July 2022

Tulare Lake Subbasin Groundwater Sustainability Plan - Amended

Volume 1

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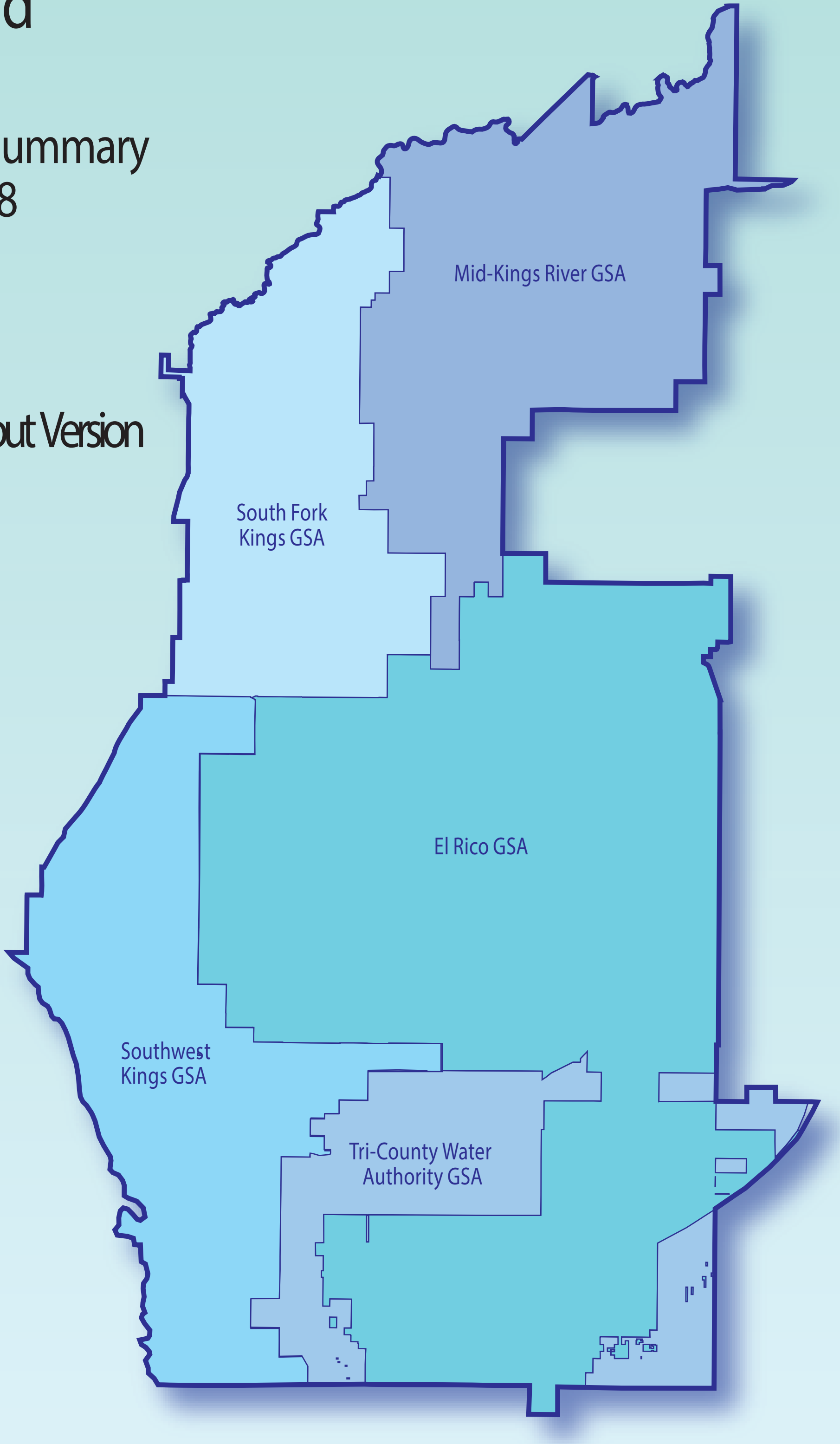

MID-KINGS RIVER
GROUNDWATER SUSTAINABILITY AGENCY

South Fork Kings
Groundwater Sustainability Agency

El Rico GSA

SWK
Southwest Kings
Groundwater Sustainability Agency

TRI-COUNTY
WATER AUTHORITY

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ACRONYMS AND ABBREVIATIONS

%	Percent
§	Section
µm/sec	micrometers per second
µS/cm	microsiemens per centimeter
A-Clay	A perched unconfined aquifer exists above a locally extensive clay layer
AF	acre-feet
AF/Y	acre-feet per year
AGR	agricultural uses
AMSL	above mean sea level
ASR	Aquifer Storage and Recovery
bgs	below ground surface
BLM	Bureau of Land Management
BMP	Best Management Practice
BPA	Basin Plan Amendment
Caltrans	California Department of Transportation
CASGEM	California Statewide Groundwater Elevation Monitoring
C-Clay	A semi-confined aquifer is present above a locally extensive clay layer
CCR	California Code of Regulations
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CGPS	Continuous Global Positioning System
CSD	Community Service(s) District
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CV-SALTS	Central Valley Salinity Alternatives for Long-term Sustainability
CVSRN	Central Valley Spatial Reference Network
DAC	Disadvantaged Community

DDW	Division of Drinking Water
DMS	Data Management System
DOF	Department of Finance
DPR	Department of Pesticide Regulation
DQO	Data Quality Objective
DTSC	Department of Toxic Substances Control
DWR	California Department of Water Resources
DWSAP	Drinking Water Source Assessment and Protection Program
EC	electrical conductivity
E-Clay or Corcoran Clay	A fully confined aquifer exists below a regionally extensive clay layer
EPA	United States Environmental Protection Agency
ETc	Crop evapotranspiration
ft	foot/feet
ft/d	foot per day
GAMA	Groundwater Ambient Monitoring and Assessment Program
GDE	Groundwater Dependent Ecosystem
GIS	Geographic Information System
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	Hydrogeologic Conceptual Model
HS	Health and Safety
ID	Irrigation District
ILRP	Irrigated Lands Regulatory Program
InSAR	Interferometric Synthetic Aperture Radar
ITRC	Cal Poly Irrigation Training & Research Center
KCWD	Kings County Water District
KDWCD	Kaweah Delta Water Conservation District
KRCD	Kings River Conservation District
KRFMP	Kings River Fisheries Management Program
KRWA	Kings River Water Association
KRWQC	Kings River Water Quality Coalition
K_{sat}	saturated hydraulic conductivity
LiDAR	Light Detection and Ranging

LU	Land Use
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
MKR	Mid-Kings River
MO	measurable objective
MSL	mean seal level
MT	minimum threshold
MUN	municipal or domestic water supplies
NASA	National Aeronautics and Space Administration
NCCAG	Natural Communities Commonly Associated with Groundwater”
PBO	Plate Boundary Observatory
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PUD	Public Utility District
PVC	polyvinyl chloride
RC	Resource Conservation
RD	Reclamation District
RMS	representative monitoring site
RWQCB	Regional Water Quality Control Board
SFK	South Fork Kings
SGMA	Sustainable Groundwater Management Act of 2014
SJRRP	San Joaquin River Restoration Program
SJVAPCD	San Joaquin Valley Air Pollution Control District
SMARA	Surface Mining and Reclamation Act
SOPAC	Scripps Orbit and Permanent Array Center
SR	State Route
Subbasin	Tulare Lake Subbasin
SURF	Surface Water Database
SWP	State Water Project
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TCWA	Tri-County Water Authority
TDS	Total Dissolved Solids
TLBWSD	Tulare Lake Basin Water Storage District

TNC	The Nature Conservancy
TV	television
U.S.	United States
UNAVCO	University Navigation Satellite Timing and Ranging Consortium
USACE	United States Army Corps of Engineering
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UWMP	Urban Water Management Plan
VOC	volatile organic chemical
WCR	Well Completion Report
WD	Water District
WHPA	Wellhead Protection Area
WWQC	Westside Water Quality Coalition
WWTP	waste water treatment plant

EXECUTIVE SUMMARY

23 CCR §354.4 *Each Plan shall include the following general information: (a) An executive summary written in plain language that provides an overview of the Plan and Description of Groundwater conditions in the basin.*

This Groundwater Sustainability Plan (GSP) was developed pursuant to the Sustainable Groundwater Management Act of 2014 (SGMA). GSPs are required under SGMA to bring the Tulare Lake Subbasin (Subbasin) into groundwater sustainability by 2040. Under SGMA, Groundwater Sustainability Agencies (GSAs) were created in groundwater subbasins to develop and implement GSPs for the subbasin.

The Tulare Lake Subbasin submitted a single GSP in January 2020 to the Department of Water Resources (DWR). DWR was required to determine whether the GSP conformed to the specific requirements of SGMA. In a letter dated January 28, 2022, DWR determined that that the GSP is incomplete. DWR stated that the GSP was considered incomplete as it "does not define undesirable results or set sustainable management criteria for groundwater levels, subsidence, and water quality in the manner consistent with SGMA and the GSP regulations." Upon receiving the incomplete determination, the Subbasin had 180 days to address the identified deficiencies and submit a revised GSP by July 27, 2022. The GSAs are submitting this 2022 Amended GSP to address the three deficiencies outlined in the determination letter. The 2022 Amended GSP consists of clean and redline strike out versions of the 2020 GSP and the attached 2022 GSP Addendum. The 2022 GSP Addendum was prepared to specifically address the incomplete determination letter from DWR. Sections of this document have been edited since the original submittal in 2020 and direct the reader to the Addendum for further details.

1.0 Introduction

Chapter 1, *Introduction*, provides the Subbasin overview and sustainability goal and information regarding the organization, management, and legal authority of the Groundwater Sustainability Agencies (GSAs).

1.1 Overview and Purpose of the Groundwater Sustainability Plan

The Subbasin is located within the southern portion of the San Joaquin Valley in the Central Valley of California (Figure ES-1). The Subbasin (Basin No. 5-22-12) is classified as a high-priority subbasin by the California Department of Water Resources (DWR) and is one of 21 basins and subbasins identified by DWR as critically overdrafted (DWR 2019a). Five local GSAs, the Mid-Kings River (MKR), South Fork Kings (SFK), Southwest Kings (SWK), El Rico (ER), and the Tri-County Water Authority (TCWA) GSAs, cooperatively developed this GSP to address the management of current and future groundwater use within the Subbasin to achieve sustainability (Figure ES-2).

The goal of the GSP is to reach Subbasin-wide groundwater sustainability within 20 years of the

GSP's implementation (DWR 2019b). The GSP will be reevaluated and updated, at a minimum, every five years (2025, 2030, 2035, and 2040) to revise, as necessary, sustainability goals and management criteria, monitoring, and implementation of groundwater projects and management strategies.

1.2 Organization and Management Structure of the GSAs

The five participating GSAs collaboratively developed this single GSP for Subbasin under an Interim Operating Agreement (Appendix F). The Interim Operating Agreement establishes mechanisms to ensure collaboration and coordination throughout the Subbasin. Each GSA was formed by local member agencies that are represented as stakeholders on each GSA Board of Directors. The Boards of Directors and their technical teams have collected and organized data from experienced groundwater consultants as well as sought feedback from groundwater users within the GSA boundaries through each SGMA phase (see Stakeholder Engagement and Communication Plan in Appendix B).

2.0 Plan Area

Chapter 2, *Plan Area*, specifies the geographic extent of the GSP including but not limited to jurisdictional boundaries, existing land uses and land use policies, identification of water resource types, density of wells, and location of communities dependent on groundwater in the Subbasin.

2.1 Summary of Jurisdictional Areas and Other Features

The Plan area is mostly located within Kings County, with small portions in Tulare and Kern counties. The groundwater basin covers approximately 837 square miles (535,869 acres) (DWR 2016b). The land overlying the Subbasin has a population of 125,907 (2010) and density of 150 persons per square mile. A major portion of the Subbasin’s population works in the agricultural production industry. The GSAs vary in acreage and location within the GSP area (Figure ES-2).

Mid-Kings River Groundwater Sustainability Agency

The MKR GSA covers approximately 152 square miles (±97,400 acres) and is located in the northeastern portion of the Subbasin (Figure ES-2) (DWR 2019d). The public and private agencies within the MKR GSA include the Kings County Water District (WD), the City of Hanford, and Kings County. Surface water delivery entities within this area are the Riverside Ditch Company, the Peoples Ditch Company, the Settlers Ditch Company, the Last Chance Water Ditch Company, the New Deal Ditch Company, and the Lone Oak Ditch Company. The primary industries are agriculture and food processing. The primary industry within the MKR GSA is agriculture. Other industries within the boundary include food processing, as well as warehousing and distribution, and commerce industry that is standard in a community of approximately 60,000 people (e.g., automotive shops, supermarkets, etc.).

South Fork Kings Groundwater Sustainability Agency

The SFK GSA covers approximately 111 square miles (±71,300 acres) and is located in the northwestern part of the Subbasin (Figure ES-2) (DWR 2019d). The public and private agencies within the SFK GSA include the City of Lemoore, Kings County, Empire West Side Irrigation District (ID), Stratford ID, Stratford Public Utility District, Lemoore Canal and Irrigation Company, John Heinlen Mutual Water Company, and Jacob Rancho Water Company. The primary industries within the SFK GSA are agriculture and food processing.

Southwest Kings Groundwater Sustainability Agency

The SWK GSA covers approximately 140.6 square miles (±93,100 acres) and is located in the western portion of the Subbasin (Figure ES-2). The public and private agencies within the SWK GSA are Dudley Ridge WD, Tulare Lake Reclamation District (RD) #761, Kettleman City Community Service District (CSD), Tulare Lake Basin Water Storage District (TLBWSD), and Kings County. Due to the poor yield and poor quality of the groundwater within the SWK GSA, only a minimal quantity of groundwater is pumped within the GSA. Groundwater levels, water quality, and subsidence are maintained at current levels. The primary industries within the GSA are agriculture, oil production, and commercial usage specific to Kettleman City.

El Rico Groundwater Sustainability Agency

The ER GSA covers approximately 357 square miles (±228,400 acres) and is located in the center of the Subbasin (Figure ES-2) (DWR 2019d). The public and private agencies within the ER GSA are the City of Corcoran, Kings County, Alpaugh ID, Melga WD, Lovelace RD, Salyer WD, Corcoran ID, Tulare Lake Drainage District, and the TLBWSD. The primary industry within the ER GSA is agriculture. Other industries within the boundary include food processing, as well as warehousing and distribution, and commerce industry that is standard in a community of approximately 10,000 people (e.g., automotive shops, supermarkets, etc.).

Tri-County Water Authority Groundwater Sustainability Agency

The TCWA GSA is a collective group of local water agencies dedicated to monitoring and regulating groundwater in the Tulare Lake Hydrologic Region. The TCWA GSA covers approximately 170.0 square miles (±108,800 acres) in the Tulare Lake and Tule subbasins (Figure ES-2) (DWR 2019d). Approximately 75.19 square miles (±48,100 acres) of the GSA's area is located within the southeastern portion of the Subbasin. The primary industry within the TCWA GSA is almost entirely agriculture.

2.2 Water Resource Monitoring and Management Programs

Monitoring and Management Programs

Groundwater Level Monitoring

The California Statewide Groundwater Elevation Monitoring (CASGEM) Program tracks long-term groundwater elevation trends throughout California. The Kings River Conservation District (KRCD) is the local agency that monitors groundwater levels within the Plan area.

Groundwater Extraction Monitoring

It is not known how many private wells are metered nor if any existing groundwater extraction monitoring programs are in place. Potential future groundwater monitoring policies are discussed in Chapter 5, *Monitoring Network*.

Groundwater Quality Monitoring

See Chapter 5, *Monitoring Network*, for information on groundwater quality monitoring within the Subbasin.

Land Surface Subsidence Monitoring

Land subsidence has been measured for many years throughout the Central Valley. The Plan area contains various local monitoring networks, which can be utilized to survey existing benchmarks to measure subsidence. See Chapter 5, *Monitoring Network*, for further information regarding subsidence in the Plan area.

Surface Water Monitoring

Kings River Water Association monitors surface water in the Kings River and the associated watershed including seasonal snowpack, reservoir stage, reservoir inflow and outflow, Kings River flows, and Kings River diversions. The Friant Water Authority monitors San Joaquin River’s water delivered through the Friant-Kern Canal. The Kaweah and St. Johns Rivers Association monitors Kaweah River water flows and deliveries, and the St. John’s River that reaches the Subbasin via Cross Creek and Tule River. DWR and TLBWSD monitor the State Water Project (SWP) and the Kings River flows that enter the Subbasin.

Irrigated Lands Regulatory Program

The Irrigated Lands Regulatory Program (ILRP) was initiated in 2003 to address pollutant discharges to surface water and groundwater from commercially irrigated lands. The program is administered by the Central Valley Regional Water Quality Control Board (RWQCB).

GSP Monitoring and Management Plans

The individual water entities located within the Plan area will be responsible for continuing to collect data for any current monitoring or management plan. The monitoring program is described further in Chapter 5, *Monitoring Network*.

Impacts to Operational Flexibility

Regulatory Decisions and Agreements

Regulatory monitoring and management programs outside the boundaries of the Subbasin have limited the operational flexibility and management of the Subbasin by reducing the Central Valley Project (CVP) and SWP delivery amounts, which include the following:

- **1992 Central Valley Project Improvement Act (CVPIA)**: Enactment of the CVPIA mandated changes in the CVP and reallocation of water supplies and reductions in pumping, particularly for the protection, restoration, and enhancement of fish and wildlife. Water supplies in the Plan area have been reduced as a result of the CVPIA.
- **2007 Biological (Wanger) Decision:** A federal decision found that United States Bureau of Reclamation (USBR) did not consider evidence that fish, including salmon and delta smelt, would be harmed by increased water exports for the Sacramento-San Joaquin Delta. The result of this curtailed SWP and CVP pumping from the Delta, reducing overall supplies to the Subbasin.

Places of Use

Agencies use of water from Kings River, Kaweah River, Tule River, SWP, and CVP are restricted to the place of use defined by their water rights. This GSP will not alter these agreements.

Contaminant Plumes

Water quality for individual monitoring wells can be found from Geotracker (SWRCB 2019a).

Kings River Fisheries Management Program

The Kings River Fisheries Management Program (KRFMP) includes numerous measures to benefit the Kings River fisheries, including year-round flows, improved temperature control, and additional monitoring. The local water entities have already adjusted agricultural operations to adapt to the KRFMP.

Conjunctive Use Programs

Conjunctive use is the coordinated and planned management of surface and groundwater resources to maximize their efficient use. Conjunctive use is utilized to improve water supply reliability and environmental conditions, reduce groundwater overdraft and land subsidence, and to protect water quality.

Relation to General Plans

Every county and city in California is required to develop and adopt a General Plan (California Government Code, §65350-65362). Six general plans are in effect within the boundaries of the

Subbasin, each of which were adopted prior to creation of the local GSAs and preparation of the GSP. The Plan area also includes four community plans within unincorporated areas (Table 2-3).

Impact of GSP on Water Demands

The General Plans of the counties of Kings, Tulare, and Kern, as well as the cities of Hanford, Lemoore, and Corcoran, make assumptions for both rural and urban development. Urban Water Management Plans prepared for the cities of Lemoore, Hanford, and Corcoran address assumed land use changes and growth rates. This GSP may use the land use change assumptions identified in the General Plans as well as other information for forecasting the anticipated water budget.

Impact of GSP on Water Supply Assumptions within Land Use Plans

Kern County General Plan

There are no anticipated impacts on Kern County lands within the Subbasin. The total Kern County land area within the Subbasin is 360 acres (Kern County 2009).

Kings County General Plan

Future projections from the Department of Finance expect the population to reach 181,218 by the year 2035 (DOF 2019). The primary water supply goal in this plan is for reliable and cost-effective infrastructure systems that permit the county to sustainably manage its diverse water resources and agricultural needs, secure additional water, and accommodate for future urban growth (Kings County 2010).

Tulare County General Plan

Tulare County's General Plan 2030 Update developed goals and policies to encourage sustainable groundwater management, such as to develop additional water sources, implement water conservation, and encourage demand management measures for residential, commercial, and industrial indoor and outdoor water uses in all new urban development (Tulare County 2012).

City of Hanford General Plan

The Land Use, Transportation, Water Resources, and Public Facilities sections of the City of Hanford's General Plan discuss various topics including water supply. The primary water supply goal in the plan is to maintain reliable and cost-effective infrastructure systems that permit the city to sustainably manage its diverse water resources and needs.

City of Lemoore General Plan

The City of Lemoore General Plan policies are geared towards preserving environmental resources such as open space, prime farmland, wetlands, special species, water resources, air quality, and other elements of value to Lemoore residents. If the city grows at the anticipated rate, demand will exceed the supply available from existing wells. There is no restriction on the number of wells the City of Lemoore may drill within city boundaries. Water quality maintenance is a more considerable challenge to meeting water demand than water quality for the City of Lemoore (City of Lemoore 2015).

City of Corcoran General Plan

The Land Use, Circulation, Safety, Conservation and Open Space, Air Quality, and Public Services and Facilities sections of the City of Corcoran's General Plan discuss various topics including water supply. The General Plan's primary water supply goal is to protect natural resources including groundwater, soils, and air quality in an effort to meet the needs of present and future generations (City of Corcoran 2014).

Permitting Process for New or Replacement Wells

In California, local jurisdictions with the authority to adopt a local well ordinance that meets or exceeds DWR Well Standards have regulatory authority over well construction, alteration, and destruction activities (DWR 2019a). After the submittal of the GSP, California Water Code §10725 - §10726.9 describes the authoritative power by the GSAs, including but not limited to imposing spacing requirements on new groundwater well construction, imposing operating regulations on existing groundwater wells, and controlling groundwater extractions. The GSA may use the powers described in the above code to provide the maximum degree of local control and flexibility consistent with sustainability goals described in the GSP.

Land Use Plans outside the Basin

In general, all future land use changes will need to consider the net groundwater impact to neighboring basins, and updates to agency General Plans will need to consider GSPs and the responsibility of each member and participating agency. GSPs for neighboring basins will be evaluated during the GSP review process. Coordination between subbasins is required as part of GSP implementation.

2.3 Additional GSP Components

Wellhead Protection

A Wellhead Protection Area is defined by the Safe Drinking Water Act Amendment of 1986 as "the surface and subsurface area surrounding a water well or wellfield supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield" (100 U.S. Code. 764). Municipal and agricultural wells constructed by the GSA member agencies are designed and constructed in accordance with DWR Bulletins 74-81 and 74-90. A permit is required from the applicable county prior to construction of a new well within the GSA's area. In addition, the GSA member agencies encourage landowners to follow the same standard for privately owned wells.

Migration of Contaminated Groundwater

Groundwater contamination can be human-induced or caused by naturally occurring processes and chemicals. Sources of groundwater contamination can include irrigation, dairy production, pesticide applications, septic tanks, industrial sources, stormwater runoff, disposal sites, and improperly constructed wells.

Databases provide information and data on known groundwater contamination, planned and current corrective actions, investigations into groundwater contamination, and groundwater quality from select water supply and monitoring wells are maintained by the State Water Resources Control Board (SWRCB), Department of Toxic Substances Control, California Department of Pesticide Regulation, and the Groundwater Ambient Monitoring and Assessment Program (GAMA).

Well Abandonment/Well Destruction Program

Well abandonment generally includes properly capping and locking a well that has not been used in over a year. Well destruction includes completely filling in a well in accordance with standard procedures listed in Section 23 of DWR Bulletin 74-81 (DWR 1981). DWR Bulletin 74-90 includes a revision in Section 23, for Subsection A and B, from Bulletin 74-81 (DWR 1991).

Replenishment of Groundwater Extractions

Groundwater replenishment occurs naturally through rainfall, rainfall runoff, and stream/river seepage and through intentional means, including deep percolation of crop and landscape irrigation, wastewater effluent percolation, and intentional recharge. The primary local water sources for groundwater replenishment in the Plan area include precipitation, Kings River, Kaweah River, Tule River, Deer Creek, Poso Creek, and various smaller local streams and an extensive network of irrigation canals.

Well Construction Policies

Proper well construction is necessary to ensure reliability, longevity, and protection of groundwater resources from contamination. All of the GSA member agencies follow state standards when constructing municipal and agricultural wells (DWR 1991).

Groundwater Projects

The GSA member agencies in general developed their own projects to help meet their water demands and will develop additional future projects to meet sustainability. Developing groundwater recharge and banking projects is considered key to stabilizing groundwater levels. The GSA will also support measures to identify funding and implement regional projects that help the region achieve groundwater sustainability.

Efficient Water Management Practices

Water conservation has been and will continue to be an important tool in local water management, as well as a key strategy in achieving sustainable groundwater management. All the GSA member agencies engage in some form of water conservation including water use restrictions, water metering, education, and tiered rates.

Relationships with State and Federal Agencies

From a regulatory standpoint, the GSAs have numerous relationships with state and federal agencies related to water supply, water quality, and water management. Relationships unique to the region include those with entities managing the Kings River and Pine Flat Dam. The Kings River provides the majority of surface water used in the area. Kings River water is impounded by Pine Flat Dam, which is owned and operated by the United States Army Corps of Engineers (USACE) (Kings County 2002). The GSA member agencies work with the USACE and SWRCB to oversee and manage their Kings River water as needed. The local agencies also developed and continue to implement the KRFMP in partnership with the CDFW.

Land Use Planning

Each of the local member agencies and water entities of the Subbasin's GSAs have an interest in land use planning policies and how they relate to the use of available water supplies.

Groundwater Dependent Ecosystems

The Nature Conservancy (TNC) worked with DWR to identify Groundwater Dependent Ecosystems (GDE) throughout the state. TNC primarily used vegetative indicators and applied them to historical aerial imagery. Imagery was cross-referenced with CASGEM well levels to identify possible GDEs. The data used in GDE identification pre-dates the baseline year of 2015, so all land use changes in the interim period may not be included. Such areas have been delineated within the Subbasin, but currently have not been confirmed.

2.4 Notice and Communication

Formation of GSAs

Representatives from cities, counties, WDs, IDs, CSDs, and private water companies participated in the formation of the GSAs. Additionally, landowners, Disadvantaged Community representatives, and industry representatives were present at GSA formation meetings.

Implementation of the GSP

SGMA implementation at the GSA level begins as DWR is reviewing this GSP. During the implementation phase, communication and engagement efforts focus on educational and informational awareness of the requirements and processes for reaching groundwater sustainability as set forth in the submitted GSP.

Decision-Making Process

Each of the five GSAs within the Subbasin operate under an Interim Operating Agreement (effective September 1, 2017) to facilitate coordination and management actions (Appendix F). The Interim Operating Agreement is categorized as a legal agreement and ensures communication and coordination of the data and methodologies used by each GSA in developing the GSPs within the Subbasin for several factors, including groundwater elevation and extraction data, surface water supply, total water use, change in groundwater storage, water budget, total water use, and sustainable yield.

Beneficial Uses and Users

The GSAs shall consider the interests of all beneficial uses and users of groundwater, as well as those responsible for implementing a GSP (California Water Code, §10723.2).

Opportunities for Public Engagement

The GSAs within the Subbasin developed a joint Communication and Engagement Plan to address how stakeholders within the individual GSA boundaries were engaged which will continue to be utilized through the GSP implementation phases. The Communication and Engagement Plan describes various elements, including public meetings and workshops, printed communication, digital communication, media coverage, and stakeholder surveys.

Interbasin Communications

Subbasin GSAs and technical consultants met with surrounding subbasins throughout the development of the GSP to discuss how to achieve sustainability on a regional level, develop interbasin agreements, and share data when possible.

3.0 Basin Setting

The Subbasin is located primarily in Kings County in the Tulare Lake Hydrologic Region of the San Joaquin Valley. Topography in the Subbasin slopes inward towards the center of the valley. The former Tulare Lake occupies this portion of the Subbasin. Chapter 3 of the GSP discusses the hydrogeologic conceptual model (HCM), groundwater conditions, the water budget, and management areas for the Subbasin.

3.1 Hydrogeologic Conceptual Model

The HCM provides a general understanding of the physical setting, characteristics, and processes that govern groundwater occurrence and movement within the Subbasin (DWR 2016c).

Geographic Setting

The Subbasin is located primarily in Kings County in the Tulare Lake Hydrologic Region of the San Joaquin Valley, California (Figure ES-1). The Subbasin covers an area of approximately 535,869 acres or about 837 square miles (DWR 2016b). It is boardered by the Kings Subbasin to the north, the Kaweah Subbasin to the northeast, the Tule Subbasin to the southeast, the Kern County Subbasin to the south, the Kettleman Plain Subbasin to the southwest, and the Westside Subbasin to the northwest. The San Joaquin Valley boardered on the west by the Coast Ranges and on the east by the Sierra Nevada Mountains (Figure ES-1).

The climate in the Subbasin is semi-arid, characterized by hot, dry summers and cool moist winters and is classified as a semi-arid climate (BSk to BSh under the Köppen climate classification), usually found within continental interiors some distance from large bodies of water. The topography of the Subbasin is generally low sloping inward from all directions toward the center of Tulare Lake. Land use in the Subbasin and surrounding areas is predominately agricultural with three primary urban areas of the cities of Hanford, Lemoore, and Corcoran.

Soil texture varies across the Subbasin. Clayey soils dominate in the Tulare Lake area. Loam and sandy loam soils border the clayey soils and are the predominant soils to the east of the lake, including areas of the Tule and Kaweah rivers watersheds; to the west, along the eastern flanks of Kettleman Hills and the Coast Ranges; and to the north and northeast, including along the Kings River watershed.

Stream flow in rivers, streams, and surface water conveyances (canals) is a significant source of groundwater recharge throughout the Subbasin by direct infiltration to the subsurface and from deep percolation where surface water is applied for agricultural irrigation. Major rivers supplying water to the Subbasin include the Kings, Kaweah, Tule, and Kern rivers. Streams emanating from the southern Sierra Nevada Mountains and the Coast Ranges are typically ephemeral and do not reach any major water course or surface impoundment in the Subbasin.

Extensive water supply delivery systems have been developed over the past 160 years within the Subbasin to move surface water supplies for irrigation, flood control, and land reclamation.

Currently, at least 34 conveyance systems (rivers, streams, canals, and diversions) are available to deliver surface water to the Subbasin. The only water generated within the Subbasin is from pumped groundwater. Pumped groundwater may be used for direct irrigation on nearby agricultural lands or piped into municipal or agricultural water delivery systems.

Water is imported into the Subbasin using facilities of the SWP located to the west and the CVP. The California Aqueduct is operated and maintained by DWR. The Friant-Kern Canal is operated and maintained by the Friant Water Authority and is used to convey water from the San Joaquin River to Kern County. The Friant-Kern Canal crosses the Kings River about 10 miles west of Pine Flat Dam, where water can be released into the River. This water can be delivered to the Subbasin through a series of canals along the Kings River and its distributaries.

Hydrogeologic Setting

During the late-Pliocene and early-Pleistocene, the terrestrial Tulare Formation was deposited as sediments, which were eroded and shed from the rising mountains into the subsiding San Joaquin Valley. Throughout much of the Valley, Tertiary-Quaternary sediments filled the basin with a mixture of sands, silts, and clays, which were deposited on alluvial fans and along the San Joaquin Basin axis by the rivers and streams emanating from the adjoining mountains.

Large-scale lacustrine deposits accumulated in the shallow lakes that developed as a result of the internal drainage. During this time, the lacustrine Corcoran Clay (E-Clay of Croft 1972) accumulated to thicknesses of as much as 300. Additionally, thick deposits of lacustrine sediments have accumulated in Tulare Lake.

The Tulare Formation is generally regarded as the most important water-bearing formation in the southern San Joaquin Valley. The Tulare Formation comprises unconsolidated clay, silt, sand, and gravel, as well as poorly consolidated sandstones and conglomerated deposited by streams and rivers emanating primarily from the Sierra Nevada and Coast Ranges.

Groundwater flow in the Subbasin has historically been influenced by five significant bounding conditions, including: Kettleman Hills on the southwest; Kings River alluvial fan on the northeast; Arroyo Pasajero fan on the northwest; Tulare Lake clay beds in the central portion of the subbasin; and the Kaweah and Tule River alluvial fans on the east.

Tulare Lake Lacustrine Deposits (Clay Plug)

The lacustrine deposits of the ancestral and former Tulare Lake are potentially the most significant controlling factor for groundwater movement in the central portion of the Subbasin. The horizontal and vertical extent of these continuous fine-grained lacustrine deposits is called the “clay plug.” Although some of the clays and sand stringers are saturated, they do not produce enough water to have been developed for groundwater extraction.

The water quality method and it was used to define the bottom of the Subbasin. Within the Subbasin, water quality of 3,000 milligrams per liter total dissolved solids (TDS), typically found at depths greater than 3,000 feet below ground surface (bgs), defines the bottom of the Subbasin using this methodology for this GSP.

Principal Groundwater Aquifers and Aquitards

Groundwater beneath the Subbasin occurs primarily in the coarser-grained Sierran sediment deposits of the alluvial fans of the Kings, Kaweah, and Tule rivers, as well as the fans of the lesser streams that drain from the Sierra Nevada Mountains into the southeastern portion of the Subbasin. On the west side of the Subbasin, some sediments may have Coast Ranges origin. The Corcoran Clay underlies most of the Subbasin, which essentially subdivides the Subbasin into two aquifer systems, an unconfined to semi-confined aquifer system above the Corcoran Clay and a confined aquifer system below the Corcoran Clay.

Fine-grained lacustrine, marsh and flood deposits underlie the valley trough and floor and were deposited in lacustrine or marsh environments (Croft 1972). These fine-grained units are critically important in the hydrology of the basin in that they restrict the downward movement of water and act as aquitards. The Corcoran Clay or E-Clay is the most extensive aquitard in the San Joaquin Valley. The low permeability of the Corcoran Clay makes it an effective aquitard. It has sharp vertical boundaries and shows up well on borehole geophysical electric logs.

Groundwater Recharge and Discharge

Groundwater recharge in the Subbasin occurs primarily by two methods: (1) infiltration of surface water from the Kings River and unlined conveyances, and (2) infiltration of applied water for irrigation of crops. Intentional recharge also occurs within the Subbasin by percolating surface water through storage ponds and old river channels. Most surface water entering the Subbasin is consumptively used or retained due to the internal drainage within the Subbasin.

Groundwater discharge in the Subbasin is predominantly by groundwater extraction along the eastern and northern portions of the Subbasin where water quality and well yields are higher than near Tulare Lake.

Primary Uses of Each Aquifer

Primary groundwater uses within the Subbasin include domestic, municipal, agricultural, and industrial. Domestic pumping is primarily from the upper unconfined and semiconfined aquifer because it is easier to access and typically has sufficient yield for domestic purposes. Municipal pumping of groundwater occurs in the cities of Hanford, Lemoore, and Corcoran and the communities of Armona and Stratford (Table 3-4). Wells for municipal purposes are typically in the deeper portions of the unconfined and semiconfined aquifer and sometimes reach into the confined aquifer. Most of the agricultural pumping in the Subbasin and in adjoining subbasins is from deep wells constructed above and below the Corcoran Clay.

3.2 Groundwater Conditions

This section contains information related to historical and current groundwater conditions necessary to understand the characteristics of groundwater flow within the Subbasin, groundwater quality, and the water budget. Subsidence is also discussed.

Groundwater Flow

Historically, groundwater movement in the Subbasin was dominated by recharge of surface water on the alluvial fans of the rivers and streams emanating from the Sierra Nevada Mountains and by the discharge sinks created by evaporation from Tulare Lake and evapotranspiration created by the swamps and marshes along the periphery of the Lake. By 1952, groundwater development had altered the potentiometric surface such that distinct pumping cones of depression had developed in the unconfined upper aquifer east of the Subbasin beneath the Kaweah and Tule River fans and within the Subbasin on the Kings River fan near Hanford (Davis et al. 1959). In 2016, groundwater cones of depression in the unconfined upper aquifer were apparent east of the Subbasin with groundwater elevations having declined 100 to more than 200 feet from the 1952 data. The groundwater cones of depression peripheral to the Subbasin changed the natural prevailing direction of groundwater flow from west-southwest toward Tulare Lake, to east, northeast, and southeast away from Tulare Lake.

Vertical Groundwater Gradients

Vertical groundwater gradients between the upper unconfined aquifer and the confined aquifer separated by the Corcoran Clay are spatially and temporally variable. Prior to widespread groundwater development, there was an upward gradient from the confined aquifer to the unconfined aquifer (including artesian conditions) beneath much of the Subbasin. As agriculture was developed, pumping from below the Corcoran Clay eventually resulted in a downward gradient beneath much of the Subbasin.

Groundwater Storage Estimates

There is an estimated at 20.5 million acre-feet (AF) of groundwater in storage in the unconfined aquifer zone. The confined aquifer has an estimated at 60.4 million AF of groundwater in storage.

Total groundwater in storage is approximately 80.9 million AF as of 2016. Overall there has been a loss of storage of about 3.84 million AF from the unconfined aquifer, a storage gain of about 1.53 million AF in the confined aquifer, resulting in a combined total loss of about 2.31 million AF between 1990 and 2016.

Groundwater Quality

Water quality geochemistry varies in groundwater beneath the San Joaquin Valley. Historically, on the west side of the valley, groundwater was always high in sulfate compared to groundwater on the east side of the valley. Near the center of the valley, groundwater had a mixed character, also being high in alkalis. The difference in chemical characteristics of the groundwater was attributed to the source area for the sediments in which the groundwater was contained. On the west side, deposits were derived from marine sedimentary rocks with high proportions of sulfur-rich minerals (such as gypsum), whereas on the east side, deposits were derived from granitic rocks with high proportions of silicates. Near the center of the valley and around the historical Tulare Lake, groundwater contained higher proportions of chloride. TDS measurements in groundwater were greater on the west side than the east.

TDS has increased in most groundwater in the San Joaquin Valley over the past 100 years. However, the spatial distribution of the TDS and individual cation-anion makeup of the groundwater still reflect the geologic provenance of the containing sediments as well as the chemical characteristics of the recharge water. The greatest TDS increases in the Tulare Lake area were in the shallow portions (i.e., unconfined to semiconfined) of the aquifer.

In general, chemicals of concern that affect water quality in the Subbasin include salinity (TDS), arsenic, nitrate, and volatile organic chemicals.

Land Subsidence

Land subsidence due to groundwater withdrawals and associated drawdown has been well documented and has affected significant areas of the San Joaquin Valley since the 1920s, including the Subbasin (Wood 2017). Between 1926 and 1970, there was approximately 4 feet of cumulative subsidence near Corcoran, 4 to 6 feet of subsidence near Hanford, and as much as 12 feet of subsidence near Pixley. Following the completion of the SWP and CVP, surface water became more readily available in the San Joaquin Valley and groundwater extraction was reduced and groundwater levels recovered. As a result, subsidence due to groundwater withdrawal was temporarily slowed or stopped.

Groundwater pumping has since increased in the San Joaquin Valley in the past 10 to 25 years due to several factors including the planting of permanent crops and a reduction of available imported surface water. Subsidence in the San Joaquin Valley was exacerbated during a moderate to severe drought from 2007 through 2009, and a severe to exceptional drought from 2012 through 2016. A Jet Propulsion Laboratory study of subsidence between June 2007 and December 2010 indicated subsidence rates were as high as 8.5 inches per year near Corcoran (Farr et al. 2015). A more recent study by the Jet Propulsion Laboratory indicted subsidence rates accelerated in some areas during the recent drought, with annual subsidence rates of 1 to 1.5 feet near Corcoran in 2015-2016 (Farr et al. 2017).

Interconnected Surface Water and Groundwater Systems

Prior to development in the late 1800s and early 1900s, groundwater and surface waters were interconnected around the Subbasin, resulting in extensive wetlands, a nearly persistent Tulare Lake, and notable artesian aquifers indicating strong upward groundwater gradients. Groundwater levels were near the ground surface beneath much of the Subbasin, and as streams and rivers flowed from the Sierra Nevada foothills and Coast Ranges towards Tulare Lake, they geographically transitioned from losing streams which recharged underlying groundwater into gaining streams that benefit from groundwater discharge.

During development, the four major rivers draining into Tulare Lake were dammed, and Tulare Lake itself was able to be reclaimed due to upstream irrigation demands. As a result, most streams and rivers draining into Tulare Lake became disconnected from the regional unconfined aquifer system.

3.3 Water Budget Information

This section provides a quantitative description of the water budget for the Subbasin including an account of the inflows, outflows, and changes in storage in the Subbasin aquifer system over time.

Inflows

Inflows consist of:

- Precipitation
- Surface Water Diversions
- Imported Groundwater Supply
- Lake Bottom Water Storage
- Intentional Recharge
- River and Canal Seepage

- Wastewater Treatment Plant Discharge
- Subbasin Boundary Groundwater Inflows

During the 1990-2016 period, estimated total inflow ranged from 1,070,860 AF (2015) to 2,203,450 AF(1990) and averaged about 1,584,140 acre-feet per year (AF/Y).

Outflows

Outflows consist of:

- Evapotranspiration
- Municipal Pumping Demand
- Agricultural Pumping Demand
- Agricultural Drains
- Subbasin Boundary Groundwater Outflows

In the 1990-2016 period, estimated total outflow ranged from 1,529,580 AF (2015) to 2,783,110 AF (1990) and averaged about 1,968,130 AF/Y.

Annual Change in Groundwater Storage

The annual change in storage (or overdraft) was estimated for the study period 1990-2016 and for the period 1998-2010, which represents a period of "normal hydrology" where Kings River flows were close to the 50-year historical average. During the 1990-2016 period, the estimated annual change in storage in the Subbasin ranged from -392,280 AF (2015) to 361,230 AF (2011) and averaged about -85,690 AF/Y over this 26-year period. During the 1998-2010 "normal hydrology" period, the estimated annual change in storage in the Subbasin ranged from -296,280 AF (2008) to 220,649 AF (2006) and averaged about –73,760 AF/Y over this 13-year period.

Estimate of Sustainable Yield

During the 1998-2010 "normal hydrology" period, the difference between average groundwater pumping (-348,700 AF/Y) and average net recharge (335,360 AF/Y) differed by only about -13,340 AF/Y. During this same period, the estimated overdraft due to pumping in the Subbasin averaged about -49,480 AF/Y (net subsurface interbasin outflows due to pumping in other subbasins account for the other -24,290 AF/Y of overdraft). If agricultural pumping in the Subbasin were reduced by an average of 49,480 AF/Y to about -299,220 AF/Y, the net change in storage should be close to zero or possibly positive. Hence, the current estimate of long-term sustainable yield for agricultural pumping is approximately -299,220 AF/Y over the historical average of 310,792 acres of irrigated land in the Subbasin.

Projected Water Budget

The projected water budget for the Subbasin represents a hypothetical forecast for the 54-year period from 2017 through 2070 based on an assumed "normal hydrology" period and estimated future climate change impacts. This forecast provides the Subbasin's GSAs with a tool to allow flexibility in groundwater management and planning of sustainability projects. The projected water budget is based on current baseline conditions of groundwater and surface water supply, water demand, and aquifer response to allow for implementation of groundwater management and projects implemented under the GSP. Groundwater modeling of the forecast conditions will be used to evaluate long-term groundwater flow trends, change in storage, and long-term groundwater sustainability under different forecast conditions and proposed groundwater sustainability projects conducted by individual GSAs.

3.4 Management Areas

In order to facilitate implementation of the GSP, management areas have been created for the Subbasin. There are five Primary Management Areas and two Secondary Management Areas. Each of these types of management areas are described in the following sections.

Primary Management Areas

Primary Management Areas have been formed from each of the five GSAs (Figure ES-2). The formation of Primary Management Areas will facilitate data management and assist with the implementation and management of the GSP. Furthermore, each GSA has unique surface water and groundwater allocations and usage, and they are best positioned to develop Best Management Practices and development of groundwater sustainability projects.

Secondary Management Areas

Two Secondary Management Areas have been formed for the Subbasin (Figure ES-2). These two Secondary Management Areas are different from the Primary Management Areas and each other due to distinctly different groundwater conditions in each area. These two areas are the Clay Plug (Management Area A) and the Southwest Poor Quality Groundwater Secondary Management Area (Management Area B).

4.0 Sustainable Management Criteria

The SGMA defines sustainable groundwater management as the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results. The avoidance of undesirable results is important to the success of GSP implementation.

Sustainable management criteria include:

- Sustainability Goal
- Undesirable Results
- Minimum Thresholds (MTs)
- Measurable Objectives (MOs)

These criteria for the Subbasin were developed through the assessment of sustainability indicators. The indicators are measured at representative monitoring sites (RMSs) in each management area of the Subbasin.

Sustainability indicators are the effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, become undesirable results. Under SGMA, sustainability indicators are: chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, land subsidence, and depletions of interconnected surface water. In the Subbasin, there is sufficient evidence to eliminate two of the sustainability indicators from further consideration – seawater intrusion and depletion of interconnected surface waters.

4.1 Sustainability Goal

The goal of this GSP is to sustainably manage groundwater resources and continue to provide an adequate water supply for existing beneficial uses and users in accordance with county and city general plans while meeting established MOs to maintain a sustainable groundwater yield. To achieve the goals outlined in the GSP, a combination of measures, including continued management practices and monitoring will be implemented over the next 20 years and continued thereafter. Additional surface water supply and infrastructure projects will be a crucial component of augmenting groundwater supplies. Management actions also will be implemented.

