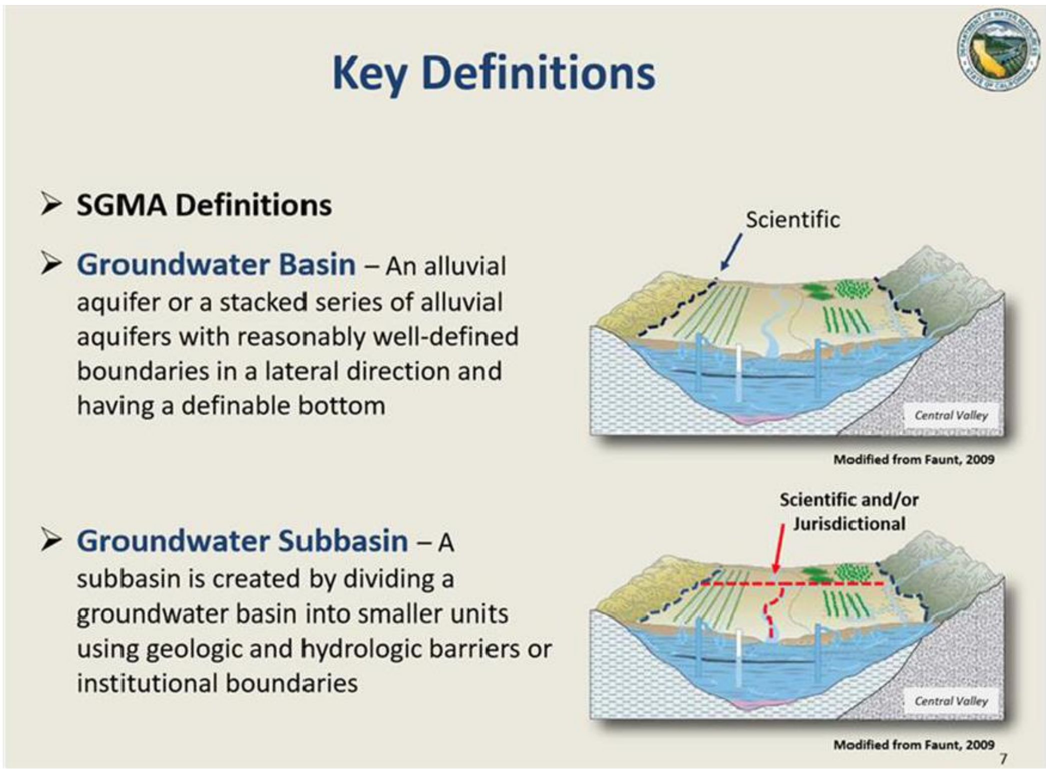


Figure 1. Groundwater basin and subbasin graphic and definitions as used in the Sustainable Groundwater Management Act of 2014. From California Department of Water Resources website (https://cwc.ca.gov/Documents/2016/07_July/July2016_Agenda_Item_10_Attach_2_Powerpoint.pdf).

Drought Conditions

California overdrafts 1.4 million-acre feet of groundwater each year and in dry years that can increase to 7 million-acre feet (Kerns & Parker, 2018). This is water that is removed from the aquifers and not replaced. Overdrafting the groundwater aquifer depletes the resource in storage and can result in numerous negative impacts including loss of vegetation, impact to rivers and streams, and degraded water quality and land subsidence. During California's recent epic drought, many wells across the state went dry bringing into focus the need to better manage this hidden resource in contrast to surface water that has been highly managed for over a century (Littleworth & Garner, 1995). The depletion of this natural resource affected individuals who relied on private wells, farmers who irrigated crops, municipal water districts providing water to customers, and industrial users alike. Such depletion of a common resource is referred to as "tragedy of the commons" (Ostrom, 2007, p. 15183).

While California is typically leading the rest of the nation in environmental regulations, it was the last of all western states to regulate groundwater extractions (Perona, 2015). In response to the most severe drought in California's recorded history (2011 to 2015), Governor Jerry Brown issued three emergency orders—B-17-2014, B-25-2014, and B-29-2015—mandating certain conservation water use restrictions for practices that were considered wasteful (California Water Boards, n.d.). He also directed the State Water Resources Control Board (SWRCB) to develop regulations that resulted in mandatory cutbacks of water use up to a 32% reduction (California Water Boards, n.d.). Lack of compliance by some regulated water districts resulted in the issuance of notices of violation and the threat of further action.

Simultaneous with the apex of the drought, a trio of legislative actions were working their way through the state legislature: Senate Bill 1168, Assembly Bill 1739, and Senate Bill 1319, which have now been codified in the state's Government Code and Water Code (Water Education Foundation [WEF], 2015). These three bills contained the tenets of the SGMA. In a state that is prone to drought cycles and has a high dependence on groundwater resources SGMA was a long-overdue management strategy (Perona, 2015).

The passage of the SGMA, outlined the structure of groundwater management and designated the Department of Water Resources as the primary agency responsible for implementation of SGMA with involvement by the SWRCB in areas of noncompliance. The initial critical focus for SGMA compliance has been on medium-priority and high-priority groundwater basins as defined by the Department of Water Resources. The act defines sustainable groundwater management as "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results" (WEF, 2015, p. 5). Following are the six specific undesirable results:

- Chronic lowering of groundwater levels
- Significant and unreasonable reductions in groundwater storage
- Significant and unreasonable seawater intrusion
- Significant and unreasonable degradation of water quality
- Significant and unreasonable land subsidence
- Surface water depletions that have significant and unreasonable adverse impact on beneficial uses. (DWR, 2015b, p. 16)

The SGMA required all high-and medium-priority nonadjudicated basins to comply with the new law in one of two ways: Submit an Alternative Management Plan (AMP) by January 1, 2017; or form a Groundwater Sustainability Agency (GSA) by July 1, 2017. Twenty of the basin areas submitted AMPs by the required deadline, providing evidence of existing plans that meet the required conditions or an analysis of basin conditions that demonstrate that the basin has operated within sustainable yield for the past 10 years, exempting the basin from certain criteria.

Understanding Basin Prioritization

Beginning in 2009, with the passage of SBx7-6, the state legislature mandated that the DWR begin collecting groundwater elevation data in an effort to understand the condition of groundwater basins throughout the state. The California Statewide Groundwater Elevation Monitoring (CASGEM) database has been a foundational tool for assessing the condition of the state's basins. During the last several years as the groundwater database has developed, trends began to emerge that required further assessment.

In 2014, prioritization was assigned to all 517 identified groundwater basins based upon the following factors outlined in DWR's (2018a) publication entitled *2018 SGMA Basin Prioritization Process and Results* published in May 2018 and available on the California DWR website:

- The population overlying the basin.
- The rate of current and projected growth of the population overlying the basin.
- The number of public supply wells that draw from the basin.
- The total number of wells that draw from the basin.
- The irrigated acreage overlying the basin.
- The degree to which persons overlying the basin rely on groundwater as their primary source of water.
- Any documented impacts on the groundwater within the basin, including overdraft, subsidence, saline intrusion, and other water quality degradation.

- Any other information determined to be relevant by the department, including adverse impacts on local habitat and local stream flows. (DWR, 2018, p. 2)

Prioritization of basins is to be updated from time to time by the DWR based upon ongoing monitoring and including such updates in the department's Bulletin 118 issued every 5 years. Of the 517 identified groundwater basins, 109 were identified as high- or medium-priority basins representing 96% of the groundwater pumping in the state (DWR, 2015a). The balance of 408 basins was classified as low- and very-low-priority basins representing the remaining 4% of groundwater pumping. Figure 2 illustrates the locations of the groundwater basins assigned a high priority shown in orange and medium-priority basins shown in light orange. Low- and very-low-priority basins are shown in green and light green respectively.

Statement of the Problem

Prior to the passage of the SGMA, only 22 groundwater basins had governance structures in place that regulated groundwater pumping through an adjudicatory process (Womble & Griffin, 2015). These basins sought self-governance to ensure that the allocation of groundwater pumping rights was formalized. With 517 defined groundwater basins identified by the DWR, only 5% were adjudicated, leaving 95% with no formalized management structure overseeing the quantity of groundwater extractions typically viewed as property rights.

SGMA mandated that governance structures be established in all high- and medium-priority basins not covered by an adjudication. The focus was on the 43 groundwater basins identified as high priority and 84 basins identified as medium priority that represented 96% of the state's total annual groundwater pumping (WEF, 2015).

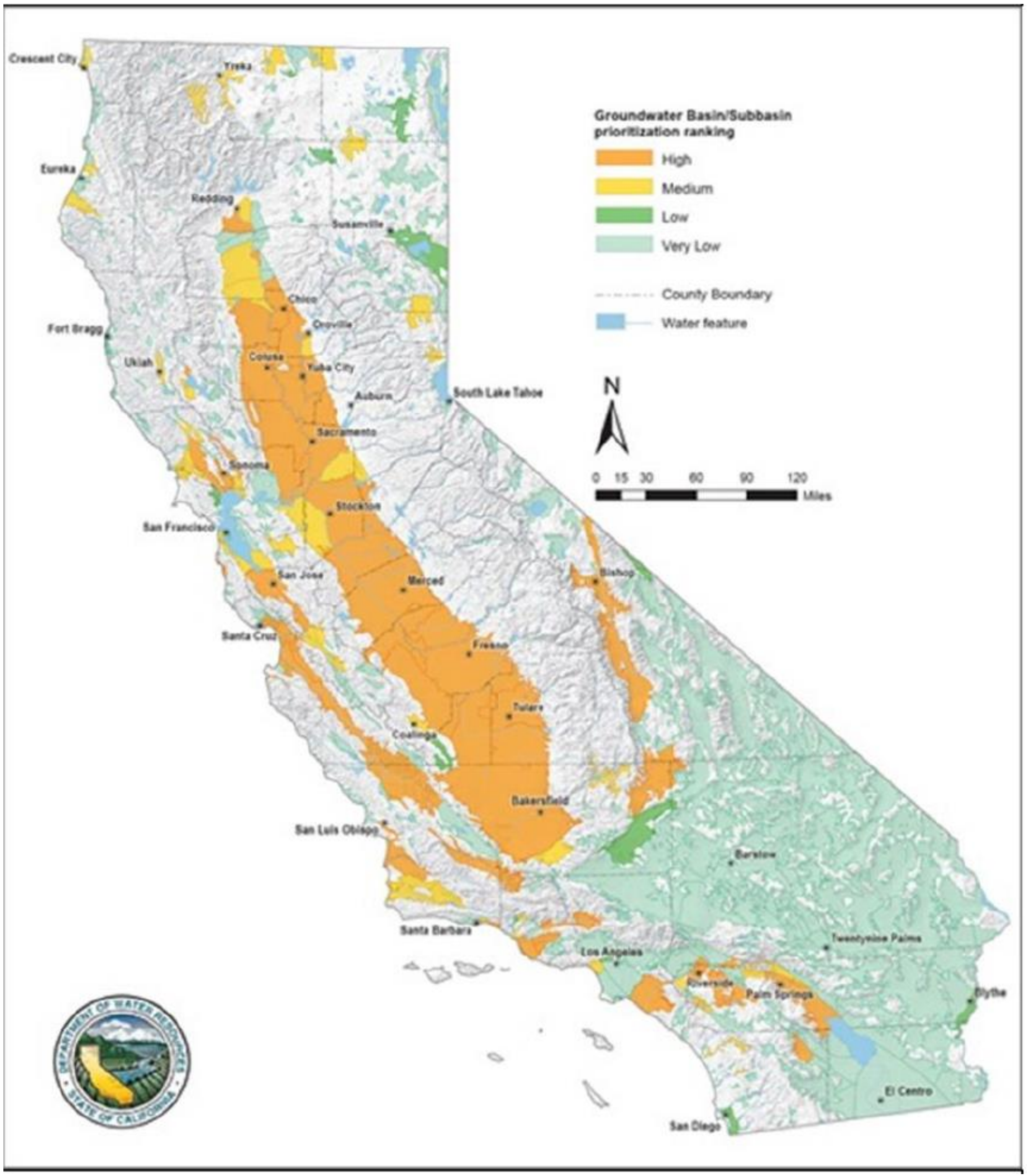


Figure 2. GASGEM basin prioritization map. From 2018 SGMA Basin Prioritization Process and Results, by California Department of Water Resources, 2018 (https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Basin-Prioritization/Files/2018-SGMA-Basin-Prioritization-Process-and-Results-Document.pdf?la=en&hash =CF36B2D7A806112FDF1BB0B62269 1982B69520D). *Note.* Basins that are high and medium priority basins—basins that are in significant overdraft, re displayed in dark orange and light orange. These basins are the primary focus of SGMA.

The law allowed for flexibility in how an area complied with the sustainability requirements by allowing for two methods of compliance. A basin could choose the formation of a GSA or submit an alternative management plan. The formation of a GSA would result in the creation of a new entity or an additional function for an existing entity that would be fee supported. Conversely, the submission of an alternative management plan would require providing evidence attesting to current practices that satisfy the newly established sustainability criteria.

In the future as basins are reclassified from low or very low priority to a medium or high priority, they will need to choose a compliance method to satisfy the sustainability requirements. A third option exists for these reclassified groundwater basins and that would be to adjudicate through a court process. Adjudications are currently exempt from compliance with the specific criteria outlined in SGMA. To date, no research has been done to compare compliance options for basins that will be reclassified in the future.

Purpose of the Study

The purpose of the study was to determine if the 17 adjudicated groundwater basins and the 18 basins that have submitted alternative management plans meet the standards of sustainability as defined in the SGMA of 2014. The research focused on the new requirements under SGMA in contrast with the terms and conditions of the separate and unique court adjudications. It is important to note that most of the adjudications occurred before groundwater management and legislation like SGMA was contemplated. Secondly, the research evaluated the alternative management plans that were developed with knowledge of SGMA's requirements. The plans were analyzed as to their responsiveness to the new sustainability standards.

The goal of the study was to evaluate two different groundwater user groups and to compare and contrast the members of both groups to the newly defined sustainability standards. The purpose of this comparison was to determine, utilizing a statistical process, the degree to which each adjudicated area or alternative management plan basin area met the criteria. There were 17 adjudicated basins and 18 alternative management plan basins that were scored based upon compliance with the sustainability standards.

The study evaluated the degree to which adjudicated basins are responsive to SGMA's sustainability standards through actions and plans that are in place. Secondly, the basins that submitted alternative management plans were evaluated regarding how their submitted plans and current practices met SGMA's standards. The results of the study provide information for basin areas that are reclassified in the future to medium priority or high priority and required to select a compliance method. Further the study provides information as to how closely adjudicated basins align with the new sustainability requirements.

Significance of the Study

The passage of the SGMA constitutes a revolutionary change to the state's previous noninterference in groundwater extractions (Bowling & Vissers, 2015). The implementation of SGMA is dynamic and contemporary. There has been a proliferation of journal articles and academic work that discuss various aspects of SGMA, but none are known to review the compliance of the two selected data sets evaluated in this research project. Of the literature published since the passage of SGMA, none has evaluated the data from basins that submitted alternative management plans to the state. These plans were intended to evidence sustainable practices that are in compliance with SGMA's specific criteria. Further, there is a void in literature regarding the comparison of the various adjudicated basins in contrast to the sustainability criteria in the new law.

SGMA requires that the DWR review the basin prioritization periodically based upon the CASGEM data and the other factors previously outlined. The possibility exists that low-priority basins may be revised to medium- or high-priority basin status based upon the relevant factors. The evaluation of alternative management plans and adjudicated areas in this analysis may be utilized in determining which option best satisfies the needs of the local basin area in response to the requirements of SGMA, the implementation of which will continue through 2042. This is a new and developing area for research as it will continue to unfold over the next 2 decades in the state's push to facilitate better management of a vital resource.

Research Questions

The research asks essentially the same question of two diverse data sets in an effort to determine the responsiveness of both groups to new sustainability criteria. For one data group, the adjudicated areas do not have the same rigorous compliance requirements as for the second group, those who have submitted alternative management plans. Both were evaluated in relation to the level of achievement related to the new sustainability requirements. There were 17 adjudicated basins evaluated along with 18 basins that had submitted alternative management plans to the state by January 2017 (DWR, 2018b).

Following are the specific questions answered by the research:

1. Do areas governed by a groundwater adjudication substantially meet the criteria of sustainability as outlined in the SGMA of 2014?
2. Do groundwater basin areas that have submitted an alternative management plan in lieu of forming a GSA meet the criteria of sustainability as outlined in the SGMA of 2014?
3. When a low- or very-low-priority basin meets the threshold to become a medium- or high-priority basin requiring further action, should that basin adjudicate or develop an alternative management plan to meet the sustainability requirements of SGMA?

Hypotheses

Null hypothesis: There is no difference in the compliance of adjudicated basins or basins that have submitted alternative management plans.

Alternative hypothesis: There is a statistically significant difference in compliance of adjudicated basins compared to basins that have submitted alternative management plans.

Research Design

The quantitative methodology employed in this study includes a through exploration of empirical publicly available data to answer the research questions. All of the data involve public agencies that have information readily available on their websites. The primary source of information reviewed for the alternative management plan areas was data posted on the DWR website, which contains a large quantity of information submitted by the alternative management plan area study group. The site is located at https://sgma.water.ca.gov/portal. A separate section within the state's portal is available for alternative management plans and adjudicated areas. Each alternative management plan submittal has its own page within the portal with all of the responsive data available through dynamic links. Adjudicated basins posted their judgement and subsequent annual reports. Adjudicated areas required additional extensive review of other websites including sites for all parties to the judgement in an effort to determine what management actions were in place that were responsive to the research questions.

The instruments developed to collect the data include a detailed scoring rubric including responsive elements from the Alternative Elements Guide developed by the DWR (2019). The rubric differed slightly for the AMP areas and the adjudicated areas. A third rubric was developed based upon professional expertise to capture responses from both groups in a uniform format that could be subjected to chi-square analysis. All three rubrics are included in Appendix A, Appendix B, and Appendix C. The first data group analyzed was the groundwater basin areas that submitted alternative management plans in lieu of forming or participating in a GSA. The second data group evaluated in this study was the adjudicated areas that are required to comply with court-ordered settlements. The adjudicated basin areas are only required to submit annual reports and respond to five specific questions. However, the analysis evaluated their nonmandatory compliance in areas consistent with groundwater sustainability as outlined for the alternative management plan areas. The purpose was to determine if adjudicated basins without the requirement to do so meet the same sustainability criteria as basins that develop an alternative management plan.

Theoretical Framework

Groundwater reserves functions similarly to surface water sources but without the visibility, unlike a lake, flowing stream, or river. When water is drawn out of a surface water facility, such as Lake Orville or Lake Mead, and not replaced, the high-water marks are visible. Conversely, as the hidden groundwater resources are depleted over time, as they have been in California, the impacts are dramatic. In many cases, there is not sufficient recharge to replace what is pumped, thereby creating overdrafting of the groundwater tables and the associated negative impacts. This overuse of a resource is referred to as a tragedy of the common resource (Ostrom, 2007) and has its basis in economic theory (Carpenter, 1998; Griffin, 2018). When a resource such as groundwater is depleted, it is no longer available for beneficial purposes and therefore creates an impact on users as well as the environment. The condition of overdrafting a basin year after year not only has negative economic impacts but can lead to significant environmental consequences including reduction of surface flows in nearby streams and loss of vegetation because the groundwater level has dropped below the root zone of the trees and other vegetation. These conditions have a compounding effect on multiple species and habitats (Rohde, Froend, & Howard, 2017). Common resource theory contemplates the importance of maintaining and protecting a resource used by all. This concept is supported in the California Code of Regulations, which implicitly includes, in the category of beneficial uses, fish and wildlife and recreational uses along with industrial and municipal needs.

