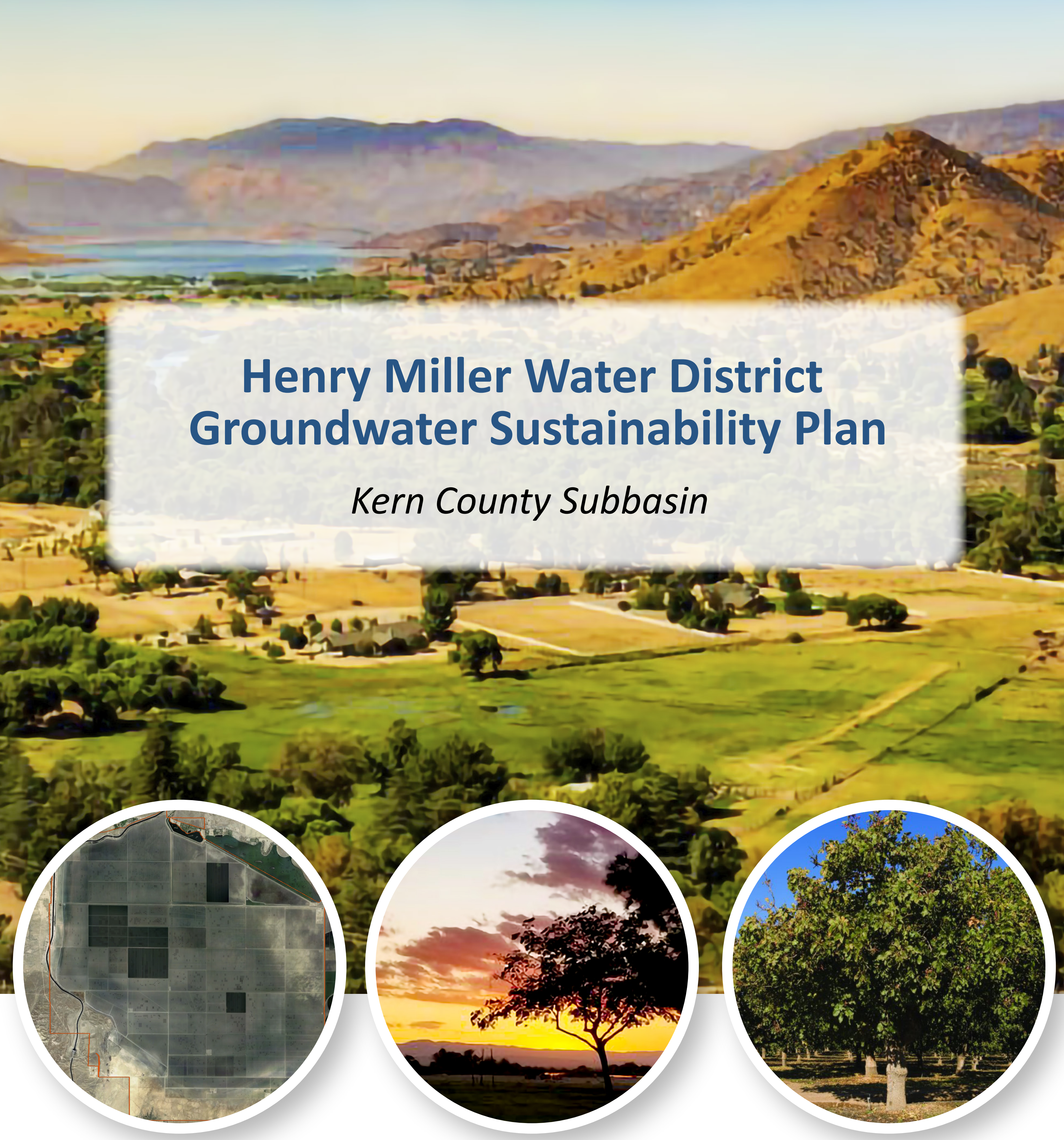


Henry Miller Water District Groundwater Sustainability Plan

Kern County Subbasin

July 2022

Luhdorff & Scalmanini
Consulting Engineers

Henry Miller Water District
Revised Groundwater Sustainability Plan

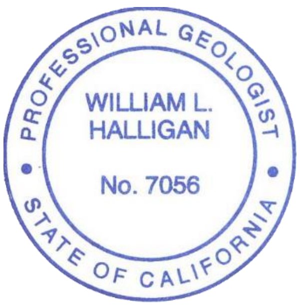
Kern County Subbasin

July 21, 2022

Henry Miller Water District
101 W. Walnut Street
Pasadena, CA 91103

DISCLAIMER

This work product is the Groundwater Sustainability Plan (GSP) for the Henry Miller Water District Groundwater Sustainability Agency (GSA). This GSP is one of five (5) individual GSPs being prepared for the Kern County Subbasin (KCS, Subbasin). Each GSP was prepared under the direction of a Professional Geologist (PG), Certified Hydrogeologist (CHG), or Professional Engineer (PE) as indicated by the stamp on each individual GSP. Each individual GSP for the Subbasin will be submitted in a coordinated manner. The stamp and signature herein represent the work completed on this GSP for the Henry Miller Water District GSA and none of the other GSPs prepared for the Subbasin. The undersigned assumes no responsibility for any errors or misleading statements presented in any other GSPs prepared in the KCS.



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CONTENTS

LIST OF APPENDICES

LIST OF TABLES PAGE

LIST OF FIGURES — AFTER PAGE

LIST OF ABBREVIATIONS & ACRONYMS

AF	Acre- Feet
AFY	Acre-Feet per year
AGR	Agricultural Supply
amsl	above mean sea level
bgs	Below Ground Surface
BMP	Best Management Practices
bmsl	Below mean sea level
BVARA	Buena Vista Aquatic Recreational Area
BVPP	Buena Vista Pumping Plant
BVWSD	Buena Vista Water Storage District
C2VSIM	California Central Valley Groundwater-Surface Water Simulation Model
CASGEM	California Statewide Groundwater Elevation Monitoring
CASP	California Aqueduct Subsidence Program
CCR	California Code of Regulations
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CGPS	Continuous Global Positioning System
CIWQS	California Integrated Water Quality System
COB	City of Bakersfield
County	County of Kern
CVP	Central Valley Project
DBCP	dibromochloropropane
DDW	Division of Drinking Water
DMG	California Division of Mines and Geology
DOGGR	Division of Oil, Gas, and Geothermal Resources
DTSC	Department of Toxic Substances
DTW	Depth to Water
DWR	Department of Water Resources
EC	Electrical Conductivity
EHD	Environmental Health Department

EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ET	Evapotranspiration
ft	Feet or Foot
ft/day	Feet per Day
FWA	Friant Water Authority
GAMA	Groundwater Ambient Monitoring and Assessment
GDE	Groundwater Dependent Ecosystem
GDEi	Groundwater Dependent Ecosystem Indicators
GPM	Gallons per Minute
GPS	Global Positioning System
GSP	Groundwater Sustainability Plan
GSA	Groundwater Sustainability Agency
GWE	Groundwater Elevations
HCM	Hydogeologic Conceptual Model
HMWD or District	Henry Miller Water District
HR2W	Human Right to Water
ID4	Improvement District #4
ILRP	Irrigated Lands Regulatory Program
InSAR	Interferometric Synthetic Aperture Radar
IRWM	Integrated Roadside Vegetation Management
ITRC	Interstate Technology and Regulatory Council
JPL	Jet Propulsion Laboratory
KCGP	Kern County General Plan
KCPHSD	Kern County Public Health Services Department
KCS	Kern County Subbasin
KCWA	Kern County Water Agency
KDSA	Kenneth D. Schmidt and Associates
KDWD	Kern Delta Water District
KFMC	Kern Fan Monitoring Committee
KGA	Kern Groundwater Authority

KRGSA	Kern River Groundwater Sustainability Agency
KRWCA	Kern River Watershed Control Authority
KTWD	Kern-Tulare Water District
LAMP	Local Agency Management Program
LSCE	Luhdorff & Scalmanini Consulting Engineers
MAs	Management Actions
MCL	Maximum Contaminant Level
MIT	Mechanical Integrity Test
MOs	Measurable Objectives
MTs	Minimum Thresholds
mg/L	Milligrams per Liter
msl	(ft above) Mean Sea Level
MUN	Municipal and Domestic Supply
MW	Monitoring Well
NASA	National Aeronautics and Space Administration
NCCAG	DWR's Natural Communities Commonly Associated with Groundwater
NEPA	National Environmental Policy Act
NRCS	Natural Resources Conservation Service
ODC	Overdraft Correction
PBO	Plate Boundary Observation
PGA	Pacific Geotechnical Associates, Inc.
PMAs	Projects & Management Actions
ppb	points per billion
ppm	points per million
ppt	points per trillion
PW	Production Well
SAGBI	Soil Agricultural Groundwater Banking Index
SDWIS	State Drinking Water Information System
SGMA	Sustainable Groundwater Management Act
SMCL	Maximum Contaminant Level
SpC	Specific Conductance

Subbasin or KCS	Kern County Subbasin
SURRGO	Natural Resources Conservation Service Soil Survey Geographical Database
SWP	State Water Project
SWSD	Semitropic Water Storage District
SWRCB	California State Water Resources Control Board
TDS	Total Dissolved Solids
TNC	The Nature Conservancy
UAVSAR	Uninhabited Aerial Vehicle Synthetic Aperture Radar
UIC	Underground Injection Control
µmhos/cm	Micromhos per Centimeter
µs/cm	Microsiemens per centimeter
USGS	United States Geologic Survey
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USDW	Underground Source of Drinking Water
USFWS	United States Fish and Wildlife Service
WDR	Water Discharge Requirements
WKWD	West Kern Water District
WRMWSD	Wheeler Ridge-Maricopa Water Storage District
WY	Water Year

EXECUTIVE SUMMARY (REG. § 354.4)

This Groundwater Sustainability Plan (GSP) for the Henry Miller Water District (HMWD) Groundwater Sustainability Agency (GSA) has been prepared pursuant to Water Code §10727. HMWD is located in the Kern County Subbasin (Basin 5-22.14) as defined by the Department of Water Resources' (DWR) Bulletin 118. The Kern Subbasin is considered to be in a condition of critical overdraft and has been designated as a high priority basin. This GSP is one of the five GSPs being prepared in the Subbasin, which collectively has and will coordinate to avoid, to the best of their abilities, any and all Undesirable Results as a result of unsustainable groundwater management practices.

HMWD formed its own GSA on March 15, 2017; it is the only Water District located within the GSA. HMWD GSA is one of five GSAs that are preparing a GSP within the Subbasin. This GSP, in coordination with the four other GSPs within the Subbasin, will provide a path to sustainability and the preservation of groundwater resources for all beneficial users of groundwater. Because the Subbasin has multiple GSPs, the GSPs are prepared under a coordination agreement. This Coordination Agreement exemplifies the ways that the various GSPs were able to work together to achieve a common goal: groundwater sustainability for the Subbasin. For example, the entire Subbasin has utilized Todd Groundwater's services to analyze historic, current, and future groundwater conditions with a C2VSIM model.

This Plan includes a description of the historic groundwater conditions in the Subbasin, a Subbasin water budget, sustainable management criteria for future monitoring, and projects and/or management actions that may be implemented to ensure groundwater sustainability is achieved by 2040 and maintained through 2070.

1. INTRODUCTION (REG. § 354.2)

1.1 Purpose of Groundwater Sustainability Plan

The purpose of this groundwater sustainability plan (GSP) is to provide a long-term path for the Henry Miller Water District (HMWD) groundwater sustainability agency (GSA) in coordination with four other GSPs being prepared for the Kern County Subbasin (Subbasin) to meet requirements set forth by the California Sustainable Groundwater Management Act (SGMA), which includes managing the groundwater resources within the Subbasin's and HMWD GSA's boundaries to prevent overdraft and achieve sustainability. The coordination agreement which all GSAs have agreed to and which governs the preparation of the GSPs for the Subbasin is presented in **Appendix A**.

This GSP describes the historical and existing hydrogeologic conditions and current management practices in the area of HMWD. It also contains the steps that will be taken to achieve sustainability over the next 20 years by preventing undesirable results via monitoring of the sustainability indicators as defined by SGMA:

- chronic lowering of groundwater levels,
- reduction in groundwater storage,
- degraded water quality,
- subsidence,
- depletion of interconnected surface water, and
- seawater intrusion

All but seawater intrusion and depletion of interconnected surface water apply to the HMWD as discussed in Sections 2.2.5 and 2.2.2, respectively, and will be monitored accordingly. Measurable objectives and minimum thresholds have been set for each sustainability indicator based on projected hydrologic conditions through the use of a numerical groundwater flow model.

This GSP incorporates Basin Setting information prepared by GEI Consultants through a coordinated effort between the Kern Groundwater Authority and HMWD GSAs. In order to provide clarity for sequential purposes in this GSP, numbers were changed on the figures and tables provided by GEI Consultants to match the figure and table sequencing in the HMWD GSP.

1.2 Sustainability Goal

HWMD GSA's goal is to continue the use of groundwater for agriculture production in a responsible and sustainable manner that maintains groundwater supplies and quality for all beneficial uses of groundwater in the region and pursuant to a Coordination Agreement which includes Subbasin-wide sustainability goals.

1.3 Agency Information (Reg. § 354.6)

1.3.1 Organization Management and Structure of GSA

President:	Jeof Wyrick
Vice President:	Joey Mendonca
Director:	Tom Hurlbutt
Director:	Charlie Riddle
Director:	Slavisa Pavlovic

The Board of Directors has final authority for plan implementation. Jeof Wyrick has been appointed the GSA Contact by the Board of Directors.

Agency Contact:	Jeof Wyrick
Mailing address:	101 W. Walnut Street Pasadena, CA 91103
Telephone:	626-583-3000
Email:	jwyrick@jgboswell.com

The Board of Directors held several meetings during the preparation and adoption of this GSP and minutes are provided as **Appendix B**. Meetings were held on the following dates:

- June 21, 2017
- June 12, 2018
- December 18, 2018
- March 12, 2019
- June 3, 2019
- August 30, 2019
- December 2, 2019
- January 10, 2020

1.3.2 Legal Authority of the GSA

HMWD (District) is a public agency overlying a portion of the Subbasin (DWR Bulletin 118 Basin 5-22-14). The District was formed in 1964, under the provisions of California Water Code Division 13, to produce, store, and distribute water for irrigation, domestic, industrial, and municipal purposes, drain and reclaim lands incidental thereto or connected therewith (Sec. 35401). The District's primary purpose was to acquire an existing agricultural water delivery and drainage system, including wells, and to obtain a long-term surface water supply from the State Water Project's (SWP) California Aqueduct. Therefore, the HMWD is qualified to form a GSA. The Notice of Intent to form a GSA and GSA formation document are provided in **Appendix C.**

As stated in Water Code §10732, the GSA has the power to develop and implement SGMA, including a GSP. The Agency can adopt standards for measuring and reporting water use, develop and implement policies designed to reduce or eliminate overdraft within the boundaries of the Agency, develop and implement conservation best management practices (BMPs), and develop and implement metering, monitoring, and reporting related to groundwater pumping.

1.3.3 Estimated Cost of Implementing the GSP

The estimated cost of implementing the GSP over the 20-year implementation period is approximately $2 million. The GSA will meet these supplemental costs by a voluntary assessment of the sole landowner in the District.

1.4 GSP Organization

Table 1-1 catalogs all GSP requirements and their location in the document.

Table 1-1: Preparation Checklist for GSP Submittal

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 3. Technical and Reporting Standards				
352.2		Monitoring Protocols	- Monitoring Protocols adopted by the GSA for data collection and management - Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	Section 3.5, Pg. 83
Article 5. Plan Contents, Subarticle 1. Administrative Information				
354.4		General Information	- Executive Summary - List of References and Technical Studies	Executive Summary: Pg. ES-1 References: Section 6, Pg. 93
354.6		Agency Information	- GSA Mailing Address - Organization and Management Structure - Contact Information of Plan Manager - Legal Authority of GSA - Estimate of Implementation Costs	Section 1.3, Pg. 1
354.8.a	10727.2.(a).4	Map(s)	- Area covered by GSP - Adjudicated areas, other agencies within the basin, and areas covered by an Alternative - Jurisdictional boundaries of federal or State land - Existing Land Use Designations - Density of wells per square mile	Section 1.5, Pg. 8
354.8.b		Description of the Plan Area	- Summary of jurisdictional areas and other features	Section 1.5.1, Pg. 8

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
354.8.c, d, e	10727.2(g)	Water resource monitoring and management programs	- Description of water resources monitoring and management programs - Description of how the monitoring networks of those plans will be incorporated into the GSP - Description of how those plans may limit operational flexibility in the basin - Description of conjunctive use programs	Section 1.5.2, Pg. 8
354.8.f	10727.2(g)	Land Use Elements or Topic Categories of Applicable General Plans	- Summary of general plans and other land use plans - Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects - Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans - Summary of the process for permitting new or replacement wells in the basin - Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	Section 1.5.3, Pg. 9
354.8.g	10727.4	Additional GSP Contents	**Description of Actions related to:** - Control of saline water intrusion - Wellhead protection - Migration of contaminated groundwater - Well abandonment and well destruction program - Replenishment of groundwater extractions - Conjunctive use and underground storage - Well construction policies - Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects - Efficient water management practices - Relationships with state and federal regulatory agencies - 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 - Impacts on groundwater dependent ecosystems	Section 1.5.4, Pg.12
354.10		Notice and Communication	- Description of beneficial uses and users - List of public meetings - GSP comments and responses - Decision-making process - Public engagement - Encouraging active involvement - Informing the public on GSP implementation progress	Section 1.5.5, Pg. 13

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 2. Basin Setting				
354.14		Hydrogeologic Conceptual Model	- Description of the Hydrogeologic Conceptual Model - Two Scaled Cross-Sections - Map(s) of Physical Characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	Section 2.1.1, Pg. 15
354.14.c.4	10727.2.(a).5	Map of Recharge Areas	- Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas	Section 2.1.1.9, Pg. 37
	10727.2.(d).4	Recharge Areas	- Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	Section 2.1.1.9, Pg. 37
354.16	10727.2.(a).1, 10727.2.(a).2	Current and historical groundwater conditions	- Groundwater elevation data - Estimate of groundwater storage - Seawater intrusion conditions - Groundwater quality issues - Land subsidence conditions - Identification of interconnected surface water systems - Identification of groundwater-dependent ecosystems	Section 2.2, Pg. 43
354.18	10727.2.(a).3	Water Budget Information	- Description of inflows, outflows, and change in storage - Quantification of overdraft - Estimate of sustainable yield - Quantification of current, historical, and projected water budgets	Section 2.3, Pg. 69
	10727.2.(d).5	Surface Water Supply	- Description of surface water supply used or available for use for groundwater recharge or in-lieu use	Section 2.3, Pg. 69
354.20		Management Areas	- Reason for creation of each Management Area - Minimum Thresholds and Measurable Objectives for each Management Area - Level of monitoring and analysis - Explanation of how management of Management Areas won't cause undesirable results outside the Management Area - Description of Management Areas	Section 2.4, Pg. 75
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria				
354.24		Sustainability Goal	- Description of the Sustainability Goal	Section 3.1, Pg. 77
354.26		Undesirable Results	- Description of Undesirable Results - Cause of Groundwater Conditions that would lead to Undesirable Results - Criteria used to define Undesirable Results for each sustainability indicator - Potential effects of Undesirable Results on beneficial uses and users of groundwater	Section 3.4, Pg. 81

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
354.28	10727.2.(d).1, 10727.2.(d).2	Minimum Thresholds	- Description of each minimum threshold and how they were established for each sustainability indicator - Relationship for each sustainability indicator - Description of how selection of the Minimum Threshold may affect beneficial uses and users of groundwater - Standards related to sustainability indicators - How each minimum threshold will be quantitatively measured	Section 3.3., Pg. 80
354.30	10727.2.(b).1, 10727.2.(b).2, 10727.2.(d).1 10727.2.(d).2	Measurable Objectives	- Description of establishment of the measurable objectives for each sustainability indicator - Description of how a reasonable margin of safety was established for each measurable objective - Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones	Section 3.2, Pg. 77
Article 5. Plan Contents, Subarticle 4. Monitoring Networks				
354.34	10727.2.(d).1, 10727.2.(d).2, 10727.2.(e), 10727.2.(f)	Monitoring Network	- Description of Monitoring network - Description of Monitoring network objectives - Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions - Description of how the monitoring network provides adequate coverage of sustainability indicators - Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends	Section 3.5, Pg. 83
			- Scientific rational (or reason) for site selection - Consistency with data and reporting standards - Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone - Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used - Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	Section 3.5, Pg. 83

GSP Regulation Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
354.36		Representative Monitoring	- Description of representative sites- Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators - Adequate evidence demonstrating site reflects general conditions in the area	Section 3.5.3, Pg.84
354.38		Assessment and Improvement of Monitoring Network	- Review and evaluation of the monitoring network - Identification and description of data gaps - Description of steps to fill data gaps - Description of monitoring frequency and density of sites	Section 3.5.4, Pg. 84
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions				
354.44		Projects and management actions	- Description of projects and management actions that will help achieve sustainability goal - Measurable objective that is expected to benefit from each project and management actions - Circumstances for implementation - Public noticing - Permitting and regulatory process - Timetable for initiation and completion, and the accrual of expected benefits - Expected benefits and how they will be evaluated - How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included. - Legal authority required - Estimated costs and plans to meet those costs - Management of groundwater extractions and recharge	Section 4, Pg.85
354.44.b.2	10727.2.(d).3		- Overdraft mitigation projects and management actions	N/A

1.5 Plan Area

1.5.1 Summary of Jurisdictional Areas and Other Features (Reg. § 354.8 b)

A map demonstrating the jurisdictional boundaries of the HMWD GSA can be seen in **Figure 1-1**. The GSA is adjacent to the West Kern Water District (WKWD) GSA, Buena Vista Water Storage District (BVWSD) GSA, Kern River Groundwater Sustainability Agency (KRGSA), and Kern Groundwater Authority (KGA) GSA.

The total area of the HMWD GSA is 26,055 acres and primarily consists of irrigated agricultural land, but also includes a manmade recreational lake, undeveloped land, the California Aqueduct, and land used for oil and gas production.

All parcels in the GSA are zoned for exclusive agriculture, with the exception of parcels 220-110-38, -42, -43, & -44, which are zoned for heavy industrial (**Figure 1-2** and **Figure 1-3**).

As mentioned, HMWD is the only Water District that comprises the GSA. The District provides supply and conveyance of water for irrigation purposes within the GSA boundaries. The landowner in the District has access to three different sources of water: SWP water, Kern River water, and groundwater (**Figure 1-4**) that the District uses conjunctively. The District has a Contractual Table A SWP supply of 35,500 acre-feet per year (AFY) and the landowner annual Kern River supply is generally just under 5,000 acre-feet (AF).

Within the GSA there are 28 active production wells used for agricultural irrigation, all owned by HMWD, which equates to well density of 0.69 wells per square mile. Well density maps for production, domestic, and public wells are provided in **Figures 1-5**, **1-6**, and **1-7**, respectively. HMWD has one (1) well for domestic use located at the HMWD office in the northeast portion of the GSA. This well is not used for drinking water purposes and supplies non-potable water. The area of the GSA where groundwater pumping occurs is comprised of the 28 active agricultural supply wells and the one non-potable domestic well, all located within the northeast region of the HMWD.

As shown by **Figure 1-8**, there are no Groundwater Dependent Communities within HMWD and therefore interconnected surface water and groundwater is not present within the District.

There are presently no adjudicated areas or alternative plans within the Subbasin. The HMWD GSA makes up approximately 1.44 percent of the area in the Subbasin.

1.5.2 Water Resources Monitoring and Management Programs (Reg. § 354.8 c, d, e)

HMWD has been involved in water monitoring programs and has been sustainably managing its water resources prior to the inception of SGMA. The District has been a member of the Kern Fan Monitoring Committee (KFMC) since 1995, which, under the supervision of the Kern County Water Agency (KCWA), monitors groundwater levels around the Kern Fan area.

The District has also participated in the California Statewide Groundwater Elevation Monitoring (CASGEM) program, thereby providing the State with semi-annual groundwater elevation readings since 2011. In addition, the District has monitored and recorded local groundwater conditions, including groundwater extraction, levels, and quality data dating back to the 1960’s.

The District has closely managed its water resources through times of drought and flood. It has been a Recharge Participant in the Pioneer Project since 1995 which has operated under the supervision of the KCWA. The Pioneer Project enables local water agencies to recharge and bank surface supplies in the groundwater aquifer of the Kern Fan, either for overdraft correction or for recovery during dry years.

The District has optimized the beneficial use of Kern River and SWP supplies through exchanges, transfers, and carryover storage, but still depends on a reliable groundwater supplies during dry periods to meet demands. This conjunctive use approach has enabled the District to historically take measures to avoid overdraft within the District. These measures include supply augmentation, through purchasing additional surface water supplies or demand reduction through the fallowing of land or changing cropping patterns to reduce water demand. Although such programs decrease operational flexibility for the landowner within the District, it is recognized that they are necessary to protect current and future water resources.

The District intends to continue using its past and current monitoring programs in the context of a GSP monitoring network. This will be described in Section 3.5.

1.5.3 Land Use Elements or Topic Categories of Applicable General Plans (Reg. § 354.8 f)

Agricultural operations have prospered on the rich soils of the District. Roughly 20,000 acres were developed and equipped for irrigation, groundwater wells were constructed, and supplemental water supplies from the SWP were contracted to meet crop demands (**Figure 1-9**). The cropping pattern within the District stayed relatively consistent from the late-1970's to the early 2010's. This generally consisted of a rotation of row crops, including cotton [primarily], tomatoes, safflower, wheat, garbanzo beans, and onions. It was rare for significant acreage to remain fallow, whether due to flood or drought, as the landowner(s) found ways to accommodate BVWSD's flood operation, and groundwater was used to meet crop demand in years of low surface water supplies.

Beginning in 2015, the cropping pattern shifted to include its first perennial planting: pistachio trees. As of early 2019, there are approximately 6,100 acres of pistachio trees, 1,000 acres of cotton, 1,100 acres of tomatoes, 300 acres of onions, and the remaining acres fallowed. A map demonstrating the 2019 cropping pattern can be viewed in **Figure 1-10**.

Fallowed lands are largely a result of the reduced surface water supplies (primarily SWP water) and the economics of farming. It is yet to be determined how this land will be used in the future, but viable options include additional farming, solar energy production, oil production, as well as storage of surface waters (i.e. reservoir). Implementation of this plan will not affect water supply assumptions for land use plans over the planning and implementation horizon. Significant cutbacks have already been made to reduce water demand in the HMWD GSP area.

The GSA will be informed of any applications for well permits by the sole landowner within its jurisdictional boundaries through the permitting process with the County of Kern (County). The County's Public Health Services Department will routinely provide GSAs with any applications that have been received.

HMWD is under the jurisdiction of the Kern County General Plan (KCGP). This Plan was developed to provide a long-term plan for the development of the County and is comprised of the following elements:

- Land Use, Open Space and Conservation,
- Energy,
- Circulation,
- River Plan,
- Noise,
- Safety, and
- Housing (2015-2023)

The element applicable to the protection of surface water and groundwater in HMWD is Land Use, Open Space, and Conservation which is Chapter 1 of the KCGP and includes the following policies, implementation measures, and goals (with their corresponding KCGP section numbers):

Physical and Environmental Constraints

Policies

Kern County will ensure that new developments will not be sited on land that is physically or environmentally constrained (Map Code 2.3 (Shallow Groundwater)) to support such development unless appropriate studies establish that such development will not result in unmitigated significant impact.

Protect and maintain watershed integrity within Kern County

Implementation Measures

A.2.(c) Cooperate with KCWA to classify lands in the County overlying groundwater according to groundwater quantity and quality limitations.

Public Facilities and Services

Goals

Ensure that adequate supplies of quality (appropriate for intended use) water are available to residential, industrial, and agricultural users within the County.

Policies

The efficient cost-effective delivery of public services and facilities will be promoted by designing areas for urban development which occur within or adjacent to areas with adequate public service and facility capacity.

Ensure that water quality standards are met for existing users and future development.

Residential

Goals

Promote the conservation of water quality and quantity in the County.

Minimize land use conflicts between residential and resource, commercial, or industrial land uses.

Policies

Provide for an orderly outward expansion of new urban development so that it maintains continuity of existing development, allows for incremental expansion of infrastructure and public service, minimizes impacts on natural environmental resources, and provides a high-quality environment for residents and businesses.

Resource

Policies

To encourage groundwater resource management for the long-term economic benefit of the County the following shall be considered:

a) Promote groundwater recharge activities in various zone districts

b) Support the development of Urban Water Management Plans and promote Department of Water Resources grant funding for all water providers

c) Support the development of groundwater management plans

d) Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water and groundwater and desalination.

General Provisions

Goals

Ensure that the County can accommodate anticipated future growth and development while maintaining a safe and healthful environment and a prosperous economy by preserving valuable natural resources, guiding development away from hazardous areas, and assuring the provision of adequate public services.

Policies

Ensure that water quality standards are met for existing users and future development

Encourage the development of the County's groundwater supply to sustain and ensure water quality and quantity for existing users, planned growth, and maintenance of the natural environment.

Encourage utilization of community water systems rather than the reliance on individual wells.

Review development proposals to ensure adequate water is available to accommodate projected growth.

New high consumptive water uses, such as lakes or golf courses, should require evidence of additional verified sources of water other than local groundwater. Other sources may include recycled stormwater or wastewater.

This General Plan was considered in the development of this GSP to ensure that the implementation of this GSP would not contradict relevant general plan policies.

1.5.4 Additional GSP Elements (Reg. § 354.8 g)

All additional GSP elements provided by SGMA were considered for their applicability in HWMD. The additional elements deemed applicable are described hereinafter.

Well Construction, Well Destruction, Abandonment Policies, and Wellhead Protection

All well construction, well destruction, and wellhead protection practices within the District must comply with and follow the specifications and requirements provided by the Kern County Public Health Services Department (KCPHSD) and the California Well Standards. An example of a well construction permit application and well destruction permit application and their associated guidelines are provided in **Appendix D and Appendix E, respectively.**

Through a collaborated process, the Subbasin GSAs worked with the KCPHSD to develop a supplemental well application for wells to be installed within the Subbasin. This application is provided as **Figure 1-11** and requires the applicant to provide information regarding the construction of the well, proposed use, and amount of water to be pumped. The application will be submitted to the KCPHSD where it will be forwarded to the appropriate water district or GSA through the Kern Groundwater Authority (KGA) Planning Manager. The district in which the well will be located then has the opportunity to provide comments and advise the applicant of the sustainable criteria that may impact the operation of the well. This process has been in place since January 2019 and demonstrates the coordination between KCPHSD Requirements and SGMA requirements concerning water well permits.

Replenishment of Groundwater Extractions

In addition to the groundwater replenishment that occurs within District boundaries, the District also delivers surface supplies to the Pioneer Project, mentioned in Section 1.5.2, for overdraft correction purposes. The District tracks this overdraft correction balance and believes it should be considered in its water budget separate from, and in addition to, the replenishment that occurs within District boundaries. The quantity of groundwater replenishment as a result of overdraft correction in the Pioneer Project will be discussed more in Section 2.3.5.

Efficient Water Management Practices

Growers within the Agency have converted to more efficient methods of irrigation since the turn of the 21st century, namely drip irrigation. There is an observed water application savings within the District when crops are grown with drip irrigation systems, as opposed to more traditional furrow or border-strip irrigation.

Because the District is located in a historic lake bottom, it is inherently a closed-recirculation system, so no irrigation water that enters the District leaves the District; any on-farm runoff is recirculated and used for subsequent irrigation. These geographic realities and a desire to minimize runoff promotes the use of efficient irrigation practices.

Impacts on Groundwater Dependent Ecosystems

Due to the depth to fresh groundwater being beyond the zone that any roots may reach, no groundwater-dependent ecosystems are present within the boundaries of HWMD. There is a perched groundwater table that exists with water of a quality that cannot sustain plant or animal life, which is described in Section 2.2.9.

1.5.5 Notice and Communication (Reg. § 354.10)

The GSA has actively provided opportunities for stakeholders to provide input throughout the GSP-preparation process. In addition to communicating with its own landowner and stakeholders, the GSA also participated in coordinated Subbasin-wide open house and workshop events on May 14 and September 24, 2019. These events featured all GSAs within the Subbasin, in addition to DWR and California State Water Resources Control Board (SWRCB) personnel, at the Kern Ag Pavilion in Bakersfield. HMWD did not receive any feedback or comments during these events on HMWD GSP development.

Agendas from 2018 and 2019 HMWD Board of Directors Meeting minutes are also attached in **Appendix C.**

Beneficial Uses and Users of Groundwater

The known groundwater beneficial uses within the GSA include:

- Agricultural Supply (AGR) - Includes uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.
- Municipal and Domestic Supply (MUN) - Includes uses of water for one domestic well user for non-potable purposes. Community and military water supply systems including, but not limited to, drinking water supply are not present within the GSA. The one domestic well within HMWD is located at the HMWD office and is not used for drinking water purposes.

There are no other beneficial uses of groundwater within the HMWD GSA. There are no impacts on beneficial uses and users of groundwater within the GSA from the production of groundwater. Through the public and stakeholder outreach efforts and coordinated GSP development efforts of the Subbasin's GSAs, there are no impacts on adjacent GSAs from HMWD groundwater extractions.

Opportunities for Public Engagement

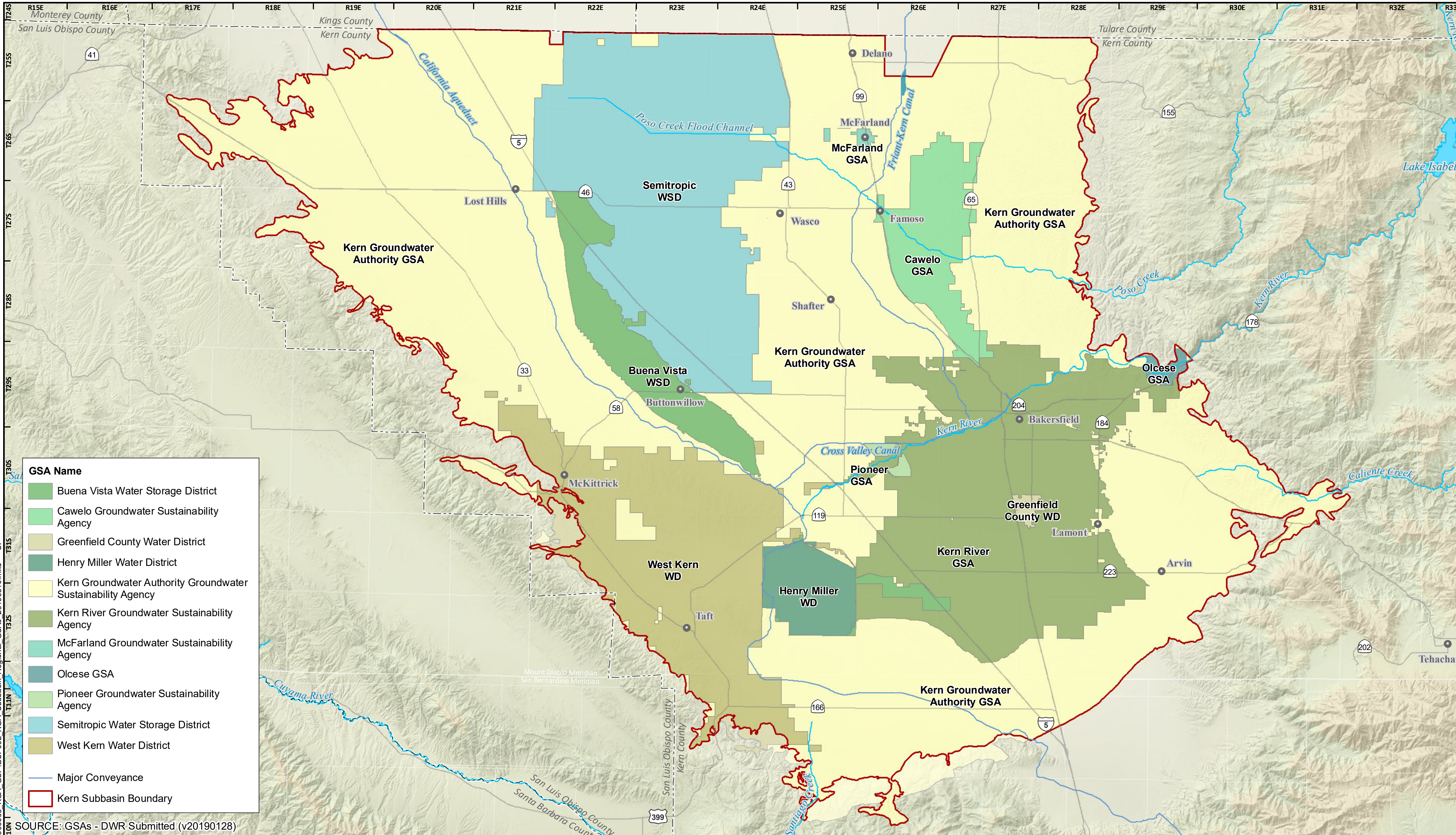
Public engagement was encouraged through the Subbasin-wide outreach events described above in Section 1.5.5. To notify the public of the GSA formation, a "Notice of Public Hearing" was provided in the Bakersfield Californian in March 2017. A public notice was also published in September 2019 that notified the public of the Draft GSP release for Public Comment and date for the public hearing and adoption of the GSP. The review period allowed the public to be engaged in the GSP development process and make comments on the plan. A letter was also provided to the Kern County Administrative Office with the Notice of Intent to Adopt the HMWD Groundwater Sustainability Plan. Similar to the Notice of Adoption and GSA formation notification process, the ongoing public notification and engagement process will include submittal of notices to the Subbasin GSAs, Kern County Administrative Office, public notices in local newspaper publications, and notifying the single landowner of Plan implementation progress.

Comments on the Plan

The Draft GSP was released for Public Comment on September 5, 2019. HMWD received 13 requests for the Draft GSP. No public comments were submitted to HMWD.

Decision Making Process

Many aspects of the GSP were determined by coordinating with other GSAs in the Subbasin. Meetings of the *Coordination Committee* and the Coordination Agreement (**Appendix A**) provided the platform for the GSAs to work together in order to make sure all required components of the GSPs were consistent. Internally, HMWD made decisions by working with their consultant and stakeholders. All items of the Plan were approved by the HMWD Board of Directors.



0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

GROUNDWATER SUSTAINABILITY AGENCIES
WITHIN SUBBASIN

JULY 2019

FIGURE 1-1

19-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP002_KGA_Subbasin_Regional_GSAs_20190819.mxd SI

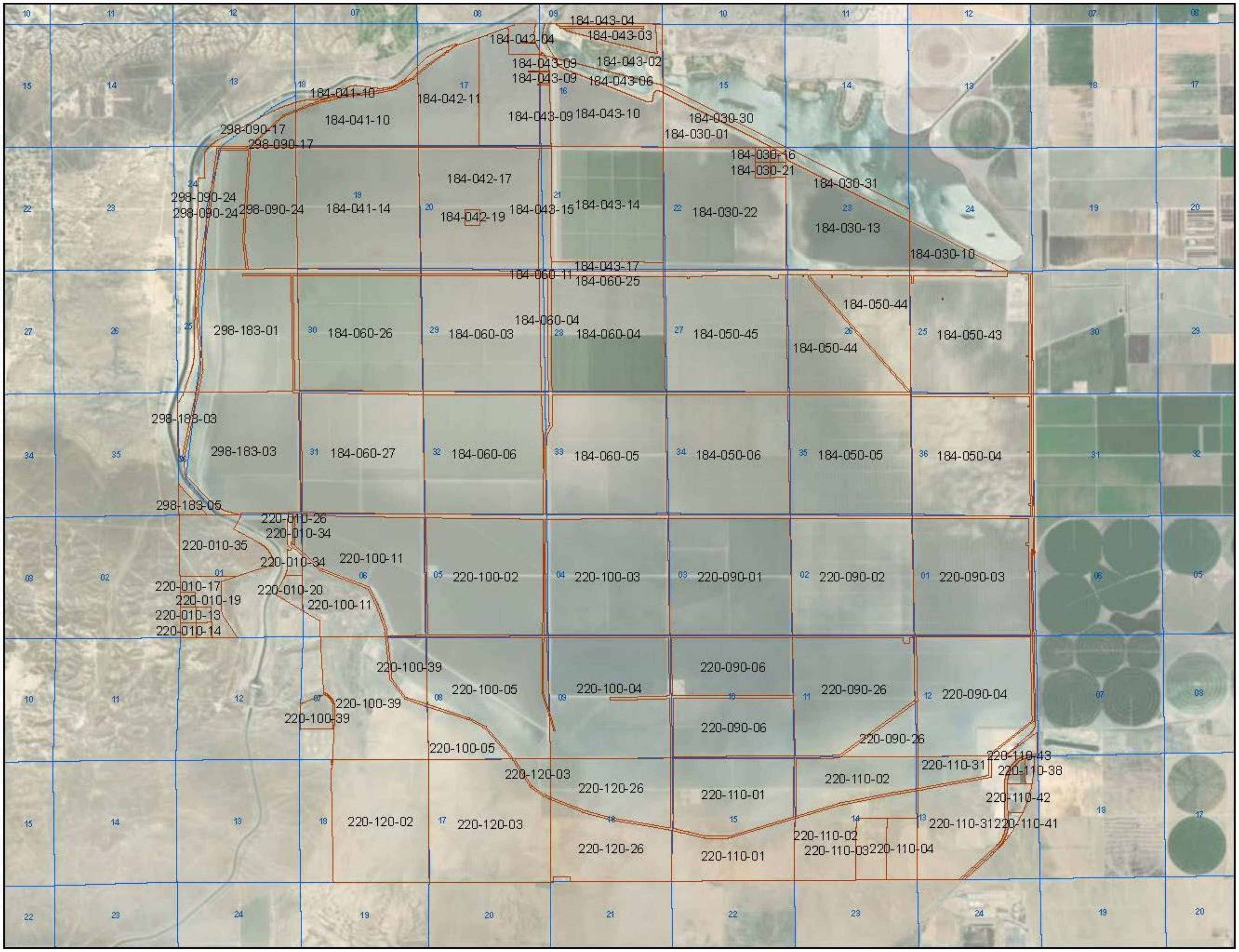
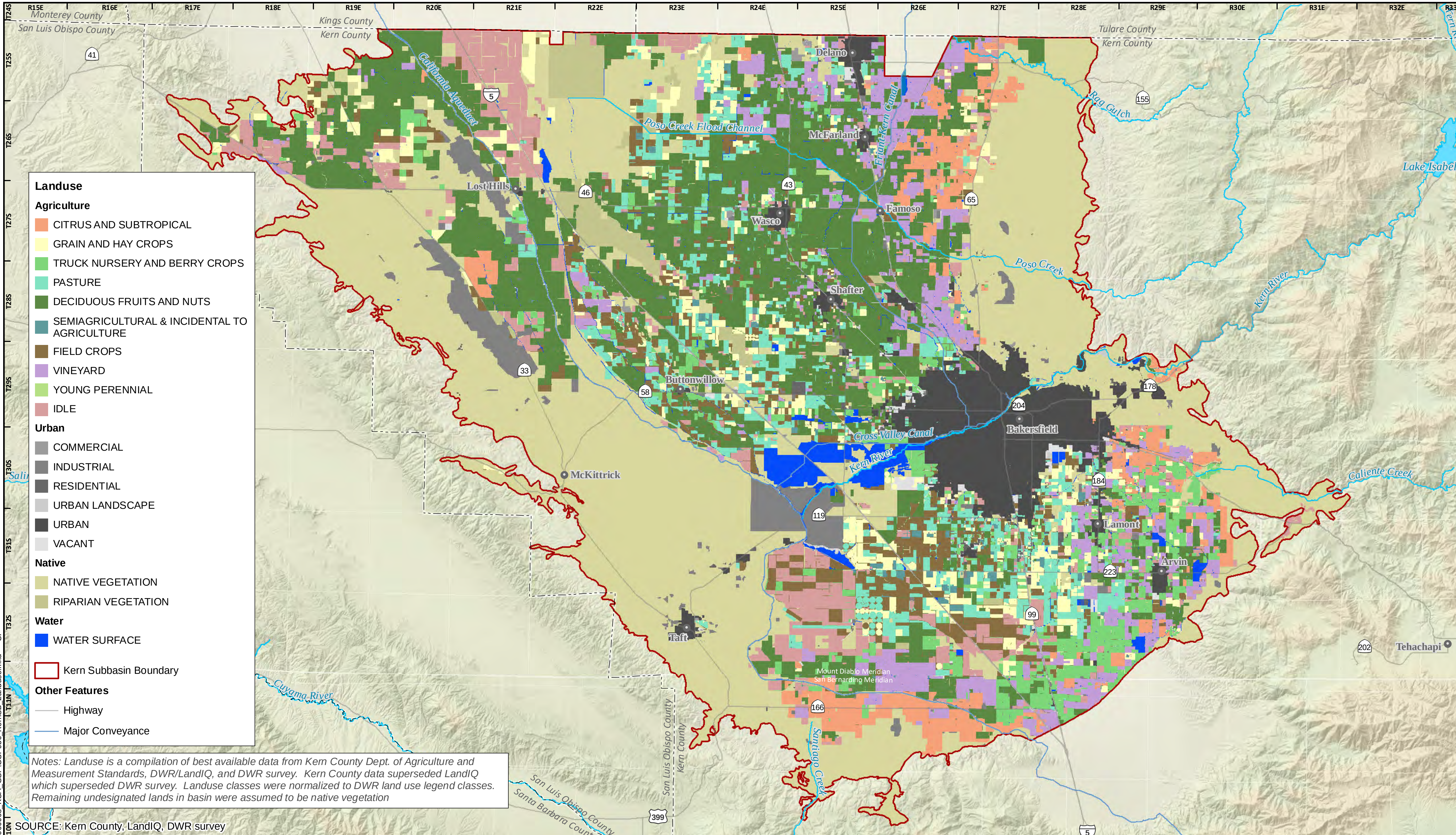


Figure 1-2. HMWD Parcel Map



0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

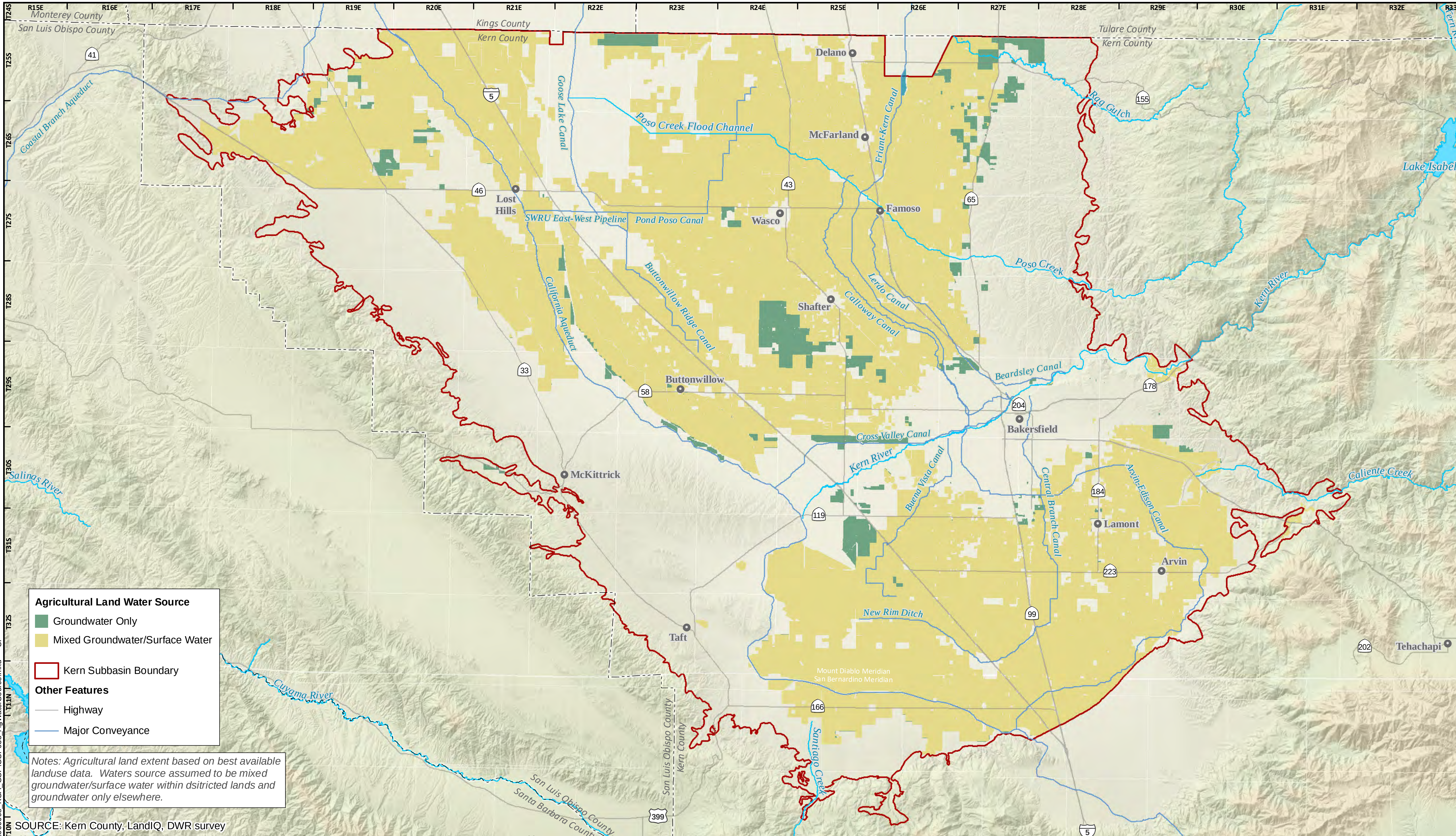
GEI Consultants

LANDUSE WITHIN KERN COUNTY SUBBASIN

JULY 2019

FIGURE 1-3

Z:\Projects\1900668_KGA_GSP\GSP036_KernSB_Landuse.mxd SI
23-Aug-2019



Z:\Projects\1900668_KGA_GSP\GSP033_AgWaterSource.mxd SI 23-Aug-2019

Kern Groundwater Authority
Basin Setting

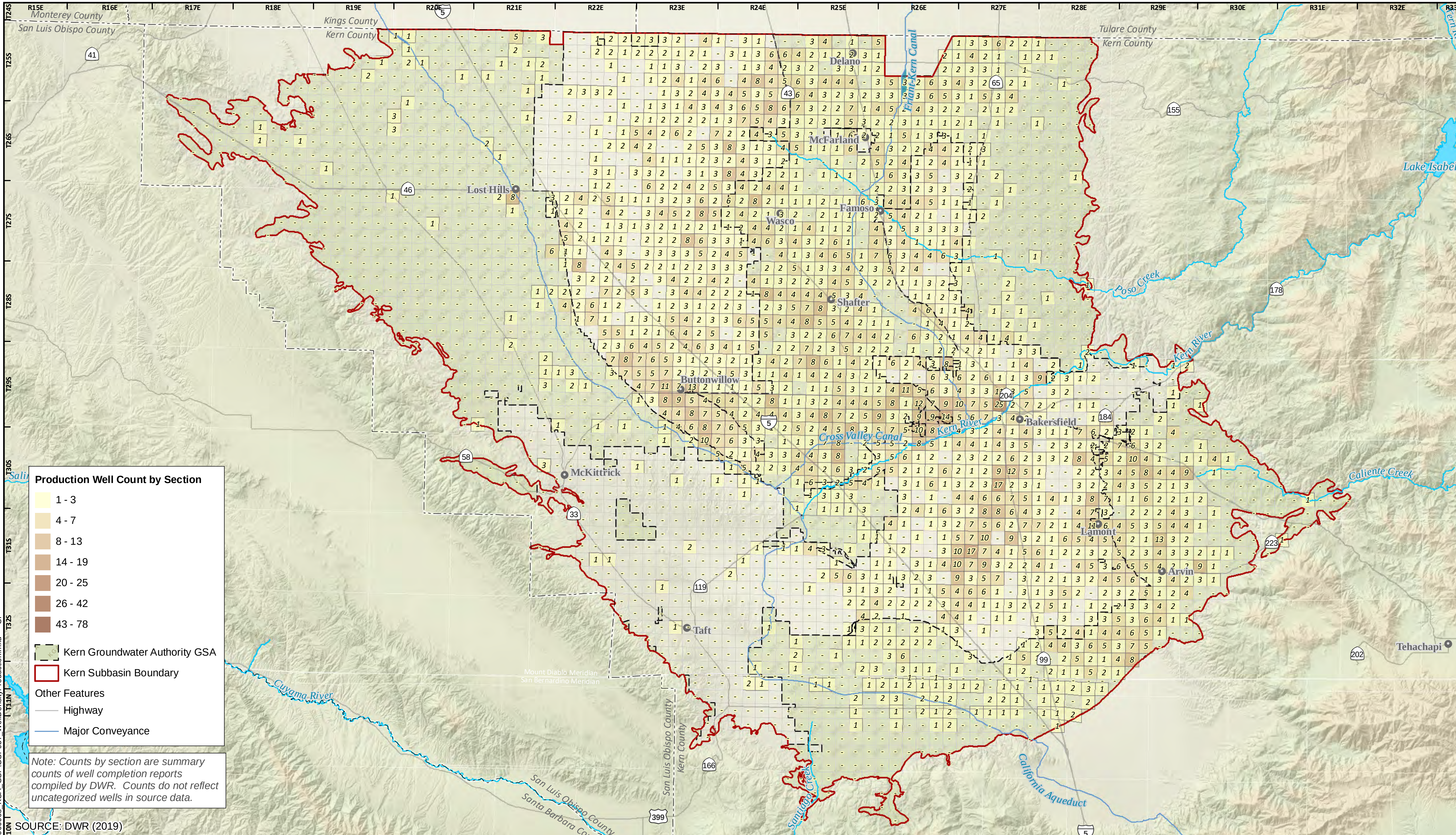
Kern County, California

GEI Consultants

AGRICULTURAL LAND WATER SOURCE
WITHIN KERN COUNTY SUBBASIN

JULY 2019

FIGURE 1-4



0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

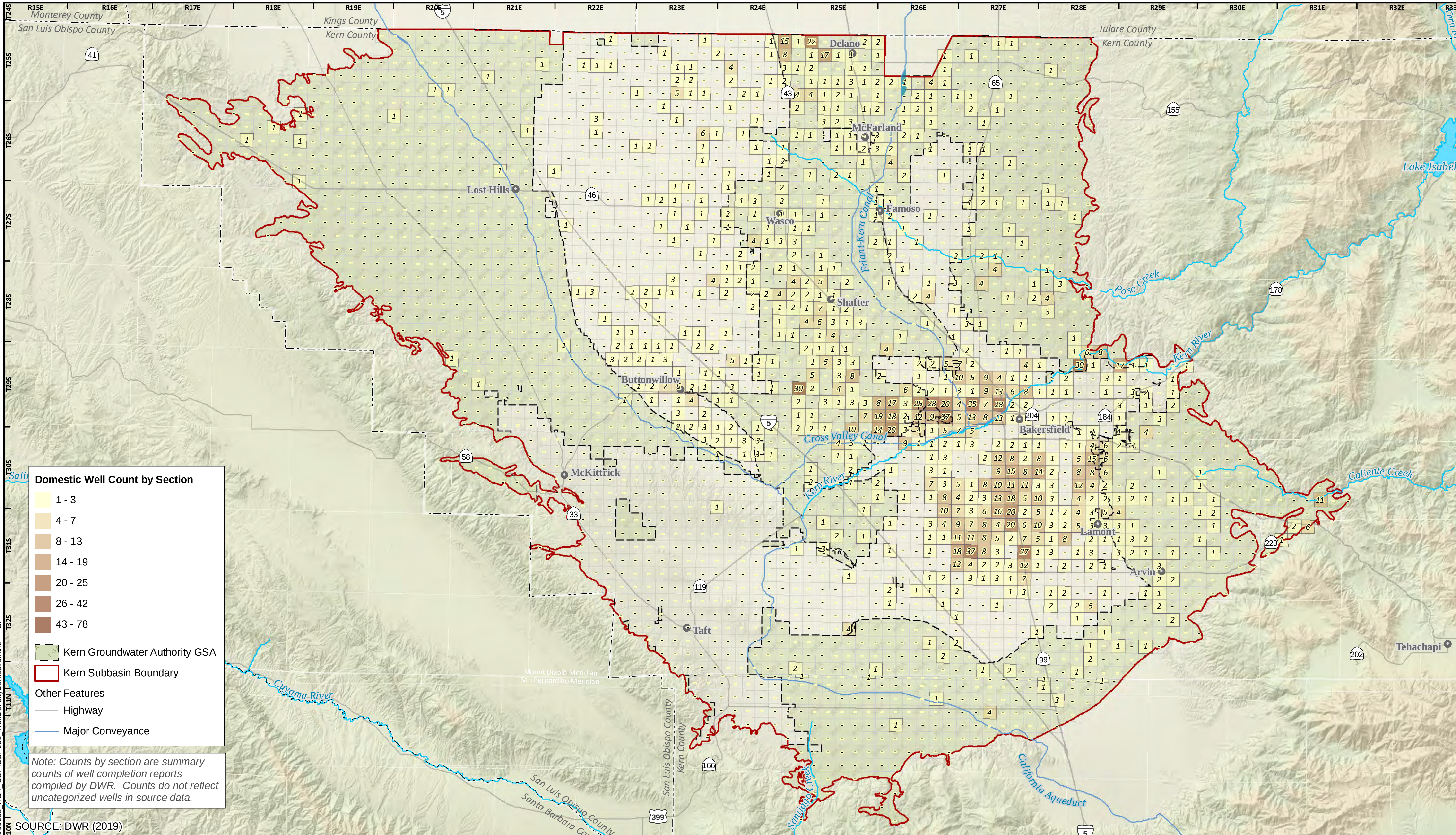
GEI Consultants

DENSITY OF WELLS PER SQUARE MILE
(PRODUCTION)

JULY 2019

FIGURE 1-5

Z:\Projects\1900668_KGA_GSP\GSP037_WellDensityProduction.mxd SI
23-Aug-2019



0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

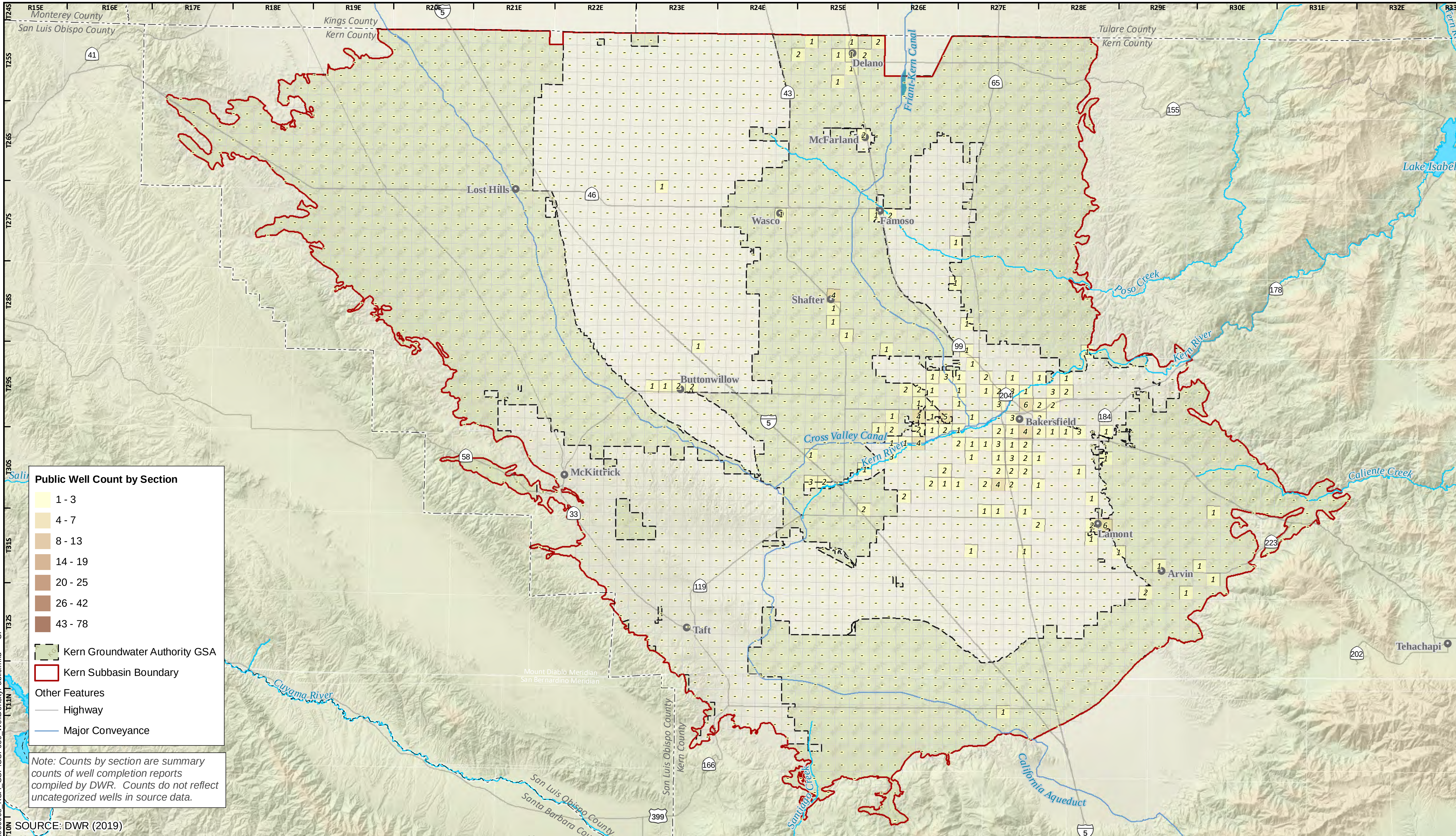
GEI Consultants

DENSITY OF WELLS PER SQUARE MILE (DOMESTIC)

JULY 2019

FIGURE 1-6

Z:\Projects\1900668_KGA_GSP\GSP038_WellDensityDomestic.mxd SI 23-Aug-2019



Z:\Projects\1900668_KGA_GSP\GSP039_WellDensityPublic.mxd SI

23-Aug-2019

Kern Groundwater Authority
Basin Setting

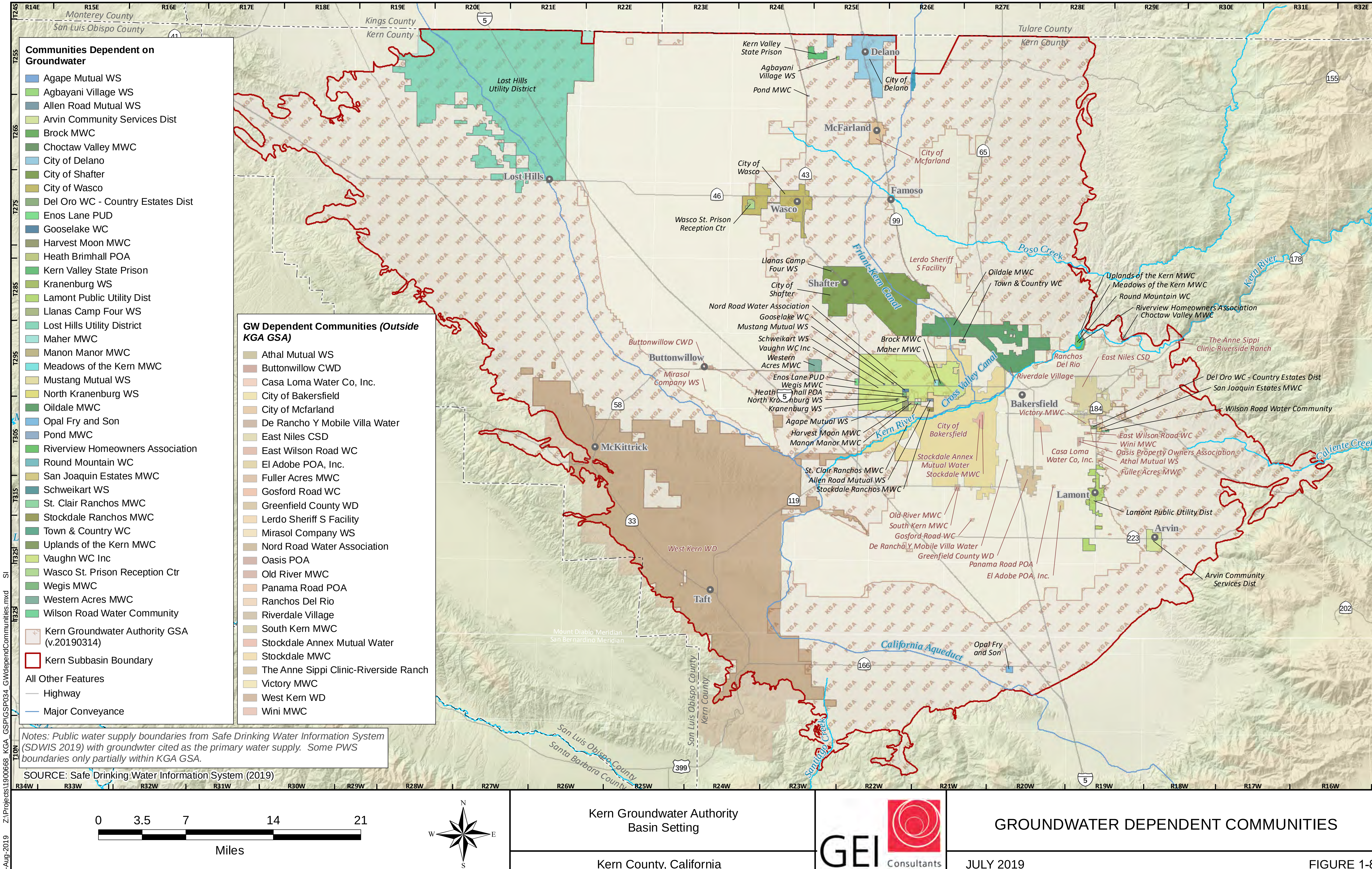
Kern County, California

GEI Consultants

DENSITY OF WELLS PER SQUARE MILE
(PUBLIC)

JULY 2019

FIGURE 1-7



Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

GROUNDWATER DEPENDENT COMMUNITIES

JULY 2019

FIGURE 1-8

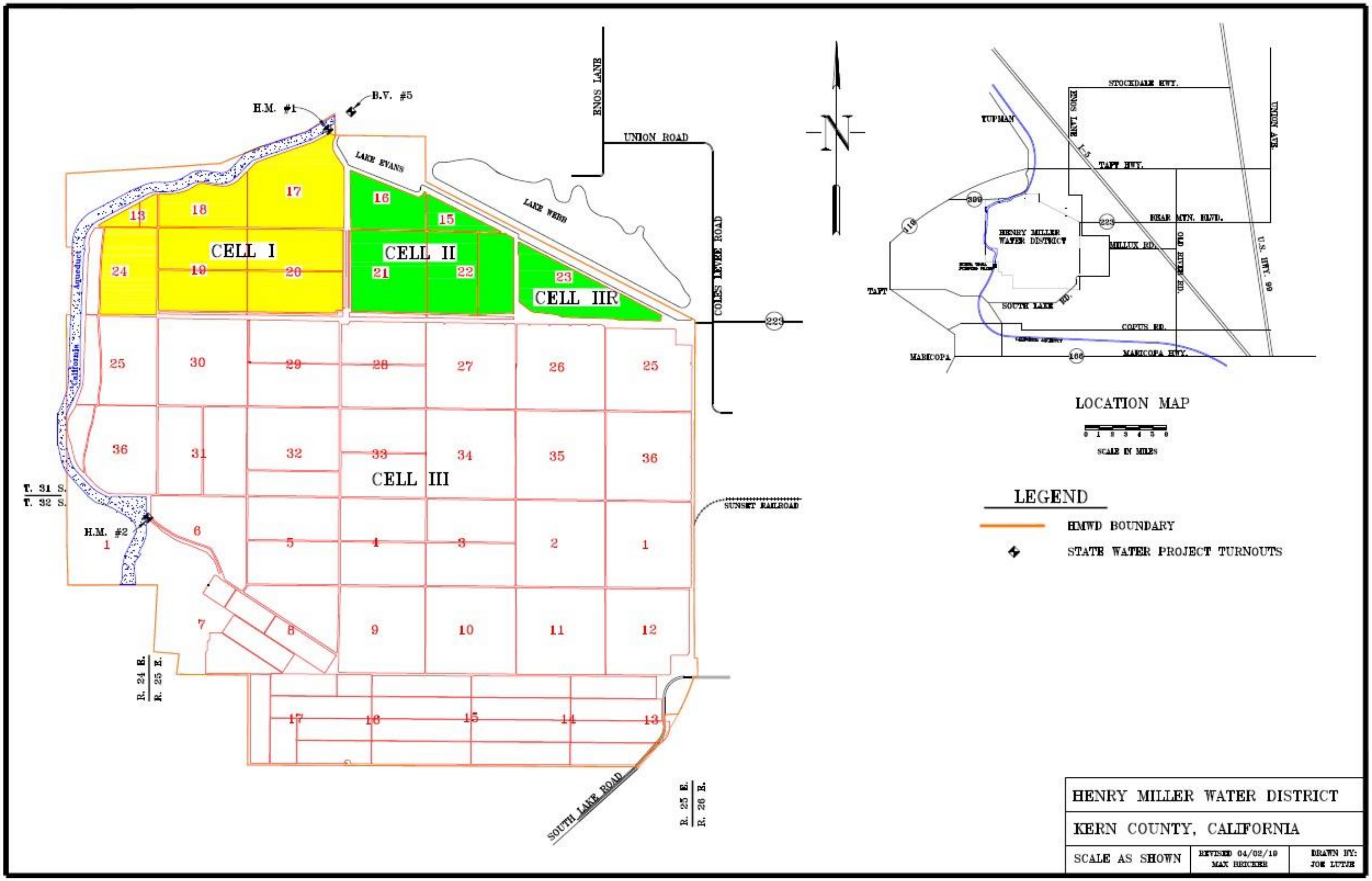


Figure 1-9. Map of HMWD Demonstrating Surface Water Storage Facilities

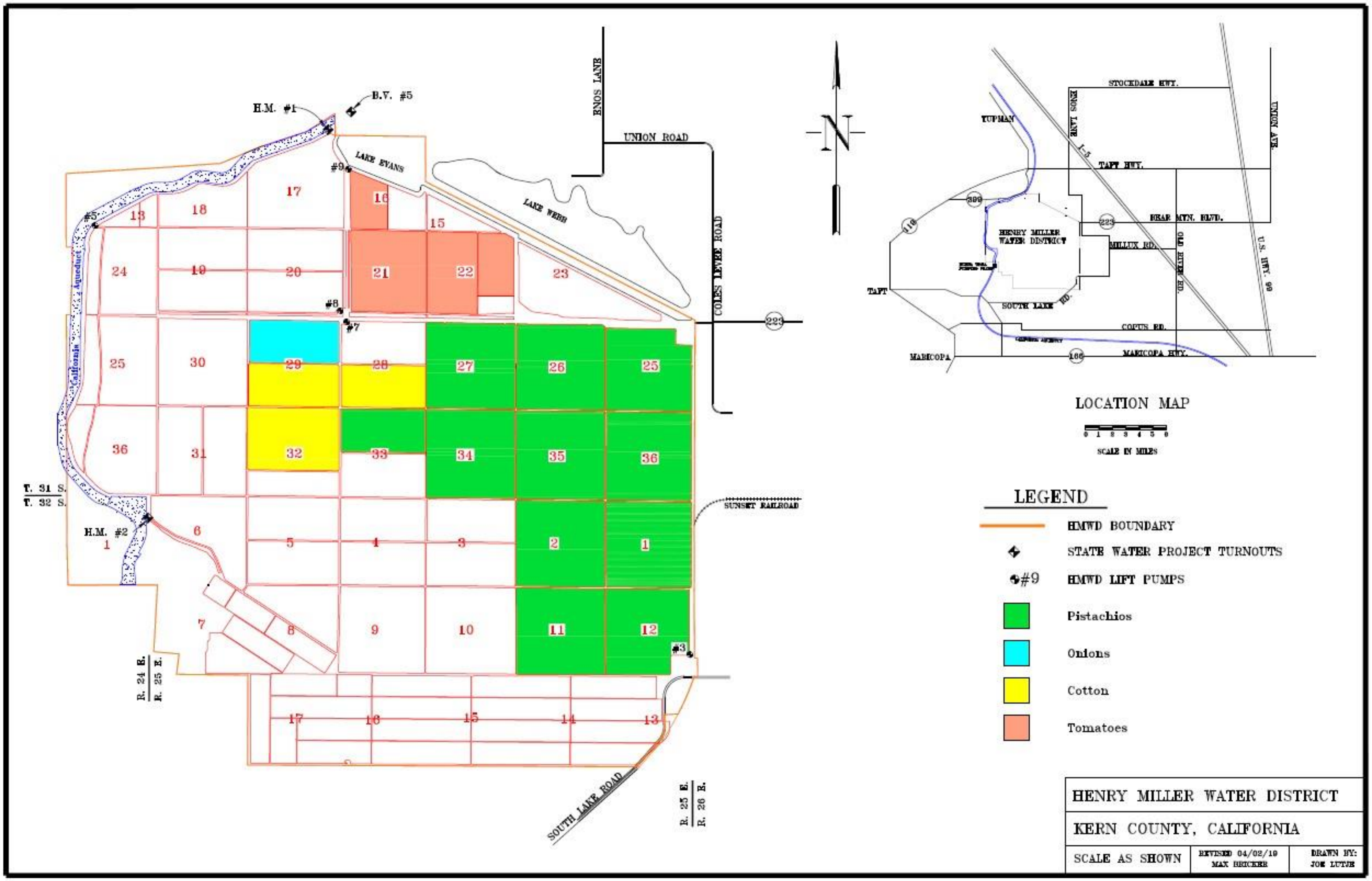


Figure 1-10. Map of the 2019 Cropping Pattern in HMWD

ENVIRONMENTAL HEALTH DIVISION

2700 M Street, Suite 300, Bakersfield, CA 93301
Phone # (661) 862-8740 Fax (661) 862-8701
Email EH@kerncounty.com

Overdrafted Basin Supplemental Well Application

FOR OFFICE USE ONLY **Corcoran Clay: ☐ Yes ☐ No** **WP** ________________

Assessor's Parcel Number: ______________________ **Township/Range/Section:** ____________

GPS Coordinates: Lat __________ **Long** __________ **Well Elevation (ft):** ____________

Water District/GSA: ______________ **Est Cumulative Extraction Volume (ac ft) by 12/31/19:** ________

☐ **Irrigation** ☐ **Livestock** ☐ **Domestic** ☐ **Municipal** ☐ **Industrial** ☐ **Other** ______________

PROPOSED WELL DESIGN INFORMATION	
Proposed Well Depth (ft):	
Proposed Well Capacity (gal):	
Estimated Pumping Rate (gal/day):	
Proposed Pumping Schedule:	
Est Annual Extraction Volume (ac ft):	

GEOLOGIC SITING INFORMATION PROPOSED WELL	
Water Table Depth (ft):	
Seasonal Fluctuations in Water Table:	
Recharge Area (Yes/No):	
Recharge Rate (if known):	
Area to be served by well (in acres):	

EXISTING ON SITE WELL INFORMATION	Well 1	Well 2	Well 3
Type/Use of Well:			
Depth (ft):			
Diameter (in):			
Screen Interval (ft):			
Pumping Rate (gal/day):			
Est. or Annual Extraction Volume (ac ft):			
Capacity or Pump Test (gal) (if available):			

In addition to the above information, the following information ***must be shown*** on a detailed site map and include actual measurements (to scale not necessary). If in the Corcoran Clay, you may include 2 maps to satisfy the requirements below.