4.2 Undesirable Results

Undesirable results occur when groundwater conditions within the Subbasin result in significant and unreasonable impacts to a sustainability indicator. The potential for undesirable results occurring in the Subbasin for all four of the sustainability indicators can be traced back to events, statewide policies, and natural causes that have occurred outside of the Subbasin and/or by entities not associated with the GSAs and others in the Subbasin. Reductions in historical allocations of surface water by federal, state, and judicial authorities have resulted in a need for the overlying Subbasin's population and enterprises to find additional viable water sources, which has resulted in an increased reliance on groundwater in this Subbasin.

The following are some examples of reductions to surface water supplies historically available within the Subbasin:

- The SWP and CVP water delivery reductions through the CVPIA (circa1992)
- Biological Opinions (circa 2007)
- The San Joaquin River Restoration program (circa 2010)

Additionally, Subbasin-wide effects to groundwater supplies may result from the following:

- Climate Change
- Changing Crop Patterns
- Subbasin Groundwater Outflows
- Increased Urbanization

These events, statewide policies, and impacts that have occurred outside of the Subbasin, by entities not associated with the GSAs, and/or out the GSAs control have resulted in an increase in groundwater pumping throughout the Subbasin.

Groundwater Levels

Certain areas show long-term decline in groundwater levels, which if not addressed, may eventually lead to a reduction in usable groundwater supplies. Given the 60- to 300-foot depth to groundwater relative to the approximately 3,000-foot-deep aquifer, it is understood that long-term declines could continue for many years before developing a situation that would truly be significant and unreasonable. Lowering groundwater levels can result in the following main impacts, the degree to which will determine if the conditions of lower groundwater levels are significant and unreasonable: water well problems, land subsidence, and deterioration of groundwater quality.

Groundwater Storage

Groundwater storage is the capacity of the underground to store water. As previously stated, there is an estimated at 20.5 million AF of groundwater in storage in the unconfined aquifer zone. The confined aquifer has an estimated at 60.4 million AF of groundwater in storage. Total groundwater is storage is approximately 80.9 million AF as of 2016. Annual changes occurred in groundwater storage from 1990 through 2016 in the upper and lower aquifer zones for each GSA area. Overall there has been a net loss of storage of about 2.31 million AF between 1990 and 2016.

Land Subsidence

Land subsidence is the lowering of the land-surface elevation from changes that take place underground. Common causes of land subsidence from human activity are pumping water, oil, and gas from underground reservoirs; dissolution of limestone aquifers (sinkholes); collapse of underground mines; drainage of organic soils; and initial wetting of dry soils (hydrocompaction) (Leake 2016). The majority of subsidence in the San Joaquin Valley has occurred due to groundwater extraction from below the Corcoran Clay layer, present at depths of 100 to 500 feet bgs, resulting in compaction and eventual subsidence in and below the Corcoran Clay layer (Ireland et al. 1984, Faunt et al. 2009).

The undesirable results related to land subsidence will be the significant loss of functionality of a critical infrastructure or facility, so the feature cannot be operated as designed, requiring either retrofitting or replacement to a point that is economically unfeasible. Potential impacts include:

- Raising flood control levees to mitigate subsidence
- Raising railroads tracks to mitigate flooding impacts related to subsidence
- Re-grading canals, including the California Aqueduct, to address grade changes related to subsidence
- Flooding of major roads and highways

The one critical infrastructure location in the Subbasin is roughly 17 miles of California Aqueduct alignment. Significant impacts to the conveyance capacity of this facility related to land subsidence caused in the Subbasin will be viewed as significant and unreasonable undesirable results. Fortunately, there does not appear to be significant subsidence along this alignment. The GSAs understand this to be related to the limited amount of groundwater pumping in that area.

Groundwater Quality

Water quality degradation has been linked to anthropogenic activities, and can result from pumping activities, as well as the known migration of contaminant plumes. Groundwater quality is currently comprehensively monitored in the Subbasin by regulatory agencies. These agencies rely on existing regulations and policies to define undesirable results related to the deterioration of groundwater quality. The agencies and coalitions include the ILRP, GAMA, RWQCB, Central Valley Salinity Alternatives for Long-term Sustainability Program (CV-SALTS), and cities and communities within the Subbasin.

4.3 Minimum Thresholds

MTs quantify groundwater conditions for each applicable sustainability indicator at each RMS. Measurements will be made at the RMSs for each sustainability indicator to determine whether an undesirable result is occurring in the Subbasin.

Groundwater Levels

The methodology used to calculate the MT is different than what was presented in the 2020 GSP. The results of the groundwater model projections were no longer used instead the MTs were based on levels that were protective of groundwater uses and users.

A-zone

A-zone wells are completed at depths of less than 100 feet in a thin unconfined aquifer that relies primarily on recharge from uncontrolled, poor quality, stormwater and agricultural run-off and leakage from irrigation canals. Historically, groundwater levels have routinely dropped to the top of the A-clay (see Appendix A), presumably making many of these wells unsuitable for water supply on a regular basis. These fluctuations in water level are not the result of pumping conditions that the GSA can regulate. They are the result of variations in precipitation, run-off, and delivery of water for irrigation.

B-zone

MTs for the B-zone were established using the OSCWR database records and reflect a condition to minimize impacts to all uses and users. The MT was calculated to represent conditions where water-levels drop below the bottom elevation of wells in the B-zone. The quantitative definition of the MT elevations is based on a statistical percentile for well completion elevations in the B-zone. The GSAs decided that the MTs would be set at the 90th percentile to minimize impacts. This represents a water elevation to protect 90 percent of the wells listed in the database.

The GSAs believe that the MT will be protective of beneficial uses in the B-zone and, in conjunction with a mitigation program (described in Appendix D), will avoid a significant and unreasonable loss of beneficial uses. The GSAs recognize that mitigation and adaptation to the proposed SMC for groundwater level requires better information on actual well conditions and will require case-by-case assessments of whether beneficial uses have been impacted at a given point in time.

C-zone

C-zone wells are completed at depths below the Corcoran Clay in a confined aquifer, so the ability to maintain sufficient groundwater supply is not dependent on the completion elevation of the well, but is more related to well performance and whether pumping causes water levels to drop below the top of the confining layer. The MT for groundwater level in the C-zone is defined with respect to the elevation of the E-clay, which is the principal regional confining unit in the Subbasin.

The MT for groundwater level in the C-zone is defined based on the expected drawdown from a C-zone well at a pumping rate of 1,000 gpm, at a specific capacity of 20 gpm/ft. The value of 1,000 gpm was selected based on discussions with stakeholders for their wells completed in the C-zone. Using this methodology, the expected drawdown is 50 feet (1,000 gpm divided by 20 gpm/ft). This expected drawdown is simply added to the elevation of the E-clay to define a groundwater elevation. If groundwater elevations fall below this level, 10% of wells in the C-zone would not be able to pump at 1,000 gpm without drawing water levels below the E-clay. The quantitative definition of significant and unreasonable lowering of groundwater levels in the C-zone is therefore a groundwater elevation of 50 feet above the elevation of the E-clay. As the E-clay varies in elevation across the Subbasin, the MT will also vary across the Subbasin.

Groundwater Storage

The MT for the groundwater storage sustainability indicator in the Subbasin is the calculated change in storage using the methodology described in Chapter 5 and using the groundwater level sustainability indicator MTs at the RMSs.

Land Subsidence

The methodology for calculating the MT for subsidence has been modified from the 2020 GSP. In considering the MT for total subsidence, the GSA considered the technical evaluation conducted on the critical infrastructure along with discussions of the operators of the infrastructure. The evaluation considered impacts from both local differential subsidence and regional impacts. In addition, the GSAs considered that many of the historic impacts have been mitigated. Based on the results of the evaluation, the GSAs set the MT at values that would be protective of the critical infrastructure. The MT was set at the calculated "GSP Implementation" values as exceedance of those values would likely represent undesirable results to critical infrastructure and land use. Impacts to critical infrastructure will be monitored using the methods described in Sections 3.8 and 3.9. This will serve as an "early warning" to areas that experience impacts and allow the GSA to evaluate if other management actions are required.

As discussed in Section 3.6, the MT for the California Aqueduct will be set at a rate of 0.01 feet per year until 2040 and limited to residual subsidence thereafter. As such, the GSAs will require all new wells within three miles of the Aqueduct to provide a subsidence evaluation and appropriate coordination with DWR as part of the requirement to obtain a permit. The limited number of existing wells in the area will be limited to historic pumping rates.

Groundwater Qualtity

The MTs for degraded water quality is established as the higher of: (1) the Upper SMCL for TDS (1,000 mg/L), chloride (500 mg/L) and sulfate (500 mg/L) and Primary MCL for nitrate as N (10 mg/L), arsenic (0.010 mg/L), uranium (20 pCi/L), and 1,2,3-TCP (0.005 µg/L) or (2) current water quality conditions for all constituents defined as data available from 2000 to January 2020 at the representative monitoring well or nearby well within the same aquifer zones using the maximum concentration detected for each constituent.

4.4 Measurable Objectives

MOs, including interim milestones in increments of five years, have been established 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.

Groundwater Levels

The process for establishing the MOs for the groundwater levels sustainability indicator is described in detail in the description for establishing MTs.

Groundwater Storage

The MO for the groundwater storage sustainability indicator in the Subbasin is the calculated change in storage using the groundwater level sustainability indicator MOs at the RMSs.

Land Subsidence

The process for describing the MOs for the land subsidence sustainability indicator is described in detail in the description for establishing MTs.

Groundwater Quality

Existing groundwater conditions will be considered as a baseline. The GSAs will not be responsible for existing groundwater quality concerns; degradation beyond existing groundwater quality conditions will be the MO. MOs will be monitored by the agencies and coalitions.

Path to Achieve and Maintain the Sustainability Goal

Interim milestones for the groundwater levels sustainability indicator were calculated at five-year intervals with project and management action implementation. The MO for groundwater storage change and subsidence were also set with five-year interim milestones. It is the intent of the GSAs to develop and implement projects and management actions by 2035, sufficient to mitigate long-term overdraft. The path to achieve the sustainability goal is continued monitoring of the data collected from the coalitions and agencies listed in this chapter at each milestone.

5.0 Monitoring Network

SGMA requires each subbasin to establish a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term groundwater trends and related surface conditions and to evaluate changes in the Sustainability Indicators.

5.1 Description of Monitoring Network

The monitoring network for the Subbasin comprises existing and proposed RMS locations. The groundwater level RMS locations as discussed below are by aquifer zone. The land subsidence RMS locations consist of the existing land subsidence monitoring locations in the Subbasin and the general areas where future extensometers may be added. The groundwater quality RMS monitoring network is composed of wells currently sampled by the local cities/municipalities/small community systems and the Kings River Water Quality Coalition (KRWQC) ILRP.

The aquifer is divided into three aquifer zones for groundwater level monitoring:

1. The A zone is the shallow portion of the aquifer above the A-Clay and in areas where shallow groundwater is present outside of the A-Clay.
2. The B zone is the unconfined portion of the aquifer above the E-Clay or Corcoran Clay and below the A-Clay where the A-Clay is present.
3. The C zone is the confined portion of the aquifer below the E-Clay.

There are areas in the Subbasin where groundwater is not used due to poor water quality and/or, in the clay plug, non-productive strata. Portions of the Subbasin where groundwater pumping does not occur are not proposed to be actively monitored at this time. These areas overlay portions of ER, TCWA, and SWK GSAs.

Monitoring Network Objectives

The objectives of the various monitoring programs include the following:

- Establish baseline groundwater levels and groundwater quality and record long-term trends going forward;
- Use data gathered to generate information for water resources evaluations and annual changes in water budget components;
- Determine the direction of groundwater flow;
- Provide comparable data from various locales within the Subbasin;

- Demonstrate progress toward achieving MOs, interim milestones, and MTs described in the GSP as they relate to the Sustainable Management Criteria; and
- Develop the data to evaluate impacts to the beneficial uses or users of groundwater.

Design Criteria

New monitoring locations will be developed, and existing networks enhanced, where necessary, using an approach similar to the Data Quality Objective (DQO) process to guide the GSAs site selection. The DQO process follows the United States Environmental Protection Agency Guidance on Systematic Planning Using the Data Quality Objective Process (EPA 2006).

Overview of Existing Programs

Government agencies and private entities currently have existing programs in place that monitor groundwater levels, groundwater quality, and land subsidence. These programs will be utilized for future data collection and will be coordinated with SGMA monitoring requirements. If data from these sources becomes unavailable in the future, the monitoring network will be modified to monitor for the appropriate sustainability indicator.

Overview of Proposed Facilities

Proposed facilities for the groundwater level network include 95 monitoring wells (or existing wells that monitor a specific aquifer zone) at 34 locations in the Subbasin. The proposed monitoring wells may be necessary if existing wells cannot be identified to fill spatial data gaps in the network.

Two extensometers are initially proposed to be located in the vicinity of Corcoran and an area south of Lemoore. If funding or other agreements are made for the construction of the proposed extensometers, the locations will be refined by the GSA(s) at that time based on up-to-date subsidence maps and benchmark data.

Groundwater Levels

Groundwater level monitoring has occurred in most areas of the Subbasin on a semi-annual basis since the 1950s. Kings County WD, KRCD, Corcoran ID, DWR, USBR, and private landowners have measured and/or are currently measuring groundwater levels as part of existing monitoring programs. These agencies will continue monitoring semi-annually for future data collection and may expand, as needed, to comply with SGMA monitoring requirements.

The proposed RMS monitoring network, when built-out, will include a density of RMSs of up to two wells for the B zone (above the E-Clay) and C zone (below the E-Clay), and one well for the

A zone (above the A-Clay where it is present) for the 36-square mile Townships wholly in the Subbasin.

Groundwater Storage

Groundwater level contour maps will be prepared and estimates of annual storage change will be evaluated by comparing current year seasonal high contour sets to previous year seasonal high contours sets which are then multiplied by specific yield values. The storage change monitoring network is the same as the water level monitoring network. RMS well locations are linked to specific aquifer zones, and as such, data from these wells will be weighted heavier than wells without construction information. It should be noted that even though a well may not have construction information, the data can still be used in constructing water level maps if the data is consistent with water levels from RMS wells.

Groundwater Quality

The Subbasin is relying on already existing groundwater quality monitoring programs. Groundwater quality monitoring may supplement, as needed, groundwater quality monitoring currently under the oversight of an existing regulatory agency or groundwater quality coalition.

Land Subsidence

For land subsidence, the existing CVSRN CGPS in the area will be used as RMSs for the Subbasin. Additional land subsidence data can be gathered to evaluate subsidence across the Subbasin. These data will be evaluated annually and if subsidence rates approach MOs at the nearest CGPS station, then additional RMSs may be added as determined by the GSA. Two extensometers are proposed in areas of known subsidence, pending funding or collaboration with DWR or the USGS.

The Subbasin is included in areas monitored for subsidence by regional water agencies or the state and federal governments. Measurement and monitoring for land subsidence is performed by USGS, KRCD, KDWCD, USACE, UNAVCO, and various private contractors. Interagency efforts between the USGS, the U.S. Coast and Geodetic Survey (now the National Geodetic Survey), and DWR resulted in an intensive series of investigations that identified and characterized subsidence in the San Joaquin Valley. National Aeronautics and Space Administration also measures subsidence in the Central Valley and has maps on their website that show the subsidence for defined periods.

Consistency with Standards

The data gathered through the monitoring networks will be consistent with the standards identified in 23 CCR §352.4 related to GSPs.

5.2 Monitoring Protocols for Data Collection and Monitoring

The DQO process will be used to develop monitoring protocols that assist in meeting MOs and sustainability goals of this GSP (EPA 2006). Groundwater level, groundwater quality (if the GSAs participate in groundwater quality monitoring), and land subsidence monitoring will generally follow the protocols identified in the DWR Best Management Practices for the Sustainable Management of Groundwater - Monitoring Protocols, Standards, and Sites (DWR 2016f). Monitoring Protocols will be reviewed at least every five years as part of the periodic evaluation of the GSP and updated as needed. The GSAs may develop standard monitoring forms in the future if deemed necessary.

5.3 Representative Monitoring

DWR has referred to representative monitoring as utilizing a subset of sites in a management area. The GSP has developed a monitoring network of RMS wells where MOs, MTs and interim milestones are defined in further detail in Section 4.4 and 4.5, *Minimum Thresholds* and *Measurable Objectives*. Groundwater conditions can vary substantially across the Subbasin and the use of a small number of representative wells in the Subbasin is not practical to cover such a large area with varying conditions. The network will strive to fill data gaps with existing wells that have well construction information and historical groundwater level data. Proposed monitoring sites may include clustered wells, if existing wells cannot be identified and used, that will be able to provide data for different aquifer zones at a single location.

5.4 Assessment and Improvement of Monitoring Network

Groundwater Levels

The CASGEM Groundwater Elevation Monitoring Guidelines (DWR 2010) were used to estimate the density of RMS wells needed for the Subbasin per the DWR's Best Management Practices for the Sustainable Management of Groundwater - Monitoring Networks and Identification of Data Gaps (DWR 2016e). As feasible, the GSAs will evaluate the RMS network and make adjustments as needed over time. Groundwater levels will be measured in October for seasonal low conditions and in February to April for the seasonal high conditions depending on the GSA. Currently, there are spatial data gaps throughout the Subbasin. Spatial data gaps are primarily in the southern/southwestern region of the Subbasin where groundwater is not used due to poor water quality, and in the lakebed area due to lack of productive strata and poor water quality.

Most of the wells monitored in unincorporated areas are privately owned. As such, well construction information, including depth and perforated interval, are not available for most of these wells. While these wells may not provide ideal data points, they will continue to be monitored even if well construction data is collected which indicates the well is a composite well (perforated across multiple aquifer zones, in the Subbasin usually across the Corcoran Clay).

The RMS groundwater level network has data gaps, such as missing construction or partial construction information for some RMS wells. The goal is to have accurate well construction information for RMS wells monitored for groundwater level that currently lack construction information within five years of plan implementation.

Groundwater Storage

Groundwater storage change will be calculated using groundwater level contour maps from seasonal high groundwater conditions of successive years. Groundwater storage calculations are largely dependent on the groundwater level monitoring network. Collection of well attribute information described above will also benefit groundwater storage change evaluations. In addition, groundwater released from clays due to subsidence will also be evaluated annually from data collected from the land subsidence monitoring network.

Annual groundwater storage changes by each GSA will be calculated so individual GSAs can evaluate progress towards meeting MOs. The data used to estimate storage change will be the water level data collected from the water level networks. The most significant data gaps in the groundwater storage change monitoring network include Information on well construction aquifer characteristics, and shallow groundwater level data near rivers, creeks, and canal systems. Other data gaps in the groundwater storage network are the same as in the groundwater level monitoring network, as described above, since storage change is dependent on changes in groundwater levels.

Water Quality

Several programs already operate with the directive of groundwater quality standards. The GSAs desire to use existing groundwater quality sampling programs for tracking of groundwater quality. The monitoring frequency is dependent on those existing monitoring schedules. Groundwater quality associated with projects and management actions will be monitored appropriately.

There are no known data gaps in monitoring groundwater quality within the Subbasin. Additional monitoring may be triggered through evaluation of the existing data from the agencies and coalitions, and in conjunction and collaboration with the agencies or coalitions, on a case-by-case basis.

Groundwater quality monitoring site selection is driven, in part, by the location of city/municipal and other community well locations. As well, the KRWQC-ILRP has several well locations north of the clay plug. At this time, the Subbasin GSAs are proposing not to sample for groundwater quality in de-designated areas which includes Secondary Management Areas A and B. Locations of future groundwater quality sampling will likely be from monitoring wells that are constructed with funds from state or federal programs in data gap areas. As described above, the Subbasin GSAs would like to work collaboratively with the agencies currently performing groundwater quality monitoring.

Land Subsidence

There are presently no known depth-discrete subsidence monitoring facilities (i.e., extensometers that can measure subsidence in specific portions of the aquifer) within the Subbasin. It is believed that the majority of subsidence occurs from compaction of clays. Extensometers would provide the data needed to differentiate subsidence at specific depth intervals. These data would be used to validate which portions of the aquifer are experiencing the most subsidence.

Land subsidence in the Subbasin is monitored through agency and government land subsidence surveying programs. The data generated by these programs are considered adequate both spatially and temporally as InSAR/LiDAR mapping covers the entire Subbasin. However, individual GSAs may develop subsidence monitoring programs as needed that may include surveys of wells, or measurement of pumping water levels in deep wells in known subsidence areas.

5.5 Data Storage and Reporting

The monitoring programs within the GSAs will be coordinated within the Subbasin. RMS well locations, construction, and groundwater level data are shared or will be shared by the different GSAs. Similarly, data reported to DWR will be collected and reported in a consistent format. GSP development and implementation will depend on the Data Management System's (DMS) ability to support GSP activities. The DMS shall also allow for upload and storage of information.

5.6 Data and Reporting Standards

Table 5-8 provides the data and reporting standards for the GSP. The standards are prescribed for identification and coordinates of monitoring sites, well identification and construction information, maps, and hydrographs.

6.0 Projects and Management Actions to Achieve Sustainability

The GSAs have developed the projects and management actions described in this chapter. Once the GSP is approved, the projects and management actions previously selected by each GSA will be advanced and implemented. Projects and management actions will be implemented in the most effective manner to create a sustainable yield for each sustainability indicator, as applicable. Costs for implementing each project was developed using information from previous projects in the Subbasin area.

Management actions are generally programs or policies developed with the objective of management through reducing water demand, improving water data gathering, and/or protecting water quality. Management actions listed in this chapter are conceptual. Each GSA will utilize this list, or other options as they may arise, to further develop and refine their own management actions as needed to achieve sustainability.

6.1 Water Supply

The Subbasin receives surface water from the SWP, the USBR's CVP, the Kings River, the Kaweah River, and the Tule River. Furthermore, flood waters occur from controlled and uncontrolled streams including the Kings River, Kaweah River, Tule River, Deer Creek, White River, Kern River, and Poso Creek. The timing and volume of surface water supply varies depending on the magnitude of the water year. In addition, each GSA is proposing to use their members' existing contracts and rights for surface water as access to import more surface water into the Subbasin.

6.2 Projects

The following project types are reviewed in Chapter 6 and provide options being considered by the GSAs and their respective partner agencies for use in implementation of this GSP. Potential projects that may be utilized by the GSAs and partners include:

- Construction of new and modification of existing conveyance facilities;
- Above-ground surface water storage projects;
- Recharge basins and/or water banking in or out of the Subbasin;
- On-farm flooding; and
- Aquifer Storage and Recovery (ASR).

Potential projects are listed and described in Table 6-1.

Conveyance Facilities Modifications and Construction of New Facilities

Modifications or improvements to existing facilities can be completed to increase conveyance efficiency and allow for greater flow capacity. Improvements of an existing system could also increase the delivery area or delivery efficiency. Total capacity may also be increased with the construction of new conveyance systems such as canals, check structures, and additional turnouts, to allow for surface water delivery to new areas. By providing a larger service area, more acreage would be able to use surface water, thus reducing the demand on groundwater pumping. It is anticipated that throughout the Subbasin, existing facilities will be improved by reshaping of existing canals, modification of canal control structures, and canal lining. Canal lining would prevent seepage losses and increase the total usable water volume. Conveyance construction and improvements will support other proposed projects in the area.

Above-Ground Surface Water Storage

Above-ground storage basins can be constructed for the purpose of capturing and retaining more surface water for direct irrigation purposes. Controlled surface water storage on the valley floor would allow users to more effectively utilize each water year's available surface water. All surface water diversions into and out of the storage basins would be measured appropriately. Groundwater pumping should decrease in direct correlation to the additional volume of surface water captured and stored in the new facilities. Additionally, if the storage basin were to replace an agricultural field, demand reduction would occur within the footprint of the designated storage basin.

Recharge Basins/Water Banking

Recharge basins could be built with the purpose of recharging water into the aquifer system with the intent of extraction later on. By recharging water in wet years, groundwater levels will improve, creating a buffer storage volume that could be extracted during periods of dryness or drought. Recharge basins would be constructed in areas containing soils associated with high infiltration rates; therefore, potential recharge volume realized is dependent upon the size of the recharge basin and the availability of flood water. These types of facilities are anticipated to be located in the northerly (SFK and MKR GSAs) and easterly portions (ER GSA) of the Subbasin due to coarser-grained soil profiles.

On-Farm Recharge

On-farm recharge is a form of groundwater recharge performed by flooding an existing agricultural production field. Potential locations for on-farm recharge will be determined by areas containing soil profiles with high infiltration potential. It will be up to each GSA to determine the most favorable locations and decide on a minimum acreage size designated for this type of project. Voluntary participation from the landowners and their delivery facilities will be utilized as part of the project. In this effort, existing local wells will recover recharge supplies.

Aquifer Storage and Recovery

ASR is an intentional recharge method utilizing direct injection of surface water into an aquifer for later recovery, usually through the use of wells. ASR well sites would be selected to directly store water in certain geologic zones for later recovery or to stabilize groundwater levels to arrest subsidence. Voluntary participation from landowners with appropriate facilities will be coordinated with the individual GSAs as funding becomes available.

6.3 Management Actions

Management actions represent options available to GSAs that will help support them in the sustainable management of groundwater. Each GSA has the flexibility to choose a list of actions that they believe will be pursued and will independently develop the policies to meet the needs of their area for achieving sustainable management. The management actions will be chosen by each GSA after the implementation of this GSP. Possible management actions are listed and described in Table 6-1. Examples of potential management actions include, but are not limited to the following:

Policies

- Voluntary fallowing programs

Outreach

- Education of groundwater use

Assessment

- Pumping fees for groundwater allocation exceedances
- Pumping fees for groundwater extractions

Groundwater Allocation

- Development of GSA level groundwater allocation
- Development of landowner groundwater allocation
- Groundwater marketing and trade
- Operation and management of groundwater extractions

New Development

- Require new developments (non-de minimis extractors) to prove sustainable water supplies if land use conversion is not a conservation measure

Monitoring and Reporting

- Flood flows (spills into the Subbasin), including Tule River, Deer Creek, Cross-Creeks and Kings River
- Registration of extraction facilities
- Require self-reporting of groundwater extraction, water level, and water quality data

- Require well flowmeters, sounding tubes, and water quality sample ports for new well construction

Existing Surface Water Contracts

- Flood flows (spills into the Subbasin), including Tule River, Deer Creek, and Cross-Creeks

7.0 Plan Implementation

Upon submittal of the GSP to DWR, GSP implementation will commence in the Subbasin. The GSAs will continue their efforts to engage the public and secure the necessary funding to successfully monitor and manage groundwater resources to avoid future undesirable results related to groundwater usage in the Subbasin. This GSP works in tandem with authorities of numerous agencies with the goal to coordinate activities in the region for the effective management of groundwater resources.

7.1 Estimate of GSP Implementation Costs

GSAs and member agencies will coordinate and implement the actions outlined in this GSP. As such, the implementation is anticipated to be performed by multiple agencies. To identify implementation costs, a draft structure of cost has been suggested and is included below:

- Regular/Ongoing SGMA Compliance Activities,
- GSP Five-Year Update,
- Plans to Fill Data Gaps,
- Projects, and
- Management Actions.

Table 7-1 lists estimated costs to develop each component of the GSP.

7.2 Schedule for Implementation

Implementation of the GSP will result in the sustainable yield of groundwater resources in the Subbasin by year 2040. Some areas within the Subbasin have existing projects. The schedule of projects and management actions are outlined below. At each five-year interim milestone, updates to the schedule will occur, as applicable, dependent on achievement of MO for each applicable sustainability indicator. Possible steps involved in the schedule of implementation include:

- Improved efforts to monitor across the Subbasin
- Begin identification of management actions through policy development
- Seek grant funding through available opportunities
- Establish project funding for some GSAs
- Develop program for voluntary fallowing
- Expansion of programs, projects and bringing new projects on-line
- If necessary, implement Management Actions relating to demand reduction

Based on the model timeline for projects to come on line:

- 2020-2025-Yield 50,000 AF, average 8,333 AF/Y
- 2026-2030-Yield 0 AF, average 0 AF/Y
- 2031-2035-Yield 660,000 AF, average 132,000 AF/Y
- 2036-2040-Yield 380,000 AF, average 76,000 AF/Y
- 2020-2040 Yield 68,125 AF/Y annual average

7.3 Mid-Kings River Groundwater Sustainability Agency

The MKR GSA is primarily a partnership between Kings County WD, the City of Hanford, and the County of Kings. The City of Hanford has developed and maintained municipal drinking water facilities for its residents for many decades. The Kings County WD has developed facilities and programs to address surface and groundwater conditions in its service area since the 1950s. The partnership of these three agencies provides a combination of resources and experience that will significant aid in SGMA implementation.

Projects

New Recharge Basins
The MKR GSAs plan to develop new recharge basins is conceptual and will be adaptive based on the productivity of facilities, the long-term availability of local wet year supplies and progress during the implementation period.

Partnership with Kings County WD
As an agency, Kings County WD has slightly different goals and a separate budget to take on efforts that address surface and groundwater conditions in almost all the MKR GSA area. The MKR GSA will work cooperatively with Kings County WD to develop the other needed basin facilities as well.

System Improvements

Kings County WD is evaluating their existing facilities used to recharge groundwater (roughly 1,100 acres) and deliver available surface water and developing projects to improve existing facilities.

Conservation Measures

The MKR GSA is aware of many different efforts by local growers to transition from current irrigation methods to more efficient irrigation systems. Some of these efforts are sprinklers, drip irrigation, and the use of drip tape (subsurface irrigation). While these methods do not change the amount that crops need to use to grow, they will reduce the amount lost to evaporation and the amount lost past the root zone.

Management Actions

Meter Requirements

The MKR GSA currently views that requiring the registration of all wells and the use of flow meters will dramatically improve the areas understanding of the most significant water balance components.

Pumping Restrictions

Currently it is believed that the historic amount of groundwater overdraft in the MKR GSA area can be addressed with new projects and programs developed through the Implementation period. However, if long-term increased demands and/or reduced surface water availability is experienced, the MKR GSA will consider implementing groundwater pumping restrictions.

Voluntary Fallowing

In the MKR GSA area there is a mixture of permanent and row crops grown in the agricultural areas. The MKR GSA Board plans to develop a program to work with row crop growers that would annually lease their property to reduce groundwater pumping in the area.

On-Farm Recharge

The MKR GSA is aware of landowners interested in on-farm recharge in the area. This effort will be continually evaluated to try to take advantage of the recharge capacity of existing fields.

Others

The MKR GSA plans to continually evaluate potential opportunities and pursue efforts that address GSA priorities with the least impact on local landowners. As the

Implementation period begins, the MKR GSA expects to learn many things over time and the hope is that this learning will help target efforts to be more and more effective.

Financing

The MKR GSA has contracted for consultant services related to GSA funding for implementation efforts and plans to hold a Proposition 218 election in 2020. Current plans are to develop a land based assessment for GSA administrative costs and a groundwater pumping charge to develop needed projects.

7.4 South Fork Kings Groundwater Sustainability Agency

SFK GSA encompasses 71,310 acres in the western portion of the Subbasin.

Projects

Recharge Basins

The SFK GSA will consider investment in surface recharge projects being proposed in MKR GSA and other GSA's north and east of the Subbasin that are tributary to the Kings River.

ASR

SFK GSA has initiated a pilot study to determine the efficacy of ASR and has applied for a CEQA exemption to pilot test an ASR well in 2020. Subject to a successful pilot test and approvals from the RWQCB and Division of Drinking Water, SFK GSA would then develop a program that would enable individual landowners to develop and initiate ASR operations when they have access to surface water suitable for underground injection.

Management Actions

Groundwater Monitoring Program

SFK GSA's groundwater level monitoring program will be generally implemented in accordance with this plan. Over time, the SFK GSA intends to rely solely on actual observed water levels rather than model results to establish progress towards sustainable pumping and avoidance of undesirable results.

Measurement of Groundwater Pumping

SFK GSA will initiate a measurement program to monitor groundwater pumping in the SFK GSA. The program will utilize a combination of metering at individual wells, remote sensing of cropping patterns, and grower surveys to determine crop type, irrigation sources, irrigation practices, and groundwater use.

Groundwater Accounting System

The SFK GSA will begin developing an accounting system that will link the measured pumping volumes with projects and policies to achieve overdraft reduction, sustainable yield, and avoidance of undesirable results.

Groundwater Pumping Fees

The SFK GSA will begin developing a fee structure for groundwater users.

Demand Reduction Program

The SFK GSA intends to initiate a program to reduce demand for groundwater. The elements of SFK GSA's demand reduction program may be as follows:

1. Enhancement of surface water delivery and on-farm efficiency improvement;
2. Seasonal cropping and dryland farming program; and
3. Land retirement or long-term fallowing contracts.

Financing

The SFK GSA is currently financed through a maximum assessment of $9.80 per acre that was approved through a Proposition 218 election in 2017 and the assessment will sunset in 2023. SFK GSA will establish a financing program that actively seeks out grants and funding partnerships that can implement the projects and management actions outlined in the GSP.

7.5 Southwest Kings Groundwater Sustainability Agency

The average annual storage change for the SWK GSA is estimated to be in surplus, thus projects to mitigate overdraft are not currently needed in this GSA. No projects have been determined at this time. Management actions may be determined at a later time and will be based upon annual monitoring results. The SWK GSA is applying for Proposition 1 Technical Support Services grant funding to offset some of the capital improvement costs associated with the development of new monitoring wells to fill existing data gaps in the monitoring network.

7.6 Tri-County Water Authority Groundwater Sustainability Agency

TCWA is a Joint Powers Authority created between local agencies cooperatively working towards groundwater sustainability by establishing a GSA between Angiola WD, Deer Creek Storm Water District, W. H. Wilbur Reclamation District, and Kings County. TCWA intends to manage groundwater within its boundaries in the Tulare Lake Hydrologic Region to accomplish the goals set forth in the GSP.

Projects

The Liberty Project is a water storage project on about 20 sections (roughly 20 x 640 acres = 12,800 acres) of private lands within Angiola WD and Kings County. This project will enable the capture and temporary storage of winter/spring flows from the Fresno Slough, Fresno ID, Mercy Springs, the Kings, Tule and Kaweah rivers, SWP Article 21, and CVP 215 waters. The project will be built in phases and will ultimately be capable of 94,000 acre-feet of surface storage. The stored water will be used in-lieu of groundwater pumping and for aquifer recharge.

Management Actions

TCWA has acted to implement certain management strategies immediately and has recognized the ability to develop additional actions and strategies over the 20-year implementation period. Management actions will be reviewed and revised by the TCWA Board of Directors at the five-year milestones to ensure sustainability is reached.

TCWA will implement its agricultural supply well metering program in 2020. To address overdraft conditions, a demand reduction of groundwater pumping may be implemented by TCWA.

7.7 El Rico Groundwater Sustainability Agency

The ER GSA and technical advisors have developed the projects and management actions described in Chapter 6. Once the GSP is approved, the projects and management actions previously selected are proposed to be advanced and implemented. Each GSA proposes their method to achieve sustainability, utilizing a combination of projects and management actions. Section 6.5, *GSA Sustainable Methods*, describes the mix of projects and management actions chosen by the GSA to meet the goals.

7.8 Identify Funding Alternatives

The Subbasin GSAs successfully pursued grant funding to help develop the GSP. A number of the GSAs have already passed Proposition 218 elections, which secured funds to generate sufficient revenue for the initial preparation of the GSP and initial GSA administrative functions. The annual operational costs have begun and are used to fund Agency operations and activities required by SGMA, including retaining consulting firms and legal counsel to provide oversight and lead the various agencies through the steps for SGMA compliance. Expenses consist of administrative support, GSP development, and GSP implementation. GSP development and GSA administrative costs are ongoing.

7.9 Data Management System

In development of this GSP, the five GSAs have developed a groundwater model that has been calibrated to estimate future scenarios. The DMS plans to build on existing data inputs in the groundwater model and develop a more formalized approach to collecting and capturing the data. As stated in Chapter 5, *Monitoring Network*, future data will be gathered to develop annual reports, as well as provide necessary information for future and ongoing update to the groundwater models at five-year intervals upon GSP implementation. The DMS that will be used is a geographical relational database that will include information on water levels, surface water diversions, land elevation measurements, and water quality testing. The DMS will allow the GSAs to share data and store the necessary information for annual reporting.

The DMS will be on local servers and data will be transmitted annually to develop a compiled repository for data analysis for the Subbasin's groundwater, as well as to allow for preparation of annual reports.

7.10 Annual Reporting

The GSAs will provide the Plan Manager the required information of groundwater levels, extraction volume, surface water use, total water use, groundwater storage changes and progress of GSP implementation for the Annual Report in accordance with the timelines required to meet the April 1st deadline each year.

7.11 Periodic Evaluations

The annual report will include updates or changes to the GSP or policy changes by the GSA's. Certain components of the GSP may be re-evaluated more frequently than every five years, if deemed necessary. This may occur, for example, if sustainability goals are not adequately met, additional data is acquired, or priorities are altered. Those results will be incorporated into the GSP when it is resubmitted to DWR every five years.

In addition, the annual report will provide an assessment to DWR in accordance with the regulatory requirements, at least every five years. The assessment will include and provide an update on progress in achieving sustainability including current groundwater conditions, status of projects or management actions, evaluation of undesirable results relating to MOs and MTs, changes in monitoring network, summary of enforcement or legal actions, and agency coordination efforts in accordance with 23 CCR §356.4.

1.0 INTRODUCTION

The legislative intent of the Sustainable Groundwater Management Act of 2014 (SGMA) is to sustainably manage California's groundwater basins. SGMA gives authority to local agencies to form Groundwater Sustainability Agencies (GSAs) and to manage groundwater basins to reach long-term groundwater sustainability through the preparation and implementation of Groundwater Sustainability Plans (GSPs) (California Water Code, §10720-10737.8). The adoption of SGMA established California's first comprehensive framework for sustainable management of groundwater basins through local agency coordination. SGMA expands the role of the California Department of Water Resources (DWR) to enforce local implementation of sustainable groundwater management practices through the review and approval of GSPs and allows for State Water Resources Control Board (SWRCB) intervention if groundwater basins do not meet sustainability requirements.

Key Features of SGMA

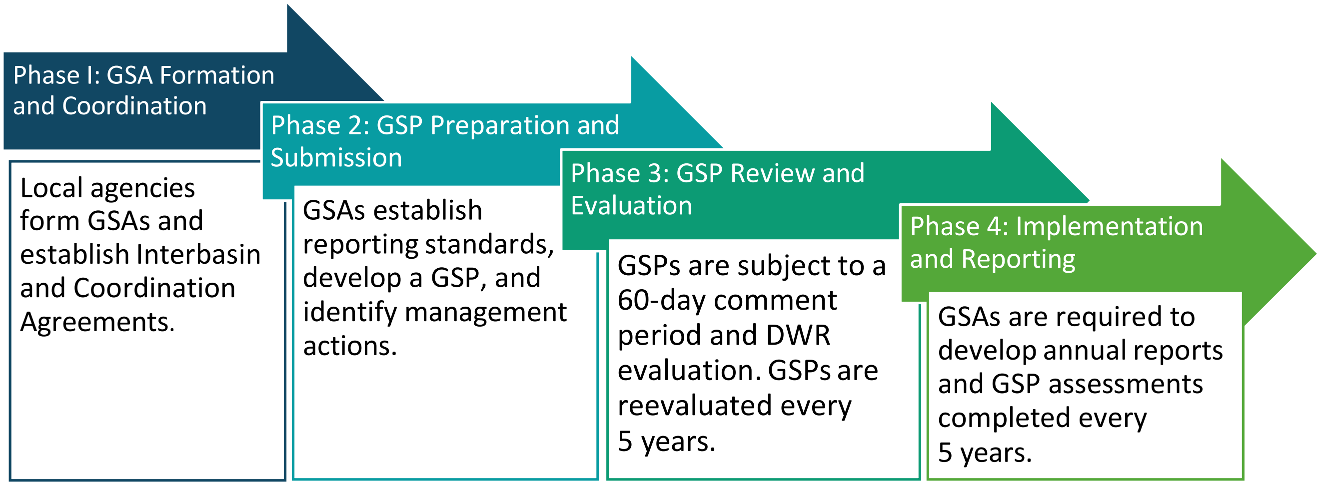
- **Senate Bill 1168 -** Requires the sustainable management of groundwater basins for long-term reliability and economic, social, and environmental benefits for future uses
- **Senate Bill 1319 -** Authorizes State Water Resources Control Board intervention to remedy a mismanaged groundwater basin
- **Assembly Bill 1739 -** Establishes criteria for sustainable management of groundwater and authorizes DWR to establish best management practices for groundwater management

DWR Statewide Bulletin 118 Report describes regional groundwater occurrence, defines California groundwater basin boundaries, identifies basins that are subject to critical conditions of groundwater overdraft, and establishes basin priority (California Water Code, §12924). California's 515 groundwater basins are classified into four categories; high-, medium-, low, or very low-priority based on conditions identified in the California Water Code, §10933(b). Conditions include the population and irrigated acreage overlying the subbasin, the degree to which the population relies on groundwater as their primary source of water, and exceedance of sustainable yield (DWR 2019b). Basin prioritization also considers any documented impacts on groundwater within the subbasin, including overdraft, subsidence, saline intrusion, water quality degradation, or other adverse impacts on local habitat and streamflows. A subbasin is subject to critical conditions of overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts (DWR 2019b).

The Tulare Lake Subbasin (Subbasin) is identified as high priority by DWR and is one of twenty-one basins considered to be in a critically-overdrafted condition (DWR 2019a). Five participating

GSAs in the Subbasin have coordinated to develop this comprehensive GSP in compliance with SGMA: Mid-Kings River (MKR), El Rico (ER), South Fork Kings (SFK), Southwest Kings (SWK), and Tri-County Water Authority (TCWA) (Appendix F). The GSAs are committed to continued coordination and compliance with annual and five-year reporting requirements during the implementation of their GSP.

Subbasins subject to critical conditions of overdraft are classified as medium-and high-priority basins under the above criteria and require the preparation and adoption of GSPs (California Water Code, §10720.7). Each GSP is required to set long-term sustainability goals as well as "interim milestones" in increments of 5 years that represent measurable groundwater conditions and target values. Data collection and annual reporting to DWR is also required to ensure conformance with SGMA following GSP adoption, to the maximum extent feasible (California Water Code, §10720.1). The GSPs therefore must be reevaluated and updated, at a minimum, every 5 years (2025, 2030, 2035, and 2040) to provide refinements to the GSPs and allow for revised management.



Phase I: GSA Formation and Coordination

Local agencies form GSAs and establish Interbasin and Coordination Agreements.

Phase 2: GSP Preparation and Submission

GSAs establish reporting standards, develop a GSP, and identify management actions.

Phase 3: GSP Review and Evaluation

GSPs are subject to a 60-day comment period and DWR evaluation. GSPs are reevaluated every 5 years.

Phase 4: Implementation and Reporting

GSAs are required to develop annual reports and GSP assessments completed every 5 years.

1.1 Subbasin Overview

The Subbasin (Basin No. 5-022.12) consists of 837 square miles (535,869 acres) in the southern region of San Joaquin Valley Groundwater Basin, within Kings County. The Kings, Kaweah, Tule, and Kern Rivers within the southern portion of the San Joaquin Valley flow into the Tulare drainage subbasin (DWR 2006). The Subbasin is bounded to the south by the Kern County Groundwater Subbasin (5-022.14), to the east by the Tule Groundwater Subbasin (5-022.13) and the Kaweah Groundwater Subbasin (5-022.11), to the north by the Kings Groundwater Subbasin (5-022.08), and the west by the Westside Groundwater Subbasin (5-022.09). The southern half of the Subbasin consists of lands in the historically present Tulare Lake bed in Kings County (DWR 2016b).

The land overlying the Subbasin has a population of 125,907 (2010) and density of 150 persons per square mile (DWR 2019a; US Census Bureau 2018). Agriculture is one of the top three industries in Kings County, and a significant portion of the Subbasin population is involved in all facets of agricultural production (DWR 2019c). As one of the primary industries, agriculture is the largest source of employment in the County.

1.2 Purpose of the Groundwater Sustainability Plan

SGMA requires GSAs for high- and medium-priority basins to halt overdraft and bring groundwater basins into balanced levels of pumping and recharge and expects subbasins to reach sustainability within 20 years of GSP implementation (DWR 2019c). GSAs establish minimum sustainability thresholds, measurable objectives, and long-term planning strategies through GSP development to achieve SGMA requirements (California Water Code, §10720; 10727). GSPs must identify the existing physical setting of the groundwater basin and assess groundwater levels to inform management actions and measurable sustainability goals (California Water Code, §10727.2).

The Subbasin GSP establishes how GSAs will monitor groundwater and use the data results to improve groundwater conditions in the basin. DWR defines sustainable groundwater management as the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results (California Water Code, §10721 [v]). Undesirable results under SGMA are defined as:

King's County is ranked the 10th largest agricultural production county in California. Top commodities include milk, cattle, cotton, almonds, pistachios, and tomatoes (Kings County Agricultural Commissioner 2017).

The Tulare Lake Subbasin contains approximately 251,994 irrigated acres of agricultural land. Approximately 50% of irrigation supplies are met by pumping groundwater (DWR 2019c).

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply
- Significant and unreasonable reduction of groundwater storage

- Significant and unreasonable sea water intrusion
- Significant and unreasonable degraded water quality including the migration of containment plumes that impair water supplies
- Significant and unreasonable land subsidence that substantially interferes with surface land uses
- Surface water depletions that have significant and unreasonable adverse impacts on beneficial uses of surface water.

The DWR GSP Emergency Regulations establish the requirements of GSP preparation and implementation in medium-and high-priority designated basins (Table 1-1; DWR 2016a).

