JULY 2022

Buena Vista GSA

Buena Vista Water Storage District

Amended Groundwater Sustainability Plan

Kern County Groundwater Subbasin

Buena Vista Groundwater Sustainability Agency

Amended

Groundwater Sustainability Plan

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Preface

The revised and resubmitted information presented in this amended GSP has been prepared in response to DWR's *Incomplete Determination of the 2020 Groundwater Sustainability Plans Submitted for the San Joaquin Valley - Kern County Subbasin*. This GSP, including all modifications, has been adopted by the Board of the BVGSA and will be implemented accordingly. All changes included in this version of the amended GSP are redlined. This version is accompanied by a clean version of the GSP where all redlined edits and additions have been accepted. Note that all modifications are contained in the body of the GSP. No modifications have been made to appendices or to figures included in the Figures Tab.

Edits and additions to the Coordination Agreement, submitted by the Kern County Subbasin Basin Coordinator, are considered a part of the BVGSA's amended GSP. Similarly, the Kern Subbasin's draft white paper submitted to the California Aqueduct Subsidence Program (CASP), which describes the methods and data suggested for use in establishing Sustainable Management Criteria for Land Subsidence affecting the California Aqueduct, has been made available by the Basin Coordinator as has CASP's letter of July 19th commenting on the draft white paper. These documents are relevant as they are the basis for the SMCs presented in Section 7.7 of this amended GSP, which will be applied to detect and control subsidence in areas of the Aqueduct that lie to the west of the BVGSA's Buttonwillow Management Area.

Lastly, there have been no modifications to the BVSGA's boundaries or other revisions to shapefiles made since the submission of the original GSP.

Introduction

The Buena Vista GSA (BVGSA, GSA) covers an agricultural area of Kern County located in the trough of California's southern San Joaquin Valley approximately sixteen miles west of the City of Bakersfield. The boundaries of the BVGSA coincide closely with those of the Buena Vista Water Storage District (BVWSD, District).

The BVGSA is bordered by the following GSAs:

- Kern Groundwater Authority GSA;
- Kern River GSA, and

- Semitropic GSA.

The BVGSA is made up largely of reclaimed swamp lands in and along the pre-development course of the lower Kern River which, after exiting the Southern Sierra Nevada mountains and flowing south and then southwest across the southern San Joaquin Valley, ran through the topographic axis of the valley toward its terminus at a drainage basin which was once Tulare Lake. The water conveyance systems in and around the GSA consist of a network of levees and diversions to control the high flows of the Kern River, as well as a system of canals for delivery of surface water. Of the GSA's total area of 50,560 acres, approximately 46,600 acres receive water service from the BVWSD. Of that acreage approximately 35,000 acres are farmed each year, primarily in tree and row crops, with this number fluctuating based on factors including water supply and market conditions. The GSA also encompasses the Community of Buttonwillow, three other public water systems and domestic users all of whom rely entirely on groundwater for domestic, municipal and commercial users.

The BVWSD has successfully followed a conjunctive management policy by which surface water is recharged when available and stored in the principal aquifer system for recovery by pumping in years when surface water is insufficient to meet demands. Prior to the construction of the State Water Project, the Kern River was the BVWSD's sole source of surface water. Kern River water is now stored in Lake Isabella for release in response to water orders from the District. With construction of the State Water Project (SWP) regulated diversions from the Kern River have been supplemented by schedulable deliveries from the California Aqueduct, which runs immediately to the west of the GSA.

Conjunctive management within the BVGSA begins with deliveries of surface water from the Kern River and the California Aqueduct with these two sources generating an average annual supply sufficient to meet District-wide demands. Thus, during years when supplies are above average, surface water is recharged, and during years when supplies are limited, recharged water is pumped as a supplemental source of supply.

A high proportion of recharge in the BVGSA takes place through seepage from facilities constructed by the BVWSD including canals, laterals and recharge basins. By contrast, due to the low infiltration rate of topsoils in the area, deep percolation of precipitation and irrigation water from farmland is not an important contributor to recharge.

The conjunctive management program that has been central to the BVWSD's operations lies at the heart of the BVGSA's approach to sustainable groundwater management which begins with careful stewardship of surface water. While the principle of conjunctive management has been followed by the BVWSD since the District's inception, the specifics have been dynamic as the mechanisms used to recharge and recover groundwater have been adapted to respond to changes in surface water supplies, cropping patterns and demands, irrigation technologies and requirements of regulatory programs. Therefore, a second principle that has guided the BVWSD in the past and will guide the BVGSA during implementation of this GSP is adaptive management. Thus, the BVGSA's strategy to supporting sustainable groundwater management will rest on continued stewardship of groundwater and surface water resources by adapting the tools for conjunctive management through planning and implementation of projects and actions.

As documented throughout this GSP, due to the BVGSA's access to surface water, its operational practices and its distinctive geology and soils, the area within the GSA has maintained relatively stable groundwater elevations through wet periods and prolonged droughts. Nevertheless, the BVGSA also recognizes how projected reductions in the availability of water from the Kern River and the State Water Project coupled with projected increases in demand due to climate change, changes in cropping pattern and introduction of new crop varieties and production practices are all likely to increase demand for water. In response, the GSP presents a suite of projects and management actions designed to enable the GSA to adapt to these anticipated changes. This suite of activities includes some that have been completed or are now underway. Significant among those is the Palms Groundwater Banking Project which is now in its second phase of implementation and the BVWSD's program to install magnetic flow meters and totalizers on all production wells in the District, a program that has now been completed.

The BVWSD has two distinct service areas separated by 15 miles as shown in Figure 1-1 – Buena Vista GSA Boundaries. The Buttonwillow Service Area (BSA) occupies 91% of the District (46,200 acres), while the Maples Service Area (MSA) occupies the remaining 9% (4,360 acres) BVWSD 2016 Engineer's Assessment Report in Support of Proposition 218 Assessment Ballot Proceeding (BVWSD, 2016). Both service areas lie within the lower Kern River watershed, where historic runoff created heavy clay soils from former swamp and overflow lands along the northern fringe of Buena Vista Lake. Because of the distance between these service areas, their boundaries have been used to define the Buttonwillow Management Area (BMA) and the Maples Management Area (MMA) of the BVGSA. (Figure 1-1 – Refer to Figures Tab)

This GSP emphasizes management of the BMA, which, as described throughout this document, is a distinct entity within the Kern County Subbasin with respect to its hydrogeologic features and management practices. For this reason, the BMA will be treated as a single unit to be managed using a uniform set of management objectives and sustainable management criteria. Because of the MMA's location within the Kern River GSA (KRGSA), the sustainable management criteria for this management area will align with those established for surrounding areas of the KRGSA.

Although land surface elevations, depths to groundwater and depths to the E-clay vary throughout the BMA, the overall relative uniformity of the management area aids in setting sustainable management criteria due to the following characteristics:

- The BMA is underlain by the E-clay at elevations ranging from approximately 10 ft AMSL to -215 feet AMSL with unconfined and semi-confined zones of the Tulare

Formation lying above the E-clay and a confined zone extending beneath the clay layer to the base of fresh groundwater.

- Analysis of screened intervals indicates that wells for all uses extract water from a production zone above the E-clay.
- Water quality in the production zone above the E-clay is better than that found beneath this layer in the eastern portion of the BMA.
- The risk of inducing subsidence by extracting water from the zone above the E-clay is likely to be lower than the risk induced by extracting water from beneath the E-clay.
- The volume of groundwater in storage above the E-clay is likely to be adequate to meet the demands of the BMA under foreseeable conditions.
- Water use throughout the GSA is overwhelmingly agricultural, therefore, the spatial distribution of demands is uniform.
- Because existing groundwater elevations and minimum thresholds and measurable objectives presented in this GSP are generally higher than those in neighboring GSAs, implementation of SGMA is unlikely to contribute to undesirable results in neighboring GSAs. This condition is likely to be maintained through implementation of the projects and management actions described in this document.

Both conjunctive management and sustainable groundwater management aim at providing a secure water supply to all users. This goal informs other elements of the GSP including the monitoring program and the communication and engagement plan. With respect to monitoring, the GSP describes monitoring networks now serving the BVWSD and the Buena Vista Coalition, an entity formed to administer the Central Valley Regional Board's Irrigated Lands Regulatory Program, and how these networks have been used to establish sustainable management criteria. The GSP then describes how these monitoring networks will be expanded and strengthened for monitoring these criteria, for filling data gaps and for updating and improving the GSA's water budget. In January 2020, the Kern County Subbasin Coordination Agreement was approved by the GSAs within the Kern County Subbasin. A copy of this coordination agreement is included as Appendix A.

Water Resources and Demand Budget

An important consideration for the BGVSA with respect to overall management of the Kern County Subbasin is the degree to which the GSA's supplies are expected to be in balance with its demands in 2020 and the extent BVWSD's water resources and demands on these resources are projected to be in balance in 2030 and 2070. These questions that can be approached through a simple water budget that combines measured values with parameters that have been agreed upon by the Kern County Subbasin Coordinating Committee. Estimates of parameters such as groundwater extraction and subsurface cross-boundary fluxes are not included as the sole purpose of this budget is to combine water the BVGSA is entitled to receive from the Kern River and the SWP with water available from native yield and precipitation. These sources of supply are then compared with water exiting the GSA through the largest and best defined flow path, evapotranspiration.

Unlike the GSP water budget described in Section 6 – Water Supply Accounting, which tracks pathways for movement of water into and out of the BVGSA, this budget is based on native yield and precipitation, the BVWSD's current and projected surface water supplies, and current and projected demands and outflows. Therefore, while the flow paths presented in the GSP budget are affected by exchanges, transfers and banking agreements that alter the location and timing of flows entering and leaving the BVGSA, this budget rests on the underlying access to water and the demands expected to be placed on those resources.

The two basin-wide parameters used as a foundation for this analysis are native yield and precipitation. For the Subbasin, 0.15 AF/ac is a generally accepted value for native yield. Values for precipitation discussed by the Coordinating Committee range from 0.15 AF/ac to 0.5 AF/ac with the BVGSA adopting 0.2 AF/ac, a number in the lower 15% of this range. Applied over the entirety of the BVGSA's two management areas, the Buttonwillow Management Area (BMA - 46,480 acres) and the Maples Management Area (MMA - 4,360 acres), use of these values for the 2020 estimate results in an average annual contribution of 7,626 AF of native yield and 10,168 AF of precipitation for a total contribution of 17,794 AF. The native yield has been held constant for the 2030 value, while precipitation, after adjustment for climate change, has been reduced by 18%. For 2070, the native yield has remained constant, while the value for precipitation is 16% below the 2020 baseline.

The BVWSD's diversions from the Kern River are based on an average entitlement of 156,000 AF/yr delivered by First Point interests to the Second Point of Measurement, undiminished by delivery losses. Buena Vista's entitlement is 96.044% of this flow or 149,828 AF/yr. This entitlement is expected to remain essentially intact during the period of SGMA implementation with the BVGSA applying a future average annual entitlement of 147,000 AF/yr for the 2030 and 2070 budgets.

Deliveries of SWP water of 13,392 estimated for 2020 are based on the BVWSD's Table A allocation of 21,600 AF/yr after adjustment by DWR's 62% projected system reliability (State Water Project Final Delivery Capability Report, DWR, 2015). Under the 2030 climate change scenario, the 2020 Table A supply is reduced by 22.3% to 10,070 AF/yr. Under the 2070 scenario, the Table A supply is reduced by 25.6% to 9,642 AF/yr.

The BVWSD has historically taken an average of 1,800 AF/yr of Article 21 water. Because of the development of the Palms and the Corn Camp water banking projects described in Section 7 – Projects, Management Actions and Adaptive Management Actions, the amount of Article 21 water to be received by the GSA in 2040 and 2070 is expected to increase to 3,900 AF/yr.

As presented throughout the GSP, consumptive demand has fluctuated considerably during the period between 1993 and 2015. Some of this fluctuation is a response to variations in the weather. However, the factors having the greatest impact on demand have been changes in cropping, particularly conversion from seasonal field crops to permanent plantings and varietal improvements. As extensive plantings of orchards are now maturing in the BVGSA and further conversions of field crops to orchards and high production vineyards are anticipated, the increase in consumptive use due to climate change is likely to be exceeded by the factors described below.

- Irrigation demand measured by the BVWSD in 2019 is approximately 100,000 AF, an average of 2.14 AF/acre over the 46,643 acres eligible to receive water service. This value is comparable to the average total ETa observed over the BVGSA from 2006 through 2015. Demand in 2020 is expected to be comparable to 2019.
- Irrigation demand in 2030 is anticipated to reach 150,000 AF/yr (3.22 AF/acre served). This increase is due to the combined impacts of climate change, maturing orchards and vineyards, and continued conversions to permanent crops;
- Irrigation demand in 2070 is anticipated to reach 175,000 AF/yr (3.75 AF/acre served). This further increase is also driven by climate change, continued cropland conversion and introduction of higher yield crop varieties having lower consumptive demands relative to yield but higher water demands per acre. The average per acre served values can be compared with a current consumptive demand for high-yielding almonds grown in the San Joaquin Valley of 4.33 AF/acre.

Most surface water outflows from the BVGSA serve transfer agreements or exchanges that are captured in the values given above for entitlements to Kern River and SWP water. An example of this is a 2017 agreement with Semitropic Water Storage District under which SWSD banked 11,238 AF in Buena Vista with the understanding that this water would be recovered by Semitropic, within their own borders. Although this water was formally transferred to Buena Vista under a Transfer Request Form with the KCWA, Buena Vista did not enter the activity in its Groundwater Account or water budget as the banked water belonged to SWSD and will be withdrawn by SWSD after adjustment for the agreed to 10 percent leave behind. Therefore, this water should be entered in SWSD's Groundwater Account.

A second example are lands managed by California Waterfowl. In addition to the lands they own and operate as a duck club and dog club, there are other lands within the District encumbered by Conservation Easements. Historically, these lands have been given the same allocation of surface water as other lands within the District. Also, lands within the District have pumped groundwater as required for their operations. To date, there have been no changes for these lands.

An on-going exception is the Castaic Water Sale, a joint project between the BVWSD and the Rosedale-Rio Bravo WSD (RRBSWD). Under this agreement, Buena Vista banks high flow Kern River water in RRBWSD, which then returns 9,250 AF/year of this water to the Castaic Lake Water Agency. Over the 17-year period between 2020 and 2036, the BVWSD is obligated to bank an additional 29,900 AF (1,759 AF/year) of Kern River water. In addition, Buena Vista contributes 2,750 AF of its SWP entitlement as a part of the sale yielding an annual combined demand of 4,509 AF/year through 2036. Because it is an obligation on the water resources available to the BVGSA, the Castaic Water Sale is accounted for in the Water Resources and Demands Budget.

Another historical exception are flows leaving the GSA via the Main Drain Canal. These flows have greatly diminished over the past 10 years as growers in Buena Vista have converted from gravity irrigation systems which produce substantial volumes of tailwater and tilewater to drip and micro-sprinkler systems which have essentially eliminated these sources of drainage. These reductions are illustrated by records showing that prior to 2013 the average annual outflow of the Main Drain Canal was 10,000 AF/yr, but that since June of 2013 there has been no recorded outflow, even during 2017 when flows on the Kern River were 270% of normal. As a result, Main Drain Canal outflows are not an element of the 2020 budget and are not included in the 2030 and 2070 budgets as future outflows are unlikely.
Table 1-1 presents the parameters and values described above with the 2020, 2030 and 2070 conditions each presented in a single column.

Table 1-1. 2020, 2030 and 2070 Resources vs. Demands

Year	2020	2030	2070
Water Resource		**Volume (AF/yr)**	
Native yield	7,626	7,626	7,626
Precipitation	10,168	8,338	8,541
Subtotal	17,794	15,954	16,167
Kern River	149,000	147,000	147,000
SWP Table A[1]	13,392	10,406	9,964
SWP - Article 21[2]	1,800	3,900	3,900
Subtotal	164,192	161,306	160,864
Available Resource	181,986	177,260	177,031
Water Demand		**Volume (AF/yr)**	
Evapotranspiration[3]	100,000	150,000	175,000
Castaic Water Sale	4,509	4,509	
Main Drain Canal[4]	-	-	-
Total Demand	104,509	154,509	175,000
Balance	77,477	22,751	2,031

[1] Table A reduced by 22% in 2030 and by 26% in 2070

[2] Article 21 increased by 2,100 AF/yr due to completion of Palms and Corn Camp water banking projects

[3] 2020 estimate based 2019 water demands measured by BVWSD

[4] Based on average Main Drain Canal outflow since June 2013. A zero outflow is used because it represents current and expected future outflows.

The 2030 and 2070 projections indicate that the impacts of climate change are expected to do little to reduce BVWSD's entitlement to the Kern River. Therefore, as demands within the BVGSA increase, the current gap between the BVWSD's entitlement to the river and its diversions to serve internal demands is likely to shrink as the District reduces transfers to other users to meet its own growing demands in the face of diminishing SWP supplies.

The water budget table for 2020, 2030 and 2070 demonstrates that when applying agreed upon values for native yield, precipitation and climate change projections, the BVGSA is in surplus and will remain in surplus through 2070 albeit with the surplus diminishing due primarily to anticipated increases in irrigation demand with climate change being an important but secondary factor. Nevertheless, due largely to the BVWSD's entitlement to the Kern River and the District's history of conjunctive management, the BVGSA has the resources and the mechanisms to remain in balance internally and to contribute to achieving sustainability throughout the Kern County Subbasin.

Communication and Engagement

An important contribution of SGMA is its emphasis on communication and engagement with the public. The BVGSA's approach to public engagement is tailored to the area's size and demographics and relies both on distribution of information via the BVWSD's website and on face-to-face meetings between stakeholders and GSA decision makers. The focus on direct communications has been successful in developing a cooperative relation between key stakeholders including the Community of Buttonwillow and landowners in the formation of the BVGSA and in the development of the GSP. As well as engaging with local stakeholders, the GSA will also communicate actively with interested parties outside the area to inform these parties about implementation of the GSP and to educate them about the physical conditions and water management practices of the BVGSA.

A second contribution of SGMA is its aim of encouraging sustainable groundwater management throughout the Kern County Subbasin. To this end, although an independent agency and not a member of the Kern Groundwater Authority (KGA), the BVGSA engages actively with neighboring GSAs including agencies who are under the KGA umbrella. The BVGSA regularly participates in technical and planning meetings and forums with other GSAs and holds monthly GSA governance meetings to support planning and implementation of the GSP. These meetings welcome public input and began with an initial workshop in 2018, which focused on public involvement and sought input on approaches, such as formation of a Technical Advisory Committee, to regularly acquire feedback from a wide variety of stakeholders including the disadvantaged Community of Buttonwillow.

1.1.2 List of References and Technical Studies

Please refer to Section 10 - References and Technical Studies.

1.2 Agency information

1.2.1 GSA Mailing Address

Buena Vista GSA
525 North Main
P. O. Box 756
Buttonwillow, CA 93206

1.2.2 Organization and Management Structure

Responsibility for development and implementation of the GSP lies with the Governance Committee of the BVGSA which is composed of members of the Buena Vista Water Storage District's Board of Directors. The Governance Committee is chaired by Tim Ashlock whose contact information is presented below.

The Governance Committee is the ultimate decision-making body for the GSA, and individuals on this committee are the principal points of contact between the GSA and stakeholders.

1.2.3 Contact Information of Plan Manager

Tim Ashlock, Engineer - Manager
Buena Vista GSA
Email: tim@bvh2o.com
Phone: (661) 764-5510

1.2.4 Legal Authority of GSA

The Sustainable Groundwater Management Act (SGMA) requires that all basins designated as high-or-medium-priority basins that are subject to critical overdraft conditions are to be managed under a groundwater sustainability plan (GSP) or coordinated GSPs (section 10720.7). The Kern County Subbasin is a high-priority basin and is identified as having critical overdraft conditions.

The BVGSA has been created to manage groundwater for a portion of the Kern County Sub-basin (Basin Number 5-22.14, DWR Bulletin 118) within the San Joaquin Valley Groundwater Basin and is the exclusive GSA within its territory with powers to comply with SGMA (SGMA, Section 10723[c][1][D]). The BVGSA notified the California Department of Water Resources (DWR) of its intent to undertake sustainable groundwater management under SGMA and was granted exclusive GSA status under SGM, Section 10723(c).

1.2.5 Estimate of Implementation Costs

Current anticipated costs for implementing projects Buena Vista GSA are presented in Section 7 – Projects, Management Actions and Adaptive Management Actions. In addition, the BVGSA anticipates participating with other GSAs into the Kern County Subbasin on basin optimization studies designed to aid in coordination of activities across the Subbasin. The BVGSA also anticipates exploring grant funding and other potential sources of revenue to expedite implementation of projects.

1.3 Maps

1.3.1 Map of BVGSA Boundaries

Figure 1-1 – Buena Vista GSA Boundaries displays the boundaries of the BVGSA and indicates the locations of the two management areas within the GSA, the Buttonwillow Management Area (BMA) and the Maples Management Area (MMA) (Figure 1-1 – Refer to Figures Tab).

1.3.2 Map of GSAs Within the Kern County Subbasin

Figure 1-2 – GSAs within Kern County Subbasin displays the locations of GSAs within the Kern County Subbasin (Figure 1-2 – Refer to Figures Tab).

1.3.3 Map of Jurisdictional Boundaries of Federal or State Land Within the BVGSA

Figure 1-3 – Federal and State Land within BVGSA displays the boundaries of state and federal lands neighboring the BVGSA. As shown on the map, no state or federal lands lie within the GSA boundaries (Figure 1-3 – Refer to Figures Tab).

1.3.4 Map of Density of Wells Per Square Mile Within the BVGSA

Figures 1-4a – Density per Square Mile of Production Wells; 1.4b – Density per Square Mile of Domestic Wells, and 1.4c – Density per Square Mile of Municipal Wells display the density of production wells, domestic wells and municipal wells, respectively within the BVGSA. Data presented on these three maps was developed from well completion report data cataloged by DWR (Figures 1-4a through c – Refer to Figures Tab).

1.4 Description of Plan Area

1.4.1 Summary of Jurisdictional Areas and Other Features

The jurisdictional area of the BVGSA closely matches that of the BVWSD. The alignment between the GSA and the WSD will facilitate sustainable groundwater management because of the close correspondence between the projects and management actions presented in this GSP and the conjunctive management operations of the District. Thus, the longstanding stewardship of surface and groundwater practiced by the District will benefit the GSA in attaining its sustainable management objectives.

1.5 Water Resource Monitoring and Management Programs

1.5.1 Description of Water Resources Monitoring and Management Programs

Established water resources monitoring and management programs within the BVGSA are primarily programs conducted by the Buena Vista Water Storage District. Most monitoring performed by the BVWSD provides information on water supplies and water use necessary for District operations. This data includes information on diversions of surface water from the Kern River and the State Water Project, deliveries to users, and groundwater extractions recorded by meters installed on all District and landowner production wells. Additional monitoring is performed by the Buena Vista Coalition to carry out their Groundwater Quality Trend Monitoring Work Plan in compliance with the Irrigated Lands Regulatory Program. Monitoring is also carried out by the public water agencies within the GSA, notably the Buttonwillow County Water District (BCWD) which serves the Community of Buttonwillow.

The BVWSD, the BCWD, and the Buena Vista Coalition are the three organizations now responsible for performing water management planning and carrying out water management programs within the BVGSA.

1.5.2 Description of How the Monitoring Networks of Those Plans will be Incorporated Into the GSP

Section 4 – Monitoring Networks – describes how the network of District monitoring wells, and wells included in the network developed for the Groundwater Quality Trend Monitoring Work Plan have been included in the networks that will be used to monitor groundwater levels and groundwater quality throughout the BVGSA. Data on pumping rates and volumes of extraction recorded by the magnetic flow meters and totalizers installed on all production wells will be used to update the BVGSA water budget.

1.5.3 Description of How Those Plans May Limit Operational Flexibility in the Subbasin

Implementation of the water resources monitoring and management programs described above is expected to complement and support operational flexibility and SGMA compliance within the BVGSA and is unlikely to limit operational flexibility.

1.5.4 Description of Conjunctive Use Programs

The BVWSD has a well-established history of conjunctive management that has enabled it to withstand prolonged droughts while being able to maintain groundwater elevations and groundwater storage. As shown in hydrographs and water budgets presented later in this GSP, the ability to use surface water from the Kern River and the SWP to meet water demands and to recharge the principal aquifer system has proven to be an effective conjunctive management program that will serve as the keystone of the BVGSA's stewardship of water resources.

Section 7 – Projects, Management Actions, and Adaptive Management Actions– describes how the BVGSA plans to expand the use of unlined canals and dedicated recharge facilities to support groundwater elevations through recharge of surface water and to enhance the GSA's conjunctive management program to prepare for anticipated increases in crop water demand and the effects of climate change.

1.6 Land Use Elements or Topic Categories of Applicable General Plans

1.6.1 Summary of General Plans and Other Land Use Plans

The 2007 Kern County General Plan (Kern County, 2007) designates land use within the BVGSA as largely intensive agriculture. The notable exception is the Specific and Rural Community Plan prepared by the Community of Buttonwillow and approved by the County. Land uses designated within the specific plan area include Buttonwillow's central business district, greenbelt areas within transmission line easements, and areas zoned for single family residences. Figure 2-38 illustrates the extent to which irrigated agriculture dominates the BVGSA. All farmland within the GSA is served by the BVWSD distribution system, and therefore all farmland is able to receive both groundwater and surface water from sources including the California Aqueduct and the Kern River. Municipal, industrial and domestic uses are all served exclusively by groundwater.

1.6.2 Description of How Implementation of the GSP May Change Water Demands or Affect Achievement of Sustainability and How the GSP Addresses Those Effects

The Buena Vista GSP anticipates an increase in irrigation water demands due to the combined effects of improved crop production practices, changes in cropping patterns and climate change. However, the GSP includes projects and adaptive management actions designed to prepare for increased demands likely to occur with or without implementation of the GSP. Therefore, implementation of the GSP will increase the BVGSA's ability to manage groundwater sustainably in the face of changing conditions but will do nothing to affect the water supply assumptions of relevant land use plans.

1.6.3 Description of How Implementation of the GSP May Affect the Water Supply Assumptions of Relevant Land Use Plans

Water supply assumptions applied in the GSP are based historical and projected deliveries from the SWP and the Kern River. The projections are adjusted to account for the effects of climate change, assumptions that were not incorporated into the 2009 land use plan. However, by incorporating changes in water supply that may result from climate change, implementation of the GSP is intended to minimize the impacts of projected water supplies on land uses within the BVGSA and within the Kern County Subbasin. Therefore, implementation of the GSP is expected to improve the ability to match future supplies with future demands within the planning area.

1.6.4 Summary of the Process for Permitting New or Replacement Wells in the BVGSA

Well replacement and construction of new wells will proceed following the permitting and approval process established by Kern County. The BVWSD has adhered to the Kern County permitting process in the past, and the BVGSA will continue to follow this process during SGMA implementation. The BVWSD supplies magnetic flow meters for installation on each production well drilled within the GSA.

1.6.5 Information Regarding the Implementation of Land Use Plans Outside the Subbasin that Could Affect the Ability of the BVGSA to Achieve Sustainable Groundwater Management

Because of the location of the BVGSA in the interior of the Kern County Subbasin, the implementation of land use plans outside the Subbasin are unlikely to affect the BVGSA's management of groundwater or the GSA's ability to attain its sustainable groundwater management goals.

1.7 Description of Actions Related To:

1.7.1 Control of Saline Water Intrusion

Intrusion of seawater is not a consideration in the BVGSA because of the GSA's location at the extreme southern end of the Central Valley. Mild inflows of saline groundwater from the west will be monitored by the GSA's groundwater quality monitoring network and blended with Kern River water delivered to the affected areas (see Section 2.2.4.5).

1.7.2 Wellhead Protection

The BVGSA adheres to Kern County's wellhead protection policies.

1.7.3 Migration of Contaminated Groundwater

Migration of contaminated groundwater will be detected and tracked by the BVGSA groundwater quality monitoring network described in Section 4 – Monitoring Networks. Migration of contaminants determined to result from irrigated agriculture will be addressed through the Irrigated Lands Regulatory Program (ILRP). Contaminants contributed by municipal or industrial users will be addressed based on the permitting requirements governing the individual users.

1.7.4 Well Abandonment and Well Destruction Program

The BVGSA follows the well abandonment and well destruction protocols established by Kern County.

1.7.5 Replenishment of Groundwater Extractions

As described throughout this GSP, the BVGSA's stewardship of its water resources is based on a program of conjunctive management of surface water and groundwater. Implementation of this program has required, and will continue to require, replenishment of groundwater extractions through operation of dedicated recharge facilities and recharge of surface water delivered through unlined canals.

Groundwater replenishment will be complemented by expansion of the area able to receive deliveries of surface water and water conservation programs, both of which will reduce demand for groundwater.

1.7.6 Conjunctive Use and Underground Storage

As described in the preceding response, conjunctive use is the cornerstone of the BVGSA's water management program. Section 7 – Projects, Management Actions, and Adaptive Management Actions – describes conjunctive management projects including expansion of an existing groundwater recharge facility, development of new recharge facilities and use of unlined canals as linear recharge features. Each of these projects will increase the GSA's ability to place surface water in underground storage.

1.7.7 Well Construction Policies

All wells constructed in the BVGSA are permitted by Kern County. In addition to County well construction ordinances, the BVGSA's Minimum Thresholds, described in Section 5 – Measurable Objectives, Minimum Thresholds, and Interim Milestones – requires that pumping be restricted to zones above the E-clay to reduce the risks of inducing subsidence and of extracting poor quality water.

1.7.8 Addressing Groundwater Contamination Cleanup, Recharge, Diversions to Storage, Conservation, Water Recycling, Conveyance, and Extraction Projects

Section 7 – Project, Management Actions, and Adaptive Management Actions – presents an array of measures that have recently been completed, are now under construction or are in various stages of planning. These activities are divided into the following categories:

- Water measurement projects;
- Sustainability monitoring projects;
- Water distribution system improvement projects;

- Groundwater recharge and recovery projects; and
- Water conservation and treatment projects.

Projects included in these categories address improvements to the BVWSD's conjunctive management practices through diversion of surface water to recharge facilities and improvements to conveyance facilities such as conversion of open ditches to pipelines. These projects are intended to take advantage of the GSA's extensive capacity to store groundwater in the underlying principal aquifer system. Monitoring of groundwater extractions is the focus of the sustainability monitoring projects and the groundwater recharge and recovery projects include facilities to reduce localized drawdown from groundwater extraction by broadening the footprint over which groundwater will be extracted. Groundwater contamination cleanup and prevention of degradation of groundwater quality will continue to be governed by permits issued to individual municipal and industrial users and by compliance with the Irrigated Lands Regulatory Program for agricultural users.

1.7.9 Efficient Water Management Practices

The BVGSA is largely an agricultural area with the Community of Buttonwillow being the only town lying within the GSA's boundaries. For this reason, the efficient water management practices relevant to the BVGSA are those presented in the Buena Vista Water Storage District's 2015 Agricultural Water Management Plan (BVWSD AWMP, 2015). The practices presented in this plan are being implemented within the boundaries of the BVGSA. The AWMP will be implemented at 5-year intervals and the Efficient Water Management Practices will be reviewed during each of these updates.

1.7.10 Relationships with State and Federal Regulatory Programs

The main regulatory program active in the BVGSA is the Central Valley Regional Board-administered Irrigated Lands Regulatory Program. Within the boundaries of the BVGSA, compliance with the ILRP is the responsibility of the Buena Vista Coalition. The BVWSD reports water usage to the Department of Water Resources as required for purveyors of agricultural water and participates in DWR's CASGEM program.

1.7.11 Review of Land Use Plans and Efforts to Coordinate with Land Use Planning Agencies to Assess Activities that Potentially Create Risks to Groundwater Quality or Quantity

Land use within the BVGSA is predominately agricultural with the Community of Buttonwillow, an active participant in the GSA, being the only town lying within the GSA's boundaries. The inclusion of Buttonwillow in the GSA and ongoing coordination with Kern County and adherence to its general plan, provide the necessary coordination and oversight with respect to potential changes in land use that could introduce risk to groundwater quality or quantity.

1.7.12 Impacts on Groundwater Dependent Ecosystems

As describe in Section 2 – Basin Setting, no groundwater dependent ecosystems have been identified in the BVGSA. This condition exists because of the depths to groundwater prevalent in the GSA, the heavily agricultural land use, and the absence of streams and other surface water bodies within the GSA.

1.8 Notice and Communication

1.8.1 Description of Beneficial Uses and Users

Beneficial uses now served in the GSA include:

- Domestic,
- Municipal,
- Industrial, and
- Agricultural.

The preponderance of water use is for irrigated agriculture with this water supplied from both surface water and groundwater sources. Water supplied to other beneficial uses is exclusively groundwater. Most municipal and domestic users are supplied by the Buttonwillow County Water District or by private wells. Agricultural users are supplied surface water and groundwater distributed through the BVWSD's distribution system and groundwater delivered directly from landowner wells. Figure 1-5 – Permitted Public Water Systems is a map of public water systems identified in the BVGSA (Figure 1-5 – Refer to Figures Tab).

1.8.2 List of Public Meetings

See public meeting list in Section 8 – Communication and Engagement Plan.

1.8.3 GSP Comments and Responses

Comments on the draft GSP and responses to these comments are presented in Appendix B.

1.8.4 Decision-Making Process

The primary decision makers for the BVGSA are the members of the Governance Committee. As described in Section 9 – Communication and Engagement Plan, the decision-making process will be informed by input from stakeholders as successful stewardship of the resources under the GSP requires a program that is broadly understood and accepted by the GSA's stakeholders and that does not conflict with projects and management actions taken by other GSAs in the Kern County Subbasin.

1.8.5 Public Engagement

The BVGSA's approach to public engagement is tailored to the size and demographics of the area, factors that will enable the GSA to engage directly with the public who are well informed on local water management issues. The GSA will also communicate actively with members of the public not familiar with the area to educate these parties about the physical conditions and water management practices that distinguish the BVGSA from neighboring areas.

The primary opportunities for the BVGSA to engage with the public will be the monthly Governance Committee meetings that will be supplemented by workshops to be convened at major milestones during implementation of the GSP. Noticed public workshops and hearings will also be held before imposing or increasing fees and before implementing adaptive management actions that may restrict groundwater extraction or otherwise affect water users.

In addition to formal meetings and workshops, the BVGSA Governance Committee is open to meeting with members of the public interested in expressing concerns or perspectives in a one-on-one setting. Targeted outreach will also be organized to encourage involvement from groups such as residents of the Community of Buttonwillow who form a distinct population within the GSA.

1.8.6 Encouraging Active Involvement

The interested parties list included in Section 9 – Communication and Engagement Plan – will be maintained by the BVGSA and parties on this list will be notified in advance of all public meetings and alerted when the GSA posts documents to its website. Interested parties can add themselves to the list through the BVGSA website. As described above, the GSA will use a variety of meeting settings and communication tools to encourage active involvement across the spectrum of stakeholders.

1.8.7 Informing the Public on GSP Implementation Process

The goal of public engagement will be to develop an understanding of the positions held by various stakeholders regarding water management priorities and to convey information about the development and implementation of the GSP, the establishment of metrics such as minimum thresholds, and the long-term objectives of the BVGSA. Stakeholders will include beneficial users of groundwater and parties affected by groundwater within the BVGSA and in neighboring areas.

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2. Basin Setting

2.1 Introduction to Basin Setting

A conceptual understanding of subsurface conditions is essential for the sustainable management of groundwater resources in the Buena Vista Groundwater Sustainability Agency (BVGSA), an agency located in the western part of the Kern County Subbasin (Subbasin) whose boundaries correspond closely to those of the Buena Vista Water Storage District (BVWSD).

This Basin Setting is based on the numerous descriptions of geologic and hydrogeologic conditions available for the area, beginning in the 1950s. These references are the foundation for both the Hydrogeologic Conceptual Model (HCM) and the Groundwater Conditions portions of the Basin Setting. Figure 2-1 shows the location of the BVGSA (Figure 2-1 – Refer to Figures Tab). See Section 10 - References and Technical Studies for a bibliography.

2.2 Hydrogeologic Conceptual Model

2.2.1 Regional Geologic and Structural Setting

The Buena Vista GSA lies within the Tulare Lake Basin and the Kern County Subbasin as defined by the California Department of Water Resources (DWR) and as shown on Figure 2-2 – Kern County Subbasin Location (Figure 2-2 – Refer to Figures Tab)

2.2.1.1 Tulare Lake Basin

A brief description of the evolution of the Tulare Lake Basin is presented below to introduce the formation of the regional aquifer system that underlies the Buena Vista GSA.

The Sierra Nevada Mountains, which form the eastern side of the San Joaquin Valley (Valley), are the eroded edge of a huge tilted block of crystalline rock. Together with the Tehachapi Mountains to the south, these pre-Tertiary granitic and metamorphic formations crop out mostly along the eastern and southeastern flank of the Valley to form an almost impermeable boundary for the groundwater basin (Page, 1986). Valley fill overlies a westward-sloping surface of basement rocks that is the subsurface continuation of the Sierra Nevada.

Near the close of the Late Cretaceous Period, tectonic movements elevated portions of the Coast Range area to the west of the Valley while concurrently dropping the valley floor to create a marine embayment that extended over much of the area of the BVGSA. During the Tertiary Period, sea water advanced and retreated within this embayment, resulting in deposits of both continental and marine sediments. During the Pleistocene and Holocene epochs, the seas retreated, and continental deposits from alluvial and fluvial systems were deposited over Tertiary-age marine deposits, with some saline water migrating from the marine deposits into the overlying and adjacent continental deposits (Page, 1986).

The Pleistocene Epoch was dominated by the presence of several lakes, and coupled with the tectonic subsidence, the lake beds generated thick deposits of clay found throughout the upper Tulare Formation. Examples of this are the Corcoran Clay and its equivalents that have been identified beneath the western half of the Subbasin including in the BVGSA. These clays have been correlated with clays beneath the Kern and Buena Vista dry lake beds that lie to the south of the BVGSA, as well as the Tulare Lake sediments found at the northern boundary of Kern County as noted in the Geological Survey Water Supply Papers 1656 and 1999-H (Wood and Dale 1964; Croft 1972). In portions of the BVGSA, these clay layers serve as impermeable to semipermeable barriers that separate shallower poor-quality groundwater from higher quality groundwater of the principal aquifer system.

Since the Pleistocene Epoch, streams and rivers have been the primary mechanisms for the deposition of continental sediments and have formed alluvial fans on both sides of the Valley. Page (1986) identified various depositional environments for the continental sediments, including flood-plain, lake, and marsh conditions on the western side resulting in the finer-grained deposits predominant in the BVGSA. Continental sediments at the southern end of the Valley have an average thickness of about 2,400 feet, as shown in the Ground Water Atlas of the United States: Segment 1, California, Nevada (Planert and Williams, 1995) and consist mostly of basin-fill or lake deposits of sand and gravel interbedded with clay and silt. These sediments comprise up to approximately 3,400 feet of the material along the Kern River near Tupman where the base of the fill is over 18,000 feet below ground surface (Davis et. al., 1959).

2.2.1.2 Geologic Features that Significantly Affect Groundwater Flow

The BVGSA lies near the western margin of the Kern Subbasin and occupies the overflow lands west of the Kern River alluvial fan within the Buttonwillow Syncline, lying between the Elk Hills and Buttonwillow Ridge, as shown in, Ground-water geology and hydrology of the Kern River alluvial-fan area, (Dale, et al, 1966). Land surface elevations in the GSA range from 290 feet above sea level in the south to 235 feet above sea level in the north. The groundwater gradient, which is generally flat along a north-south alignment north of 7th Standard Road, steepens south of this boundary with a gradient of 5 to 6 feet per mile extending almost the entire distance to the southeast end of the GSA.

The GSA is made up largely of reclaimed swamp lands located in and along the pre-development course of the lower Kern River which, after flowing south and then southwest across the southern San Joaquin Valley, runs north through the topographic axis of the Valley toward its ultimate terminus at a drainage basin which was once Tulare Lake. The water conveyance systems in and around the GSA consist of a network of levees and diversions to control the high flows of the Kern River, as well as a system of canals that delivers surface water to the lands within the BVWSD.

Natural groundwater flow moves from the flanks toward the axis of the Valley and northwestward (Page, 1986) with the asymmetrical, northwestward-trending valley trough that runs through the center of the BVGSA being the principal structure controlling the occurrence and movement of groundwater with most of the confinement of groundwater occurring near the axis of the Valley due to extensive confining beds of the Corcoran Clay (Page 1986). Figure 2-3 – Approximate Thickness and Extent of the Corcoran Clay - presents the extent, depth, and approximate thickness of the Corcoran Clay as estimated by the USGS (Page, 1986) (Figure 2-3 – Refer to Figures Tab). Figure 2-4 – Geologic Units – is a general map of geologic features defining the BVGSA and surrounding lands in the Kern County Subbasin (Page 1986). (Figure 2-4 – Refer to Figures Tab)

2.2.2 Lateral Basin Boundaries

The lateral boundaries of the BVGSA are determined by the jurisdictional boundaries of the GSA. As shown in Figures 2-4, 2-15, 2-16, 2-17 and 2-18, the jurisdictional boundaries of the GSA align closely with geologic features and soil characteristics of the area. The GSA shares parts of its northern, eastern, and southern boundaries with the Semitropic- and Rosedale-Rio Bravo Water Storage Districts, the Kern-Delta Water District (KDWD), the Kern Water Bank Authority (KWBA) and the West Kern Water District (WKWD). The GSA shares its western boundary with undistricted lands which separate the GSA from the Belridge Water Storage District and oilfield properties farther to the west. Like districted lands in the valley floor, these undistricted lands fall within the jurisdiction of the County of Kern and the Kern County Water Agency (KCWA). Some undistracted lands lie within the boundaries of the BVGSA as shown on Figure 1-1 – Buena Vista GSA Boundaries. (Figure 1-1 – Refer to Figures Tab)

2.2.3 Bottom of the Basin

The base of fresh groundwater is commonly defined as the bottom of the basin, and measurements of specific conductance (SpC) and/or total dissolved solids (TDS) are often used to define fresh groundwater. The USGS (Page, 1973) utilized the SpC value of 3,000 micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µS/cm) and considered that value to be generally equivalent to a TDS concentration of 2,000 milligrams per liter (mg/l), which can be a limiting factor for irrigation. Note that the conversion factor (SpC to TDS) is 0.67, which is the midpoint of the typical range of 0.55 to 0.75, USGS Geological Study Water-Supply Paper 2254 (Hem, 1985) with the appropriate conversion depending on the chemical composition of the groundwater.

Figure 2-5 – Base of Fresh Groundwater, illustrates that the base of fresh groundwater within the boundaries of the BVGSA is relatively uniform due to the GSA's compact size. The base of fresh groundwater in the BVGSA is approximately 400 feet below mean sea level (MSL) along the North-South alignment of the BMA. However, the base of fresh groundwater approaches sea level to the west of the BMA and dips abruptly to approximately 800 feet below MSL to the southeast. (Figure 2-5 – Refer to Figures Tab)

2.2.4 Principal aquifers and aquitards

The western portion of the Kern County Subbasin is underlain by an alluvial aquifer system that is heterogeneous in texture and structure. The aquifer system underlying the BVGSA features shallow, perched groundwater, unconfined and semi-confined aquifers and deeper confined groundwater beneath the Corcoran Clay.

2.2.4.1 Principal Aquifers Used for Water Production

The production horizons of the principal aquifer system in the BVGSA include unconfined, semi-confined and confined zones consisting of a sequence of interbedded, laterally discontinuous Tertiary and Quaternary age material. These sandy and silty sediments of non-marine origin from the Kern River and Tulare Formations overlay older marine deposits.

As discussed in the introduction of this GSP, the BVGSA is characterized as two distinct service areas: 91% of the acreage is in the Buttonwillow Service Area (BSA) with the remaining 9% lying in the Maples Service Area (MSA). The report *The Geology and Groundwater Hydrology of the Buena Vista Water Storage District, Buttonwillow, CA* (Sierra Scientific, 2013) describes the principal production aquifers of each service area. The MSA is underlain by Kern Fan-type non-marine sediments, i.e., mostly unconsolidated sands and silts, with the Corcoran Clay equivalent at a depth of about 500 feet bgs and the Paloma Clay at a depth of about 1,500 feet bgs (Sierra Scientific, 2013). The aquifer under the BSA consists of a sequence of interbedded, laterally discontinuous, Quaternary sandy and silty sediments of non-marine origin. Down to a depth of about 200 feet, silty sediments tend to predominate, but from 200 to 600 feet bgs sandy and silty sediments occur in approximately equal proportion.

In the BSA, most irrigation wells exploit sandy strata and are completed to depths of between 200 to 500 feet bgs because of the better water quality and better productivity at these depths. The local irrigation wells have 200- to 300-foot-long screened intervals and deliver sustained flows of between 3.9 and 5.3 cfs at discharge/drawdown ratios in the range of 0.04 to 0.09 cfs/feet. In the northern half of the BSA, the near-surface sediments have significant clay content and create a separate, shallow perched water table 2 to 12 feet deep.

2.2.4.2 Formation Names

The sediments beneath the BVGSA are composed of inter-bedded material of non-marine origin which originated from separate sediment sources to the east and to the west. These sediments, which inter-finger under the GSA, are the thin, distal terminations of thicker deposits of differing textures and compositions and are characteristic of their separate sources. The alluvial, fluvial and lacustrine sediments from the east are part of the Kern River Formation and are characteristic of sediments derived from the igneous granitic bedrock of the Sierra Nevada range. The alluvial sediments from the west are part of the Tulare Formation and are characteristic of reworked marine sediments derived from the ranges to the west. A veneer of recent alluvium deposited by swamps, rivers, and lakes covers the Pleistocene deposits over most of the southern

San Joaquin Valley producing a depositionally-complex and laterally-discontinuous stratigraphy that influences the movement and the chemistry of groundwater.

Although formations can be mapped at the surface, much of the material is not distinctive in the subsurface and designation of a formation is difficult. The following description of geologic formations is provided to explain the contribution of these formations to the groundwater system. From oldest to youngest, the deposits include the: Kern and the Tulare Formations, older alluvium, and younger alluvium and flood basin deposits (Page, 1986). Confining or semi-confining fine-grained beds include the Corcoran Clay of the Tulare Formation and other lesser clay layers.

Tulare (including Corcoran Clay) Formation

The Tulare Formation is Pliocene to Pleistocene in age and contains up to 2,200 feet of interbedded, oxidized to reduced sands; gypsiferous clays and gravels derived primarily from Coast Range sources (marine rocks). Sandy material is found from about 200 to 400 feet below ground surface (bgs) and is used by most wells in the region for water supply.

The Tulare Formation within the BVGSA is broken up by three distinct clay layers: A, C, and E-clay layers, which are described below:

- The A-clay is the uppermost of the clay layers. It occurs 20 to 30 feet bgs and is the cause of the shallow, perched groundwater identified in piezometers throughout the northern part of the GSA
- The C-clay is about 30 feet thick and occurs at a depth of about 200 feet bgs. The C-clay is laterally discontinuous and provides semi-confining conditions
- The E-clay occurs at depths ranging from 300 to 450 feet bgs in the BSA and is a known barrier to vertical flow of groundwater

These three clay layers create the three groundwater aquifers found throughout the BVGSA:

- The Perched Aquifer above the A-clay, found throughout the northern portion of the BSA
- The shallow aquifer between the A- and C-clays
- The deep aquifer between the C- and E-clays

As shown on Figure 2-3, the Corcoran Clay underlies almost the entirety of the BSA at depths ranging from 300 feet bgs in isolated areas in the northern part of the GSA to 450 feet bgs near Buttonwillow. The Corcoran Clay is generally very fine grained; however, isolated, coarser zones are possible, particularly where the clay is less than 20 feet thick, as identified by Page (1986). Laboratory tests indicate that the clay is highly susceptible to compaction (Faunt, et al, 2009).

Terrace Deposits

Overlying the Tulare Formation are older alluvium and Terrace Deposits composed of up to 250 feet of Pleistocene-age lenticular deposits of clay, silt, sand, and gravel that are loosely consolidated to cemented. This unit is moderately to highly permeable and yields large quantities of water. Because the Terrance Deposits are often indistinguishable from the underlying Tulare Formation, these formations together constitute the principal aquifer in the BVGSA (DWR 2006).

Younger Alluvium and Flood Basin Deposits

The Holocene-age younger alluvium and flood basin deposits vary in character and thickness. In the southwestern portion of the Subbasin the unit grades into fine-grained flood basin deposits underlying the historic beds of Buena Vista and Kern lakes which lie to the south of the BVGSA. The flood basin deposits consist of silt, silty clay, sandy clay, and clay interbedded with poorly permeable sand layers. These flood basin deposits are difficult to distinguish from underlying fine-grained older alluvium with the total thickness of both units being as great as 1,000 feet (Page, 1986; and DWR 2006).

Kern River Formation

The Kern River Formation is Miocene to Pliocene in age (possibly early Pleistocene age) and includes from 500 to 2,600 feet of poorly sorted, lenticular deposits of clay, silt, sand, and gravel derived from the Sierra Nevada Mountains. The formation crops out in a crescent-shaped belt about 50 miles long and up to 12 miles wide and reaches its maximum thickness of 2,600 feet in the subsurface west of the outcrop (Bartow, 1983). The formation consists of poorly sorted fluvial sandstone and conglomerate with interbeds of siltstone or mudstone and becomes finer grained northward and westward. Some of the thicker siltstone or mudstone interbeds may represent deposits from small ephemeral lakes or ponds (Bartow, 1983).

2.2.4.3 Physical Properties of Each Aquifer and Aquitard

Aquifer parameters within the BVGSA are available from both well pumping tests and calibrated groundwater models. Data are summarized on Figure 2-6 – Hydraulic Conductivity Values. Aquifer properties reported herein include hydraulic conductivity, which is a function of the capacity to move or transmit water (transmissivity) through an aquifer of a given saturated thickness, and specific yield (unconfined systems) and storage coefficient (confined systems), which are functions of an aquifer’s ability to store and release water from storage (storativity).

Aquifer data derived from pumping tests were taken from three sources: 1) relatively short (1.5- to 5-hour) pumping tests by the USGS at irrigation wells during the late 1950s and 1960, Aquifer-Test Compilation for the San Joaquin Valley, California (McClelland, 1962), 2) constant rate pumping tests from engineering consultants in the 2000s (Todd, 2018), and 3) aquifer tests performed by URS between late 2009 and early 2010 on seven irrigation wells located within about 1.2 miles of the intersection of 7th Standard Rd and Main Drain Rd. The depths of wells tested in the first two studies varied from 98 to 1,500 feet bgs (median: 650 feet bgs), and the pumping rates varied from 44 to 4,480 gallons per minute (gpm) (median: 2,500 gpm). The analysis included the use of water level recovery data from pumping wells and water levels from observation wells.

From these tests, the hydraulic conductivity was estimated to range between 3 to 250 feet per day (feet/day) (median: 60 feet/day), which is consistent with published ranges for clean, medium- to coarse-grained sand, Basic Groundwater Hydrology (Heath, 1983) or for a fine sand to coarse gravel, Fundamentals of Groundwater (Schwartz and Zhang, 2003). These values also fall within the range of the groundwater models that were calibrated with these data (C2VSim; CVHM; Todd, 2018; and ESA, 2017). The tests performed by URS resulted in an estimated average transmissivity in the central part of the BSA of 18,200 ± 4,400 feet/day. Using the net sand thickness of the aquifer estimated from E-logs of the tested wells, these transmissivity values equate to hydraulic conductivities in the range of 30 to 80 feet/day, values within the range of those estimated by the earlier studies.

The Corcoran Clay varies in lithology from fine (clay and silt) to coarse (sand) texture. Groundwater Availability of the Central Valley Aquifer, California (Faunt et. al., 2009), compiled and estimated horizontal hydraulic conductivities within the range of 0.0024 to 33 feet/day, which is consistent with the range expected for silt to fine/medium sand as shown on Figure 2-6. A range of vertical hydraulic conductivities was estimated from permeameters and field tests between 6.6 x 10-6 feet/day to 1.5 x 10-3 feet/day (Faunt et al, 2009). However, permeameter tests may underestimate hydraulic conductivity while "short circuiting" of intra-borehole flow may lead to overestimates.

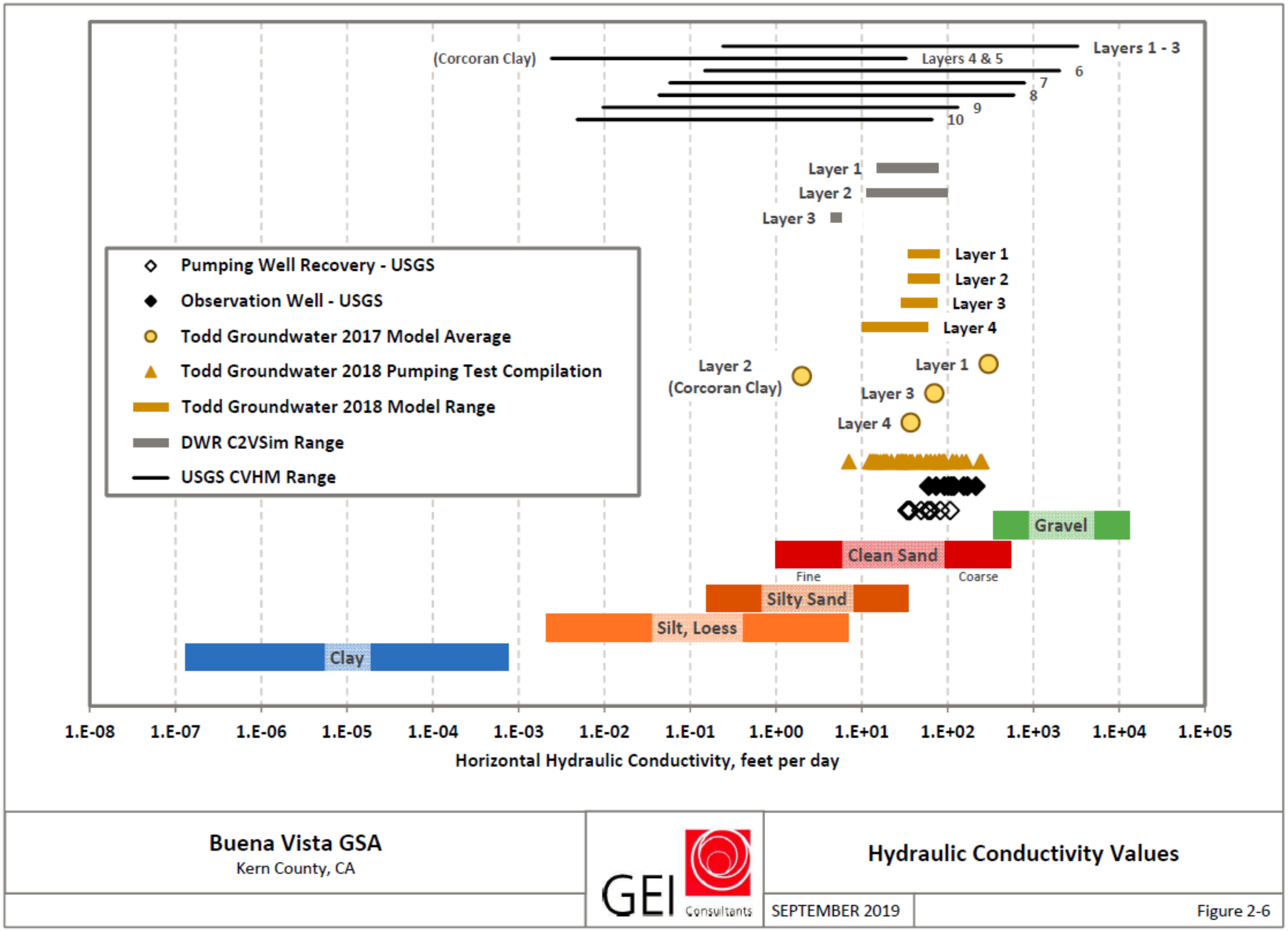

Figure 2-6. Hydraulic Conductivity Values

Specific Yield and Storage Coefficient

Aquifer storage is an important characteristic of the groundwater system and is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in hydraulic head. For unconfined aquifers, specific yield is the term for storativity, while the storage coefficient is used for confined aquifers.

Gravity drainage is the primary mechanism for the release of water from the pore space of an unconfined aquifer. Total porosity is the sum of specific yield and specific retention where the latter is controlled by cohesion between water molecules and the adhesion of water to the aquifer particles. The expansion of water and compression of the aquifer are negligible components of storativity for an unconfined aquifer but quite important for a confined aquifer. Conversely, gravity drainage is not important to a confined aquifer unless that aquifer is dewatered in a specific area. As such, the unconfined storativity can be 100 to 10,000 time greater than confined storativity (Heath, 1983).

For confined systems, aquifer compressibility can be further divided between elastic and inelastic storage, where elastic storage is related to support by the water and inelastic storage is related to the skeletal support of the aquifer particles. For the Central Valley, the elastic storage may be 30 to several hundred times larger than the inelastic storage (Faunt et al., 2009; Ireland et al., 1984). When fine-grained layers are prominent in an aquifer system and for confining layers, significant volumes of water can be released from inelastic specific storage during over-pumping, and the compression of the skeletal particles will result in a permanent loss in storage capacity of fine-grained layers. This structural change will then be manifested at the surface as subsidence.

Specific yield of unconfined aquifers and the storage coefficient of confined aquifers within the area have been estimated by laboratory testing of sample cores, calculations based on lithology type, pumping tests, and groundwater modeling (Dale, 1966; Davis et al., 1959; Davis et al., 1964; Faunt et al., 2009; DWR, 2013; ESA, 2017 and 2018). A range is presented in Table 2-1 and is consistent with published values for similar grain sizes and lithology, Summary of Hydrologic and Physical Properties of Rock and Soil Materials, as Analyzed by the Hydrologic Laboratory of the U.S. Geological Survey, 1948-60 (Heath, 1983; Morris and Johnson, 1967).