☐ Distance to potential sources of pollution, including but not limited to, septic systems, sewer lines, wells (all types), animal/fowl enclosures, or transmission lines; either existing or proposed.

☐ Distance from lakes, ponds, streams within 300 ft of proposed well

☐ If in Corcoran Clay, location of canals, ditches, pipelines, utility corridors, and roads within 2 miles.

Submitted By ______________________ Title ______________ Date __________

Figure 1-11. Kern County Public Health Services – Overdrafted Basin Supplemental Well Application

2 BASIN SETTING

Chapter 2 was generated through a coordinated effort to describe the basin setting of the Subbasin in its entirety. This chapter was prepared by the KGA for use by those GSAs who supported this coordinated effort.

2.1 Introduction

This basin setting focuses on the area encompassed within the jurisdiction of the KGA, its participating members agencies, and collaborators. **Figure 2-1** presents the current extent of the KGA jurisdictional area and member agencies. Due to the proximity of adjacent GSAs, details and data from adjacent GSAs are included herein. This basin setting is intended to represent an overview of the entire Subbasin. Additional details are included in the basin setting description of other GSPs prepared in the Subbasin and in the management area plans prepared by KGA member agencies.

2.1.1 Hydrogeologic Conceptual Model (Reg. § 354.14)

Numerous descriptions and reports of local hydrogeologic conditions are available for the Subbasin. Details from previous investigations relating to the regional geologic and structural setting of the Subbasin; geologic features affecting groundwater flow; vertical and lateral boundaries; primary aquifers and aquitards; groundwater elevations and flow direction over time; and water quality are described below. This information is the foundation for the hydrogeologic conceptual model (HCM).

This HCM has been prepared under the supervision of Matthew Mayry, Certified Hydrogeologist.

Kern County and Lateral Boundaries

The Subbasin (5-022.14) (**Figure 2-2**), is within the southernmost portion of the Tulare Lake Hydrologic Region of the San Joaquin River Basin (5-022). The Subbasin encompasses a surface area of 1,792,000 acres (2,800 square miles) and contains approximately 32,000 feet (ft) (6 miles) of marine and continental sediments (DWR, 2006; Page, 1986). The Subbasin has approximately 40,000,000 AF of groundwater storage with another 10,000,000 AF of storage capacity, including areas where water levels have declined (DWR, 2006). A recent U.S. Geological Survey (USGS) estimate of sediment thickness is 3 miles for the San Joaquin Valley (Faunt et al., 2009). Continental sediments comprise up to approximately 3,400 ft of the material along the Kern River near the town of Tupman (western side of the valley), and the base of the fill is over 18,000 ft deep (Davis et al., 1959).

The lateral boundaries of the Subbasin, are defined by various jurisdictional and geomorphic segments, as presented by DWR (2016b). The Subbasin is bounded by the Sierra Nevada on the east; by the Tehachapi mountains, San Emigdio mountains, and White Wolf Subbasin (5-022.18) on the south; and the Coast Range (Temblor Range) on the west. To the north of Subbasin are the following Subbasins: Kettleman Plain (5-022.17), Tulare Lake (5-022.12), and Tule (5-022.13).

Figure 2-2. Kern County Subbasin and Vicinity

Regional Geologic and Structural Setting

A brief description of the evolution of valley sediments and fill is included below, as it relates to the regional aquifer system of the Tulare Lake Region of the San Joaquin Valley Basin.

During pre-Tertiary time granitic rocks were deposited in the present-day area of the Sierra Nevada and Tehachapi Mountains (eastern and southeastern flanks of the Subbasin). Plutonic and tectonic activity also formed metamorphics that occur along the margins of the Subbasin. As tectonic activity uplifted these granitic and metamorphic deposits, erosion with subsequent transport of sediment into the basin occurred. These rocks form an almost impermeable boundary for the groundwater basin, but fractures and joints permit small yields of water to wells (Page, 1986).

Near the end of the Late Cretaceous, tectonic movements elevated the Coast Ranges to the west of the Central Valley which created a marine embayment in the present-day Southern San Joaquin region. During the Tertiary, seas advanced and retreated within this southern embayment, resulting in deposits comprised of both continental and marine sediments. The most recent of which are the Pyramid Hills, Vedder Sand, Olcese Sand, Santa Margarita Formation, and San Joaquin and Etchegoin Formations.

During the late Tertiary, uplift of basement occurred near present-day Bakersfield forming what researchers have termed the Bakersfield Arch. The Arch effectively resulted in depocenters for thick sequences of sediment to accumulate to the north and south of the Kern River (Bartow, 1991; Vasconcellos, 2016; **Figure 2-3**) during later Tertiary and Quaternary time. Tertiary crustal uplift and shifting caused the formation of the Sierra Nevada, Temblor, and Coast Ranges (Bartow, 1991). Crustal deformation along the proto-San Andreas and present-day San Andreas led to the formation of the structural traps for oil and gas accumulation throughout the west-side.

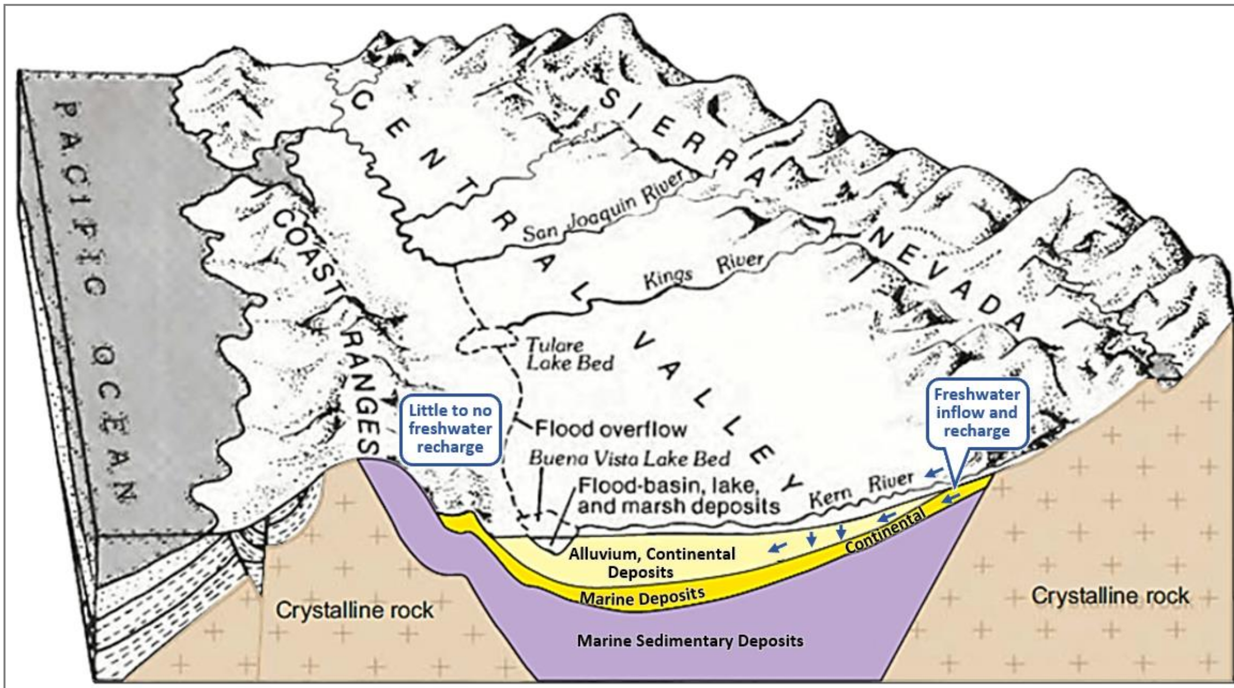
The Quaternary Period (Pleistocene and Holocene), marked a time when the seas retreated, and continental deposits from alluvial and fluvial systems formed (Tulare and Kern River Formations (Page, 1986). Marine rocks and deposits are, in part, the source rocks for the Tulare Formation on the west and the granitic from the Sierra Nevada on the east are the source rocks for the Kern River Formation. Some of the marine deposits on the west, contain saline water, that could have migrated into adjacent and overlying continental deposits (Page, 1986). Overall, the continental rocks make up most of the regional aquifer system in the central and eastern sides of the Subbasin while brackish to freshwater deposits and eroded marine deposits of the Coast Range make up a very small portion of the water-bearing units on the western side of the Subbasin.

The Pleistocene Epoch was dominated by brackish and freshwater lakes within the Subbasin, resulting in thick deposits of clay, as found throughout the upper Tulare Formation. In particular, the Corcoran Clay has been mapped over much of the San Joaquin Valley (including Tulare Lake Region), and its equivalents have been correlated to clays beneath the Kern and Buena Vista dry lake beds in the southern part of the Subbasin, as well as the Tulare Lake sediments on the northern boundary of Kern County (Croft 1972; Page, 1986) (**Figure 2-4**). This clay makes up a considerable impermeable to semipermeable zone that divides shallower poor-quality water from higher quality water of the regional aquifer system.

Since the Pleistocene Epoch, stream channels, lakes, and rivers have deposited alluvium throughout the Subbasin. Alluvial fans have formed on both sides of the valley, but most notably on the eastern side where the Sierra Nevada granitics are the main source of sediment (Poso Creek Fan, Kern River Fan, and

Caliente Creek Fan). On the eastern side of the valley, these stream channels are large, laterally migrating distributary channels. Over time, shifting stream channels have created coalescing fans, forming broad sheets of inter-fingering, wedge-shaped lenses of gravel, sand, and finer detritus (Page, 1986), which make up the shallow continental water-bearing deposits of the regional aquifer system. Page (1986) identified various depositional environments for the continental sediments, including alluvial fan and deltaic conditions on the eastern side of the valley, and flood-plain, lake, and marsh conditions on the western side. Consequently, coarse-grained deposits are predominant on the eastern side while fine-grained deposits are predominant within the central and western areas of the Subbasin.

Figure 2-5 is a conceptual block diagram that generally illustrates the highlands surrounding the Subbasin with folded beds separating the west side from the east side. This diagram displays the succession of marine deposition to more recent continental deposition and alluvium with fresher water deposits.



Modified from: Todd, 2017; Page, 1986

Figure 2-5. Conceptual Block Diagram Looking North from Kern River

The geologic history discussed above is related to the stratigraphy described below, and as summarized in **Table 2-2**. The description also includes a discussion of the portions of the formations that bear groundwater that have been utilized historically.

Stratigraphy

The Oligocene Pyramid Hills and Vedder Sands are interbedded sandstone and siltstone deposited in a shallow to deep marine environment and in a limited non-marine environment. They may produce fresh groundwater on the east and southeast sides of the Subbasin (Page, 1986).

The Miocene Olcese Sand and Santa Margarita Sandstone are current sources of drinking water in the northeastern portion of the Subbasin where they occur as confined aquifers (KTWD, 2016). The origin of the Miocene Olcese Sand and Santa Margarita Sandstone varies from continental to marine going from east to west across the Subbasin (Scheirer, et al, 2007a). The Miocene Olcese Sand ranges up to 600 ft in thickness and consists of unconsolidated medium- to coarse-grained sand containing a few pebble and siltstone beds. The formation is exposed in the Poso Creek area (Page, 1986) and is utilized by the Olcese Water District in the Kern River Canyon. The Santa Margarita Sandstone ranges in thickness from 200 to 600 ft and consists of coarse-grained sand (DWR 2006), and includes an upper bed of fine, silty, well sorted gray sand, and a lower bed of brownish-gray and brown fossiliferous micaceous sandy siltstone. According to Page (1986), the sandstone is a major aquifer that reportedly yields as much as 1,950 gallons per minute (gpm) to wells. Croft (1972) reported that the formation also yields water to wells in the foothills southeast of Bakersfield. The Round Mountain Silt is an aquitard that separates the Miocene Olcese Sand from the Santa Margarita Sandstone and acts as a confining unit for the Miocene Olcese Sand (KTWD, 2016). This silt unit consists mostly of a gray and brown siltstone that contains beds of diatomite and silty sand (Page, 1986), and ranges in thickness from 0 to about 200 ft.

The Mio-Pliocene Etchegoin Formation varies considerably, ranging from clay and silt to sand, gravel, and sandstone. It ranges in thickness from a few tens of feet to more than 2,000 ft. Several wells near the foothills and a few deep wells in the valley derive fresh water from the Etchegoin; however, its depth is more than 3,000 ft beneath most of the valley and is limited to deep well production (Page, 1986).

Overlying the Etchegoin Formation is the Pliocene San Joaquin Formation of marine deposition. It contains silt and silty sandstone, with a conglomerate at the base of the formation. In the deep subsurface northeast of the Kettleman Hills, the formation is considered a shoreline deposit because the material is coarser and more permeable than in the Kettleman Hills area and yields fresh water to many wells. The San Joaquin Formation is the youngest marine deposit in the Central Valley (Page, 1986), representing the end of marine deposition in this area. Overlying sediments were deposited by alluvial, fluvial, and lacustrine processes.

The Tulare Formation is Plio-Pleistocene in age, and in conjunction with the Kern River Formation (Mio-Pliocene to possibly early Pleistocene), represents west-east facies change across the Subbasin. The Tulare and Kern River formations are moderately to highly permeable and are major freshwater sources within the Subbasin (Page, 1986; SWSD, 2012).

The Tulare Formation (western-central Subbasin) contains up to 2,200 ft of interbedded, oxidized to reduced sands, gypsiferous clays, and gravels derived primarily from Coast Range sources. The permeable deposits of the Tulare Formation are divided into upper and lower units, separated by the E-modified Corcoran Clay member (Corcoran Clay) of the formation. Groundwater beneath the Corcoran Clay is typically confined to semiconfined (Page, 1986; SWSD, 2012). In addition to its confining properties, laboratory tests indicate that the clay is highly susceptible to compaction (Faunt, et al., 2009). On the west side of the Subbasin, the Tulare Formation is also divided by upper and lower units by potential equivalents to the Corcoran Clay that are reported locally (Rector, 1983; Geomega, 2001). While the central part of the basin was deposited in a fluvial-lacustrine environment, the west side has lacustrine claystones, fan-delta deposits, debris-flow dominated alluvial-fan deposits, but also paleosols representing an arid to semiarid setting (Nilsen and Campbell, 1996). The difference in Tulare deposition illustrates fundamental differences between the west side and east side aquifer system.

The Corcoran Clay occurs laterally in the north Subbasin (~34 miles wide in extent) from Delano to Lost Hills (**Figure 2-4**) and narrows to the south where it is not a confining bed in the Kern Fan Area. Although the USGS data present a clay in the western part of the Kern Fan area, local data do not support the presence of an extensive confining clay in the Kern Fan area. A clay in the south part of the Subbasin has been correlated as the Corcoran Clay by many investigators including Croft (1972) and Page (1986). It extends from Buena Vista Lake Beds to just east of Arvin and DiGiorgio (~31 miles wide in extent). In the south Subbasin, the Corcoran Clay is present at depths between 250 and 650 ft (DWR, 1981). Within the central area of the Subbasin between the Kern River and Highway 46, the depth to the Corcoran Clay varies from 300 to 450 ft. Further north to the county line, the depth varies from 200 to 750 ft. The Corcoran Clay, most notably the modified E-clay (Page, 1986) is generally very fine grained; however, isolated, coarser zones are possible, particularly where the clay is less than 20 ft thick. The thickness of the clay is as much as 100 ft in a small area of the southern Subbasin but typically varies between 20 and 40 ft. In the northern Subbasin, the clay might be as thick as 60 to 80 ft in isolated areas, but the thickness typically varies between 10 and 30 ft. The Corcoran Clay does not exist under the Kern Alluvial Fan (Kern Fan), where the shallow unconfined layers are separated from deeper layers by an intermediate zone of interbedded sands and silts which retard vertical groundwater flow and create an increase in semi-confinement with depth. The Corcoran Clay is also not present in the eastern/northeastern part of the Subbasin from the cities of McFarland and Bakersfield, to Edison (Faunt et al., 2009).

The Kern River Formation includes from 500 to 2,000 ft of poorly sorted, lenticular deposits of clay, silt, sand, and gravel derived from the Sierra Nevada. The Kern River Formation crops out in the east Subbasin and reaches its maximum thickness of 2,600 ft in the subsurface west of mapped outcrops (Bartow and Pittman, 1983). The formation consists mostly of poorly sorted fluvial sandstone and conglomerate with interbeds of siltstone or mudstone that becomes finer grained northward and westward. Some of the thicker siltstone or mudstone interbeds may represent deposits of small ephemeral lakes or ponds (Bartow and Pittman, 1983). The Kern River Formation is coarsest in its easternmost exposures, generally the area south of the Kern River, where the composition includes a cobble conglomerate with boulders near the base and pebbly sandstone. (Bartow and Pittman, 1983). Two oil-producing zones occur in the lower part of the formation where it is believed to have migrated to the Kern River Formation from older marine sediments (Bartow and Pittman, 1983).

The Kern River Formation unconformably overlies the Chanac Formation and may be contemporaneous with the Etchegoin, San Joaquin, and the Tulare formations (Bartow and Pittman, 1983 and Bartow, 1991); however, Graham and others (1988) concluded that the Kern River Formation predates the Corcoran Clay, which has a basal age of about 725,000 years. Radiometric dating of a volcanic ash layer near the top of the Kern River Formation at the Kern River oilfield may agree with the aforementioned basal age; however, others dated this ash bed at 6 million years which would place the Kern River Formation solely in the Miocene (Scheirer et al., 2007a). Nevertheless, the gradational relationship between the Kern River Formation and seemingly younger units such as the Etchegoin, San Joaquin, and Tulare formations would have to be reexamined.

Older alluvium and terrace deposits overly the Tulare and Kern River formations. These deposits also make up a portion of the regional aquifer system. They are composed of up to 250 ft of Pleistocene-age lenticular deposits of clay, silt, sand, and gravel that are loosely consolidated to cemented. These deposits are moderately to highly permeable and yield sufficient water to wells. They are often indistinguishable from the underlying Tulare and Kern River formations (DWR, 2006).

The Holocene-age younger alluvium and flood basin deposits vary in character and thickness in the Subbasin. Along the eastern and southern Subbasin margins, these younger deposits consist of up to 150 feet of interstratified and discontinuous beds of clay, silt, sand, and gravel. In the southwestern portion of the Subbasin, the deposits are finer-grained and less permeable as they grade into fine-grained flood basin deposits underlying the historic lakebeds of Buena Vista and Kern lakes in the southern portion of the Subbasin. 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 (Page, 1986; DWR, 2006).

As described above for the deposition of the Tulare and Kern River formations and Quaternary facies differ from west to east across the basin. The below diagram (**Figure 2-6**) illustrates the general distribution of facies fluvial-deltaic deposition dominating the east-side; alluvial, lacustrine, and marsh deposition dominating the central portions of the basin, and alluvial and debris flow deposition dominating the western side of the Subbasin during the Quaternary.

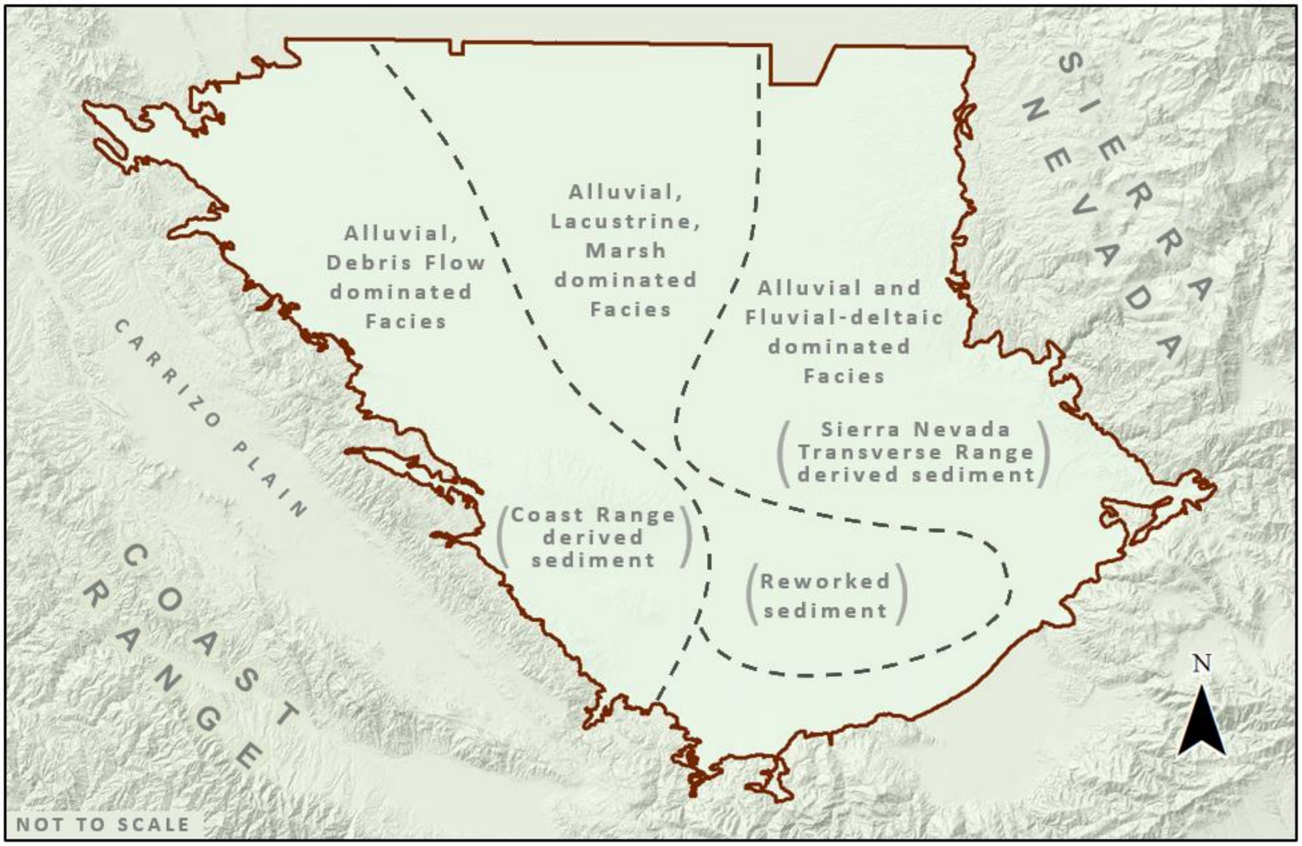


Figure 2-6: Generalized Quaternary Depositional Facies

Geologic Features that Significantly Affect Groundwater Flow

The primary structure in the Subbasin that affects groundwater flow is the large asymmetric structural trough (San Joaquin Valley Syncline) that has been the depocenter of thousands of feet of sediments since late Mesozoic time (Bartow, 1991). Groundwater naturally flows northwest along the trend of the syncline. Likewise, the Bakersfield Arch is a broad southwest-plunging arch of basement rock that separates the small Maricopa-Tejon sedimentary basin at the south end with the remainder of the sedimentary basin to the north and west (**Figure 2-3**, from Bartow, 1991). Groundwater recharging from the Kern River will flow north and south along the flanks of the arch away from the center of the Subbasin.

Numerous faults and folds are located in the Subbasin, as shown in local geologic maps (**Figures 2-3, 2-7, and 2-8**). Bartow (1991) identified portions of three types of structural regions in Subbasin, excluding the Bakersfield Arch. The northeastern third of the Subbasin, including the north half of the Arch, is located on the minimally-deformed eastern limb of the valley syncline. Normal faulting is associated with the Bakersfield Arch, occurring mostly in the older sediments (QPc; Ts) but extending into and concealed by the younger sediments (Qoa, Q; Qs), notably the Pond-Poso Creek Fault. Fault orientations vary from northwest to northeast due to alternating compressional and extensional forces.

Faults

Several faults have historical displacement or have been identified as features that affect groundwater flow. The following are: Pond-Poso Fault, Edison Fault, White Wolf Fault, Kern Front Fault, Premier Fault, New Hope Fault, and small portions of the Pond Fault (California Geological Survey, 2010a). The Edison Fault and White Wolf Faults also affect the flow groundwater (DWR, 2006).

The southeastern quarter of the Subbasin, including the south half of the Bakersfield Arch, is considered to be “highly deformed” and the “most complex tectonic history” (Bartow, 1991) due to the alternating north-south compressional and extensional forces since the Cretaceous Period. The southern boundary of the Subbasin is delineated by the northeast-trending White Wolf Fault, a reverse fault with active displacement (DMG, 1955), that may have originally been a normal fault (Bartow, 1991). The White Wolf Fault separates the Subbasin from the new White Wolf Subbasin to the south. Two northeast-trending thrust faults are located at the southwestern corner of the Subbasin, including the Wheeler Ridge and Pleito Faults. During the 1952 Bakersfield earthquake, a group of small ground fractures developed in an alignment just north and subparallel to White Wolf Fault. Numerous normal faults are located along the eastern margin of the southern Subbasin, including the Edison Fault and many unnamed fault segments that were active during the 1952 earthquake. More detailed descriptions of local faults and folds of interest are described in the chapters herein.

Folds

Several concealed folds have been delineated in the central Subbasin, the Paloma anticline, Buttonwillow and Semitropic anticlines, San Joaquin Valley syncline, and other unnamed anticlines and synclines in the Subbasin.

West-Side Fold Belt and Groundwater Flow

The west-side fold belt includes anticlines: Kettleman Hills, Lost Hills, Elk Hills, and at the east boundary of the fold-belt, Buttonwillow and Semitropic anticlines (Bartow, 1991) (**Figure 2-7**; Page, 1986). These structures are oriented toward the northwest, subparallel to the Coast Range and the San Andreas Fault. Page (1986) and DWR (2006), identified the anticlinal folds of the highlands, specifically Lost Hills, as restrictions to groundwater flow within the lowlands, and this condition likely applies to other anticlines in the Subbasin.

Structurally, and to a large degree, lithological, the western side differs from the central and eastern portions of the Subbasin. Western Plio-Pleistocene deposits are derived from weathering and erosion of the Coastal Range made up of marine deposits yielding clays and silts and some sands. On the other hand, the east side is made up of quartzose and feldspathic coarser sized sediments from the Sierra Nevada.

In addition to structure, the thickness of fresh water bearing deposits and the sources of groundwater recharge differ between the west side and the central and east side of the Subbasin. In general, the differences result in more restrictive localized groundwater system with poorer quality water on the west side of the Subbasin.

Kern County Subbasin Boundaries

As described above, the lateral boundaries are defined by jurisdictional and structural boundaries (DWR, 2003, 2016a, 2016b). Within the jurisdictional boundaries of the Subbasin, are effective lateral boundaries of usable groundwater or effective extents of the principal aquifers.

These boundaries will be discussed in the remainder of this section, and include the presence or absence of: a sufficient quantity of groundwater for beneficial use; water quality changes rendering groundwater unusable; and aquifer exemptions of portions of the Subbasin that either contain commercially producible hydrocarbons or minerals, are high in total dissolved solids, and/or are otherwise isolated from the rest of the Subbasin by geologic boundaries. The characteristics of the effective groundwater Subbasin, as described above, also apply to the bottom of the groundwater basin and are discussed in Section 2.1.1.5.

Criteria for the Extent of Groundwater of Beneficial Use in the Subbasin

An aquifer may not be suitable for beneficial use if:

- It is not currently serving as a source of drinking water,
- It has commercially producible minerals or hydrocarbons, or
- It is not expected to supply a public water system and
- It is either economically or technologically infeasible for treatment or recovery now or in the future for domestic, agricultural, or industrial use.

The purpose of this GSP is not to exempt aquifers, nor is it to define the maximum depth or water quality concentration at which groundwater is economically recoverable or treatable now or in the future. However, by applying the criteria of 40 CFR §144.3 and 40 CFR §146.4, active oil and gas aquifers and exempted aquifers are not a part of the groundwater basin for beneficial use.

The groundwater Subbasin's extent, where no exemptions or commercially producible hydrocarbons exist, likely ranges between 3,000 milligrams per liter ([mg/L] and 10,000 mg/L total dissolved solids (TDS) depending on the feasibility of treatment and recovery of the groundwater for beneficial use. The estimated lateral extents of the Subbasin are further presented with the bottom of the Subbasin and cross sections of this plan.

Bottom of Subbasin

As described above, the following whichever is shallowest, are the lateral and vertical boundaries of the groundwater Subbasin:

- depth to producible minerals or hydrocarbons,
- depth to and aerial extent of exempted aquifers,
- depth that makes recovery of water for domestic, commercial, or industrial purposes no longer economically or technologically feasible, or
- the depth at which groundwater cannot now or in the future serve as a source of drinking water.

For example, water bearing zones below the depth to producible hydrocarbons are not within the groundwater basin; likewise, water bearing zones below an exempted aquifer are not within the groundwater basin.

In some parts of the Subbasin the lateral and bottom boundaries of the groundwater are subject to depths to producible hydrocarbons and extent of depths to aquifer exemptions. As described above, any water bearing zone below these three criteria are outside of the groundwater Subbasin. The available depth to hydrocarbons and aquifer exemptions at the time of this GSP compilation, although possibly generalized, are incorporated into **Figures 2-9** and **2-10** for comparison.

As discussed above, it is not the intent of this plan to evaluate at which depth the groundwater is economically recoverable or treatable in the future; but, for discussion purposes only, a TDS of 2,000 mg/L is presented in **Figure 2-9**, to consider the vertical and lateral distribution of a fresh groundwater dataset in the Subbasin. A TDS of 2,000 mg/L has been mapped throughout the region by Page (1973), historically, it was considered a limiting TDS concentration for the irrigation of most crops (Page, 1973); however, it does not define the bottom of the groundwater Subbasin (or the depth to water that is no longer economically or technologically feasible for groundwater beneficial use). Other local datasets for a TDS of 2,000 mg/L are included in management area plans.

By comparison the depth to TDS of 10,000 mg/L (Gillespie et. al. 2017) (one of the criteria for classification as an underground source of drinking water (USDW)) is presented on **Figure 2-10**. As discussed above, this depth may not represent the USDW if there are aquifer exemptions or producible hydrocarbons shallower in the subsurface.

In addition to the datasets mentioned above, the SWRCB Resolution Number 88-63 (SRWCB, 1988), has also listed criteria for the suitable sources of drinking water for municipal or domestic water supply. These sources are defined as waters that: have a TDS of less than 3,000 mg/L; are reasonably expected by Regional Boards to supply a public water system, including sufficient yield; are not contaminated or beyond reasonable treatment; and are not exempted by 40 CFR §146.4 (SRWCB, 1988). At this time, there is no dataset developed to present basin-wide correlations of the SRWCB 88-63 base of drinking water.

An additional informal description of the bottom of the Subbasin may be referred to by some researchers, at times, as the “current operational bottom of the Subbasin” which basically describes the depth of active groundwater well pumping; however, this description should not be used to satisfy SGMA requirements § 354.14(b)(3) of the California Code. The range of well depths and perforations generally deepen in the alluvial aquifer system from the margins of the basin toward well discharge points in the south-central and north-central Subbasin. The historical operational bottom of the depth and/or the current operational bottom of the basin are not mapped herein because the operational bottom of the Subbasin has increased with depth as groundwater elevations have decreased over the years. In general, groundwater wells extend to depths of more than 1,000 ft (Page, 1986), and the maximum thickness of freshwater deposits is calculated at about 4,400 ft, occurring at the south end of the valley (Page, 1986). Cross sections included in this plan provide a representation of current well depths in the Subbasin.

Page (1973) Base of Freshwater

Although, not the bottom of the groundwater basin, the base of fresh groundwater (**Figure 2-9**) has historically been defined by Page (1973), as the depth at which specific conductance (SpC) is 3,000 micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µS/cm), and is considered to be generally equivalent to a TDS concentration of 2,000 mg/L. These values have been reported because they may be considered a limiting factor for irrigation. The conversion factor from SpC to TDS used for this determination was 0.67, which is midway between the typical range of 0.55 to 0.75 (Hem, 1985), and is dependent on the composition of groundwater.

The base of fresh groundwater is quite variable in the Subbasin ranging over 4,000 ft, as listed below:

Elevation, Location			Depth, feet feet msl	below ground
Southeast,	T31S/R28E-Section 32,	West of Arvin	> -4400	~ 4700
Northwest,	T26S/R20E-Section 34,	Lost Hills area	0	~ 400
Northeast,	T25S/R27E-Section 6,	South of Richgrove	-2800	~ 3300
East central,	T29S/R27E-Section 12,	Oildale	-2000	~ 2500
West central,	T29S/R24E-Section 16,	East of Buttonwillow	-800	~ 1100

On the east side of the Subbasin, the base of fresh groundwater trends parallel to nearby faulting. The 2,400-ft below mean sea level (bmsl) contour (and other deep contours) on **Figure 2-9** represents a northwest-trending trough of fresh groundwater between Bakersfield and Wasco. This trough lies between the concealed Poso Creek fault to the northeast and the pre-Quaternary Greeley Fault on the southwest that extends from the Kern River to the Kern National Wildlife Refuge. This “graben” of deeper fresh groundwater appears to be trending with these faults.

A smaller, northwest-trending trough of fresh groundwater is located east of Delano and south of Richgrove on the west side of several northeasterly-trending faults. This trough of fresh groundwater may be more of an indicator of freshwater in the Santa Margarita and Olcese aquifers.

On the west side of the Subbasin, notably, west of Lost Hills, Buttonwillow, and Elk Hills, Page (1973), reported very little data for groundwater less than 3,000 µmhos/cm. The lack of data is a combination of evidence suggesting that there is very little fresh water (<3,000 µmhos/cm), on the west side as corroborated by other sources (Gillespie et. al., 2017; and Metzger and Landon, 2018), and a potential data gap where additional data may be useful.

Gillespie et. al. 10,000 mg/L TDS

The depth to groundwater with a TDS of 10,000 mg/L (**Figure 2-10**), is the deepest possible USDW. Gillespie et. al. (2017) and Kong (2016) developed these data based on geochemical analysis of water samples and geophysical log analysis. The depth to 10,000 mg/L TDS is generally consistent with regional trends within the Subbasin. Southeast of the city of Bakersfield, the 10,000 mg/L TDS is mapped to a depth of 6000 ft. This is consistent with the knowledge that this area of the Subbasin receives the greatest amount of fresh water recharge from the Sierras.

In the Maricopa depocenter in the south part of the Subbasin a couple miles north of Wheeler Ridge the 10,000 mg/L TDS contour may be as deep as 10,000 ft. No chemical analysis data were available to verify this geophysical log interpretation; however, the results from Page (1973), also mapped the depth to 2000 mg/L groundwater at 4600 ft (which was the deepest fresh water in the Subbasin) (Gillespie et. al., 2017). The Maricopa depocenter appears to have fresh water that extends deeper than anywhere else in the Subbasin.

Salinities in the west Subbasin are much higher, and depths to the base of USDW are more variable (Gillespie et. al., 2017). The structural complexity along the west side of the valley may be a contributing factor to the variable distribution of water salinity in this area. Gillespie et. al. (2017), cite that numerous wells contain waters between 3000 and 10,000 parts per million (ppm) in the nonmarine Tulare Formation and overlying alluvium in the western Subbasin.

Figure 2-11 below is a conceptual profile illustrating the general difference between the shallow and deep aquifer systems (fresh water continental deposits and alluvium, and saline water marine deposits), and the differences between the west and east side aquifer systems. In general, groundwater is more saline on the westside, while the freshwater column is thickened in the eastern-central part of the Subbasin.

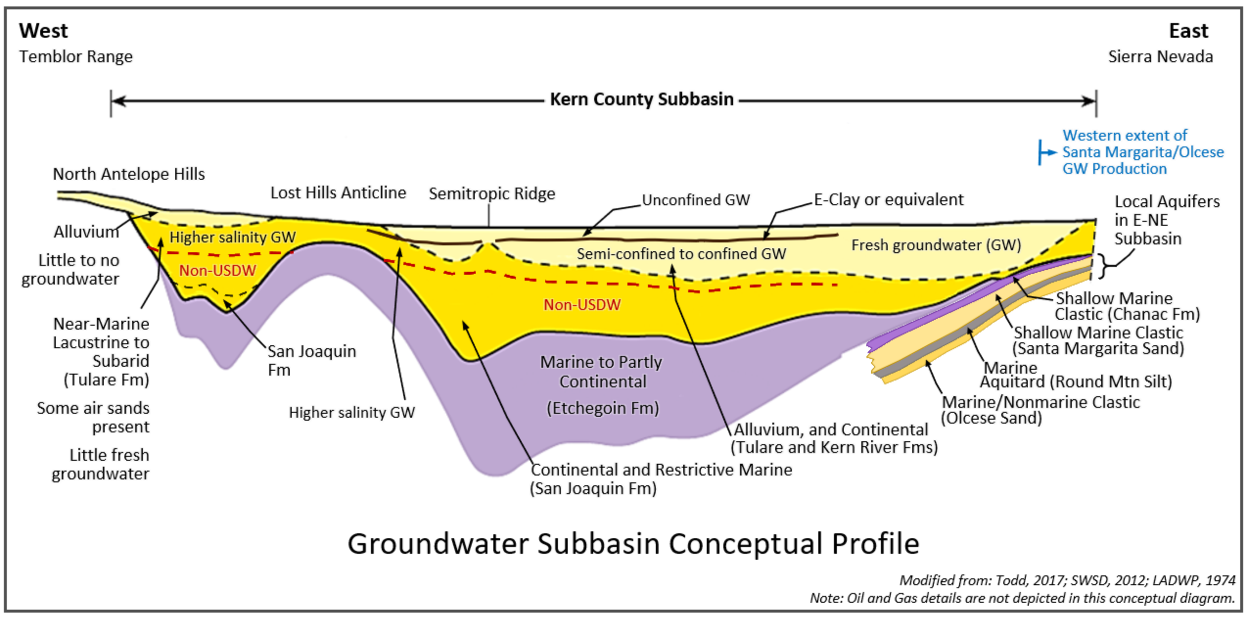


Figure 2-11. Groundwater Subbasin Conceptual Profile

Principal Aquifers and Aquitards

The groundwater aquifers of the Subbasin are geologically diverse with differing zones of confined, semiconfined, and unconfined groundwater conditions. As depicted in the below **Figure 2-12**, the primary aquifer system occurs in the central-northern, central, and central southern portions of the Subbasin. It consists of the Tulare formation, Kern River formation, and overlying alluvium. On the eastern side of the Subbasin are the confined Santa Margarita, Olcese, Pyramid Hills, and Vedder Sands. Groundwater wells extract water where these aquifers are not exempted and where they are feasible for groundwater supply use without hydrocarbons, On the western side of the Subbasin, very little usable groundwater occurs. In the northwest, groundwater supply production is likely limited and may occur in alluvium and/or the Tulare Formation.

In addition to the formations described above, groundwater may also be pumped from the San Joaquin and Etchegoin (Page, 1986; Bartow and Pittman, 1983) in the central portion of the Subbasin; however, little information is available to further document the groundwater characteristics or extraction within these zones.

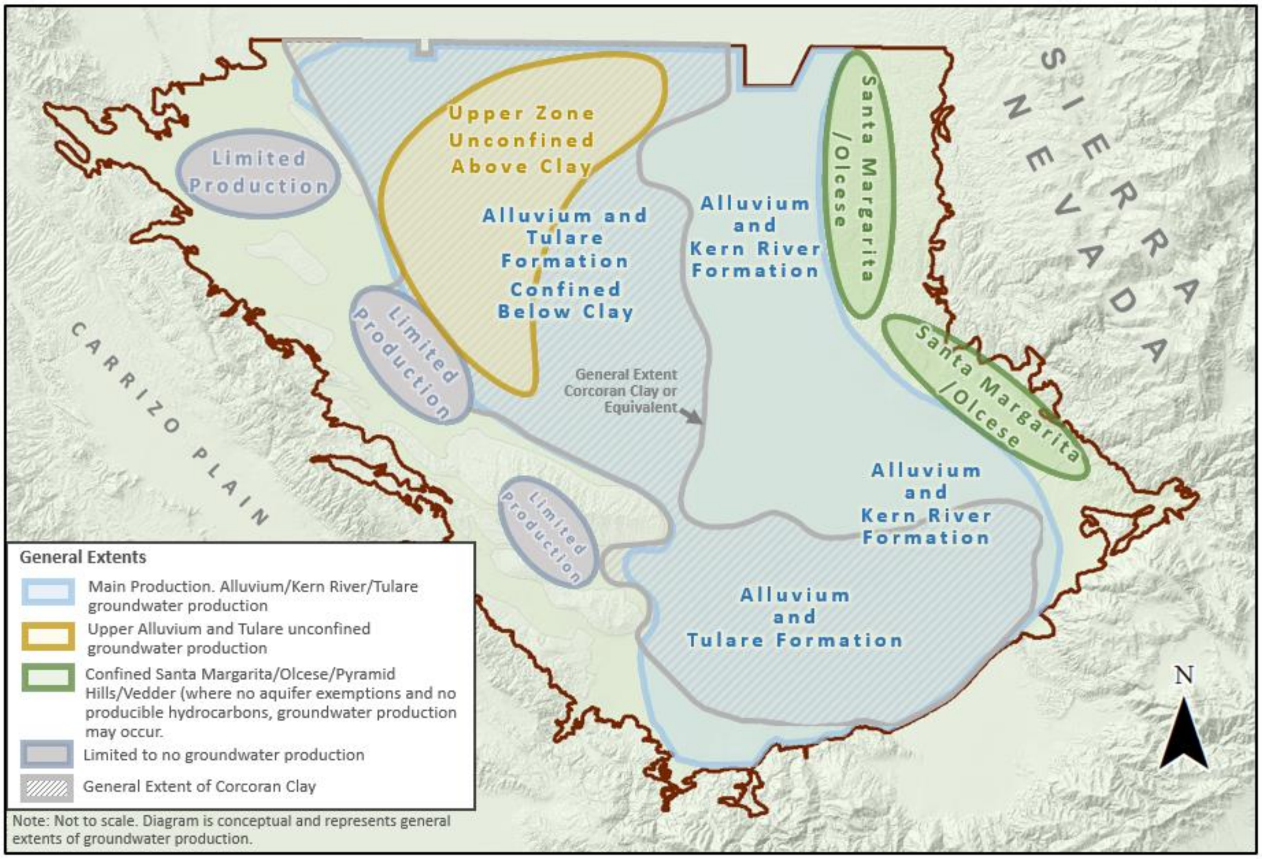


Figure 2-12. General Distribution of Groundwater Aquifer Supply Production in Kern County Subbasin

Formation Names

Table 2-2 presents the hydrostratigraphy and summary of the geologic units of interest with general details and a general summary of deposition and aquifer context.

The Subbasin groundwater system is dominated by alluvial/fluvial deposits on a basin-wide scale and produces an intricate, heterogenous grouping of aquifers. Although formations can be mapped across the Subbasin, much of the material is not distinctive in the subsurface and designation of a particular formation is difficult. Additionally, the E-modified layer of the Corcoran Clay member of the Tulare Formation is correlated across much of the Tulare Lake Hydrologic Region; however, there are still localized debates and questions on the extent and correlation of the E modified clay.

Refer to the discussion on stratigraphy in section 2.2.1.2. for a brief description of the formations and their general context in relation to the aquifer system.

Primary Aquifer System

The primary aquifer system of the Subbasin is within the Tulare and Kern River formations and overlying alluvium. It includes differing zones of confined, semiconfined, and unconfined groundwater conditions, due to the presence of clays that act as local aquitards. The Corcoran Clay and other equivalent clays occur within the Tulare Formation in the central and southern parts of the Subbasin (Page, 1983 and Page, 1986). Where extensive clays are present, some areas of the aquifer system may consist of a deeper confined zone and a shallower unconfined to semi-confined zone. Within the eastern portion of the Subbasin and in the vicinity of the Kern River Alluvial Fan, the aquifer system is made up of an unconfined to semi-confined zone. Shallow zones are also present locally in the northwestern and southern portions of the central Subbasin. The shallow zone is not a part of active groundwater extraction, but data are included in the groundwater conditions section of this report to evaluate changes over time.

Some researchers in the Subbasin define the primary aquifer system as one principal aquifer because the confining beds such as the E-modified Corcoran Clay or equivalent, are not laterally continuous across the Subbasin, or lithologically consistent allowing for continuous confinement. In addition, there are older wells in some parts of the Subbasin, that are screened across the Corcoran Clay which could allow interconnection of water between the upper and lower zones. However, for the past few decades, local county enforcement has worked to eliminate well construction practices with screens across encountered upper unconfined zones and lower confined zones.

In addition, to the aquifer zones described above, there is a shallow groundwater zone occurs above the A-Clay or other shallow clay; however, this zone has poor quality water and is not a part of the groundwater supply aquifer system.

Table 2-2 below is a summary of generalized aquifer characteristics of the primary aquifer system.

Table 2-2: Primary Aquifer System of Kern County Subbasin

Generalized Hydrostratigraphy	Relative Depth	Basin Extent	Water Quality	Corresponding Formations
Unconfined Zone	Middle to Deep	East side "main production zone"	Good	Eastside Alluvium and Kern River Formation
		Central, above the Corcoran Clay	Moderate	Central Subbasin, above the Corcoran Clay Member (E) of the Tulare Formation, or other equivalent fine-grained layers.
Confined, Semi-confined, or Lower Zone		Central "main production zone"	Good to Moderate	Confined to Semiconfined. Alluvium, Kern River Formation, and Tulare Formation

Eastern Confined Aquifers

Along the eastern margins of the Subbasin, other principal aquifers, where classified as USDWs and not exempted, include, semiconsolidated rock such as the Santa Margarita Sandstone, and Olcese Sands. These confined aquifers are hydraulically separated from the Kern River Formation aquifer system by Pliocene marine deposits. Other aquifers to the east, where classified as USDWs and not exempted, include the Pyramid Hills, Vedder Sand, and the Chanac Formation (Page, 1986; Bartow and Pittman, 1983). The extent of groundwater production in these aquifers is limited by the extent of producible hydrocarbons, aquifer exemptions, and increased salinity with depth.

West-side Aquifers

Alluvial aquifer zones on the west side of the Subbasin may contain groundwater that is higher in TDS. This groundwater occurs in the fold belt associated with folded and faulted strata. Where aquifers are classified as USDWs and not exempted per 40 CFR §144.3, groundwater may be pumped for beneficial use. The Tulare Formation makes up most of the aquifer system on the west side; however, the Tulare Formation differs in facies and origin than what is documented in the central portion of the Subbasin. West-side aquifers are described in more details in the management area plans.

Physical Properties of Each Aquifer and Aquitard

Aquifer parameters within the Subbasin are available from both well pumping tests and calibrated groundwater models. Data are summarized in **Table 2-3** and **Figure 2-13**. Aquifer properties reported herein include hydraulic conductivity which is a volume of water that will move in a unit of time, under a unit hydraulic gradient through a unit area, and the 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).

Table 2-3: Aquifer Parameters for Kern County Subbasin

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	--	--	--
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				
White-Poso Unit (upper 200 ft)	--	--	--	0.086 to 0.095
Kern River Unit (upper 200 ft)	--	--	--	0.125 to 0.132
Edison-Maricopa Unit (upper 200 ft)	--	--	--	0.12 to 0.14
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

Hydraulic Conductivity

Aquifer data derived from pumping tests were taken from two sources: 1) relatively short (1.5- to 5-hour) pumping tests by the USGS at irrigation wells during the late 1950s and 1960 (McClelland, 1962), and 2) from constant rate pumping tests from engineering consultants in the 2000's (Todd, 2018). The depth of these test wells varied from 98 to 1,500 ft below ground surface (bgs) (median: 650 ft bgs), and pumping rates varied from 44 to 4,480 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 and ranges from 3 to 250 ft per day (ft/day; median: 60 ft/day), which is consistent with published ranges for clean, medium- to coarse-grained sand (Heath, 1983), or for a fine sand to coarse gravel (Schwartz & Zhang, 2003). These values also fall within the range of the groundwater models that were partially calibrated with these data (C2VSim; CVHM; Todd, 2018; Todd, 2017) (**Figure 2-13**).

The Corcoran Clay of the Tulare Formation is most commonly known for its fine-grained beds; however, lithology does vary from fine (clay and silt) to coarse (sand) texture (Page, 1986; Faunt et al., 2009). These coarser-grained beds are isolated and principally occur where the Corcoran Clay is less than 20 ft thick. Faunt et al., (2009) compiled and estimated horizontal hydraulic conductivities within the range of 0.0024 to 33 ft/day, which is within the range of silt to fine/medium sand (**Figure 2-13**) (Heath, 1983). A range of vertical hydraulic conductivity was estimated from permeameters and field tests between 6.6 x 10^{-6} ft/day to 1.5 x 10^{-3} ft/day (Faunt et al., 2009), representing a potential vertical anisotropy range of 3.6 x 10^{2} to 2.2 x 10^{4}. As noted by Faunt et al., (2009) laboratory permeameter tests may have underestimated the hydraulic conductivity while field testing may have overestimated hydraulic conductivity due to potential for intra-borehole flow across the clay. Additionally, recent inelastic compaction of the Corcoran Clay in areas of subsidence may have further reduced vertical hydraulic conductivity (Faunt et al., 2009).

Specific Yield and Storage

Storage of an aquifer is primarily described and quantified by the storativity or the volume of water released from storage per unit surface area of the aquifer per unit decline in hydraulic head (Heath, 1983). It is important to note that while storativity applies to both confined and unconfined systems, it can be further simplified for these two systems. Storativity accounts for aquifer compression and water expansion (specific storage components), which are the primary factors for estimating storage in confined systems; thus, for confined systems, the specific storage or storage coefficient is most often reported. In contrast, for unconfined systems, the specific yield or effective porosity (gravity-driven dewatering of an aquifer) better represents storativity because aquifer compressibility and water expansion are somewhat negligible in unconfined systems. For unconfined systems, specific yield is most often reported, and is a function of porosity and specific retention.

For confined systems, the aquifer compressibility of the storage coefficient can be further defined as elastic and inelastic skeletal specific storage, where inelastic storage will be lost once compression and dewatering occur. It is estimated that in the Central Valley, the inelastic specific storage typically is 30 to several hundred times larger than the elastic skeletal specific storage (Faunt et al., 2009; Ireland et al., 1984). Where fine-grained deposits with inelastic storage are thick in the aquifer system, water released could be a major source of water, but could also result in a permanent loss in storage capacity of fine-grained sediments.

Specific yield of unconfined zones and the storage coefficient of confined zones within the Subbasin have been estimated by laboratory testing of sample cores, calculation based on lithology type, and groundwater model calibration (Dale et al., 1966; Davis et al., 1959; Davis et al., 1964; Faunt et al., 2009; DWR, 2013; Todd, 2017 and 2018). A range is presented in **Table 2-3** and is within the range of values published for similar grain sizes and lithology (Heath, 1983; Morris and Johnson, 1967) (generally 0.02-0.40).

General Water Quality of Principal Aquifers

As required in the regulations, this section is a general summary of water quality of the principal aquifers in the Subbasin. This section does not replace the discussion of water quality issues under Groundwater Quality Section 2.2.3.

This discussion provides a high-level description of water quality variation in the principal alluvial aquifer system of the Subbasin, both laterally (from west to east across the Subbasin) and vertically (shallow–deep within the Subbasin). For local details on water quality for specific areas of an aquifer, refer to the management area plans.

TDS are discussed in this section only for the purpose of comparing and contrasting different portions of the aquifer system for Subbasin characterization. For details regarding water quality issues and current groundwater conditions, refer to Section 2.2.3 and individual management area plans. In general, water quality is higher in TDS in the western third of the Subbasin than in the rest of the Subbasin. Higher nitrate and other solutes concentrations are typically present in shallow perched zones and in the unconfined zone above the Corcoran Clay. Groundwater is progressively fresher and lower in TDS below the Corcoran Clay, toward the center of the basin, and in the eastern half of the Subbasin. In contrast, arsenic concentrations increase with depth and in close proximity near portions of the Corcoran Clay. Arsenic and salinity progressively increase with depth approaching the base of USDW.

Kern County Water Agency Water Supply Reports which end in 2011 presented groundwater quality maps using data pre-1997. These maps report that unconfined groundwater (typically above the E-modified Corcoran Clay) in the central portion of the Subbasin generally ranges from less than 500 to 1,500 ppm for TDS, while the west side unconfined groundwater ranges from 1,000 to 5,000 ppm for TDS. The confined aquifer zone (typically below the E-modified clay) in the central portion of the Subbasin generally ranges from less than 200 to 500 ppm for TDS, while west side confined water typically ranges from 1,000 to 4,000 ppm.

The high TDS groundwater in the west side with respect to the east side has recently been reported in a preliminary groundwater salinity mapping study conducted by the USGS (Metzger and Landon, 2018). Within the Subbasin, the study reported much higher TDS in west side water when compared with east side groundwater. Metzger and Landon suggest that higher TDS could be related to a combination of natural conditions (west side sediments derived from marine deposits with some connate water) and anthropogenic factors such as infiltration from disposal ponds and/or agricultural drainage ponds. The researchers suggest that groundwater on the east side of the Subbasin have the lowest TDS and greatest depths to non-USDWs because they are adjacent to Sierra Nevada that is a source of low TDS (fresh water $Ca\text{-}HCO_3$ type) recharge, whereas, aquifer zones on the west side of the Subbasin have higher TDS values. The west side aquifer zones likely receive very little recharge from the Temblor Range which is made up of marine deposits, and west side aquifer zones such as the west side Tulare Formation likely contain connate water derived from marine deposits (Wood & Dale, 1964). This higher TDS water (Na/Ca-SO_4 type) in west side water is consistent with historical reports and is documented for more than 60 miles from north to south in the Subbasin (KCDEH, 1980; KCDEH and KCWA, 1982; Sierra Scientific Services, 2013). Additional sections of this GSP provided by west side entities, discuss further details on the west-side Subbasin aquifer system.

Primary Use of Each Principal Aquifer

The unconfined zone in the eastern portion of the Subbasin and in the Kern Fan, and the confined zone below the Corcoran Clay are the primary production zones of the Subbasin aquifer system. In addition, the upper unconfined zone is pumped for beneficial use in the north central and west central areas of the Subbasin. The primary uses of the Subbasin aquifer system include agricultural, municipal, domestic, and storage for the banking of surface water.

Summary of Beneficial Uses and Users of Groundwater

Land use in the Subbasin includes agriculture, urban/industrial/residential, and open space use. According to the 2014 SGMA legislation, beneficial users of groundwater and property interests potentially affected by the use of groundwater include:

- Agricultural Users
- Domestic Users
- Municipal Well Operators
- Public water systems
- Local Land Use Planning Agencies, and
- Environmental Users

According to DWR well completion reporting and the CASGEM program, groundwater wells are constructed for a variety of uses including:

- Domestic / Residential
- Irrigation
- Stock
- Municipal / Public
- Monitoring / Observation
- Industrial
- Cathodic Protection
- Other / Unknown

Data Gaps and Uncertainty

The primary data gaps in the hydrogeologic conceptual model include:

- Physical properties of the westside aquifers and eastside aquifers,
- Physical properties of the upper zone of the primary aquifer system,

- Groundwater characterization on the eastern and western flanks of the Subbasin and in the upper and shallow zones, and
- Groundwater quality of the primary aquifer zones and confined zones on the eastern and western flanks of the Subbasin, from wells screened solely in a single aquifer zone.

As improvements to monitoring networks are made, data can be used to fill data gaps in the Subbasin.

Cross Sections

A general summary of regional subsurface information is provided below in the context of cross sections developed for this plan. Where applicable, detailed discussions of the subsurface are included in some management area plans of the Subbasin.

Cross sections were developed to illustrate the subsurface conditions of the Subbasin. The locations of the cross sections discussed below are provided on **Figure 2-8**. Section A-A' north of the Kern River (**Figure 2-14a**) is northeast-trending and perpendicular to the numerous faults and folds within the valley. Section B-B' north of the Kern River (**Figure 2-14b**) is northwest-trending to be parallel to the axis of the valley. Geologic and hydrogeologic data were compiled from DWR well logs, DOGGR well logs, Page (1973), Gillespie et al (2017), *California Oil and Gas Fields* (DOGGR, 1998), and other regional investigations.

Cross sections spanning the southern and southeastern portions of the Subbasin were developed for management area plans and are included herein (**Figures 2-14c** to **2-14g**). For a discussion of the subsurface across the White Wolf Fault, data including a cross section are presented in the *White Wolf Subbasin Technical Report* (EKI, 2016), that was a part of the 2016 Basin Boundary Modification Request.

A-A' North of the River

A-A' north of the river illustrates the change in hydrogeology from west to east. The westside has a thin fresh water zone due to a shallow base of fresh water. The geology on the westside is dominated by marine deposits and the overlying Tulare formation consists of alluvial fan and debris flow facies primarily from sediments derived from the Coast Range marine deposits. To the east of the California Aqueduct, the Corcoran Clay of the Tulare includes diatomaceous clay and other fine-grained deposits associated with basin center facies. Section A-A' includes seismic form lines from the PGA (1991) investigation that show general structure of bedding that are consistent with mapped Buttonwillow and Semitropic folds and the structure of the base of the Tulare. In contrast, traditionally mapped Corcoran Clay layers which are available through the USGS and DWR (C2VSIM on Section A-A'), correlate clays that do now follow the general bedding forms observed in seismic lines. Future investigation may clarify the discrepancies between these interpretations.

The upper zone groundwater elevation is plotted on section A-A' which is generally considered to pertain to wells screened above the Corcoran Clay. Section A-A' displays wells screened in the upper zone above the Corcoran Clay which is the primary groundwater production zone to the west of Interstate 5 (I-5). Some groundwater production in the upper zone occurs east of I-5 with wells screened above the mapped

Corcoran Clay and other wells screened across the Corcoran Clay. The upper zone likely extends further west and east; however, additional data were not available to continue the correlation.

The main regional groundwater surface is plotted across the basin. The groundwater is generally confined where wells are below the Corcoran Clay and semiconfined where wells are outside the extent of the Clay. As described in section 2.2.1.3, Pond-Poso Fault has been documented to affect groundwater flow. High resolution water level data across the fault, however, were not available for this cross section.

The central portion of the Subbasin (just west of the Pond-Poso Fault), has a much thicker aquifer zone with a deeper base of freshwater and thicker deposits of continental sediments (Kern River formation) derived from the Sierra Nevada where freshwater recharge into the Subbasin predominates.

Further to the east, wells have been drilled deeper (greater than 2000 ft) in order to extract fresh groundwater from the Santa Margarita formation and Olcese Sand. Although these aquifers are separate from the main alluvial aquifer system of the valley by Plio-Miocene Marine Deposits, some wells are screened across the continental deposits (Kern River formation), extending through marine and into the Santa Margarita formation and Olcese Sand.

B-B' North of the River

Section B-B' from northwest to southeast trends through a portion of the Subbasin with a deep base of freshwater. Seismic form lines confirm bedding gradually rise to the south onto the Bakersfield Arch beginning from just north of the City of Shafter southward toward the City of Bakersfield and the Kern River. The alluvium and Kern River formation become thicker toward the south where the Kern River has been a major source of the sediment input into the Subbasin.

South of the River Cross Sections

Cross sections developed for management area plans in the southern portion of the Subbasin are included herein (**Figures 2-14c** to **2-14g**). These sections present the base of fresh water where it is deepest in the central southern area of the Subbasin southwest of the city of Arvin. They also present the White Wolf Fault and Edison Fault which alter groundwater flow. In general, water wells are screened in the upper 1000 ft of the subsurface across the southern portions of the Subbasin, in the Kern River Formation and Tulare Formation. In the southeastern portion of the Subbasin, faulting and folding has created a thinner column of Kern River Formation deposits to the east of Lamont. The top of the Chanac Formation may be as shallow as 900 ft bgs in T31S-R29E. Consequently, data on the base of fresh water were not readily available for plotting in the southeastern portion of the Subbasin.

Cross sections across the White Wolf Fault are provided in the *White Wolf Subbasin Technical Report* (EKI, 2016). Historical sections document change in groundwater elevations (generally a 50 ft decline) across the fault from south to north. Displacement of beds across the fault increases with depth. In general, groundwater aquifer thickness is not significantly affected by displacement across the fault. Additional information is available at the Basin Boundary Modification website: https://sgma.water.ca.gov/basinmod/basinrequest/preview/34.

Mapped Physical Characteristics

Topographic Information

Figure 2-15 presents a basin-wide topographic map of the Subbasin. The rim elevation of the Subbasin varies from approximately 600 ft msl along the White Wolf Fault on the south to over 2,000 ft in the foothills of the adjacent San Emigdio Mountains. On the east and west sides, the rim elevations vary between 1,000 and 2,000 ft msl. As such, the topography of the Subbasin slopes toward the center of the valley on three sides, and the 400-ft contour line generally defines a long and narrow valley floor, which slopes to the northwest. The lowest land surface elevations are approximately 210 ft msl and are located along the County line between Highway 43 and Interstate 5 (18 of 24 miles). Within the Subbasin, prominent topographic features include the Elk Hills, and the Buttonwillow and Semitropic ridges.

Surficial Geology (Including Location of Geologic Sections)

The surficial geology of the Subbasin has been documented in a variety of previous investigations and is presented on **Figures 2-3**, **2-7**, and **2-8** (Bartow, 1991; Page, 1986; and CGS, 2010b) According to the California Geological Survey (2010b), the center of the basin consists mainly of Pleistocene to recent unconsolidated and semi-consolidated alluvial (Q of **Figure 2-7**), lake, playa, and terrace deposits. Older Pleistocene alluvium (Qao) is present in the eastern portion of the basin 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. Small remnants of older continental sediments are included along the southeastern flank of the Subbasin, including undivided

Tertiary-age sandstone, shale, conglomerate, breccia, and lake deposits (Tc) and Miocene-age sandstone, shale, conglomerate, and fanglomerate (Mc) plus smaller remnants of older marine sediments: Miocene-age sandstone, siltstone, shale, conglomerate, breccia (M). These remnant units would include the Santa Margarita Formation, Round Mountain Silt, and Olcese Sand.

Bartow (1991) provides a similar map (**Figure 2-3**) as the California Geological Survey 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. As discussed further below, the map shows the location of the Bakersfield Arch as well as three structural regions within the Subbasin.

Page's (1986) presentation of the surficial geology, as shown by **Figure 2-7** better displays the lakebed deposits. Recent river deposits (Qr) associated with the present-day Kern River, are shown as a long, narrow strip from the mouth of the Kern Canyon, and are comprised of gravel, sand, silt, and minor amounts of clay. 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 historical Kern Lake Bed, Buena Vista Lake Bed, Goose Lake Beds, and the southern edge of the Tulare Lake Bed. 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. Like the other maps, remnants of older continental deposits are shown along the rim of the Subbasin, primarily the southeastern side, including Oligocene to Miocene deposits (Tcmo) of gravel, conglomerate, sand, and clay; and Eocene to Miocene deposits (Tcme) of conglomerate, sandstone, fanglomerate, claystone, and breccia plus limited occurrences of undifferentiated marine deposits (Tm) of sand, clay, silt, sandstone, shale, mudstone, and siltstone of Eocene to Pliocene ages.