1.3 Sustainability Goal

23 CCR §354.24 *Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline.*

1.3.1 Goal Description

This GSP aims to manage groundwater resources to continue to provide an adequate water supply for existing beneficial uses and users in accordance with counties and cities general plans while meeting established measurable objectives to maintain a sustainable yield. This goal aims to continue to provide adequate water supply for existing beneficial uses and users while ensuring the future, sustainable use of groundwater. Additionally, the sustainability goal works as a tool for managing groundwater, basin-wide, on a long-term basis to protect quality of life through the continuation of existing economic industries in the area including but not limited to agriculture.

GSAs in the Subbasin will work collectively to manage groundwater resources in the Subbasin, develop sustainability projects, and implement management actions, where appropriate. Section 3.2, *Groundwater Conditions*, provides insight to current and historical groundwater conditions, as well as a model for a 50-year forecast water budget to quantify groundwater level stability. Historic and hydrologic modeling estimates were used to develop a sustainable yield, which aims to stabilize forecasted groundwater levels. This goal was established in a manner that is transparent to the public and stakeholders to ensure the local population has a voice in the development of the programs. With the implementation of management actions and projects, as well as the continued interim monitoring and reassessment of activities, groundwater levels will be maintained at levels that will not create undesirable results.

1.3.2 Discussion of Measures

To achieve the goals outlined in the GSP, a combination of measures, including continued management practices and monitoring will be implemented over the next 20 years and continued thereafter. Additional surface water supply and infrastructure projects will be a crucial component of the supply system in diverting these waters to areas that provide the most benefit for offsetting the use of groundwater. Management actions will be implemented to help mitigate overdraft based on the demand from beneficial uses and users. Projects and management actions are discussed in further detail in Chapter 6, including a general timeline on when implementation will take place. When combined with consistent monitoring practices for each of the sustainability indicators, the GSAs will coordinate how individual GSAs pursue sustainability on a Subbasin level.

1.3.3 Explanation of How the Goal Will be Achieved in 20 Years

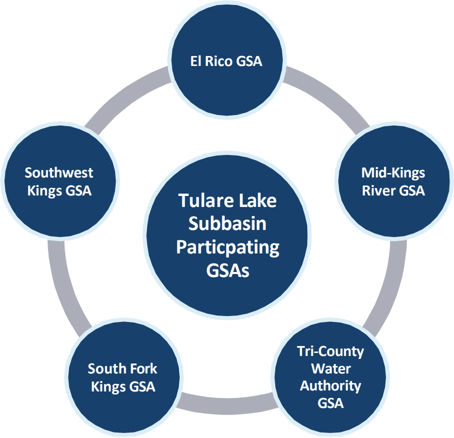
The goal of this Subbasin will be achieved in the next 20 years by the following:

- Understanding the existing condition’s interaction with future conditions;
- Analyzing and identifying the effects of existing management actions on the Subbasin;
- Implementing this GSP and its associated measures including project and management actions to halt and avoid future undesirable results;
- Collaborating between agencies to achieve goals and protect beneficial uses; and
- Assessing at each five-year interim milestone implemented project and management action’s successes and challenges.

1.4 Groundwater Sustainability Agency Information

23 CCR § 354.6(a) *The name and mailing address of the Agency.*

Five participating GSAs comprise the Subbasin: MKR, ER, SFK, SWK, and TCWA (Table 1-2). These GSAs have the authority and responsibility to sustainably manage the Subbasin under SGMA (California Water Code, §10723).



1.4.1 Organization and Management Structure of the GSA(s)

23 CCR § 354.6(b) *The organization and management structure of the Agency, identifying persons with management authority for implementation of the Plan.*

The five participating GSAs collaboratively developed this single GSP for Subbasin under an Interim Operating Agreement (Appendix F). Each GSA was formed by local member agencies that represent stakeholders on the GSA Board of Directors (Table 1-3). The Board of Directors and technical teams will collect and organize data from experienced consultants as well as seek feedback from groundwater users within the GSA boundaries through each SGMA phase (Appendix B). The GSA decision-making process is divided into various organization's roles. Below includes a description of each organization's responsibilities:

- **Subbasin Management Team-** Each GSA has a representative on the team who worked collaboratively to jointly develop this GSP and manage groundwater in the basin.
- **Board of Directors-** Adopts policies in regard to the development and implementation of the participating GSAs and the GSP.
- **Stakeholder/Advisory Committees-** Makes recommendations to the Board of Directors and technical consultants based on feedback from stakeholders to ensure this GSP accounts for representative local interests of all beneficial users. The committees work to encourage active involvement of a diverse, social, cultural, and economic elements of each GSA's population. Not all participating GSAs elected to have stakeholder/advisory committees.

1.4.2 Legal Authority of the GSA(s)

23 CCR § 354.6(d) *The legal authority of the Agency, with specific reference to citations setting forth the duties, powers, and responsibilities of the Agency, demonstrating that the Agency has the legal authority to implement the Plan.*

SGMA delegates the responsibility and authority to sustainably manage groundwater to local agencies through adoption and implementation of a GSP in medium-or high-priority basins (California Water Code, §10720). SGMA provides "local [GSAs] with the authority and the technical and financial assistance necessary to sustainably manage groundwater" (California Water Code, §10720.1). GSAs have regulatory authority including but not limited to adoption of regulations, conduction of investigations, and requirement of registered groundwater extraction facilities to sustainability manage groundwater within the basin (California Water Code, §10725). The five participating GSAs overlying Subbasin are coordinating to develop one comprehensive GSP (California Water Code §10723[a]). Each GSA overlies a portion of the Subbasin (DWR Bulletin 118, Basin No. 5-022.12). The five GSAs have established an Interim Operating Agreement to ensure coordination in developing and implementing the GSP.

The Subbasin is designated as a high-priority basin and therefore requires preparation of a GSP that will achieve groundwater sustainability in the basin within 20 years of implementation (California Water Code, §10720.7; 10727.2[b]). GSAs are required to lead communication, outreach, and engagement efforts within the basin and develop and implement a GSP on a basin-wide scale to sustainable manage groundwater at the local level.

1.4.3 Estimated Cost of Implementing the GSP and the GSA's Approach to Meet Costs

23 CCR § 354.6(e) An estimate of the cost of implementing the Plan and a general description of how the Agency plans to meet those costs.

The costs for implementing the GSP fall into a number of categories. The first is past and current planning functions. The GSAs have been for several years advancing development of the GSP and it has cost a significant amount of money. The historic and current planning functions have been broken down by the GSAs by a proportionate cost breakdown identified in Table 1-4. Applying this methodology to the past and present planning functions has resulted in an annual cost to the Subbasin of roughly $400,000. This is shown in Table 1-5. Implementation of the plan consists of annual ongoing and planning functions as well as implementation of projects and management actions. These estimated costs are shown on Table 1-6.

Some of the past costs have been paid for with grants from the State of California and for that the GSAs are grateful. There is opportunity to pursue additional grants and the GSAs fully intend to pursue additional grants that may become available. For the remainder of the ongoing costs and project financing for projects the local users will look to each of the GSA's constituency. Each GSA is responsible to its local area to identify the means in which to pay for the improvements and the level and detail to which management actions will be implemented. It is clear that each of the GSAs intend to implement projects to mitigate the overdraft and become sustainable. Management actions are identified as a possible tool and will be developed if the GSAs are unable to reach sustainability through the development of projects.

1.5 Interim Operating Agreement

Each of the five GSAs within the Subbasin operate under an Interim Operating Agreement (effective September 1, 2017) to facilitate coordination and management actions (Appendix F). SGMA expects local agencies to collaborate on a subbasin-wide scale and a combination of GSAs may be formed using a "joint powers agreement, a memorandum of agreement, or other legal agreement" (California Water Code, §10723 [b]). The Interim Operating Agreement is categorized as a legal agreement and ensures communication and coordination of the data and methodologies used by each GSA in developing the GSPs within the Subbasin for several factors, including groundwater elevation and extraction data, surface water supply, total water use, change in groundwater storage, water budget, total water use, and sustainable yield. Each GSA entered the Interim Operating Agreement to set forth their mutual intent to develop a single GSP for the Subbasin and authorize research and data collection required for the GSP according to a mutually agreeable timeline. Under this agreement, the GSAs agree to utilize their best efforts in preparing the GSP. Additionally, the SWK GSA and SFK GSA have a data sharing agreement with the Westlands Water District.

1.6 Groundwater Sustainability Plan Organization

The Subbasin GSP is organized as follows:

- **The Executive Summary** provides a summary overview of this GSP and a description of groundwater conditions at the basin, including management strategies and implementation actions.
- **Chapter 1. Introduction:** Includes the purpose of the GSP under SGMA to sustainably manage groundwater, the sustainability goals, the specifics of the participating GSAs, and the outline of the organization to this GSP.
- **Chapter 2. Plan Area:** Specifies the geographic extent of the GSP including but not limited to jurisdictional boundaries, existing land uses and land use policies, identification of water resources types, density of wells, and location of communities dependent on groundwater in the Subbasin.
- **Chapter 3. Basin Setting:** Describes the physical setting and characteristics of the current Subbasin conditions relevant to the GSP, including a Hydrogeologic Conceptional Model of the basin conditions, current and historic groundwater conditions, management areas, and a water budget.
- **Chapter 4. Sustainable Management Criteria:** Establishes criteria for sustainable groundwater management in the Subbasin, including how the GSAs will characterize undesirable results, and minimum thresholds and measurable objectives for the sustainability indictors.
- **Chapter 5. Monitoring Network:** Describes the GSP's monitoring network to collect sufficient data on groundwater conditions and to assess the plan's implementation through monitoring protocols on data collection and an established management system.
- **Chapter 6. Projects and Management Actions:** Outlines the project and management actions of the GSAs to meet the sustainability goal of the basin in a manner that can be maintained.
- **Chapter 7. Plan Implementation:** Consists of estimated GSP implementation costs, funding sources, GSP implementation schedule, and a plan for annual reporting and evaluation.

- **Chapter 8. References:** Includes a list of all references used to develop the GSP.
- **Appendices:** Includes additional information including but not limited to GSA contact information, the Interim Operating Agreement, Communication and Engagement Plan, Hydrogeologic Models, and the GSP checklist.
- 2022 GSP Addendum: Includes additional information including revised sustainable management criteria for groundwater level, land subsidence, and groundwater quality.

The Tulare Lake Subbasin submitted a single GSP in January 2020 to the Department of Water Resources (DWR). DWR was required to determine whether the GSP conformed to the specific requirements of SGMA. In a letter dated January 28, 2022, DWR determined that that the GSP is incomplete. DWR stated that the GSP was considered incomplete as it “does not define undesirable results or set sustainable management criteria for groundwater levels, subsidence, and water quality in the manner consistent with SGMA and the GSP regulations.” Upon receiving the incomplete determination, the Subbasin had 180 days to address the identified deficiencies and submit a revised GSP by July 27, 2022. The GSAs are submitting this 2022 Amended GSP to address the three deficiencies outlined in the determination letter. The 2022 Amended GSP consists of clean and redline strike out versions of the 2020 GSP and the attached 2022 GSP Addendum. The 2022 GSP Addendum was prepared to specifically address the incomplete determination letter from DWR. Sections of this document have been edited since the original submittal in 2020 and direct the reader to the Addendum for further details.

2.0 PLAN AREA

23 CCR §354.8 *Each Plan shall include a description of the geographic areas covered, including the following information:*

- *One or more maps of the basin that depict the following, as applicable:*
- *The area covered by the Plan, delineating areas managed by the Agency as an exclusive Agency and any areas for which the Agency is not an exclusive Agency, and the name and location of any adjacent basins.*
- *Adjudicated areas, other Agencies within the basin, and areas covered by an Alternative.*
- *Jurisdictional boundaries of federal or state land (including the identity of the agency with jurisdiction over that land), tribal land, cities, counties, agencies with water management responsibilities, and areas covered by relevant general plans.*
- *Existing land use designations and the identification of water use sector and water source type.*
- *The density of wells per square mile, by dasymetric or similar mapping techniques, showing the general distribution of agricultural, industrial, and domestic water supply wells in the basin, including de minimis extractors, and the location and extent of communities dependent upon groundwater, utilizing data provided by the department, as specified in section 353.2, or the best available information.*

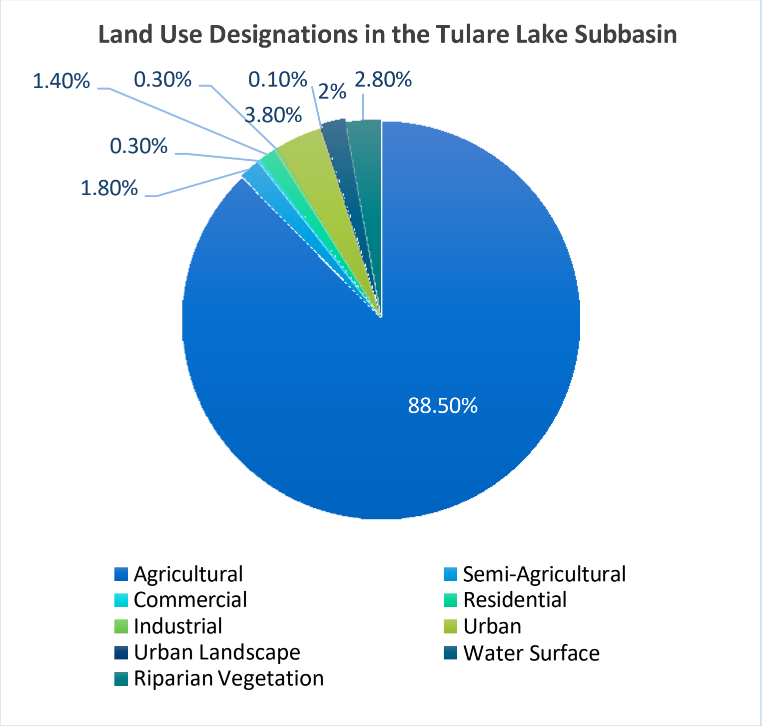
The Tulare Lake Subbasin (Subbasin) is located within the southern portion of the San Joaquin Valley Basin in the Central Valley of California. The Subbasin is defined under Department of Water Resources (DWR) Bulletin 118 as a high-priority basin (Basin No. 5-22.012). The Subbasin covers approximately 837 square miles (535,869 acres) including portions of the Kings, Kern, and Tulare counties (DWR 2016b). The five Groundwater Sustainability Agencies (GSAs) located within the Subbasin are the Mid-Kings River (MKR), South Fork Kings (SFK), Southwest Kings (SWK), El Rico (ER), and Tri-County Water Authority (TCWA) (Figure 2-1). There is no overlap among the GSAs and there are no adjudicated areas in the groundwater basin.

Tulare Lake Subbasin Prioritization Factors

- **Area:** ~837 square miles (535,869 acres)
- **Population (2010):** ~125,907
- **Projected Population Growth (2030):** ~176,446
- **Population Density:** ~150 persons/ square mile
- **Public Supply Wells:** ~75
- **Total Wells:** ~9,380
- **Irrigated Acres:** ~251,994
- **Groundwater Supply:** ~50% of water supplies
- **Total Storage Capacity:** ~17.1 million acre-feet (AF)

Source: DWR 2019b.

There are 28 total water management entities in the Subbasin GSA Plan area (Plan area) that have signed on as members of GSAs (Figure 2-3 through Figure 2-7). Federal lands located within the Plan area include Bureau of Land Management (BLM) parcels and administrative offices, the Santa Rosa Rancheria lands owned by the Bureau of Indian Affairs, and portions of the California Aqueduct regulated by the United States Bureau of Reclamation (USBR) (BLM 2019). State lands include the California State Prison Corcoran, Avenal State Prison, California Judicial Council courthouses, California Department of Transportation (Caltrans) storage facilities, portions of the Coastal and California Aqueducts regulated by DWR, State Routes 41, 198, and 43 and Interstate 5 (DGS 2019). Future planned development of these thoroughfares includes



expansion to allow for additional vehicle capacity. A portion of the proposed California High Speed Rail alignment traverses portions of the MKR and ER GSAs (Figure 2-8; Figure 2-10) (High-Speed Rail Authority 2019). Tribal lands located within the Plan area include the Santa Rosa Indian Community of the Santa Rosa Rancheria (DWR 2017a).

Land uses within the Plan area were surveyed by DWR in 2014, with additional surveys for Kings, Kern, and Tulare Counties in 2003, 2006, and 2007, respectively (Figure 2-8 through Figure 2-12). The Plan area is primarily comprised of agricultural and urban land use designations. Agriculture accounts for the largest percentage of land use in the Subbasin (Table 2-1). The primary land use designations for urban land are residential, commercial, and industrial, with groundwater being the main source of water (Table 2-2; DWR 2017a).

The Subbasin is supplied by surface water from the Kings River, the Tule River, the Kaweah and St. John’s Rivers, and unregulated streams including Deer Creek and Poso Creek, the California Aqueduct, and the Friant-Kern Canal. High precipitation rain events also convey natural surface water flows to the Plan area from Cottonwood Creek and Deer Creek. In 1995, DWR estimated the total groundwater storage capacity of the basin to be 17.1 million acre-feet (AF) to a depth of 300 feet, and 82.5 million AF to the base of fresh groundwater (DWR 2016b).

Figure 2-2 is a map of well density in the GSA area. There are an estimated 9,380 known wells within the Plan area, based on DWR continuous well records starting from 1940 (DWR 2019c). These records exclude test wells and recently drilled wells which have not been reported to DWR as of 2018. Any wells that have been decommissioned without issuance of a Kings County permit are mapped as active. DWR did not have information readily available to sort the wells based on domestic or irrigation use. The map does not necessarily show where pumping is concentrated since there is no differentiation between the different well uses.

2.1 Summary of Jurisdictional Areas and Other Features

23 CCR §354.8(b) *A written description of the Plan area, including a summary of the jurisdictional areas and other features depicted on the map.*

2.1.1 Groundwater Sustainability Plan (GSP) Area

The Plan area includes the jurisdictional boundaries of the MKR, SFK, SWK, TCWA, and ER GSAs (Figure 2-1). The majority of the Plan area is located within Kings County, with small areas in Tulare and Kern Counties. The Kings Subbasin is the northern boundary of the Plan area, with the Westside and Kettleman Plains Subbasins on the western boundary, the Kaweah and Tule Subbasins to the East, and Kern County Subbasin to the south (DWR 2019d). The Plan area is comprised of five GSAs and 28 entities, which are described further below. Water use sector and water source type vary by agency (Table 2-2). Many private domestic and private community wells are used in rural and semi-rural areas throughout the Subbasin.

2.1.2 Mid-Kings River Groundwater Sustainability Agency

The MKR GSA covers approximately 152 square miles (±97,400 acres) and is located in the northeastern portion of the Subbasin (Figure 2-3) (DWR 2019d). The public and private agencies within the MKR GSA include the Kings County Water District WD, the City of Hanford, and Kings County. Surface water delivery entities within this area are the Riverside Ditch Company, the Lemoore Canal and Irrigation Company, the Peoples Ditch Company, the Settlers Ditch Company, the Last Chance Water Ditch Company, the New Deal Ditch Company, the Lone Oak Ditch Company, and the Lakeside Ditch Company. The primary industry within the MKR GSA is agriculture. Other industries within the boundary include food processing, as well as warehousing and distribution, and commerce industry that is standard in a community of approximately 60,000 people (e.g., automotive shops, supermarkets, etc.).

2.1.2.1 <u>Kings County Water District</u>

Formed in the 1950s, the Kings County WD area is approximately 223 square miles (±143,000 acres) in northeastern Kings County in the central portion of the San Joaquin Valley. Surface water is obtained from the Kings River and Kaweah and St. John's Rivers through ditch company stock ownership. Kings County WD owns ditch stock for Kings River supplies in Lemoore Canal and Irrigation Company, Peoples Ditch Company, Settlers Ditch Company, and the Last Chance Water Ditch Company and ditch stock for Kaweah River supplies from Lakeside Ditch Company. Kings County WD also purchases surplus water from the Friant Division of the Central Valley Project (CVP), when available. There are numerous intentional recharge basins located in the Kings County WD, including the Apex Ranch Conjunctive Use Project, which is a groundwater bank that uses 50 acres of dry Kings River channel as a recharge area (Kings CWD 2011). Kings County WD is also responsible for managing flood water deliveries to the Old Kings River channel – a former river channel which is delivered wet year supplies through Peoples Ditch.

2.1.2.2 <u>Kings County</u>

Kings County, founded in 1893, is located on the western side of California's San Joaquin Valley. Kings County covers an area of approximately 1,391 square miles (890,240 acres), 1,024 square miles (±655,132 acres) of which are dedicated to harvested crops and other agricultural uses (Kings County 2019). U.S. Census Bureau estimates Kings County has a population of 151,336 as of 2018 (U.S. Census Bureau 2018) and is the 10th largest agricultural production county in the state, grossing over two billion dollars in 2017. Top commodities produced in Kings County include cattle, milk, cotton, pistachios, almonds, tomatoes, and grapes.

2.1.2.3 <u>City of Hanford</u>

The City of Hanford, incorporated in 1891, is located 30 miles southeast of Fresno in northern Kings County. The City of Hanford encompasses approximately 25 square miles (16,000 acres) and has a population of over 55,000. The sole source of water for the City of Hanford is groundwater, currently delivering 11,640 AF per year (AF/yr). The City of Hanford operates a wastewater treatment facility that discharges treated wastewater to percolation ponds or to farmlands for irrigation purposes (City of Hanford 2011).

2.1.2.4 <u>Peoples Ditch Company</u>

The Peoples Ditch Company, organized in 1873, is a pre-1914 water right holder on the Kings River that delivers water to the MKR and ER GSAs. Peoples Ditch Company's main canal system is located within the MKR GSA. The Peoples Ditch diversion off the Kings River is just upstream of Peoples Weir, south of Kingsburg. Peoples Ditch Company controls a portion of the storable volume behind Pine Flat Dam. The City of Hanford and Peoples Ditch Company have agreements regarding stormwater conveyance to Peoples Ditch and maintenance of facilities through the City of Hanford (City of Hanford 2017). Surface water diversions for Peoples Ditch Company average over 144,400 AF/yr over the last 100+ years of record (DWR 2012).

2.1.2.5 <u>Last Chance Water Ditch Company</u>

Last Chance Water Ditch Company, established in 1873, is a pre-1914 water right holder on the Kings River. The Last Chance Main Canal system and side ditches are located in the Hanford-Armona area in the central San Joaquin Valley. The Last Chance Main Canal diversion off the Kings River is just upstream of the Last Chance Weir, northeast of the 12th Avenue and Elder Avenue intersection. Last Chance Water Ditch Company controls a portion of the storable volume behind

Pine Flat Dam, and surface water diversions for the company average over 62,200 AF/yr over the last 60+ years of record (KRCD 2009).

2.1.2.6 Santa Rosa Rancheria

The Santa Rosa Rancheria community is comprised of approximately 700 residents. The Rancheria encompasses 2.8 square miles (±1,800 acres) within Kings County. The Rancheria relies on groundwater pumping for the majority of its water consumption (DWR 2019b).

2.1.2.7 Armona Community Services District

Armona Community Services District (CSD) serves the unincorporated community of Armona in Kings County. Armona CSD operates two groundwater wells that supply the population of 3,200 residents with 600 AF/yr (Armona CSD 2015). Recent discussions with Armona CSD staff in November of 2019 suggest the population has increased to 4,150 (Armona CSD 2019).

2.1.2.8 Home Garden Community Services District

Home Garden CSD serves the unincorporated community of Home Garden in Kings County. Groundwater wells provide water for 1,700 residents of the community (Home Garden CSD 2015).

2.1.2.9 Settlers Ditch Company

Settlers Ditch Company stock is a derivative of Peoples Ditch Company stock. In contrast, the Settlers Ditch Company has a separate Board of Directors and the ditch system is not viewed as part of Peoples Ditch Main Canal. Settlers Ditch delivery system is east of Hanford and generally north of Highway 198 (Kings CWD 2011).

2.1.2.10 New Deal Ditch Company

The New Deal Ditch Company holds a dry ditch stock, which gives access to deliver other stock water supplies through the New Deal Ditch. The New Deal Ditch begins at the end of the Peoples Ditch near the basin southwest of the 12th Avenue and Houston Avenue intersection. The New Deal Ditch generally delivers surface water to Peoples Ditch Company within part of the Kings County WD service area (Kings CWD 2011).

2.1.2.11 Lakeside Irrigation Water District

Lakeside Irrigation WD was formed in 1962 and its 31,991 acre service area is almost entirely within Kings County WD. Lakeside Irrigation WD has roughly the norther third of its service area in the Subbasin and the MKR GSA, while the southern two-thirds is in the Kaweah Subbasin and the Greater Kaweah GSA. There are 56 miles of open ditch in the Lakeside system as well as 10 recharge/regulation basins.

Lakeside Ditch Company, established in 1874, is a pre-1914 water right holder on the Kaweah River. The Lakeside canal system is located in the area southeast of Hanford in the central San Joaquin Valley. The Lakeside diversion off the Kaweah River is northeast of the 5th Avenue and Grangeville Boulevard intersection, just east of the Lakeland Canal. Kings County WD is a Lakeside Ditch Company stock holder as is Lakeside Irrigation WD.

2.1.3 South Fork Kings Groundwater Sustainability Agency

The SFK GSA covers approximately 111 square miles (±71,313 acres) and is located in the northwestern part of the Subbasin (Figure 2-4) (DWR 2019d). The public and private agencies within the SFK GSA include the City of Lemoore, Kings County, Empire Westside Irrigation District (ID), Stratford ID, Stratford Public Utility District (PUD), Company, Lemoore Canal and Irrigation Company, John Heinlen Mutual Water Company, and Jacob Rancho Water Company. The primary industries within the SFK GSA are agriculture and food processing (Appendix B).

2.1.3.1 City of Lemoore

The City of Lemoore, incorporated in 1900, lies within the northern portion of Kings County. The City of Lemoore encompasses an area of 6.82 square miles (±4,371 acres) and includes over 25,000 residents. Water supplies are approximately 8,300 AF/yr, with groundwater acting as the sole source for the City of Lemoore. The majority of water deliveries are metered. The City of Lemoore operates a wastewater treatment plant where treated wastewater is delivered to local farms for agricultural use (City of Lemoore 2015).

2.1.3.2 Empire Westside Irrigation District

Empire Westside ID was formed in 1931 and is a Kings River member unit. Its service area of 6,400 acres stretches from northwest to southwest of Stratford in Kings County. Empire Westside ID has a storage share of the Kings River of 13,000 AF and is a State Water Project Contractor (KRCD 2009).

2.1.3.3 Stratford Irrigation District

Stratford ID was formed in 1916 and is a Kings River member unit. Its service area is near Stratford in Kings County and encompasses 9,800 acres. Stratford ID has a storage share of the Kings River of 11,000 AF (KRCD 2009).

2.1.3.4 Stratford Public Utility District

Stratford PUD serves a population of 1,300 in the unincorporated community of Stratford within Kings County. Stratford PUD operates three groundwater wells that serve 340 metered service connections (Kings County 2015).

2.1.3.5 Lemoore Canal and Irrigation Company

Lemoore Canal and Irrigation Company was established in 1870. As a mutual water company, it serves the stockholders of the Lemoore area. The Company encompasses 52,300 acres and has a storage share of the Kings River of 100,000 AF (KRCD 2009).

2.1.3.6 John Heinlen Mutual Water Company

The John Heinlen Mutual Water Company serves an area of 13,100 acres near Lemoore in Kings County. The Company has a storage share of 10,000 AF of the Kings River (KRCD 2009).

2.1.3.7 Jacob Rancho Water Company

Jacob Rancho Water Company is a private water company operating within the SFK GSA.

2.1.4 Southwest Kings Groundwater Sustainability Agency

The SWK GSA covers approximately 140.6 square miles (±90,000 acres) and is located in the western portion of the Subbasin (Figure 2-5). The public and private agencies within the SWK GSA are Dudley Ridge WD, Tulare Lake Reclamation District (RD) #761, Kettleman City CSD, and Tulare Lake Basin Water Storage District (TLBWSD). Due to the poor yield and poor quality of the groundwater within the SWK GSA, only a minimal quantity of groundwater is pumped within the GSA. Groundwater levels, water quality, and subsidence are maintained at current levels. The primary industries within the GSA are agriculture, oil production, and commercial usage specific to Kettleman City (Appendix B).

2.1.4.1 Tulare Lake Basin Water Storage District

TLBWSD, formed in 1926, is located in Kings and Tulare Counties. TLBWSD has a service area of 296.88 square miles (±190,000 acres). TLBWSD obtains surface water from the Kings River, with supplemental deliveries from the Tule and Kaweah Rivers and the State Water Project (SWP). In a representative year, TLBWSD delivers approximately 324,400 AF (TLBWSD 2015).

2.1.4.2 Dudley Ridge Water District

Dudley Ridge WD, organized in 1963, is located in Kings County south of Kettleman City. Dudley Ridge WD services agricultural lands and encompasses an area of 58.77 square miles (±37,615 acres). Dudley Ridge WD water supply consists of water from the SWP and local transfers. Dudley Ridge WD does not use local groundwater due to low yields and poor quality. However, landowners within Dudley Ridge WD now import groundwater from the Angiola ID well field in Tulare County through canals across the Tulare Lake Bed. The annual water use for the Dudley Ridge WD is approximately 45,000 AF (Dudley Ridge WD 2012).

2.1.4.3 Tulare Lake Reclamation District #761

Tulare Lake RD #761 is located in the central San Joaquin Valley. Its boundaries primarily lie within the TLBWSD and encompass approximately 54.69 square miles (±35,000 acres). Tulare Lake RD #761 averages annual deliveries of approximately 24,500 AF from the Kings River (DWR 2012).

2.1.4.4 Kettleman City Community Service District

Kettleman City CSD serves a population of approximately 1,500 residents in the unincorporated community of Kettleman City. Historically, Kettleman City CSD has provided approximately 315 AF/yr from groundwater wells (Kettleman City CSD 2009). The CSD will now rely on surface water from their new Surface Water Treatment Facility. Their groundwater wells will now only be used as a back-up emergency supply

2.1.5 El Rico Groundwater Sustainability Agency

The ER GSA covers approximately 357 square miles (±228,400 acres) and is located in the center of the Subbasin (Figure 2-6) (DWR 2019d). The public and private agencies within the El Rio GSA are the City of Corcoran, Kings County, Alpaugh ID, Melga WD, Lovelace RD, Salyer WD, Corcoran ID, Tulare Lake Drainage District, and the TLBWSD. The primary industry within the ER GSA is agriculture. Other industries within the boundary include food processing, as well as warehousing and distribution, and commerce industry that is standard in a community of approximately 10,000 people (e.g., automotive shops, supermarkets, etc.) (Appendix B).

2.1.5.1 City of Corcoran

The City of Corcoran, incorporated in 1914, lies on the eastern side of Kings County. The City of Corcoran has a population of approximately 22,215 and encompasses approximately 7.5 square miles (4,800 acres). The City of Corcoran relies on groundwater to supply its residents with approximately 5,000 AF/yr of domestic water supply (City of Corcoran 2014).

2.1.5.2 Tulare Lake Basin Water Storage District

TLBWSD, formed in 1926, is located in Kings and Tulare Counties. TLBWSD has a service area of 296.88 square miles (±190,000 acres). TLBWSD obtains surface water from the Kings River, with supplemental deliveries from the Tule and Kaweah Rivers and the SWP. In a representative year, TLBWSD delivers approximately 324,400 AF (TLBWSD 2015).

2.1.5.3 Alpaugh Irrigation District

The Alpaugh ID was formed in 1915 and encompasses approximately 15.625 square miles (±10,000 acres). It is located on the southeastern edge of the Subbasin and is within the ER GSA. Alpaugh ID relies mostly on groundwater for its deliveries, operating 18 wells with the capability to deliver approximately 4,000 AF/yr. Alpaugh ID is a subcontractor with Tulare County for up to 100 AF/yr of CVP water. Alpaugh ID does not have other surface water contracts but utilizes small allotments of flood waters in the Homeland Canal (USBR 2018).

2.1.5.4 Corcoran Irrigation District

Corcoran ID was formed in 1919 to provide irrigation water to land within its boundaries. Corcoran ID encompasses approximately 34.38 square miles (±22,000 acres). Corcoran ID obtains most of its surface water from the Kings River, with supplemental deliveries from the Kaweah and St. John’s Rivers and USBR Section 215 water (Irrigation Training and Research Center 2008).

2.1.5.5 Lovelace Reclamation District #739739

Lovelace RD #739739 encompasses approximately 9.22 square miles (±5,900 acres) located north of TLBWSD. Lovelace RD’s primary function is flood control (DWR 2012).

2.1.5.6 Salyer Water District

Salyer WD is located in and around the TLBWSD. Salyer WD encompasses approximately 16.25 square miles (±10,400 acres) (DWR 2012).

2.1.5.7 Tulare Lake Drainage District

Tulare Lake Drainage District is a California Drainage District located in Kings, Tulare, and Kern Counties.

2.1.5.8 Melga Water District

Melga WD was formed in 1953 and encompasses approximately 117.19 square miles (±75,000 acres) mostly within the TLBWSD. Surface water supplies are obtained from the SWP and Kings River with periodic availability from the Kaweah and Tule Rivers (DWR 2012).

2.1.6 Tri-County Water Authority Groundwater Sustainability Agency

The TCWA GSA is a collective group of local water agencies dedicated to monitoring and regulating groundwater in the Tulare Lake Hydrologic Region. The TCWA GSA covers approximately 170.0 square miles (±108,800 acres) in the Tulare Lake and Tule Subbasins (Figure 2-7) (DWR 2019d). Approximately 75.19 square miles (±48,120 acres) of the GSA's area is located within the southeastern portion of the Subbasin. The primary industry within the TCWA GSA is almost entirely agriculture (Appendix B).

2.1.6.1 Tulare County

Tulare County, formed in 1852, encompasses approximately 4,839 square miles (±3,096,950 acres) and is located south of Fresno County. As of the 2010 census, the population was 442,179 (U.S. Census Bureau 2018; Tulare County 2019).

2.1.6.2 Kings County

Kings County, founded in 1893, is located on the western side of California's San Joaquin Valley. Kings County covers an area of approximately 1,391 square miles (890,240 acres). U.S. Census Bureau estimates Kings County has a population of 151,336 as of 2018 (U.S. Census Bureau 2018). Federal lands located within the Plan area include BLM parcels and administrative offices, the Santa Rosa Rancheria lands owned by the Bureau of Indian Affairs, and portions of the California Aqueduct regulated by the USBR (BLM 2019)

2.1.6.3 Angiola Water District

Angiola WD, formed in 1957, is an agency within the TCWA GSA. Irrigation wells within the area are mostly owned by the Angiola WD. Groundwater pumping supplements the fluctuating surface water supplies sourced from SWP, CVP, Kings River, Tule River, Deer Creek, and floodwaters from Tulare Lake (DWR 2012).

2.1.6.4 *Atwell Island Water District*

Atwell Island WD encompasses approximately 11.1 square miles (±7,100 acres). Atwell Island WD delivers surface water supplies from subcontracts with the County of Tulare of up to 50 AF/yr. Atwell Island WD does not operate any groundwater wells or recharge facilities (DWR 2012).

2.1.6.5 *W.H. Wilbur Reclamation District #825*

According to databasin website, W.H. Wilbur RD #825 is located within the TCWA GSA.

2.1.6.6 *Deer Creek Storm Water District*

According to Local Agency Formation Commission website for Tulare County, Deer Creek Storm WD is located within the TCWA GSA.

2.2 Water Resources Monitoring and Management Programs

2.2.1 Monitoring and Management Programs

23 CCR §354.8(c) *Identification of existing water resource monitoring and management programs, and description of any such programs the Agency plans to incorporate in its monitoring network or in development of its Plan. The Agency may coordinate with existing water resource monitoring and management programs to incorporate and adopt that program as part of the Plan.*

2.2.1.1 *Groundwater Level Monitoring*

The California Statewide Groundwater Elevation Monitoring (CASGEM) Program tracks long-term groundwater elevation trends throughout California. The Kings River Conservation District (KRCD) is the local agency that monitors groundwater levels within the Plan area. KRCD facilitates collaboration between local monitoring entities and DWR. The data is collected twice a year, in the spring and the fall (DWR 2012).

Kings County WD monitors groundwater levels on a regional scale and has monitored the groundwater since the 1950s. Kings County WD collects water level data from up to 280 wells in the spring and fall (Kings CWD 2011).

2.2.1.2 *Groundwater Extraction Monitoring*

It is not known how many private wells are metered nor if any existing groundwater extraction monitoring programs are in place. Potential future groundwater monitoring policies are discussed in Chapter 5, *Monitoring Network*.

2.2.1.3 Groundwater Quality Monitoring

See Chapter 5, *Monitoring Network,* for information on groundwater quality monitoring within the Subbasin and see Chapter 4, *Sustainable Management Criteria*, for existing groundwater quality monitoring.

2.2.1.4 Land Surface Subsidence Monitoring

Land subsidence has been measured for many years throughout the Central Valley. The Plan area contains various local monitoring networks, which can be utilized to survey existing benchmarks to measure subsidence. The United States Geological Survey (USGS), National Aeronautics and Space Administration (NASA), and KRCD also measure subsidence in the Central Valley. DWR commissioned NASA's Jet Propulsion Laboratory to utilize airborne and satellite radar data to measure ongoing land subsidence throughout California and produce maps showing how subsidence varies seasonally and regionally. USGS and NASA have published maps on their websites that show the subsidence monitoring results for a defined time period (USGS 2019; NASA 2017). KRCD also has a 7-mile grid that monitors new and existing benchmarks for land subsidence. Caltrans has a benchmark correction control network with historic elevation updates showing ground movement within the Subbasin at various locations. See Chapter 5, *Monitoring Network,* for further information regarding subsidence in the Plan area.

2.2.1.5 Surface Water Monitoring

Kings River Water Association (KRWA) monitors surface water in the Kings River and the associated watershed including seasonal snowpack, reservoir stage, reservoir inflow and outflow, Kings River flows, and Kings River diversions. The Friant Water Authority monitors San Joaquin River's water delivered through the Friant-Kern Canal. The Kaweah and St. Johns Rivers Association monitors Kaweah River water flows and deliveries, and the St. John's River that reaches the Subbasin via Cross Creek and Tule River. DWR and TLBWSD monitor the SWP and the Kings River flows that enter the Subbasin.

2.2.1.6 Irrigated Lands Regulatory Program

According to the Waterboards website, the Irrigated Lands Regulatory Program (ILRP) was initiated in 2003 to address pollutant discharges to surface water and groundwater from commercially irrigated lands. The primary purpose of the ILRP is to address key pollutants of concern including salinity, nitrates, and pesticides introduced through runoff or infiltration of irrigation water and stormwater. Surface water quality has been monitored for several years, and in the future, groundwater quality will be monitored. The program is administered by the Central Valley Regional Water Quality Control Board (RWQCB).

Under the ILRP rules, agricultural crop growers may form “third party” coalitions to assist with required monitoring, reporting, and education requirements for irrigated agriculture. The Kings River Water Quality Coalition (KRWQC) was established in 2009 as a Joint Powers Agency to combine resources and regional efforts to comply with the regulatory requirements of the ILRP. The KRWQC area and supplemental areas cover most of the Plan area (KRWQC 2016). The Westside Water Quality Coalition (WWQC) was formed in 2013 as part of the ILRP. Dudley Ridge WD is within the boundaries of the WWQC (WWQC 2019). Regional information on surface and groundwater quality is available from the individual coalitions.

2.2.1.7 GSP Monitoring and Management Plans

The individual water entities located within the Plan area will be responsible for continuing to collect data for any current monitoring or management plan. The monitoring program is described further in Chapter 5, *Monitoring Network*.

2.2.2 Impacts to Operational Flexibility

23 CCR §354.8(d) *A description of how existing water resource monitoring or management programs may limit operational flexibility in the basin, and how the Plan has been developed to adapt to those limits.*

2.2.2.1 Regulatory Decisions and Agreements

Regulatory monitoring and management programs outside the boundaries of the Subbasin have limited the operational flexibility and management of the Subbasin, by reducing the CVP and SWP delivery amounts, which include the following:

- **1992 Central Valley Project Improvement Act (CVPIA)**: The CVPIA is a multipurpose federal water legislation providing for water resource management throughout the western United States (U.S.). Enactment of the CVPIA mandated changes in the CVP and reallocation of water supplies and reductions in pumping, particularly for the protection, restoration, and enhancement of fish and wildlife. Water supplies in the Plan area have been reduced as a result of the CVPIA. Supplies were impacted due to pumping restrictions within the Delta and development of refuge supplies from previously available contract supplies, which led to decreased allocations for Mid-Valley Canal and Cross Valley Canal contracts.
- **2007 Wanger Decision:** A federal decision found that USBR did not consider evidence that fish, including salmon and delta smelt, would be harmed by increased water exports for the Sacramento-San Joaquin Delta. The result of this curtailed SWP and CVP pumping from the Delta, reducing overall supplies to the Subbasin.

2.2.2.2 Places of Use

Agencies use of water from Kings River, SWP, and CVP are restricted to the place of use defined by their water rights. This GSP will not alter these agreements.

2.2.2.3 Contaminant Plumes

Water quality for individual monitoring wells can be found from Geotracker (SWRCB 2019a). See Chapter 3, *Basin Setting,* for more information on water quality in the Subbasin.

2.2.2.4 Kings River Fisheries Management Program

A partnership has been forged between KRCD, the KRWA, and the California Department of Fish and Wildlife (CDFW) to create the Kings River Fisheries Management Program (KRFMP). This program includes numerous measures to benefit the Kings River fisheries, including year-round flows, improved temperature control, and additional monitoring. However, this comes at the expense of some operational flexibility for Kings River water users. The Kings River provides the majority of the surface water used in the Subbasin area (KRFMP 1999).

Several requirements are placed on Pine Flat Reservoir and Kings River operations, as a part of the program. These include maintaining a minimum of 100,000 AF in Pine Flat Reservoir, temperature control pool (10 percent [%] of the reservoir's capacity), and October through March minimum fish flow releases below Pine Flat Dam (KRFMP 1999).

The local water entities have already adjusted agricultural operations to adapt to the KRFMP. In the future, additional recharge and banking facilities could help the program to further adapt by providing a place to store Kings River waters when supply exceeds irrigation demands.

2.2.3 Conjunctive Use Programs

23 CCR §354.8(e) *A description of conjunctive use programs in the basin.*

Conjunctive Use *is the deliberate combined use of groundwater and surface water, which involves actively managing the aquifer systems as an underground reservoir.*

Conjunctive use is the coordinated and planned management of surface and groundwater resources to maximize their efficient use. Conjunctive use is utilized to improve water supply reliability and environmental conditions, reduce groundwater overdraft and land subsidence, and to protect water quality. Conjunctive use can include using surface water when it is available and relying on groundwater when surface water supplies may run out seasonally or are limited during droughts. Conjunctive use also includes cyclic storage where surplus surface waters are recharged during wet years and groundwater is pumped during dry periods.

Surface water is also used for groundwater banking (recharge) in areas that allow surface water to be stored in the aquifer for use at a later date. Kings County WD operates numerous recharge basins within its district. Within Kings County WD, the Apex Ranch Conjunctive Use Project uses 50 acres of dry Kings River channel as a recharge area. Alpaugh ID has storage ponds that provide incidental recharge (Kings CWD 2011). Corcoran ID operates percolation basins with a 10,000 AF capacity capable of recharging 200 AF/day (DWR 2012). The City of Corcoran has an agreement with Corcoran ID to discharge stormwater into their ditch network for the purpose of recharge (City of Corcoran 2014). Additionally, the City of Hanford has a very similar agreement with Peoples Ditch Company.

2.3 Relation to General Plans

2.3.1 Summary of General Plans/Other Land Use Plans

23 CCR §354.8(f) *A plain language description of the land use elements or topic categories of applicable general plans that include the following: A summary of general plans and other land use plans governing the basin.*

Every county and city in California is required to develop and adopt a General Plan (California Government Code, §65350-65362). A General Plan is a comprehensive long-term plan for development of the county or city, which consists of a statement of development policies and identifies objectives, principles, standards, and proposals for the area. To an extent, a General Plan acts as a "blueprint" for development.

The General Plan must contain seven state-mandated elements; however, any additional elements the legislative body of the county or city wishes to adopt can be included. The seven mandated elements are: Land Use, Circulation, Housing, Noise, Open Space, Conservation, and Safety. The General Plan may be adopted in any form deemed appropriate or convenient by the legislative body of the county or city, including the combining of elements. Within the Plan area, agencies with jurisdiction over land uses have adopted General Plans (Table 2-3).

As noted in Section 2.1.6.6, a relatively small portion of the ER GSA extends into Kern County. The extension consists of 640 acres and is a portion of a 1,080-acre parcel (Figure 2-11), used as evaporation ponds and owned by the Tulare Lake Drainage District. It is considered unlikely that any Kern County General Plan policies have any practical relevance to the Plan area.

2.3.2 Impact of GSP on Water Demands

23 CCR §354.8(f)(2) *A general description of how implementation of existing land use plans may change water demands within the basin or affect the ability of the Agency to achieve sustainable groundwater management over the planning and implementation horizon, and how the Plan addresses those potential effects.*

All of the General Plans in the Plan area were adopted prior to the development of the GSA and this GSP; therefore, the General Plans did not consider the impacts of this GSP's implementation.