Table 2-1. Aquifer Parameters for BVGSA

Data Source	Calculated Horizontal Hydraulic Conductivity (feet/day)	Vertical Anisotropy Kh/Kz	Storage Coefficient	Specific Yield
Kern Pumping Tests Compilation (Todd, 2018)	7 to 250	--	0.0008 to 0.034	--
USGS - Kern Pumping Tests (Observation Wells)	20 to 1600	--	0.0004 to 0.002	--
USGS - Kern Recovery Tests	100 to 800	--	--	--
URS – Aquifer Tests	30 to 80	--	--	--
USGS - CVHM Range	0.24 to 3300	--	--	0.09 to 0.40
DWR - C2VSim Range				
Layer 1	15 to 78	275 to 500	--	0.12 to 0.40
Layer 2	< 1 to 100	20 to 4000	5.E-07 to 8.E-06	--
Layer 3	3.0 to 7.0	60 to 100	--	--
Todd Groundwater 2018 Model Range				
Layer 1	32 to 85	10 to 200	--	0.15 to 0.25
Layer 2			3.E-02	0.02 to 0.21
Layer 3	29 to 75	50 to 500	1.4E-07 to 9.4E-07	0.00004 to 0.00022
Layer 4	10 to 70	500		0.0011 to 0.0019
Todd Groundwater 2017 Model Average				
Layer 1	300 to 335	1150 to 1200	--	0.21
Layer 2	2	1050 to 1250	8.6E-06 1.4E-05	--
Layer 3	67 to 70	1000	0.00024	--
Layer 4	22 to 37	2200 to 3700	0.00058	--
USGS - Water Supply Paper 1618				
USGS - Water Supply Paper 1618				
Clay and Fine-Grained Units	--	--	--	0.03
Silt, Gravelly Clay, Sandy Clay Units	--	--	--	0.05
Fine, tight sand, tight gravel	--	--	--	0.10
Loose, well sorted sand, gravel	--	--	--	0.25

Data Sources: Davis et al, 1959 and 1964; Dale et al, 1966; DWR, 2013; Faunt et al, 2009; McClelland, 1962; ESA, 2017 and 2018.

2.2.4.4 Structural Properties that Restrict Groundwater Flow

Fold structures are present in the older sediments on the western side of the Valley and help define the geological setting of the BVGSA. Most of the folds are anticlines which appear as ridges that crop out approximately 30 to 50 feet or more above the valley floor, including Buttonwillow Ridge, Semitropic Ridge, Lost Hills, and Elk Hills. The Cenozoic Evolution of the San Joaquin Valley (Bartow, 1991). Many anticlines are shown to be concealed beneath younger sediments along the San Joaquin Syncline and other lesser synclines. Similarly, several northwest-trending faults are concealed by the younger sediments but have also been mapped within some of the islands of older sediments as shone in Figure 2-4 (Figure 2-4 - Refer to Figures Tab).

Numerous faults are found near the BVGSA and have been grouped by age of displacement (CGS, 2010). Most of these faults are oriented toward the northwest, parallel to the San Andreas Fault, however several faults are oriented northeasterly. Overall, it is unclear how many of these faults are barriers to groundwater flow, although Faunt et. al. (2009), included four northwest-trending "potential horizontal flow barriers" in the Central Valley Hydrologic Model (CVHM) groundwater model.

The BSA is contained within the flanks of the doubly-plunging Buttonwillow Syncline (Figure 8. PGA, 1991, Plate IX detail, Structure Map on Base E-Clay) and is geologically separated from the main sub-basin to the east by the doubly-plunging Buttonwillow Anticline (PGA, 1991). There is no surface expression to the Buttonwillow Syncline, but the axial ridge of the Buttonwillow Anticline forms the 3-mile-wide Buttonwillow Ridge which is about 30 feet higher than the flat lands overlying the syncline. The presence of these geologic features is also expressed in the groundwater contours along the eastern flank of the BVGSA as illustrated in Figures 2-29a and 2-29b (Figures 2-29a and 2-29b - Refer to Figures Tab).

2.2.4.5 General water quality of principal aquifers

Introduction

The groundwater hydrology of the BVGSA is notable because of the complex interfingering of material from various sources influences both groundwater flow in the GSA and the mineral chemistry of the waters in the area. Most of the naturally occurring groundwater in the GSA is of one of three types:

- Low-moderate TDS, Ca-HCO_3 water;
- Moderate-high TDS, Na/Ca-SO_4 water, and
- High-very high TDS, Na-Cl water.

The areas where these distinct types of groundwater mix are characterized by waters of intermediate chemistry.

The chemistry of the low TDS, Ca-HCO_3 groundwater resembles the chemistry of Kern River water, the main source of recharge for most of the Subbasin. This water is referred to as east-side water because it is characteristic of surface waters which drain from the granitic Sierra Nevada Mountains. East-side water recharges the Subbasin along the Kern River recharge mound, and along Poso Creek during wetter years and is widespread across the interior of the Subbasin down to depths of 600 to 700 feet bgs.

The chemistry of the moderate-high TDS, Na/Ca-SO_4 groundwater resembles the chemistry of runoff that drains from outcrops of Miocene-Pliocene marine sediments and is primarily found along the western margin of the Subbasin for more than 60 miles. This type of water is referred to as west-side water based on the theory, originally advanced in the early 1960s by the U.S. Geological Survey (USGS), that the Miocene and younger marine sediments of the Coast Ranges are the source of poor-quality groundwaters observed along the western margin. Far less runoff occurs on the west side than on the east side resulting in less groundwater recharge being contributed from the west side. As such, west-side SO_4 groundwater is limited in comparison to the HCO_3 groundwater from the east side.

The high-TDS, Na-Cl groundwater is generally found in the deeper parts of the Subbasin, regardless of what type of groundwater it underlies. This saline groundwater is likely to be connate water trapped during the deposition of the marine sediments. Within the BVGSA, groundwater quality is influenced by each of these three main water types and has exhibited TDS values ranging from a minimum of 110 mg/L (4/9/1964) to a maximum of 6,640 mg/L (7/11/1989) with TDS varying by location and depth.

While TDS is a major component in the determination of groundwater quality beneath the BVGSA, both nitrate and arsenic concentrations are also monitored to ensure satisfactory water quality.

Nitrate (NO_3) is a polyatomic ion often naturally occurring in groundwater in low concentrations. These low concentrations can be increased by application of nitrogen fertilizer, runoff from feedlots and dairies, and percolation of industrial and septic wastewater. Two equivalent MCLs are commonly used for nitrate in drinking water: 10 mg/L for nitrate as nitrogen and 45 mg/L for nitrate as nitrate.

Although arsenic is a naturally occurring element, high concentrations of arsenic in drinking water are hazardous to humans. Its presence in groundwater is a result of the dissolution of arsenic minerals in sediments. The primary MCL for arsenic is 10 μg/L.

Data Gaps

Gaps in water quality data will be filled through continued monitoring performed as part of the Buena Vista Coalition’s reporting under its Groundwater Quality Trend Monitoring Work Plan (GQTMWP) carried out for compliance with the Regional Board’s Irrigated Lands Regulatory Program (ILRP) with data collected until this program entered into the GAMA database. Public water systems in the GSA will continue reporting to the State Drinking Water Information

System (SDWIS). Data reported to both GAMA and SDWIS is available to the BVGSA to augment data collected through the BVGSA's groundwater quality monitoring network.

2.2.4.6 Maps and Description of General Water Quality from GAMA

Data from the GeoTracker-GAMA (Groundwater Ambient Monitoring and Assessment Program) database was downloaded to a data management system (DMS) to aid in assessment of water quality in the BVGSA and other GSAs in Kern County. Within the BVGSA, the DMS was populated with 172 records collected from 106 wells for TDS, 333 records collected from 122 wells for nitrate, and 268 records from 8 wells for arsenic. This data is drawn from a monitoring period that extends from 1937 through 2017. Table 2-2 summarizes the data within the DMS for BVGSA.

Table 2-2. Inventory of TDS and Nitrate Data within DMS

	TDS		Nitrate		Arsenic	
	Records Collected	No. of Wells	Records Collected	No. of Wells	Records Collected	No. of Wells
BVGSA	172	106	333	122	268	8

Salinity

Total Dissolved Solids (TDS) was selected as the primary index of salinity in groundwater. TDS is commonly included with initial groundwater quality assessments and routine water quality sampling events and is defined as the total quantity of inorganic salts and organic matter that remain after water from a sample has been evaporated. Because numerous individual constituents contribute to TDS, waters of similar TDS concentrations may differ in the composition of their salt loads. Electrical conductivity (EC) is an indirect measure of TDS and can be used as a surrogate where the TDS values equal approximately 2/3 of the EC value.

As described in the introduction to this section, natural sources contribute to TDS in the BVGSA and explain some of the variability in both TDS concentrations and the chemistry associated with salt loads. As well as natural sources, anthropogenic sources of salts such as deep percolation of irrigation water affect salt concentrations in groundwater.

The BVGSA is part of an inland groundwater basin with no significant outflow. Because salts imported into the area have no natural outlet, the complex hydrogeologic processes that dissolve, transport, dilute, concentrate, and precipitate salts have the net effect of increasing the mass of salts residing in the area (KCWA, 2012). The most prominent of these mechanisms involves salts conveyed in water imported via the California Aqueduct and applied to irrigated lands. As most of the applied water either evaporates or is transpired by plants, the imported salts concentrate in the remaining irrigation water, most of which percolates to groundwater. The same mechanism applies to water introduced by the Kern River. However, as the TDS of river water is lower than that of water imported from the Bay-Delta, its contribution to groundwater salinity is also lower.

Recharge of water from the California Aqueduct and the Kern River results in percolation of recharged water that is of higher quality than the underlying groundwater. Thus, recharge through unlined canals and recharge ponds dilutes the salt concentration in the groundwater underlying the GSA. However, the overall mass of salt stored in the regional and subbasin-wide aquifer system will increase because of the closed nature of the Subbasin.

For the purposes of salinity analysis, the BSA is separated into the Southern BSA and the Northern BSA with 7th Standard Road forming the boundary between the two areas. In the Northern BSA, the TDS from tested wells varies from 208 to 6,640 mg/L, while in the Southern BSA, the TDS varies from 87 to 2,310 mg/L. The TDS of the shallow, perched zone in the Northern BSA ranges from 850 to 5,500 mg/L based on data from shallow piezometers. Groundwater salinity has generally been increasing over the past 20 years. The sources of salinity are not fully understood but may include groundwater inflow from the west.

Historical (prior to 2000) TDS concentrations are summarized below in Table 2-3. Minimum and maximum concentrations and the dates these values were sampled are recorded for the entire BSA, the Northern BSA, and the Southern BSA.

Table 2-3. Historical (prior to 2000) TDS Records

HISTORICAL [prior to 2000]				
Area	Minimum TDS		Maximum TDS	
	[mg / L]	[date]	[mg / L]	[date]
BVGSA	110	4/9/1964	6640	7/11/1989
Northern BSA	208	7/24/1976	6640	7/11/1989
Southern BSA	110	4/9/1964	2310	10/12/1964

Recent (2001 through 2017) TDS concentrations are summarized in Table 2-4, below.

Table 2-4. Recent (2001 through 2017) TDS Records

RECENT [2001 through 2017]				
Area	Minimum TDS		Maximum TDS	
	[mg / L]	[date]	[mg / L]	[date]
BVGSA	87	10/25/2007	1700	2/11/2015
Northern BSA	1030	7/16/2002	1700	2/11/2015
Southern BSA	87	10/25/2007	560	5/31/2012; 6/24/2015

TDS concentrations in the BVGSA are mapped in Figure 2-7 – Historical TDS Monitoring Results (2000 and Earlier) to indicate historical concentrations observed between 1937 and 2000 (137 records) and in Figure 2-8 – Recent TDS Monitoring Results (2001 through 2017) to show more recent concentrations observed between 2001 and 2017 (35 records). Partitioning the data into these two periods provides insights into the effect changes in cropping patterns and introduction of modern irrigation management practices may have had on TDS concentrations. The distribution of maximum TDS concentrations in Figures 2-7 and 2-8 are displayed by circles of olive green at each sample location with the colors shading from light olive green for the lowest concentrations to dark olive green for the highest (Figures 2-7 and 2-8 – Refer to Figures Tab).

The recent data show the persistence of the highest TDS concentrations evident in the historic data along the western edge of the Subbasin, an area which includes the BSA and lands to the west. Observations of high TDS concentrations in this area are consistent with the theory that poor-quality waters are derived from sources to the west and are diluted and ion-exchanged as they mix with waters derived from the Sierra Nevada Mountains. This band of high-salinity water, together with its associated basin-ward decrease in salinity, can be followed for more than 60 miles along the western subbasin margin. These findings are also consistent with the KCWA Water Supply Reports, which illustrate historical salinity concentrations in the western portion of Kern County where the alluvial fan may thin and wells may be screened in bedrock formations rather than alluvium. (Figure 2-8 – Refer to Figures Tab)

Nitrate

Nitrate (NO_3) is a form of nitrogen that can be produced naturally by the atmosphere or by decomposing organic matter. Naturally occurring nitrate concentrations are generally less than 10 milligrams per liter nitrate as nitrogen and generally do not exceed 20 mg/L in groundwater (Water Quality Data: Analysis and Interpretation, Hounslow, 1995). However, naturally occurring concentrations can be augmented by application of nitrogen fertilizers, runoff from feedlots or dairies, percolation of wastewater and food processing waste, and leachate from septic systems, Addressing Nitrate in California's Drinking Water, (Harter, T. et al., 2012).

Two equivalent MCLs are commonly used for nitrate in drinking water: 10 mg/L for nitrate as nitrogen and 45 mg/L for nitrate as nitrate (CCR, 2014). The difference in the MCLs is due to the molecular weight of the oxygen atoms associated with nitrate. Because the State Water Resources Control Board's GAMA Program expresses the nitrate MCL in terms of nitrogen, the nitrate as nitrogen standard will also be applied in the GSP.

Treated wastewater from the Community of Buttonwillow is regulated by the RWQCB under an individual waste discharge requirement (WDR). Recharge from septic systems is present in the BVGSA but is not measured or estimated and is not believed to be significant due to the low number of households outside the Community of Buttonwillow. Recharge from wastewater generated by food processing, confined animal facilities, and other industries is also regulated under individual WDRs and is not believed to be significant.

As with salinity analysis, the BVGSA is separated into the Southern BSA and the Northern BSA. In the Northern BSA, the nitrate from tested wells varies from 0.05 to 46.08 mg NO_3-N / L; in the Southern BSA, the nitrate varies from 0.01 to 6.78 mg NO_3-N / L. Nitrate concentrations in groundwater have generally been steady for the last 20 years, apart from occasional spikes in concentration. The data shows that these spikes recover within 1-2 years.

Historical (prior to 2000) nitrate concentrations are summarized in Table 2-5, below. Minimum and maximum concentrations and dates the values were sampled are recorded for the full BVGSA, the Northern BSA and the Southern BSA.

Table 2-5. Historical (prior to 2000) Nitrate Records

HISTORICAL [prior to 2000]				
Area	Minimum Nitrate		Maximum Nitrate	
	[mg NO_3-N / L]	[date]	[mg NO_3-N / L]	[date]
BVGSA	0.0226	1955; 1956; 1959; 1964; 1966; 1969	46.0836	1989
Northern BSA	0.0452	1945; 1956; 1961; 1964	46.0836	1989
Southern BSA	0.0226	1956; 1959; 1964; 1966; 1969	2.2590	1964

Recent (2001 through 2017) nitrate concentrations are summarized in Table 2-6, below.

Table 2-6. Recent (2001 through 2017) Nitrate Records

RECENT [2001 through 2017]				
Area	Minimum Nitrate		Maximum Nitrate	
	[mg NO_3-N / L]	[date]	[mg NO_3-N / L]	[date]
BVGSA	0.0136	2014	8.7197	2007
Northern BSA	0.1000	2017	8.7197	2007
Southern BSA	0.0136	2014	6.7770	2012

As with TDS, nitrate concentrations in the BVGSA were mapped to indicate historic concentrations observed between 1942 and 2000 and more recent concentrations observed between 2001 and 2017 to provide insights into the effect changes in cropping patterns, fertilizer management and introduction of modern irrigation management practices may have had on nitrate concentrations.

The distribution of maximum concentrations of nitrate in wells during the period from 1947 to 2000 is shown on Figure 2-9 – Historical Nitrate Monitoring Results (2000 and Earlier), and more recent maximum nitrate concentrations reported between 2001 and 2017 are shown on Figure 2-10 – Recent Nitrate Monitoring Results (2001 through 2017). Maximum nitrate concentrations at each location are represented by circles shaded from olive to dark brown. While less data is available for the recent period, the spatial distribution observed in the recent data resembles that of the historic period. Both the historical and the current distributions show high concentrations in the northwest near Lost Hills and the Buttonwillow Ridge, and in the southwest just south of the Elk Hills (Figures 2-9 and 2-10 – Refer to Figures Tab).

Arsenic

In addition to TDS and nitrate, GeoTracker-GAMA data for arsenic were examined because of the importance of this constituent to drinking water safety. Arsenic is a naturally occurring element commonly found in alluvial sediments derived from volcanic sources. Its presence in groundwater is a result of the dissolution of arsenic minerals in sediments. The primary MCL for arsenic is 10 μg/L.

As with salinity and nitrate analyses, the BVGSA is separated into the Southern BSA and Northern BSA for analysis of arsenic. In the Northern BSA, the arsenic from tested wells varies from 2 to 870 μg / L and in the Southern BSA, the arsenic varies from 1.3 to 43 μg / L. Groundwater concentrations of arsenic have generally been steady for the last 20 years, except for occasional spikes in concentration around 1990 and 2010. The data shows that these spikes recover within 1-2 years.

Historical (prior to 2000) nitrate concentrations are summarized in Table 2-7, below. Minimum and maximum concentrations, in addition to the corresponding date of sampling are recorded for all of the BVGSA, the Northern BSA, and the Southern BSA.

Table 2-7. Historical (prior to 2000) Arsenic Records

HISTORICAL [prior to 2000]				
Area	Minimum Arsenic		Maximum Arsenic	
	[μg / L]	[date]	[μg / L]	[date]
BVGSA	4	1989; 1991	870	1989
Northern BSA	4	1989	870	1989
Southern BSA	4	1991	35	2000

Recent (2001 through 2017) arsenic concentrations are summarized in Table 2-8, below.

Table 2-8. Recent (2001 through 2017) Arsenic Records

RECENT [2001 through 2017]				
Area	Minimum Arsenic		Maximum Arsenic	
	[μg / L]	[date]	[μg / L]	[date]
BVGSA	1.3	2016	43	2006
Northern BSA	2	2012	9.3	2007; 2009
Southern BSA	1.3	2016	43	2006

Figure 2-11 – Historical Arsenic Monitoring Results (2000 and Earlier) - presents data preceding 2000 and Figure 2-12 – Recent Arsenic Monitoring Results (2001 to 2017) - displays data collected between 2001 and 2017. In each of these figures, circles shown in light to dark magenta signify maximum arsenic concentrations. The discussion of arsenic in Section 5 and shown on Figure 5-14 which maps recent maximum arsenic concentrations reported in the BMA provides additional background on the current distribution of arsenic in the area. (Figures 2-11, 2-12, and 5-14 – Refer to Figures Tab)

Table 2-9 summarizes data on TDS, nitrate, and arsenic for the BVGSA that is displayed in Figures 2-7 through 2-12.

Table 2-9. Basic Statistics on TDS, Nitrate and Arsenic Monitoring

Metric	TDS	Nitrate as Nitrogen	Arsenic
Number of wells monitored	109	122	8
Maximum concentration	6,640 mg/L	46.08 mg NO_3-N / L	870 µg/L
Minimum concentration	87 mg/L	0.014 mg NO_3-N / L	1.3 µg/L
First reading	1937	1942	1980

2.2.4.7 Primary Use of the Principal Aquifer System

Introduction

The Buena Vista GSA is comprised almost entirely of irrigated farmland with the Community of Buttonwillow being the only municipality within its boundaries. While a substantial proportion of agricultural demand is supplied by surface water, the Community of Buttonwillow and individual domestic and industrial users rely entirely on groundwater, with groundwater elevations sustained by agricultural operations that recharge surface water diverted from the Kern River and SWP. As detailed in other sections of this GSP, groundwater users rely on relatively shallow unconfined and semi-confined aquifer zones above the Corcoran Clay.

Agricultural Water Use

Kern River water began being used for irrigation in the late 1850’s when small private ditches diverted water for the irrigation of grains. Development of land within the boundaries of what is now the BVGSA began with the formation of Swamp Land District No. 121 under the Swamp and Overflow Act of 1850. Created on December 22, 1870, District No. 121 hired engineers to survey, plan, design and construct drains, canals and other features necessary for land reclamation with the intent of diverting surface water from the Kern River and from surface storage within Buena Vista Lake to develop lands north of and surrounding the lake.

Although much of the land within the district could claim riparian water rights due to proximity to Buena Vista Slough, Kern Lake and Buena Vista Lake, the district also filed notices of appropriation for water rights for diversion of Kern River water for irrigation. On July 2, 1877, the district executed an agreement with the Kern Valley Water Company, which effectively transferred the appropriative water rights, canals, other assets and reclamation responsibilities from the district, a public agency, to the company, a private firm. Among the partners in the Kern Valley Water Company were two former meat supply merchants from San Francisco, Henry Miller and Charles Lux who had set out to build a cattle and sheep empire in the Southern San Joaquin Valley.

As the upstream diversions increased, controversies arose resulting in lengthy litigation between upper and lower river users. Much of today's California water law resulted from the California Supreme Court's decision in the historic case of Lux v. Haggin (69 Cal. 255; 10 P. 674; 1886). The ruling created what is now known as the "California Doctrine" which recognizes both riparian and appropriative water rights. Despite the court's decision, the dispute continued and was finally settled in the historic Miller-Haggin Agreement of July 1888. This agreement, as amended, continues to serve as the basis by which the flow of the Kern River is allocated among "First and Second Point" interests.

Under the Miller-Haggin Agreement, the Second Point interests, namely Miller and Lux, were granted an apportionment of approximately one-third of the Kern River flows from March through August. A subsequent amendment also granted Second Point interests some of the Kern River flows resulting from winter runoff. The Second Point water right amounted to an average entitlement of about 158,000 AF/yr, delivered by First Point interests to the Second Point of measurement, undiminished by delivery losses.

After the death of Henry Miller in 1916, the Miller and Lux Land Company began selling much of its land to its tenant farmers who were largely emigrants from Italy. The new landowners soon realized that an entity would be needed to succeed the company in representing the many interests vested in the water right and to provide irrigation service. The Buena Vista Water Storage District was organized in 1924 to fulfill this need and began operations following issuance of its 1927 Project Report. Upon its formation, the District became the owner and operator of the irrigation and drainage facilities developed by the Miller and Lux Land Company and, as the successor to the Second Point interests under the Miller-Haggin Agreement, became entitled to provide for the distribution of the Second Point water rights that were tied to the Company's lands.

Table 2-10 presents the total acreage within the BVGSA, and the number of acres typically devoted to irrigated agriculture. Table 2-11 presents the current distribution of major crops by acreage as reported in the BVWSD AWMP, 2015. Table 2-12 presents the same information by percentage of irrigated acreage. The last column in Tables 2-11 and 2-12, Other, represents a variety of fruits, vegetables, and ornamental crops.

Table 2-10 Total and Irrigated Areas of the Buena Vista GSA (Acres)[1]

Total Area	Lands Receiving Service
50,560	46,643 (92%)

Table 2-11. Key Crops Grown in the Buena Vista GSA (irrigated acreage)

Nut Crops	Grain / Alfalfa	Grapes	Cotton	Other	Total
9,185	8,433	2,575	8,182	4,062	32,437

Table 2-12. Key Crops Grown in the Buena Vista GSA (% of irrigated acreage)

Nut Crops	Grain / Alfalfa	Grapes	Cotton	Other
28%	26%	8%	25%	13%

Agricultural land use and water use are closely linked and are subject to change due to a variety of factors. For example, the on-going conversion from annual to permanent crops has important implications to groundwater management. First, conversion to permanent crops represents a "hardening" of demand as crop water requirements must be met year in and year out regardless of hydrologic conditions with the consequence that fallowing land during dry periods becomes an increasingly costly practice. Second, conversion to drip and micro-sprinkler irrigation has accompanied the shift to permanent crops, which has resulted in irrigation applications more closely matching crop demands. The higher application efficiency of drip and micro-sprinkler irrigation has reduced the volumes of surface and groundwater deliveries needed to satisfy crop demands. Although the shift in irrigation practices has diminished deep percolation of irrigation water, deep percolation has always played a minor role in groundwater recharge due to the GSA's restrictive surface soils.

Municipal, Domestic and Industrial Water Use

As noted above, the BVGSA encompasses the Community of Buttonwillow. The Community has a total surface area of 6.9 square miles and a population of 1,508 living in 406 housing units at the time of the 2010 census and lies entirely within the Buttonwillow Management Area. Buttonwillow relies entirely on groundwater extracted from underlying aquifers with most domestic and municipal water uses being for landscape irrigation at homes, commercial properties, and parks. Data available from DWR identified 59 domestic wells within the BMA.

Municipal, commercial and industrial wells deliver approximately 1,500 AF to industrial customers, largely agricultural yards and processing facilities. A large proportion of this use is consumptive due partly to evapotranspiration of land applied wastewater.

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[1] 2016 Engineer's Assessment Report in Support of Proposition 218 Assessment Ballot Proceeding, Buena Vista Water Storage District

2.2.5 Data Gaps

Because of the extensive metering of surface water supplies and usage within the BVGSA and the metering of all production wells in the GSA, the primary uses of the principal aquifer system and the contribution of water from this system to the GSA's overall water supply is well documented with no apparent data gaps.

2.2.6 Cross Sections

Cross sections were developed to illustrate the subsurface conditions of the BVGSA along its north-south axis and east-west axis. The cross sections rely on data from a USGS Water Supply Paper (Croft 1972) and Western Oil and Gas Association Westside Groundwater Study (Rector 1983). Figure 2-13a illustrates the path that both the north-south and east-west cross sections take through BVGSA. Figure 2-13b – North-South Cross Section G-G' is northeast-trending to be perpendicular to the numerous faults and folds within the Valley. Figure 2-13c – West-East Cross Section D-D' is west-trending to be parallel to the axis of the Valley. (Figures 2-13a through 2-13c – Refer to Figures Tab)

2.2.7 Principal Characteristic Descriptions and Maps

2.2.7.1 Topographic Information

Figure 2-14 – Topographic Features – is a topographic map of the Kern County Subbasin and of the BVGSA. As described previously, the GSA occupies low-lying lands that follow the topographic axis of the Subbasin. The lowest land surface elevations are approximately 210 feet AMSL and are located along the County line between Highway 43 and Interstate 5. Prominent topographic features bordering the GSA include the Elk Hills and the Buttonwillow and Semitropic ridges (Figure 2-14 – Refer to Figures Tab)

2.2.7.2 Surficial Geology

The surficial geology of the Subbasin has been documented in previous investigations and is presented on Figures 2-4, 2-15 and 2-16 (respectively Page, 1986; CGS, 2010; and Bartow, 1991). These investigations identify numerous faults and folds located within the Subbasin including features which influence and define the BVGSA.

According to the USGS Phase 2 Report, (CGS, 2010), the formations within the BVGSA consist mainly of Pleistocene to Recent unconsolidated and semi-consolidated alluvial lake (Q of Figure 2-15 – Geology of Kern County Subbasin), playa, and terrace deposits. Older Pleistocene alluvium (Qao) is present in the eastern portion of the Subbasin on top of Pliocene-Pleistocene deposits (QPc) of sandstone, shale and gravel deposits, including the Kern River Formation. The QPc unit includes the Tulare Formation and occurs as islands, surrounded by recent alluvium, within the center of the northern Subbasin, along the western side and within the alluvium.

Bartow (1991) provides a similar map (Figure 2-16 – Generalized Geologic Units) - as the CGS map but refers to Quaternary alluvial and lacustrine sediments (Qs) on the valley floor and

Tertiary sedimentary rocks (TS) along the flanks and for the islands of older rocks in the valley center. Bartow also identified portions of three types of structural regions shown on Figure 2-16.

The structure of the western portion of the Subbasin, including the BVGSA, is characterized by numerous northwest-trending folds that are subparallel to the nearby right-lateral, strike-slip San Andreas Fault. Most of the folds are anticlines which have been mapped in the older sediments (QPc; Ts) and appear as ridges that crop out approximately 30 to 50 feet or more above the valley floor, including the Buttonwillow and Semitropic ridges, Lost Hills, and Elk Hills. Many anticlines are shown to be concealed beneath younger sediments (Q; Qs) along with the San Joaquin Syncline and other lesser synclines. Similarly, several northwest-trending faults are concealed by the younger sediments but have also been mapped within some of the islands of older sediments (Figures 2-15 and 2-16 – Refer to Figures Tab).

Page (1986) provides a somewhat different interpretation of the surficial geology of the BVGSA and its surroundings (Figure 2-4). The center of the valley floor is underlain by Recent flood basin (Qb) – clay, silt, and some sand; and by Pliocene to Recent lacustrine and marsh deposits (QTl) – clay, silt, and some sand with extensive subsurface clay layers (A, C, E/Corcoran). The former unit is associated with the original Kern River drainage and flood basin while the latter unit is associated with the beds of the historical Kern Lake, Buena Vista Lake, and Goose Lake, and the southern edge of the Tulare Lakebed. The remainder of the valley is underlain by Miocene to recent continental deposits (QTc) – a heterogenous mixture of gravel, sand, silt, and clay with some layers of conglomerate, sandstone, siltstone, and claystone.

2.2.7.3 Soil Characteristics

Introduction

Soils within the BVGSA and neighboring areas are generally fine-textured originating from the historic Buena Vista and Kern lakebeds and swamp and overflow lands which continue north along the historical drainage paralleling Goose Slough, Goose Lake, and the southern edge of the Tulare Lake depositional environment. These soils are typically saline and high in pH. For example, the northern portion of the Buena Vista WSD includes heavy, poorly-drained soils underlain by a shallow, perched water table containing groundwater with salinity exceeding 2,000 mg/L. These conditions result in poor infiltration, water encroaching into the root zone, and moderately saline soils (Soil Survey of Kern County, California, Northwestern Part, 1988). Detailed soil survey data can be found in two USDA reports: Soil Survey of Kern County, California Northwestern Part, and Southwest Part (USDA, 1988 and 2007), including recent online updates.

The remainder of the GSA includes medium-textured soils which are relatively low in salinity and within the optimal pH range for crop production.

Hydrologic Soils Groups

For the purposes of SGMA, a useful index of a soil's capacity to infiltrate precipitation and applied irrigation water is the National Resources Conservation Service (NRCS) Hydrologic Soil

Group classification. Hydrologic Soils Groups typical of the BVGSA are defined below and are displayed on Figure 2-17 – Hydrologic Soils Groups – which was developed using data from the NRCS' Soil Survey Geographic Database (SSURGO).

- Hydrologic Group A – "Soils in this group have low runoff potential when thoroughly wet. Water transmitted freely" (NRCS, 2012). Group A soils have a high infiltration rate due to well drained sands or gravelly sands and have the highest permeability and potential for contributing to groundwater recharge.
- Hydrologic Group B – "Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission is unimpeded" (NRCS, 2012). Group B soils are moderately well drained due to moderately fine to coarse textures and have the second highest potential permeability and potential for contributing to groundwater recharge.
- Hydrologic Group C – "Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission is somewhat restricted" (NRCS 2012). This group has restricted potential to contribute to groundwater recharge. Group C soils have a low infiltration rate due to their fine texture or because of a layer that impedes downward movement of water. These soils are present at various points along the northwestern side of the Kern County Subbasin including the BVGSA.
- Hydrologic Group D – "Soils in this group have high runoff potential when thoroughly wet. Water transmission is very restricted" (NRCS, 2012). This group has a very limited capacity to contribute to groundwater recharge. These soils have a very slow infiltration rate due to the presence of clay and are located primarily along the northern boundary of the BVGSA.

Taxonomic Soil Orders

Figure 2-18 – Taxonomic Soil Orders of the Kern County Subbasin – displays taxonomic soil orders present in the BVGSA as defined by SSURGO mapping obtained from the DWR SGMA Data Viewer website (2018). This figure shows the six soil orders present in the BVGSA, with the most prominent being Aridisols, Entisols and Inceptisols evident along the eastern highland mixed with Alfisols, Mollisols, and Vertisols (Figures 2-17 and 2-18 – Refer to Figures Tab).

Based on the NRCS publication Keys to Soil Taxonomy (NRCS, 12th edition, 2014), the following characteristics are associated with each of these soil types:

- Aridisols are dry soils characterized by a low humus, light colored surface horizon with a subsurface accumulation of soluble salts, silicate clays, and possibly a cemented layer of calcium carbonate, calcium sulfate (gypsum) or silica.
- Entisols are characterized by the absence of soil horizons due to recent deposition or active erosion under extreme wet or dry conditions.
- Inceptisols exhibit a weak appearance of soil horizons overlying a weathering-resistant parent material.

- Alfisols are characterized by well-developed soil horizons enriched with aluminum- and iron-bearing (Al/Fe) minerals but depleted of calcium carbonate. Translocated clays typically form a layer with relatively high amounts of mineral nutrients (calcium, magnesium, sodium, and potassium).
- Mollisols are characterized by a thick, dark surface horizon of humus, which typically originates from native grass vegetation with mineral nutrients present in most horizons.
- Vertisols are clay-rich soils (>30%) with significant cracking during the dry season due to the shrink-swell response of the clay minerals during the dry and wet seasons. The shrink-swell action produces significant vertical mixing of the soil.

2.2.7.4 Delineation of Recharge, Potential Recharge, and Discharge Areas

Introduction

Recharge to aquifers in the BVGSA occurs through several mechanisms that fit into two general categories:

- Direct recharge
- In-lieu recharge

Direct Recharge

Direct recharge takes place through operation of BVWSD facilities including unlined irrigation canals, and dedicated groundwater recharge projects. Due to the nature of the BVGSA's soils and irrigation practices, deep percolation of applied irrigation water contributes little to aquifer recharge. Key recharge facilities within the BVGSA are presented in Figure 2-19 – Existing Recharge and Spreading Centers (Figure 2-19 – Refer to Figures Tab)

In-lieu Recharge (Conjunctive Use)

In-lieu recharge refers to instances where surface water is applied to lands that otherwise would have been irrigated using groundwater. Because of the history of the BVWSD's use of water from the Kern River and the State Water Project, in-lieu recharge in the BVGSA can be viewed not as substitution of surface water for established groundwater use, but as avoidance of reliance on groundwater due to established use of surface water.

Existing and Potential Recharge Sites and Mechanisms

Existing and potential recharge mechanisms in the BVGSA include conversion of cropped land to recharge ponds, and infiltration of storm water through recharge facilities. Both mechanisms are exemplified by the Palms Project discussed in Section 7 – *Projects and Management Actions*.

2.2.7.5 Surface Water Bodies

Figure 2-20 – Surface Water Features – shows the location of surface water bodies in or bordering the BVGSA, including the Kern River, the California Aqueduct and the Buena Vista Aquatic Recreational Area (BVARA).

The most important local source of surface water for the GSA is the Kern River, which has been regulated by the Isabella Dam and Reservoir since 1954. The dam and reservoir are operated by the U.S. Army Corps of Engineers, and the distribution of water is administered by the Kern River Watermaster. (Kennedy/Jenks Consultants, 2011) (Figure 2-20 – Refer to Figures Tab).

2.2.7.6 Source and Point of Delivery for Imported Water Supplies

Introduction

The BVGSA conjunctively uses surface water from local and imported sources. The Kern River is the source of local supply, and the State Water Project (SWP) is the avenue for delivery of imported water.

Sources of Imported Water

Imported water is supplied by the State Water Project (SWP) conveyed through the California Aqueduct. For the purposes of this analysis, historical averages are based on the 26-year period extending from 1991 through 2016, unless noted otherwise. This period is of sufficient length to capture a wide range of water supply conditions and, as the facilities used to import water have been in place throughout this period, changes in infrastructure have not greatly affected the pattern of deliveries. Over the period from 1995 through 2005, water imported via the SWP supplied 36% of the surface water available to the BVGSA with the Kern River being the source of the remaining 64%. Kern River water is delivered to the BVGSA through the East Side Canal and, also, wheeled through the California Aqueduct through exchange with Kern River contractors further upstream.

The proportion of surface water and groundwater used on an annual basis varies widely depending on hydrologic conditions, and over the years, regulatory requirements have impacted the availability of imported water. Environmental constraints on pumping from the Sacramento/San Joaquin River Delta have limited the reliability of SWP supplies. The following section provides background on imported water delivered via the California Aqueduct to the BVGSA.

State Water Project

The Kern County Water Agency (KCWA) was formed in the 1960s to contract with the California Department of Water Resources (DWR) for the importation of SWP water to Kern County. The California Aqueduct, the SWP's principal conveyance feature, transports water from the Bay-Delta along the west side of the San Joaquin Valley to the Kern County Subbasin. Individual water districts, including the BVWSD, hold contracts with the KCWA for a share of the imported water. The BVWSD's contract with the KCWA provides for two types of water;

relatively firm Table A water and surplus water (Article 21) delivered through six turnouts from the aqueduct. Figure 2-21 – California Aqueduct and Points of Delivery to BVWSD – displays the alignment of the California Aqueduct and the location of turnouts supplying the BSA. (Figure 2-21 – Refer to Figures Tab)

Table A Water takes its name from an exhibit to the contract between the DWR and the SWP contracting agencies that serves as the basis for allocating available water among the agencies. Table 2-13 shows the maximum annual Table A deliveries for the entire SWP service area, the San Joaquin Valley, and the BVWSD.

Table 2-13. Maximum Annual SWP Table A Amounts

(Source: SWP Delivery Reliability Report 2005) (Units: AF)		
SWP Service Area	**San Joaquin Valley**	**BVWSD**
4,172,786	1,133,556	21,300

Due to a variety of factors including hydrologic conditions, reservoir storage, and projected runoff, the SWP is unable to deliver full Table A amounts in most years. Accordingly, a percent allocation is set each year which is applied to each contractor’s Table A amount. Table 2-14 shows the historical deliveries of Table A water to the KCWA from 1991 through 2016, along with Article 21 (surplus), carryover and turnback water for the same period.

Table 2-14 Historical Deliveries of SWP Water (AF) to Kern County Water Agency

(Source: SWP Delivery Reliability Reports for 2002, 2003, 2007, 2017)					
Year	**Table A**	**Article 21**	**Carryover**	**Turnback**	**Total**
1991	-	-	8,965	-	8,965
1992	480,462	-	2,758	-	483,220
1993	1,127,774	-	40,156	-	1,167,930
1994	598,685	58,474	-	-	657,159
1995	1,089,063	59,671	2,795	-	1,151,529
1996	1,117,060	15,653	52,350	-	1,185,063
1997	1,102,807	10,264	-	-	1,102,807
1998	856,906	-	1,684	-	858,590
1999	1,077,755	58,241	-	42,154	1,178,150
2000	825,856	78,908	13,193	233,202	1,151,159
2001	363,204	23,233	92,052	6,502	484,991
2002	670,884	21,951	15,680	20,543	729,058
2003	841,697	27,891	22,380	8,419	900,387
2004	640,190	86,513	40,120	5,075	771,898
2005	893,439	453,078	9,851	22,397	1,378,765
2006	961,882	256,634	5,418	18,610	1,242,544
2007	592,423	99,861	19,645	4,683	716,612
2008	275,555	-	2,896	883	279,334
2009	325,426	-	56,367	544	382,337
2010	411,821	-	55,419	3,044	470,284
2011	753,707	194,119	119,773	16,068	1,083,667
2012	560,969	-	32,477	2,180	595,626
2013	314,466	-	73,303	37,005	424,774
2014	1,393	-	24,717	520	26,630
2015	173,581	-	43,265	707	217,553
2016	458,759	-	-	3,533	462,292
Historical Average	**635,222**	**55,557**	**28,279**	**16,387**	**735,051**

Total deliveries of SWP water to the KCWA have averaged 735,051 AF per year during the period from 1991-2016, with these annual deliveries ranging from 8,965 AF and 26,630 AF in 1991 and 2014, respectively, to 1,378,765 AF in 2005.

Article 21 Water, unlike Table A water, cannot be scheduled; rather, it must be taken at the time it is declared to be available. The following conditions govern the availability of Article 21 water:

- Available only when deliveries do not interfere with Table A allocations and SWP operations
- Available only when excess water is available in the Delta
- Cannot be stored within the SWP system. Contractors must be able to use the Article 21 water directly or store it in their own system

Due to these conditions, Article 21 water is only available during wet months, typically December through March. The BVGSA is conditionally allocated 3,745 AF of any surplus supply.

Surface water deliveries enter the BVGSA through two flow paths: 1) California Aqueduct turnouts, and 2) the East Side Canal. Each of these points of entry is equipped with flow measurement to quantify the volume of water entering the BVGSA. It is important to note that water measured as being delivered through California Aqueduct turnouts is not entirely SWP allocation. This is the case because water transferred or exchanged between BVWSD and other agencies may be routed for delivery through the California Aqueduct.

Figure 2-22 – Historical Deliveries from CA Aqueduct Turnouts to BVGSA – shows total deliveries through turnouts from the SWP's CA Aqueduct to the BVGSA from 1993 through 2015. Figure 2-23 – Historical Surface Water Deliveries to BVGSA – shows both CA Aqueduct and East Side Canal deliveries from 1993 through 2015.

Section 6 – Water Supply Accounting – provides detailed information on SWP deliveries to the BVWSD used in the BVGSA's water budget.

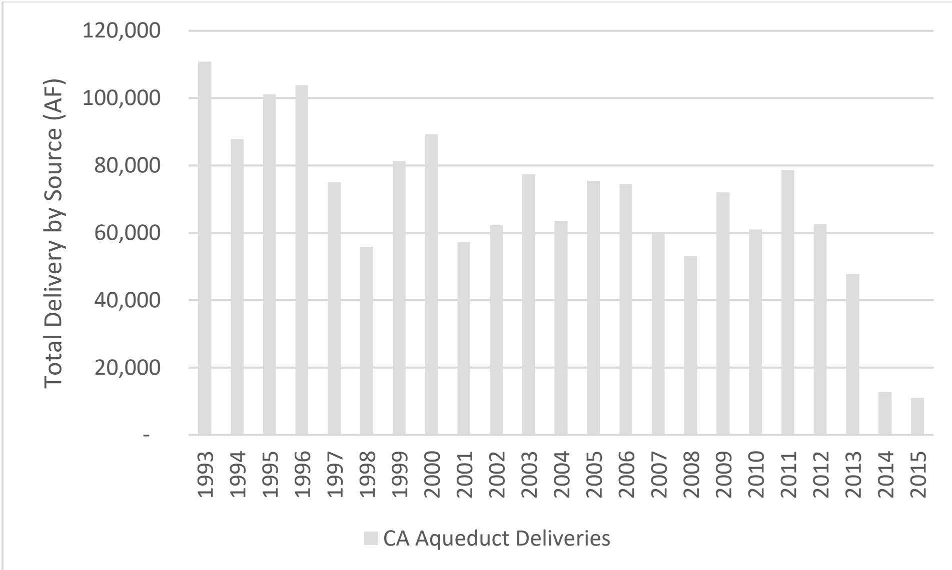

Figure 2-22. Historical Deliveries from CA Aqueduct Turnouts to BVGSA

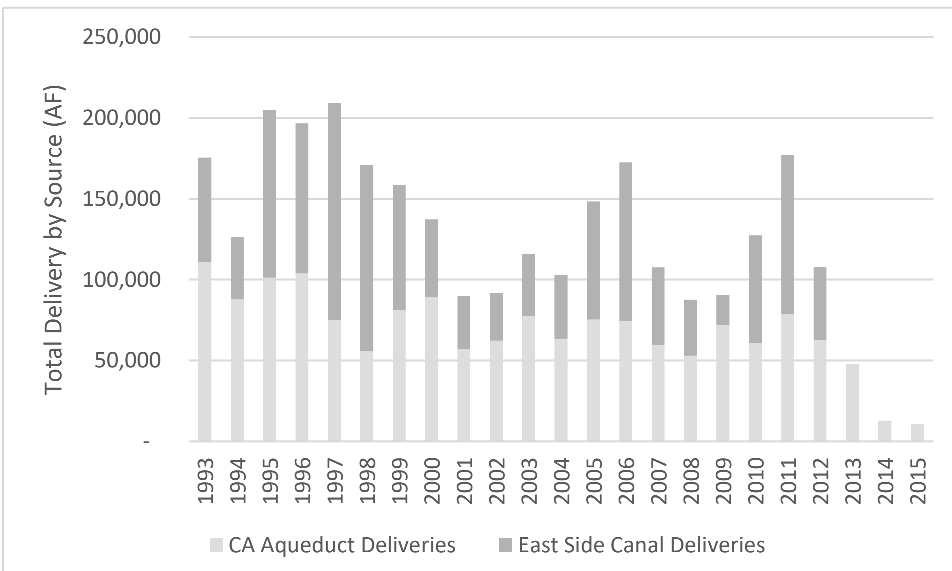

Figure 2-23. Historical Deliveries of Surface Water to the BVGSA

2.3 Groundwater Conditions

2.3.1 Description of Current and Historical Groundwater Conditions

Based on historical groundwater data from USGS and KCWA (Page, 1986; and KCWA), groundwater flows from the uplands along the south, east, and west margins of the Kern County Subbasin toward the center of the Subbasin and from the Kern River towards the north and south due to recharge by the river and from groundwater banking along the river. Groundwater in the BMA generally migrates in a southerly direction along the axis of the Subbasin that runs through the center of the GSA until it leaves the GSA as subsurface underflow or is captured by pumping wells for irrigation or potable consumption. Generally, groundwater levels observed over the past 20 years have been stable in the north while declining in the south which suggests the north-to-south gradient has been increasing.

2.3.2 Groundwater Elevation, Flow Directions, and Lateral/ Vertical Gradients

2.3.2.1 Groundwater Elevation Contour Maps for Each Principal Aquifer

Groundwater elevation contour maps for the main production zone of the aquifer system were prepared for Spring 2015 (seasonal high) (Figure 2-24 – Spring 2015 Groundwater Elevations) as well as Fall 2015 (seasonal low) (Figure 2-25 – Fall 2015 Groundwater Elevations) to provide a 'baseline' snapshot of groundwater flow trends across the BVGSA at the inception of SGMA. Because pumping extracts water from the aquifer above the E-clay, and only three district monitoring wells, all in the south of the BMA, observe groundwater levels beneath the E-clay, no maps were prepared for this lower zone. (Figures 2-24 and 2-25 – Refer to Figures Tab)

Groundwater elevations during Spring 2015 in the principal aquifer system ranged from less than 80 feet AMSL in the extreme south of the BMA to 200 feet AMSL in an area surrounding the Lerdo Highway.

Groundwater elevation data for the Fall 2015 were limited due to the high demand for pumping. However, general groundwater elevation trends are consistent with historical trends. Groundwater elevations in the principal aquifer system ranged from less than minus 50 feet AMSL to greater than 200 feet AMSL.

2.3.2.2 Hydrographs Capturing Historical Highs, Lows, and Vertical Gradients

Hydrographs for district monitoring wells reported to CASGEM by the BVWSD are provided as Figures 2-26a through 2-26m. The hydrographs represent the available data from 1992 to 2015 for each of the monitoring wells. Additional hydrographs presented in Appendix C, include:

- District Monitoring Wells (DMWs)
- District Wells
- Measured Landowner Wells
- Shallow Piezometers (Northern BSA)