In considering the adverse effects from overuse, it becomes clear that some form of intervention is necessary to balance the resource. There is an expectation that government has an obligation to protect water and the environment for the beneficial enjoyment of and use by the public (Klass & Huang, 2009). The Public Trust Doctrine aligns with that ideology and can further be applied to groundwater that impacts surface water (Womble & Griffin, 2015); however, others argue that it should also apply to environmental protection (Bowling & Vissers, 2015; Ryan, 2001; Sax, 1980). This is consistent with the mandate for sustainability outlined in SGMA that requires the avoidance of certain negative environmental impacts.

Assumptions, Limitations, and Delimitations

Assumptions

The determination to utilize secondary data for the quantitative research was based upon the assumptions that empirical data from public agencies would be readily available and adequate in nature to perform the research. The data available on the various websites and documents are assumed to be correct and accurate. Further, it was assumed that there would be less subjectivity in the scoring of each of the data sets. Lastly, the overarching assumption was made that this research would provide some beneficial and useful findings to aid areas in evaluating compliance options.

Limitations

The nature of quantitative research precludes the opportunity to seek clarification through the means of interviews. Interpretation is left to the evaluation of data that may be subjective to a certain degree. The research as designed will provide a conclusion based only upon the interpretation of the facts lacking the possible enrichment of dialogue.

Delimitations

A significant delimiting factor for this research is disclosure of what the study has chosen not to cover (Simon & Goes, 2013). Due to the sheer enormity of the data set size of basins electing to form a GSA, the study was limited to two more manageable data sets. The size of the data sets selected is relatively small at 17 and 18 and as such is also a delimiting factor in the research study. The fact that no other research in this area has been completed to date can be viewed as a delimitation because there is no validation of the interest nor usefulness of research in this area.

Definitions of Terms

There is a certain vernacular in the discourse regarding the SGMA that is not common nomenclature for the layperson. Some definitions specific to the study will be helpful in a better understanding of the topic.

Adjudication. An adjudication is a court-ordered settlement among water users in a region that establishes a governance structure and accountability among the parties.

Alternative management plans. Alternative plans submitted by a basin as an alternative to forming or participating in a GSA and show management of the resource that meets sustainability criteria.

Aquifer. "A body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant quantities of groundwater to wells and springs" (DWR, 2013, para. 21).

Groundwater management programs. "A coordinated and ongoing activity undertaken for the benefit of a groundwater basin, or a portion of a groundwater basin, pursuant to a groundwater management plan adopted pursuant to this part" (Cal. Water Code § 10752).

Groundwater sustainability agency (GSA). The primary agency, made up of local agencies overlying a groundwater basin responsible for achieving sustainability within the required timeframe under SGMA.

Groundwater sustainability plan (GSP). The plan developed by the GSA for meeting sustainability criteria as mandated by SGMA

Groundwater. "All water beneath the surface of the earth within the zone below the water table in which the soil is completely saturated with water, but does not include water which flows in know and definite channels" (Cal. Water Code § 10752).

Groundwater basin. Any basin identified in the department's Bulletin No. 118, dated September 1975, and any amendments to that bulletin, but does not include a basin in which average well yield, excluding domestic wells that supply water to a single-unit dwelling, is less than 100 gallons per minute. (Cal. Water Code §10752).

High priority basin. A prioritization of a basin based upon a cumulative numerical threshold between 21 and 42 points based upon components listed in Water Code section 109233(b) intended to ensure sustainable management of groundwater basins (DWR, 2018a).

Medium priority basin. A prioritization of a basin based upon a cumulative numerical threshold between 14 and 21 points based upon components listed in Water Code section 109233(b) intended to ensure sustainable management of groundwater basins (DWR, 2018a).

Overdraft. A condition wherein more water is removed from the groundwater aquifer than is being recharged through rainfall, snowmelt or through percolating imported water. Pumping water in excess of what can be naturally recharged.

Sustainable Groundwater Management Act of 2014. A trio of legislation that forms the tenets of groundwater legislation in the state of California

Sustainable yield. As defined in SGMA, means the maximum quantity of water—calculated over a base period representative of long-term conditions in the basin and including any temporary surplus—that can be withdrawn annually from a groundwater supply without causing an undesirable result.

Sustainability criteria. SGMA outlines specific criteria that must be met for a groundwater basin to be considered sustainable.

Undesirable result. as defined in SGMA, means any of six undesirable metrics outlined in the legislation that is caused by groundwater conditions occurring within a basin.

Usufructuary. The right of use of something in which one has no property interest (Hutchins, 1956).

Watermaster. Means a Watermaster appointed by a court or pursuant to other provisions of law (Cal. Water Code § 10752).

Water year. The time span between October 1 and September 30 of the next year.

Organization of the Study

Chapter 1 provided an introduction and overview of the study by laying a foundation for the convergence of circumstances that precipitated the urgency for groundwater governance. The increasing dependence on the invisible resource created consequences that had dramatic ramifications. During the recent epic drought, groundwater pumping filled the gap in the supply left by drier-than-average conditions. Years of cumulative overdrafting of groundwater reserves had severe consequences. SGMA's passage was to ensure that the resource gained long overdue oversight. The problem statement outlines the purpose of the study to determine if adjudicated areas and areas that have submitted alternative management plans comply with the sustainability criteria in lieu of forming yet another layer of government outlined in the law known as a GSA. The research questions provided the specific focus of the study while the limitations of the study and the significance of the study were provided to help contextualize the basis and limited focus of the research. The definitions of terms were intended to familiarize the reader with unique terms specific to the subject matter.

Remainder of the Study

The balance of the study provides a comprehensive background on the development of the oversight of water, along with a review of applicable literature including laws and prior applicable research in Chapter 2. Chapter 3 describes the methodology and resources utilized to gather the qualitative secondary data. Chapter 4 provides an analysis of the data including the findings. The conclusion of the research, Chapter 5, presents the summary of the findings and recommendations for future areas of study that were not considered within the limitations of this research.

CHAPTER 2: REVIEW OF THE LITERATURE

Whiskey's for drinkin' and water's for fightin'.

—Mark Twain

Access to clean water was declared a human right by the United Nations General Assembly in 2010, and further embraced in the state of California with the passage of Assembly Bill 685, signed into law by Governor Brown in 2012 amending Section 106.3 of the state's Water Code.

The discourse about water resource management is intrinsically a topic in the realm of public administration as government is looked upon to provide essential services to enhance quality of life, a concept supported by the public trust theory. The purpose of this study was to evaluate two or the three potential approaches that comply with the new groundwater management law. Two approaches, adjudication and alternative management plans, allow the use of an existing management structure while the third, the creation of a Groundwater Sustainability Agency (GSA), requires the formation of a new government entity. The law acknowledges adjudicated groundwater basins and excuses them from stricter compliance requirements and also allows basin areas that believe they are already in compliance to provide evidence through the submittal of an alternative management plan. The objective was to determine if compliance could be satisfied short of creating another layer of bureaucracy understanding that every layer of governance comes at a cost and often a loss of transparency for the public.

In an effort to build a foundation for the reader, Chapter 2 lays an historical foundation of California water rights and the development of complex management more than a century old that began when California was part of Mexico with Pueblo water rights that are still acknowledged today. A discussion of the development of state oversight in water resource management provides context for groundwater management as the state has gathered information over time to better understand the resources. Public administration theory is introduced to provide substantiation for the expectation of intervention in resource management to ensure sustainability of vital common-pool resources. Finally, the chapter concludes with a focus on pertinent literature.

Background of Water Rights

California's Water Rights Schema

Within the complex labyrinth of the state's system of surface and groundwater rights, California Water Code section 102 clarifies that the uses are all subject to state oversight: "All water within the State is the property of the people of the state, but the right to the use of water may be acquired by appropriation in the manner provided by law" (Hutchins, 1956, p. 308). Further, in the California State Constitution, Article X, Section 2, it is stated that water is for "reasonable" and "beneficial" use, the terms of which can be redefined as affirmed by the state Supreme Court (Boxall, 2015b; Sawyers, 2005). The state further asserts that while most water rights are property rights, the possession is only for the use (California Water Boards, 2018). Further the balance of beneficial uses is weighed among recreational, aesthetic, economic, and environmental uses (Sawyers, 2005). Therefore, most water rights are usufructuary rights and can be usurped by the state regardless of the type of right if a use is determined not to be reasonable and beneficial or if supplies are diminished as seen in the recent drought. Of course, this is subject to careful evaluation under the strictures of case law and due process; however, over time, greater emphasis has been placed on environmental needs as in the concept of *co-equal goals* which describe the concept that the water for the environment is equal to other water uses. This term was given stature in case law involving the state's challenges over the State Water Project Delta conveyance system.

The application of this concept is seen in the focus under the Sustainable Groundwater Management Act (SGMA) of the connectedness of surface and groundwater resources. The management or even the recognition of surface water has not typically been a function of groundwater management. Water Code section 354.38 of Title 23 states that a "numerical groundwater and surface water model" should be used to quantify the depletion of the surface water due to groundwater pumping (DWR, 2016a, p. 22).

It is helpful to understand the complexity of water rights within the context of SGMA. The sustainability mandates will require compromises among various rights holders. The discussion of water rights is complicated and contentious. Unlike surface water rights, groundwater has essentially been unregulated except in localized areas (Mettler, 2016). There are five basic water rights related to surface water use, which include riparian, appropriative, prescriptive, pueblo, and federal reserved right (Langridge, Brown, Rudestam, & Conrad, 2016) and three primary classifications involving groundwater rights include overlying, appropriative, and prescriptive. However, some pueblo rights also extend to groundwater use (Littleworth & Garner, 1995).

The various classifications of water rights can further be complicated by the application of certain doctrines such as "first in time, first in right," which refers to the hierarchy among appropriative rights wherein those who have had the surface right to a particular use longer than another have a more superior right than the one who came later (Littleworth & Garner, 1995, p. 40). Similarly, the doctrine of correlation in groundwater uses asserts that one cannot be deprived of the use of water beneath one's own property by the depletion of the resource by another.

Pueblo Rights

The pueblo rights are unique to California due to its history of once being under the control of Spain and later Mexico until the Mexican War ended in 1848 and California became part of the United States (Hutchins, 1956). Pueblo water rights established under Spanish rule prior to 1848 are the only water rights that hold a superior position and until 2015 were considered exempt from the state-mandated curtailment (WEF, 2018). The pueblo water rights established the right to water in an entire watershed for use by the pueblo or community (Eisenhower, 2010). The two large metropolitan areas that have perfected their claim of pueblo rights for surface water naturally occurring in the pueblos are the cities of San Diego and Los Angeles (WEF, 2018). The city of Los Angeles in a California supreme court case defended the pueblo rights originally established in 1781 and upheld its rights as the successor to the original pueblo (Littleworth & Garner, 1995). Similarly, San Diego has also been successful in defending its pueblo water rights, a claim also vetted through the state's supreme court (Hutchins, 1956). This superior right to surface water, and in some cases groundwater, increases with population and through annexations of land to the cities (WEF, 2018).

Pre-1914

In 1902, the federal government became involved in western water with the passage of the Reclamation Act, which was later the genesis for the creation of the

Bureau of Reclamation (Attwater & Markel, 1988). This act focused on the construction of water projects such as dams and conveyance systems in the arid west. In 1914, the California Water Commission, later re-named the State Water Resources Control Board (SWRCB) was created to oversee a newly created permit system for the state's surface water (Littleworth & Garner, 1995). The commission was to allocate available surface water resources to appropriators—those who requested a permit for use based upon availability with consideration as to beneficial use (Attwater & Markel, 1988).

Pre-1914 appropriative rights established prior to the creation of the Water Commission hold a superior and protected water right to most other appropriative rights. Pre-1914 rights are one of the last to receive curtailment or use restrictions from the SWRCB (formerly the Water Commission). However, curtailment orders were issued in 2015 during the recent drought, the first time in more than 40 years (Boxall, 2015a).

Riparian Rights

A Riparian water right, a holdover from English Common Law, is the right to use water from a surface water source abutting land owned by the user, however, it is not a quantified right to a certain amount of water (Littleworth & Garner, 1995; Hutchins, 1956). The water can be diverted from the stream or river and used on the property for reasonable and beneficial uses. Most Riparian rights predate 1914 and as such have a superior right. This right is strongly tied to property ownership from the date the right was secured. Riparian rights are correlative in nature, in that one cannot drain the stream dry to the detriment of another. This concept was perfected in *Lux v. Haggin* wherein the California Supreme Court supported the right of downstream owner not to be deprived of use due to the overuse of upstream appropriators (Igler, 1996).

Appropriative

Appropriative water rights followed with the onset of the gold rush and hydraulic mining. The appropriative rights initially related to the diversion of surface water and later expanded to those acquiring a right. A pre-1914 appropriative water right is a senior water right. After 1914, as required by the Water Commission Act, appropriative water rights had to be approved by the SWRCB through a permitting process (Atwater & Markle, 1988).

Groundwater Rights

Groundwater rights fall primarily into three categories: overlying, appropriative, and prescriptive. Overlying water rights are an ownership right possessed by one who owns the land and has the right to the water under that property. This concept is absent any correlation of use with others who share the common resource of the same aquifer. Appropriative rights are the exercised rights of those who pump water in one location and transport it to another. Most municipal agencies pumping groundwater are exercising an appropriative groundwater right.

Prescriptive water rights relate to users who have established the right based upon unchallenged historical use. The doctrine of correlative rights can be implemented in a case of oversubscription of a basin or a watershed's resource by asserting that one user does not have a disproportionate right over another and he or she must correlate usage among other basin pumpers.

It is important to note that the SGMA does not modify the current groundwater rights schema (Blomquist, 2016) but rather requires that the resource be managed through a more integrated local approach with the requirement to avoid six specific undesirable results that would indicate the lack of sustainability. The six items are (a) chronic lowering of groundwater, (b) reductions in groundwater storage, (c) seawater intrusion, (d) degradation of water quality, (e) land subsidence, and (f) surface water depletions. These six undesirable results or outcomes, if not mitigated, will require intervention by the SWRCB in its new breadth of authority given by SGMA. The SWRCB has the ability to mandate certain actions to ensure sustainability in a basin or intervene in other ways.

Groundwater Management

Department of Water Resources Involvement

In 2009, SBx7-6 was signed into law that required the collection of data related to the state's groundwater resources (DWR, 2015b). This legislation required groundwater users to report pumping on an annual basis to the California Statewide Groundwater Elevation Monitoring (CASGEM) database (DWR, 2015b). Based upon the analysis of the data in CASGEM, the Department of Water Resources (DWR, 2015b) was required to identify basins with groundwater declines and assign a priority level ranging from high, medium, low, and very low. The prioritization of meeting sustainability was focused on the basins that were classified by the DWR as high- or medium-priority basins. This characterization was critical in the development of SGMA. Following are the prioritization criteria:

- The population overlying the basin.
- The rate of current and projected growth of the population overlying the basin.
- The number of public supply wells that draw from the basin.
- The total number of wells that draw from the basin.

- The irrigated acreage overlying the basin.
- The degree to which persons overlying the basin rely on groundwater as their primary source of water.
- Any documented impacts on the groundwater within the basin, including overdraft, subsidence, saline intrusion, and other water quality degradation.
- Any other information determined to be relevant by the department, including adverse impacts on local habitat and local stream flows. (DWR, 2018, p. 2)

Adjudicated Groundwater

In basins that are adjudicated, a court determines the allocation of water rights based upon specific and unique factors in the basin. This is often the result of lawsuits because of perceived inequity in groundwater use and correlative rights. The resulting court settlements or stipulated judgments in such matters are referred to as adjudications. These settlements predate the passage of SGMA in 2014. The problem, prior to the passage of SGMA, has been the perpetual overdrafting of groundwater basins without proper management oversight to ensure sustainability. The exception to this has been adjudicated groundwater basins that, for various reasons have recognized the need for a coordinated governance structure to address the usage of groundwater. The DWR recognizes 22 adjudicated groundwater basins that are exempt from SGMA per California Water Code section 10720.8. This study evaluated 17 of those basin areas.

Adjudicatory process. The process to adjudicate pre-SGMA typically involved litigation among parties over the perceived inequity in the use and allocation of groundwater. There are numerous reasons why adjudications were formed; they span the gamut from securing a production right to addressing basin overdraft (Langridge et al., 2016). The courts were viewed as the best arbiter to provide a lasting equitable solution based upon competing interests for a finite groundwater resource. While never perfect, the share-the-pain approach where all parties must comply with the final outcome brings a degree of resolution to the core issue that serves as the impetus for the litigation and stabilizes the use of the resource for all parties.

Prior to the implementation of the SGMA of 2014, there were 22 adjudicated basins that were formed as far back as the 1920s (Langridge et al., 2016). The majority of adjudications occurred in the 3-decade span between 1960 and 1980 when more than 13 adjudications were solidified with court decisions. The purpose for the adjudications varied, but the most common thread was to protect pumping rights (Langridge et al., 2016).

The process is costly, extensive, and controversial and has taken from 3 to 18 years to complete (Langridge et al., 2016; Mettler, 2016). In some areas, there has been more than one attempt to adjudicate groundwater rights—often decades apart—as in the Mojave Adjudication when the first attempt to adjudicate occurred in 1976 (Blomquist, 1992) and the second attempt was finalized in a stipulated judgment in 1995. During the process, there are often compromises made and settlement negotiations among the parties to reach an agreed-upon solution.

Adjudicatory process post-SGMA. The passage of SGMA provided a venue for the conversation of how to expedite groundwater adjudications, one of the management options for groundwater basins outlined in the new legislation. Tandem bills (SB226 and AB1390) were signed into law October 2015 that now provide for a more streamlined process. Previously adjudications have taken several years to complete and in some cases a decade or more, resulting in negotiated settlements. The legislation strives to streamline the process and make it more cost effective while conforming the outcome to SGMA's sustainability and reporting requirements (DWR, 2015a).

California's Drought Cycles

One only needs to look at the unpredictable cycles of drought in the state to understand the necessity for better water resource management. The U.S. Geologic Survey (2018) provides data related to drought cycles and has identified the 1928-1934, 1976-1977, 1987-1992, and 2012-2016 as significant drought events in modern history. These droughts, ranging from 2 to 7 years in duration, had a significant impact on water availability coupled with a state that has grown from less than 2 million at the turn of the century to over 39 million in 2016 (Johnson, 2016). It is often not realized that a drought is occurring or has occurred until trends emerge often taking more than 2 years. Droughts are never declared until they are well underway. As with the 1976-1977 drought, the anomalies of those 2 years did not emerge until after the drought had ended.

The drought years of 2011-2015 were the worst since recordkeeping began in 1895 (Pitzer, 2017) and further exacerbated the challenge of a diminishing supply for a growing population. Although in the past decade, per capita water use has reduced significantly, the unpredictability of climate conditions presents a feast-or-famine scenario for water resources. The DWR was tasked with developing a reporting system for monitoring groundwater. In 2009, SB 6 x7 passed through the state legislature and was signed into law establishing a statewide groundwater monitoring program. CASGEM has collected groundwater data that help develop a prioritization model that, through monitoring groundwater elevations, identified areas of significant overdraft (WEF, 2015). The findings were represented in Bulletin 118.