The General Plans of Kings, Tulare, and Kern County, as well as the City of Hanford, Lemoore, and Corcoran make assumptions for both rural and urban development. Urban Water Management Plans (UWMPs) prepared for the City of Lemoore, Hanford, and Corcoran address assumed land use changes and growth rates. This GSP may use the land use change assumptions identified in the General Plans as well as other information for forecasting the anticipated water budget, described later in this GSP. See Chapter 3, *Basin Setting,* for more information.

2.3.3 Impact of GSP on Water Supply Assumptions within Land Use Plans

23 CCR §354.8(f)(3) *A general description of how implementation of the Plan may affect the water supply assumptions of relevant land use plans over the planning and implementation horizon.*

There are six General Plans within the Plan area. The counties of Kings, Kern and Tulare and cities of Lemoore, Hanford, and Corcoran each possess a General Plan. The General Plan sections that cover the effect of the water supply are summarized below. Impacts due to implementation of the Plan vary and planning efforts will continue to be coordinated, with each entity and their respective plan to be updated at the five-year milestones.

2.3.3.1 County of Kern General Plan

There are no anticipated impacts on Kern County lands within the Subbasin. The total Kern County land area within the Subbasin is 360 acres (Kern County 2009).

2.3.3.2 Kings County General Plan

Kings County ranks as the seventh fastest-growing county in population in California. The estimated 2018 population of Kings County was 151,366 (U.S. Census Bureau 2018). Future projections from the Department of Finance (DOF) expect the population to reach 181,218 by the year 2035 (DOF 2019). The Land Use (LU), Resource Conservation (RC), and Health and Safety (HS) sections of the Kings County General Plan discuss various topics including water supply. The primary water supply goal in this plan is for reliable and cost-effective infrastructure systems that permit the County to sustainably manage its diverse water resources and agricultural needs, secure additional water, and accommodate for future urban growth (Kings County 2010).

2.3.3.3 County of Tulare General Plan

Tulare County's General Plan 2030 Update developed goals and policies to encourage sustainable groundwater management, such as to develop additional water sources, implement water conservation, and encourage demand management measures for residential, commercial, and industrial indoor and outdoor water uses in all new urban development (Tulare County 2012).

2.3.3.4 City of Hanford General Plan

The Land Use, Transportation, Water Resources, and Public Facilities sections of the City of Hanford's General Plan discuss various topics including water supply. U.S. Census Bureau estimated the 2018 population to be 56,910 (U.S. Census Bureau 2018), City of Hanford staff suggest the population has increased to approximately 58,000 (City of Hanford 2019), which accounts for approximately 37% of the population of Kings County. The 2016 General Plan anticipates the population to increase to 90,000 by 2035. The annual gross water use in 2015 was 11,640 AF or 188 gallons per capita per day. The General Plan's 2020 urban water use targets 179 gallons per capita per day, which is intended to be maintained through the 2035 plan horizon. The anticipated gross annual water use by 2035 can be expected to be 18,045 AF (City of Hanford 2011). The primary water supply goal in the plan is to maintain reliable and cost-effective infrastructure systems that permit the City to sustainably manage its diverse water resources and needs.

2.3.3.5 City of Lemoore General Plan

The City of Lemoore General Plan policies are geared towards preserving environmental resources such as open space, prime farmland, wetlands, special species, water resources, air quality, and other elements of value to Lemoore residents. The estimated 2018 population of Lemoore was 26,474 (U.S. Census Bureau 2018). Sufficient land was allocated in the General Plan to accommodate for future population projections, which are expected to reach 48,250 by 2030. According to the 2005 City of Lemoore UWMP, the City of Lemoore's 2005 maximum day demand was approximately 12.8 million gallons per day, which is well within the current supply capacity of 19.2 million gallons per day. If the City grows at the anticipated rate, demand will exceed the supply available from existing wells. Since Lemoore is not located within an adjudicated water basin, there is no restriction on the number of wells the City of Lemoore may drill within City boundaries. Water quality maintenance is a more considerable challenge to meeting water demand than water quality for the City of Lemoore (City of Lemoore 2015).

2.3.3.6 City of Corcoran General Plan

The Land Use, Circulation, Safety, Conservation and Open Space, Air Quality, and Public Services and Facilities sections of the City of Corcoran's General Plan discuss various topics including water supply. U.S. Census Bureau estimated the 2018 total population of Corcoran to be 21,676 (U.S. Census Bureau 2018). By 2030, the population is expected to reach 26,888. The City of Corcoran's entire water supply is provided by local groundwater. The average daily demand in 2010 was 5.9 million gallons per day. Projected daily demand in 2030 is expected to increase to 5.5 million gallons per day, so projected water use targets a 20% use reduction. The General

Plan's primary water supply goal is to protect natural resources including groundwater, soils, and air quality in an effort to meet the needs of present and future generations (City of Corcoran 2014).

2.3.4 Permitting Process for New or Replacement Wells

> ***23 CCR §354.8(f)(4)*** *A summary of the process for permitting new or replacement wells in the basin, including adopted standards in local well ordinances, zoning codes, and policies contained in adopted land use plans.*

In California, local jurisdictions with the authority to adopt a local well ordinance that meets or exceeds DWR Well Standards have regulatory authority over well construction, alteration, and destruction activities (DWR 2019a). After the submittal of the GSP, California Water Code §10725 - §10726.9 describes the authoritative power by the GSAs, including but not limited to imposing spacing requirements on new groundwater well construction, imposing operating regulations on existing groundwater wells, and controlling groundwater extractions. The GSA may use the powers described in the above code to provide the maximum degree of local control and flexibility consistent with sustainability goals described in the GSP.

2.3.4.1 Kings County

The Kings County General Plan Resource Conservation Policy A1.6.3 states the following regarding well installations:

- *Protect groundwater by enforcing the requirements for installation of wells in conformity with the California Water Code, the Kings County Well Ordinance, and other pertinent state and local requirements.*

Kings County adheres to DWR Well Standards guidelines for the construction of groundwater wells that are intended to protect the groundwater quality and reduce the adverse effects caused by improper well construction (DWR 1981; DWR 1991). Kings County has the sole authority for establishing and enforcing the standards for construction and deconstruction of water wells. In accordance with the California Water Code §13801, Kings County Ordinance No. 587 has provisions that require permits for well construction, reconstruction and deepening, with oversight provided by the County's Health or Building Officials, and stipulates that no person shall dig, bore, drill, deepen, modify, repair, or destroy a well, cathodic protection well, observation well, monitoring well or any other excavation that may intersect groundwater without first applying for and receiving a permit unless exempted by law (Kings County 2000; 2001). The permittee is required to complete the work authorized by the permit within 180 days of the date of issuance of the permit.

Installation of domestic supply wells in Kings County must follow separate guidelines and regulations. Domestic wells installation requires completion of necessary permits, California Environmental Quality Act (CEQA) review, DWR and Drinking Water Source Assessment and Protection Program (DWSAP), and site and well inspections. A well is not to discharge into the water distribution system until the above documents have been submitted to the Division Office and a field inspection of the well installation has been made by Kings County Environmental Health Services (Kings County Public Health Department 2009).

2.3.4.2 County of Kern

Kern County stipulates the contractor as the responsible party to construct, deepen, or reconstruct an agricultural well in accordance with Kern County Ordinance Code, §14.08 (Kern County 2019). In addition, the contractor must also meet standards set by DWR, with the exception of modifications by updated DWR revisions (DWR 1981; DWR 1991). The responsibility lies with the owner to ensure the following have been included and completed:

- Install surface slab
- Implement watertight sanitary seal
- Use of approved backflow protection device (chemigation, air gap)
- Use of down-turned, screened casing air vent
- Disinfection of access/sounding tube
- Unthreaded sample tap installation
- Approved Flow Meter-NSF 61 installed
- Collection of water samples from the well to conduct a Water Quality Analysis for Arsenic Fluoride, Ethylene dibromide, Dibromo chloropropane and Gross Alpha

The Water Quality Analysis test must be performed by a state-certified laboratory. Final approval cannot be issued until all water quality tests have been received by Kern County and the surface construction features have been approved by Kern County Public Health Services Department 2018 (Kern County 2018).

2.3.4.3 County of Tulare

Tulare County approved a water well ordinance in September 2017 (Tulare County Ordinance Code, Part IV. Health, Safety and Sanitation, Chapter 13. Construction of Wells) that addresses agricultural and domestic water wells. Well construction, destruction, and setback requirements have been altered under Tulare County Ordinance Code Part IV Chapter 13 (Tulare County 2017). This ordinance places restrictions on the drilling of new wells on previously non-irrigated land where the land has not had a well or has not had surface water in the past. Tulare County Environmental Health Services Division is responsible for the permitting and enforcement within the portion of the Subbasin in Tulare County. Tulare County Ordinance Code Part IV Chapter 13, Article 3 stipulates the following:

- *Except as otherwise provided in sections 4-13-1250 and 4-13-1255 of this Article, it shall be unlawful for any person to construct, deepen, reconstruct or destroy any well, or soil boring, or cause any of those acts to be done, unless a permit has first been issued to him or to the person on whose behalf the work is undertaken. The Tulare County Health Officer may prescribe conditions if he determines that they are required to prevent contamination or pollution of underground waters. Permit conditions are appealable pursuant to section 4-13-1275 of this Article. A well permit shall be valid for six (6) months from the date of issuance.*

2.3.5 Land Use Plans Outside the Basin

23 CCR §354.8(f)(5) *To the extent known, the Agency may include information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management.*

In general, all future land use changes will need to consider the net groundwater impact to neighboring basins, and updates to agency General Plans will need to consider GSPs and the responsibility of each member and participating agency. GSPs for neighboring basins will be evaluated during the GSP review process. Coordination between subbasins is required as part of GSP implementation. A discussion of some potential management actions, including policy changes are described in Chapter 6, *Projects and Management Actions*.

Relevant land use plans for Kern and Tulare counties are discussed in Section 2.3.3, *Impact of GSP on Water Supply Assumptions within Land Use Plans*. There are no nearby cities that have land use plans.

2.3.5.1 Fresno County General Plan

The Public Facilities and Services section of the Fresno County General Plan discusses general public facilities and services; funding; water supply and delivery; wastewater collection, treatment, and disposal; storm drainage and flood control; and numerous other services (Fresno County 2000). The goal of the water supply and delivery section is to ensure the availability of an adequate and safe water supply for domestic and agricultural consumption. The relevant policies are listed below:

- Policy PF-C.12 - The County shall approve new development only if an adequate sustainable water supply to serve such development is demonstrated.

- Policy PF-C.13 - In those areas identified as having severe groundwater level declines or limited groundwater availability, the County shall limit development to uses that do not have high water usage or that can be served by a surface water supply.
- Policy PF-C.23 - The County shall regulate the transfer of groundwater for use outside of Fresno County. The regulation shall extend to the substitution of groundwater for transferred surface water.
- Policy PF-C.26 - The County shall encourage the use of reclaimed water where economically, environmentally, and technically feasible.

2.4 Additional GSP Elements

> ***23 CCR §354.8(g)*** *A description of any of the additional Plan elements included in the Water Code Section 10727.4 that the Agency determines to be appropriate.*

2.4.1 Saline Water Intrusion

Saline (or brackish) water intrusion is the induced migration of saline water into a freshwater aquifer system. Saline water intrusion is typically observed in coastal aquifers where over-pumping of the freshwater aquifer causes salt water from the ocean to encroach inland, contaminating the fresh water aquifer. The Subbasin is approximately 70 miles from the Pacific Ocean, and the potential for adverse impacts of saline intrusion in the Subbasin are considered low.

2.4.2 Wellhead Protection

A Wellhead Protection Area (WHPA) is defined by the Safe Drinking Water Act Amendment of 1986 as "the surface and subsurface area surrounding a water well or wellfield supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield" (100 U.S. Code. 764). The WHPA may also be the recharge area that provides the water to a well or wellfield. Unlike surface watersheds that can be easily determined from topography, WHPAs can vary in size and shape depending on subsurface geologic conditions, the direction of groundwater flow, pumping rates, and aquifer characteristics.

According to the EPA website, the Federal Wellhead Protection Program was established by Section 1428 of the Safe Drinking Water Act Amendments of 1986. The purpose of the program is to protect groundwater sources of public drinking water supplies from contamination, thereby eliminating the need for costly treatment to meet drinking water standards. The program is based on the concept that the development and application of land use controls, usually applied at the local level, and other preventative measures can protect groundwater.

According to the Safe Drinking Water Act, states may be delegated primary implementation and enforcement authority for the drinking water program. To date, California has no State-mandated program and relies on local agencies to plan and implement programs. Wellhead Protection Programs are not regulatory in nature, nor do they address specific sources. They are designed to focus on the management of the resource rather than control a limited set of activities or contaminant sources.

Contaminants from the surface can enter an improperly designed or constructed well along the outside edge of the well casing or directly through openings in the wellhead. A well is also the direct supply source to the customer, and such contaminants entering the well could then be pumped out and discharged directly into the distribution system. Essential to any wellhead protection program is proper well design, construction, and site grading to prevent intrusion of contaminants into the well from surface sources.

Wellhead protection is performed primarily during design and can include requiring annular seals at the well surface, providing adequate drainage around wells, constructing wells at high locations, and avoiding well locations that may be subject to nearby contaminated flows. Wellhead protection is required for potable water supplies and is not generally required, but is still recommended, for agricultural wells.

Municipal and agricultural wells constructed by the GSA member agencies are designed and constructed in accordance with DWR Bulletins 74-81 and 74-90. A permit is required from the applicable county prior to construction of a new well within the GSA's area. In addition, the GSA member agencies encourage landowners to follow the same standard for privately owned wells. Specifications pertaining to wellhead protection include (DWR 1981; DWR 1991):

- Methods for sealing the well from intrusion of surface contaminants;
- Covering or protecting the boring at the end of each day from potential pollution sources or vandalism; and
- Site grading to assure drainage is away from the wellhead.

2.4.3 Migration of Contaminated Groundwater

Groundwater contamination can be human-induced or caused by naturally occurring processes and chemicals. Sources of groundwater contamination can include irrigation, dairy production, pesticide applications, septic tanks, industrial sources, stormwater runoff, and disposal sites. Contamination can also spread through improperly constructed wells that provide a connection between two aquifers or improperly abandoned/destroyed wells that provide a direct conduit of contaminants to aquifers.

The following databases provide information and data on known groundwater contamination, planned and current corrective actions, investigations into groundwater contamination, and groundwater quality from select water supply and monitoring wells.

2.4.3.1 State Water Resources Control Board

The State Water Resources Control Board (SWRCB) maintains an online database that identifies known contamination cleanup sites, known leaking underground storage tanks, and permitted underground storage tanks. The online database contains records of investigation and actions related to site cleanup activities (SWRCB 2019a).

2.4.3.2 Department of Toxic Substance Control

The State of California Department of Toxic Substances Control (DTSC) provides an online database with access to detailed information on permitted hazardous waste sites, corrective action facilities, as well as existing site cleanup information. Information available through the online database includes investigation, cleanup, permitting, and/or corrective actions that are planned, being conducted, or have been completed under DTSC's oversight (DTSC 2019).

2.4.3.3 California Department of Pesticide Regulation

The California Department of Pesticide Regulation (DPR) maintains a Surface Water Database (SURF) containing data from a wide variety of environmental monitoring studies designed to test for the presence or absence of pesticides in California surface waters. As part of DPR's effort to provide public access to pesticide information, this database provides access to data from DPR's SURF (DPR 2019).

2.4.3.4 Groundwater Ambient Monitoring and Assessment Program

The SWRCB Groundwater Ambient Monitoring and Assessment (GAMA) program collects data by testing untreated raw water for naturally occurring and man-made chemicals and compiles all of the data into a publicly accessible online database (SWRCB 2019b).

2.4.4 Well Abandonment/Well Destruction Program

Well abandonment generally includes properly capping and locking a well that has not been used in over a year. Well destruction includes completely filling in a well in accordance with standard procedures listed in Section 23 of DWR Bulletin 74-81 (DWR 1981). DWR Bulletin 74-90 includes a revision in Section 23, for Subsection A and B, from Bulletin 74-81 (DWR 1991). The following revision is stated for Subsection A, Item 1:

DWR's Bulletin 74-90 establishes California Well Standards, which states:

A monitoring well or exploration hole subject to these requirements that is no longer useful, permanently inactive or "abandoned" must be properly destroyed to:

- Ensure the quality of groundwater is protected, and;
- Eliminate a possible physical hazard to humans and animals.

- *Obstructions. The well shall be cleaned, as needed, so that all undesirable materials, including obstructions to filling and sealing, debris, oil from oil-lubricated pumps, or pollutants and contaminants that could interfere with well destruction are removed for disposal. The enforcing agency shall be notified as soon as possible if pollutants and contaminants are known or suspected to be in a well to be destroyed. Well destruction operations may then proceed only at the approval of the enforcing agency. The enforcing agency should be contacted to determine requirements for proper disposal of materials removed from a well to be destroyed.*

The following revision from DWR Bulletin 74-90 states for Subsection B:

- *Wells situated in unconsolidated material in an unconfined groundwater zone. In all cases the upper 20 feet of the well shall be sealed with suitable sealing material and the remainder of the well shall be filled with suitable fill or sealing material from Bulletin 74-81.*

The remainder of Section 23 from DWR Bulletin 74-81 is unchanged.

Proper well destruction and abandonment are necessary to protect groundwater resources and public safety. Improperly abandoned or destroyed wells can provide a conduit for surface or near-surface contaminants to reach the groundwater. In addition, undesired mixing of water with different chemical qualities from different strata can occur in improperly destroyed wells.

The administration of a well construction, abandonment, and destruction program has been delegated to the counties by the California State legislature. Kings County requires that wells be abandoned according to State standards documented in DWR Bulletins 74-81 and 74-90. Due to staff and funding limitations, enforcement of the well abandonment policies is limited.

2.4.5 Replenishment of Groundwater Extractions

Primary groundwater replenishment sources in the Plan area:

- Kings River
- Kaweah River
- Tule River
- Deer Creek
- Poso Creek
- Precipitation
- Various smaller streams

Replenishment of groundwater is an important technique in management of a groundwater supply to mitigate groundwater overdraft. Groundwater replenishment occurs naturally through rainfall, rainfall runoff, and stream/river seepage and through intentional means, including deep percolation of crop and landscape irrigation, wastewater effluent percolation, and intentional recharge. The primary local water sources for groundwater replenishment in the Plan area include precipitation, Kings River, Kaweah River, Tule River, Deer Creek, Poso Creek, and various smaller local streams. For more information, refer to Section 2.2.3, *Conjunctive Use Programs*, of the GSP.

2.4.6 Well Construction Policies

Proper well construction is necessary to ensure reliability, longevity, and protection of groundwater resources from contamination. All of the GSA member agencies follow state standards when constructing municipal and agricultural wells (DWR 1991). Kings County has adopted a well construction permitting program consistent with state well standards to help assure proper construction of private wells. Kings County maintains records of all wells drilled in the Plan area.

State well standards address annular seals, surface features, well development, water quality testing and various other topics (DWR 1991). Well construction policies intended to ensure proper wellhead protection are discussed in Section 2.4.2, *Wellhead Protection*.

2.4.7 Groundwater Projects

The GSA member agencies in general developed their own projects to help meet their water demands and will develop additional future projects to meet sustainability. Developing groundwater recharge and banking projects is considered key to stabilizing groundwater levels. Chapter 6, *Project and Management Actions to Achieve Sustainability*, provides descriptions, estimated costs, and estimated yield for numerous proposed projects.

The GSA will also support measures to identify funding and implement regional projects that help the region achieve groundwater sustainability. This can include recharge projects that take advantage of local areas conducive to recharge and areas where recharge provides the most benefit to the GSA. This can reduce the burden for certain agencies from having to recharge within their boundaries if they do not have suitable land or soils.

2.4.8 Efficient Water Management Practices

Water conservation has been and will continue to be an important tool in local water management, as well as a key strategy in achieving sustainable groundwater management. All the GSA member agencies engage in some form of water conservation including water use restrictions, water metering, education, tiered rates, etc. These water conservation programs were tested during the 2014-2015 drought, which included state-mandated urban water restrictions for the first time. Details of water conservation programs can be found in various documents, such as individual UWMPs (City of Corcoran 2017; City of Lemoore 2015; City of Hanford 2011). Existing efficient water management practices include recycled water use and high efficiency irrigation practices.

2.4.9 Relationships with State and Federal Agencies

From a regulatory standpoint, the GSAs have numerous relationships with state and federal agencies related to water supply, water quality, and water management. Relationships that are common to all water agencies, such as regulation of municipal water by the California Division of Drinking Water (DDW), are not discussed here. Many of the GSA member agencies receive grants from various agencies for water-related projects. Grants are obtained from agencies including but not limited to DWR, SWRCB, and USBR. The GSA member agencies work closely with these state and federal agencies to track grant programs and administer and implement grant contracts. Relationships unique to the region are summarized below.

2.4.9.1 Kings River Water

The Kings River provides the majority of surface water used in the area. Kings River water is impounded by Pine Flat Dam, which is owned and operated by the United States Army Corps of Engineers (USACE) (Kings County 2002). The water rights permits were obtained from the SWRCB; however, allocation and management of water is largely controlled by the KRWA. The GSA member agencies work with the USACE and SWRCB to oversee and manage their Kings River water as needed. The local agencies also developed and continue to implement the KRFMP in partnership with the CDFW.

2.4.10 Land Use Planning

Land use policies are documented in various reports, such as General Plans, specific land use plans, and plans for proposed developments. Updating some of these plans is a multi-year process and not all plan updates can be fully completed concurrently with the GSP development. These land use plans are expected to be modified gradually over time to be consistent with the goals and objectives of this GSP. Some smaller communities rely on county policies and have no formal land use. Land use is shown in Figures 2-8 through 2-12.

Each of the local member agencies and water entities of the Subbasin's GSAs have an interest in land use planning policies and how they will impact their continued development and water supplies.

The following GSA member agencies have direct land use planning authority:

- Kings County
- Kern County
- Tulare County
- City of Corcoran
- City of Hanford
- City of Lemoore

2.4.11 Impacts on Groundwater Dependent Ecosystems

The Nature Conservancy (TNC) worked with DWR to identify Groundwater Dependent Ecosystems (GDE) throughout the state. TNC primarily used vegetative indicators and applied them to historical aerial imagery. Imagery was cross-referenced with CASGEM well levels to identify possible GDEs. The data used in GDE identification pre-dates the baseline year of 2015, so all land use changes in the interim period may not be included. Given the depth to groundwater throughout the Subbasin, it is believed that no GDEs exist.

2.5 Notice and Communication

Stakeholders gathered monthly to develop the recommended GSA formation governance structure for the Subbasin. Representatives from cities, counties, WDs, IDs, CSDs, and private water companies participated in the formation of the GSAs. Additionally, landowners, Disadvantaged Community (DAC) representatives, and industry representatives were present at GSA formation meetings.

2.5.1 Implementation of the GSP

SGMA implementation at the GSA level begins as DWR is reviewing this GSP. During the implementation phase, communication and engagement efforts focus on educational and informational awareness of the requirements and processes for reaching groundwater sustainability as set forth in the submitted GSP. Active involvement of all stakeholders is encouraged during implementation, and public notices are required for any public meetings, as well as prior to imposing or increasing any fees. Public outreach is also completed by the individual GSAs with collaborative efforts subbasin-wide when target audiences span more than one GSA boundary.

2.5.2 Decision-Making Process

23 CCR §354.10 (d) *A communication section of the Plan that includes the following:*

- *An explanation of the Agency's decision-making process.*

Each of the five GSAs within the Subbasin operate under an Interim Operating Agreement (effective September 1, 2017) to facilitate coordination and management actions (Appendix F). The Interim Operating Agreement is categorized as a legal agreement and ensures communication and coordination of the data and methodologies used by each GSA in developing the GSPs within the Subbasin for several factors, including groundwater elevation and extraction data, surface water supply, total water use, change in groundwater storage, water budget, total water use, and sustainable yield. The governing body of the GSP consists of a single authorized representative from each of the five member GSAs. Significant decisions require a unanimous vote of the representatives, while less significant decisions only require a four-fifths vote.

The Subbasin GSAs' decision-making process is broken down by the roles of the Subbasin management team, their respective Board of Directors, and any Stakeholder/Advisory Committees. The roles of the boards and GSA entities are outlined below.

- **Subbasin Management Team –** Comprised of a representative from each of the five GSAs working collaboratively to jointly manage groundwater within the Subbasin and to develop a GSP. These individuals met on a monthly and then bi-weekly basis throughout the GSP development and public review phases.
- **Boards of Directors –** Adopts general policies regarding development and implementation of the individual GSAs and the GSP.
- **Stakeholder/Advisory Committees –** Represents all beneficial uses and users of groundwater within the individual GSA boundaries and makes recommendations to the Boards of Directors and technical consultants regarding feedback from stakeholders to account for local interests. Not all GSAs have Stakeholder/Advisory Committees, and while allowed within SGMA, these committees are not required.

2.5.3 Beneficial Uses and Users

> ***23 CCR §354.10*** *Each plan shall include a summary of information relating to notification and communication by the Agency with other agencies and interested parties including the following:*
>
> - *A description of the beneficial uses and users of groundwater in the basin, including the land uses and property interests potentially affected by the use of groundwater in the basin, the types of parties representing those interests, and the nature of consultation with those parties.*
> - *A list of public meetings at which the Plan was discussed or considered by the Agency.*
> - *Comments regarding the Plan received by the Agency and a summary of any responses by the Agency.*

The GSAs shall consider the interests of all beneficial uses and users of groundwater, as well as those responsible for implementing a GSP (California Water Code, §10723.2). The interests of all beneficial uses and users of groundwater within the Subbasin by GSA are identified in Table 2-4. Engagement with groundwater users occurs in the following phases of the development and implementation of the GSP:

2.5.4 Opportunities for Public Engagement

> ***23 CCR §354.10 (d)(2)*** *Identification of opportunities for public engagement and a discussion of how public input and response will be used.*

The GSAs within the Subbasin developed a joint Communication and Engagement Plan to address how stakeholders within the individual GSA boundaries were engaged through stakeholder education, opportunities for input, and public review during GSP development and implementation (Appendix B). Stakeholders were invited to public meetings through distribution of meeting notices to the Subbasin GSAs' district and member agency distribution lists, community organizations' contact lists, and press releases and public service announcements. Press releases were distributed to local media outlets announcing the meeting dates, times and locations. Local community organizations, such as the Kings County Farm Bureau, were asked to distribute meeting notices via email to their membership/contact lists. Public meetings held during the preparation and submission phase of the GSP were geared towards an overview of the SGMA,

Stakeholder Key Interests related to groundwater include:

- Drinking Water
- Domestic, everyday usage
- Agriculture – farming, dairy, and livestock
- Industrial (food processing)
- Recreational

the GSP development process, stakeholders' expectations of public review and implementation, distribution of stakeholder surveys and solicitation of stakeholder input, and question/answer sessions. This segment of public meetings gave stakeholders an opportunity to be involved in GSP development and share their thoughts and concerns.

2.5.4.1 Communication & Outreach Methods

There were a variety of opportunities, venues, and methods for the Subbasin's GSAs to connect with and engage stakeholders throughout GSA formation, GSP development, GSP review, which will continue to be utilized through the GSP implementation phases. Additional discussion of Communication and Outreach Methods is presented in Section 1.2 of the 2022 GSP Addendum.

Printed Communication

Printed materials incorporated the visual imagery established through individual GSA branding efforts and was tailored for specific means of communication throughout the phases of GSP development, public review, and implementation. Printed materials were also translated into Spanish, when necessary for diverse stakeholder education.

- **Fliers –** Fliers designed and tailored for stakeholder audiences, encompassed infographics and text with key messages that were pertinent for the appropriate phase of GSP development. Distribution was via GSA-website posting, direct mail, email, and direct distribution as handouts throughout communities, GSA, and Subbasin-wide outreach meetings. For outreach to DACs/Severely Disadvantaged Communities, fliers were available in both English and Spanish languages.
- **Letter Correspondence –** When letter correspondence was necessary, particularly during the public review and implementation phases, letters were distributed via email and/or direct mail. Letters included pertinent facts and explanations communicated to specific stakeholder groups.
- **Presentation Materials –** PowerPoint presentations were utilized at educational/outreach public meetings. For a consistent Subbasin-wide message, a draft presentation was developed for the GSP development and public review phases, with placeholder slides for GSAs to update with GSA-specific information. Handouts of presentations were distributed to stakeholders in attendance, emailed to the Interested Parties list, and/or posted on individual GSAs' websites for stakeholders to access, particularly if they were unable to attend.

Digital Communication

Digital communication outlets were also designed to incorporate the Subbasin GSAs' branding and was a significant means of communication through the GSP development and public review phases and will continue during the implementation phase.

- **Websites –** Public meeting notices, agendas, and minutes of the Board of Directors and Stakeholder/Advisory Committee meetings were posted on the individual GSAs' websites. These websites serve as integral resources for stakeholders within the Subbasin boundary. Electronic files of printed materials, presentations and other educational resources, and direct links to stakeholder surveys (English and Spanish versions) were also accessible via the websites. Websites will be maintained throughout the implementation phase of this GSP. This serves as a way for stakeholders to easily educate themselves on the GSP process and phases.
- **Interested Parties List –** As required by SGMA §10723.4 "Maintenance of Interested Persons List," the Subbasin's GSAs maintain contact lists and regularly distribute emails to those who have expressed interest in the GSAs' progress. These emails consist of meeting notices and other documents that are pertinent to the Subbasin GSAs and their communication efforts. This process will continue through the GSP implementation phase.
- **Email Blasts –** Email blasts for meeting notices, stakeholder surveys, public review notices, and other crucial information were coordinated with community organizations and stakeholder groups by utilizing their distribution lists. Examples of these organizations are Kings County Farm Bureau and water/irrigation districts within the individual GSAs' boundaries.

Media Coverage

Press releases were written and distributed to the media list of local newspaper publications. These press releases focused on notification of public engagement opportunities, such as targeted stakeholder meetings, public review/comment processes and opportunities. Press releases will continue during GSP implementation for meetings and notifications.

Stakeholder Surveys

Stakeholder surveys were used for the deliberate polling of stakeholders to give them a direct voice in the GSP development phase. The SFK and SWK GSAs circulated physical surveys, while the remaining three GSAs conducted verbal surveys through one-on-one discussions with stakeholders within their GSA boundaries. For the GSAs who administered physical stakeholder surveys, they developed both online and printed versions of their surveys. Survey links were posted as Google Forms on the individual GSAs' websites and were utilized in email blasts to the Interested Parties Lists. Hardcopies were also available for distribution throughout the respective GSA. Feedback received from the surveys was taken into consideration during the development of the GSP.

2.5.5 Encouraging Active Involvement

23 CCR §354.10(d) *A description of how the Agency encourages the active involvement of diverse social, cultural, and economic elements of population within the basin.*

- *The method the Agency shall follow to inform the public about progress implementing the Plan, including the status of projects and actions.*

Through Stakeholder Committees and, in some instances an Advisory Committee, GSAs are able to encourage the active involvement of diverse social, cultural, and economic elements of the population within the Subbasin prior to and during the development and implementation of this GSP. Printed materials are tailored for specific means of communication throughout the phases of the GSP development, public review, and implementation. As stated above, printed materials are translated into Spanish. Fliers, fact sheets, letter correspondence, presentation materials stakeholder surveys, and newsletters are the forms of printed communication between the public and GSAs. Digital communication and media coverage serve as an additional means of communication between the public and GSAs. During this GSP's implementation, specific stakeholders are informed of upcoming compliance requirements. Addresses of the area's property owners within the GSAs' boundaries can be obtained through Kings County. Meetings were held in a range of areas within the Subbasin to encourage attendance.

2.5.5.1 Subbasin Public Meetings

Public meetings to ensure equitable community access occurred within each GSA throughout the GSP's phases. Each GSA provided a list of previous and ongoing public meetings to track the effectiveness of outreach efforts (Appendix B).

2.5.6 Interbasin Communications

Subbasin GSAs and technical consultants met with surrounding subbasins throughout the development of the GSP to discuss how to achieve sustainability on a regional level, develop interbasin agreements, and share data when possible. A list of interbasin communications is included in Appendix B.

3.0 BASIN SETTING

23 CCR §354.12 *This Subarticle describes the information about the physical setting and characteristics of the basin and current conditions of the basin that shall be part of each Plan, including the identification of data gaps and levels of uncertainty, which comprise the basin setting that serves as the basis for defining and assessing reasonable sustainable management criteria and projects and management actions. Information provided pursuant to this Subarticle shall be prepared by or under the direction of a professional geologist or professional engineer.*

Key Features of the Tulare Lake Subbasin

- **Area:** ~837 square miles (535,869 acres)
- **Population (2010):** ~125,907
- **Projected Population Growth (2030):** ~176,446
- **Population Density:** ~150 persons/ square mile
- **Public Supply Wells:** ~75
- **Total Wells:** ~9,380
- **Irrigated Acres:** ~251,994
- **Groundwater Supply:** ~50% of water supplies
- **Total Storage Capacity:** ~17.1 million acre-feet

Source: DWR 2019b

The Tulare Lake Subbasin (Subbasin) is located primarily in Kings County in the Tulare Lake Hydrologic Region of the San Joaquin Valley. The San Joaquin Valley is relatively flat and elongates to the northwest and is bounded on the west by the Coast Ranges and on the east by the Sierra Nevada Mountain Range. The Subbasin is located in the south-central portion of the greater San Joaquin Valley. Topography in the Subbasin slopes inward towards the center of the valley. The former Tulare Lake occupies this portion of the Subbasin. Land use in the Subbasin and surrounding areas is predominately agricultural with localized urban areas of Hanford, Lemoore, and Corcoran. This chapter discusses the hydrogeologic conceptual model (HCM), groundwater conditions, the water budget, and management areas for the Subbasin. Additional discussion of the Basin Setting is presented in Section 1.3 of the 2022 GSP Addendum.

The HCM, discussed in Section 3.1, acts as a sustainable groundwater management tool for the Subbasin's Groundwater Sustainability Agencies (GSAs) and provides a basis for the numerical groundwater flow model developed for the Subbasin (Appendix D). The HCM includes a description of the geographic, geologic and hydrogeologic setting, and a discussion of data gaps and uncertainties associated with the HCM.

Groundwater conditions, provided in Section 3.2, include current and historical groundwater conditions in support of the Groundwater Sustainability Plan (GSP) to ensure historical and present challenges are adequately described. The groundwater conditions section includes a description of current and historical groundwater conditions, current and potential subsidence in the Subbasin, a summary of groundwater quality, interconnected surface and groundwater systems, and groundwater dependent ecosystems.

The water budget, discussed in Section 3.3, provides a quantitative description of the historical, current, and 50-year projected inflows and outflows of the Subbasin. Additionally, the water budget will be used to develop an estimate of existing overdraft in the Subbasin and establish baseline conditions for the purpose of understanding future water supply reliability and for development of sustainable management actions and projects within the Subbasin. The historical water budget was used to develop and calibrate a numerical groundwater model of the Subbasin (Appendix D) and develop a 50-year forecast of future conditions, assuming normal hydrologic conditions adjusted for estimated climate change. The forecast model will be used as a planning tool to evaluate overdraft, develop sustainable management projects, and to evaluate management practices and projects' abilities to meet measurable objectives to avoid undesirable results.

Additionally, management areas, discussed in Section 3.4, have been delineated to facilitate data management and GSP implementation.

3.1 Hydrogeologic Conceptual Model

> **23 CCR §354.14(a)** *Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterize the physical components and interaction of the surface water and groundwater systems in the basin.*

The HCM provides a general understanding of the physical setting, characteristics, and processes that govern groundwater occurrence and movement within the Subbasin (DWR 2016c). It comprises a compilation of available information to portray the geographic setting, regional geology, basin geometry, water quality, and consumptive water uses (municipal, agricultural, and industrial) in the Subbasin. The HCM looks at the groundwater and surface water interactions and assesses the inflows and outflows to and from the Subbasin. Subbasin boundaries are often a combination of physical and political boundaries, so subbasin boundaries often do not reflect the actual physical hydrologic boundaries of an area. Thus, the area of study in an HCM is often larger than the designated subbasin boundaries. The HCM also provides the foundation for the numerical groundwater model, delineating the boundary conditions, the hydrogeologic layers, and the model domain needed to provide an accurate representation of the groundwater flow system.

3.1.1 Geographic Setting

The Subbasin is located primarily in Kings County in the Tulare Lake Hydrologic Region of the San Joaquin Valley, California (Figure 3-1). The Subbasin covers an area of approximately 535,869 acres or about 837 square miles (DWR 2016b). The Subbasin contains five GSAs: El Rico (ER), Mid-Kings River (MKR), Southwest Kings (SWK), South Fork Kings (SFK), and Tri-County Water Authority(TCWA) (Figure 3-2). It is bounded by the Kings Subbasin to the north, the Kaweah Subbasin to the northeast, the Tule Subbasin to the southeast, the Kern County Subbasin to the south, the Kettleman Plain Subbasin to the southwest, and the Westside Subbasin to the northwest (Figure 3-3).

The San Joaquin Valley is relatively flat and is oriented in a northwest-southeast direction and is bounded on the west by the Coast Ranges and on the east by the Sierra Nevada Mountains (Figure 3-4).

Flow from the rivers and streams of the Sierra Nevada Mountains are largely regulated by a series of dams and reservoirs, which capture runoff from winter precipitation. Most of the runoff falls as snow in the adjoining highlands. The flow from the reservoirs is fed into man-made canals and modified streambeds that carry surface water primarily to agricultural users (Figure 3-5).

3.1.1.1 Climate

The climate in the Subbasin is semi-arid, characterized by hot, dry summers and cool moist winters and is classified as a semi-arid climate (BSk to BSh under the Köppen climate classification), usually found within continental interiors some distance from large bodies of water. The wet season occurs from November through March with 80 percent (%) of precipitation falling during this season. The valley floor often receives little to no rainfall in the summer months. Precipitation typically occurs from storms that move in from the northwest off the Pacific Ocean. Occasionally storms from the southwest, which contain warm sub-tropical moisture, can produce heavy rains.

Historical annual precipitation records over a span of 118 years have been recorded by the Hanford weather station. The Hanford weather station is located in the northern portion of the Subbasin where precipitation averages 8.28 inches per year. From 1899 to 2017, rainfall has ranged from a minimum of 3.37 inches in 1947 to a maximum of 15.57 inches in 1983 (NOAA 2019) (Table 3-1). Monthly precipitation in the area ranges between 0.00 and 6.69 inches per month. Typically, precipitation decreases from northeast to southwest across the Subbasin due to the rain shadow of the Coast Ranges. Figure 3-6 provides a map of the 30-year average annual precipitation across the Subbasin from January 1989 through December 2010 using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) database, maintained by the Oregon State University (PRISM 2018).

3.1.1.2 Topography

The topography of the Subbasin is generally low sloping inward from all directions toward the center of Tulare Lake (Figure 3-7). From the northeast edge to the center of Tulare Lake, ground surface elevations range from about 292 to 188 feet above mean sea level (AMSL). The highest elevations within the Subbasin of approximately 405 feet AMSL occur along the northeast flank of Kettleman Hills. Drainage within the Subbasin is internal flowing toward Tulare Lake.

3.1.1.3 Land Use

Land use in the Subbasin and surrounding areas is predominately agricultural with three primary urban areas of the cities of Hanford, Lemoore, and Corcoran. Land use was evaluated using California Department of Water Resources (DWR) land use maps for 1990 through 2006 and annual United States Department of Agriculture (USDA) CropScape maps from 2006 through 2016 (DWR 2016d; USDA 2016). These maps were provided in Geographic Information System (GIS) formats, allowing for aggregation of similar land uses to simplify analysis. A total of 24 land uses were identified and evaluated (Table 3-2). Land use maps for eight different time periods between 1990 and 2016 are presented in Figures 3-8a to 3-8d.

Between 1990 and 2016, the 535,869-acre Subbasin had an average of approximately 61% of its surface area or 342,400 acres of crops, 7,490 acres of riparian land or land covered by water, 140,540 acres of fallow or undeveloped forest land, 9 acres of industrial parks, and about 22,860 acres of urban areas (Figures 3-8a to 3-8d; Table 3-2) (Wood 2018). The mix of crops grown, and the areas of fallow lands has changed over time as agricultural practices changed in response to agricultural markets and water conditions. During the 2010-2015 drought, fallowed acreage increased while riparian, cotton, and pasture acreage all decreased (Figures 3-8a to 3-8d) (Table 3-2) (Wood 2018). Cotton showed the most change with a decrease of more than 100,000 acres (approximately 46%) between 1996 and 2015. The data also show an overall increase in permanent crops over time, with substantial increases (about 52,260 acres or 250%) in almonds, stone fruit, and pistachios from 1995 to 2016.

3.1.1.4 Soils

Many soil surveys have been conducted across the Subbasin by the USDA Natural Resources Conservation Service (NRCS 2018). The surveyed areas may have been mapped at different times, at different scales, and with varying levels of detail, occasionally resulting in abrupt soil survey area boundaries and incomplete data sets.

Soil texture is interrelated with groundwater flows as it affects water holding capacity and vertical water movement through the soil profile. Soil textural classifications vary across the Subbasin. Clayey soils are dominant in the interior of the Subbasin, corresponding with Tulare Lake (Figure 3-9) (Soil Survey Staff 2018).

Clayey soils dominate in the Tulare Lake area. Loam and sandy loam soils border the clayey soils and are the predominant soils to the east of the lake, including areas of the Tule and Kaweah rivers watersheds; to the west, along the eastern flanks of Kettleman Hills and the Coast Ranges; and to the north and northeast, including along the Kings River watershed.

Salts in soil are commonly sourced from parent rock and can be a result of evapotranspiration concentrating salt within irrigation water. The saturated hydraulic conductivity (K_{sat}) of a soil affects a saturated soil's ability to move water through soil pore spaces under a hydraulic gradient. K_{sat} is very low in the lake of the Subbasin (Figure 3-10), ranging only from 0.0-10.0 micrometers per second (µm/sec) (NRCS 2018). These clay soils tend substantially limit percolation and basin recharge in this area. As the soil textures become coarser (sandier), the conductivity tends to improve. The K_{sat} increases north of the lake, in the Kings River watershed, to 10.0-40.0 µm/sec. Similar conductivities are also present in alluvial fan channels emanating from the Kettleman Hills and Sierra Nevada Mountain ranges.

Some soil profiles in the area contain natural levels of salts.

3.1.1.5 Rivers, Streams, and Tulare Lake

Stream flow in rivers, streams, and surface water conveyances (canals) is a significant source of groundwater recharge throughout the Subbasin by direct infiltration to the subsurface and from deep percolation where surface water is applied for agricultural irrigation. The modern-day surface water conveyances that supply the Subbasin are primarily described as follows (Figure 3-5):

Kings River

The Kings River is the one of the largest sources of surface water supply to the Subbasin, contributing most of the surface runoff in the Subbasin. The Kings River is a 133-mile long river with a watershed of approximately 1,500 square miles above Pine Flat Dam (USBR 2003). It is the largest river draining the southern Sierra Nevada Mountains with headwaters in and around Kings Canyon National Park. The Kings River has three main tributaries, the North Fork, Middle Fork and South Fork. The flow of the North Fork is regulated by several dams, Courtright and Wishon Reservoirs, used to generate hydroelectric power. Pine Flat Dam at a maximum elevation of approximately 952 feet in the foothills of the Sierra Nevada Mountains captures the controlled flow from the North Fork as well as well as the combined unregulated flow from the South and Middle Forks and the controlled flow from the North Fork of the Kings River (USBR 2003). The dam is owned by the United States Army Corps of Engineers (USACE) and has a maximum capacity of about 1,000,000 acre-feet (AF) of water (KRCD and KRWA 2009). The primary purpose of the dam is flood control and secondary purposes include irrigation, hydroelectric power generation, and recreation. The flow in the Kings River below Pine the Flat Dam is controlled by the dam and distributed into various canals and distributary channels by diversion structures described in Section 3.1.1.6.

Kaweah River

The Kaweah River is located in Tulare County and drains the high Sierra Nevada Mountains, with headwaters in Sequoia National Park. Above Lake Kaweah, the main stem of the Kaweah River is about 33 miles long with a drainage area of about 561 square miles (SCE 2016). Prior to stream regulation, the main trunk of the Kaweah River historically flowed southwestward entering the San Joaquin Valley near Lemon Cove. The river separated into several distributary channels forming the alluvial plain known as the Kaweah Delta, upon reaching the edge of the valley. During periods of high flow, these channels historically carried sufficient water to reach Tulare Lake.

In the 1920s, weirs were built at McKay's Point to partition water into the St. Johns and Kaweah rivers (KDWCD 2018). In 1962, the USACE constructed Terminus Dam to provide flood control for the cities and lands below the dam. In 2004, six fuse gates were installed on the dam to raise the lake level by 21 feet and increase the capacity of Kaweah Lake to about 185,000 AF (IWP and DC 2004). In addition to flood control, the dam and reservoir also provide irrigation water for agriculture on the Kaweah Delta (KDWCD 2018). Below the dam, most of the flow is controlled by a network of diversions, canals, and improved distributary channels. During below average rainfall years, minimal, if any, water reaches the Tulare Lake; however, during years with average to above average runoff, water from the Kaweah River system has reached the Tulare Lake and is stored or used for irrigation in ER GSA. The primary purpose of the dam is flood control and secondary purposes include irrigation, hydroelectric power generation, and recreation.