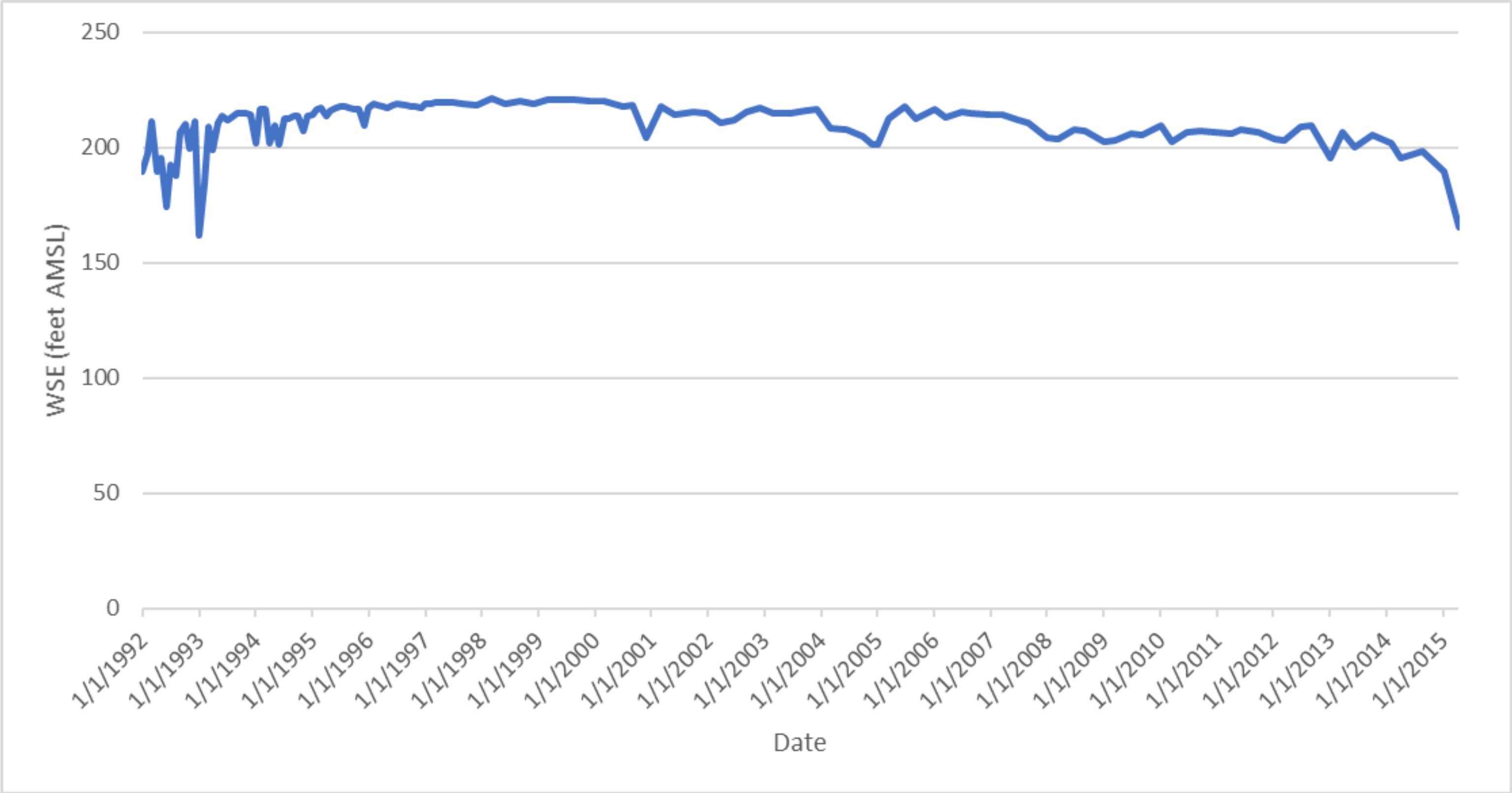

Figure 2-26a. DMW01 Hydrograph

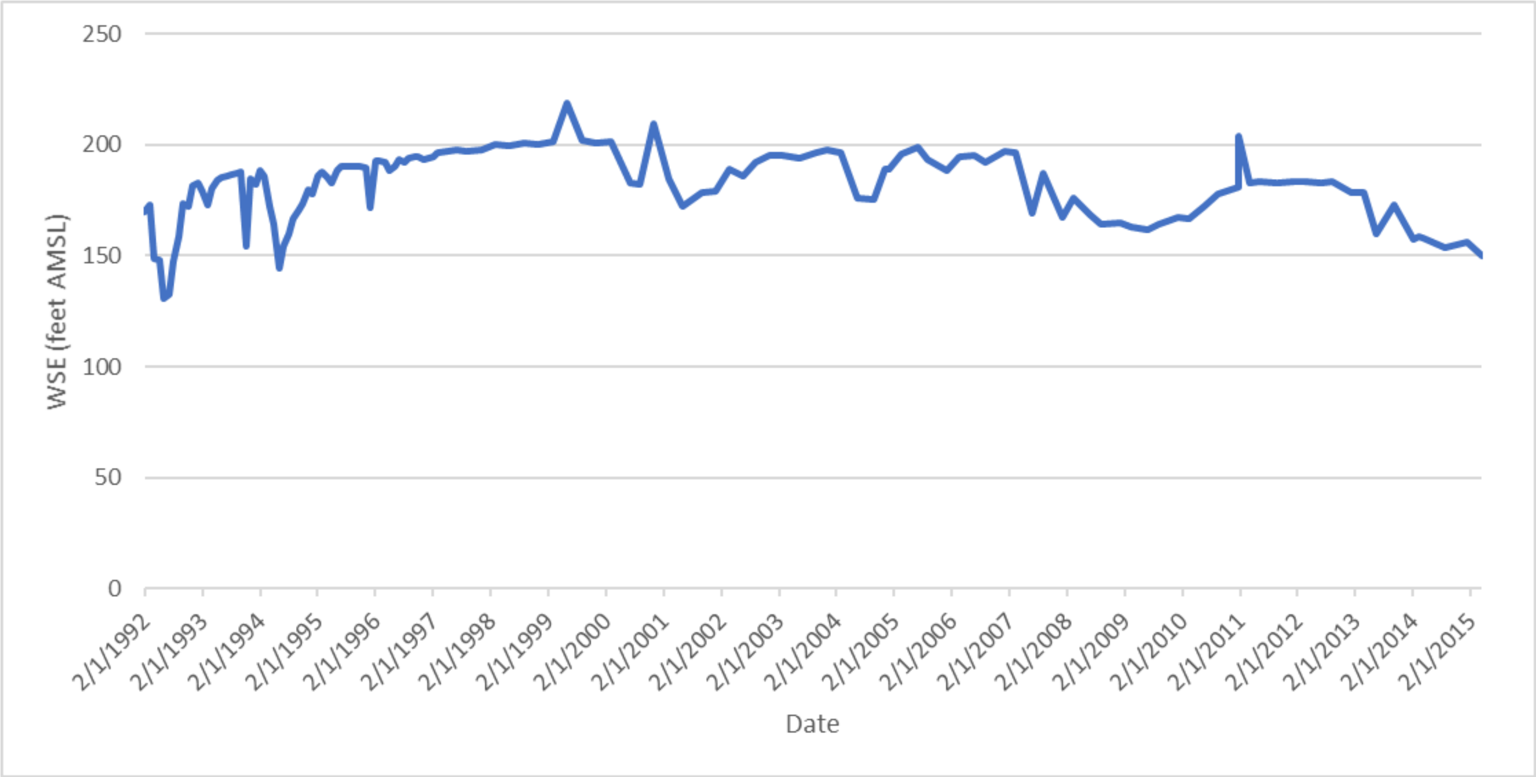

Figure 2-26b. DMW02 Hydrograph

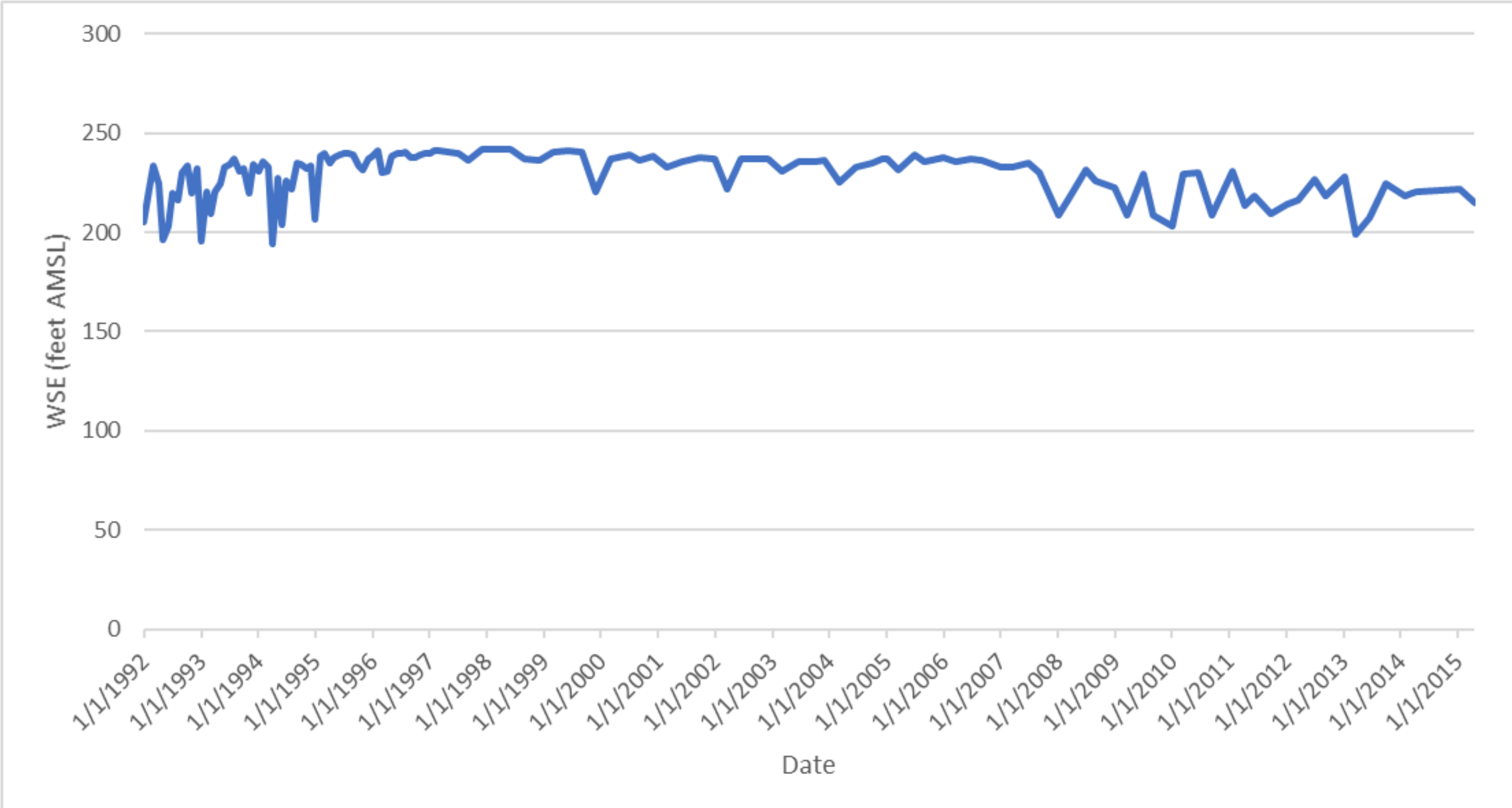

Figure 2-26c. DMW04 Hydrograph

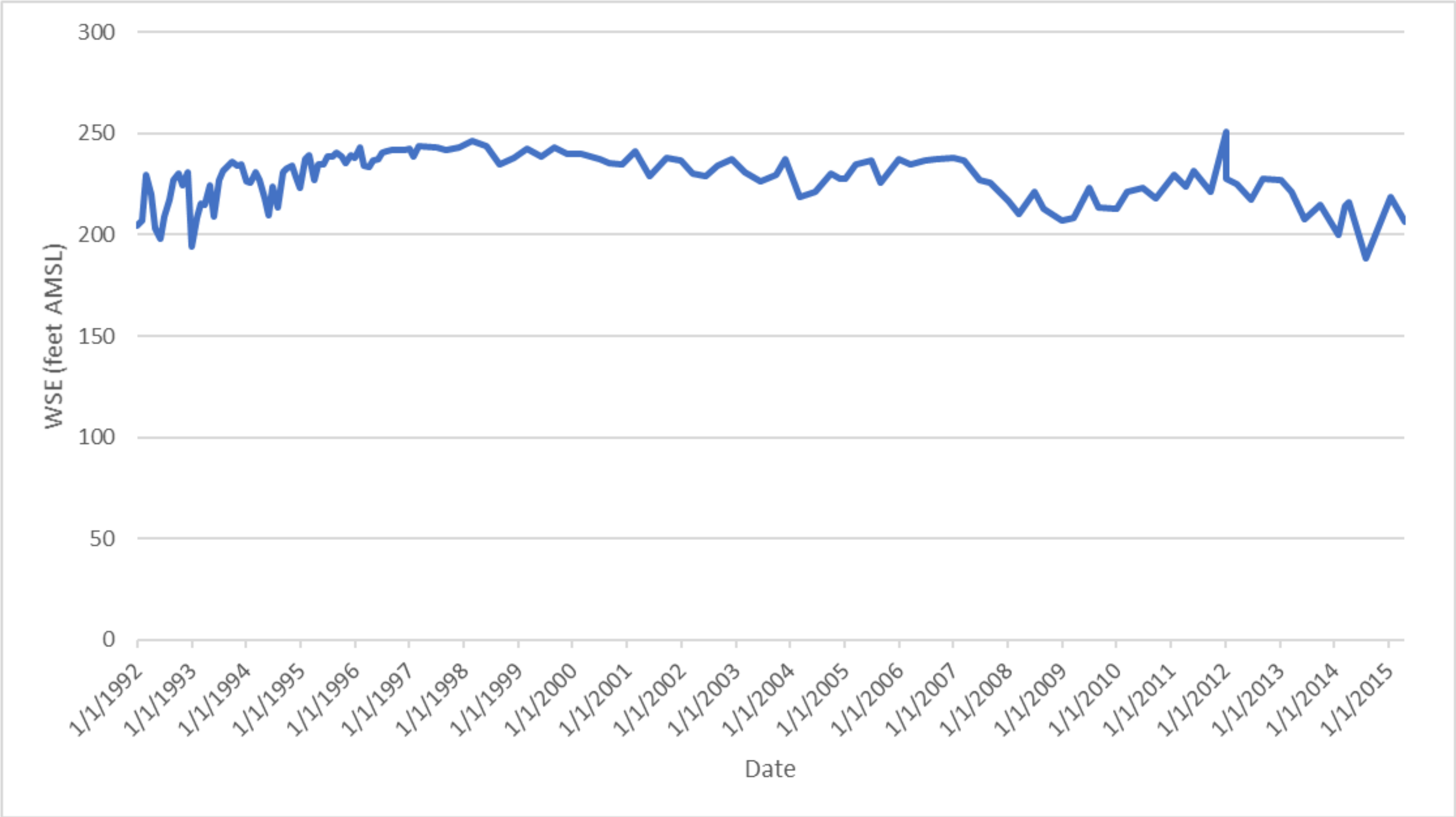

Figure 2-26d. DMW05 Hydrograph

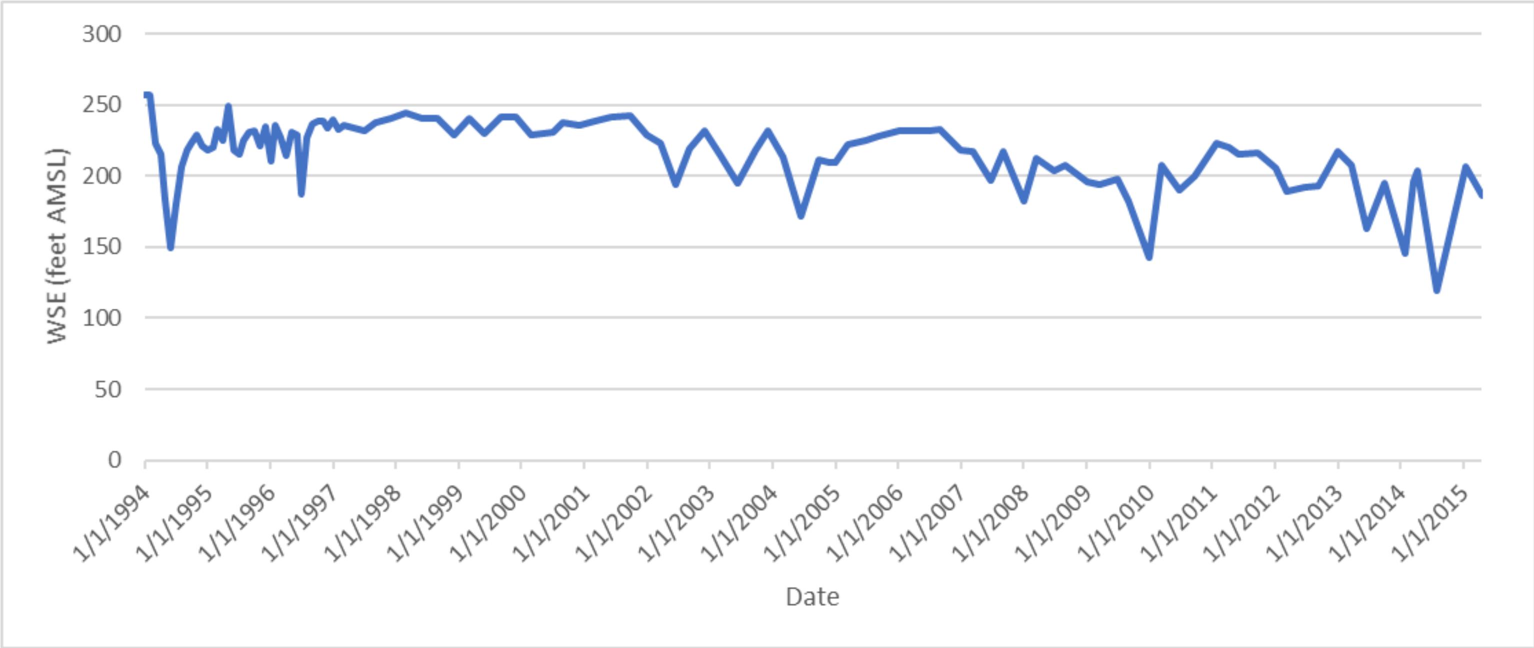

Figure 2-26e. DMW06 Hydrograph

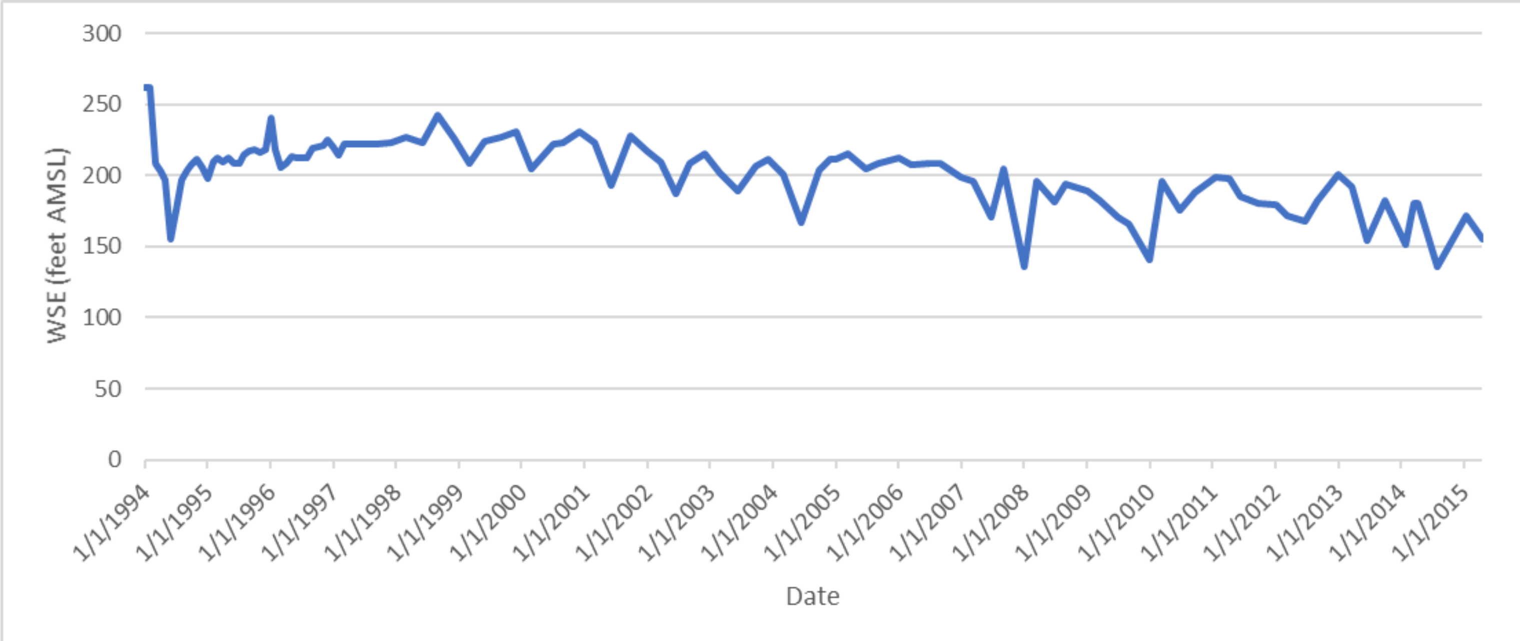

Figure 2-26f. DMW07 Hydrograph

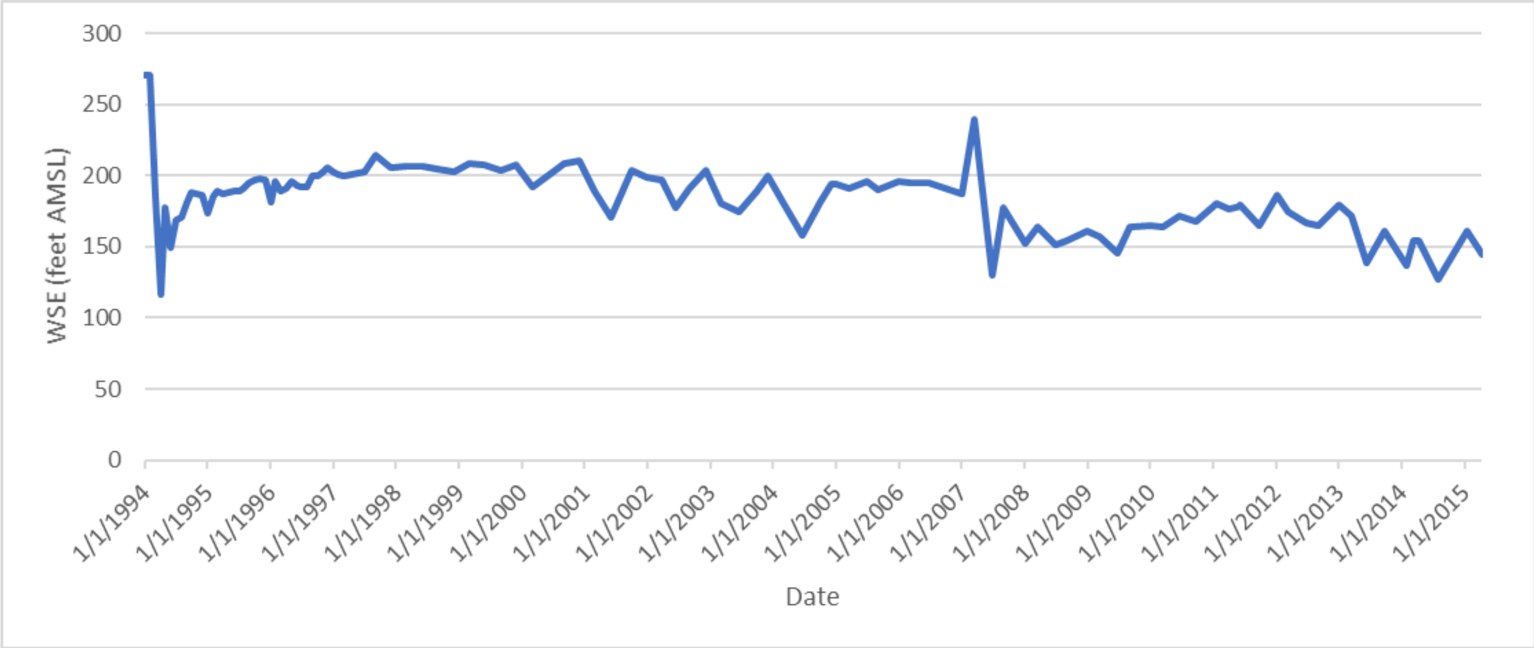

Figure 2-26g. DMW08 Hydrograph

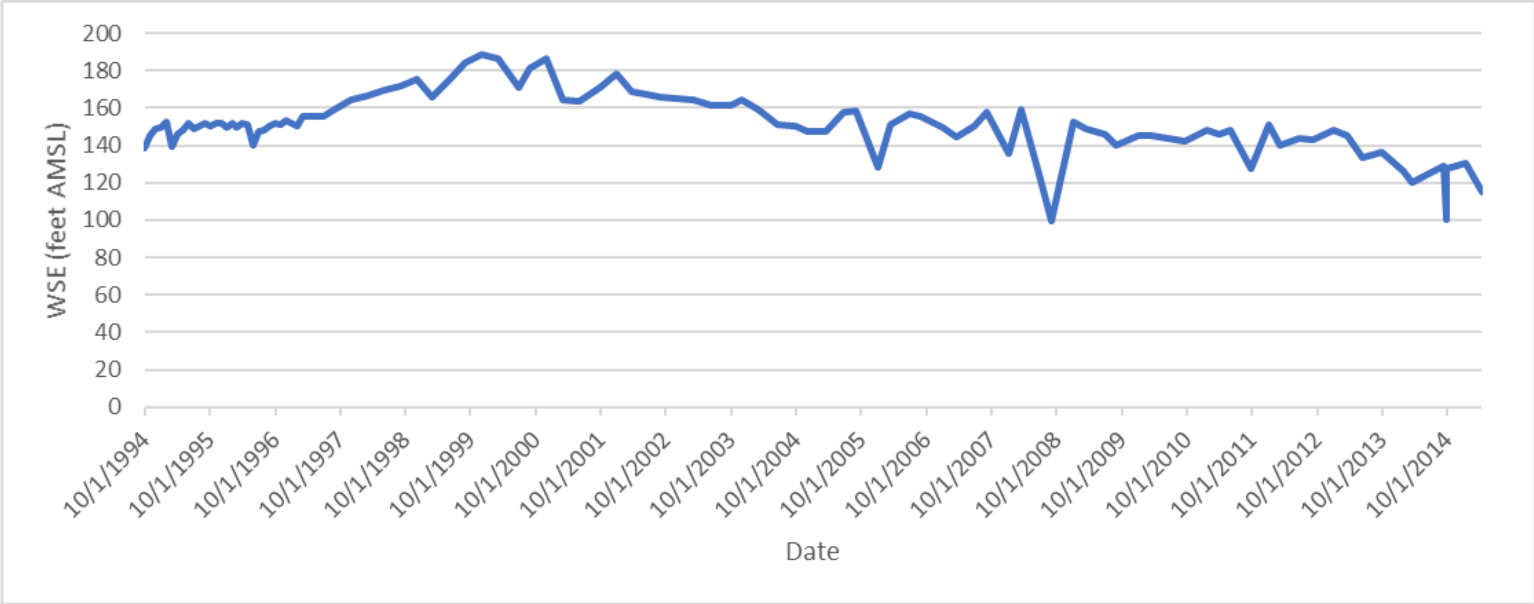

Figure 2-26h. DMW010a Hydrograph

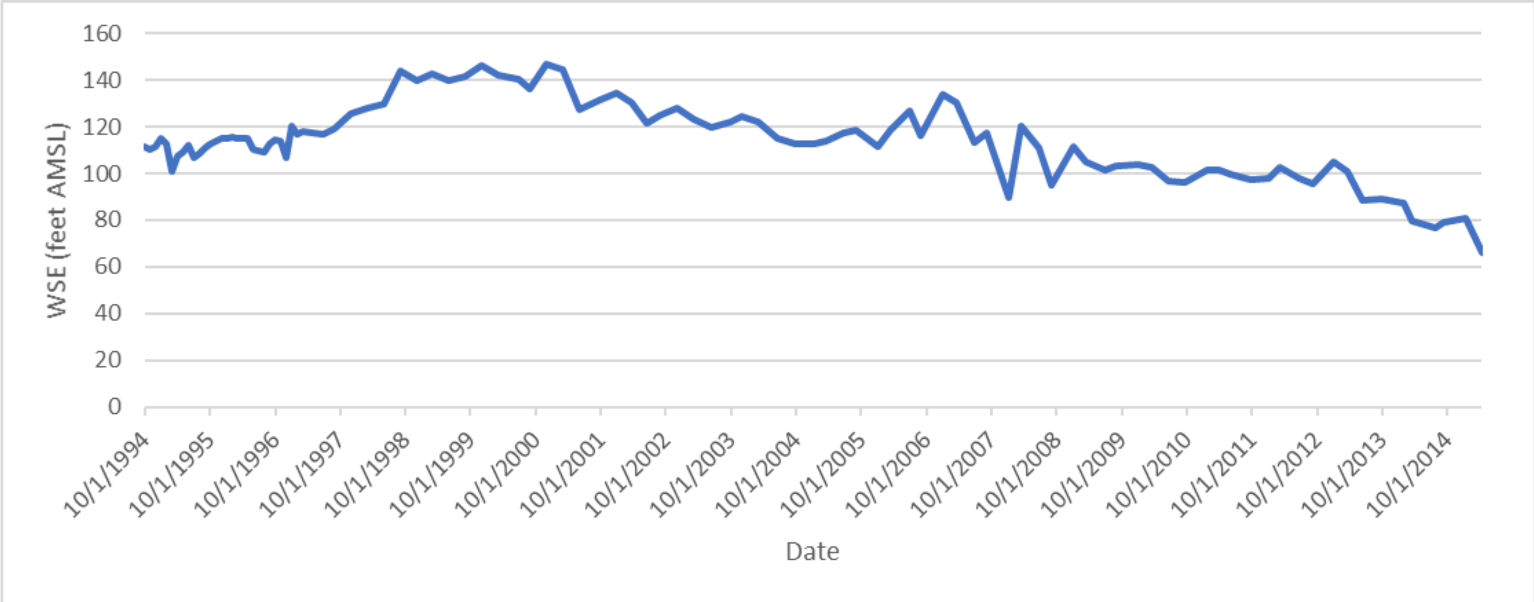

Figure 2-26i. DMW10b Hydrograph

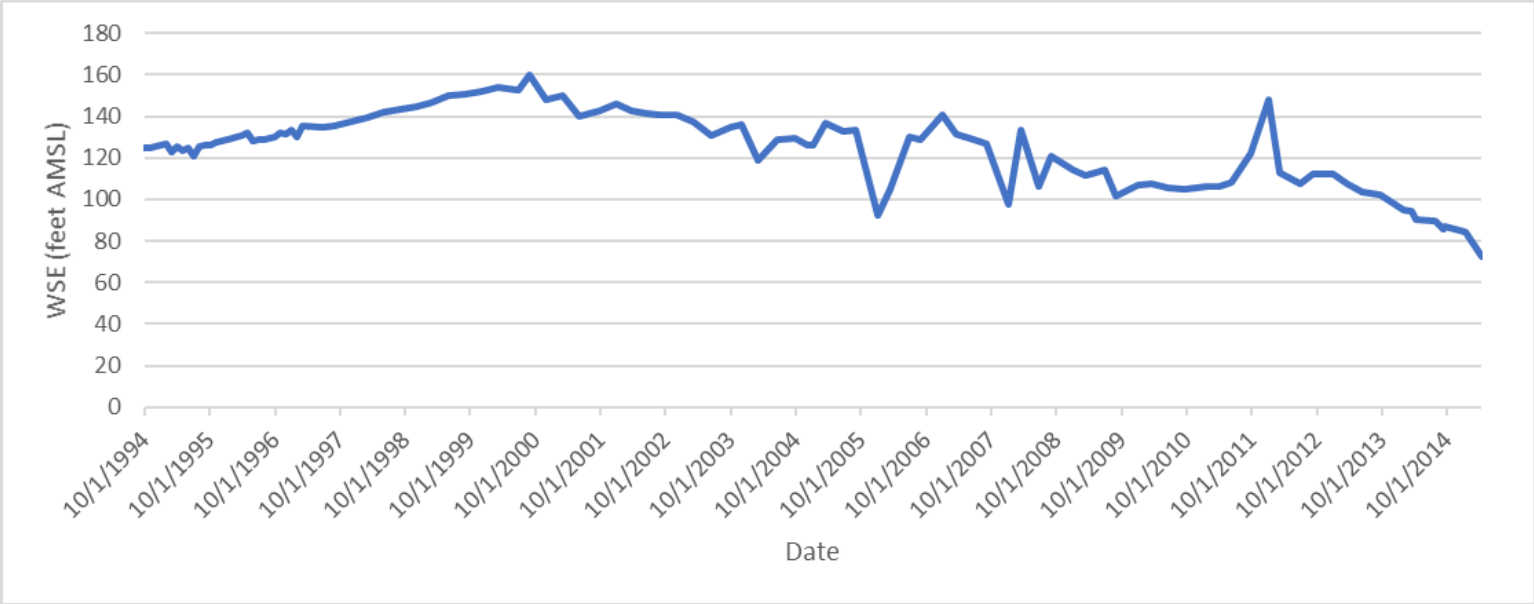

Figure 2-26j. DMW12a Hydrograph

Figure 2-26k. DMW12b Hydrograph

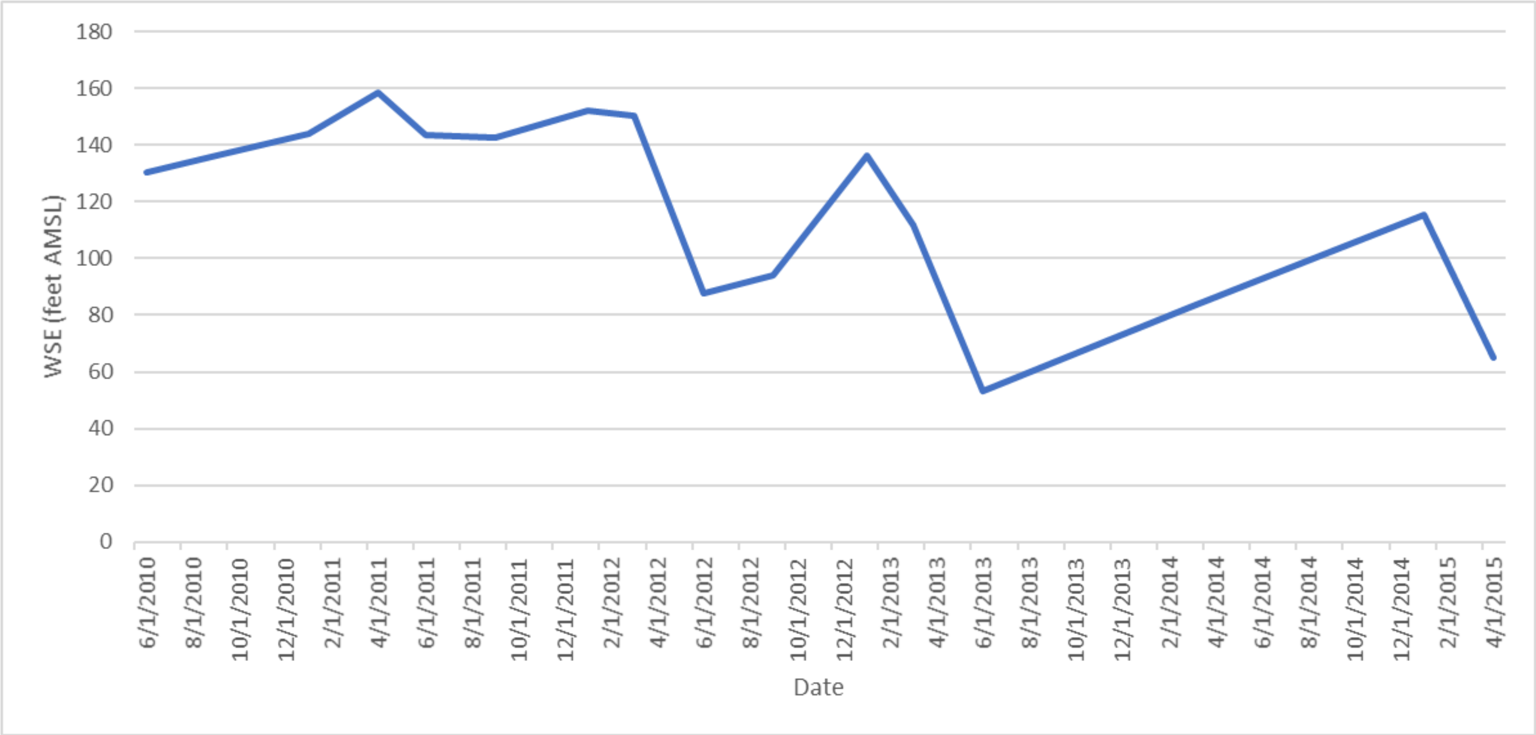

Figure 2-26l. M01 Hydrograph

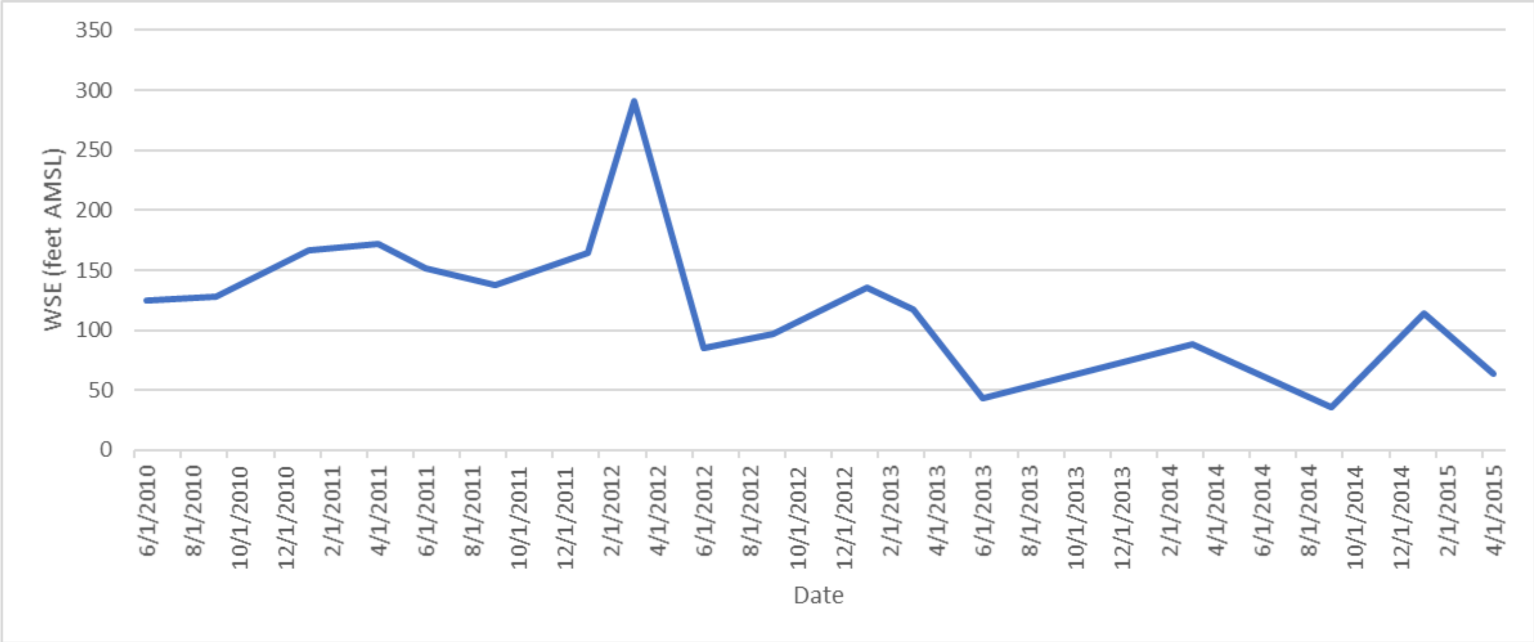

Figure 2-26m. M02 Hydrograph

2.3.3 Cumulative Change in Storage

An estimated change in groundwater storage for the BVGSA was calculated for two periods. The first period was between a "wet" water year (Spring 2011) and a "critically dry" water year (Spring 2015), and the second period was between Spring 2015 and Spring 2017. The change in groundwater elevations for the Spring highs were evaluated by superimposing data across the area that were available for 2011, 2015, and 2017. Differences in groundwater elevations for these periods were calculated using Microsoft Excel models that were then verified with the three-dimensional analysis capabilities of ArcGIS™ to estimate an overall volume of change.

Change in storage is the product of the volume of aquifer material lying between groundwater elevations at the beginning and end of the period over which the change takes place and 'storage' values representing the storage capacity of a unit of aquifer material. The heterogeneity of the lithology of the shallow, unconfined, and confined zones results in a wide range of values for storage: specific yield for unconfined zones and coefficient of storage for confined zones. As a result, change in groundwater storage was estimated using a reasonable range of values for unconfined zones of the aquifer system, as almost all groundwater extraction takes place above the confining C-clay. According to the USGS (1989), the Tulare Basin has a median value for specific yield of 0.101 for unconfined groundwater, based on ten subareas, including a value of 0.094 for the BVGSA (subarea 47). This value of specific yield is similar to the value of 0.15 developed by the BVWSD and confirmed in the Preliminary Water Supply Analysis, a California Energy Commission study (Conway, Fio, and Deverel, 2013) carried out for the now-terminated Hydrogen Energy California (HECA) project. Because of the uncertainty associated with specific yield, a range of 0.10 to 0.20 has been used when estimating change of storage within the BMA.

Figures 2-27a, 2-27b, and 2-27c display estimates of groundwater level contours for 2011, 2015, and 2017, respectively. Figure 2-27d shows the change in groundwater level contours between 2011 and 2015 and Figure 2-27e shows the change between 2015 and 2017. The resulting estimated change in storage for 2011 to 2015 varied from -132,389 AF to -264,777 AF for the 4-year period of drought. For 2015 to 2017, the estimated change in groundwater storage varied from 34,635 AF to 69,269 AF for the 2-year period of drought recovery. These estimates illustrate the degree of uncertainty now associated with estimating change in storage. (Figures 2-27a through 2-27e – Refer to Figures Tab)

To better account for aquifer heterogeneity, a groundwater model is being developed by Todd Groundwater for the Kern County Subbasin, based on the DWR's C2VSim fine-grid model. Change in storage estimates computed by the model will be compared with the estimates presented in this Basin Setting and, once validated, may be used to update the Basin Setting.

2.3.4 Annual Change in Storage, Considering Annual Use and Water Year Type

Section 6 – Water Supply Accounting – Water Budget presents an extensive analysis of water supplies available to the BVGSA and of the uses and destinations of these supplies. Based on this analysis the annual change in storage by water year type after consideration of use during these year types is as follows:

- Wet year – 35,772 AF;
- Above Normal year – 9,368 AF;
- Below Normal year – 24,409 AF;
- Dry year – 24,833 AF, and
- Critically Dry year – 73,535 AF.

As described in the water budget analysis, the period used for developing the water budget (1993 through 2015) was weighted at the extremes with Wet years being the most frequent year type (8 occurrences) and Below Normal years being the least frequent (2 occurrences).

2.3.5 Seawater Intrusion

The BVGSA is located over 60 miles from the Pacific Ocean and the Kern County Subbasin is bounded by the Coast Range mountains on the west side. Due to its location, seawater intrusion is not an issue for the BVGSA.

2.3.6 Groundwater Quality

Introduction

Section 2.2.4.5 – General Water Quality of Principal Aquifers provides a discussion of groundwater quality in the BVGSA that focuses on three constituents found in varying degrees throughout the GSA, salts (TDS), nitrate and arsenic. Each of these constituents is found in the parent material of local aquifers, and TDS and nitrate are also introduced through human activity. This section focuses on locations, identified by regulatory agencies, where groundwater quality has been degraded due to industrial and commercial activity.

2.3.6.1 Map and Description of Known Sites and Plumes

Locations of impacted groundwater were identified by reviewing information available on the SWRCB Geotracker website, the California Department of Toxic Substances Control (DTSC) EnviroStor website, and the Environmental Protection Agency’s (EPA) National Priorities List (NPL). Cases that have been closed by the supervisory agency are not considered.

Figure 2-30 – Sites of Potential Groundwater Impacts – from EnviroStor and Geotracker databases, present the locations and details of known impacted groundwater or potentially impacted groundwater within the Kern County Subbasin. The sites were divided into the following categories based on regulatory designation (Figure 2-28 – Refer to Figures Tab):

- Other Sites with Corrective Action (Current)

- Sites Needing Evaluation (Active or Inactive)
- Federal Superfund-Listed Sites
- Leaking Underground Storage Tank (LUST) Cleanup Sites
- Sites in the DTSC Site Cleanup Program (Active)
- Produced Water Ponds Sites (Open Assessments or Inactive-Permitted)
- Underground Injection Control Sites (Open Assessment or In Review)

Of the 50 open cases within the boundaries of the Kern County Subbasin, 9 were identified as impacting groundwater within the Subbasin, however none were identified as impacting groundwater within the BVGSA.

2.3.7 Land Subsidence

Inelastic land subsidence is a major concern in areas of active groundwater extraction due to canal and infrastructure damage, permanent reduction in the groundwater storage capacity of the aquifer, well casing collapse, and increased flood risk in low lying areas.

Several processes contribute to land subsidence. These include, in order of decreasing significance: aquifer compaction by overdraft, hydrocompaction (shallow or near-surface subsidence) of moisture deficient deposits above the water table that are wetted for the first time since deposition, petroleum reservoir compaction due to oil and gas withdrawal, and subsidence caused by tectonic forces (Ireland et al., 1984).

Inelastic subsidence typically occurs in the clay layers within aquifers and aquitards due to the withdrawal of water in storage within these layers during over-pumping, which induces the permanent rearrangement or collapse of the clay layer structure. Clay particles are supported by water at the time of deposition and over-pumping dewaters the clay. Groundwater cannot re-enter the clay structure after collapse. This condition represents a permanent loss of the storage volume in the clay layers due to a reduction of porosity in these layers. This storage reduction does not substantially decrease usable groundwater storage in the aquifer because the clay layers do not typically store significant amounts of recoverable groundwater (LSCE, 2014). However, the groundwater quality of the aquifers could be impacted by the lesser quality groundwater in the clay layers. The surface displacement of subsidence represents the reduced thickness of the impacted clay layers, and this vertical displacement causes damage to wells and structures.

Historical documentation of subsidence has relied on various types of data, including topographic mapping and ground surveys, declining groundwater levels, borehole extensometer, and continuous global positioning satellite (CGPS) stations. Recent subsidence studies have utilized satellite- and aircraft-based Interferometric Synthetic Aperture Radar (InSAR) within the Central Valley and along the California Aqueduct and Friant-Kern Canal. Much of the InSAR work has been led by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL).

The USGS estimates that about 75 percent of the subsidence in the San Joaquin Valley occurred in the 1950s and 1960s, a period that coincides with extensive groundwater development, Land Subsidence in the United States (Galloway, et al., 1999). Importantly, water levels during this period were continuing to fall to then-historic lows each year, changing pore pressures in sediments for the first time, which would be associated with larger amounts of subsidence (ESA, 2017).

InSAR data published in a study commissioned by the California Water Foundation showed up to 0.5 feet of subsidence from 2007 to 2011 across most of the Kern County Subbasin north of the Kern River, Land Subsidence from Groundwater Use in California (LSCE, 2014). Portions of the California Aqueduct are located along the western boundary of the BVGSA and more focused InSAR data show variable conditions with up to 6 inches of subsidence in the area bounded by the aqueduct, Interstate 5, the Lerdo Highway and the Kern River Flood Channel Canal between April 2014 and June 2016, especially north of Buttonwillow. Note that InSAR data are subject to uncertainty and this aqueduct area showed up to 2 inches of uncertainty.

Five continuous CGPS stations are located in the Kern County Subbasin north of the Kern River and have been recording their location since late 2005 (stations P544, P563, and P565), 2006 (station 564), and 2007 (station P544). These stations are monitored as a part of UNAVCO's Plate Boundary Observation (PBO). Between 2008 and 2017, subsidence varied from 1.7 to 2.9 inches at three stations near the BVGSA along Interstate 5 (P544, P545, P563), and the rate decline was relatively steady.

According to the report "Land Subsidence from Groundwater Use in California" (Luhdorff & Scalmanini Consulting Engineers, 2014), subsidence is on-going and leading to significant impairment of the California Aqueduct. According to DWR (2014), the Kern County Subbasin was rated at a high risk for future subsidence due to 1) a significant number of wells (51%) with water levels at or below historic lows; 2) documented historical subsidence; and 3) documented current subsidence. However, the BVGSA has displayed little evidence of any of these tendencies. This may be due to the BVWSD's historical reliance on surface water. This access to surface water has supported groundwater elevations and limited the volume of groundwater extraction which has fueled subsidence in other parts of the Subbasin. Future subsidence will depend on whether water levels decline below previous low levels and remain low for a considerable length of time. A more complete analysis of subsidence in the BVGSA is presented in Section 5 – Minimum Thresholds, Measurable Objectives and Interim Milestones.

2.3.7.1 Cumulative Total Subsidence

The tabulated data shown in Table 2-15 includes cumulative inches of subsidence within the Subbasin and BVGSA and a calculated approximate annual rate for the period over the data collection period. The data for the entire Subbasin is sourced from 1926 through 1970 and the data specifically for BVGSA reflects more recent observations from 2006 through 2019. The more recent data is collected from UNAVCO CGPS unit P563 and approximate values are reported in Table 2-15 due to variations in daily CGPS solutions. An analysis of subsidence in the BVGSA is presented in Section 5 – Minimum Thresholds, Measurable Objectives and Interim Milestones.

Table 2-15. Cumulative Subsidence and Approximate Annual Rate of Subsidence

Subbasin Area	Date Range	Cumulative Subsidence (inches)	Calculated Annual Rate of Subsidence (inches/year)	Source
Kern County Subbasin	1926 - 1970	<12 – 120	<0.3 - 2.7	Polland, et al., 1975 Ireland, et al., 1984 Topographic Maps and Leveling Data.
BVGSA (P563)	2006 - 2019	~ 3.15	~ 0.24	UNAVCO CGPS Processed Daily Position Time Series, 2019

2.3.7.2 Annual Rate of Subsidence

Estimates of annual rates of subsidence are presented in Table 2-15 and in Figures 2-29 and 2-30.

2.3.7.3 Map of Subsidence Locations

Historical subsidence within the BVGSA is shown on Figure 2-29 – Historical Subsidence. Recent subsidence, as measured by recent studies and monitoring points, is plotted on Figure 2-30 – Recent Subsidence (2015-2016). This figure displays CGPS data locations, which are monitored continuously by UNAVCO and data from these locations are plotted with recent calculated rates of subsidence. The approximate extents of the UAVSAR and InSAR studies in the vicinity of the BVGSA are also displayed on Figures 2-29 and 2-30 (Figures 2-29 and 2-30 – Refer to Figures Tab).

2.3.8 Interconnected Surface Water Systems

Interconnected surface water systems are surface waters that are hydraulically connected by a continuous saturated zone to an underlying aquifer (DWR, 2016). Because no streams cross the boundaries of the BVGSA to feed lakes, ponds or other surface water bodies, natural surface water is not connected to the groundwater system.

Nearby surface water bodies, such as the Buena Vista Aquatic Recreation Area (BVARA) lakes, are situated in either natural or man-made depressions and are now dependent on managed water deliveries, principally from the Kern River and seepage that is recovered by wells and returned to the lakes.

2.3.9 Identify Groundwater Dependent Ecosystems

Introduction

Groundwater Dependent Ecosystems (GDEs) are ecological communities that depend on groundwater emerging from aquifers or groundwater occurring near the ground surface.

In the BVGSA, potential GDEs are likely to be associated with wetlands and riparian areas that are supported either by groundwater or by a combination of groundwater and surface water. Ephemeral wetlands covered by water seasonally are likely to be supported by irrigation deliveries and precipitation and are unlikely to be surface expressions of groundwater. Features such as groundwater recharge basins that are artificially flooded with surface water, although having the potential to provide habitat, also depend on diversion of surface water rather than groundwater.

Methodology

The distribution of GDEs in the BVGSA was assessed based on a series of research efforts beginning with the paper, Mapping Groundwater Dependent Ecosystems in California (Plos 1, 2010). This research was published by scientists at The Nature Conservancy of California (TNC) and used geospatial data to map hydrologic features characteristic of potential GDEs. The methodology applied in this research mapped the following variables as surrogates to represent ecosystem dependence on groundwater:

- Density of springs and seeps
- Density of groundwater dependent wetlands and associated vegetation alliances
- Percent of discharge from groundwater (baseflow) in streams.

Density of Springs and Seeps

Locations of seeps and springs were identified based on data extracted from the National Hydrography Dataset (NHD Plus) and were mapped as the top priority since all seeps and springs are GDEs. Because the NHD Plus maps springs and seeps as point data, these were evaluated by their density (number of springs and seeps per hectare). Although the data on springs and seeps does not contain information on the volume of flow discharged from these features, this is not believed to compromise the value of the analysis as mapping of springs and seeps is used to identify habitat areas rather than to assess their importance as water sources. For this reason, calculating the density of these features is believed to be sufficient to characterize their contribution to GDEs in the Kern County Subbasin.

Figure 2-31 – Location of Springs and Seeps, which displays the results of this mapping, shows a dense population of springs and seeps in the mountains and foothills on the flanks of the Kern County Subbasin but no springs or seeps are mapped in the BVGSA.

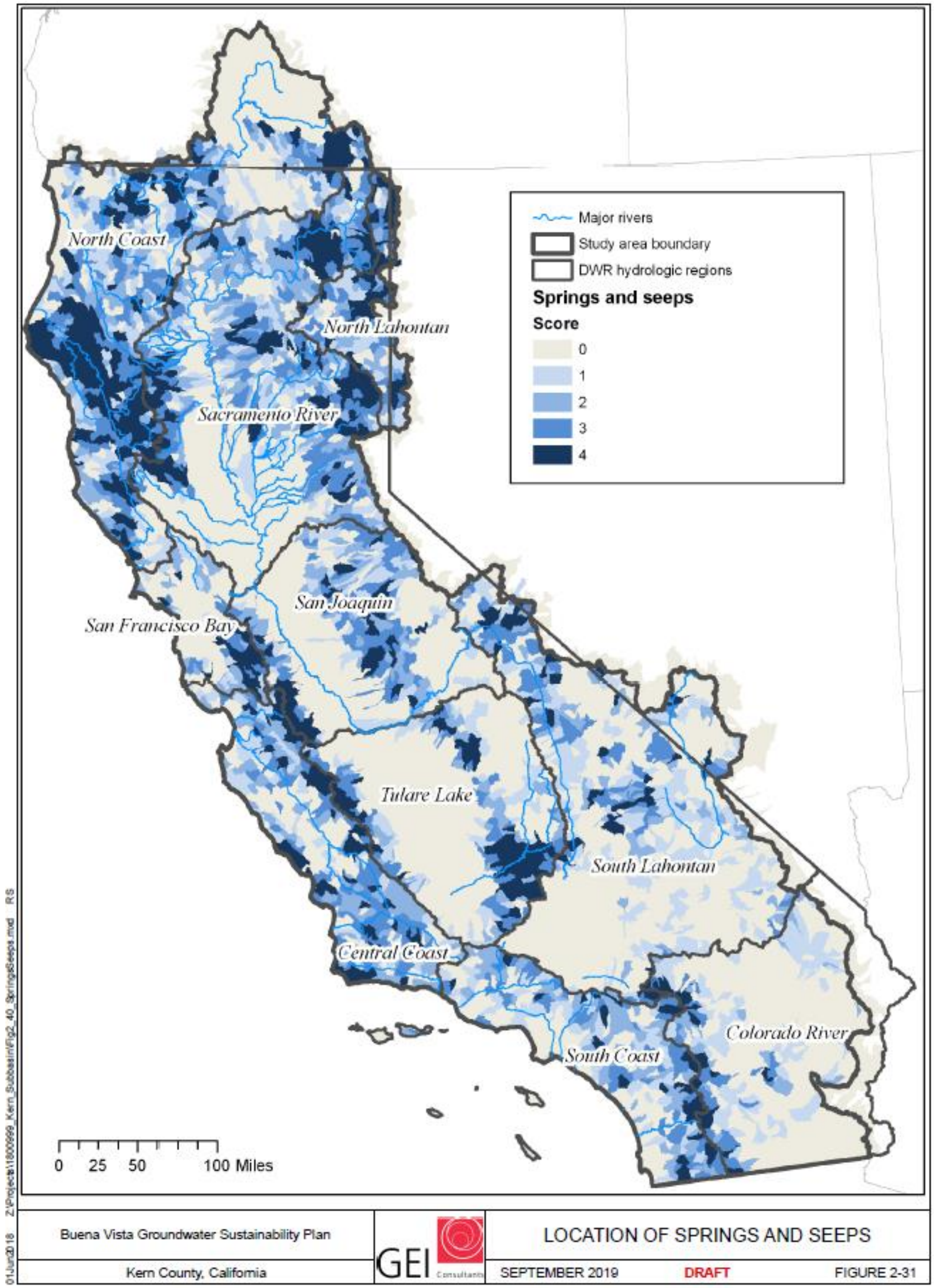

Figure 2-31. Location of Springs and Seeps

Density of Groundwater Dependent Wetlands

Areas where groundwater flow sustains wetlands were addressed in *Mapping Groundwater Dependent Ecosystems in California* using the following analytical sequence.

- Data on wetlands and groundwater dependent vegetation alliances were pooled from multiple sources to generate a single composite GIS layer. This layer was used to map all wetlands and vegetation types that may have some level of groundwater dependence as determined from the data source's metadata and consultation with ecologists familiar with the specific ecosystems.
- Although all springs and seeps are groundwater dependent features, the groundwater dependence of wetlands is a function of their hydrologic, geologic, and climatic setting. To screen data for wetlands that are supported by precipitation or surface water diversions and that may not be groundwater dependent, associations between wetlands and the presence of hydric or partially hydric soils were mapped using the NRCS STATSGO2 database. This step filtered out surface water dependent wetlands, such as vernal pools and wetlands fed from canal diversions, from consideration as GDEs.

Figure 2-32 – Groundwater Dependent Wetlands displays the results of this analysis. The figure shows a dense population of groundwater dependent wetlands in the mountains and foothills in the eastern and western flanks of the Kern County Subbasin, but much of the Central Valley floor south of Tulare Lake is mapped as having no groundwater dependent wetlands or as having a very low density of these wetlands. No areas within the BVGSA are mapped as having potential groundwater dependent wetlands.

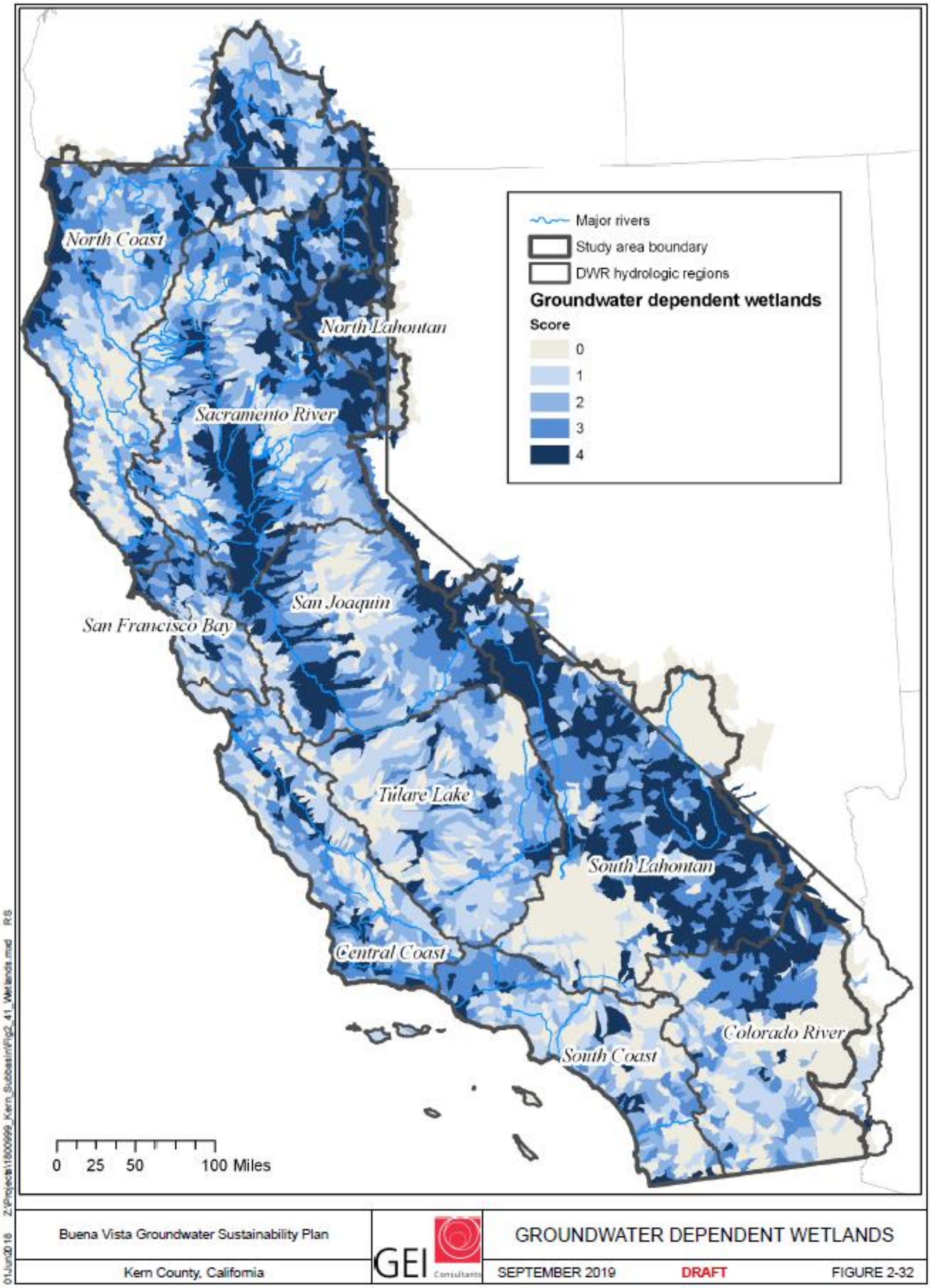

Figure 2-32. Groundwater Dependent Wetlands

Groundwater Dependent Streams

Groundwater dependent stream segments were identified in the research reported in *Mapping Groundwater Dependent Ecosystems in California* using the baseflow component of streamflow as an index of the degree to which groundwater discharge supports streamflow. This was accomplished by first mapping stream segments using NHD Plus data. Baseflow percentages associated with these segments were drawn from U.S. Geological Survey (USGS) data on the baseflow index (BFI) of individual stream segments, an index which defines the ratio of baseflow to total flow. This method estimates the annual base-flow volume of unregulated rivers and streams and computes an annual base-flow index for multiple years of data at one or more gage sites. BFI data were applied in two ways.

- In watersheds where a USGS stream gage was operational, BFI values were assigned from gage data. In watersheds with multiple stream gages, an average value was assigned.
- For watersheds where gaging data were not available, a BFI was assigned using interpolated values from a coterminous watershed.

As with the previous two factors used to determine the density of potential GDEs, Figure 2-33 – Base Flow Index shows base flow as being a contributor to stream flow in the mountains and foothills to the east of the valley floor. As no natural streams traverse the BVGSA, the association between baseflow and streamflow is not relevant for assessment of GDEs in the GSA.

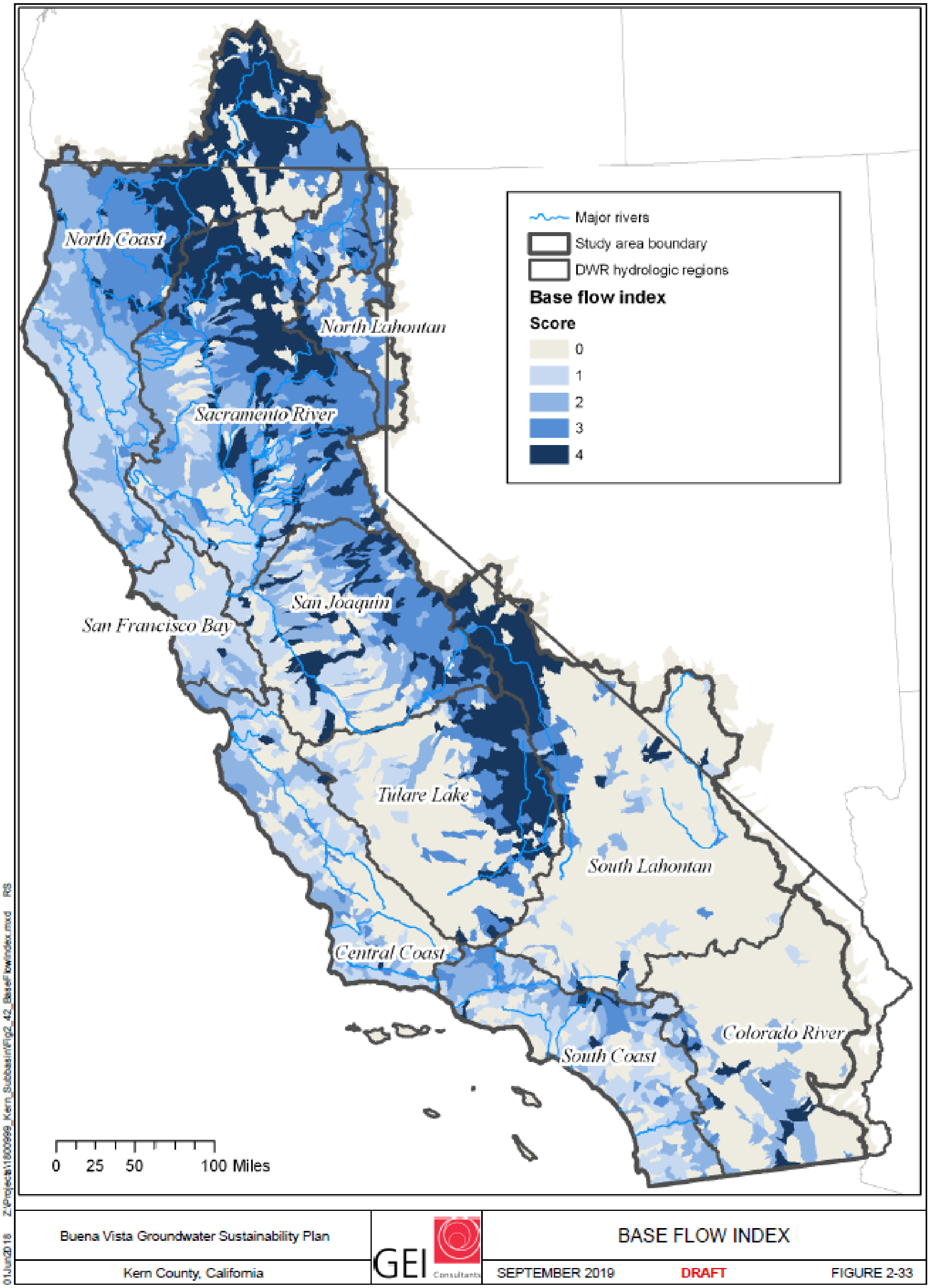

Figure 2-33. Base Flow Index

2.3.9.1 Define and Identify GDEs

The variables referenced in Mapping Groundwater Dependent Ecosystems in California were used to map overall ecosystem dependence on groundwater by combining rankings of the three variables (springs, wetlands, and streams). The results of this mapping of overall groundwater dependence of ecosystems in the Kern County Subbasin are displayed on Figure 2-34 – Groundwater Dependence. As evident in the earlier figures, there is a high level of groundwater dependence in the mountains and foothills on the east side of the Subbasin. However, except for riparian lands adjacent to the Kern River, mapped as having a medium ranking, all lands on the valley floor, including the BVGSA, are mapped as having either no groundwater dependence or very low groundwater dependence. Figure 2-35 – Groundwater Dependent Wetlands and Vegetation Alliances Scored by Groundwater Basin, displays how the Kern County Subbasin was scored in *Mapping Groundwater Dependent Ecosystems in California* relative to other California subbasins with respect to the prevalence of groundwater dependent wetlands and vegetation alliances (Figure 2-35 – Refer to Figures Tab).