The Department of Water Resources Groundwater Bulletin 118

In 1952, *Water Quality Investigation Report No. 3: Ground Water Basins in California*, was the first state-published report identifying 223 areas that contained usable groundwater (DWR, 2018a). Subsequent to this initial report, the first Bulletin 118 was published in 1975 and contained information on 248 of 461 identified groundwater basins. Seven bulletins have been published since then. Beginning with the 1999 report, the scrutiny of groundwater basin management heightened with each subsequent publication, much driven by legislation mandating greater oversight of groundwater extraction and sustainable management practices. The 2014 Bulletin 118 update outlined the mandated responsibility of the DWR to prioritize basins from very low-priority to high-priority basins. DWR's prioritization under SBX7 6 was critical to the implementation of SGMA and its intent to ensure sustainability in critical groundwater basins. Crucial to this evaluation was the establishment of a data management system that collected groundwater data in an effort to determine the condition of basins and provide information for management oversight.

Basin Prioritization

The seasonal water-level data collected since 2009 through the CASGEM system have built a critical data set that has helped to determine the priorities of the basins. Priorities assigned to basins by the DWR were high, medium, low, or very low, based upon population statistics, groundwater reliance, and impacts such as water quality, subsidence, and overdraft (DWR, 2018a). Further, the assigned priorities have provided a roadmap for SGMA oversight as the initial focus was on basins assigned a high- or medium-priority status. The DWR is circulating the 2018 SGMA Basin Prioritization Process and Results that will be finalized after public comment in 2019. A summary of basin priority criteria can be found on the DWR (2018a) website.

Identification of Groundwater Pumping

In November 2009, legislation was passed known as SBX7 6, which mandated that groundwater pumpers provide groundwater elevation data to the state DWR. The elevation data reported over time would provide critical information regarding groundwater overdraft, which signifies an overuse of the resource. While individual data points were innocuous enough, the data over time showed overproduction of groundwater resources and amplified the need for groundwater management (DWR, 2015b). From 2009 through 2014, the year SGMA was adopted, the DWR compiled several years of groundwater data that showed conditions of overpumping based on declines in groundwater elevations.

In some high agriculture regions, such as the Central Valley, nearly 2-million acre-feet of water each year is overdrafted (Pitzer, 2017). This is water that is removed from the groundwater aquifer and not replaced through rainfall or snowmelt. This condition has been identified in SGMA as adverse and unstainable. The majority of the Central Valley from Bakersfield to Stockton is in critical overdraft (DWR, 2018a).

Focus on High- and Medium-Priority Basins

The DWR is the primary responsible state agency for the implementation of the SGMA as outlined in the law (Pitzer, 2017). Through mandatory reporting requirements, DWR had identified 31 of the 515 groundwater basins that were designated as high-priority basins indicating significant overdraft and 84 basins as medium priority (DWR, 2015b, 2016b). These two basin groups account for 96% of the average groundwater use and 88% of the population as of 2010 (DWR, 2015b). Fifteen of the 21 groundwater basins identified as in critical overdraft are located in the San Joaquin Valley, an area known for providing a large amount of the nation's fresh fruits, nuts, and vegetables (Pitzer, 2017).

Sustainable Groundwater Management Act

Prior to the passage of the SGMA, there was minimal oversight of groundwater pumping. The complexity of California's water rights schema further complicated the conversation of groundwater rights. However, changes in reduced snowpack and the characteristics of rainfall, including frequency and duration, coupled with the historic recent drought (Hanak et al., 2016), fostered a groundswell of support for better management of groundwater, which in drought years has been the state's emergency supply of water. Typically, 40% of the state's annual water demand is met by pumping groundwater; however, in years of drought, 60% to 70% of the total annual water demand is pumped from groundwater resources.

SGMA was written to encourage local control and local solutions by allow three means of compliance. If a medium- or high-priority basin was not adjudicated, thus exempting it from the majority of SGMA's compliance, then a basin could form a GSA or submit an alternative management plan attesting to current practices that provide sustainability for the basin. It was envisioned that under state oversight, each groundwater service area working collaboratively can develop a plan to avoid the effects of overuse of groundwater resources. Because each groundwater basin is unique, complex localized solutions, rather than a one-size-fits-all approach, are preferable in developing the Groundwater Sustainability Plans that must be implemented by each GSA. The alternative to not complying with any of the three options is the threat of state intervention from the SWRCB, an arm of the state that has the ability to mandate actions, assess fines, and issue numerical compliance standards with rigid implementation timeframes. This is the proverbial stick compared to the "carrot" of selecting one of the three compliance methods allowed under SGMA.

The intent of the legislation was to address multiple facets of groundwater management including prohibitions such as the six negative impacts outlined above as well as to provide a path toward groundwater sustainability. The SGMA directed the DWR to provide oversight and guidance, which included the development of Groundwater Sustainability Plans (GSPs) due to the state January 1, 2017, and a framework of best management practices (BMPs) that will lead to sustainability. These BMPs were required to be developed by the DWR and available on their website by January 1, 2017, as outlined in Water Code section 10729(d). The BMPs were "designed to achieve sustainable groundwater management and have been determined to be technologically and economically effective, practicable, and based on best available science" (DWR, 2017, p. 1).

SGMA provides a long-term solution for California's previously unmanaged groundwater resources. Groundwater users can achieve sustainability through a selected approach as long as they avoid the six negative impacts outlined previously (Womble & Griffin, 2015). Each of the high- and medium-priority areas, as defined by the DWR, are required to develop plans outlining how they will manage the resource to avoid the six specific impacts. SGMA also includes provisions for state intervention in high- and medium-priority basins that are nonresponsive to the new management mandates (Kennedy, 2015). A basin in this context is a groundwater basin or subbasin identified and defined in DWR's Bulletin 118 (Cal. Water Code §10721).

The DWR basin boundaries, as defined in Bulletin 118, have been modified to a degree by local groundwater management areas and do not completely comport to the textbook definition of a hydrologic basin, which in concept is a geographic area where any precipitation that occurs would flow to a stream or groundwater basin within it (DWR, 2013). In the context of this study, *basin* refers to DWR's definition as it relates to SGMA implementation.

Attaining Sustainability

The mandate of SGMA is avoidance of the six undesirable results that, if avoided, will achieve sustainability (Womble & Griffin, 2015). Sustainable groundwater management is defined in SGMA as "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results" (Cal. Water Code §10721[v]). These six undesirable results include

- Chronic lowering of groundwater levels
- Significant and unreasonable reductions in groundwater storage
- Significant and unreasonable seawater intrusion
- Significant and unreasonable degradation of water quality
- Significant and unreasonable land subsidence
- Surface water depletions that have significant and unreasonable adverse impacts on beneficial uses. (DWR, 2015b, p. 16)

Implementation

The 20-year implementation timeline has been harshly criticized by many as the criticality of groundwater management has been amplified in the recent years of drought (Mettler, 2016). The timeline for fully implementing management actions under the SGMA spans a 25-year time period. Some critics say implementation is long overdue and should be hastened, while others opine that the problem was created over a 100-year timeframe and will take time to correct (Pitzer, 2017).

Responsibility for implementation is shared between the DWR and the SWRCB. The DWR deals primarily with the mechanics of the legislation such as reviewing plans and monitoring the newly formed GSAs as well as administering grant funds to support the planning efforts (Pitzer, 2017). The SWRCB has legal authority to issue violations, fines, and other means of intervention to ensure compliance that will be utilized as a last resort (Pitzer, 2017).

Theory Integration

Sustainable management of the state's natural resources engenders confidence that government is protecting that which is a right for the people of the state to use and enjoy. The theory of the public trust doctrine synthesizes with the state's codified sovereignty over water resources. Further, it has been asserted that the state has an obligation to protect the resources for the benefit of the state's inhabitants (Slater, 1995). The concept of state's obligation to protect common resources such as water dates back to the Roman Empire and is also found in English common law (Bowling & Vissers, 2015).

In 1971, the California Supreme Court expanded the concept of public trust to evolve with the public's needs (Slater, 1995). This doctrine is salient to the consideration of water resources and has been protected by state law and perfected by case law over time. A notable case that helped perfect the public trust doctrine's application to surface water resources was *National Audubon Society v. Superior Court* in 1983, otherwise known as the landmark Mono Lake decision (O'Dea, 2014). The common pool resource theory is complimentary to the theory of the public trust and acknowledges that people left to their own devices have the propensity to abuse a resource (Hardin, 1968). Therefore, government has an obligation to preserve such resources.

Application of Theory to Groundwater Management

Management of vital natural resources is an important role of public administration. The human right to water has been the focus in recent years in policy action in many nations around the world and California has likewise adopted a human right to water policy framework. The public trust theory and the common pool resource theory are integral in the discussion of water resource management. As such, the common pool resource theory contemplates management of the resources for the perpetual benefit of the users through collective action (Hardin, 1968). The public trust theory can be viewed as a compliment of the common pool resource theory to a degree by asserting that government has the right and obligation to protect certain rights of its citizens and can do so through judicial remedies (Sun, 2010). The public trust theory is responsive and sensitive to an affirmative obligation to preserve, for the public, resources that are expected to be available. In the context of resource management, there is an unspoken obligation with the public trust theory to ensure sustainability of certain natural resources for the public good (Slater, 1995).

Public Trust Doctrine Theory

Implementation of the public trust doctrine varies from state to state. In California, the legal application of the public trust doctrine, in essence, establishes the state as the trustee responsible for protecting certain resources (O'Dea, 2014). A hallmark in assertion of this doctrine in California involved the imperiled Mono Lake in the 1983 *National Audubon Society v. Superior Court* case (O'Dea, 2014; Littleworth & Garner, 1995). California Water Code section 102 states that "All water within the State is the property of the people of the State, but the right to the use of the water may be acquired by appropriation in the manner provided by law" (Hutchins, 1956, p. 67).

The public trust doctrine in California has been applied primarily to navigable water ways, an area under the purview of the SWRCB, which is the designed entity in California that allocates the use of surface water rights as outlined in the Water Code. During the drought of 2012-2016, SWRCB issued the water restrictions and associated guidelines mandated by Governor Brown's executive orders. The "curtailment orders," or reduction-in-use orders issued by the SWRCB affected some of the most superior water rights including the pre-1914 rights.

With the SGMA the SWRCB now has expanded authority to provide oversight in addressing groundwater unsustainability; therefore, one could expect that the SWRCB's curtailment authority may be expanded to groundwater in the future as part of its legal evaluation under the public trust doctrine. This would be a drastic expansion of the authority of the board but not beyond the realm of possibility given its expanded authority. If this did occur, it would render all water resources usufructuary in nature subjecting groundwater to the same curtailment threats as surface water. The expansion of the public trust doctrine would be consistent with the philosophy of Joseph Sax (1980) who asserted that the principles of the public trust doctrine should be more broadly asserted rather than only to the narrow legal application related to navigable waterway.

In October 2018, a California court of appeal upheld that the public trust doctrine does apply to groundwater extractions that impact waterbodies (Gray, 2018). In litigation involving the Scotts River Valley, the court asserted that the public trust doctrine does indeed apply to both navigable and nonnavigable waterways that are dewatered by groundwater pumping (Kibel & Gatenbien, 2018). Further the court asserted that the obligation to uphold the public trust is embodied not just with the SWRCB, as it has been for decades, but also with local governments (Kibel & Gatenbien, 2018), which marks a broadening of the prior application of the public trust doctrine (Cantor, Owen, Harter, Nylen, & Kiparsky, 2018). In the seminal public trust case, *National Audobon Society v. Superior Court*, the expansion of the concept of public trust was that it should be used to protect the public's resources wherever feasible. The intersection of the legal application of the public trust doctrine as it relates to navigable water ways is when the extraction of groundwater negatively impacts surface water quantities as it relates to legally defined beneficial uses.

Common Pool Resource Theory

The theory of common pool resources is rooted in European culture dating as far back as the 15th century where common grazing areas and other natural resources were shared by all (Bravo & De Moor, 2008). Common resources include free goods such as air, water, groundwater basins, natural areas, fishing areas, and other resources that humans expect to have in order to exist (Carpenter, 1998; Ostrom, 2000). An observation written by William Forester Lloyd in 1833 was thought to be the beginning of the formal conversation regarding the importance of the commons, which contemplated the potential of overgrazing as a result of a herdsman's greed wishing to add just one more head of cattle (Hardin, 1968). The hypothetical essay considered that if every herdsman added another animal, the result would be the ruin of the use of the commons for all due to overgrazing (Hardin, 1968). This concept was later expounded upon by Garret Hardin in an article entitled, "The Tragedy of the Commons," published in 1968 wherein Hardin contemplated the negative impact of overpopulation. The assertion was that man, left to his own devices would knowingly allow for the destruction, or "fouling," of the commons so that they were no longer a usable resource for the good of the whole (Hardin, 1968). Hardin and others have asserted that a self-interested person cannot act in any other way and that governance of the commons is best done through an administrative law process such as regulations or rules (Hardin, 1968; Ostrom, 2000). This would be analogous to the oversight of surface water use in California by the SWRCB as the entity that issues use permits and promulgates curtailment (of water use) notices.

There are those who disagree with Hardin (1968) and decry his doomsday decree. Carpenter (1998) and Ostrom (2000) both discussed the sustainability of mutually managed commons. Carpenter (1998) asserted that common pool resource use does not always lead to Hardin's "tragedy of the commons" because there exists motivation to maintain the resource for perpetual use. Ostrom (2000) asserted that there is empirical evidence of locally managed commons that thrive in contrast to the proponents who believe that the commons should be controlled by government. An applicable example of managed commons would be groundwater adjudications that have resulted in mutually derived management structures of groundwater in a basin.

Literature and Information Relevant to the Topic

The foundational document referenced in the study is the law itself, which originated from Senate Bill 1168, Assembly Bill 1739 and Senate Bill 1319 have now been included in the state's Government Code and Water Code (WEF, 2015). An evaluation completed by UC Santa Cruz that was commissioned by the SWRCB after SGMA's passage into law entitled "An Evaluation of California's Adjudicated Groundwater Basins" (Langridge et al., 2016) looked briefly at the question of whether adjudicated basins addressed sustainability. The study determined, based upon its limited research, that they did not (Langridge et al., 2016). This academic work stated that one of the shortcomings was the limited timeframe to complete the report and the lack of available data. Some of the data that were lacking in 2016 are now available for consideration.

Duke University's Nicholas Institute for Environmental Policy Solutions developed a working paper entitled *Sharing Groundwater: A Robust Framework and Implementation Roadmap for Sustainable Groundwater Management in California* (Young & McAteer, 2017). The study by Young and McAteer (2017) evaluated SGMA's implementation through creating a suggested framework for implementation with lessons learned from the Australia drought decades prior to SGMA. This study encourages a robust exchange of data and resources to meet the goals of sustainability.

A recently released study by University of Berkeley Law department entitled, *"Navigating Groundwater-Surface Water Interactions under the Sustainable Groundwater Management Act"* (Cantor et al., 2018) is another academic study on one aspect of SGMA. This timely report, released in March 2018, discussed the new area of groundwater management introduced by SGMA of groundwater-surface water interaction. The study provides the connection between surface water and groundwater as it is now required to be managed under SGMA and provides input related to the legal and institutional challenges of addressing this particular requirement.

With these and other academic works on the various components of the SGMA and numerous professional journal articles available, ample resources have been evaluated. In addition, the 18 alternative management plan areas and information regarding the 17 adjudicated basins considered in the study are posted on the DWR (2018b) website.

Conclusions

Water rights in the state of California have always been a contentious and complicated proposition. Mark Twain (n.d.) is credited with the quote, "Whiskey's for drinkin' and water's for fightin.'" This is a fair analogy as to the struggles that encompass The Golden State's water rights schema, which has wide variability in priority of rights and geographic differences. The complexity of the various water rights doctrines complicates solutions that seek to restrict pumping within newly defined constraints of sustainability as outlined in the SGMA.

Chapter 2 contained an historical overview of water rights and provided context for the complexity of the topic. Applicable law and literature has also been introduced in this chapter.

Remainder of the Study

The methodology used to conduct this analysis is contained in Chapter 3 and Chapter 4 provides an analysis of the data including the findings. Chapter 5 provides a summary of the findings and recommendations for future areas of study that were not considered within the confines of this research.

CHAPTER 3: RESEARCH METHODOLOGY

When the well is dry we know the value of water.

—Benjamin Franklin

This study evaluates the compliance of basin areas that submitted an alternative plan as compliance with the Sustainable Groundwater Management Act of 2014 and reviews available secondary data relevant to adjudicated basin areas to determine whether they meet sustainability criteria outlined in the new law.

Chapter 3 is intended to provide a thorough understanding of the methodology of the analysis and the steps taken to develop a meaningful analysis tool from which to determine the level of compliance. The analysis begins with detailed information on the development of the scoring rubric used for both the alternative plan areas and the adjudicated areas. A review of the selected populations and why some were excluded is also included in this chapter. The research questions are discussed in detail followed by a review of the reliability and validity of the data and results. A conclusion for Chapter 3 includes a summary and review of the remainder of the study.

This chapter includes the research questions, the hypotheses, and a description of the research methodology. The latter includes the sampling procedure and population, instrumentation, and procedures for data collection and analysis.

Background

Throughout California's history, water rights have been a source of contention, which is further exacerbated by prolonged periods of drought. While California is typically ahead of the rest of the nation in environmental regulations, it was the last state to regulate groundwater extractions through the adoption of the Sustainable Groundwater

Management Act of 2014 (SGMA). Groundwater accounts for approximately 38% of water use in California (Mettler, 2016) and many groundwater basins are in overdraft. Further, California overdrafts 1.4 million-acre feet of groundwater each year. Overdraft refers to water that is removed from the aquifers and not recharged. Overdrafting the aquifer depletes the resource in storage referred to as "tragedy of the commons" (Hardin, 1968) and can result in numerous negative impacts including loss of vegetation, waterways, and species as well as degraded water quality. SMGA, for the first time in groundwater management, requires a response related to a holistic stewardship of the common interconnected resource of ground and surface water.

Problem Statement

The question to be answered by the research is whether adjudicated basins are equally as responsive to the new sustainability requirements outlined in the SGMA of 2014, as basins that submitted an alternative management plan attesting to current responsive practices. Specifically, the hypotheses were as follows:

Null hypothesis: There is no difference in the compliance of adjudicated basins and basins that have submitted alternative management plans.

Alternative hypothesis: There is a statistically significant difference in compliance of adjudicated basins compared to basins that have submitted alternative management plans.

Water rights in California are very complex with multiple use classifications and priorities of use that are further complicated by court settlements or stipulated judgements known as adjudications. The majority of these settlements predate the passage of SGMA and focus primarily on water rights (Langridge et al., 2016).

The 17 adjudicated groundwater basins evaluated in the study have, through collective agreements, formed local governance that results in regular accountability among the parties. Annual reports are submitted as required by the court of jurisdiction each year to ensure compliance with each specific judgement. Adjudications are locally derived solutions that utilized the previous lengthy judicial process; however, SB226 and AB1390, now codified, streamline the adjudicatory process and require alignment with SGMA's standards henceforth. Additionally, since the adoption of SGMA, which mandated groundwater management, 18 basin areas were evaluated that have submitted alternative management plans in lieu of adjudicating or forming groundwater sustainability agencies (GSAs) as permitted in the law. SGMA's standards are intended to help stop, if not reverse, the significant overdraft of some of California's critical groundwater basins. The problem, as outlined in a large body of literature, is a lack of management or oversight to ensure that the basins are sustainable. Similarly, the 18 basins that have submitted the alternative management plans have been allowed to provide evidence to the state of existing governance and management actions that ensure sustainability in lieu of forming or joining the GSAs as outlined in SGMA.

These two groups, adjudicated basins and alternative management plan basins, were the focus of a systematic empirical evaluation that determined, based upon statistical analysis of the data, whether they both comply with the sustainability standards outlined in the SGMA of 2014. Some have conjectured that it would have been more effective for the state to mandate adjudications or local management plans rather than the multidecade process for full implementation of SGMA with the formation of GSAs.