Tule River

The Tule River is located in Tulare County and drains highlands in the southern Sierra Nevada Mountains. The Tule River has three main tributaries, the North Fork, Middle Fork, and South Fork, with a maximum length of about 28 miles at the North Fork and below the confluence of Middle Fork, as well as a drainage area of about 390 square miles above Lake Success (USACE 2017). The Tule River below Porterville splits into two main channels. Eventually, these channels merge again downstream and flow into the Tulare Lake, south of Corcoran. By the early 1900s many diversions were constructed to move water into irrigation ditches that spread across the Tule River fan. Lake Success was constructed primarily for flood control purposes and has a capacity of about 82,000 AF (https://www.spk.usace.army.mil/Locations/Sacramento-District-Parks/Success-Lake). Since the lake's construction, the Tule River flows to the Tulare Lake on average and above average rainfall years, and Tule River water is stored or used for irrigation.

The primary purpose of the dam is flood control and secondary purposes include irrigation, hydroelectric power generation, and recreation.

Kern River

The Kern River is located in Kern County and drains the southern slopes of the Sierra Nevada Mountains. The Kern River was dammed by Isabella Dam in 1953. Occasionally, during times of very high runoff, the Kern River could flow into the Tulare Lake and the water is stored or used for irrigation in Tulare Lake Basin Water Storage District. The primary purpose of the dam is flood control and secondary purposes include irrigation and recreation.

Streams of the Tulare Lake Subbasin

Streams emanating from the southern Sierra Nevada Mountains, south of the Tule River, drain lower elevations and more arid areas of the Sierra Nevada Mountains. These streams, White River, Deer, Mill, Cottonwood, Dry, and Poso Creeks, typically lose their discharge to percolation into the alluvial fans before entering the Tulare Lake. Currently, most of these streams have diversions on them, which channel their flows to delivery systems for irrigation. Cottonwood and Dry Creeks contribute to the Kaweah River system and add supplies to the Subbasin in wet years. Dry Creek’s runoff is accounted for in the Kaweah River system. Poso Creek has few diversions for irrigation and remains important in and near Tulare Lake. These streams account for a small percentage of the runoff delivered into the Subbasin.

Streams emanating from the Coast Ranges are typically ephemeral and do not reach any major water course or surface impoundment in the Subbasin.

Tulare Lake

Currently, a system of open canals and pumping systems allow for the efficient distribution of irrigation water throughout the area.

3.1.1.6 Water Supply Delivery System

Extensive water supply delivery systems have been developed over the past 160 years within the Subbasin to move surface water supplies for irrigation, flood control, and land reclamation. Currently, at least 34 conveyance systems (rivers, streams, canals, and diversions) are available to deliver surface water to the Subbasin (Figure 3-5). The only water generated within the Subbasin is from pumped groundwater. Pumped groundwater may be used for direct irrigation on nearby agricultural lands or piped into municipal or agricultural water delivery systems. Much of the land within the Subbasin has associated water rights to the Kings, Kaweah, and Tule rivers as well as some of the minor streams of the Subbasin. These water allocations are supplied by the many irrigation and water districts within the Subbasin.

Water is imported into the Subbasin using facilities of the State Water Project (SWP) located to the west and the Central Valley Project (CVP). The California Aqueduct is operated and maintained by DWR. The California Aqueduct originates in the southwestern corner of the Sacramento-San Joaquin Delta and runs down the west side of the San Joaquin Valley and over the Tehachapi Mountains into southern California. Water from the California Aqueduct can be turned out at Lateral A, which delivers water to the Subbasin at or above the Empire Weir No. 2. This water can be distributed to the Subbasin through the series of canals below the Empire Weir No. 2.

The Friant-Kern Canal is operated and maintained by the Friant Water Authority and is used to convey water from the San Joaquin River to Kern County. The canal originates at Friant Dam, which is operated by the United States Bureau of Reclamation. The Friant-Kern Canal flows southeasterly along the western flank of the Sierra Nevada foothills through Fresno, Tulare, and Kern counties. The Friant-Kern Canal crosses the Kings River about 10 miles west of Pine Flat Dam, where water can be released into the river. This water can be delivered to the Subbasin through a series of canals along the Kings River and its distributaries.

3.1.2 Geologic Setting

The Subbasin is located in the south-central portion of the greater San Joaquin Valley. The major geologic features of this portion of the San Joaquin Valley are the San Andreas Fault, the Garlock Fault, and the three bounding mountain ranges: the Coast Ranges to the west, the Sierra Nevada Mountains to the east, and the Tehachapi and San Emigdio Mountains to the south (Figure 3-12). The San Joaquin Valley elongates to the northwest and stretches approximately 250 miles from the Sacramento-San Joaquin delta on the north to the Tehachapi and San Emigdio Mountains on the south. The valley is filled with marine and continental sedimentary rocks that are more than 30,000 feet in total thickness.

3.1.3 Geologic Structure

The geologic structure of the San Joaquin Valley is complex and has evolved considerably through geologic time. The San Joaquin Valley was formed generally as a structural trough subsiding between two uplifts: the tectonically-driven tilted block of the Sierra Nevada Mountains and the folded and faulted mountains of the Coast Ranges. The axis of the trough is asymmetrical, with the deepest portion of the trough closer to the Coast Ranges. The southern Sierra block forms the eastern limb of the valley syncline or trough (Bartow 1991). It is a southwest-plunging ridge of basement rock, primarily Mesozoic plutonics, upon which has accumulated more than 10,000 feet of Tertiary sediments in the vicinity of the Subbasin.

The west-side fold belt runs along the western portion of the Subbasin and comprises the low-lying portion of the eastern Coast Ranges (Figure 3-12). The fold belt is characterized by Cenozoic sedimentary rocks that have been deformed by thrust faults. The fold belt formed adjacent and subparallel to the San Andreas Fault, a major strike-slip transform fault between the North American and Pacific plates. These sedimentary rocks dip steeply beneath the San Joaquin Valley to the east and are found at depths of more than 3,000 feet below the Valley floor. The Kettleman Hills on the west side of the Subbasin are part of the west-side fold belt.

3.1.4 Basin Development

During late Mesozoic and early Cenozoic time, much of the current San Joaquin Valley was part of a forearc basin that was open to the Pacific Ocean allowing deep marine sediment deposition into the San Joaquin basin (Bartow 1991). As plate boundaries shifted and movement along the San Andreas Fault began in the late Miocene, the San Joaquin Basin west of the fault was beginning to close off creating an extensive inland sea. During the Pliocene, marine sediments of the Etchegoin Formation and the primarily marine San Joaquin Formation were deposited in the shallowing sea bottom of the basin.

During the late-Pliocene and early-Pleistocene, the terrestrial Tulare Formation was deposited as sediments, which were eroded and shed from the rising mountains into the subsiding San Joaquin Valley. As the San Joaquin Valley evolved during the Pleistocene, the tilting of the Sierran block and the push from the thrust belts on the west side aided in the subsidence of the Valley trough. Throughout much of the valley, Tertiary-Quaternary sediments filled the basin with a mixture of sands, silts, and clays, which were deposited on alluvial fans and along the San Joaquin Basin axis by the rivers and streams emanating from the adjoining mountains.

The periodic glacial and wet Pleistocene climate produced times when the sediment loads from the mountains exceeded the subsidence rate in the Valley creating aggrading alluvial fans that cut off the flow of the San Joaquin Valley rivers to the sea (Atwater et al. 1986). Large-scale lacustrine deposits accumulated in the shallow lakes that developed as a result of the internal drainage. Corcoran Lake appears to have covered most of the Valley during the mid-Pleistocene (Bartow 1991) from about present-day Stockton to Bakersfield and roughly from Interstate 5 to State Route (SR) 99 (Figure 3-13). During this time, the lacustrine Corcoran Clay (E-Clay of Croft 1972) accumulated to thicknesses of as much as 300 feet (Figure 3-14a-c). Additionally, thick deposits of lacustrine sediments have accumulated in Tulare Lake. Due to the anomalously rapid tectonic subsidence in the Tulare Lake area and the internal drainage from the Kings, Kaweah, and Tule rivers, as well as early-on the Kern River into the lake, thick lacustrine deposits in addition to the Corcoran Clay have accumulated beneath the Tulare Lake. The total thickness of the Tulare Lake clays, including the Corcoran Clay, is more than 3,000 feet as labeled as QTf on Figure 3-14a-c.

3.1.5 Stratigraphy

Table 3-3 is a generalized stratigraphic column for the Subbasin. It represents a synthesis of stratigraphic descriptions from published reports for the area (Davis et al. 1959; Hilton et al. 1963; Croft and Gordon 1968; Loomis 1990; and Wood 2018). Stratigraphic units and their importance to groundwater occurrence and movement are described below.

3.1.5.1 Basement Complex

The basement complex beneath the Subbasin comprises primarily Sierran plutonic and metamorphic rocks, while the western margin of the basin is underlain primarily by Coast Ranges ophiolite (Scheirer 2007). The depth to the basement complex ranges from about 6,000 feet on the eastern margin of the Valley to about 30,000 feet below ground surface (bgs) on the western margin (Scheirer 2007). The depth to basement complex is such that the basement rocks do not affect the usable groundwater beneath the Subbasin.

3.1.5.2 Miocene and Pre-Miocene Sedimentary Deposits

The Miocene and pre-Miocene sedimentary deposits are found deep below the Subbasin and have been encountered in deep exploration borings drilled for oil and gas deposits. The water contained in these deposits is saline or the depth to these deposits are such that that they do not affect the usable groundwater beneath the Subbasin with the exception of the Santa Margarita Formation to the east.

The Santa Margarita Formation is a gray sandstone of upper Miocene age that is present at a depth of about 1,100 feet bgs beneath Terra Bella (Hilton et al. 1963). The formation dips steeply to the west and is about 4,300 feet deep near SR 99 at Earlimart. The Santa Margarita Formation has been tapped as an aquifer in the area from Terra Bella to Richgrove, about 25 miles east of the eastern Subbasin boundary. The Santa Margarita Formation is separated from the usable groundwater in the Plio-Pleistocene Tulare Formation by about 2,000 to 3,000 feet of mostly fine-grained marine deposits of the Pliocene San Joaquin and Etchegoin Formations. Groundwater in the Santa Margarita Formation increases in salinity content to the west and the approximate position of the saline to freshwater interface is about 20 miles east of the Subbasin. Thus, the Santa Margarita is likely too deep and too saline to yield usable groundwater beneath the Subbasin for usage.

3.1.5.3 Upper Miocene to Pliocene Etchegoin

The Etchegoin Formation is a shallow water marine formation of upper Miocene and early Pliocene age that crops out in the Kettleman Hills west of the Subbasin. The Etchegoin Formation comprises silty and clayey sands, sandy silt, silty clay, blue sandstone, and conglomeratic sandstone (Woodring et al. 1940). The Etchegoin dips steeply to the east from the Kettleman Hills. Deep exploratory borings for oil and gas have encountered the Etchegoin beneath the Subbasin at depths of 3,500 to 4,000 feet bgs. Geophysical logs indicate that water in the Etchegoin Formation is saline and its groundwater is unusable beneath the Subbasin.

3.1.5.4 Pliocene San Joaquin Formation

The San Joaquin Formation is a shallow marine formation of mid-to-upper Pliocene age that also contains some near-shore continental deposits. It comprises a basal conglomerate member and overlying thin beds of poorly-sorted, fine-grained sandstone amongst thick beds of siltstone and claystone (Loomis 1990; Woodring et al. 1940). The formation crops out in the Kettleman Hills and dips steeply to the east beneath the Subbasin.

In the Kettleman Hills area, the top of the San Joaquin Formation is conformable with the overlying Tulare Formation and is marked by the uppermost Mya zone, which is described as a transition from marine deposits (Mya fossils) to continental deposits (Tulare Formation) of lake, swamp, and stream origin (Woodring et al. 1940). In the Kettleman Hills area, monitoring wells indicate the sandstones within the San Joaquin Formation contain saline water and do not yield sufficient water to be classified as an aquifer (Wood 2018). The formation is in contact with the base of the Tulare Formation beneath the Subbasin, with the contact typically about 3,000 feet bgs (Page 1983). The San Joaquin Formation is considered too deep and too saline to yield usable groundwater beneath the Subbasin.

3.1.5.5 Pliocene-Pleistocene Tulare Formation – Continental Deposits

The Tulare Formation is generally regarded as the most important water-bearing formation in the southern San Joaquin Valley. The Tulare Formation is a continental deposit that overlies the San Joaquin Formation and has been assigned to the upper Pliocene and Pleistocene epochs. It has been described mostly by investigators on the west side of the valley, where it crops out in the west-side fold belt anticlines. The type section is generally taken to be the Kettleman Hills, where 1,700 to 3,500 feet of the Tulare Formation have been described on the east and west flanks of North Dome, respectively (Woodring et al. 1940). Other investigators, particularly on the east side of the valley, have described continental deposits, primarily of Sierran origin, that are time-correlative with the Tulare Formation such as the Kern River, Laguna, Turlock Lake, Riverbank, and Modesto formations (Lettis and Unruh 1991).

The Tulare Formation is defined as the uppermost continental deposits deformed by the west-side fold belts (Woodring et al. 1940). This was relatively clear in the Kettleman Hills area; however, in other west-side folds (e.g., Lost Hills), the quaternary alluvium has also been deformed as uplift continues into the Holocene. In the Tulare Lake area, the east side Plio-Pleistocene deposits that overlie the San Joaquin Formation with the Tulare Formation are mapped (Page 1983). In the subsurface, because of textural and depositional similarities, it is difficult to separate recent alluvial deposits from sediments of the Tulare Formation (Davis et al. 1959). Based on existing research in the Tulare Lake area, the Tulare Formation in this report is considered an ongoing sequence of Plio-Pleistocene continental deposits above the San Joaquin Formation that continue to be deposited today in the Holocene period. These deposits can be subdivided into Sierra and Coast Range origins. Each source area contributes different grain sizes and mineralogy that will affect potential well yields and groundwater quality. They also can be subdivided by lacustrine units, older alluvium, and younger alluvium. The different units has a bearing on groundwater occurrence and movement.

The Tulare Formation comprises unconsolidated clay, silt, sand, and gravel, as well as poorly consolidated sandstones and conglomerates. These sediments have been deposited by streams and rivers emanating primarily from the Sierra Nevada and Coast Ranges. The Coast Ranges are composed of gypsiferous marine shales, sandstones and volcanic rocks, sediments sourced from the Coast Ranges, which are generally gypsiferous, typically finer-grained, and contain more angular lithic fragments than Sierran sediments (Page 1983). The granitic source rocks of the Sierra yield sediments with abundant quartz, feldspars, and micas, and are typically coarser-grained and more rounded than the Coast Ranges sediments. Thus, areas of the Subbasin comprised of Sierran sediments tend to have greater water storage capacity due to higher levels of porosity than areas comprised of sediments from the Coast Ranges.

Sedimentary facies of the Tulare formation range from mid-to-distal alluvial fan deposits, marsh deposits, lacustrine deposits, overbank and flood deposits, and fluvial deltaic deposits entering Tulare Lake, and terrestrial shoreline deposits. In terms of depositional environments for the Tulare Formation, the Subbasin is dominated by the lacustrine environment of Tulare Lake in the southern portion of the Subbasin (Figures 3-14a-c). In the northern portion, the depositional environment is dominated by mid-to-distal alluvial fan deposits of the Kings River. The northwestern corner of the Subbasin contains a strip of basin deposits along the South Kings River, west of Lemoore and Stratford. To the east of the Subbasin, the depositional environment comprises mid-to-distal alluvial fan deposits of the Kaweah and Tule rivers.

3.1.6 Lateral Basin Boundaries and Geologic Features Affecting Groundwater Flow

Groundwater flow in the Subbasin has historically been influenced by five significant bounding conditions, including: Kettleman Hills on the southwest, Kings River alluvial fan on the northeast, Arroyo Pasajero fan on the northwest, Tulare Lake clay beds in the central portion of the Subbasin, and the Kaweah and Tule River alluvial fans on the east (Figure 3-15).

3.1.6.1 Kettleman Hills Anticline

The Kettleman Hills anticlinal structure is located on the southwest edge of the Subbasin (Figure 3-15). The Kettleman Hills anticline exposes the late Miocene-Pliocene Etchegoin Formation along its axis, with the younger San Joaquin and Tulare Formations exposed along its flanks. To the west, these formations dip steeply beneath the Kettleman Plain, where the Tulare Formation reaches an estimated thickness of 4,000 feet (Stewart 1946). Groundwater recharge to the Subbasin from direct infiltration on the Kettleman Hills is almost non-existent due to low precipitation, low relief of the Hills, and minimal eastern exposure of the Tulare Formation. The lack of groundwater recharge is evident due to the lack of development of significant alluvial fans on the east side of the Hills. Inter-basin movement of groundwater from the Kettleman Plain to the Subbasin is blocked by the synclinal structure of the Kettleman Plain and the anticlinal structure of the Kettleman Hills, which places thousands of feet of steeply dipping marine claystones and siltstones between the Tulare Formation beneath the Kettleman Plain and the Tulare Formation beneath the San Joaquin Valley. Additionally, the Tulare Formation has been eroded off the tops of each of the Kettleman domes and the San Joaquin Formation exposed in the gaps between the domes, essentially leaving no connection between the Tulare Formation on either side of the Kettleman Hills. Hence there is little or no groundwater flow between the Kettleman Hills and the Subbasin.

3.1.6.2 Kings River Fan

The Kings River alluvial fan extends northward from the Tulare Lake to beyond the northeastern boundary of the Subbasin (Figure 3-15). The fan deposits comprise a series of sand beds and intervening silty to clayey layers with paleosol interludes. Coarser deposits are present higher on the fan north and east of the Subbasin and finer deposits are more prevalent toward the distal end of the fan, within the Subbasin near the center of the valley. Where the historical Kings River entered Tulare Lake, the depositional environment changed from fluvial and alluvial to deltaic, with the sandier beds interfingering with finer lacustrine deposits within the lake. The Kings River, which forms the northern boundary of the Subbasin, appears to provide persistent recharge to the fan deposits along its course. Because of the size of the Kings River drainage area and the magnitude of its flows, the Kings River fan typically contains thicker and coarser sediments than the fans of the lesser Kaweah and Tule Rivers. The fan below the Subbasin is divided into upper and lower aquifers by the Corcoran Clay, which stretches east to west across the fan beneath the Subbasin, extending up fan to about SR 99 (Figures 3-14a-b). The Corcoran Clay layer often has very limited transmissivity and can confine lower aquifers beneath this layer while also preventing or limiting percolation of water from upper aquifers into lower aquifers. The Kings River alluvial fan is a significant source of groundwater inflow and outflow to/from the northern portion of the Subbasin.

3.1.6.3 Los Gatos Creek and Arroyo Pasajero Fan

Los Gatos Creek emanates from the Diablo Range, which is a part of the Coast Ranges, west of Coalinga and grades eastward toward the valley floor. Although the Los Gatos Creek fan is not within the Subbasin, it borders the Subbasin to the northwest (Figure 3-15). The creek is ephemeral and creek flows only reach the valley floor and areas near the Subbasin during periods of extremely high precipitation. As such, there is little or no groundwater flow between the Los Gatos Creek and the Subbasin.

The Los Gatos Creek fan has prograded eastward during the wetter climates of the Pleistocene. Coast Range sediments extend perhaps 15 to 18 miles into the Valley and to a depth of several hundred feet above the Corcoran Clay (Croft 1972; Miller et al. 1971). Another lobe of the Coast Range sediments lies beneath the Corcoran Clay and also extends approximately 15 to 18 miles into the Valley. These sediments comprise sands, silts, and clays of relatively fine-grained textures (Meade 1967). Additionally, sands from the Diablo Range consist of darker minerals and contain more lithic fragments. Grains are subounded to subangular andesite, serpentinite, and chert with some weathered mica flakes. Below the Coast Range sediments are described as floodplain and deltaic/lacustrine deposits of Sierran origin (Miller et al. 1971). The Sierran deposits are described as lighter in color and micaceous, primarily biotite with more than 25% feldspars (Meade 1967). These Sierran deposits extend down to the top of the San Joaquin Formation marking the base of the Tulare Formation.

Groundwater in the Coast Range sediments show a distinct sulfate type of water derived from the marine formations from which the sediments originated (Davis and Coplen 1989). This contrasts with the bicarbonate-type water typical of the Sierran sediments. The total dissolved solids (TDS) of the Coast Range sediments are also typically higher than the Sierran sediments. Wells on the Los Gatos Creek fan typically tap the Sierran deposits below the Corcoran Clay.

3.1.6.4 Tulare Lake Lacustrine Deposits (Clay Plug)

The lacustrine deposits of the ancestral and former Tulare Lake are potentially the most significant controlling factor for groundwater movement in the central portion of the Subbasin. The center of the Tulare Lake depositional system is elongate from northwest to southeast with continuous lacustrine deposits extending like down through the interior portions of the lake to the top of the San Joaquin Formation, which beneath the Subbasin is 2,600 to 3,000 feet bgs (Figures 3-14a-c). The area with continuous lacustrine sediments from the surface to the underlying San Joaquin Formation is roughly 23 miles long by 12 miles wide (Figure 3-15). The horizontal and vertical extent of these continuous fine-grained lacustrine deposits is called the "clay plug." The lacustrine deposits are primarily silts and clays with occasional interbedded fine sands. The deposits are under reduced conditions in nearly all locations where coring has occurred, which indicates little, if any, subaerial contact or oxygenated water since the sediments were emplaced (Miller et al. 1971). Although some of the clays and sand stringers are saturated, they do not produce enough water to have been developed for groundwater extraction. Near the northern, southern, and eastern peripheries of the lacustrine plug, coarser deposits interfinger with the fine-grained sediments. Coarser and more transgressive sediments are present on the eastern, Sierran periphery compared to the western, Coast Range periphery. Where present, the clay plug acts as a barrier to groundwater flow beneath the Subbasin.

3.1.6.5 Kaweah and Tule River Fans

The Kaweah and Tule River fan sediments to the east of the Subbasin have similar deposition to the sediments beneath the Kings River fan; however, they are not as laterally extensive and appear to be thinner and more interbedded than the Kings River deposits (Figure 3-15). Near the toe of the Kaweah and Tule River fans, deposits become more deltaic and interbed with the lacustrine deposits of the Tulare Lake. Similarly, to the Kings River fan deposits, the Kaweah and Tule River fans below the Subbasin are divided into upper and lower aquifers by the Corcoran Clay, which stretches east to west across the fan beneath the Subbasin, extending up fan to the area of SR 99 (Figure 3-14b). The Kaweah and Tule River fan deposits comprise well graded course Sierran sediments with ample water storage capacity and have been extensively developed for groundwater extraction east of Tulare Lake and the Subbasin. The Kaweah and Tule River fans are a significant source of groundwater inflow and outflow to/from the eastern portion of the Subbasin.

3.1.7 Definable Bottom of the Basin

The DWR published Best Management Practices (BMPs) for HCMs for the sustainable management of groundwater (DWR 2016c). Identifying a definable bottom of the Subbasin is one key step in addressing the issue of total basin water storage, as well as the depth to which water can feasibly be extracted. In their section on "Definable Bottom of the Basin," DWR noted "several different techniques or types of existing information can be used in the evaluation of the definable bottom of the basin and extent of fresh water." One method would be to define the base of the water-bearing formations below which no significant groundwater movement occurs, such as the depth to bedrock or some other low permeability formation. A second method would be to evaluate the chemistry of the groundwater beneath the basin vertically and then map the elevation at which the groundwater exceeded a pre-determined criterion for fresh water.

The criteria for fresh water, however, is inconsistent in that it has been defined as a TDS content at approximately 2,000 milligrams per liter (mg/L), 3,000 mg/L, and 10,000 mg/L by various sources (Page 1973; RWQCB 2015; and 49 Code of Federal Regulations 146.4) Additionally, in their BMPs (DWR 2016c), DWR noted they will be constructing a freshwater map for the Central Valley that assumes the base of fresh water is defined by California's secondary maximum contaminant level recommendation of 1,000 mg/L. Because of these inconsistencies, the definable bottom of the basin will be discussed below using two different methods.

3.1.7.1 Geologic Method

A case can be made, on a geologic basis, to define the bottom of the Subbasin at the base of the Tulare Formation, above the underlying San Joaquin Formation. The Tulare Formation is a continental deposit that includes sediments deposited in the San Joaquin Basin from the Pliocene to the present. The Tulare Formation is the primary groundwater aquifer for the southern San Joaquin Valley, including the Subbasin. The Tulare Formation overlies the San Joaquin Formation, a predominantly marine formation comprising significant thicknesses of claystone and siltstone along with minor beds of fine-grained sandstone, which contain brackish water (Wood 2018). Sandstone beds are of low permeability and do not yield sufficient water to be considered an aquifer or a suitable source for agricultural or municipal uses. Even if some sandstone beds contained water that might meet water quality criteria, they are of low permeability and do not yield sufficient water to be considered an aquifer (Wood 2018). Thus, the contact between the Tulare Formation and the underlying San Joaquin Formation would fit the definition for a geologic barrier to groundwater flow under DWR criteria.

The contact between the Tulare Formation and the San Joaquin Formation was previously mapped as the top of the upper Mya zone near the central and southern portions of the Subbasin (Figure 3-16) (Page 1981; Page 1983). Sources included identifications of the upper Mya zone in well logs from 292 oil and gas exploratory borings as well as structure contour maps and geologic sections done for oil and gas fields in the area. These data show that the approximately water bearing depth of the Tulare Formation ranges from about 4,000 feet bgs near the axis of the San Joaquin syncline, which lies to the east of the Kettleman Hills to approximately 2,500 feet bgs near the southeastern corner of Kings County. The study's map did not extend into the northern portion of the Subbasin, so the contact between the Tulare and San Joaquin Formations has been estimated from oil and gas exploration wells in the area (Wood 2018). The depth to the base of the Tulare Formation in the northern portion of the Subbasin ranges from 2,700 to 2,200 feet bgs, rising to the north (Figure 3-16). Near the City of Corcoran, the depth of the Tulare Formation is greater at approximately 3,400 feet bgs.

Studies have shown that portions of the Tulare Formation do not yield groundwater that meets water quality criteria for beneficial uses, particularly in and surrounding the Tulare Lake. These criteria are examined in detail in the following section.

3.1.7.2 Water Quality Method

Several potential criteria exist for determining the extent of fresh water in a groundwater basin; however, the criteria adopted by the California Regional Water Quality Control Board (RWQCB), Central Valley Region, appears to be the most appropriate for the Subbasin. The RWQCB is the state agency that has been charged with adopting and enforcing water quality control plans, or basin plans, to protect state waters. The Subbasin is within the boundaries of the Tulare Lake Hydrologic Region (Figure 3-1) as defined by the RWQCB and therefore subject to the Tulare Lake Basin Plan (Basin Plan).

The Basin Plan describes designated beneficial uses of groundwater to be protected, water quality objectives to protect those uses, and a program for implementation to achieve the objectives (RWQCB 2015). Beneficial uses of groundwater in the Tulare Lake Hydrologic Region include municipal, agricultural, and industrial. The Basin Plan incorporates the Sources of Drinking Water Policy Resolution No. 88-63, adopted by the State Water Resources Control Board (SWRCB), which states all surface and ground waters of the State are considered to be suitable, or potentially suitable for municipal or domestic water supplies (MUN) with the exception of water that has a TDS exceeding 3,000 mg/L and is additionally not reasonably expected by the RWQCB to supply a public water system (SWRCB 2006). Regarding agricultural uses (AGR), the Basin Plan is not explicit to the numerical criteria for determining beneficial use; however, the Basin Plan contains a narrative regarding an exception to the AGR designation if pollution by natural processes or human activity is documented that cannot be reasonably treated by BMPs or economically achievable treatment practices to achieve water quality suitable for agricultural uses.

In 2014, the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS), a stakeholder group that was created to develop a comprehensive Salt and Nitrate Management Plan for the Central Valley, identified a need to define the salinity-related requirements for the protection of both the MUN and AGR beneficial uses. This evolved into the development of a technical information and environmental and economic analysis in support of a MUN and AGR beneficial use evaluation project for a portion of the historical Tulare Lake (RWQCB 2017). A beneficial use evaluation report was submitted on behalf of CV-SALTS proposing portions of the groundwater body beneath the historical Tulare Lake be de-designated for MUN and AGR beneficial uses (KDSA et al. 2015). The evaluation report affirmed the criteria for exemption from MUN to be a TDS of 3,000 mg/L. CV-SALTS has also provided a literature review, which affirmed guidelines that stated only the most salt-tolerant crops may be sustainably irrigated with water exceeding 3,000 microsiemens per centimeter (µS/cm) or less (a TDS of about 2,000 mg/L) (CV-SALTS 2013; Ayers and Westcot 1985). As part of the literature review, CV-SALTS also identified acceptable salt levels for livestock watering to be water with an electrical conductivity (EC) of 5,000 µS/cm or less (a TDS of about 3,000 mg/L).

The RWQCB adopted the preferred alternative for MUN beneficial use de-designation to be the application of the Sources of Drinking Water Policy exception 1a, where water quality exceeds an EC of 5,000 µS/cm (RWQCB 2017). The report further proposed the preferred alternative for AGR beneficial use de-designation be based on a 5,000 µS/cm EC threshold value (3,000 mg/L) taken from the Canadian Council of Ministers for the Environment for all classes of livestock (CCME 2007). These criteria were accepted by the RWQCB (Resolution R5-2017-0032) on April 6, 2017, and adopted by the SWRCB (Resolution No. 2017-0048) on September 6, 2017.

Based on the body of work by CV-SALTS and the regulatory acceptance of the criteria for de-designation of MUN and AGR of an EC of 5,000 µS/cm (approximately 3,000 mg/L TDS), the criteria for determining the extent of fresh groundwater in the Subbasin was set at 3,000 mg/L TDS. Within the Subbasin, water quality of 3,000 mg/L TDS, typically found at depths greater than 3,000 feet bgs, could define the bottom of the Subbasin using this methodology for this GSP.

3.1.8 Hydrogeologic Setting: Principal Groundwater Aquifers and Aquitards

The current hydrogeology of the Subbasin is complex in that the only physical boundaries are the Kettleman Hills on the southwestern edge and the Kings River on the northeastern edge of the Subbasin. The remaining edges of the Subbasin are based on political boundaries and water management areas, and the actual physical water-bearing formations of the Subbasin extend into these adjacent areas. Groundwater beneath the Subbasin occurs primarily in the coarser-grained Sierran sediment deposits of the alluvial fans of the Kings, Kaweah, and Tule rivers, as well as the fans of the lesser streams that drain from the Sierra Nevada Mountains into the southeastern portion of the Subbasin. A study conducted in the 1960s subdivided the coarser-grained deposits into three units, older and younger alluvium and undifferentiated continental deposits (Croft and Gordon 1968). These deposits are primarily Sierran in origin and were deposited during the Quaternary period by the major stream channels emanating from the Sierra Nevada Mountains. On the west side of the Subbasin, some sediments may have Coast Ranges origin, but the axis of Tulare Lake is close to the Kettleman Hills and its finer-grained sediments, which leaves little room for potentially coarser-grained Coast Ranges sediment deposition on the west side. The Corcoran Clay underlies most of the Subbasin, which essentially subdivides the Subbasin into two aquifer systems, an unconfined to semi-confined aquifer system above the Corcoran Clay and a confined aquifer system below the Corcoran Clay.

The younger alluvium is generally thinner than the older alluvium and is present in current stream channels and as a veneer over the older alluvium as the deposits stretch to the west. The younger alluvium is primarily arkosic and is considered of Holocene age. It occurs entirely above the Corcoran Clay and is unconfined. In places, it may contain groundwater perched above any one of a number of relatively continuous clay layers.

The older alluvium is widespread throughout the San Joaquin Valley and represents deposition from both the Coast Ranges on the west side of the Valley and the Sierra Nevada Mountains on the east. The older alluvium is generally identified by its stratigraphic position on terraces of the major rivers, though as mentioned earlier, there is no current method to differentiate it in the subsurface from the Tulare Formation. The older alluvium is considered Pleistocene to Holocene in age and it is typically bifurcated by the Corcoran Clay such that groundwater contained in the older alluvium may be either confined or unconfined.

Beneath the older alluvium are the undifferentiated continental deposits, which beneath the Subbasin are Sierran in origin. The deposits are beneath the Corcoran Clay, and as such, groundwater contained in the undifferentiated Tulare Formation is all confined.

Lacustrine deposits have been identified in the Subbasin principally beneath the Tulare Lake. Geologic cross sections illustrate the thick and continuous nature of these clay deposits beneath the lake (Croft 1972; Croft and Gordon 1968; Davis et al. 1959). Additionally, six individual lacustrine clays were identified in the subsurface and had sufficient lateral extent to be considered important in affecting groundwater movement (Croft 1972). These clays were identified in geophysical logs and named the A- through F-Clays, with the E-Clay being equivalent to the Corcoran Clay. Though the A- through D-Clays may be important locally in restricting downward movement of groundwater, Corcoran Clay or E-clay is the most significant (KDSA et al. 2015). The Corcoran Clay has been identified beneath Tulare Lake and extends beyond the

Subbasin in all directions except for a small area in the northeast corner of the Subbasin (Croft 1972).

Marsh and flood basin deposits are found typically near the modern axis of the San Joaquin Valley, along the distal reaches of the streams in the southern Valley. These deposits comprise silts and clays that can be relatively thick in some locations creating local areas of perched groundwater.

For purposes of monitoring, as described in Chapter 5, the aquifers are divided into three aquifer zones:

- The A zone is the shallow portion of the aquifer above the A-Clay and in areas where shallow groundwater is present outside of the A-Clay,
- The B zone is the unconfined portion of the aquifer above the E-Clay or Corcoran Clay and below the A-Clay where the A-Clay is present, and
- The C zone is the confined portion of the aquifer below the E-Clay.

The main aquifers and aquitards are described in greater detail in the following sections.

3.1.8.1 Unconfined Aquifer

The unconfined and semi-confined upper portions of the regional freshwater aquifer are found above the Corcoran Clay. This upper portion of the regional freshwater aquifer is generally comprised of coarse- to medium-grained sediments (i.e., sand and gravel) with silt and clay interbeds. The depth to first groundwater beneath a large portion of the Subbasin is less than 15 feet bgs in a zone situated above the A-Clay (Figure 3-17).

Groundwater within the rest of the Subbasin and surrounding areas are typically found between depths of 30 and 250 feet bgs, depending on location and the season or year when the water levels are measured. The shallow groundwater areas typically have poor water quality, and the shallow soils require drainage to grow crops (KDSA et al. 2015) (Figure 3-17). In areas where groundwater is below 15 feet, the shallow unconfined aquifer is subject to large swings in water levels due to groundwater recharge, which occurs primarily along stream channels, unlined surface water conveyances, and artificial recharge basins. In thicker sections of the unconfined aquifer, pumping for agricultural uses may create significant drawdown of the water table during the irrigation season and under prolonged drought conditions. Nearer the Tulare Lake, where the upper aquifer is substantially interbedded with lacustrine deposits, the groundwater producing zones are thinner and become increasingly finer-grained limiting groundwater withdrawals to primarily relatively low demand domestic uses.

3.1.8.2 Confined Aquifer

The sediments below the Corcoran Clay comprise the lower confined portion of the regional freshwater aquifer. This lower portion of the regional freshwater aquifer is generally comprised of clay, silt, sand, and gravel (Page 1983).

Few maps are available showing groundwater elevations in the confined aquifer beneath the Subbasin and surrounding areas (Harder and Van de Water 2017). In fall 1998 and 1999, groundwater was at an elevation of about 100 feet below mean sea level (MSL) at a depth of about 300 feet bgs near Corcoran, decreasing in elevation to the south towards an apparent pumping center near Alpaugh. The coarser and thicker sections of sediments below the Corcoran Clay lend themselves to development of higher capacity wells that withdraw groundwater for municipal and agricultural uses. However, the limited extent of highly productive fresh groundwater aquifers within the boundary of the Subbasin, generally along the coarse-grained sediments within the alluvial fans (e.g., Kings River fan), concentrates these wells in the eastern portion of the Subbasin and in adjoining subbasins to the east, beyond the finer-grained deltaic and lacustrine deposits grading into the Tulare Lake. Because of the effectiveness of the Corcoran Clay as an aquitard, recharge to the confined aquifer likely occurs primarily in the upper portions of the alluvial fans beyond the Corcoran Clay's eastern extent.

The sediments within the southern portion of the Tulare Lake consist of a thick, continuous sequence of clays, forming a clay plug. There are no significant production wells within the clay plug due to the fine-grained nature of the sediments; however, there may be a few stock watering wells in this area.

3.1.8.3 Aquitards

Fine-grained lacustrine, marsh and flood deposits underlie the Valley trough and floor and were deposited in lacustrine or marsh environments (Croft 1972). These fine-grained units are critically important in the hydrology of the basin in that they restrict the downward movement of water and act as aquitards. These nearly impermeable gypsiferous fine sand, silt and organic clay deposits are more than 3,000 feet thick beneath parts of Tulare Lake and spread out laterally and interfinger with the coarser sediments found along the basin margins (Croft 1972; Page 1983). The clayey or silty clay units interbedded within the Tulare Formation are designated by letters A through F (Croft 1972). The A-, C- and E-Clay units are the primary fine-grained units underlying significant portions of the Subbasin and can isolate different waters and bounds the freshwater aquifers. However, beneath Tulare Lake, these individual clay units are not distinguishable from the other clay deposits that form the massive clay plug beneath the center of the lake (KDSA et al. 2015).

A-Clay

The A-Clay is a dark greenish gray or blue, organic clay found approximately 60 feet bgs in the Tulare Lake area (KDSA et al. 2015). A-Clay is approximately 10 to 60 feet in thickness and in some places a sand lens separates the A-Clay into an upper and lower unit (Croft 1972). However, due to similarities in the sedimentary deposits beneath Tulare Lake, A-Clay was not able to be positively identified in all areas (Page 1983). Outside of Tulare Lake area and near rivers and streams, groundwater above the A-Clay can be an important source of shallow groundwater for domestic and limited AGR uses. In Tulare Lake area, groundwater above the A-Clay is typically too saline for MUN or AGR usage and has been exempted from MUN and AGR beneficial use (RWQCB 2017). The delineated lateral extent of the A-Clay is shown in Figure 3-17 delineated by Croft (1972) and Page (1983) is shown on Figure 3-14a-c and Figure 3-17 (Croft 1972; Page 1983).

C-Clay

The C-Clay consists of yellowish-brown to bluish-gray silty-clay and is found approximately 230 feet bgs in the Tulare Lake area (KDSA et al. 2015). The C-Clay is about 10 feet thick and is structurally warped and folded (Croft 1972). C-Clay could not be positively identified beneath Tulare Lake in previous studies (Page 1983). Outside of the Tulare Lake area, most of the groundwater production from public supply wells is from wells that tap water below the C-Clay (KDSA et al. 2015). In the Tulare Lake area, groundwater above the C-Clay is typically too saline for MUN or AGR usage (RWQCB 2017) and has been exempted from MUN and AGR beneficial use. The delineated lateral extent of the C-Clay is shown on Figure 3-18 and in cross sections A to A’, B to B’, and C to C’ (Figures 3-14 a-c) (Croft 1972; Page 1983).

Corcoran Clay (E-Clay)

The Corcoran Clay is the most extensive aquitard in the San Joaquin Valley. The Corcoran Clay is composed of dark-greenish gray, mainly diatomaceous, silt, clay, silty clay, clayey silt and sand that was deposited in a lake that occupied the San Joaquin Valley (Croft 1972). The lateral extent and depth of the Corcoran Clay is shown on Figure 3-19a and its thickness on Figure 3-19b. The Corcoran Clay is warped into a major, asymmetric, northwest trending syncline that has been additionally deformed with smaller, subordinate folds.

Recently, a detailed evaluation of the presence of the Corcoran Clay beneath Tulare Lake area was undertaken in support of a de-designation of beneficial uses for groundwater beneath this lake area (KDSA et al. 2015). This study identified the Corcoran Clay as being present at depths of about 400 to more than 800 feet bgs throughout the Subbasin. Within the clay plug itself, due to the continuous fine-grained lacustrine nature of the sediments, similar to that of the Corcoran

Clay, the Corcoran Clay cannot be delineated. The low permeability of the Corcoran Clay makes it an effective aquitard. It has sharp vertical boundaries and shows up well on borehole geophysical electric logs. The Corcoran Clay appears to extend out to the east of the Subbasin near SR 99. On the west, it rises sharply with the Tulare and underlying San Joaquin Formations. E-clay is more difficult to recognize as it approaches the west-side fold belts. Geophysical well logs indicate that the Corcoran Clay, although the largest single confining bed in the Subbasin, constitutes only a small percentage of the total cumulative thickness of clay layers in the unconsolidated sediments beneath the Tulare Lake clay plug.

3.1.9 Hydraulic Parameters

Two significant hydraulic parameters for groundwater resources are hydraulic conductivity and storage coefficient. The hydraulic conductivity is directly proportional to the rate at which groundwater will move under a unit hydraulic gradient. The storage coefficient is the amount of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit head change. When referring to an unconfined aquifer, the storage coefficient is called the specific yield and is related to the amount of water drained from the pore spaces in the aquifer and given as a percent of the total volume of the aquifer material. For a confined aquifer, the amount of water released is derived from limited compressibility of the water and primarily by the compression of the aquifer. No drainage of the water pores is involved.

A method referred to as "*yield factor*" was utilized to approximate relative permeability, also known as hydraulic conductivity (Croft and Gordon 1968). The yield factor is equal to 100 times the specific capacity of a pumping well divided by the thickness of saturated material penetrated by the well (Croft and Gordon 1968). Specific capacity is calculated by dividing the discharge from the well by the amount of drawdown created by pumping. The study used pump-efficiency tests supplied by Pacific Gas and Electric Company and Southern California Edison Company to calculate the specific capacities of numerous wells in the Tulare Lake area. These data were compiled and indicated increasing yield factor or permeability moving away from Tulare Lake, largely related to the increasing coarseness of sediments further removed from the lacustrine fine-grained sediments within the lake (Figure 3-20).

Specific yields have been estimated for various areas of the San Joaquin Valley based on average grain size in the unconfined aquifers (Davis et al. 1964). On the Kings River alluvial fan, the specific yield was estimated to be 14.1%. On the Kaweah and Tule River fans, specific yield was estimated to be 9.5%. The storage coefficient for the confined aquifer has not been estimated specifically for the area within the Subbasin; however, a method is provided for estimating storage coefficient by multiplying the thickness of the confined aquifer in feet by a factor of $1x10^{-4}$ (Lohman 1972).

In support of the Central Valley Hydrologic Model (CVHM), scientists from the United States Geological Survey (USGS) developed a geologic texture model to describe the coarseness or fineness of basin-fill materials that make up the hydrogeologic system and used this model to estimate hydraulic properties including hydraulic conductivity and storage properties for every cell in the CVHM model grid (Faunt, ed. 2009) (Figure 3-21). Hydraulic conductivities derived from these texture models would range from approximately 1 foot per day (ft/d) to about 70 ft/d. Specific yields estimated for the CVHM ranged from 9% to 40% and varied based on the percentage of coarse-grained deposits with higher specific yields from coarser-grained deposits. The specific storage (storage coefficients divided by the thickness of the unit) ranged from 1.4×10^{-4} per foot (ft) for inelastic aquifers, 1.0×10^{-6} per ft for coarse-grained elastic aquifers, and 4.5×10^{-6} per ft for fine-grained elastic aquifers. The compressibility of water is estimated to be 1.4×10^{-6} per ft and must be added to the specific storage of the matrix to determine the confined specific storage.

3.1.10 Groundwater Recharge and Discharge

Groundwater recharge in the Subbasin occurs primarily by two methods: (1) infiltration of surface water from the Kings River and unlined conveyances, and (2) infiltration of applied water for irrigation of crops. Recharge from infiltration of direct precipitation is minor owing to the low annual rainfall and the predominance of fine-grained surface soils. Some recharge enters the Subbasin by subsurface flow from adjoining subbasins; however, this is a minor component as most pumping for irrigation lie to the north and east of the Subbasin due to the more favorable hydraulic properties of the sediments outside of the Subbasin. Intentional recharge also occurs within the Subbasin by percolating surface water through storage ponds and old river channels, though the magnitude of this component is small compared to the groundwater demand in the Subbasin. Most surface water entering the Subbasin is consumptively used or retained due to the internal drainage within the Subbasin.

Groundwater discharge in the Subbasin is predominantly by groundwater extraction along the eastern and northern portions of the Subbasin where water quality and well yields are higher than near Tulare Lake. Some discharge is impacted by direct soil evaporation and evapotranspiration, particularly in areas where groundwater is less than 10 feet bgs. Additionally, some discharge occurs by tile drains in agricultural areas that have high groundwater levels to lower the groundwater table to below the root zone to sustain agriculture. Groundwater discharge also occurs by subsurface movement of groundwater from the Subbasin toward adjoining subbasins. Potential groundwater recharge based on soil classification and potential groundwater extraction based on subsurface sediment texture varies (Figure 3-22).

3.1.11 Primary Uses of Each Aquifer

The upper unconfined and semiconfined aquifer and the lower confined aquifer are sometimes used for different purposes based on economics and water quality. Primary groundwater uses within the Subbasin include domestic, municipal, agricultural, and industrial.

3.1.11.1 Domestic Pumping

Domestic pumping is primarily from the upper unconfined and semiconfined aquifer because it is easier to access and typically has sufficient yield for domestic purposes.

3.1.11.2 Municipal Pumping

Municipal pumping of groundwater occurs in the Subbasin by the cities of Hanford, Lemoore, Stratford, and Corcoran (Table 3-4). Wells for municipal purposes are typically in the deeper portions of the unconfined and semiconfined aquifer and sometimes reach into the confined aquifer. Municipal uses require larger sustained yields than domestic uses; therefore, municipal pumping looks to deeper zones with longer well screens than domestic wells. The municipal pumping demand varies seasonally, peaking in the summer months.