Soil Characteristics

Soils within the Subbasin have two general origins that are approximately delineated by the trough of the valley, which also mirror depositional patterns as mapped in surficial geology. The eastern alluvial fans were deposited primarily by runoff from the Sierra Nevada, Tehachapi, and Transverse mountain ranges. These soils are of igneous and metamorphic origin; are typically well drained, very low in salinity, and ideal quality for agriculture. The northwestern alluvial fans originated from Coast Range sedimentary rock formed on the sea bottom. This northwest region tends to have more areas with poorly drained soils of relatively marginal quality (Provost & Pritchard, et al., 2015). The Groundwater Quality Assessment Report (Provost & Pritchard, et al., 2015) describes five areas of different soil texture in the Subbasin: the clay rim area of fine grained texture near the historical lake beds, the foothills of medium texture, the Kern Fan region derive from river deposition, northern areas with some alluvium and other sources, and Wheeler Ridge/Arvin Edison with coarse soil. These five areas contain the different soil types described below.

Soils in the center of the Subbasin are generally categorized into three types according to texture. Fine-grained soils are found in the southwest, the historical lake beds, and northwest corners of Subbasin. Coarse grained soils within the Poso Creek fan, Kern River fan, and Caliente creek fan. And the moderate infiltration of soils along the distal edges of the fans. The lake bed areas are composed of fine-grained soils of the historical Buena Vista and Kern lakebeds, and swamp and overflow lands, which continue north along the historical drainage paralleling the Goose Slough, Goose Lake, and southern edge of the Tulare Lake depositional environment. Medium to coarse grained soils are distributed in the Poso Creek and Kern River drainage beds as well as the proximal and medial portions of the Kern Fan, and the south boundary of the Subbasin.

Figure 2-16 and **2-17** present the soil distribution within the Subbasin as defined by U.S. Dept. of Agriculture (USDA), National Resources Conservation Service, Soil Survey Geographical Database (SSURGO) as obtained from the DWR SGMA Data Viewer website (2018). **Figure 2-16** shows that six soil orders are present in the Subbasin, including Aridisols and Entisols throughout most of the Subbasin, with Inceptisols along the eastern highland, and much lesser amounts of Alfisoils, Mollisols, and Vertisols. According to the online Encyclopedia Britannica (EB, 2018), Ardisols 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 (EB, 2018). 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 (EB, 2018). 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, and mineral nutrients are present in most horizons (EB, 2018). Humus and Al/Fe-bearing minerals do not migrate to subsurface layers. 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 (EB, 2018). The shrink-swell action produces significant vertical mixing of the soil.

Figure 2-17 shows the distribution of hydrogeologic soil groups, which is based largely on four categories of infiltration rates: high, moderate, slow, and very slow. Group A soils have a high infiltration rate due to well drained sands or gravelly sands. Group B soils are moderately well drained due to moderately fine to coarse textures. These soils are present on the east, west, and south sides of the valley floor. 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 along the valley floor, along the eastern highlands, and at various locations along the northwestern side of the Subbasin. Group D soils have a very slow infiltration rate due to the presence of clay and are located primarily along the northern Subbasin boundary within the valley floor. More detailed soil survey data can be found in four USDA reports on various portions of the Subbasin: *Soil Survey of Kern County, California* (USDA, 1981, 1988, 2007, and 2009), including recent online updates.

Natural Recharge, Direct Recharge Areas, and Potential Recharge Areas

Direct recharge and potential recharge areas are differentiated in this section from natural recharge. Natural recharge occurs by groundwater underflow from adjacent sources, precipitation outgaining evapotranspiration in a Subbasin, or from natural surface waters flowing into the Subbasin. On the other hand, direct recharge is either planned or unplanned application of surface water by unlined conveyance, field application, managed recharge, and spreading operations. This section focuses mainly on direct recharge and potential recharge to the Subbasin, but briefly discusses natural recharge to the Subbasin. In-lieu recharge is not discussed in this section because it does not provide an actual input to the groundwater system for budgeting purposes, but only curtails or reduces the amount of groundwater that would have been pumped. In-lieu recharge is discussed in other sections of this GSP. This section may not include all localized recharge activities and facilities, but these local activities and facilities are further described within the individual management area plans.

Natural recharge to the Subbasin occurs mainly by underflow or surface recharge from the eastern and southern highlands (Sierra Nevada and Tehachapi Mountains). The surface water bodies as a source of recharge are discussed in the next section. In general, natural in-situ recharge by precipitation is absent in Subbasin, and may only occur in extreme wet years, because typically evapotranspiration outgains the amount of natural precipitation to the Subbasin (Provost and Pritchard et. al., 2015). The absence of natural recharge by in-situ precipitation in the Subbasin further illustrates the lack of recharge to the west side of the Subbasin where it is likely that very little if any freshwater underflow recharges the west side. In contrast, the east side is dominated by recharge from the Kern River and the Sierra Nevada.

Significant direct recharge to groundwater in the Subbasin occurs through managed recharge and water banking (storage) projects; as well as unmanaged recharge through natural waterways, unlined spill basins and regulating (balancing) reservoirs, percolation of applied water to crops that descend below the root zone, and unlined canals. Numerous sources of water are recharged by various projects, including local surface water (Kern River, Poso Creek, and other drainages) and imported water (SWP] and CVP).

The major areas of direct recharge (facilities and drainages) are presented in **Figure 2-18**. Additional areas of unmanaged or managed recharge may include agricultural land where excess irrigation water percolates below the root zone, wastewater treatment spreading areas, and urban drainage spreading areas. Additional locations of natural recharge from surface water features may include springs, seeps, ephemeral/intermittent streams flowing into the Subbasin (**Figure 2-19**). The surface water features are described in more detail in the following section.

Since the late 1980s, large-scale groundwater recharge/banking operations have been constructed along the Kern River. Given the permeable nature of sediments within the Kern River Fan, most of the enhanced recharge projects involve surface spreading through ponds, low-lying fields, or basins. Some projects are dedicated to the replenishment of the groundwater basin, while other projects store surplus SWP and CVP water for subsequent extraction; and some banking projects do both. (Todd, 2017).

The Soil Agricultural Groundwater Banking Index (SAGBI) can further estimate groundwater recharge suitability to quantify recharge of deep percolated applied irrigation water and potential recharge from future managed recharge within the Subbasin. The California Soil Resource Lab at University of California Davis has developed an online application (https://casoilresource.lawr.ucdavis.edu/sagbi/) to present the SAGBI, which estimates groundwater recharge suitability based on five major factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. The application includes mapping coverage of the SAGBI and indicates a moderately good to excellent rating for the Poso Creek alluvial fan in the north central Subbasin, the Kern River alluvial fan in the central area, and in much of the southeastern to southwestern corners of the Subbasin. SAGBI ratings are moderately poor to very poor along the eastern margin, central western margin, as well as the center of the valley from the former Kern and Buena Vista lake beds, and north along the Goose Neck Slough to the Tulare Lake Bed. While moderately good to good SAGBI is shown for much of the western margin, this area is underlain by marine sediments and is not likely to be a useful area for recharge. The SAGBI ratings generally agree with mapped soil data where higher rated SAGBI soil corresponds with moderate to high infiltration soils. Note that an abrupt east-west alignment of good versus poor SAGBI occurs in the southern central Subbasin and is likely due to the methods and results of historical soil surveys.

Groundwater discharge areas in the Subbasin are limited due to the depth of usable groundwater, typically greater than 100 ft throughout the Subbasin. Shallow, poor-quality groundwater (above the A-clay) does occur in the west central and southern areas. These shallow groundwater areas may support salt-tolerant vegetation. Effects of a shallow water table and evapotranspiration may discharge poor quality shallow groundwater from these areas to the surface. Historically, flowing wells were present throughout much of the valley floor (Mendenhall, 1916), including the Buena Vista and Kern lakes and the area to the north (>180 square mi), and from Buttonwillow north beyond the county line (>400 square mi). Over 100 flowing wells were identified in 1905 and reductions in flow were recognized in the following years. According to the USGS groundwater model (Faunt, 2009), the Kern River is a groundwater discharge area along a nominal 7-mile reach within Bakersfield, east of Highway 99; however, the city of Bakersfield measures flow at six weirs along the river across the valley and shows an overall loss of flow (seepage) from the Kern River.

Surface Water Bodies

Figure 2-19 presents the location of surface water bodies in the Subbasin according to the National Hydrography Dataset. These water bodies include the California Aqueduct (SWP) and federal Friant-Kern Canal, and other local canals that help convey Kern River water and imported surface water to beneficial users in the Subbasin. This dataset also includes the Kern River, Poso Creek, Caliente Creek, and other significant ephemeral streams, spring, and seeps, that are sources of recharge from the mountains on the east, southeast, and south sides of the Subbasin. The National Hydrography Dataset also includes wetlands delineations around the Kern Wildlife Refuge. The refuge is now sustained by imported surface water typically wheeled from the California Aqueduct and conveyed by the Goose Lake Canal to the refuge (USFWS, 2005).

The most important source of naturally occurring surface water for the Subbasin 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. The Kern River is approximately 164 miles long and is fed by rain and snowmelt from the Southern Sierra Nevada, including Mount Whitney. The last 35 to 40 miles of river crosses the Subbasin.

Local streams, many of which are ephemeral, provide additional local surface water during the wet season and during above normal and wet water years. A very small percentage of minor stream runoff is collected and used for irrigation; the majority of these irregularly occurring flows likely serve to recharge local groundwater basins (Kennedy and Jenks, 2011).

Source and Point of Delivery for Imported Water Supplies

Imported water is supplied by the Central Valley Project's (CVP) Friant-Kern Canal and California Department of Water Resources through the SWP. CVP water from the Friant Division is conveyed to users in the Subbasin through the Friant-Kern Canal, and SWP water is conveyed through the California Aqueduct together with CVP water from the Delta Division. Treated produced water is also used as an imported source of water to the groundwater Subbasin for beneficial use.

Central Valley Project – Friant Division

The CVP Friant-Kern Canal diverts water from Millerton Reservoir, created by Friant Dam on the San Joaquin River, and extends southward a distance of 152 miles through Fresno, Tulare and Kern counties to its terminus at the Kern River in Bakersfield. The capacity of Millerton Reservoir is about 520,000 AF, but 130,000 AF of this storage lies below the intake for the Friant-Kern Canal.

Water districts along the east side of the San Joaquin Valley entered into long-term water supply contracts with Reclamation, which provide for the delivery of three types of water; Class 1, Class 2, and Section 215.

Class 1 Water is the supply of water stored in or flowing through Millerton Lake which, subject to the contingencies described in the Contracts, will be available for delivery from Millerton Lake and the Friant-Kern and Madera Canals as a dependable water supply during each Contract Year.

Class 2 Water is the supply of water which can be made available subject to the contingencies described in the Contracts for delivery from Millerton Lake and the Friant-Kern and Madera Canals in addition to the supply of Class 1 Water. Because of its uncertainty as to availability and time of occurrence, such water will be undependable in character and will be furnished only if, as, and when it can be made available as determined by the Contracting Officer.

Section 215 Water is a temporary supply of water, other than Class 1 Water or Class 2 Water, made available to the Contractors in addition to water provided pursuant to water service contracts, including water made available that is not subject to acreage limitation pursuant to Section 215 of the Reclamation Reform Act of October 12, 1982 (96 Stat. 1263), as amended. The historical allocation priorities for Section 215 Water are as follows:

- Long-term contractors
- Cross Valley contractors
- Other parties within the Friant Division service area with direct delivery capabilities
- CVP contractors outside of the Friant Division service area
- Other parties

Central Valley Project – Delta Division

In 1973, DWR completed the initial facilities of the SWP, including the main line of the California Aqueduct. Portions of the SWP were constructed for use in conjunction with the facilities of the CVP. As the state and federal projects developed, a group of water users planned the Cross-Valley Canal as a means of taking delivery of CVP water conveyed through the California Aqueduct. The Cross-Valley Canal was completed in 1975 and, in 1976, the water users entered into three-party contracts with DWR and Reclamation. Under these contracts, CVP water available to Reclamation in the Delta can be pumped by the SWP's Harvey O. Banks Pumping Plant into the California Aqueduct for delivery to the Tupman turnout where this water is diverted into the Cross-Valley Canal. This federal water, conveyance of which is subordinate to conveyance of SWP water, can then be delivered to water users in the Subbasin.

State Water Project

The Kern County Water Agency was formed in the 1960s to contract with the DWR for the importation of SWP water to Kern County. The California Aqueduct, the SWP's principal conveyance feature, transports water from the Delta along the west side of the San Joaquin Valley to the Subbasin. Individual water districts holding contracts with Kern County Water Agency have turnouts directly from the aqueduct into their service areas or receive water via the Cross-Valley Canal.

Two types of water are available from the SWP, including relatively firm Table A Water and surplus Article 21 Water. 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 water among the agencies.

While the reliability of SWP water is less than was anticipated when the contracts were executed, a contract amendment, introduced in the Monterey Agreement of 1994, put agricultural and urban contractors on equal footing respecting the allocation of water supply during shortages. Prior to the amendment, agricultural contractors were burdened with a larger share of any shortages.

Article 21 Water, unlike Table A water, cannot be scheduled; rather, it must be taken at the time it is declared to be available and is analogous to Section 215 Water for the CVP-Friant contractors. 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
- Available only when conveyance capacity is not being used for SWP purposes or scheduled SWP deliveries
- Cannot be stored within the SWP system. In other words, the 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 the wet months of the year, typically December through March.

Produced Water

Water brought to the surface when oil is extracted is often referred to as "produced water." Produced water is groundwater that is commingled with hydrocarbons and located within the hydrocarbon bearing reservoir. Produced water is generated as oil is extracted for use. Often, produced water is returned to the original geological formation for enhanced oil recovery or disposal. Some produced water is suitable for beneficial use with treatment, though most is higher in salinity and must undergo extensive treatment and be blended with other water before use. New technology and the need to find new sources of water are driving the ability to process and treat produced water for beneficial use.

2.2 Groundwater Conditions

Annual groundwater elevation contour maps covering much of the Subbasin have historically been prepared by KCWA in Water Supply Reports since before the 1990s until 2012. These maps provide seasonal high groundwater level conditions from spring water level data, and generally depict groundwater flow conditions over time consistent with flow directions observed in 2015. Groundwater conditions are also monitored through a number of local and joint district activities, as well as state mandated programs, such as CASGEM.

2.2.1 Groundwater Trends

Based on historical groundwater trends from USGS and the KCWA (Page, 1986; and KCWA), groundwater flows into the Subbasin mostly from the uplands along the south and east margins of the Subbasin. Below is a generalized diagram depicting groundwater flow into the Subbasin (**Figure 2-20**). In the absence of pumping or significant barriers, groundwater naturally flows from high elevation points of recharge to lower elevation points with less recharge. In general, groundwater flow diverges to the north and south away from natural and managed recharge points along the Kern River. The river flows into Subbasin roughly along the axis of the Bakersfield Arch, which has a broad topographical rise that gradually dips to the north and south; thus, the rough alignment of the river effectively splits the Subbasin into northern and southern groundwater flow regimes. Groundwater to the south of the river flows toward discharge points at pumping wells within the south-central areas of the Subbasin, and groundwater to the north of the river migrates toward the northwest discharge points at pumping wells and continues north until it leaves the Subbasin as subsurface underflow. **Figure 2-20** presents the approximate location of the San Joaquin Valley (Buttonwillow) Syncline which likely affects the flow of westside groundwater from significantly impacting the main production zone of the Subbasin. In general, groundwater elevation trends near the river may be highly variable due to high volumes of managed groundwater recharge and extractions associated with groundwater banking projects. Groundwater elevation patterns further away from banking operations show more seasonal responses from pumping and recharge, and, an overall, long-term decline in groundwater level in the majority of the Subbasin.

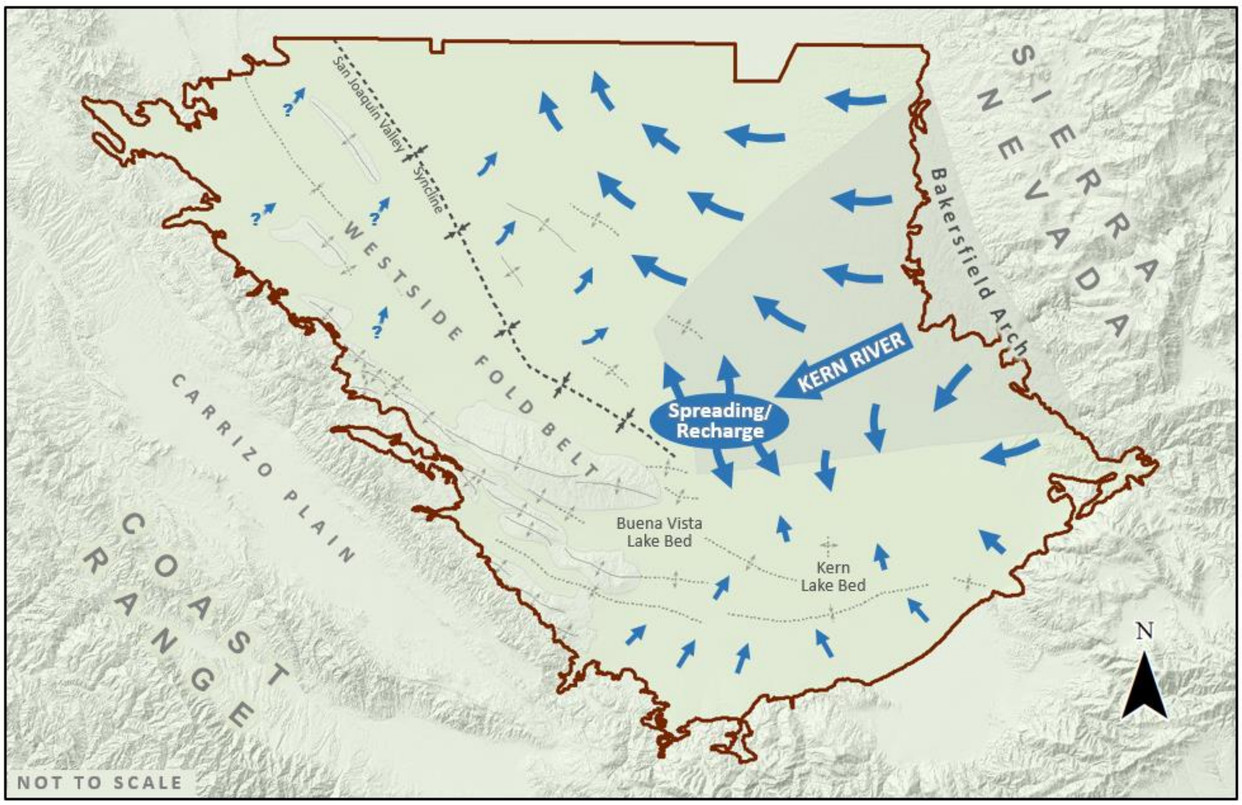


Figure 2-20. Generalized Diagram of Groundwater Flow in Kern County Subbasin

2.2.1.1 Elevation and Flow Directions

Groundwater elevation contour maps were prepared for Spring 2015 to provide relatively current groundwater flow trends across the Subbasin since the inception of SGMA. Contours were prepared for Spring 2015 (seasonal high) in the primary aquifer zone or "main production zone" which is generally confined below the E-clay or Corcoran and unconfined to semiconfined outside the extent of the E-clay (**Figure 2-21**). Contours for the "Upper Zone" by Kenneth D. Schmidt and Associates (KDSA) (2018) are presented on **Figure 2-22** for Spring 2015 data. They represent the upper unconfined to semiconfined zone (above the E-clay or equivalent) underlying the northwest-central part of the Subbasin. A Fall 2015 contour map was also developed to represent seasonal low groundwater conditions in the primary aquifer zone (**Figure 2-23**). At this time, there were insufficient data to contour a fall 2015 upper zone map. In addition, to production zones, depth contours developed by the Kern County Water Agency (2012) for the shallow unconfined zone (above the A-clay or equivalent) are presented on **Figure 2-24**.

These contours were developed from Summer 2011 and are generally representative of 2015 conditions. In general, shallow elevations are fairly constant over time.

Regional Contours

In general, groundwater flow directions reported are consistent with historical trends, with groundwater flowing from the uplands on the south, east, and west of the Subbasin toward the center of the Subbasin. Groundwater tends to diverge at the Kern River with flow to the south of the river toward pumping well discharge points, and flow to the northwest of the river toward pumping wells, and further north until it leaves the Subbasin. Based on 2015 groundwater elevations, the divergence to the North and to the South along the river is less notable due to the drought conditions which resulted in greater groundwater use with very little recharge during 2013 to 2015. Depressions in the groundwater potentiometric do occur south of the river; however, a general trend of flow toward the north and center “trough” of the Subbasin is apparent.

Groundwater elevations during Spring 2015 in the main production zone of the aquifer system ranged from less than minus 100 ft msl in the north-central part of the Subbasin to greater than 300 ft msl in the eastern and southeastern part of the Subbasin.

Groundwater elevation data for the Fall 2015 were limited in availability due to the high demand for pumping; therefore, the data range is incomplete, it may be affected by pumping, and it represents only a partial dataset; however, general groundwater flow trends are consistent with historical trends. Groundwater elevation data for the Fall 2015 in the main production zone of the aquifer system ranged from less than minus 150 ft msl (north-central Subbasin) to greater than 250 ft msl (south-southeast Subbasin). Contours in the upper unconfined zone of north-central Subbasin and shallow zone of Subbasin were not prepared for Fall 2015 due to a lack of sufficient data.

Upper Zone Contours

Groundwater elevations during Spring 2015 in the upper zone of the north central part of the Subbasin ranged from 220 ft msl to 160 ft msl. Within Townships 27S and the northern half of 28S, groundwater in the Upper Zone flows northeasterly. Within the southern half of Township 28S and 29S, groundwater flows southeasterly. Some of this flow may be affected by the Buttonwillow Syncline and Buttonwillow Ridge (anticline). As observed in Cross Section A-A’ of North of the River (**Figure 2-14A**), beds from this groundwater aquifer system are deformed (folded).

Shallow Depth Contours

Groundwater depths in the shallow zone historically range from approximately 20 to 25 ft bgs to less than 5 ft bgs (ranging from 200 ft msl to 245 ft msl). Representative contour maps were chosen from the KCWA's 2011 Water Supply Report (KCWA, 2012) (**Figure 2-24**), because more recent data from 2011 to 2015 are limited in extent; nonetheless, the recent data agree with DWR published maps of shallow perched groundwater in the San Joaquin Valley (DWR, 2009), and with the KCWA's historical water supply reports. Shallow groundwater is not significantly impacted by groundwater pumping in the production zone, as observed by the relatively consistent shallow groundwater depths and extents in historical water supply reports from the KCWA and DWR across multiple water year types. The source of shallow groundwater as mapped by the KCWA, is derived from the percolation of applied irrigation water, as well as historical natural percolation during large storm events. The extent of shallow groundwater, which is typically perched on shallow fine-grained sedimentary units and likely disconnected from the productive aquifer system, is relatively consistent with Page's (1986) extent of mapped surficial fine-grained flood deposits (**Figure 2-7** and shallow clay units related to the "A" Clay of the Corcoran Clay (KCWA, 1976). During the mid to late 1980's, sufficient data were collected for the KCWA's water supply report to show that, at times, the perched shallow groundwater units to the north of the river and to the south of the river have been joined at the northwest of the Kern River Fan, generally following the extent of flood plain deposits as mapped by Page (1986).

While shallow groundwater data is collected in certain regions of the Subbasin, the current data collection effort does not provide sufficient data to understand the interconnection between the lower production aquifer and the shallow purged groundwater system that existing in portions of the basin. This data gap will be addressed in projects and management actions identified in individual management area plans.

Horizontal Gradients

The following is a summary of general regional groundwater flow direction and general regional horizontal gradients based on the contour maps presented herein. For more detailed trends, refer to management area plans.

Groundwater in Spring 2015 for the main production zone (confined below the E-clay and semi-confined outside of the clay) in the east-northeast flows southwesterly at a gradient of 0.011 ft/ft. In the north-central area, groundwater flows northwesterly at a gradient of 0.002 ft/ft. In the central area of the Subbasin near the Kern River and banking activities, groundwater flows north to northwesterly at a gradient of 0.002 to 0.004 ft/ft. In the southeast, groundwater flows southwesterly at a gradient of 0.025 ft/ft. In the south, groundwater flows northwesterly to southeasterly at gradients of 0.004-0.012 ft/ft and 0.004 ft/ft respectively. In the southwest, groundwater flows northeasterly at a gradient of 0.001 ft/ft. Groundwater in the Bakersfield area flows away from the river from 0.005 to 0.011 ft/ft in a southeasterly to northwesterly gradient.

Groundwater in Fall 2015 for the main production zone (confined below the E-clay and semi-confined outside of the clay) in the east-northeast flows west to southwesterly at a gradient of 0.015 ft/ft. In the north-central area, groundwater flows northwesterly at a gradient of 0.002 ft/ft. In the central area of the Subbasin near the Kern River groundwater flows toward the banking activities northeasterly and southwesterly at gradients of 0.006 ft/ft and 0.003 ft/ft respectively. In the southeast, groundwater flows southwesterly at a gradient of 0.016 ft/ft. In the south, groundwater flows northwesterly to southeasterly at gradients of 0.007 ft/ft and 0.008 ft/ft respectively. In the southwest, groundwater flows northwesterly at a gradient of 0.005 ft/ft.

Groundwater in Spring 2015 for the upper unconfined zone (unconfined above the E-clay) in the north half of Township 28S and 27S flows northeasterly at a gradient of 0.002 ft/ft. In the south half of T28S and T29S, groundwater flows southeasterly at a gradient of 0.003 ft/ft. In the far north mapped area of the upper unconfined zone, groundwater flows at a gradient of 0.001 ft/ft northwesterly and 0.004 ft/ft westerly.

2.2.1.2 Hydrographs and Vertical Gradients

Hydrographs presenting change in groundwater elevation over time and vertical groundwater gradients for specific areas of the Subbasin are provided in the chapters herein for local management areas. In general, hydrographs presented in the management area plans indicate that groundwater elevations decline during below normal water years (as defined by the water year index), and groundwater elevations begin recovering during above normal water years.

2.2.2 Seawater Intrusion

The Subbasin is located in the Central Valley, more than 40 miles from the Pacific Ocean. Seawater intrusion will not affect the Subbasin.

2.2.3 Groundwater Quality

To characterize groundwater quality in the Subbasin, a literature review was conducted using USGS studies and other technical reports, as well as data extracted from GeoTracker and EnviroStor to identify contaminant plumes. The SWRCB's Human Right to Water portal was used to identify contaminants that are commonly violating drinking water standards and an evaluation of the groundwater water quality was conducted using data from local Water Districts and the State Drinking Water Information System (SDWIS), which collects sample results from all State regulated public water systems. This section of the report provides a brief introduction to the contaminants most commonly found in the Subbasin. A more focused evaluation of the groundwater is provided in the management area plans for each member agency that comprises the KGA.

Characterization of groundwater quality was conducted to comply with (California Code of Regulations (CCR) – Title 23 – Waters; Subarticle 2 §354.16(d) – Groundwater Conditions: groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes. Constituents evaluated and the methodology used were consistent with guidance provided in:

- Assembly Bill 1249 (AB 1249) which states that "if the IRWM region has areas of nitrate, arsenic, perchlorate, or hexavalent chromium contamination, the (IRWM) Plan must include a description of location, extent, and impacts of the contamination; actions undertaken to address the contamination, and a description of any additional actions needed to address the contamination" (Water Code §10541.(e)(14)).

- Division of Drinking Water's (DDW) Human Right to Water (HR2W) portal, which identifies the contaminants that public water systems have received maximum contaminant level (MCL) violations. Commonly found contaminants were trended and occurrence data was evaluated.
- Water Quality Control Plan for Tulare Lake Basin (Basin Plan), dated May 2018, which is the State Board's implementation plan for Water Code §106.3. The amended Basin Plan requires permittees to "address the immediate needs of those drinking groundwater that exceeds the drinking water standard for nitrate."

Incorporating guidance from these sources was intended to incorporate the major constituents of concern and characterize groundwater in a manner that is consistent with current water quality focused programs. Of the regulated drinking water constituents considered, the most common water quality issues within the Subbasin are: nitrate, arsenic, boron, hexavalent chromium, dibromochloropropane (DBCP), 1,2,3-trichloropropane (TCP), TDS, sodium, and chloride. This water quality discussion is divided by constituent to explain the drinking water and agricultural standards and how these constituents impact beneficial uses in the different regions of the Subbasin. Since the predominant land use in the Subbasin is for agricultural purposes, agricultural Water Quality Goals (as established by Ayers and Westcott) are referenced for evaluation of groundwater salinity (SWRCB, 2016a). The most applicable standard, Drinking Water Standard or agricultural goals will be used as a reference point when discussing each constituent.

Maps created to show constituent prevalence were developed using data extracted from the Groundwater Ambient Monitoring and Assessment (GAMA) Groundwater Information System. Only wells from the Public Water System dataset were used because they provide more consistent results since compliance monitoring frequency is regulated by DDW. To depict the highest contaminant values, the maximum concentrations were plotted, rather than average concentrations, from each public water system spanning a 10-year timeframe (2009-2019). These maps are intended to provide a general overview of constituent prevalence and concentrations. They should not be interpreted as indicating contamination throughout the region because constituent concentrations typically vary depending on well construction and local hydrogeologic conditions. More detailed analysis of water quality trends is discussed in the individual management area plans.

2.2.3.1 Arsenic

Arsenic has a primary drinking water MCL of 10 parts per billion (ppb) and an agricultural goal of 100 ppb. Reports published by the Department of Pesticide Regulation and USGS studies and the hydrogeology of the Subbasin indicate that the major source of arsenic in this Subbasin is naturally occurring from erosion of natural deposits. Throughout the southern San Joaquin Valley, arsenic-rich minerals such as arsenopyrite, a common constituent of shales and apatite, and phosphorites are the most common sources of arsenic leaching materials in the aquifer (Burton et al, 2012). In the Subbasin, these minerals are mostly found in lake bed deposits or the Corcoran Clay. USGS reports that most of the highest arsenic detections are near the City of Delano and at the southwest extents of the Kern Fan, near the City of Bakersfield.

Since arsenic is mostly derived from natural geochemical processes, elevated concentrations are localized and appear to be associated with lake bed areas where there are thick clay deposits: Tulare Lake, Kern Lake, and Buena Vista Lake (Bulletin 118, DWR). In the Subbasin, consistently high concentrations generally concentrate in the center of the valley along the north margin of Buena Vista lake bed. Data trending indicates that its predominately found in wells constructed deeper than 1,000 bgs. Trending of the public water system wells in the Kern Fan indicates elevated arsenic is consistently found in wells constructed deeper than 650 ft bgs, and when groundwater elevations decline. A study conducted by USGS reports that arsenic is the trace element most frequently present at high concentrations in the Subbasin. Concentrations found in nearly 1,400 samples ranged from 10 to 30 ppb (Burton et al, 2012).

Severe drought conditions from 2012 through 2016 resulted in groundwater levels significantly declining throughout the County; subsequently, wells located in the Kern Fan are showing higher concentrations of arsenic from the deeper aquifers into the pumping zone due to the proportion of water from the deeper screened intervals increasing. Consequently, higher concentrations of arsenic have been observed in municipal wells. As groundwater levels temporarily recovered in 2017, there was a noticeable correlation to lower arsenic concentrations.

Findings from a study conducted by Negrini et. al (2008) explain that the thickest part of the coarsening-upward unit in the Kern Fan is in the same region as the wells with elevated arsenic concentrations. The study identified a large-scale sedimentary sequence (a specific geologic sequence) that was primarily prevalent in most of the wells in this study area. This sequence unit consists mostly of uniformly fine-grained silts and clays and the unit abruptly thickens basin-wide. The thickest part of this unit was found to have groundwater arsenic concentrations above 50 ppb. Depth interval containing sediments from this unit generally coincide with intervals having elevated arsenic concentrations. It was also found that at the same depth interval, arsenic is in an easily exchangeable state in the bulk sediment where oxidizing geochemical conditions dissolve the pyrite and release arsenic into the groundwater.

In addition to the lake bed areas, there is common arsenic detections associated with the Corcoran Clay. Mineral deposits transported by rivers into the San Joaquin Valley, from the Sierra Nevada and the coastal mountain ranges, became enriched with arsenic mineral deposits then adsorbed on the clay surfaces that were buried over time. When the oxygen deprived mineral deposits come into contact with oxygenated water, the result is dissolution of arsenic within the clay pore and into the groundwater. These deposits typically begin at depths greater than 180 ft bgs. Occurrence of arsenic in groundwater and any associations to the Corcoran Clay are addressed at the management area plans water quality sections.

2.2.3.2 Nitrate

Nitrate as nitrogen has an acute drinking water MCL of 10 ppm; there is no agricultural goal. Sources of nitrate contamination in groundwater are runoff and leaching from fertilizer use; leaching from septic systems and sewage; confined animal facilities; and very small concentrations from erosion of natural deposits. Typically wells in the San Joaquin Valley have higher nitrate concentrations in the shallower zones. However, higher nitrate concentrations can also occur in deep wells, depending on source concentrations, lithology, and well construction. Dubrovsky et al (2010) considers background nitrate concentrations above 1 ppm to indicate human activity.

Although the agricultural industry is believed to be a primary contributor to nitrate contamination of the groundwater basins in the Central Valley, based on mass loading calculations, irrigation practices in this Subbasin have been improved to reduce nitrate leaching into groundwater. In a study conducted for the Kern River Watershed Coalition Authority (KRWCA, 2013), it is acknowledged that nitrate leaching from agricultural irrigation is not like other basins to the north because irrigation practices are more efficient here, which reduced nitrate leaching into the groundwater. This assessment is supported by a comparison of the Nitrate Hazard Index results from 1990 and 2012, which shows a significant reduction in nitrate risk to groundwater.

KRWCA is leading the Irrigated Lands Regulatory Program (ILRP) for the Subbasin and have provided results from the initial groundwater sampling that took place in fall of 2018 (KRWCA, 2019). Their groundwater trend monitoring program requires nitrate sampling of first encounter groundwater during spring and fall each year. Trends are not ascertained yet since fall of 2018 was the first year of monitoring and these are the only results that are publicly available. Of the 26 representative wells sampled (14 domestic and 12 irrigation), nitrate results ranged from 1.1 to 21 ppm with a median value of 9.9 ppm. Nine of the wells sampled exceed 10 ppm: of these, seven wells are domestic and two are used for irrigation. Nitrate concentrations of these wells is included in **Figure 2-25**, although they are not specifically labeled as first encounter groundwater wells.

In addition to studies evaluating agricultural impacts of nitrate contamination, studies investigating the correlation of other potential nitrate sources were also reviewed. Dubrovsky et al (2010) finds that domestic wells located in agricultural areas are not only influenced by irrigation practices and/or livestock as a potential nitrate source, but also from septic systems. A USGS study (Burton et al, 2012) was conducted in the Southeast San Joaquin Valley and the Subbasin. This study used statistical analysis of land uses, well construction data, water quality parameters and number of septic systems around each study well to determine that land uses fairly represent nitrate sources impacting the well. Some of the data obtained for the Burton et. al, (2012) study was from the State Water Board's GAMA Domestic Well Project, where wells were sampled in 2006 (Shelton, 2006). The Project analyzed 29 of the 181 domestic study wells in the Kaweah Subbasin study area, for stable isotopes of nitrogen and oxygen. Wells with higher nitrate concentrations (median of 5 ppm and mean of 11 ppm) were targeted for this study. Testing showed that 28 of the 29 impacted wells have nitrate characteristics consistent with a dairy manure or septic system source. Septic systems elevate groundwater nitrate concentrations since they only remove half of the nitrogen in the wastewater, leaving the remaining half to percolate to groundwater (McCalasand, 2019). One of the 29 wells showed an isotopic composition indicative of a synthetic fertilizer. While the isotopic composition of nitrate varies with land use, it is consistent between nitrate source (soil, fertilizer, manure, septic or community wastewater). Private well sampling for stable isotopes of nitrate was not conducted in the Kern County Subbasin.

Kern County Environmental Health Department (EHD) updated their program and ordinance with the development of the County's Local Agency Management Program (LAMP) to comply with the State Water

Board's policy on septic systems (SWRCB, 2012). This was adopted to allow local agencies to continue use of septic systems, while protecting water quality and public health. An analysis was conducted to estimate baseline septic systems in the County. Four basic elements used in their analysis were parcel development status; general soil/septic systems suitability mapping; hydrologic areas; and groundwater basins. Since it was assumed that incorporated areas have municipal sewer systems that either serve or are available to these parcels, only non-sewered unincorporated areas of the County were included in the analysis. This study revealed that approximately 30-percent of developed parcels within the Subbasin rely on septic systems. KGA is working with the County to document the location of these septic systems. A partial list of system recently inspected was provided and is shown in **Figure 2-25**.

Prior to the State's policy, EHD has been collecting water quality data on newly drilled wells to gain an understanding of groundwater quality. Initial assessment showed about eight percent of the wells tested are above the nitrate MCL; data from 1998 through 2019 are included in **Figure 2-25**. While there is currently a data gap, it is anticipated that continued work with the County and through the implementation of their LAMP that the domestic well water quality data and location of septic systems will be available to KGA. Although not all septic system location data is available at the time of this evaluation, it is noted areas with septic systems and domestic wells, generally show elevated nitrate concentrations.

Studies conducted by UC Davis, Center for Watershed Sciences have evaluated nitrate sources in the Tulare Lake Basin and documented that on a regional scale, groundwater nitrogen loading from sewer collection system leaks and septic systems is negligible compared to fertilizers. However, when looking at a local level, septic systems can be a significant source of nitrate contamination to domestic wells in peri-urban areas surrounding cities, or in areas of relatively high rural household density (Viers et. al, 2012). Findings also indicate that disadvantaged communities with water quality issues are in these same areas. Septic systems are considered low-hanging fruit (Dzurella et al, 2012), but is an important issue to address due to its impact to localized drinking water sources.

Data gaps often identified in these studies include lack of localized data such as location of septic systems, proximity of domestic wells to septic systems, and water quality of unregulated domestic wells. Reports such as Viers et al, (2012) and the initial assessment for the LAMP report have acknowledged these data gaps. To better assess nitrate sources, future monitoring programs should be geared towards better data collection methods to conduct a more comprehensive evaluation on septic system impacts to groundwater. Additionally, nitrate issues need to be evaluated on a local level rather than regional approach, especially when looking at the impacts to human health and consumption of water from unregulated domestic wells.

2.2.3.3 Boron

There is no federal or state MCL for boron. However, California does have a Notification Level of 1,000 ppb, and there is an agricultural goal of 700 ppb. The agricultural goal is set to protect various agricultural uses of water, including irrigation of various types of crops and stock watering. These levels are used as a baseline to compare against and are not intended to represent an acceptable maximum value for the Subbasin. Since most of the land use in the Subbasin is irrigated lands, the agricultural goal for boron is used as a reference point, rather than the drinking water Notification Level. The most prevalent sources of boron in drinking water are from leaching of rocks and soils, wastewater, and fertilizer/pesticides applications.

According to the USGS Scientific Investigations Report 2011-5218 (Burton et al, 2012) boron is most commonly found in the southern part of the Subbasin near the Tehachapi Mountains. Even though the USGS study for boron was limited to the southern part of the Subbasin, it was concluded that elevated concentrations of boron may be naturally occurring. Boron is potentially associated with sediments in the aquifer derived from marine deposits that are naturally high in boron from the Coast Ranges and San Emigdio Mountains. Saline waters have also been found to contain relatively high concentrations of boron, groundwater that underlies the freshwater aquifer could contribute high boron concentrations in deep wells.

2.2.3.4 Hexavalent Chromium

There is no federal MCL for hexavalent chromium. In July 2014, California adopted a primary MCL of 10 ppb, which was invalidated as of September 2017. While DDW is repeating the regulatory process for adopting a new MCL, the federal MCL of 50 ppb for total chromium applies. There is no agricultural goal for hexavalent chromium.

Hexavalent chromium can come from anthropogenic and natural sources. Anthropogenic sources include discharges of dye and paint pigments, wood preservatives, chrome-plating liquid wastes, and leaching from hazardous waste sites into the environment. Naturally occurring chromium is a metal found in ore deposits containing other elements, mostly as chrome-iron ore. Chromium is also prevalent in soil and plants: the phenomenon of releasing chromium into groundwater is believed to be similar geochemical processes to arsenic. Generally, natural chromium in the environment occurs as trivalent chromium (Cr3) then is oxidized to a hexavalent state (Cr6+). This typically occurs in oxidizing conditions such as alkaline pH range (between 8 and 14 units) or in the presence of manganese dioxide; in these conditions, naturally occurring hexavalent chromium is likely to exist.

The presence of manganese oxide minerals within ultramafic and serpentinite derived soils and/or sediments can trigger the oxidation of chromium, leading to the presence of naturally occurring hexavalent chromium in the aquifers (SWRCB, 2017; Groundwater Information Sheet 2017). While studies have not been conducted on the types of soils and sediments in the Subbasin where hexavalent chromium is present, the relatively low concentrations (typically in the range of 5 – 13 ppb) indicate the source is naturally occurring (GAMA). Additionally, GeoTracker and EnviroStor databases were searched for open contamination cleanup sites and do not identify any point source contamination in the Subbasin.

2.2.3.5 Synthetic Organic Chemicals

Synthetic organic chemicals predominately found in the Subbasin are dibromo-3-chloropropane (DBCP) and 1,2,3-trichloropropane (TCP). Both chemicals have very low drinking water MCLs. There are no agricultural goals. DBCP has a primary MCL of 0.2 ppb; sources of contamination are a banned nematicide that is still present in soils and groundwater due to runoff or leaching from former use on soybeans, cotton, vineyards, tomatoes, and tree fruit. Since its use was banned in 1977, groundwater contaminant concentrations in municipal wells have shown either steady or decreasing trends. In 2008 the Department of Public Health (transferred to State Water Board as DDW in July 2014) estimated the median half-life of DBCP in the Central Valley is 20 years. This is consistent with the public well data that has been evaluated for this Subbasin.

TCP has a primary MCL of 5 parts per trillion (ppt), which became effective in January 2018 and requires all active drinking water sources are tested at least quarterly during 2018. Since the MCL is set at the detection limit, any well with a detection is identified as exceeding the standard. According to the Water Boards Q1 Report, there is a clear correlation between the location of the of drinking water sources contaminated with TCP and agricultural activities (SWRCB, TCP Sampling in Q1 2018).

In the past, TCP was present as an impurity in certain soil fumigants (1,3-D soil fumigants) used to kill nematodes. TCP also has some limited industrial uses. Throughout the Central Valley, most of the TCP found in groundwater was introduced through agricultural application of soil fumigants sold under the trade names of D-D and Telone. In the mid-1970s, Telone was reformulated and the name changed to Telone II. D-D was discontinued in 1984. Telone II remains on the market today but no longer contains TCP. Because TCP was an impurity in these soil fumigants, the potential groundwater contamination was not disclosed to distributors or users, by the product manufacturers. Application rates were not tracked, making it difficult to determine where groundwater contamination is likely to occur. TCP is a highly stable compound, meaning that it is resistant to degradation and has a half-life of hundreds of years (Samin et. al. 2012).

Many large public water systems (serving more than 10,000 population) began sampling their wells for TCP using a low-level analytical method around 2003, as a requirement of the Unregulated Chemical Monitoring Rule. From this data, DDW determined that the most impacted counties are Kern, Fresno, Tulare, Merced, and Los Angeles. Since a primary MCL was adopted, all water systems were required to test their wells quarterly beginning January 2018. Occurrence data from the State Water Board's DDW shows 94 of California's public water systems have 562 TCP impacted wells (DDW, June 2016). In Kern County, 18 water systems have 124 impacted wells, or approximately 52 percent of their total wells (State Water Board, June 2016).

Figure 2-26 provides a graphical representation of TCP concentrations for the public water system wells within the Subbasin (data extracted on April 29, 2019). To simplify the figure, only the maximum concentrations from January 2018 to April 2019 are shown. Results from the initial compliance monitoring indicates that increased testing requirements directly increased the prevalence of TCP impacted wells in the Subbasin.

the maximum concentrations from January 2018 to April 2019 are shown. Results from the initial compliance monitoring indicates that increased testing requirements directly increased the prevalence of TCP impacted wells in the Subbasin.

2.2.3.6 Total Dissolved Solids (TDS), Sodium and Chloride

Based on drinking water standards, the recommended secondary maximum contaminant level (SMCL) of total dissolved solids is 500 ppm with an upper limit of 1,000 ppm and chloride is 250 ppm with an upper limit of 500 ppm. There is no drinking water standard for sodium; however Water Quality Goals for Agriculture, published by the Food and Agriculture Organization of the United Nations in 1985, has set agricultural goals for TDS, sodium, and chloride at 450 ppm, 69 ppm, and 106 ppm, respectively. The criteria identified are protective of various agricultural uses of water, including irrigation of various types of crops and stock watering. These levels are used as a baseline to compare against and are not intended to represent an acceptable maximum value for the Subbasin. Since a majority of the land use in the Subbasin is irrigated lands, the agricultural goals for TDS, sodium, and chloride are used for this portion of the water quality evaluation. However, some GSAs may elect not to use these agricultural water quality goals because local land uses (crops) are not limited by these goals.

The Burton et. al (2012) report states that in general the higher concentrations of TDS may be affected by sediments from the Tehachapi and San Emigdio Mountains and the Coast Ranges which contain marine deposits. Report findings showed positive correlations between agricultural land use and TDS levels but concluded that higher concentrations of TDS in the Subbasin may primarily be from natural sources as well as human activities. The same findings were true for chloride concentrations.

In a preliminary groundwater salinity mapping study conducted by USGS Scientific Investigations (Report 2018-5082, Metzger and Landon, 2018), groundwater salinity related to the distribution of 31 oil fields and adjacent aquifers was mapped across major oil-producing areas of central and southern California. The objective of this mapping study was to define groundwater with TDS concentrations less than 10,000 ppm using data from petroleum and groundwater wells, and to document data gaps. The study concluded that there is no hydrogeological connection between oil wells and water wells in the mapped regions. This conclusion is based on salinity mapping and well construction: the top perforation of the oil wells is deeper than the bottom perforation of water wells, except for oil fields in the north eastern part of the County. Well perforations in the north eastern part showed little to no vertical separation. Additionally, the study found that the west side of the San Joaquin Valley (in Kern County) generally has the highest TDS levels at the shallowest depths.

Salinity defined in the chapters of this report are sometimes general, referring to TDS levels, or may be more specific to address the ions of concern based on predominant land uses. TDS is comprised of several dissolved minerals (calcium, phosphates, nitrates, sodium, potassium, and chloride), most of which have minimal impact on beneficial uses of the groundwater. Throughout the Subbasin, sources of salinity identified include a combination of naturally occurring marine deposits; infiltration from produced water disposal ponds; perched water subject to evaporative pumping; or agricultural drainage ponds.

Sodium and chloride ions contribute to TDS and in this region are more important to evaluate due to its impact to the agricultural industry. Both sodium and chloride show similar trends in the wells evaluated; therefore, some sections of the water quality evaluation collectively refer to these ions as salinity. There is slightly more focus on sodium since it is an important measurement to crop yield.

2.2.3.7 Groundwater Contaminant Sites

An evaluation of documented groundwater contaminant sites in the Subbasin were identified through the GAMA Groundwater Information System. GAMA contains information from other programs and databases, such as SWRCB – GeoTracker and Department of Toxic Substances (DTSC) – EnviroStor databases. The data included in this basin setting is in response to the emergency regulations § 354.16(d), that requests within the GSP, "a description and map of the location of known groundwater contamination sites and plumes." However, it is not the intent of this section to evaluate or confirm whether any of these sites as listed by regulatory agencies are impacting groundwater with beneficial use. Furthermore, this GSP cannot guarantee the accuracy of the data acquired from these regulatory sources. This section presents cases as were listed from the regulatory databases that may document potentially impacted groundwater sites. Programs listed below were reviewed from GAMA. There are two figures to graphically represent the distribution of sites; **Figure 2-27** shows permitted facilities and **Figure 2-28** shows clean-up sites.

- Waste Discharge Requirements (WDR)
- Underground Storage Tank (UST)
- Leaking Underground Storage Tank (LUST)
- Cleanup Program Sites
- DTSC Hazardous Waste Sites
- Department of Pesticide Regulation
- Underground Injection Control (UIC) Wells
- Oil and Gas Sites
- Irrigated Lands Regulatory Program Sites
- Confined Animal SitesPermitted Facilities with Waste Discharge Requirements Orders

While GeoTracker does not include water quality data for WDRs a list of sites and their general location is accessible through the State Board's California Integrated Water Quality System (CIWQS). The general location of Confined Animal Facilities is also available through this database. **Figure 2-27** is a graphical representation of the known WDRs and Confined Animal Sites in the Subbasin. A total of 264 sites were identified; however, 43 sites are not included in this figure because latitude/longitude coordinates were not available to confirm that the site are within the Subbasin. The intent of mapping the location of the sites is to provide an idea of where the WDRs and Confined Animal Sites are located throughout the Subbasin.

The ILRP is permitted as a third-party WDR, like the WDR permit for Confined Animal Sites. However, site specific information is not publicly available because there are too many enrolled parcels under the Order. The KRWCA reports on the program. Relevant reports were reviewed and incorporated into the water quality discussion.

Underground Injection Control Permitted Wells

UIC permitted wells are not included in the list of groundwater contaminant sites because the UIC program's objective is to confine injected fluid to the approved injection zone so that injected fluid does not migrate to a zone where it could degrade valuable groundwater or hydrocarbon resources. Wells permitted under the State's Class II UIC program are presented on **Figure 2-29**. The UIC program's objective is to confine injected fluid to the approved injection zone so that injected fluid does not migrate to a zone where it could degrade valuable groundwater or hydrocarbon resources (DOGGR, April 2019). This program requires that any injection well have at least two cemented strings of casing across any underground source of drinking water located above a proposed injection zone, an annual Mechanical Integrity Test (MIT) and an annual step-rate test to ensure that groundwater is protected.

Data acquired from the regulatory sources listed above are included in **Table 2-4** (Envirostor and Geotracker Databases) only if they applied to the following criteria in the order listed below:

1. potential media of concern defined as “groundwater,” “other groundwater,” or “drinking groundwater,”
2. potential contaminant of concern defined, or “unknown,”
3. the site/case reported as “not closed”, and had one of the following statuses:
    - active cleanup
    - active land use restrictions
    - open remediation
    - open site assessment
    - open – eligible for closure
    - inactive-action required
    - other evaluation
    - under review
    - open-inactive
    - inactive-permitted
    - inactive-unpermitted

There is a total of 77 sites identified within the Subbasin. **Figure 2-28** and **Table 2-4**, with cross referenced Map IDs, present the locations and details of known impacted groundwater or potentially impacted groundwater within the Subbasin. **Table 2-4** provides the Site/Facility Name, Site Regulatory Identification and Status, associated site address and latitude/longitude, CalEnviroScreen Score (if applicable), as well as any identified constituents of concern impacting the groundwater at these sites.

2.2.4 Land Subsidence

Inelastic (irrecoverable) land subsidence (subsidence) is a sustainability indicator that often occurs in the region due to over pumping of aquifers with a high percentage of fine-grained deposits. Inelastic land subsidence has the potential to alter the land surface in ways that could increase flood risk in low lying areas, and damage well casing, canals, and other linear infrastructure. This section summarizes land subsidence data collected within the Subbasin and discusses documented impacts and potential impacts of land subsidence in or near the Subbasin.

2.2.4.1 Processes leading to Land Subsidence

Several processes contribute to land subsidence in the Subbasin and include, in order of decreasing magnitude: compaction of fine-grained materials by groundwater pumping; 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). Subsidence associated with oil and gas activities may be included on datasets in figures and tables of this GSP due to the regional method of data collections such as LANDSAT and satellite-based Interferometric Synthetic Aperture Radar (InSAR). If significant impacts to critical infrastructure associated with oil and gas activities are identified by regional subsidence monitoring, they will be communicated to DOGGR to address as appropriate pursuant to Public Resources Code 3315.

Inelastic compaction or land subsidence occurs in the fine-grained beds of the aquifer system. Clays and silts, although not very permeable, are typically highly porous. In many of these fine-grained layers, pore spaces are supported by water at the time of deposition. This water is essentially groundwater storage to the Subbasin, although the majority of it is a component of inelastic storage, and therefore, it is not reusable. During over-pumping conditions, groundwater is pumped from pore spaces between grains of sand and gravel. Once the aquifer system is pumped beyond the sustainable yield, the lowered water pressure in the sand and gravel causes slow drainage of water from the clay and silt beds. The subsequent release of water and water pressure from the clay and silt beds result in compaction (the beds become thinner) as clay particles supported by water in pore spaces rearrange and collapse. Groundwater cannot re-enter the clay structure after the collapse. This condition represents a permanent loss of the water storage volume in the clay layers. The effects of compaction are also seen as a lowering of the land surface, otherwise known as land subsidence.

2.2.4.2 Impacts due to Land Subsidence

There are various impacts of land subsidence on surface land uses and groundwater use that are documented in the County and adjacent study areas. Some of these references are from historical investigations while others are current. Both provide examples of potential future impacts of long-term subsidence in the study area.

Loss in Groundwater Storage and Increased Pumping Lifts

As described above, inelastic land subsidence can lead to the reduction in storage of fine-grained units. The reduction in storage ultimately leads to increased pumping lifts. Ireland et. al. (1984), explained that during compaction of fine-grained units caused by overdraft, there is a one-time release of water that is a short-term benefit to users because it results in extra water released from clay storage that is not renewable. **Figure 2-30** below provides a conceptual diagram illustrates how over-pumping and subsidence leads to increased pumping lifts.

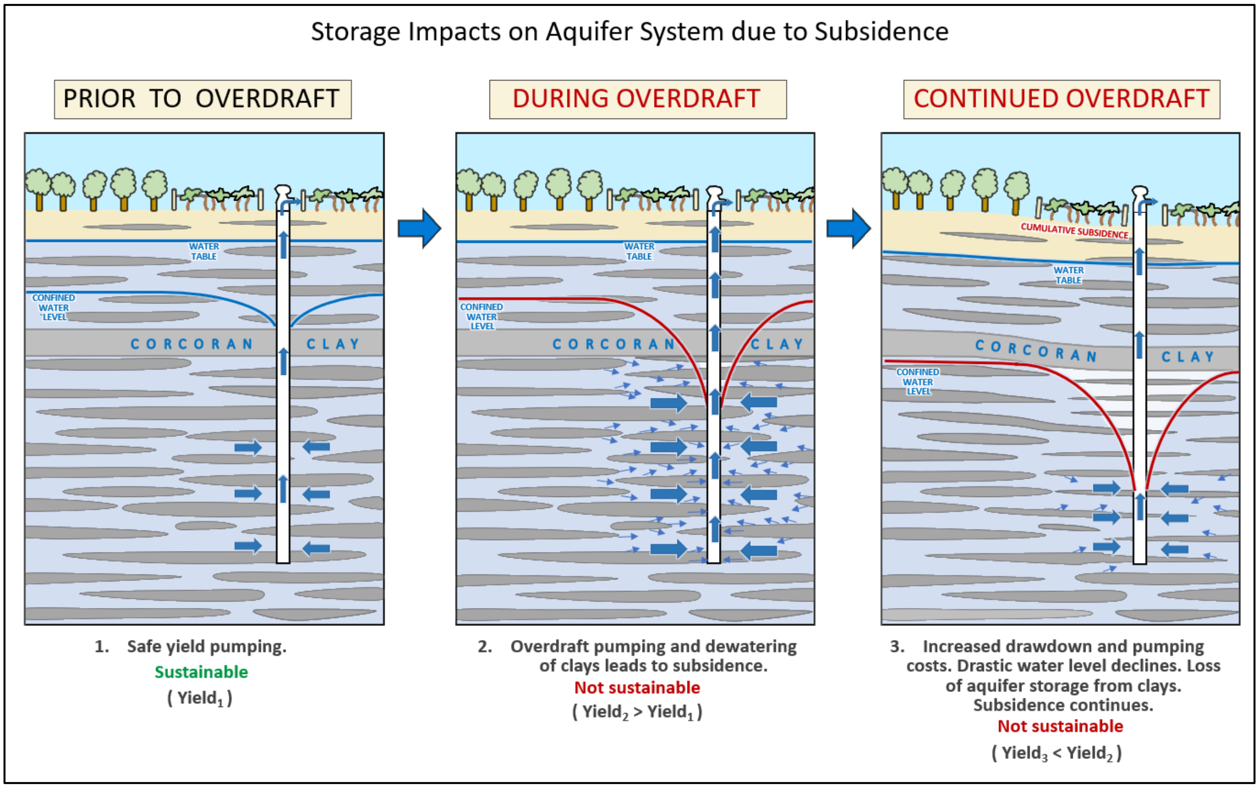


Figure 2-30. Conceptual Diagram of Impacts of Over-Pumping and Subsidence

Ireland et. al. (1984) documented the above phenomenon in the Los Banos-Kettleman City area. In the late 1960’s, water levels were drawn down to historical lows with subsidence rates that exceeded 1 ft per year. Water levels subsequently recovered, and subsidence nearly ceased in the middle 1970’s with the delivery of surface water. During the drought of 1976-1977, a second cycle of overdraft and subsidence occurred. Water level declines were more rapid during the second cycle due to the loss of one-time storage from the first event. In addition, subsidence rates typical of those during the first event were observed (Ireland et al, 1984). In 1980, wet conditions and more available surface water resulted in groundwater levels recovering to pre-drought conditions and subsidence rates nearly ceased (Ireland et al, 1984).

Ojha et. al. (2019), references recent studies suggesting that subsidence between 2007 and 2015 in the Central Valley (primarily San Joaquin Valley) resulted in losses of 0.4% to 5.25% storage capacity in the aquifer system. However, this storage reduction does not substantially decrease usable or renewable storage for groundwater because the clay layers do not typically store significant amounts of recoverable, usable groundwater (LSCE, 2014). Nonetheless, it is estimated in the past, that by the mid-1970s, about one-third of the volume of water pumped from storage in areas such as Los Banos-Kettleman City, came from compaction of fine-grained beds (Poland and others, 1975; Faunt et al, 2009). Although the largest body of clay is the Corcoran Clay, a relatively insignificant volume of water has been released from storage in the Corcoran Clay (Faunt et al, 2009), likely because of its large thickness and low permeability.

Ojha et. al. (2019) suggests that loss in storage due to subsidence may impact the overall aquifer system by increasing the replenishment time of the aquifer which could pose challenges to water management in the future.

Surface Linear Infrastructure

Large-scale linear infrastructure is most susceptible to the regional subsidence caused by regional groundwater withdrawal. When subsidence rates are not equal across a region, differential compaction can occur. This differential compaction or subsidence may result in the formation of new low-lying areas for which canal designs have not taken into account. Newly formed low-lying areas are what impact large-scale linear infrastructure such as canals; often reducing freeboard and capacity. Examples of infrastructure that have been impacted by subsidence in the Southern San Joaquin Valley include the Friant-Kern Canal and California Aqueduct.

CVP

The Friant Kern Canal impacts have been well documented to the north of the Subbasin in an approximate five-mile stretch across Deer Creek (FWA, 2018). Subsidence was roughly 2 ft of the canal invert. Due to land subsidence the canal's water delivery capability has been reduced by nearly 60% to some contractor's (FWA, 2018). In contract, within the Subbasin, the Friant Kern Canal has experienced a few inches subsidence near Poso Creek (Mileposts 127 to 137).

SWP

The California Aqueduct was constructed in some areas with historical subsidence. "In an effort to prevent future subsidence from affecting the operation of the Aqueduct (and future water deliveries), extra freeboard was also added to [certain stretches] of the Aqueduct" (DWR, 2017c). During initial operation, only a few places experienced lining cracks including an area with a concrete culver undercrossing just downstream of the Buena Vista Pumping Plant experienced settlement (DWR, 2017c).

Two segments of the Aqueduct were raised in 1989 and 1996 in Kern County (**Table 2-5**; DWR, 2017c). The first between MP 194.94 and 197.05 (T25S-R20E) in 1989, and the second between MP 206.10 and 207.94 (T27S-R21E). In general, this northwest portion of the basin is far from the main groundwater production in the central part of the Subbasin, so it is uncertain if groundwater supply extraction contributes to land subsidence in this area. Swanson (1998) also reported subsidence in this area along a 29-mile reach of the California Aqueduct, the cause of which was uncertain. The subsidence rates increased during dry periods and decreased during wet periods. Swanson (1998) recommended that observation wells and an extensometer be installed along this reach "to determine the cause of the subsidence because there is little ground-water pumping in the immediate area."

Table 2-5: Aquifer Parameters for Kern County Subbasin

Year	Pool	Spec	Milepost		Station		Length (miles)	Maximum Raise (inches)
			From	To	From	To		
1989	22	89-26	182.39	184.82	718+00	846+00	2.43	30
1989	22	89-26	194.94	197.05	1373+41.59	1485+00	2.11	39
1996	22	96-19	206.10	207.94	1962+84	2059+99.2	1.84	30

Fault Movement

Within the Subbasin, Pond-Poso Fault movement has been detected during dry years. Although the impact to infrastructure is unknown. Holzer (1980) observed fault movement along the Pond-Poso Fault from February 1977 to March 1979. This fault movement was observed during seasons of water level decline, and he concluded that 9 inches of offset had occurred along the Pond-Poso Fault System since the 1950's. In addition, Holzer (1980) observed that fault offset of groundwater levels was greater during dry years when the lowest seasonal water level low occurred.

Impacts to Well Casing

Although not in the Subbasin, just north of Subbasin, Wilson (1968) documented well casing failures attributed to land subsidence. Wilson reported that during 1950-1961 in a part of the Los Banos-Kettleman Hills area, wells that were screened primarily below the Corcoran Clay experienced screen failures associated with compaction or land subsidence.

Degraded Water Quality

Degradation of water quality due to land subsidence has been studied in the San Joaquin Basin to the north of the Subbasin. Smith et. al. (2018), hypothesizes that poor water quality in clays may be released to the aquifer system during over pumping and compaction of clays. Specifically, data north of the Subbasin in the San Joaquin Valley may indicate that areas with a thicker Corcoran Clay extent have seen an increase in arsenic concentrations as subsidence rates have increased due to over pumping (Smith et. al., 2018).

2.2.4.3 Land Subsidence Monitoring

Historical documentation of subsidence has relied on various types of data, including ground surveys, declining groundwater levels, and borehole extensometers. Recent subsidence studies have relied on ground surveys, borehole extensometers, continuous GPS stations, and remote sensing to collect data.

Each method has advantages and drawbacks. An extensometer measures a discrete subsurface interval, or typically the interval of the ground surface to the total depth of the extensometer. On the other hand, CGPS and InSAR monitor overall change in ground surface relative to a datum such as sea level, regardless of the depth interval. Moreover, InSAR provides information over a wide area.

Remote Sensing

Within the Central Valley, and in particular the Subbasin, researchers have utilized remote sensing techniques such as InSAR and aircraft-based L-band SAR or Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR). These surveys have been led by the National Aeronautics and Space Administration (NASA) and Jet Propulsion Laboratory (JPL), as well as other international researchers. The benefit of remote sensing is that large areas of land can be surveyed with no invasive actions or land surface access complications. DWR has commissioned studies (TRE Altamira, 2019) to evaluate the accuracy of remote sensing and identify additional processing and calibration methods for accuracy.

The following is a summary of recent remote sensing findings with respect to the TRE Altamira report:

- InSAR data with nearby UNAVCO CGPS have been processed and calibrated for northern Subbasin to the north of Visalia using the TRE Altamira-patented method SqueeSAR.
- InSAR calibration by TRE Altamira reports accuracy to 20 mm (0.07 ft) at 95% confidence interval.
- The calibration points include UNAVCO CGPS points (subsidence results as great as 8 inches over the time period of 2015 to 2018).
- Other points in the SOPAC network including Corcoran and Lemoore stations were not included in calibration; however, Ojha et al (2019) demonstrated that LEMA Lemoore and CRCN Corcoran (high subsidence areas) (at least 50 inches of subsidence between 2015 to 2018) may correlate well with InSAR.

Filling data gaps in the San Joaquin Valley with high subsidence areas lacking calibration monitoring points such as CGPS may be beneficial for future remote sensing work and calibration.

2.2.4.4 Historical Subsidence Results

Within the Subbasin, subsidence has been documented from leveling by the National Geodetic Survey at up to 12 ft from 1926 to 1970 (Ireland et al., 1984). USGS estimates that about 75 percent of the subsidence occurred in the 1950s and 1960s, corresponding to extensive groundwater development (Galloway, et al., 1999). Water levels during this period were continuing to fall to historic lows each year, for the first time, which were associated with larger amounts of subsidence (Todd, 2017).

Subsidence was also measured by USGS borehole extensometers in the west Subbasin from 1978 to 1983 (26S/23E-16H2 and 16H3) and to the south of Bakersfield from 1963 to 1978 in Extensometer 32S-28E-20Q1). These two extensometers have since been abandoned; however, a couple new extensometers have been installed in the Subbasin.

2.2.4.5 Recent Subsidence Results

Recent subsidence data is summarized in **Table 2-6**. **Table 2-3** includes a summary of InSAR data published in a subsidence study commissioned by the California Water Foundation. Subsidence was measured at 0 to 0.5 ft from 2007 to 2011 across the Subbasin (LSCE, 2014). Subsidence was measured from 2005 to 2017 in the north and west Subbasin (based on six continuous GPS (CGPS) stations (BVPP, P544, P545, P563, P564, P565). These CGPS stations are monitored as a part of UNAVCO's Plate Boundary Observation (PBO).

Two extensometers have produced current data: 25S/22E-35B1 and 30S/25E-16L. Data for these extensometers are also included in **Table 2-6**.

JPL provided a progress report of InSAR subsidence monitoring in California (Farr et al., 2015), for data processed from the Japanese PALSAR for 2006 to 2010, Canadian Radarsat-2 for the period May 2014 through January 2015. From April 2014 to January 2015, subsidence was measured along the California Aqueduct from State Route 58 south to White Wolf Fault. Additional InSAR subsidence monitoring was reported by JPL (Farr et al., 2016) in 2016 for data from the European Space Agency's satellite-borne Sentinel-1A from the period May 2015 through September 2016, and NASA airborne UAVSAR for the period March 2015 through June 2016. The ESA's Sentinel-1A surveyed the entire San Joaquin and Tulare Basins, and subsidence was estimated between 4 and 8 inches in the north central portion of Subbasin as well as in the south of the Subbasin. The UAVSAR southern flight line along the California Aqueduct measured as much as 12 inches of subsidence, from April 2014 to June 2016, between east of BVPP and Wind Gap Pumping Plant near Old River Road.

According to Luhdorff & Scalmanini Consulting Engineers (LSCE), Borchers and Carpenter (2014), subsidence is on-going and leading to significant impairment of the California Aqueduct and the Friant-Kern Canal. According to DWR (2014) the 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. Moreover, greater amounts of subsidence are occurring to the north of Subbasin in the Tulare Subbasin. The amount of future subsidence will depend on whether future water levels decline below previous low levels and remain low for a considerable amount of time. Maintaining water levels above the previous low water levels may limit the risk of future subsidence.

2.2.4.6 Annual Rate of Subsidence

The following tabulated data includes cumulative inches of subsidence within Subbasin, and a calculated approximate annual rate for the time period for the data collection period.

Table 2-6: Land Subsidence Data

Subbasin Area	Date Range	Cumulative Subsidence (inches)	Calculated Annual Rate of Subsidence (inches/year)	Source
Historical Range in the Subbasin	1926 - 1970	12 - 96	~ 0.3 - 2.2	Ireland, 1984. Topographic Maps and Leveling Data.
North Central Subbasin	1978 - 1983	-0.04 – 1.5	-0.001 – 0.03	Extensometer 26S/23E-16H2 and -H3, USGS
South of Bakersfield	1963 – 1977	23.3	~0.14	Extensometer 32S-28E-20Q1, USGS
North and West Subbasin	2005 - 2017	0.1 – 11.7 0.2	~0 – 1.3	CGPS PBO. (BVPP, P544, P545, P563, P564, P565).
South central Subbasin	2006-2016	9.8 - 11.5	~1.1	CGPS (BKR1/BKR2, ARM1)
West Subbasin and South of Bakersfield	Jan. 2007 – Mar. 2011	6.0	~1.4	LSCE, 2014. Compiled from InSAR.
North Central Subbasin	Dec. 2013 – Mar. 2018	3.2	~0.8	SWSD Extensometer 25S22E35B001M
Central Subbasin	July 1994 - June 2018	-3 (negative value indicates uplift)	Not Presented Here.	Kern Fan Extensometer 30S/25E-16L According to AECOM (2016), data from extensometer show "little response to changes in water level changes during recharge or recovery operations."
Southwest Subbasin along California Aqueduct	Apr. 2014 – Jan. 2015	0.5 - 5	~0.7 – 6.7	UAVSAR. InSAR Canadian Radarsat-2 (Farr et al., 2015)
North Central Subbasin	May 2015 – Sep. 2016	~1 - 12	~1.3 – 9.2	InSAR ESA Sentinel-1A (Farr et al., 2016)
Southwest Subbasin along California Aqueduct	Apr. 2014 – Jun. 2016	0 - 16	~0 – 7.4	UAVSAR (Farr et al., 2016)

Map of Subsidence Locations

Subsidence within the Subbasin measured by historical studies is plotted on **Figure 2-31**. Subsidence as measured by recent studies and monitoring points including the UAVSAR and InSAR datasets is plotted on **Figures 2-32** and **2-33**, respectively. Corresponding rates of subsidence are presented on **Figures 2-34** and **2-35**. CGPS data locations, which are monitored continuously by UNAVCO, are plotted with recent calculated subsidence.