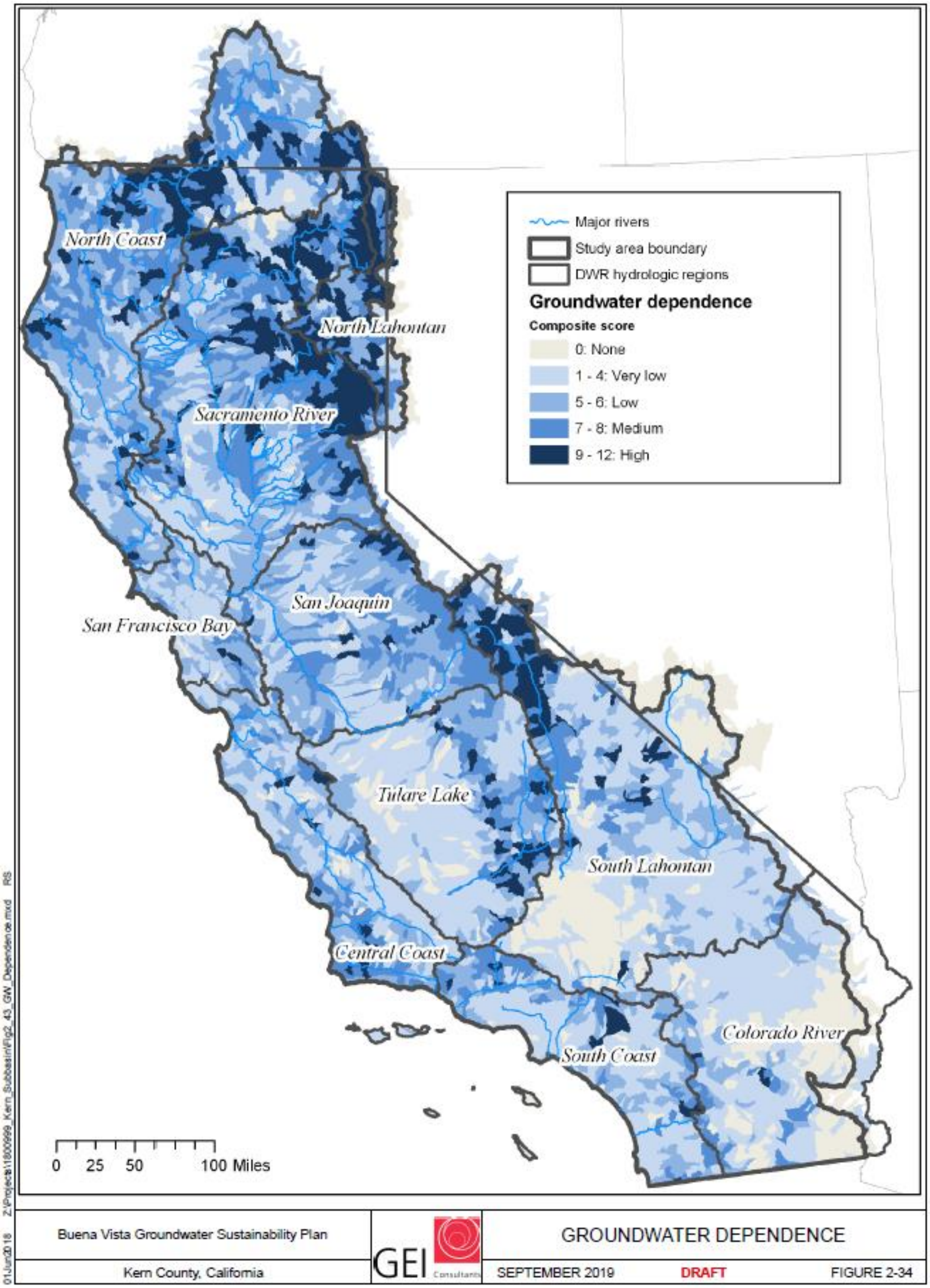

Figure 2-34. Groundwater Dependence

Mapping Groundwater Dependent Ecosystems in California predates the passage of the SGMA and uses a methodology that relies heavily on hydrologic data to indicate areas where hydrologic conditions may be suitable to support GDEs. The Nature Conservancy has recently developed the guidance document Groundwater Dependent Ecosystems Under the Sustainable Groundwater Management Act (TNC, January 2018) which refines their earlier approach by incorporating detailed vegetation datasets not available in 2010.

Recognizing that detailed understanding of groundwater levels, hydrology and geology are not available at a statewide scale, TNC's new methodology emphasizes use of vegetation and wetland datasets to identify potential GDEs, with determination of which potential GDEs are truly groundwater dependent being based on local knowledge of geologic and hydrologic conditions. In the Central Valley, the new methodology relies heavily on high-resolution mapping by the California Department of Fish and Wildlife (DFW) as part of their Vegetation Classification and Mapping Program (VegCAMP) This mapping and other data are used to flag potential GDEs by identifying wetlands and vegetation alliances that are commonly supported by groundwater. Maps based on these datasets were released in May 2018.

2.3.9.2 Mapping of Potential GDEs

Figure 2-36 – Potential Groundwater Dependent Ecosystems: Wetlands and Figure 2-37 - Potential Groundwater Dependent Ecosystems: Vegetation are extracted from The Nature Conservancy's May 2018 mapping for the BVGSA. As shown in the hydrographs presented in Figures 2.26a through 2.26m, water levels in areas mapped by the TNC as being potentially groundwater dependent are unlikely to be supported by groundwater. Therefore, the potential GDEs shown in Figures 2-36 and 2-37 are likely to overstate the prevalence of actual GDEs (Figures 2-36 and 2-37 – Refer to Figures Tab).

The preceding observations drawn from the TNC's 2018 resilient land mapping tool is supported by mapping produced using the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset developed by the California Department of Water Resources (DWR), The Nature Conservancy (TNC), and the California Department of Fish and Wildlife (CDFW).

The NCCAG dataset is based on 48 layers of publicly available data developed by state or federal agencies that map vegetation, wetlands, springs, and seeps in California (DWR, 2019). A technical working group with representatives from DWR, CDFW, and TNC reviewed the datasets compiled to assemble the NCCAG. The NCCAG dataset attempts to extract mapped vegetation and wetland features that have indicators suggesting dependence on groundwater. The data presented in NCCAG display vegetation polygons that have indicators of GDEs based on published and/or field observations of phreatophytic vegetation defined as a "deep-rooted plant that obtains water that it needs from the phreatic zone (zone of saturation) or the capillary fringe above the phreatic zone" (TNC, 2018b). The dominance of phreatophytic plant species in a mapped vegetation type is a primary indicator of GDEs.

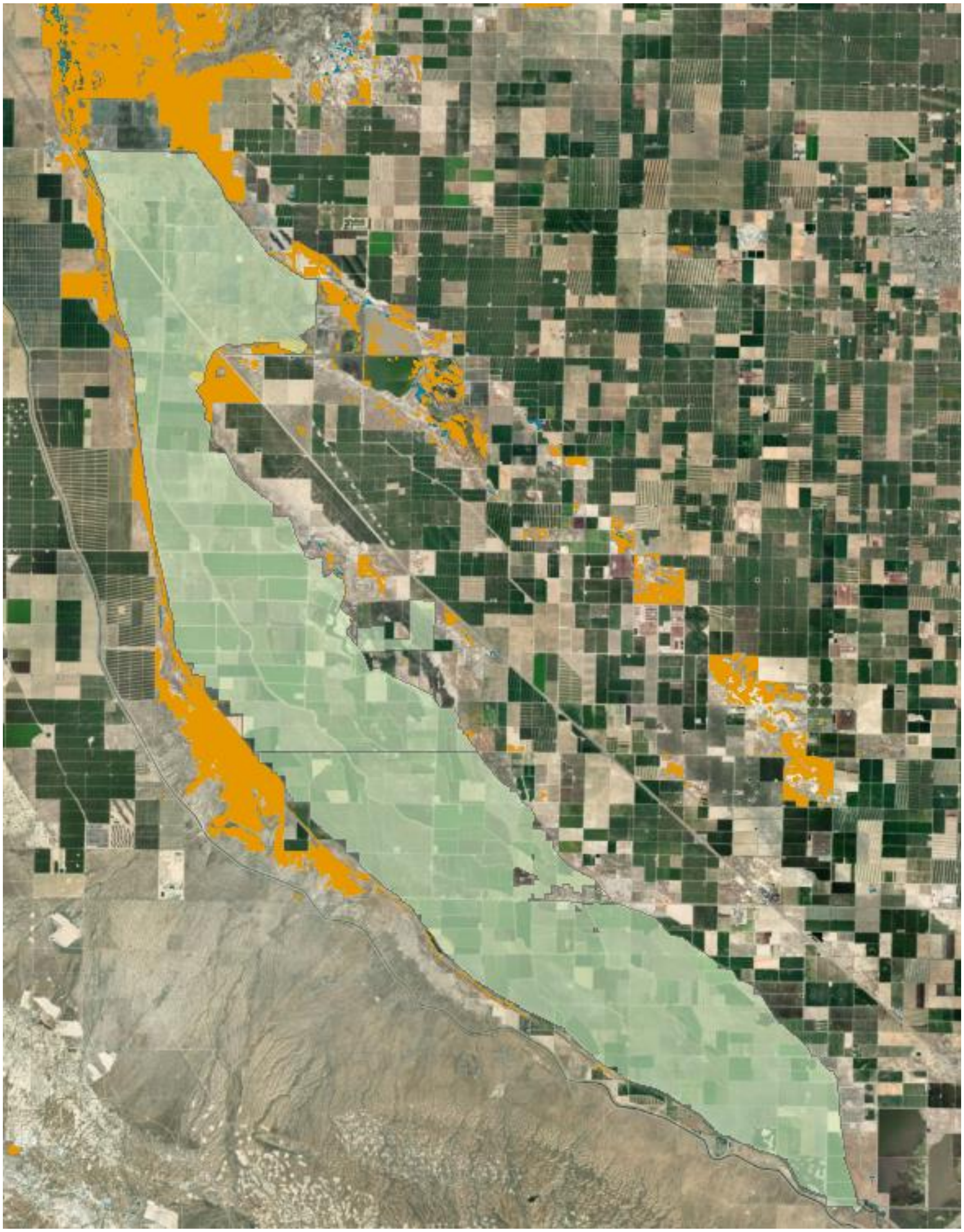

Figure 2-38. NCCAG Mapping of the Buttonwillow Management Area and Vicinity

A list of plant species considered to be phreatophytes based on peer-reviewed scientific literature on rooting depths, published lists of phreatophytes, expert field observations, and vegetation alliance descriptions is publicly available (Klausmeyer et al., 2018; TNC, 2018a).

While developing the NCCAG dataset of areas with indicators of GDEs, the technical working group attempted to exclude vegetation and wetland types and polygons that are less likely to be associated with groundwater. Mapping Indicators of Groundwater Dependent Ecosystems in California: Methods Report (Klausmeyer et al.’ 2018). The working group attempted to remove any polygons that are not likely to be GDEs where they occurred in areas where they are likely to be supported by alternate artificial water sources (e.g. local seepage from agricultural irrigation canals), or where appropriate available data indicated the shallow groundwater depth is located well below the rooting zone, (Klausmeyer et al., 2018.

Figure 2-38 – NCCAG Mapping of the Buttonwillow Management Area and Vicinity - shows the NCCAG data layer (orange and blue) in relation to the Buttonwillow Management Area (BMA) boundary (green). As is the case with older mapping presented in this section, the NCCAG mapping shows little overlap of the shapes, meaning that few potential GDEs or wetlands are mapped as lying within the BMA. The area mapped in Figure 2-40 along the western fringe of the BMA coincides with the location of the Kern River Flood Channel Canal. In addition, there are other areas mapped as GDEs that lie immediately to the east of the BMA.

2.3.9.3 Recommended Actions

The vegetation data presented in the NCCAG dataset is a latest available starting point for the identification of GDEs as the dataset includes the best available public datasets and has been screened to include only areas that have indicators of groundwater dependent vegetation. DWR has stated in the “Summary of the “Natural Communities Commonly Associated with Groundwater” Dataset and Online Web Viewer” (DWR, 2018) that use of the NCCAG dataset is not mandatory and does not represent DWR’s determination of a GDE. Rather, NCCAG can provide a starting point for the identification of GDEs within a groundwater basin.

Additional information, such as near surface groundwater depth obtained from piezometers, information about subsurface stratigraphy and geology on confining layers, and information on local land use and hydrology can be used to confirm whether vegetation in areas identified by the NCCAG as potential GDEs is, in fact, reliant on groundwater.

2.3.10 Management Areas

The BVWSD has two distinct service areas separated by 15 miles. The Buttonwillow Service Area (BSA) occupies 91% of the District (46,200 acres; 43,710 receiving service), while the Maples Service Area (MSA) occupies the remaining 9% (4,360 acres; 2,933 receiving service)[2]. Because the locations of these service areas are not contiguous, their boundaries have been used

[2] 2016 Engineer’s Assessment Report, in Support of Proposition 218 Assessment Ballot Proceeding, Buena Vista Water Storage District,

to define the Buttonwillow Management Area (BMA) and the Maples Management Area (MMA).

This GSP emphasizes management of the BMA, which, as described throughout this document, is a distinct entity within the Kern County Subbasin with respect to its hydrogeologic features and management practices. For this reason, the BMA will be treated as a single unit to be managed using a uniform set of management objectives and criteria.

Because of the MMA's location within the KRGSA, Sustainable Management Criteria for this MA will align with those established for other areas of the KRGSA.

3. Sustainability Goal and Undesirable Results

3.1 Introduction and Definitions

Under SGMA, sustainable management of groundwater through attainment of a locally-defined sustainability goal is assessed though monitoring of six sustainability indicators presented in the SGMA legislation. Undesirable results occur when conditions related to any of the sustainability indicators become significant and unreasonable on a scale that jeopardizes sustainable groundwater management basin-wide. Therefore, determining whether a groundwater basin is being managed sustainably relies on monitoring of sustainability indicators at locations throughout the basin.

This section provides a narrative description of the sustainability goal and of undesirable results as they pertain to the BVGSA and describes some of the practices that have been applied to manage surface and groundwater supplies. Section 5 – Minimum Thresholds, Measurable Objectives and Interim Milestones describes the methodologies used to quantify minimum thresholds, and measurable objectives, the metrics used to monitor attainment of the sustainability goal and avoidance of undesirable results, as well as laying out interim milestones, the checkpoints established to measure progress.

3.2 Sustainability Indicators

The six sustainability indicators are guideposts used to warn of groundwater conditions occurring throughout a subbasin that, when significant and unreasonable, lead to undesirable results, as described in the California Water Code Section 10721 (x). The indicators are:

1. Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued;
2. Significant and unreasonable reduction of groundwater storage;
3. Significant and unreasonable seawater intrusion;
4. Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies;
5. Significant and unreasonable land subsidence that substantially interferes with surface land uses, and
6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

In the BVGSA, undesirable results are likely to be associated with four of these sustainability indicators. Significant and unreasonable seawater intrusion is not relevant given the GSA's inland location in Kern County, and, as discussed in Section 2- Basin Setting, the potential for depletions of interconnected surface waters is small given the following factors:

- The absence of streams flowing into or through the BVGSA (see Section 2 – Basin Setting, Figure 2-20), and
- The depths of principal aquifers which make it unlikely that groundwater pumping has the potential to deplete surface water (see Section 2 – Basin Setting, Figures 2-5).

SGMA encourages local control of groundwater management. To this purpose, the four sustainability indicators of interest within the BVGSA have been defined to fit the conditions of the Kern County Subbasin using language agreed upon by each of the GSAs within the Subbasin, as follows:

- Chronic lowering of groundwater levels: The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth to water, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

  Declining groundwater levels during a prolonged drought are not alone sufficient to confirm a chronic lowering of groundwater levels. Extractions and groundwater recharge can be managed to ensure that reductions in groundwater levels or storage during a drought are offset by increases in groundwater levels during other periods.
- Significant and unreasonable reduction of groundwater storage: The point at which significant and unreasonable impacts, as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater of overlying users over an extended drought period.
- Significant and unreasonable degraded water quality: The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, affect the reasonable and beneficial use of, and access to, groundwater by overlying users.
- Significant and unreasonable subsidence: The point at which significant and unreasonable impacts, as determined by a subsidence rate in the Subbasin, that affect the surface land users or critical infrastructure.

The process for setting quantitative minimum thresholds for each of the above sustainability indicators is described in Section 5 – Minimum Thresholds, Measurable Objectives, and Interim Milestones.

3.3 Sustainability Goals

The central sustainability goal in the Kern County Subbasin is to maintain groundwater elevations in principal aquifers within a range that avoids the occurrence of undesirable results and that allows groundwater to remain a reliable source of water supply, particularly during prolonged droughts. Attainment of this goal in the BVGSA requires the establishment of measurable objectives at a level that will enable the GSA to operate during a prolonged drought before groundwater levels reach a minimum threshold.

Although groundwater overdraft has been observed to be less extreme in the Buena Vista GSA than in other parts of the Kern Subbasin, the ongoing transition from annual crops to orchards and vineyards is expected to both increase and harden demand within the GSA, amplifying the importance of effective management of both surface water and groundwater. The scale of investment, long life span, and increased demand associated with permanent crops coupled with concerns over the long-term reliability of both local and imported sources of surface water highlight the significance of sustainable groundwater management.

Thus, success in sustaining groundwater elevations within an operating range bounded by measurable objectives and minimum thresholds and observed through the GSAs monitoring network is of primary importance to meet the GSA's commitment to groundwater users to protect their ability to access the resource.

Improvement of water quality is a second aspect of the sustainability goal. As protection of beneficial uses of groundwater is the primary objective of the Central Valley Regional Water Quality Control Board's (CVRWQCB) Irrigated Lands Regulatory Program (ILRP), due to the high proportion of water and land use devoted to irrigated agriculture, the water quality aspects of the GSA's sustainability goal will be achieved through close coordination with implementation of the ILRP. Later, as the State Water Resource Control Board (SWRCB) and the CVRWQCB begin implementing the Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS), attainment of the water quality aspect of the BVGSA's sustainability goal will also be closely coordinated with the CV-Salts program.

Protection against subsidence is a third aspect of BVGSA's sustainability goal. The primary cause of subsidence in this region is overdraft of groundwater. Groundwater withdrawals are considered to cause unreasonable and significant subsidence if subsidence affects critical infrastructure or "substantially interferes with surface land uses", (CCR Title 23 Waters 354.28(c)(5). In addition to threatening the stability of infrastructure such as highways and changing the gradient in water conveyance facilities, subsidence has the potential to directly impact groundwater users in the Buena Vista GSA as it reduces groundwater storage capacity by compacting material within the aquifer. In addition to groundwater withdrawal, oil and gas production and tectonic forces may contribute to subsidence in or near the BVGSA.

3.4 Undesirable Results within the BVGSA

3.4.1 Chronic Lowering of Groundwater Levels

The most significant undesirable result for the BVGSA is chronic lowering of groundwater levels, a condition that would increase the cost of pumping for all users and could lead to groundwater elevations falling below the levels of well-screens, a particular concern of domestic well owners because domestic wells are typically shallower than ag wells and the capacity to pay for deepening domestic wells is limited.

BVWSD has been monitoring groundwater levels since 1991 in both the perched aquifer and the principal production aquifer. The principal aquifer, although comprised of shallow and deep zones, has groundwater extracted primarily from the deep zone. For this reason, no existing monitoring wells are screened to observe only the shallow zone, however due to the connection between the shallow and deep zones, the shallow zone is assumed to behave similarly to the deep zone. The perched aquifer – prominent in the northern half of the GSA – is monitored with a network of 58 piezometers.

Historically, groundwater elevations within the BVGSA range from about 230 feet above mean sea level (AMSL) in the north, to -10 feet AMSL in the south. BVWSD, 2016. This gradient suggests that groundwater flows from north to south. Furthermore, over the past 20 years, groundwater elevations in the north have remained stable, while elevations in the south have gradually declined as shown in Appendix C – Groundwater Hydrographs. Groundwater elevations in the GSA fluctuate in response to the hydrologic conditions that govern deliveries of surface water from the Kern River and the California Aqueduct and that influence patterns of demand. The fluctuations are moderated by the conjunctive management practices of the BVWSD.

The existing monitoring network that will be relied on initially for monitoring measurable objectives and detecting breaches of minimum thresholds is described in greater detail in Section 2 - Basin Setting and in Section 5 - Minimum Thresholds, Measurable Objectives, and Interim Milestones. The program for filling data gaps and developing a comprehensive network for monitoring measurable objectives and detecting undesirable results is described in Section 4 - Monitoring Network.

Historically, groundwater elevations within the BVGSA range from about 230 feet above mean sea level (AMSL) in the north, to -10 feet AMSL in the south, BVWSD, 2016. This gradient suggests that groundwater flows from north to south. Furthermore, over the past 20 years, groundwater elevations in the north have remained stable, while elevations in the south have gradually declined as shown in Appendix C – Groundwater Hydrographs. Groundwater elevations in the GSA fluctuate in response to the hydrologic conditions that govern deliveries of surface water from the Kern River and the California Aqueduct and that influence patterns of demand. The fluctuations are moderated by the conjunctive management practices of the BVWSD.

3.4.2 Reduction in Groundwater Storage

As well as maintaining pumping depths within an acceptable range, the minimum thresholds for groundwater elevations described in Section 5 - Minimum Thresholds, Measurable Objectives, and Interim Milestones are also intended to minimize the undesirable result of groundwater storage reduction. This loss of storage would constrain the amount of groundwater usable for industrial, municipal, domestic, and agricultural purposes, ultimately affecting all users in the BVGSA and in the Subbasin.

As with chronic lowering of groundwater elevations, the undesirable result of unreasonable and significant reduction of groundwater storage would occur during extended periods of groundwater production in excess of the sustainable yield. Changes in the volume of groundwater in storage will be monitored by tracking groundwater elevation.

3.4.3 Degraded Water Quality

Degradation of groundwater quality will lead to an undesirable result should the BVGSA fail to maintain concentrations of groundwater constituents at levels acceptable for designated beneficial uses. The minimum thresholds for these constituents are presented in Section 5 - Minimum Thresholds, Measurable Objectives, and Interim Milestones.

Groundwater quality will continue to be observed using existing monitoring wells. As described in Section 4 – Monitoring Networks, the water quality monitoring network will also include selected wells monitored through the Groundwater Quality Trend Monitoring Work Plan developed by the Buena Vista Coalition for compliance with the Irrigated Lands Regulatory Program (ILRP).

3.4.4 Subsidence

Land subsidence due to groundwater extractions within the BVGSA will lead to an undesirable result if these extractions jeopardize critical infrastructure. Historical subsidence within the BVGSA has been limited and has not been observed to have affected infrastructure. However, because of the potential for pumping within the BVGSA to damage facilities including the California Aqueduct, subsidence will be monitored as described in Section 4 – Monitoring Networks. In addition, the BVGSA discourages groundwater extraction from beneath the E-clay, in part, because of the potential for extraction from this confined zone to induce subsidence.

3.5 Application of Sustainable Management Criteria

Attainment of the sustainability goal and avoidance of undesirable results within the BVGSA will be guided by analysis of data generated from the GSA's monitoring network with the aim of managing groundwater levels, water quality and subsidence within the bounds set by measurable objectives and minimum thresholds established at each of the GSA's monitoring sites. The development of measurable objectives and minimum thresholds is presented in Section 5 - Minimum Thresholds, Measurable Objectives, and Interim Milestones.

Effective management will be particularly important during periods when groundwater production exceeds long-term sustainable yield, a condition that will be observed through monitoring to detect chronic lowering of groundwater levels, an undesirable result also associated with the occurrence of the following undesirable results:

- Significant and unreasonable reduction of groundwater storage;
- Significant and unreasonable degraded water quality, and
- Significant and unreasonable land subsidence.

Based on hydrographs presented in Appendix C – Groundwater Hydrographs, chronic lowering of groundwater levels is expected to be less pronounced in the Buena Vista GSA than in other areas of the Kern County Subbasin. This is attributable to two factors, which are described in detail in Section 2 - Basin Setting:

1. As discussed throughout this GSP, geologic, hydrologic and soils conditions in the BVGSA are distinct because the BVWSD was developed on reclaimed lakebed and swamp lands lying to the west of structural features such as the Buttonwillow and Semitropic ridges. These distinctions, illustrated in Section 2.2 - Hydrogeologic Conceptual Model, result in groundwater elevations that are typically higher than in areas to the east.

2. The BVWSD has rights to divert water from the Kern River and holds a contract with the Kern County Water Agency to receive deliveries from the State Water Project, whose major distribution facility, the California Aqueduct, runs along the western boundary of the BVGSA. Access to water from these sources has enabled the BVWSD to conjunctively manage its surface water entitlements and groundwater use. Conjunctive management has provided the BVWSD with an important tool for achieving its sustainability goal by protecting groundwater underlying the GSA for use during droughts when surface water supplies are limited and by providing the capacity to replenish groundwater storage that has been depleted by prolonged drought.

The BVWSD's surface water resources, aided by its physical setting, have been used to implement projects and management programs that carry out the BVWSD's long-term strategy of conjunctive management and have modified this strategy in response to changes in cropping patterns and irrigation practices. Throughout, conjunctive management has been the backbone of BVWSD's operations and will serve as the umbrella for projects developed by the BVGSA to support sustainable groundwater management under SGMA. These projects are described in Section 7 – Project, Management Actions, and Adaptive Management Actions.

Currently, the Buena Vista GSA's primary mechanism for groundwater recharge is seepage from its unlined canals. Section 6 – Water Supply Accounting includes a water budget that documents the average rate of seepage from the 144 miles of unlined canal in the GSA as 31,141 AF/year which equates to 0.67 feet of seepage for each acre within the GSA boundaries. The importance of canal seepage is underscored by the fact that in locations where canals are being replaced by pipelines to improve the efficiency of water delivery, rather than being abandoned, some reaches of canal are being retained as dedicated linear recharge facilities for use during wet years when surface water supplies exceed demands.

In addition, as deep percolation of applied irrigation water diminishes through the introduction of high-efficiency, low-volume application techniques such as drip and micro-sprinkler irrigation, the District is developing dedicated recharge and recovery projects such as the Palms Project, so that improvements to the BVWSD's conveyance facilities and in on-farm irrigation practices can proceed without jeopardizing the District's capacity for conjunctive management. The Palms Project, as with other projects described in Section 7 – Projects, Management Actions and Adaptive Management Actions shows how groundwater recharge in the BVWSD is transitioning from incidental seepage from canals toward use of dedicated facilities including canal reaches that have been converted to linear recharge basins and large-scale recharge and recovery projects such as the Palms Project.

The BVWSD is now in the process of implementing projects to expand the District's conjunctive management capabilities and is also offering programs to efficiently manage groundwater production capacity. A typical project is the Northern Area Pipeline, a phased effort to distribute surface water in the northern part of the District through pipelines rather than the original canal network. This project enables growers to better manage water deliveries and reduces groundwater pumping by

- Facilitating distribution of surface water;
- Increasing the efficiency of on-farm irrigation practices, and
- Extending the season during which surface water is typically available.

An example of a capacity management program is the "Landowner Well Use Program" which reimburses participating landowners for utilization of their unused well capacity during dry years. This use of privately-owned wells enables the District to avoid the need to construct new district-owned wells that would create capacity needed only during droughts. Agricultural Water Management Plan, (BVWSD, 2014)

Furthermore, the 2016 draft of the Groundwater Monitoring Protocol for Buena Vista WSD describes the District's program, now complete, to install magnetic flow meters on all production wells in the District, both district- and privately-owned. The comprehensive ability to measure groundwater pumping at all wells, other than small domestic wells, coupled with the District's on-going program to improve measurement of surface water deliveries, gives the BVGSA access to timely, accurate information on use of surface water and groundwater throughout the GSA.

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4. Monitoring Networks

4.1 Introduction

As outlined in DWR's GSP regulations and guidance documents, monitoring networks will be established to monitor each relevant sustainability indicator within the BVGSA. Section 2 - Basin Setting describes the monitoring networks that now exist in the BVGSA. This section discusses monitoring network objectives and monitoring rationales and describes the proposed monitoring network for each relevant sustainability indicator. Data gaps and planned actions to address these gaps are presented for each sustainability indicator.

4.2 Monitoring Network Objectives

The objective of the BVGSA Monitoring Networks is to gather spatial and temporal data on parameters including groundwater levels, groundwater quality and land surface elevations sufficient to characterize groundwater conditions as defined by locally-established management objectives and undesirable results as defined in Section 3 – Sustainability Goal and Undesirable Results and Section 5 – Minimum Thresholds, Measurable Objectives and Interim Milestones.

All monitoring network objectives were developed in accordance with the California Department of Water Resource's 23 CCR §354.34, which requires that monitoring networks:

- Demonstrate progress toward achieving measurable objectives described in the Plan;
- Monitor impacts to the beneficial uses or users of groundwater;
- Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds, and
- Quantify annual changes in water budget components.

The monitoring networks created in this GSP are intended to monitor four, relevant undesirable results:

- Chronic lowering of groundwater levels;
- Reduction in groundwater storage;
- Degraded groundwater quality, and
- Land subsidence.

The section describes the monitoring networks developed by the BVGSA to monitor groundwater and subsidence. These networks will be used to characterize groundwater levels, quality, flow gradient and direction, and land surface elevations to provide a sound technical foundation for groundwater management. The monitoring networks developed for the GSA are consistent with networks developed by other GSAs within the Kern County Subbasin to form a coherent approach to data collection that will provide uniform, reliable data in a format that can be easily consolidated and analyzed to assess groundwater conditions and subsidence throughout the Subbasin. This data will be used to guide development and implementation of projects and programs needed to support basin-wide sustainability.

4.3 Description of Monitoring Networks

Groundwater within the BVGSA is influenced by groundwater extraction, subsurface flux, and recharge from distribution and application of irrigation water. The BVGSA's groundwater monitoring network is intended to quantify groundwater elevations; flow directions and gradients; and groundwater quality parameters in the principal aquifer system. In addition, all production wells are equipped with magnetic flow meters and totalizers, so groundwater extraction in the GSA is closely monitored.

As well as data compiled from monitoring groundwater elevations and metering well discharges, the BVGSA relies on CIMIS climatologic data, data on surface water deliveries from the California Aqueduct and the Kern River, and subsidence data from the Continuously Operating Reference Stations (CORS) network and Interferometric Synthetic Aperture Radar (InSAR) data distributed by DWR.

4.3.1 Collection of Sufficient Data

A goal of the BVGSA monitoring program is to establish networks of monitoring locations that capture the hydrologic, geologic, and land use differences across the GSA and that can be monitored at a frequency sufficient to detect changes in groundwater conditions throughout the GSA. Thus, the selection of wells included in the groundwater monitoring network is pivotal to the GSA's ability to monitor performance relative to the Sustainable Management Criteria described in Section 5 – Minimum Thresholds, Measurable Objectives and Interim Milestones.

Due to their distribution throughout the GSA, their period of record, and the confidence that can be placed in data collected from dedicated monitoring wells, the backbone of the GSA's initial monitoring network is the existing system of 11 District Monitoring Wells located at 9 sites throughout the Buttonwillow Management Area (BMA) described in Section 2 – Basin Setting. This network will be supplemented by selected wells drawn from network presented in the Buena Vista Coalition's Groundwater Quality Trend Monitoring Work Plan (GQTMWP, 2018) developed for compliance with the ILRP and a small number of district production wells and landowner wells. Wells in the GQTMWP network are located in areas where groundwater quality, particularly nitrate contamination, is a potential concern and are monitored following a protocol that includes both groundwater quality sampling and groundwater level measurement.

As discussed later in this section, the network of District Monitoring Wells will be supplemented by wells located in the southern portion of the BMA where extensive pumping occurs within the GSA and in neighboring areas immediately beyond the GSA's boundaries and, also, includes wells targeted to locations of uncertain or unknown groundwater conditions and to locations along the GSA's boundaries.

In addition to providing a representative characterization of conditions in the principal aquifer system, wells selected for the BVGSA's initial monitoring network have a period of record adequate to confirm their reliability as sources of water level and water quality data. The BVGSA has given preference to wells with regular monitoring schedules (limited data gaps) and long periods of record. These attributes facilitate interpretation of data by enabling groundwater conditions observed during the period preceding SGMA implementation to be compared with data collected going forward.

4.3.2 Implementation of Monitoring Networks

Data collected from the monitoring networks will be used to demonstrate progress towards the goals described above of:

- Monitoring impacts to beneficial uses or users of groundwater;
- Documenting changes in groundwater conditions relative to measurable objectives and minimum thresholds, and
- Quantifying annual changes in water budget components.

Achieving Measurable Objectives

For each sustainability indicator, measurable objectives presented in Section 5 – Minimum Thresholds, Measurable Objectives, and Interim Milestones will be assessed at 5-years intervals to confirm how measurable objectives compare with the interim milestones established by the GSA for attaining sustainability. The schedule for 5-year updates is as follows:

- 5-year update (2025);
- 10-year update (2030);
- 15-year update (2035), and
- 20-year update (2040).

Monitor Impacts to Beneficial Uses or Users of Groundwater

As described in Section 2 – Basin Setting, the beneficial users of groundwater within the BVGSA include agricultural pumpers, municipal users (Community of Buttonwillow), and dispersed domestic and industrial pumpers. While a substantial proportion of agricultural demand is supplied by surface water, the Community of Buttonwillow and individual domestic and industrial users subsist on groundwater, with groundwater elevations sustained through recharge of water delivered to the BVWSD from the Kern River and the SWP.

The BVGSA's monitoring network is designed to provide the information necessary to prevent impacts to beneficial uses and users of groundwater by collecting data on aquifer conditions, water quality and subsidence. This information will enable the GSA to associate changes in groundwater elevations with pumping intensity, monitor the risk of dewatering individual wells and make management decisions necessary to mitigate declines in groundwater elevations.

Monitor Changes in Groundwater Quality

As described in Section 2 - Basin Setting, undesirable groundwater quality includes high concentrations of total dissolved solids (TDS), nitrates, and arsenic. TDS has been and will continue to be managed to the tolerance levels of crops, and nitrates and arsenic will continue to be managed to the MCLs as discussed in Section 2.2.4.6 of the Basin Setting.

Water quality monitoring by the BVGSA will be performed in parallel with the monitoring and reporting performed by the Buena Vista Coalition under their GQTMWP. Water quality data collected by the network of monitoring wells will enable the BVGSA to avoid undesirable results by providing the capability to detect isolated contaminant plumes and to observe large-scale trends.

Quantify Annual Changes in Water Budget Components

Data from the monitoring networks will be used to update the GSA water budget described in Section 6 – Water Supply Accounting with the following components of the budget being measured directly by the GSA:

- Precipitation: source - spatial CIMIS;
- Evapotranspiration: source - ITRC METRIC;
- Surface inflows: sources – measured California Aqueduct deliveries, Kern River deliveries, and exchanges and transfers;
- Surface outflows: sources – measured exchanges and transfers, and outflows in the Main Drain Canal;
- Groundwater extraction: sources - flow totalizer data from all production wells within the GSA, and
- Change in groundwater storage: sources – observed changes in groundwater elevations and estimates of specific yield associated with the aquifer zones where changes in elevations are observed.

Groundwater elevation data collected by the GSA monitoring networks will be used, in tandem with data presented in the Section 2.2 – Hydrogeologic Conceptual Model and from numerical groundwater models, to monitor changes in storage in the principal aquifer system. Two schematic diagrams of the BVGSA water budget are shown in Figure 4-1 and Figure 4-2 and development of the water budget is described in detail in Section 6 - Water Supply Accounting. Figure 4-1 shows the Buena Vista GSA water budget (both surface water and groundwater systems) and Figure 4.2 shows the Buena Vista GSA groundwater budget (only groundwater system).

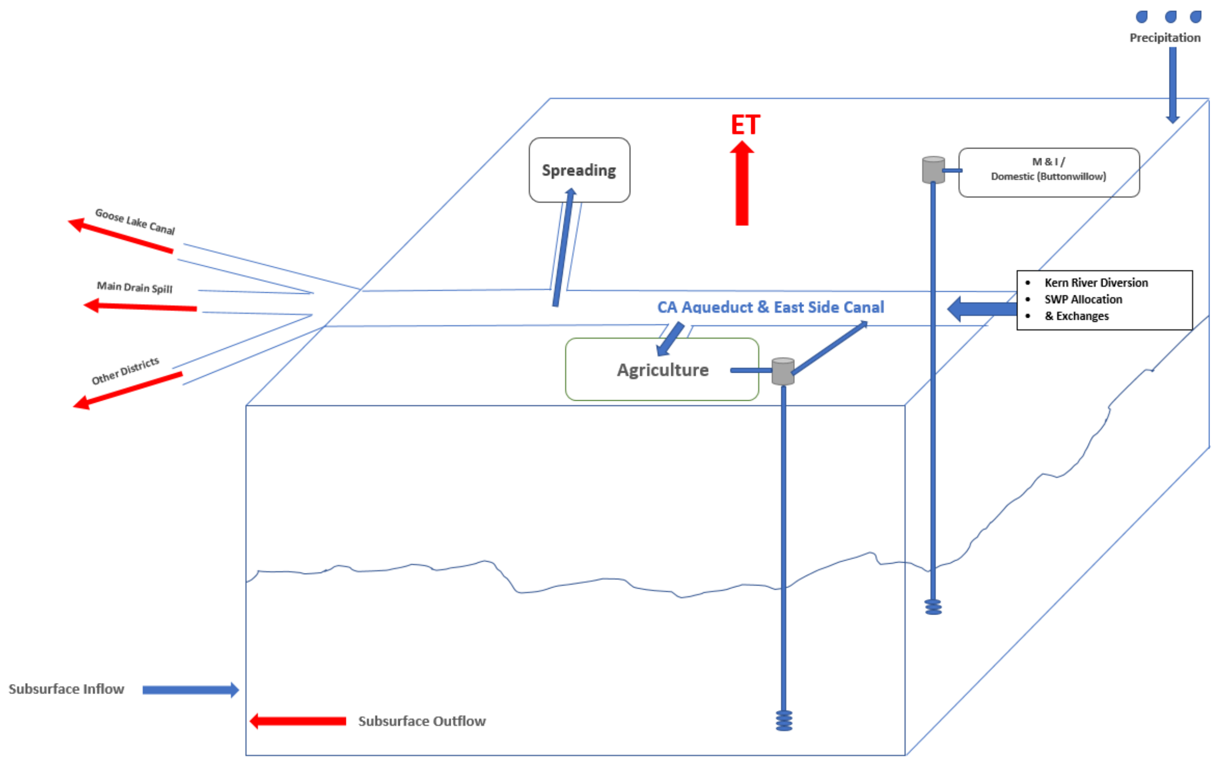


Figure 4-1. Buena Vista GSA Water Budget Diagram

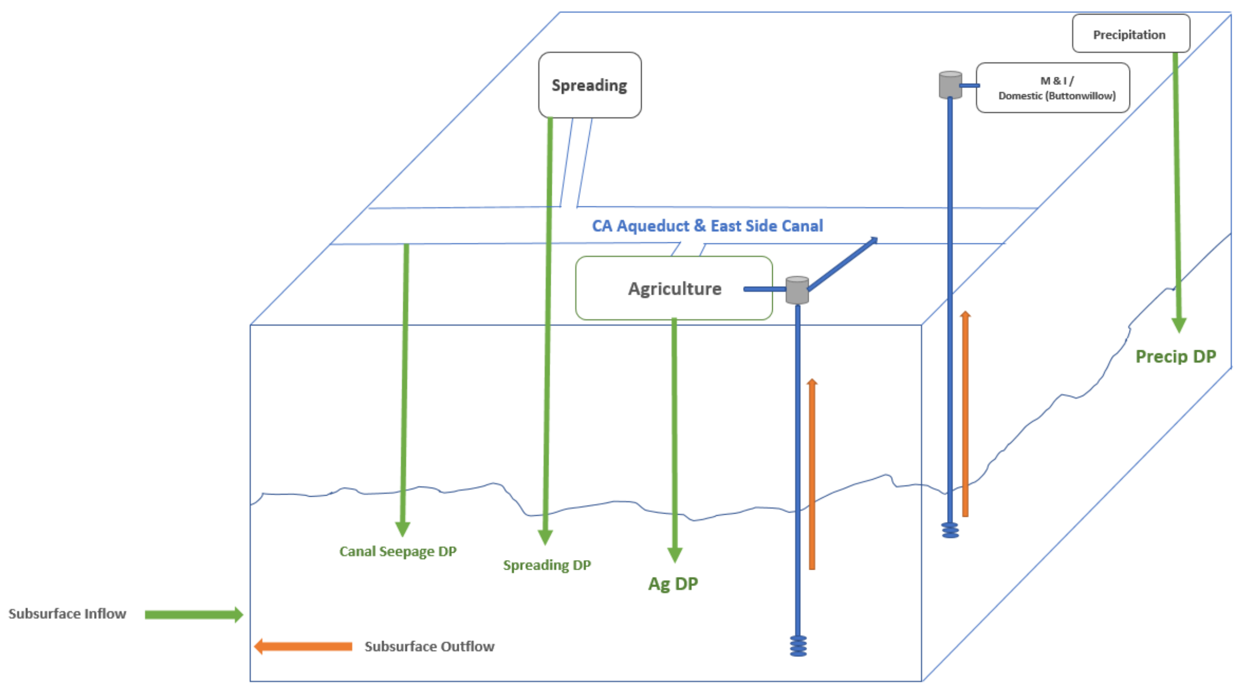


Figure 4-2. Buena Vista GSA Groundwater Budget Diagram

4.3.3 Monitoring Rationale and Site Selection

This section explains the rationale underlying the selection of wells included in the BVGSA monitoring networks and discusses the criteria considered for site selection.

The purpose of the monitoring networks is to observe each of the four sustainability indicators important to management of the BVGSA. To this end, the monitoring networks are designed to provide comprehensive coverage of the principal aquifer system underlying the GSA, with monitoring sites selected to observe specific sustainability indicators. Wells included in the networks emphasize observation of groundwater elevations to monitor changes in groundwater levels and as a proxy for assessing changes in groundwater storage with monitoring of groundwater quality being the other function of these wells.

The existing BVWSD monitoring program includes approximately 45 active shallow piezometers installed to monitor perched water conditions that affect irrigation operations in the District's northern area. While a selection of these piezometers is included in the Buena Vista Coalition's GQTMWP to monitor groundwater quality in first-encountered groundwater, only three piezometers are included in the monitoring networks established for SGMA as data on the perched aquifer is not directly relevant to sustainable management of the principal aquifer system. An exception to this approach is three piezometers that will serve as sentinels to detect the influence on water quality of shallow groundwater entering the GSA from the west.

The monitoring networks created for the Buena Vista GSP are designed to detect changes in groundwater conditions prior to the onset of undesirable results. With knowledge of changing conditions, the BVGSA can be managed to ensure that interim milestones and measurable objectives are achieved and that overall groundwater sustainability goals are met prior to 2040. If monitoring data shows the potential for undesirable results, the BVGSA can introduce projects or management actions that mitigate these issues.

Further explanation of the development and implementation of the network is presented below for each of the four relevant sustainability indicators. Each section includes the following sub-sections:

- Representative Monitoring;
- Monitoring Frequency;
- Spatial Density;
- Map of Monitoring Site Locations;
- Monitoring Protocols;
- Data Gaps, and
- Plan to Fill Data Gaps.

In general, selection of sites for monitoring wells follows criteria aimed at achieving adequate spatial distribution across the GSA, targeted monitoring in areas of uncertain conditions or intensive groundwater extraction, and adherence to SGMA regulations and BMPs.

Each of the following sub-sections addresses monitoring for an individual sustainability indicator and applies the criteria listed above to identify the locations best suited to monitoring that indicator. The budget and schedule associated with the creation and implementation of the monitoring networks are discussed in Section 7 - Projects and Management Actions.

4.3.4 Data Sources and Existing Monitoring

Section 2 – Basin Setting provides an overview of existing monitoring programs within the BVGSA and of wells that, although not currently used for monitoring, could be added to the existing monitoring network to provide supplemental data and fill data gaps.

4.4 Monitoring Networks for Sustainability Indicators

This section of the GSP provides a detailed explanation of the monitoring networks created to support sustainable groundwater management in the BVGSA. Descriptions are provided for monitoring each of the four relevant sustainability indicators, and data gaps are identified that will be addressed to complete the monitoring program.

4.4.1 Groundwater Level Monitoring

> ***§354.34(c)***: *Each monitoring network shall be designed to accomplish the following for each sustainability indicator: (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: (A) A sufficient density of monitoring wells to collect representative measurements through depth-discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer. (B) Static groundwater elevation measurements shall be collected at least two times per year, to represent seasonal low and seasonal high groundwater conditions.*

4.4.1.1 Representative Monitoring

The network for monitoring groundwater levels will rest on the existing network of BVWSD monitoring wells, which are now used for CASGEM reporting. Currently there are 9 BVWSD monitoring well sites reported to CASGEM, with nested wells at two of the sites. All sites provide water level data for the principal aquifer system along the primary north-south axis of the BMA, and all are dedicated monitoring wells, so data collected at these locations is not influenced by pumping at the sites.

The monitoring network will be supplemented by inclusion of 3 BVWSD production wells all of which lie along the eastern boundary of the GSA and are now monitored under the Buena Vista

Coalition’s GQTMWP. Lastly, 1 landowner well located in the southeastern portion of GSA is included in the monitoring network. While 3 monitoring wells are located in the north of the BMA, the monitoring network in this area includes no production wells because of the limited groundwater extraction from the area.

As noted in Section 2 – Basin Setting, a shallow perched water table is present in the northern portion of the BMA. Due to the presence of the perched aquifer, this area is managed so that perched groundwater does not intrude into the root zone of overlying crops, and the BVWSD uses a network of piezometers to aid in management of the affected area. Selected piezometers from the BVWSD’s network are included in the monitoring network operated for the GQTMWP. However, the primary purpose of these piezometers is to manage a localized groundwater quality and agronomic problem that is not central to sustainable groundwater management in the BVGSA or the Kern County Subbasin. Therefore, while data from these piezometers is available to the BVGSA, the piezometers are not included in the GSA’s monitoring network with the exception of the 3 intended to observe the quality of groundwater inflow from the west.

Table 4-1. BVGSA Groundwater Level Monitoring Well Locations

Well Name	Well Type	Latitude	Longitude
DMW01	District Monitoring	35.60135	-119.61765
DMW02	District Monitoring	35.57162	-119.58081
DMW04	District Monitoring	35.51369	-119.59844
DMW05	District Monitoring	35.48532	-119.56483
DMW06	District Monitoring	35.45265	-119.53460
DMW07	District Monitoring	35.40209	-119.50110
DMW08	District Monitoring	35.39058	-119.44817
DMW10a	District Monitoring	35.35362	-119.43412
DMW10b	District Monitoring	35.35362	-119.43412
DMW12a	District Monitoring	35.31847	-119.37473
DMW12b	District Monitoring	35.31847	-119.37473
DW03	District Production	35.38104	-119.41521
DW05	District Production	35.38929	-119.43253
DW06	District Production	35.39731	-119.44775
D15	Landowner	35.34627	-119.37374

4.4.1.2 Management Areas and Hydrologic Zones

The BVWSD has two distinct service areas separated by 15 miles, the Buttonwillow Service Area (BSA) and the Maples Service Area (MSA). Because the locations of these service areas are not contiguous, their boundaries have been used to define the Buttonwillow Management Area (BMA) and the Maples Management Area (MMA). This GSP emphasizes management of the BMA which will be administered using a uniform set of management objectives and minimum thresholds.

For the Maples Management Area (MMA), the initial monitoring plan relies on the two landowner irrigation wells, M01 and M02, now reported to CASGEM. As with other aspects of management of the MMA, improvements to the initial monitoring plan will be developed in coordination with the Kern River GSA, and monitoring data collected by this MA will be used to support the monitoring network established by the KRGSA.

To guide neighboring GSAs in establishing similar minimum thresholds and measurable objectives, GSAs in the Kern County Subbasin have created Hydrogeologic Zones as described in Section 5 – Minimum Thresholds, Measurable Objectives and Interim Milestones. The boundaries of these zones were informed by groundwater elevations and then further adjusted to group areas with similar groundwater quality and historic rates of land subsidence. Figure 4.3, displays Hydrogeologic Zones in the Subbasin and shows the close correspondence between the boundaries of the BMA and those of Hydrogeologic Zone 6 (HZ 6) while the MMA lies entirely within HZ 10 (Figure 4-3 - Refer to Figures Tab)

4.4.1.3 Monitoring Frequency

BVWSD will measure water levels at all wells in its monitoring network on a semi-annual basis – Spring and Fall. All wells will be measured within one week of one another following a schedule that will be developed by the BVGSA in coordination with other GSAs in the Kern County Subbasin. Groundwater pumping typically peaks during the summer growing season and slows in the winter. Therefore, spring levels represent an annual high prior to summer irrigation demands while fall levels represent an annual low.

Groundwater elevation data will be used to observe annual changes and for analysis of long-term trends. Analysis of groundwater level trends together with data on surface water deliveries and metered groundwater extractions available from all production wells will be important tools for tracking the GSA’s progress in meeting its measurable objectives and in determining the appropriate management actions to support sustainable groundwater management.

4.4.1.4 Spatial Density

A total of 13 monitoring sites is included in the network for monitoring groundwater levels. This total consists of 9 district monitoring wells, 3 district production wells and 1 landowner well. These 13 wells are distributed over the 72 square-mile area of the BMA resulting in a monitoring network with a spatial density of one site per 5.5 square miles.

4.4.1.5 Map of Network for Groundwater Level Monitoring

Figure 4.4a is a map of the network for monitoring groundwater levels in the BMA. Figure 4.4b displays the wells in this network that have been selected for monitoring minimum thresholds and measurable objectives.

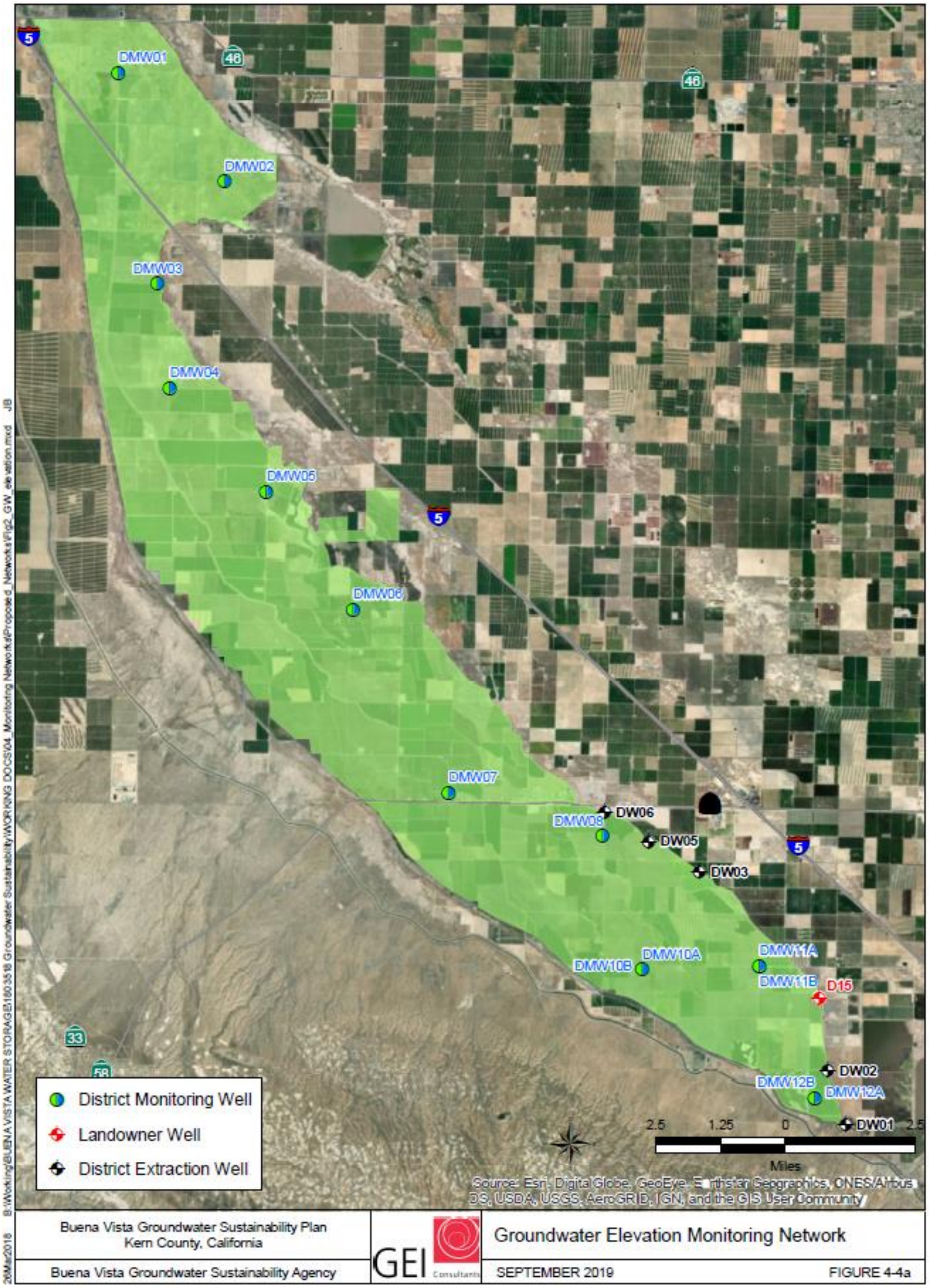


Figure 4-4a. Map of Network for Groundwater Level Monitoring

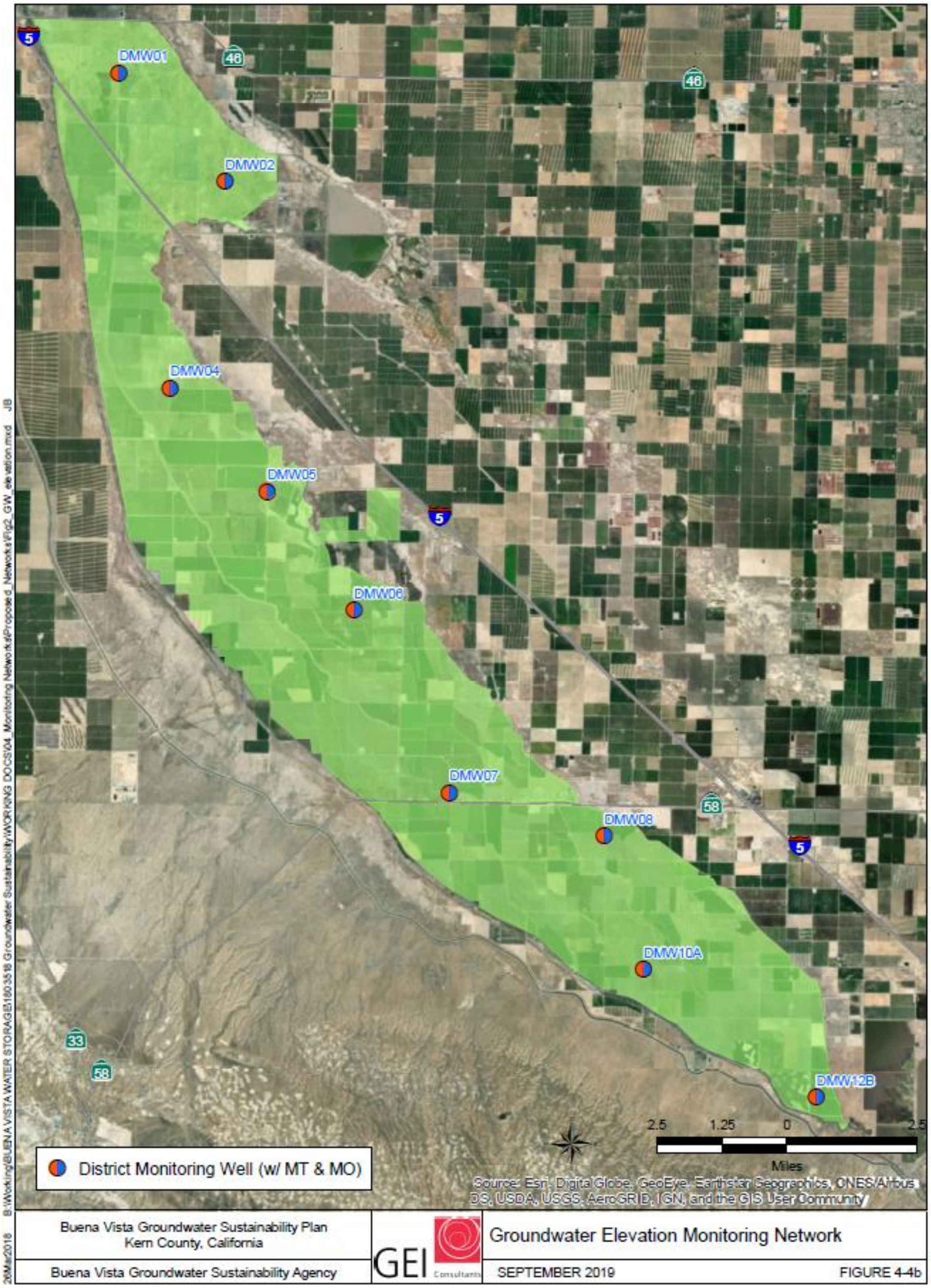


Figure 4-4b. Representative Wells for Minimum Thresholds and Measurable Objectives

4.4.1.6 Monitoring Protocols

Monitoring protocols used in the BVGSA will be consistent with those established throughout the Kern County Subbasin. Appendix D presents a draft protocol for the BVGSA.

4.4.1.7 Data Gaps

The initial plan for monitoring groundwater elevations includes 9 district monitoring wells, 3 district production wells and 1 landowner well. The BVGSA will evaluate the quality of data obtained from these wells and may identify data gaps based on data quality. The frequency of monitoring and density of the monitoring program may be adjusted in response to highly variable temporal and spatial conditions, adverse impacts to beneficial uses and any observed impacts to adjacent GSAs. The GSA has also identified a need to strengthen its monitoring program in the southern portion of the BMA as the Palms Project is developed.