3.1.11.3 Agricultural Pumping

Agricultural pumping requires large quantities of water and water quality not impacted by elevated TDS, chloride, and boron concentrations. The requisite quantity and quality can be achieved by drilling into the deeper portions of the upper aquifer and below the Corcoran Clay into the lower confined aquifer. Thus, most of the agricultural pumping in the Subbasin and in adjoining subbasins is from deep wells.

3.1.11.4 Industrial Water Pumping

Industrial use depends on application. Groundwater used to provide steam for power generation or heating needs to contain low TDS and may require treatment. Some industrial use such as dust control may not be dependent on water quality.

3.1.12 Uncertainty and Data Gaps

The HCM is being used to characterize groundwater conditions in the Subbasin and to provide the basis and assumptions used to construct and run the groundwater model. The groundwater model is being used to estimate changes over time in groundwater levels, flow directions, and storage given a set of inflows (precipitation, surface water, underflow in, etc.) and outflows (evapotranspiration, pumping, underflow out, etc.). Prior to SGMA, there were no requirements to manage or report groundwater usage. As a result, most water supply entities do not know the location, construction, and pumping history of many pumping wells within their jurisdiction. Although depth to groundwater measurements are collected periodically from many wells, the lack of well construction data makes it difficult to interpret the data. Furthermore, most of these entities often do not have a good historical accounting of which parcels have received surface waters and at what rates. Hence, these inputs and outputs need to be approximated by other means than direct measurement.

The data utilized for the HCM and subsequently the construction and calibration of the groundwater model were provided by various private parties, public agencies, and data extracted from existing numerical models of the area.

Much of the hydrologic data used in the HCM and to construct and calibrate the groundwater model are based on estimates or inferred from multiple data sources. As noted above, most water suppliers do not know the historical delivery of surface water to various parcels within their jurisdiction. Hence, it was necessary to assume that all irrigated parcels received some surface water allotment. Likewise, the location, construction, and pumping history of most of the irrigation wells in the Subbasin are not known. Hypothetical irrigation well locations were assumed to be distributed with relatively uniform spacing across the model domain. The hypothetical irrigation wells were also assumed to have completion intervals and frequency similar to that of a small subset of wells with known constructions. Hypothetical irrigation well pumping was estimated based on a water balance method using estimated agricultural demand based on reported crop type minus the assumed distribution of surface water supplies. While these simplifying assumptions and estimates are reasonable given the sparseness of measurements, they add uncertainty to the HCM and the groundwater model.

Overtime, under SGMA, more accurate data regarding well construction, water level measurement, spatial and temporal groundwater pumping, and surface water deliveries should be collected and utilized to update the HCM and the groundwater models of the Subbasin. As the HCM and the groundwater model are updated with actual measurement instead of estimates, the HCM and the groundwater model will become more useful tools for managing groundwater in the Subbasin.

3.2 Groundwater Conditions

> **23 CCR §354.16** *Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions based on the best available information…*

This section contains information related to historical and current groundwater conditions necessary to understand the characteristics of groundwater flow within the Subbasin, groundwater quality, and the water budget. Subsidence and its overall effect on groundwater storage, surface and groundwater interactions, and groundwater dependent ecosystems is also discussed.

3.2.1 Historical Changes in Groundwater Flow

Historically, groundwater movement in the Subbasin was dominated by recharge of surface water on the alluvial fans of the rivers and streams emanating from the Sierra Nevada Mountains and by the discharge sinks created by evaporation from Tulare Lake and evapotranspiration created by the swamps and marshes along the periphery of the Lake. Maps of unconfined groundwater conditions in the San Joaquin Valley between 1905 to 1907 (Figure 3-23) showed groundwater flow converging on the Tulare Lake bottom and confined flowing wells (artesian) in the Subbasin along the center of the valley and as far east as Goshen, Tulare, and Pixley (Mendenhall et al. 1916). Water levels indicated groundwater recharge on the Kings, Kaweah, and Tule River fans.

By 1952, groundwater development had altered the potentiometric surface such that distinct pumping cones of depression had developed in the unconfined upper aquifer east of the Subbasin beneath the Kaweah and Tule River fans and within the Subbasin on the Kings River fan near Hanford (Figure 3-24) (Davis et al. 1959). These groundwater depressions interrupted the through flow of groundwater from the alluvial fans west of the Sierra Nevada Mountains to the Tulare Lake area.

In 2016, groundwater cones of depression in the unconfined upper aquifer were apparent east of the Subbasin with groundwater elevations having declined 100 to more than 200 feet from the 1952 data (Figure 3-25). Based on available groundwater elevation data, the groundwater cones of depression peripheral to the Subbasin changed the natural prevailing direction of groundwater flow from west-southwest toward Tulare Lake, to east, northeast, and southeast away from Tulare Lake.

There were insufficient data available for confined aquifer only wells to prepare potentiometric surface maps for the confined aquifer system.

3.2.2 Recent Groundwater Elevation Data and Flow

In 1990, the DWR mapped groundwater levels in the unconfined aquifer at an elevation of about 260 feet AMSL near Kingsburg, decreasing toward the Tulare Lake bottom (Figure 3-26). Groundwater elevations beneath Hanford were about 170 feet AMSL and about 140 feet AMSL near Corcoran. There were several groundwater cones of depression in the water table near Hanford, north and south of Corcoran, and around Alpaugh. The Kings River appears to be a natural groundwater divide, a losing stream that provides a significant source of groundwater recharge to the unconfined aquifer. In general, groundwater flowed into the Subbasin from the Kings, Kaweah, and Tule subbasins and out of the Subbasin to the Westside Subbasin to the west-northwest (Figure 3-26).

In 1995, groundwater in the unconfined aquifer was at an elevation of about 260 feet AMSL near Kingsburg, decreasing toward the Tulare Lake bottom (Figure 3-26). Groundwater elevations beneath Hanford were about 150 feet AMSL and about 110 feet AMSL near Corcoran. By 1995, the cones of depression in the water table between Hanford and Corcoran had merged into a single large depression. The Kings River continued to be a natural groundwater divide. In general, groundwater flowed into the Subbasin from the Kings, Kaweah, and Tule subbasins and out of the Subbasin to the Westside Subbasin.

In 2000, groundwater in the unconfined aquifer was at an elevation of about 250 feet AMSL near Kingsburg, decreasing toward the Tulare Lake bottom (Figure 3-26). Groundwater elevations beneath Hanford were about 150 feet AMSL and less than 100 feet AMSL near Corcoran. The Kings River continued to be a natural groundwater divide. In general, groundwater flowed into the Subbasin from the Kings and Kaweah subbasins and out of the Subbasin to Tule and Westside subbasins.

In 2005, groundwater in the unconfined aquifer was at an elevation of about 260 feet AMSL near Kingsburg, decreasing toward the Tulare Lake bottom. Groundwater elevations beneath Hanford were about 140 feet AMSL, about 10 feet lower than in 2000. No data were collected in the Corcoran area (Figure 3-27). Throughout the Subbasin, groundwater levels had declined about 10 feet or greater than in 2000, during a period of average rainfall. The Kings River continued to be a natural groundwater divide. In general, groundwater flowed into the Subbasin from the Kings, Kaweah, and Tule subbasins and out of the Subbasin to the Westside Subbasin.

In 2010, groundwater in the unconfined aquifer was at an elevation of about 250 feet AMSL near Kingsburg, decreasing toward the Tulare Lake bottom. Groundwater elevations beneath Hanford were about 130 feet AMSL, and less than 10 feet AMSL near Corcoran (Figure 3-27). Throughout the Subbasin, groundwater levels had further declined about 10 feet or more feet since 2005. The Kings River continued to be a natural groundwater divide. In general, groundwater flowed into the Subbasin from the Kings, Kaweah, and Tule subbasins and out of the Subbasin to the Westside Subbasin.

In 2016, after roughly five years of severe drought, groundwater in the unconfined aquifer was at an elevation of about 230 feet AMSL near Kingsburg, decreasing toward the Tulare Lake bottom. In the Hanford area, groundwater levels were about 110 feet AMSL, about 20 feet lower than in 2010 (Figure 3-27). Cones of depression in the water table west, north, and southeast of Corcoran had deepened to -40 feet AMSL. In general, groundwater flowed into the Subbasin from the Kings and Kaweah subbasins and out of the Subbasin to the Tule and Westside subbasins.

Wells with groundwater monitoring records are shown in Figure 3-28a. The hydrographs for these wells were evaluated to look at seasonal trends. Hydrographs for representative wells with unknown construction, wells completed in the unconfined aquifer, and wells completed in the confined aquifer are shown on Figures 3-28b-d.

3.2.3 Vertical Groundwater Gradients

Vertical groundwater gradients between the upper unconfined aquifer and the confined aquifer separated by the Corcoran Clay are spatially and temporally variable. Prior to widespread groundwater development, there was an upward gradient from the confined aquifer to the unconfined aquifer (including artesian conditions) beneath much of the Subbasin (Figure 3-23). As agriculture was developed, pumping from below the Corcoran Clay eventually resulted in a downward gradient beneath much of the Subbasin. Pumping from a confined aquifer (which is a function of the storage coefficient) will often result in a larger change in head compared to pumping from an unconfined aquifer (which is a function of the specific yield) for the same volume of pumping. This is because the specific yield is typically several times larger than storage coefficient. Due to the different yield factors and the seasonal nature of agricultural pumping, groundwater levels in the confined aquifer tend to decrease much more than in the unconfined aquifer during the summer months, increasing the vertical gradients. As a result, vertical gradients tend to show a large range seasonally. As of December 2016, vertical gradients range between approximately 0.0 to 0.504 ft/ft (0.0 to 50 ft/100 ft) downward.

3.2.4 Groundwater Storage Estimates

Groundwater storage is the capacity of an aquifer system to yield groundwater. The amount of groundwater in storage (i.e., groundwater volume) is a function of the saturated thickness of the aquifer, the area of the aquifer, and the storage coefficients of an aquifer, which is the specific yield for unconfined aquifers and specific storage for confined aquifers. The specific yield of the Subbasin’s aquifer system above the E-Clay (Corcoran Clay) ranges from 0.01 to 0.3 (unconfined), while the specific storage ranges between $1x10^{-5}$/ft and $4.5x10^{-2}$/ft for semi-confined intervals above the E-Clay (Wood 2018). The specific storage of confined sediments below the Corcoran Clay ranges between $2.5x10^{-7}$/ft and $1.25x10^{-3}$/ft (Wood 2018).

The Subbasin groundwater model and DWR estimates were used to calculate groundwater in storage for the principal aquifers (unconfined above the E-Clay and confined below the E-Clay) within the Subbasin boundaries based on 2016 conditions. The unconfined aquifer has an average specific yield of 8.5% (DWR, 2006) and an average saturated thickness of 451 feet over the 535,869 acres of the Subbasin. This yields an estimated at 20.5 million AF of groundwater in storage in the unconfined aquifer zone. The confined aquifer has an estimated average specific yield of 4.91% and an average saturated thickness of 2,294 feet over the 535,869 acres of the Subbasin. This yields an estimated 60.4 million AF of groundwater in storage in the confined aquifer zone. Total estimated groundwater in storage as of 2016 is approximately 80.9 million AF, slightly less than the DWR estimate of 82.5 million AF as of 1995 (DWR, 2006).

The groundwater model was also used to estimate the overall change in groundwater storage over the model calibration period of 1990 to 2016 for the unconfined and confined aquifers. Change in groundwater storage over time is a function of the change in hydraulic head of the aquifer, the aquifer area, and the storage coefficients. Groundwater storage can be negatively impacted by decreasing groundwater head and an overall reduction of the aquifers area resulting from declining groundwater.

Annual changes occurred in groundwater storage from 1990 through 2016 in the upper and lower aquifer zones for each GSA area (Figures 3-29a and b). Overall there has been a loss of storage of about 3.84 million AF from the unconfined aquifer, a storage gain of about 1.53 million AF in the confined aquifer, and a total loss of about 2.31 million AF between 1990 and 2016.

Permanent loss of groundwater storage capacity occurs when dewatering of an aquifer results in compression of sediments also known as subsidence due to loss of hydrostatic pore pressure that formerly offset compressional loading of the sediment overburden. Compaction of sediments permanently reduces effective porosity of an aquifer thus reducing overall aquifer storability. Between 1990 and 2016, the average subsidence across the Subbasin was approximately 1.42 feet with most of the compaction probably occurring in the fine-grained sediments within the confined aquifer. Assuming that the reduction in effective porosity of the fine-grained sediments is about 4.91%, then an average of 1.42 feet of subsidence (compaction) over the 535,869 acres of the Subbasin would result in a permanent loss of groundwater storage capacity beneath the Subbasin on the order of 37,360 AF, or approximately 0.05% of the total groundwater in storage in 2016.

3.2.5 Groundwater Quality

Water quality geochemistry varies in groundwater beneath the San Joaquin Valley (Mendenhall et al. 1916). On the west side of the valley, groundwater was always high in sulfate compared to groundwater on the east side of the valley. Near the center of the valley, groundwater had a mixed character, also being high in alkalis. Most of the water sampled represented essentially pre-development conditions. The difference in chemical characteristics of the groundwater was attributed to the source area for the sediments in which the groundwater was contained (Mendenhall et al. 1916). On the west side, deposits were derived from marine sedimentary rocks with high proportions of sulfur-rich minerals (such as gypsum), whereas on the east side, deposits were derived from granitic rocks with high proportions of silicates. Near the center of the Valley and around the historical Tulare Lake, groundwater contained higher proportions of chloride. It was also noted that TDS measurements in groundwater were greater on the west side than the east.

These findings were confirmed by an additional study in 1956, which concluded groundwater quality is markedly different vertically than horizontally (Davis et al. 1959). The increase in groundwater development between the initial and secondary reports resulted in the latter study subdividing groundwater into unconfined and semiconfined waters that have generally free communication with land surface, the fresh water confined beneath the Corcoran Clay, and brackish and saline marine connate waters that occur at depth beneath the useful aquifers throughout most of the Valley. These studies reported the confined fresh groundwater had lower TDS and a higher percentage of sodium than the unconfined or semi-confined aquifer. The differences between groundwater (carbonate) and west groundwater (sulfate) continued into the 1950s. The groundwater beneath the axial trough was highly variable because of evaporative concentration, variable mixing of east and west groundwater, and recharge of surface water along stream courses of Sierran rivers.

In 2018, a study undertook a comparison of historical groundwater quality data from the historical report of 1916 and modern samples from 1993-2015 to quantify anthropogenic contributions to salinity changes in groundwater quality (Hansen et al. 2018). Findings indicate TDS had increased in most groundwater in the San Joaquin Valley over the past 100 years. However, the spatial distribution of the TDS and individual cation-anion makeup of the groundwater still reflect the geologic provenance of the containing sediments as well as the chemical characteristics of the recharge water. The greatest TDS increases in the Tulare Lake area and eastward were in the shallow portions (i.e., unconfined to semiconfined) of the aquifer.

Excluding water above the A-Clay, the historical data did not indicate any substantial differences in TDS between shallow and deep groundwater. Modern increases in TDS in the shallower groundwater were hypothesized to be due to land usage, which is primarily agricultural in this area (Hansen et al. 2018). The changes to individual cations and anions suggest dissolution of silicate minerals possibly caused by increases in carbonic acid in the soil zone due to agricultural practices. An increase in bicarbonate concentrations were the highest contributor to increases in TDS over the past 100 years. Migration of higher TDS water to deeper portions of the unconfined/semiconfined aquifer was postulated to be the result of high rates of agricultural pumping, along with more limited municipal pumping creating downward vertical movement from upper to lower portions of the upper aquifer. Only limited changes to the TDS and chemical makeup of the lower, confined aquifer were apparent, assuming that the historical chemistry reflected both native conditions for both the upper and lower aquifers (Hansen et al. 2018).

Deep groundwater near the boundary of the continental deposits and the Tertiary marine deposits (San Joaquin Formation) has been estimated to exhibit TDS upwards of 2,000 mg/L based on limited groundwater samples and interpretation of geophysical logs of deep borings. This water represents saline connate water contained or adjacent to the marine deposits.

The SWRCB maintains a database of water quality data (GeoTracker) collected from various state regulatory programs, the USGS, and the University of California Davis Nitrate Study. These datasets were obtained for the Subbasin to gain a general overview of water quality. In general, chemicals of concern that generally affect water quality in the San Joaquin Valley were screened including naturally occurring and anthropomorphic. These included salinity (TDS), arsenic, nitrate, and volatile organic chemicals (VOCs). Figure 3-30 shows the area-wide distribution of TDS in groundwater. Figure 3-31 shows the distribution of arsenic in groundwater. Figure 3-32 shows the distribution of nitrate in groundwater, and Figure 3-33 shows the distribution of VOCs in groundwater.

South of Stratford and Corcoran, groundwater quality diminishes, and portions of the Tulare Lakebed have been de-designated as not suitable for municipal, domestic, agricultural irrigation, and stock watering supply (RWQCB 2017). The primary constituents of concern for the de-designated areas included boron, chloride, sodium, salinity (EC), and TDS (RWQCB 2017). Prior to amendment of the Water Quality Control Plan for the de-designation of MUN and AGR use of groundwater in areas of poor water quality in the Subbasin, characterization studies were conducted to evaluate the potential for the migration of poor water quality from the de-designated areas or the capture of poor quality water by wells near the de-designated area (KDSA et. al. 2015). The results of these characterization studies are summarized in RWQCB Resolution R5-2017-0032 as follows: basin-wide groundwater flows to the center of the Tulare Lakebed, poor water quality is present in a shallow saline aquifer above the Corcoran Clay, and better water quality is present in the aquifer located below the Corcoran Clay.

Data Gap: The available data from GeoTracker and other public sources generally do not distinguish groundwater quality by aquifer zone. Therefore, the depth intervals for water quality data presented in Figures discussed above are unknown and represent a data gap. Well completion data should be reviewed to potentially identify completion intervals for the reported wells, and subsequent water quality samples should only be collected from wells with known construction.

3.2.6 Land Subsidence

Alluvial aquifer systems including those found in the San Joaquin Valley typically consist of a granular mineral skeleton of sand, silt, and clay, and pore-spaces filled with water (LSCE 2014). When water is withdrawn (i.e., pumped) from an aquifer, the fluid pressure in the pore space, also known as pore pressure, is reduced and the weight of the overlying materials must be increasingly supported by the granular mineral skeleton of the aquifer system. As the pressure on the granular skeleton including effective stress increases, some compression of the aquifer system skeleton may occur causing elastic deformation. When the effective stress exceeds the previous maximum effect stress on the aquifer skeleton (pre-consolidation stress) then some rearrangement of the mineral grains, typically clays, may occur and result in permanent compaction resulting in inelastic deformation. For individual thin clay lenses, the amount of compaction is relatively small. However, the combined compaction of many clay lenses within an aquifer system can result in significant subsidence at the ground surface.

Land subsidence due to groundwater withdrawals and associated drawdown has been well documented and has affected significant areas of the San Joaquin Valley since the 1920s, including the Subbasin (Wood 2017). Between 1926 and 1970, there was approximately 4 feet of cumulative subsidence near Corcoran, 4 to 6 feet of subsidence near Hanford, and as much as 12 feet of subsidence near Pixley (Figure 3-34). Following the completion of the SWP and CVP, surface water became more readily available in the San Joaquin Valley and groundwater extraction was reduced and groundwater levels recovered. As a result, subsidence due to groundwater withdrawal was temporarily slowed or stopped.

Groundwater pumping has since increased in the San Joaquin Valley in the past 10 to 25 years due to several factors including the planting of permanent crops and a reduction of available imported surface water. At the same time, some existing wells were deepened or the pumps were lowered, and new wells were installed into deep, previously un-pumped and unconsolidated portions of the confined aquifer beneath the Corcoran Clay. Pumping from the confined aquifer eventually exceeded the pre-consolidation stress of the aquifer system, resulting in the resumption and acceleration of compaction of the fine-grained sediments in the confine aquifer system and associated subsidence at the land surface.

Subsidence in the San Joaquin Valley was exacerbated during a moderate to severe drought from 2007 through 2009 and a severe to exceptional drought from 2012 through 2016. A Jet Propulsion Laboratory study of subsidence between June 2007 and December 2010 indicated subsidence rates were as high as 8.5 inches per year near Corcoran (Farr et al. 2015) (Figure 3-35a). A more recent study by Jet Propulsion Laboratory indicted subsidence rates accelerated in some areas during the recent drought, with annual subsidence rates of 1 to 1.5 feet near Corcoran in 2015-2016 (Farr et al. 2017) (Figure 3-35b).

Groundwater pumping and drawdown and consequent subsidence are anticipated to continue until withdrawals from the deep confined aquifer can be managed so that sustainable groundwater pumping is achieved. Most of the aquifer compaction is inelastic, so subsidence is mostly irreversible even if groundwater pumping decreases and groundwater level recover.

3.2.7 Surface Water Systems

The established surface water system is described in detail in Section 3.1.1.5. The historical conditions of surface water flow have been significantly altered by irrigation demand and flood control/reclamation projects since the turn of the 20th century. In pre-development in the 1800s, runoff from the southern Sierra Nevada Mountains south of the San Joaquin River south to Kern River collected in three terminal lakes: Tulare Lake, Kern Lake, and Buena Vista Lake. This internal drainage configuration created vast regions of adjoining Tule marshes and riparian woodland wetlands. Tulare Lake in the 1870s was reported to have an area of approximately 446,000 acres or 697 square miles and an elevation of about 200 feet AMSL (BCI 1874). The surface area of Tulare Lake was about 505,000 acres or 790 square miles at its highest overflow level of 216 feet AMSL. The lake level and its aerial extent fluctuated during wet and dry periods.

Prior to development, Tulare Lake received runoff from the major and minor streams of the Southern Sierra Nevada described in Section 3.1.1.5. Tulare Lake also received overflow from Buena Vista Lake which in turn received overflow from Kern Lake (Figure 3-36). The major rivers formed broad deltaic and alluvial fans as they flowed from the Sierra Nevada foothills into the San Joaquin Valley, creating multiple distributary channels and sloughs that shifted periodically, especially during flooding events.

Natural hydrology of the Subbasin has been altered over the last century for flood control, irrigation, land reclamation, and water conservation priorities. Concerns about flood control and water supplies resulted in the construction of Pine Flat Dam on the Kings River, Terminus Dam on the Kaweah River, Success Dam on the Tule River, and Isabella Dam on the Kern River. The modern-day surface water conveyances that supply the Subbasin are primarily man-made canals and streambeds.

3.2.8 Interconnected Surface Water and Groundwater Systems

Prior to development in the late 1800s and early 1900s, groundwater and surface waters were interconnected around the Subbasin, resulting in extensive wetlands, a nearly persistent Tulare Lake, and notable artesian aquifers indicating strong upward groundwater gradients (Figure 3-23 and 3-36). Groundwater levels were near the ground surface beneath much of the Subbasin, and as streams and rivers flowed from the Sierra Nevada foothills and Coast Ranges towards Tulare Lake, they geographically transitioned from losing streams which recharged underlying groundwater to into gaining streams which benefit from groundwater discharge (Figure 3-37).

During development, the four major rivers draining into Tulare Lake were dammed, and Tulare Lake itself was able to be reclaimed due to upstream irrigation demands. As a result, most streams and rivers draining into Tulare Lake became disconnected from the regional unconfined aquifer system. The 1952 potentiometric surface maps show the Kings River was a losing stream from the Sierra Nevada foothills to where it crossed SR 198 (Figure 3-24). South of SR 198 and north of Tulare Lake, groundwater contours converge indicating the lower reach of the Kings River may have gained water due to groundwater discharge. The Tule and Kaweah rivers were losing streams in 1952. Potentiometric surface maps from 1990 show that the Kings, Kaweah, and Tule rivers are all losing streams (Figure 3-26).

In the past 160 years, the expanded use of surface water and groundwater extraction have resulted in a significant lowering of the regional water table, causing isolation of surface waters from groundwater beneath most of the Subbasin. Shallow, perched groundwater often is present in the vicinity of surface water conveyances and below recharge facilities; however, these shallow zones are disconnected from the regional unconfined aquifer. Other localized shallow perched zones may exist elsewhere in the Subbasin, but these are not considered a significant source of groundwater.

Though surface water is not connected to groundwater in the Subbasin, shallow groundwater near the Kings River potentially responds to changes in river flows. As described in Chapter 5, the GSP monitoring plan recognizes that a data gap exists in this area to be filled with a shallow monitoring well. Data from shallow wells in this area, once they become available, will be evaluated to better understand the relationship between shallow groundwater above the A-Clay, flows in the Kings River, and shallow groundwater use. The need for additional monitoring of shallow groundwater in the future in this area will be evaluated by the GSAs.

3.2.8.1 <u>Groundwater Dependent Ecosystems</u>

Groundwater Dependent Ecosystems (GDEs) are ecosystems that rely upon shallow groundwater for their sustainability. Depletion of groundwater and lowering of the water table has detrimental effects on GDE existence. GDEs differ from surface water dependent wetlands because they are sustained by natural surface water or artificially conveyed surface water. In some instances, such as the Kern Wildlife Refuge at the southern border of the Subbasin, a wetland may be artificially maintained by conveyed surface water delivery and deep groundwater pumping. Historically, the

Tulare Lake region appears to have supported a mix of both GDEs and surface water dependent wetlands (Figure 3-37), which were mostly eliminated when upstream water diversions and impoundments drained the lake.

Remaining GDEs within the Subbasin were evaluated using the California Natural Resources Agency DWR Open Data "*Natural Communities Commonly Associated with Groundwater*" (NCCAG) database. The database contains two habitat indicators that could indicate the presence of GDEs: (1) wetland features commonly associated with surface expression of groundwater under natural unmodified conditions, and (2) vegetation types (phreatophytes) commonly associated with the subsurface presence of groundwater. It should be noted that this dataset does not represent DWRs determination of a GDE. However, it can be used as an initial screening tool for identifying GDEs within the Subbasin.

Figure 3-38 shows the distribution of remaining wetland features that could be associated with groundwater. Note how few wetlands remain compared to pre-development (Figure 3-37). The remaining wetland consists of semi-permanent/seasonally flooded lake shore wetlands; semi-permanent/seasonally flooded or saturated marsh land; and riparian seasonally or permanently flooded wetlands. The NCCAG database identified 23 species of phreatophytes and five vegetative habitats within the Subbasin that could be associated with GDEs (Figure 3-38). All listed wetlands and phreatophyte areas within ER GSA are not GDE's due to the lack of groundwater in the listed areas.

Most of these vegetation types/plant species are associated with riparian habitat that rely on percolation of imported surface water. Salt tolerant phreatophytes such as iodine bush, quail bush, alkali bulrush, curlyton knotweed, hardstem bulrush, shrubby seepweed, spinescale, alkali goldenbush, and tamarisk can be found in the alkali sink or in brackish water marsh habitat. These plants are typically found in areas of shallow perched groundwater with high salinity (Figure 3-38). The lateral extent of shallow perched groundwater is dependent on available recharge associated with surface water conveyances, occasional flood events, agricultural irrigation, evapotranspiration, and land reclamation in areas where tile subsurface drains have been installed. The subsurface tile drains have controlled groundwater elevations by subsurface drainage.

It is anticipated that the existing imported surface water supplies into the Subbasin will continue unabated into the foreseeable future and may even increase as additional water supply projects are developed. Hence leakage from the surface water conveyances will continue to seasonally recharge shallow groundwater in the vicinity of the existing riparian phreatophytes.

Limited studies have shown that groundwater pumping from the principal unconfined aquifer system in the immediate vicinity of the Kings River may induce limited drawdown (i.e., leakage) of shallow groundwater above the A-Clay into the regional aquifer system (P&P, 2009). The studies indicate that increased pumping does not significantly increase leakage, suggesting that the leakage rate primarily dependent based on the vertical conductivity of the A-Clay. It is anticipated that the groundwater pumping from the unconfined aquifer in the vicinity of existing riparian phreatophytes will not increase in the foreseeable future and may even decrease as additional water supply projects are developed. Hence, the combined effects of steady or increased surface water supplies and steady or decreased groundwater pumping in the vicinity of the existing riparian phreatophytes are not likely to adversely impact the availability of shallow groundwater in the vicinity of the existing riparian phreatophyte areas.

3.3 Water Budget Information

23 CCR §354.18(a) *Each Plan shall include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical form.*

This section provides a quantitative description of the water budget for the Subbasin including an account of the inflows, outflows, and changes in storage in the Subbasin aquifer system over time. This includes historical, current, and projected water budget and the changes in the Subbasin's storage. Within a subbasin, if total outflows exceed total inflows, both groundwater levels and groundwater in storage will decline, and the subbasin may be considered in a state of overdraft. When inflows and outflows are in balance, both groundwater levels and groundwater in storage will remain stable over time. Safe Yield is that volume of groundwater that may be utilized within a subbasin without long-term overdraft.

The historical water budget information will be utilized to estimate future conditions related to supply, demand, hydrology, and surface water supply reliability to construct a baseline forecast to understand future projected conditions and for development of management actions and projects.

As discussed more fully in Section 3.3.7.1, agriculture in the Subbasin is primarily dependent on surface water deliveries from the Kings River system, not precipitation. The annual surface water deliveries from the Kings River system to the Subbasin for the period 1966 through 2016 were used to calculate the long-term average surface water deliveries of approximately 627,710 acre-feet per year (AF/Y) without the 2012-2016 drought years. Within the 1990-2016 study period, the 1998-2010 interval has average surface water diversions of approximately 620,630 AF, very close to the long-term average of 627,710 AF/Y (excluding the drought years). Hence, the 13-year period from 1998 through 2010 may be considered a cycle of "normal hydrology" where the average Kings River surface water deliveries are near the long-term mean. The 1998-2010 "normal hydrology" period includes 1 average, 6 above-average, and 6 below-average surface water delivery years.

3.3.1 Inflows, Outflows, and Change in Storage

The Subbasin's water budget describes the inflows to and outflows from the Subbasin's hydrogeologic system. Inflow and outflow can occur from the hydraulic boundaries of the system, from various sources within the model domain such as inflow from adjacent subbasins, rainfall, lakes, and seepage from rivers and canals, and from the exit points such as wells, drainage systems, or outflow to adjacent subbasins. The boundaries, sources, and sinks identified within the model domain are discussed below.

3.3.1.1 Inflows

Inflows consist of precipitation, surface water diversions for irrigation, imported groundwater, lakebed storage, intentional recharge, seepage from streams and conveyances, and groundwater inflow from adjacent subbasins.

Precipitation

Precipitation can be a significant source of water to the Subbasin and surrounding area in wet years. Given the large areal extent of the Subbasin and surrounding area, it was determined using a single weather station to estimate precipitation would be inadequate to represent the entire Subbasin. Instead, the PRISM database maintained by the Oregon State University was used to estimate monthly precipitation from January 1990 through December 2016 across the Subbasin (Figure 3-39). The PRISM database contains monthly total precipitation for the entire United States using a 4-kilometer grid. The monthly precipitation values are statistically derived values based on local weather stations and corrections for topographic variations. The monthly precipitation data were summed by Subbasin area to estimate the potential annual precipitation volume (Figure 3-39).

Not all rainfall is available for use by crops – some falls on impervious surface, some is taken up by dry soils, some is intercepted by foliage and evaporates before it can infiltrate, and some deep percolates and recharges groundwater. Monthly effective precipitation was calculated by multiplying the monthly PRISM data sets by the Precipitation / Effective Precipitation ratios presented in the Food and Agriculture Organization 56 (Allen et al. 1998) (Table 3-1, Figure 3-40). Effective precipitation varies annually in the Subbasin (Figure 3-39). Between 1990 and 2016, the estimated volume of effective precipitation not utilized by crops (i.e., deep percolated) ranged from 430 AF in a dry year (2013) to 80,580 AF in a wet year (2010) and averaged approximately 23,700 AF/Y within the Subbasin.

Data Gap: The volume of effective precipitation utilized by crops, taken-up by soil, and deep percolated needs to be quantified across the Subbasin based on soil types and crops grown.

Surface Water Diversions

Surface water diversions from external sources are another significant source of water to the Subbasin. There are 34 rivers, streams, canals, and diversions entering and within the Subbasin that have recorded diversions (Figure 3-5). Surface water delivery and diversion records within the Subbasin for the past 50-years were obtained via direct contacts with the various GSAs and member water management agencies within the GSAs (Table 3-5). Between 1966 and 2016, surface water diversions ranged from 107,210 AF in a dry year (2015) to 1,056,880 AF in a wet year (1982) and averaged approximately 590,700 AF/Y of water across the Subbasin (Table 3-5). If the drought years of 2012-2016 are ignored, the long-term average is approximately 627,710 AF/Y.

Between 1990 and 2016, surface water diversions ranged from 107,210 AF in a dry year (2015) to 1,038,050 AF in a wet year (1996) and averaged approximately 559,440 AF/Y of water across the Subbasin (Table 3-5).

The surface water diversions are not delivered uniformly across the Subbasin and are highly variable by GSA with most surface water diversion going to the ER GSA and least amount of surface water going to TCWA GSA (Figure 3-41).

Data Gap: The volume of surface water delivered needs to be better quantified by parcel and GSA by month across the Subbasin.

Imported Groundwater Supply

One unique feature of the Subbasin is the importation of groundwater supplies from adjacent subbasins. Interests within the ER and TCWA GSAs operate well fields in the adjacent Tule Subbasin and import the pumped groundwater into the Subbasin as an additional water supply. Between 1990 and 2016, ER GSA operated up to 52 wells in the Creighton Ranch well field, which delivered up to 68,730 AF in a dry year (2014) and as little as 0 AF in wet years (1996-1999) and averaged approximately 39,320 AF/Y in non-wet years. The TCWA GSA operated up to 51 wells in the Angiola Water District (WD) well field, which delivered groundwater to SWK GSA and TCWA GSA lands in the Tulare Lake Subbasin (about 60%) and to TCWA GSA lands in Tule Subbasin (about 40%). Between 1990 and 2016, the Angiola WD well field delivered up to 23,100 AF in a dry year (2009) and as little as 0 AF in wet years (1996-1999) and averaged approximately 15,950 AF/Y in non-wet years (Figure 3-42).

Data Gap: The volume of groundwater imported and applied needs to be better quantified by parcel and GSA by month across the Subbasin.

Lake Bottom Water Storage

Another unique feature of the Subbasin is the utilization of certain portions of the historical lake for storage of surface water inflows, including flood waters. This stored surface water is used as an irrigation supply, thereby reducing long-term demand for groundwater. Tulare Lake storage is occurring mostly in the ER GSA management area and also in a small area of the TCWA GSA. There is no Tulare Lake storage in MKR GSA, SWK GSA, or SFK GSA areas.

Lake storage facilities have the capacity to store approximately 70,000 AF at any given time. During flood events, as an example of conjunctive use, some fields can be flooded allowing for the storage of significant volumes of water, in some years up to 450,000 AF in the ER GSA management area (Figure 3-42). When available, the storage water is typically utilized to supplement surface water deliveries in lieu of groundwater pumping.

Data Gap: The volume of water stored in surface impoundments and applied as surface water needs to be better quantified by parcel and GSA by month across the Subbasin.

Intentional Recharge

Groundwater recharge in the Subbasin also occurs from intentional percolation of surface water in storage ponds and water banks. Kings County WD has performed intermittent intentional recharge operation in 25 basins totaling about 720 acres throughout the MKR GSA when water is available. Kings County WD also has operated a water bank on the Old Kings River channel since 2002. Approximately 73,600 AF of water has been recharged over this 17-year period via percolation through approximately 150 acres of ponds (Figure 3-43), and approximately 48,500 AF have been recovered utilizing five recovery wells since 2002. This leaves a positive balance of approximately 25,100 AF in the aquifer system as of 2016.

As part of a lawsuit settlement, Kings County WD has been infiltrating Kings River flood waters along the Old Kings River channel since the 1940s (referred to as Condition 8 water). Condition 8 water is surface water that naturally would have infiltrated along an approximately 7.75-mile reach of the Old Kings River channel during high river flow years had the river not been diverted for irrigation. Between 1990 and 2016, Condition 8 recharge has ranged from as little as 0 AF in most years and as much as 36,800 AF in flood years (1995) and averaged approximately 30,370 AF/Y in wet years (Figure 3-43).

The Corcoran Irrigation District also owns and operates nine percolation basins totaling about 2,760 acres. Estimated percolation rates are about 0.25 ft/d. A review of aerial photographs suggests only one or two basins are typically utilized each year between March and September when surface water is available, percolating an estimated average of 23,500 AF/Y (Figure 3-43). During wet years, as much as 147,700 AF of water has been estimated to be percolated using these percolation basins.

In the Chamberlain Ranch area (ER GSA), 640 acres has been utilized for percolation basins. In 2017, approximately 5,000 AF was recharged.

Immediately adjacent to the eastern boundary of the ER GSA in the Tule Subbasin, there are recharge basins that are operated by ER GSA landowners. These recharge facilities are covered by a neighboring GSP.

Data Gap: The volume of intentional recharge needs to be better quantified by recharge facility by month across the Subbasin.

River and Canal Seepage

Seepage losses from river and canals provide another source of water to the Subbasin and surrounding areas. There are over 290 miles of major streams and canals within the Subbasin, in addition to many more miles of small distribution ditches on individual farms. Most of the stream and canals are unlined and can have significant seepage losses. Ownership of canal and river seepage is to be determined. There are a few anecdotal reports of seepage rates along a few reaches of some rivers and canals, but there are no known available seepage tests along the majority of the river and canal reaches in the Subbasin. Hence, river and canal seepage estimates are based on the calibrated groundwater model.

Between 1990 and 2016, seepage loss from rivers and streams are estimated to range between 60,440 AF in a dry year (2015) to 231,840 AF in a wet year (1993) and average approximately 141,360 AF/Y (Figure 3-44). Most of the seepage loss occurs on the Kings River in the MKR GSA and in the ER GSA (outside of the clay plug area) due to its size and number of canals delivering surface water to the GSA. The TCWA GSA management area has the lowest amount of seepage loss.

Data Gap: The volume of river and canal leakage needs to be better quantified by various river and canal reaches across the Subbasin.

Wastewater Treatment Plant Discharge

There are a number of small to mid-sized wastewater treatment plants (WWTPs) throughout the Subbasin operated by, including but not limited to, various cities, municipalities, the Department of Defense, Native American facilities, and manufacturing plants. At most of the WWTPs, treated wastewater is discharged into seepage ponds, used as recycled water, or utilized for irrigation by local farmers. The ratio of WWTP seepage to re-use is not well documented and needs further investigation.

Data Gap: The ratio of WWTP seepage to re-use is not well documented and needs further investigation. The volume of monthly WWTP seepage reaching groundwater needs to be better quantified by WWTP pond across the Subbasin.

Subbasin Boundary Groundwater Inflows

The Subbasin is located within the larger Tulare Lake Hydrologic Region and, except for the Kettleman Hills bordering the southwest potion of the Subbasin, the remaining Subbasin boundaries represent political not hydrogeological boundaries. As such. groundwater is free to move across political boundaries into or out of the Subbasin. Groundwater inflows represent groundwater entering the Subbasin across its boundary from adjacent subbasins. Groundwater flowing into the Subbasin is considered a net gain of groundwater and has the potential to increase available storage with the Subbasin (Table 3-6a). Total inflow into the Subbasin ranges from about 83,220 AF (2011) to 181,210 AF(1990) and averaged about 118,310 AF/Y (Figure 3-45). The highest inflows are from the Kings (197,84 AF/Y) and Kern (24,910 AF/Y) subbasins. The inflow from the Kern Subbasin is misleading in that most of the groundwater from the Kern Subbasin is entering through the southeast corner of the Subbasin and then flowing out into the Tule Subbasin.

In the Upper Aquifer, inflow into the Subbasin ranges from about 32,180 AF (2011) to 60,940 AF (1990) and averages about 43,980 AF/Y (Table 3-6b). In the Lower Aquifer, inflow into the Subbasin ranges from about 51,040 AF (2011) to 120,270 AF (1990) and averages about 74,330 AF/Y (Table 3-6c).

Total Subbasin Inflows

Total inflows into the Subbasin consists of precipitation, surface water imports, groundwater imports, applied pond storage (flood waters), intentional recharge, seepage losses from surface water conveyances, seepage losses from WWTPs, and subsurface inflows from surrounding subbasins. During the 1990-2016 period, estimated total inflow ranged from 1,070,860 AF (2015) to 2,203,450 AF(1990) and averages about 1,584,140 AF/Y. Water balance inflows are summarized annually on Table 3-7 by Land Surface Water Budget and Subsurface Water Budget. The Subsurface Water Budget is further divided by Upper and Lower Aquifer zones for groundwater pumping, interbasin flow, and change is storage.

3.3.1.2 Outflows

Outflows consist of evapotranspiration, agricultural pumping, municipal pumping, agricultural drains, and groundwater outflow to adjacent subbasins. Litigation is pending regarding the outflow of surface water from the Subbasin.

Evapotranspiration

Crop evapotranspiration (ETc) is the largest outflow of water from the Subbasin. ETc varies seasonally and by crop type, typically peaking during the summer months (ITRC 2003). DWR crop data sets from 1995, 1998, and 2006 were used to estimate crop acreage on a 40-acre spacing from 1990 to 2006 throughout the Subbasin. Starting in 2007, CropScape started producing annual estimates of crop acreage on a 40-acre spacing. Annual crop demand was calculated for each crop type on a 40-acre basis as follows:

Annual Crop Acreage (acres) * Annual Crop ETc (feet/yr) = ET_Demand (AF/Y)

Note some crop types do not receive irrigation water and have zero crop irrigation demand (Table 3-8). Crop irrigation demand, also referred to as farm demand was calculated as follows to account for this variable:

(Crop ET-Demand (AF/Y) – Effective Precipitation (AF/Y)) / Irrigation Efficiency (percent) = Farm Demand (AF/Y)

Between 1990 and 2016, the total farm irrigation demand in the Subbasin ranged from approximately 624,650 AF (2015) to 1,232,450 AF (1999), with an average crop irrigation demand of approximately 1,018,560 AF/Y over this 26-year period (Table 3-6a) (Figure 3-46). As shown in the DWR and CropScape data sets, the mix of crops grown and fallow lands has changed over time as agricultural practices were altered. A chart of annual crop demand shows total crop water demand has generally decreased since 2000 (Table 3-8). For example, cotton showed the most change with a decrease of near 50% between 1995 and 2016. Annualized tables and charts of crop demand for the Subbasin's GSAs are presented in the Model Report in Appendix D.

Data Gap: Crop distribution maps are not available for all years of the study period and those that are available may not capture double cropping or multi-cropping areas. Likewise, estimating ET demand based on typical crop evapotranspiration (ETc) data and assumed irrigation efficiencies may lead to errors in estimated demand. Better quantification of monthly Farm Demand is needed on a parcel and GSA basis across the Subbasin.

Municipal Pumping Demand

Municipal pumping of groundwater occurs in the Subbasin by the communities of Hanford, Lemoore, Armona, Stratford, and Corcoran (Table 3-4). Between 1990 and 2016, reported municipal pumping has ranged from 9,110 AF (1991) to 26,700 AF (2002) and averaged 14,910 AF/Y over this 26-year period (Figure 3-47). The municipal pumping demand varies seasonally, peaking in the summer months.

Agricultural Pumping Demand

Agricultural pumping is typically not recorded over much of California, including the Subbasin. However, agricultural pumping demand on a 40-acre spacing can be estimated as follows:

Farm Demand (AF/Y) – Surface Water Deliveries (AF/Y) = Un-Met Demand (AF/Y)

Un-Met Demand (AF/Y) – Return Flows (AF/Y) – Lake Bottom Water Storage (AF/Y) = Ag_Pumping Demand (AF/Y)

Where: Return Flows are recycled unused surface water
Lake Bottom Water Storage is surface water deliveries or flood waters stored in ponds

The Agricultural Pumping Demand per 40-acre spacing can then be summarized by each GSA (Figure 3-47). Although this simple water balance approach does not account for the areal distribution of surface water diversions or farm delivery requirements, it does provide a reasonable estimate of agricultural pumping in the Subbasin and GSA-specific scale. Based on this analysis, pumping demand in the Subbasin from 1990 through 2016 has ranged from 77,680 AF (2011) to 618,840 AF (1990) and averaged 318,410 AF/Y over this 26-year period (Table 3-6a, Figure 3-47).

In the Upper Aquifer, estimated pumping in the Subbasin ranges from about 126,310 AF (2011) to 363,970 AF (1990) and averages about 246,814 AF/Y (Table 3-6b). In the Lower Aquifer, estimated pumping in the Subbasin ranges from about zero AF (2011) to 254,870 AF (1990) and averages about 134,595 AF/Y (Table 3-6c).

Data Gap: The lack of accurate data regarding the location, completion intervals, and monthly pumping data for most agricultural water supply wells is likely the most significant data gap in the Subbasin. Accurate information regarding the location, completion intervals, and monthly pumping for the agricultural supply wells in the Subbasin would eliminate the need to estimate agricultural pumping based on assumed crop demand and would significantly reduce uncertainty in the Subbasin water balance. Better quantification of monthly agricultural pumping is needed on a parcel and GSA basis across the Subbasin.