Data Gaps in Subsidence Understanding

There are data gaps in land subsidence that will be considered for future data collection. These data gaps include subsidence monitoring along points of critical infrastructure such as the Friant Kern Canal and California Aqueduct.

As described herein, there are a valuable dataset of CGPS monitoring points with which to pair water level monitoring data; however, InSAR data show that many of the CGPS points are not in zones of high subsidence, nor adjacent to critical infrastructure. Therefore, CGPS points alone are useful as quality control points, but they are likely not situated in areas of high subsidence or near critical infrastructure to facilitate decision making on sustainable management criteria.

InSAR is a dataset that may be able to fill the gaps between CGPS points. Continued InSAR data collection can fill the temporal data gap in the record. Correlations between CGPS and InSAR could confirm InSAR results in high subsidence areas near Subbasin, as they have been demonstrated in low subsidence and other areas (Tre Altamira, 2019; and Ojha et al, 2019).

As the water level monitoring network is established in the Subbasin, collocated temporal water level data with CGPS data can be collected to evaluate the relationship between active subsidence and residual subsidence with respect to water level change over time. The understanding of residual subsidence will better inform sustainable management criteria for setting thresholds.

2.2.5 Interconnected Surface Water Systems

Interconnected surface water systems are surface waters that are hydraulically connected by a continuous saturated zone to an underlying aquifer 23-CCR § 351(o). Within the Subbasin, there are no interconnected natural surface water systems in monitored areas associated with the pumping zone of the regional aquifer system.

The following are naturally occurring surface water bodies within the Subbasin:

- Kern River: Flows within the Subbasin (located within the Olcese and Kern River GSAs) are a function of hydrologic conditions in the Kern River watershed and regulation by Isabella Dam and Reservoir; and
- Poso Creek and other minor streams: Streamflow is unregulated and is ephemeral within the Subbasin, principally occurring during “wet” months of “wet” years.

Other surface water bodies, such as the Buena Vista Aquatic Recreation Area lakes, are situated in former basins of natural surface water bodies but are now dependent on managed water deliveries.

Since the advent of groundwater pumping in the Subbasin and subsequent impoundment and regulation of flow of the Kern River, groundwater levels near the river are no longer connected with the river bed by a continuous saturated zone. Water quality data suggest that some portion of the recharge to the principal water-bearing aquifer underlying the far eastern portion of the Subbasin (the Olcese Sand Aquifer) may come from percolation of Kern River surface water via seepage through the Kern Gorge Fault and/or through the overlying shallow alluvium. However, such recharge occurs independent of groundwater production in the principal aquifer, and there is no known pumping from the shallow alluvium zone itself. Thus, there is no interconnected surface water under the influence of groundwater pumping in the principal aquifer in this area and no impacts to interconnected surface water have been observed.

The observation that there are now no interconnected surface water systems in the Subbasin is reflected in the aquifer characterization found in locally developed groundwater models. For example, groundwater levels in the Kern Delta Water District (KDWD) Superposition Model are indicated to be disconnected from the Kern River and other simulated streams (Todd, 2017). See the Kern River GSA GSP, which addresses in more detail the lack of interconnected surface water around the Kern River bed, as the area in around the Kern River bed is located within the jurisdiction of the Kern River GSA. The information below, as required by GSP regulations, is provided for completeness of the KGA GSP basin setting, however, for a more detailed discussion of interconnected surface water systems related to the Kern River, see the Olcese and Kern River GSAs GSPs, as the Kern River is outside of the jurisdictional area of the KGA.

Groundwater Elevation and the Kern River

Recent maps of groundwater contours developed by the KCWA Improvement District 4 indicate there is a significant separation between the potentiometric surface near the river channel and the elevation of the river bed in areas where groundwater elevations have been mapped near the Kern River. The Hydrologic Profile from the most recent *Kern Fan Operations Report* (KCWA, 2018), illustrates prevailing groundwater conditions both spatially and temporally near the Kern River. This profile, which is transverse to the axis of the Kern River, indicates that during “wet” years, such as 1998 and 2006, groundwater elevations are highest directly below the Kern River bed while, during “dry” years, groundwater levels have declined to depths greater than 200 ft below the river bed. This prevailing pattern suggests that, during wet years, recharge to groundwater from the Kern River channel and nearby water banking operations forms a groundwater mound that gradually flows away from the river to the north and the south. Conversely, in dry years, there is an overall decrease in groundwater levels due to the lack of recharge from the Kern River and nearby water banking operations.

Hydrographs

Upstream of the Improvement District 4 monitoring coverage is a segment of the river, near Hart Park and the First Point of Measurement within Subbasin, that has available groundwater elevation data from the KCWA for supply wells 29S/28E-02A01 and 29S/28E-10K01. These wells are located upgradient of Rocky Point Weir, and groundwater elevation data are plotted against the elevation of the adjacent river bed. In general, water levels in the wells consistently ranged from approximately 27 to 49 ft lower than the river bed between 1995 to 2016 (**Figure 2-36**). In 2017, the water level in 29S/28E-02A01 appeared to rise; however, the rise was not consistent with the last 20 years of data; subsequent measurements could confirm the water level in 29S/28E-02A01. The Kern River is outside of the KGA jurisdictional area. For more information see the Olcese and Kern River GSA GSPs.

Stream Gaging

Stream gaging data for the Kern River are available for stations upstream of the Subbasin at Democrat Springs (USGS 11192500 and USGS 11192000), as well as at the First Point of Measurement upstream of Beardsley River Weir and Rocky Point Weir. Differences in annual flow volumes were calculated between Democrat Springs and the First Point of Measurement (factoring in diversions between these points) for water years 1990 through 2016. These data were plotted against monthly precipitation data by water year (**Figure 2-37**), and also by month for selected water years (1993, 1994, 2005, 2008, and 2011), (**Figures 2-38** to **2-42**).

In general, streamflow tends to increase between Democrat Springs and the First Point of Measurement during wet years (i.e. 1993, 1998, 2005, and 2011), which in part reflects surface water inflow from tributaries along this segment of the River. In contrast, Kern River flows decrease during some dry years such as 2001, 2008, 2009, and 2013, but also exhibit gains during the periods from 2001 to 2002 and from 2013 to 2014.

The Kern River is outside of the KGA jurisdictional area. For more information see the Olcese and Kern River GSA GSPs.

Data Gaps

Although available data confirm that the Kern River is not interconnected with the underlying groundwater downstream of the First Point of Measurement, it appears that the Kern River from Democrat Springs to the First Point of Measurement may be gaining flow, with accretion from groundwater being one of the sources contributing to these gains. However, available data between these two locations (approximate 22 1/2-mile reach) are not adequate to refine the assessment of gaining and losing segments from the east boundary of the Subbasin to the First Point of Measurement (approximate 10-mile reach). In this regard, there are several mapped springs throughout the Kern River Canyon, with an absence of any mapped springs below the mouth of the canyon within the Subbasin, indicating that the majority of gains are likely within the canyon. For additional information see the Olcese and Kern River GSA GSP.

2.2.6 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are ecological communities that depend on groundwater emerging from aquifers or groundwater occurring near the ground surface (shallow water table). In the Kern Subbasin, potential GDEs are likely to be associated with wetlands and riparian areas that are supported either by shallow groundwater or by a combination of shallow groundwater and surface water. As discussed previously, shallow groundwater is present in west-central and southern portions of the Subbasin. 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. For example, the Kern National Wildlife Refuge, is now sustained by imported surface water (USFS, 2005). Other features having the potential to provide habitat, such as groundwater recharge basins that are artificially flooded with surface water, also depend on diversion of surface water rather than a shallow groundwater table. The distribution of potential GDEs in the Kern Subbasin was assessed based on DWR's Natural Communities Commonly Associated with Groundwater (NCCAG) data.

The following is taken from the DWR Natural Communities dataset website for NCCAG (DWR, 2019):

> "The Natural Communities dataset is a compilation of 48 publicly available State and Federal agency datasets that map vegetation, wetlands, springs, and seeps in California. A working group comprised of DWR, the California Department of Fish and Wildlife (CDFW), and The Nature Conservancy (TNC) reviewed the compiled dataset and conducted a screening process to exclude vegetation and wetland types less likely to be associated with groundwater and retain types commonly associated with groundwater, based on criteria described in Klausmeyer et al., 2018. Two habitat classes are included in the Natural Communities dataset: (1) wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions; and (2) vegetation types commonly associated with the sub-surface presence of groundwater (phreatophytes)."

The data included in the Natural Communities dataset do not represent DWRs determination of a GDE. However, the Natural Communities dataset can be used by GSAs as a starting point when approaching the task of identifying GDEs within a groundwater basin."

Figure 2-43 shows CDFW lands in the Central Region. Similarly, **Figure 2-44a** and **2-44b** shows potential location of wetlands and GDEs in the Subbasin, respectively, as identified in the National Hydrography Dataset. These NCCAG maps are described herein to evaluate the potential for GDEs in the Subbasin and HMWD. In addition, the surface water bodies from the National Hydrography Dataset are also discussed in relation to potential GDEs.

The below discussion presents NCCAG dataset of the Subbasin. Any further details regarding these mapped datasets are provided in the management area plans. Where data gaps exist, future monitoring and GSP updates will seek to fill these gaps, as described in the management area plans of the individual KGA members.

NCCAG Mapped Data

Figure 2-19 displays the locations of seeps and springs based on data extracted from the National Hydrography Dataset at the base of the mountains and foothills in the southeast, southwest, and northwest edges of the Subbasin.

Figure 2-44a and **2-44b** displays NCCAG data in the Subbasin. NCCAG features are mapped along spring-fed streams in the southwest along the perimeter of the Subbasin: Santiago Creek to San Emigdio Creek situated in the Wind Wolves Preserve. Toward the east, Pleitito and Pleito Creeks have mapped NCCAG datasets. Potential spring-fed streams to the southeast of Sycamore Canyon Golf Course may have associated NCCAG mapped data. In the southeast corner of the Subbasin, in the highlands along the Caliente Creek drainage are mapped NCCAG features. On the eastern side of the Subbasin, NCCAG wetlands and vegetation are mapped along the Kern River and Poso Creek. On the northern boundary of the Subbasin, NCCAG wetlands and vegetation are mapped in the Kern River channel to the southwest of Kern Wildlife Refuge. Along the western edges of the Subbasin, there are mapped NCCAG features.

Groundwater potentiometric surfaces from Kern Fan Monitoring Reports (KCWA, 2016) indicate that underlying aquifers are not connected with stream channels. Some flow in the Kern River, as well as in Poso Creek and other mountain-front creeks, is likely to be sustained periodically by release of bank storage (surface water stored in stream banks), but the underlying groundwater is too deep to sustain flow in the valley floor.

Evaluation of NCCAG Results

The conditions in the center of the Subbasin suggest that the groundwater production aquifer does not reach the shallow subsurface. The production aquifer lies at depths that prevent surface water expressions or accessibility for vegetation. The respective chapters within this GSP may present additional data regarding NCCAG mapped dataset.

Based on the NCCAG dataset along the margins of the Subbasin where spring-fed streams exist, further confirmation is needed to evaluate the presence of GDEs. Chapter-level GSPs, where necessary, provide local details regarding the current understanding of potential GDEs in the respective area.

In the west-central and southern-central Subbasin, shallow groundwater levels are present. These clays have historically been a concern regarding encroachment of poor-quality perched groundwater into crop root zones. The shallow groundwater in the west-central and southern-central Subbasin is not well suited for agricultural or domestic water supply; therefore, existing water management practices and practices that may be introduced through the implementation of SGMA are unlikely to draw on the shallow groundwater that may support potential GDEs.

2.3 Water Budget (Reg. § 354.18)

The water budgets listed below are a result of the C2VSIM modeling work performed by Todd Groundwater. The final TODD groundwater Memorandum titled “SGMA Water Budget Development using C2VSimFG-Kern in support of the Kern County Subbasin Groundwater Sustainability Plans (GSPs)” is as provided in **Appendix F**. Todd was provided with surface water supply information from the GSA and Satellite Imagery Evapotranspiration (ET) information from the ITRC; with this information Todd was able to compute 1) groundwater pumped, and 2) change in groundwater storage, over the historic and current periods.

The hydrologic base period was from 1995 through 2014. This 20-year period was chosen due to its hydrology corresponding to the long-term average hydrology and the availability of data over the period. The 50-year period for the projected water budget utilized the 20-year hydrologic base period and repeated it 2.5 times, in order to project conditions to 2070.

The projected water budget utilizes historic and current water budget information and incorporates projected changes, such as SWP/CVP operating criteria and/or 2030- and 2070-Climate Change factors, to adjust future supplies and demands. When analyzing the need for Projects and Management Actions with projected water budgets, GSAs in the Kern Subbasin based it on a projected water budget with 2030-Climate Change factors to determine the magnitude of its projected groundwater balance deficit. The 2013 land use served as the basis for future crop demands, as it was decided by all parties in the Subbasin that it best represented average conditions.

2.3.1 Description of Inflows, Outflows, and Change in Storage

The historic, current, and future water budgets were comprised of the inflow and outflow parameters are as follows:

Inflows

- Deep Percolation
- Managed Recharge and Canal Seepage

Outflows

- Net GW/SW Interactions
- Groundwater Pumping

2.3.2 Current Water Budget

Table 2-7: Current Year Water Budget for HMWD GSA WY15. (TODD)

Water Year	Deep Percolation (AF)	Managed Recharge and Canal Seepage (AF)	Net GW/SW Interactions (AF)	GW Pumping (AF)	Operational Groundwater Flux (AF)
2015	2,246	249	0	-14,878	-12,383

The water year (WY) 2015 is used as the current water budget. Below is more data on the GSA's current water budget:

- Surface water deliveries: 29,329 AF
- Precipitation: 2,757 AF (3.56 inches over cropped acres using CIMIS Station No. 146: Belridge)
- Cropped acreage: 9,294 acres
- Crop ET demand: 28,398 AF

2.3.3 Historical Water Budget

Table 2-8: Historical Water Budget for HMWD GSA WY95-WY14

Water Year	Deep Percolation (AF)	Managed Recharge and Canal Seepage (AF)	Net GW/SW Interactions (AF)	GW Pumping (AF)	Operational Groundwater Flux (AF)
1995	6,642	850	0	-4,309	3,183
1996	5,913	1,187	0	-6,975	126
1997	6,459	1,179	0	-1,987	5,651
1998	10,734	796	342	-6,608	5,264
1999	16,920	1,342	0	-5,901	12,361
2000	8,387	1,554	0	-6,478	3,464
2001	5,630	1,050	0	-10,501	-3,820
2002	3,880	1,260	0	-10,326	-5,186
2003	3,227	1,375	0	-7,520	-2,919
2004	3,487	1,530	0	-9,818	-4,801
2005	4,021	1,456	0	-2,717	2,760
2006	5,756	1,654	0	-7,468	-58
2007	4,663	1,570	0	-12,061	-5,829
2008	2,889	705	0	-13,804	-10,211
2009	2,024	555	0	-11,964	-9,385
2010	2,003	998	0	-6,097	-3,097
2011	5,278	1,609	0	-2,217	4,671
2012	7,664	1,327	0	-2,703	6,288
2013	5,861	893	0	-3,344	3,410
2014	3,533	281	0	-11,595	-7,781
Total	**114,973**	**23,173**	**342**	**-144,394**	**-5,907**
Average	**5,749**	**1,159**	**17**	**-7,220**	**-295**

Below is more data on the GSA's historic water budget, in terms of averages:

- Surface water deliveries: 32,298 AF
- Precipitation: 6,762 AF (4.46 inches over cropped acres)
- Cropped acreage: 17,119 acres
- Crop ET demand: 35,803 AF

2.3.4 Projected Water Budget

TODD Groundwater provided subbasin-level projected water budgets for the Kern Subbasin using the C2VSimFG-Kern for future baseline conditions and 2030 and 2070 Climate Conditions over a 50-year planning and implementation horizon. The summary of results of the projected water budget for the entire Subbasin is shown in **Table 2-9** below. These scenarios can be described as follows:

- **Future Baseline Conditions:** Repeat historical hydrology with future water supply reliability provided by DWR.
- **2030 Climate Conditions:** Adjust historical hydrology for 2030 climatic conditions and water supply reliability provided by DWR.
- **2070 Climate Conditions:** Adjust historical hydrology for 2070 climatic conditions and water supply reliability provided by DWR.

The future baseline water budget simulates how the Subbasin aquifer would respond if the recent hydrology was repeated with current expected surface water availability and land use. The baseline simulation results indicate that the Subbasin has an average overdraft of 324,326 AFY. With the implementation and completion of management actions/projects stated by GSAs within the Subbasin, the baseline simulation results indicate that the Subbasin has an average surplus of 85,578 AFY.

The 2030 Scenario simulates how the Subbasin aquifer would respond assuming hydrologic conditions representing a potentially drier climate (no or limited amount of snowpack) and are based on DWR Climate Change Guidance (DWR 2018). The 2030 Climate Change simulation results indicate that the Subbasin has an average annual overdraft of 372,120 AFY. With the implementation and completion of management actions/projects stated by GSAs within the Subbasin, the 2030 Scenario indicates an average deficit of approximately 46,829 AFY.

The 2070 Scenario simulates how the Subbasin aquifer would respond assuming hydrologic conditions representing a potentially very dry climate and are based on DWR Climate Change Guidance (DWR 2018). The 2070 Climate Change simulation results indicate that the Subbasin has an average annual overdraft of 472,336 AFY. With the implementation and completion of management actions/projects stated by GSAs within the Subbasin, the 2070 Scenario indicates that the Subbasin has an average deficit of approximately 45,969 AFY.

Table 2-9: Summary of Simulated Change in Groundwater Storage Results over the 2041 to 2070 Sustainability Period (TODD Groundwater)

C2VSimFG-Kern Model Scenario	Change in Groundwater Storage (AFY)	
	C2VSimFG-Kern Model Results	Adjusted Model Results
Historic	-277,114	-277,114
Baseline	-324,326	-324,326
Baseline with Projects	42,144	85,578
2030 Climate Change	-380,900	-372,120
2030 Climate with Projects	-12,861	46,829
2070 Climate Change	-489,828	-472,336
2070 Climate with Projects	-118,273	-45,969

For the HMWD GSA, there are three (3) projected water budgets for the GSA – baseline, 2030 climate change-based hydrology, and 2070 climate change-based hydrology. The projected water budgets cover a 50-year period. The irrigated acres in each projected water budget are based on 2013 land use, consistent with all other GSAs in the Subbasin. The projected surface water supplies, precipitation, and Crop ET demand are based on historical values, but are adjusted to reflect imported water supply operational criteria as well as climate change. The three projected water budgets are displayed below.

Baseline

- Surface water deliveries: 27,482 AFY
- Precipitation: 3,290 AFY (4.46 inches per year average over cropped acres)
- Cropped acreage: 8,858 acres
- Crop ET demand: 19,440 AFY
- Estimated groundwater pumping: 777 AF

2030-hydrology

- Surface water deliveries: 26,778 AFY
- Precipitation: 3,290 AFY (4.46 inches per year over cropped acres)
- Cropped acreage: 8,858 acres
- Crop ET demand: 20,035 AFY
- Estimated groundwater pumping: 964 AF

2070-hydrology

- Surface water deliveries: 25,681 AFY
- Precipitation: 3,290 AFY (4.46 inches per year over cropped acres)
- Cropped acreage: 8,858 acres
- Crop ET demand: 20,966 AFY
- Estimated groundwater pumping: 1,369 AFY

The "Estimated groundwater pumping" number is derived from the annual change in hydrology, resulting in some drought years where surface deliveries are minimal, and a factor of 1.10 between Crop ET demand and applied water is required. The 2030 and 2070 calculations also account for climate change influences on ET and surface water supplies.

Because of the small deficit in "Operational GW Flux" in the historic water budget, when groundwater pumping averaged more than 7,000 AFY, the projected water budgets appear close to the GSA's actual groundwater usage. However, it should be noted that future land use and crop demand is subject to change on behalf of the stakeholders, so the GSA will be required to manage its water budgets in an adaptive manner, and possibly implement Projects and Management Actions if necessary.

2.3.5 Overdraft Correction Account

In addition to the groundwater extraction and replenishment that occurs within the Plan Area of this GSP, the District also delivers surface water supplies to the Pioneer Project to recharge for Overdraft Correction

(ODC) purposes, as discussed in Section 1.5.2. Although this replenishment occurs in the Kern Alluvial Fan area, the GSA still recognizes this activity as a component of its Water Budget within the Kern Subbasin.

From 1995 to 2014, the hydrologic base period, the District started with an account balance of zero AF and ended with an ODC account balance of 43,382 AF, or an annual average contribution of **2,169 ac-ft**. As of January 31, 2019, the District's ODC account balance was 57,993 AF. A figure demonstrating the account balance, which is overseen by the KCWA, can be seen in **Figure 2-45.**

When considering the groundwater replenishment from the ODC activity at the Pioneer Project, it more than makes up for the deficit in the GSA's modeled groundwater balance within the Plan Area. Because the Subbasin is considering its groundwater aquifer(s) to be hydraulically connected, the GSA intends to include its ODC account balance into its GSA Water Budget.

2.3.6 Sustainable Yield Estimate

The GSAs within the Subbasin utilized the results of the C2VSimFG-Kern model to agree on a subbasin-wide sustainable yield. The C2VSim model used two methods of estimating the amount of groundwater pumping that would avoid the undesirable result of a reduction in groundwater storage over the historical base period from 1995 to 2014. The methods of estimating the subbasin-wide sustainable yield are 1) sustainable yield from groundwater pumping and 2) sustainable yield from groundwater recharge. The subbasin-wide sustainable yield from groundwater pumping was determined by subtracting the groundwater storage decline from the groundwater pumping, as determined by the model results, to produce a sustainable yield of approximately 1,313,000 AFY. The sustainable yield as determined by groundwater recharge also produced a sustainable yield of approximately 1,313,000 AFY. This was determined by subtracting the subsurface outflows from the average annual groundwater recharge in the subbasin. Therefore, the subbasin-wide sustainable yield is approximately 1,313,000 AFY with an estimated level of uncertainty of plus or minus 10%-20%. The subbasin-wide sustainable yield value is part of the finalized coordination agreement between the GSAs.

The HWMD sustainable yield was determined to be 6,900 AFY. This was determined by the difference between the historical average groundwater pumping (7,220 AF) and the historical average groundwater flux (or storage decline) (295 AFY).

2.4 Management Areas (Reg. § 354.20)

2.4.1 Reason for MA Creation

Management Areas (MAs) are designated within the Subbasin to leverage existing relationships with water users for local water accounting and management actions of imports, exports, water consumption and conservation, and groundwater pumping. The MAs will preserve groundwater management practices and implement additional requirements set forth in this GSP. Due to naturally occurring poorer water quality in some areas of HMWD, groundwater in these areas is generally not suitable for agriculture or domestic beneficial uses without treatment or other measures. Because of the water quality and the Geologic Setting of HMWD within the dry Buena Vista Lakebed, HMWD has formed a Management Area.

2.4.2 Minimum Thresholds and Measurable Objectives for Each MA

Each MA will develop applicable Minimum Thresholds (MTs) and Measurable Objectives (MOs) for their monitoring network. These MTs and MOs will be accessible to the KGA and KRGSA for coordination, GSA input, and the benefit of the Subbasin. Adjacent MAs may operate under different MTs and MOs due to variation in groundwater conditions across the subbasin. For example, as described in the Basin Setting, TDS in groundwater vary across the Subbasin due to naturally high concentrations of TDS in shallow and very deep aquifer zones. Additionally, groundwater levels are generally higher along the margins of the Subbasin and where other structural or lithologic controls create natural "highs" in groundwater levels. Differences in MTs are not limited to water quality and groundwater levels as described above. If changes to the MTs and MOs are warranted, justification will be provided in the 5-year GSP updates.

2.4.3 Monitoring of Each MA

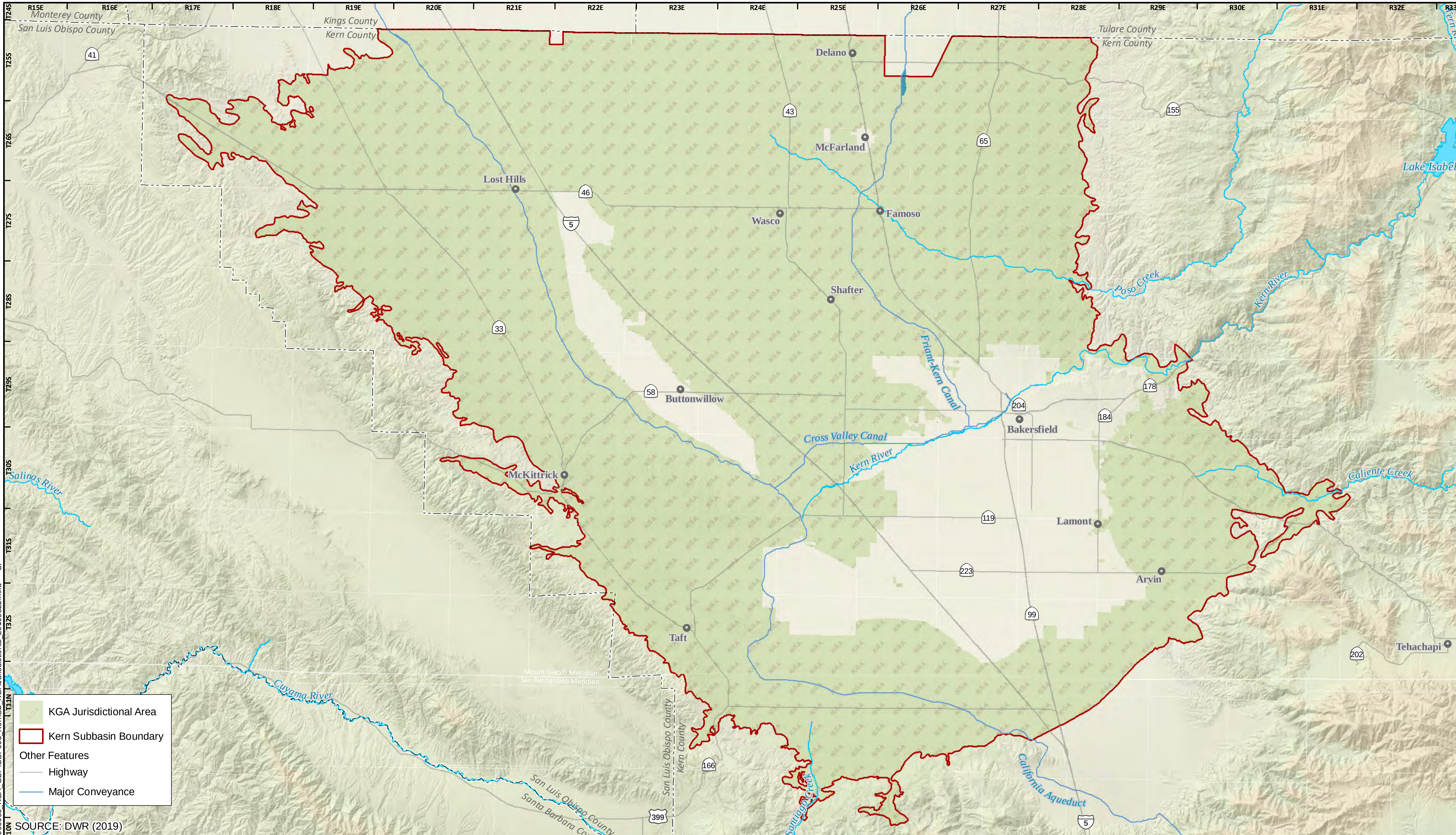
Each MA is responsible for monitoring within their respective jurisdiction. Results of monitoring and reporting will be provided to the KGA at agreed upon terms. Where necessary, the KGA will work with the MAs to accomplish the goals of the MAs. If changes to the MAs are warranted, justification will be provided in the 5-year GSP updates.

2.4.4 Description of Differences Among MA and How Different MTs and MOs in Neighboring MAs Will be Addressed

Differences in MTs and MOs in neighboring Management Areas have been addressed through outreach and communication efforts with neighboring GSAs. These efforts during the development of this GSP did not result in any disagreements between HMWD and negiboring GSAs. Outreach and communication efforts will continue during the GSP implementation process with neighboring GSAs to address any substantial discrepancies in MOs and MTs.

2.4.5 Description of Conditions in Each MA

Due to the observance of poorer water quality in some areas of the GSA, groundwater pumping is being managed to minimize impacts on the beneficial uses of groundwater within the GSA.



Kern Groundwater Authority
Basin Setting

Kern County, California

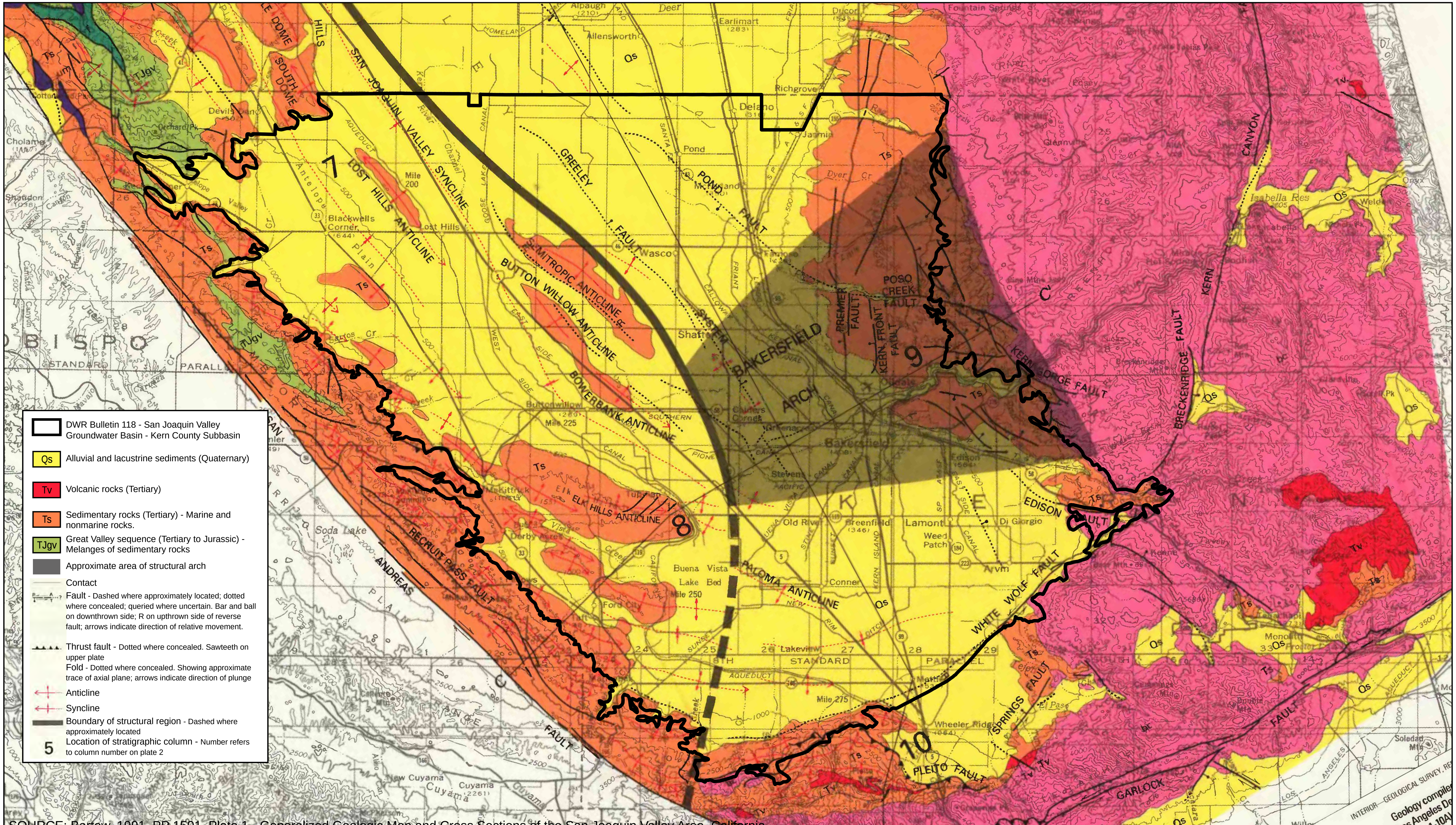
GEI Consultants

JURISDICTIONAL AREA OF KERN GROUNDWATER AUTHORITY

AUGUST 2019

FIGURE 2-1

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP003_KernSB_KGAJurisdictional_20190822.mxd SI



SOURCE: Bartow, 1991. PP 1501. Plate 1 - Generalized Geologic Map and Cross Sections of the San Joaquin Valley Area, California

10 5 0 10
Miles

N W E S

Kern Groundwater Authority
Basin Setting

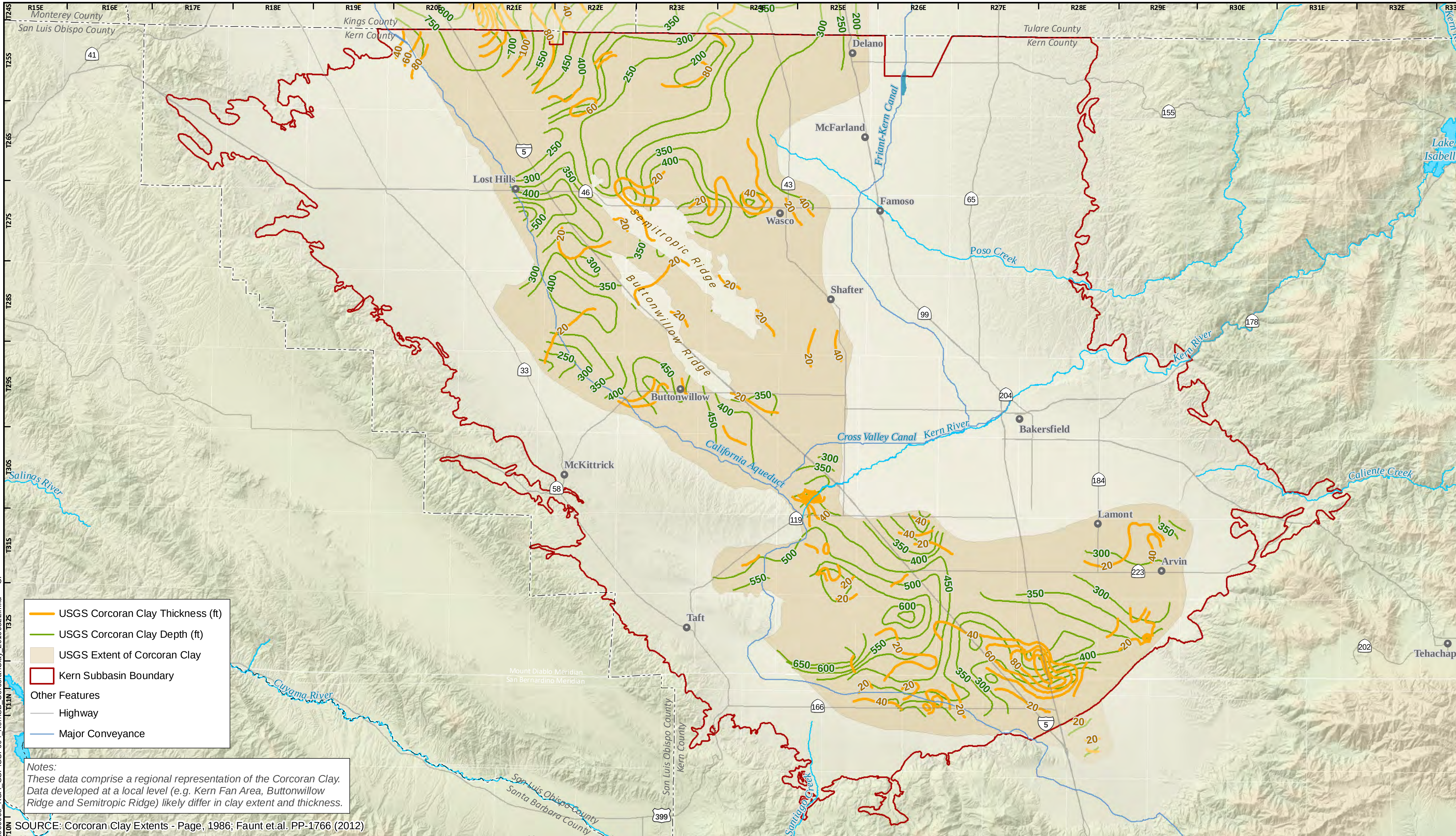
Kern County, California

GEI Consultants

GEOLOGIC MAP (BARTOW, 1991)

AUGUST 2019

FIGURE 2-3



Kern Groundwater Authority
Basin Setting

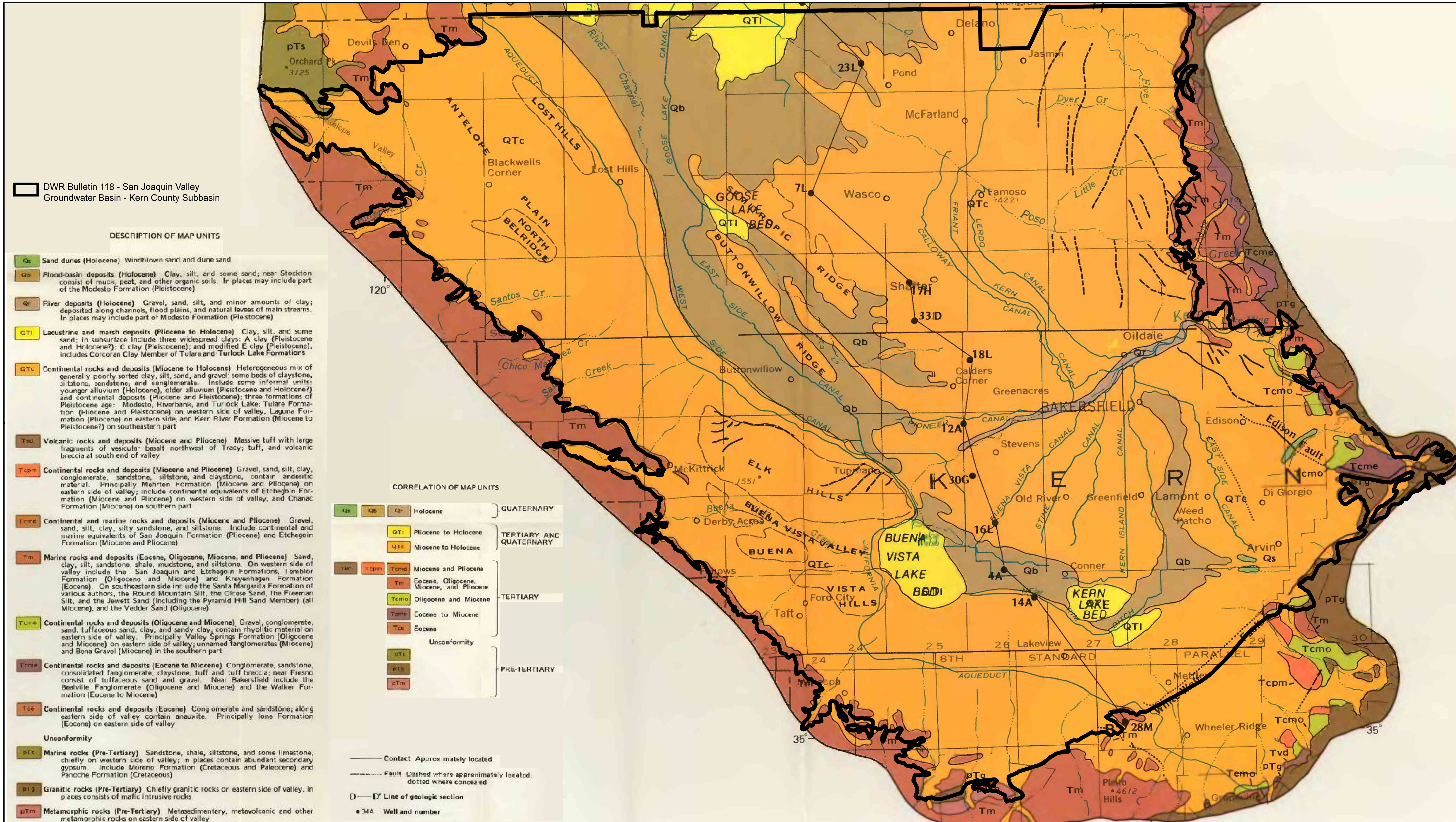
Kern County, California

GEI Consultants

APPROXIMATE THICKNESS AND EXTENT OF E-MODIFIED CORCORAN CLAY

JULY 2019

FIGURE 2-4



SOURCE: Page, 1986, PP 1401-C Plate 2 - Geologic Map of the San Joaquin Valley, California

10 5 0 10
Miles

N
W E
S

Kern Groundwater Authority
Basin Setting

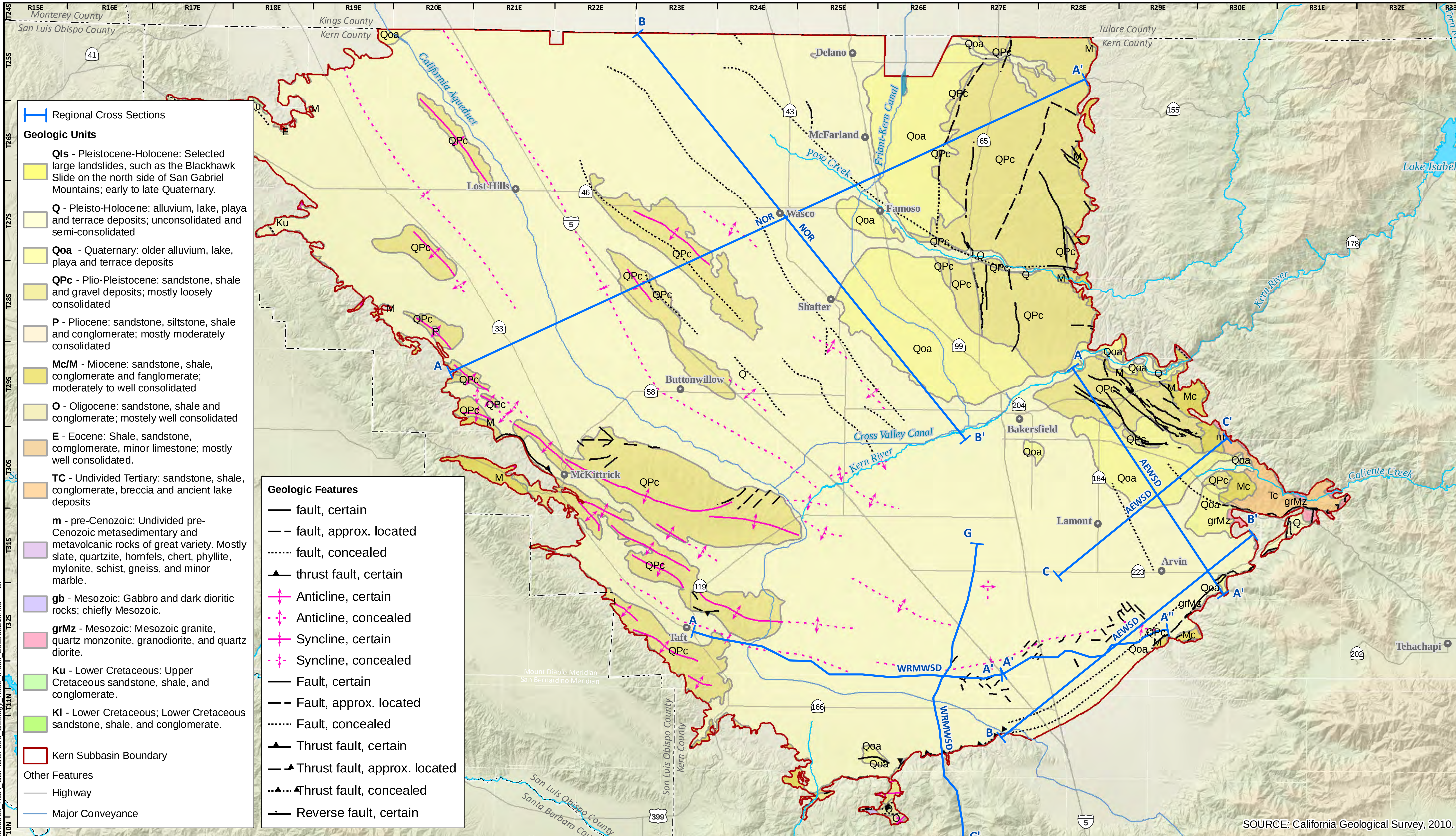
Kern County, California

GEI Consultants

GEOLOGIC MAP (PAGE, 1986)

AUGUST 2019

FIGURE 2-7



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21-Aug-2019

Kern Groundwater Authority
Basin Setting

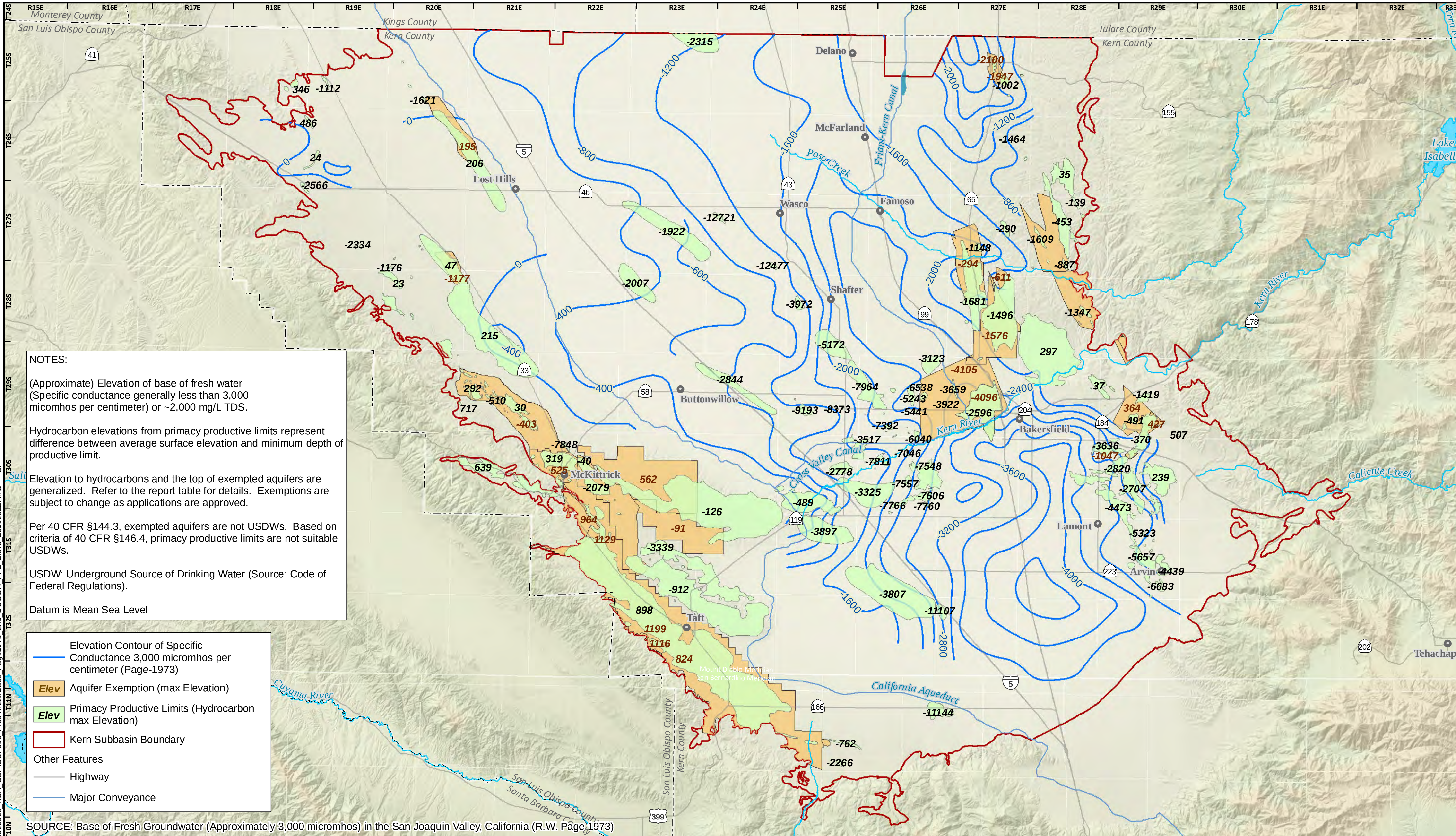
Kern County, California

GEI Consultants

GEOLOGIC INDEX MAP (CGS, 2010)

AUGUST 2019

FIGURE 2-8



Kern Groundwater Authority
Basin Setting

Kern County, California

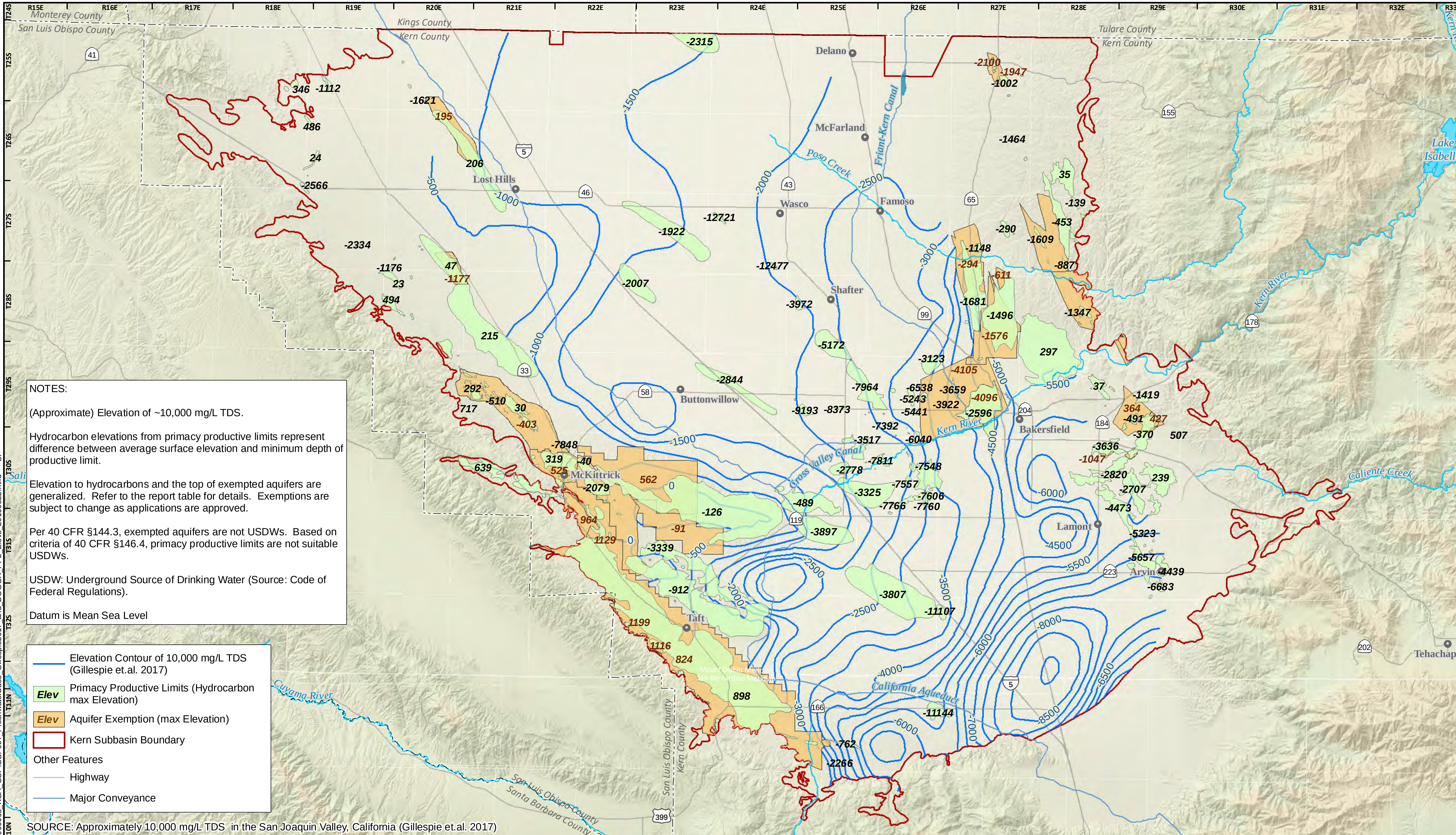
GEI Consultants

BASE OF FRESH WATER BY PAGE (1973) WITH NON-USDWS

AUGUST 2019

FIGURE 2-9

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP006_FreshwaterBase_Page1973_and_DOGGR_PPL_Elevs_20190822.mxd SI



0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

ELEVATION CONTOURS OF 10,000 MG/L TDS WITH NON-USDWS

AUGUST 2019

FIGURE 2-10

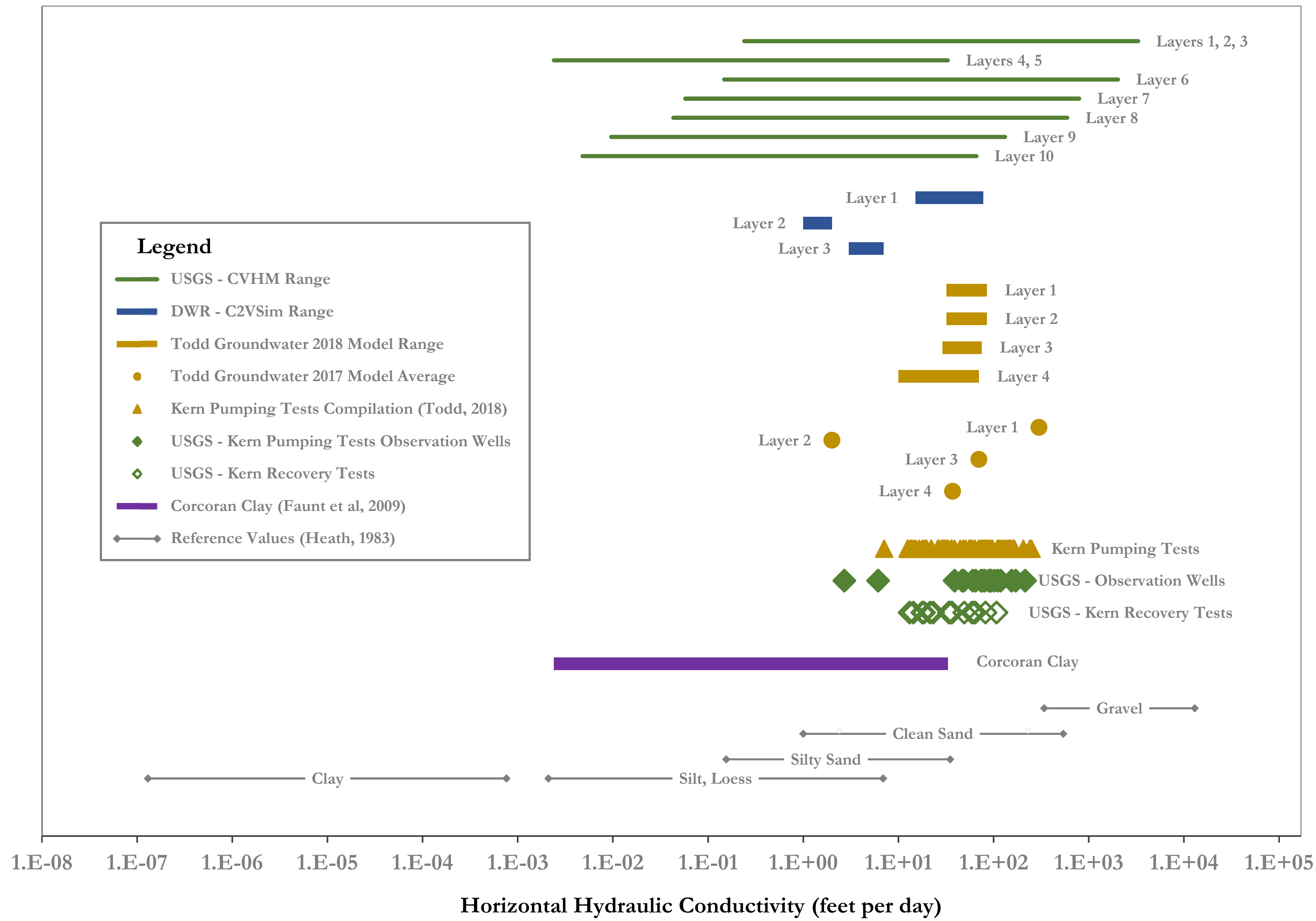
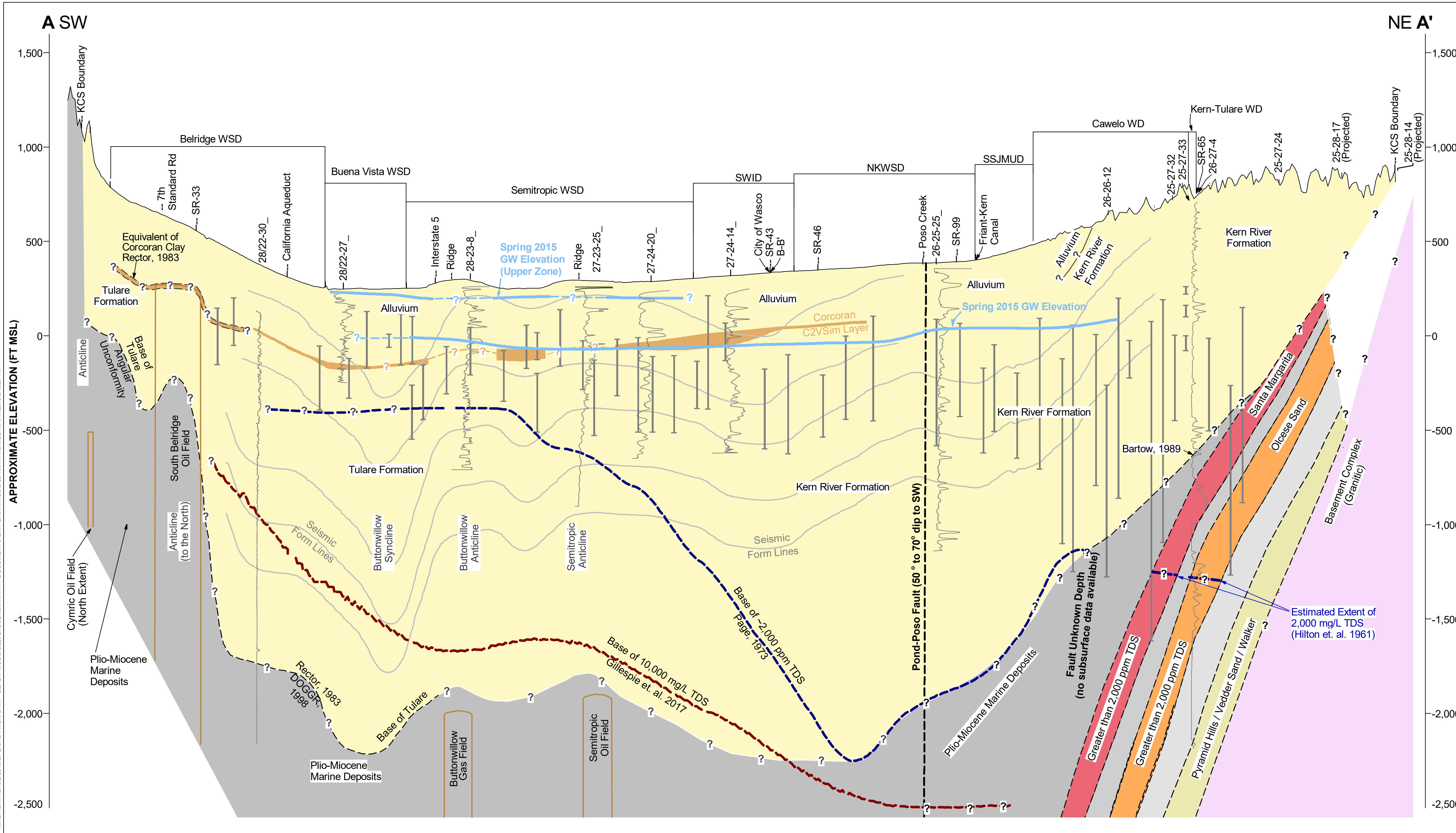


Figure 2-7.pptx

Kern Groundwater Authority Basin Setting	GEI Consultants	HYDRAULIC CONDUCTIVITY VALUES	
Kern County, California		AUGUST 2019	FIGURE 2-13



Approximate Scale
0 1.8 3.7 Miles
Vertical Exaggeration = 39x

- Well Perforated Intervals
- Resistivity (ohm-m)
- Seismic Form Lines (PGA, 1991)
- Groundwater Elevation (Spring 2015)
- Corcoran Layer C2VSIM Model
- Alluvium / Kern River Formation / Tulare Formation
- Plio-Miocene Marine Deposits (Etchegoin/San Joaquin)
- Oil Field Primacy Extents (Approximate) (DOGGR, 1998)

Kern Groundwater Authority
Basin Setting

Kern County, CA

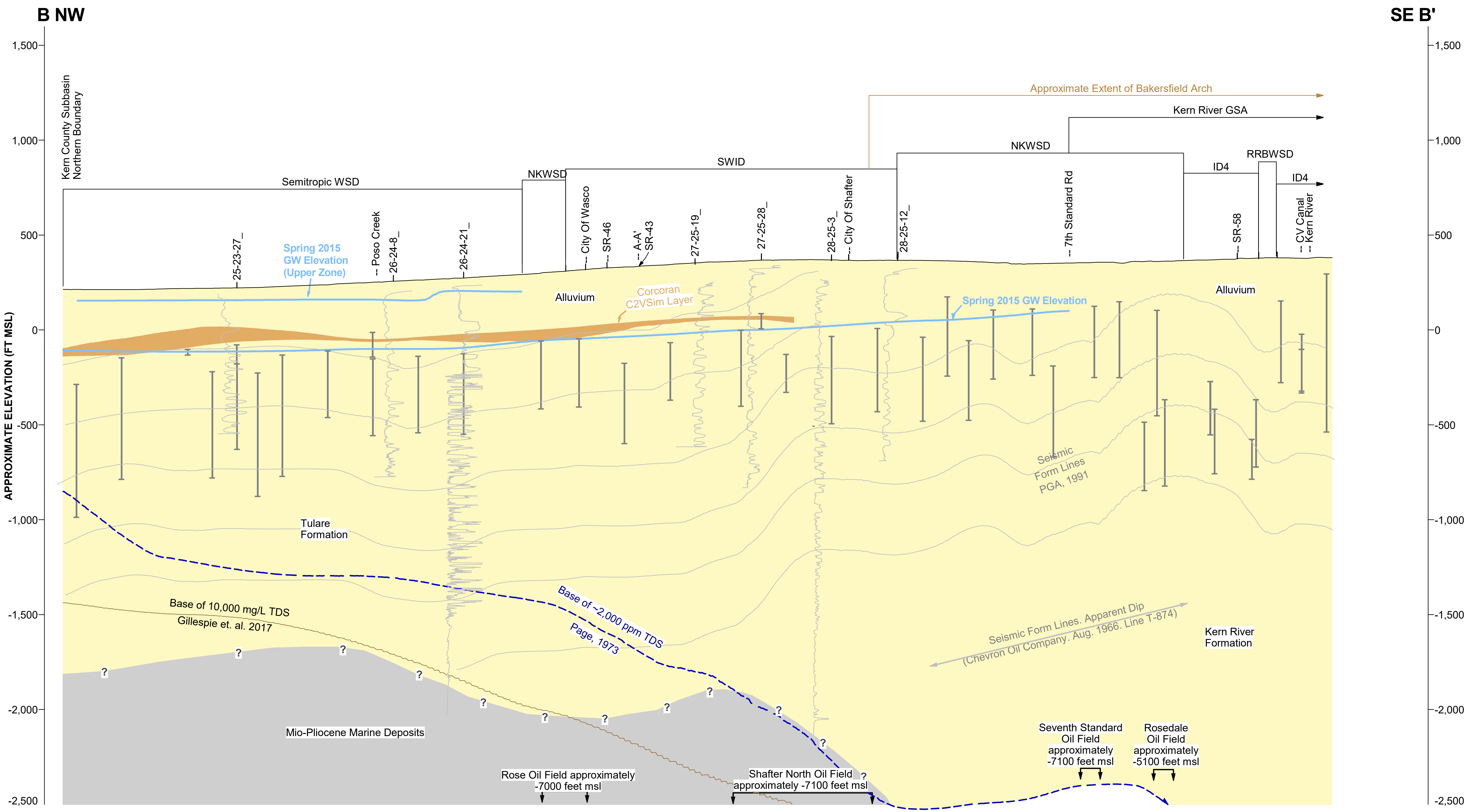
GEI Consultants

CROSS SECTION A-A' NORTH OF RIVER

AUGUST 2019

FIGURE 2-14A

Output Scale: Distance 1 inch = 19485 ft. H: to ft. V: 1 inch = 494 ft, 1500 to -2500 ft



NOTE: Although contacts with the Top of San Joaquin Formation (Mio-Pliocene Marine Deposits) are reported in Oil and Gas records for some of this cross section, facies changes are likely occurring and can cause difficulty in correlation along the cross section.

Miles
0 1.4 2.9
Vertical Exaggeration = 31x

Well Perforated Intervals
Resistivity (0-100 ohm-m)
Seismic Form Lines (PGA, 1991)
Groundwater Elevation (Spring 2015)
Corcoran Layer C2VSIM Model
Alluvium / Kern River Formation / Tulare Formation
Mio-Pliocene Marine Deposits

Kern Groundwater Authority
Basin Setting

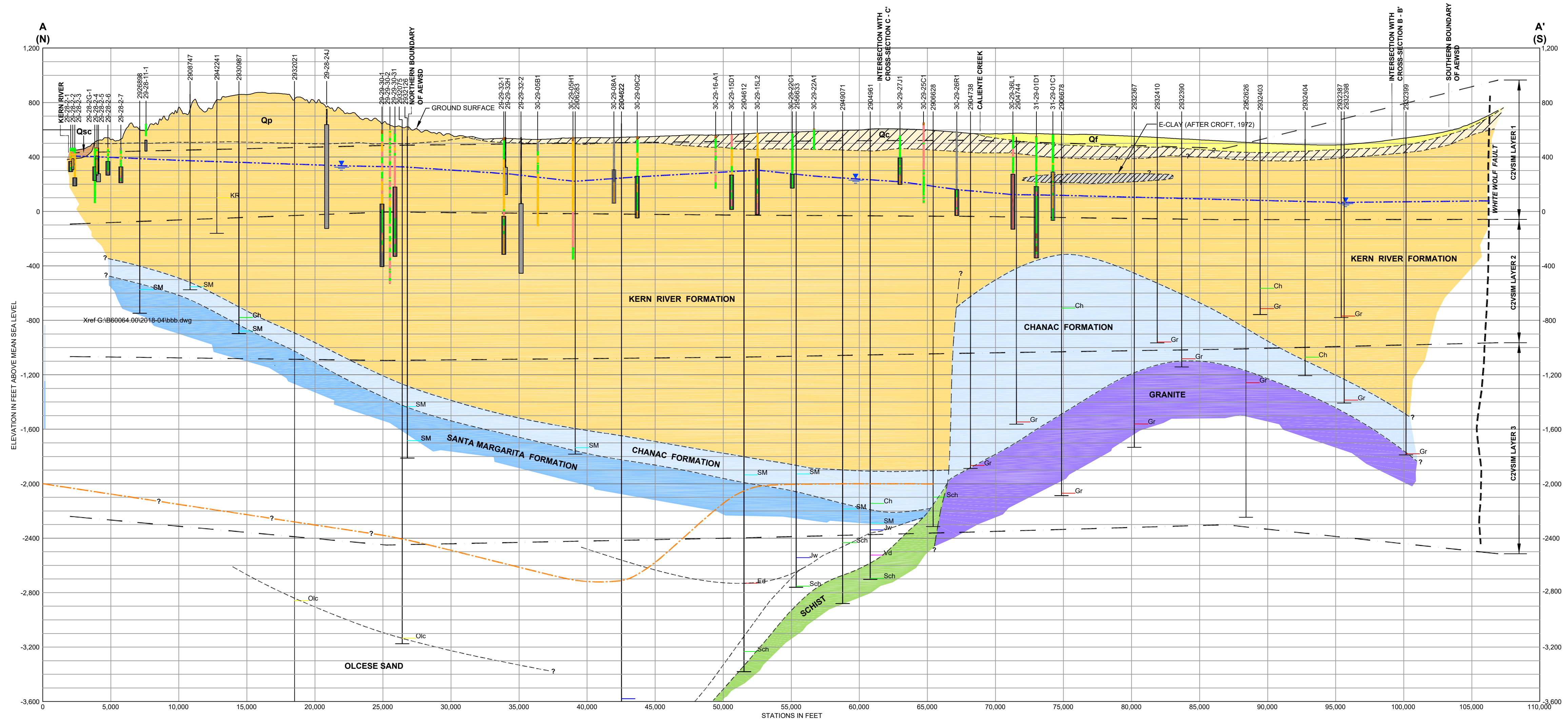
Kern County, CA

GEI Consultants

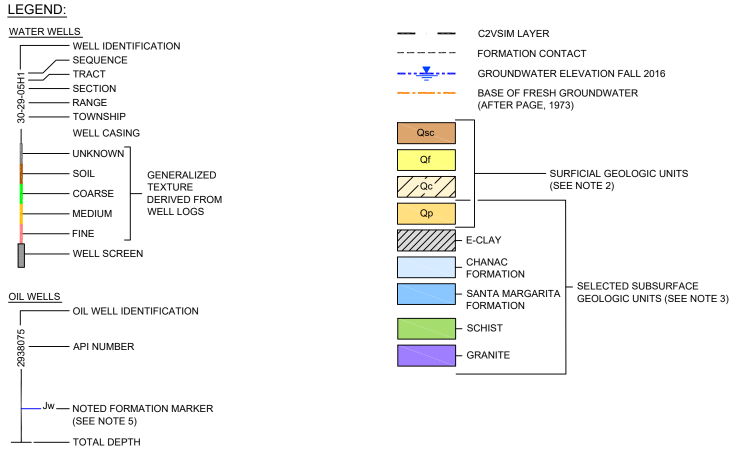
CROSS SECTION B-B' NORTH OF RIVER

AUGUST 2019

FIGURE 2-14B



GEOLOGIC CROSS-SECTION A - A'



ABBREVIATIONS:

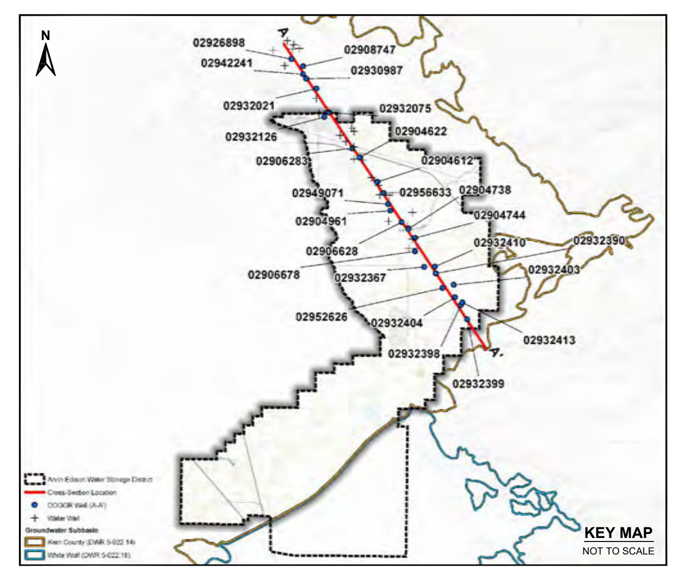
AEWSD = ARVIN-EDISON WATER STORAGE DISTRICT
API = AMERICAN PETROLEUM INSTITUTE
C2VSIM = CALIFORNIA CENTRAL VALLEY GROUNDWATER-SURFACE WATER SIMULATION MODEL
CDMG = CALIFORNIA DIVISION OF MINES AND GEOLOGY
DOGGR = DIVISION OF OIL, GAS & GEOTHERMAL RESOURCES

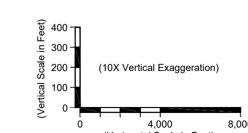
SOURCES:

1. CDMG, 1964, CALIFORNIA DIVISION OF MINES AND GEOLOGY, GEOLOGIC MAP, OLAF P. JENKINS EDITION, BAKERSFIELD SHEET.
2. CROFT, 1972. CROFT, M.G., 1972, SUBSURFACE GEOLOGY OF THE LATE TERTIARY AND QUATERNARY WATER-BEARING DEPOSITS OF THE SOUTHERN PART OF THE SAN JOAQUIN VALLEY, CALIFORNIA, USGS WATER SUPPLY PAPER 1999-H, 29 PP.
3. BARTOW, 1984. BARTOW, J.A. TERTIARY STRATIGRAPHY OF THE SOUTHEASTERN SAN JOAQUIN VALLEY, CALIFORNIA, USGS BULLETIN 1529-J, 1984.
4. DOGGR OIL WELL RECORDS.
5. PAGE R.W., 1973. BASE OF FRESH GROUNDWATER (APPROXIMATELY 3,000 MICROMHOS) IN THE SAN JOAQUIN VALLEY, CALIFORNIA. USGS HYDROLOGIC INVESTIGATIONS ATLAS HA-489.