4.4.1.8 Plans to Fill Data Gaps

The BVGSA will implement a program to install new monitoring wells in instances where data obtained from district and landowner production wells is of questionable quality. In addition, monitoring wells installed during development of the Palms Project will be incorporated into the monitoring network to increase coverage in the southern portion of the BMA.

4.4.2 Groundwater Storage Monitoring

> ***23 CCR §354.34(c)(2)****: Reduction of Groundwater Storage. Provide an estimate of the change in annual groundwater in storage.*

4.4.2.1 Representative Monitoring

The BMP for Groundwater Monitoring (DWR, 2017) notes:

> *While change in groundwater storage is not directly measurable, change in storage can be estimated based on measured changes in groundwater levels… and a clear understanding of the Hydrogeologic Conceptual Model…. The HCM describes discrete aquifer units and the specific yield values associated with these units. This data, together with information on aquifer thickness and connectivity, can be used to calculate changes in the volume of groundwater storage associated with observed changes in groundwater elevation.*

As suggested in the preceding passage from DWR's BMP on Groundwater Monitoring, measured changes in groundwater levels can serve as a proxy for changes in storage. For this reason, the network for monitoring changes in groundwater storage is the same network as that proposed for monitoring changes in groundwater levels. Table 4-2 presents the latitude and longitude of each of the 9 district monitoring wells, 3 district production wells, and 1 landowner well included in the GSA groundwater storage monitoring network.

Table 4-2. Groundwater Storage Monitoring Well Locations

Well Name	Well Type	Latitude	Longitude
DMW01	District Monitoring	35.60135	-119.61765
DMW02	District Monitoring	35.57162	-119.58081
DMW04	District Monitoring	35.51369	-119.59844
DMW05	District Monitoring	35.48532	-119.56483
DMW06	District Monitoring	35.45265	-119.53460
DMW07	District Monitoring	35.40209	-119.50110
DMW08	District Monitoring	35.39058	-119.44817
DMW10a	District Monitoring	35.35362	-119.43412
DMW10b	District Monitoring	35.35362	-119.43412
DMW12a	District Monitoring	35.31847	-119.37473
DMW12b	District Monitoring	35.31847	-119.37473
DW03	District Production	35.38104	-119.41521
DW05	District Production	35.38929	-119.43253
DW06	District Production	35.39731	-119.44775
D15	Landowner	35.34627	-119.37374

4.4.2.2 Management Areas

Data collected from the groundwater level monitoring network will be used to estimate changes in groundwater storage. Therefore, the management areas described above for groundwater level monitoring will apply to monitoring changes in groundwater storage.

4.4.2.3 Monitoring Frequency

Data collected from the groundwater level monitoring network will be used to estimate changes in groundwater storage. Therefore, the monitoring frequency used for groundwater level monitoring will apply to monitoring changes in groundwater storage.

4.4.2.4 Spatial Density

Data collected from the groundwater level monitoring network will be used to estimate changes in groundwater storage. Therefore, the spatial density of the groundwater level monitoring network will also apply to the network used to monitor changes in groundwater storage.

4.4.2.5 Map of Network for Groundwater Storage Monitoring

Figure 4.5a is a map of the network for monitoring changes in groundwater storage in the BMA. Figure 4.5b displays wells that have been selected for monitoring minimum thresholds and measurable objectives with respect to groundwater storage.

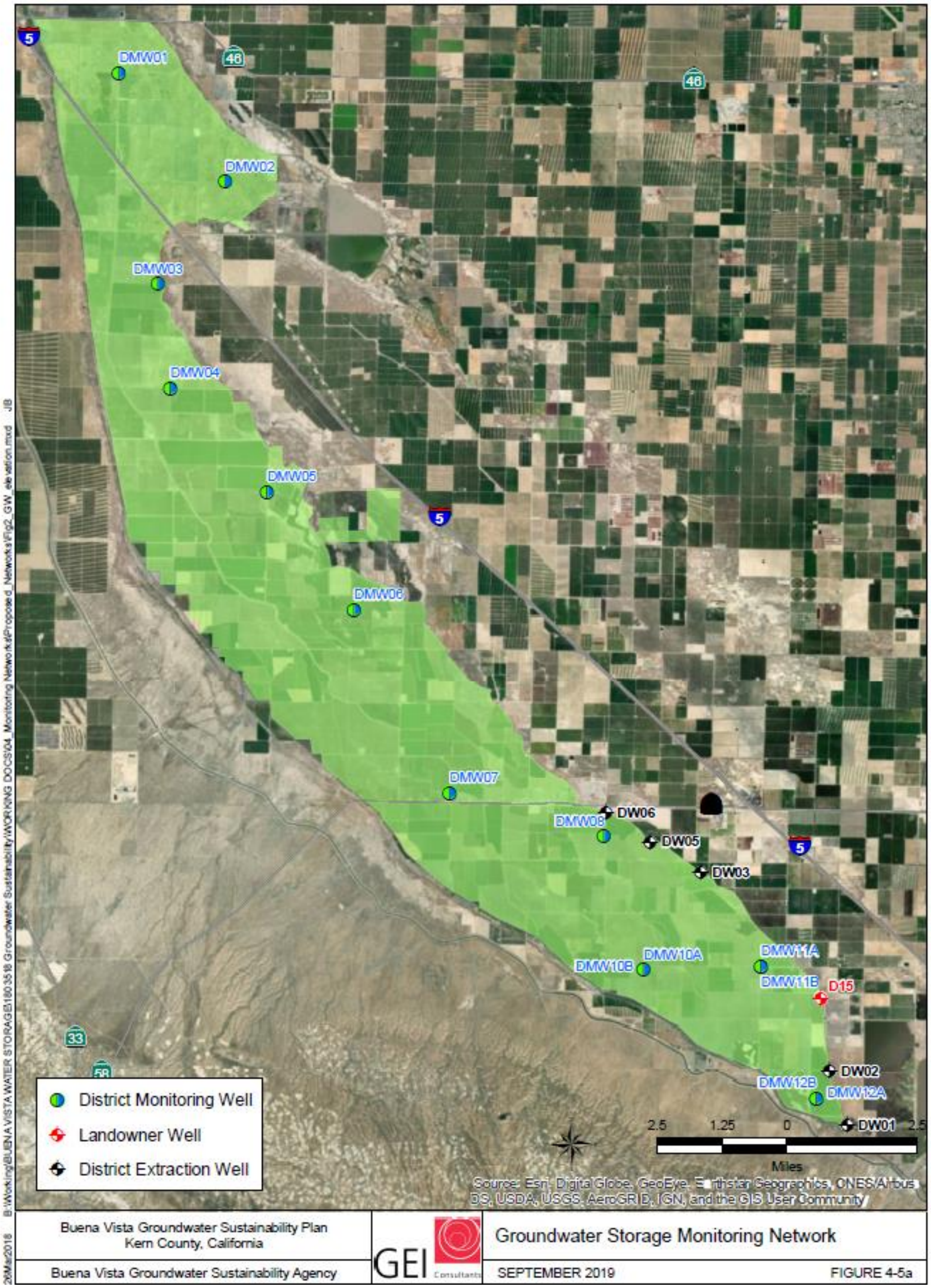


Figure 4-5a. Map of Network for Groundwater Storage Monitoring

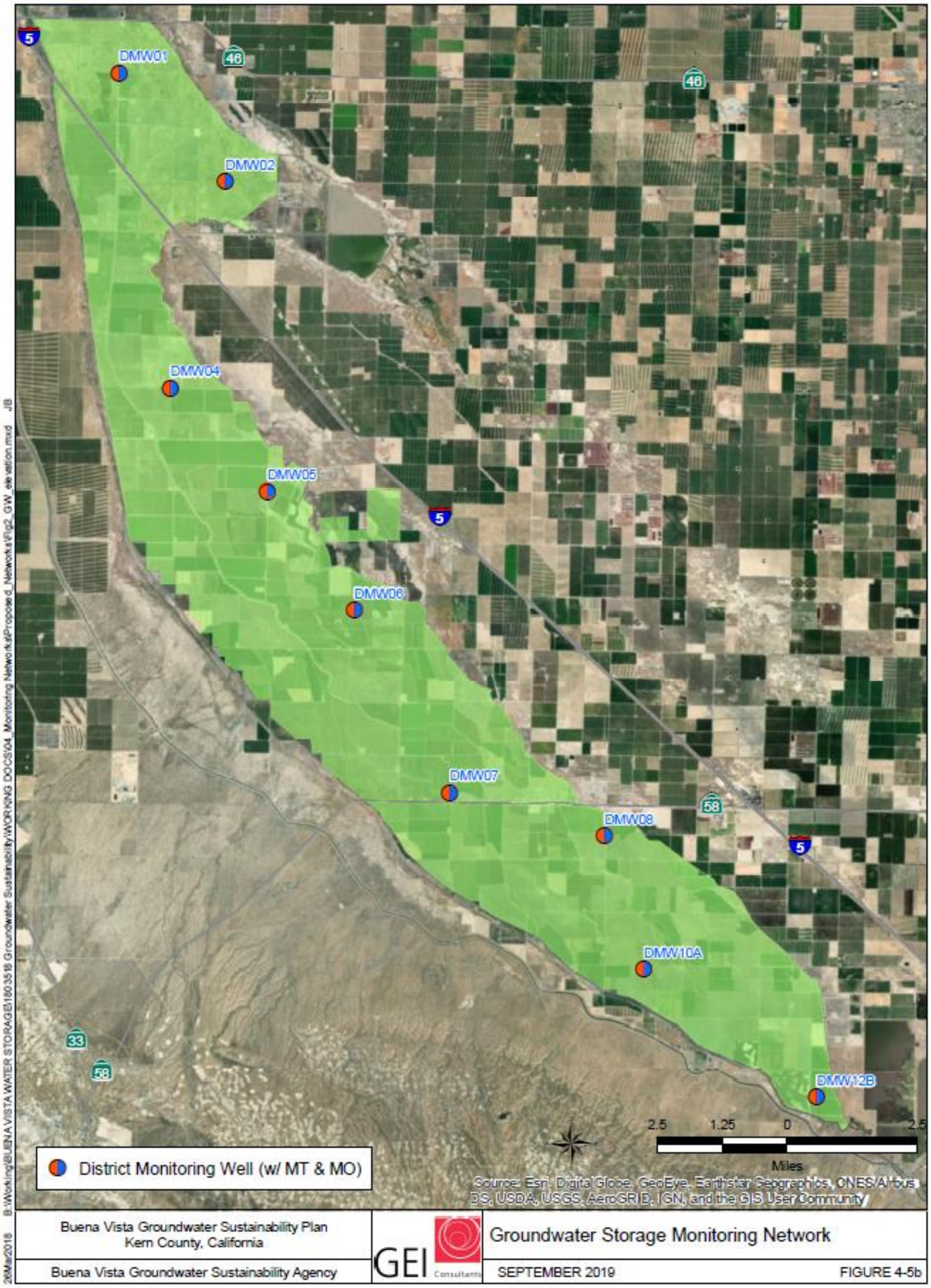


Figure 4-5b. Representative Wells for Minimum Thresholds and Measurable Objectives

4.4.2.6 Monitoring Protocols

Data collected from the groundwater level monitoring network will be used to estimate changes in groundwater storage. Therefore, the protocols used for monitoring groundwater levels will apply to monitoring changes in groundwater storage.

4.4.2.7 Data Gaps

The data gaps identified above for the groundwater level monitoring network also pertain to the network for monitoring changes in groundwater storage.

4.4.2.8 Plans to Fill Data Gaps

The recommendations noted above for the network for monitoring groundwater levels also pertain to the network for monitoring change in groundwater storage.

4.4.3 Groundwater Quality Monitoring

> ***23 CCR §354.34(c)(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.*

4.4.3.1 Representative Monitoring

Monitoring of the groundwater quality sustainability indicator will be carried out in parallel with the GQTMWP that has been developed by the Buena Vista Coalition for compliance with the Central Valley Regional Board's Irrigated Lands Regulatory Program (ILRP). The CRWQCB, Central Valley Region General Order R5-2013-0120 requires growers who are members of a third-party coalition within the Tulare Lake Basin to comply with the Waste Discharge Requirements (WDRs) of the ILRP. After approval of the General Order, the Buena Vista Coalition, which covers an area that corresponds closely with that of the BVGSA, received approval to act as a Third Party to implement the General Order.

Wells included in the monitoring network established for the GQTMWP target areas where data reported through the GAMA system has indicated active or incipient water quality concerns. While data reported by GAMA in other areas of the GSA indicate that water quality is not problematic, additional wells have been included in the initial SGMA groundwater quality monitoring network to observe the quality of groundwater flows in the following boundary areas:

- The southern boundary where groundwater flux is driven by pumping within the GSA and in neighboring water banks, and
- The northwestern flank where poor quality groundwater is believed to flow into the GSA. Because of the scarcity of deep wells in this area, the initial monitoring plan relies on 3 piezometers to observe the influence of water flowing from the west.

The southwestern flank of the GSA is not targeted for water quality monitoring because there is no need to coordinate with land users to the west. Similarly, monitoring is not necessary along much of the eastern flank because of the geological structures that obstruct groundwater flow in this area. The Hydrogeologic Conceptual Model presented in Section 2 – Basin Setting describes the geology of this boundary.

Table 4-3 presents the latitude and longitude of each of the 6 deep wells and the 4 piezometers included in both the GQTMWP and the GSA groundwater quality monitoring networks. The table also shows the locations of wells in the GSA network that will supplement those monitored by the Buena Vista Coalition. As shown in Figure 4-6, these monitoring locations are distributed so the greatest concentrations of sites are found either in areas that have experienced groundwater quality problems in the past or at locations where the monitoring point can serve as a sentinel for down-gradient areas.

Table 4-3. Groundwater Quality Monitoring Locations

Well Name	Well Type	Latitude	Longitude	GQTMWP
DMW01	District Monitoring	35.60140	-119.61755	No
DMW04	District Monitoring	35.51370	-119.59845	Yes
DMW06	District Monitoring	35.45265	-119.53460	No
DMW08	District Monitoring	35.39058	-119.44817	Yes
DMW12a	District Monitoring	35.31847	-119.37473	No
DMW12b	District Monitoring	35.31847	-119.37473	No
DW03	District Production	35.38104	-119.41521	Yes
DW05	District Production	35.38929	-119.43253	Yes
DW06	District Production	35.39731	-119.44775	Yes
Domestic Well	Domestic	35.37812	-119.44101	Yes
PIEZ-015	Shallow Piezometer	35.58645	-119.59749	Yes
PIEZ-023	Shallow Piezometer	35.55796	-119.61786	Yes
PIEZ-034	Shallow Piezometer	35.51404	-119.61547	Yes
PIEZ-035	Shallow Piezometer	35.49936	-119.61650	Yes

4.4.3.2 Management Areas

As discussed throughout this GSP, the BVGSA has been divided into two management areas, the Buttonwillow Management Area (BMA) with boundaries that closely parallel those of the BVWSD's Buttonwillow Service Area and the much smaller Maples Management Area (MMA), with boundaries identical to the BVWSD's Maples Service Area and which lies within the Kern River GSA (GSA). The two management areas are separated by approximately 15 miles with the MMA lying entirely within the Kern River GSA.

4.4.3.3 Monitoring Frequency

Following the GQTMWP developed for the Buena Vista Coalition, groundwater quality data collected for monitoring the groundwater quality sustainability indicator will be collected on a semi-annual basis.

4.4.3.4 Spatial Density

A total of 13 sites is included in the network for monitoring quality. This total consists of 5 District monitoring wells, 3 District production wells, 1 domestic and 4 piezometers. These 13 sites are distributed over the 72 square-mile area of the BMA resulting in a monitoring network with a spatial density of one site per 6.8 square miles.

4.4.3.5 Map of Network for Groundwater Quality Monitoring

Figure 4.6a is a map of the network for monitoring water quality in the BMA. Figure 4.6b displays wells selected for monitoring minimum thresholds and measurable objectives with respect to groundwater quality.

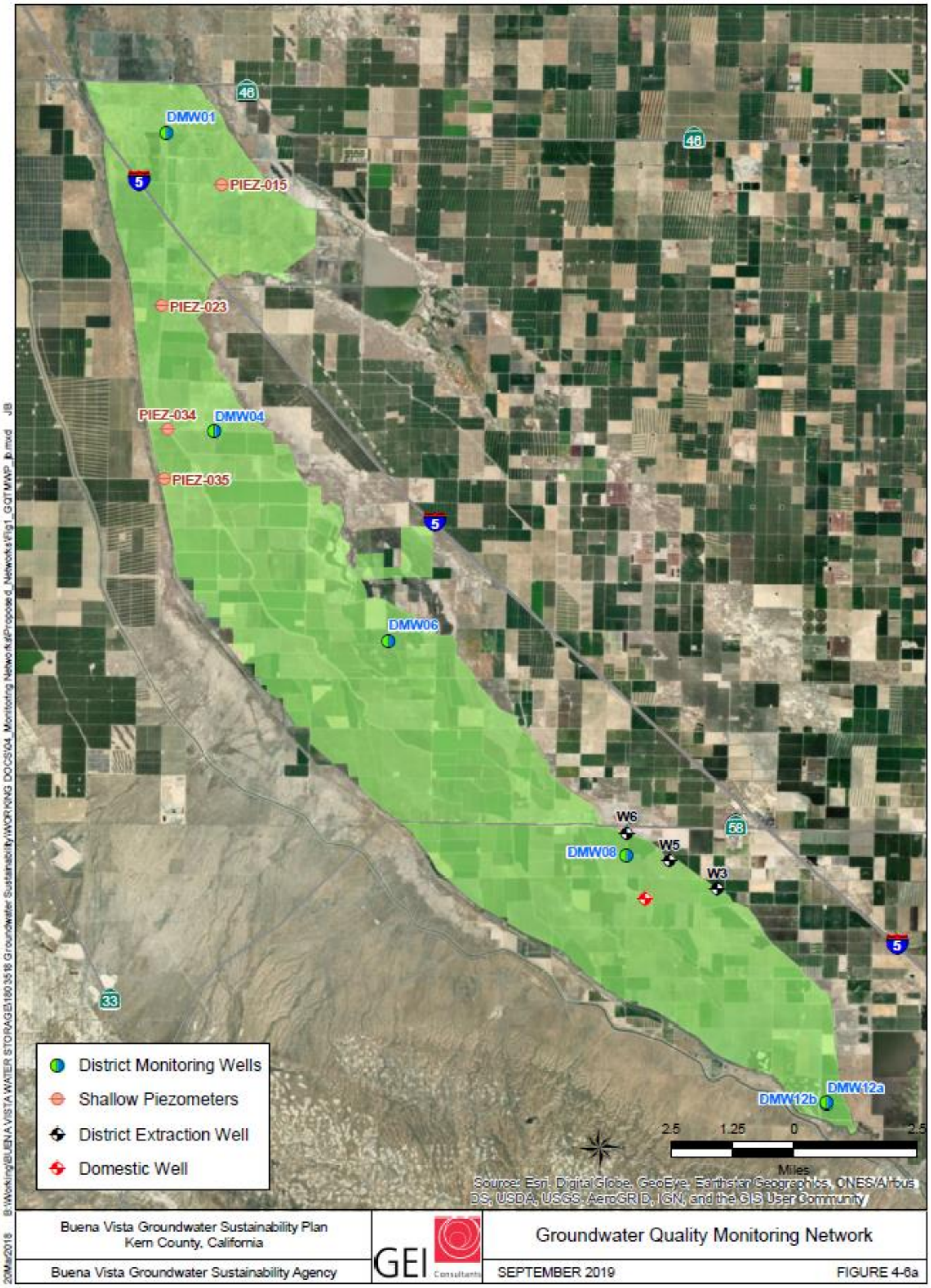


Figure 4-6a. Map of Network for Groundwater Quality Monitoring

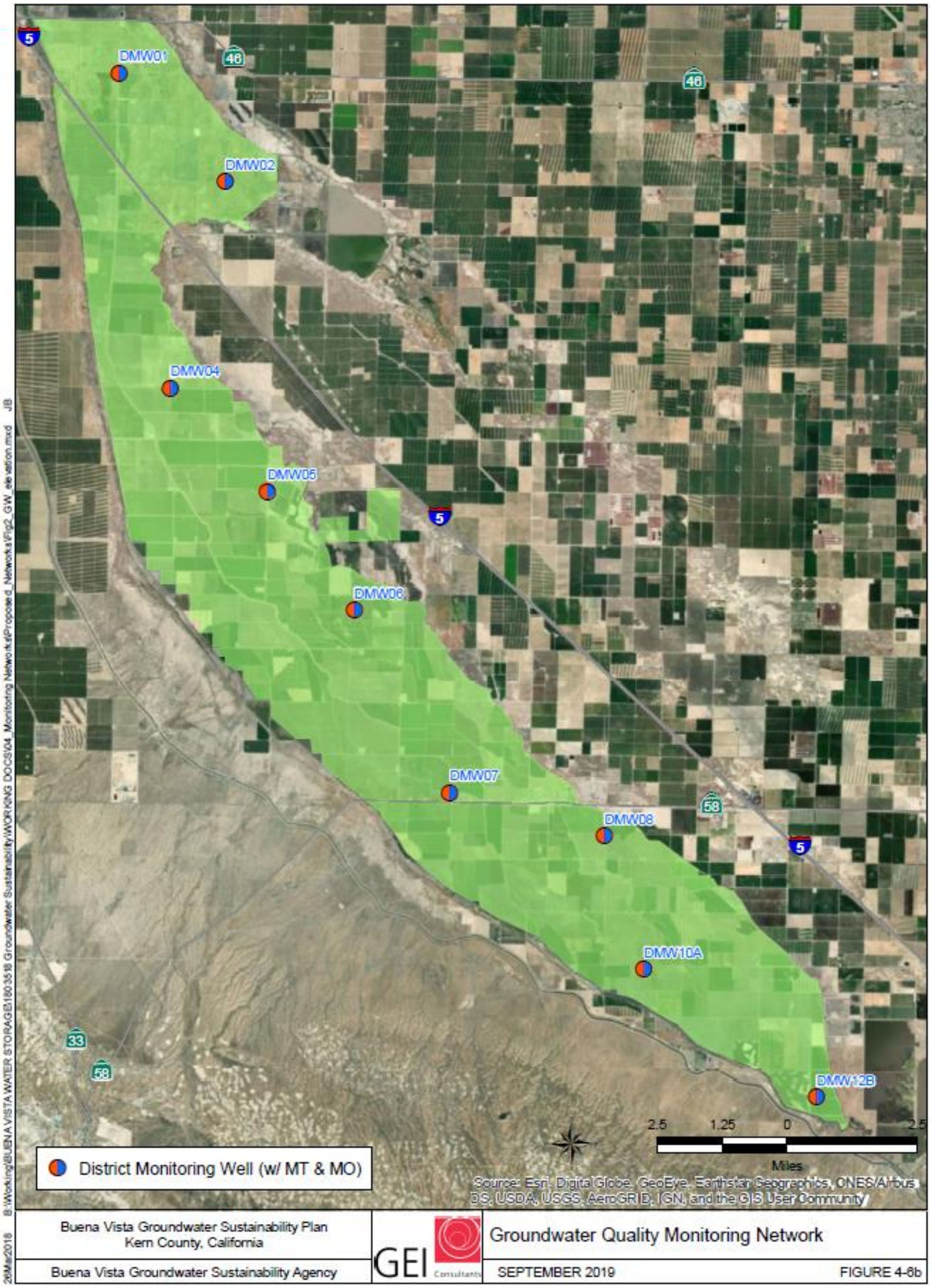


Figure 4-6b. Representative Wells for Minimum Thresholds and Measurable Objectives

4.4.3.6 Monitoring Protocols

Water quality samples will be analyzed by a third-party laboratory for the constituents shown below in Table 4-4.

Table 4-4. List of Water Quality Constituents Analyzed from Monitoring Program

Constituents		
Total alkalinity	Fluoride (F)	Potassium (K)
Bicarbonate (HCO_3)	Hardness as $CACO_3$	Sodium (Na)
Boron (B)	Iron (Fe)	Sodium adsorption (SAR)
Calcium (Ca)	Magnesium (Mg)	Electrical conductivity (EC)
Carbonate (CO_3)	Manganese (Mn)	Sulfate (SO_4)
Chloride (Cl)	Nitrate (NO_3)	Total dissolved solids (TDS)
Copper (CU)	pH	Zinc (Zn)

Water quality monitoring will include sampling and laboratory analysis of the nitrate concentration of the groundwater. Nitrate concentrations will be reported in units of milligrams per liter (mg/L) as nitrogen. Readings of selected water quality parameters will be taken in the field at the time of the sampling. Parameters to be measured in the field include electrical conductivity at 25 °C (EC) in µS/cm, pH, temperature (in °C), and dissolved oxygen (DO) in mg/L and anions and cations. Additional sampling protocols are included in Appendix D.

Every five years, wells used for monitoring groundwater quality will be tested for a suite of constituents that is more extensive than that tested on an annual basis. The constituents to be sampled and analyzed for reporting in the five-year GSP updates include total dissolved solids (TDS) and major cations such as boron, calcium, sodium, magnesium, and potassium and anions including carbonate, bicarbonate, chloride, and sulfate.

4.4.3.7 Data Gaps

Due to the predominance of irrigated agriculture as a land use in the BVGSA, groundwater quality monitoring conducted by the Buena Vista Coalition for compliance with the ILRP is likely to be protective of beneficial uses in the GSA. Therefore, the network for monitoring groundwater quality presented in this section is likely to be adequate for groundwater quality monitoring throughout the period of SGMA implementation. The one exception may be identification of existing wells or construction of new wells to replace the piezometers included in the proposed network to monitor the migration of poor-quality water from the west. As with other aspects of the groundwater quality monitoring program, changes in monitoring frequency and in the location of monitoring sites are likely to be driven by the compliance requirements of the Irrigated Lands Regulatory Program and other programs that focus specifically on protection of groundwater quality.

4.4.3.8 Plans to Fill Data Gaps

Data collected by the groundwater quality monitoring network will be examined to determine its effectiveness in supporting sustainable groundwater management. While no data gaps are now apparent, data gaps identified in the future will be addressed as needed.

4.4.4 Land Subsidence Monitoring

> ***23 CCR §354.34(c)(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.*

4.4.4.1 Representative Monitoring

The principal objective of the subsidence monitoring program is to support the monitoring activities of Caltrans and DWR to avoid generating groundwater conditions within the BVGSA that might contribute to subsidence of Interstate Highway 5 and the California Aqueduct, two facilities of regional and statewide importance that run immediately adjacent to the BVGSA.

Infrastructure within the BVGSA includes state and county roads, power lines, and water conveyance and control facilities including earth-lined canals and pipelines. This infrastructure has not experienced damage from subsidence in the past. Given that the range of groundwater elevations expected during implementation of SGMA is within the range of elevations that has been experienced in the past, the GSA does not anticipate subsidence will result in damage to infrastructure within its boundaries in the future.

Subsidence is monitored directly at GPS stations P545 and P563, two participating stations of the Continuously Operating Reference Stations (CORS) network that provides Global Navigation Satellite System (GNSS) data. The two CORS stations are part of the National Geodetic Survey (NGS), an office of NOAA's National Ocean Service that manages the CORS network on behalf of a group of government, academic, and private organizations. As of August 2015, the CORS network included almost 2,000 stations, contributed by over 200 different organizations, that support three-dimensional positioning, meteorology, space, weather, and geophysical applications throughout the United States. CORS enhanced post-processed coordinates approach a few centimeters relative to the National Spatial Reference System, both horizontally and vertically.

Data from the two CORS stations, both located immediately east of the BVGSA, will be supplemented through monitoring of ground surface elevations using data provided by DWR from the Interferometric Synthetic Aperture Radar (InSAR) network that measures vertical ground surface displacement. InSAR data is collected by the European Space Agency Sentinel-1A satellite and processed by the National Aeronautics and Space Administration's (NASA) Jet Propulsion Laboratory (JPL). This data currently provides cumulative vertical ground surface displacement from June 2015 to January 2017 for lands within the BVGSA.

4.4.4.2 Management Areas

As discussed throughout this GSP, the BVGSA has been divided into two management areas, the Buttonwillow Management Area (BMA) with boundaries that closely parallel those of the BVWSD's Buttonwillow Service Area and the much smaller Maples Management Area (MMA), with boundaries identical to the BVWSD's Maples Service Area. The two management areas are separated by approximately 15 miles with the MMA lying entirely within the Kern River GSA. Because of the lack of subsidence observed in the BVGSA, no additional management areas have established for targeted subsidence control.

4.4.4.3 Monitoring Frequency

Both the CORS network and InSAR monitor subsidence on a continuous basis. Cumulative InSAR data requires post processing, so the availability of these datasets is dependent on the work of NASA's JPL.

4.4.4.4 Spatial Density

The locations of CORS stations used for subsidence monitoring are shown in Figure 2-30 - Recent Subsidence (2015 to 2016) below. InSAR mapping is regional. (Figure 2-30 – Refer to Figures Tab)

4.4.4.5 Map of Network for Monitoring Subsidence

Figure 2-30 is a map of the recent subsidence in the BVGSA mapped using data from InSAR and showing the location of the CORS stations used for monitoring subsidence in the BMA.

4.4.4.6 Monitoring Protocols

Protocols for monitoring subsidence are established by the organizations that perform the monitoring, the National Geodetic Survey in the case of the CORS system and the JPL in the case of InSAR.

4.4.4.7 Data Gaps

As described in Section 2 – Basin Setting, little subsidence has been detected in the BVGSA, and subsidence has not been observed in buildings, canals, roads and other infrastructure within the GSA. Because control of subsidence is not now believed to be a problem, there are no plans to expand the BVSGA's subsidence monitoring system beyond the CORS stations and InSAR data described above. However, as also noted in Section 2, should subsidence be observed, data available from sources external to the BVGSA which the GSA does not manage, would be supplemented by a program of surveys implemented by the GSA to closely monitor subsidence at structures identified as being at risk.

4.4.4.8 Plans to Fill Data Gaps

For the reasons noted above, due to the lack of observed subsidence, there are now no plans to fill gaps in the monitoring system. Should evidence of subsidence be observed in facilities within or near the BVGSA, the GSA would initiate a topographic survey program to monitor the rate and extent of subsidence at the affected locations.

4.4.5 Seawater Intrusion Monitoring Network

> ***23 CCR §354.34(c)(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.*

Monitoring of seawater intrusion into the BVGSA is not needed due to the isolation of the Kern County Subbasin from the ocean and from estuaries or other saline bodies of water connected to the ocean.

4.4.6 Depletions of Interconnected Surface Water Monitoring Network

> ***23 CCR §354.34(c)(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.*

Monitoring of depletions of interconnected surface waters is not needed in the BVGSA because there are no rivers, streams or lakes that lie within the GSA's boundaries. The Kern River Flood Channel Canal lies immediately west of the GSA but is used to convey floods waters only under exceptional circumstances.

5. Minimum Thresholds, Measurable Objectives, and Interim Milestones

5.1 Introduction

The BVGSA has coordinated with other GSAs in the Kern County Subbasin to define sustainability objectives and undesirable results and to establish the three sustainable management criteria (SMCs): measurable objectives (MOs), minimum thresholds (MTs), and interim milestones (IMs). The objective of this coordination is to develop an approach to groundwater management within the BVGSA that will contribute to sustainable management throughout the subbasin. Figure 5-1, from the draft BMP for Sustainable Management Criteria (DWR, 2017), illustrates the relation between MTs, MOs, and IMs.

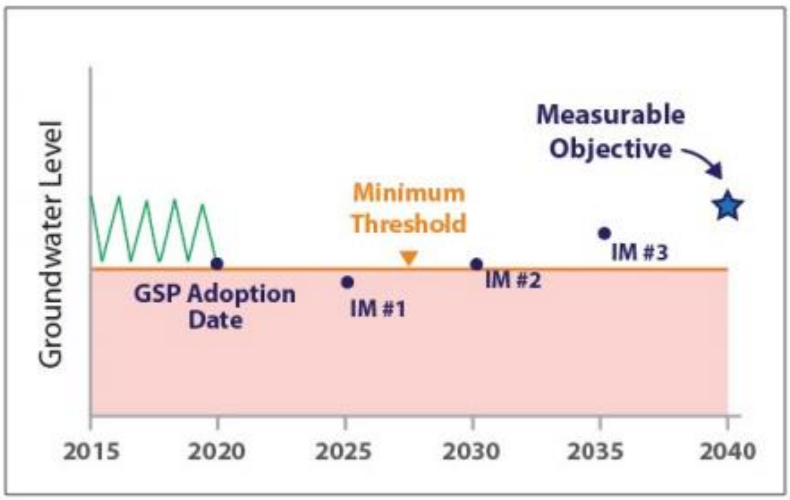


Figure 5-1. Example MT, IM, and MO

The minimum thresholds, measurable objectives, and interim milestones described and quantified in this section will be applied to avoid undesirable results related to the following sustainability indicators:

- Chronic lowering of groundwater levels;
- Significant and unreasonable reduction of groundwater storage;
- Significant and unreasonable degraded water quality, and
- Significant and unreasonable land subsidence.

As explained in Section 2 - Basin Setting and Section 3 - Sustainability Goal and Undesirable Results, the two remaining undesirable results are not considered to be relevant to management of the BVGSA.

- Significant and unreasonable sea water intrusion, and
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of surface water

The following are suggested considerations for all minimum thresholds presented in the draft BMP for Sustainable Management Criteria (DWR, 2017):

1. The information and criteria relied upon to establish and justify the minimum thresholds for each sustainability indicator. The justification for the minimum threshold shall be supported by information provided in the basin setting, and other data or models as appropriate, and qualified by uncertainty in the understanding of the basin setting.
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.
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.
4. How minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests.
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.
6. How each minimum threshold will be quantitatively measured, consistent with the monitoring network requirements described in Sub article 4.

Minimum thresholds set in the Buttonwillow Management Area for chronic lowering of groundwater levels and significant and unreasonable reduction of groundwater storage are unlikely to contribute to undesirable results for any SMC in other parts of the subbasin. This is because, as illustrated by groundwater contour maps, the BMA is largely isolated from areas in the Kern County Subbasin to the east. As a result of this isolation, groundwater levels tend to be higher than in other parts of the subbasin and minimum thresholds protective of groundwater levels are correspondingly higher.

5.2 Role of Hydrogeologic Zones

Coordinated development of measurable objectives and minimum thresholds for GSAs in the Kern County Subbasin begins with the concept of Hydrogeologic Zones (HZs). These zones, shown on Figure 5-2, have been agreed to by each of the GSAs located north of the Kern River to enable establishment of sustainable management criteria based on shared hydrogeologic characteristics and groundwater conditions such as depth to groundwater, base of fresh groundwater, attributes of principal aquifers, and water quality constituent concentrations (Figure 5-2 - Refer to Figures Tab). Definition of these HZs is the first step in the following three-tiered approach to establishment of SMCs.

- Tier 1: Establishment of MTs and MOs: MTs and MOs are defined for each monitoring site in an HZ which represents an area of common physical characteristics defined independently of GSA and district boundaries. Use of HZs to guide development of MTs and MOs enabled these metrics to be informed by the physical characteristics of the portion of the Subbasin within which they are located. HZs also provide overlying GSAs a shared frame of reference for defining and adjusting MTs and MOs in ways that avoid conflict with SMCs established in neighboring HZs.
- Tier 2: Management of MTs and MOs: GSAs overlying each HZ are collectively responsible for managing surface water and groundwater within each HZ to meet the mutually agreed upon MOs and avoid breaching MTs. The Tier 2 management responsibilities recognize that each GSA has unique tools such as surface water entitlements and recharge facilities it can deploy to manage the portion of the HZ for which it is responsible. Therefore, while the guidelines for setting MTs and MOs within an HZ are common to all overlying GSAs, each GSA has the flexibility to use the management tools at its disposal to maintain groundwater elevations, stored groundwater volumes, water quality constituent concentrations and ground surface elevations within the bounds set by the MTs and MOs.
- To provide each GSA the latitude to use the full range of available management options, interim milestones will be established by the GSAs with these milestones determined by the projects and programs each GSA will introduce to attain sustainable groundwater management by 2040. Because the GSAs overlying an HZ are likely to follow different paths in achieving their shared objectives, the IMs marking these paths are also likely to differ.
- Tier 3: Management Areas (MAs): When needed to aid in management of a sustainability indicator, management areas may be established with the MA boundaries based on the extent of the concern the MAs are designed to address (e.g., contaminant plume location, critical infrastructure alignment). Depending on the location of the undesirable result, MAs may lie within a single GSA or may span GSAs.

  The BVWSD has two distinct service areas separated by 15 miles, the Buttonwillow Service Area and the smaller Maples Service Area. Because the locations of the services areas are not contiguous, their boundaries have been used define the Buttonwillow Management Area, BMA, and the Maples Management Area, MMA.

In summary, the three-tiered structure established within the Kern County Subbasin:

- Defines MTs and MOs within HZ boundaries that have been delineated based on shared physical conditions;
- Manages MTs and MOs within GSAs boundaries that have been delineated by jurisdiction, and
- Allows for management of sustainability indicators through formation of MAs having boundaries delineated by the extent of the sustainability indicator of concern or, as in the case of the BVGSA, by physical separation between MAs.

5.3 Application of Three-tiered Structure in the BVGSA

As shown on Figure 5.2, the BVGSA falls largely within HZ 6 with the extreme southern portion of the BMA lying in HZ 10 along with the entirety of the MMA, an MA surrounded by the Kern River GSA. Section 2 - Basin Setting describes distinguishing features of HZ 6 including soil characteristics, base of fresh groundwater and location of the E-clay (Corcoran Clay). The correspondence between the boundaries of the BMA and HZ 6 further illustrates how the hydrogeology, soils, and other features that distinguish HZ 6 were among the factors that led to the development of land within what is now the BVWSD, development which began as a reclamation effort in the 1870s with the formation of Swamp Land District No. 121 under the Swamp and Overflow Act of 1850.

Figures 2-24 and 2-25 of the Basin Setting show groundwater elevations characteristic of HZ 6 and illustrate how groundwater elevations differ between HZ 6 and neighboring areas. These groundwater elevations were central to defining the boundaries of HZ 6 and demonstrate the need for monitoring to provide a foundation for coordination with neighboring GSAs.

The close correspondence between the boundaries of HZ 6 and the BMA simplifies definition of SMCs because the criteria fall primarily within the purview of a single GSA. Therefore, as the BVGSA will be the sole GSA involved in development of SMCs, there will be no need for internal coordination with other overlying GSAs. However, the responsibility remains for coordination between the BVGSA and its neighbors to confirm that the SMCs drafted within HZ 6 do not conflict with those established in adjacent areas or create mismatches at boundaries that compromise the effectiveness of the SMCs on either side of the boundaries.

The MMA, being a small area within the Kern River GSA (KRGSA), will follow the guidelines established by that GSA for setting MTs and MOs. Adherence to the guidelines of the KRGSA will avoid a situation where a small island of land under the jurisdiction of the BVGSA, complicates SGMA compliance on the part of the KRGSA.

Cooperation among GSAs in the Kern County Subbasin in preparing the Basin Setting and in establishment of HZs were early steps in coordinated management of the Subbasin. Continued coordination will be required to ensure that projects and practices proposed by the BVGSA do not lead to undesirable results in neighboring areas and that practices introduced in neighboring areas do not interfere with sustainable groundwater management within the BVGSA. Outreach and coordination efforts by the BVGSA are described in detail in Section 9 - Outreach and Engagement Plan.

With respect to formation of management areas, as described in Section 2 - Basin Setting, there are hydrogeologic and water quality differences within the BMA that could have led to subdivision of this portion of the GSA into two or more MAs. However, these differences have existed since the formation of the BVWSD, and the District has been managed in ways that recognize and accommodate these differences.

Because of the BVWSD's history of managing the Buttonwillow Service Area by sharing resources within this unit, the BVGSA will adopt the approach of cooperative management and will not subdivide this area into MAs. The rationale for the unified approach is described in the Engineer's Assessment Report prepared for a Proposition 218, BVWSD, 2016(the Right to Vote on Taxes Act) process successfully completed in 2016[3]. This assessment report notes that the benefits of operations and capital improvements exercised by the BVWSD accrue to all persons who own land within the District because the benefits of the District's capital improvement projects enhance customer service and water management throughout the District. All lands within the District's Service Area have been identified as lands falling within this category and receiving the aforementioned benefits.

Buttonwillow Management Area

5.4 Chronic Lowering of Groundwater Levels

5.4.1 Minimum Thresholds

The draft BMP on Sustainable Management Criteria (DWR, 2017) provides the following definition of minimum thresholds and of the term as it pertains to chronic lowering of groundwater levels:

> Minimum thresholds are quantitative values for groundwater conditions at representative monitoring sites that, when exceeded individually or in combination with minimum thresholds at other monitoring sites, may cause an undesirable result(s). Thus, sustainability indicators become undesirable results when a GSA-defined combination of minimum thresholds is exceeded at a scale determined to compromise basin-wide sustainability. The minimum threshold metric for the chronic lowering of groundwater levels sustainability indicator shall be a groundwater elevation measured at the representative monitoring site.

[3] Buena Vista Water Storage District: 2016 Engineer's Assessment Report in Support of Proposition 218 Assessment Ballot Proceeding, June 2016.

5.4.1.1 Establishment

For the Buttonwillow Management Area, minimum thresholds set for monitoring of groundwater levels are based on historical groundwater conditions as expressed by hydrographs at representative monitoring wells. Minimum thresholds also consider depths, and screened intervals of domestic, industrial, agricultural, and municipal wells to be protective of these uses. Initial MTs have been established for each of the representative monitoring sites discussed in Section 4 - Monitoring Networks. These initial values will be modified during SGMA implementation as data gaps are filled and as the monitoring network is refined.

Section 3 - Sustainability Goal and Undesirable Results presents avoidance of the undesirable result of chronic lowering of groundwater levels as a critical objective for the BVGSA. Minimum thresholds for this undesirable result were established at each of the representative monitoring sites through analysis of well and groundwater elevation data. These analyses were carried out in the following sequence.

- Hydrographs were developed for each of the 11 monitoring wells operated by the BVWSD and reported to CASGEM. These monitoring wells are located at nine sites throughout the BMA with two of the sites, DMW 10 and DMW 12, having dual completion monitoring wells. The hydrographs developed for each monitoring well extend from September 2011 through October 2018, a period that captures changes in groundwater elevations observed during California's recent drought. Projections of these trend lines from fall 2016 base observations ranged from an increase of 6 feet to a decline of 239 feet with projected groundwater levels ranging from 47 feet bgs, a decline of 20 feet (0.8 feet/year) to 593 feet bgs, a decline of 354 feet (14.7 feet/year) As these trend lines assume a continuation of the severe drought that characterized the period from 2011 through 2018, projecting these trends through 2040 represents a "worst case" scenario of the minimum threshold at each of these monitoring sites.
- The "worst case" representations were then adjusted to arrive at MTs that reflect operating conditions at each monitoring location. These adjustments were based on factors including depths of confining and semi-confining clay layers and well construction information for domestic, agricultural, municipal and industrial wells.

Table 5-1 shows the groundwater levels observed in the Fall of 2016 at each of the 11 district monitoring wells reported to CASGEM, the corresponding "worst case" MT at these sites and the slope of the hydrograph used to project water levels observed between 2011 and 2018 to the 2040 "worst case" condition. Well Completion Reports for these wells can be found in Appendix E.

Table 5-1. Fall 2016 Water Levels and Projected 2040 Levels

Well ID	Fall 2016 Levels (feet bgs)	Hydrograph Slope	2040 Projected Levels (feet bgs)
dmw01	60	-0.00878	137
dmw02	80	-0.00891	158
dmw04	27	-0.00229	47
dmw05	42	-0.00418	79
dmw06	75	0.00078	69
dmw07	93	-0.00028	95
dmw08	127	-0.00877	204
dwm10a[1]	157	-0.01171	260
dmw10b[2]	216	-0.02089	400
dmw12a[3]	225	-0.01744	378
dmw12b[4]	239	-0.04021	593

[1] Nested monitoring well DMW 10: screened above E-clay
[2] Nested monitoring well DMW 10: screened below E-clay
[3] Nested monitoring well DMW 12: screened below E-clay
[4] Nested monitoring well DWM 12: screened above E-clay

5.4.1.2 Considerations Used

- What are the historical groundwater conditions in the basin? Historical groundwater conditions in the BVGSA are presented in Section 2 - Basin Setting. Groundwater hydrographs included in the Basin Setting and in Appendix C - Groundwater Hydrographs, display the range of groundwater elevations observed in the GSA over the period extending from 1993 through 2015, a period that corresponds with that used for C2VSim modeling of the Subbasin.
- What are the average, minimum, and maximum depths of municipal, agricultural, and domestic wells? Table 5-2 displays mean, median, minimum, and maximum depths of municipal, agricultural, domestic and industrial wells identified using data provided by DWR. Industrial well users have been identified as agricultural yards and processors, municipal wells have been identified as being in or near the Community of Buttonwillow.

Table 5-2. Well Depth Data

Well Depth Statistics				
	Domestic (feet)	**Industrial (feet)**	**Municipal (feet)**	**Agricultural (feet)**
Maximum Well Depth	522	500	700	1101
Minimum Well Depth	150	150	443	138
Median Well Depth	360	346	498	460
Mean Well Depth	356	330	547	477

- What are the screen intervals of the wells? Figures 5-3 through 5-6 display average depths of tops and bottoms of screens for domestic, industrial, municipal, and agricultural. Maximum, minimum, median and mean length of screened intervals for the four well types are shown in Table 5-3.

Table 5-3. Well Screen Interval Characteristics

Well Screen Interval Statistics				
	Domestic (feet)	**Industrial (feet)**	**Municipal (feet)**	**Agricultural (feet)**
Maximum Screen Length	300	320	300	800
Minimum Screen Length	8	60	80	6
Median Screen Length	42	99	297	264
Mean Screen Length	65	131	226	262

Table 5-4 shows well screen locations relative to the top of the E-clay. This table presents data on well depths and screened intervals derived from CASGEM, from DWR's SGMA Data Viewer website and from well completion reports available from the BVGSA and DWR. The information presented in this table indicates that the main production zones are the unconfined and semi-confined aquifers above the E-clay. The numeric data used to estimate well depths is supported by notes in the well completion reports that describe how drillers frequently bore until encountering the E-clay and then screen above this layer. This practice appears to be particularly prevalent in agricultural wells.

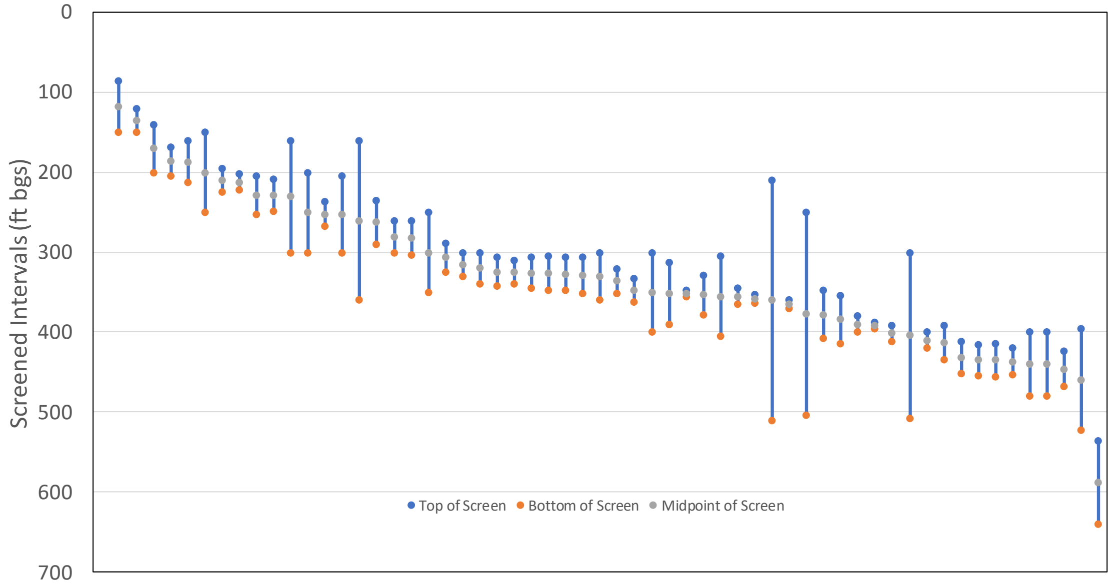


Figure 5-3. Screened Intervals: Domestic Wells

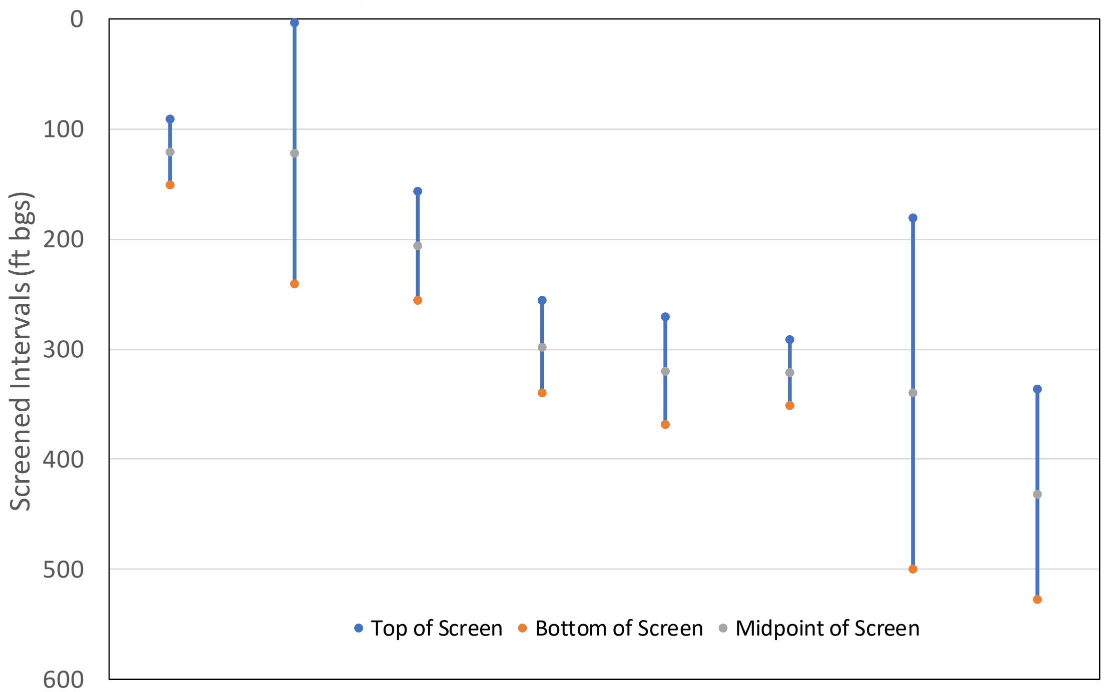


Figure 5-4. Screened Intervals: Domestic Wells

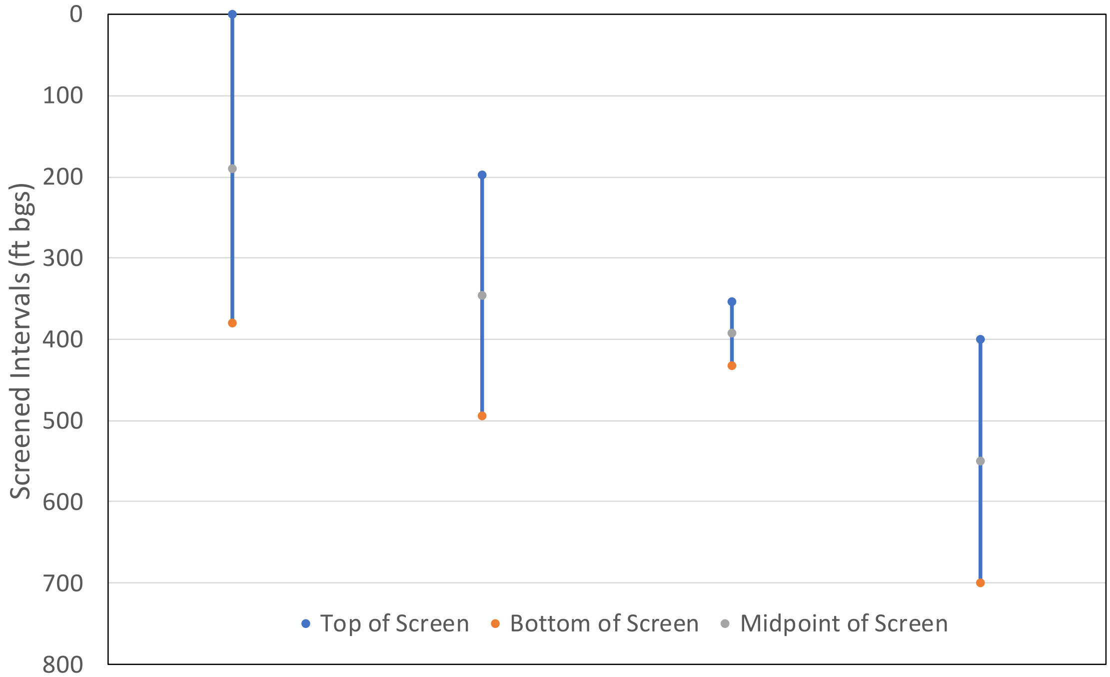


Figure 5-5. Screened Intervals: Municipal Wells

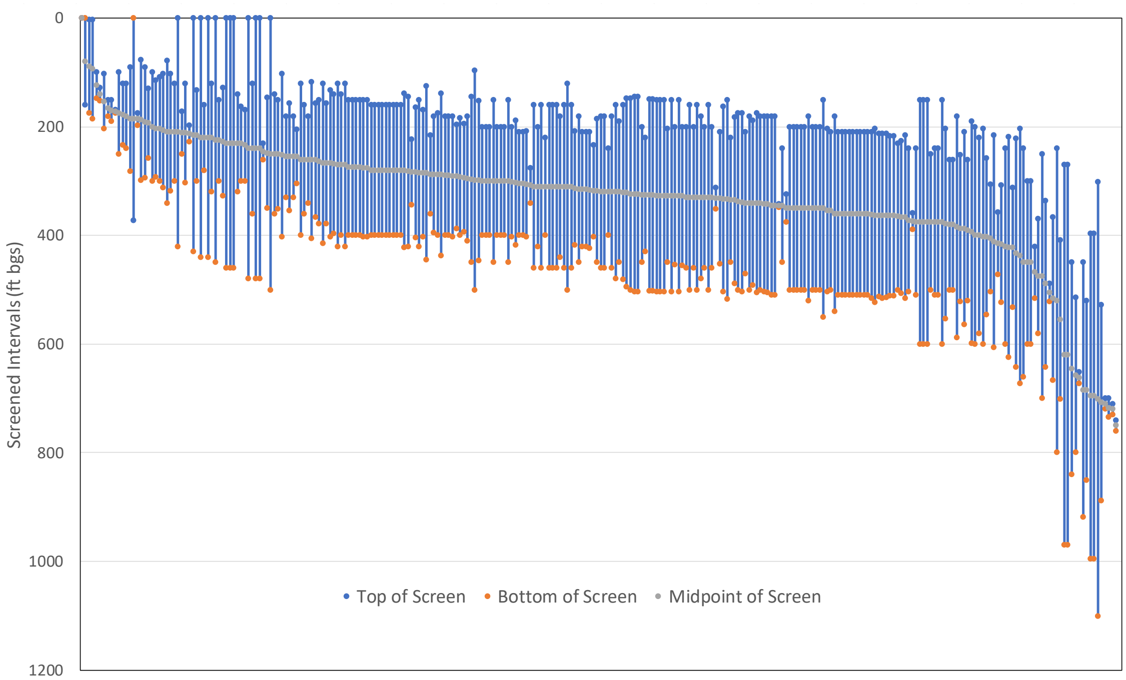


Figure 5-6. Screened Intervals: Agricultural Wells

Table 5-4. Well Screen Locations Relative to the E-clay

Screen Location Relative to E-clay	Domestic		Industrial [5]		Municipal [4]		Agricultural	
Above E-clay [1]	38	64%	5	71%	0	0%	57	22%
Near E-clay [2]	19	32%	2	29%	3	100%	198	75%
Below E-clay [3]	2	3%	0	0%	0	0%	8	3%
Total # of Wells / Total %	59	100%	7	100%	3	100%	263	100%

[1] Above E-clay: bottom perforation less than 400 feet below ground surface
[2] Below E-clay: top perforation greater than 500 feet below ground surface
[3] Near E-clay: bottom perforation between 400 and 500 feet below ground surface
[4] All municipal wells are in or near the community of Buttonwillow
[5] Industrial uses have been identified as agricultural yards and processing facilities

- What impacts do water levels have on pumping costs (e.g., energy cost to lift water)? Data provided by the BVWSD indicate that the energy cost to lift water in the BVGSA is approximately $30 / AF. Analysis that considered current PG&E costs, average irrigation well screened interval depth, and typical pumping costs per foot of lift per acre-foot, United States Data Center Usage Report, (Lawrence Berkeley National Laboratory, 2016) found the District estimate to be conservatively low.

- What are the adjacent basins' minimum thresholds for groundwater elevations? The BVGSA lies within the Kern County Subbasin and does not border any adjacent basins. Minimum thresholds for groundwater elevations in the adjacent Kern Groundwater Authority GSA are shown in Appendix F. The table in Appendix F was taken directly from the Kern Groundwater Authority's Umbrella GSP.

- What are the potential impacts of changing groundwater levels on groundwater dependent ecosystems? As described in Section 2 - Groundwater Conditions, historical depths to groundwater are below elevations that have the potential to support groundwater dependent ecosystems (GDEs). Therefore, establishment of MTs below historical groundwater levels is unlikely to have any impact on GDEs.