Agricultural Drains

Agricultural drains are used beneath several areas of the Subbasin to keep soil from becoming waterlogged in the root zone by return flows. Typically, a tile or French drain system is used with tiles buried approximately 4 to 6 feet bgs draining to sumps. Subsurface drainage collected in the sumps is pumped via pipeline to evaporation basins. Locations vary of subsurface drains and evaporation basins within the Subbasin (Figure 3-22). Agricultural drainage volume were not available and were estimated with a numerical model. Between 1990 and 2016, estimated groundwater withdrawal from agricultural drains ranged from 0 to about 20,850 AF (2004), and averaged 5,720 AF/Y. These estimates may be low. Most of the agricultural drainage is occurring in the ER and TCWA GSAs (Figure 3-48). Between 1990 and 2016, the ER GSA estimated agricultural drain withdrawals ranged from 0 to 20,590 AF (2004) and averaged about 5,440 AF/Y. The TCWA GSAs groundwater withdrawals from drains ranged from about 0 to 1,190 AF (2008) and averaged about 54 AF/Y. Table 3-6a shows the contribution of agricultural drainage to the overall water balance.

Data Gap: The use and operation of agricultural drains in the Subbasin is not well documented and needs further investigation. The volume of monthly drain discharge needs to be better quantified by GSA across the Subbasin.

Subbasin Boundary Groundwater Outflows

The Subbasin is located within the larger Tulare Lake Hydrologic Region, and with the exception of the Kettleman Hills bordering the southwest portion of the Subbasin. Groundwater outflows represent groundwater exiting the Subbasin across its boundary in to adjacent subbasins. Groundwater flowing out of the Subbasin is considered a net loss of groundwater and has the potential to reduce available storage with the Subbasin (Table 3-6a) (Figure 3-49). Outflow from the Subbasin ranges from about 111,280 AF (1990) to 160,350 (2016) AF, and averaged 136,520 AF/Y. The largest outflows are to the Kaweah, Kings, and Tule subbasins.

In the Upper Aquifer, outflow from the Subbasin ranged from about 42,520 AF (1993) to 60,070 AF (2016) and averaged about 43,980 AF/Y (Table 3-6b). In the Lower Aquifer, outflow from the Subbasin ranged from about 58,790 AF (1990) to 100,470 AF (2014) and averaged about 86,980 AF/Y (Table 3-6c).

Total Subbasin Outflows

Total outflows into the Subbasin consists of evapotranspiration, well pumping, agricultural drains, and subsurface outflows to surrounding subbasins. During the 1990-2016 period, estimated total outflow ranged from 1,529,580 AF (2015) to 2,783,110 AF (1990) and averaged about 1,968,130 AF/Y. Water balance outflows are summarized annually on Table 3-7 by Land

Surface Water Budget and Subsurface Water Budget. The Subsurface Water Budget is further divided by Upper and Lower Aquifer zones for groundwater pumping, interbasin flow, and change is storage.

3.3.2 Annual Change in Groundwater Storage

Change in groundwater storage within an aquifer is the difference between the sum of the inflows and the sum of the outflows. An increase in aquifer storage results when the sum of the inflows exceeds the sum of the outflows. Conversely, a decrease in storage results when the sum of the outflows exceeds the sum of the inflows. When inflows equal outflows, no change in storage occurs. With a large basin such as the Subbasin, localized variability in the inflows verses the outflows may occur in areas where groundwater storage increases during a specific water year while conversely in other areas a decrease in storage may occur within the Subbasin. An example of this variability could be attributed to areas where recharge basins may be located as opposed to areas where heavy groundwater pumping may be occurring. During the 1990-2016 period, estimated total annual change in storage in the Subbasin storage ranged from -392,280 AF (2015) to 361,230 AF (2011) and averaged about -85,690 AF/Y over this 26-year period (Table 3-6a, Figure 3-29a).

In the Upper Aquifer, estimated total annual change in storage in the Subbasin ranged from about -392,440 AF (1990) to 197,340 AF (2011) and averaged about -142,210 AF/Y (Table 3-6b, Figure 3-29b). In the Lower Aquifer, estimated total annual change in storage in the Subbasin ranged from about -113,050 AF (2014) to 275,064 AF (1993) and averaged about 56,520 AF/Y (Table 3-6c, Figure 3-29c).

3.3.3 Quantification of Overdraft

As defined by DWR, overdraft occurs where the average annual amount of groundwater extraction exceeds the long-term average annual supply of replenishment to the basin (DWR 2016b). Effects of overdraft can include land subsidence, groundwater depletion, and degradation of water quality and/or chronic lowering of groundwater levels. DWR Bulletin 118 defines critical overdraft as "*when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts*" (DWR 2016b).

The Subbasin sits at the lowest point of the Tulare Lake Hydrologic Region and receives both surface water inflows from several streams including Kings River, Kaweah River, St. Johns River, Tule River, and Deer Creek as well as the SWP. Nonetheless in some years, especially during extended drought cycles (e.g., 2012-2016), agricultural water demand exceeds the surface water inflows. This has led to the drilling of wells to develop groundwater resources to fulfill unmet water demand. Under recent historical conditions the average annual outflow exceeded the average annual inflow.

Overdraft is estimated using the historical water balance record beginning at the time when the net change in storage became negative, lasting over a period with no significant recovery in storage. As discussed in Sections 3.3.1.1 and 3.3.7.1, the period 1998-2010 represents a “normal hydrology period” with average surface water deliveries that were close to the long-term average surface water deliveries not counting the 2012-2016 drought. As such, the 1998-2010 period is a better for estimating the long-term “normal hydrology” than the 1990-2016 period which includes the exceptional drought.

Estimated overdraft (change in storage) was calculated over the Normal Hydrology Period of 1998 to 2010 and ranged from -296,280 AF (2008) to 220,649 AF (2006) and averaged about –73,760 AF/Y over this 13 year period (Table 3-6a, Figure 3-50a).

In the Upper Aquifer, estimated overdraft in the Subbasin was calculated over the Normal Hydrology Baseline Period of 1998 to 2010 and ranged from about -222,720 AF (2001) to 117,740 AF (2006) and averaged about -103,180 AF/Y (Table 3-6b, Figure 3-50b). In the Lower Aquifer, estimated overdraft over the Normal Hydrology Baseline Period ranged from about -85,580 AF (2008) to 136,360 AF (1998) and averaged about 29,410 AF/Y (Table 3-6c, Figure 3-50c). The Subbasin has been divided into management areas consisting of individual GSAs to quantify overdraft in each GSA area. The overall change in storage within the Subbasin and individual GSA management areas was calculated using the groundwater model. Table 3-6a-c and Figures 3-50a-c shows the annualized amount of overdraft in each GSA management area and the Subbasin for the total aquifer system, upper aquifer, and, lower aquifer.

3.3.4 Estimate of Sustainable Yield

Sustainable Yield is defined as the maximum quantity of water calculated over long-term conditions in the Subbasin including any temporary excess that can be withdrawn over a period of time without causing an undesirable result. Sustainability indicators are evaluated to determine when significant and unreasonable results occur indicating an exceedance in sustainable groundwater yields within the basin.

As presented in Chapter 4, the primary undesirable results of concern in the Subbasin are chronic lowering of groundwater levels, loss of groundwater storage, and subsidence. These undesirable results are all reflected in some way through the change in groundwater storage in the Subbasin.

Hence, an estimate of sustainable yield has been developed by examining the causes and magnitude of changes in storage in the Subbasin.

As shown on Land Surface Water Budget (Table 3-7), the estimated applied pumped groundwater for irrigation for the 1998-2010 "normal hydrology" period averaged about -348,700 AF/Y. During the same period, the Subsurface Water Budget (Table 3-7) indicates that the total estimated deep percolation (deep infiltration of applied water, stream leakage, and intentional recharge) averaged about 335,360 AF/Y. This is a difference of only -13,340 AF/Y. In other words, net recharges off-sets about 96% of total groundwater pumped for irrigation from the Subbasin. Hence, within the Subbasin, net recharge and net agricultural pumping are in near balance.

The Subsurface Water Budget also shows that during the 1998-2010 "normal hydrology" period net subsurface interbasin outflows from the Subbasin averaged about -24,290 AF/Y or about 33% of the average change in storage (i.e., overdraft) in the Subbasin of about 73,770 AF/Y (Table 3-7). The outflows can be attributed to increased groundwater pumping in the surrounding subbasins, which is beyond the control of the GSAs in the Subbasin. Hence, the overdraft in the Subbasin during the 1998-2010 "normal hydrology" period resulting from actions within the Subbasin is approximately -49,480 AF/Y (-73,770 AF/Y + 24,290 AF/Y).

As indicated above, during the 1998-2010 "normal hydrology" the difference between average applied groundwater for irrigation (-348,700 AF/Y) and average net recharge (335,360 AF/Y) differs by only about -13,340 AF/Y. During this same period, the estimated overdraft due to agricultural pumping in the Subbasin averaged about -49,480 AF/Y. If agricultural pumping were reduced by an average of 49,480 AF/Y to about -229,220 AF/Y, the net change in storage should be close to zero or possibly positive. Hence, the current estimate of long-term sustainable yield for agricultural pumping is approximately -229,220 AF/Y over the historical average of 310,792 acres of irrigated land (Table 3-2) in the Subbasin.

3.3.5 Current Water Budget

The current water budget is represented by the last full calendar year (2016) in which data are available. Estimated values for 2016 include: farm demand 67,794 AF, surface water supply 227,760 AF, imported groundwater 70,860 AF, pumping groundwater 428,423 AF, net recharge 154,700 AF, and net interbasin flow of -58,250 AF. Total outflows of -588,770 exceed total inflows of 256,800 AF, resulting in a change in storage of -294,320 AF. The current water budget for this period is summarized on Table 3-7 by Land Surface Water Budget and Subsurface Water Budget. The subsurface water budget is further divided by Upper and Lower Aquifer zones for groundwater pumping, interbasin flow, and change is storage.

3.3.6 Historical Water Budget

The historical water budget for the Subbasin covers a period of 27 years extending back to 1990 and is based on the set of available data records. Precipitation records span a period from 1899 to 2017 (Table 3-1). Evapotranspiration from the nearest California Irrigation Management Information System station covers a period of October 1982 through 2018. Surface water delivery data from the SWP is available since 1966, and GSA surface water delivery data on their canal systems are available since 1990. State and Tulare County land use records are available from 1990 to 2006 updated at 5-year intervals. USDA CropScape annual cropland data are available from 2007 to 2017. Groundwater pumping demand is based on both records of municipal pumping and projected rates of agricultural pumping as described in Section 3.3.1.2 from 1990 to the present. The historical water budget has been discussed in previous Sections 3.3.1 through 3.3.4 and is summarized annually on Table 3-7 for land surface water budget and subsurface water budget. The Subsurface Water Budget is further divided by Upper and Lower Aquifer zones for groundwater pumping, interbasin flow, and change in storage.

Subbasin inflows and outflows are calculated in the calibrated groundwater model based on general head boundary conditions that include groundwater elevations and groundwater flux. These are estimated based on historical groundwater elevations measured in wells at or near the Subbasin boundary and estimates of aquifer hydraulic parameters such as hydraulic conductivity, aquifer thickness.

Historical change in storage as described in Section 3.3.2 is the net difference between the inflows and the outflows. Change in storage is summarized annually on Table 3-7 by Subsurface Water Budget. The Subsurface Water Budget is further divided by Upper and Lower Aquifer zones for groundwater pumping, interbasin flow, and change is storage.

3.3.6.1 Historical Demands and Sustainability

Historical water conditions that affect sustainable yields include: (1) population growth in urban centers, 2) changes in agricultural demand, and 3) availability of surface water. Average agricultural water demand comprises 96% of total water use within the Subbasin, while urban use comprises 4%. Surface water deliveries have varied over time with a peak of 1,036,880 AF in 1996 to a low of 107,070 AF in 2015.

A review of U.S. Census Bureau data indicates the Kings County area exhibited a population of 151,336 as of 2018 (U.S. Census Bureau 2018) with a growth of approximately 48,632 people between 1990 and 2017, with most growth occurring in the Hanford-Lemoore area. The major urban areas saw increases in population of 25,602 people in Hanford, 12,733 people in Lemoore, and 8,471 people in Corcoran, accounting for 96% of the population growth in Kings County. These communities rely solely on groundwater for water supply. Estimates of urban pumping within the GSP area increased from 9,370 AF in 1990 to 18,410 AF in 2013 (Table 3-4). Reported urban pumping decreased during 2014-2016 in response to the drought.

Historical annual agricultural pumping demand of groundwater within the Subbasin is an estimated parameter dependent on several water balance components. It is dependent on crop type and the amount of row crops fallowed in a given year due to limited availability of surface water resources or economic circumstance. Historical agricultural pumping demand is calculated based on crop coefficient multiplied by reference evapotranspiration yielding crop evapotranspiration. Farm water demand is crop evapotranspiration minus effective precipitation divided by the irrigation efficiency of the irrigation method. Agricultural pumping is farm water demand minus applied surface water minus imported groundwater. Different crop types have different water requirements and changes in cropping pattern affect the amount of agricultural demand within the Subbasin. Historical crop demand is shown in tables and graphs in the Model Report in Appendix D. As shown by the tables and graphs, overall groundwater usage for agriculture has remained the top water user in the Subbasin and has varied over time since 1990 due surface water availability, climatic conditions, and other factors.

Heavy groundwater demand is directly associated with years of limited surface water supply. Fallowing of row crops during drought years offsets this increased demand to some extent. The relationship between available surface water deliveries, groundwater pumping, and crop demand impacts the water budget (Figure 3-51).

3.3.7 Projected Water Budget

The projected water budget for the Subbasin represents a hypothetical forecast for the 54-year period from 2017 through 2070 based on an assumed “normal hydrology” period and estimated future climate change impacts. This forecast provides the Subbasin’s GSAs with a tool to allow flexibility in groundwater management and planning of sustainability projects. The projected water budget is based on current baseline conditions of groundwater and surface water supply, water demand, and aquifer response to allow for implementation of groundwater management and projects implemented under the GSP. Groundwater modeling of the forecast conditions will be used to evaluate long-term groundwater flow trends, change in storage, and long-term groundwater sustainability under different forecast conditions and proposed groundwater sustainability projects conducted by individual GSAs.

Increases in urban population increased demand for groundwater resources within these communities. The estimated 2018 population of Kings County of 151,366 is expected to reach

181,218 by the year 2035 (DOF 2019). Continued urban population growth will likely increase the demand on groundwater resources. Some of the increase in urban demand will be offset by the conversion of agricultural land into housing; however, urban demand will continue to incrementally increase water demand unless future aggressive water conservation is implemented. Additional surface water sources or improved management of groundwater resources (e.g., increased recharge) could help offset increased urban water demand. Municipal pumping was assumed to increase slowly from about 25,060 AF (2017) to about 30,160 AF (2070).

Data Gap: Better estimates of urban demand growth should be developed for the forecast models.

3.3.7.1 Establishment of the Normal Hydrology Baseline Period

Long-term precipitation records are often used to evaluate hydrologic cycles for watersheds and subbasins. Typically, the cumulative departure from the long-term mean precipitation is used to evaluate hydrologic trends. Periods where the cumulative departure starts and ends near the long-term mean are often considered a “normal” cycle. This approach is appropriate to use where the hydrologic cycle is dominated by precipitation. However, agriculture in the Subbasin is primarily dependent on surface water supplies not precipitation. Surface water deliveries to the Subbasin is dominated by deliveries from the Kings River system. The Kings River flows are managed by Pine Flat dam, so surface water deliveries on the Kings River do not necessary follow precipitation. For example, annual precipitation in the City of Hanford was 15.13 inches and 9.16 inches during 2010 and 2011, respectively. However, surface water deliveries from the Kings River were the reverse, at 706,100 AF and 1,037,100 AF during 2010 and 2011, respectively.

The Kings River surface water deliveries are the largest and most consistent source of surface water to the subbasin. There are occasional surface water (or flood water) deliveries to the Subbasin from the Kaweah River, St. Johns River, Tule River, Deer Creek, and the SWP, but these are relatively small compared to the Kings River deliveries. Therefore, surface water deliveries from the Kings River were used to evaluate the long-term hydrology of the Subbasin.

Annual surface water deliveries from the Kings River system to the Subbasin for the period 1966 through 2016 were used to calculate the long-term average surface water deliveries of approximately 590,700 AF/Y including the recent drought years. A plot of the annual surface water deliveries and cumulative departure shows that Kings River hydrology and associated water deliveries fluctuate widely depending upon snow pack and rainfall (Figure 3-52). As discussed in Sections 3.3.1.1 and 3.3.7.1, the period 1998-2010 represents a “normal hydrology baseline period” with average surface water diversions of approximately 620,630 AF, close to the long-term average of 627,710 AF/Y without the 2012-2016 drought years. The cumulative departure from average surface water deliveries shows, although the period between

1994 and 2016 starts and ends at the long-term mean, it would not be considered a "normal hydrology" period because it includes a part of an exceptional drought from 2012 to 2015 (Figure 3-52). Instead, a downward offset of the historical cumulative departure shows the 13-year period from 1998 through 2010 represents a period of "normal hydrology baseline period " cycle where the average is near the long-term mean (Figure 3-52).The 1998-2010 baseline period includes 1 average, 6 above-average, and 6 below-average surface water delivery years (Figure 3-52).

3.3.7.2 Normal Hydrology Forecast Period

During the 13-year 1998-2010 normal hydrology baseline period, Kings River surface water deliveries averaged about 620,633 AF/Y, just slightly below (1.13%) the 50-year long-term average of 627,710 AF/Y not including the 2012-2016 drought. These historical surface water deliveries used for the forecast were reduced to account for the permanent transfer of some SWP contracts out of the Subbasin.

The resulting 13-year "normal hydrology" cycle was used to create a 54-year forecast of future Kings River hydrology from 2017 through 2070. When the forecast was constructed in mid-2018, 2017 was already a known "wet" year with about 170% of Kings River flow, and 2018 was shaping up to be a relatively normal year. Hence, the 2017-2070 forecast was constructed using 2011 and 2010 as analogs for the 2017 and 2018 hydrology. The 13-year "normal hydrology" cycle was then repeated four times to complete the 54-year forecast (Figure 3-52).

3.3.7.3 Climate Change

The DWR provides guidance on how to incorporate climate change into hydrology forecasts. There are two basic approaches that have been used to simulate climate change in water resource modeling: (1) transient analysis and (2) climate period analysis (DWR 2018).

In a transient analysis, the climate change signal strengthens incrementally over time. In general, years further into the future are warmer than years closer to the beginning of the simulation, and the most severe changes to climate tend to occur toward the later years of the simulation. In California, where monthly precipitation variability is extreme, transient analysis can be difficult to interpret. In a transient analysis, monthly variability can completely obscure the climate change signal because each year of the simulation has both monthly variability and a climate change signal, making it difficult to determine which is causing shifts in precipitation.

In a climate period analysis, climate change is modeled as a shift from a baseline condition, usually historically observed climate where every year or month of the simulation it is shifted in a way that represents the climate change signal at a future 30-year climate period. Climate period analysis provides advantages in this situation because it isolates the climate change signal independent of the monthly variability signal. In a climate period analysis, monthly variability is based on the reference period from which change is being measured, meaning that all differences between the future simulation and the reference period are the result of the climate change signal alone.

Climate period analysis was utilized to modify the 54-year forecast of “normal hydrology” to account for future climate change. The 2017-2070 forecast incorporates climate period analysis using the 2030 and 2070 monthly change factors (CNRA 2018) for each forecast analog month (Figure 3-52). The 2030 monthly change factors were applied to the forecast months January 2017 through December 2030. The 2070 monthly change factors were applied to the forecast months January 2031 through December 2070. There is a notable increase in magnitude of the 2070 change factors compared to the 2030 change factors. This tends to result in wetter wet-periods and dryer dry-periods compared to the 2030 change factors. However, the 2070 climate change factors tend to average just 0.999 or just below average while the 2030 climate change factors tend to average about 1.011 times higher than average. As a result, the 2030 climate change factors tend to have a greater impact on long-term forecasts than do the 2070 climate change factors.

A chart of forecast Kings River surface water deliveries shows a comparison of annual normal forecasts, annual normal forecast with climate change, and the difference in annual surface water deliveries between the with- and without-climate change forecasts (Figure 3-52). The figure shows future climate change may, using the DWR mandated assumptions, result in more Kings River flows in some years, and less flow in other years compared to the baseline conditions.

3.3.7.4 <u>54-Year Forecast Hydrology with Climate Change</u>

The climate change factors were also applied to 54-year forecasts of monthly inflows (effective precipitation, SWP surface water deliveries, lake storage, and canal and river seepage) and outflows (agricultural demand) for the “normal hydrology” forecast. Outflows due to agricultural demand were based on current cropping patterns and account for maturing of young permanent tree crops and the replanting of tree crops on a 25-year cycle (except pistachios, which have a life span approaching 100 years). This methodology allows for the fallowing and replanting of non-permanent crops due to historical response of available surface waters.

3.4 Management Areas

> **23 CCR §354.20(a)** *Each Agency may define one or more management areas within a basin if the Agency has determined that creation of management areas will facilitate implementation of the Plan. Management areas may define different minimum thresholds and be operated to different measurable objectives than the basin at large, provided that undesirable results are defined consistently throughout the basin. (b) basin that includes one or more management areas shall describe the following in the Plan:*
>
> *(1) The reason for the creation of each management area.*
> *(2) The minimum thresholds and measurable objectives established for each management area, and an explanation of the rationale for selecting those values, if different from the basin at large.*
> *(3) The level of monitoring and analysis appropriate for each management area.*
> *(4) An explanation of how the management area can operate under different minimum thresholds and measurable objectives without causing undesirable results outside the management area, if applicable.*
> *(c) If a Plan includes one or more management areas, the Plan shall include descriptions, maps, and other information required by this Subarticle sufficient to describe conditions in those areas.*

In order to facilitate implementation of the GSP, management areas have been created for the Subbasin. There are five Primary Management Areas and two Secondary Management Areas. Each of these types of management areas are described in the following sections.

3.4.1 Primary Management Areas

Primary Management Areas have been formed from each of the five GSAs. (Figure 3-53). The formation of Primary Management Areas will facilitate data management and assist with the implementation and management of the GSP. Furthermore, each GSA has unique surface water and groundwater allocations and usage, and they are best positioned to develop BMPs and development of groundwater sustainability projects.

Minimum thresholds and measurable objectives developed for each GSA management area described in Chapter 4 will be based on the groundwater conditions within each individual GSA management area.

Groundwater data collected from each GSA will be entered into a Data Management System to facilitate analysis of measurable objectives and undesirable results. A groundwater model has been developed for the Subbasin and adjacent areas to assist sustainable groundwater management in and between individual GSAs. Each GSA will coordinate with adjacent GSAs and adjacent subbasins to monitor within the San Joaquin Valley Basin if undesirable results in the adjacent managements areas are being contributed to by activities within that GSAs management area. The GSAs will coordinate corrective action, if necessary.

3.4.2 Secondary Management Areas

Two Secondary Management Areas have been formed for the Subbasin (Figure 3-53). These two Secondary Management Areas are different from the Primary Management Areas and each other due to distinctly different groundwater conditions in each area. These two areas are the Clay Plug (Management Area A) and the Southwest Poor Quality Groundwater Secondary Management Area (Management Area B).

3.4.2.1 Clay Plug

The Tulare Lake clay layers are a significant controlling factor for groundwater movement in the Subbasin. The clay plug does not transmit groundwater and is a hydrologic "dead" zone. As such, the area has never been developed for groundwater extraction. The southern portion of Tulare Lake deposition is made up of continuous lacustrine deposits extending like a tap root through the interior portions of the lake to the top of the San Joaquin Formation, which is 2,600 to 3,000 feet bgs (Figures 3-14a-c). The area with continuous lacustrine sediments from the surface to the underlying San Joaquin Formation is roughly 23 miles long by 12 miles wide. These sediments of continuous lacustrine deposits is called the clay plug. The clay plug does not transmit groundwater and is a hydrologic "dead" zone. As such, the area has never been developed for groundwater extraction.

Prior to amendment of the Water Quality Control Plan for the de-designation of MUN and AGR use of groundwater in areas of poor water quality in the Subbasin, characterization studies were conducted to evaluate the potential for the migration of poor water quality from the de-designated areas or the capture of poor quality water by wells near the de-designated area (KDSA et. al. 2015). The results of these characterization studies are summarized in RWQCB Resolution R5-2017-0032 as follows: basin-wide groundwater flows to the center of the Tulare Lakebed, poor water quality is present in a shallow saline aquifer above the Corcoran Clay, and better water quality is present in the aquifer located below the Corcoran Clay.

A zone-of-capture analysis was also completed that determined if areas outside of the proposed de-designated areas could extract groundwater from within the de-designated area. The results indicated that wells near the horizontal boundary would not draw water from within the proposed de-designated area nor influence groundwater flow direction (RWQCB 2017b). The characterization studies and the zone-of-capture analyses confirmed that no active wells in the fringe areas will draw water within the proposed de-designation area zone nor be impacted by groundwater from within the proposed de-designated zone.

Because this area, due to its historical depositional environment, is isolated from the regional groundwater flow regime in the Subbasin, it is being treated differently than other areas for monitoring purposes and the establishment of compliance points.

3.4.2.2 Southwest Poor Quality Groundwater

As described in Section 3.2.5 and shown on Figure 3-30, groundwater in the southwest corner of the Subbasin contains very high TDS concentrations. The groundwater in this area has poor water quality and limited supply. This is evidenced by that fact that there are no agricultural wells in the area, and due to the lack of water supply development, it is being treated differently than other areas for monitoring purposes and the establishment of compliance points.

4.0 SUSTAINABLE MANAGEMENT CRITERIA

23 CCR §354.22 *This Subarticle describes criteria by which an Agency defines conditions in its Plan that constitute sustainable groundwater management for the basin, including the process by which the Agency shall characterize undesirable results, and establish minimum thresholds and measurable objectives for each applicable sustainability indicator.*

The Sustainable Groundwater Management Act (SGMA) defines sustainable groundwater management as the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results. The avoidance of undesirable results is important to the success of Groundwater Sustainability Plan (GSP) implementation. Development of the sustainable management criteria for the Tulare Lake Subbasin (Subbasin) was based on available information and data developed for the Hydrogeologic Conceptual Model (HCM), the characterization of groundwater conditions, and the water budget (DWR 2017b).

Sustainable management criteria include:

- Sustainability Goal
- Undesirable Results
- Minimum Thresholds (MTs)
- Measurable Objectives (MOs)

These criteria for the Subbasin were developed through the assessment of sustainability indicators and the identification of significant and unreasonable conditions for each of the indicators. The indicators are measured at representative monitoring sites in each management area of the Subbasin.

Sustainability Indicators

Sustainability indicators are the effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, become undesirable results. Under SGMA, sustainability indicators and the undesirable results that can occur for each indicator, are:

- Chronic lowering of ***groundwater levels*** indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon.
- Significant and unreasonable reduction of ***groundwater storage***.
- Significant and unreasonable ***seawater intrusion***.
- Significant and unreasonable degraded ***water quality***, including the migration of contaminant plumes that impair water supplies.

- Significant and unreasonable **land subsidence** that substantially interferes with surface land uses.
- Depletions of ***interconnected surface water*** that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

While the default position under SGMA for GSAs is that all six sustainability indicators apply to a basin, SGMA allows for a sustainability indicator to not apply in a basin, based on evidence that the indicator does not exist and could not occur. In the Subbasin, there is sufficient evidence to eliminate two of the sustainability indicators from further consideration – seawater intrusion and depletion of interconnected surface waters. The evidence for eliminating these two indicators is presented in Chapter 3. The remainder of this chapter will address the other four sustainability indicators with three of those indicators discussed more in depth in the 2022 GSP Addendum.

Management Areas

Differences in jurisdictional boundaries, water use, water source type, geology, and/or aquifer characteristics indicate that the use of management areas within the Subbasin may facilitate the sustainable management of groundwater in the subbasin. Although, the hydrogeologic conceptual model, water budget, and notice and communication activities for these areas are consistent across the entire GSP area. These management areas are presented in Chapter 3.

Representative Monitoring Sites

Representative monitoring sites (RMSs) are where MTs and MOs are set and monitored. RMSs can be used for one sustainability indicator or multiple sustainability indicators. The location, type, and monitoring of the RMSs selected for the Subbasin are described in detail in Chapter 5.

4.1 Sustainability Goal

> **23 CCR §354.24** *Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline. The Plan shall include a description of the sustainability goal, including information from the basin setting used to establish the sustainability goal, a discussion of the measures that will be implemented to ensure that the basin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved within 20 years of Plan implementation and is likely to be maintained through the planning and implementation horizon.*

4.1.1 Goal Description

The goal of this GSP is to manage groundwater resources to continue to provide an adequate water supply for existing beneficial uses and users while meeting established MOs to maintain a sustainable groundwater yield. This goal will continue to provide adequate water supply for existing beneficial uses and users while ensuring the future sustainable use of groundwater. Additionally, the sustainability goal works as a tool for managing groundwater, basin-wide, on a long-term basis to protect quality of life through the continuation of existing economic industries in the area, including but not limited to agriculture.

The Groundwater Sustainability Agencies (GSAs) in the Subbasin will work collectively to manage groundwater resources in the Subbasin, develop sustainability projects, and implement management actions, where appropriate. Historical and hydrologic modeling estimates were used to estimate the sustainable yield, which would stabilize forecasted groundwater levels. This goal was established in a manner that is transparent to the public and stakeholders to ensure the local population has a voice in the development of the programs. With the implementation of management actions and projects, as well as the continued interim monitoring and reassessment of activities, stable groundwater levels will be achieved by 2040 and then maintained in to the future at levels that will not create undesirable results.

4.1.2 Discussion of Measures

To achieve the goals outlined in the GSP, a combination of measures, including continued management practices and monitoring will be implemented over the next 20 years and continued thereafter. Additional surface water supply and infrastructure projects will be a crucial component of augmenting groundwater supplies. Management actions also will be implemented. Projects and management actions are discussed in further detail in Chapter 6 and their implementation is described in Chapter 7. When combined with regular monitoring for each of the sustainability indicators, the GSAs will coordinate how they pursue sustainability in the Subbasin.

4.1.3 Explanation of How the Goal will be Achieved in 20 Years

The sustainability goals of this Subbasin will be achieved in the next 20 years by:

- Understanding the interaction between existing and future conditions;
- Analyzing and identifying the effects of existing management actions on the Subbasin;
- Implementing this GSP and its associated measures including projects and management actions to halt and avoid future undesirable results;
- Collaborating between agencies to achieve goals and protect beneficial uses; and
- Assessing at interim milestones (at five-year intervals) the successes and challenges of the implemented projects and management actions.

4.2 Undesirable Results

23 CCR §354.26(a) *Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.*

Undesirable results occur when groundwater conditions within the Subbasin result in significant and unreasonable impacts to a sustainability indicator. The following sections describe the undesirable results for each sustainability indicator and how undesirable results potentially could affect the beneficial uses and users of groundwater in the Subbasin.

4.2.1 Identification of Undesirable Results

The potential for undesirable results occurring in the Subbasin for all four of the sustainability indicators can be traced back to events, statewide policies, and natural causes that have occurred outside of the Subbasin and/or by entities not associated with the GSAs and others in the Subbasin. Reductions in historical allocations of surface water by federal, state, and judicial authorities have resulted in a need for the overlying Subbasin population and enterprises to find additional viable water sources, which has resulted in an increased reliance on groundwater in this Subbasin.

The following are some examples of reductions in surface water supplies historically available within the Subbasin. The reductions total approximately 2,155,000 acre-feet per year (AF/Y) of surface water:

- The State Water Project (SWP) and Central Valley Project (CVP) water delivery reductions through the Central Valley Project Improvement Act (circa 1992) have resulted in:
    - a decrease of SWP deliveries to the Subbasin by an average of 600,000 AF/Y;
    - decreased pumping due to Fall X-2 restrictions by an average of 300,000 AF on the SWP;
    - a decrease of CVP San Luis Unit deliveries by an average of 780,000 AF/Y;
    - a decrease of diversions of about 400,000 AF/Y due to Oroville releases that cannot be pumped into the SWP; and
    - unallocated project yield being developed into contracted supplies (Cross-Valley Contracts and Mid-Valley Canal efforts).
- Biological Opinions (circa 2007) have resulted in:
    - a decrease of SWP deliveries by an average 240,000 AF/Y; and
    - a decrease of CVP San Luis Unit deliveries by an average of 325,000 AF/Y.
- The San Joaquin River Restoration program (circa 2010) has resulted in:
    - reduced deliveries from the Friant Division CVP by an average 210,000 AF/Y.

Additionally, Subbasin-wide effects to groundwater supplies may result from the following:

- Climate Change
    - Information developed by California Department of Water Resources (DWR) suggests that warmer conditions could lead to more rain and/or earlier snow melt runoff (DWR 2017b).
    - Studies indicate increased temperatures could result in higher evapotranspiration rates, which could increase demand.
- Changing Crop Patterns
    - An increase in conversions from annual crops to permanent crops with a higher and more constant water demand could result in an increase in groundwater demand, assuming the same number of acres are irrigated.
- Subbasin Groundwater Outflows
- Increased Urbanization
    - Increases in land use for cities and communities in areas not currently irrigated could result in an increase in demand in certain GSAs.

These events, statewide policies, and natural causes that have occurred outside of the Subbasin, by entities not associated with the GSAs, and/or out the GSAs control, have resulted in an increase in groundwater pumping throughout the Subbasin. The potential for undesirable results to occur for each sustainability indicator due to this increase in pumping is described in the following sections.

4.2.1.1 Groundwater Levels

Based on collected data in the Subbasin, certain areas show long-term decline in groundwater levels, which if not addressed, may eventually lead to a reduction in usable groundwater supplies. Given the 60- to 300-foot depth to groundwater relative to the approximately 3,000-foot-deep freshwater aquifer, it is understood that long-term declines could continue for many years before developing a situation that would truly be significant and unreasonable.

Measurements of groundwater depths and respective elevations in water wells have been collected intermittently across the Subbasin since the early 1900s as discussed in Chapter 3. In the 1940s, pumping began to alter natural groundwater flow conditions, so local groundwater depressions developed. Between 1952 and the end of a five-year drought in 2016, these cones of depression had spread, resulting in groundwater elevation declines from 100 feet to more than 200 feet from 1952 data. The 2016 groundwater elevations are mostly available for the northern third of the GSP area and ranges from approximately 220 feet above mean sea level (MSL) in the very northern end of the GSP area to approximately -120 feet below MSL northwestof the City of

Corcoran. Groundwater pumping in the east and central portions of the GSP area, as well as pumping in the neighboring subbasins, has contributed to groundwater level decline, which in turn has contributed to higher energy costs and well deepening.

Lowering groundwater levels can result in the following main impacts, the degree to which will determine if the conditions of lower groundwater levels are significant and unreasonable:

- Water well problems
- Subsidence
- Deterioration of groundwater quality

Additional discussion of undesirable results of groundwater levels is presented in Section 2.3 of the 2022 GSP Addendum.

Water Well Problems

Declining groundwater levels have three main effects on water wells. First, as the depth to water increases, the water must be lifted higher to reach the land surface. As the lift distance increases, so does the energy required to drive the pump. Thus, power costs increase as groundwater levels decline. Depending on the use of the water and the energy costs, it may no longer be economically feasible to use water for a given purpose. Second, groundwater levels may decline below the bottom of existing pumps, necessitating the expense of lowering the pump, deepening the well, or drilling a deeper replacement well. Third, the yield of the well may decline below usable rates.

Land Subsidence

Land subsidence is “a gradual settling or sudden sinking of the Earth’s surface owing to subsurface movement of earth materials.” Though several different earth processes can cause subsidence, more than 80 percent (%) of the subsidence in the United States is related to the withdrawal of groundwater (Galloway and others, 1999). Additional discussion of undesirable results of land subsidence is presented in Section 3.6 of the 2022 GSP Addendum.

Deterioration of Groundwater Quality

Under natural conditions the boundary between freshwater and saltwater tends to be relatively stable, but pumping can cause saltwater to migrate, resulting in saltwater contamination of the water supply. In inland aquifers, withdrawal of good-quality water from the upper parts of the aquifers can allow underlying saline water to move upward and degrade water quality. Additionally, where ground water is pumped from an aquifer, surface water of poor or differing quality may be drawn into the aquifer. This can degrade the water quality of the aquifer directly or mobilize naturally occurring contaminants in the aquifer. Additional discussion of degraded groundwater quality undesirable results is presented in Section 4.4 of the 2022 GSP Addendum.

4.2.1.2 Groundwater Storage

The amount of groundwater in storage (i.e., groundwater volume) is a function of the saturated thickness of the aquifer, the area of the aquifer, and the storage coefficients of an aquifer, which is the specific yield for unconfined aquifers and specific storage for confined aquifers.

The Subbasin groundwater model and DWR estimates were used to calculate groundwater in storage for the principal aquifers (unconfined above the E-Clay and confined below the E-Clay) within the Subbasin boundaries based on 2016 conditions. Total estimated groundwater in storage as of 2016 is approximately 80.9 million AF, slightly less than the DWR estimate of 82.5 million AF as of 1995 (DWR, 2006).

Annual changes occurred in groundwater storage from 1990 through 2016 in the upper and lower aquifer zones for each GSA area. Overall, there has been a loss of storage of about 3.84 million AF from the unconfined aquifer, a storage gain of about 1.53 million AF in the confined aquifer, and a total loss of about 2.31 million AF between 1990 and 2016.

Permanent loss of groundwater storage capacity (i.e., subsidence) occurs when dewatering of an aquifer results in compression of sediments due to loss of hydrostatic pore pressure that formerly offset compressional loading of the sediment overburden. Compaction of sediments permanently reduces effective porosity of an aquifer thus reducing overall aquifer storability. Between 1990 and 2016, the permanent loss of groundwater storage capacity beneath the Subbasin was estimated to be on the order of 37,360 AF, or approximately 0.05% of the total groundwater in storage in 2016.

4.2.1.3 Land Subsidence

Land subsidence is the lowering of the land-surface elevation from changes that take place underground. Common causes of land subsidence from human activity are pumping water, oil, and gas from underground reservoirs; dissolution of limestone aquifers (sinkholes); collapse of underground mines; drainage of organic soils; and initial wetting of dry soils (hydrocompaction) (Leake 2016). The majority of subsidence in the San Joaquin Valley has occurred due to groundwater extraction from below the Corcoran Clay layer, present at depths of 100 to 500 feet below ground surface, resulting in compaction and eventual subsidence in and below the Corcoran Clay layer (Ireland et al. 1984; Faunt et al. 2009).

Land subsidence due to groundwater withdrawals and associated drawdown has been well documented and has affected significant areas of the San Joaquin Valley since the 1920s, including the Subbasin (Wood 2017). Between 1926 and 1970, there was approximately 4 feet of cumulative subsidence near Corcoran, 4 to 6 feet of subsidence near Hanford, and as much as

12 feet of subsidence near Pixley (Figure 3-34). Following the completion of the SWP and CVP, surface water became more readily available in the San Joaquin Valley and groundwater extraction was reduced and groundwater levels recovered. As a result, subsidence due to groundwater withdrawal was temporarily slowed or stopped. However, groundwater pumping has since increased in the San Joaquin Valley in the past 10 to 25 years due to several factors. Pumping from the confined aquifer eventually exceeded the pre-consolidation stress of the aquifer system, resulting in the resumption and acceleration of compaction of the fine-grained sediments in the confined aquifer system and associated subsidence at the land surface. Subsidence in the San Joaquin Valley was exacerbated during a moderate to severe drought from 2007 through 2009 and a severe to exceptional drought from 2012 through 2016.

Computer modeling was performed to forecast subsidence resulting from groundwater elevation lowering through 2040 with two scenarios. Scenario 1 does not utilize projects and management actions, and Scenario 2 includes the implementation of projects and management actions. The two scenarios were compared to illustrate the potential reduction in subsidence in the Subbasin with the implementation of projects and management actions. The areas with the largest simulated subsidence are on the western boundary of the South Fork Kings (SFK) GSA and the northeastern boundary of the El Rico GSA (Figure 4-1).

The undesirable results related to land subsidence will be the significant loss of functionality of a critical infrastructure or facility, so the feature(s) cannot be operated as designed, requiring either retrofitting or replacement to a point that is economically unfeasible. Modeled subsidence data was used to estimate future subsidence through the implementation period. Due to inelastic soil behavior, subsidence is mostly irreversible even if groundwater pumping decreases and groundwater levels recover. Potential impacts include:

- Raising flood control levees to mitigate subsidence;
- Raising railroads tracks to mitigate flooding impacts related to subsidence;
- Re-grading canals, including the SWP Aqueduct, to address grade changes related to subsidence; and
- Flooding of major roads and highways.

The one critical infrastructure location in the Subbasin is roughly 17 miles of California Aqueduct alignment. Significant impacts to the conveyance capacity of this facility related to land subsidence caused in the Subbasin will be viewed as significant and unreasonable undesirable results. Fortunately, there does not appear to be significant subsidence along this alignment. The GSAs understand this to be related to the limited amount of groundwater pumping in that area.

The California Aqueduct boarders the Subbasin, from approximately Kettleman City and south along the western boundary of Southwest Kings GSA adjacent to the alluvial groundwater basin (Figure 4-1 and Figures 3-1 to 3-11 of the 2022 GSP Addendum). A recent subsidence map covering the period from May 2015 to September 2016 as processed by the Jet Propulsion Laboratory shows minimal subsidence in this area. This is the same general location of Interstate 5 in the Subbasin, which has experienced minimal subsidence over the same period as well. Forecast simulations show that subsidence in this area are projected to continue to be minimal.

The GSAs will continue to collect and evaluate subsidence data from subsidence monitoring locations along the area of the California Aqueduct and Interstate 5, even though it does not appear that subsidence along these facilities where they about the Subbasin is problematic. Additional discussion of undesirable results of land subsidence is presented in Section 3.6 of the 2022 GSP Addendum.

4.2.1.4 Groundwater Quality

Water quality degradation has been linked to some anthropogenic activities (see Chapter 3) and can result from pumping activities. Groundwater pumping may result in water quality degradation due to the migration of contaminant plumes. Additionally, in some areas pumping from deep wells has caused naturally occurring soil contaminants (arsenic, uranium) to leach out and dissolve into groundwater, which may cause undesirable results.

There are no known anthropogenic contaminant plumes within the Subbasin; however, elevated concentrations of total dissolved solids (TDS) and chloride in groundwater have been known to exist in some areas of the western Subbasin since the early 1900s. TDS is considered to have increased over the past 100 years. Additionally, groundwater water quality typically varies with depth above and below the Corcoran Clay. Beneath many portions of the Subbasin, TDS is lower beneath the Corcoran Clay.

Groundwater quality is currently comprehensively monitored in the Subbasin by regulatory agencies. These agencies rely on existing regulations and policies to define undesirable results related to the deterioration of groundwater quality. The agencies and coalitions include the Irrigated Lands Regulatory Program (ILRP), Groundwater Ambient Monitoring and Assessment Program (GAMA), Regional Water Quality Control Board (RWQCB), Central Valley Salinity Alternatives for Long-term Sustainability Program (CV-SALTS), and cities and communities within the Subbasin.

See the following links for additional information on the exceedance categories and monitoring schedules:

- ILRP - https://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/
- GAMA - https://www.waterboards.ca.gov/gama/
- RWQCB - https://www.waterboards.ca.gov/
- CV-SALTS - https://www.waterboards.ca.gov/centralvalley/water_issues/salinity/

In Secondary Management Areas A and B, the agricultural uses (AGR) and municipaluses (MUN) of groundwater have been delisted within the Basin Plan (SWRCB R5-2017-0032) and currently are not required to be monitored according to the RWQCB and the Tulare Lake Basin Plan Amendment unless projects are proposed that would trigger monitoring in this area. Additional discussion of degraded groundwater quality undesirable results is presented in Section 4.4 of the 2022 GSP Addendum.

4.2.2 Potential Effects to Beneficial Uses and Users

4.2.2.1 Groundwater Levels

Discussed in Section 2.1 of the attached 2022 GSP Addendum.

4.2.2.2 Groundwater Storage

Decreases in groundwater levels also result in a decrease of groundwater in storage. Decreases of groundwater in storage could reach the point that agricultural and municipal water users would have a decreased capacity to access adequate groundwater during times of prolonged drought. This would be a significant undesirable result.

4.2.2.3 Land Subsidence

Discussed in Section 3.2 of the attached 2022 GSP Addendum.

4.2.2.4 Groundwater Quality

Discussed in Section 4.1 of the attached 2022 GSP Addendum.

4.3 Minimum Thresholds

> **23 CCR §354.28** (a) *Each Agency in its Plan shall establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site established pursuant to Section 354.36. The numeric value used to define minimum thresholds shall represent a point in the basin that, if exceeded, may cause undesirable results as described in Section 354.26.*

This section, in conjunction with Sections 2.4, 3.7, and 4.5 of the 2022 GSP Addendum describes the MTs established for the sustainability indicators applicable in the Subbasin: groundwater levels, groundwater storage, land subsidence, and groundwater quality. The MTs quantify groundwater conditions for each applicable sustainability indicator at each RMS. Undesirable results may occur in the Subbasin related to a specific sustainability indicator if the MT numeric values are exceeded for that indicator, as defined in Section 4.3.3.

The MTs for each of these indicators are described in the following section. The measurement and monitoring of MTs, the definition of an exceedance that may result in undesirable results, and the potential effects on beneficial uses and users of groundwater are described in subsequent sections.

4.3.1 Description of the Minimum Thresholds

The information in this section provides a description of the processes to establish the MTs at each of the RMSs. The MT at each RMS is listed in Table 2-10 of the 2022 GSP Addendum.