NOTES:

1. WELL IDENTIFICATION BASED ON PUBLIC LAND SURVEY SYSTEM.
2. SURFICIAL GEOLOGY AS SHOWN ON CDMG (1964). SURFICIAL GEOLOGY MAP UNIT SYMBOLS ARE:
   - Qsc - RECENT STREAM CHANNEL DEPOSITS
   - Qf - RECENT FAN DEPOSITS
   - Qc - PLEISTOCENE NON-MARINE
   - Qp - PLIO-PLEISTOCENE NON-MARINE
3. SUBSURFACE GEOLOGIC UNITS BASED ON BARTOW (1984) & CROFT (1972) AND DOGGR OIL WELL RECORDS.
4. SEE FIGURE 8a FOR CROSS-SECTION LOCATION. WELLS SHOWN ON CROSS-SECTION ARE LOCATED WITHIN 1/2 MILE OF CROSS-SECTION LINE.
5. FORMATION MARKERS FROM DOGGR OIL WELL RECORDS INCLUDE: Ch (CHANNAC), SM (SANTA MARGARITA), Olc (OLCESE), Ed (EDISON), Jw (JEWETT), Vd (VEDDER), Sch (SCHIST) AND Gr (GRANITE).



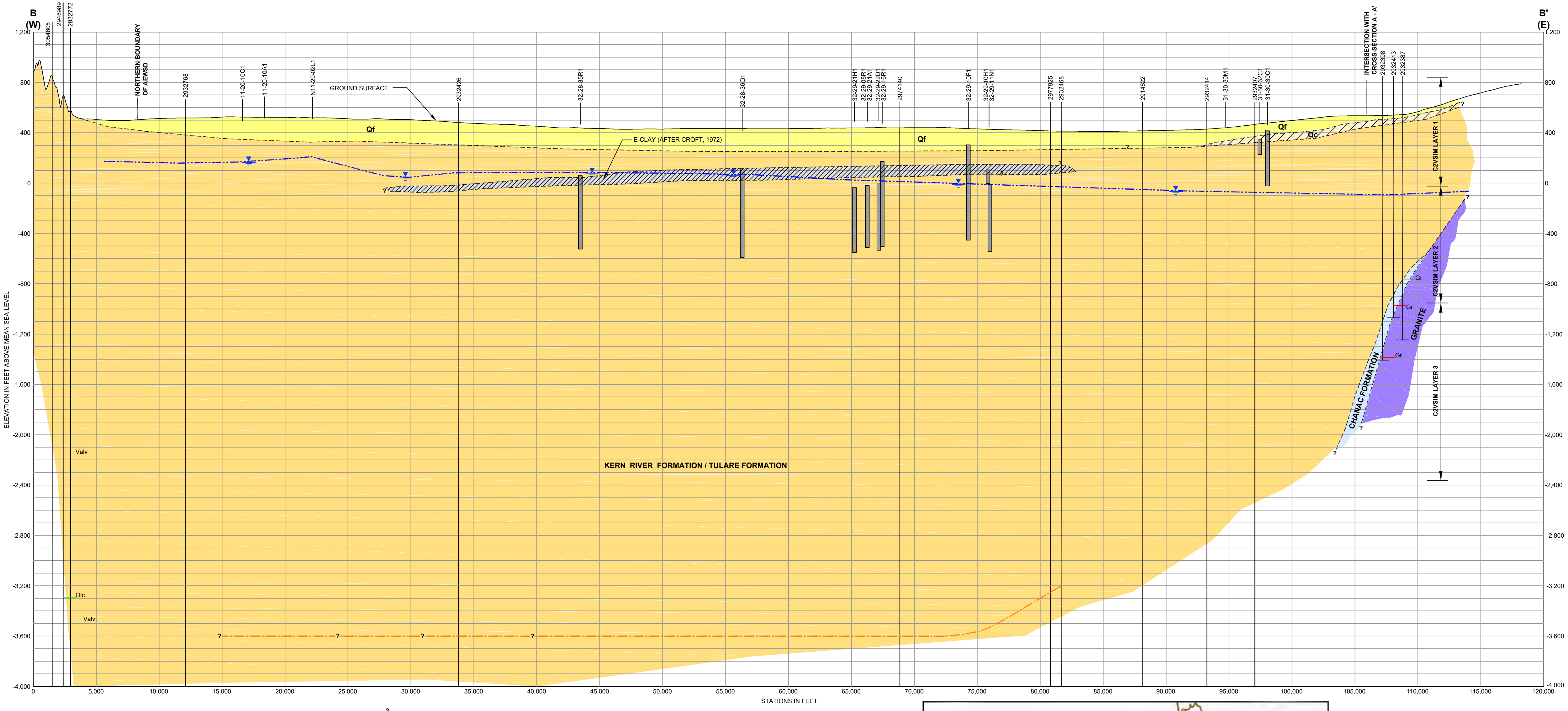


GEOLOGIC CROSS-SECTION A - A'

Arvin-Edison Water Storage District
Kern County, CA
June 2018
EKI B60064.01
Figure HCM-13

Source: EKI, 2019. Arvin-Edison Water Storage District Groundwater Sustainability Plan.

Kern Groundwater Authority Basin Setting	GEI Consultants	**GEOLOGIC CROSS SECTIONS A-A' (AEWSD)**
Kern County, California		NOVEMBER 2019 — FIGURE 2-14C



GEOLOGIC CROSS-SECTION B - B'

LEGEND:

WATER WELLS

- WELL IDENTIFICATION
- SEQUENCE
- TRACT
- SECTION
- RANGE
- TOWNSHIP
- WELL CASING
- UNKNOWN
- SOIL
- COARSE
- MEDIUM
- FINE
- WELL SCREEN

GENERALIZED TEXTURE DERIVED FROM WELL LOGS

OIL WELLS

- OIL WELL IDENTIFICATION
- API NUMBER
- NOTED FORMATION MARKER (SEE NOTE 5)
- TOTAL DEPTH

- C2VSIM LAYER
- FORMATION CONTACT
- GROUNDWATER ELEVATION FALL 2016
- BASE OF FRESH GROUNDWATER (AFTER PAGE, 1973)

SURFICIAL GEOLOGIC UNITS (SEE NOTE 2): Qsc, Qf, Qc, Qp

SELECTED SUBSURFACE GEOLOGIC UNITS (SEE NOTE 3):

- E-CLAY
- CHANAC FORMATION
- SANTA MARGARITA FORMATION
- GRANITE

ABBREVIATIONS:

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SOURCES:

1. CDMG, 1964, CALIFORNIA DIVISION OF MINES AND GEOLOGY, GEOLOGIC MAP, OLAF P. JENKINS EDITION, BAKERSFIELD SHEET.
2. CROFT, 1972. CROFT, M.G., 1972, SUBSURFACE GEOLOGY OF THE LATE TERTIARY AND QUATERNARY WATER-BEARING DEPOSITS OF THE SOUTHERN PART OF THE SAN JOAQUIN VALLEY, CALIFORNIA, USGS WATER SUPPLY PAPER 1999-H, 29 PP.
3. BARTOW, 1984. BARTOW, J.A. TERTIARY STRATIGRAPHY OF THE SOUTHEASTERN SAN JOAQUIN VALLEY, CALIFORNIA, USGS BULLETIN 1529-J, 1984.
4. DOGGR OIL WELL RECORDS.
5. PAGE R.W., 1973. BASE OF FRESH GROUNDWATER (APPROXIMATELY 3,000 MICROMHOS) IN THE SAN JOAQUIN VALLEY, CALIFORNIA. USGS HYDROLOGIC INVESTIGATIONS ATLAS HA-489.

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   - Qc - PLEISTOCENE NON-MARINE
   - Qp - PLIO-PLEISTOCENE NON-MARINE
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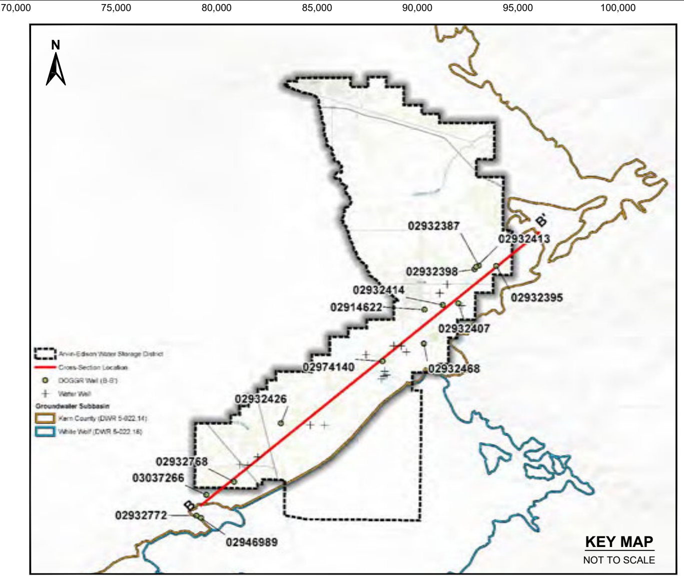
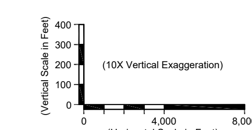
5. FORMATION MARKERS FROM DOGGR OIL WELL RECORDS INCLUDE: Ch (CHANNAC), SM (SANTA MARGARITA), Olc (OLCESE), Ed (EDISON), Jw (JEWETT), Vd (VEDDER), Sch (SCHIST) AND Gr (GRANITE).





GEOLOGIC CROSS-SECTION B - B'

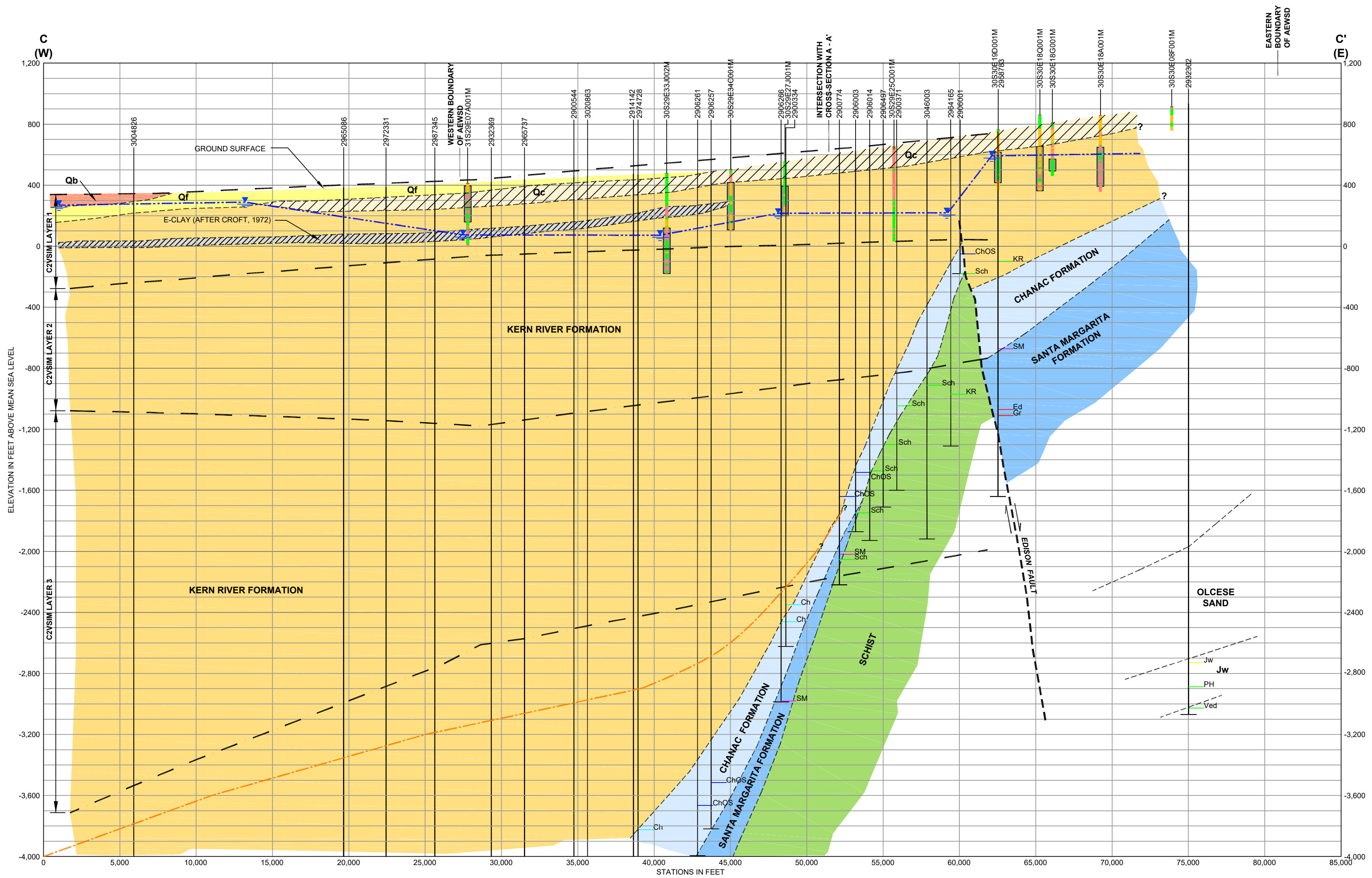
Arvin-Edison Water Storage District
Kern County, CA
June 2018
EKI B60064.01

eki environment & water

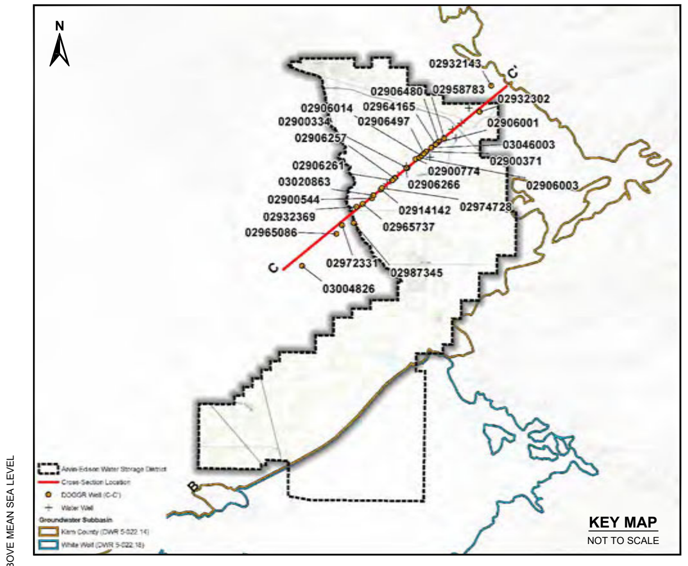
Figure HCM-14

Source: EKI, 2019. Arvin-Edison Water Storage District Groundwater Sustainability Plan.

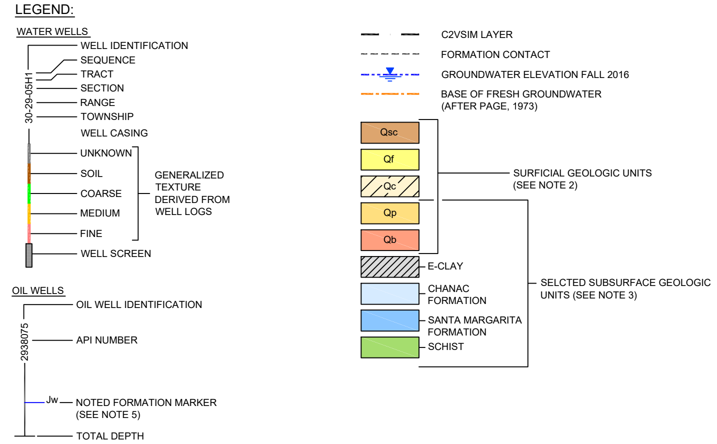
Kern Groundwater Authority Basin Setting	GEI Consultants	GEOLOGIC CROSS SECTIONS B-B' (AEWSD)
Kern County, California		NOVEMBER 2019 — FIGURE 2-14D



GEOLOGIC CROSS-SECTION C - C'



LEGEND:



ABBREVIATIONS:

AEWSD = ARVIN-EDISON WATER STORAGE DISTRICT

API = AMERICAN PETROLEUM INSTITUTE

C2VSIM = CALIFORNIA CENTRAL VALLEY GROUNDWATER-SURFACE WATER SIMULATION MODEL

CDMG = CALIFORNIA DIVISION OF MINES AND GEOLOGY

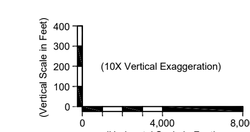
DOGGR = DIVISION OF OIL, GAS & GEOTHERMAL RESOURCES

SOURCES:

1. CDMG, 1964, CALIFORNIA DIVISION OF MINES AND GEOLOGY, GEOLOGIC MAP, OLAF P. JENKINS EDITION, BAKERSFIELD SHEET.
2. CROFT, 1972. CROFT, M.G., 1972, SUBSURFACE GEOLOGY OF THE LATE TERTIARY AND QUATERNARY WATER-BEARING DEPOSITS OF THE SOUTHERN PART OF THE SAN JOAQUIN VALLEY, CALIFORNIA, USGS WATER SUPPLY PAPER 1999-H, 29 PP.
3. BARTOW, 1984. BARTOW, J.A. TERTIARY STRATIGRAPHY OF THE SOUTHEASTERN SAN JOAQUIN VALLEY, CALIFORNIA, USGS BULLETIN 1529-J, 1984.
4. DOGGR OIL WELL RECORDS.
5. PAGE R.W., 1973. BASE OF FRESH GROUNDWATER (APPROXIMATELY 3,000 MICROMHOS) IN THE SAN JOAQUIN VALLEY, CALIFORNIA. USGS HYDROLOGIC INVESTIGATIONS ATLAS HA-489.

NOTES:

1. WELL IDENTIFICATION BASED ON PUBLIC LAND SURVEY SYSTEM.
2. SURFICIAL GEOLOGY AS SHOWN ON CDMG (1964). SURFICIAL GEOLOGY MAP UNIT SYMBOLS ARE:
   - Qsc - RECENT STREAM CHANNEL DEPOSITS
   - Qf - RECENT FAN DEPOSITS
   - Qc - PLEISTOCENE NON-MARINE
   - Qp - PLIO-PLEISTOCENE NON-MARINE
   - Qb - RECENT BASIN DEPOSITS
3. SUBSURFACE GEOLOGIC UNITS BASED ON BARTOW (1984) & CROFT (1972) AND DOGGR OIL WELL RECORDS.
4. SEE FIGURE 8a FOR CROSS-SECTION LOCATION. WELLS SHOWN ON CROSS-SECTION ARE LOCATED WITHIN 1/2 MILE OF CROSS-SECTION LINE.
5. FORMATION MARKERS FROM DOGGR OIL WELL RECORDS INCLUDE: Ch (CHANNAC), SM (SANTA MARGARITA), Olc (OLCESE), Ed (EDISON), Jw (JEWETT), Vd (VEDDER), Sch (SCHIST) AND Gr (GRANITE).



GEOLOGIC CROSS-SECTION C - C'

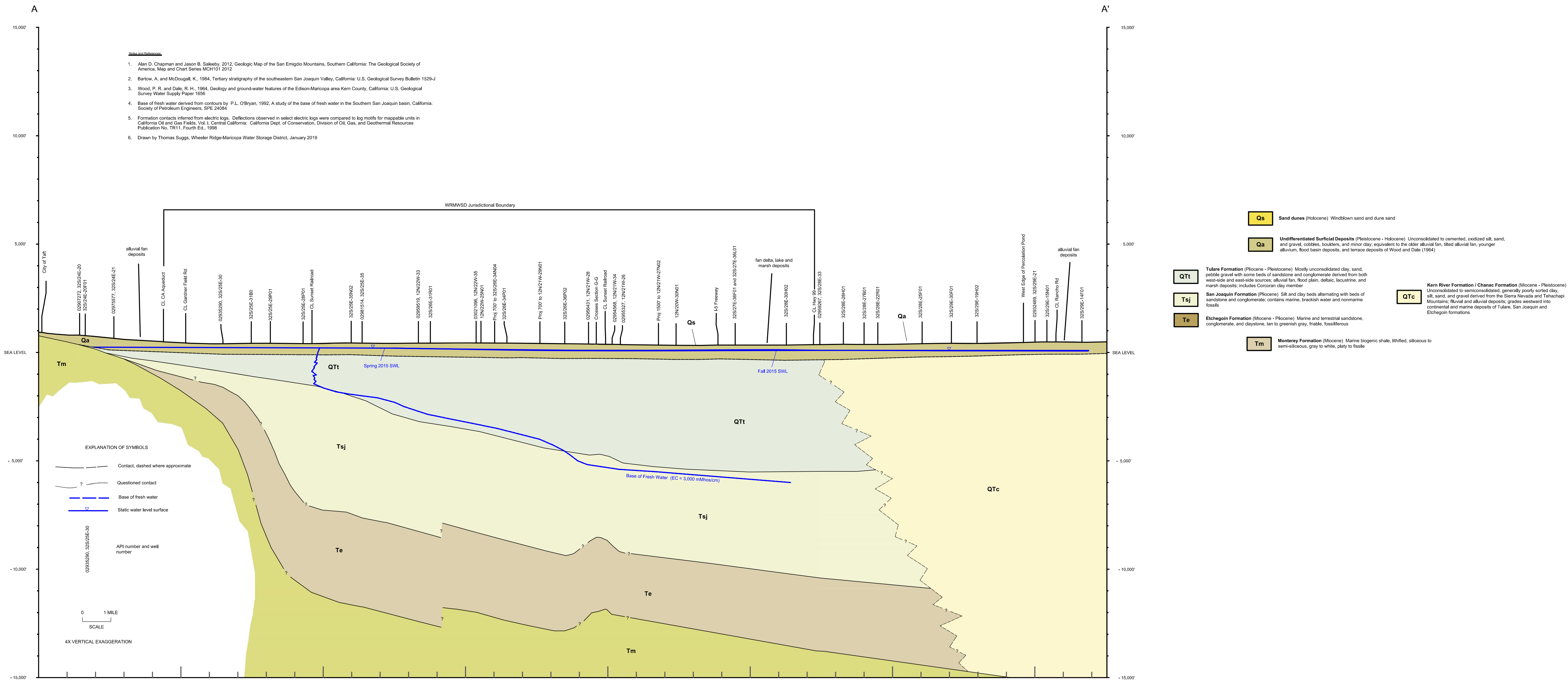
Arvin-Edison Water Storage District
Kern County, CA
June 2018
EKI B60064.01

eki environment & water

Figure HCM-15

Source: EKI, 2019. Arvin-Edison Water Storage District Groundwater Sustainability Plan.

Kern Groundwater Authority Basin Setting	GEI Consultants	**GEOLOGIC CROSS SECTIONS C-C' (AEWSD)**
Kern County, California		NOVEMBER 2019 FIGURE 2-14E

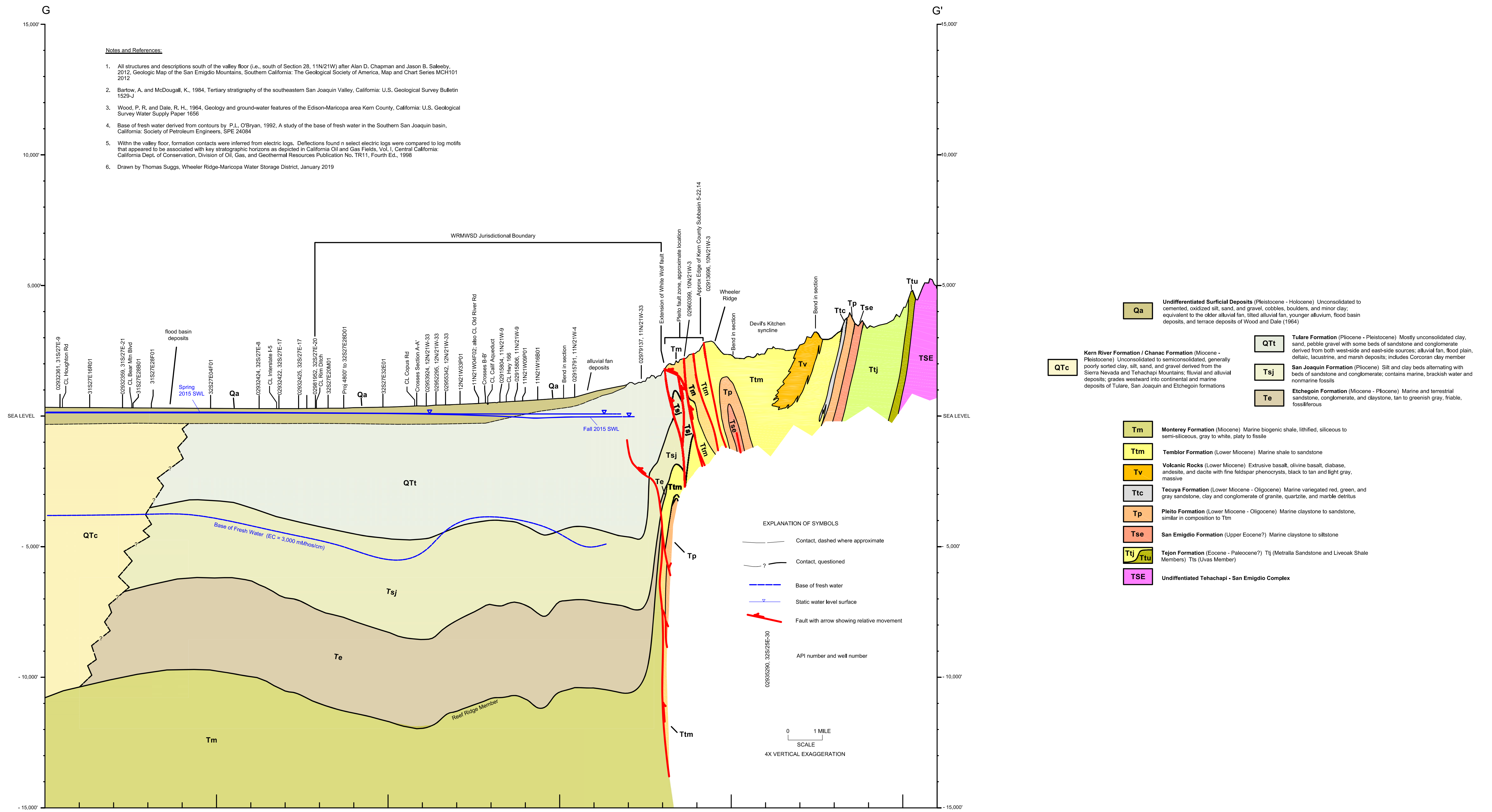


GEOLOGIC CROSS SECTION A-A', SAN JOAQUIN VALLEY, CALIFORNIA

FIGURE 2-19F

Source: 2019 Wheeler Ridge Maricopa Water Storage District Groundwater Sustainability Plan.

Kern Groundwater Authority Basin Setting	GEI Consultants	**GEOLOGIC CROSS SECTIONS A-A' (WRMWSD)**
Kern County, California		NOVEMBER 2019 FIGURE 2-14F



GEOLOGIC CROSS SECTION G-G', SAN JOAQUIN VALLEY, CALIFORNIA

Source: 2019 Wheeler Ridge Maricopa Water Storage District Groundwater Sustainability Plan.

FIGURE 2-19G

Kern Groundwater Authority Basin Setting	GEI Consultants	GEOLOGIC CROSS SECTIONS G-G' (WRMWSD)
Kern County, California		NOVEMBER 2019 FIGURE 2-14G

0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

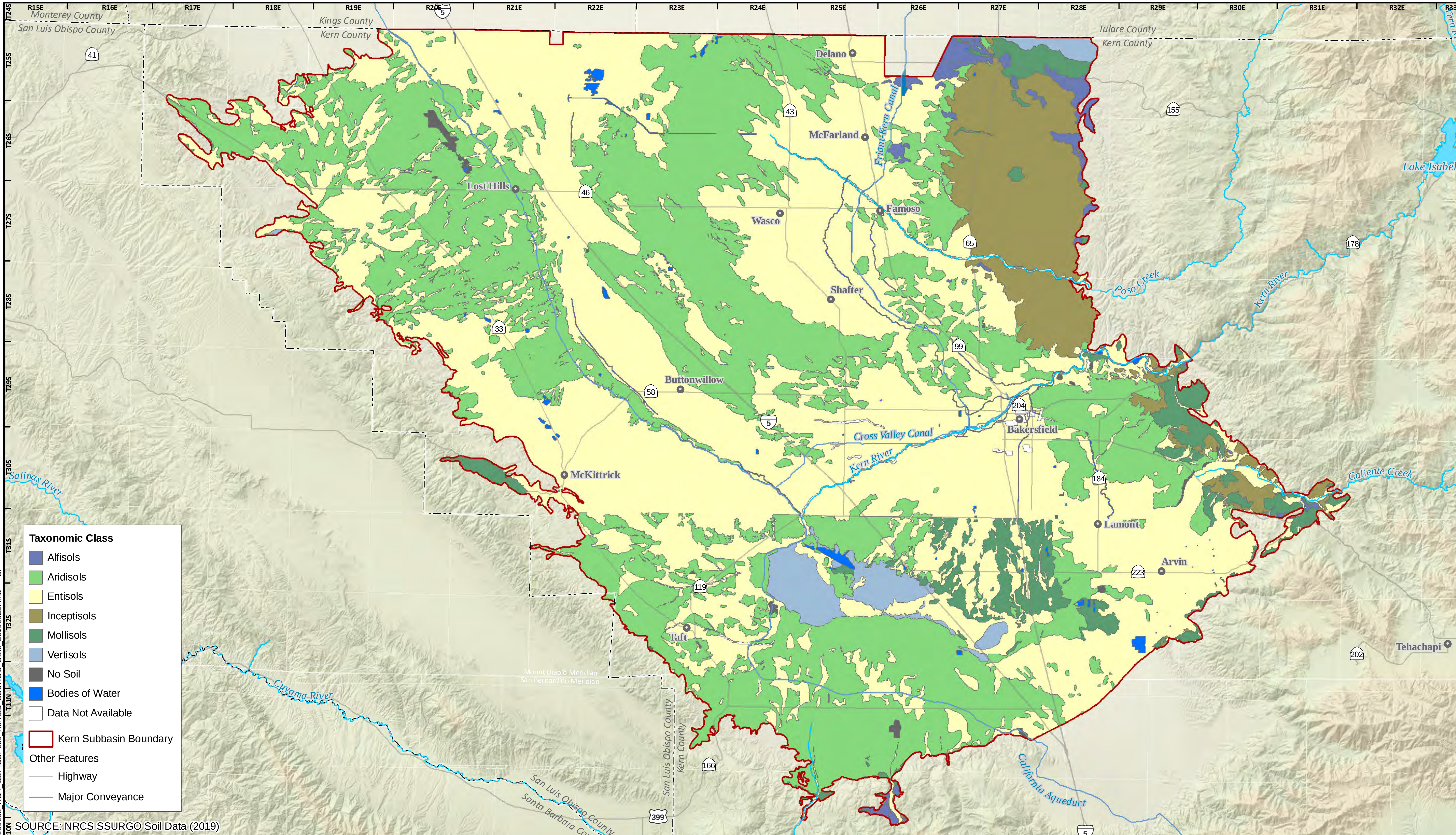
GEI Consultants

TOPOGRAPHIC FEATURES

AUGUST 2019

FIGURE 2-15

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP008_Topographic_Features_20190822.mxd SI



Kern Groundwater Authority
Basin Setting

Kern County, California

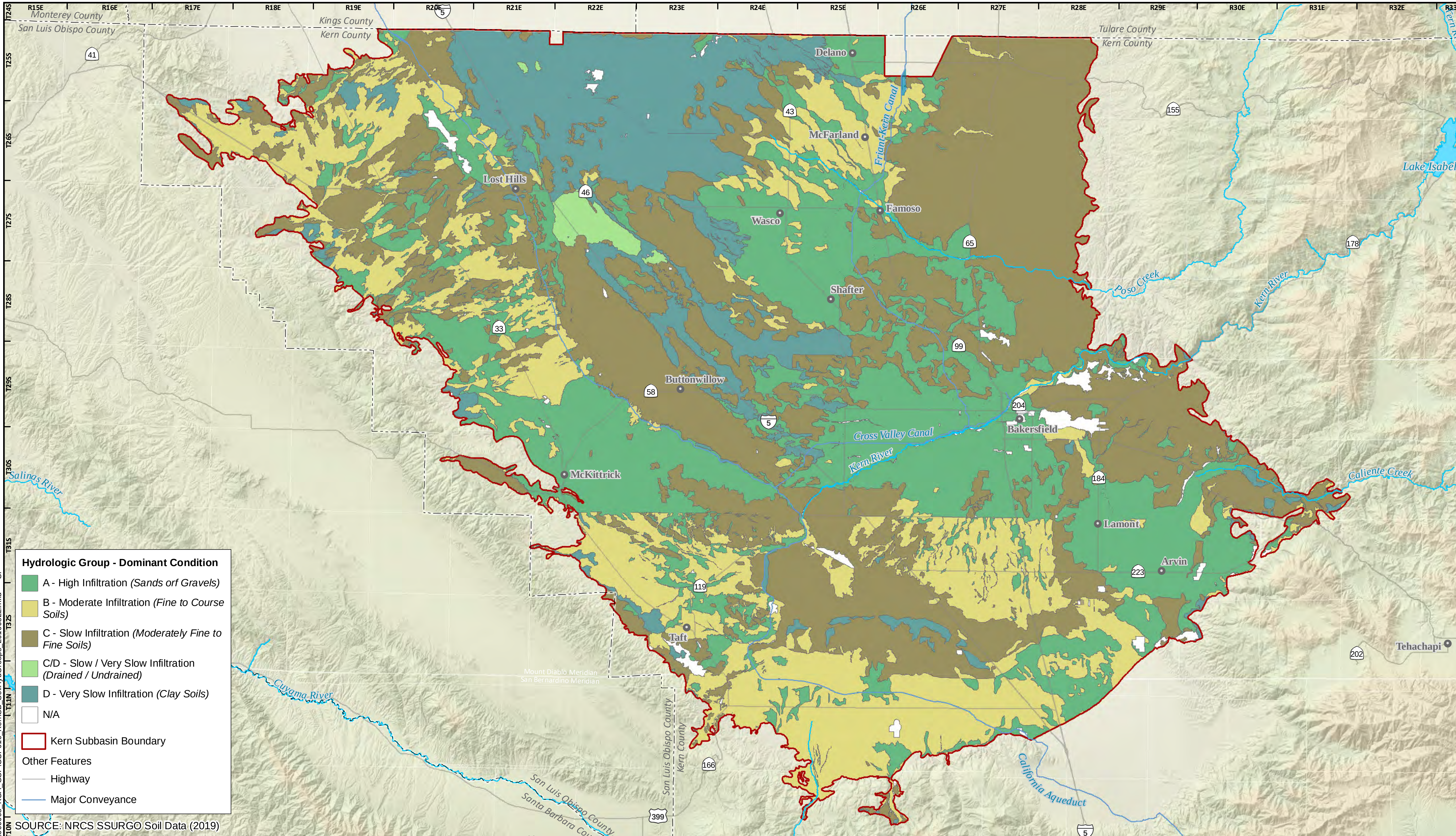
GEI Consultants

SOILS OF KERN COUNTY SUBBASIN

AUGUST 2019

FIGURE 2-16

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP009_KernSB_SSURGO_Soils_20190822.mxd SI



Z:\Projects\1900668_KGA_GSP\GSP010_KernSB_SoilHydGroups_20190822.mxd SI

22-Aug-2019

0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

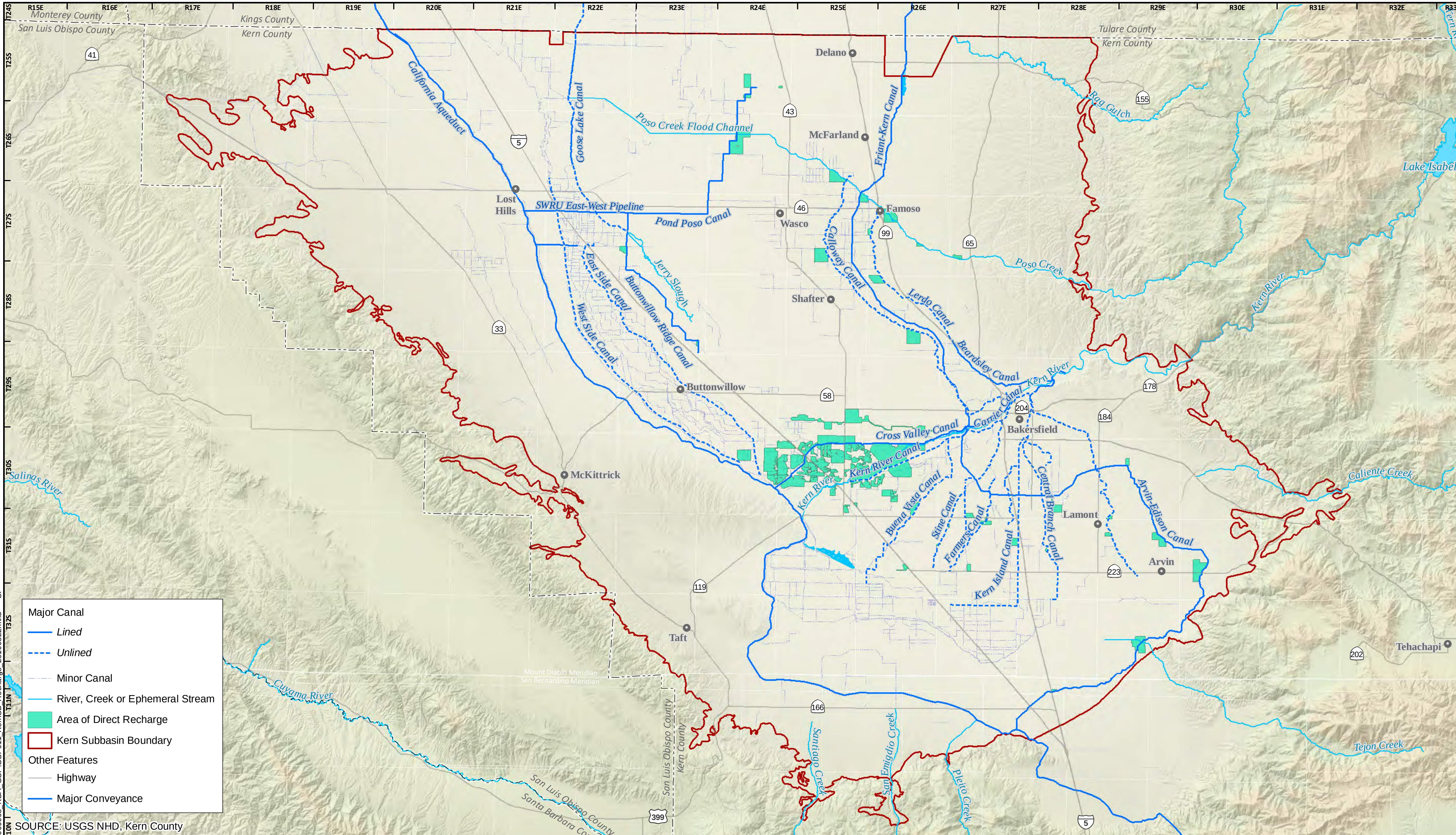
Kern County, California

GEI Consultants

HYDROLOGIC SOIL GROUPS

AUGUST 2019

FIGURE 2-17



0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

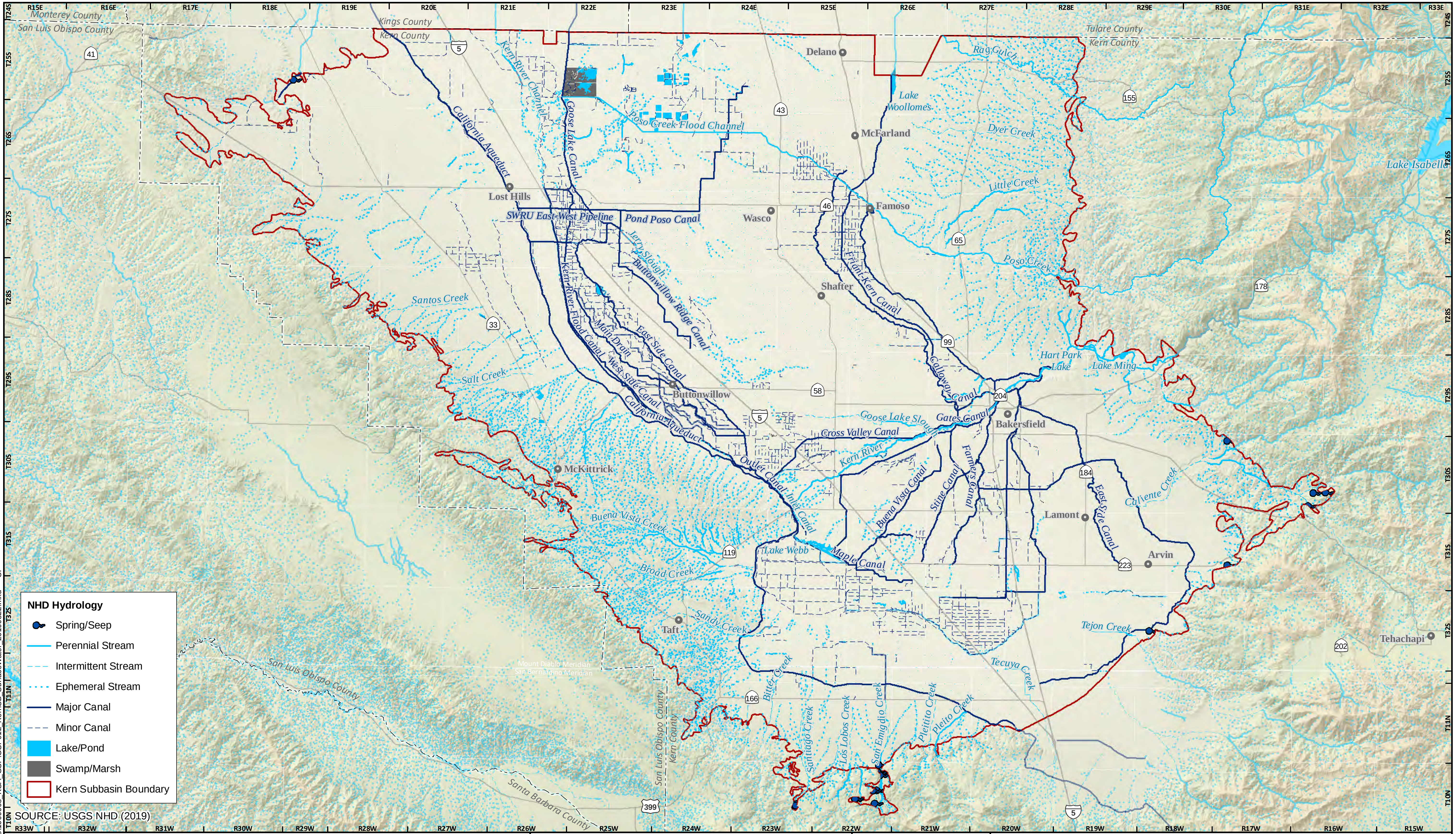
GEI Consultants

AREAS OF DIRECT RECHARGE

AUGUST 2019

FIGURE 2-18

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP011_KernSB_Recharge_20190822.mxd SI



Kern Groundwater Authority
Basin Setting

Kern County, California

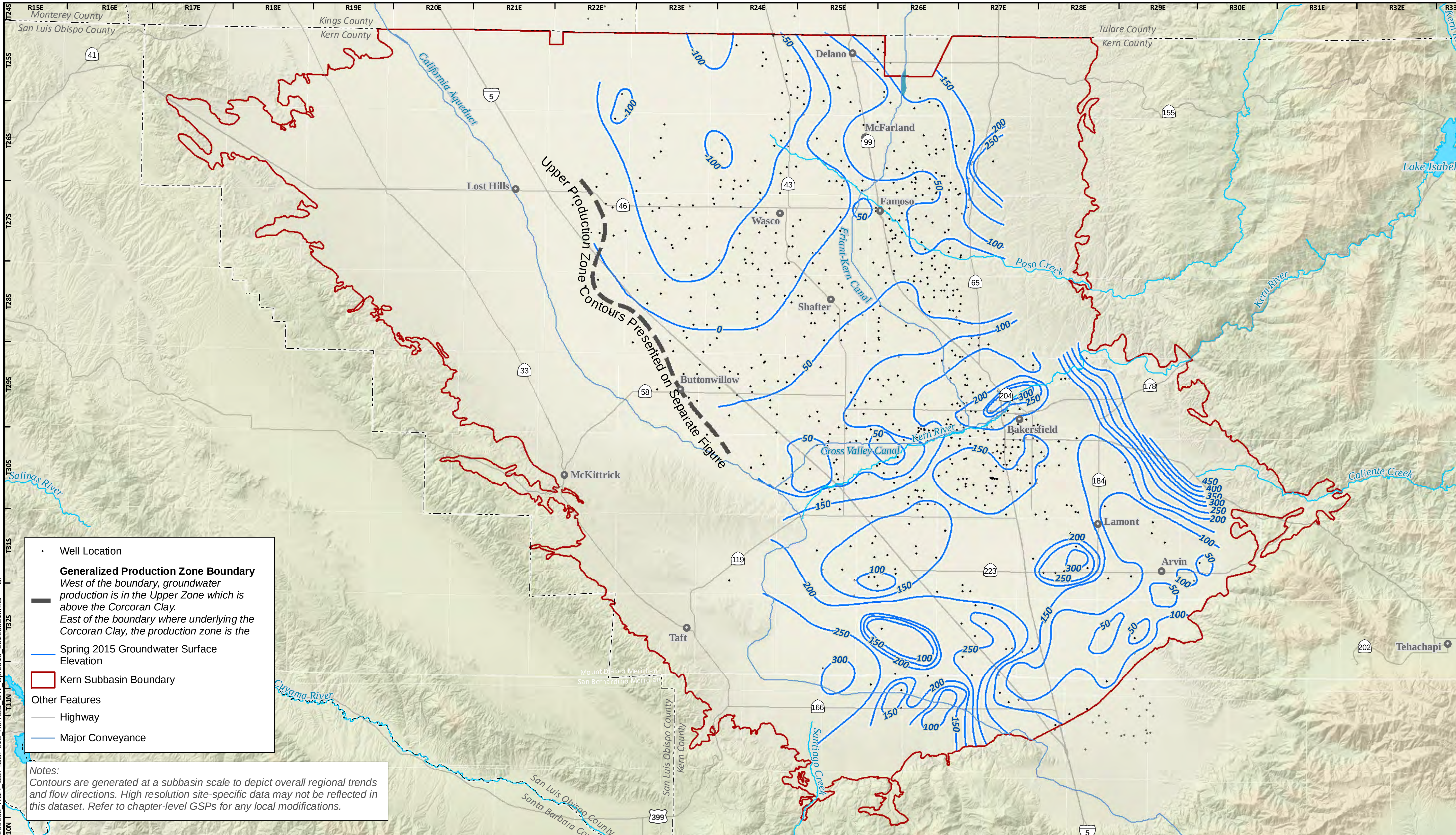
GEI Consultants

SURFACE WATER FEATURES
FROM NATIONAL HYDROGRAPHY DATASET

AUGUST 2019

FIGURE 2-19

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP012_KernSB_SurfaceWater_20190822.mxd SI



0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

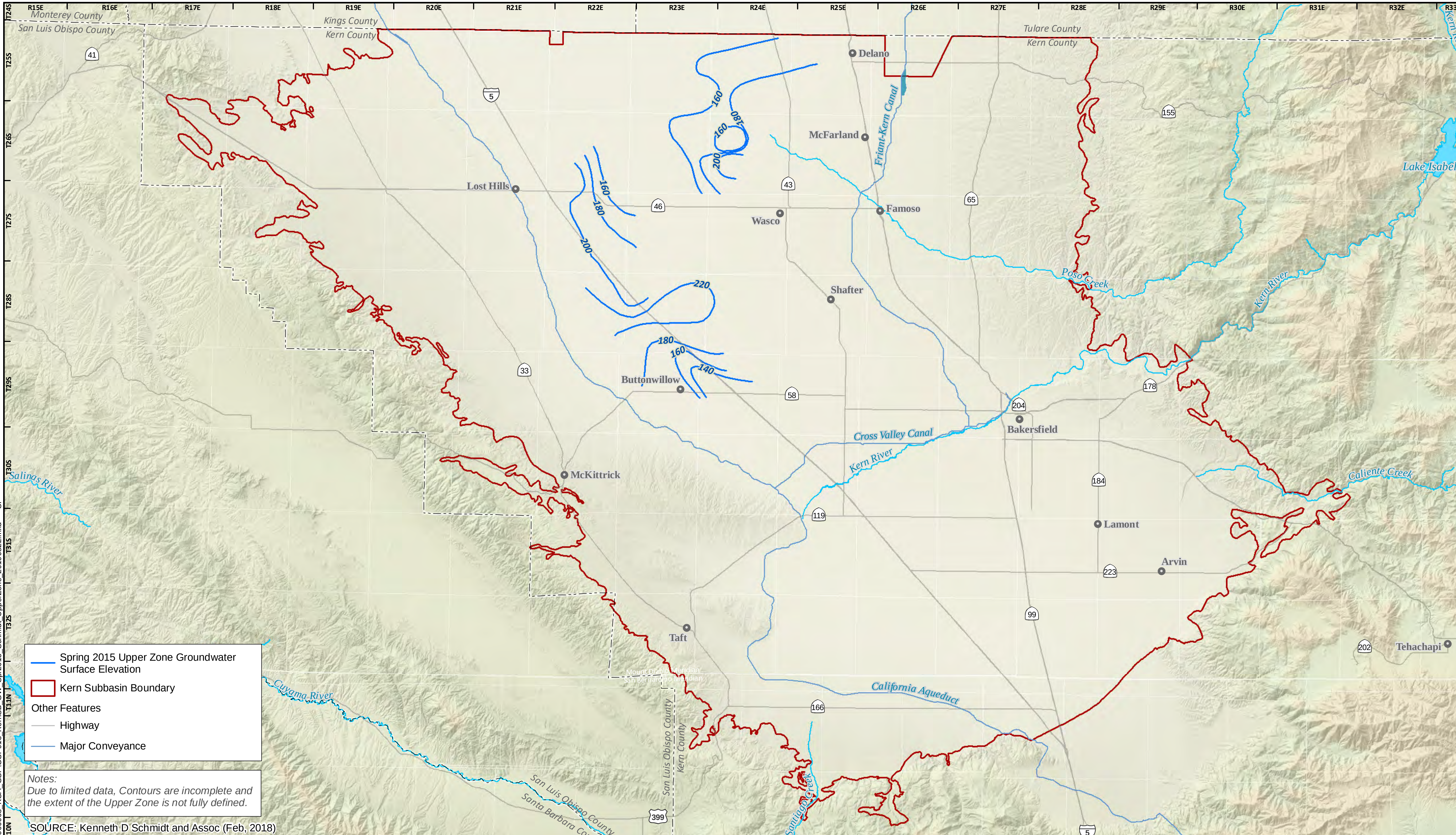
Kern County, California

GEI Consultants

SPRING 2015 REGIONAL GROUNDWATER ELEVATIONS

AUGUST 2019

FIGURE 2-21



Z:\Projects\1900668_KGA_GSP\GSP015_KernSB_GW_Spr2015_Schmidt_UpperZone_20190822.mxd SI

22-Aug-2019

0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

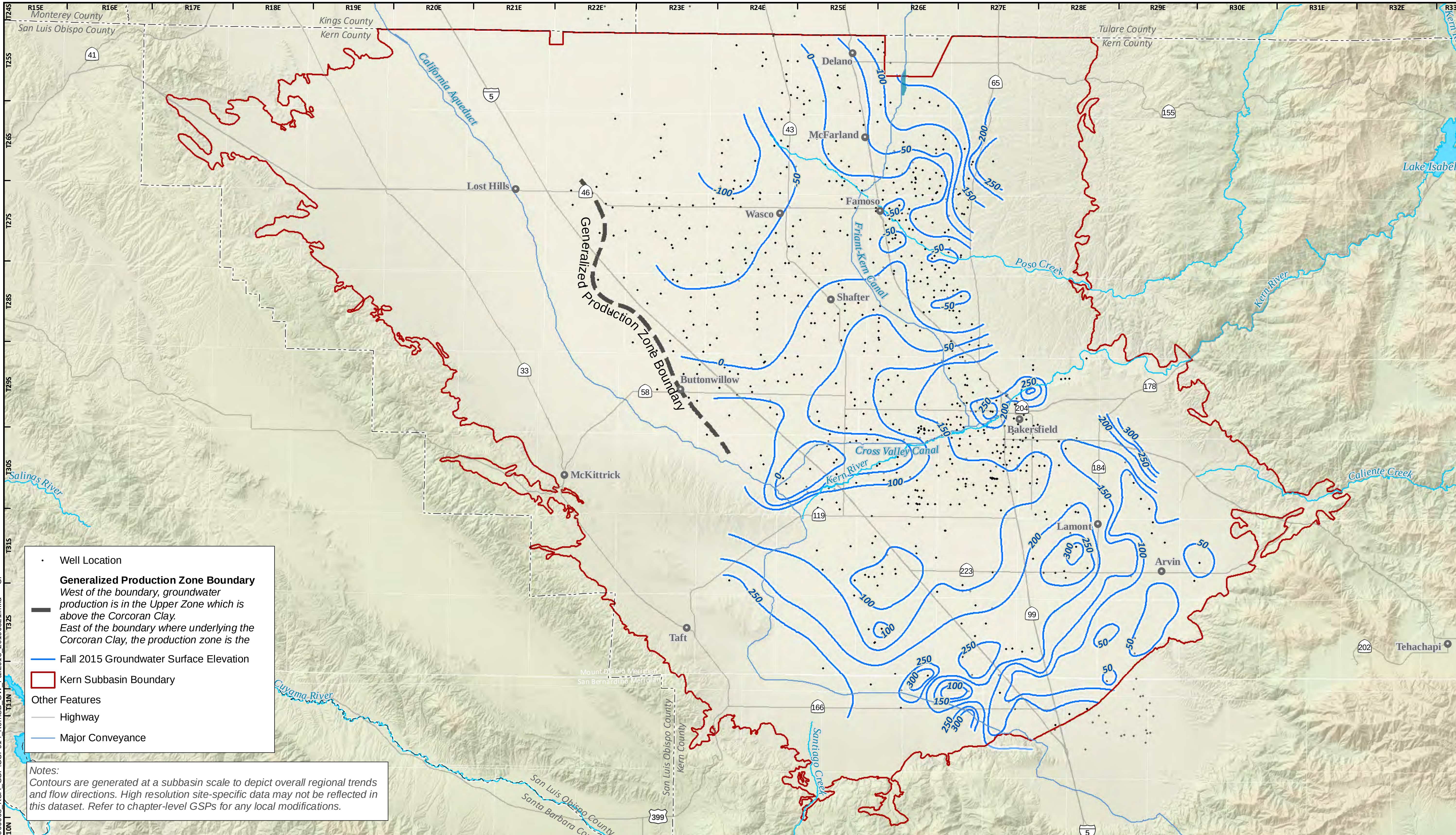
Kern County, California

GEI Consultants

SPRING 2015 UPPER ZONE GROUNDWATER ELEVATIONS

AUGUST 2019

FIGURE 2-22



0 3.5 7 14 21

Miles

N W E S

Kern Groundwater Authority
Basin Setting

Kern County, California

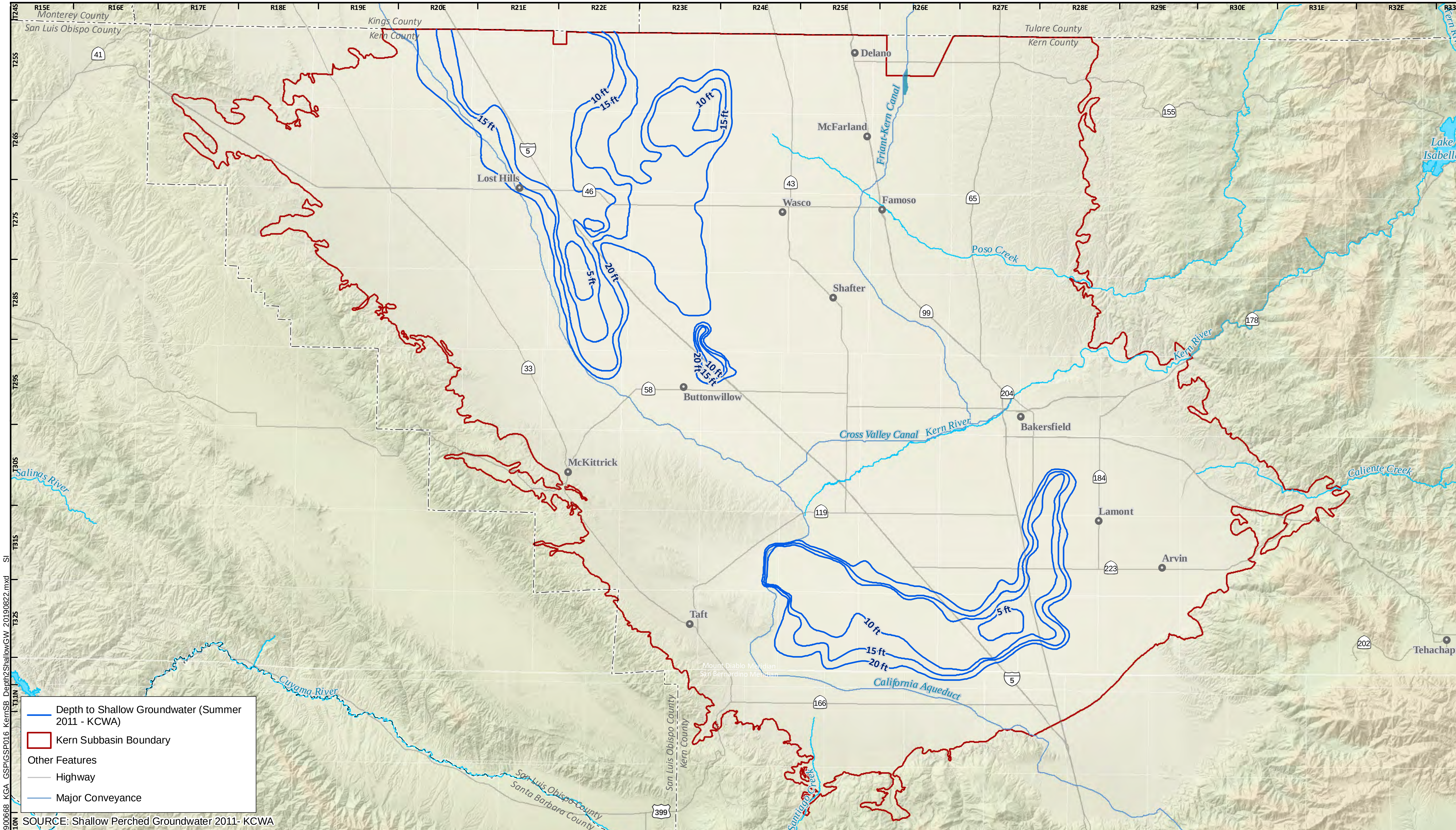
GEI Consultants

FALL 2015 REGIONAL GROUNDWATER ELEVATIONS

AUGUST 2019

FIGURE 2-23

21-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP014_KernSB_GW_Fall2015_20190821.mxd SI



Kern Groundwater Authority
Basin Setting

Kern County, California

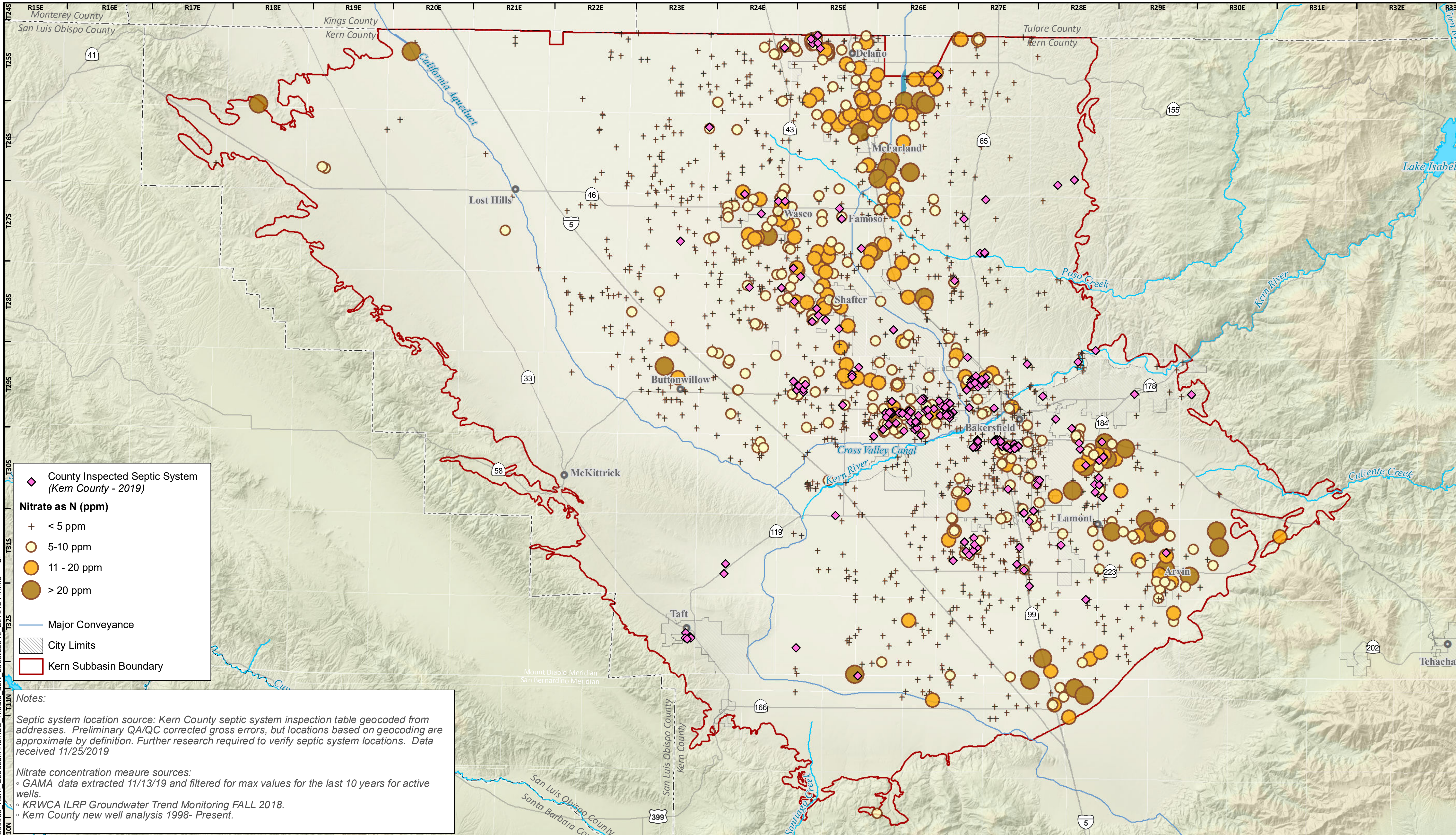
GEI Consultants

SUMMER 2011 UPPER ZONE GROUNDWATER ELEVATIONS

AUGUST 2019

FIGURE 2-24

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP016_KernSB_Depth2ShallowGW_20190822.mxd SI



Notes:

Septic system location source: Kern County septic system inspection table geocoded from addresses. Preliminary QA/QC corrected gross errors, but locations based on geocoding are approximate by definition. Further research required to verify septic system locations. Data received 11/25/2019

Nitrate concentration meaure sources:
◦ GAMA data extracted 11/13/19 and filtered for max values for the last 10 years for active wells.
◦ KRWCA ILRP Groundwater Trend Monitoring FALL 2018.
◦ Kern County new well analysis 1998- Present.