The evaluation provides valuable insight for low and very low basins in the event a basin, currently exempt from compliance, is required in the future to meet SGMA's standards. The California Department of Water Resources (DWR) is required to evaluate the criteria for basin prioritization every 5 years and to modify basin classification (very low, low, medium, high) as necessary based upon the established criteria.

Purpose Statement

The purpose of the study was to determine if the 17 adjudicated groundwater basins and the 18 basins that have submitted alternative management plans meet the standards of sustainability as defined in the SGMA of 2014. The evaluation provides relevant data regarding the viability of adjudicated basins and alternative management plan basins to meet the sustainability criteria in lieu of the formation of a GSA.

Research Design

A scoring instrument was developed to evaluate each of the submitted alternative management plans and to evaluate compliance of adjudicated basins in meeting the selected criteria. The qualitative research evaluated empirical data to determine compliance with each of the selected elements. A chi-square statistical analysis was applied to respond to the hypothesis. The basis for the scoring instruments was the Alternative Elements Guide developed by the DWR (2019). The guide is located on the DWR's website.

Research Methodology

The quantitative research analyzed existing empirical data for the two selected study groups—adjudicated groundwater basins and alternative management plan basins—to determine the level of compliance between the two groups in relation to the new sustainability criteria outlined in SGMA utilizing a chi-square statistical analysis.

Population and Sample

The study sample size consists of the 17 adjudicated basins that predate the implementation of SGMA, and the 18 basin areas that submitted an alternative management plan in lieu of forming a GSA. Both sample sets are easily identifiable.

Initially there were 20 alternative plan areas that had filed with the state by January 1, 2016; however, since the initial submittal date, two basins elected to participate in a GSA and no longer sought approval for an alternative management plan. Therefore, the analysis consists of 18 of the 20 original basins. Additionally, in 2015, there were 29 adjudicated basin areas that submitted annual reports; in 2016, the submittals were 26 annual reports, and in 2017, there were 21 annual reports submitted. The sample set of adjudicated basin areas was further reduced by various factors to a sample size to 17 adjudicated basins.

The quantitative component of the research consists of reviewing data related to the groundwater basin areas and to compare those data to the requirements of SGMA. For instance, water levels, water use over time, and other pertinent data would be derived from reviewing readily available data such as existing basin records. Data from adjudicated groundwater basins have been submitted to the DWR and are available on its website. In addition, most adjudicated areas have a court-appointed overseer called a Watermaster. The Watermaster, as an arm of the court, compiles annual reports and other pertinent data that are available on the respective basin's website. For the basins that have submitted the alternative management plans, the data review for alternative management plan submittals consisted of material submitted by the basin areas that they deemed responsive. These data were posted on the state's SGMA portal accessible on the DWR (2018b) website in the Alternative Reporting System tab. For adjudicated basins, information was reviewed on the DWR website for adjudicated basins annual reporting system. Included in this location were the annual reports for 3 years as well as additional relevant information. In addition, a detailed web search revealed documents and other technical data from the various websites of involved public agencies that were responsive to the research questions.

The data from adjudicated basins were evaluated from the perspective of the functionality of the adjudication in relation to SGMA's outlined criteria. For the alternative basins that have submitted the plans, the analysis consisted of reviewing the data they posted on the SGMA portal self-certifying responsive actions (DWR, 2018b).

Data Validity

The reliability of the data is verifiable for the adjudicated basins because a formalized structure exists with accountability among basin participants through the Watermaster with court validation. Public agencies are frequently participants from whom data are readily obtained from websites of governing agencies.

The reliability of data for the areas submitting an alternative management plan is limited to the content of the planning documents submitted to the state by January 1, 2017. These documents have had local validation and support as they will be binding upon the region if accepted by the state as an alternative to the formation of the GSA. If not found to be acceptable, the state can require an area to join or form a GSA (DWR, 2015b).

In some areas, the evaluation criteria may not be applicable characterized by an "NA" in the scoring criteria discussed as follows. Figure 3 illustrates the location of the basins to be evaluated. Given the criteria of seawater intrusion that were evaluated, the inland and desert basins are not impacted and therefore would reflect an NA in the scoring rubric. The alternative management plan areas self-selected what was not applicable. Adjudicated basins were scored with an NA when it was obvious a criterion did not apply such as seawater instruction within a desert basin. Otherwise the scoring was silent for adjudicated areas and only the affirmative responses were scored as observed.

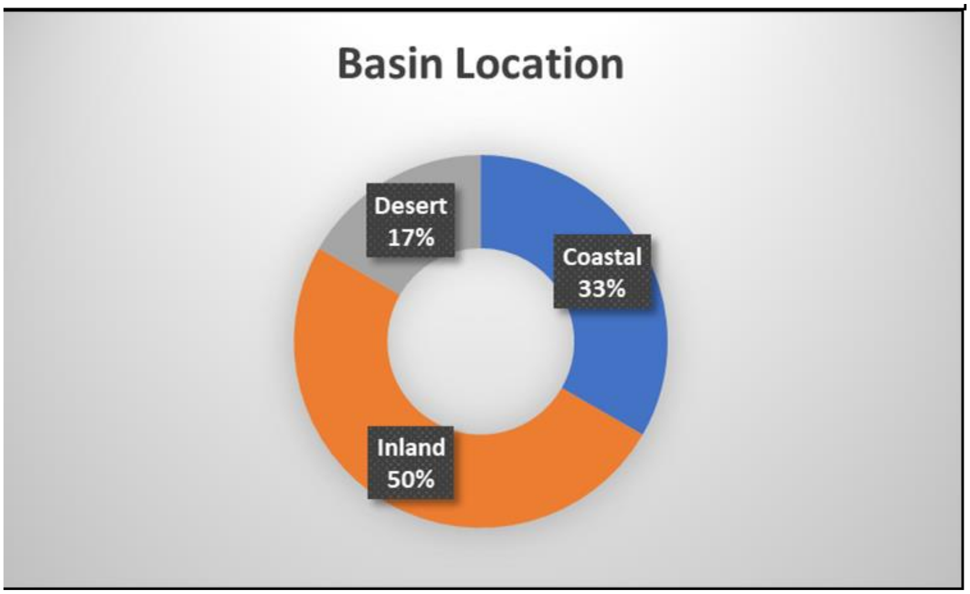


Figure 3. Location of basins.

Alternative Elements Guide

Medium- to high-priority basin areas that chose compliance through submittal of an alternative management plan were required to submit a completed Alternative Elements Guide comprised of 230 line items to demonstrate that they had existing plans, reports, resolutions, and the like that they self-certified as responsive to the various specific elements (DWR, 2019). For additional information, a copy of the Alternative Elements Guide can be downloaded from the DWR (2019) website, and California Code of Regulations Title 23 can be located through a query on a standard search engine. The guide is divided into 19 different sections that are reflective of the California Code of Regulations Title 23, Chapter 1.5, Subchapter 2 for Groundwater Sustainability Plans (DWR, 2016a). Specifically, Article 9 outlines the compliance requirements for alternative management plans. Following the requirements of Section 10733 of the State Water Code, Article 3, technical and reporting standards, the Alternative Elements Guide Excel spreadsheet provides a column in which the respondent can list the document(s) responsive to an element or provide a specific response (DWR, 2019). Of the 18 plans evaluated, there was no standard response format. Because of the uniqueness of each submittal, professional knowledge of groundwater management was required to evaluate the documents posted on DWR's (2018b) SGMA portal to determine responsiveness of the plans to SGMA's requirements. Adjudicated basins were evaluated utilizing a similar process that was also based upon excerpts from the Alternative Elements Guide (DWR, 2019).

Evaluation Instrument for Alternative Management Plans

To facilitate evaluating the alternative management plans, a grading instrument was developed utilizing the Alternative Elements Guide format. By selecting 77 of the most relevant elements from the 230 elements in the guide, a spreadsheet was designed that would facilitate a comprehensive review of each alternative management plan consistent with Article 9 of the Water Code.

An example of the designed interim evaluation instrument is included in Appendix A. Figure 4 presents elements excerpted from the scoring instrument to aid in the narrative of the process.

The first step in developing the scoring guide for alternative management plan areas was to review the 230 elements in the Alternative Elements Guide to determine which elements would provide responsiveness to the six undesirable results (DWR, 2016c) that are to be avoided with proper groundwater management listed as follows:

1. Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continuing over the planning and implementation horizon.
2. Significant and unreasonable reduction of groundwater storage.
3. Significant and unreasonable seawater intrusion.
4. Significant and unreasonable degraded water quality, including migration of contaminant plumes that impairs water supplies.
5. Significant and unreasonable land subsidence that substantially interferes with surface land uses.
6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water. (DWR, 2016c, p. 2)

Seventy-seven of the 230 elements from the original guide were selected as being specifically responsive to the six listed criteria. These elements were then assigned to an undesirable results criteria (1 through 6) and responsiveness was evaluated accordingly to ensure that each of the six elements could be sufficiently evaluated. Figure 4 displays at

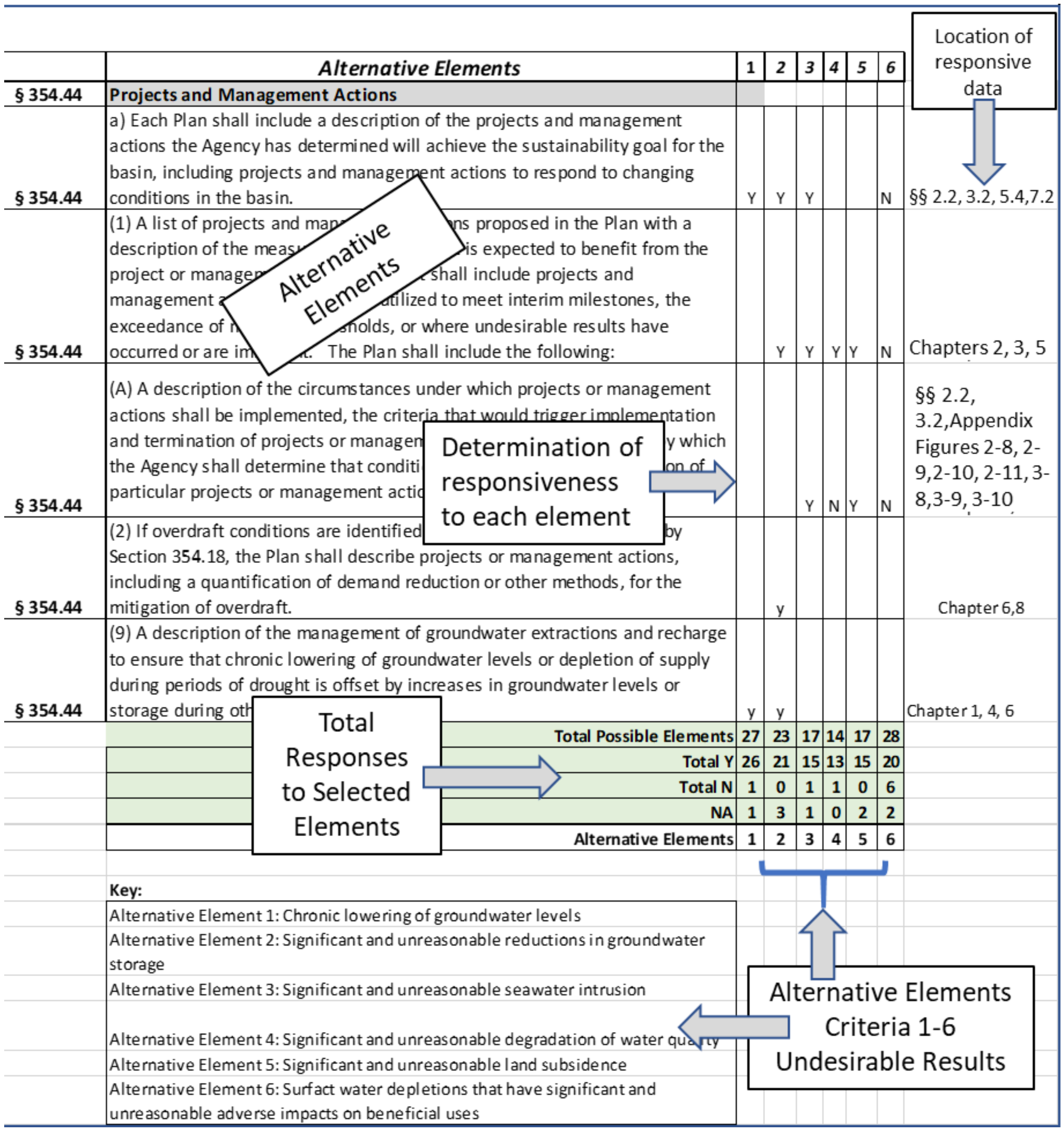


Figure 4. Elements of a scoring instrument for AMPs. Adapted from Alternative Elements Guide, by California Department of Water Resources, 2019 (https://www.google.com/search ?q=SGMA+alternative +elements+guide&rlz=1C1CHBF_enUS783US785&oq=SGMA +alternative+elements+guide&aqs=chrome..69i57.4478j0j7&sourceid=chrome&ie =UTF-8).

the bottom of the chart the graded responses of a scoring instrument. The data evaluated for the response was located on the original completed submittal by each alternative management plan area and copied into a column on the created scoring instrument. The data referenced in each corresponding column were reviewed to determine the responsiveness for the criteria (1 through 6) for all 77 selected elements. In many cases, this required reviewing multiple documents for one element to determine if it was responsive, which was notated with a "Y" on the spreadsheet signifying it met the required criteria. An "N" was scored if it was determined that the plan was not responsive and for elements that were self-certified by the alternative management plan submittal as not applicable, an NA was notated.

In an effort to determine responsiveness for all six criteria, specific compliance elements were assigned to each criterion. As noted on Figure 4, a specific compliance element could be assigned to one or more criteria. In Figure 4, the total responses to the selected elements display that Criterion 1, chronic lowering of groundwater levels, had a total of 27 maximum possible responses. Criterion 2, reduction in groundwater storage, had 23 potential responses. Criterion 3, seawater intrusion, had 17 possible responses.

Criterion 4, degradation of water quality, had 14 responses. Criterion 5, land subsidence, had 17 possible responses. Lastly, Criterion 6, surface water depletion, had 28 possible responses. The actual responses per criterion differed from one plan to the next because there were items that were not applicable. For instance, inland basins are not impacted by seawater intrusion; therefore that criterion would not be applicable (NA) for that element. A desert area may not have interconnected surface water so monitoring the time and location of depletion as listing for compliance with Water Code section

354.28 would not apply. Items that were not applicable were removed from the final tally so that the score would not be skewed by these elements.

Evaluation Instrument for Adjudicated Areas

The instrument for adjudicated areas is similar to the instrument for the alternative management plan areas and utilizes the Alternative Elements Guide (DWR, 2016c) as the foundational resource. The rubric for adjudicated areas includes 52 possible elements compared to the 77 elements used for the alternative management plans. The adjudicated basins were responsive to the six unique mandatory elements due by April of each year. Following are these unique mandatory elements for each adjudicated area:

- Collecting annual groundwater data
- Annual groundwater extractions (pumping)
- Surface water supply used
- Total water use (surface and groundwater)
- Change in groundwater storage
- Submittal of an annual report. (Cal. Water Code § 10720.8)

The elements above reflect the only annual requirements for the adjudicated basins. If they complied with these six items, they were deemed compliant. However, the crux of the study was to compare the current practices of adjudicated areas with the current practices of the areas that submitted alternative management plans and determine if the current actions between the two groups were equally compliant or different.

The scoring instrument for adjudicated areas included seven different areas for scoring including the mandatory elements listed above, general basin information, and the six undesirable impacts of groundwater depletion listed previously in this chapter.

Following is a list of the scoring categories in the instrument for adjudicated basins (Appendix B):

Mandatory Reporting Elements = 6 questions

General Basin Information = 10 questions

Chronic Lowering of Groundwater Levels = 13 questions

Reduction in Groundwater Storage = 5 questions

Seawater Intrusion = 3 questions

Degradation of Water Quality = 4 questions

Land Subsidence = 3 questions

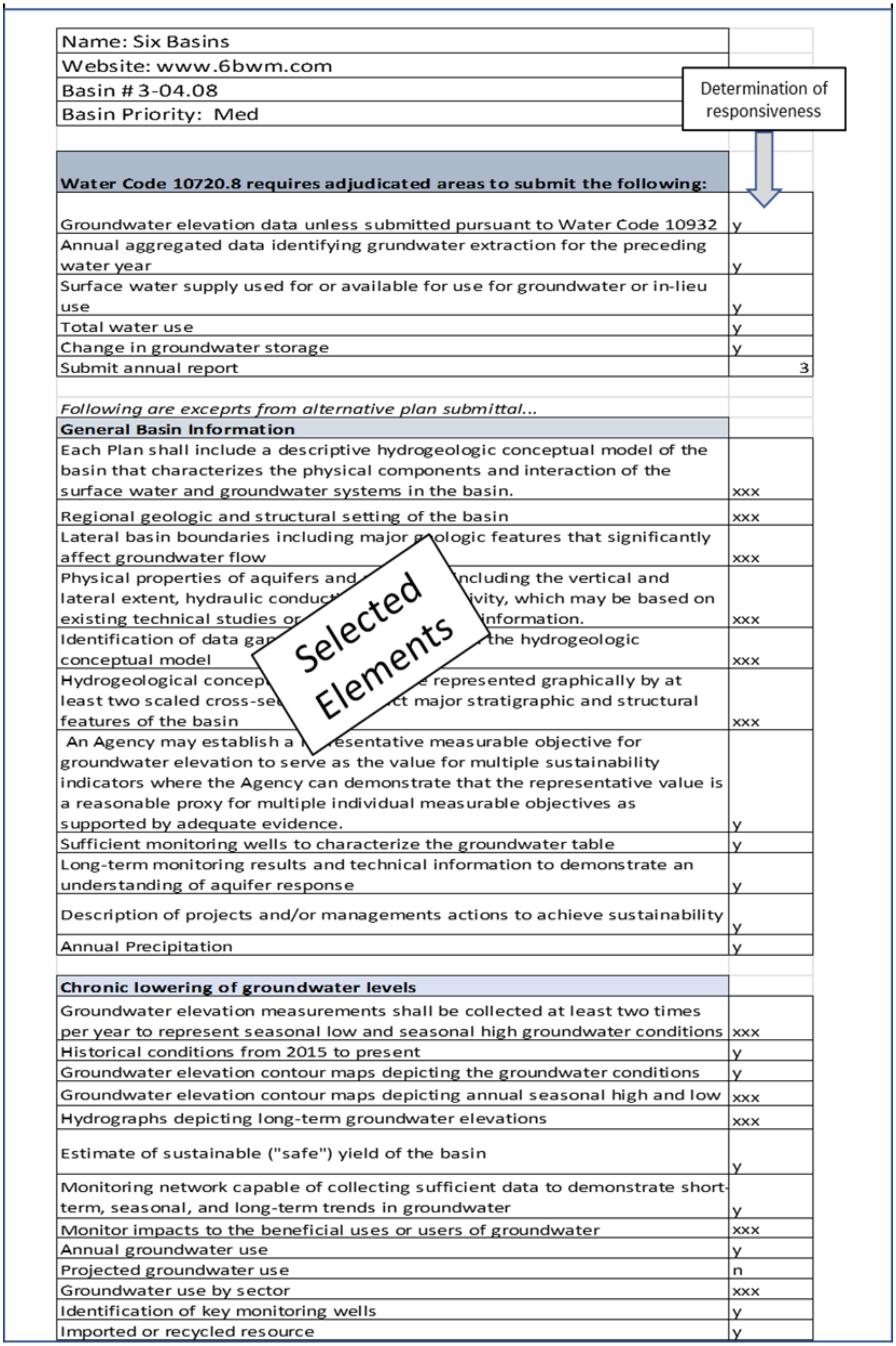
Surface Water Depletion and Impact on Beneficial Uses = 7 questions

A search of empirical data in each of the adjudicated areas provided data responsive to the categories listed above in many cases. In contrast to the alternative management plan submittals that specified the location of the data they deemed responsive to each criterion, research for adjudicated areas required an extensive online data search. For adjudicated basins, the material reviewed included the annual reports and judgments submitted to the DWR. In addition, Groundwater Management Plans, Integrated Regional Water Management Plans, Urban Water Management Plans, and websites for agencies that are a party to the respective adjudications were reviewed to evaluate programs and processes that the adjudicated areas had in place that would be responsive to the specific elements outlined above. A review of court-assigned Watermaster websites was also part of the data review process. The data did not always prove easy to locate and, in some cases, did not exist.