- Which principal aquifer, or aquifers, are the representative monitoring sites evaluating? Based on information provided in Section 2 - Basin Setting, Section 4 – Monitoring Networks and information presented above in Tables 5.2 through 5.4, wells in the BVGSA monitoring network used as representative monitoring sites draw from zones of the Tulare Formation located above the E-clay, the principal production aquifer for the BVGSA. MTs were established at each of the representative monitoring wells to evaluate groundwater levels in this aquifer. In addition to the representative monitoring wells used to establish sustainable management criteria, the BVGSA's monitoring program includes three wells that extend beneath the E-clay. These wells, DMW 10b, DMW 11b and DMW 12a, are all included in nested pairs of wells with their counterpart wells, DMW10a, DMW11a, and DMW 12a all monitoring groundwater conditions above the E-clay.

5.4.1.3 Quantitative Minimum Thresholds

Although land surface elevations, depths to groundwater and depths to the E-clay vary throughout the BMA, the overall geometry of the management area, and of the corresponding HZ 6, aids in setting minimum thresholds due to the following characteristics:

- The BMA is underlain by the E-clay at elevations ranging from approximately 10 ft AMSL to -215 feet AMSL with unconfined and semi-confined zones of the Tulare Formation lying above the E-clay and a confined zone extending beneath the clay layer to the base of fresh groundwater.
- Analysis of screened intervals indicates that wells for all uses extract water from a production zone above the E-clay.
- Water quality in the production zone above the E-clay is better than that found beneath this layer.
- The risk of inducing subsidence by extracting water from the zone above the E-clay is likely to be lower than the risk induced by extracting water from beneath the E-clay.
- The volume of groundwater in storage above the E-clay is likely to be adequate to meet the demands of the BMA under foreseeable conditions.
- Water use throughout the GSA is overwhelmingly agricultural, therefore, the spatial distribution of demands is uniform.

Figure 5-7 - Longitudinal Cross Section of the BMA is based on Figure 2-13b and illustrates many of the points presented above. As well as showing the extent of the E-clay, the cross section illustrates the presence of the A- and C-clay lenses in the northern portion of the GSA that are described in Section 2 - Basin Setting (Figure 5-7 – Refer to Figures Tab). These three clay layers can be described briefly as follows:

- The A-clay occurs 20 to 30 feet bgs and is the cause of the shallow, perched groundwater identified in piezometers throughout the northern part of HZ 6.
- The C-clay is about 30 feet thick and occurs at a depth of about 200 feet bgs. The C-clay is laterally discontinuous and provides semi-confining conditions.
- The top of the E-clay occurs at depths ranging from 225 to 540 feet bgs and is a barrier to vertical flow of groundwater.

These clay layers create three aquifer zones:

- the perched aquifer above the A-clay, found throughout the northern portion of the BMA.
- the shallow, semi-confined aquifer lying between the A- and C-clays, and
- the deep aquifer lying between the C- and E-clays.

As the C-clay is perforated by numerous wells, it behaves as a semi-confining layer. Therefore, for the purposes of water accounting, the shallow and deep aquifers are grouped together as the principal production aquifer. Permeable sediments are also present below the E-clay, however because the water quality below the E-clay is poor and pumping from below the E-clay increases the risk of subsidence, most wells are constructed in the high yielding sands and silts above the E-clay, as shown in Table 5-4.

The hydrogeologic features of the BMA noted above and displayed in Figure 5-7 provide a physical setting for visualizing MTs and other management metrics. The Fall 2015 baseline groundwater elevations recorded in the 11 district monitoring wells and displayed on Figure 5-7 show shallow groundwater levels in district monitoring wells lying in the northern part of the area with depths to groundwater progressively increasing as the location of the wells moves south out of the semi-confined portion of the principal aquifer and as the depth to the E-clay increases. This progressive deepening of the fall 2015 groundwater levels is paralleled by a corresponding deepening of the "worst case" MTs.

Figure 5-7 also illustrates that in every instance, the "worst case" MTs lie above the top of the E-clay. Therefore, should groundwater levels breach these thresholds, the gap between the MT and the E-clay would provide an additional buffer for drought response that would not be likely to induce subsidence or diminish water quality. Therefore, continued reliance on the principal aquifer throughout SGMA implementation appears to be a practical approach to sustainable groundwater management.

Although the "worst case" MTs present useful first approximations, these MTs were refined based on the well construction data presented in tables 5-2 through 5-4 and other considerations when setting final MTs. The key objectives in refining the "worst case" MTs were:

- Determining sufficiently protective minimum thresholds in the southern portion of the GSA where the "worst case" MTs projected for 2040 are substantially lower than groundwater levels observed in 2015. The large difference between these levels is due to the steeply declining hydrographs used to compute the "worst case" condition. Because these hydrographs show the influence of groundwater banks located immediately outside the boundaries of the BVGSA, they represent a management condition that is beyond the full control of the GSA. To protect against triggering an undesirable result within the boundaries of the BVGSA due to the activities of an external party, MTs in these areas have been adjusted to conservative levels.

- Recognizing constraints on future operations in the northern portion of the BMA underlain by the A-clay where limited pumping during the baseline period resulted in high 2016 groundwater elevations and shallow hydrograph slopes leading to "worst case" MTs that may be overly restrictive.

For the reasons described above, the E-clay constitutes a physical floor for sustainable management of groundwater in the BMA. Limiting groundwater extraction to zones above the E-clay avoids the risks of degrading of water quality and inducing subsidence that may result from pumping beneath the E-clay, two undesirable results discussed in greater detail later in this section.

The operational impacts of the “worst case” MTs were assessed by examining the depths and screened intervals of active wells. As shown in Table 5-4, all municipal wells extend to the E-clay as do 75 percent of agricultural wells. The well depths and screened intervals reported for these wells suggest pumping from levels extending to the E-clay is economically viable. By contrast, only 29 percent of industrial wells and 32 percent of domestic wells extend to the E-clay. Moreover, while the mean screened interval of agricultural wells is 262 feet and of municipal wells is 226 feet, the mean screened intervals of domestic and industrial wells are much narrower (65 feet and 131 feet, respectively).

Using domestic and agricultural wells as examples, Figures 5-8a and 5-8b show the distribution of top perforations and bottom perforations of domestic wells and Figures 5-9a and 5-9b show these distributions for agricultural wells. Comparison of these two sets of figures reveals the narrow shift that illustrates the short screens (65-foot mean length) typical of domestic wells and the wider shift that illustrates the longer screens (262-foot mean length) typical of agricultural wells.

Domestic wells screens have top perforations at a mean depth of 300 feet bgs with 72 percent of screens having top perforations between 200 and 400 feet bgs. Agricultural well screens have shallower top perforations with a mean depth of 198 feet bgs and with 82 percent of screens having top perforations at between 100 to 300 feet bgs.

The mean depth of the bottom perforations of domestic wells is 365 feet bgs with 74 percent of wells having bottom perforations between 200 and 400 feet. The bottom perforations of agricultural wells are deeper with a mean depth of 459 feet bgs and with 79 percent of agricultural wells having bottom perforations between 350 and 550 feet bgs.

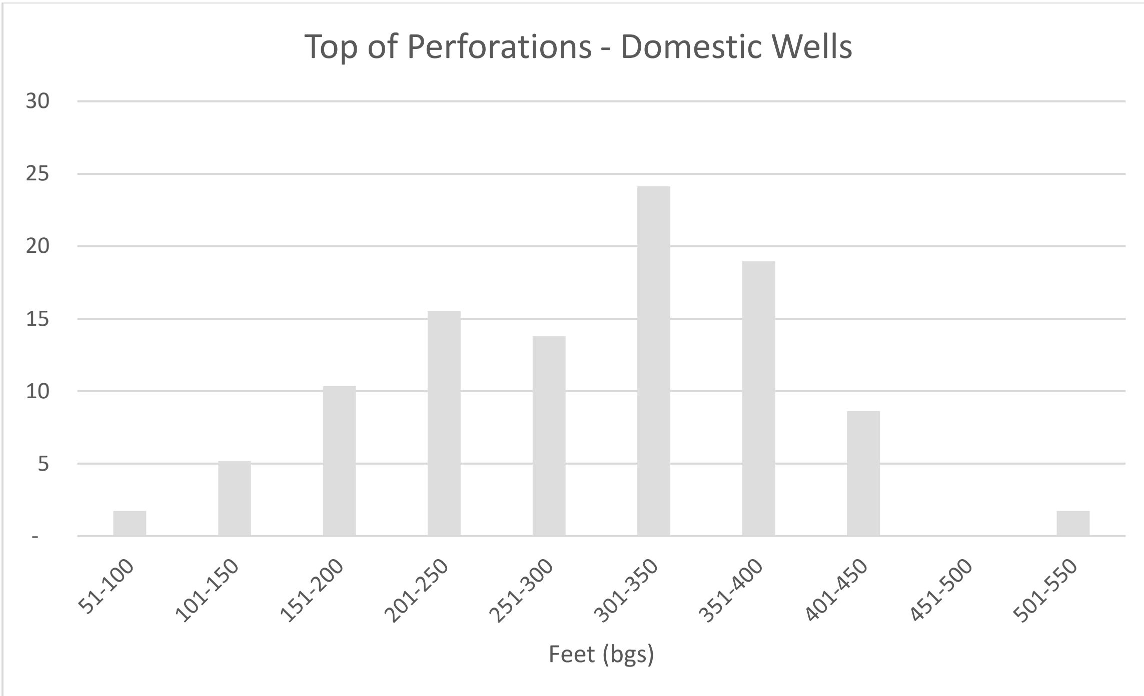


Figure 5-8a. Distribution of top perforations for domestic wells

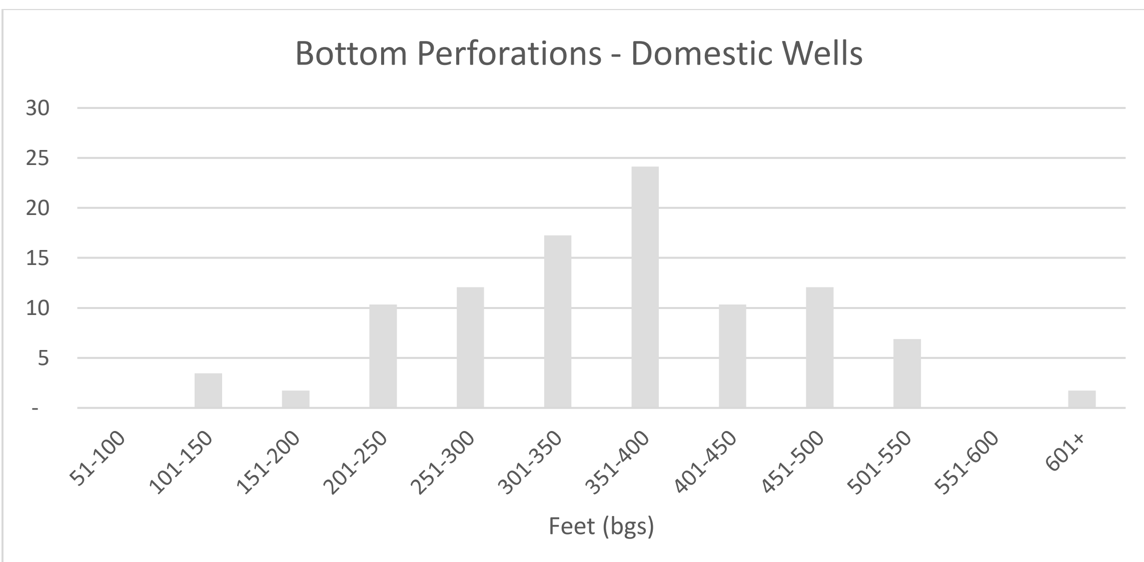


Figure 5-8b. Distribution of bottom perforations for domestic wells

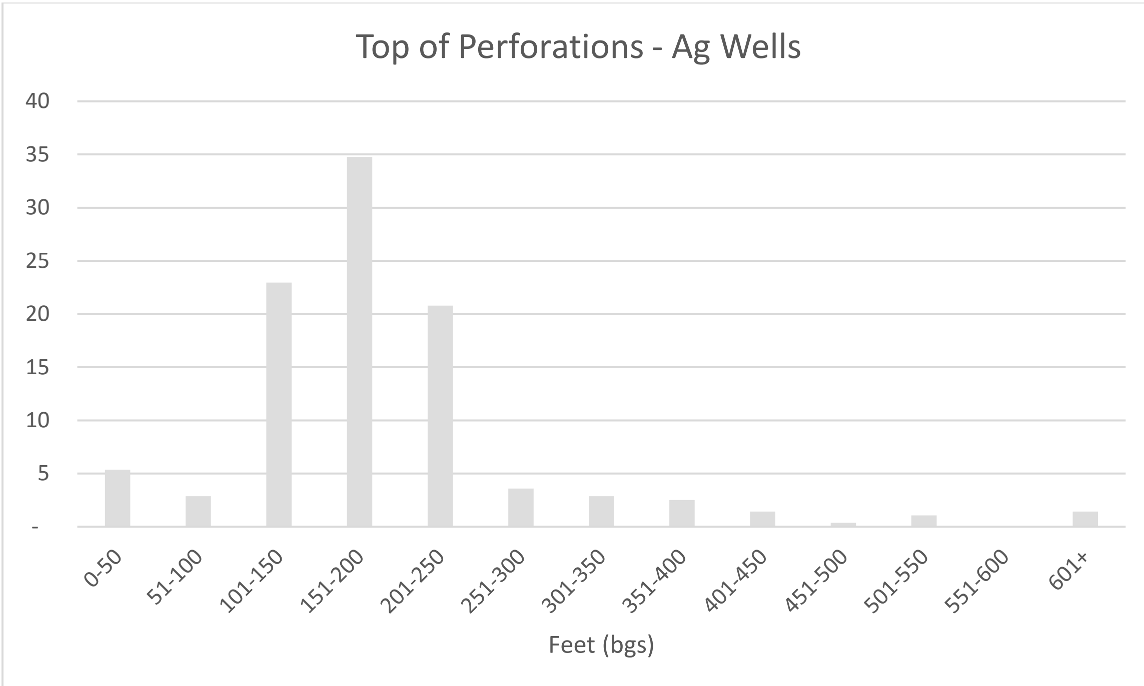


Figure 5-9a. Distribution of top perforations for agricultural wells

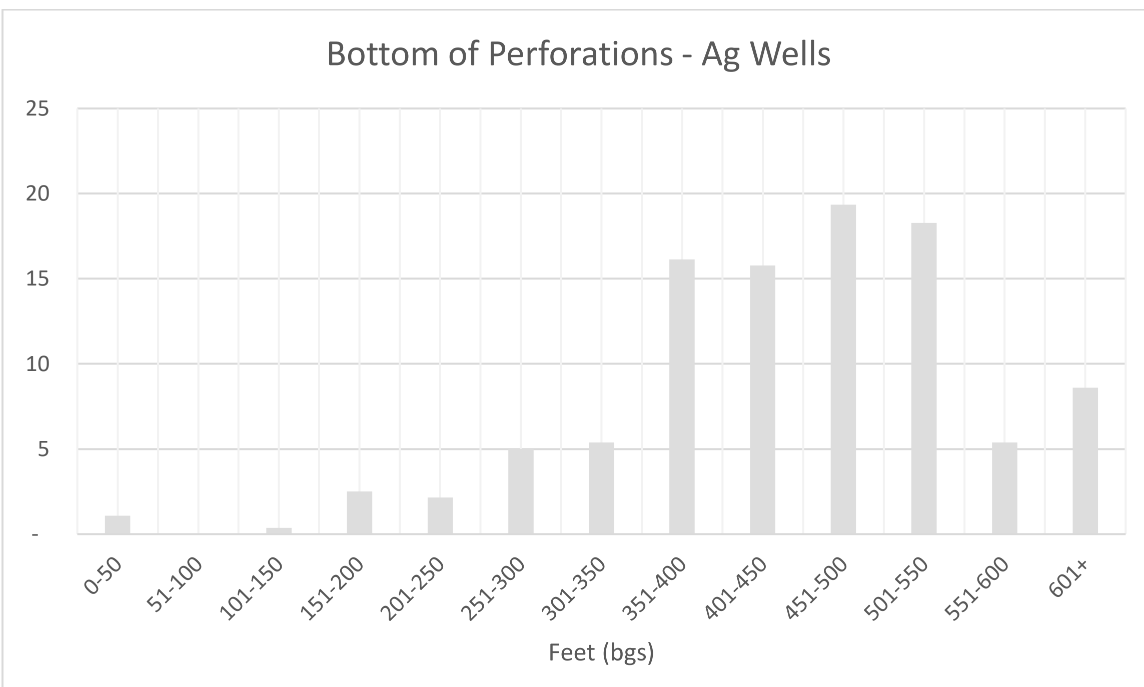


Figure 5-9b Distribution of bottom perforations for agricultural wells

Figures 5-10a through 5-10j apply data on domestic and municipal wells together with information on local hydrogeology to guide recommendations for final MTs for the network of monitoring wells. Each of the 10 charts in this series displays the clay sequences and 2015 groundwater elevations shown on Figure 5-7 together with the projected 2040 “worst case” MTs. Figures 5-10c through 5-10j also display the screened intervals of domestic wells with each domestic well shown on the figure associated with the nearest monitoring well. Figures 5-10g and 5-10h, which represent the monitoring location nearest the Community of Buttonwillow, show bars displaying the screened intervals for the Community’s domestic wells and municipal wells, respectively.

Figure 5-10a. Minimum Threshold and Measurable Objective Setting for DMW 01

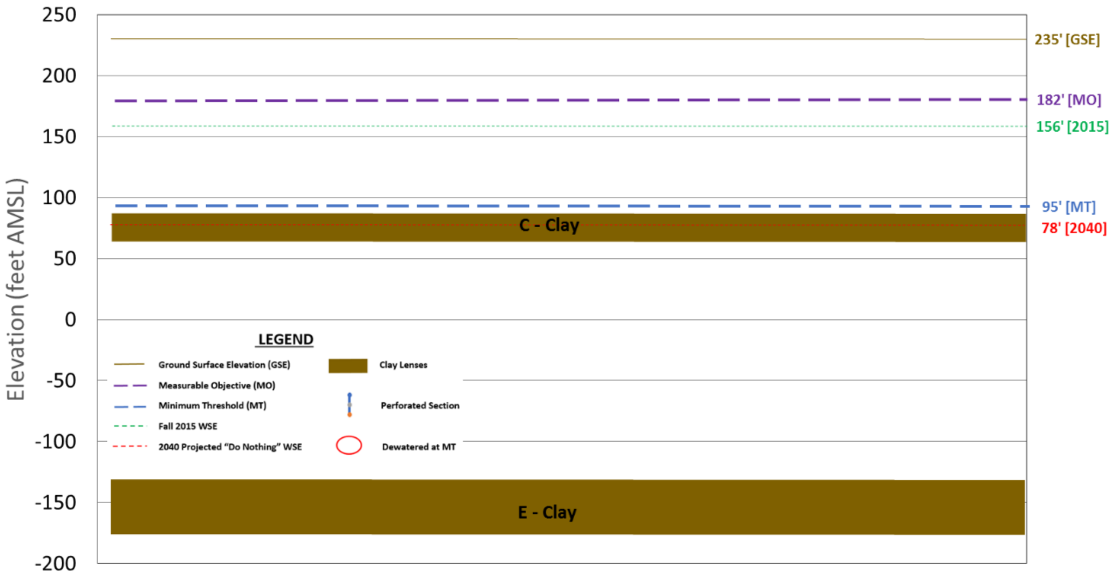


Figure 5-10b. Minimum Threshold and Measurable Objective Setting for DMW 02

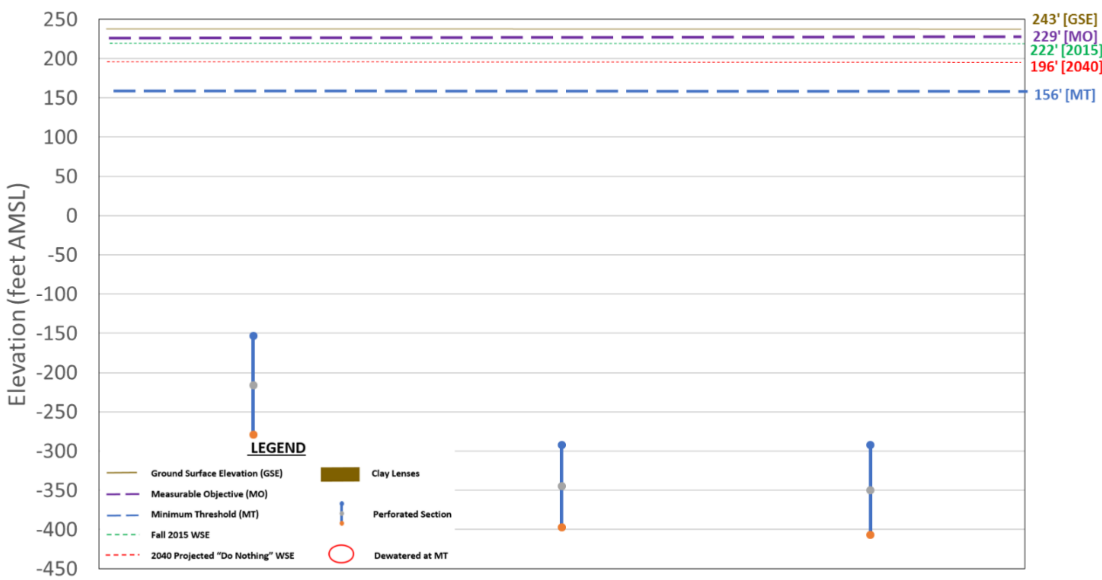


Figure 5-10c. Minimum Threshold and Measurable Objective Setting for DMW 04

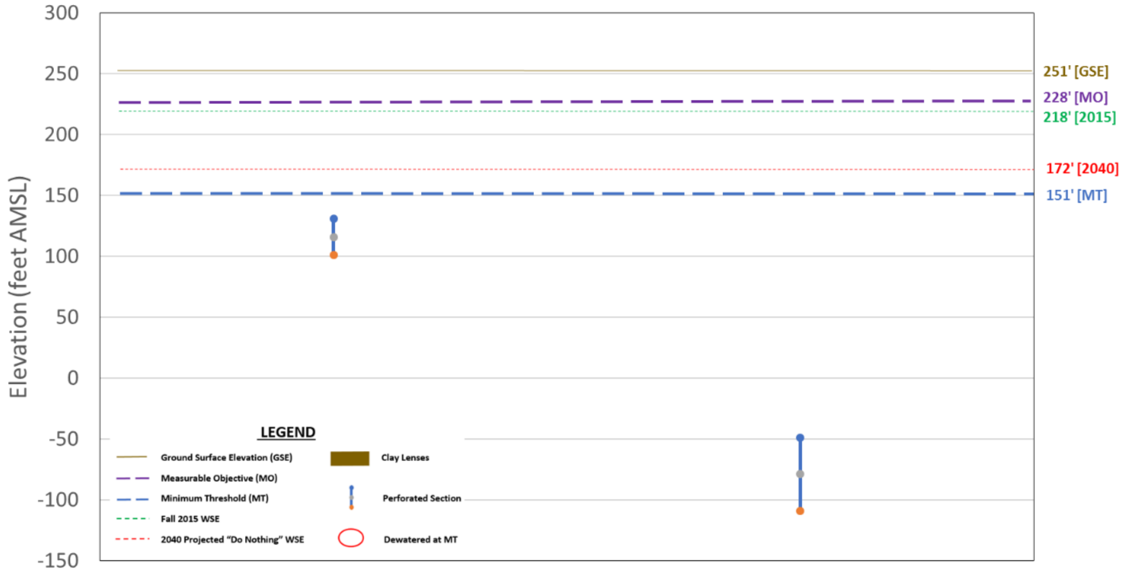


Figure 5-10d. Minimum Threshold and Measurable Objective Setting for DMW 05

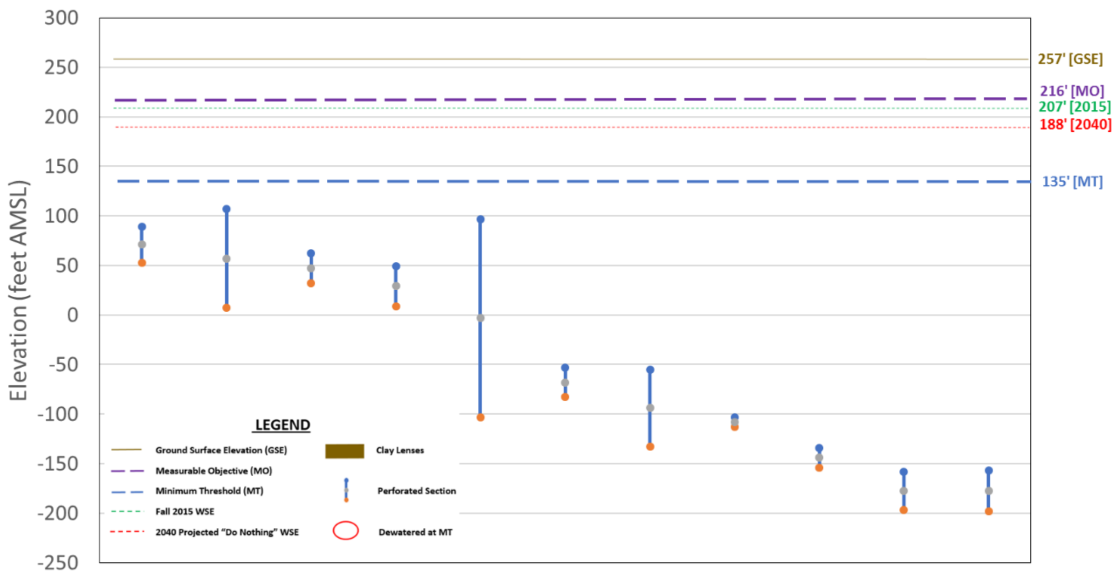


Figure 5-10e. Minimum Threshold and Measurable Objective Setting for DMW 06

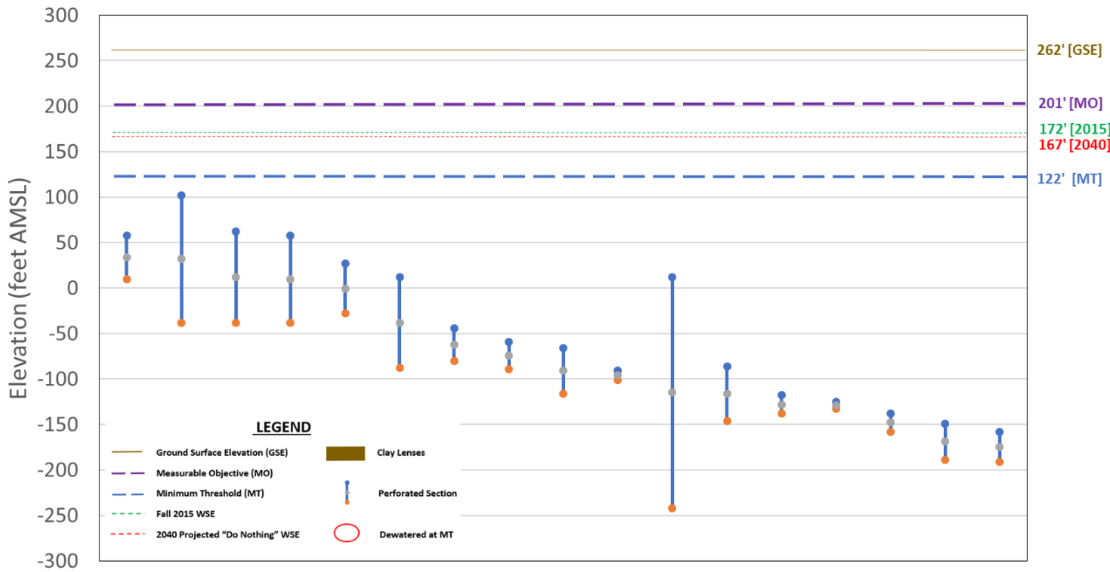


Figure 5-10f. Minimum Threshold and Measurable Objective for DMW 07

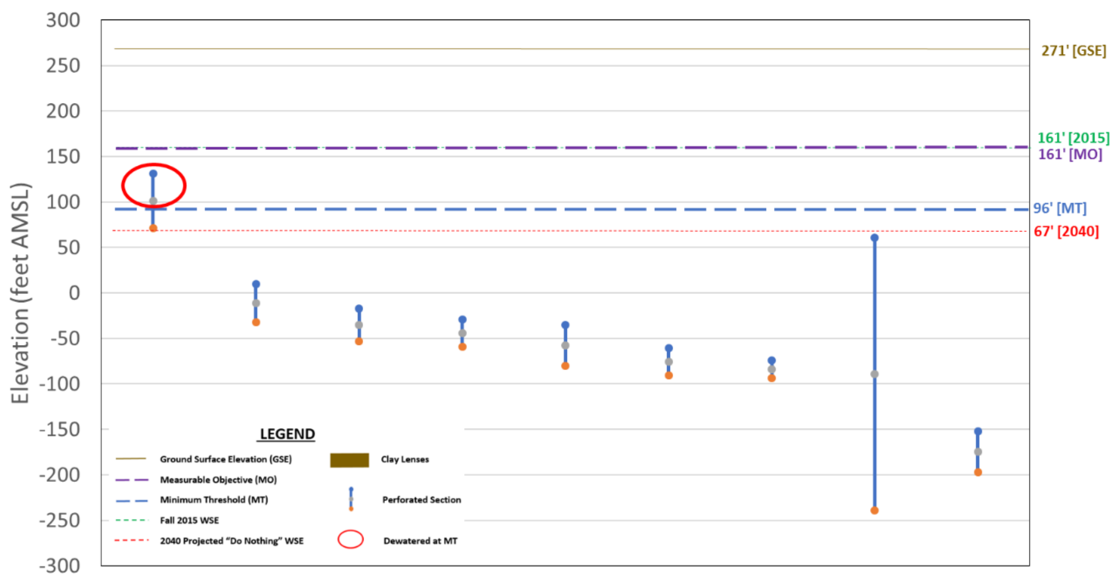


Figure 5-10g. Minimum Threshold and Measurable Objective for DMW 08 (Domestic Wells)

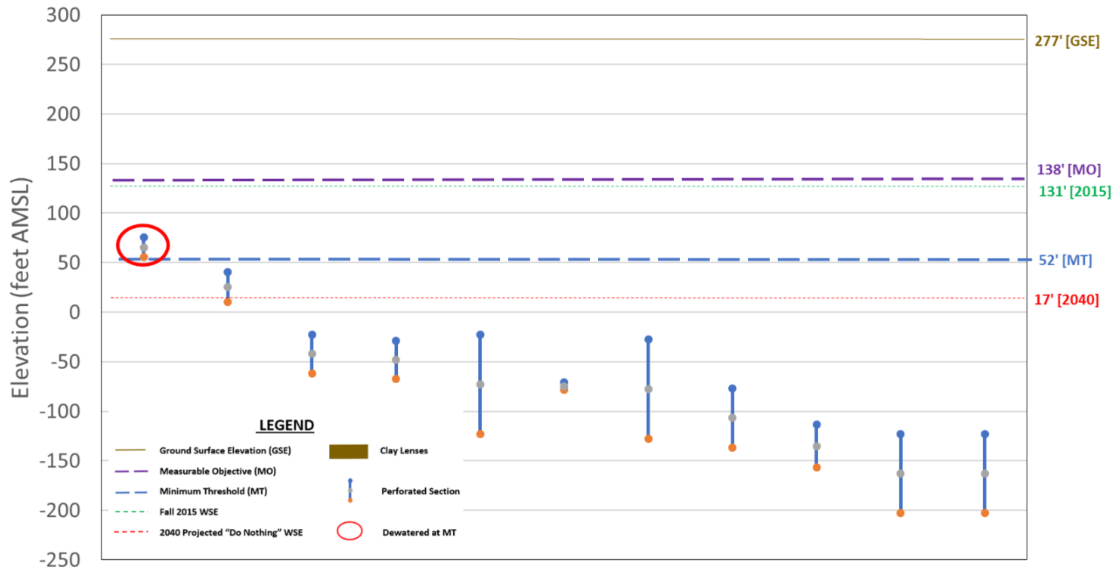


Figure 5-10i. Minimum Threshold and Measurable Objective for DMW 10a

Figure 5-10i. Minimum Threshold and Measurable Objective Setting for DMW 12b

Table 5-5 summarizes the MTs recommended for each representative monitoring well based on the information presented in the preceding series of figures.

Table 5-5. Recommended MTs at Nine Monitoring Sites

DMW No.	Figure No.	Recommended MT Elevation (ft AMSL)	Difference from 2015 Water Level (ft)
DMW 01	5.10a	El 139 ft (97 ft bgs)	-50
DMW 02	5.10b	El 95 ft (140 ft bgs)	-61
DMW 04	5.10c	El 156 ft (87 ft bgs)	-66
DMW 05	5.10d	El 151 ft (100 ft bgs)	-67
DMW 06	5.10e	El 135 ft (122 ft bgs)	-72
DMW 07	5.10f	El 122 ft (140 ft bgs)	-50
DMW 08[1]	5.10g	El 96 ft (175 ft bgs)	-65
DMW 08[2]	5.10h	El 96 ft (175 ft bgs)	-65
DMW 10a[3]	5.10i	El 52 ft (225 ft bgs)	-79
DMW 12b[4]	5.10j	EL -70 ft (359 ft bgs)	-172

1 DMW 08 relative to Domestic Wells
2 DMW 08 relative to Municipal Wells
3 Nested monitoring well DMW 10: screened above the E-clay
4 Nested monitoring well DMW 12: screened above the E-clay

For wells screened above the E-clay at each monitoring site, recommended MTs were set according to the following criteria.

- No recommended MTs were set below the top of confining or semi-confining clay layers. In most instances the governing confining layer is the E-clay. However, in the northern portion of the BMA, the semi-confining C-clay layer governed based on well designs now being prepared for the City of Porterville. This criterion is intended to minimize the risk of subsidence of critical infrastructure, a potentially costly, irreversible undesirable result.
- Recommended MTs were targeted to minimize loss of production from existing domestic and municipal wells. The GSA will develop a mitigation plan for responding to situations where declining groundwater levels interfere with groundwater production. These mitigation plans will be modeled after plans that have been approved by DWR for mitigation of wells affected by pumping for groundwater substitution transfers.
- Recommended MTs are intended to retain existing groundwater gradients within the GSA by establishing a floor for groundwater extraction that parallels groundwater elevations observed in the Fall of 2015 as illustrated below in Figure 5-12.
- Consistent with other management areas in the Subbasin, an undesirable result in the BMA is triggered when groundwater levels decline below established MTs in 40 percent

or more of the representative monitoring wells in the BMA over four consecutive bi-annual SGMA required monitoring events.

5.4.2 Measurable Objectives and Interim Milestones

The SGMA regulations describe measurable objectives and how they relate to the sustainable management of groundwater in the California Code of Regulations:

§ 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.
(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.
(c) Measurable objectives shall provide a reasonable margin of operational flexibility under adverse conditions which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty.
(d) 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.
(e) Each Plan shall describe a reasonable path to achieve the sustainability goal for the basin within 20 years of Plan implementation, including a description of interim milestones for each relevant sustainability indicator, using the same metric as the measurable objective, in increments of five years. The description shall explain how the Plan is likely to maintain sustainable groundwater management over the planning and implementation horizon.

5.4.2.1 Establishment

As described above, measurable objectives are quantitative goals that represent the Subbasin's desired groundwater conditions and allow GSAs to achieve their sustainability goals within 20 years. These objectives are set for each sustainability indicator at every representative monitoring site and use the same metrics as minimum thresholds, allowing monitored groundwater elevations to be effectively compared to both the measurable objectives (the desired level) and the minimum thresholds (the trigger level for assessment of undesirable results) to determine the margin of operational flexibility available at a given point in time as illustrated in Figure 5.1.

The BVGSA has established measurable objectives at each representative monitoring site. These MOs, together with the recommended MTs discussed above, are designed to aid in sustainable management of groundwater by allowing the GSA to:

- Withstand droughts of durations of a minimum duration of 10 years without violating any of its recommended minimum thresholds;
- Minimize the risk of significant and unreasonable subsidence;
- Minimize the risks of significant and unreasonable impacts on water quality;
- Minimize the number of existing wells whose operation is compromised by reductions in groundwater elevations, and
- Provide a margin of operational flexibility that accommodates the impacts of climate change on water supply, water use and drought response.

5.4.2.2 Considerations Used

Figures 5.11a through 5.11i show spring groundwater elevations observed at each of the nine BVGSA monitoring sites from 1993 through 2018, a period beginning in the year used as the starting point for both the groundwater modeling being prepared for the Kern County Subbasin and with the ITRC METRIC data used to estimate evapotranspiration for water budgets developed by GSAs throughout the Subbasin.

These figures illustrate how effectively the conjunctive management policies established by the BVWSD have performed throughout most of the GSA in maintaining stable groundwater elevations over a broad range of hydrologic and water supply conditions and during a period of major changes in cropping patterns and irrigation practices, a transition driven by the shift from annual crops, such as cotton, to perennial fruit and nut plantings, such as pistachios and grapes. This series of figures also demonstrates the ample margin of operational flexibility that exists between observed water levels and the proposed minimum thresholds.

Figures 5-11h and 5-11i complement figures 5-10i and 5-10j in illustrating that groundwater levels in the southern area of the BVGSA fluctuate over a wider range than in other locations, a result, as noted above, due to subsurface outflows from the BVGSA and the influence of water banks that lie immediately beyond the GSA's boundaries. One of the objectives of the BVWSD's Palms Groundwater Recharge Project, described in Section 7 – Projects, Management Programs Actions and Adaptive Management Actions, is to store water diverted from the Kern River to dampen the fluctuations caused by these conditions. The first phase of this project entered operation in 2017.

In light of the BVWSD's ability to maintain an ample operational margin throughout the entire BMA between observed groundwater levels and the proposed minimum thresholds and because groundwater levels in the BVGSA are typically higher than in surrounding areas, recommendations for measurable objectives have been guided by the observed water levels. Use of existing groundwater levels to inform measurable objectives minimizes shifts in groundwater gradients within the BMA and facilitates coordination between the BVGSA and its neighbors by minimizing changes in gradients between the GSA and surrounding areas.

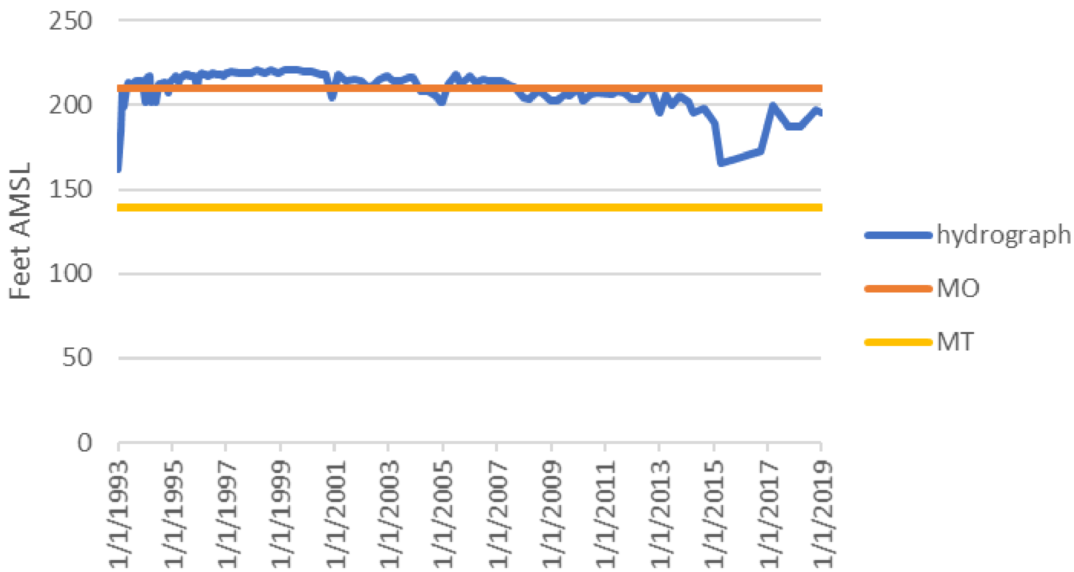


Figure 5-11a. DMW 01 Hydrographs [1993 – 2018], MO, and MT

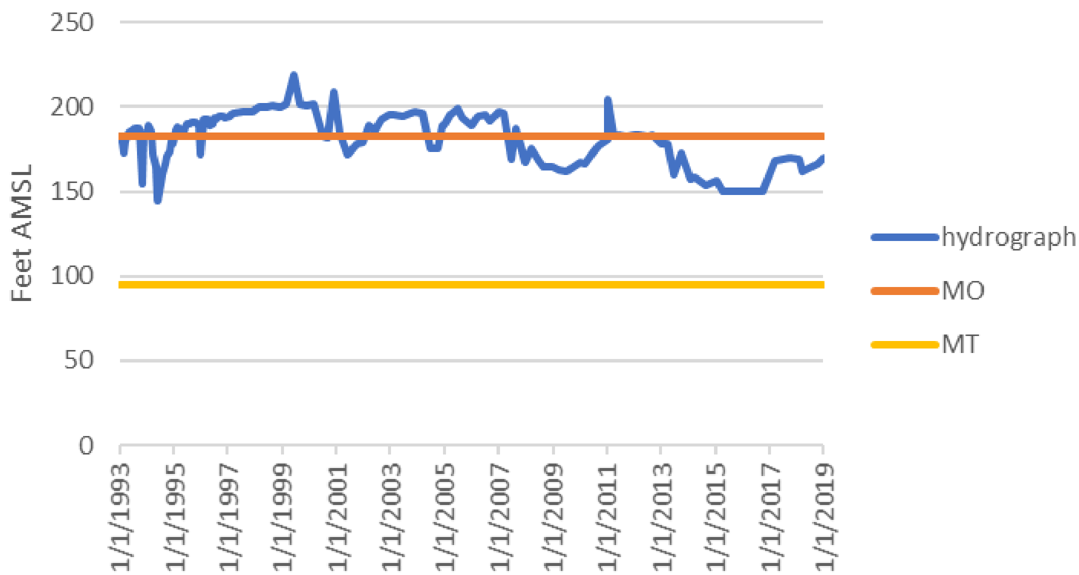


Figure 5-11b. DMW 02 Hydrographs [1993 – 2018], MO, and MT

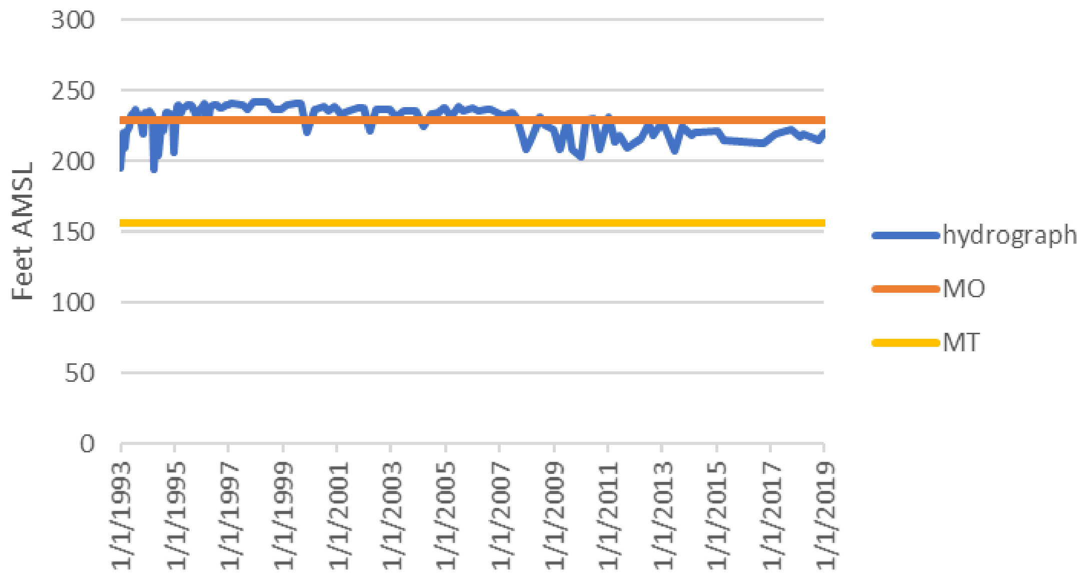


Figure 5-11c. DMW 04 Hydrographs [1993 – 2018], MO, and MT

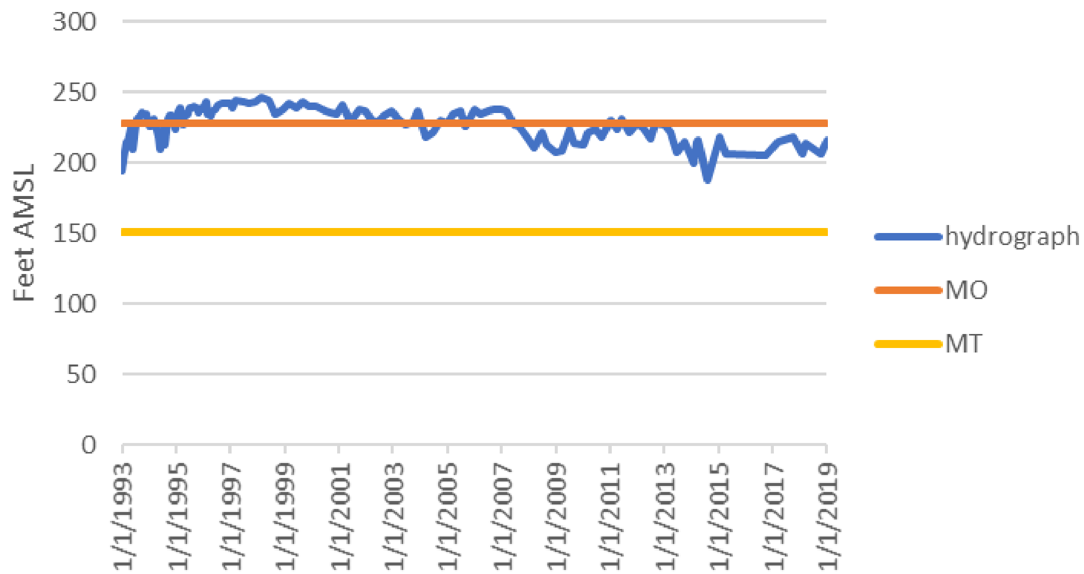


Figure 5-11d. DMW 05 Hydrographs [1993 – 2018], MO, and MT

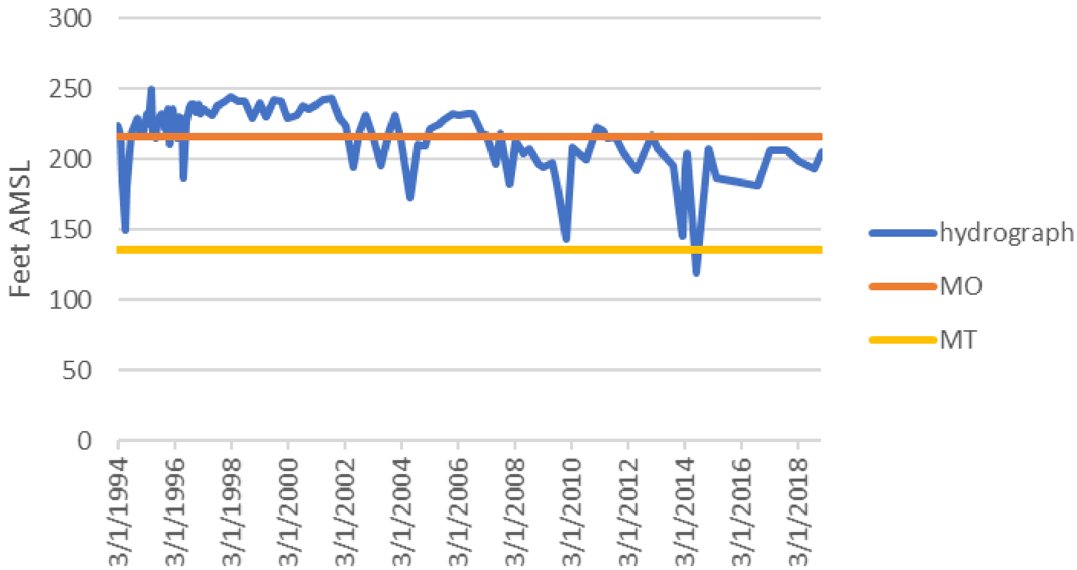


Figure 5-11e. DMW 06 Hydrographs [1993 – 2018], MO, and MT

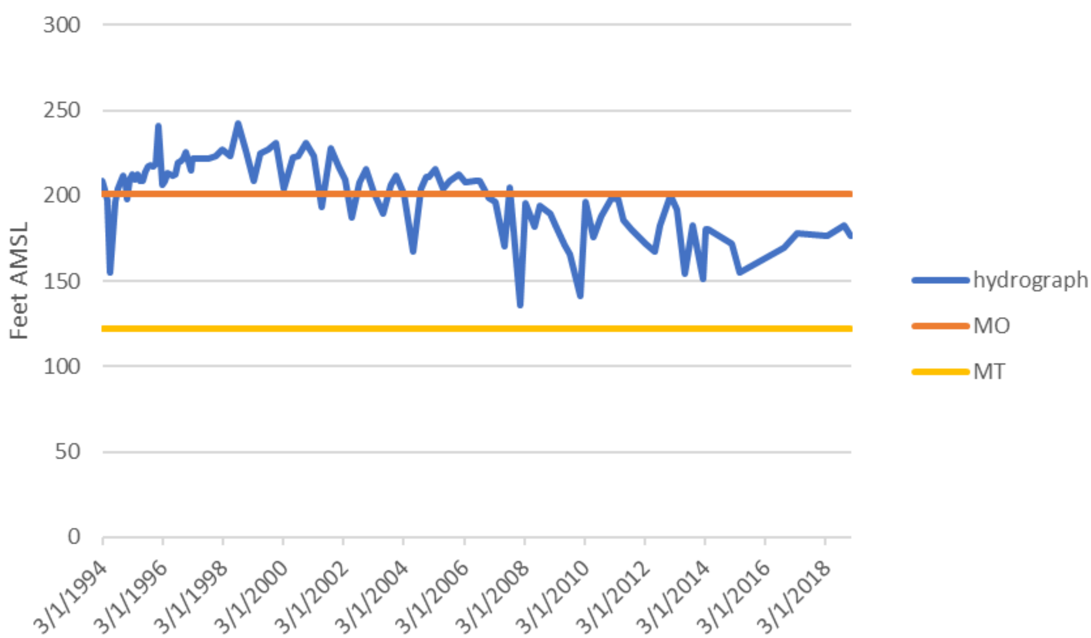


Figure 5-11f. DMW 07 Hydrographs [1993 – 2018], MO, and MT

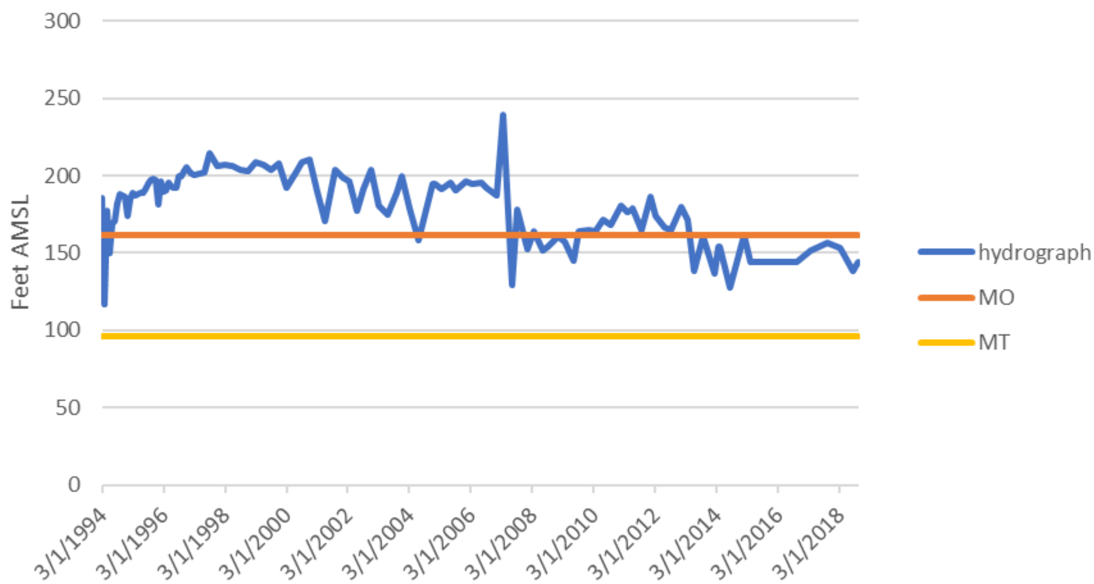


Figure 5-11g. DMW 08 Hydrographs [1993 – 2018], MO, and MT

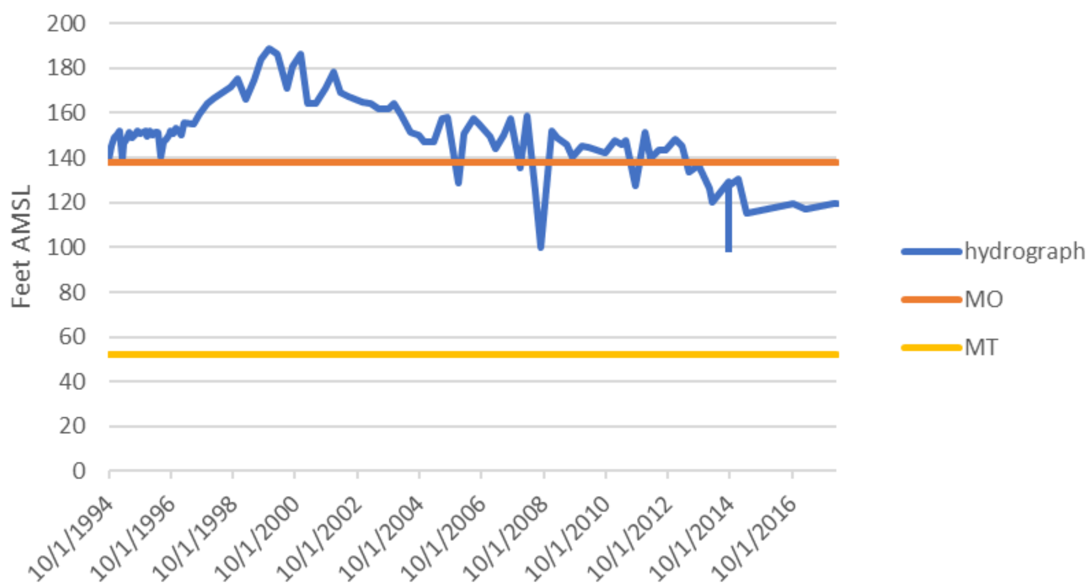


Figure 5-11h. DMW 10a Hydrographs [1993 – 2018], MO, and MT

Figure 5-11i. DMW 12b Hydrographs [1993 – 2018], MO, and MT

5.4.3 Margin of Operational Flexibility

The margin of operational flexibility within the BVGSA is the range in water levels established at each representative monitoring site between the measurable objective and the minimum threshold. The capacity to respond to droughts available within the margin of operational flexibility can be augmented during extreme drought by lowering groundwater elevations below the recommended MTs to the top of the E-clay. Although groundwater levels could be drawn below the recommended MTs on a temporary basis, operation below the MTs may require mitigation for well owners impacted during this period.

Table 5-6 summarizes the MOs, MTs, and margins of operational flexibility recommended at each of the 9 representative monitoring sites in the BVGSA network for observing chronic lowering of groundwater levels. Figure 5-12 is a graphical presentation of this data illustrating the relation between the January 2015 water levels, MOs and MTs and how the recommended margin of operational flexibility expands in the southern portion of the BMA because of the need to account for operations in adjacent areas.

Table 5-6. January 2015 Water Levels and Projected 2040 Levels

Well ID	January 2015 Levels (ft AMSL)	Recommended MOs (ft AMSL)	Recommended MTs (ft AMSL)	Margin of Operational Flexibility (ft)
dmw01	189	210	139	71
dmw02	156	182	95	87
dmw04	222	229	156	73
dmw05	218	228	151	77
dmw06	207	216	135	81
dmw07	172	201	122	79
dmw08	161	161	96	65
dwm10a[1]	131	138	52	86
dmw12b[2]	102	16	-70	86

1 Nested monitoring well DMW 10: screened above E-clay

2 Nested monitoring well DWM 12: screened above E-clay

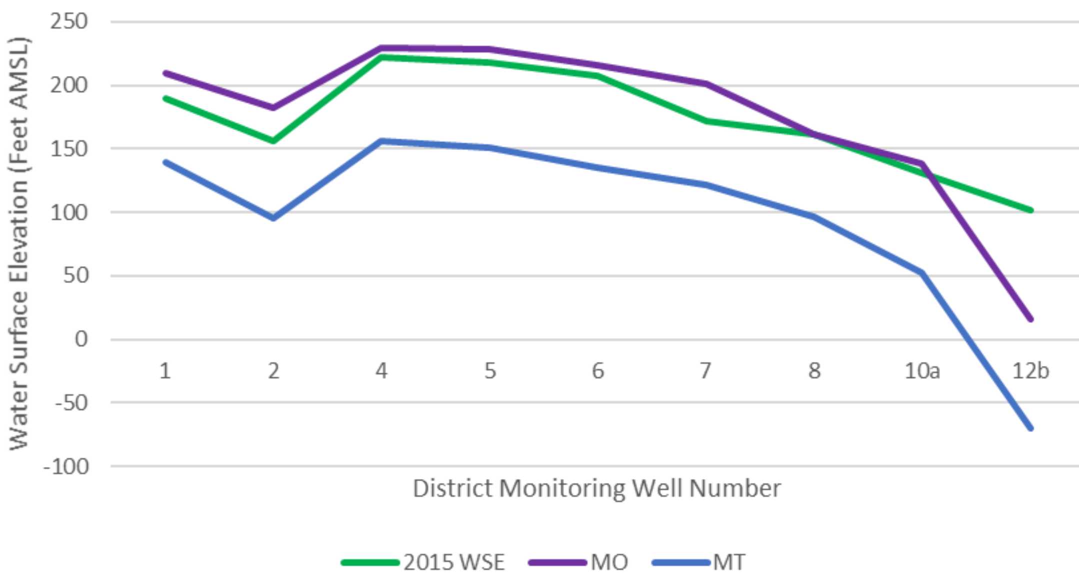


Figure 5-12. MT and MO Relative to 2015 WSE

5.4.4 Interim Milestones

Because the measurable objectives for groundwater elevations align closely with historic water levels in most of the BMA, no MA-wide interim milestones have been established to correct chronic lowering of groundwater elevations. In the extreme south of the BMA, the measurable objective has been set some distance below historic water levels because of the influence water banking activity in neighboring areas has on groundwater levels. Nevertheless, the margin of operational flexibility in this area is slightly higher than those set at most other representative monitoring locations. While no interim milestone has been set in this area, it is recognized that groundwater levels are likely to fluctuate over a wider range than in other locations because of the activity of neighboring water banks and in response to development and operation of the Palms Project described in Section 7 – Projects, Management Actions, and Adaptive Management Actions.