Kern Groundwater Authority
Basin Setting

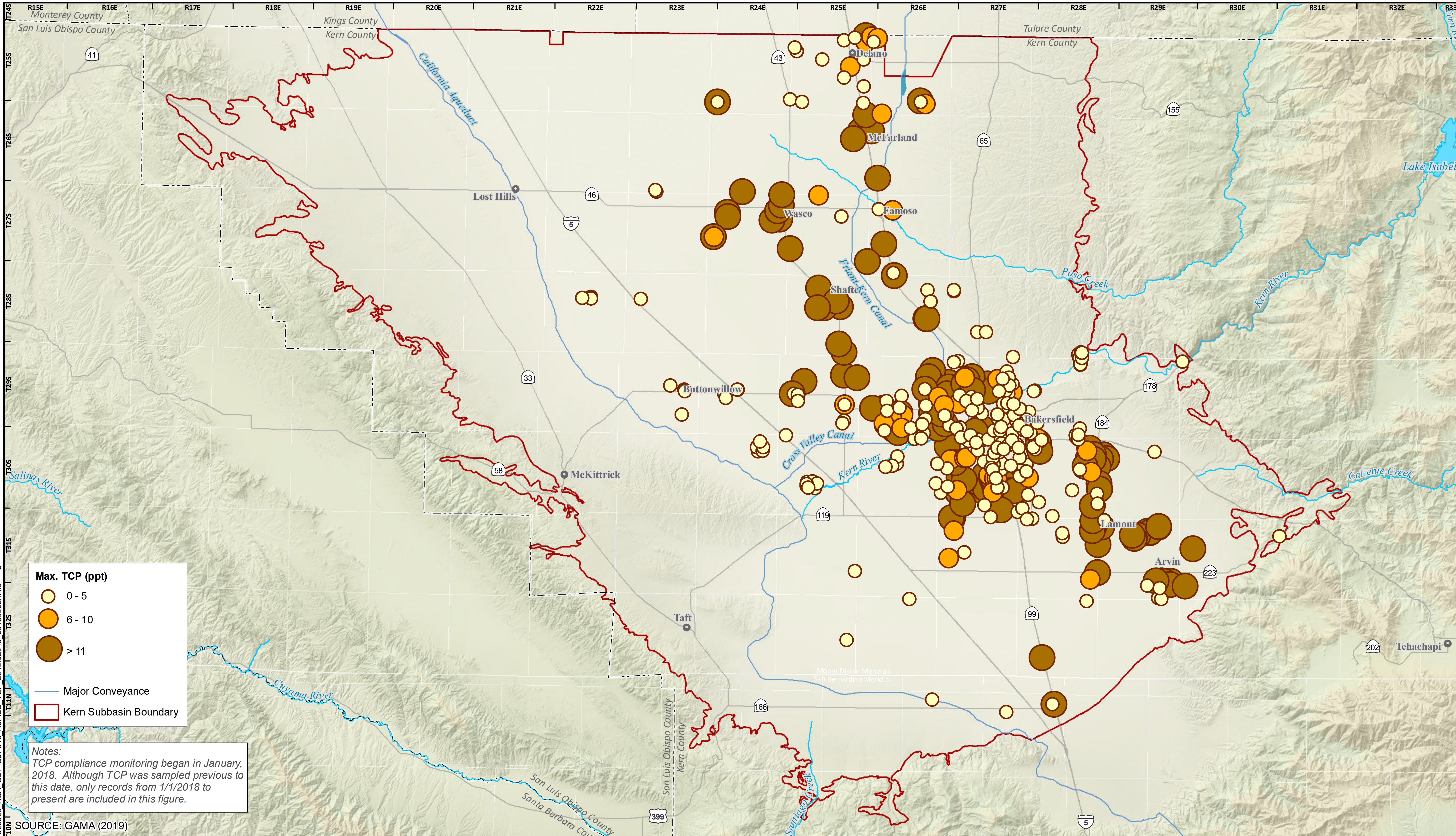
Kern County, California

GEI Consultants

NITRATE CONCENTRATIONS AND SEPTIC SYSTEMS

DECEMBER 2019

FIGURE 2-25



0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

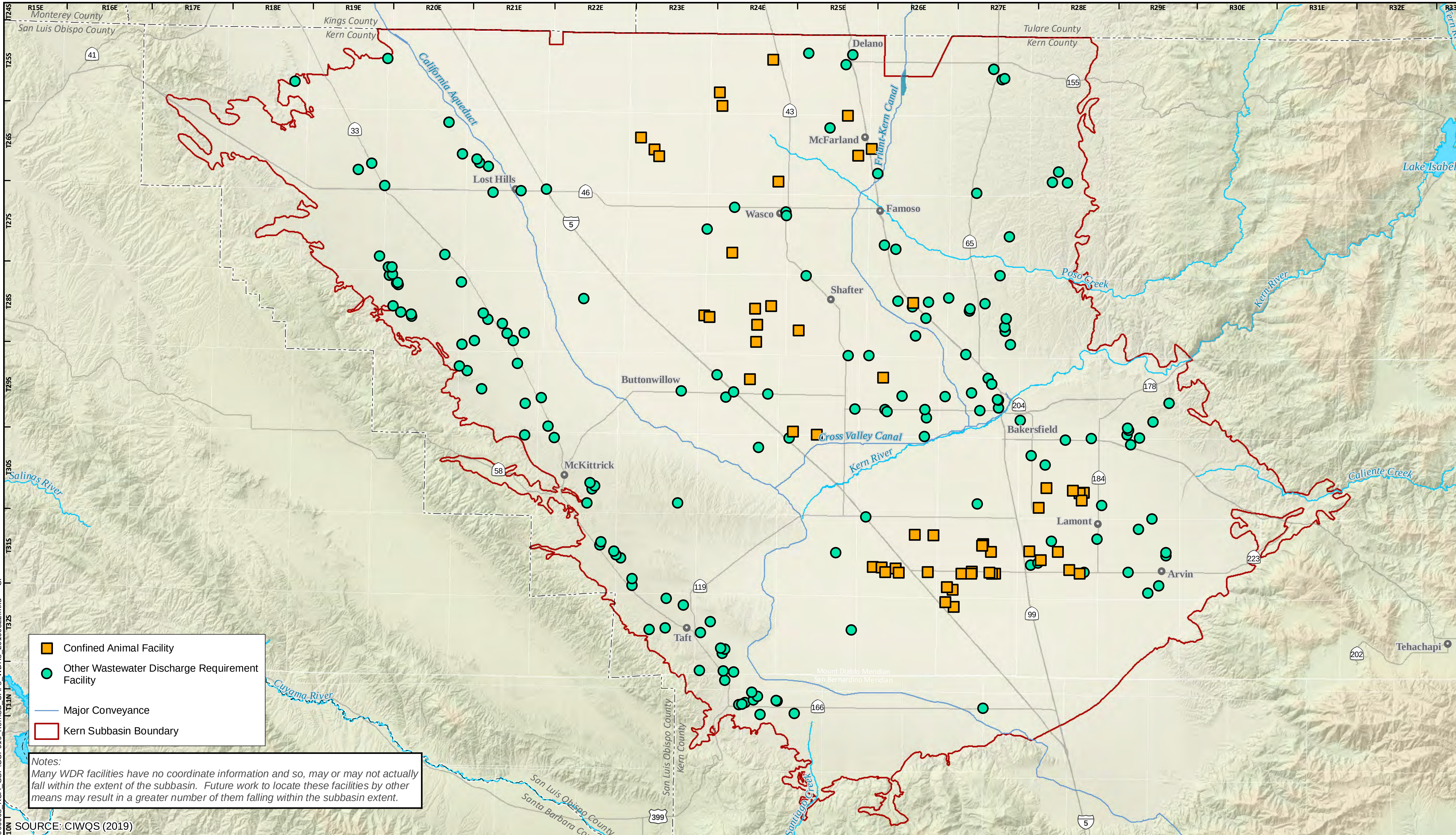
GEI Consultants

MAXIMUM TCP CONCENTRATIONS FROM PUBLIC SUPPLY WELLS FROM JAN. 2018 – APR. 2019

JULY 2019

FIGURE 2-26

Z:\Projects\1900668_KGA_GSP\GSP018_KernSB_TCP_2018to2019_20190822.mxd SI
12-Dec-2019



0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

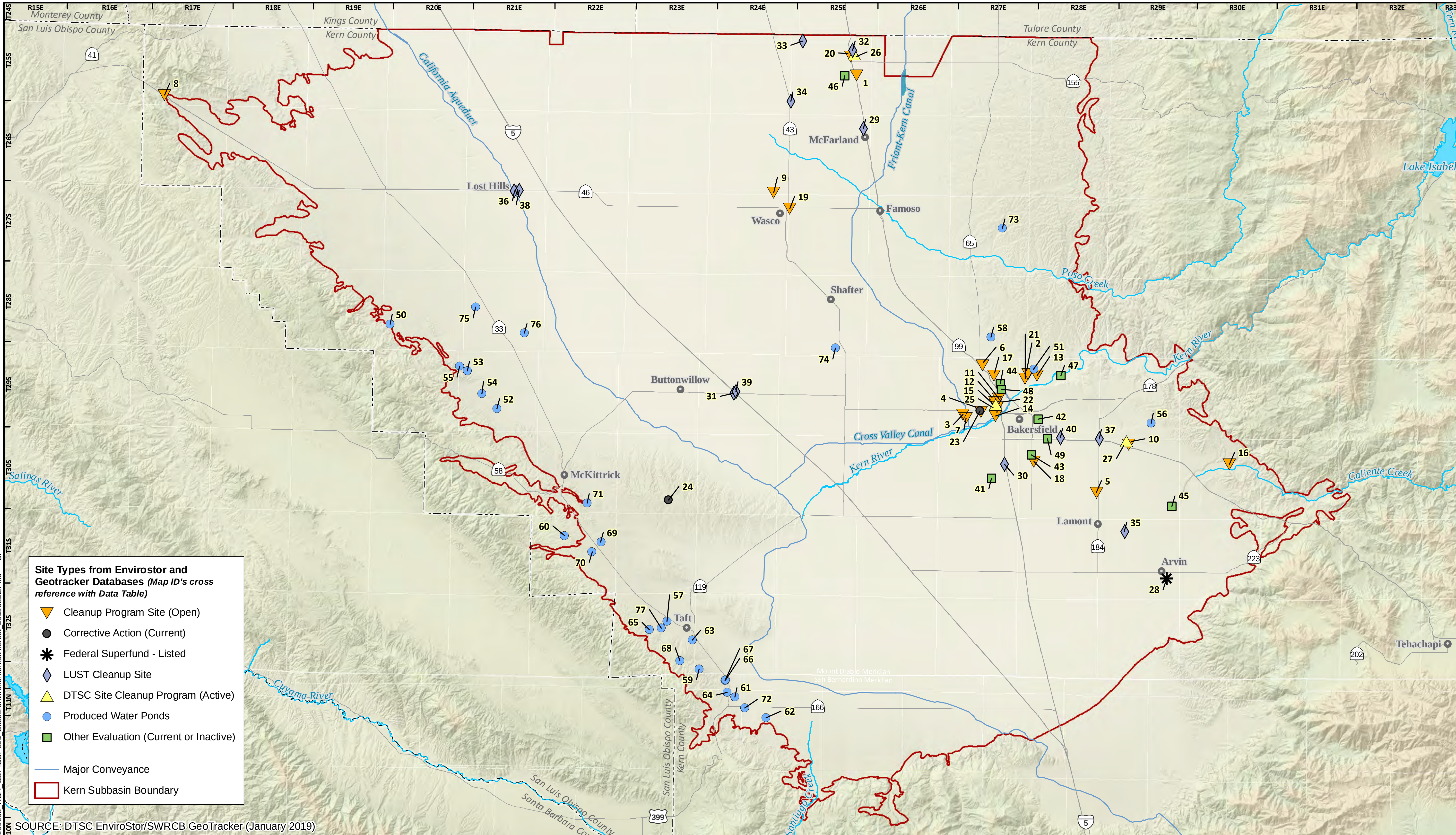
GEI Consultants

PERMITTED DISCHARGE LOCATIONS

AUGUST 2019

FIGURE 2-27

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP019_KernSB_CAFs_WDRs_20190822.mxd SI



Z:\Projects\1900668_KGA_GSP\GSP021_Sitesofenvironementalinterest_20190822.mxd SI

22-Aug-2019

0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

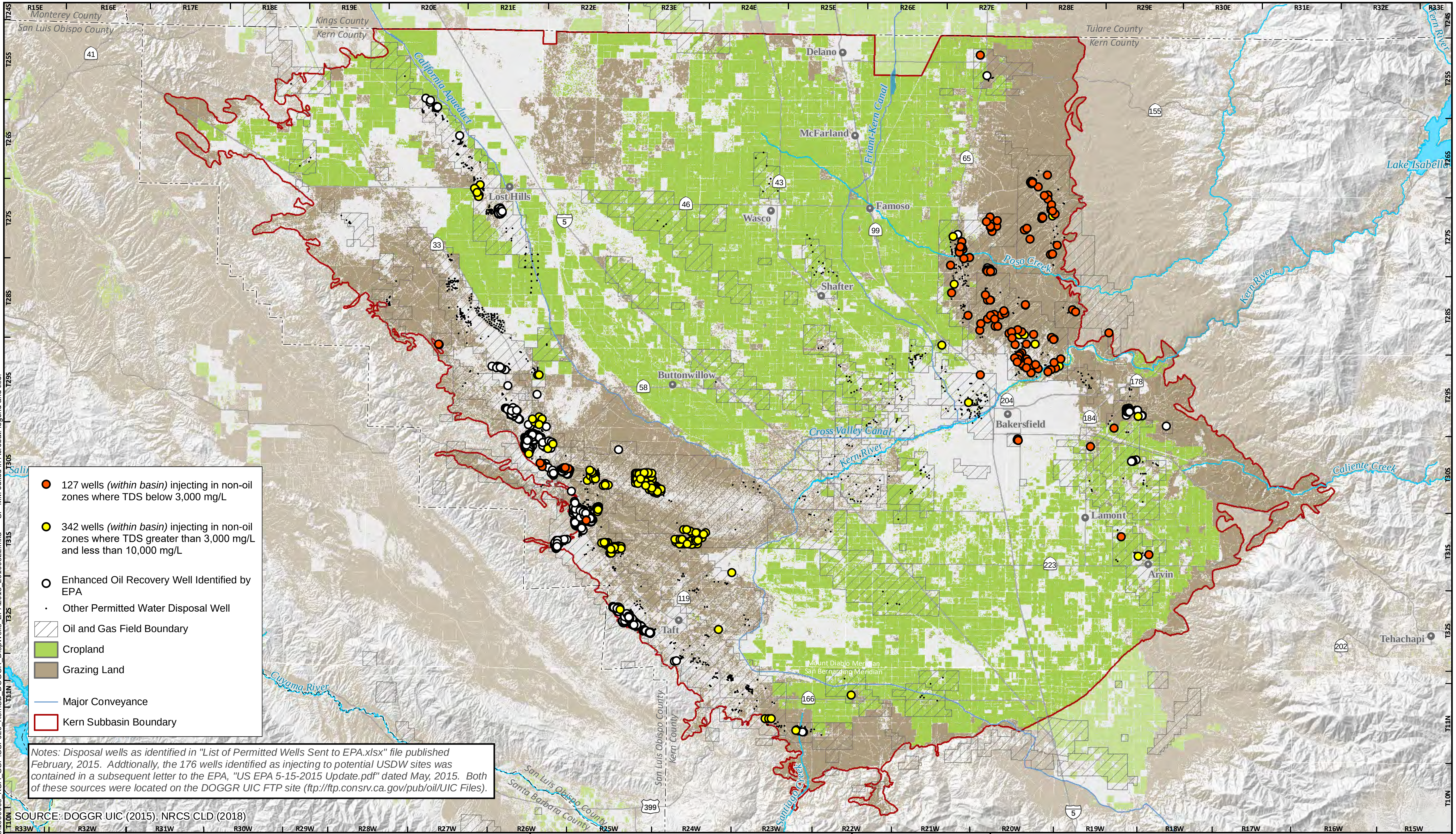
Kern County, California

GEI Consultants

CLEAN-UP SITES LISTED IN ENVIROSTOR AND GEOTRACKER DATABASES

AUGUST 2019

FIGURE 2-28



0 3.5 7 14 21

Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

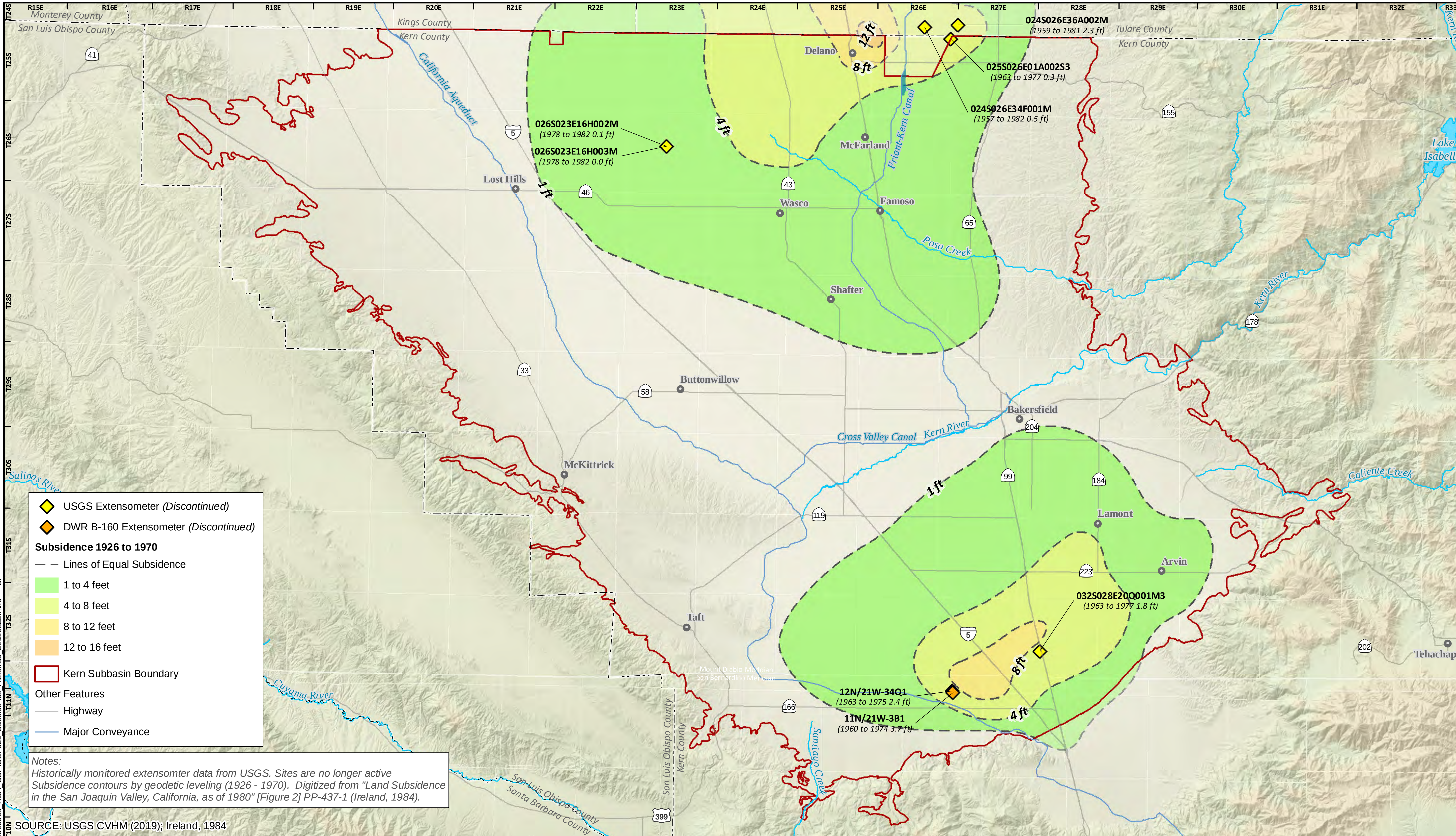
GEI Consultants

OIL AND GAS WELLS IN THE
UNDERGROUND INJECTION CONTROL PROGRAM

AUGUST 2019

FIGURE 2-29

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP020_KernSB_DOGGR_DispWells_EPA2015_20190822.mxd SI MM edited in Acrobat, legend and title.



Kern Groundwater Authority
Basin Setting

Kern County, California

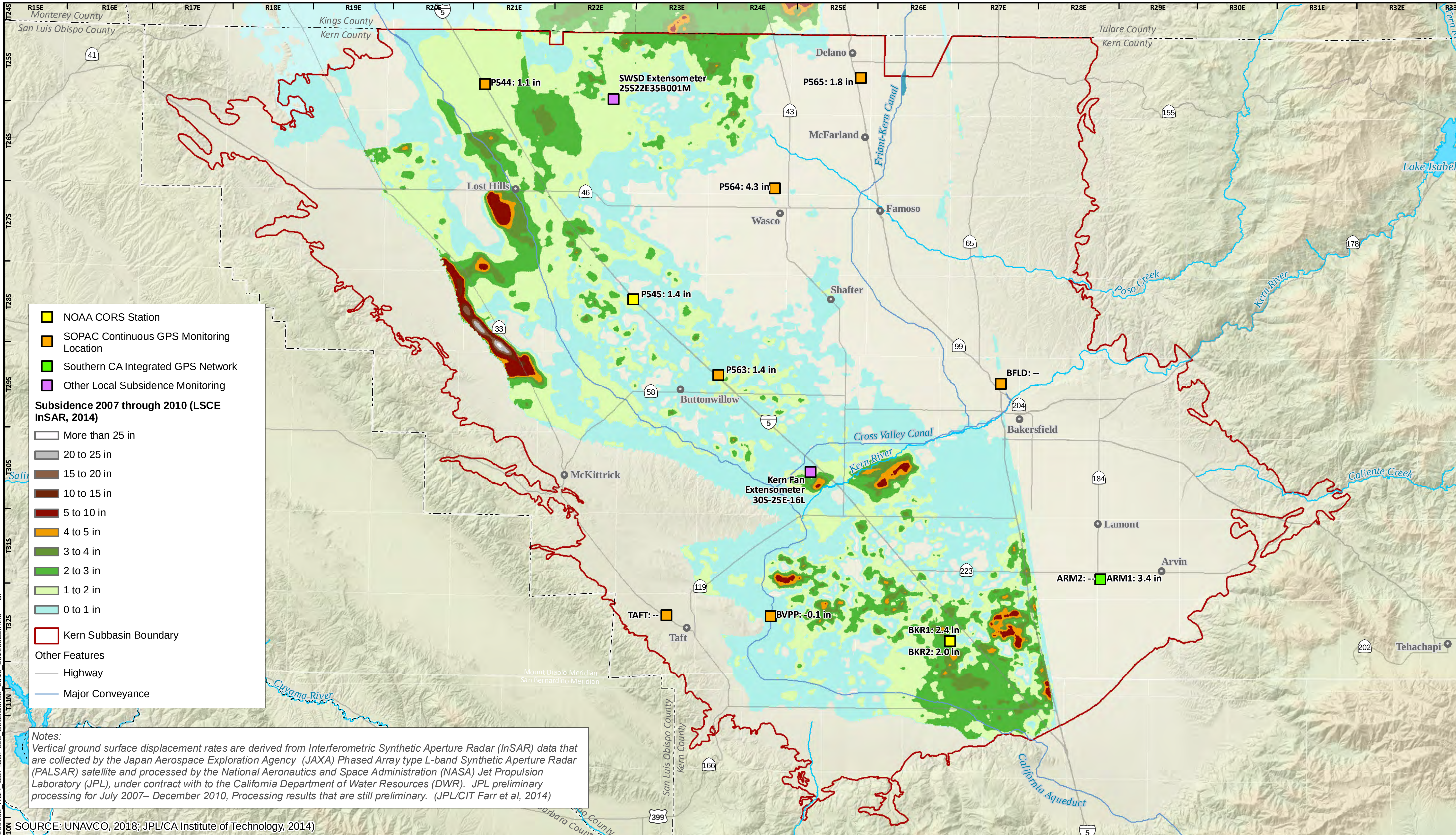
GEI Consultants

HISTORICAL SUBSIDENCE

AUGUST 2019

FIGURE 2-31

Z:\Projects\1900668_KGA_GSP\GSP022_Subsidence_Historical_20190822.mxd SI
22-Aug-2019



0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

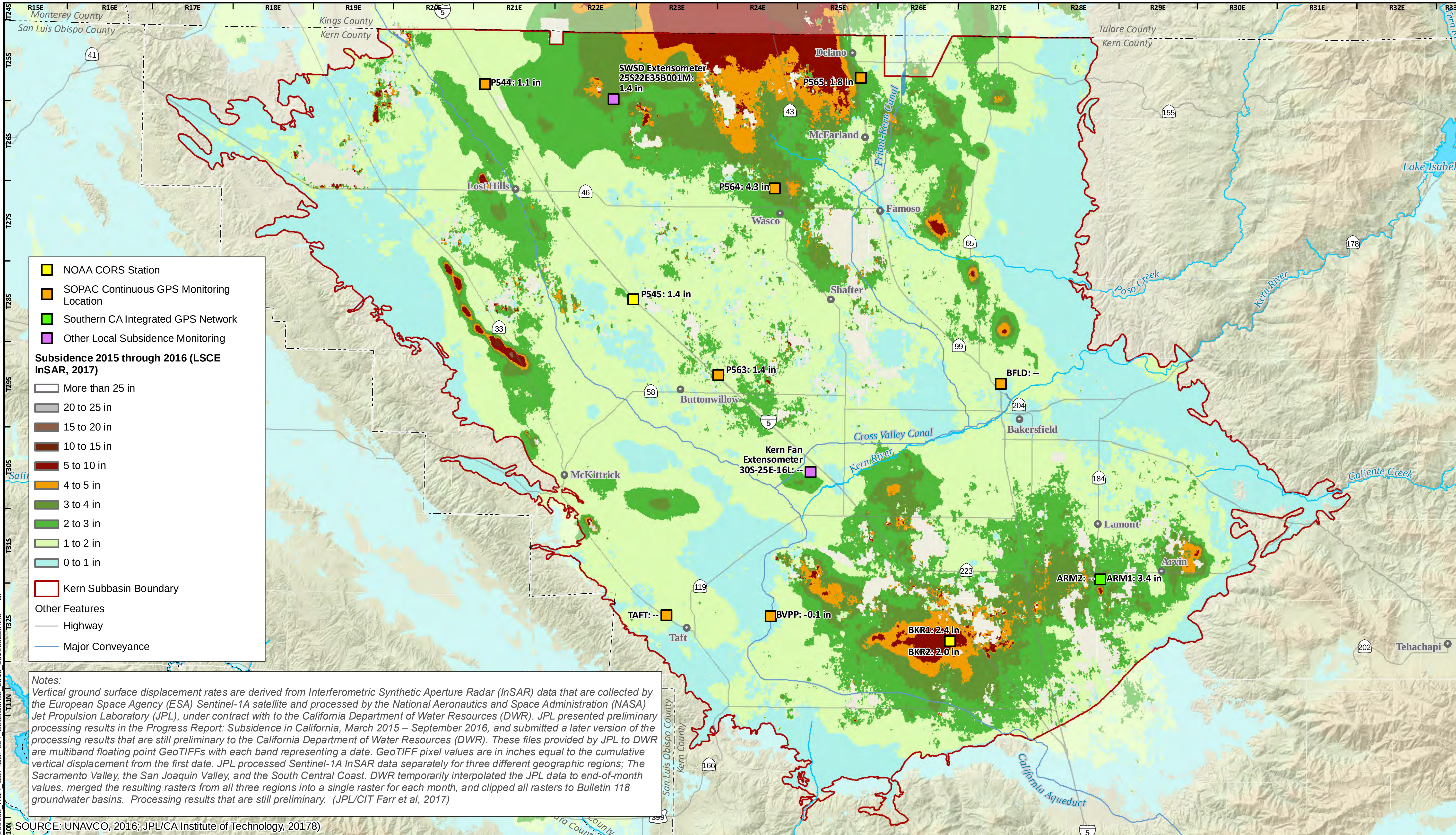
GEI Consultants

SUBSIDENCE 2007 - 2010

AUGUST 2019

FIGURE 2-32

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP023_Subsidence_2010_20190822.mxd SI



Notes:
Vertical ground surface displacement rates are derived from Interferometric Synthetic Aperture Radar (InSAR) data that are collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), under contract with to the California Department of Water Resources (DWR). JPL presented preliminary processing results in the Progress Report: Subsidence in California, March 2015 – September 2016, and submitted a later version of the processing results that are still preliminary to the California Department of Water Resources (DWR). These files provided by JPL to DWR are multiband floating point GeoTIFFs with each band representing a date. GeoTIFF pixel values are in inches equal to the cumulative vertical displacement from the first date. JPL processed Sentinel-1A InSAR data separately for three different geographic regions; The Sacramento Valley, the San Joaquin Valley, and the South Central Coast. DWR temporarily interpolated the JPL data to end-of-month values, merged the resulting rasters from all three regions into a single raster for each month, and clipped all rasters to Bulletin 118 groundwater basins. Processing results that are still preliminary. (JPL/CIT Farr et al, 2017)

SOURCE: UNAVCO, 2016; JPL/CA Institute of Technology, 20178)

0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

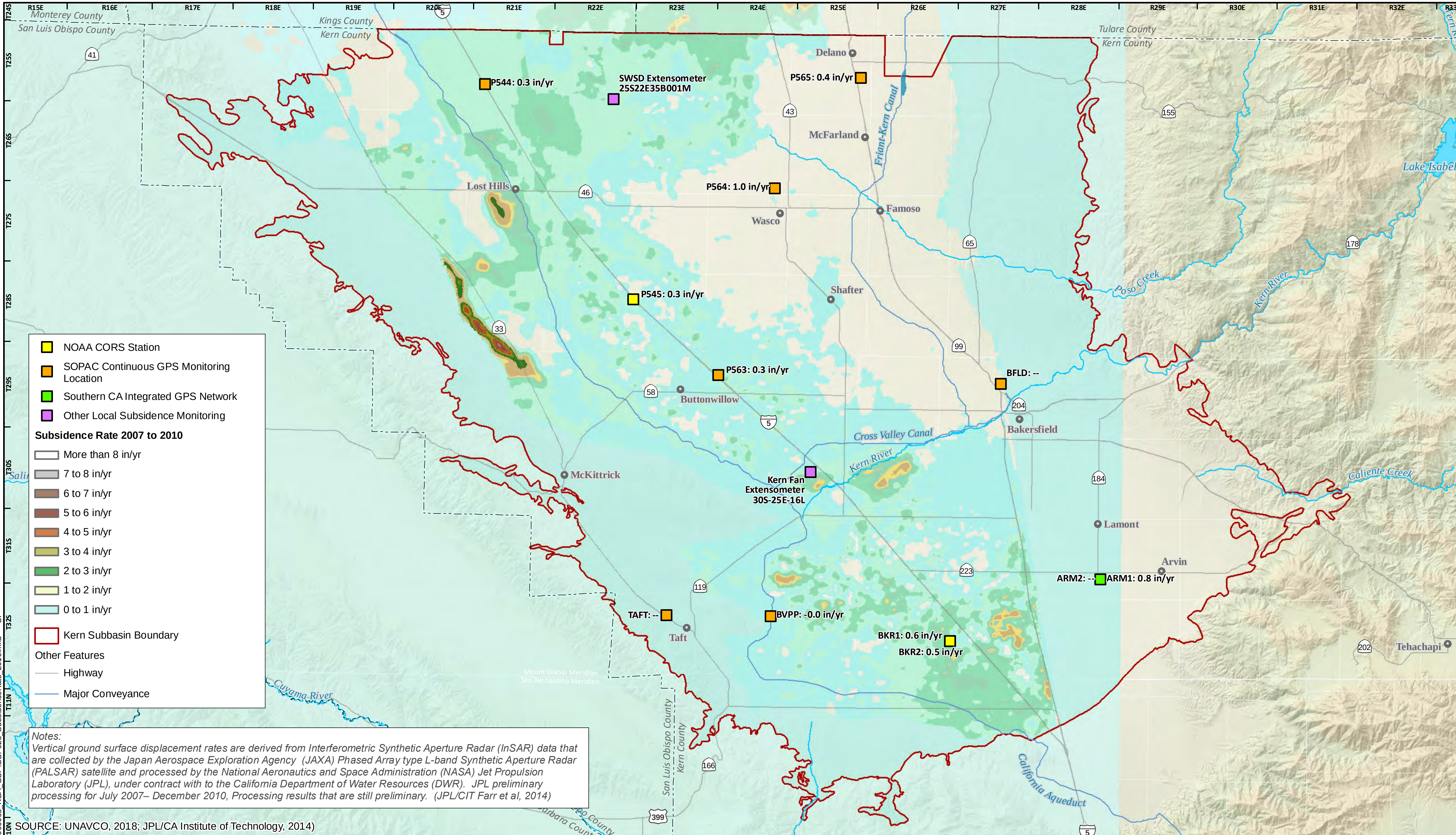
GEI Consultants

SUBSIDENCE 2015 - 2016

AUGUST 2019

FIGURE 2-33

22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP024_Subsidence_2016_20190822.mxd SI



22-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP028_SubsidenceRate_2010.mxd SI

Kern Groundwater Authority
Basin Setting

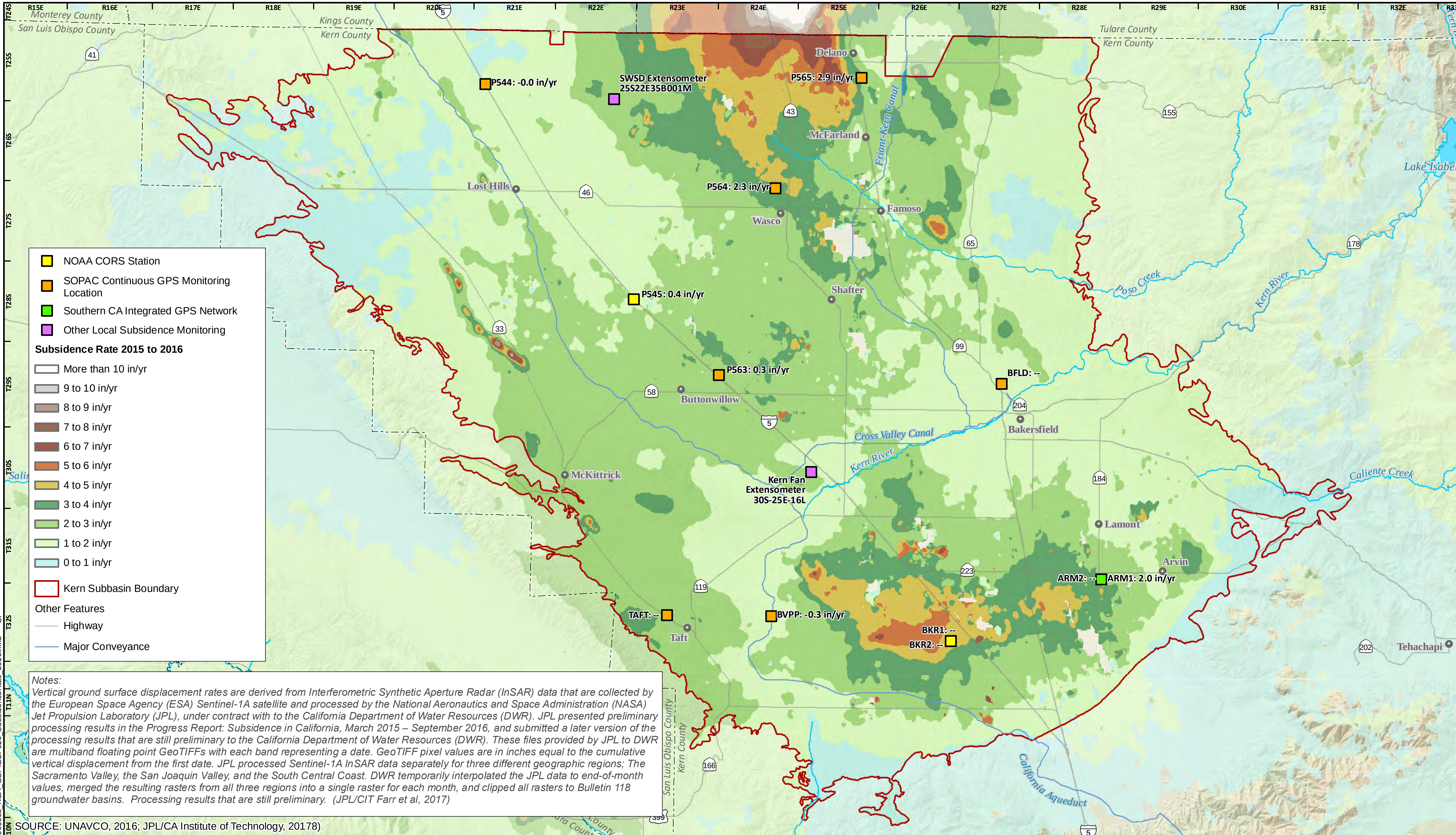
Kern County, California

GEI Consultants

RATE OF SUBSIDENCE 2007-2010

AUGUST 2019

FIGURE 2-34



Notes:
Vertical ground surface displacement rates are derived from Interferometric Synthetic Aperture Radar (InSAR) data that are collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), under contract with to the California Department of Water Resources (DWR). JPL presented preliminary processing results in the Progress Report: Subsidence in California, March 2015 – September 2016, and submitted a later version of the processing results that are still preliminary to the California Department of Water Resources (DWR). These files provided by JPL to DWR are multiband floating point GeoTIFFs with each band representing a date. GeoTIFF pixel values are in inches equal to the cumulative vertical displacement from the first date. JPL processed Sentinel-1A InSAR data separately for three different geographic regions; The Sacramento Valley, the San Joaquin Valley, and the South Central Coast. DWR temporarily interpolated the JPL data to end-of-month values, merged the resulting rasters from all three regions into a single raster for each month, and clipped all rasters to Bulletin 118 groundwater basins. Processing results that are still preliminary. (JPL/CIT Farr et al, 2017)

SOURCE: UNAVCO, 2016; JPL/CA Institute of Technology, 20178)

0 3.5 7 14 21
Miles

Kern Groundwater Authority
Basin Setting

Kern County, California

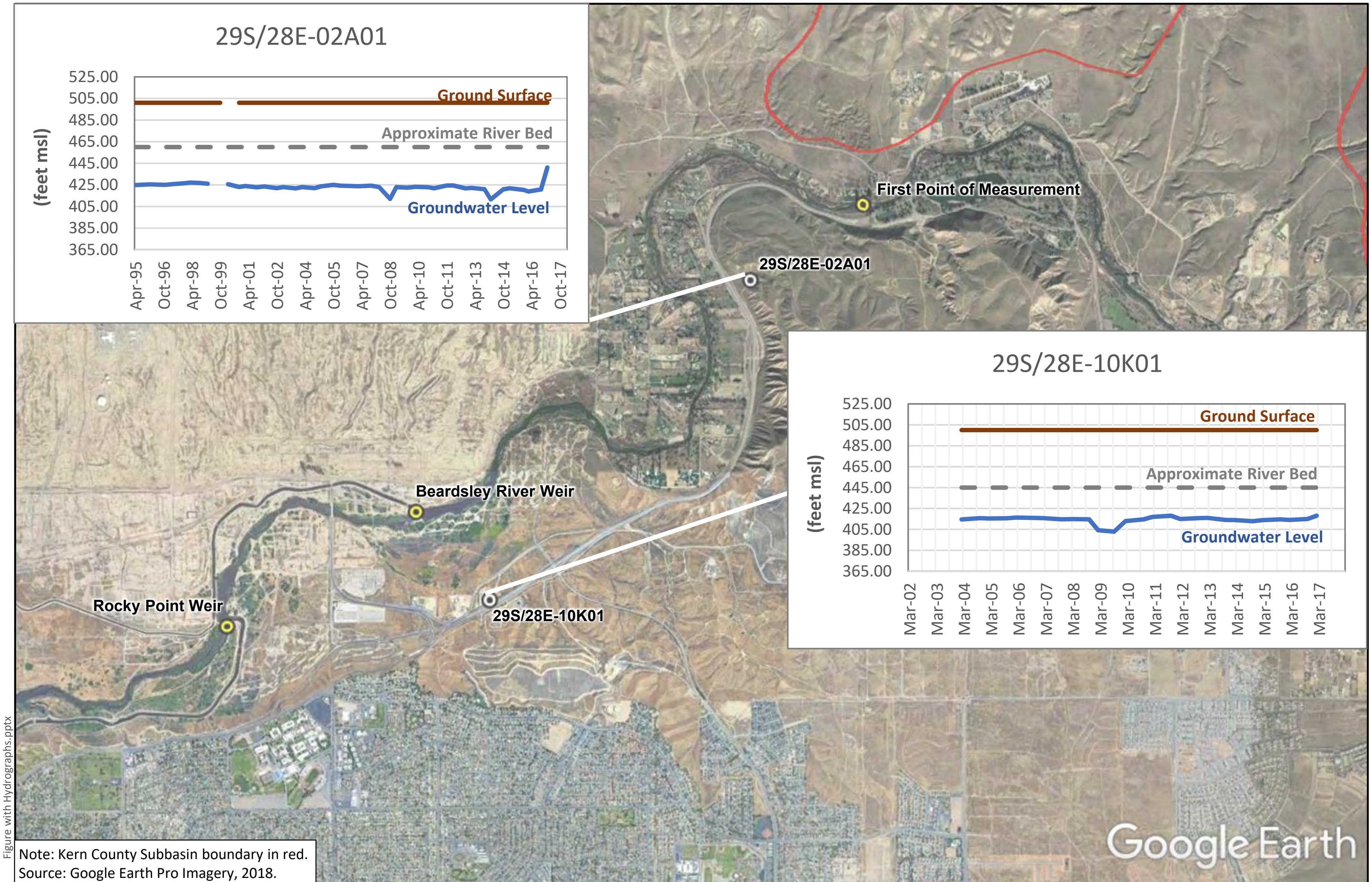
GEI Consultants

RATE OF SUBSIDENCE 2015-2016

AUGUST 2019

FIGURE 2-35

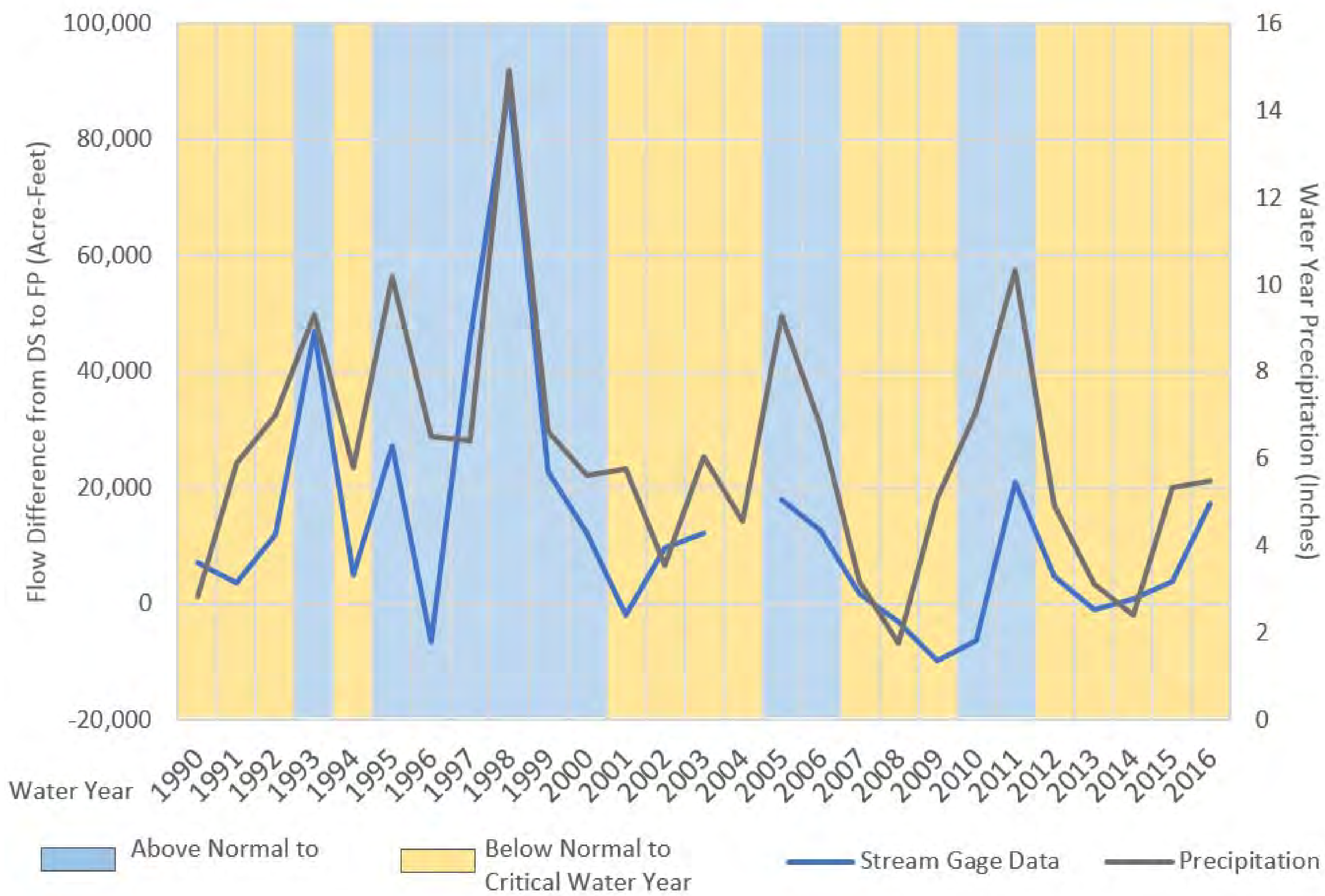
21-Aug-2019 Z:\Projects\1900668_KGA_GSP\GSP029_SubsidenceRate_2016.mxd SI



Note: Kern County Subbasin boundary in red.
Source: Google Earth Pro Imagery, 2018.

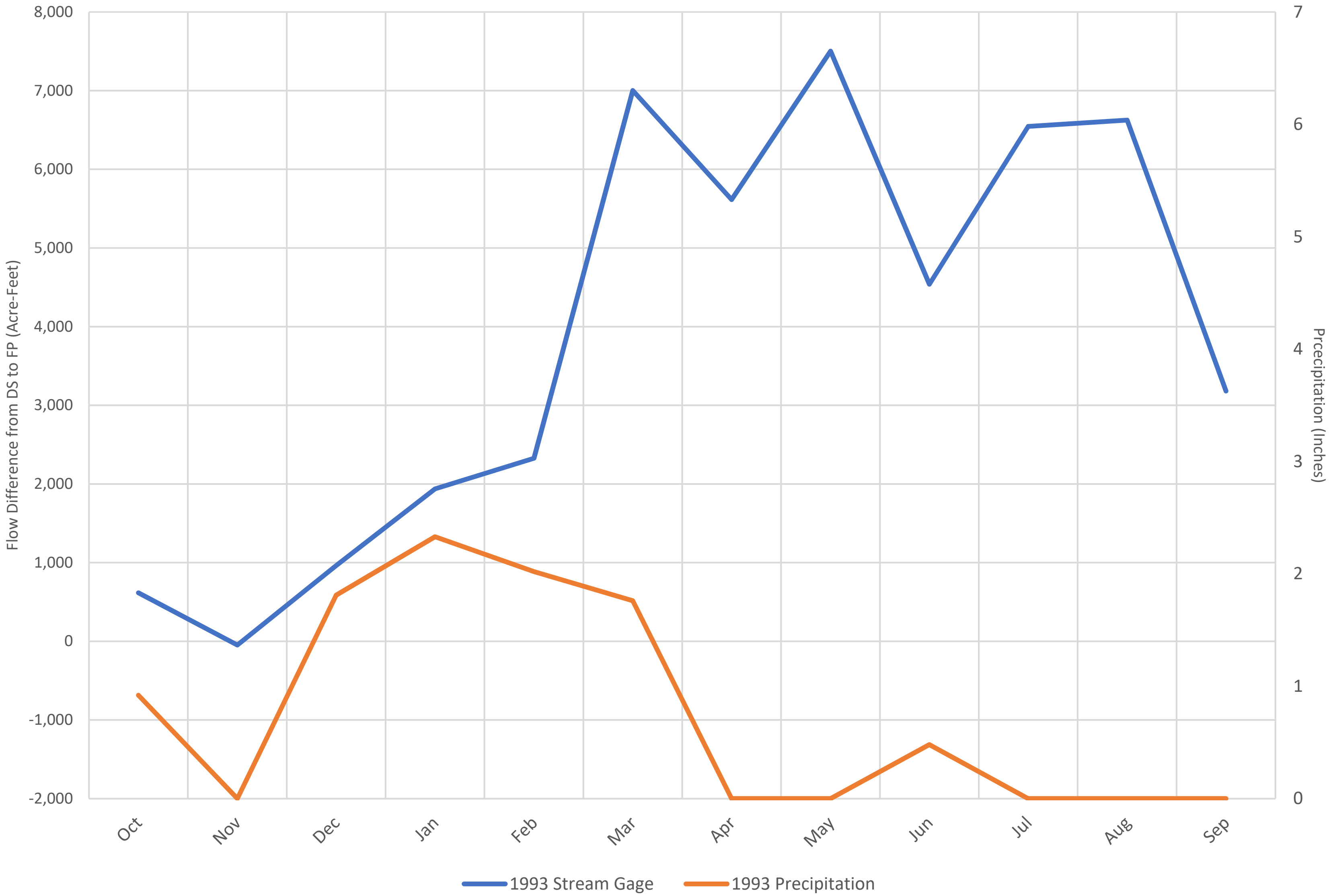
Figure with Hydrographs.pptx

0 0.5 Mile (Approximate) N W E S	Kern Groundwater Authority Basin Setting	GEI Consultants	SUPPLY WELL HYDROGRAPHS
	Kern County, California		AUGUST 2019 — Figure 2-36



Source: Kern River Gaging Stations from Democrat Springs to First Point of Measurement

Kern Groundwater Authority Basin Setting	GEI Consultants	KERN RIVER GAGING DATA DEMOCRAT SPRINGS TO FIRST POINT OF MEASUREMENT	
Kern County, California		AUGUST 2019	Figure 2-37



Source: Kern River Gaging Stations from Democrat Springs to First Point of Measurement

Figure 2-26.pptx

Kern Groundwater Authority Basin Setting	GEI Consultants	Kern River Monthly Gaging Data for 1993 Democrat Springs to First Point of Measurement
Kern County, California		AUGUST 2019 — Figure 2-38

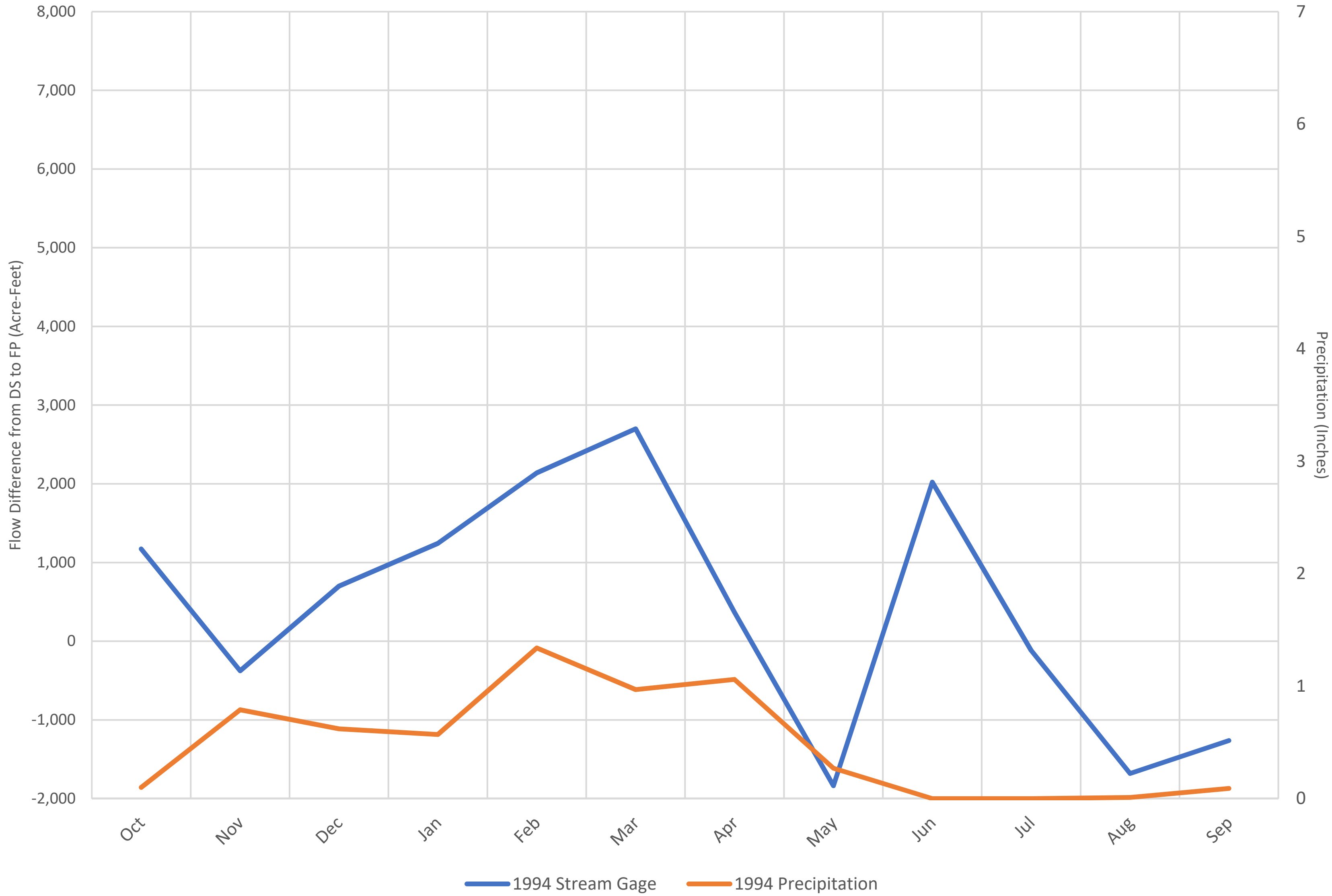
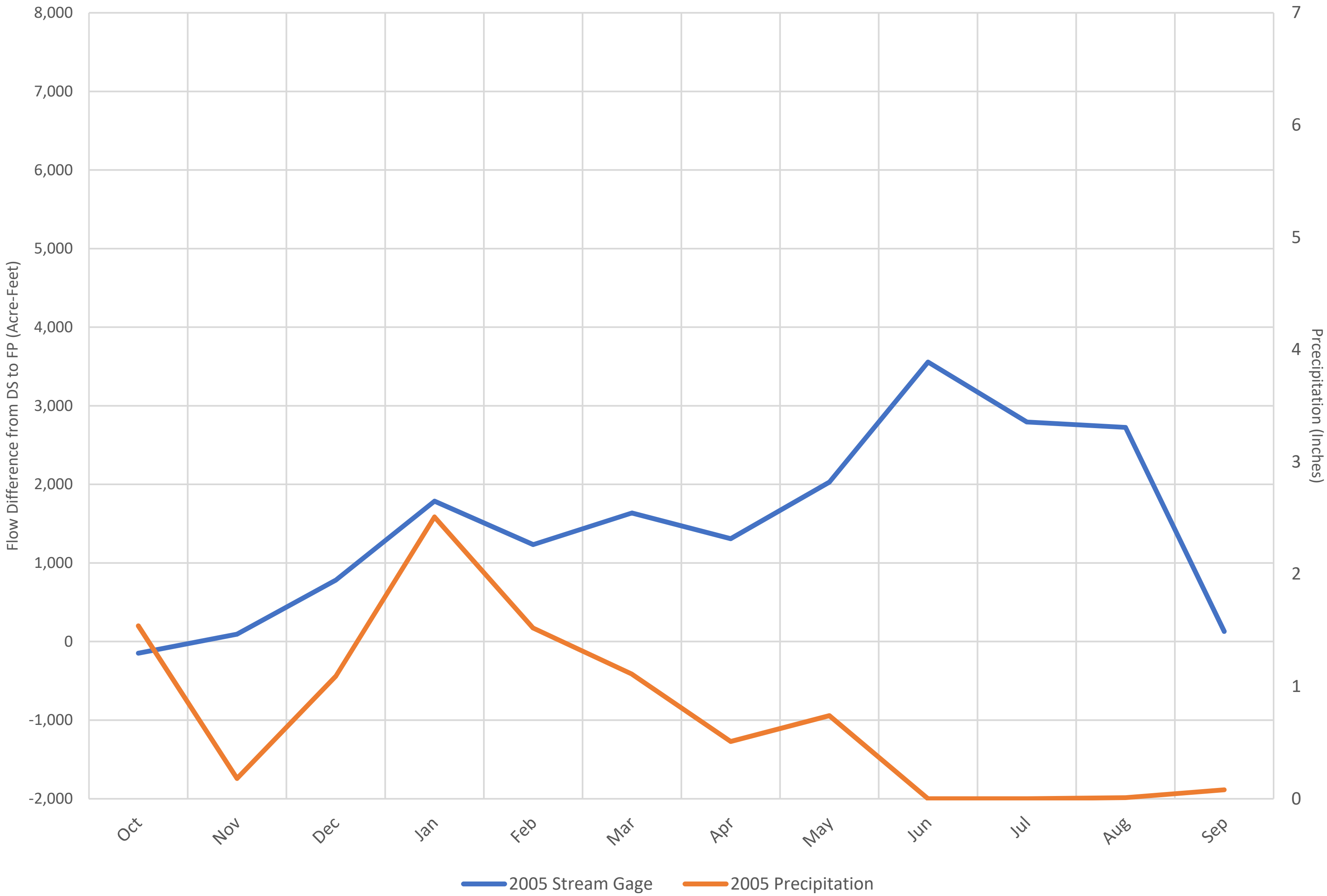


Figure 2-26.pptx

Source: Kern River Gaging Stations from Democrat Springs to First Point of Measurement

Kern Groundwater Authority Basin Setting	GEI Consultants	Kern River Monthly Gaging Data for 1994 Democrat Springs to First Point of Measurement
Kern County, California		AUGUST 2019 — Figure 2-39



Source: Kern River Gaging Stations from Democrat Springs to First Point of Measurement

Figure 2-26.pptx

Kern Groundwater Authority Basin Setting	GEI Consultants	Kern River Monthly Gaging Data for 2005 Democrat Springs to First Point of Measurement
Kern County, California		AUGUST 2019 — Figure 2-40

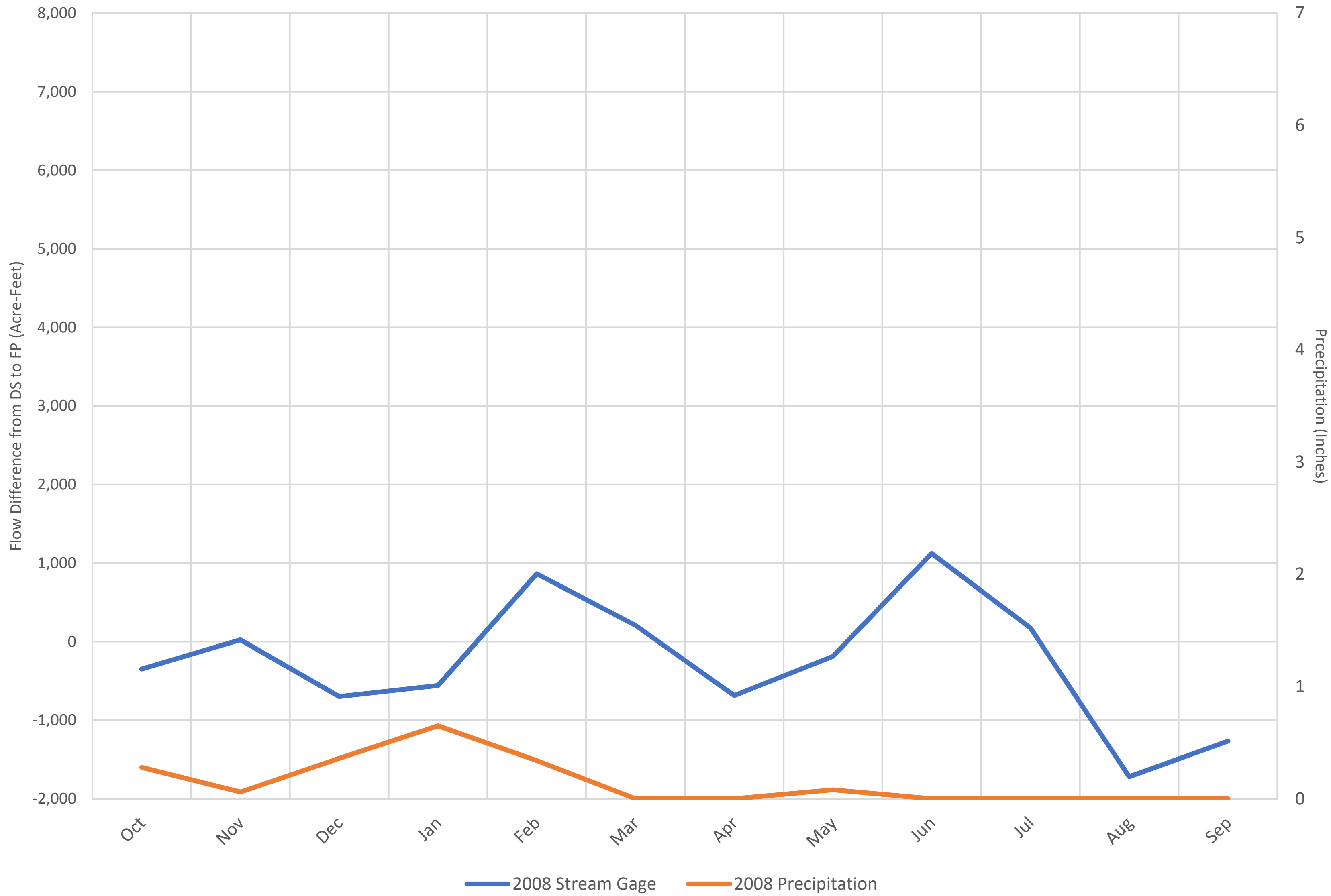


Figure 2-26.pptx

Source: Kern River Gaging Stations from Democrat Springs to First Point of Measurement

Kern Groundwater Authority Basin Setting	GEI Consultants	Kern River Monthly Gaging Data for 2008 Democrat Springs to First Point of Measurement
Kern County, California		AUGUST 2019 Figure 2-41

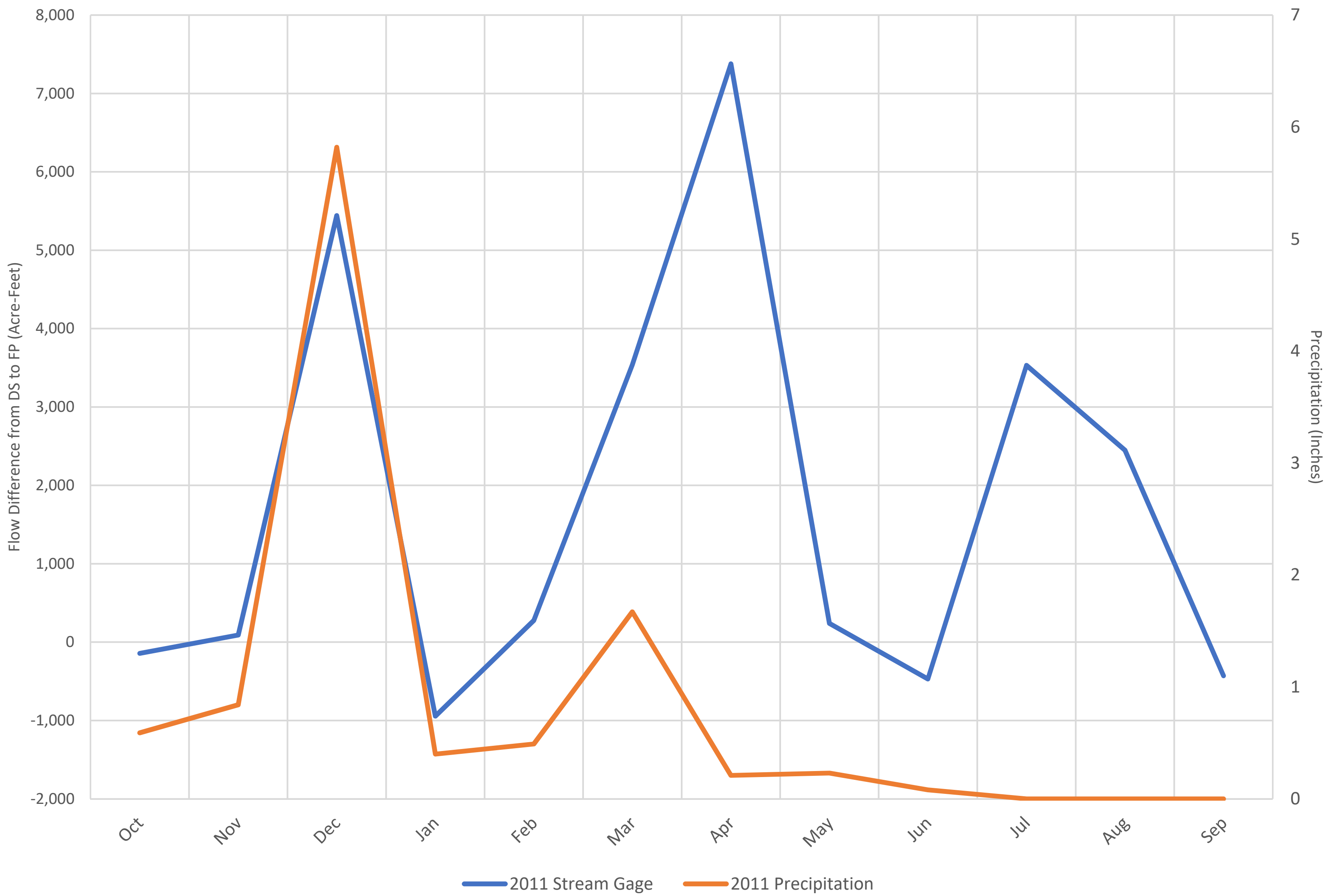
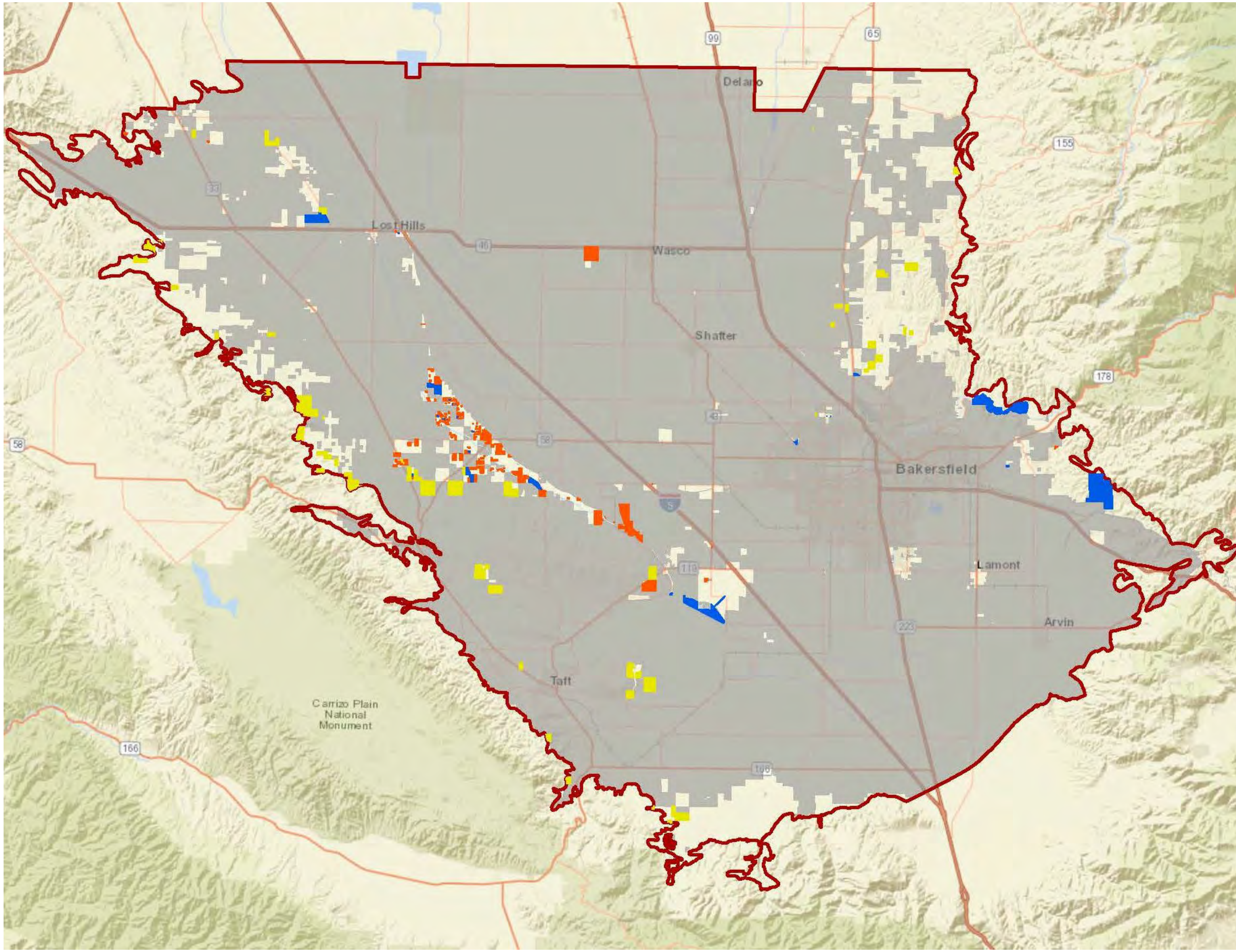


Figure 2-26.pptx

Source: Kern River Gaging Stations from Democrat Springs to First Point of Measurement

Kern Groundwater Authority Basin Setting	GEI Consultants	Kern River Monthly Gaging Data for 2011 Democrat Springs to First Point of Measurement
Kern County, California		AUGUST 2019 Figure 2-42



Kern Groundwater Authority

SJV Kern County GW Subbasin (DWR B118, 2019)

White Area Parcels

By Agency

- County
- Federal
- State

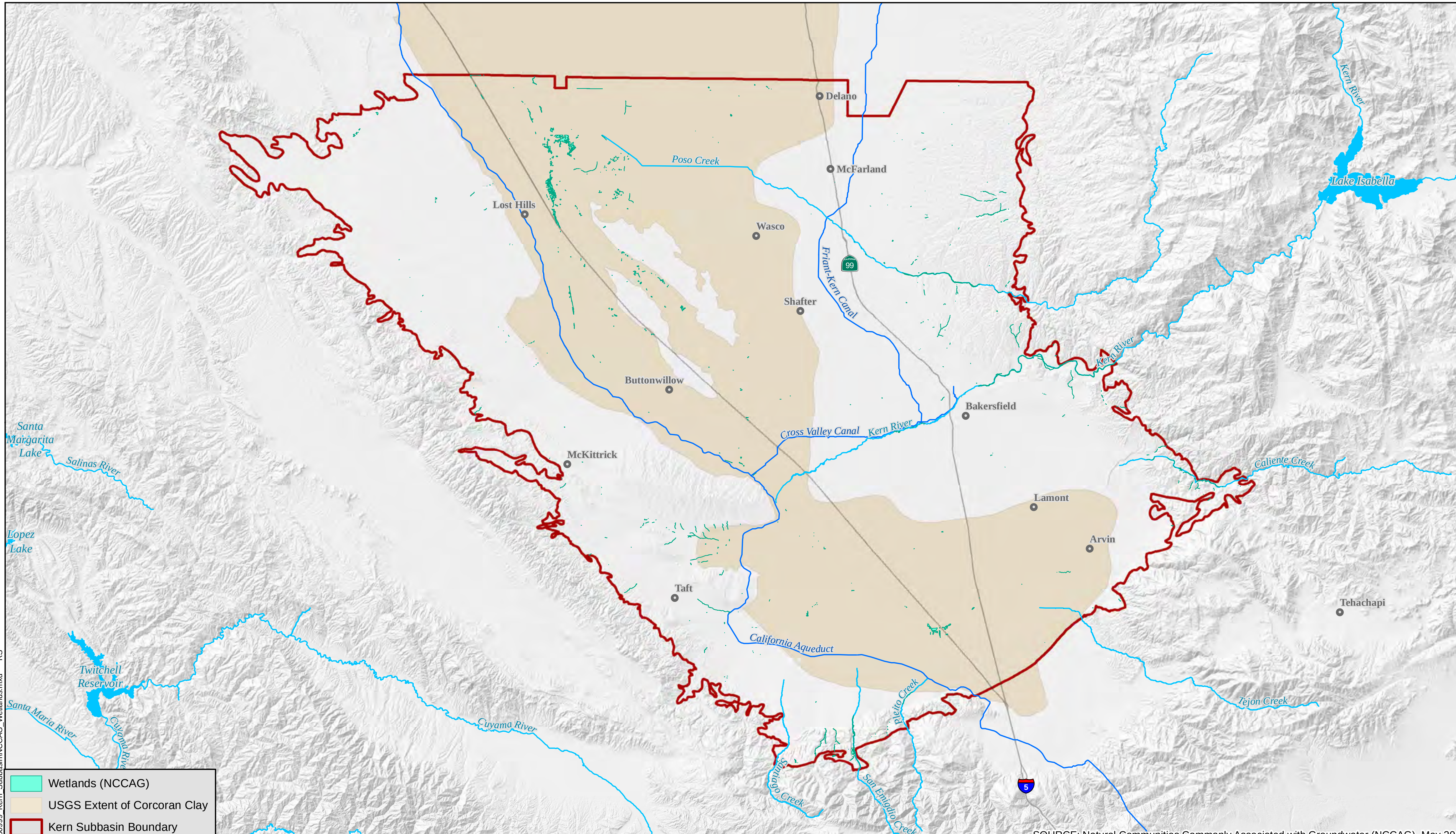
Areas Covered by Agencies

- District Boundary and Managment Areas (parcels)

EST. 1968 PROVOST& PRITCHARD CONSULTING GROUP
An Employee Owned Company

0 5 10 Miles

Kern County Groundwater Authority	GEI Consultants	STATE AND FEDERAL LANDS IN THE KERN COUNTY SUBBASIN
Kern County, California		December, 2019 — Figure 2-43



03Jan2019 Z:\Projects\1800999_Kern_Subbasin\NCCAG_Wetlands.mxd RS

Kern Groundwater Authority
Basin Setting

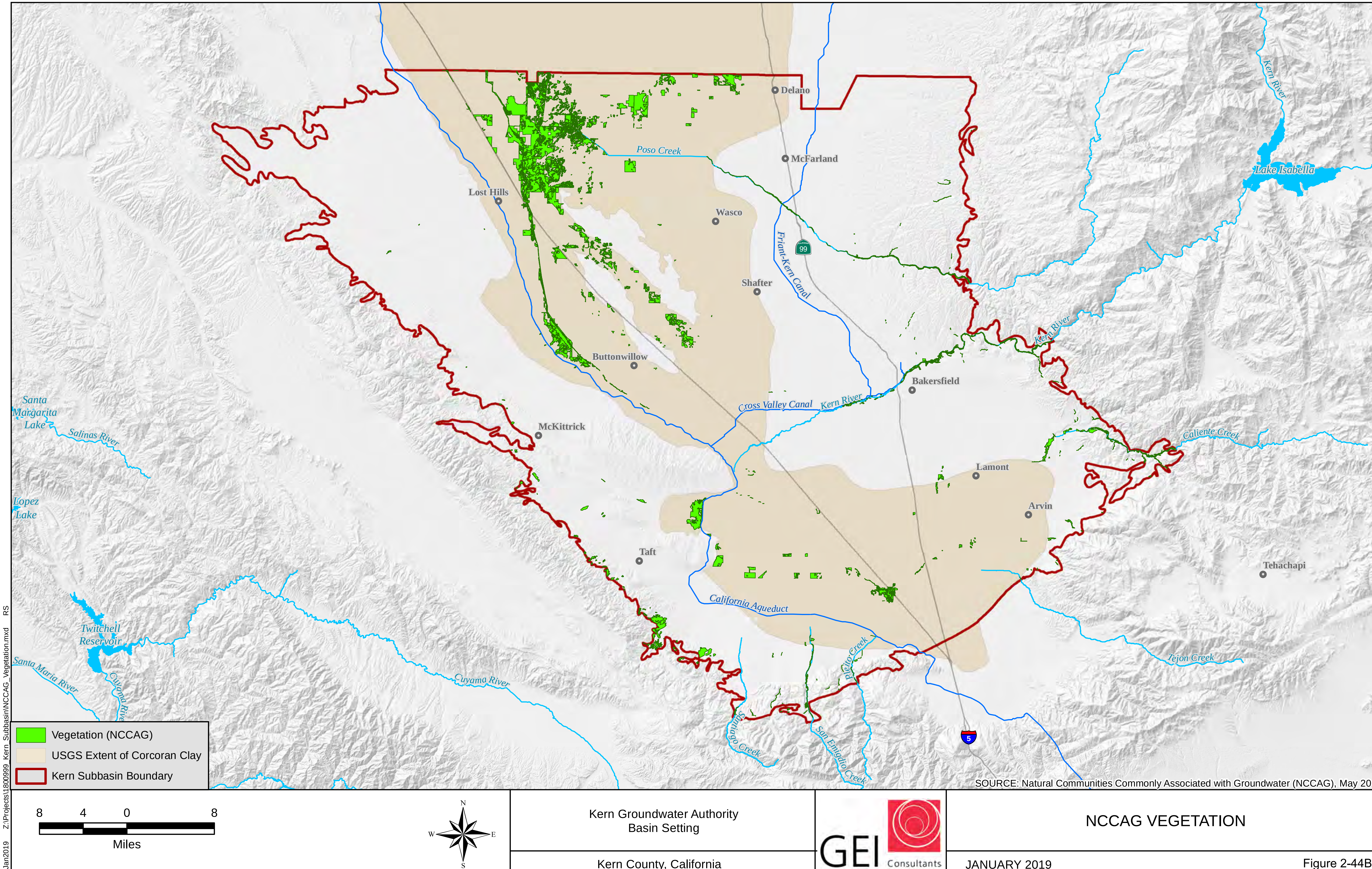
Kern County, California

GEI Consultants

NCCAG WETLANDS

JANUARY 2019

Figure 2-44A



03Jan2019 Z:\Projects\1800999_Kern_Subbasin\NCCAG_Vegetation.mxd RS

Kern Groundwater Authority
Basin Setting

Kern County, California

GEI Consultants

NCCAG VEGETATION

JANUARY 2019

Figure 2-44B

Kern County Water Agency
Estimated Summary of Overdraft Correction Accounts
As of January 31, 2019

Preliminary - Subject to Revision

Quantities in acre-feet

District	Estimated Balance as of December 31, 2017	Estimated Balance as of January 31, 2019					
		Pioneer Property	2800 Acres	Pioneer Project Subtotal	Berrenda Mesa	Kern Water Bank [1]	Total
Buena Vista WSD	38,466	38,466	0	38,466	0	0	38,466
Henry Miller WD	57,993	42,311	375	42,686	2,584	12,723	57,993
Kern County Water Agency	55,030	35,356	7,121	42,477	0	12,553	55,030
Kern Delta WD	72,928	56,882	409	57,291	1,508	14,129	72,928
Rosedale-Rio Bravo WSD	207,143	155,543	3,268	158,811	1,225	47,107	207,143
Total	431,560	328,558	11,173	339,731	5,317	86,512	431,560

[1] Does not include purchase of 2011 4% reserve water.