Review of the annual reports and the judgments for the adjudicated areas indicated that sustainability as defined by the SGMA was not the primary focus of the various adjudications, but rather the adjudications came about primarily as a result of disputes over water rights (Langridge et al., 2016). The dispute could concern only groundwater rights or only surface water rights as in the Santa Margarita adjudication. However, in response to various water supply mandates over the past decades, most areas have additional programs and best management practices in place that provide some level of sustainability particularly to substantiate adequate water supply. The programs and processes that many adjudicated areas have implemented after the court order are responsive to many of the areas included in the scoring instrument. Figure 5 provides a sample of the scoring instrument used for alternative management plan basins, an example of which is included in Appendix A.

Comparative Data Set for Both Alternative Management Plans and Adjudicated Basins

A third scoring rubric was developed that allowed the testing of the hypotheses in comparing the responsiveness of alternative management plans to that of the adjudicated basin areas. This rubric selected information that was available from both unique groups. Based upon the researcher's professional expertise, the following condensed rubric was developed to capture the essence of responsiveness to each of the six scoring elements or undesirable results to be avoided. The data set received review by two interraters who were professionals in the field. Their evaluation confirmed that the data set utilized to compare the adjudicated areas and the alternative management plan areas was appropriate for the intended evaluation.



Name: Six Basins	
Website: www.6bwm.com	
Basin # 3-04.08	
Basin Priority: Med	
Water Code 10720.8 requires adjudicated areas to submit the following:	
Groundwater elevation data unless submitted pursuant to Water Code 10932	y
Annual aggregated data identifying grundwater extraction for the preceding water year	y
Surface water supply used for or available for use for groundwater or in-lieu use	y
Total water use	y
Change in groundwater storage	y
Submit annual report	3
Following are exceprts from alternative plan submittal...	
General Basin Information	
Each Plan shall include a descriptive hydrogeologic conceptual model of the basin that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.	xxx
Regional geologic and structural setting of the basin	xxx
Lateral basin boundaries including major [illegible]ologic features that significantly affect groundwater flow	xxx
Physical properties of aquifers and [illegible]ncluding the vertical and lateral extent, hydraulic conduc[illegible]ivity, which may be based on existing technical studies or [illegible]nformation.	xxx
Identification of data ga[illegible] the hydrogeologic conceptual model	xxx
Hydrogeological concep[illegible] represented graphically by at least two scaled cross-se[illegible]ct major stratigraphic and structural features of the basin	xxx
An Agency may establish a [illegible]esentative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence.	y
Sufficient monitoring wells to characterize the groundwater table	y
Long-term monitoring results and technical information to demonstrate an understanding of aquifer response	y
Description of projects and/or managements actions to achieve sustainability	y
Annual Precipitation	y
Chronic lowering of groundwater levels	
Groundwater elevation measurements shall be collected at least two times per year to represent seasonal low and seasonal high groundwater conditions	xxx
Historical conditions from 2015 to present	y
Groundwater elevation contour maps depicting the groundwater conditions	y
Groundwater elevation contour maps depicting annual seasonal high and low	xxx
Hydrographs depicting long-term groundwater elevations	xxx
Estimate of sustainable ("safe") yield of the basin	y
Monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater	y
Monitor impacts to the beneficial uses or users of groundwater	xxx
Annual groundwater use	y
Projected groundwater use	n
Groundwater use by sector	xxx
Identification of key monitoring wells	y
Imported or recycled resource	y

Figure 5. Elements of scoring areas for adjudicated instrument. Adapted from Alternative Elements Guide, by California Department of Water Resources, 2019 (https://www.google.com/search?q=SGMA+alternative +elements+guide&rlz=1C1CHBF_enUS783US785&oq=SGMA+alternative+elements+guide&aqs=chrome..69i57.4478j0j7&sourceid=chrome&ie=UTF-8).

The comparative data set allowed the envisioned comparison between the alternative management plans and the adjudicated areas in a chi-square format of observed results. Following are the elements for each of the evaluated criterion:

Criterion 1: Chronic Lowering of Groundwater Levels

The nine elements selected to evaluate Criterion 1 include basic data and tools necessary for understanding and monitoring the condition of the groundwater. A manager cannot manage what he or she doesn't know; therefore, the ability to properly characterize the groundwater through elevation data, knowing how much can be pumped without overdrafting the resource and knowing current usage scenarios and projected demands are basic tools in understanding a basin's groundwater conditions. Critical to this understanding is a thorough monitoring network comprised of groundwater monitoring wells with transducers or other sounding devices that record the groundwater elevations and provide data from which trends can be assessed (see Figure 6).

354.34	Groundwater elevation measurements shall be collected at least two times per year to represent seasonal low and seasonal high groundwater conditions
354.18	Historical conditions from 2015 to present
354.16	Groundwater elevation contour maps depicting the groundwater conditions
354.16	Groundwater elevation contour maps depicting annual seasonal high and low
354.18	Estimate of sustainable ("safe") yield of the basin
354.34	Monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater
354.26	Monitor impacts to the beneficial uses or users of groundwater
354.34	Annual groundwater use
354.34	Projected groundwater use
	Expected = 9

Figure 6. Criterion 1: Chronic lowering of groundwater levels. Adapted from Alternative Elements Guide, by California Department of Water Resources, 2019 (https://www.google.com/search?q=SGMA+alternative +elements+guide&rlz=1C1CHBF_enUS783US785&oq=SGMA+alternative+elements+guide&aqs=chrome..69i57.4478j0j7&sourceid=chrome&ie=UTF-8).

Criterion 2: Reduction in Groundwater Storage

Understanding the impacts of demand on storage is a critical element to ensuring that overdraft of a basin does not occur over the planning period. SGMA does allow for reduction in storage during a drought period with sufficient recharge and other demand management measures that ensure it is not a chronic unmitigated condition over the planning horizon defined as a 50-year period (DWR, 2016a). Hydrographs are an excellent pictorial of groundwater dynamics and can be reflective of seasonal changes as well as long-term information on a specific data point. The more data points from key monitoring wells, the better the overall picture of the basin. Quantifying both the cumulative change in storage and the annual reduction in storage along with the recharge is similar to managing a bank account with credits, debits, and long-term loans (see Figure 7).

354.16	Change in groundwater storage based on data, demonstrating the annual cumulative change
354.28	Threshold of water use/elevation that indicates depletion of supply
354.28	Groundwater elevation decline based upon historical trends and water use.
354.28	The annual amount of reduction in storage
354.14	Annual groundwater recharge
354.16	Hydrographs depicting long-term groundwater elevations
354.34	Identification of key monitoring wells
	Expected = 7

Figure 7. Criterion 2: Reduction in groundwater storage. Adapted from Alternative Elements Guide, by California Department of Water Resources, 2019 (https://www.google.com/search ?q=SGMA+alternative +elements+guide&rlz=1C1CHBF_enUS783US785&oq=SGMA +alternative+elements+guide&aqs=chrome..69i57.4478j0j7&sourceid=chrome&ie =UTF-8).

Criterion 3: Seawater Intrusion

Seawater intrusion impacts a small percentage of the overall basins evaluated. Of the 35 basins reviewed in the study, only 10 are located in coastal areas that would be impacted by seawater intrusion. The three significant elements in evaluating seawater include mapping the intrusion, determining via water quality testing the infiltration into groundwater, and finally, understanding of the rate and extent of the infiltration (see Figure 8).

354.28	Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.
354.25/34	Chloride concentration isocontours used for defining seawater intrusion or other related information
354.34	Rate and extent of seawater intrusion monitored/calculated/Min Threshold
	Expected = 3

Figure 8. Criterion 3: Seawater intrusion. Adapted from Alternative Elements Guide, by California Department of Water Resources, 2019 (https://www.google.com/search ?q=SGMA+alternative +elements+guide&rlz=1C1CHBF_enUS783US785&oq =SGMA+alternative+elements+guide&aqs=chrome..69i57.4478j0j7&sourceid=chrome&ie =UTF-8).

Criterion 4: Degradation of Water Quality

Every water agency in the state has tested for water quality for decades. Every few years, new items are added to the testing requirements based upon emerging contaminants of concern and laboratory testing advancements. Water quality is one of the most widely understood and available data sets across the country. Most testing requirements are set forth by the Environmental Protection Agency (EPA) and can be enhanced with tougher restrictions by a state's EPA that has the authority to make the requirements more stringent but cannot relax the requirements of the federal EPA. The four general criteria selected for water quality reflect the importance of understanding the water quality within the basin including any plumes of contamination from anthropogenic causes as well as naturally occurring water quality such as arsenic. Past practices have now been found to affect current water quality such as barrels of a contaminant that have been buried that are now leaching into the groundwater or former industrial practices causing legacy water quality issues. What was not known in the past regarding water quality has had current impacts on the resource. The four general water quality requirements evaluated ensure that a basin has a firm understanding of the current conditions and any impending threats to the groundwater resource (see Figure 9).

354.14	General water quality of the principal aquifers
354.16	Groundwater quality issues that may affect the supply and beneficial uses of groundwater
354.16	Identification of any plumes of contamination or areas of poor water quality
354.34	Collect sufficient data to determine/understand water quality
	Expected = 4

Figure 9. Criterion 4. Degradation of water quality. Adapted from Alternative Elements Guide, by California Department of Water Resources, 2019 (https://www.google.com/search?q=SGMA +alternative +elements+guide&rlz=1C1CHBF_enUS783US785&oq=SGMA+alternative +elements+guide&aqs=chrome..69i57.4478j0j7&sourceid=chrome&ie =UTF-8).

Criterion 5: Land Subsidence

Most of the 35 areas evaluated did not have an issue with subsidence. Focus on this topic arose primarily from the farming activities throughout the Central Valley from Bakersfield to Redding. Some parts of the Central Valley have experienced several feet of subsidence from the extraction of large amounts of groundwater over nearly a century of agricultural operations. The extraction of groundwater causes the fine grains of earth to collapse causing the settling known as subsidence, a condition that cannot be repaired. Emphasizing the best course of action is prevention. The three selected criteria provide sufficient detail regarding a basin's evaluation of subsidence. Again using the adage that a manager cannot manage what he or she doesn't know, it is important for a basin to complete the scientific measurements to ascertain if subsidence is or is not an issue, what the total amount of subsidence is, and the annual rate of subsidence, if any. Once known, the undesirable element can be managed and mitigated through appropriate water management action (see Figure 10).

354.28	Completed study to determine if any subsidence exists or establishment of minimal thresholds
354.34	Cumulative total of land subsidence
354.16	Annual rate of subsidence
	Expected = 3

Figure 10. Criterion 5. Land subsidence. Adapted from Alternative Elements Guide, by California Department of Water Resources, 2019 (https://www.google.com/search?q=SGMA +alternative +elements+guide&rlz=1C1CHBF_enUS783US785&oq=SGMA+alternative +elements+guide&aqs=chrome..69i57.4478j0j7&sourceid=chrome&ie =UTF-8).

Criterion 6: Surface Water Depletions.

Monitoring surface water is new to the groundwater management schema. Utilizing monitoring well data to develop graphs and charts for monitoring the seasonal, annual, and decadal changes has typically been the extent of responsible groundwater management. With the implementation of SGMA, there is a new requirement to understand, monitor, and measure the interaction between groundwater and surface water to the extent that monitoring wells will have to be installed near waterways in addition to stream-flow gauges to better understand the “spatial and temporal exchanges between surface water and groundwater” (DWR, 2016a, p. 24), as stated in the California Code of Regulations, Title 23. Six specific questions were selected to ascertain current monitoring practices in the adjudicated and alternative management plan areas. In addition to monitoring the interconnectedness of surface and ground water, the act requires the identification of groundwater-dependent ecosystems. This requires monitoring native plant species that depend upon a high groundwater table. Further, the new criteria could require the monitoring of marshland and meadow areas that may be negatively impacted when the depth to groundwater increases causing the groundwater to fall below the root zone of vegetation (see Figure 11).

354.34	Monitor surface water and groundwater to calculate depletions of surface water caused by groundwater extractions.
354.16	Identification of groundwater dependent ecosystems within the basin, utilizing data or the best available information.
354.34	Depletion of interconnected surface water caused by groundwater use
354.34	Monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term surface conditions
354.34	Groundwater flow direction and hydraulic gradients between aquifer and surface water
354.18	Sources of surface water supply / use for groundwater recharge described in annual volume
	Expected = 6

Figure 11. Criterion 6: Surface water depletions that have significant and unreasonable adverse impacts on beneficial uses. Adapted from Alternative Elements Guide, by California Department of Water Resources, 2019 (https://www.google.com/search?q=SGMA+alternative +elements +guide&rlz=1C1CHBF_enUS783US785&oq=SGMA+alternative+elements+guide&aqs=chrome ..69i57.4478j0j7&sourceid=chrome&ie =UTF-8).

Conclusions

Chapter 3 provided detailed information on the three different scoring sets, which included a scoring rubric for alternative management plan areas, a scoring rubric for adjudicated groundwater areas, and the third scoring rubric that included the most salient elements for statistical analysis. The comparative data set allows comparison between the alternative management plan and the adjudicated areas in a chi-square format of observed results with 35 sample groups.

Remainder of the Study

The balance of the study includes Chapter 4 and Chapter 5. Chapter 4 provides the analysis of the data including the findings. Chapter 5 provides a summary of the findings and recommendations for future areas of study that were not considered within the defined scope of this research.

CHAPTER 4: FINDINGS

In one drop of water are found all the secrets of all the oceans.

—Khalil Gibran

In this research, the null hypothesis stated that there would not be a statistically significant difference between 18 adjudicated basins and the 17 alternative management plan basins related to each group's responsiveness to the requirements of the Sustainable Groundwater Management Act (SGMA). Conversely, the alternative hypothesis was that there would be a statistically significant difference in the compliance of both groups. Each of the six undesirable criteria specifically outlined in SGMA was individually evaluated utilizing a chi-square statistical analysis to affirm or reject the null hypothesis.

It is important to note that the adjudications predate the concepts of SGMA in some cases by decades. Therefore, some of the contemporary water management practices outlined in SGMA were not contemplated when the adjudications were completed. Most, as stated previously, were to settle water rights disputes; however, over time as best management practices have developed, areas covered by adjudications have adopted additional management practices that are now specifically required by SGMA. Therefore, the heart of the study was to determine if these previously adjudicated basins meet the new requirements now outlined in SGMA.

The theoretical construct of the public trust doctrine and the common pool resource theory intersect in the arena of water resource management. Under scrutiny in recent years has been groundwater, the subject of this study. In some areas, depending upon the geology, once the groundwater is severely overdrafted, significant consequences occur to the resources themselves through subsidence and water quality degradation and to the environment through imperiled habitat and diminished stream flows.

The intent of this study was to determine if the level of compliance by the two selected groups was statistically similar. The two groups include the 18 basin areas that submitted alternative management plans and 17 previously adjudicated basin areas that are technically exempt from compliance. The purpose of evaluating these two specific groups was to provide relevant data in the emerging area of groundwater management that will assist other basins in determining a pathway to compliance. As new basins are reclassified, they will need to determine a method for complying with the SGMA. The evaluation of both adjudicated basins and basins that have submitted alternative management plans will provide data relevant to two of the three compliance options allowed by the state. Periodically, typically every 5 years, the state reviews the basins based on specific criteria and determines if a change in priority is necessary. If a basin is reassigned a priority of medium or high, it must comply with SGMA.

Research Questions

The research asks essentially the same question of two diverse data sets in an effort to determine the responsiveness of both groups to new sustainability criteria. One data group, the adjudicated areas, does not have the same rigorous compliance requirements as the second group, those that have submitted alternative management plans. Both were evaluated in relation to the achievement related to the new sustainability requirements. There were 17 adjudicated basins evaluated along with 18 basins that had submitted alternative management plans to the state by January 2017 (DWR, 2018b).

The following questions were answered by the research:

1. Do areas governed by a groundwater adjudication substantially meet the criteria of sustainability as outlined in the SGMA of 2014?
2. Do groundwater basin areas that have submitted an alternative management plan in lieu of forming a GSA meet the criteria of sustainability as outlined in the SGMA of 2014?
3. When a low- or very-low-priority basin meets the threshold to become a medium- or high-priority basin requiring further action, should that basin adjudicate or develop an alternative management plan to meet the sustainability requirements of SGMA?

Presentation of Results

Each of the six compliance criteria is presented individually with a cross-tabulation and the chi-square results. A 95% confidence level is used for each of the statistical calculations represented by an alpha of .05.

Hypotheses for Criterion 1—Groundwater

Criterion 1 is defined as "chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continuing over the planning and implementation horizon" (Cal. Water Code § 10721, p. 1). The null hypothesis stated that there was no significant difference between Group1 and Group 2. The alternative hypothesis stated that there was a statistically significant difference between Group 1, adjudicated basins, and Group 2, alternative management plan areas.

Cross-tabulation. As noted by the cross-tabulation table, there were nine separate answers denoted by numbers 1 through 9 across the top of the table. Of the 17 members in Group 1, adjudicated areas, one respondent had one affirmative answer from the list of nine possible answers compared to zero respondents in Group 2, alternative plan basins, which had zero participants with only one affirmative response. Conversely, looking to the right side of the table, Group 1 had no participants who had nine affirmative responses compared to Group 2, which had 13 participants who had nine affirmative responses. Nine was the maximum number of affirmative responses. This is typical for all six criteria. The total number of participants in Group 1 was 17 and in Group 2 was 18 for a total of 35 participants (see Table 1).

Table 1

Groundwater Cross-Tabulation

	Groundwater								
Group	1	2	4	5	6	7	8	9	Total
1	1	1	1	1	8	2	3	0	17
2	0	0	1	1	0	1	2	13	18
Total	1	1	2	2	8	3	5	13	35

Results. Table 2 displays the results of the chi-square test, which include the Pearson chi-square, Likelihood ratio, Fisher's exact test, and Linear-by-Linear Association. The value of the chi-square of 23.524 has a footnote "a," which states that 14 cells (87.5%) have expected counts of less than 5; therefore, the chi-square test was violated, which then required that the Fisher's exact test be utilized in the analysis. The Fisher's exact results showed .000, which is less than the alpha of .05; therefore the null had to be rejected signifying that there was a statistically significant difference between Group 1, adjudicated areas, and Group 2, alternative management plan basins.

Table 2

Chi-Square Test Results for Groundwater

Test	Value	*df*	Asymtotic significance (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)	Point probability
Pearson chi-square	23.524[a]	7	.001	.000		
Likelihood ratio	32.397	7	.000	.000		
Fisher's exact test	26.558			.000		
Linear-by-linear association	12.360[b]		.000	.000	.000	.000
N of valid cases	35					

[a]14 cells (87.5%) have expected count less than 5. The minimum expected count is .49.
[b]The standardized statistic is 3.516.