5.4.5 Representative Monitoring

As discussed in the preceding section, Sustainable Management Criteria for monitoring chronic lowering of groundwater levels were established at each of the BVGSA's 9 representative monitoring sites. These sites will be observed throughout the implementation of SGMA to monitor this sustainability indicator. A more complete discussion of the BVGSA's monitoring network is presented in Section 4 – Monitoring Networks.

5.4.6 Management Areas

The BVGSA has two management areas, the Buttonwillow MA (BMA) which aligns closely with the boundaries of the BVWSD's Buttonwillow Service Area and the Maples MA (MMA) whose boundaries match those of the BVWSD's Maples Service Area. The two MAs are physically distinct being separated by 15 miles. The MMA lies within HZ 10 and within the Kern River GSA (KRGSA). Because of the MMA's location within the KRGSA, Sustainable Management Criteria for this MA align with those established for other areas of the KRGSA as presented below in Section 5.9. As described throughout this GSP, the BMA is a distinct entity with respect to its hydrogeologic features and management practices. For this reason, the BMA will be treated as a single unit allowing groundwater levels to be monitored and managed consistently throughout the entire MA.

5.5 Reduction in Groundwater Storage

5.5.1 Minimum Thresholds

The draft BMP on Sustainable Management Criteria (DWR, 2017) defines the minimum threshold for significant and unreasonable reduction in groundwater storage as follows:

> The minimum threshold for reduction of groundwater storage is a volume of groundwater that can be withdrawn from a basin or management area, based on measurements from multiple representative monitoring sites, without leading to undesirable results. Contrary to the general rule for setting minimum thresholds, the reduction of groundwater storage minimum threshold is not set at individual monitoring sites. Rather, the minimum threshold is set for a basin or management area.

5.5.1.1 Establishment

Chronic lowering of groundwater levels is an undesirable result that increases the cost to access groundwater and, because of its local impacts, is governed using MTs established for individual monitoring sites. In contrast, significant and unreasonable reduction in groundwater storage constrains the amount of groundwater available at any cost. Both sustainability indicators have broad implications on the Kern County Subbasin's capacity to manage groundwater sustainably.

Since the primary causes of both chronic lowering of groundwater levels and significant reductions in groundwater storage are extended periods of extraction beyond the sustainable yield, the BVGSA has used data from wells included in the GSA's representative monitoring network to glean information on historic groundwater elevations. This information, together with data on the characteristics of the principal aquifer, was then used to define the volume of groundwater that can be extracted within the GSA's boundaries without leading to undesirable results.

The minimum threshold set for changes in groundwater storage is related to minimum thresholds for groundwater levels as both are monitored by observing groundwater elevations at representative monitoring wells. Breaches in minimum thresholds for groundwater levels are observed directly and may trigger localized responses. Change is storage is derived from changes in water levels that are used to estimate the volume of groundwater in storage in the entire Buttonwillow Management Area. Therefore, although there is a clear relation between monitoring of minimum thresholds for changes in elevation and changes in storage, the minimum thresholds for groundwater levels are local trigger elevations, while the minimum threshold for storage is a volume of groundwater storage in the entire management area.

5.5.1.2 Considerations Used

What are the historical trends, water year types, and projected water use in the basin? Historical trends in water use in the BVGSA's portion of the Kern County Subbasin have been shaped by agricultural land use and by water year types. As land and water uses within the BVGSA are projected to remain dominated by irrigated agriculture, the same factors that have influenced past trends are expected to extend into the future. Section 2 - Basin Setting provides an extensive discussion of water uses within the BVGSA and of historical and projected trends.

Table 5.7 lists water year types from 1993 through 2017 for the Sacramento Valley and San Joaquin Valley indices. Both indices are shown because of the BVWSD's access to water diverted from the Kern River and exported from the Sacramento-San Joaquin Delta.

Table 5-7. Sacramento Valley and San Joaquin Valley Water Year Types

Year	Year Type	
	Sacramento Valley	San Joaquin Valley
1993	AN	W
1994	C	C
1995	W	W
1996	W	W
1997	W	W
1998	W	W
1999	W	AN
2000	AN	AN
2001	D	D
2002	D	D
2003	AN	BN
2004	AN	D
2005	AN	W
2006	W	W
2007	D	C
2008	C	C
2009	D	BN
2010	BN	AN
2011	W	W
2012	BN	D
2013	D	C
2014	C	C
2015	C	C
2016	BN	D
2017	W	W

C – Critical
D - Dry
BN - Below Normal
AN - Above Normal
W – Wet

What groundwater reserves are needed to withstand future droughts? The elevation differences between the recommended measurable objectives and recommended minimum thresholds used to monitor chronic lowering of groundwater levels have been applied to estimate the volume contained between these two boundaries with this volume being the reserve capacity available to withstand future droughts. Surfaces for these groundwater elevations were created using numerical models and GIS techniques based on elevations from the monitoring sites and other wells within and adjacent to the BSA. The data was used to create surfaces for the MOs and MTs that defined the upper and lower bounds of the drought reserve portion of the principal aquifer system (the margin of operational flexibility). This volume, together with a range of specific yield estimates of the principal aquifer system [0.10 and 0.20], presented in Section 2 - Basin Setting, resulted in a required drought reserve contained within the margin of operational flexibility that ranges from 362,000 AF to 724,000 AF, which, when combined with the reserve requirements for other areas of the Kern County Subbasin, form the basis for computing the volume of groundwater that can be withdrawn from the Subbasin without leading to undesirable results. Table 5-8 presents a summary of the calculation to arrive at an estimate for the drought reserve.

Table 5-8. Estimated Drought Reserve

Total Volume	3,620,000	AF
Specific Yield: Low	0.10	
Specific Yield: High	0.20	
Drought Reserve: Low	**362,000**	**AF**
Drought Reserve: High	**724,000**	**AF**
Drought Reserve: Average	**543,000**	**AF**

In addition to the drought reserve contained within the margin of operational flexibility, water stored within the aquifer zone lying between the recommended MTs and the top of the E-clay, estimated by the methods described above, yield an average value of 1,804,000 AF that can be accessed on a temporary basis to augment the storage available above the recommended MTs. During these extreme events, the recommended MTs will remain the primary metrics for avoidance of undesirable results. Table 5-9 presents a summary of the calculation to arrive at an estimate for water that is available for temporary access.

Table 5-9. Estimated Temporary Access Drought Reserve

Total Volume	12,029,000	AF
Specific Yield: Low	0.10	
Specific Yield: High	0.20	
Temporary Access: Low	**1,203,000**	**AF**
Temporary Access: High	**2,405,000**	**AF**
Temporary Access: Average	**1,804,000**	**AF**

- Have production wells ever gone dry? One production well, DW-1, in the extreme south of the BVGSA went dry in 2015 during the recent drought. Water levels in this well have since recovered, and the well is back in operation. The location of DW-1, in an oil field area near Tupman is not typical of other production wells in the GSA, and no other wells in the BVGSA have ever gone dry. The preceding tables of well depths and screened intervals for agricultural, municipal, domestic and industrial wells (Tables 5-2 and 5-3) show that minimum wells depths in all categories extend below groundwater levels observed during the recent drought with the exception of this one location.

- What is the effective storage of the basin? This may include understanding of the:
  - Average, minimum, and maximum depth of municipal, agricultural, industrial and domestic wells.

Table 5-10 presents mean, median, minimum and maximum depths of municipal, agricultural, industrial and domestic wells, information also shown in Table 5-2.

Table 5-10. Well Depth Data (duplicate of Table 5-2)

Depth (ft)/ Use	Municipal	Agricultural	Domestic	Industrial
Maximum	700	1,101	522	500
Minimum	443	138	150	150
Median	498	460	360	346
Mean	547	477	356	330

  - Impacts on pumping costs (i.e., energy cost to lift water).

The effective storage of the BMA portion of the Kern County Subbasin is defined as the storage capacity of the principal aquifer between pumping levels observed in 2015 and the top of the E-clay. This definition restricts effective storage to the aquifer zone that can be accessed without raising risks of significant and unreasonable levels of subsidence or reductions of groundwater quality. As displayed below in Table 5-11, the effective storage capacity of the principal aquifer between the January 2015 groundwater contour and the top of the E-clay is estimated to be 2,329,000 AF, 129 percent of the reserve requirement computed above.

Table 5-11. Estimated Effective Storage of the BMA

Total Volume	15,529,000	AF
Specific Yield: Low	0.10	
Specific Yield: High	0.20	
Effective Storage: Low	**1,553,000**	**AF**
Effective Storage: High	**3,106,000**	**AF**
Effective Storage: Average	**2,329,000**	**AF**

- What are the adjacent basin's minimum thresholds? The BVGSA lies within the Kern County Subbasin and does not border any adjacent basins. The minimum thresholds for groundwater storage in the neighboring Kern Groundwater Authority GSA is presented in its Umbrella GSP and included in Appendix F. Note that the Kern Groundwater Authority GSA utilized groundwater levels as a proxy for groundwater storage.

- Consistent with other management areas in the Subbasin, an undesirable result in the BMA is triggered when groundwater levels decline below established MTs in 40 percent or more of the representative monitoring wells in the GSA over four consecutive bi-annual SGMA required monitoring events. As described above, there is considerable reserve storage between the MTs and the E-clay so that if water levels were to drop below MTs, storage would remain above the E-clay to allow time for implementation of corrective actions.

5.5.2 Measurable Objectives and Interim Milestones

Based on the following language from the SGMA regulations governing measurable objectives, the BVGSA will use the representative measurable objectives described above for groundwater elevations to serve as a proxy for attainment of measurable objective related to groundwater storage within the boundaries of the GSA. The groundwater storage objectives established for the GSA will contribute to definition of the measurable objective for the Kern County Subbasin.

> *(d) 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 value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence.*
> *(e) Each Plan shall describe a reasonable path to achieve the sustainability goal for the basin within 20 years of Plan implementation, including a description of interim milestones for each relevant sustainability indicator, using the same metric as the measurable objective, in increments of five years. The description shall explain how the Plan is likely to maintain sustainable groundwater management over the planning and implementation horizon.*

5.5.2.1 Establishment

As described above, the measurable objectives for groundwater elevations align closely with elevations observed in 2015. As these groundwater elevations serve as proxies for groundwater storage, it follows that storage volumes estimated for 2015 will serve as proxies for measurable objectives within the BMA that can be used in development of the basin-wide measurable objectives for groundwater storage required by SGMA.

As described above, the measurable objectives and minimum thresholds at each of the 9 monitoring sites used in the BMA to observe chronic lowering of groundwater levels have been applied in the computation of the drought reserve requirements with this estimate contributing to determination of the overall groundwater reserve capacity for the Subbasin.

5.5.2.2 Considerations used

The primary consideration used in setting measurable objectives is to maintain groundwater storage adequate to enable the Kern County Subbasin to weather future droughts without leading to undesirable results. The margin of operational flexibility set for chronic lowering of groundwater levels was used in estimating the groundwater reserves available for responding to drought.

5.5.3 Margin of Operational Flexibility

The margin of operational flexibility within the BVGSA is the volume of effective storage between the recommended MOs and the recommended MTs defined for management of chronic lowering of groundwater elevations. This volume, displayed in Table 5-8 of approximately 543,000 AF, constitutes the GSA's drought reserve. As displayed in Table 5-9, the capacity to respond to droughts available within the margin of operational flexibility can be augmented by approximately 1,804,000 AF of temporary access storage available between the recommended MTs and the top of the E-clay. Although groundwater storage could be reduced below the volume maintained by adherence to the recommended MTs on a temporary basis, operation below the MTs may require mitigation for well owners impacted during this period.

5.5.4 Interim Milestones

While no interim milestones for chronic reduction of groundwater levels, the proxy for reduction of groundwater storage, have been set in the BMA, it is recognized that groundwater levels are likely to fluctuate in the southern portion of the MA which will result in fluctuations in groundwater storage due to the activity of neighboring water banks and in response to development and operation of the Palms Project. Therefore, groundwater conditions in the BVGSA are unlikely to affect setting of interim milestones for the Kern County Subbasin.

5.5.5 Representative Monitoring

Sustainable management criteria for reductions in groundwater storage are addressed using the same monitoring network and metrics as chronic lowering of groundwater levels using data collected throughout the Subbasin to monitor basin-wide minimum thresholds and measurable objectives.

An important data gap related to estimating reductions in groundwater storage is the completeness and reliability of aquifer parameters available to convert observed changes in groundwater levels to corresponding changes in storage. Continued development and calibration of groundwater models is expected to improve our understanding of these relations for various aquifer materials and conditions.

5.5.6 Management Areas

Because reduction of groundwater storage has sustainable Management Criteria set at a Subbasin scale, monitoring of groundwater levels in the BMA and in the KRGSA will be used to capture the influence of changes in storage within the BVGSA's two management areas on Subbasin-wide minimum thresholds and measurable objectives. Section 5.10 discusses change of storage in the context of the MMA.

5.6 Degraded Water Quality

5.6.1 Minimum Thresholds

The minimum threshold metric for degraded water quality shall be water quality measurements that indicate degradation at the monitoring site. This can be based on migration of contaminant plumes, number of supply wells, volume of groundwater, or the location of a water quality isocontour within the basin. Depending on how the GSA defines the degraded water quality minimum threshold, it can be defined at a site, along the isocontour line, or as a calculated volume. While groundwater elevations are not used as proxies for determination of minimum thresholds, recharge of water from the Kern River and SWP that supports groundwater levels also protects groundwater quality because of the high quality of the recharged water.

5.6.1.1 Establishment

The purpose of this section is to review groundwater quality conditions in the BVGSA that may affect the supply and beneficial uses of groundwater as stated under CCR §354.16. This section includes a discussion of water quality standards and information relevant to groundwater quality within the GSA.

Agricultural Wells

Agricultural wells are used to meet crop demands during periods when deliveries of surface water are insufficient. The Buena Vista Coalition monitors groundwater quality through its participation in the Irrigated Lands Regulatory Program (ILRP). Data collected for the (ILRP's) Groundwater Quality Trend Monitoring Work Plan (GQTMWP) and reported through the GAMA database will be a major source for monitoring water quality in agricultural wells.

Domestic Wells

Domestic wells are used exclusively to supply general household needs of the property owner and are typically shallower than municipal or agricultural wells. Therefore, domestic wells are the first to be impacted by surface contaminants leaching into the groundwater.

Currently, information about domestic wells is limited. However, there is an effort being led by the SWRCB, as well as multiple other agencies, to explore the best sources of information and conduct a Needs Assessment of domestic wells in areas vulnerable to contamination.

Public Water Systems

While land use within the BVGSA is predominately agricultural, 4 public water systems have been identified through the GAMA (Groundwater Ambient Monitoring and Assessment) data base. Two of these systems, the Buttonwillow County Water District and the Mirasol Company, are classified as community water systems, meaning there are at least 15 service connections, or

25 year-round residents are served. The remaining systems are non-transient, non-community (NTNC) water systems. Table 5-12 lists the 4 public water systems and their classification, estimated population served, number of connections and number of wells. Figure 1-5 – Permitted Public Water Systems shows their locations within the Buttonwillow Management Area (BMA). (Figure 1-5, Refer to Figures Tab)

Community and NTNC water systems are required to test for most regulated constituents at least once every 3 years. Water quality data from regulated drinking water systems is available through the State Drinking Water Information System (SDWIS).

Table 5-12. Public Water Systems Within the BVGSA

Water System #	Water System Name	Type	Population Served	Number of Connections	Number of Wells
1500152	Mirasol Company	C	29	13	2[2]
1510011	Buttonwillow CWD[1]	C	1,266	442	3
1500495	Aera Energy – LLC	NTNC	50	80	5[3]
1503671	Sunnygem Juice Plant	NTNC	60	7	1

C = Community water system
NTNC = Nontransient non-community water system
[1] Well #1 taken out of service because of TDS level of 1,100 mg/L
[2] Water quality data from 1 Mirasol Company well reported in SDWIS
[3] Water quality data from 2 Aera Energy wells reported in SDWIS

Source: Tulare Lake Basin Water Alliance

5.6.1.2 Considerations Used

- What are the historical and spatial water quality trends in the basin? Figures 2-7 through 2-12 are pairs of maps displaying the spatial distribution of three water quality constituents prominent in the BVGSA: Nitrate, TDS, and Arsenic. Each of the constituents is displayed in two figures, the first based on data covering the period up to 2000 and the second based on data from 2001 through 2017.
- What is the number of impacted supply wells? Only one production well, Buttonwillow CWD Well #1 has been taken out of service because of water quality limitations, high TDS levels. Two BVWSD production wells, DW-3 and DW-6, have reported nitrate readings that exceeded 40 mg/L. Both wells remain active and are in a High Vulnerability Area defined by the ILRP that is being managed under a Groundwater Quality Management Plan developed by the Buena Vista Coalition.
- What aquifers are primarily used for providing water supply? The principal aquifer system for the BVGSA lies in the Tulare Formation.
- What is the estimated volume of contaminated water in the basin? Although water in the principal production aquifer varies in quality, all water in this aquifer is generally suitable for domestic and agricultural purposes.
- What are the spatial and vertical extents of major contaminant plumes in the basin, and how could plume migration be affected by regional pumping patterns? There are no major contaminant plumes identified within the boundaries of the BVGSA.
- What are the applicable local, State, and federal water quality standards? Federal and state drinking water standards are often referenced when discussing water quality. However, because the predominant land use in the BVGSA is agriculture, the agricultural *Water Quality Goals* (Ag Goals) will also be considered for evaluation of groundwater

quality, and the most applicable metric, Drinking Water Standard or Ag Goal, will be used as a reference point when discussing each constituent.

- What are the major sources of point and nonpoint source pollution in the basin, and what are their chemical constituents? Major sources of non-point source pollution in the BVGSA include irrigated agriculture and septic systems. There are no major point sources of pollution in the GSA.
- What regulatory projects and actions are currently established to address water quality degradation in the basin (e.g., an existing groundwater pump and treat system), and how could they be impacted by future groundwater management actions? The major regulatory program in force in the BVGSA is the Central Valley Regional Water Quality Control Board's Irrigated Lands Regulatory Program. This program addresses degradation of water quality resulting from practices associated with irrigated crop production.
- What are the adjacent basin's minimum thresholds? The BVGSA lies within the Kern County Subbasin and does not border any adjacent basins. Minimum thresholds for water quality in the Kern Groundwater Authority GSA, an adjacent GSA to BVGSA, are included in Appendix F. Note that the Kern Groundwater Authority GSA utilized groundwater levels as a proxy for water quality. Minimum thresholds established for water quality in the BVGSA tier off those established by existing regulatory programs governing water quality in the area for irrigated agriculture and for municipal use. Because these standards apply uniformly over the GSA, the corresponding minimum thresholds are also uniform and are the lower of the two standards as shown in Table 5-13 - List of Constituents and Standards. Because MTs are based on established standards, all MTs align with state, federal, or local standards.
- An undesirable result will exist if any applicable beneficial use COC value that is greater than the current MCL and a value increase of greater than 10 percent from the 2015-2020 value. Because water uses in the BVGSA are dominated by agriculture, management of groundwater quality will be governed by compliance with the Irrigated Lands Regulatory Program.

5.6.2 Measurable Objectives and Interim Milestones

5.6.2.1 Establishment

As described in Section 2 – Basin Setting, the BVGSA is part of an inland groundwater basin with no significant outflow. Because salts imported into the area have no natural outlet, the complex hydrogeologic processes that dissolve, transport, dilute, concentrate, and precipitate salts have the net effect of increasing the mass of salts residing in the area (KRWCA, 2015). The most prominent of these mechanisms involves salts conveyed in water imported via the California Aqueduct and applied to irrigated lands. Because of the dominance of irrigated agriculture in the GSA, the water quality conditions faced by the BVGSA are characteristic of rural areas with an absence of contaminate plumes or clean-up sites associated with more industrialized areas.

The goal of water quality management under SGMA in the BVGSA is to avoid degradation of groundwater quality by supporting the objectives of established water quality regulatory programs and to correct exceedances in constituent concentrations detected under these programs. For this reason, no Measurable Objectives have been established for water quality that are specific to compliance with SGMA.

5.6.2.2 Considerations Used

Groundwater conditions in the BVGSA were evaluated using a combination of water quality data from representative wells (used to establish and monitor sustainable management criteria) and data on wells belonging to public water systems drawn from the 7 wells reported in the SDWIS system. All available water quality data was evaluated to identify constituents of concern. Not all constituents identified in Table 5-13 as being commonly found in the Kern County Subbasin are found at concerning concentrations in the BVGSA.

Table 5-13. List of Constituents and Standards

Constituent	Units*	Drinking Water Standard	Agricultural Water Quality Goal	Minimum Thresholds
Arsenic	ppb	10	100	10
Boron	ppb	1,000	700	700
Chloride	ppm	250	106	106
Dibromochloropropane (DBCP)	ppt	2	n/a	2
Hexavalent Chromium	ppb	n/a	n/a	n/a
Nitrate (nitrate as nitrogen)	ppm	10**	n/a	10
Sodium	ppm	n/a	69	69
1,2,3-Trichloropropane (TCP)	ppt	5	n/a	5
Total Dissolved Solids (TDS)	ppm	500***	450	450

*ppt = parts per trillion
ppb = parts per billion
ppm = parts per million

**equivalent to an MCL of 45 for Nitrate as NO_3
***Secondary MCL

TCP, Cr6 and DBCP

TCP is a newly regulated synthetic organic chemical. The State Water Board reports that contamination in the Central Valley is predominately from legacy applications of certain soil fumigants. The drinking water MCL is 5 ppt; there is no Ag goal. While TCP contamination is widespread throughout the Subbasin, there appears to be less occurrence in areas such as the BVGSA where the E-clay is present. Of the 7 public supply wells tested, none have data reported on TCP.   Similarly, all public water supply wells in the BVGSA report concentrations of Cr6 and DBCP that are below the levels of detection. None of these three constituents are monitored in wells reported in the BVWSD's STORM database.

Boron

Boron has not been reported for any of the 7 public water supply system wells in the SDWIS database. The boron levels reported in the STORM database are all below the Ag Goal of 700 ppb with a maximum reported reading of 385 ppb at DMW 03.

Nitrate

Nitrate contamination is a significant concern in rural communities, particularly where agriculture is the predominant land use. However, other significant sources of nitrate may include municipal water treatment plants and septic systems. Since municipal services (drinking water or wastewater collection systems) are available only for the Community of Buttonwillow, domestic and public wastewater disposal in most of the BVGSA is through onsite septic systems.

Nitrate can be naturally present at low concentrations in groundwater, typically less than 2 ppm. Moderate and high concentrations generally occur because of human activities. Septic systems typically contribute moderate concentrations between 5 and 15 ppm of nitrate as nitrogen. Typically, higher concentrations (greater than 20 ppm) are associated with fertilizers applied to crops. Nitrate contamination is a significant public health concern because of its acute health effects. High concentrations of nitrate are typically found in unconfined aquifers such as the BVGSA's principal aquifer system.

Examination of data from the BVWSD STORM database showed nitrate levels are generally well below the MCL with only 3 readings over the drinking water MCL. Two of these readings (10.23 mg/L and 10.62 mg/L) were recorded at DW06 and one (10.39 mg/L) was recorded at DW03. Both wells lie in the Southern High Vulnerability Area designated under the Irrigated Land Regulatory Program for the Buena Vista Coalition. A Groundwater Quality Management Plan has been developed for monitoring groundwater in this area and for correcting the causes of observed exceedances. The elevated nitrate concentrations observed in DW03 and DW06 and noted on Table 5-14 may result from agricultural practices, operation of a nearby wastewater treatment plant or a combination of factors.

Table 5-14. Summary of Nitrate Prevalence in BVGSA Wells

Nitrate Concentrations (ppm) (# of readings)		
0-5	**6-10**	**>11**
83	8	3

Data from the SDWIS system for the 7 wells belonging to public water systems showed no readings above 5 ppm as shown in Table 5-15.

Table 5-15. Summary of Nitrate Prevalence Among Public Water Systems

	Nitrate Concentrations (# of readings)		
Water System	**0-5 ppm**	**6-10 ppm**	**>11 ppm**
1500152 – Mirasol Company	11	0	0
1510011 – Buttonwillow CWD [1]	30	0	0
1500495 – Aera Energy – LLC [2]	28	0	0
1503672 – Sunnygem Juice Plant	4	0	0
Total number of readings	73	0	0

[1] Total number of readings from 3 wells
[2] Total number of readings from 2 wells

Sodium and Chloride

Land uses within the BVGSA are predominately agricultural, and for this reason both the State Water Board's Ag goals and the drinking water standards are appropriate metrics. Sodium and chloride have an agricultural goal of 69 and 106 ppm, respectively. Drinking water standards do not apply a limit for sodium. The recommended drinking water limit for chloride is 250 ppm and the upper limit is 500 ppm.

Ag goals published in 1985 by the Food and Agriculture Organization of the United Nations are established to be protective of agricultural uses of water, including irrigation of various types of crops and stock watering. Water having constituent concentrations at or below the thresholds presented in the Water Quality Goals database should not have limitations for agricultural uses.

Because TDS is a focal point of the CV-SALTS and ILRP programs and the impacts of high sodium concentrations on soils can be managed through common agronomic practices such as application of gypsum, the focal point of this discussion will be on chloride because of its potential to limit both agricultural and domestic water uses. Tables 5-16 and 5-17 summarize chloride concentrations in representative monitoring wells and in wells belonging to public water systems. These tables indicate a strong spatial distribution of chloride within the GSA with high chloride levels characterizing readings from wells in the northern portion of the BMA with chloride levels declining as one moves south. This spatial distribution is evident both for wells belonging to public water systems and for wells monitored by the BVWSD. While two of the BVWSD's three sets of nested monitoring wells (DMW 10a, b and DMW 11a,b) show chloride concentrations below the Ag threshold above and below the E-clay, the southernmost of the nested monitoring wells, DMW 12a, b, show average chloride readings of 1,466 mg/L in the aquifer below the E-clay and 75 mg/L in the upper aquifer, an average reading similar to those of each of the other nested monitoring wells.

Table 5-16. Summary of Chloride Prevalence Within the BVGSA

Chloride Concentrations (ppm) (# of readings)			
< 106	**107-250**	**251-500**	**>500**
54	12	6	38

Table 5-17. Summary of Chloride Prevalence Among Public Water Systems

	Chloride Concentrations (# of readings)			
Water System	**< 106**	**107-250 ppm**	**251-500 ppm**	**> 500 ppm**
1500152 – Mirasol Company	2	2	0	0
1510011 – Buttonwillow CWD [1]	4	3	4	0
1500495 – Aera Energy – LLC [2]	0	0	1	9
1503672 – Sunnygem Juice Plant	0	0	0	1
Total number of readings	4	5	5	10

[1] Total number of readings from 3 wells
[2] Total number of readings from 2 wells

Figure 5-13 shows maximum chloride concentrations recorded in the STORM data base at each of the District Monitoring Wells and at the 7 public water system wells reported in SDWIS. This figure illustrates the distribution of chloride concentrations along the north/south axis of the BMA, a distribution also found for sodium. (Figure 5-13 - Refer to Figures Tab)

Arsenic

The most common sources of arsenic are natural geochemical processes that leach metals from sediments, particularly in the lakebed areas and where dark clay deposits occur. Studies conducted by USGS found that arsenic is in an easily exchangeable state where oxidizing geochemical conditions, caused by groundwater containing higher oxygen content, dissolve the pyrite (a mineral which can contain arsenic) and release arsenic into the groundwater. Geophysical Research Letters, Understanding Rapid Adjustments to Diverse Forcing Agents, (Smith et. al., 2018) found that over-pumping in areas of the San Joaquin Valley that have experienced land subsidence due to compaction of the lakebed deposits (clay layers) have resulted in the release of high arsenic pore water from the clay layers into the groundwater. The E-clay is present in a majority of the BVGSA, although, as noted throughout this GSP, groundwater is not extracted from beneath this confining layer and high rates of subsidence have not been observed.

There are clear differences in the arsenic concentrations reported for 7 public water system wells in SDWIS and in the BVWSD wells reported in STORM. For the BVWSD wells, all readings are below the 100 ppb Ag Goal, however, there are many instances where readings exceed the 10 ppb primary drinking water standard as shown on Table 5-18.

Table 5-18. Summary of Arsenic Prevalence Within the BVGSA

Arsenic Concentrations (ppb) (# of readings)		
0-10	**11-100**	**>100**
42	130	0

Data on public water system wells displayed in Table 5-19 show readings below the primary drinking water standard of 10 ppb for all wells except for the Sunnygem Juice Plant where all readings are close to or in excess of the 100 ppb Ag Goal.

Table 5-19. Summary of Arsenic Prevalence Among Public Water Systems

	Arsenic Concentrations (# of readings)		
Water System	**0-5 ppb**	**6-10 ppb**	**>10 ppb**
1500152 – Mirasol Company	0	4	0
1510011 – Buttonwillow CWD[1]	7	5	0
1500495 – Aera Energy - LLC[2]	11	21	0
1503672 – Sunnygem Juice Plant	0	0	11
Total number of readings	18	30	11

[1] Total number of readings from 3 wells
[2] Total number of readings from 2 wells

Figure 5-14 is a map showing maximum arsenic concentrations at each of the wells reported in the STORM and SDWIS databases. As Figure 5-14 illustrates, maximum arsenic concentrations in the BMA are below the drinking water and Ag Goal south of the Community of Buttonwillow and tend to fall between the 10 ppb drinking water standard and the 100 ppb Ag Goal further north. As the figure illustrates, Sunnygem Well No. 2 has recorded maximum arsenic concentrations at or above the Ag Goal and as shown in Table 5-18, all readings from this well are above the drinking water standard. District Monitoring Well 4, which lies near the Sunnygem facility also displays an elevated maximum arsenic reading while the Aera wells immediately to the east have maximum concentrations below the drinking water standard. (Figure 5-14, Refer to Figures Tab)

Contamination Plumes

A search of contamination plumes within the BVGSA was conducted using both GeoTracker and EnviroStor databases. Based on this search, no facilities were identified as having active cleanup efforts overseen by the Regional Board. Figure 2-28 – Sites of Potential Groundwater Impacts displays the results of this search. (Figure 2-28 – Refer to Figures Tab)

5.6.3 Margin of Operational Flexibility

No margin of operational flexibility has been established for water quality in the BVGSA because most constituents of concern are regulated by the Regional Board under the ILRP. Therefore, to avoid conflict in management approach, the BVGSA will delegate groundwater quality to the BV Coalition. At this time, no contaminant plumes have been identified in the GSA and there are no active cleanup sites. In the event that contaminants outside the purview of the ILRP are identified, the BVGSA will coordinate with the appropriate regulatory agency to determine a suitable response program including a margin of operational flexibility.

5.6.4 Interim Milestones

No interim milestones for groundwater quality have been established for the BVGSA as only isolated occurrences of problematic water quality constituent levels have been identified and these are being address under the Groundwater Quality Management Plans prepared by the BV Coalition.

5.6.5 Representative Monitoring

Groundwater quality within the BVGSA is now monitored at production and monitoring wells owned by the BVWSD, at a small number of private wells identified in the GQTMWP, 2018, and at wells belonging to the public water systems listed in Table 5-12. Water quality data from these sources is available from the BVWSD's STORM data management system and from the EPA's STORETS data base. Groundwater elevations are available from STORM and from DWR's California Statewide Groundwater Elevation Monitoring (CASGEM) system.

Wells included in the existing groundwater quality monitoring network report data from locations throughout the GSA. Additional wells have been included in the SGMA groundwater quality monitoring network to observe the quality of groundwater flows in the following boundary areas:

- The southern boundary where groundwater flux is driven by pumping within the GSA and in neighboring water banks, and
- The northern area where poor quality groundwater is believed to flow into the GSA from the west. Because of the scarcity of deep wells in this area, the initial monitoring network includes 4 piezometers that will serve as sentries to observe the influence of water flowing from the west.

Table 5-20 presents the latitude and longitude of each of the 6 deep wells and the 4 piezometers included in both the GQTMWP and the GSA groundwater quality monitoring networks. The table also shows the locations of 4 District Monitoring Wells that will supplement those monitored by the Buena Vista Coalition. As shown in Figure 4-6a – Map of Network for Groundwater Quality Monitoring, these monitoring locations are distributed so the greatest concentrations of sites are found either in areas that have experienced groundwater quality problems in the past or at locations where the monitoring point can serve as a sentinel for down-gradient areas.

Table 5-20. Groundwater Quality Monitoring Locations

Well Name	Well Type	Latitude	Longitude	GQTMWP
DMW01	District Monitoring	35.60140	-119.61755	No
DMW04	District Monitoring	35.51370	-119.59845	Yes
DMW06	District Monitoring	35.45265	-119.53460	No
DMW08	District Monitoring	35.39058	-119.44817	Yes
DMW12a	District Monitoring	35.31847	-119.37473	No
DMW12b	District Monitoring	35.31847	-119.37473	No
DW03	District Production	35.38104	-119.41521	Yes
DW05	District Production	35.38929	-119.43253	Yes
DW06	District Production	35.39731	-119.44775	Yes
Domestic Well	Domestic	35.37812	-119.44101	Yes
PIEZ-015	Shallow Piezometer	35.58645	-119.59749	Yes
PIEZ-023	Shallow Piezometer	35.55796	-119.61786	Yes
PIEZ-034	Shallow Piezometer	35.51404	-119.61547	Yes
PIEZ-035	Shallow Piezometer	35.49936	-119.61650	Yes

5.6.6 Management Areas

The BVGSA has two management areas, the Buttonwillow MA (BMA) which aligns closely with the boundaries of the BVWSD's Buttonwillow Service Area and the Maples MA (MMA) whose boundaries match those of the BVWSD's Maples Service Area. The two MAs are physically distinct being separated by 15 miles. Because of the MMA's location within the Kern River GSA (KRGSA), Sustainable Management Criteria for water quality within this MA align with those established for the surrounding KRGSA as described below in Section 5.11. Although groundwater quality varies within the BMA, the area will be treated as a single unit so that groundwater quality can be managed consistently throughout the entire MA.

5.7 Subsidence

5.7.1 Minimum Thresholds

The SGMA regulations define the minimum threshold metric for significant and unreasonable land subsidence to be the “rate and the extent of land subsidence”.

As discussed above under the MT for chronic lowering of groundwater levels, avoidance of unreasonable subsidence is directly related to management of groundwater elevations and pumping rates. Unlike other sustainability indicators, the harmful effects of subsidence result from the damage it may cause to critical infrastructure and the costs of repairing or mitigating those damages. In the instance of the BVGSA, critical infrastructure that could be affected by subsidence includes the California Aqueduct and Interstate Highway 5. To avoid damage to these and other facilities, the MTs described earlier for chronic lowering of groundwater levels have been set at elevations that are intended to be protective of critical infrastructure. In addition, as discussed in Section 4 - Monitoring Network, subsidence will also be measured directly to eliminate the uncertainty associated with inferring subsidence from changes in groundwater elevations.

5.7.1.1 Establishment

Section 2.3.7 of the Basin Setting describes historic subsidence in the BVGSA. Subsidence is monitored directly through GPS stations P545 and P563, two participating stations of the Continuously Operating Reference Stations (CORS) network that provides Global Navigation Satellite System (GNSS) data. The two CORS stations lie along Interstate 5 which follows the crest of the Buttonwillow Ridge. Because of their placement along this geologic structure, there is some question regarding how well data collected from these stations represents ground movement in the BVGSA.

CORS stations P545 and P563 are part of the National Geodetic Survey (NGS), an office of NOAA's National Ocean Service that manages the CORS network, a multi-purpose cooperative endeavor involving government, academic, and private organizations. Each agency shares its data with NGS, and NGS in turn analyzes and distributes the data. As of August 2015, the CORS network contained almost 2,000 stations, contributed by over 200 different organizations, that support three-dimensional positioning, meteorology, space, weather, and geophysical applications throughout the United States. CORS enhanced post-processed coordinates approach a few centimeters relative to the National Spatial Reference System, both horizontally and vertically.

Data from the two CORS stations will be supplemented through monitoring of ground surface elevations using data provided by DWR from the Interferometric Synthetic Aperture Radar (InSAR) network that measures vertical ground surface displacement. InSAR data is collected by the European Space Agency Sentinel-1A satellite and processed by the National Aeronautics and Space Administration’s Jet Propulsion Laboratory. This data provides cumulative vertical ground surface displacement from June 2015 to January 2017 for lands associated with the BVGSA.

Land surface elevations monitored using data available through CORS and InSAR will be analyzed together with data on groundwater levels to determine whether groundwater levels can serve as an indicator, and possible predictor, of subsidence. Initial analyses have relied heavily on data available from the CORS program, which has a period of record extending from 2011 through the present. Because of its short period of record, InSAR was used only to confirm relations identified through CORS data. However, during the period of SGMA implementation, the BVGSA may choose to expand its use of InSAR both for direct observation of land surface elevations and in efforts to correlate changes observed in these elevations with those observed in groundwater levels.

Preliminary analyses to identify correlations between changes in groundwater levels and changes in ground surface elevations were carried out as follows:

- Annual minimum groundwater elevations were plotted for the period from 2011 through 2018 and compared with annual minimum land surface elevations for the same period. The comparison of minimum values for both parameters focused the initial examination on identification of clear trends and mitigated differences in the timing of data collection.
- Figures 5-15a and 5-15b present an initial comparison between land surface elevations recorded at P545 and P563 and groundwater levels observed in district monitoring wells.

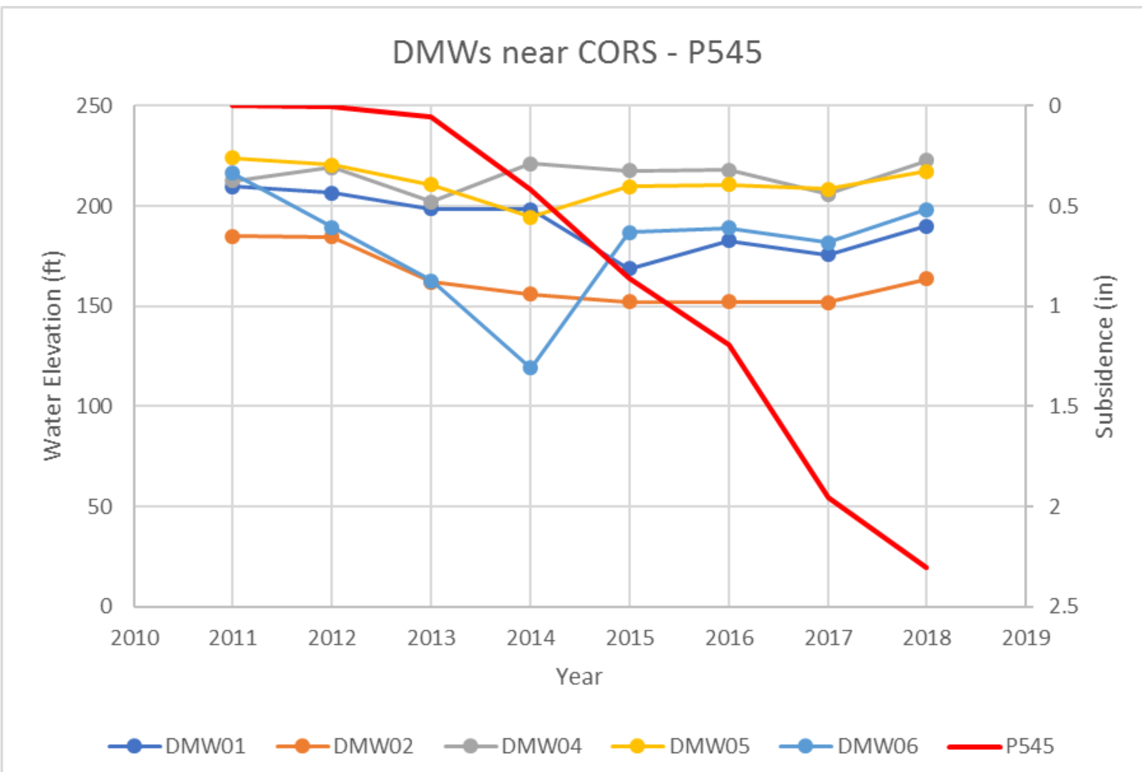


Figure 5-15a. District Monitoring Well levels versus cumulative subsidence – P545

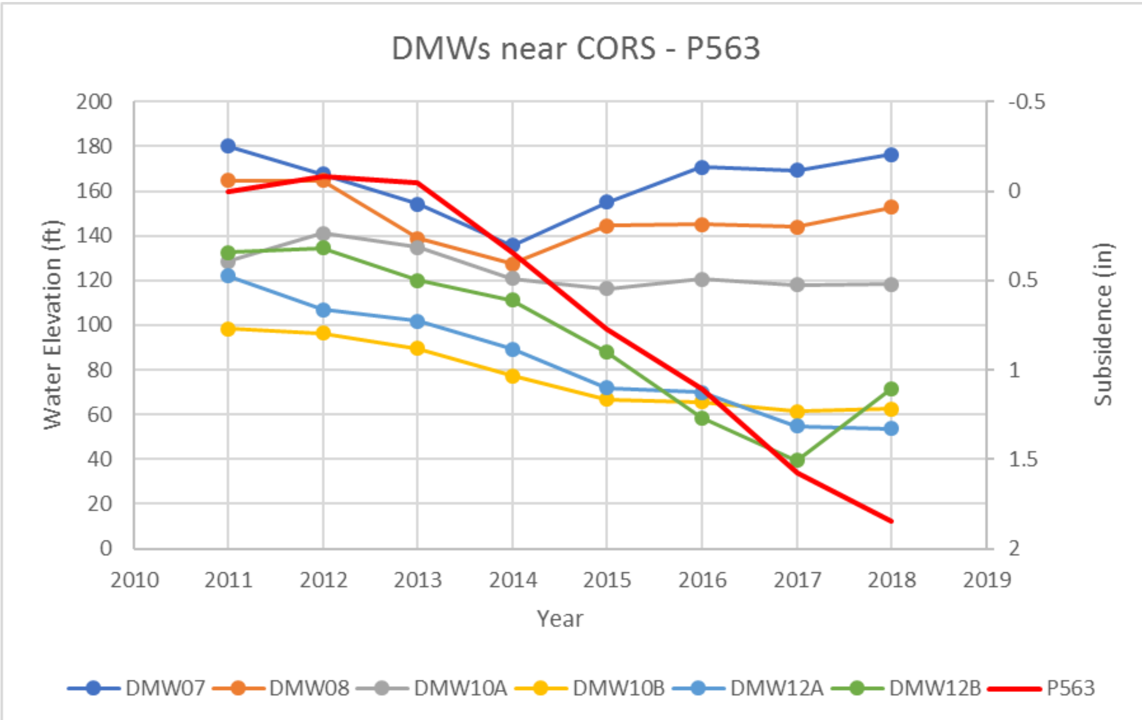


Figure 5-15b. District Monitoring Well levels versus cumulative subsidence – P563

- Based on the data plotted on figures 5-15a and 5-15b, the following wells were chosen to represent groundwater conditions at each station:
  - P545: DMW01 and DMW02
  - P563: DMW10A and DMW12B

Characteristics of each well are shown on Table 5-21.

Table 5-21. Characteristics of wells chosen for association with CORS land elevation data

Local Well	State Well	Total Well Depth	Top Perf	Bottom Perf	Nearest CORS	Distance to CORS (miles)	Direction to CORS (degrees)	WCR[1]
DMW01	27S22E08A001M	300	280	300	P545	4.40	315	X
DMW02	27S22E23D001M	300	260	300	P545	4.65	335	X
DMW10A	30S24E06B003M	450	?	?	P563	4.55	185	
DMW12B	30S24E14M003M	455	?	?	P563	7.4	150	

[1]Wells know to have Well Completion Reports (WCRs)

Cumulative changes in annual minimum water levels for DMW01 and DMW02 are plotted together with cumulative changes in annual minimum land surface elevations at P545 in figures 5-16a and 5-16b, and cumulative changes in annual minimum water levels in DMW10A and

DMW12B are plotted with cumulative changes in annual minimum land surface elevations at P563 in Figures 5-16c and 5-16d.

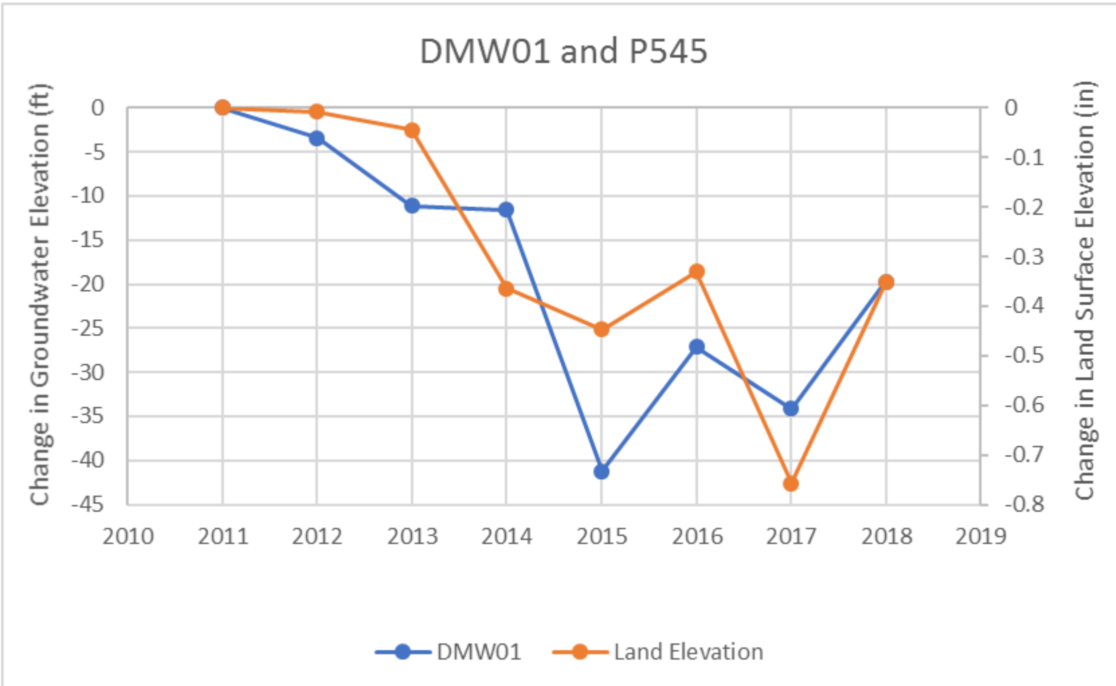


Figure 5-16a. Change in annual minimum groundwater and land surface elevations

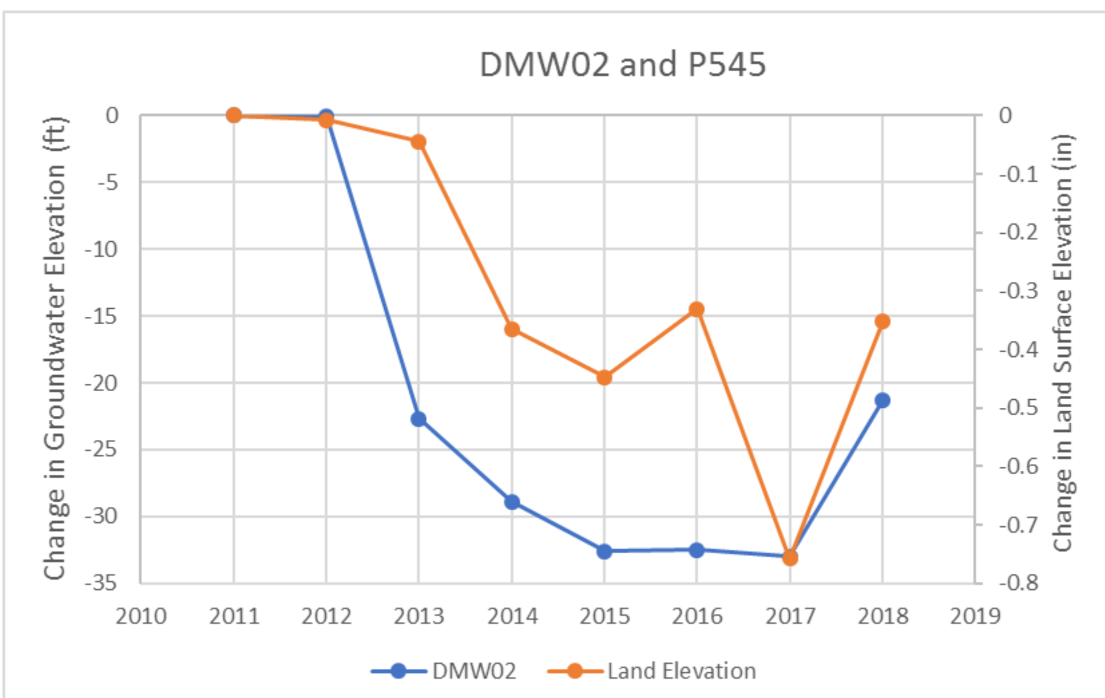


Figure 5-16b. Change in annual minimum groundwater and land surface elevations

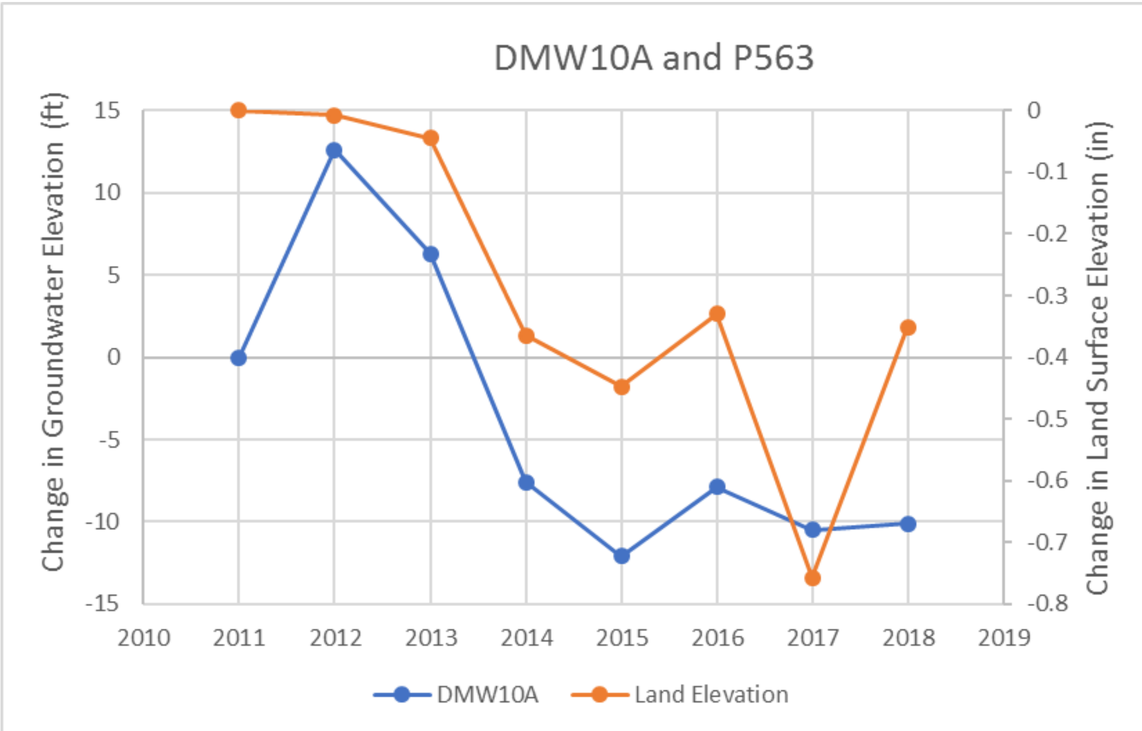


Figure 5-16c. Change in annual minimum groundwater and land surface elevations

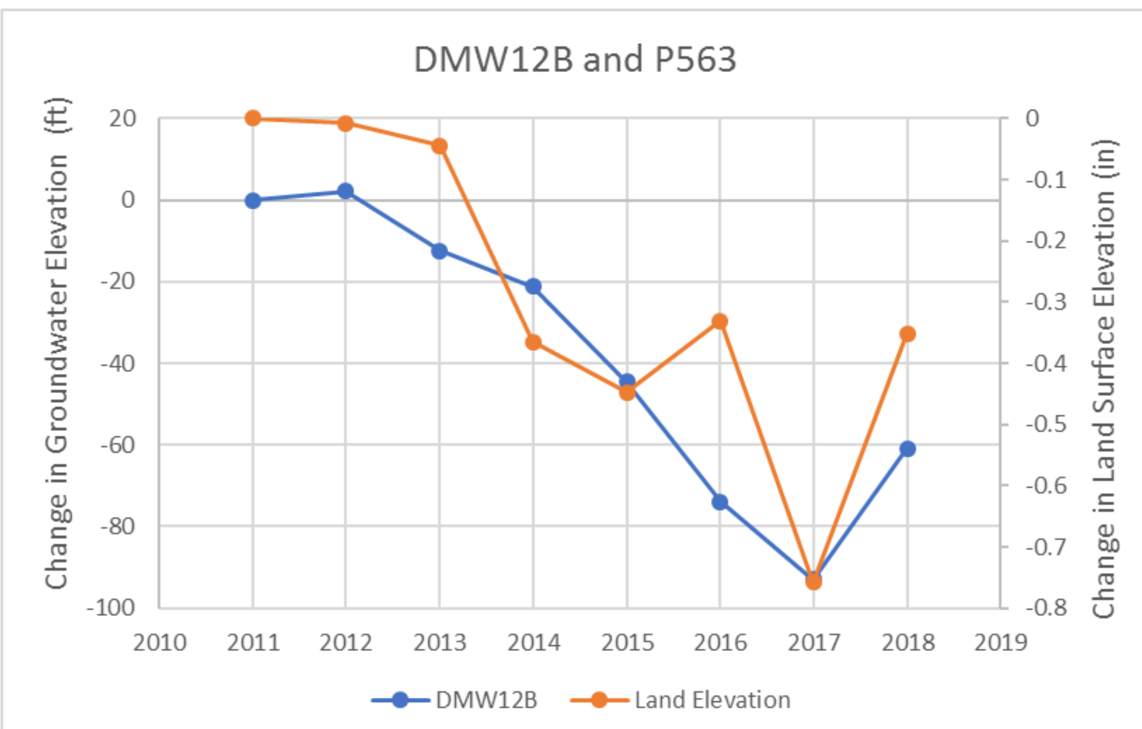


Figure 5-16d. Change in annual minimum groundwater and land surface elevations

Figures 5-16a through 5-16d show a distinct response in land surface elevation to changes in water level, a response that suggests a correlation between the two parameters. As more data is collected, the extent of this correlation both in terms of its magnitude and lags in response time will be examined using statistical packages capable of developing linear and non-linear response models.

As shown in Table 5-21, the district monitoring wells that would be used to develop these response models lie between 4.4 and 7.4 miles from the nearest CORS station. Because of the distance between the CORS stations and the nearest monitoring wells, InSAR data spanning the twenty months between June 2015 and January 2017 was analyzed to perform a supplemental analysis. InSAR data was downloaded in raster format from the California Natural Resources Agency (CNRA) website. Once downloaded, ArcGIS was used to extract elevation values at the site of each monitoring well on a monthly timestep, and cumulative changes in land elevations were then plotted together with groundwater elevations from the associated well as shown on Figures 5-17a and 5-17b.