Figure 2-45 HMWD Overdraft Account Balance as of January 31, 2019

Table 2-1. Generalized Hydrostratigraphy of Kern County Subbasin

Age	Geologic Units of Interest	General Description	Deposition		AE	General Hydrogeologic Context
Recent	Alluvium	Discontinuous beds of sand, silt, clay and gravel, becoming finer grained toward the valley.	Continental / Alluvial	Alluvial Fans		Shallow unconfined aquifer in some areas of the subbasin.
Pleistocene	Older Alluvium		Continental / Alluvial			
	Tulare Formation	Interbedded gravel, sand, silt, and clay.	Continental / Alluvial	Marine, Debris Flows, Fluvial, Semi-arid to arid (West)/ Fluvial-Lacustrine (East)		Major freshwater aquifer of the subbasin.
	Corcoran Clay	Silt and clay. Lacustrine.	Continental / Alluvial			Confining/semi-confining aquitard in the west-central and central-southern subbasin.
	Tulare Formation	Interbedded gravel, sand, silt, and clay.	Continental / Alluvial		**AE**	Major fresh water aquifer of the subbasin.
	Kern River Formation **AE**	Alluvial Fan Deposits. Interbedded gravel, sand, silt, and clay. Fresh water production on east side of the valley.				
Pliocene	San Joaquin Formation	Siltstone, clayey, diatomaceous with thin lenticular sand beds.	Transitional	Continental and brackish to restrictive marine		Fresh water production limited to deep wells.
Miocene	Etchegoin Formation	Clay and silt to sand, gravel, and sandstone	Transitional	Marine to partly continental	**AE**	Fresh water production limited to deep wells.
	Santa Margarita Sandstone	Fine to coarse white sand, gravel, and sandstone.	Transitional / Marine	Shallow Marine Clastic	**AE**	Fresh water aquifer on east/northeast side of the valley
	Chanac Formation **AE**	Conglomerate with lenses of coarse sand and clays Non-Marine Clastic. Limited fresh water production on east side.				
	Round Mountain Silt	Brown siltstone, diatomaceous	Marine	Marine		Aquitard on east side of the subbasin.
	Olcese Sand	Light gray sandstone with a few pebble and siltstone beds.	Marine	Marine/ nonmarine clastic wedge	**AE**	Fresh water aquifer on the east/northeast side of the subbasin.
	Freeman-Jewett Silt	Brown siltstone with interbedded ash.	Marine	Marine to shallow water	**AE**	Aquitard
Oligocene	Pyramid Hills and Vedder Sands	Interbedded sandstone and siltstone	Marine	Marine to shallow water	**AE**	Possible fresh water aquifer on the east/northeast side of the subbasin.

Data sources from: Page, 1986; Bartow, 1983 and 1991; Provost and Pritchard, 2003; Todd Engineers et al, 2007; Scheirer et al, 2007; SWSD, 2012; Tor Nilsen, 1996; and KTWD, 2016.

Aquifer Exemptions present (AE) - California Department of Conservation, https://www.conservation.ca.gov/dog/Pages/Aquifer-Exemptions-Status.aspx.

Table 2-4
GeoTracker and EnviroStor Sites with Potential Groundwater Media
Kern Groundwater Authority
Kern County, California
(Updated January 2019)

New Map ID	Site / Facility Name	ENVIROSTOR/ Geotracker ID	Source	Program Type	Status	Address	City	Zip	CALEnviroscreen Score	X Coord	Y Coord	Constituents of Concern
1	CROP PRODUCTION SERVICES (CPS) DELANO	SL185724257	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	930 WOOLOMES AVE	DELANO	93215-9553	---	-119.2422	35.7466	VOCs and Pesticides, NITRATE, OTHER CHLORINATED HYDROCARBONS, OTHER SOLVENT OR NON-PETROLEUM HYDROCARBON
2	CHEVRON USA (AKA: CHEVRON REFINERY & WAIT TANK YD)	SL205064267	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	2525 NORTH MANOR STREET	BAKERSFIELD	93308	---	-119.0087	35.4238	BENZENE, CRUDE OIL, LEAD, OTHER PETROLEUM
3	PG&E KERN POWER PLANT (FORMER:COFFEE RD. OVERPASS)	SLT5FP024290	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	2401 COFFEE ROAD	BAKERSFIELD	93308-5748	---	-119.094919	35.37920074	BENZENE, CRUDE OIL, OTHER PETROLEUM
4	BAKERSFIELD REFINERY	SL205314279	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	6451 ROSEDALE HIGHWAY	BAKERSFIELD	93308	---	-119.071219	35.38198244	BTEX, TPH, MTBE / TBA / OTHER FUEL OXYGENATES, OTHER SOLVENT OR NON-PETROLEUM HYDROCARBON
5	KERN OIL & REFINING	SL372524510	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	7724 E PANAMA LANE	BAKERSFIELD	93307-9210	---	-118.9169	35.2954	BTEX, TPH, MTBE / TBA / OTHER FUEL OXYGENATES, PAHs
6	BAKERSFIELD AIRPORT BUSINESS PARK (CHEVRON LAND/D)	SL0602981532	Geotracker	CLEANUP PROGRAM SITE	OPEN - VERIFICATION MONITORING	UNICORN RD. AT HWY 99/65	BAKERSFIELD	93308	---	-119.0698	35.4328	CRUDE OIL
7	SUNLAND REFINING CORPORATION	SL205224272	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	2152 COFFEE ROAD	BAKERSFIELD	93308-5746	---	-119.0911102	35.37550916	CRUDE OIL, GASOLINE, MTBE / TBA / OTHER FUEL OXYGENATES
8	CHEVRON - ANTELOPE PUMP STATION	SL0602985189	Geotracker	CLEANUP PROGRAM SITE	OPEN - ASSESSMENT & INTERIM REMEDIAL ACTION	STATE ROUTE 46	LOST HILLS	93249	---	-120.164723	35.71251	CRUDE OIL, WASTE OIL / MOTOR / HYDRAULIC / LUBRICATING
9	WASCO AIRPORT	SLT5FQ444336	Geotracker	CLEANUP PROGRAM SITE	OPEN - VERIFICATION MONITORING	PALM AVE & MCCOMBS	WASCO	93280	---	-119.3505	35.6184	DDD / DDE / DDT, OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
10	J. R. SIMPLOT - EDISON	SLT5FS324450	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	430 PEPPER DR.	EDISON	93220	---	-118.8745	35.3485	DIBROMOCHLOROPROPANE (DBCP), FERTILIZER, PESTICIDES/HERBICIDES
11	SAN JOAQUIN REFINING CO - FRUITVALE REFINERY	SL205714283	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	STANDARD STREET	BAKERSFIELD	93308	---	-119.048	35.3972	DIESEL
12	BAKERSFIELD REFINERY - AREA 3	T10000001848	Geotracker	CLEANUP PROGRAM SITE	OPEN - VERIFICATION MONITORING	3663 GIBSON STREET	BAKERSFIELD	93308	---	-119.0527654	35.39330068	DIESEL, GASOLINE
13	WEST COAST OIL REFINERY, BAKERSFIELD	SL0602978387	Geotracker	CLEANUP PROGRAM SITE	OPEN - INACTIVE	1157 CHINA GRADE LOOP	BAKERSFIELD	93308	---	-118.9975	35.4225	DIESEL, GASOLINE, LEAD
14	APEX BULK COMMODITIES	T10000011271	Geotracker	CLEANUP PROGRAM SITE	OPEN - ASSESSMENT & INTERIM REMEDIAL ACTION	2111 BRICYN LANE	BAKERSFIELD	93308	---	-119.05178	35.37789	DIESEL, OTHER PETROLEUM
15	SAN JOAQUIN DRUM	SLT5FR634417	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	3930 GILMORE AVE	BAKERSFIELD	93308-6214	---	-119.05165	35.39017952	METALS/HEAVY METALS, PESTICIDES/HERBICIDES, VOLATILE ORGANIC COMPOUNDS
16	J. R. SIMPLOT - BENA (AKA: BENA FERTILIZER)	SLT5FS304448	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	NONE	EDISON	93220	---	-118.7406	35.3276	NITRATE, OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
17	WESTERN FARM SERVICE INC-1610 NORRIS ROAD BAKERSFIELD	SL186364605	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	1610 NORRIS RD	BAKERSFIELD	93308-2234	---	-119.0541923	35.42200027	OTHER CHLORINATED HYDROCARBONS
18	GARRIOTT CROPDUSTERS	SLT5FQ134306	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	2010 S UNION AVE	BAKERSFIELD	93307-4154	---	-119.0003209	35.32892143	OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
19	SIMPLOT WASCO	SLT5FS184436	Geotracker	CLEANUP PROGRAM SITE	OPEN - REMEDIATION	541 HWY 46	WASCO	93280-1433	---	-119.3289256	35.60078769	OTHER INSECTICIDES / PESTICIDE / FUMIGANTS / HERBICIDES
20	WIP - DELANO, PCE	SL0602943992	Geotracker	CLEANUP PROGRAM SITE	OPEN - INACTIVE		DELANO	93215	---	-119.2496	35.7672	PCE
21	WITCO REFINERY (OILDALE)	SLT5FQ474339	Geotracker	CLEANUP PROGRAM SITE	OPEN - SITE ASSESSMENT	1134 MANOR STREET	BAKERSFIELD	93308-3553	---	-119.0129	35.419	PETROLEUM/FUELS/OILS
22	SABRE REFINERY	SLT5FQ334326	Geotracker	CLEANUP PROGRAM SITE	OPEN - INACTIVE	W. BAKERSFIELD-ROSEDALE AREA	BAKERSFIELD	93308	---	-119.05	35.3876	TOTAL PETROLEUM HYDROCARBONS (TPH)
23	BIG WEST OF CALIFORNIA LLC	80001738	EnviroStor	CORRECTIVE ACTION (CURRENT)	REFER: RWQCB	6451 ROSEDALE HWY	BAKERSFIELD	93308	81-85%	-119.072547	35.383247	BTEX, MTBE
24	OCCIDENTAL OF ELK HILLS INC	80001254	EnviroStor	CORRECTIVE ACTION (CURRENT)	ACTIVE - LAND USE RESTRICTIONS, POST CLOSURE RCRA PERMIT	28590 HIGHWAY 119	TUPMAN	93276	76-80%	-119.484792	35.281959	Metals, Petroleum, PCBS, Radioactive isotopes, Volatile Organics
25	ASSURED TRANSPORTATION SITE	15420001	EnviroStor	DTSC SITE CLEANUP PROGRAM (ACTIVE)	ACTIVE	3228 GIBSON ST	BAKERSFIELD	93308	81-85%	-119.051671	35.3904494	Halogenated Organic Compounds, Tetrachloroethylene (PCE)
26	DELANO PCE PLUME	60001327	EnviroStor	DTSC SITE CLEANUP PROGRAM (ACTIVE)	ACTIVE	MAIN STREET AND 10TH AVENUE	DELANO	93215	66-70%	-119.2456698	35.76910534	Tetrachloroethylene (PCE)
27	J R SIMPLOT, EDISON	15070030	EnviroStor	DTSC SITE CLEANUP PROGRAM (ACTIVE)	ACTIVE - LAND USE RESTRICTIONS	430 PEPPER DRIVE	EDISON	93220	81-85%	-118.8778	35.35147831	Organochlorine pesticides (8081 OCPS), Volatile Organics (8260B VOCS)
28	BROWN AND BRYANT, INC., ARVIN FACILITY	15280011	EnviroStor	FEDERAL SUPERFUND - LISTED	ACTIVE	600 S DERBY ST	ARVIN	93203	81-85%	-118.8231039	35.20314691	DINOSEB and Volatile Organics (8260B VOCS)

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(Updated January 2019)

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29	FASTLANE MINI MART	T0602912732	Geotracker	LUST CLEANUP SITE	OPEN - ELIGIBLE FOR CLOSURE	201 ELMO HWY	MCFARLAND	93250	---	-119.2322588	35.68861163	Gasoline
30	HOWARDS MINI MARKET	T10000000635	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	3300 PLANZ ROAD	BAKERSFIELD	93309	---	-119.0392612	35.325438	Diesel, Gasoline
31	JEFFRIES BROS, OASIS	T10000007369	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	35750 HWY 58	BUTTONWILLOW	93206	---	-119.39992	35.39946	Benzene, Diesel, Ethylbenzene, Gasoline, MTBE / TBA / Other Fuel Oxygenates, Naphthalene, Toluene, Xylene
32	LOGRECCO PROPERTY	T0602925877	Geotracker	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	1330 HIGH STREET	DELANO	93215	---	-119.247728	35.773859	Gasoline
33	NORTH KERN STATE PRISON	T0602900672	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	2737 CECIL AVE W	DELANO	93216	---	-119.3145731	35.7831358	Gasoline
34	POND MERCANTILE	T0602900113	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	29310 POND RD.	POND	93280	---	-119.3292703	35.71777716	Gasoline
35	RIBIER MARKET	T0602900267	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	11228 EDISON RD S	LAMONT	93241	---	-118.8792731	35.25343586	gasoline
36	ROBERTSONS MARKET	T0602902377	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	21124 HWY 46(FORMERLY 62160 HWY 46)	LOST HILLS	93249	---	-119.6964148	35.6153236	Diesel, Gasoline
37	SAMCO FOOD STORE NO. 3	T10000009045	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	8101 EAST BRUNDAGE LANE	BAKERSFIELD		---	-118.91375	35.35406	Diesel, Gasoline
38	TAYLOR AUTOMATED FUELS	T0602900529	Geotracker	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	61700 HWY 46, (NW CORNER OF HWY 46 AND LOST HILLS RD)	LOST HILLS	93249	---	-119.6900572	35.61639925	Gasoline
39	TRAVEL CENTERS OF AMERICA	T10000010004	Geotracker	LUST CLEANUP SITE	OPEN - SITE ASSESSMENT	27769 LAGOON DRIVE	BUTTONWILLOW	93206	---	-119.39723	35.40124	Benzene, Diesel, Gasoline, MTBE / TBA / Other Fuel Oxygenates, Naphthalene, Toluene, Xylene
40	WHOLESALE FUELS, INC.	T10000007773	Geotracker	LUST CLEANUP SITE	OPEN - REMEDIATION	2200 EAST BRUNDAGE LANE	BAKERSFIELD	93307	---	-118.96564	35.35471	Benzene, Ethylbenzene, Gasoline, MTBE / TBA / Other Fuel Oxygenates, Naphthalene, Toluene, Xylene
41	BAKERSFIELD DISCOVERY PROJECT	60001630	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - ACTION REQUIRED	PACHECO ROAD AND STINE ROAD	BAKERSFIELD	93318	66-70%	-119.056751	35.310412	Tetrachloroethylene (PCE), Trichloroethylene (TCE)
42	BAKERSFIELD PLATING WORKS	15340012	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: OTHER AGENCY	527 EAST 19TH	BAKERSFIELD	93305	81-85%	-118.9954948	35.37490554	Metals (cadmium, chromium III/VI. Copper. Lead, Nickel)
43	BC CHEMICALS	15280041	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: RWQCB	1511 SOUTH UNION AVENUE	BAKERSFIELD	93307	91-95%	-119.0036166	35.33598464	Arsenic
44	CALTRANS SERVICE YARD	60001605	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - NEEDS OTHER EVALUATION (CURRENT OR INACTIVE)	1200 OLIVE DRIVE	OILDALE	93308	86-90%	-119.046228	35.413042	PCE, TCE
45	EASTLAND FLYING SERVICE	15070006	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - NEEDS OTHER EVALUATION (CURRENT OR INACTIVE)	16849 MT. VIEW ROAD	LAMONT	93241	76-80%	-118.816845	35.28164	Carbaryl, 8141A OPPS, Toxaphene
46	KERN COUNTY DUMP	15490017	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: RWQCB	SE OF XING OF STRADLEY & WOOLOMES AVES	DELANO	93215	96-100%	-119.25779	35.74616	Tetrachloroethylene, trichloroethylene, Dichlorodifluoromethane, 1,1 Dichloroethane
47	KERN COUNTY GUN CLUB	15860001	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	REFER: OTHER AGENCY	2818 CHINA GRADE LOOP	BAKERSFIELD	93308	76-80%	-118.965412	35.422405	Lead, Other Organic Solids, Polynuclear aromatic hydrocarbons
48	RAIN FOR RENT	60001771	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	INACTIVE - NEEDS OTHER EVALUATION (CURRENT OR INACTIVE)	3404 STATE STREET	OILDALE	93308	96-100%	-119.044861	35.406524	Unknown
49	SPARKLE/BRUNDAGE CLEANERS	60002071	EnviroStor	OTHER EVALUATION (CURRENT OR INACTIVE)	BACKLOG	1517 W. BRUNDAGE ROAD	BAKERSFIELD	93304	96-100%	-118.9824817	35.3539159	Tetrachloroethylene, trichloroethylene
50	CARNEROS CREEK, THETA	L10009422184	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	CARNEROS CREEK OIL FIELD	LOST HILLS		---	-119.85852	35.46844	Crude Oil
51	CHEVRON USA INC-KERN RIVER-SAN JOAQUIN	T10000007105	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	KERN RIVER OIL FIELD	MALTHA		---	-119.001769	35.428919	Crude Oil
52	CYMRIC OIL FIELD, BOWLES LEASE	T10000006948	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	SW OF LOKEN RD / LOST HILLS RD	MCKITTRICK	93251	---	-119.71424	35.37855	Crude Oil
53	CYMRIC OIL FIELD, LEHI-RICHARDSON LEASE	T10000007036	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	CYMRIC OIL FIELD	MCKITTRICK		---	-119.754775	35.418844	Crude Oil
54	CYMRIC OIL FIELD, OVERLAND ANDERSON LEASE	T10000007035	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NE TAFT (S20, T29S, R21E, MDB&M)	MCKITTRICK	93251	---	-119.73454	35.3944	Crude Oil
55	CYMRIC OIL FIELD, USL LEASE	T10000007037	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	CYMRIC OIL FIELD	MCKITTRICK		---	-119.765	35.42378	Crude Oil
56	EDISON OIL FIELD, RACETRACK LEASE	T10000007136	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	EDISON OIL FIELD	EDISON		---	-118.84515	35.37177	Other inorganic / salt, TDS, Crude Oil
57	J&K, MIDWAY-SUNSET OIL FIELD, JADE KERN PROJECT LEASE	T10000006764	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	KRISTIN STREET NE 1/4, SEC 15 T32S R23E MDB&M	TAFT	93268	---	-119.48427	35.14988	Crude Oil
58	KERN FRONT NO. 2	T10000007097	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	KERN FRONT OIL FIELD	SACO		---	-119.05882	35.46374	Crude Oil

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59	MIDWAY-SUNSET OIL FIELD, BERRY & EWING LEASE	T10000007297	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.44121	35.09873	Crude Oil
60	MIDWAY-SUNSET OIL FIELD, C. E. HOUCHIN ET AL LEASE	T10000006771	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	SEC 9, T31S, R22E, MDB&M	FELLOWS	93224	---	-119.62194	35.24141	Crude Oil
61	MIDWAY-SUNSET OIL FIELD, FULTON LEASE	T10000007030	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTHEAST OF MARICOPA (S1, T11N, R24W, SBB&M)	MARIPOSA	93252	---	-119.39335	35.06877	Crude Oil
62	MIDWAY-SUNSET OIL FIELD, HAVENSTRITE LEASE	T10000006789	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.35188	35.0463	Crude Oil
63	MIDWAY-SUNSET OIL FIELD, JAMESON TRUST LEASE	T10000006947	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	7026 DARNOCH WAY	WEST HILLS	91307	---	-119.45068	35.13032	Crude Oil
64	MIDWAY-SUNSET OIL FIELD, JAMESON TRUST LEASE	L10002548641	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.40374	35.0736	Crude Oil
65	MIDWAY-SUNSET OIL FIELD, LOCKWOOD LEASE	T10000007029	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	WEST OF TAFT	TAFT	93628	---	-119.5077454	35.14047576	Crude Oil
66	MIDWAY-SUNSET OIL FIELD, MOCO 35 LEASE (PLASTIC-LINED POND 3)	T10000007039	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTH OF MARICOPA (S35, T12N, R24W, MDB&M)	MARICOPA	93252	---	-119.4057919	35.08717628	Crude Oil
67	MIDWAY-SUNSET OIL FIELD, MOCO 35 LEASE (PONDS 1&2, SAND PITS)	T10000007031	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTH OF MARICOPA (S35, T12N, R24W, MDB&M)	MARIPOSA	93252	---	-119.4065	35.08679	Crude Oil
68	MIDWAY-SUNSET OIL FIELD, NATIONAL USL LEASE	T10000007032	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	TWO MILES SOUTHWEST OF TAFT (S35, T32S, R23E, MDB&M)	TAFT	93268	---	-119.46687	35.10715	Crude Oil
69	MIDWAY-SUNSET OIL FIELD, SHALE 14 LEASE	T10000007033	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	1.5 MILES SOUTHEAST OF DERBY ACRES (S14, T31S, R22E)	DERBY ACRES	93224	---	-119.57365	35.23502	Crude Oil
70	MIDWAY-SUNSET OIL FIELD, W & S LEASE	T10000007034	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	2 MILES SOUTHEAST OF DERBY ACRES (S14, T31S, R22E)	DERBY ACRES	93224	---	-119.5852	35.22457	Crude Oil
71	MIDWAY-SUNSET OIL FIELD, WEBBER LEASE	T10000006776	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	LDD ENERGY - NE ¼ SECTION 34, T30S, R22E, MDB&M	FELLOWS	93224	---	-119.59296	35.27708	Crude Oil
72	MIDWAY-SUNSET, HOYT LEASE	T10000006779	Geotracker	PRODUCED WATER PONDS	UNDER REVIEW	MIDWAY-SUNSET OIL FIELD	MARICOPA		---	-119.37986	35.05688	Crude Oil
73	POSO CREEK, POSO	T10000007301	Geotracker	PRODUCED WATER PONDS	INACTIVE - UNPERMITTED	LINN OPERATING INC - NW OF BRONZE HILL RD. & WHITE CROWN DR.	MCFARLAND	93250	---	-119.0452	35.58195	Crude Oil
74	RIO BRAVO OIL FIELD, KERNCO LEASE	T10000006733	Geotracker	PRODUCED WATER PONDS	OPEN - INACTIVE	NW OF 7TH STANDARD RD / TRANSPORT LN S1/2 OF THE NE1/4 OF SECTION 34, T28S, R25E, MDB&M	SHAFTER	93263	---	-119.2656	35.44952	Crude Oil
75	S. BELRIDGE OIL FIELD, HILL LEASE	SL0602935481	Geotracker	PRODUCED WATER PONDS	INACTIVE - PERMITTED	SEC 19, T28S, R21E, MDB&M	SOUTH BELRIDGE OIL FIELD		---	-119.7453854	35.4882413	Other inorganic, Salt
76	SOUTH BELRIDGE OIL FIELD, SOUTH WASTEWATER DISPOSAL FACILITY	SL0602990565	Geotracker	PRODUCED WATER PONDS	INACTIVE - PERMITTED	SOUTH BELRIDGE OIL FIELD	SPICER CITY		---	-119.6796305	35.46115366	Other inorganic / salt
77	VAUGHN-MIDWAY-SUNSET OIL FIELD, USL 15	T10000006813	Geotracker	PRODUCED WATER PONDS	OPEN - SITE ASSESSMENT	NORTHWEST IF MIDOIL RD / THOMAS ST	TAFT	93268	---	-119.49199	35.14231	Crude Oil

Source: DTSC Envirostor: https://www.envirostor.dtsc.ca.gov/public/ and SWRCB Geotracker: http://geotracker.waterboards.ca.gov/

3 SUSTAINABLE MANAGEMENT CRITERIA

3.1 Sustainability Goal (Reg. § 354.24)

The goal of HMWD GSA's sustainability plan is to balance the extraction and replenishment of groundwater in a manner that allows for future operations without undesirable results, which should result in a long-term flat trend line for groundwater levels and a zero long-term change in groundwater storage.

The District will ensure that it is operating within its long-term sustainable yield by implementing its proposed projects and management actions if groundwater conditions so warrant them. These will be covered in greater depth in Chapter 4. It is expected that the GSA will achieve and maintain its sustainability goal within the 20-year implementation period by managing annual water budgets, monitoring groundwater conditions, and addressing water supplies and demands.

Because there will be a single MA within the GSA, the Sustainable Management Criteria for groundwater levels will be uniform throughout the GSA.

3.2 Measurable Objectives (Reg. § 354.30)

Measurable objectives (MOs) were established to quantify the sustainable management of groundwater conditions for each sustainability indicator. Interim Milestones represent the trend of groundwater conditions, in 5-year increments, required to reach sustainable conditions over the 20-year implementation period. The MOs described below are only associated with the HMWD GSA; the GSA will manage its groundwater operations with the intent of meeting the measurable objective for each sustainability indicator. The sustainability indicators Seawater Intrusion and Depletion of Interconnected Surface Water were not considered when creating measurable objectives, as those indicators are not applicable to the HMWD GSA. MOs were developed based on the items discussed in § 354.30 of the GSP regulations:

1. 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.
2. Measurable objectives shall be established for each sustainability indicator, based on quantitative values using the same metric and monitoring sites as are used to define the minimum thresholds.
3. 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.
4. 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. 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.

3.2.1 Groundwater Levels

The MO for groundwater levels is for all static groundwater levels to average no more than **150' bgs** by 2040. The interim milestones were based on the progression of groundwater levels from recent groundwater levels of approximately 115 ft bgs to the MO. The 2025, 2030, and 2035 interim milestones are 124, 133, and 142 ft, respectively. The MO is representative of baseline 2015 conditions. While groundwater levels have gone lower than the MO in drought periods, they subsequently return to a higher elevation and remain more consistent outside of drought years. A hydrograph depicting both past (2011-present) groundwater levels and future levels (including MO) can be seen in **Figure 3-1**.

The MO was established based on past history, recognition of current levels, and anticipated future conditions under sustainable management.

Table 3-1: Groundwater Levels Measurable Objective and Interim Milestones

Recent Measurement (ft bgs)	Interim Milestone 2025 (ft bgs)	Interim Milestone 2030 (ft bgs)	Interim Milestone 2035 (ft bgs)	Measurable Objective (ft bgs)
115	124	133	142	150

3.2.2 Groundwater Quality

The MO for groundwater quality in HMWD is for constituents of concern to not degrade at a rate higher than 10% every five (5) years. For example, if most recent TDS concentrations are 1,000 mg/L, it is the objective of the GSA for the 2025 and 2030 concentrations to be less than 1,100 mg/L and 1,200 mg/L, respectively.

Over time, the groundwater in the District has trended toward higher concentrations of Sodium, Chloride, Sulfates, and TDS, among other minerals, which can be injurious to the farming operations that apply the groundwater to crops. There is a slight correlation between lowering groundwater levels and increased concentrations of TDS, Na, and SO4 – this correlation is discussed further in Section 3.3.5. Historical records do not show an apparent correlation between sustainability indicators and Cl concentrations.

The mineral analysis data for MW #28 generally represents median conditions for the District with respect to constituents of concern and is therefore the representative monitoring site for this sustainability indicator. Most recent concentrations of these constituents in MW #28 are as follows:

- Sodium: 170 mg/L
- Chloride: 29 mg/L
- Sulfates: 510 mg/L
- TDS: 870 mg/L

Table 3-2: Water Quality Measurable Objectives and Interim Milestones

Constituent	Recent Measurement (mg/L)	Interim Milestone 2025 (mg/L)	Interim Milestone 2030 (mg/L)	Interim Milestone 2035 (mg/L)	Measurable Objective (mg/L)
Sodium	170	175	180	185	190
Chloride	29	30	31	31	32
Sulfates	510	520	535	547	560
TDS	870	895	920	940	955

3.2.3 Change in Storage

The MO for change in storage is zero once the maintenance of stable groundwater conditions is achieved by 2040. The interim milestones of change in storage are based on the path from recent groundwater levels of 115 ft bgs to the measurable objective of 150 ft bgs by 2040 shown as a 5-year incremental change in storage from the baseline to 2040. The interim milestones for change in storage for 2025, 2030, and 2035 are approximately 18,800 AF using a storage coefficient of 0.08 and the total area of the GSA (26,055 acres) with a total decline in storage of approximately 73,000 AF over the 20-year implementation period before the measurable objective of zero change in storage is achieved by 2040. The interim milestones in change in storage are equivalent to the change in groundwater level interim milestones described in Section 3.2.1.

Table 3-3: Change in Groundwater Storage Measurable Objective and Interim Milestones

Baseline (AF)	Interim Milestone 2025 (AF)	Interim Milestone 2030 (AF)	Interim Milestone 2035 (AF)	Measurable Objective (AF)
0	-18,800	-18,800	-18,800	0

3.2.4 Land Subsidence

For land subsidence, the Kern Subbasin has developed a Basin-wide Coordinated GSP Subsidence Plan. Within the Subsidence Plan, the Basin adopted two classifications for critical infrastructure: Management Area Critical Infrastructure and Regional Critical Infrastructure.

> *Management Area Critical Infrastructure* is defined as infrastructure located within a particular Subbasin Management Area whose loss of significant functionality due to inelastic subsidence if caused by SGMA related Subbasin groundwater extractions would have significant impacts to beneficial users within that Subbasin Management Area. Each Subbasin Management Area has identified their respective Management Area Critical Infrastructure in their Management Area Plan or individual GSP.

> *Regional Critical Infrastructure* is defined as infrastructure located within the Subbasin that serves multiple areas of the Subbasin and whose loss of significant functionality due to inelastic subsidence, if caused by SGMA related Subbasin groundwater extractions, would have significant impacts to beneficial users. The Subbasin has collectively determined that the only

infrastructure that meets the definition for Regional Critical Infrastructure are the California Aqueduct and the Friant-Kern Canal.

Historically, the District has not observed any significant or unreasonable impacts to management area infrastructure due to land subsidence. This has been evidenced by observations such as a lack of well failures due to subsidence related compression breaks and no changes in operations of District canals. Due to the lack of significant historical land subsidence within the District and affected infrastructure, HMWD does not have any Management Area Critical Infrastructure for land subsidence.

Regarding Regional Critical Infrastructure, the District does not lie within close proximity of the Friant-Kern Canal. However, the District lies within the eastern portion of a 5-mile-wide corridor, centered on the Aqueduct. The Aqueduct pools that intersect the District boundary within the corridor include a portion of Pool 29, all of Pool 30, and a limited portion of Pool 31. The District has not defined SMC for Pool 31 as there are no District wells within the 5-mile corridor, thus subsidence along Pool 31 is not attributable to District groundwater use. Recent studies from the DWR California Aqueduct Subsidence Program Report (CASP) indicate that the Aqueduct Pools within close proximity of HWMD have not experienced any consistent trend of subsidence since the Aqueduct was constructed in the 1960's (DWR, 2019a and DWR, 2022).

The Interim Measurable Objective for land subsidence for the California Aqueduct is defined as the avoidance of a permanent loss (associated with inelastic subsidence) of conveyance capacity as attributable to subsidence as limited by remaining concrete liner freeboard for a specific Aqueduct Pool that exceeds the average observed rate from 2016-2022. Using the 2022 CASP survey data, the average observed rate was calculated to be -0.05 ft/yr for all Pools of the Aqueduct within the Kern Subbasin. The MO rate of subsidence is calculated and assessed as an average annual rate over a rolling 6-year monitoring period. Using the 2022 elevations as a baseline measurement of 0 ft, the subsidence Interim Measurable Objective total extent for the remainder of the 20-year implementation period to 2040 is -0.90 ft. The Interim Measurable Objective and Interim Milestones for the Aqueduct Pools near HMWD wells within the 5-mile-wide corridor are listed below in **Table 3-4**

Table 3-4: Land Subsidence Interim Measurable Objective and Interim Milestones

CA Aqueduct Pools 29 and 30		
2022 Baseline (ft)	[1]Interim Measurable Objective Rate (ft/yr)	[2]Interim Measurable Objective 2040 (ft)
0.00	-0.05	-0.90
[1]The MO rate is calculated over a rolling 6-yr period; the interim rate identified for the MO is for subsidence due to activities under the purview of SGMA. The interim rate is established based upon findings from the 2022 CASP survey data, the ECI draft report, and LBNL preliminary study (DWR, 2022; ECI, 2021; LBNL, 2022). The Interim Rate will be updated in the 2025 GSP Update.		
[2]The interim extent of subsidence for the term 2022 – 2040 utilizes the Interim MO Rate and will be updated as the MO rate for subsidence is updated in the 2025 GSP Update.		

The above methodology for developing MOs for the Aqueduct, recognizing the baseline subsidence rate as calculated from the latest CASP survey data, is supported by the findings of the Earth Consultants International (ECI) draft report, and Lawrence Berkely National Laboratory (LBNL) Study (DWR, 2022; ECI, 2021; LBNL, 2022). The Subsidence Rate and total extent for the MO is interim, pending the collection and analysis of additional data, and will be reviewed in the 2025 GSP Update.

The Interim Measurable Objectives are only valid until 2025 and they will be updated in the 2025 GSP Update. Within HMWD, the Interim Mos only apply when the permanent loss of freeboard is a result of subsidence due to SGMA-related groundwater extractions from agricultural beneficial uses/users. Permanent loss of freeboard from land subsidence due to other causes including but not limited to: oil or gas production, natural compaction of shallow underlying soils beneath or near the Aqueduct, or any other cause that is not within the jurisdiction of a GSA, shall not be considered as a loss of freeboard that contributes to the amount specified for any MO.

3.3 Minimum Thresholds (Reg. § 354.28)

Minimum Thresholds (MTs) were established to quantify groundwater conditions for each sustainability indicator that, if exceeded, may cause undesirable results to occur. The MTs described below are only associated with the HMWD GSA; the GSA will manage its groundwater operations with the intent of avoiding the MTs for each sustainability indicator. The sustainability indicators *Seawater Intrusion* and *Depletion of Interconnected Surface Water* were not considered when creating MTs, as those indicators are not applicable to the HMWD GSA. MTs were developed based on the items discussed in § 354.28 of the GSP regulations:

1. The information and criteria relied upon to establish and justify the minimum threshold 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 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 from each sustainability indicator.
3. How minimum thresholds have been selected to avoid causing undesirable results in adjacent basins or affecting adjacent basins ability to achieve sustainability goals.
4. How minimum thresholds may affect the interests of beneficial users 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.

3.3.1 Groundwater Levels

The groundwater level MT is based on historical groundwater levels, the potential for a future decline in levels due to an extended drought period, and the well and pump information (well screen locations and pump setting depths) for the production wells. The MTs were set to the following:

- Static depth to groundwater of 350' bgs. If groundwater levels decline below this value in 40% or more of any representative monitoring wells within the management area over four (4) consecutive bi-annual SGMA required monitoring events, the GSA has exceeded its MT.

At the MT, a subset of the wells in the management area (approximately 30%) will have pump settings that would be shallower than the MT, however, all wells contain significant screened well casing sections deeper than the MT. As such, access to usable groundwater at 30% of the wells would be only temporarily unavailable once the MT is reached. Once pump settings are lowered for affected sites, access to usable groundwater would be reestablished. Prior to lowering pump settings at 30% of the well sites, analysis using specific capacity of the wells has determined that sufficient water could be produced from the remaining wells to meet projected beneficial use by beneficial users with an operational buffer to account for unforeseen land use and climatic changes. Additionally, the one-time cost to lower the subset of the pumps to 350' bgs would be economically feasible for HMWD and is not considered an undesirable result by the agricultural beneficial users. 350' bgs was chosen because it is shallower than the lowest historical water level measurement observed within the management area during 2014 drought conditions, allows for enough water for overlying beneficial uses and users with an operational buffer, would not create a significant and unreasonable economic cost to lower pump setting depths, and is not projected to have a detrimental effect on other sustainability indicators. See Section 3.3.5 below for additional discussion on the relationship between the established minimum threshold for groundwater levels and the other sustainability indicators. Groundwater level hydrographs from which the MTs were developed are provided in **Figure 3-1.**

3.3.2 Groundwater Quality

The MT for groundwater quality is based on the constituents of concern at the representative monitoring site for groundwater quality, MW #28. If at any time two (2) of the following concentrations for the various constituents are exceeded for any two (2) consecutive years, it is considered that the GSA has exceeded its MT:

- Sodium: 540 mg/L
- Chloride: 550 mg/L
- Sulfate: 1,000 mg/L
- TDS: 2,000 mg/L

These MT values are based on concentrations that the District has observed in other MWs that operate for irrigation purposes. Since water in HMWD is not used for drinking water, the MTs established for water quality are based on agricultural use and only apply to the irrigation wells. Therefore, the Environmental Protection Agency (EPA) Federal Drinking Water Standards do not apply to this sustainability indicator. The District will manage groundwater extractions to minimize the application of saline water to crops, but it will not voluntarily preclude itself from pumping poorer-quality groundwater until these thresholds are reached. Until that point is reached, the poorer quality groundwater can still provide beneficial use to its overlying landowner, especially when blended with better quality water supplies.

3.3.3 Change in Storage

The MT for change in storage is when the volume of groundwater underlying the GSA is equivalent to a static water level of **350' bgs**. for any four (4) consecutive bi-annual SGMA required monitoring events. The MT for change in storage is equivalent to an annual change in ground water levels from the measurable objective to the MT which is 416,000 AF. An undesirable result would occur from a change in storage that exceeds this value.

3.3.4 Land Subsidence

For the Aqueduct Pools in close proximity to the District, the interim Minimum Threshold is defined as:

the avoidance of a permanent loss (associated with inelastic subsidence) of conveyance capacity as attributable to subsidence as limited by remaining concrete liner freeboard for a specific Aqueduct Pool that exceeds twice the average observed rate from 2016-2022. Using the 2022 CASP survey data, twice the average observed rate was calculated to be -0.10 ft/yr for all Pools of the Aqueduct within the Kern Subbasin. The MT rate of subsidence is calculated and assessed as an average annual rate over a rolling 6-year monitoring period.The above methodology for developing MTs for the Aqueduct, recognizing the baseline subsidence rate as calculated from the latest CASP survey data, is supported by the findings of the ECI draft report, and the LBNL Study (DWR, 2022; **ECI,** 2021; LBNL, 2022). The Subsidence Rate and total extent for the MO is interim, pending the collection and analysis of additional data, and will be updated in the 2025 GSP.

The Interim Minimum Thresholds are only valid until 2025 and they will be updated in the 2025 GSP Update, and within HMWD, only apply when the permanent loss of freeboard is a result of subsidence due to SGMA-related groundwater extractions from agricultural beneficial uses/users. Permanent loss of freeboard from land subsidence due to other causes including but not limited to: oil or gas production, natural compaction of shallow underlying soils beneath or near the Aqueduct, or any other cause that is not within the jurisdiction of a GSA, shall 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 pool of the Aqueduct within a Management Area was determined to be -0.10 ft/yr over a 6-year period, and SGMA-related beneficial uses within the jurisdiction of a GSA were deemed to cause -0.07 ft /yr of subsidence within that pool while non-jurisdictional uses were deemed to cause -0.15 ft/yr, the Management Area would only consider the -0.07 ft/yr subsidence rate (and related loss of pool freeboard) when evaluating MT compliance, and in that case would not determine that an MT exceedance has occurred.

Discussions with the DWR CASP team indicate that ideal conditions within the Aqueduct would be to operate within plus or minus 1 ft of the typical design minimum freeboard of 2.5 ft, but the Aqueduct can operate at design capacity with close to 0 ft of freeboard in many cases. An assessment of historical water operations and existing freeboard conditions from the 2019 CASP report and 2022 CASP survey data revealed that there have not been significant and unreasonable impacts delivering water to beneficial users in pools with the least amount of freeboard in the Kern Subbasin (DWR. 2019a). These pools in a worst case have concrete liner elevations almost 1 foot below the original design water surface, thus revealing that the Aqueduct design water surface elevation was very conservative and exceeds the required elevation for normal operations. Current 2022 freeboard conditions from GPS measurements indicate that at the subsidence MT there would be an average of 0.7 ft of freeboard in Pool 29, and 1.53 ft of freeboard in Pool 30. These two Pools border the GSA and feature three turnouts through which the District can utilize to deliver surface supplies; those turnouts are BV-5 (mile post 242.85), HM-1 (mile post 243.09), and HM-2 (mile post 249.85). The most recent subsidence data from Pools 29 and 30 are presented as **Figure 3-2 and Figure 3-3**. The subsidence SMC compared with the current liner top and water level based on design freeboard are presented in **Figure 3-4 and 3-5.**

The Kern Subbasin and DWR CASP team have agreed, as proponents for the sustainable management of the Aqueduct, to continue to work collaboratively to assess the causes and potential solutions to subsidence on the Aqueduct. The DWR CASP group is currently conducting a study to investigate the causes of subsidence within the Subbasin and identify recommended thresholds for the Aqueduct. The results of the study are projected to be released before the 2025 GSP updates. When data from the study is made available, land subsidence MTs will be re-evaluated and updated if appropriate.

Table 3-5: Land Subsidence Interim Minimum Threshold

CA Aqueduct Pools 29 and 30	
[1]Interim Minimum Threshold Rate from 2022-2040 (ft/yr)	[2]Interim Minimum Threshold Total Extent from 2022-2040 (ft)
0.10	1.80
[1]The MT rate is calculated over a rolling 6-yr period; the interim rate identified for the MT is for subsidence due to activities under the purview of SGMA. The interim rate is established based upon findings from the 2022 CASP survey data, the ECI draft report, and LBNL preliminary study (DWR, 2022; ECI, 2021; LBNL, 2022). The Interim Rate will be updated in the 2025 GSP Update.	
[2]The interim extent of subsidence for the term 2022 – 2040 utilizes the Interim MT Rate and will be updated as the MT rate for subsidence is updated in the 2025 GSP Update.	

3.3.5 Relationship Between the Established Minimum Threshold and Sustainability Indicator(s)

The District determined that use of the minimum groundwater elevation thresholds at each of the listed wells within the monitoring network will help avoid the undesirable results of chronic lowering of groundwater elevations within the management area and neighboring management areas within the Subbasin, since it is expected to preserve access to adequate water resources for beneficial users within the Subbasin. The GSA is not located within close proximity to neighboring subbasins, so undesirable results due to groundwater elevation thresholds are not expected for beneficial users of groundwater in neighboring subbasins.

Groundwater elevation MTs can influence other sustainability indicators. Among other considerations, the groundwater elevation MTs were selected to avoid undesirable results for other sustainability indicators. The anticipated effects of the groundwater elevation MTs on other sustainable management criteria are as follows:

1. Change in groundwater storage – As discussed in Section 3.3.3, MTs have been set at levels to avoid undesirable results related to the quantity of groundwater stored within the management area. Thus, the groundwater level MT within the GSA would not cause an undesirable result for the change in groundwater storage sustainability indicator.
2. Degraded water quality - Water quality could be affected by deepened groundwater elevations if increased pumping causes increased concentrations of constituents related to water quality. A review of historical water quality trends compared with management area pumping trends indicates there is some relationship between increased pumping and increases in TDS, SO4, and Na and no correlation with Cl concentrations. Specific capacity calculations and mutual well interference estimates were used to establish the volume of pumping needed to reduce groundwater levels to the MT.

   Using historic relationships between water quality and pumping trends, water quality was projected to levels expected to occur if pumping were to increase to the point where water levels reached the groundwater level MT. Water quality constituents are expected to remain below water quality MT values if future pumping resulted in groundwater levels at the MT. Thus, the groundwater level MT within the GSA would not cause an undesirable result for the water quality sustainability indicator. The WQ MT values compared with the projected constituent concentrations at groundwater level MTs are as follows:

   - Sodium water quality MT is 540 mg/L and the projected concentration at the groundwater level MT is 207 mg/L.
   - Chloride does not have a significant correlation with pumping and is not expected to increase with pumping.
   - Sulfate water quality MT is 1,000 mg/L and the projected concentration at the groundwater level MT is 649 mg/L.
   - TDS water quality MT is 2,000 mg/L and the projected concentration at the groundwater level MT is 1,060 mg/L.

   Historic water quality trends and projected water quality at groundwater level MTs for Well 28 are shown in **Figure 3-6**.
3. Subsidence - Historic groundwater level trends in wells within one (1) mile of the Aqueduct and subsidence trends along Pool 29 and Pool 30 were examined. A recent period between 2013 and 2015 where subsidence occurred concurrent to groundwater level declines during an extended drought was examined to establish a relationship between the groundwater level and subsidence sustainability indicators.

   Total subsidence between 2013 and 2015 was divided by the total groundwater level declines within that period. This produced a rate expressed as the amount of subsidence that is projected to occur for every 1 ft of water level decline assuming the rate would be applicable to future conditions. The historic water level trends and subsidence trends indicate that subsidence begins to occur when groundwater levels decline to approximately 150 ft b.g.s. The subsidence rate relationship was multiplied by 200 to predict the amount of subsidence that would occur should groundwater levels decline to the 350 ft MT. This method assumes all subsidence is a result of groundwater level declines within the District which is unlikely as subsidence trends are not always correlative to the water level trends but represents a "worst-case scenario". Due to the data gaps that exist for subsidence, individual contributions from specific subsidence causes related to groundwater extraction (e.g. compaction of clay layers) are not examined using this method, however, total subsidence is examined and would thus indicate that specific contributions to subsidence would be less than the total amount examined herein.

Within the proximity of HMWD, the average amount of anticipated freeboard in Pool 29 and Pool 30 when groundwater levels decline to the groundwater level MT is greater than the average amount of freeboard that would be available at the interim MT established for subsidence for those pools. In other words, less subsidence would occur when groundwater elevations reach the MT compared to the subsidence MT for the Aqueduct Pools. Thus, the groundwater level MT within the GSA would not cause an undesirable result for the land subsidence sustainability indicator. Historic subsidence trends and water levels in wells within one (1) mile of the aqueduct are presented in **Figure 3-7** and **Figure 3-8** and projected liner top elevations at water level MTs are presented in **Figure 3-9** and **Figure 3-10**.

3.4 Undesirable Results (Reg. § 354.26)

Undesirable results describe conditions that occur when significant and unreasonable effects on any of the sustainability indicators are caused by groundwater conditions in the Subbasin. Undesirable results were collectively established for the Kern County Subbasin. The language used to define the undesirable results for the sustainability indicators within the Subbasin is as described in the subsequent subsections.

3.4.1 Groundwater Levels

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

A management area exceedance is triggered when groundwater levels decline below established MTs in 40% or more of any representative monitoring wells within the management area over four consecutive bi-annual SGMA required monitoring events.

3.4.2 Groundwater 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.

This is determined when the MT for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent MAs that represent at least 15% of the subbasin or greater than 30% of the designated monitoring points within the basin. MTs shall be set by each of the MAs through their respective GSPs.

3.4.3 Change in 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 by overlying users over an extended drought period.

A management area exceedance is triggered when groundwater levels decline below established MTs in 40% or more of any representative monitoring wells within the management area over four consecutive bi-annual SGMA required monitoring events.

3.4.4 Land Subsidence

The Subbasin's coordinated definition for a basin-wide undesirable result for land subsidence is:

> The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, affects the surface land uses or critical infrastructure.
>
> This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.
>
> Additionally, an undesirable result for land subsidence is the point at which the amount of inelastic subsidence, if caused by SGMA-related Subbasin groundwater extractions, creates a significant and unreasonable impact (requiring either retrofitting or replacement to a point that is economically unfeasible to the beneficial users) to surface land uses or critical infrastructure. A significant loss in functionality that could be mitigated through retrofitting and is considered economically feasible to the beneficial users would not be considered undesirable.
>
> An undesirable result for land subsidence is further identified as the occurrence of a single minimum threshold exceedance along either the Aqueduct or the Friant-Kern Canal.

Each Aqueduct Pool has a unique existing freeboard condition according to the 2019 DWR Subsidence Report, therefore the amount of subsidence (e.g. vertical displacement or settlement) that may occur without causing an undesirable result at the MO and MT can be unique comparing all pools.

Based on the findings of the 2019 DWR CASP, subsidence has reduced original design freeboard and has potentially impacted conveyance capacity in select Aqueduct pools in the Subbasin. Maintaining reasonable operating freeboard and conveyance capacity is critical to long-term sustainability of the Aqueduct.

The remaining sustainability indicators, *Seawater Intrusion* and *Depletions of Interconnected Surface Water*, are not considered to be applicable to the Subbasin, and therefore will not have definitions or MTs assigned to them.

These undesirable results are the result of a long-term trend of groundwater overdraft.

3.5 Monitoring Network

The HMWD monitoring network was developed based on Subarticle 4 of the GSP regulations. The HMWD monitoring network will allow for the characterization of groundwater conditions within the GSP area capturing both long-term and seasonal trends. The purpose of the monitoring network is to track conditions as they relate to each sustainability indicator to reach the sustainability goal in 2040.

3.5.1 Description of Monitoring Network (Reg. § 354.34)

The wells that HMWD intends to use in its monitoring network are shown in the table below:

Table 3-6: List of HMWD Monitoring Wells

Section-Township-Range	Well Name	Latitude	Longitude	Well Pad Elevation (ft above msl)	Total Depth	Perf. Interval
15-31S-25E	HMWD #20	35°13'46.01"N	119°17'11.29"W	296.6	1000 ft.	300-1000
27-31S-25E	HMWD #28	35°12'31.02"N	119°16'41.90"W	283.8	1000 ft.	300-1000
25-31S-25E	HMWD #27	35°12'31.57"N	119°15'7.20"W	289.4	1000 ft.	300-1000
25-31S-25E	HMWD #26	35°11'51.26"N	119°14'8.77"W	289.7	970 ft.	270-970
36-31S-25E	HMWD #18	35°10'52.01"N	119°14'9.01"W	286.7	1008 ft.	324-1008

These wells were selected for the Monitoring Network because they properly demonstrate the conditions that span over the entire area of groundwater production in the GSA. Of the 28 agricultural production wells, these five are dispersed throughout the GSA, cover the area pumping will occur, have existing data that has been collected through CASGEM which depicts historical trends, and are perforated at depths that are consistent with the remaining wells. A map depicting their locations can be seen in **Figure 3-11**. Established MOs and MTs for groundwater levels will apply to each well in the HMWD monitoring network and will capture seasonal high and seasonal low values. Established MOs and MTs for change in storage will be calculated based on groundwater elevations at all wells in the HMWD monitoring network. The Monitoring Network will be used to monitor progress toward achieving MOs described in Section 3.2, monitor impacts to the beneficial uses of groundwater; one domestic (non-drinking water) and agriculture, and monitor changes in groundwater conditions. The density of monitoring sites in HMWD is greater than the suggested approach by DWR BMP documents

For monitoring land subsidence, the GSA intends to implement the monitoring plan identified in the Basin-wide Coordinated GSP Subsidence Plan for the Portions of the CA Aqueduct near the District as follows:

Monitoring Plan – Land Subsidence, CA Aqueduct:

Subsidence will be assessed in a five-mile-wide monitoring corridor (i.e., 2.5 miles on either side of the Aqueduct). Since physical access to surveying benchmarks along the Aqueduct for independent parties is limited, the Aqueduct subsidence monitoring reports produced by DWR will be one of the sources to identify the rate and magnitude of subsidence (i.e., change in freeboard) on the Aqueduct. The DWR reports provide complete coverage of each Pool within the Subbasin and represent one method to monitor subsidence for the Aqueduct. Below, **Table 3-8** provides the latest range of available freeboard by pool using the latest DWR survey data through 2022. The amount of remaining concrete liner was calculated relative to the original as-built liner elevations or subsequent liner raises where applicable.

As a supplement to the DWR subsidence monitoring reports, InSAR data will, at a minimum, be reviewed on an annual basis to inform Management Areas of whether subsidence rates could lead to an undesirable result. InSAR data will be ground-truthed by comparison to NOAA CORS station P545, SOPAC CGPS location P544, and available local existing extensometers in or adjacent to the subsidence monitoring corridor for the Aqueduct, in addition to any future CORS, CGPS, extensometer, or other pertinent facilities that may be constructed in the future in or adjacent to the monitoring corridor discussed below in coordination with DWR-CASP staff.

Monitoring Corridor

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 DWR-CASP report, and current land use along the Aqueduct.

Areas of Interest (AOIs)

Pools that have experienced subsidence which has significantly reduced freeboard and, in some cases, impacted flow capacity will be identified as “Areas of Interest” and be subject to focused monitoring by the collection and ground-truthing of InSAR data on an annual basis and the preparation of focused studies or investigations to assess the cause of subsidence in consultation with the adjacent Management Areas and DWR. If it is determined that the sole or principal cause of subsidence in a particular AOI is groundwater extraction for SGMA-related beneficial use, these sites will be identified for additional Subbasin monitoring stations in the future and/or management actions based on the data. Current AOIs for the Subbasin include the Kern bowl (a portion of Pool 23, all of Pools 24, 25 and a portion of Pool 26), Maricopa bowl (a portion of Pool 30, all of Pools 31 and 32), and Pleito bowl (a portion of Pool 34 and all of Pool 35). Studies conducted by the Management Areas on the west side have concluded that subsidence between Aqueduct Mile Post 195 to approximately 214 (i.e., Pools 23 through 25) is attributable to oil and gas activities. As such, the subsidence attributable to oil and gas activities at the Kern Bowl is beyond the ability of the Subbasin to control or mitigate. Further, additional study of the Maricopa and Pleito bowls is required to more fully understand potential causes of identified subsidence.

Watch Areas (WAs)

The 2019 DWR-CASP Report and 2022 CASP survey data show that subsidence in several pools has been minimal with top of concrete liner elevations in 2017 being comparable to those measured when the Aqueduct was constructed over 50 years ago, accordingly, neither freeboard nor capacity has been significantly impacted (i.e., undesirable results have not been experienced). Any significant loss of conveyance capacity from design specifications was found to be caused from aging concrete liner with increased hydraulic roughness and other factors. Pools that have experienced minimal subsidence historically will be identified as "Watch Areas". Watch Areas will be monitored utilizing annual ground-truthed InSAR data and the most current DWR-CASP Aqueduct report. In the event that future monitoring determines that conditions have changed, the subject Watch Area may be redesignated as an AOI. Pool specific Monitoring Classification, and Management Areas associated with each Pool are summarized in **Table 3-7** below:

Table 3-7: CA Aqueduct Pools in Kern Subbasin and Associated Management Areas

CA Aqueduct Pool	Management Area Within 5-Mile Corridor	Pool Monitoring Classification
Pool 23	KGA (WDWA)	AOI/WA
Pool 24	KGA (WDWA, SWSD), BVGSA	AOI
Pool 25	KGA (WDWA), BVGSA	AOI
Pool 26	KGA (WDWA), BVGSA	AOI/WA
Pool 27	KGA (WKWD), BVGSA	WA
Pool 28	KGA (WKWD, KWB), BVGSA	WA
Pool 29	KGA (WKWD, KWB), HMGSA	WA
Pool 30	KGA (WKWD), HMGSA	AOI/WA
Pool 31	KGA (WKWD), HMGSA, SOKR	AOI
Pool 32	KGA (WKWD), SOKR	AOI
Pool 33	SOKR, KGA	WA
Pool 34	SOKR, KGA	AOI/WA
Pool 35	SOKR, KGA	AOI

Table 3-8: CA Aqueduct Pools in Kern Subbasin and Monitoring Classification Extent

CA Aqueduct Pool	2022 Range of Available Freeboard by Pool (Ft)[4]	Watch Area Mile Post (MP) Extent	Area of Interest Mile Post (MP) Extent
Pool 23	1.48 to 3.74	MP-184.5 to MP-194	[1]MP 194 to MP 197
Pool 24	0 to 2.19	N/A	[1]MP-197 to MP 208
Pool 25	0 to 3.43	MP-216 to MP-218	[1]MP-208 to MP-216
Pool 26	1.67 to 4.01	MP-216 to MP-222.5	[2]MP-222.5 to MP-223.5
Pool 27	3.62 to 4.32	MP-223.5 to MP- 231.5	N/A
Pool 28	1.51 to 4.35	MP-231.5 to MP-238	N/A
Pool 29	2.18 to 2.92	MP-238 to MP-244.5	N/A
Pool 30	2.65 to 8.11	MP-249.5 to MP-251	[2]MP-244.5 to 249.5
Pool 31	0.97 to 4.61	N/A	[3]MP-249.5 to MP-256.5
Pool 32	3.20 to 4.86	N/A	[3]MP-256.5 to MP 261.5
Pool 33	5.72 to 6.53	MP-261.5 to 267.5	[3]N/A
Pool 34	5.07 to 6.01	MP- 267.5 to 269.5	[3]MP-269.5 to MP- 271.5
Pool 35	3.59 to 6.64	N/A	[3]MP- 271.5 to MP- 278.5

[1]Vicinity of Lost Hills Oil Field; [2]Potential geotechnical effects; [3]Potential oil and other effects;
[4] California Aqueduct Adjusted NGVD29 Kettleman-Edmonston+Lat Long (CASP) Report, June 2022

The GSA intends to continue to monitor California Aqueduct Pools 29 and 30 to determine if groundwater extractions significantly impact critical infrastructure. Because of the Pools' proximity to the GSA, this portion of the Aqueduct would be most susceptible to any influence on its underlying geology that is the result of groundwater overdraft. Based on the definitions set forth in Chapter 3.4, the Aqueduct is the only critical infrastructure near the HMWD GSA service area that could lead to an undesirable result if impacted, so the GSA will focus its attention on the monitoring of Pools 29 and 30.

3.5.2 Monitoring Protocols for Data Collection and Monitoring (Reg. § 352.2)

Monitoring protocols for the District will be aligned and consistent with the protocols of other GSAs to ensure comparable data and methodologies. For Subbasin-wide Monitoring Network & Protocols, refer to Appendix 3 of **Attachment A**. The periods in which semi-annual groundwater depths will be measured will take place between January 15 – March 30 and September 15 – November 15. Water quality will be measured on an annual basis, and subsidence will be monitored as information is made available from the Department of Water Resources. Monitoring protocols are based on the *Best Management Practices for the Sustainable Management of Groundwater: Monitoring Protocols, Standards, and Sites produced by DWR* provides information regarding acceptable methods of measuring groundwater levels, quality, storage, and land subsidence. Wells within the Monitoring Network will be quantitatively assessed by comparing observed values to the MOs, MTs, and Interim Milestones described in Section 3.

3.5.3 Representative Monitoring (Reg. § 354.36)

MW HMWD #28 has been selected as a representative monitoring site for water quality purposes. Because of its location, historical water quality trends, and near-median standing for TDS among the 28 wells, HMWD #28 will serve as an indicator for groundwater quality conditions in the GSA. This well will be quantitatively assessed by comparing observed values the MOs, MTs, and Interim Milestones described in Section 3.

3.5.4 Assessment and Improvement of Monitoring Network (Reg. § 354.38)

HMWD GSA believes that the monitoring network described above has and will adequately demonstrate groundwater conditions in the Plan Area without the occurrence of data gaps, as the area in which pumping will occur is covered by the Monitoring Network. Although they couple as production wells, the wells in the monitoring network have been used to track groundwater levels and correlate them with groundwater quality for decades. Due to the location of the HMWD domestic well in the northeast region on the GSA near several of the production wells used for agriculture, the monitoring network wells will also monitor groundwater conditions in the one (1) domestic well located within HMWD.

It is recognized that there may be a need to include additional wells designated for monitoring in the future. If and when it is decided that these wells need to be drilled, the GSA will analyze the proper placement and depth of each well to fill any data gaps that may be present with the current network.

Based on our average groundwater extraction that was estimated by the C2VSim model for the historic period, the density of wells should be no less than four wells per 100 square miles, according to the BMPs. The GSA is approximately 40 square miles and has a monitoring network consisting of five monitoring wells, so the density is adequate. Monitoring frequency will be reviewed under conditions of minimum threshold exceedances, highly variable spatial or temporal conditions, adverse impacts to beneficial users of groundwater, or adversely affecting the ability of an adjacent basin to achieve sustainability.