The test results for Criterion 1 show definitively that rejection of the null hypothesis is appropriate, but no differentiation in the value between the two groups was rendered as it related to whether one group was more compliant with SGMA than the other. A review of the cross-tabulation table revealed that in Group 2, more of the 17 groups responded affirmatively to the groundwater compliance criterion than in Group 1, which, although not statistically verified, would indicate that Group 2, in responses related to groundwater, was more responsive to the SGMA criteria.

The statistical analysis clearly shows that the null hypothesis was rejected in favor of the alternative hypothesis, indicating that there was a statistical difference in compliance. From a review of the cross-tabulation table, it was determined that the alternative management plan areas were consistently more responsive to the nine metrics; however, 13 of the 17 adjudicated basins were responsive to six or more of the nine specific items. Two of the questions focused on seasonal conditions, a third asked for projected groundwater use, and another related to beneficial uses. These four questions are specific targets under SGMA that would not typically be contemplated in an adjudicated basin. Minor adjustments in monitoring protocols would ensure that adjudicated areas are capturing trends important in SGMA.

Hypothesis for Criterion 2—Reduction of Storage

Criterion 2 is defined as "significant and unreasonable reduction of groundwater storage" (Cal. Water Code § 10721, p. 1). The null hypothesis states that there was no significant difference between Group1 and Group 2. The alternative hypothesis states that there is a statistically significant difference between Group 1, adjudicated basins, and Group 2, alternative management plan areas.

Cross-tabulation. As noted by the cross-tabulation table, there were seven separate answers denoted by numbers 1 through 7 across the top of the table. Of the 17 members in Group 1, adjudicated areas, one respondent had one affirmative answer from the list of seven possible answers compared to zero respondents in Group 2, alternative management plan basins, that had zero participants with only one affirmative response. Conversely, looking to the right side of the table, Group 1 had two participants who had seven affirmative responses compared to Group 2, which had 10 participants who had seven affirmative responses. Seven was the maximum number of affirmative responses. The total number of participants in Group 1 was 17 and Group 2 was 18 for a total of 35 participants.

Table 3

Overdraft Cross-Tabulation

Control	Overdraft								
group	0	1	2	3	4	5	6	7	Total
1	1	2	1	2	5	3	1	2	17
2	0	0	0	1	1	3	3	10	18
Total	1	2	1	3	6	6	4	12	35

Results. Table 4 displays the results of the chi-square test, which include the Pearson chi-square, Likelihood ratio, Fisher's exact test, and Linear-by-Linear Association. The value of the chi-square of 13.316 has a footnote "a," which states that 14 cells (87.5%) had expected counts of less than 5; therefore, the chi-square test was violated, which then requires that the Fisher's exact test be utilized in the analysis. The Fisher's exact results show .032, which is less than the alpha of .05; therefore the null must be rejected, signifying that there was a statistically significant difference between Group 1, adjudicated areas, and Group 2, alternative management plan basins.

Table 4

Results of Chi-Square Tests for Overdraft Compliance

Test	Value	*df*	Asymtotic significance (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)	Point probability
Pearson chi-square	13.316[a]	7	.065	.034		
Likelihood ratio	15.636	7	.029	.057		
Fisher's exact test	12.701			.032		
Linear-by-linear association	11.438[b]	1	.001	.000	.000	.000
N of valid cases	35					

[a]14 cells (87.5%) have expected count less than 5. The minimum expected count is .49.
[b]The standardized statistic is 3.382.

The test results for Criterion 2 show definitively that rejection of the null hypothesis was appropriate, but no differentiation in the value between the two groups was rendered as it related to which group was more compliant with SGMA than the other. A review of the cross-tabulation table revealed that in Group 2, more of the 17 participants in the group responded affirmatively to the overdraft compliance criterion than in Group 1, which, although not statistically verified, could indicate that Group 2, in responses related to overdraft, was more responsive to the SGMA criteria.

The results indicated that the null hypothesis was rejected and the alternative hypothesis was affirmed for this question. The adjudicated basins had significant affirmative responses to three of the seven questions but had six or less positive responses to four of the questions compared to the alternative management plan group, which had 10 participants who were responsive to all of the seven of the criteria. This indicates that the participants from the alternative management plan basin were more responsive. Adjudicated basins have not historically evaluated cumulative change or depletion of supply because they were operating within a stipulated judgement that set particular operational standards or parameters for basin pumping. This might include a specific allocation of water rights to be pumped by each participant with the understanding that if this allotment is not exceeded then the tenets of the adjudication would be met. The adjudication would not require the monitoring of seasonal high and lows nor impacts to beneficial uses that are a required consideration under SGMA.

Hypothesis for Criterion 3—Seawater

Criterion 3 is defined as “significant and unreasonable reduction of groundwater storage” (Cal. Water Code § 10721, p. 1). The null hypothesis states that there was no significant difference between Group1 and Group 2. The alternative hypothesis states that there was a statistically significant difference between Group 1, adjudicated basins, and Group 2, alternative management plan areas.

Cross-tabulation. As noted by the cross-tabulation table, there were three separate answers denoted by numbers 1 through 3 across the top of the table. Of the 17 members in Group 1, adjudicated areas, 13 participants had no affirmative responses regarding seawater compliance and Group 2 had 10 participants who had no affirmative response. Conversely, looking to the right side of the table, Group 1 had no participants who had three affirmative responses compared to Group 2, which had eight participants with three affirmative responses. Three was the maximum number of affirmative responses. The total number of participants in Group 1 was 17 and Group 2 was 18 for a total of 35 participants. One explanation for the lack of responses was that the majority of the participants lived inland and were not affected by seawater intrusion (see Table 5).

Table 5

Seawater Cross-Tabulation

	Seawater				
Group	0	1	2	3	Total
1	13	1	3	0	17
2	10	0	0	8	18
Total	23	1	3	8	35

Results. Table 6 displays the results of the chi-square test, which include the Pearson chi-square, Likelihood ratio, Fisher's exact test, and Linear-by-Linear Association. The value of the chi-square of 12.373 has a footnote "a," which states that six cells (75%) had expected counts of less than 5; therefore, the chi-square test was violated, which then required that the Fisher's exact test, with a value result of 12.461, be utilized in the analysis. The Fisher's exact results showed .002, which was less than the alpha of .05; therefore the null had to be rejected signifying that there was a statistically significant difference between Group 1, adjudicated areas, and Group 2, alternative management plan basins.

Table 6

Chi-Square Results for Seawater

Test	Value	*df*	Asymtotic significance (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)	Point probability
Pearson chi-square	12.373[a]	3	.006	.002		
Likelihood ratio	16.999	3	.001	.001		
Fisher's exact test	12.461			.002		
Linear-by-linear association	4.387[b]	1	.036	.035	.022	.010
N of valid cases	35					

[a]6 cells (75.0%) have expected count less than 5. The minimum expected count is .49.
[b]The standardized statistic is 2.095.

The test results for Criterion 3 show definitively that rejection of the null hypothesis was appropriate, but no differentiation in the value between the two groups was rendered as it related to which group was more compliant with SGMA than the other. A review of the cross-tabulation table revealed that in Group 2, more of the 17 participants in the group responded affirmatively to the seawater compliance criterion than the Group 1 participants. Although not statistically verified, the table indicates that Group 2, in responses related to seawater, was more responsive to the SGMA criteria.

Responsiveness for this criterion did not necessarily represent responsiveness or nonresponsiveness because many of the basins were inland and not affected by seawater. The statistical analysis did indicate that the null hypothesis should be rejected, indicating that there was a statistically significant difference in compliance between Group 1, adjudicated basin, and Group 2, alternative management plan basins, and review of the cross-tabulation data table indicated that among the alternative management plan group, eight participants did respond affirmatively to all three elements compared to the adjudicated groups, which only had four respondents affirm any of the questions. This indicates that the alternative management plan basins were more responsive.

Hypothesis for Criterion 4—Water Quality

Criterion 4 is defined as "significant and unreasonable degraded water quality, including migration of contaminant plumes that impairs water supplies" (Cal. Water Code § 10721, p. 1). The null hypothesis states that there was no significant difference between Group1 and Group 2. The alternative hypothesis states that there was a statistically significant difference between Group 1 and Group 2.

Cross-tabulation. As noted by the cross-tabulation table, there were four separate answers denoted by numbers 1 through 4 across the top of the table. Of the 17 members in Group 1, adjudicated areas, there was one participant who had no affirmative responses regarding water quality compliance, and Group 2 had zero participants who had no affirmative responses. Conversely, looking to the right side of the table, Group 1 had 12 participants who had four affirmative responses compared to Group 2, which had 13 participants who had four affirmative responses. Four was the maximum number of affirmative responses. The total number of participants in Group 1 was 17 and Group 2 was 18 for a total of 35 participants.

Table 7

Group Quality Cross-Tabulation

	Group quality					
Group	0	1	2	3	4	Total
1	1	0	3	1	12	17
2	0	2	0	3	13	18
Total	1	2	3	4	25	35

Results. Table 8 displays the results of the chi-square test, which include the Pearson chi-square, Likelihood ratio, Fisher's exact test, and Linear-by-Linear Association. The value of the chi-square of 7.017 has a footnote "a," which states that six cells (80%) had expected counts of less than 5; therefore, the chi-square test was violated, which then required that the Fisher's exact test be utilized in the analysis. The Fisher's exact results showed .150, which is greater than the alpha of .05; therefore, the null hypothesis was not rejected, signifying that there was not a statistically significant difference between Group 1, adjudicated areas, and Group 2, alternative management plan basins, related to SGMA's water quality compliance.

Table 8

Chi-Square Results for Group Quality

Test	Value	*df*	Asymtotic significance (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)	Point probability
Pearson chi-square	7.017[a]	4	.135	.125		
Likelihood ratio	9.376	4	.052	.122		
Fisher's exact test	6.126			.150		
Linear-by-linear association	.167[b]	1	.683	.760	.404	.113
N of valid cases	35					

[a]8 cells (80.0%) have expected count less than 5. The minimum expected count is .49.
[b]The standardized statistic is .408.

The test results for Criterion 4 show that the null hypothesis cannot be rejected. This result is not entirely surprising because water agencies have been required to monitor water quality for many years for public health and safety reasons. Water quality testing requirements are promulgated by the federal Environmental Protection Agency (EPA) and the state EPA.

Stringent water quality testing requirements are mandated upon all water districts that provide potable water to customers. Compliance is required by both adjudicated areas and alternative management plan basins. It was of little surprise that in this criterion, the statistical analysis indicated that the null hypothesis should be accepted, and it affirmed that there was no statistically significant difference between the two study groups because the water quality testing protocols are universal throughout all water districts in the state. Group 1 and Group 2 are made up primarily of water districts.

Hypothesis for Criterion 5—Subsidence

Criterion 5 is defined as “significant and unreasonable land subsidence that substantially interferes with surface land uses” (Cal. Water Code § 10721, p. 1). The null hypothesis states that there was no significant difference between Group1 and Group 2. The alternative hypothesis states that there was a statically significant difference between Group 1, adjudicated basins, and Group 2, alternative management plan areas.

Cross-tabulation. As noted by the cross-tabulation table, there were three separate answers denoted by numbers 1 through 3 across the top of the table. Of the 17 members in Group 1, adjudicated areas, 15 respondents had no affirmative answers from the list of three possible answers, compared to six respondents in Group 2, alternative management plan basins, who had zero affirmative responses. Conversely, looking to the right side of the table, Group 1 had no participants who had three affirmative responses compared to Group 2, which had five participants with three affirmative responses. Three was the maximum affirmative responses by each participant. The total number of participants in Group 1 was 17 and Group 2 was 18 for a total of 35 participants (see Table 9). One explanation for the lack of responses from either group was that subsidence is not a universal issue among groundwater basins but relates more to localized issues such as the excessive groundwater pumping over an extended period of time, which causes the waterbearing sediments to collapse as documented in the Central Valley of California.

Table 9

Group Subsidence Cross-Tabulation

	Group subsidence				
Group	0	1	2	3	Total
1	15	0	2	0	17
2	6	4	3	5	18
Total	21	4	5	5	35

Results. Table 10 displays the results of the chi-square test, which include the Pearson chi-square, Likelihood ratio, Fisher's exact test, and Linear-by-Linear Association. The value of the chi-square of 13.039 has a footnote "a," which states that six cells (75%) had expected counts of less than 5; therefore, the chi-square test was violated, which then required that the Fisher's exact test be utilized in the analysis. The Fisher's exact results showed .001, which was less than the alpha of .05; therefore, the null hypothesis had to be rejected, signifying that there was a statistically significant difference between Group 1, adjudicated areas, and Group 2, alternative management plan basins.

Table 10

Chi-Square Results for Group Subsidence

Test	Value	*df*	Asymtotic significance (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)	Point probability
Pearson chi-square	13.039[a]	3	.005	.002		
Likelihood ratio	16.634	3	.001	.001		
Fisher's exact test	12.616			.001		
Linear-by-linear association	8.796[b]	1	.003	.002	.002	.001
N of valid cases	35					

[a]6 cells (75.0%) have expected count less than 5. The minimum expected count is 1.94.
[b]The standardized statistic is 2.966.

The test results for Criterion 5 show definitively that rejection of the null was appropriate, but no differentiation in the value between the two groups was rendered as it related to which group was more compliant with SGMA than the other. A review of the cross-tabulation table reveals that in Group 2, more of the 17 participants responded affirmatively to the groundwater compliance criterion than in Group 1 which, although not statistically verified, would indicate that Group 2 was more responsive to the SGMA criteria.

Subsidence, like seawater, has not been something monitored by adjudicated areas as evidenced by 15 of the 17 adjudicated basins having no affirmative responses to the three questions regarding subsidence compared to six of the alternative management plan basins that had no affirmative responses. Typically, adjudicated basins do not monitor for subsidence because it is not typically a factor in the stipulated agreement. All but two of the adjudicated basins were nonresponsive to the questions related to subsidence. However, given the fact that this is not applicable in most areas, the limited analysis utilizing the chi-square may not accurately capture this nuance. The results only indicate that there is a statistically significant difference in the responsiveness of the two groups.

Hypothesis for Criterion 6—Surface Water

Criterion 6 is defined as "depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water" (Cal. Water Code § 10721, p. 1). The null hypothesis states that there was no significant difference between Group1 and Group 2. The alternative hypothesis states that there was a statistically significant difference between Group 1, adjudicated basins, and Group 2, alternative management plan areas.

Cross-tabulation. As noted by the cross-tabulation table, there were six separate answers denoted by numbers 1 through 7 across the top of the table. Of the 17 members in Group 1, adjudicated areas, eight respondents had zero affirmative answers from the list of six possible answers compared to zero respondents in Group 2, alternative management plan basins, that who no participants with zero affirmative responses. Conversely, looking to the right side of the table, Group 1 had no participants who had six affirmative responses compared to Group 2, which had six participants who had six affirmative responses. Six was the number of maximum affirmative responses per participant. The total number of participants in Group 1 was 17 and Group 2 was 18 for a total of 35 participants (see Table 11).

Table 11

Group Surface Cross-Tabulation

	Group surface							
Group	0	1	2	3	4	5	6	Total
1	0	5	1	2	1	0	0	17
2	0	0	1	1	4	6	6	18
Total	8	5	2	3	5	6	6	35

Results Table 12 displays the results of the chi-square test, which include the Pearson chi-square, Likelihood ratio, Fisher's exact test, and Linear-by-Linear Association. The value of the chi-square of 27.127 has a footnote "a," which states that 14 cells (100%) have expected counts of less than 5; therefore, the chi-square test was violated, which then required that the Fisher's exact test be utilized in the analysis. The Fisher's exact results showed .000, which is less than the alpha of .05, therefore the null hypothesis had to be rejected, signifying that there was a statistically significant difference between Group , adjudicated areas, and Group 2 alternative management plan basins.

Table 12

Chi-Square Results for Group Surface

Test	Value	*df*	Asymtotic significance (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)	Point probability
Pearson chi-square	27.127[a]	6	.000	.000		
Likelihood ratio	36.896	6	.000	.000		
Fisher's exact test	27.846			.000		
Linear-by-linear association	24.682[b]	1	.000	.000	.000	.000
N of valid cases	35					

[a]14 cells (100.0%) have expected count less than 5. The minimum expected count is .97.
[b]The standardized statistic is 4.968.

The test results for Criterion 6 show definitively that rejection of the null hypothesis was appropriate, but no differentiation in the value between the two groups was rendered as it related to which group was more compliant with SGMA than the other. A review of the cross-tabulation table does reveal that in Group 2, there were significantly more affirmative responses regarding surface water compliance than in Group 1, which, although not statistically verified, would indicate that Group 2 is more responsive to the SGMA criteria related to surface water than Group 1.

This is a new consideration under SGMA as the interaction between surface water and groundwater has been formally introduced into the overall water management conversation. It is not surprising that only two of the adjudicated basins responded affirmatively to three of the six elements and one basin responded affirmatively to four of the six elements that were evaluated to confirm SGMA compliance. The one basin that responded affirmatively to four elements was a unique 1940 adjudication over surface water rights between landowners. That adjudication recognized the impact of groundwater on surface water. All other adjudications are primarily about groundwater rights as indicated by eight respondents from Group 1 not responding affirmatively to any of the six questions used to evaluate in this criterion.

Conclusion

The analysis shows that adjudicated basins and alternative management plan areas were not similar for Criteria 1, 2, 3, 5, and 6. A review of the cross-tabulation tables for each of the calculations reveals that the alternative management plan areas were more responsive to the SGMA criteria than the adjudicated basins. It is important to note that the alternative management plan basins self-certified to criteria that had full knowledge of, whereas the adjudicated basins were graded based upon current practices without knowledge of SGMA's requirements when the adjudications were formed. All adjudicated basins did comply with the mandatory reporting requirements under SGMA, so even though the adjudicated areas were not found be to statistically similar to the self-certified alternative management plan basins, they did exhibit some management practices for which compliance was not required by GSAs and alternative management plan basins.

Remainder of the Study

This study concludes with Chapter 5 with an evaluation and interpretation of the results and recommendations for future research.

CHAPTER 5: CONCLUSIONS

> But whoever drinks of the water that I will give him will never be thirsty again. The water that I will give him will become in him a spring of water welling up to eternal life.
>
> —John 4:14 ESV

Discussion

The Sustainable Groundwater Management Act (SGMA) allows for the adaptive localized management of critical common pool resources (Blomquist, 2016) that previously had been less acknowledged and less understood in the greater resource narrative. SGMA brings into focus the necessity for a holistic approach in the management of groundwater. The requirement to evaluate stream flows and groundwater interactions is a more complex approach than suggesting best management practices to evaluate the interaction. SMGA now requires this as an element to be avoided that is addressed specifically in the legislation. Further, SGMA encourages the integration of land use practices that will facilitate sustainability as the understanding of the sustainable safe yield of groundwater basins is more widely understood. Silos of governmental operations such as planning, flood control, water, and wastewater will need to coordinate on a higher level in an effort to fully and effectively manage the state's water resources through an integrated approach.

Theory Development and Applicability

Legal application of the public trust doctrine to groundwater resource management may expand in the future as case law develops and the concept of the interaction of surface and groundwater is perfected as it relates to navigable waterways and beneficial uses. Historically the public trust doctrine has been limited to navigable waterways but may see expansion with the implementation of SGMA. The recent Scott's

River superior court decision affirmed that the public trust doctrine “fully applies” to the dewatering of the Scott’s River and its tributaries through groundwater pumping (Frank, 2018). If not appealed, this is an expansion of prior application that will be cited in future cases.