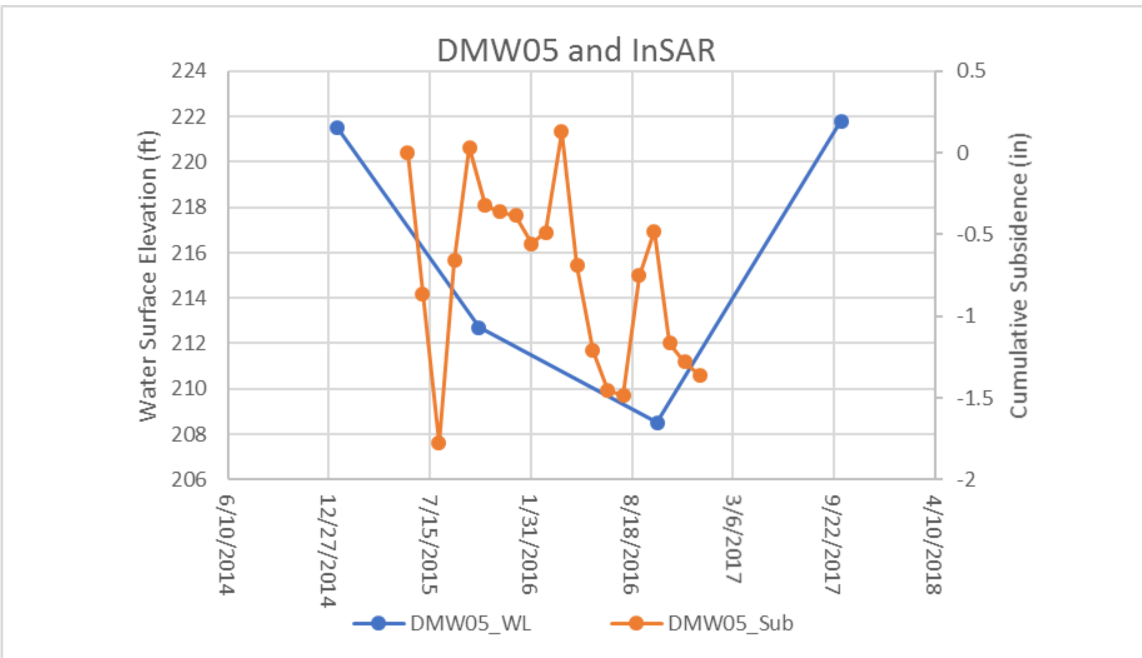


Figure 5-17a. Observed groundwater and land surface elevations

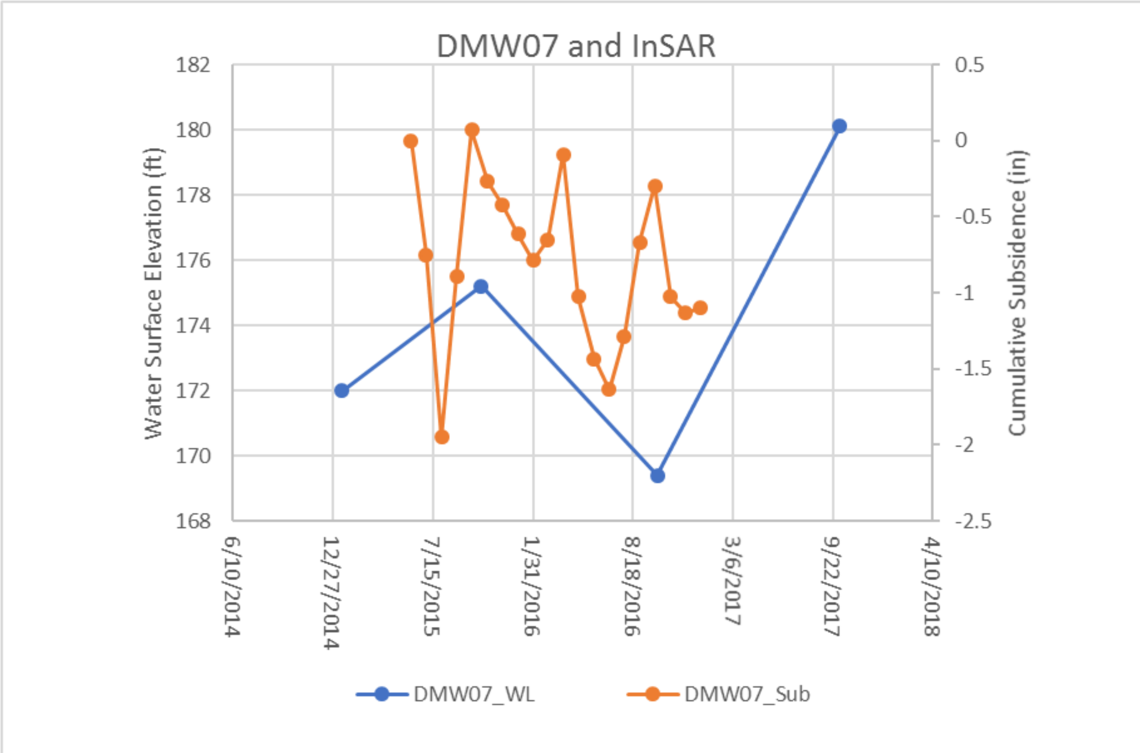


Figure 5-17b. Observed groundwater and land surface elevations

Unlike the CORS data where only annual minimums were plotted to highlight major tendencies in land surface elevations, the monthly InSAR data displays more "noise". Although DMW 05 and DMW 07 lie 9.5 miles apart, both show similar, cyclical patterns of change in land surface elevations with annual minimum elevations occurring in July, secondary minimums occurring in February and primary and secondary maximums in May and September. The timing of the minimum and maximum groundwater elevations appears counterintuitive as groundwater pumping that would be expected to cause subsidence typically continues after the annual July minimum land surface elevations are observed while maximum elevations occur not long after the peak period for groundwater pumping.

A possible explanation for the cycles of subsidence and rebound observed through InSAR lies in the soil types found in the Buttonwillow MA. Soils in the area originated from Coastal Range sedimentary rock formed on the sea bottom and are typically fine-textured and poorly drained. Classified as Alfisols, the soils result from weathering processes that leach clay minerals and other constituents out of the surface layer and into the subsoil, where they can hold and transmit moisture. Section 2 - Basin Setting provides more information on the characteristics of soils within the BVGSA.

Analysis of data from the CORS sites and from InSAR suggests that short-term oscillations in land surface elevations may result from swelling of the soil profile due to percolation of water from precipitation and irrigation and shrinkage during periods when the water content is being depleted by drainage and evapotranspiration.

This analysis suggests that the frequent fluctuations observed in land surface elevation may be caused by behavior of the soil profile that is independent of the mechanisms that drive subsidence. The preceding figures also show that minimum land surface elevations at wells in the BVGSA monitoring network are lower in 2015 than in 2016 indicating an overall recovery in land surface elevations that coincides with a period when water levels initially declined and then began to rise. Thus, in addition to the "noise" resulting from the oscillations described above, an overall uplift is evident when comparing all monthly levels for the two years. Figures 2-30 and 2-31 show longer term changes in land surface elevations also developed through data from the CORS and InSAR systems (Figures 2-30 and 2-31, Refer to Figures Tab).

5.7.1.2 Considerations Used

Considerations recommended in the BMP for Monitoring Networks and Identification of Data Gaps (DWR, 2017) when establishing minimum thresholds for land subsidence at a given representative monitoring site may include, but are not limited to:

- Do principle aquifers in the basin contain aquifer material susceptible to subsidence?

  The principal production aquifer in the BVGSA is the Tulare Formation. This formation is Pliocene to Pleistocene in age and contains up to 2,200 feet of interbedded, oxidized to reduced sands and gypsiferous clays and gravels derived primarily from Coast Range sources. Sandy material is found from about 200 to 400 feet below ground surface (bgs) and is used by most wells in the region for water supply. As described in Section 5.4 – Chronic Lowering of Groundwater Levels, most wells are screened to produce water from zones above the E-clay. Therefore, because of the characteristics of the aquifer material and the fact that groundwater extraction is concentrated in areas above the E-clay, the principal production aquifer is not susceptible to subsidence.

- What are the historical, current, and projected groundwater levels, particularly the historical lows?

  Data on groundwater levels for wells in the BVGSA's monitoring network are available from 1993 to the present. Historical groundwater elevations in the BMA have ranged between 145 and 246 feet AMSL in the Northern BMA (north of 7th Standard Road) and between 40 and 249 feet bgs in the Southern BMA (south of 7th Standard Road). Typical current (fall 2018) groundwater levels are 196 feet AMSL in the north (average of DMW01, DMW02, DMW04, and DMW05) and 142 feet AMSL in the south (average of DMW06, DMW07, DMW08, DMW10A, DMW12B).

  Projected groundwater levels are expected to remain within the historical range because of the BVWSD's access to surface water and continuously evolving conjunctive management practices. This assessment is supported by the groundwater elevations observed within the BVGSA during the recent drought.

- What is the historical rate and extent of subsidence?

Historical rates and extents of subsidence in the BVGSA are described in Section 2 - Basin Setting. Five continuous CORS stations are located north of the Kern River in the Kern County Subbasin and have been in operation since late 2005 (stations P544, P563, and P565), 2006 (Station 564), and 2007 (Station P544). These stations are monitored as a part of UNAVCO's Plate Boundary Observation (PBO) program. Between 2008 and 2017, cumulative subsidence varied from 1.7 to 2.9 inches at three stations near the BVGSA along Interstate 5 (P544, P545, P563), with subsidence occurring at a relatively steady rate.

- What are the land uses and property interests in areas susceptible to subsidence?

  Wells in the BVGSA are screened above the E-clay as detailed in Section 5.4 – Chronic Lowering of Groundwater Levels. This fact, coupled with the hydrogeologic conditions and observed subsidence described in Section 2 - Basin Setting, suggests that observed subsidence has not been significant or unreasonable and that pumping-induced subsidence is unlikely to become significant or unreasonable given the BVGSA's intent to limit groundwater extraction within its boundaries to zones above confining clay layers.

- What is the location of infrastructure and facilities susceptible to subsidence (e.g., canals, levees, pipelines, major transportation corridors)?

  The main infrastructure susceptible to subsidence within or near the BVGSA are Interstate 5 and the California Aqueduct. Interstate 5 parallels the BVGSA's eastern boundary and bisects the GSA for approximately 4 miles in the northern portion of the BMA and 2.5 miles in the MMA.

  The California Aqueduct parallels the BVGSA's westerly boundary lying between 0.1 miles and 2 miles west of the BMA and approximately 7 miles west of the MMA. Because of the significance of the Aqueduct, its proximity to the BMA and the potential for subsidence to affect its structure and operation, special compliance measures are being put in place by DWR, the BVGSA and other GSAs near the Aqueduct to detect and control subsidence of this feature. These measures, as they relate to the BVGSA, are described at the end of this section.

- What are the adjacent basin's minimum thresholds? The BVGSA lies within the Kern County Subbasin and does not border any adjacent basins. The minimum thresholds for subsidence in the adjacent GSA of Kern Groundwater Authority GSA are presented in the Umbrella GSP for the Kern Groundwater Authority and in the table in Appendix F. Note that the Kern Groundwater Authority GSA utilized groundwater levels as a proxy for subsidence.

- As 1) no impacts to critical infrastructure have been identified within the BMA, 2) it is not clearly understood how groundwater pumping in different areas of the Subbasin affects subsidence, and 3) a regional approach is in the process of being developed to define an undesirable result, Buena Vista has identified land subsidence as a data gap. As a result, no minimum thresholds are established for land subsidence within the BMA at this time. Because of its critical importance and the level of analysis now available regarding subsidence on the California Aqueduct, quantitative SMCs for subsidence of this structure are presented at the end of this section.

5.7.1.3 Quantitative Minimum Thresholds

Although land surface elevations, depths to groundwater, depths to the E-clay and extent of the C-clay vary throughout the BMA, the overall geometry of the management area aids in setting minimum thresholds due to the following characteristics:

- The GSA is underlain by the E-clay at elevations ranging from approximately 10 ft AMSL to -215 feet AMSL with unconfined and semi-confined zones of the Tulare Formation lying above the E-clay and a confined zone extending beneath the clay layer to the base of fresh groundwater. The C-clay extends above the E-clay in the northern portion of the BMA.
- The risk of inducing subsidence by extracting water from the zone above the E-clay is likely to be lower than the risk induced by extracting water from beneath the clay. Similarly, extracting groundwater from beneath the C-clay may increase the risk of subsidence.

5.7.2 Measurable Objectives and Interim Milestones

5.7.2.1 Establishment

Because historical occurrence of subsidence in the BVGSA has been minimal, no measurable objectives or interim milestones have been established for control of subsidence. However, the minimum thresholds established for control of chronic reduction of groundwater levels are set above restrictive clay layers (C-clay and E-clay) to avoid future subsidence. Measurable Objectives for subsidence may be introduced in the future if subsidence is observed and if corrective measures are determined to be needed.

5.7.2.2 Considerations Used

Although lands within the BVGSA have not evidenced a history of inelastic land subsidence, the GSA recognizes the potential for subsidence to damage infrastructure with the GSA, and for chronic lowering of groundwater levels within the GSA to affect critical infrastructure that lies immediately outside the GSA's boundaries with the California Aquduct believed to be the most sensitive of these features to inelastic land subsidence.

As described in Section 4 – Monitoring Networks, the BVGSA will monitor subsidence using data from CORS stations that lie to the east of the GSA supplemented by InSAR data. Although a clear relation between inelastic subsidence and changes in groundwater elevations has yet to be established in the GSA, the GSA will operate on the presumption that such a relation exists.

Therefore, while changes in groundwater elevations will not be used at this time as a proxy for subsidence, the GSA will discourage groundwater extraction from confined aquifer zones underlying the C-clay and E-clay because of the potential for pumping from these zones to induce subsidence.

5.7.3 Margin of Operational Flexibility

No margin of operational flexibility has been established for subsidence due to the lack of either observed subsidence or of any established correlation between changes in groundwater elevation and subsidence. Should subsidence be observed, and a correlation developed and confirmed between changes in groundwater elevations and inelastic subsidence, this may provide a basis for introducing a margin of operational flexibility.

5.7.4 Interim Milestones

No interim milestones have been developed as subsidence is an undesirable result to be avoided rather than corrected.

5.7.5 Representative Monitoring

Subsidence will be actively monitored within the BVGSA using data from the CORS and InSAR systems supplemented by observations from DWR on subsidence of the California Aqueduct and Caltrans on I-5, the two critical infrastructure facilities having the potential to be affected by the operations of the BVGSA. Up to this point, subsidence has not been observed on infrastructure within the BVGSA. Should subsidence be detected on canals, control structures or roadways within the GSA, a surveying program will be implemented to monitor subsidence at affected facilities to ascertain the extent and cause.

5.7.6 Management Areas

The BVGSA has two management areas, the Buttonwillow MA (BMA) which aligns closely with the boundaries of the BVWSD's Buttonwillow Service Area and the Maples MA (MMA) whose boundaries match those of the BVWSD's Maples Service Area. The two MAs are physically distinct being separated by 15 miles. Because of the MMA's location within the Kern River GSA (KRGSA), the Sustainable Management Criteria for subsidence within this MA align with those established for the surrounding KRGSA as described below in Section 5.12.

5.7.7 California Aqueduct – Definition of Undesirable Results

The California Aqueduct runs parallel to the western boundary of the BMA and has been identified as critical infrastructure in the Kern County Subbasin. The definition used throughout the Subbasin of an undesirable result for land subsidence is the point at which the amount of inelastic subsidence, if caused by Subbasin groundwater extractions, creates a significant and unreasonable impact to surface land uses or critical infrastructure.

A variety of subsurface conditions and mechanisms, not all completely understood, can cause subsidence. Although groundwater extractions for agriculture or other uses have potential to cause subsidence, recent studies conducted on the west side of the Subbasin have identified soluble soils, natural differential compaction and oil and gas production as other potential contributors to subsidence along the Aqueduct.

As none of the subsidence modes besides groundwater extraction for beneficial uses within the BMA are within the control or jurisdiction of the BVGSA, identifying the subsurface conditions and mechanisms causing subsidence will be a critical first step toward managing current and future impacts and identifying appropriate management actions.

Based on the findings of the 2019 DWR California Aqueduct Subsidence Program (CASP) report, subsidence has reduced the original design freeboard and potentially impacted conveyance capacity in Aqueduct pools to the west of the BMA. Because maintaining a minimum operating freeboard and conveyance capacity is critical to long-term sustainability of the Aqueduct, observed reductions in freeboard will be used as a benchmark for determining inelastic subsidence and identifying potential undersirable results.

The subsidence-related monitoring plan and SMCs for the BMA discussed below are based on a white paper developed by the Kern Subbasin after initial coordination with CASP staff. On July 19, 2022 the Kern Subbasin received a letter from CASP commenting on the white paper and requesting continued collaboration to refine MOs and MTs to improve the approach for detecting and controlling subsidence of the California Aqueduct. While the MOs and MTs presented below do not address the comments presented in the CASP letter, these comments will be addressed through forthcoming coordination between the CASP, the BVGSA and other GSAs in the Subbasin.

5.7.8 California Aqueduct – Monitoring Plan

The subsidence monitoring corridor for the Aqueduct will include lands within 2.5 miles on either side of the Aqueduct (i.e., total of five miles wide centered on the Aqueduct). The width of the monitoring corridor was based on a review of Subbasin hydrogeology, historical InSAR datasets, the 2019 CASP report, and current land uses along the Aqueduct.

Access to surveying benchmarks within the monitoring corridor is limited. Therefore the Aqueduct subsidence monitoring reports produced by DWR every 2 to 6 years will be the primary source of information used to calculate the rate and magnitude of changes in Aqueduct freeboard with these changes being used to represent rates and magnitudes of subsidence. Since the CASP reports provide complete coverage of each of the pools adjacent to the BMA, these surveys are the best data available to monitor subsidence.

As a supplement to the DWR reports, InSAR data will be reviewed on an annual basis to inform the BVGSA of whether subsidence rates could lead to an undesirable result in canal pools to the west of the BMA. InSAR data will be ground-truthed by comparison to NOAA CORS station P545, SOPAC CGPS location P544 and existing extensometers in or adjacent to the Aqueduct. To insure that the best available information is used when updating the BVGSP, data from CORS, CGPS, extensometer, and other pertinent facilities in use in or near the Aqueduct will also be considered after coordination with staff and with neighboring GSAs.

5.7.9 California Aqueduct – Areas of Interest

Aqueduct pools that have experienced subsidence which has significantly reduced freeboard and, in some cases, impacted flow capacity have been identified as Areas of Interest (AOIs) that will be subject to monitoring by the collection and ground-truthing of InSAR data on a semi-annual basis and the preparation of studies or investigations to assess the cause of subsidence in consultation with DWR. If it is determined that the sole or principal cause of subsidence in a particular AOI is groundwater extraction for beneficial use, these sites will be identified for additional monitoring stations in the future and may be designated for management actions. The AOIs that parallel the western boundary of the BMA are Pools 24 and 25 and a portion of Pool 26. Studies conducted on the west side have concluded that subsidence in pools 24, 25 and 26 is attributable to oil and gas activities and is beyond the ability of the BVGSA to control or mitigate.

5.7.10 California Aqueduct – Watch Areas

The 2019 CASP report, shows that subsidence in several pools has been minimal with the top of lining elevations in 2017 being comparable to those measured when the Aqueduct was constructed over 50 years ago. As freeboard has not been reduced in these locations, no undesirable results have been experienced that could be attributed to subsidence. Any significant loss of conveyance capacity from design specifications was found to be caused from aging concrete lining with increased hydraulic roughness and other factors. Pools that have experienced minimal subsidence historically have been identified as “Watch Areas”.

Portions of pools 25 and 26 and all of pools 27 and 28 that lie to the west of the BMA have been designated as Watch Areas (WAs). These areas will be monitored annually utilizing ground-truthed InSAR data and the most current CASP report. In the event that future monitoring determines that conditions have worsened, Watch Areas may be redesignated as AOIs. Monitoring Classification, and Management Areas associated with each pool are summarized in the below in tables 5-22 and 5-23.

Table 5-22. California Aqueduct Pools Adjacent to the BMA

Aqueduct Pool	GSAs Within 5-Mile Corridor	Pool Monitoring Classification
Pool 24	KGA (WDWA, SWSD), BVGSA (BMA)	AOI
Pool 25	KGA (WDWA), BVGSA (BMA)	AOI/WA
Pool 26	KGA (WDWA), BVGSA (BMA)	AOI/WA
Pool 27	KGA (WKWD), BVGSA (BMA)	WA
Pool 28	KGA (WKWD, KWB), BVGSA (BMA)	WA

Table 5-23. California Aqueduct Pool Adjacent to the BMArea and Monitoring Classification Extent

Aqueduct Pool	Watch Area Extent	Area of Interest Extent
Pool 24	N/A	[1]MP-197 to MP 208
Pool 25	MP-216 to MP-218	[1]MP-208 to MP-216
Pool 26	MP-216 to MP-222.5	[2]MP-222.5 to MP-223.5
Pool 27	MP-223.5 to MP- 231.5	N/A
Pool 28	MP-231.5 to MP-238	N/A
[1]Vicinity of Lost Hills Oil Field; [2]Potential geotechnical effects		

5.7.11 California Aqueduct – Minimum Thresholds

Minimum thresholds for land subsidence for the California Aqueduct are defined within the Subbasin as the avoidance of a permanent loss (associated with inelastic subsidence) of no more than a discrete amount of remaining lining freeboard for a specific Aqueduct pool identified in the 2019 CASP Report (2017 baseline survey) relative to the original as-built lining elevations or subsequent lining raises where applicable.

As previously stated, each pool has a unique existing freeboard condition. Therefore, the amount of subsidence or settlement that may occur without causing an undesirable result varies among the pools. As such, GSAs within the Subbasin have agreed on a methodology for developing MTs that recognizes 3 distinct tiers of Aqueduct pools as described below:

Tier 1 Pools are defined as having existing freeboard significantly greater than the minimum design freeboard of 2.5 ft. No Tier 1 pools lie near the western boundary of the BMA.

Tier 2 Pools are defined as having existing freeboard that is either greater or close to the minimum design freeboard of 2.5 ft. Pools 26 and 27 meet this definition and have not experienced conveyance issues related to lack of freeboard. The methodology for developing MTs was set by first determining the average amount of existing freeboard relative to the original as-built lining elevations or subsequent lining raises where applicable. The MT was determined by multiplying the average existing freeboard by 75 percent.

Tier 3 Pools are defined as having existing freeboard that is significantly less than the minimum design freeboard of 2.5 ft. Pools 24, 25 and 28 fall into this category. The methodology for developing MTs was set by first determining the average amount of existing freeboard relative to the original as-built lining elevations or subsequent lining raises where applicable. The MT was determined by multiplying the average existing freeboard by 75 percent.

Pool specific MTs, and tier classifications associated with each Pool are summarized in the below in Table 5-24.

Table 5-24. California Aqueducts Pools Adjacent to the Buttonwillow Management Area

CA Aqueduct Pool	Freeboard Classification	Minimum Threshold (ft)
Pool 24	Tier 3	*-0.38 **
Pool 25	Tier 3	*-0.38 **
Pool 26	Tier 2	*-1.89 **
Pool 27	Tier 2	*-2.62 **
Pool 28	Tier 3	*-0.78 **
*Placeholder, using 75% of 2017 freeboard listed in Table 4-3 of 2019 CASP Report, this should be replaced by calculated values using the CASP spreadsheet data similar to WRMWSD		

The MTs will be reviewed and revised as needed to reflect new information in the 2025 update to the BVGSP and in each subsequent five-year update. The MTs only apply when the permanent loss of freeboard is a result of subsidence due to groundwater extractions from the following beneficial uses/users: agricultural, domestic, municipal, or urban. Permanent loss of freeboard from land subsidence due to other causes including: oil and gas production, natural compaction of shallow underlying soils beneath or near the Aqueduct, or any other cause that is not within the jurisdiction of the BVGSA, will not be considered as a loss of freeboard that contributes to the amount specified for any MT.

For example, if the MT for subsidence for a particular Aqueduct pool were determined to be 1.00 ft, and if beneficial uses within the jurisdiction of the BVGSA were deemed to cause 0.80 ft of subsidence within that pool while natural shallow compaction was deemed to cause 1.00 ft, the BVGSA would only consider the 0.80 ft of subsidence (and related loss of pool freeboard) when evaluating MT compliance, and in this instance would not determine that an MT exceedance has occurred.

5.7.12 California Aqueduct – Measureable Objectives and Interim Milestones

The Measurable Objective for land subsidence for the California Aqueduct is defined within the Kern County Subbasin as the avoidance of a permanent loss (associated with inelastic subsidence) of no more than a discrete amount of remaining concrete lining freeboard for a specific Aqueduct pool identified in the 2019 CASP report (2017 baseline survey) relative to the original as-built lining elevations or subsequent lining raises where applicable.

Discussions with the DWR CASP staff indicate that ideal conditions within the Aqueduct would be to operate within plus or minus 1 ft of the design minimum freeboard of 2.5 ft, but the Aqueduct can operate at or near design capacity with close to 0 ft of freeboard.

Each pool has a unique existing freeboard condition, meaning that some pools have much more operational freeboard than ideally required, some pools have either more than or close to the amount of freeboard ideally required, and some pools have less freeboard than ideally required, a condition that limits DWR's operational flexibility. Therefore, the amount of inelastic subsidence or settlement that may occur without causing an undesirable reduction in capacity is unique to each of the pools. As such, the BVGSA and other GSAs in the Subbasin have agreed on a methodology for developing MOs that recognizes 3 distinct tiers of Aqueduct pools as described below:

Tier 1 Pools are defined as having existing freeboard that is significantly greater than the minimum design freeboard of 2.5 ft. No Tier 1 Pools lie near the western boundary of the BMA.

Tier 2 Pools are defined as having existing freeboard that is either greater than or close to the minimum design freeboard of 2.5 ft. Pools 26 and 27 meet this definition and have not experienced conveyance issues related to lack of freeboard. The methodology for developing MOs for Tier 2 Pools was set by first determining the average amount of existing freeboard relative to either the original as-built lining elevations or to subsequent lining raises where applicable. The MO was determined by multiplying the average existing freeboard by 50 Percent. In areas where the MO has not already been reached, the following IMs have been established: 2025 IM at 50 percent of the MO, 2030 IM at 80 percent of the MO, 2035 IM at 90 percent of the MO, and the MO by 2040.

Tier 3 Pools are defined as having existing freeboard that is significantly less than the minimum design freeboard of 2.5 ft. Pools 24, 25 and 28 fall into this category. The methodology for developing MOs was set by first determining the average amount of existing freeboard relative to the original as-built lining elevations or subsequent lining raises where applicable. The MO was determined by multiplying the average existing freeboard by 50 percent. The following IMs have been established for Tier 3 Pools: 2025 IM at 50 percent of the MO, 2030 IM at 80 percent of the MO, 2035 IM at 90 percent of the MO, and the MO by 2040.

Pool specific IMs, MOs, and tier classifications associated with each pool are summarized in the below in Table 5-25.

Table 5-25. Subsidence Measurable Objectives for Aqueducts Pools Adjacent to the BMA

Aqueduct Pool	Freeboard Classification	2025 IM (ft)	2030 IM (ft)	2035 IM (ft)	Measurable Objective (ft)
Pool 24	Tier 3	-0.13	-0.20	-0.23	*-0.25 **
Pool 25	Tier 3	-0.13	-0.20	-0.23	*-0.25 **
Pool 26	Tier 2	-0.63	-1.01	-1.13	*-1.26 **
Pool 27	Tier 2	-0.88	-1.40	-1.58	*-1.75 **
Pool 28	Tier 3	-0.26	-0.41	-0.46	*-0.51 **
*Placeholder, using 50% of 2017 freeboard listed in Table 4-3 of 2019 CASP Report, this should be replaced by calculated values using the CASP spreadsheet data similar to WRMWSD.					

The subsidence-related MOs and IMs apply only when the permanent loss of freeboard is a result of subsidence due to groundwater extractions from the following beneficial uses/users: agricultural, domestic, municipal, and urban. Permanent loss of freeboard from land subsidence due to other causes including but not limited to: oil and gas production, natural compaction of shallow underlying soils beneath or near the Aqueduct, or any other cause that is not within the jurisdiction of the BVGSA, shall not be considered as a loss of freeboard that contributes to the amount specified for any MO or IM. The MOs and IMs will be reviewed and revised as needed to reflect new information in the 2025 update of the BVGSP and in each subsequent five-year update.

For example, if beneficial uses within the jurisdiction of the BVGSA for a particular Aqueduct pool were deemed to cause 0.40 ft of subsidence while non-jurisdictional beneficial uses were deemed to cause 0.50 ft, the BVGSA would consider only the 0.40 ft of subsidence (and related loss of pool freeboard) when evaluating MO compliance, and in this instance would not determine that an MO exceedance has occurred.

Maples Management Area

5.8 Introduction

The BVGSA has coordinated with other GSAs in the Kern County Subbasin to define SMCs and undesirable results and to establish the following SMCs: measurable objectives (MOs), minimum thresholds (MTs), and interim milestones (IMs). The objective of this coordination is to develop an approach to sustainable groundwater management that has uniform objectives throughout the subbasin.

For the Maples Management Area (MMA), the relationship between the MTs for each sustainably indicator will be consistent will the relationships established for the surrounding Kern River GSA (KRGSA). Because conditions in the MMA are strongly influenced by conditions in the KRGSA, this consistency with the relationships established by the KRGSA will minimize breach of MTs that would trigger conditions that may lead to determination of undesirable results.

Buena Vista has two monitoring wells located within the MMA, MO1 and MO2. SMCs were established at these locations based upon data from the four wells in the KRGSA monitoring network that are closest to the MMA and that all lie within the KRGSA's Agricultural Management Area. Table 5-22 identifies these four wells, and Figure 5-18 shows their locations together with those of the MMA and of wells MO1 and MO2.

Table 5-22. Identification of MO1, MO2 and Four Proximate KRGSA Monitoring Wells

Well Identifications and Ground Surface Elevations		
Monitoring Well ID	**State Well Number**	**Ground Surface Elevation (ft, msl)**
MO1	352014N1192172W001	296
MO2	352015N1192094W001	295
RMW-037	31S/26E-16P01	302
RMW-042	31S/26E-32B	290
RMW-200	31S/27E-07N	293
RMW-038	31S/27E-19D01	317

As discussed at the beginning of this section, the conditions of HZ 10 demonstrate the similarities between the MMA and surrounding area in the KRGSA. The formulation and application of the HZs is presented in BVSP Section 4.4.1.2 – Management Areas and Hydrologic Zones.

Two important similarities between the BMA and the MMA are illustrated on BVGSP Figure 2-3 - Approximate Thickness and Extent of Corcoran Clay and KRGSP Figure 3-8 - Soil Textures. Figure 2-3 shows how, like the BMA, the MMA is underlain by the E-clay (Corcoran Clay). While the E-clay is found from 300 to 450 feet bgs in the BMA, the top of the clay layer lies between 500 and 550 feet bgs in the MMA. Figure 3-8 shows that the soils of the MMA developed from the same Holocene Quaternary flood basin deposits that characterize the BMA.

Because the MMA is a small area within the KRGSA, adherence to the procedures developed by the KRGSA in setting SMCs for the MMA promotes establishment of management objectives and practices over the MMA that are consistent with those being applied in surrounding areas.

5.9 Chronic Lowering of Groundwater Levels

5.9.1 Minimum Thresholds

The Draft BMP For Sustainable Management Criteria (DWR 2017) provides the following definition of MTs and of the term as it pertains to chronic lowering of groundwater levels:

> Minimum thresholds are quantitative values for groundwater conditions at representative monitoring sites that, when exceeded individually or in combination with minimum thresholds at other monitoring sites, may cause an undesirable result(s). Thus, sustainability indicators become undesirable results when a GSA-defined combination of minimum thresholds is exceeded at a scale determined to compromise basin-wide sustainability. The minimum threshold metric for the chronic lowering of groundwater levels sustainability indicator shall be a groundwater elevation measured at the representative monitoring site.

BVGSP Section 3 - Sustainability Goal and Undesirable Results presents avoidance of the undesirable result of chronic lowering of groundwater levels as a critical objective of the BVGSA. Initial MTs for chronic lowering of groundwater levels have been established for wells MO1 and MO2, the two representative monitoring sites established by the BVGSA in the MMA. As part of the process for five-year updates of the BVGSP, these initial values may be modified as data gaps are filled and as the monitoring networks within the MMA and the KRGSA are refined.

Hydrographs for MO1 and MO2 are presented as figures 5-19 and 5-20. Figure 5-19, the hydrograph for MO1 covers a period from June 2010 through April 2015, while Figure 5-20, the hydrograph for MO2, spans the period from September 2011 through October 2020. Information on these two monitoring wells is complemented by information from the four KRGSA monitoring wells located near the MMA shown on Figure 5-18. Historical groundwater conditions are also presented in BVGSP Section 2 - Basin Setting and in Appendix C - Groundwater Hydrographs both of which include hydrographs from MO1 and MO2.

Information on ground surface elevations, and historic high and low water levels recorded in MO1 and MO2 and the four nearby KRGSA monitoring wells used to establish SMCs for the MMA are shown in Table 5-23, below.

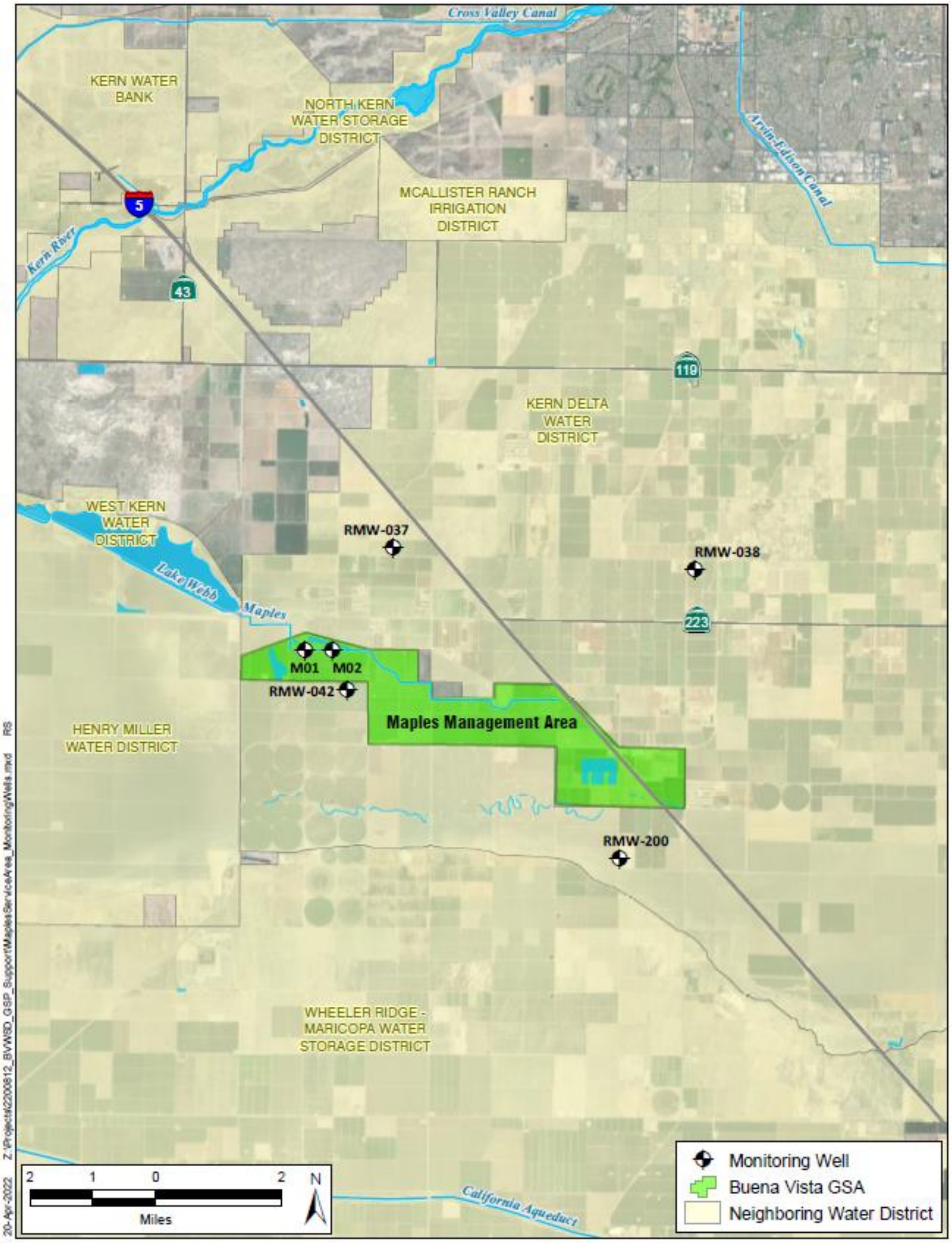
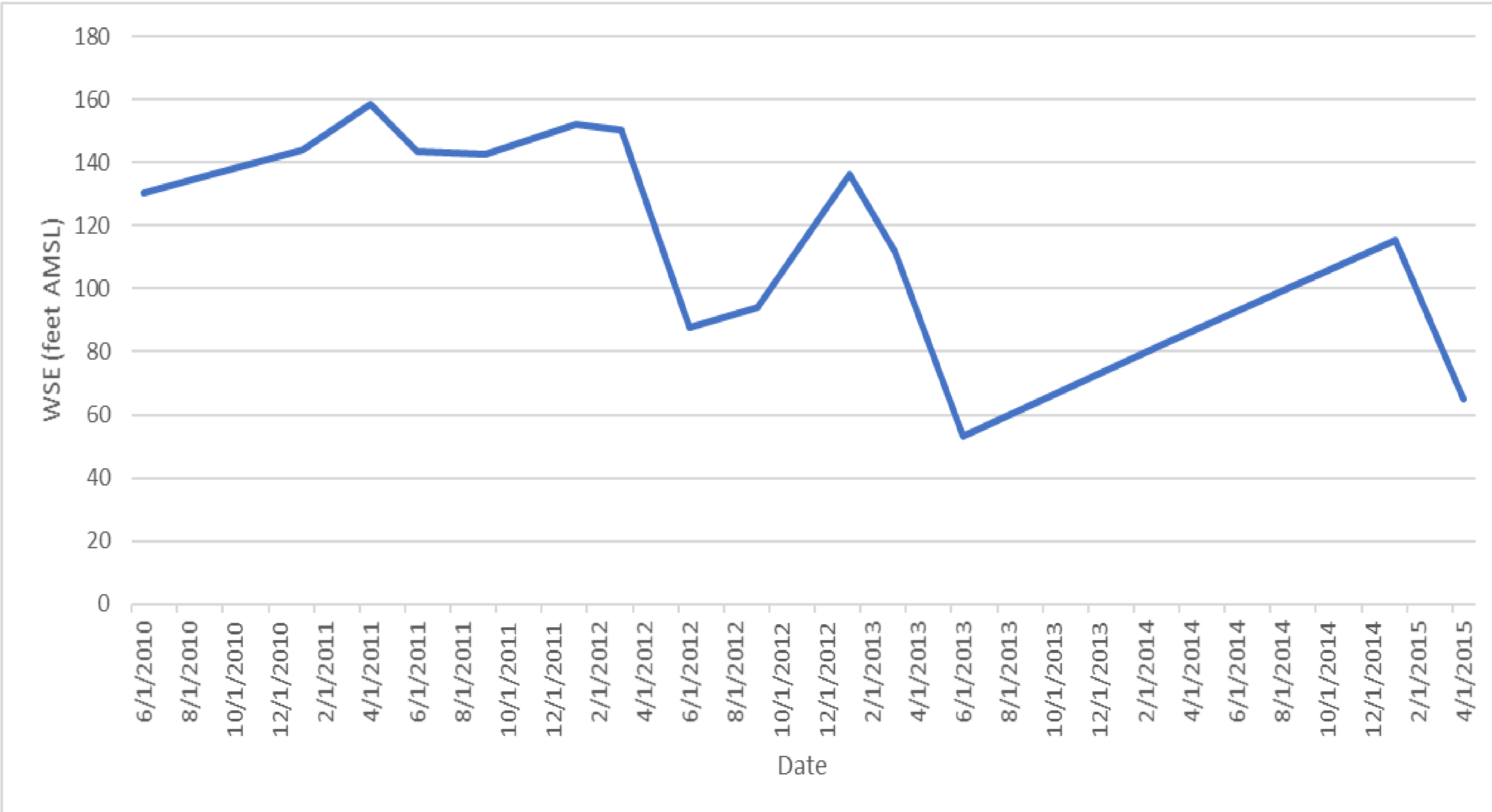


Figure 5-18. Maples Service Area Monitoring Wells and KRGSA Benchmark Wells


180
160
140
120
100
80
60
40
20
0
WSE (feet AMSL)
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
4/1/2011
6/1/2011
8/1/2011
10/1/2011
12/1/2011
2/1/2012
4/1/2012
6/1/2012
8/1/2012
10/1/2012
12/1/2012
2/1/2013
4/1/2013
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8/1/2013
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12/1/2013
2/1/2014
4/1/2014
6/1/2014
8/1/2014
10/1/2014
12/1/2014
2/1/2015
4/1/2015
Date

Figure 5-19. Hydrograph of Well MO1

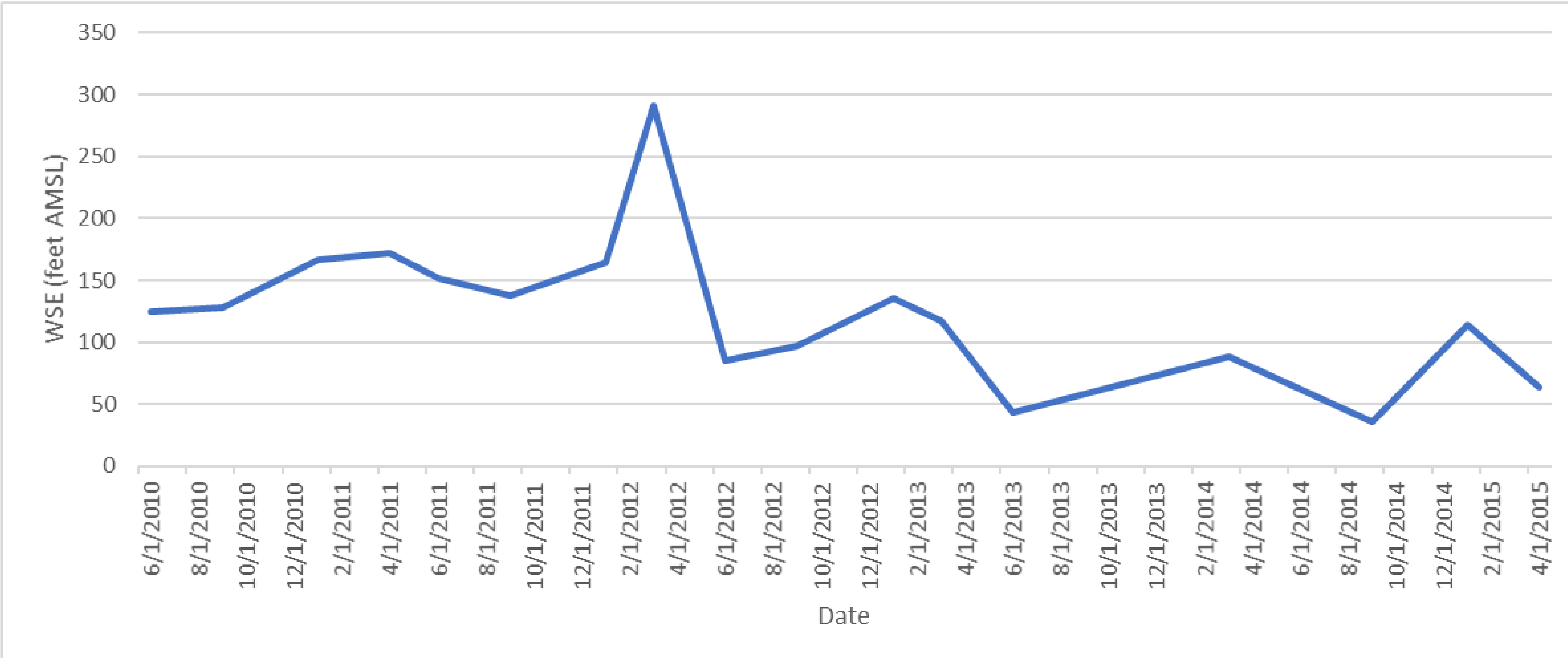

Figure 5-20. Hydrograph of Well MO2

Table 5-23. Historic Water Level Data

Well Identification and Water Level Data			
Monitoring Well ID	Ground Surface Elevation (ft, msl)	Historic High Water Level (ft, msl)	Historic Low Water Level (ft, msl)
MO1	296	155	40
MO2	295	141	47
RMW-037	302	202	59
RMW-042	290	191	5
RMW-200	293	170	58
RMW-038	317	200	97

Based on information provided in KRGSP Section 3 - Basin Setting, wells in the MMA and surrounding areas of the KRGSA draw from zones of the Tulare Formation. MTs for MO1 and MO2 were established in this aquifer. .

In addition to its small size and uniform land surface elevations and depths to groundwater, the following features of the MMA aid in setting MTs:

- The MMA is underlain by the E-clay at elevations ranging from approximately 500 feet to 550 feet bgs with a confined zone of the Tulare Formation extending beneath the clay layer to the base of fresh groundwater.
- Water use throughout the MMA is overwhelmingly agricultural, therefore, the spatial distribution of demands is uniform.
- Unlike the BMA where the A-clay and the C-clays create separate aquifer zones in the northern part of the MA, in the MMA there are no intermediate clay layers above the E-clay.

The hydrogeologic features of the MMA noted above provide a physical setting for MTs and other SMCs. The Spring 2015 groundwater elevations observed at MO1 and MO2 on 4/11/2015 were respectively 226 feet and 227.5 feet bgs. There were no Fall recordings at MO1 in 2014, 2015 or 2016. At MO2, the Fall 2014 (9/24/2014) groundwater elevation was 255.4 feet bgs and the Fall 2016 elevation (10/16/2016) was 285.7 feet bgs. All of these readings suggest substantial groundwater storage exists between prevalent groundwater levels and the top of the E-clay. As in the BMA, the E-clay constitutes a physical floor for sustainable management of groundwater in the MMA. Limiting groundwater extraction to zones above the E-clay avoids the risks of degrading water quality and inducing subsidence that may result from pumping beneath the E-clay.

MTs for MO1 and MO2 were set so that they would be based on rules similar to those used to establish MTs for nearby KRGSA monitoring wells. This approach was applied so that MTs in the MMA would fall within the range of elevations as MTs set by the KRGSA. For this reason, the 30-foot adjustment to the low water level used to determine the MTs shown in Table 5-24 at both MO1 and MO2 is within the range of adjustments made to the KRGSA wells, and as shown on Table 5-24, produces MTs that are intermediate to those developed for nearby KRGSA monitoring wells.

Consistent with the surrounding KRGSA and the BMA, a management area exceedance in the MMA is triggered when groundwater levels decline below established MTs in 40 percent or more of any representative monitoring wells within the management area over four consecutive bi-annual SGMA required monitoring events. Therefore, a management area exceedance could be triggered by groundwater levels observed at either of the two monitoring wells in the MMA.

Table 5-24. MT Designations for Chronic Lowering of Groundwater Levels

MTs Relative to Ground Surface and Historic Water Levels					
Monitoring Well ID	Ground Surface (ft msl)	High Water Level (ft msl)	Low Water Level (ft msl)	MT Relative to Historic Low (ft)	MT (ft msl)
MO1	296	155	40	-30	10
MO2	295	141	47	-30	17
RMW-037	302	202	59	-50	9
RMW-042	290	191	5	-50	-45
RMW-200[1]	293	170	58	-20	38
RMW-038	317	200	97	-50	47

[1] MT at RWM-200 set to be protective against subsidence

Table 5-25 summarizes the MTs recommended for representative monitoring wells MO1 and MO2 together with the difference between these MTs and the Spring 2015 groundwater levels noted earlier.

Table 5-25. Recommended MTs for MO1 and MO2

Recommended MTs and Difference from Spring 2015 Water Levels		
Monitoring Well ID	Recommended MT Elevation (ft msl)	Difference from Spring 2015 Water Level (ft)
M01	10 ft msl (286 ft bgs)	-60
M02	17 ft msl (278 ft bgs)	-51

5.9.2 Measurable Objectives and Interim Milestones

The SGMA regulations describe MOs and how they relate to the sustainable management of groundwater in the California Code of Regulations:

§ 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.
(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.
(c) Measurable objectives shall provide a reasonable margin of operational flexibility under adverse conditions which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty.
(d) 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.
(e) Each Plan shall describe a reasonable path to achieve the sustainability goal for the basin within 20 years of Plan implementation, including a description of interim milestones for each relevant sustainability indicator, using the same metric as the measurable objective, in increments of five years. The description shall explain how the Plan is likely to maintain sustainable groundwater management over the planning and implementation horizon.

As described above, MOs are quantitative goals that represent the subbasin’s desired groundwater conditions and allow GSAs to achieve their sustainability goals within 20 years. These objectives are set at every representative monitoring site and use the same metrics as MTs, allowing monitored groundwater elevations to be effectively compared to both the MOs (the desired level) and the MTs (the trigger level for assessment of undesirable results) to determine the margin of operational flexibility available at a given point in time as illustrated in Figure 5-1.

The BVGSA has established MOs at MO1 and MO2, the two representative monitoring sites in the MMA. These MOs, together with the MTs discussed above, are designed to aid in sustainable management of groundwater by allowing the BVGSA to:

- Withstand droughts of a minimum duration of 10 years without violating any of its recommended MTs;
- Minimize the number of existing wells whose operation is compromised by reductions in groundwater elevations, and
- Provide a margin of operational flexibility that accommodates the impacts of climate change on water supply, water use and drought response.

As is the case for MTs, MOs for MO1 and MO2 have been based on rules that correspond to those used to establish MOs for nearby KRGSA monitoring wells. The goal of this approach is to establish MOs that are consistent in their formulation and in their levels with those set at nearby locations in the KRGSA. Because of the relatively short period of record available for MO1 and MO2, it is likely that the range of high and low water levels recorded at these locations does not display the same amplitude as those shown for KRGSA monitoring wells that have longer reporting periods. For this reason, as shown in Table 5-26, the -50-foot and -40-foot adjustments to the high water levels used to determine the MOs at MO1 and MO2, respectively, are lower than those applied to the KRGSA monitoring wells to produce MOs that are within the range of those developed for the nearby KRGSA wells.

Table 5-26. MO Designation for Chronic Lowering of Groundwater Levels

MOs Relative to Historic Water Levels					
Monitoring Well ID	**Ground Surface (ft msl)**	**High Water Level (ft msl)**	**Low Water Level (ft msl)**	**MO Relative to Historic High (ft)**	**MO (ft msl)**
MO1	296	155	40	-50	105
MO2	295	141	47	-40	101
RMW-037	302	202	59	-96	106
RMW-042	290	191	5	-118	73
RMW-200	293	170	58	-66	104
RMW-038	317	200	97	-77	123

5.9.3 Margin of Operational Flexibility

The margin of operational flexibility within the MMA is the difference in water levels between the MO and the MT at each representative monitoring site. The capacity to respond to droughts available within the margin of operational flexibility can be augmented during extreme droughts by lowering groundwater elevations below the recommended MTs.

Table 5-27 summarizes the MOs, MTs and the resulting margins of operational flexibility for chronic lowering of groundwater levels at the two representative monitoring sites in the MMA and at the four KRGSA monitoring wells used as benchmarks for establishing MTs and MOs at MO1 and MO2. This table shows that the MTs and MOs established for the MMA result in margins of operational flexibility that are comparable to those of the KRGSA's benchmark monitoring wells.

Table 5-27. Margin of Operational Flexibility

Operating Zone Based on MTs and MOs				
Monitoring Well ID	Ground Surface (msl)	MT (msl)	MO (msl)	Operating Zone (MO-MT) (ft)
MO1	296	10	105	95
MO2	295	17	101	84
RMW-037	302	9	106	97
RMW-042	290	-45	73	118
RMW-200	293	38	104	66
RMW-038	317	47	123	76

Because historic water levels in the MMA are well within the margin of operational flexibility, no IMs have been established to correct chronic lowering of groundwater elevations.

5.9.4 Representative Monitoring

As discussed in the preceding section, SMCs for monitoring chronic lowering of groundwater levels have been established for the two Buena Vista monitoring wells within the MMA. These sites will be observed throughout implementation of SGMA to monitor this sustainability indicator.

5.10 Reduction in Groundwater Storage

5.10.1 Minimum Thresholds

The Draft BMP For Sustainable Management Criteria (DWR 2017) defines the MT for significant and unreasonable reduction in groundwater storage as follows:

> The minimum threshold for reduction of groundwater storage is a volume of groundwater that can be withdrawn from a basin or management area, based on measurements from multiple representative monitoring sites, without leading to undesirable results. Contrary to the general rule for setting minimum thresholds, the reduction of groundwater storage minimum threshold is not set at individual monitoring sites. Rather, the minimum threshold is set for a basin or management area.

Chronic lowering of groundwater levels is an undesirable result that increases the cost to access groundwater and, because of its local impacts, is governed using MTs established for individual monitoring sites. In contrast, significant and unreasonable reduction in groundwater storage constrains the amount of groundwater available at any cost. Both sustainability indicators have broad implications on the Kern County Subbasin's capacity to manage groundwater sustainably. Historical trends in water use in the MMA have been shaped by agricultural land use and by water year types. As land and water uses within the MMA are projected to remain dominated by irrigated agriculture, the same factors that have influenced past trends are expected to extend into the future.

Since the primary causes of both chronic lowering of groundwater levels and significant reductions in groundwater storage are extended periods of extraction beyond the sustainable yield, the BVGSA has used MOs and MTs set at the two monitoring wells in the MMA to estimate the volume of groundwater that can be extracted within the MMA's boundaries without leading to an undesirable result.

The elevation differences between the recommended MOs and MTs used to monitor chronic lowering of groundwater levels have been applied to estimate the volume contained between these two boundaries, approximately $17x10^9$ cubic feet or 390,000 AF. The total volume between the MOs and MTs, together with a range of specific yield estimates of the principal aquifer system [0.10 and 0.20], presented in BVGSA Section 2 -Basin Setting, results in a drought reserve contained within the margin of operational flexibility of between 39,000 AF and 78,000 AF. This reserve, when combined with the reserves available from other areas of the Kern County Subbasin, form the basis for computing the volume of groundwater that can be withdrawn without leading to an undesirable reduction in groundwater storage. Table 5-28 presents a summary of the calculation used to estimate the MMA's drought reserve. Extraction of groundwater in excess of this drought reserve would constitute a breach of the MT set in the MMA for this sustainability indicator.

Table 5-28. Estimated Drought Reserve

Calculation of Estimated Drought Reserve		
Total Volume between MO and MT	390,000	AF
Specific Yield: Low	0.10	
Specific Yield: High	0.20	
Drought Reserve: Low	39,000	AF
Drought Reserve: High	78,000	AF
Drought Reserve: Average	58,500	AF

Consistent with the KRGSA and the BMA, an exceedance is triggered when groundwater levels decline below established MTs in 40 percent or more of any representative monitoring wells within the MMA over four consecutive bi-annual SGMA required monitoring events. In the case of the MMA, an exceedance can be triggered by water levels observed at a single monitoring well. As is the case with the BMA, there is considerable reserve storage between the MTs and the E-clay so that if water levels were to drop below MTs, storage would remain above the E-clay to allow time for implementation of corrective actions.

5.10.2 Measurable Objectives and Interim Milestones

The BVGSA will use the representative MOs set for chronic lowering of groundwater levels as proxies for attainment of the MO related to groundwater storage within the boundaries of the MMA. The groundwater storage objectives established for the MMA will contribute to definition of the measurable objective for the Kern County Subbasin.

As described above, the MOs and MTs at MO1 and MO2 used to observe chronic lowering of groundwater levels in the MMA have been applied to compute the volume of the drought reserve for the MMA with this estimate contributing to determination of the overall groundwater reserve capacity of the Subbasin.

5.10.3 Margin of Operational Flexibility

The margin of operational flexibility set for chronic lowering of groundwater levels in the MMA was used to estimate the groundwater reserves available for responding to drought. The volume of effective storage within the margin of operational flexibility, approximately 58,500 AF, represents the MT for reduction of groundwater storage. Extractions that reduce storage within the margin of operational flexibility by more than this MT constitute a trigger warning of a possible undesirable result.

5.10.4 Representative Monitoring

SMCs for reductions in groundwater storage are monitored using the same network and metrics as chronic lowering of groundwater levels. In the case of the MMA, monitoring of reductions in groundwater storage would rely on observations taken at MO1 and MO2..

An important data gap related to estimating reductions in groundwater storage is the completeness and reliability of aquifer parameters available to convert observed changes in groundwater levels to corresponding changes in storage. Continued development and calibration of groundwater models is expected to improve our understanding of these relations for various aquifer materials and conditions.

5.11 Degraded Water Quality

Unlike the other sustainability indicators, water quality is already regulated by a variety of federal, state, and local agencies. In the case of the MMA and the KRGSA's Agricultural MA, the most notable of these programs is the Central Valley Regional Board's Irrigated Lands Regulatory Program. Neither the BVGSA nor the KRGSA have the mandate or authority to duplicate existing programs nor are either of these GSAs required to correct for historical issues, naturally-occurring degradation, or degradation caused by others. Both GSAs propose to coordinate with established water quality management programs through data sharing and analysis.

5.11.1 Minimum Thresholds

As noted above, GSAs are not required to correct for historical water quality concerns, naturally-occurring degradation, or degradation caused by others. Accordingly, the KRGSA has set water quality MTs 50 feet below the historic low water levels for areas of the Agricultural MA other than areas in the north of the MA not affected by arsenic. Because no water quality data is available from MO1 and only one measurement, made on March 14, 2012, is available from MO2, there is no baseline for water quality established at the BVGSA's two representative monitoring wells. Therefore, the approach taken by the KRGSA that protects beneficial uses in the Agricultural MA by linking chronic declines in groundwater levels with degradation of groundwater quality is an appropriate standard for protecting beneficial uses in the MMA. Table 5-29 presents the recommended water quality MTs for the two monitoring wells in the MMA and for the four KRGSA monitoring wells used for benchmarking. As with the MTs for chronic lowering of groundwater levels, the MTs set for MO1 and MO2 are similar to those set for the KRGSA benchmark wells with the objective of providing an equitable basis for SGMA compliance for wells within the MMA and in nearby areas of the KRGSA.

Table 5-29. Recommended Water Quality MTs for MO1 and MO2 and Nearby Wells

Water Quality MTs		
Monitoring Well ID	Recommended MT (ft msl and bgs)	Difference from Historic Low Water Level (ft)
M01	-10 ft msl (306 ft bgs)	-50
M02	-3 ft msl (298 ft bgs)	-50
RMW-037	9 msl (293 ft bgs)	-50
RMW-042	-45 msl (335 ft bgs)	-50
RMW-200	8 msl (285 ft bgs)	-50
RMW-038	47 msl (270 ft bgs)	-50

The standard for the KRGSA's Agricultural Management Area is than an undesirable result will be triggered when groundwater levels in 40 percent or more of the representative monitoring wells in the MA remain below the MT over a period of two years. Because of the MMA's location within the Agricultural Management Area, this standard will be applied to the two monitoring wells within the MMA with an exceedance in either of the two wells constituting an undesirable result.

5.11.2 Measurable Objectives and Interim Milestones

KRGSP Section 5.7.4.2 - KRGSA Agricultural Management Area defines the water quality MOs for monitoring wells in the Agricultural MA south of the arsenic-affected area as the average of (mid-point between) the high groundwater level and the MT. The MMA lies south of the arsenic-affected zone of the Agricultural MA, and the one water quality reading from MO2 reports an arsenic reading below the MCL. MOs based on the average of the high groundwater