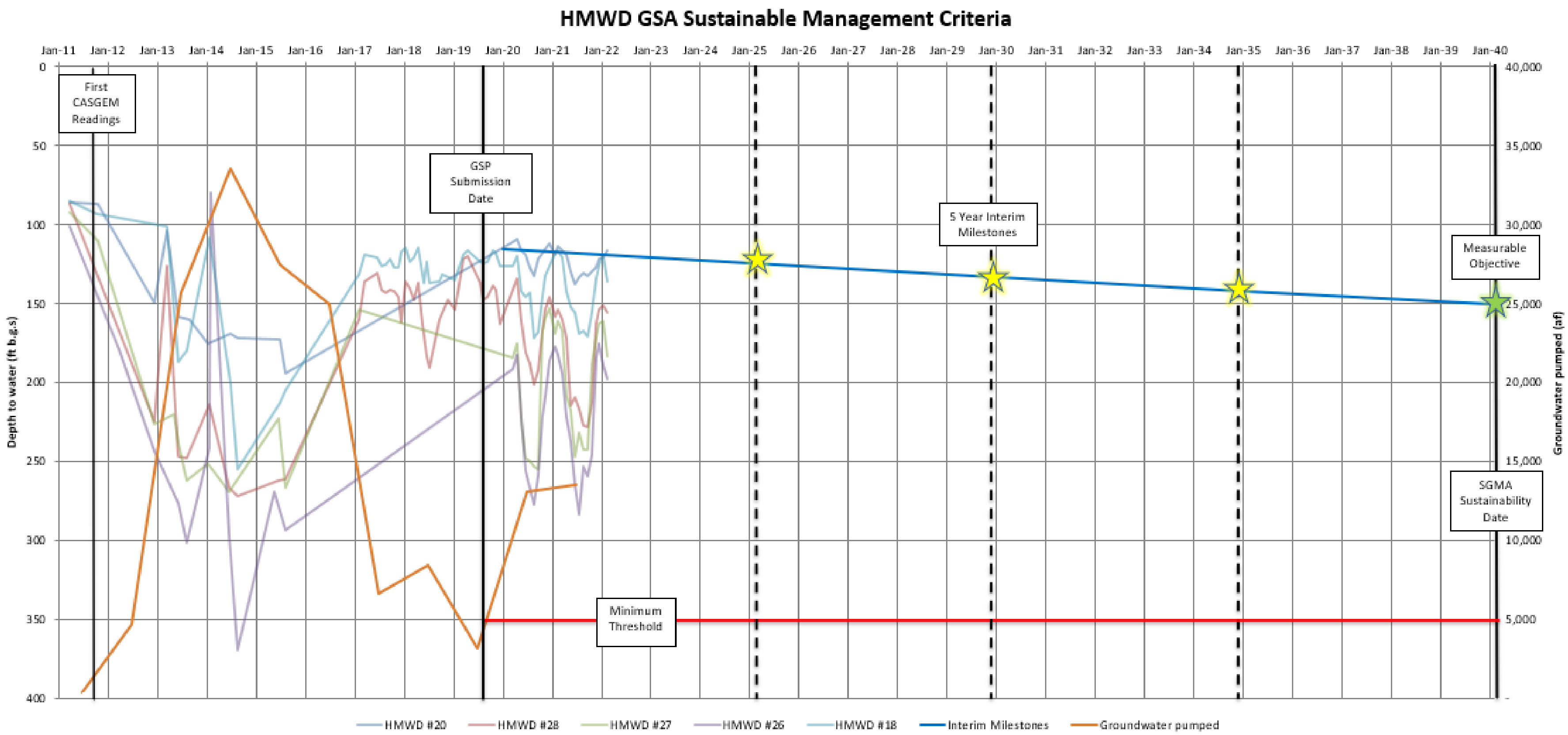
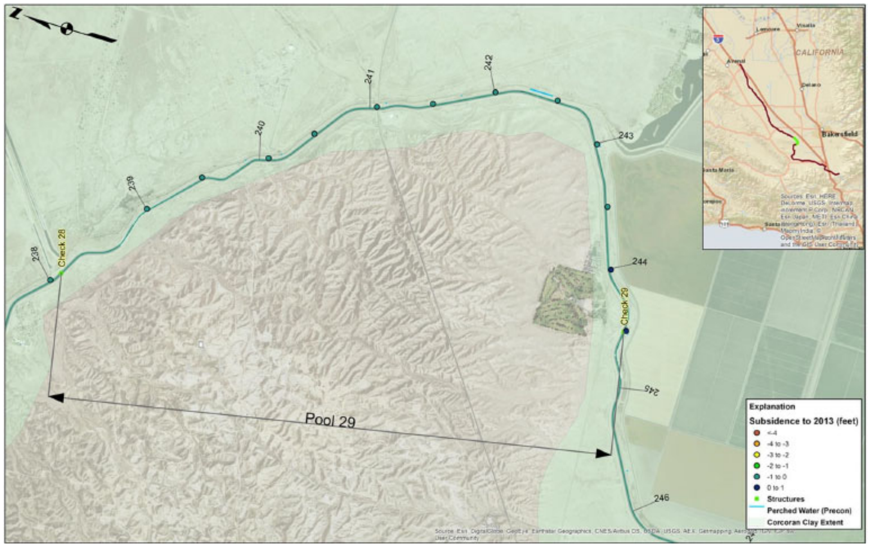


Figure 3-1: Hydrograph of MWs 2011-Present & HMWD Sustainable Management Criteria



Row Labels	2022 Freeboard (ft)	Initial (As-Built) Freeboard (ft)	Top of Concrete Liner 2022 (ft)	Top of Concrete Liner - Initial As-Built (ft)	Design WSE (ft)	Top of Concrete Liner at MT (ft)	Freeboard at MT (ft)
238.5	2.32	3.13	300.55	301.36	298.23	298.75	0.52
239	2.61	3.16	300.72	301.27	298.11	298.92	0.81
239.5	2.66	3.19	300.65	301.18	297.99	298.85	0.86
239.83	2.67	3.23	300.58	301.14	297.91	298.78	0.87
240.07	2.69	3.23	300.55	301.09	297.86	298.75	0.89
240.13	2.62	3.15	300.46	300.99	297.84	298.66	0.82
240.5	2.52	3.14	300.28	300.90	297.76	298.48	0.72
241.06	2.54	3.32	300.16	300.94	297.62	298.36	0.74
241.5	2.45	3.22	299.97	300.74	297.52	298.17	0.65
242	2.40	3.21	299.80	300.61	297.40	298.00	0.60
242.34	2.18	3.17	299.50	300.49	297.32	297.70	0.38
242.5	2.52	3.22	299.80	300.50	297.28	298.00	0.72
242.84	2.21	3.18	299.41	300.38	297.20	297.61	0.41
243	2.64	3.25	299.80	300.41	297.16	298.00	0.84
243.09	2.64	3.26	299.78	300.40	297.14	297.98	0.84
243.5	2.64	3.21	299.69	300.26	297.05	297.89	0.84
244	2.91	3.28	299.84	300.21	296.93	298.04	1.11
244.53	3.11	3.40	299.91	300.20	296.80	298.11	1.31
						ave =	0.77

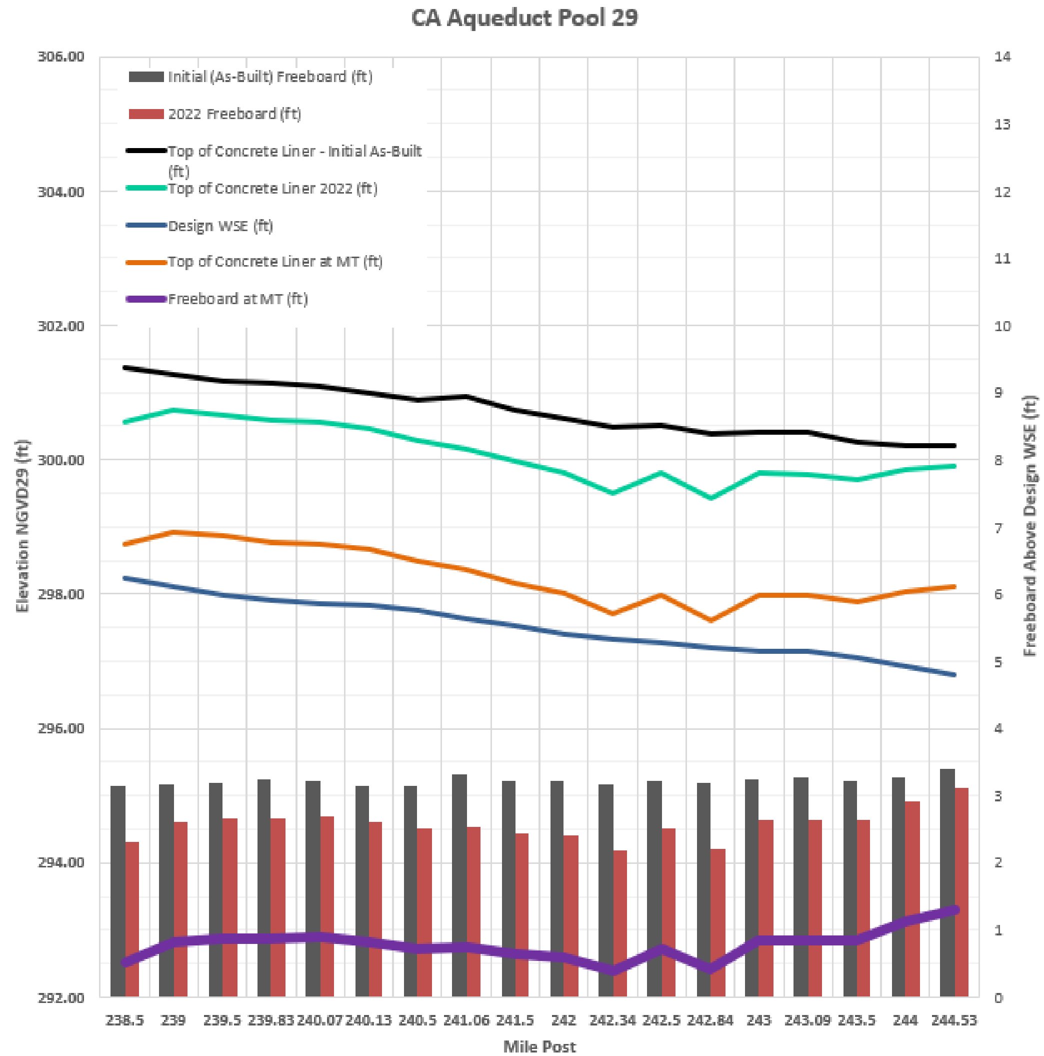


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Figure 3-2 Aqueduct Subsidence Findings, Pool 29 (DWR)

Henry Miller Water District GSP
Kern Subbasin

Row Labels	2022 Freeboard (ft)	Initial (As-Built) Freeboard (ft)	Top of Concrete Liner 2022 (ft)	Top of Concrete Liner - Initial As-Built (ft)	Design WSE (ft)	Top of Concrete Liner at MT (ft)	Freeboard at MT (ft)
244.65	3.13	3.37	299.81	300.05	296.68	298.01	1.33
245.09	3.34	3.49	299.89	300.04	296.55	298.09	1.54
245.5			299.63	299.81		297.83	
246	2.88	3.40	299.16	299.68	296.28	297.36	1.08
246.5	3.10	3.56	299.23	299.69	296.13	297.43	1.30
247	2.65	3.50	298.63	299.48	295.98	296.83	0.85
247.5	2.92	3.60	298.76	299.44	295.84	296.96	1.12
248	3.13	3.65	298.82	299.34	295.69	297.02	1.33
248.13	3.15	3.67	298.80	299.32	295.65	297.00	1.35
248.5	3.52	3.74	299.06	299.28	295.54	297.26	1.72
248.97		3.70		299.10	295.40		
249.5	2.78	2.87	298.02	298.11	295.24	296.22	0.98
249.65	2.68	2.89	297.88	298.09	295.20	296.08	0.88
249.85	2.94	3.14	298.08	298.28	295.14	296.28	1.14
250	2.76	2.95	297.85	298.04	295.09	296.05	0.96
250.5	2.83	3.06	297.78	298.01	294.95	295.98	1.03
250.99	8.11	8.37	302.91	303.17	294.80	301.11	6.31
						ave =	1.53

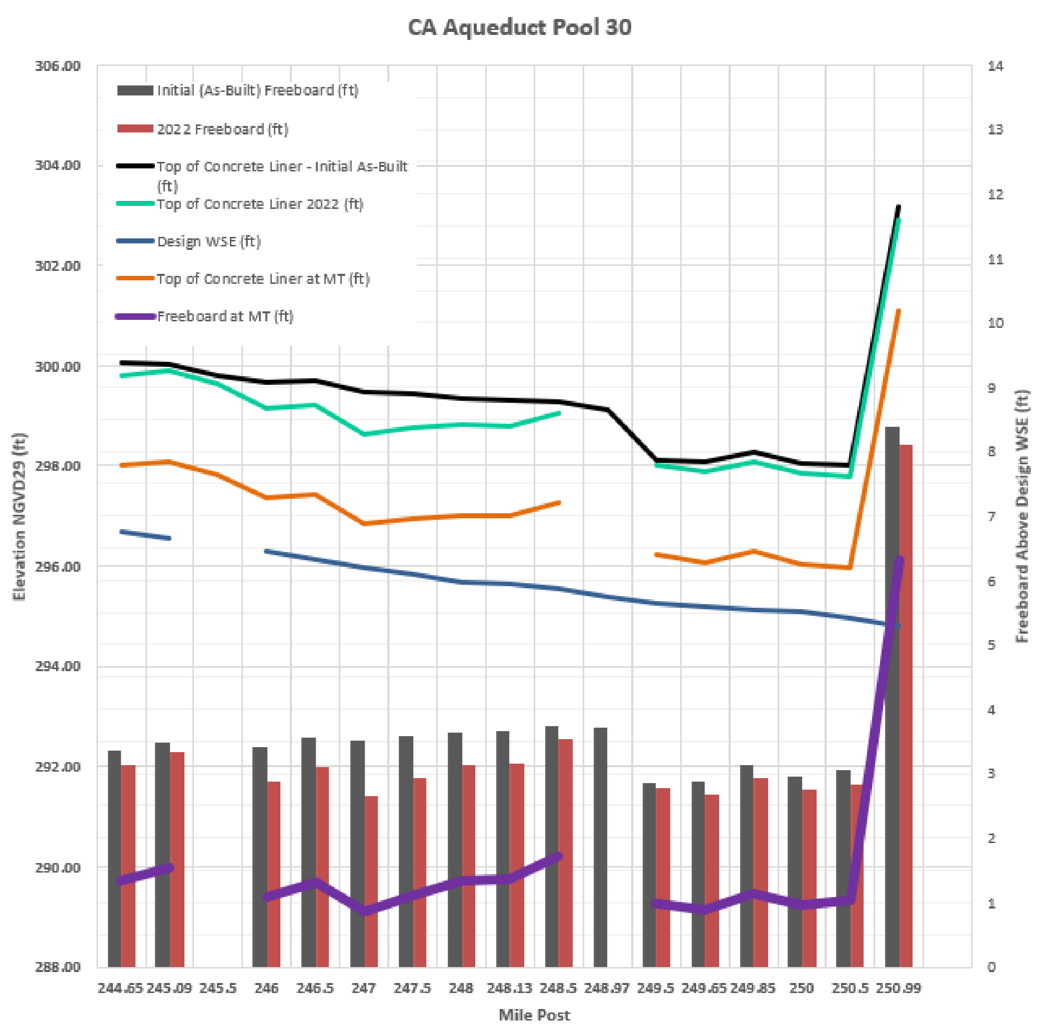

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Figure 3-3 Aqueduct Subsidence Findings, Pool 30 (DWR)

Henry Miller Water District GSP
Kern Subbasin

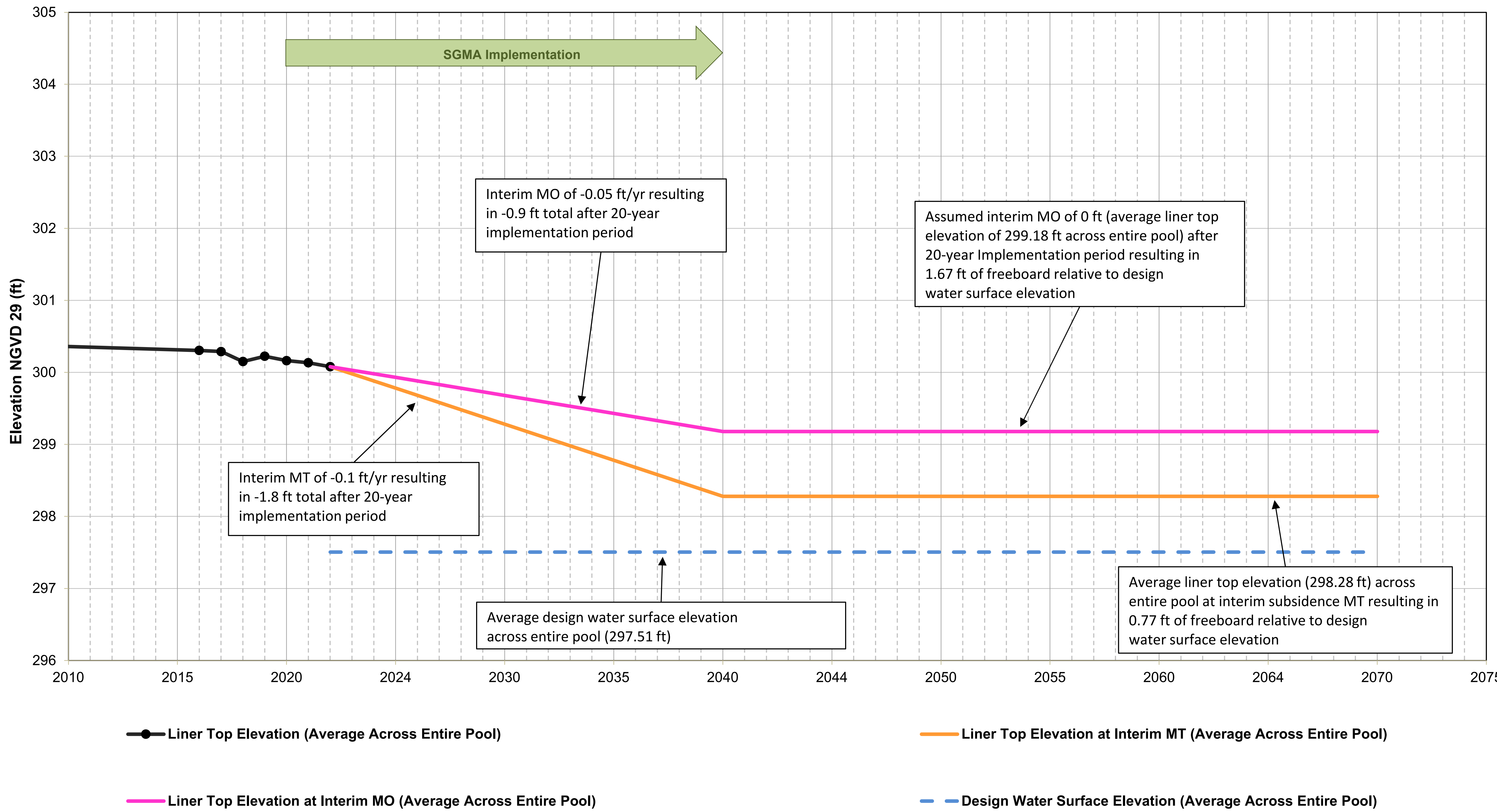

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Figure 3-4 Pool 29 Subsidence Sustainable Management Criteria

Henry Miller Water District GSP
Kern Subbasin

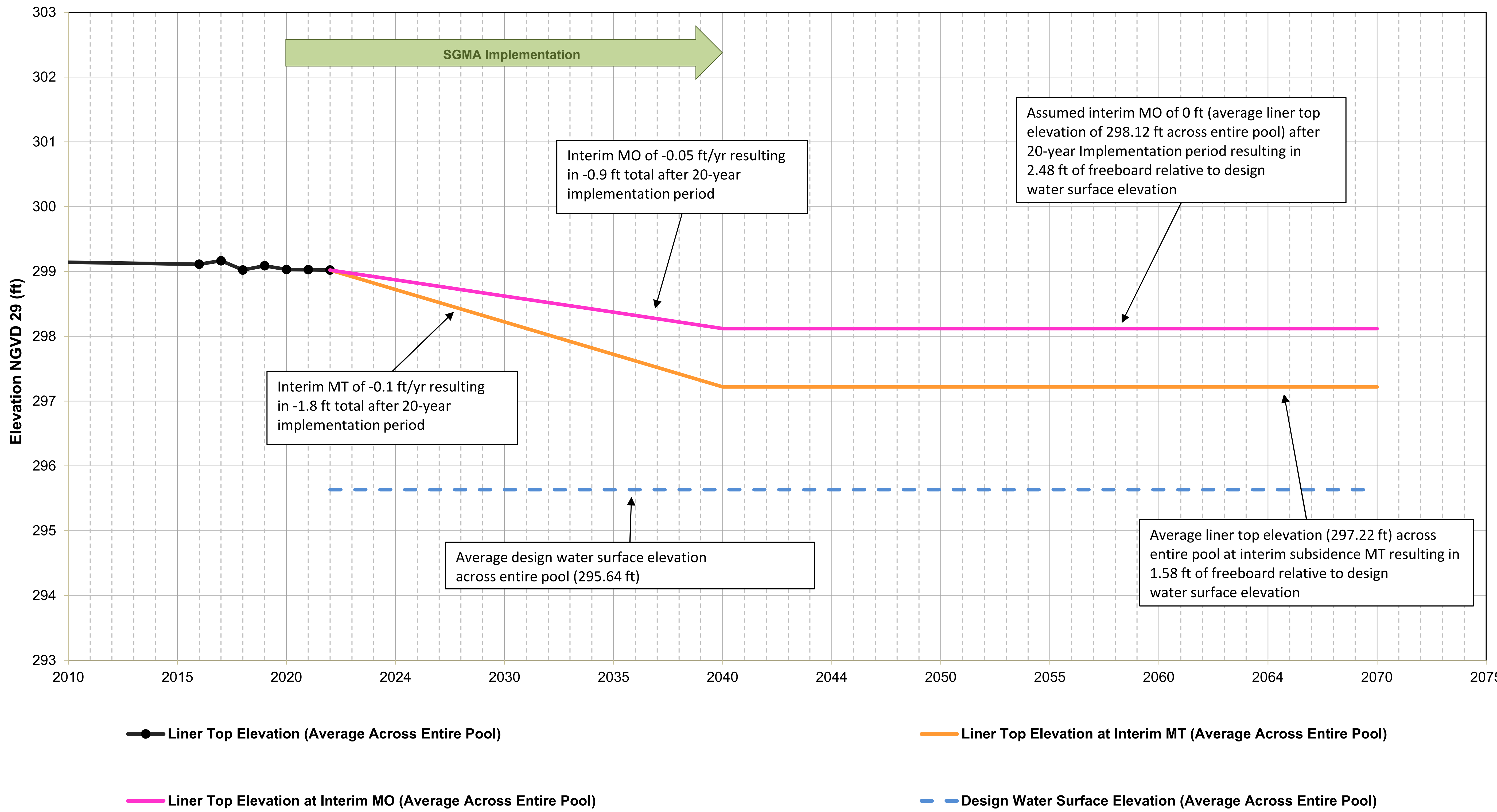

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Figure 3-5 Pool 30 Subsidence Sustainable Management Criteria

Henry Miller Water District GSP
Kern Subbasin

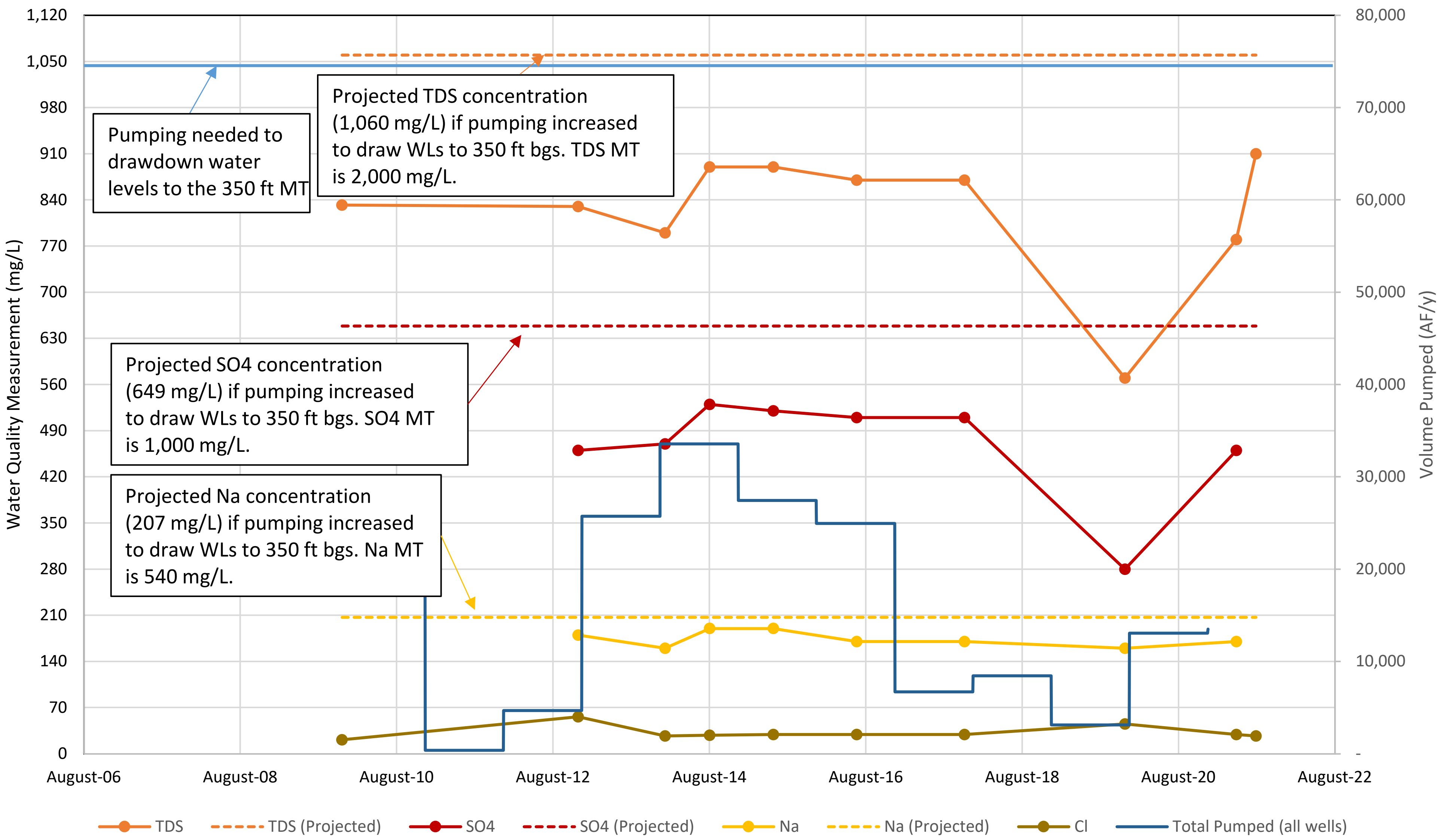

Figure 3-6 Relationship Between Water Level MT and Water Quality SMC

Henry Miller Water District GSP
Kern Subbasin

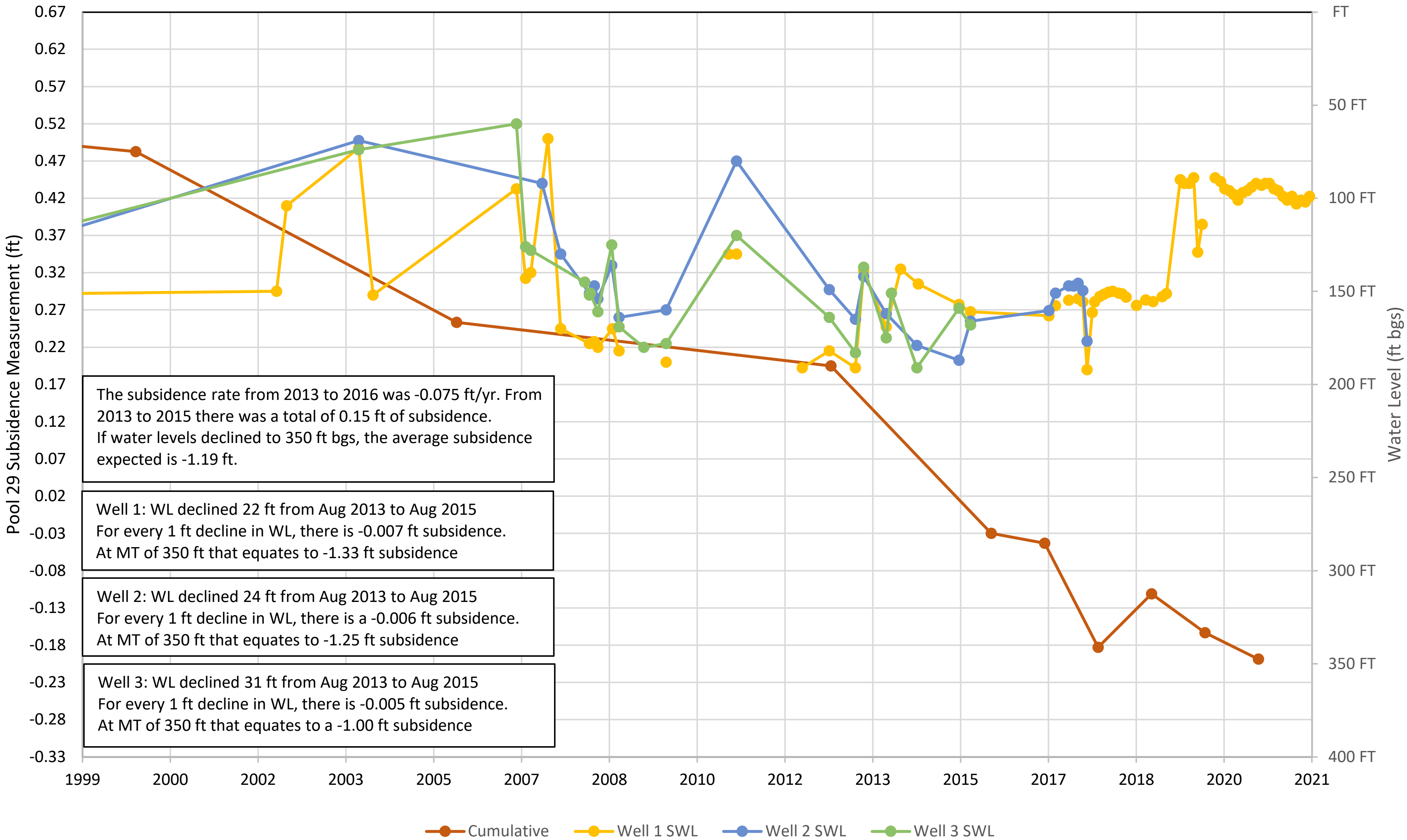

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Figure 3-7 Pool 29 Subsidence Trends and WLs in Wells Within 1-Mile Of Aqueduct

Henry Miller Water District GSP
Kern Subbasin

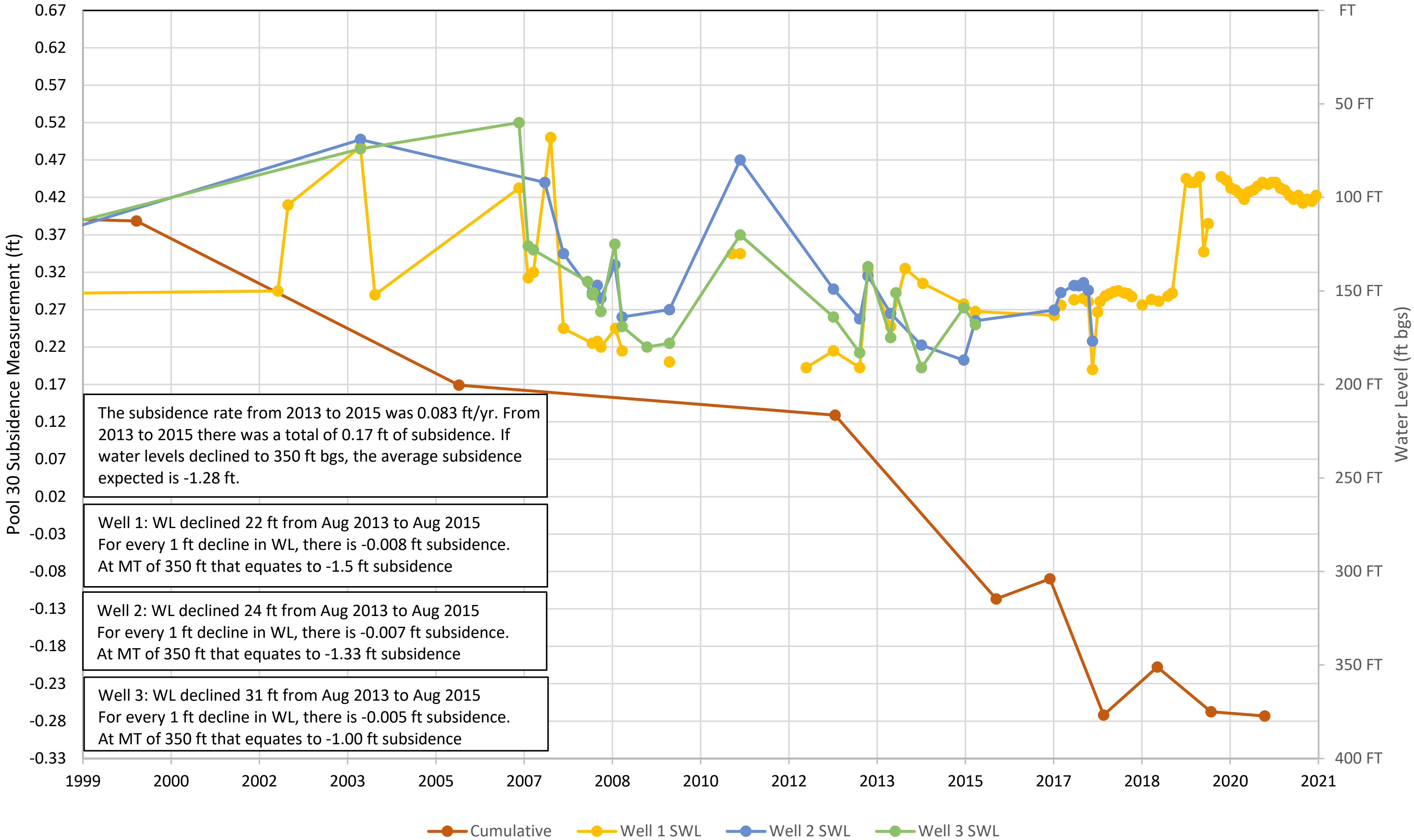

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Figure 3-8 Pool 30 Subsidence Trends and WLs in Wells Within 1-Mile Of Aqueduct

Henry Miller Water District GSP
Kern Subbasin

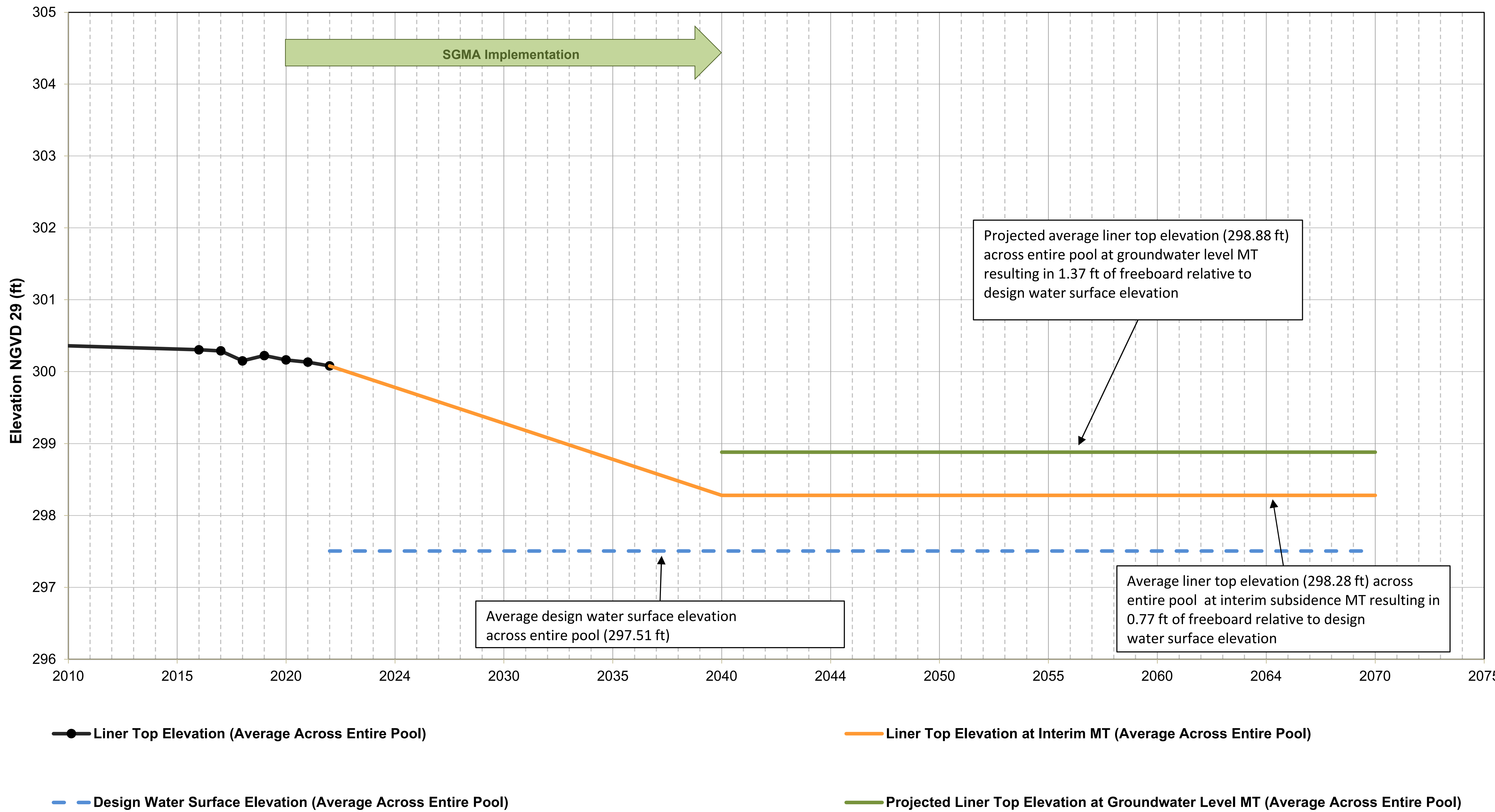

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Figure 3-9 Pool 29 Groundwater Level MT Relationship to Subsidence SMC

Henry Miller Water District GSP
Kern Subbasin

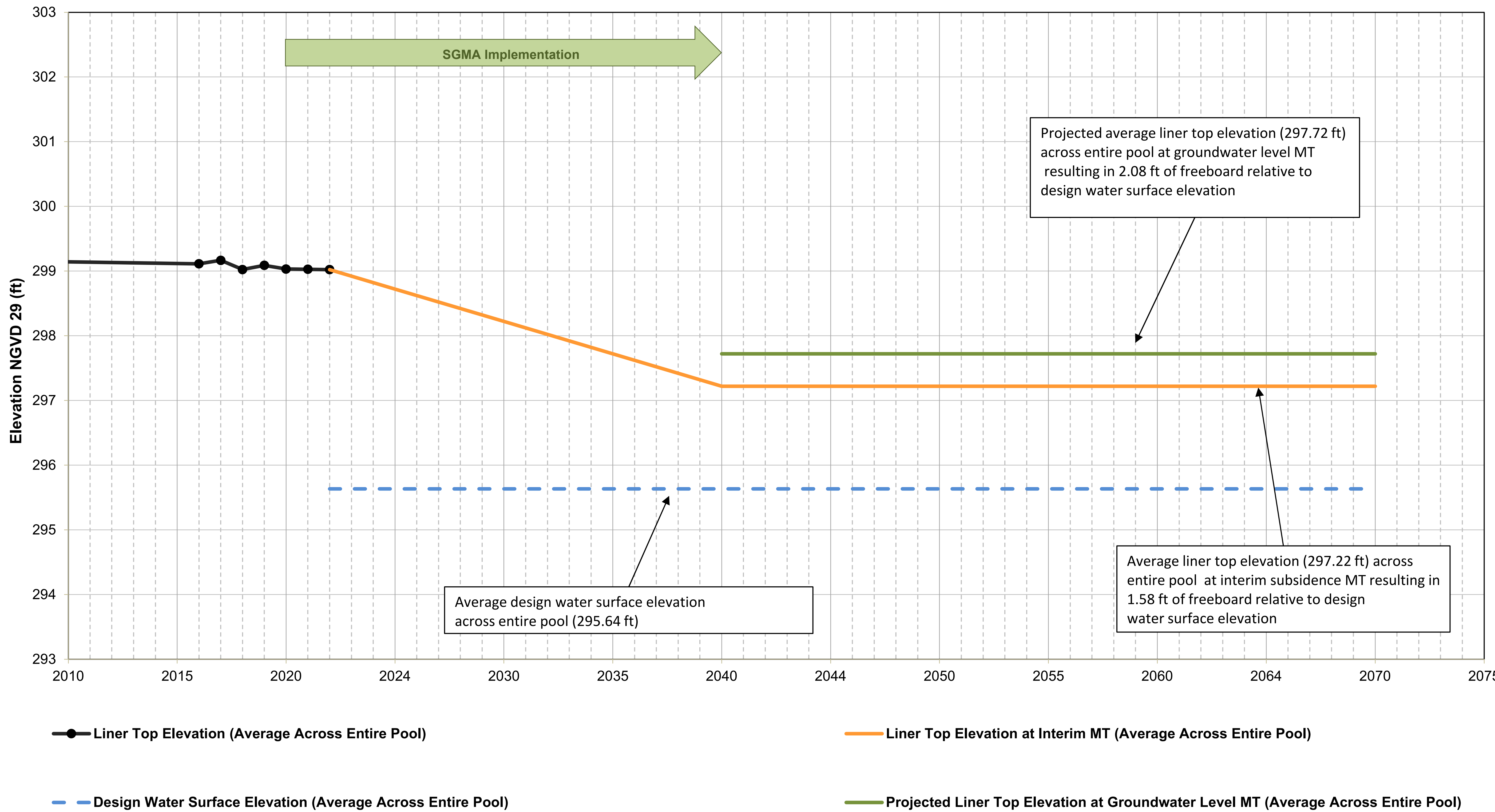

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Figure 3-10 Pool 30 Groundwater Level MT Relationship to Subsidence SMC

Henry Miller Water District GSP
Kern Subbasin

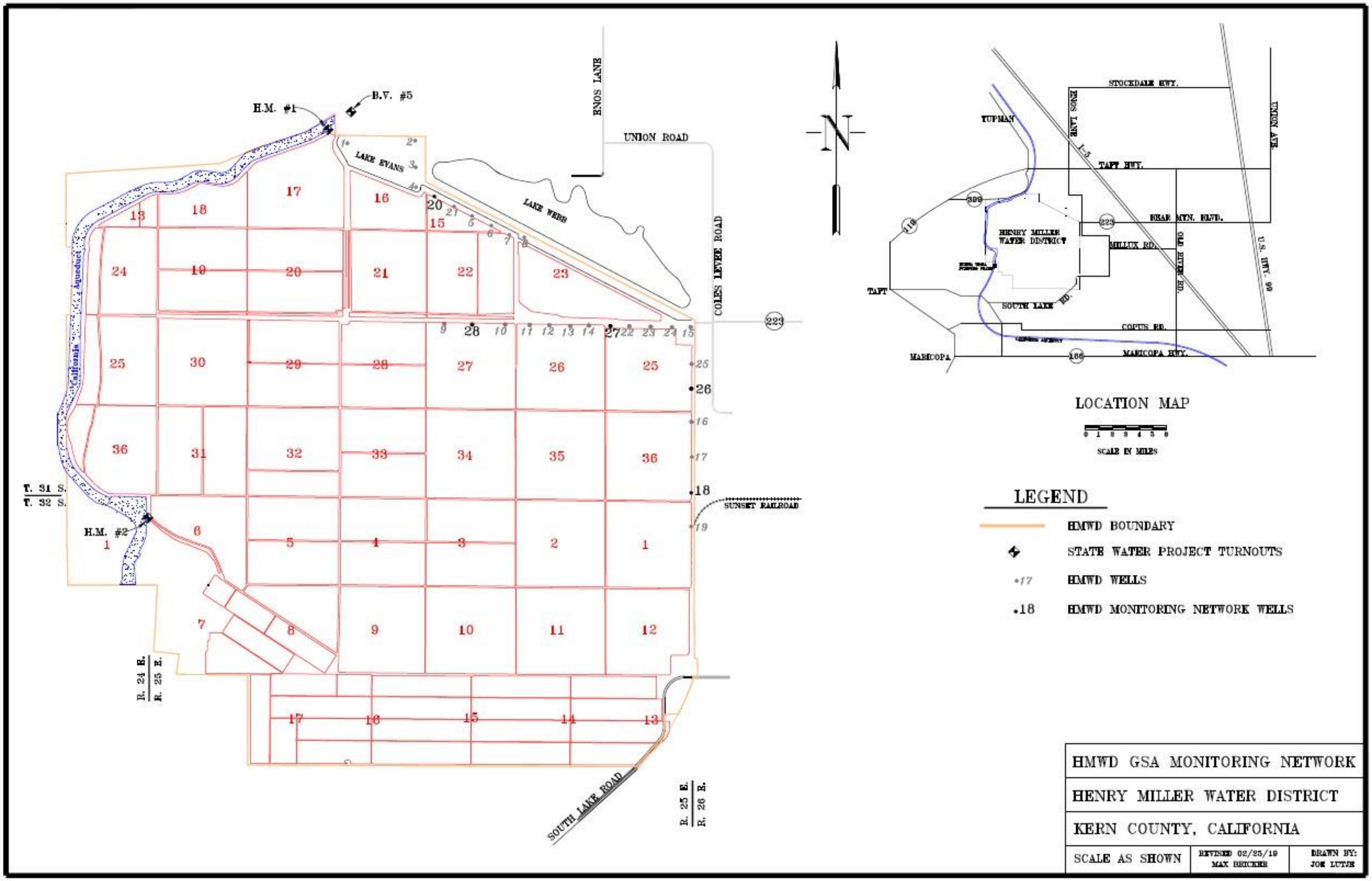

Figure 3-11. HMWD GSA Monitoring Network Map

4 PROJECTS AND MANAGEMENT ACTIONS (REG. § 354.44)

4.1 Project #1: Optimizing the recovery of Pioneer Project banked supplies in dry years

HMWD is a Recharge Participant in the Pioneer Project. Therefore, the District has a second priority right to recover banked water supplies from the Project. Since its inception in 1995, the District has banked SWP, Kern River, CVP, and other water in the Pioneer Project (or related Kern Fan facilities) for future recovery or flexibility with exchanges/transfers. In efforts to supplement supplies to the District in years when other surface supplies are sparse, the District could recover its banked supplies and deliver said water to lands within the District.

4.1.1 Measurable Objective that is Expected to Benefit from the Project or Management Action

Recovering banked supplies is expected to offset a decline in local water levels and a negative change in groundwater storage.

4.1.2 Circumstances for Implementation

The project may be implemented in a circumstance where HMWD's supplies are below their average quantities and the District would otherwise pump groundwater beyond its sustainable yield. The project would require the ability to recover and deliver the water; this may be difficult in certain years, when the Recovery Participants maximize their first priority to recover and preclude Participants, such as HMWD, from recovering their banked supplies.

4.1.3 Overdraft Mitigation Projects and Management Actions

The purpose of this project is to avoid overdraft in HMWD.

4.1.4 Time-Table for Initiation and Completion

In the event of a banked water recovery, HWMD will coordinate with Pioneer Project participants and stakeholders as needed.

4.1.5 Expected Benefits and how they will be Evaluated

The purpose of recovering banked water supplies is to prevent the decline of conditions below MT levels and prevent future MT exceedances for each of the applicable sustainability indicators.

4.1.6 How the Project will be Accomplished

HMWD will coordinate with the Pioneer Project as necessary to recover needed supplies.

4.1.7 Estimated Cost of Project

HMWD bears a portion of the recharge facility operations, maintenance, and facility costs through the contractual agreement already established with the Pioneer Project. Since this agreement is already in place, no additional costs will be incurred to implement this Project.

Other descriptive items outlined by SGMA were reviewed and deemed inapplicable to the implementation of this project including: public noticing, permitting and regulatory process, legal authority required, management of groundwater extractions and recharge, and additional GSP elements in Water Code § 10727.4.

4.2 Project #2: Demand reduction due to land fallowing in dry years

Prior to SGMA, the District recognized the changing landscape of CA water resources and developed a plan with its landowner to investigate a long-term crop plan with a focus on a limited acreage footprint of permanent crops, with the ability to fallow a significant majority of the District's irrigable lands in future years with limited surface water and groundwater supplies. The District irrigable lands now total less than 1/3 permanent crops, with over 2/3 of the lands being available to implement this project in future years as necessary.

4.2.1 Measurable Objective that is Expected to Benefit from the Project or Management Action

Demand reduction due to land fallowing is expected to offset a decline in local water levels and a negative change in groundwater storage.

4.2.2 Circumstances for Implementation

Historically, surface water supplies available to the District can be highly variable due to varying water year hydrology. If water year variability resulting in drought conditions continues to persist in the future, the project may be implemented in a circumstance where HMWD's surface water supplies are below their average quantities, and, instead of offsetting the lack of surface water with groundwater pumping that could exceed the District's sustainable yield, the District could implement this project, thereby voluntarily fallowing land within the District resulting in significant demand reduction. The fallowing would occur on lands where annual row crops would historically have been planted and irrigated primarily with groundwater.

4.2.3 Overdraft Mitigation Projects and Management Actions

The purpose of this project is to avoid overdraft in HMWD.

4.2.4 Time-Table for Initiation and Completion

In the event of making a determination for demand reduction due to voluntary land fallowing, HWMD will coordinate with its landowner as needed to develop a reasonable water plan that provides the landowner ample time for developing a crop plan in the year where the project is utilized. The project could be initiated and completed on a near real-time basis if needed.

4.2.5 Expected Benefits and how they will be Evaluated

The purpose of demand reduction due to land fallowing is to prevent the decline of conditions below MT levels and prevent future MT exceedances for each of the applicable sustainability indicators.

4.2.6 How the Project will be Accomplished

HMWD will coordinate with its landowner as needed to ensure successful implementation of the project in the year where the project is utilized. This may be accomplished through regular communication via board of director meetings, or other typical means.

4.2.7 Estimated Cost of Project

Since the District already provides water supply forecasting and other services related to water year projections for water supplies and crop water use, no additional costs will be incurred to implement this Project.

Other descriptive items outlined by SGMA were reviewed and deemed inapplicable to the implementation of this project including public noticing, permitting and regulatory process, legal authority required, management of groundwater extractions and recharge, and additional GSP elements in Water Code § 10727.4.

5 PLAN IMPLEMENTATION

The implementation of the GSP and associated costs are summarized in this chapter of the GSP. As discussed in Chapter 4, the only project to be implemented under this GSP is the recovery of Pioneer Project banked water supplies in dry years. The costs associated with implementing this project and the GSP, the implementation schedule, and plans for reporting are described below.

5.1 Estimate of GSP Implementation Costs (Reg. § 354.6)

Costs associated with implementing the HMWD GSP and GSA will occur over the 20-year implementation period include: operations, monitoring, reporting, management, administration, and development and implementation of the Projects and Management Actions (PMAs), with additional costs resulting from plan updates and periodic reporting. These costs are estimated on an annual basis and discussed in further detail below.

5.1.1 Operations and Monitoring Costs

Monitoring tasks, as described in Chapter 3, include semi-annual data collection activities and review of groundwater levels and water quality and annual review of groundwater storage data and land subsidence for the monitoring network. Related tasks include data analysis, monitoring equipment maintenance and replacement, metering of groundwater extractions, HMWD's portion of the cost to conduct five-year updates to the Subbasin's groundwater model, and annual reporting to DWR. These tasks can be described as follows with the estimated annual cost of each task presented in **Table 5-1**:

- **Groundwater Level Monitoring:** Since groundwater levels will be monitored in designated CASGEM wells, groundwater level monitoring devices and monitoring schedules are already in place for semi-annual measurements on these wells. Data be reviewed and submitted in annual reports in accordance with this GSP.
- **Groundwater Quality Monitoring:** Semi-annual water quality samples are currently taken at each of the HMWD wells. Data will be reviewed and submitted in annual reports in accordance with this GSP.
- **Subsidence Monitoring:** This will occur on an annual basis through the review of the *California Aqueduct Subsidence Studies.* Costs will only include review and reporting.
- **Equipment Maintenance:** Maintenance and repairs to monitoring instruments such as transducers, dataloggers, etc. will occur as necessary.
- **Groundwater Model Update:** Model updates will occur through the Subbasin's selection of a consultant and be performed on a basin-wide basis. Thus, HMWD will share this cost with other GSAs within the Subbasin.
- **Annual DWR Reporting:** Annual reports will be prepared and submitted to DWR by April 1st of each year.
- **Project Management, Coordination, and Outreach:** GSA and GSP Management, correspondence between HMWD and adjacent GSAs, and stakeholder outreach will occur as necessary.

Table 5-1: Operations and Monitoring Costs

Task No.	Description	Estimated Annual Cost
1	Groundwater Level Monitoring	$3,520
2	Water Quality Monitoring	$6,720
3	Pump Metering	$3,520
4	Subsidence Monitoring	$1,740
5	Data Management System	$7,040
6	Annual Comprehensive DWR Reporting	$21,120
7	Project Management, Coordination, and Outreach	$8,800
	Total	**$52,480**

5.1.2 Management, Administration, and Other Costs

The implementation of this GSP may result in administration and management costs and expenses such as legal fees, audit services, and insurance. These management and administration costs are already accounted for in day-to-day HMWD operations and the GSP implementation is not expected to increase the costs of these items.

5.1.3 Plan Update Costs

Every 5 years, and any instance when the GSP is amended during the implementation period, an update will be prepared in coordination with the other GSAs in the Subbasin and submitted to DWR. The update will incur costs associated with the professional services necessary for GSP preparation including reviewing and updating the Water Budget, Sustainable Yield, overdraft to be submitted to DWR. Estimated costs for these tasks are shown in **Table 5-2** below.

Table 5-2: Plan Update Costs

Task No.	Description	Estimated Additional Cost for 5-Year Plan Update
1	GSP Update	$140,000
2	Public Outreach and Coordination	$25,000
	Total	**$165,000**

5.1.4 Projects and Management Actions Development Costs

As discussed in Chapter 4, the only project that will be implemented under this plan is the continuation of HMWD participation in banked water supplies from the Pioneer Project. Ongoing coordination with adjacent GSAs is already included in the Public Outreach and Coordination costs presented in **Table 5-1**. Therefore, this project will not incur additional costs.

Table 5-3: Projects and Management Actions Development Costs

Task No.	Description	Estimated Annual Cost
1	Recovery of Banked Pioneer Project Supplies	$0
2	Demand Reduction due to Land Fallowing in Dry Years	$0
	Total	**$0**

5.1.5 Environmental Impact Report Cost

Since the only PMA implemented under this GSP is already in place, it will not create additional impacts on the environment, so CEQA, an Environmental Impact Assessment (EIA), and NEPA will not be applicable unless any additional PMAs are added throughout the implementation of the plan.

5.1.6 Total Costs

Annual implementation costs are expected to vary based on updates, implementation status, updates to data management and modeling systems, management needs, potential equipment maintenance or replacement, reporting requirements, professional services, and various other sources that could impact the cost. Since the GSP will be implemented over a 20-year period, an annual inflation value of 3% and 10% contingency was assumed for planning and budgeting purposes. The total estimated cost of implementing the HMWD GSP over the 20-year implementation period is approximately $2 million dollars as presented in **Table 5-4** below.

Table 5-4: Total Implementation Cost

Fiscal Year	Operations & Monitoring Costs	Management, Administration, & Other Costs	5-Year Annual Reviews & Updates	10% Contingency	Total
2020	$36,180	$0	$0	$3,618	$39,798
2021	$37,265	$0	$0	$3,727	$40,992
2022	$38,383	$0	$0	$3,838	$42,222
2023	$39,535	$0	$0	$3,953	$43,488
2024	$40,721	$0	$0	$4,072	$44,794
2025	$41,943	$0	$165,000	$20,694	$227,637
2026	$43,201	$0	$0	$4,320	$47,521
2027	$44,497	$0	$0	$4,450	$48,947
2028	$45,832	$0	$0	$4,583	$50,415
2029	$47,207	$0	$0	$4,721	$51,927
2030	$48,623	$0	$189,750	$23,837	$262,210
2031	$50,082	$0	$0	$5,008	$55,090
2032	$51,584	$0	$0	$5,158	$56,742

Fiscal Year	Operations & Monitoring Costs	Management, Administration, & Other Costs	5-Year Annual Reviews & Updates	10% Contingency	Total
2033	$53,132	$0	$0	$5,313	$58,445
2034	$54,725	$0	$0	$5,473	$60,198
2035	$56,367	$0	$218,213	$27,458	$302,038
2036	$58,058	$0	$0	$5,806	$63,864
2037	$59,800	$0	$0	$5,980	$65,780
2038	$61,594	$0	$0	$6,159	$67,753
2039	$63,442	$0	$0	$6,344	$69,786
2040	$65,345	$0	$250,944	$31,629	$347,918
Total	**$1,037,515**	**$0**	**$524,304**	**$186,142**	**$2,047,564**

5.1.7 Funding Sources

The funding source for implementing the GSP will be from the District's sole landowner and will be built into the landowners annual District budget.

5.2 Schedule for Implementation

Implementation of this GSP will begin following the submission to DWR on January 31, 2020. Annual and periodic evaluations will occur throughout the implementation period as described in the sections below.

5.3 Annual Reporting

The GSA will submit an Annual Report to DWR each year following the adoption of the GSP. Annual reports will include the information specified by DWR: measurements for the preceding water year (groundwater levels, water quality, meter readings, meter calibration data, and subsidence data, as necessary). Updates to the GSP, including updates to the model, data management system, and any GSP amendments will also be included with the GSP implementation progress. Reports will be submitted to DWR by April 1st every year and as needed following any significant SGMA amendments or changes to the GSP. The Annual Report will include:

- **General Information:** An executive summary will be prepared to discuss any significant findings or recommendations from the reporting period. A basin map, similar to or the same as the one provided in this GSP, will also be provided.
- **Monitoring Data:** All data collected for the reporting period; groundwater levels, water quality, surface water levels, and subsidence will be provided. Groundwater elevation data will also be presented using maps that depict the seasonal high and seasonal low groundwater levels and hydrographs of current and historical conditions, with a written description of the interpretation of the data, observed data gaps, and recommendations, as needed.

- **Groundwater Extraction Data:** Groundwater extraction data will be obtained from HMWD pumping records and metered extractions for the preceding water year and presented in tables, a map, and a written description. The measurement method, accuracy of measurements, and locations and volume of groundwater extractions will also be presented and discussed.
- **Surface Water Supply:** Surface water quantities, supplied or available, will be presented and discussed as necessary.
- **Total Water Use:** Total water use within the GSA will be evaluated through direct and indirect methods such as production and delivery records and meter readings and Management Plans and other sources of estimation where necessary. This information will be presented in table that shows the water use by sector (only agriculture in HMWD), method of measurement, and accuracy of the measurements.
- **Changes in Groundwater Storage:** Estimated change in groundwater storage for each aquifer will be determined using the same method as presented earlier in this GSP.
- **Implementation Progress:** Progress toward implementing the GSP will be evaluated, discussed, and updated as necessary; milestones, significant updates and changes, the implementation schedule, and implementation tasks and costs.

5.4 Periodic Evaluations and Reporting

HMWD will evaluate the GSP every 5 years, at a minimum, and during any amendment periods and provide a report to DWR. The Periodic Evaluation will be inclusive of all the elements generally included in the Annual Report with additional evaluation on the implementation progress and the progress of the GSP toward reaching the sustainability goal. It will be submitted with the Annual Report by April 1st on the year it is due. GSP updates will be prepared and submitted by January 31 on 2025, 2030, 2035, and 2040. The Periodic Evaluation will also be available to stakeholders and the public. It will include the items described above for the Annual Report in addition to:

- **Current Groundwater Conditions:** An evaluation and description of groundwater conditions over the reporting period relative to the interim milestone, MOs, MTs, and undesirable results will be presented via graphs, figures, and a written description.
- **Implementation of Projects and Management Actions:** The PMA will be evaluated to determine the implementation status, progress toward reaching the GSP sustainability goal, and the effect of the PMA on groundwater conditions. Re-evaluation of the PMA will occur if necessary.
- **Plan Elements:** The basin setting, management areas, and sustainable management criteria will be evaluated, as necessary, for any reconsiderations or revisions. This will also include the progress of the plan toward meeting the sustainability goal and interim milestones for each sustainability indicator.
- **Basin Setting Evaluation:** The basin setting will be evaluated for any significant changes or new information that may have developed during the reporting period. This will include significant changes in water use and potential overdraft conditions.

- **Monitoring Network:** The monitoring network will be evaluated for its functionality, potential data gaps, and areas that are not meeting data and reporting standards set by SGMA. This will also include a discussion of potential improvements and new data collection facilities, if necessary.
- **New Information:** Any new information that may have developed since the Plan adoption, last amendment, or last periodic evaluation will be presented.
- **Relevant Actions:** Any actions taken by the GSA that impact the implantation of the GSP such as regulations or ordinances related to the plan, development of new PMAs, or other changes will be provided.
- **Enforcement or Legal Actions:** A description of any enforcement or legal actions taken by the GSA will be included.
- **Plan Amendments:** Any amendments, completed or proposed, to the plan since the previous periodic evaluation will be discussed.
- **Summary of Coordination:** A description of GSA coordination and land use agencies will be presented if necessary.
- **Other Information:** Any other appropriate and relevant information pursuant to SGMA, the Plan Implementation, and DWR review will be included.

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APPENDICES

APPENDIX 1

APPENDIX 1

Buena Vista Water Storage District

Henry Miller Water District

Kern Groundwater Authority Groundwater Sustainability Agency

Kern River Groundwater Sustainability Agency

Olcese Water District Groundwater Sustainability Agency

APPENDICES
2 & 4

TODD GROUNDWATER

January 7, 2020

MEMORANDUM

To: Mark Mulkay, Kern River GSA
Patty Poire, Kern Groundwater Authority GSA

From: Michael Maley, Todd Groundwater
Charles Brush, Hydrolytics LLC

Re: **SGMA Water Budget Development using C2VSimFG-Kern in support of the Kern County Subbasin Groundwater Sustainability Plans (GSPs)**

1. INTRODUCTION

In compliance with the Sustainable Groundwater Management Act (SGMA), the multiple Groundwater Sustainability Agencies (GSAs) of the Kern County Subbasin (**Figure 1**) have successfully coordinated on the development of Groundwater Sustainability Plans (GSPs). The Kern County Subbasin, the largest in the State, was designated as critically-overdrafted by the California Department of Water Resources (DWR). Water management in the Kern County Subbasin is complex. It involves more than 30 water districts/systems, contains large groundwater banking projects of State-wide importance, and provides large quantities of groundwater to support both large urban centers and one of the top agricultural-producing areas in the country. In addition, most agencies are involved in conjunctive management of local surface water, imported state and federal water, and groundwater.

Within this complex water management setting, GSAs recognized that a numerical modeling tool would be needed to meet GSP regulations for assessment of historical, current, and future projected water budgets that are developed on a Subbasin-wide basis (§357.4(b)(3)). The California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) is anticipated to be DWR's primary tool for evaluating water management in the Central Valley and is specifically referenced in the GSP regulations for application to GSP water budgets (§354.18(f)); therefore, C2VSim was selected by the GSAs for GSP compliance.

This technical memorandum describes the process and approach for selection, revisions, and application of the C2VSim to the Kern County Subbasin. The memorandum documents the development of Subbasin water budgets and presents the results. This document is being prepared as an attachment to Subbasin GSPs and as an attachment to the Kern County Subbasin GSAs' coordination agreement.

1.1 Background

During late 2016 and 2017, Subbasin GSAs held a series of meetings and workshops to evaluate potential modeling tools for GSP application. Although numerous existing models had been developed by various entities in the Subbasin over time, none of those models covered the entire Subbasin or incorporated all of the local water budget components necessary to meet GSP requirements.

During the time that the Subbasin was evaluating various modeling alternatives, DWR was in the process of updating the regional C2VSim model through water year (WY) 2015. In particular, the GSP regulations stated that DWR would provide the C2VSim model "for use by Agencies in developing the water budget." Todd Groundwater developed an approach for review, revisions, and application of the C2VSim model to the Kern County Subbasin. In March 2017, the Kern River GSA (KRGSA), on behalf of the Subbasin GSAs, entered into a contract with Todd Groundwater to conduct the proposed scope of work. The Kern Groundwater Authority (KGA), on behalf of the Subbasin GSAs, also retained Woodard & Curran to conduct a peer review of the Todd Groundwater C2VSim model revisions and application for the Kern County Subbasin.

DWR released the C2VSim Fine Grid Public Beta model (C2VSimFG-Beta) on May 18, 2018 (CNRA, 2018). An initial model review indicated that the C2VSimFG-Beta generally had good historical precipitation, streamflow, land use and crop acreage for the entire Central Valley. Historical water supply and demand data were also generally good in the Sacramento Valley and San Joaquin River hydrologic regions; however, data were considered less reliable in the Tulare Lake hydrologic region including Kern County. To address this concern, Todd Groundwater – working with all Subbasin GSAs –revised the Kern County portion of C2VSimFG-Beta for WY1985 to WY2015. This revised version of C2VSim for the Kern County Subbasin, referred to herein as the C2VSimFG-Kern model, was used to develop historical, current and projected-future water budgets in accordance with the requirements in the GSP regulations.

The Central Valley portion of Kern County contains two groundwater subbasins, the Kern County Subbasin (5-022.14) and the White Wolf Subbasin (5-22.18) based on DWR Bulletin 118 (DWR, 2016A). All of the agencies that deliver water in White Wolf Subbasin also deliver water in the Kern County Subbasin and participated in the C2VSim revision. The White Wolf Subbasin portion of C2VSimFG-Beta model was included in this update to ensure coordination of groundwater conditions between the two subbasins. These are considered separate groundwater basins under SGMA with the Kern County Subbasin listed by DWR as critically-overdrafted with a GSP deadline of January 30, 2020, whereas the White Wolf Subbasin is listed as medium priority with a GSP deadline of January 30, 2022. Therefore, only the model results for the Kern County Subbasin are evaluated and reported here.

1.2 General Approach

The current C2VSim model has a detailed finite element mesh that closely follows local hydrologic features. As a regional model, the C2VSimFG-Beta may over-generalize local conditions within the Kern County Subbasin so as to be inconsistent with local site-specific data and knowledge. To address this concern, the managed water supply and demand inputs were updated to better represent the local water balance. To do this, the more general assumptions in C2VSimFG-Beta were replaced with local data and knowledge that are regionally or locally significant over the WY1995 to WY2015 Hydrology Period. Local managed water supply input data (e.g., surface water deliveries, land use, irrigation demand, return flows, and groundwater banking) were collected and applied to C2VSim. Improvement of Kern County data focused on incorporating:

- Surface water delivery volumes, application areas and use by water district,
- Groundwater banking recharge, recovery and application of recovered water,
- Irrigation demand from recent analyses of remote sensing data of evapotranspiration in the Kern County Subbasin based (ITRC, 2017),
- Urban demand for the Subbasin focusing on Metropolitan Bakersfield, and
- Data on other water sources and demands of local significance to individual districts/GSAs.

Compiling the data needed for the model revision required a coordinated effort from the Subbasin GSAs (**Figure 1**) to provide locally derived data on managed water supply and demand that was used to revise the C2VSimFG-Beta for the Kern County Subbasin. The Subbasin GSAs also coordinated on selection of consistent study periods for the C2VSimFG-Kern water budget analyses. Based on technical considerations and a review of regional data, the following study periods were selected:

- Historical Water Budget - WY1995 through WY2014 (Section 3.2), and
- Current Water Budget - WY2015 (Section 3.2),
- Projected Water Budget - WY2021 through WY2070 using 50 years of hydrologic data based on historical data (Section 6.1).

Todd Groundwater also coordinated data collection and model revision efforts with a Technical Peer Review Team and local agencies to ensure input data were accurately represented in the model. Tabulated input data, model files and model-derived water budgets were provided to the Technical Peer Review Team for review of accuracy and appropriateness. Model input data and results were also provided to Kern County Subbasin water districts and local water purveyors for their review. Comments and data issues were reconciled and incorporated into the revised C2VSimFG-Kern model.

1.3 Acknowledgements

These regional model revisions were enhanced by the participation of the many agencies that provided local water budget input data. Todd Groundwater worked with the member agencies, and their consultants, including the Kern River GSA, Kern Groundwater Authority GSA, Henry Miller Water District GSA, Olcese Water District GSA, and Buena Vista GSA to coordinate acquisition of input data from other agencies in formats that could be easily incorporated into the C2VSim model. On-going review of interim model results by these agencies, including local zonal water budgets, groundwater hydrographs and other model results, helped ensure that the revised model reproduced local mass balance estimates across the Subbasin.

Woodard & Curran conducted an on-going peer review of model input files at the request of the GSAs in the Kern County Subbasin. Todd Groundwater worked with Woodard & Curran throughout the historical model revision process. The C2VSimFG-Kern input files for the Kern County Subbasin revised historical simulation were provided to DWR for incorporation into future C2VSim public releases.

Dr. Charles Brush of Hydrolytics LLC was added to the Todd Groundwater modeling team. As an early developer of C2VSim for DWR, he provided his experience and expertise with the C2VSim. This collaborative effort provided further assurance that the significant model revisions could be managed in an efficient manner to meet the expedited schedule for water budget development.