Commons theory has previously been thoroughly developed and remains strongly applicable to groundwater management under SGMA. The economic basis for development of the theory continues to hold validity as much of the state’s economy has developed based upon the availability of water to serve the numerous beneficial uses including a growing population. Elinor Ostrom, who developed the common pool resource theory, asserted that locally derived rules and governance structures support common pool resource management (Aladjem & Sunding, 2015). The governance structures encouraged within the SGMA framework foster such an approach. Further, adjudicated basins adopted this solution-oriented collective governance approach long before SGMA’s adoptions. Elinor Ostrom in her book *Governing the Commons* (1990) chronicled the changes that occurred among parties during several adjudications in the Los Angeles area that sought a localized solution to manage competing demands for groundwater. The emergence of these governance structures supported her theory that locally derived collaborative solutions can occur to better manage common pool resources.

The validity of the theory continues to have relevance and applicability to groundwater use under SGMA given the emphasis for local management solutions of the common resource that can be achieved through alternative management plans, formation of a groundwater sustainability agency (GSA), or through adjudication.

New Adjudications

Senator Pavley, the author of SB1168 and SB1319, two of the three bills that outlined the tenets of SGMA, also authored SB226, to foster expedited adjudications, one of the three options for SGMA compliance. Previously, the adjudicatory process has taken a protracted period of time with intervening parties, cross-complaints and appeals often taking years to arrive at a judgment. SB226 along with AB1390 codified the process for expedited adjudications by amending the Water Code and the Code of Civil Proceedings that fits within the framework of SGMA. The intent was to "harmonize" the adjudicatory process with SGMA (DWR, 2015a). The expedited process will help foster a more timely solution for local areas that elect this option over alternative management plans or the formation of GSAs.

Adjudications of the future will adhere to the basin boundaries established by the California Department of Water Resources (DWR), as identified in Bulletin 118, which is updated every 5 years. This significantly streamlines the boundary process, which previously has included protracted court procedures to determine boundaries along jurisdictional, geographical, and/or basin boundaries. The features of post-SGMA adjudications have been woven into the Code of Civil Procedure through the adoption of SB226 in 2014 (DWR, 2015a). Lastly, new adjudications will have to conform to SGMA and the DWR will review each adjudication and provide an opinion to the courts.

DWR's Prioritization Process

The DWR Basin Prioritization process is dynamic and will continue to evolve over time due to SGMA's requirement that the assessment of basin conditions is an ongoing process. The 2014 DWR Basin Prioritization results and the 2018 SGMA Basin

Prioritization process are available on the DWR (2018a) website. The 2018 Basin Prioritization includes some proposed changes in basin classification from the 2014 process, which has reclassified some basins from low or very low priority to medium or high priority, triggering the necessity to comply with SGMA. DWR has identified 517 groundwater basins. In the 2014 basin prioritization, 109 basins were classified as high or medium priority compared to the 2018 prioritization, which tentatively shows 113 basins as medium or high priority. Three new basins on the 2018 draft list were reclassified as medium priority while eight basins were reclassified from medium to high priority and four basins were reduced in priority. A new addition in the 2018 basin evaluation was information relevant to adverse impacts on local habitat and stream flows. This requirement was included in the SGMA legislation adopted in 2014; however, no data were available at that time (DWR, 2018a). Henceforth, these criteria will be added to all subsequent basin prioritization evaluations. These changes evidence the dynamic nature of the basin prioritization process that will occur from time to time.

As new basins are required to comply with SGMA due to modification in priority, compliance is allowed through the formation of a GSA, submission of an alternative management plan as evaluated in this study or through the new expedited adjudicatory process.

Local Governance

The intent of the SGMA legislation was to facilitate local solutions with the focus on avoidance of six specifically defined criteria discussed throughout this study. The protracted implementation timeline of 20 years is intended to allow for area-specific compliance derived through a collaborative process. This is atypical of similar legislation that directed a state entity to aggressively implement requirements and demand immediate adherence as was witnessed in the drought legislation in which the State Water Resources Control Board (SWRCB) heavy handedly meted out reduction mandates and steep fines. Intended to be a long-term solutions-oriented process, SGMA encourages localized coordination with one entity in each basin taking the lead (Milman, Galindo, Blomquist, & Conrad, 2018). This would be accomplished through the formation of a new governance structure called a Groundwater Sustainability Agency. The structure could be a joint powers authority or one entity within a basin that assumes the responsibility and leadership for groundwater sustainability. The open-ended nature of the governance structure and the path to sustainability is hallmarked as one of SGMA's strengths. The legislation does not dictate the "how" being the process but rather outlines the "what" as the end result of sustainability within the 20-year timeline.

Implications of Study Results

The results would indicate that the alternative management plan basins that self-certified their compliance with the SGMA were more responsive then the adjudicated basins except in the area of water quality. In the area water quality, they were both equally responsive to the new requirements primarily because water quality testing is universal among adjudicated water purveyors and nonadjudicated water purveyors.

This study results indicate that alternative management plan are a compliant alternative to meeting the requirements of SGMA. However, with the new expedited adjudicatory process and the requirements for newly adjudicated basins to be responsive to SGMA, adjudications post-SGMA are an equally responsive option for new basins that are reprioritized through the DWR Basin Prioritization process.

It is important to note that while alternative management plan are more responsive to five of the six criteria evaluated, all of the adjudicated basins were compliant with their specific mandatory requirements which included (a) collecting annual groundwater data, (b) quantifying annual groundwater extractions, (c) total water use, (d) change in groundwater storage, and (e) submission of annual reports each year. The comparison indicated that if required to comply with SGMA's criteria as the alternative management plan basin are required to do, previous adjudicated basins will need to alter their management activities to varying degrees to achieve the same level of compliance.

Research Conclusions

The recent implementation of the SGMA of 2014 was a revolutionary change in water management and encouraged an integrated approach to water resource management with concepts such as surface water and groundwater interactions becoming a regulated practice for groundwater users. Surface water in the state has been regulated for 100 years, whereas groundwater has been a property-related right for the most part and not subject to the same scrutiny as the more visible surface water. While SGMA does not suggest any interference with the property interest of groundwater rights per se, it does require specific data gathering, analysis, and observation in order to understand the impacts of groundwater pumping and required mitigation of the undesirable results that can occur with unregulated pumping. Over the 20-year implementation timeframe, in order to achieve sustainability, there are six criteria that must be avoided, which include (a) chronic lowering of groundwater levels, (b) reductions in groundwater storage, (c) seawater intrusion, (d) degradation of water quality, (e) land subsidence, and lastly, (f) surface water depletions that have a significant and unreasonably adverse impact on beneficial uses. The governance structure to manage the groundwater is left up to the local basins to determine.

It will be important to watch the development of groundwater management as droughts come and go, precipitation cycles change, and the importance of strategic groundwater management is realized among all groundwater users. The need for additional above-ground storage, such as large reservoirs to capture rainfall when available, will help reduce some of the historic stresses on groundwater, which has filled the gap in supply for decades (Hanak et al., 2016).

Contribution to the Discipline

This study provides data that will contribute to the broader conversation of groundwater management. As basins are reclassified, the information in this study will help basins determine the appropriate structure to meet SGMA's requirements. Periodically the DWR (2018a) will reclassify groundwater basin as medium or high priority from low or very low priority. Further, the study provides a primer of water rights that will provide input for other researchers. Lastly, the study succinctly outlines the progression in groundwater management through legislation that will serve as a resource for future studies.

Study Limitations

There were three primary limitations to this study. First, the evaluation of the alternative management plans was done based upon self-certified management actions that have not yet been reviewed and deemed sufficient by the DWR. The successful implementation of SGMA over time in areas that submitted the alternative management plan will provide veracity for their initial submittals. Further the plan data may provide a false indication of sustainable practices in contrast to the adjudicated areas that have been evaluated in this study based upon verifiable data.

The second primary limitation of the study was the freshness of the legislation that has created extensive dialogue on the topic. Due to the proliferation of articles and studies, the contemporary nature of the subject created a challenge in narrowing the literature review and creating the specific focus for this study. Some relevant data may have been missed due to the enormity of the conversation occurring in the academic, legal, and journalistic realms regarding the SGMA. The creation of research in a new area of governance has a unique challenge in finding the relevant and salient elements.

Lastly, the ability to locate comparable data for all of the adjudicated basins to locate an appropriate comparison to the data provided by the alternative management plan basins proved to be a challenge that required extensive data searches for each adjudicated area. The possibility exists that some relevant information was not located.

Future Research

Alternative management plan basins are required to submit updates to the DWR every 5 years. Monitoring their progress toward sustainability would provide valuable data for the water community and validation of their initial responses.

Monitoring future adjudications and former adjudications to determine how and if they are meeting the sustainability goals outlined in SGMA would continue to build the body of knowledge on how adjudicated basins fit into the new narrative of groundwater management.

Understanding and evaluating the surface water-groundwater connection has never been a requirement until SGMA. This area will continue to develop as it includes *beneficial uses*, a term that can be redefined by the state and case law at any time. In an era of coequal goals that value environmental demands equal with humans needs, the focus on surface water-groundwater interaction will continue to expand in interpretation and will provide data for important research in the future.

Lastly, monitoring the development of regulatory oversight related to groundwater governance under SGMA will be valuable to the water community. It would appear that SGMA has opened the door for the SWRCB to have oversight of groundwater pumping because of its regulatory authority granted under SGMA that allows its intervention in areas of noncompliance. It would seem that the possibility exists for the board to issue a type of curtailment order against a groundwater pumper in the future. The SWRCB currently issues curtailment orders on surface water uses. Monitoring this potential would be of great interest.

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APPENDICES

APPENDIX A

Scoring Rubric for Alternative Management Plan Basins

Alternative Elements Guide

	Alternative Elements	1	2	3	4	5	6	2-010 Livermore Valley
Article 5 - Plan Contents								
SubArticle 1	**Administrative Information**							
§ 354.4.	**General Information**							
§ 354.8.	(2) A general description of how implementation of existing land use plans may change water demands within the basin or affect the ability of the Agency to achieve sustainable groundwater management over the planning and implementation horizon, and how the Plan addresses those potential effects.	y				y	y	Section 1.3.3.2 Land Use Planning; Section 1.3.3.4 General Plans
§ 354.14.	(D) General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.				y			Section 2.3.8 Groundwater Quality
§ 354.14.	(5) Identification of data gaps and uncertainty within the hydrogeologic conceptual model	NA	y	NA	NA	NA	NA	Section 2.2.3 Basin Hydrostratigraphy; Section 2.2.2.2 Main Basin Management Area; Section 2.2.2.3 Subareas within the Main Basin; Section 2.2.2.4 Fringe Management Area; Section 2.2.2.5 Uplands Management Area; Section 2.3.2 Groundwater Use
§ 354.14.	(4) Delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.		y					Figure 2-7 Surficial Clays above Upper Aquifer; Figure 2-26 Depth to Groundwater, Upper Aquifer; Section 2.3.10 Surface Water - Groundwater Interaction
§ 354.14.	(5) Surface water bodies that are significant to the management of the basin.						y	Section 2.1.3 Livermore-Amador Valley Streams; Figure 2-4 Surface Water Bodies and Monitoring Sites; Figure 2-39 Current Mining Area and Future Chain of Lakes
§ 354.16.	**Groundwater Conditions**							
§ 354.16.	Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:							y
§ 354.16.	(a) Groundwater elevation data demonstrating flow directions, lateral and vertical gradients, and regional pumping patterns, including:	y						Section 2.3.3 Groundwater Occurrence and Flow; Section 2.3.4 Groundwater Levels
§ 354.16.	(1) Groundwater elevation contour maps depicting the groundwater table or potentiometric surface associated with the current seasonal high and seasonal low for each principal aquifer within the basin.	y	y					Figure 2-24 Groundwater Elevation Map Upper Aquifer Spring 2015; Figure 2-27 Groundwater Elevation Map Lower Aquifer Spring 2015
§ 354.16.	(2) Hydrographs depicting long-term groundwater elevations, historical highs and lows, and hydraulic gradients between principal aquifers.		y					Figure 2-20 Key Well Water Levels in Amador West Subarea 1973 to 2015; Figure 2-21 Hydrographs; Figure 2-22 Groundwater Basin Management: Historical Groundwater Elevations at Fairgrounds Key Well
§ 354.16.	(b) A graph depicting estimates of the change in groundwater in storage, based on data, demonstrating the annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions, including the annual groundwater use and water year type.		y					Figure 2-30 Diagram of Groundwater in Storage in Main Basin Management Area; Figure 2-3 Sta. 15E Rainfall 1974-2015 (with water year types); Figure 2-19 Groundwater Use 1974-2015 (showing drought years)

§ 354.16.	(c) Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.			NA				Not applicable; Livermore Valley Groundwater Basin is an inland basin not susceptible to seawater intrusion.
§ 354.16.	(e) The extent, cumulative total, and annual rate of land subsidence, including maps depicting total subsidence, utilizing data available from the Department, as specified in Section 353.2, or the best available information.					y		Section 2.3.9 Land Subsidence Monitoring; Figure2-38 Surface Elevation and Groundwater Levels at Mocho Wellfield; no map available as there is no evidence of inelastic land subsidence.
§ 354.16.	(f) Identification of interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems, utilizing data available from the Department, as specified in Section 353.2, or the best available information.						y	Section 2.1.4 Springs and Groundwater Dependent Ecosystems; Figure 2-26 Depth to Water; Section 2.3.10 Surface Water- Groundwater Interaction
§ 354.16.	(g) Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or the best available information.						y	Section 2.1.4 Springs and Groundwater Dependent Ecosystems; Figure 2-26 Depth to Water; Section 2.3.10 Surface Water- Groundwater Interaction
§ 354.18.	**Water Budget**							
§ 354.18.	(a) Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form.	y					y	Section 2.4 Water Budget (Main Basin) Section 2.4.2.5 Estimated Groundwater Budget for the Fringe Management Area; Section 2.4.2.6 Estimated Groundwater Budget for the Uplands Management Area; Section 2.4.3 Historical Groundwater Budget; Section 2.5 Projected Water Budget and Future Management
§ 354.18.	(b) The water budget shall quantify the following, either through direct measurements or estimates based on data:							Section 2.4.1 Overview of Methodology; Table 2-13 Groundwater Inflows and Outflows
§ 354.18.	(1) Total surface water entering and leaving a basin by water source type.						y	Section 2.4.2.2 Inflow Components; Table 2-15 Stream Recharge Components
§ 354.18.	(2) Inflow to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.	y						Section 2.4.2.2 Inflow Components; Table 2-14 Areal Recharge Components; Table 2-15 Stream Recharge Components; Table 2-16 Subsurface Groundwater Flow
§ 354.18.	(4) The change in the annual volume of groundwater in storage between seasonal high conditions.		y					Section 2.4.2.4 Change in Groundwater Storage and Total Storage
§ 354.18.	(5) If overdraft conditions occur, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.	NA	NA					No overdraft conditions exist.
§ 354.18.	(7) An estimate of sustainable yield for the basin.	y						Section 2.4.4 Maintaining Sustainable Yield
§ 354.18.	(1) Current water budget information shall quantify current inflows and outflows for the basin using the most recent hydrology, water supply, water demand, and land use information.		y					Attachments B and C Annual Reports, 2015 WY and 2014 WY. Section 2.4.1 Overview of Methodology; Section 2.4.2 Current Groundwater Budget
§ 354.18.	(A) A quantitative evaluation of the availability or reliability of historical surface water supply deliveries as a function of the historical planned versus actual annual surface water deliveries, by surface water source and water year type, and based on the most recent ten years of surface water supply information.						y	Attachment F UWMP, 2015; Attachment G Water Supply Evaluation Update, 2016. Section 2.4.4 Maintaining Sustainable Yield; Section 2.4.4.2 Imports and Surface Water Supplies

§ 354.18.	(B) A quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the tools and methods used to estimate and project future water budget information and future aquifer response to proposed sustainable groundwater management practices over the planning and implementation horizon.	y						Att. B, 2015 WY Annual Report.Section 2.4.1 Overview of Methodology; Section 2.4.3 Historical Groundwater Budget; Section 2.6.2 Groundwater Model Update and Improvements
§ 354.18.	(C) A description of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability of the Agency to operate the basin within sustainable yield. Basin hydrology may be characterized and evaluated using water year type.	y					y	Attachment F UWMP, 2015; Attachment G Water Supply Evaluation Update, 2016. Section 2.4.4 Maintaining Sustainable Yield; 2.4.4.1 Zone 7 Artificial Recharge and Pumping; Figure 2-22 Groundwater Basin Management: Historical Groundwater Elevations at Fairgrounds Key Well
§ 354.20.	**Management Areas**							
SubArticle 3	**Administrative Information**							
§ 354.24.	**Sustainability Goal**							
§ 354.26.	**Undesirable Results**							
§ 354.26.	(1) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.	y		NA	y	y	y	Section 3.3.1 Groundwater Levels; Section 3.3.2 Groundwater Storage; Section 3.3.3 Groundwater Quality; Section 3.3.4 Land Subsidence; Section 3.3.5 Surface Water Groundwater Interaction
§ 354.26.	(2) The criteria used to define when and where the effects of the groundwater conditions cause undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.	y	y	NA	y	y	y	Definition of Undesirable Results; see respective sections: Section 3.3.1.1 Groundwater Levels; Section 3.3.2.1 Groundwater Storage; Section 3.3.3.1 Groundwater Quality; Section 3.3.4.1 Land Subsidence; Section 3.3.5.1 Surface Water Groundwater Interaction
§ 354.28.	**Minimum Threshold**							
§ 354.28.	(2) The relationship between the minimum thresholds for each sustainability indicator, including an explanation of how the Agency has determined that basin conditions at each minimum threshold will avoid undesirable results for each of the sustainability indicators.	y	y	NA	y	y	y	See discussions of Minimum Thresholds: Section 3.3.1.2 Groundwater Levels; Section 3.3.2.2 Groundwater Storage; Section 3.3.3.2 Groundwater Quality; Section 3.3.4.2 Land Subsidence; Section 3.3.5.2 Surface Water Groundwater Interaction
§ 354.28.	(3) How minimum thresholds have been selected to avoid causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals.			NA				Section 3.3 Sustainability Indicators; Section 1 Agency Information and Plan Area; Zone 7 has sustainably managed the basin to avoid undesirable results for at least 10 years, including coordination with other agencies; adjacent basins are very low priority.
§ 354.28.	(5) How state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the Agency shall explain the nature of and basis for the difference.				y			Minimum Thresholds are established in respective sections: Section 3.3.1.2 Groundwater Levels; Section 3.3.2.2 Groundwater Storage; Section 3.3.3.2 Groundwater Quality; Section 3.3.4.2 Land Subsidence; Section 3.3.5.2 Surface Water Groundwater Interaction

§ 354.28.	(6) How each minimum threshold will be quantitatively measured, consistent with the monitoring network requirements described in Subarticle 4.	y	y	NA	y	y	y	Minimum Thresholds are established in respective sections: Section 3.3.1.2 Groundwater Levels; Section 3.3.2.2 Groundwater Storage; Section 3.3.3.2 Groundwater Quality; Section 3.3.4.2 Land Subsidence; Section 3.3.5.2 Surface Water Groundwater Interaction
§ 354.28.	(1) Chronic Lowering of Groundwater Levels. The minimum threshold for chronic lowering of groundwater levels shall be the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results. Minimum thresholds for chronic lowering of groundwater levels shall be supported by the following:							Section 3.3.1.2 Minimum Thresholds Groundwater Levels
§ 354.28.	(A) The rate of groundwater elevation decline based on historical trends, water year type, and projected water use in the basin.	na						Not applicable; groundwater elevations are not declining chronically. See Section 2.3.3 Groundwater Occurrence and Flow; Section 2.3.4 Groundwater Levels
§ 354.28.	(2) Reduction of Groundwater Storage. The minimum threshold for reduction of groundwater storage shall be a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results. Minimum thresholds for reduction of groundwater storage shall be supported by the sustainable yield of the basin, calculated based on historical trends, water year type, and projected water use in the basin.		y					Section 3.3.2.2 Minimum Thresholds Groundwater Storage; see also Section 2.4.4 Maintaining Sustainable Yield
§ 354.28.	(3) Seawater Intrusion. The minimum threshold for seawater intrusion shall be defined by a chloride concentration isocontour for each principal aquifer where seawater intrusion may lead to undesirable results. Minimum thresholds for seawater intrusion shall be supported by the following:			NA				Seawater Intrusion Indicator is not applicable; Livermore Valley Groundwater Basin is an inland basin not susceptible to seawater intrusion.
§ 354.28.	(B) A description of how the seawater intrusion minimum threshold considers the effects of current and projected sea levels.			NA				Not applicable; Livermore Valley Groundwater Basin is an inland basin not susceptible to seawater intrusion.
§ 354.28.	(4) Degraded Water Quality. The minimum threshold for degraded water quality shall be the degradation of water quality, including the migration of contaminant plumes that impair water supplies or other indicator of water quality as determined by the Agency that may lead to undesirable results. The minimum threshold shall be based on the number of supply wells, a volume of water, or a location of an isocontour that exceeds concentrations of constituents determined by the Agency to be of concern for the basin. In setting minimum thresholds for degraded water quality, the Agency shall consider local, state, and federal water quality standards applicable to the basin.				y			Section 3.3.3.2 Minimum Thresholds Groundwater Quality
§ 354.28.	(5) Land Subsidence. The minimum threshold for land subsidence shall be the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results. Minimum thresholds for land subsidence shall be supported by the following:					y		Section 3.3.4.2 Minimum Threshold Land Subsidence

§ 354.28.	(A) Identification of land uses and property interests that have been affected or are likely to be affected by land subsidence in the basin, including an explanation of how the Agency has determined and considered those uses and interests, and the Agency's rationale for establishing minimum thresholds in light of those effects.					y		Section 3.3.4.1 Definition of Undesirable Results Land Subsidence
§ 354.28.	(B) Maps and graphs showing the extent and rate of land subsidence in the basin that defines the minimum threshold and measurable objectives.					na		No map available as there is no evidence of inelastic land subsidence; see also Figure 2-38 regarding elastic land subsidence
§ 354.28.	(6) Depletions of Interconnected Surface Water. The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results. The minimum threshold established for depletions of interconnected surface water shall be supported by the following:						y	Section 3.3.5.2 Minimum Thresholds Surface Water Groundwater Interaction
§ 354.28.	(A) The location, quantity, and timing of depletions of interconnected surface water.						y	Section 3.3.5.1 Undesirable Results Surface Water -Groundwater Interaction
§ 354.28.	(B) A description of the groundwater and surface water model used to quantify surface water depletion. If a numerical groundwater and surface water model is not used to quantify surface water depletion, the Plan shall identify and describe an equally effective method, tool, or analytical model to accomplish the requirements of this Paragraph.						y	Section 3.3.5.1 Undesirable Results Surface Water -Groundwater Interaction
§ 354.28.	(d) An Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence.		y					See respective sections on Minimum Thresholds: Section 3.3.1.2 Groundwater Levels; Section 3.3.2.2 Groundwater Storage; Section 3.3.4.2 Land Subsidence; Section 3.3.5.2 Surface Water Groundwater Interaction
§ 354.30.	**Measurable Objectives**							
	(a) Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.	na						Section 3.2 Basin Management Objectives and Sustainable Management Objectives; the Livermore Valley Groundwater Basin has been sustainably managed for more than 10 years and will continue to be sustainably managed.
	(b) Measurable objectives shall be established for each sustainability indicator, based on quantitative values using the same metrics and monitoring sites as are used to define the minimum thresholds.						y	Section 3.2 Basin Management Objectives and Sustainable Management Objectives; Section 3.3 Sustainability Indicators
SubArticle 4	**Monitoring Networks**							
§ 354.34.	**Monitoring Network**							
§ 354.34.	(a) Each Agency shall develop a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation.	y						Section 4 Monitoring Networks

§ 354.34.	(b) Each Plan shall include a description of the monitoring network objectives for the basin, including an explanation of how the network will be developed and implemented to monitor groundwater and related surface conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial density to evaluate the affects and effectiveness of Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:						y	Section 4.1 Objectives
§ 354.34.	(3) Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds.	y						Section 4.1 Objectives; Section 3 Sustainable Management Criteria
§ 354.34.	(4) Quantify annual changes in water budget components.							Section 4.1 Objectives; Section 4.2 Climate Monitoring; Section 4.3 Surface Water Monitoring; Section 4.4 Chain of Lakes and Quarry Operations Monitoring; Section 4.5 Groundwater Elevation Monitoring; see also Section 2.3.2 Groundwater Use and Section 2.4 Water Budget
§ 354.34.	(c) Each monitoring network shall be designed to accomplish the following for each sustainability indicator:							Section 4 Monitoring Networks
§ 354.34.	(1) Chronic Lowering of Groundwater Levels. Demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features by the following methods:	y						Section 4.5 Groundwater Elevation Monitoring
§ 354.34.	(B) Static groundwater elevation measurements shall be collected at least two times per year, to represent seasonal low and seasonal high groundwater conditions.	y						Section 4.5 Groundwater Elevation Monitoring; Appendix C-1; Appendix C-2
§ 354.34.	(2) Reduction of Groundwater Storage. Provide an estimate of the change in annual groundwater in storage.		y					Section 4.5 Groundwater Elevation Monitoring; Section 2.4.2.4 Change in Groundwater Storage and Total Storage; Section 3.3.2 Groundwater Storage
§ 354.34.	(3) Seawater Intrusion. Monitor seawater intrusion using chloride concentrations, or other measurements convertible to chloride concentrations, so that the current and projected rate and extent of seawater intrusion for each applicable principal aquifer may be calculated.			NA				Not applicable; Livermore Valley Groundwater Basin isan inland basin not susceptible to seawater intrusion.
§ 354.34.	(4) Degraded Water Quality. Collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues.				y			Section 4.6 Groundwater Quality Monitoring
§ 354.34.	(5) Land Subsidence. Identify the rate and extent of land subsidence, which may be measured by extensometers, surveying, remote sensing technology, or other appropriate method.					y		Section 4.7 Land Surface Elevation Monitoring
§ 354.34.	(6) Depletions of Interconnected Surface Water. Monitor surface water and groundwater, where interconnected surface water conditions exist, to characterize the spatial and temporal exchanges between surface water and groundwater, and to calibrate and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. The monitoring network shall be able to characterize the following:						y	Section 4.3 Surface Water Monitoring; Section 4.4 Chain of Lakes and Quarry Operations Monitoring; see also 3.3.5 Surface Water - Groundwater Interaction

§ 354.34.	(A) Flow conditions including surface water discharge, surface water head, and baseflow contribution.						y	Section 4.3 Surface Water Monitoring; Section 4.4 Chain of Lakes and Quarry Operations Monitoring
§ 354.34.	(B) Identifying the approximate date and location where ephemeral or intermittent flowing streams and rivers cease to flow, if applicable.						na	Section 4.3 Surface Water Monitoring; Section 4.4 Chain of Lakes and Quarry Operations Monitoring
§ 354.34.	(C) Temporal change in conditions due to variations in stream discharge and regional groundwater extraction.						y	Section 4.3 Surface Water Monitoring; Section 4.4 Chain of Lakes and Quarry Operations Monitoring
§ 354.34.	(d) The monitoring network shall be designed to ensure adequate coverage of sustainability indicators. If management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the basin setting and sustainable management criteria specific to that area.		y	NA	y	y		Section 4 Monitoring Networks
§ 354.34.	(1) Amount of current and projected groundwater use.	y						See also Section 2.3.2 Groundwater Use
	(4) Whether the Agency has adequate long-term existing monitoring results or other technical information to demonstrate an understanding of aquifer response.		y					Section 4 Monitoring Networks; Section 2 Basin Setting
§ 354.34.	(3) For each sustainability indicator, the quantitative values for the minimum threshold, measurable objective, and interim milestones that will be measured at each monitoring site or representative monitoring sites established pursuant to Section 354.36.	y	y	NA	y	y	y	See discussions of Minimum Thresholds: Section 3.3.1.2 Groundwater Levels; Section 3.3.2.2 Groundwater Storage; Section 3.3.3.2 Groundwater Quality; Section 3.3.4.2 Land Subsidence; Section 3.3.5.2 Surface Water Groundwater Interaction
§ 354.36.	**Representative Monitoring**							
§ 354.36.	(1) Significant correlation exists between groundwater elevations and the sustainability indicators for which groundwater elevation measurements serve as a proxy.					y		See discussion of groundwater elevations as proxy in sections on Minimum Thresholds: Section 3.3.1.2 Groundwater Levels; Section 3.3.2.2 Groundwater Storage; Section 3.3.4.2 Land Subsidence; Section 3.3.5.2 Surface Water Groundwater Interaction
§ 354.36.	(2) Measurable objectives established for groundwater elevation shall include a reasonable margin of operational flexibility taking into consideration the basin setting to avoid undesirable results for the sustainability indicators for which groundwater elevation measurements serve as a proxy.							See Section 2 Basin Setting and discussions of groundwater elevations as proxy in respective sections on Minimum Thresholds: Section 3.3.1.2 Groundwater Levels; Section 3.3.2.2 Groundwater Storage; Section 3.3.4.2 Land Subsidence; Section 3.3.5.2 Surface Water Groundwater Interaction
§ 354.38.	**Assessment and Improvement of Monitoring Network**							
§ 354.38.	(b) Each Agency shall identify data gaps wherever the basin does not contain a sufficient number of monitoring sites, does not monitor sites at a sufficient frequency, or utilizes monitoring sites that are unreliable, including those that do not satisfy minimum standards of the monitoring network adopted by the Agency.	na		NA	na		na	Section 4.10 Evaluation of the Monitoring Networks and Data Gaps
§ 354.38.	(1) The location and reason for data gaps in the monitoring network.	na	na			na		At this time, no major data gaps are identified. See Section 4.10 Evaluation of the Monitoring Networks and Data Gaps
§ 354.38.	(d) Each Agency shall describe steps that will be taken to fill data gaps before the next five-year assessment, including the location and purpose of newly added or installed monitoring sites.		na	NA		na		Section 4.10 Evaluation of the Monitoring Networks and Data Gaps

§ 354.38.	(e) Each Agency shall adjust the monitoring frequency and density of monitoring sites to provide an adequate level of detail about site-specific surface water and groundwater conditions and to assess the effectiveness of management actions under circumstances that include the following:							Section 4.10 Evaluation of the Monitoring Networks and Data Gaps
§ 354.38.	(1) Minimum threshold exceedances.						y	Section 4.10 Evaluation of the Monitoring Networks and Data Gaps
§ 354.40.	**Reporting Monitoring Data to the Department**							
SubArticle	**Projects and Management Actions**							
§ 354.44	**Projects and Management Actions**							
§ 354.44	a) Each Plan shall include a description of the projects and management actions the Agency has determined will achieve the sustainability goal for the basin, including projects and management actions to respond to changing conditions in the basin.	y	y	NA			y	Section 1.3.4 Water Resource Management Programs; Section 5 Projects and Management Actions
§ 354.44	(1) A list of projects and management actions proposed in the Plan with a description of the measurable objective that is expected to benefit from the project or management action. The list shall include projects and management actions that may be utilized to meet interim milestones, the exceedance of minimum thresholds, or where undesirable results have occurred or are imminent. The Plan shall include the following:		y	NA	y	y	y	Section 5.2 Groundwater Supply: 5.2.1 Import of Surface Water; 5.2.2 Conjunctive Use; 5.2.3 Well Master Plan; 5.2.4 Chain of Lakes Recharge Projects; 5.2.5 Recycled Water Use; 5.2.6 Water Conservation Section 5.3 Groundwater Quality: 5.3.1 Well Ordinance Program; 5.3.2 Toxic Site Surveillance Program; 5.3.3 Salt Management; 5.3.4 Nutrient Management; 5.3.5 OWTS Management
§ 354.44	(A) A description of the circumstances under which projects or management actions shall be implemented, the criteria that would trigger implementation and termination of projects or management actions, and the process by which the Agency shall determine that conditions requiring the implementation of particular projects or management actions have occurred.			NA	y	y	y	See Section 5 for ongoing projects and management actions implemented by Zone 7 for sustainable management
§ 354.44	(2) If overdraft conditions are identified through the analysis required by Section 354.18, the Plan shall describe projects or management actions, including a quantification of demand reduction or other methods, for the mitigation of overdraft.		NA					No overdraft conditions exist.
§ 354.44	(9) A description of the management of groundwater extractions and recharge to ensure that chronic lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater levels or storage during other periods.	y	y					Section 2.3.2 Groundwater Use (Groundwater Pumping Quota); Section 5.2 Groundwater Supply (Projects and Management Actions)
	Total Possible Elements	**26**	**24**	**17**	**14**	**17**	**28**	
	Total Y	**20**	**19**	**0**	**12**	**14**	**26**	
	Total N	**0**	**0**	**0**	**0**	**0**	**0**	
	NA	**6**	**5**	**17**	**2**	**3**	**2**	
	Total elements subject to analysis	**20**	**19**	**0**	**14**	**14**	**26**	
	Alternative Elements							

APPENDIX B

Scoring Rubric for Adjudicated Basin Areas

Name:
Website:
Basin #
Basin Priority:

Water Code 10720.8 requires adjudicated areas to submit the following:	
Groundwater elevation data unless submitted pursuant to Water Code 10932	
Annual aggregated data identifying grundwater extraction for the preceding water year	
Surface water supply used for or available for use for groundwater or in-lieu use	
Total water use	
Change in groundwater storage	
Submit annual report	

Following are exceprts from alternative plan submittal...

General Basin Information	
Each Plan shall include a descriptive hydrogeologic conceptual model of the basin that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.	354.14
Regional geologic and structural setting of the basin	354.14
Lateral basin boundaries including major geologic features that significantly affect groundwater flow	354.14
Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.	354.14
Identification of data gaps and uncertainty within the hydrogeologic conceptual model	354.14
Hydrogeological conceptual model shall be represented graphically by at least two scaled cross-sections to depict major stratigraphic and structural features of the basin	354.14
An Agency may establish a representative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence.	354.28
Sufficient monitoring wells to characterize the groundwater table	354.34
Long-term monitoring results and technical information to demonstrate an understanding of aquifer response	354.34
Description of projects and/or managements actions to achieve sustainability	354.44

Annual Precipitation / water budget inflows/outflows/water supply	354.18

Chronic lowering of groundwater levels	
Groundwater elevation measurements shall be collected at least two times per year to represent seasonal low and seasonal high groundwater conditions	354.16
Historical conditions from 2015 to present	354.16
Groundwater elevation contour maps depicting the groundwater conditions	354.16
Groundwater elevation contour maps depicting annual seasonal high and low	354.16
Hydrographs depicting long-term groundwater elevations	354.16
Estimate of sustainable ("safe") yield of the basin	354.16
Monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater	354.34
Monitor impacts to the beneficial uses or users of groundwater	354.34
Annual groundwater use	354.34
Projected groundwater use	354.34
Groundwater use by sector	356.2
Identification of key monitoring wells	354.34
Imported or recycled resource	

Reduction in Groundwater Storage	
Change in groundwater storage based on data, demonstrating the annual cumulative change	354.16
Threshold of water use/elevation that indicates depletion of supply	354.28
Groundwater elevation decline based upon historical trends and water use.	354.28
The annual amount of reduction in storage	354.28
Annual groundwater recharge	354.14

Seawater Intrusion	
Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.	354.28
Chloride concentration isocontours used for defining seawater intrusion or other related information	354.25/34
Rate and extent of seawater intrusion monitored/calculated	354.34

Degradation of water qualtiy	
General water quality of the principal aquifers	354.28
Groundwater quality issues that may affect the supply and beneficial uses of groundwater	354.16
Identification of any plumes of contamination or areas of poor water quality	354.16
Collect sufficient data to determine/understand water quality	354.34

Land Subsidence

Completed study to determine if any subsidence exists	354.34
Cumulative total of land subsidence	354.34
Annual rate of subsidence	354.16

Surface water depletions that have signficiant and unreasonable adverse ipacts on beneficial uses	
Monitor surface water and groundwater to calculate depletions of surface water caused by groundwater extractions.	354.34
Identification of groundwater dependent ecosystems within the basin, utilizing data or the best available information.	354.16
Depletion of interconnected surface water caused by groundwater use	354.34
Monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term surface conditions	354.34
Groundwater flow direction and hydraulic gradients between aquifer and surface water	354.34
Sources of surface water supply used or available for use for groundwater recharge described in annual volume	356.2

APPENDIX C

Scoring Rubric Developed for Chi-Square Test That Integrates Both Study Groups

Criteria 1	**Chronic lowering of groundwater levels**
354.34	Groundwater elevation measurements shall be collected at least two times per year to represent seasonal low and seasonal high groundwater conditions
354.18	Historical conditions from 2015 to present
354.16	Groundwater elevation contour maps depicting the groundwater conditions
354.16	Groundwater elevation contour maps depicting annual seasonal high and low
354.18	Estimate of sustainable ("safe") yield of the basin
354.34	Monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater
354.26	Monitor impacts to the beneficial uses or users of groundwater
354.34	Annual groundwater use
354.34	Projected groundwater use
	Expected = 9

Criteria 2	**Reduction in Groundwater Storage**
354.16	Change in groundwater storage based on data, demonstrating the annual cumulative change
354.28	Threshold of water use/elevation that indicates depletion of supply
354.28	Groundwater elevation decline based upon historical trends and water use.
354.28	The annual amount of reduction in storage
354.14	Annual groundwater recharge
354.16	Hydrographs depicting long-term groundwater elevations
354.34	Identification of key monitoring wells
	Expected = 7

Criteria 3	**Seawater Intrusion**
354.28	Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.
354.25/34	Chloride concentration isocontours used for defining seawater intrusion or other related information
354.34	Rate and extent of seawater intrusion monitored/calculated/Min Threshold
	Expected = 3

Criteria 4	**Degradation of water qualtiy**
354.14	General water quality of the principal aquifers
354.16	Groundwater quality issues that may affect the supply and beneficial uses of groundwater
354.16	Identification of any plumes of contamination or areas of poor water quality
354.34	Collect sufficient data to determine/understand water quality
	Expected = 4

Criteria 5	**Land Subsidence**
354.28	Completed study to determine if any subsidence exists or establishment of minimal thresholds
354.34	Cumulative total of land subsidence
354.16	Annual rate of subsidence
	Expected = 3

Criteria 6	**Surface water depletions that have signficiant and unreasonable adverse impacts on beneficial uses**
354.34	Monitor surface water and groundwater to calculate depletions of surface water caused by groundwater extractions.
354.16	Identification of groundwater dependent ecosystems within the basin, utilizing data or the best available information.
354.34	Depletion of interconnected surface water caused by groundwater use
354.34	Monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term surface conditions
354.34	Groundwater flow direction and hydraulic gradients between aquifer and surface water
354.18	Sources of surface water supply / use for groundwater recharge described in annual volume
	Expected = 6