4.3.1.1 Groundwater Levels

The process for establishing the MTs for the groundwater levels sustainability indicator for the Subbasin is based on the information developed for the HCM and as described in other portions of the GSP.

1. Groundwater levels in the Subbasin generally are declining, though at different rates at different locations in the Subbasin (Chapter 3, Section 3.2.2).
    - The groundwater level declines have been effectively managed by the GSA member agencies. The rate and degree to which groundwater levels have declined over the long-term have not been significant and unreasonable (Chapter 4, Section 4.2; Section 2.3 of the 2022 GSP Addendum).
2. The GSAs of the Subbasin will be implementing projects and management actions designed to reduce the rate of groundwater level decline in the Subbasin and eventually stabilize groundwater levels into the future (Chapter 6).
    - Implementation of the projects and management actions by the GSAs is anticipated to begin in 2025 and be completed by 2035 (Chapter 7).

3. The results of forecast simulations using the calibrated groundwater model indicate that the implementation of the projects and management actions by the GSAs proposed in this GSP will begin to reduce the rate of groundwater level decline in the Subbasin by 2035 and will stabilize groundwater levels by 2040. Addition discussion is presented in Section 2.4 of the 2022 GSP Addendum.

4.3.1.2 Groundwater Storage

The estimated amount of groundwater in storage in the Subbasin above the base of fresh groundwater is roughly 82.5 million AF (DWR 2016b) while groundwater use in the Subbasin is in overdraft by an average of roughly 0.07 million AF/Y. Although the reductions in groundwater storage will be addressed through the GSP implementation period, the long-term regional overdraft could continue for many years without significant risk to the beneficial uses and users of groundwater in the Subbasin.

The MT for the groundwater storage sustainability indicator in the Subbasin is the calculated change in storage using the groundwater level sustainability indicator MTs at the RMSs. Groundwater level contour maps will be prepared and estimates of annual storage change will be calculated by comparing current year seasonal high to the previous year seasonal high groundwater contour sets. The resulting change in head will then then be multiplied by specific yield values to estimate change in storage.

4.3.1.3 Land Subsidence

The process for establishing the MTs for the land subsidence sustainability indicator for the Subbasin is based on the following concepts, each of which was developed using the information developed for the HCM and as described in other portions of the GSP.

1. Land subsidence in the Subbasin generally is occurring, though at different rates at different locations in the Subbasin (Chapter 3, Section 3.2.2).
    - Land subsidence has been effectively managed by the GSA member agencies. The rate and degree to which subsidence has occurred have not been significant and unreasonable (Chapter 4, Section 4.2; Section 3.2 of the 2022 GSP Addendum).
2. Continued land subsidence in the Subbasin may result in impacts to beneficial uses and users that are significant and unreasonable, or undesirable (Chapter 4, Section 4.2; Section 3.2 of the 2022 GSP Addendum). If this were to occur, the GSAs may not be able to manage and/or mitigate the effects to infrastructure and land use.
3. The GSAs of the Subbasin will be implementing projects and management actions designed to reduce the rate of land subsidence in the Subbasin and eventually stabilize land subsidence into the future (Chapter 6).

  - Implementation of the projects and management actions by the GSAs is anticipated to begin in 2025 and be completed by 2035 (Chapter 7).
4. The results of forecast simulations using the calibrated groundwater model indicate that the implementation of the projects and management actions by the GSAs proposed in this GSP will reduce the rate of land subsidence in the Subbasin by 2035 and land subsidence will subsequently stabilize within the Subbasin.

Addition discussion is presented in Section 3.7 and 3.8 of the Addendum.

4.3.1.4 Groundwater Quality

Groundwater quality in the northern portion of the Subbasin encompassing the Mid-Kings River GSA and SFK GSA is generally excellent for irrigation and satisfactory for MUN and industrial use (KCWD 2011). South of Stratford and Corcoran and portions of the Tulare Lakebed have been delisted for MUN and AGR beneficial use. Shallow groundwater contamination from fuel hydrocarbons, chemicals, or solvents are localized in the urbanized areas of Lemoore and Hanford and some smaller communities. Limited regional data are available for determining current nutrient concentrations based on groundwater depth and location. Shallow groundwater can have elevated concentrations of nitrates and TDS, but the majority of the region is generally below California Maximum Contaminant Levels (MCLs).

Existing groundwater conditions will be considered as a baseline. The GSAs will not be responsible for existing groundwater quality concerns; MTs will be determined as described by the agencies and coalitions which include ILRP, GAMA, RWQCB, CV-SALTS, and cities and communities within the Subbasin for the various constituents they monitor. Addition discussion is presented in Section 4.5 of the Addendum.

4.3.2 Measurement of Minimum Thresholds

Measurements will be made at the RMSs for each sustainability indicator to determine whether an undesirable result is occurring in the Subbasin.

4.3.2.1 Groundwater Levels

Groundwater elevations will be monitored at each RMS, and contour maps will be generated with the available data to show the groundwater elevations throughout the Subbasin. For more information regarding wells and RMSs in the monitoring network, refer to Chapter 5, *Monitoring Network*. Additional information is also provided in Section 2 of the 2022 GSP Addendum.

4.3.2.2 Groundwater Storage

Groundwater elevations will be monitored and contour maps will be generated to calculate groundwater storage change and will be updated every five years. For more information regarding the wells in the monitoring network, refer to Chapter 5, *Monitoring Network*.

4.3.2.3 Land Subsidence

Additional discussion is presented in Section 3 of the Addendum.

4.3.2.4 Groundwater Quality

Additional discussion is presented in Section 4 of the 2022 GSP Addendum.

4.3.3 Definition of a Minimum Threshold Exceedance

The MTs quantify groundwater conditions for each applicable sustainability indicator at each RMS. Undesirable results may occur in the Subbasin related to a specific sustainability indicator if the MT numeric values are exceeded for that indicator, as defined in the following sections.

4.3.3.1 Groundwater Levels

Groundwater level MT exceedance is discussed further in Section 2 of the 2022 GSP Addendum. Groundwater levels exceeding the MT would trigger a series of actions and measures as described in Chapter 6, *Projects and Management Actions,* which would include projects and policy implementation. Further discussion of protective efforts taken on by the GSAs is presented in Section 2.8 of the 2022 GSP Addendum.

4.3.3.2 Groundwater Storage

The loss of groundwater in storage calculated when groundwater levels exceed the MT in more than 45% of all monitored wells within a consecutive three-year period will be considered significant and unreasonable.

4.3.3.3 Land Subsidence

Land subsidence MT exceedance is discussed in Section 3 of the 2022 GSP Addendum.

4.3.3.4 Groundwater Quality

Discussion of groundwater quality MT exceedance is discussed in Section 4 of the 2022 GSP Addendum.

4.3.4 Potential Effects to Beneficial Uses and Users

4.3.4.1 Groundwater Levels

Discussed in Section 2.1 of the 2022 GSP Addendum.

4.3.4.2 Groundwater Storage

Some decline of groundwater in storage has and is likely to continue to occur in the Subbasin. The MTs for groundwater storage recognizes both the need to address groundwater storage and the needed timeframe to substantially reduce the rate of depletion. The MTs will require the implementation of management actions with the goal of demand reduction and/or the inclusion of additional water supply. Additional information on projects and policies are defined in Chapter 6, *Projects and Management Actions*.

4.3.4.3 Land Subsidence

Discussed in Section 3.2 of the 2022 GSP Addendum.

4.3.4.4 Groundwater Quality

Discussed in Section 4.1 of the 2022 GSP Addendum.

4.4 Measurable Objectives

> **23 CCR §354.30** *(a) Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin with 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.*

This section describes the measurable objectives established for the Subbasin, including interim milestones in increments of five years, to achieve the sustainability goal within 20 years of GSP implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.

4.4.1 Description of Measurable Objectives

4.4.1.1 Groundwater Levels

The process for establishing the MOs is summarized below and discussed in Section 2.6 of the 2022 GSP Addendum.

MOs for the groundwater levels sustainability indicator in the Subbasin were established as follows:

1. Groundwater level changes in the Subbasin in the future were forecasted using the groundwater model starting from 2016 levels at each of the RMSs. The groundwater model assumed:
    a. Lands were fallowed during the 2011-2016 drought were brought back into production using historical cropping patterns.
    b. Lands that were converted to permanent crops during the drought were

   assumed to remain in permanent crops.
   c. Water use, surface water deliveries, etc. in the Subbasin generally remained the same into the future.
   d. The "normal" hydrologic cycle, as described in Chapter 3, Section 3.3.7.1.
   e. No projects or management actions were implemented.
2. The average forecasted groundwater level in July 2035 at each RMS was selected as the MO in 2040 at each RMS.
3. The groundwater model was then used to simulate water level changes in the Subbasin into the future with the projects and management actions described in Chapter 6 and implemented using the above schedule.
4. The simulation results indicated that with the projects and management actions implemented, the MOs at nearly all the RMSs are achieved by 2040.

Further discussion of groundwater level MOs is presented in Section 2.6.

4.4.1.2 Groundwater Storage

The MO for the groundwater storage sustainability indicator in the Subbasin is the calculated change in storage using the groundwater level sustainability indicator MOs at the RMSs. Groundwater level contour maps will be prepared and estimates of annual storage change will be calculated by comparing current year seasonal high to the previous year seasonal high groundwater contour sets. The resulting change in head will then then be multiplied by specific yield values to estimate change in storage.

4.4.1.3 Land Subsidence

The process for establishing the MOs is summarized below and discussed in Section 3.10 of the 2022 GSP Addendum.

MOs for the land subsidence sustainability indicator in the Subbasin were established as follows:

1. The average forecasted subsidence in July 2035 at each RMS was selected as the MO in 2040 at each RMS.
2. The groundwater model was then used to simulate land subsidence in the Subbasin into the future with projects and management actions implemented using the above schedule.
   a. The simulation results indicated that with the projects and management actions, the MOs at the RMSs are achieved by 2040.

4.4.1.4 Groundwater Quality

The process for establishing the MOs is summarized below and discussed in Section 4.7 of the 2022 GSP Addendum.

The GSAs will not be responsible for existing groundwater quality concerns; degradation beyond existing groundwater quality conditions will be the MO. MOs will be monitored by the agencies and coalitions. The GSA will not be responsible for water quality issues currently being addressed by each responsible agency or coalition, nor will the GSAs be responsible for water quality issues associated with influences other than water quality issues associated with implementation of this GSP. Within the Subbasin, no correlation has been found between water quality and groundwater levels.

4.4.2 Operational Flexibility

4.4.2.1 Groundwater Levels

The process for establishing the MOs is summarized below and discussed in Section 4.7 of the 2022 GSP Addendum.

Operational flexibility is the difference between the MO and MT. It allows for periods of drought and seasonal variation, which are deemed reasonable to the GSAs in the Subbasin while operating under a normal hydrologic water supply period. The operational flexibilities for each of the RMS locations with sustainability criteria are shown on the hydrographs. Operational flexibility has also been considered in how the MT exceedance was established (Section 2 of the 2022 GSP Addendum)

4.4.2.2 Groundwater Storage

Groundwater storage operational flexibility is based on an average, allowing room for expected reductions in groundwater storage in below normal hydrologic periods and increases in groundwater storage in hydrologic wet periods. The path to achieve MOs also relies on the coordination effort with the surrounding subbasins and/or GSAs.

The MO for groundwater storage change was set with five-year interim milestones. It is the intent of the GSAs to develop and implement projects and management actions by 2035, sufficient to mitigate long-term overdraft. Proposed projects may increase water supply while some management actions may decrease water demand. Projects and management actions may be adjusted over the implementation period in response to conditions driven by the courts, climate, and hydrology that speed or retard the goals of this GSP from being met.

4.4.2.3 Land Subsidence

For the Subbasin, the operational flexibility is minimal since subsidence is mostly irreversible, and the goal is to decrease the rate of subsidence.

4.4.2.4 Groundwater Quality

Each coalition and agency listed above has regulations that provide landowners compliance alternatives and allows continued operations.

4.4.3 Path to Achieve and Maintain the Sustainability Goal

4.4.3.1 Groundwater Levels

The MO at 2040 for each of the RMSs was selected from the forecasted modeling data. Mitigation of current groundwater elevation decline will be achieved by implementing projects and management actions through the implementation period. The projects will utilize existing and potential additional water supply and programs implemented can decrease water demand. Programs may be adjusted over the implementation period in response to conditions and if GSP MOs are not being met. Each subsequent five-year milestone measurement period may contain modifications to the MO and MT or contain additional measures or actions to achieve the MO elevation or groundwater depth by 2040 and beyond.

Table 2-10 of the 2022 GSP Addendum lists the 2020 original MO and MT at each RMS location with program implementation alongside the newly established MT determined in the 2022 GSP Addendum.

4.4.3.2 Groundwater Storage

The Subbasin has access to very strong surface water resources and millions of AF of stored groundwater. Current water budget evaluations estimate that the Subbasins overdraft is an average of roughly 73,770 AF/Y. The path to achieve and maintain sustainability will be to develop planned projects that can use more of the wet year surface water available to parties in the Subbasin so that the areas long-term overdraft is mitigated. The Subbasin will also pursue many management actions to better measure the amount of groundwater being pumped, monitor changing conditions and address various SGMA related Subbasin issues. The projects developed and planned by parties within the Subbasin appear to yield more than what is needed to address the areas overdraft on an average annual basis. However, like many other subbasins, the Tulare Lake Subbasin will only be able to achieve sustainability if their neighboring subbasins address the overdraft conditions in their areas as well.

The MO for groundwater storage change was set with five-year interim milestones. It is the intent of the GSAs to develop and implement projects and management actions by 2035, sufficient to mitigate long-term overdraft. Proposed projects may increase water supply while some management actions may decrease water demand. Projects and management actions may be adjusted over the implementation period in response to conditions driven by the courts, climate, and hydrology that speed or retard the goals of this GSP from being met.

4.4.3.3 Land Subsidence

The path to sustainability on subsidence is through the development of projects and implementation of management actions that lead to stabilized groundwater levels which thereby diminishes the need to develop deeper wells. Similar to previous periods when subsidence was minimized or arrested, additional surface water was made usable and actions were taken to stabilize groundwater levels.

Further discussion is provided in Section 3 of the 2022 GSP Addendum.

4.4.3.4 Groundwater Quality

The path to achieve the sustainability goal is continued monitoring and evaluation of the data collected from the coalitions and agencies listed in this chapter at each milestone. Additional discussion is presented in Section 4 of the 2022 GSP Addendum.

5.0 MONITORING NETWORK

23 CCR §354.34(a) *Each Agency shall develop a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation.*

This chapter describes the existing and proposed monitoring networks as proposed by the Tulare Lake Subbasin (Subbasin) Groundwater Sustainability Agencies (GSAs). Data collected from the monitoring network will be evaluated for short-term, seasonal, and long-term trends for the following sustainability groundwater indicators: groundwater levels, related surface conditions (i.e., land subsidence), and groundwater quality. Information collected through the Subbasin's monitoring network will support the implementation of this Groundwater Sustainability Plan (GSP).

The Sustainable Groundwater Management Act (SGMA) requires each subbasin to establish a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term groundwater trends and related surface conditions (23 California Code of Regulations [CCR] §354.34). A comprehensive monitoring network is essential to evaluate GSP implementation and measure progress towards groundwater sustainability. The sustainability indicators necessary to comply with SGMA monitoring and reporting requirements include chronic lowering of groundwater levels, reduction of groundwater storage, degraded water quality, land subsidence, seawater intrusion and depletions of interconnected surface water.

While the default position under SGMA for GSAs is that all six sustainability indicators apply to a basin, SGMA allows for a sustainability indicator to not apply in a basin, based on evidence that the indicator does not exist and could not occur. In the Subbasin, there is sufficient evidence to eliminate two of the sustainability indicators from further consideration – seawater intrusion and depletion of interconnected surface waters. The evidence for eliminating these two indicators is presented in Chapter 3.

The adequacy of the monitoring network is described for each sustainability indicator, as well as the quantitative values for the minimum thresholds (MTs), measurable objectives (MOs), and interim milestones. This chapter also includes a review of each monitoring network for monitoring frequency and density, identification of data gaps, plans to fill data gaps, and hydrogeologic rationale for future site selection. Consistent data collection and reporting standards will be incorporated into the network for reliable and accurate data. This information will be reviewed and evaluated during each five-year assessment. Monitoring programs for sustainability indicators are described, including the proposed monitoring strategies in compliance with SGMA, adequacy and scientific rationale, and history for each monitoring program.

5.1 Description of Monitoring Network

23 CCR §354.34(b) *Each Plan shall include a description of the monitoring network objectives for the basin, including an explanation of how the network will be developed and implemented to monitor groundwater and related surface conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial density to evaluate the affects and effectiveness of Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:*
(1) Demonstrate progress toward achieving measurable objectives described in the Plan.
(2) Monitor impacts to the beneficial uses or users of groundwater.
(3) Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds.
(4) Quantify annual changes in water budget components.

The number of existing and proposed representative monitoring site (RMS) locations are summarized by GSA and Sustainability Indicator in Table 5-1. The groundwater level RMS locations as discussed below are shown by aquifer zone, in Figure 2-10 of the 2022 GSP Addendum. Figure 3-11 of the 2022 GSP Addendum shows the existing land subsidence monitoring locations in the Subbasin and Figure 5-4 shows the general areas where future extensometers may be added and the original subsidence monitoring network. The groundwater quality RMS monitoring network is composed of wells currently sampled by the local cities/municipalities/small community systems, and the Kings River Water Quality Coalition (KRWQC)-Irrigated Lands Regulatory Program (ILRP) (Figure 4-10 of the 2022 GSP Addendum). Tables 2-10, 3-2, and 4-1 of the 2022 GSP Addendum summarize the RMS locations by GSA as shown on Figures 2-10, 3-11, and 4-10 of the 2022 GSP Addendum identify the location, , existing monitoring program, and aquifer zone monitored. Groundwater level RMS (existing and proposed) locations are distributed across the Subbasin in areas where groundwater is used and by aquifer zone (discussed below). This vertical and horizontal distribution of groundwater level RMSs will allow the GSAs to develop the data needed to evaluate groundwater conditions in the various aquifer zones, discussed below, and will be used to inform the Subbasin GSAs as to plan progress in meeting MOs, interim milestones, and MTs.

Due to the complexity of the hydrogeologic setting in the Subbasin as discussed in Section 3.1, *Hydrogeologic Conceptual Model*, the aquifer is divided into three aquifer zones for groundwater level monitoring:

- The A zone is the shallow portion of the aquifer above the A-Clay and in areas where shallow groundwater is present outside of the A-Clay. The A-Clay boundary is presented on Figure 5-1 with the original A-Zone RMS wells.
- The B zone is the unconfined portion of the aquifer above the E-Clay (Corcoran Clay) and below the A-Clay where the A-Clay is presented on Figure 5-2 with the original B-Zone RMS wells.

- The C zone is the confined portion of the aquifer below the E-Clay and presented on Figure 5-3 with the original C-Zone RMS wells.

Figure 2-10 of the 2022 GSP Addendum presents the current RMS groundwater level network.

The groundwater level monitoring network also considers the Tulare Lake Basin Plan Amendment (BPA) in areas de-designated for municipal (MUN) and agricultural (AGR) uses (see Chapter 3, Sections 3.1.7.2, *Water Quality Method*, and 3.1.8.3, *Aquitards*, and Section 5.4.3, *Water Quality*, below for more details). Groundwater monitoring in those areas and aquifer zones is not proposed as decided by the GSAs that overly this area. These areas are Secondary Management Area A and Secondary Management Area B (Figure 4-1 of the 2022 GSP Addendum and Figures 5-1 to 5-3). Other sites are monitored for groundwater levels in the Subbasin and provide additional data to prepare groundwater level maps. These locations are not RMSs and the GSAs desire to keep these data private.

The C-Clay is another lacustrine clay between the A-Clay and the E-Clay; therefore, it is in the B zone (see Figure 3-17 for a map of the C-Clay and Section 3.1.8.3, *Aquitards*, for details on the various lacustrine clays layers). Most of the groundwater production from public supply wells near the lakebed is from wells that tap water below the C-Clay (KDSA et al. 2015). Water above the C-Clay in the clay plug area is typically too saline for MUN or AGR usage and has been exempted from MUN and AGR beneficial use (RWQCB 2017a). The Subbasin GSAs will evaluate groundwater level data where the C-Clay is present, and if future groundwater data indicates a need to separate out portion(s) of the aquifer in certain areas between the C- and E-Clays as another aquifer zone, the GSAs may do so at a that time.

There are areas in the Subbasin where groundwater is not used due to poor water quality and/or, in the clay plug, non-productive strata. Portions of the Subbasin where groundwater pumping does not occur are not proposed to be actively monitored at this time, as described further in Chapter 3, *Basin Setting*. These areas overlay portions of El Rico (ER), Tri-County Water Authority (TCWA), and Southwest Kings (SWK) GSAs. These GSAs desire to seek funding and work collaboratively with state, federal and other potential funding sources to construct monitoring facilities in Secondary Management Areas A and B (Figure 4-1 of the 2022 GSP Addendum). If monitoring facilities in these areas are constructed, they will be added to the monitoring network. Secondary Management Areas A and B are in the areas de-designated for AGR and MUN use and currently are not required to have new monitoring for water quality according to the Regional Water Quality Control Board (RWQCB), Tulare Lake BPA unless projects are proposed in these areas that would trigger new monitoring (see Chapter 3, Sections 3.1.7.2, *Water Quality Method*, and 3.1.8.3, *Aquitards*, and Section 5.4.3, *Water Quality*, below). In this event, these facilities could be incorporated into the monitoring network for SGMA.

South Fork Kings Groundwater Sustainability Agency

The groundwater level monitoring network for the South Fork Kings (SFK) GSA consists of four A-zone RMS wells and two areas for proposed shallow RMS wells (Figures 2-10 of the 2022 GSP Addendum and Figure 5-1; Tables 5-1 and 2-10 of the 2022 GSP Addendum). Three of the four A-zone RMS locations are dedicated monitoring wells installed with one well monitored by Kings River Conservation District (KRCD). The GSA Groundwater Level RMS network also includes several other wells consisting of monitoring, agricultural, and municipal wells. Three of the RMS locations are based on existing monitoring well clusters (eight total wells) installed by the KRCD. SFK GSA will pursue existing wells to fill data gap areas and has installed one monitoring well since the 2020 GSP submittal. If existing wells cannot be found to monitor a given aquifer zone in a data gap area, the GSA will seek funding to install dedicated monitoring wells in data gap areas.

Mid-Kings River Groundwater Sustainability Agency

Mid-Kings River (MKR) GSA intends to include abandoned, unused, or idle wells in the monitoring network as they become available and data can be collected on which aquifer zone a given well monitors. In the event that a given well is not perforated to monitor a specific aquifer zone, then MKR GSA would install dedicated monitoring well(s) or use an existing well if one can be found to monitor that zone (Figure 2-10 of the 2022 GSP Addendum; Tables 5-1 and 2-10 of the 2022 GSP Addendum). MKR GSA has six dedicated monitoring wells owned by Kings County Water District (WD). The Kings County WD dedicated monitoring wells will continue to be monitored and will be used as RMSs. The long-term plan for MKR GSA is to develop roughly seven more dedicated monitoring locations that would be used as RMSs. The Kings County WD also has a groundwater monitoring network that relies on existing agricultural wells. Kings County WD intends to continue monitoring those wells to continue the historic record that has been developed. The MKR GSA will evaluate water levels from these wells (some are perforated in a single aquifer but many are composite wells) to understand the relationship of water level in these wells to water level data from wells that are known to monitor a specific aquifer zone.

Southwest Kings and Tri-County Water Authority Groundwater Sustainability Agencies

SWK and TCWA will concentrate their efforts to include existing or abandoned/idle wells with known construction information to minimize the need to build dedicated monitoring wells (Figures 5-2 to 5-3 and Figure 2-10 of the 2022 GSP Addendum; Tables 5-1 and Table 2-10 of the 2022 GSP Addendum).

El Rico Groundwater Sustainability Agency

ER GSA will include existing wells in the monitoring network and only construct dedicated monitoring wells as a last resort. About 104 wells in ER GSA are measured for water level including wells monitored by Corcoran Irrigation District (ID) and private landowners (Figures 5-1 to 5-3 and 2-10 of the 2022 GSP Addendum; Tables 5-1 and 2-10 of the 2022 GSP Addendum). Most Corcoran ID wells and 99 of the private wells in the ER GSA have pumping records (Appendix D, Table D2-4). Wells in the ER GSA are mostly perforated below the Corcoran Clay in the C zone; however, some are perforated above the Corcoran Clay in the B zone (2-10 of the 2022 GSP Addendum).

5.1.1 Monitoring Network Objectives

> **23 CCR §354.34(b)** *Each Plan shall include a description of the monitoring network objectives for the basin, including an explanation of how the network will be developed and implemented to monitor groundwater and related surface conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial density to evaluate the effects and effectiveness of Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:*
>
> *(1) Demonstrate progress toward achieving measurable objectives described in the Plan.*
> *(2) Monitor impacts to the beneficial uses or users of groundwater*
> *(3) Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds.*
> *(4) Quantify annual changes in water budget components.*

The objectives of the various monitoring programs include the following:

- Establish baseline groundwater levels and groundwater quality and record long-term trends going forward;
- Use data gathered to generate information for water resources evaluations and annual changes in water budget components;
- Determine the direction of groundwater flow;
- Provide comparable data from various locales within the Subbasin;
- Demonstrate progress toward achieving measurable objectives, interim milestones, and minimum thresholds described in the GSP as they relate to the Sustainable Management Criteria; and
- Develop the data to evaluate impacts to the beneficial uses or users of groundwater.

The path to achieving the objectives of the monitoring network includes collecting and evaluating the data needed for the Subbasin GSAs to monitor the Subbasin's progress in meeting MOs, interim milestones, and MTs relative to groundwater conditions and impacts to beneficial users of groundwater. The data collected through the monitoring network will also help quantify changes in the water budget components.

Groundwater level monitoring, groundwater storage estimations, and groundwater quality monitoring will utilize existing monitoring, irrigation, municipal, industrial, domestic, and proposed monitoring wells for RMSs. Below is a summary of the Subbasin GSA's planned monitoring networks. Monitoring is not proposed in areas outside of the Subbasin. Data sharing agreements are being developed or will be developed with adjacent groundwater subbasins in order to evaluate boundary conditions. Currently, the SFK GSA has a data sharing agreement with North Fork Kings GSA. SFK and SWK GSAs have data sharing agreements with Westlands WD.

5.1.2 Design Criteria

New monitoring locations will be developed and existing networks enhanced, when necessary, using an approach similar to the Data Quality Objective (DQO) process to guide the GSAs site selection. The DQO process follows the U.S. Environmental Protection Agency (EPA) Guidance on Systematic Planning Using the Data Quality Objective Process (EPA 2006). The DQO process is also outlined in the California Department of Water Resources (DWR) Best Management Practices for the Sustainable Management of Groundwater - Monitoring Networks and Identification of Data Gaps (DWR 2016e) and Monitoring Protocols, Standards, and Sites (DWR 2016f). While the DQO process was not developed specifically to guide the selection of new monitoring locations under SGMA, it does provide a repeatable process for site selection and evaluation so that the GSAs approach site selection in a similar manner.

The dedicated monitoring wells to be installed above the A-Clay or above the E-Clay in the Subbasin are recommended to be 4-inch Schedule 80 polyvinyl chloride (PVC) casings. Deep monitoring wells installed below the E-Clay are recommended to be 5- or 6-inch Schedule 80 PVC casings. This will ensure that representative water quality samples may be collected at these locations. Additional groundwater quality information will be collected and reviewed from agencies and entities currently monitoring for groundwater quality. Monitoring wells constructed in subsiding areas or deep monitoring wells extending below the Corcoran Clay may need to be designed with compression sections to help avoid collapse of the casings as decided by the individual GSA. Blank casing sections should be steel instead of PVC and casing centralizers should be installed. If abandoned wells are included in monitoring networks they need to be re-developed prior to beginning data collection to ensure they are not plugged and to remove any accumulated downhole equipment lubricant (oil), if present. Groundwater level data collected from these wells would need to be evaluated annually to ensure they continue to provide valid data. If the collected data appears to deviate from nearby wells in the same aquifer zone the wells will need to be re-developed as needed. Abandoned wells may not be included in the groundwater quality monitoring network as they will likely not have pumps in them, and evacuating enough volume to properly purge the well prior to sampling, using low-flow pumps, would not be cost effective.

5.1.3 Overview of Existing Programs

Government agencies and private entities currently have existing programs in place that monitor groundwater levels, groundwater quality, and land subsidence. These programs will be utilized for future data collection and will be coordinated with SGMA monitoring requirements. If data from these sources becomes unavailable in the future, the monitoring network will be modified to monitor for the appropriate sustainability indicator. Below are the various programs currently in place that will be described further in Sections 5.1.5 to 5.1.8.

Groundwater Levels

- Kings County WD
- Apex Ranch
- KRCD
- California Statewide Groundwater Elevation Monitoring (CASGEM)
- Municipal monitoring programs
- Corcoran ID
- Private landowners in parts of ER GSA

Groundwater Quality

- Municipal public supply wells monitoring programs
- Groundwater Ambient Monitoring and Assessment Program
- ILRP
- Central Valley Salinity Alternatives for Long-term Sustainability
- Groundwater monitoring at sites with RWQCB wastewater discharge requirements
- Groundwater monitoring at subsurface drainage evaporation ponds

Land Subsidence

- United States Geological Survey (USGS) Monitoring
- National Aeronautics and Space Administration (NASA) Monitoring
- Central Valley Spatial Reference Network (CVSRN) Continuous Global Positioning System (CGPS) Stations
- KRCD network
- Kaweah Delta Water Conservation District (KDWCD) benchmarks
- California Aqueduct subsidence monitoring benchmarks

- University Navigation Satellite Timing and Ranging Consortium (UNAVCO)
- National Geodetic Survey (formerly U.S. Coast and Geodetic Survey)
- United States Army Corps of Engineering (USACE)

Existing facilities that are not associated with an existing program include private wells for AGR or domestic use. Including these wells in the existing monitoring networks will be the responsibility of the individual GSA.

5.1.4 Overview of Proposed Facilities

Proposed facilities for the groundwater level network include 34 monitoring wells (or existing wells that monitor a specific aquifer zone) to fill existing data gap areas (Figures 5-1 through 5-3 of the former RMS groundwater level network and Figure 2-10 of the 2022 GSP Addendum). The two proposed extensometers are initially proposed to be located in the vicinity of Corcoran and an area south of Lemoore (Figure 5-4). If funding or other agreements are made for the construction of the proposed extensometers, the locations will be refined by the GSA(s) at that time based on up-to-date subsidence maps and benchmark data. The proposed monitoring wells may be necessary if existing wells cannot be identified to fill spatial data gaps in the network. There are three general types of data gaps to consider for monitoring networks.

- Temporal: Insufficient frequency of monitoring. For instance, data may be available from a well only in the fall since it is rarely idle in the spring. In addition, a privately owned well may have sporadic access due to locked security fencing, roaming dogs, change in ownership, etc. Going forward, wells in the monitoring network will be measured at a minimum in October for the seasonal low and in February through April for the seasonal high, as determined by the GSA, which will mitigate temporal inconsistencies.
- Spatial: Insufficient number or density of monitoring sites in a specific area.
- Insufficient quality of data: Data may be available but be of poor or questionable accuracy. Inaccurate data may at times be worse than no data, since it could lead to incorrect assumptions or biases. The data may not appear consistent with other data in the area, or with past readings at the monitoring site. The monitoring site may not meet all the desired criteria to provide reliable data, such as having information on well perforation depth, etc. Well location information on Well Construction Reports is often inaccurate (making it difficult or uncertain to match wells with their well logs), and these wells will need to be field located.

5.1.5 Groundwater Levels

Groundwater level monitoring has occurred in most areas of the Subbasin on a semi-annual basis since the 1950s (Provost & Pritchard 2011; WRIME 2005). Kings County WD, KRCD, Corcoran ID, DWR, and the United States Bureau of Reclamation (USBR) and private landowners have measured and/or are currently measuring groundwater levels as part of existing monitoring programs. Well logs and construction information are not available for all of these wells but as described in Section 5.4.1.2*, supplemental well construction data may be collected in the future*. Since 2009, DWR has also asked local agencies to collect and report groundwater level data under the CASGEM program. Kings County WD, KRCD, and Tulare Lake bed water agencies participate in CASGEM and report groundwater level data on a semi-annual basis (Provost & Pritchard 2011; DWR 2010; Summers Engineering 2012; WRIME 2005). These agencies will continue monitoring semi-annually for future data collection and may expand, as needed, to comply with SGMA monitoring requirements. Each agency will monitor groundwater levels in October and a minimum of 90 days later in February through April each year to provide consistency in the timing of measurements. Groundwater level data collection protocols will follow methods in the DWR's Best Management Practices for the Sustainable Management of Groundwater - Monitoring Protocols, Standards, and Sites (DWR 2016f).

RMS groundwater level locations have MOs to gauge the effectiveness of plan implementation measures and evaluate MTs that define undesirable results in the Subbasin. The proposed RMS monitoring network, when built-out, will include a density of RMSs of up to two wells for the B zone (above the E-Clay) and C zone (below the E-Clay), and one well for the A zone (above the A-Clay where it is present) for the 36-square mile Townships wholly in the Subbasin where the GSAs desire to monitor (Figures 5-1 to 5-3 and Figure 2-10 of the 2022 GSP Addendum). Generally, if more than about half of a Township is within the Subbasin, RMS well densities were kept the same as for those Townships wholly in the Subbasin. Greater RMS well densities are focused around concentrated pumping areas and cities including Hanford, Lemoore, Corcoran and unincorporated communities. Data on the depth and perforated intervals of the monitoring wells or existing wells is required according to SGMA guidelines unless the GSA can demonstrate that such information is not needed to understand and manage groundwater in the Subbasin. The GSAs plan to obtain additional construction information on wells in the monitoring networks that lack well construction information. Some of the wells in the monitoring network do not have consistent measurements for consecutive years throughout their operational life for numerous reasons including lack of access, breaks in well casings, wells running during data collection, damaged or broken well sounding equipment, oil in the casings fouling of sounding equipment, bees, and other unforeseen circumstances. The GSAs will work with landowners to alleviate these issues as possible and include redundancy in the monitoring networks when feasible. Groundwater levels will be measured in the monitoring network wells each, as described above, in October and February through April. The timing of water level data collection will be coordinated between the GSAs so that the data is collected in as short a period as practicable.

Groundwater levels are measured in the various networks and types of wells including:

- Kings County WD: The Kings County WD encompasses a land area of approximately 143,000 acres between Tulare Lake Subbasin and Kaweah Subbasin. Water level measurements are taken semi-annually on average from 255 wells in both the spring and fall. The Kings County WD's monitoring program is divided into two distinct monitoring programs: (1) Apex Ranch Conjunctive Use Project Monitoring Program and (2) a district-wide monitoring program. The Kings County WD began routinely measuring groundwater levels district-wide in the 1950s. The district-wide data collection effort also includes data sharing with adjacent districts and groundwater basins and evaluates groundwater levels above the A-Clay and above the E-Clay.
- Apex Ranch Conjunctive Use Project Monitoring Program: The monitoring network consists of 40 to 45 off-site and on-site, agricultural, domestic, and dedicated monitoring wells. Several of the monitoring wells, both on site and off site, are equipped with data loggers that allow for data collection at set intervals and flexibility in the frequency that the data can be collected. These data are continuously recorded throughout the year.
- KRCD: Current groundwater level monitoring program includes semi-annual groundwater level measurements (WRIME 2005). KRCD also samples wells for the KRWQC-ILRP Groundwater Trend Monitoring.
- Corcoran ID: The Corcoran ID monitors water level elevation in approximately 74 wells in the Subbasin. Based on available data it appears that about 45 percent (%) of these wells are perforated above the Corcoran Clay in the B zone and about 55% are perforated below the Corcoran Clay in the C zone. Most Corcoran ID wells have some pumping records. The number of wells pumped in Corcoran ID can change from year to year.
- CASGEM Wells: DWR collects groundwater levels reported by local agencies and reports them through the CASGEM program. There are currently 17 CASGEM wells in the Subbasin.
- Municipal Wells: Most municipal wells are available for water level and/or water quality monitoring in Hanford, Lemoore, Corcoran, Armona, Home Garden, Kettleman City, Stratford, and others.
- Private Wells in ER GSA: There are approximately 99 private wells in ER GSA with reported historical pumping records and construction information, and 30 wells with some water level data. Of the 30 wells with water level data, 8 appear to be B zone (above the Corcoran Clay) and 22 appear to be perforated below the Corcoran Clay in the C zone.
- Wells in Adjacent GSAs: Groundwater level data from adjoining subbasins will also be collected through data sharing agreements to help provide better interpretation of GSA boundary flow conditions. Long-term agreements still need to be prepared to collect/share data with other subbasins.

5.1.6 Groundwater Storage

A groundwater model was originally developed for the Subbasin in 2017-2018 and further refined in 2019 (Appendix D). The groundwater model was used to estimate the overall annual change in groundwater storage over the model calibration period of 1996 to 2016 for the unconfined and confined portions of the aquifer. The groundwater model calculates the change in groundwater storage over time using the change in hydraulic head of the aquifer, and the assumed storage coefficients or specific yield of the dewatered sediments.

In the future, for annual reporting, groundwater level contour maps will be prepared and estimates of annual storage change will be calculated by comparing current year seasonal high to the previous year seasonal high groundwater contour sets. The resulting change in head will then then be multiplied by specific yield values (see Section 3.1.9) to estimate change in storage.

The storage change monitoring network is the same as the water level monitoring network. RMS well locations are linked to specific aquifer zones, and as such, data from these wells will be weighted heavier than wells without construction information. It should be noted that even though a well may not have construction information, the data can still be used in constructing water level maps if the data is consistent with water levels from RMS wells.

5.1.7 Groundwater Quality

The Subbasin is relying on already existing groundwater quality monitoring programs. Groundwater quality monitoring may supplement, as needed, groundwater quality monitoring currently under the oversight of an existing regulatory agency or groundwater quality coalition. See Section 3.2.5 for more information on existing groundwater quality monitoring in the Subbasin.

5.1.8 Land Subsidence

For land subsidence, the existing CVSRN CGPS in the area will be used as RMSs for the Subbasin. Additional land subsidence data can be gathered from the entities listed in Section 5.1.3 to evaluate subsidence across the Subbasin. These data will be evaluated annually and if subsidence rates approach MOs at the nearest CGPS station, then additional RMSs may be added as determined by the GSA. The GSAs are exploring partnership opportunities with KRCD or other similar entities to potentially expand the land subsidence monitoring network in the Subbasin. Two extensometers are proposed in areas of known subsidence, pending funding or collaboration with DWR or the USGS. Regional-based Light Detection and Ranging (LiDAR) subsidence maps may also be evaluated to identify areas of subsidence, in areas where there are no current benchmarks. As funding opportunities become available, additional subsidence monitoring facilities may include extensometers for depth discrete subsidence monitoring near or in the areas shown on Figure 5-4 depicting the original subsidence RMS network. Figure 3-11 displays the RMS network developed as part of the 2022 GSP Addendum.

Land subsidence is discussed in further detail in Section 3.2.6, *Land Subsidence*. The Subbasin is included in areas monitored for subsidence by regional water agencies or the state and federal governments. Measurement and monitoring for land subsidence is performed by USGS, KRCD, USACE, UNAVCO, and various private contractors. Interagency efforts between the USGS, the U.S. Coast and Geodetic Survey (now the National Geodetic Survey), and DWR resulted in an intensive series of investigations that identified and characterized subsidence in the San Joaquin Valley. NASA also measures subsidence in the Central Valley and has maps on their website that show the subsidence for defined periods (NASA n.d.).

Surface land subsidence caused by excessive groundwater withdrawals that has the potential to impact critical infrastructure is identified as the sustainability indicator for land subsidence by the Subbasin GSAs, see C 4. Potential critical infrastructure currently in the Subbasin, as defined by the GSAs is listed in Section 3 of the 2022 GSP Addendum. Plans for infrastructure currently in the design stage can be adjusted to accommodate expected continued subsidence, for example, the California High- Speed Rail (LSCE, Borchers and Carpenter 2014). Individual GSAs may work with the other agencies/authorities to mitigate potential effects of subsidence, if needed. Deep groundwater pumping adaptive management programs or policies will be determined as needed by the GSA.

The California Aqueduct borders the Subbasin from about Kettleman City and south along the western boundary of SWK GSA adjacent to the alluvial groundwater basin. The GSAs will continue to collect and evaluate subsidence data from subsidence monitoring locations along the area of the California Aqueduct and Interstate 5.

The GSAs have initially defined MTs for subsidence in the Subbasin at two CVSRN-CGPS stations: LEMA and CORC and 25 KRCD subsidence monitoring points. See Section 3, Table 3-3, and Figure 3-11 of the 2022 GSP Addendum for the Sustainable Management Criteria and monitoring location.

5.1.9 Consistency with Standards

> **23 CCR §354.34(g)** *Each Plan shall describe the following information about the monitoring network:*
> *(2) Consistency with data and reporting standards described in Section 352.4. If a site is not consistent with those standards, the Plan shall explain the necessity of the site to the monitoring network, and how any variation from the standards will not affect the usefulness of the results obtained.*

The data gathered through the monitoring networks will be consistent with the standards identified in 23 CCR §352.4 related to Groundwater Sustainability Plans. The main topics of

23 CCR §352.4 are outlined below:

- Data reporting units (water volumes including surface water deliveries, estimates of groundwater pumping, etc., reported in acre-feet [AF], etc.)
- Monitoring site information (site identification number, description of site location, etc.)
- Well information reporting (CASGEM well identification number or other unique identifier, measuring point elevation, casing perforations, etc.)
- Map standards (data layers, shapefiles, geodatabases submitted in accordance with the procedures described in Article 4 of the SGMA regulations – Procedural issues related to submission of plans and public comment to those plans, etc.)
- Hydrograph requirements (hydrographs shall use the same datum and scaling to the greatest extent practical, etc.). Hydrographs will also be plotted showing depth to water as well as groundwater elevation.

5.2 Monitoring Protocols for Data Collection and Monitoring

23 CCR §352.2 *Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:*
(a) Monitoring protocols shall be developed according to best management practices;
(b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.;
(c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary.

23 CCR §354.40 *Monitoring data shall be stored in the data management system developed pursuant to Section 352.6. A copy of the monitoring data shall be included in the Annual Report and submitted electronically on forms provided by the Department.*

The DQO process will be used to develop monitoring protocols that assist in meeting MOs and sustainability goals of this GSP (EPA 2006). The DQO process includes the following:

- State the problem;
- Identify the goal;
- Identify the inputs;
- Define the boundaries of the area/issue being studied;
- Develop an analytical approach;
- Specify performance or acceptance criteria; and
- Develop a plan for obtaining data.

Groundwater level, groundwater quality (if the GSAs participate in groundwater quality monitoring), and land subsidence monitoring will generally follow the protocols identified in the DWR Best Management Practices for the Sustainable Management of Groundwater - Monitoring Protocols, Standards, and Sites (DWR 2016f). Monitoring Protocols will be reviewed at least every five years as part of the periodic evaluation of the GSP and updated as needed. The GSAs may develop standard monitoring forms in the future if deemed necessary.

The following comments and exceptions to the Best Management Practices (BMPs) should be noted:

- SGMA regulations require that groundwater levels be measured to the nearest 0.1-foot. The BMP suggests measurements to the nearest 0.01-foot; however, this is not practical for many measurement methods. In addition, this level of accuracy would have little value since groundwater contours maps typically have 10- or 20-foot intervals, and storage calculations are based on groundwater levels rounded to the nearest foot. The accuracy of groundwater level measurements will vary based on the well type and condition. For instance, if significant oil is found in an agricultural well then readings to the nearest foot are likely the best one can achieve. As well, a methodology will need to be developed to keep track of the amount of oil in these wells, and if possible, have the oil removed when the pump is removed for other reasons.
- Water level data will be collected and sounding equipment maintained using standard operating procedures. When feasible well sounding equipment will be dedicated for either irrigation or domestic wells.
- Wells will be surveyed to a horizontal accuracy of 0.5 foot, preferably to 0.1 foot or less.
- In subsiding areas periodic measurements may be required to determine the elevations of the measuring points for measured wells. Individual GSAs may develop subsidence monitoring programs as needed.
- Unique well identifiers will be labeled on all public wells, and on private wells if permission is granted.
- The BMPs state that static groundwater elevation measurements should be taken preferably within a one- to two-week period. This is likely not feasible due to the large number of wells in the Subbasin and the differing seasonal high groundwater conditions by GSA. As described above, for semi-annual (two times per year) monitoring, measurements are to be taken in October for the seasonal low groundwater condition and February through April for the seasonal high groundwater condition depending on the GSA. In addition, where groundwater quality and funding allows, individual GSAs may install data loggers in wells, most likely in dedicated monitoring wells and a select subset of existing wells.
- If a vacuum or pressure release is observed, then water level measurements will be measured every five minutes until they have stabilized.
- In the field, water level measurements will be compared to previous records; if there is a significant difference, then the measurement will be verified by measuring the well to double-check the measurement. If there is a reason that the person measuring the well can determine for why the measurement is inconsistent, it will be noted.
- For water quality monitoring (if or when the GSAs perform water quality sampling), field parameters for pH, electrical conductivity, and temperature will only be collected when

required for the parameter being monitored. Determining if a well has been purged adequately may be ascertained by calculating a run time before sampling. For irrigation wells, samples will be taken when the well has been running long enough that an adequate volume has been removed (typically 3 to 5 well bore volumes and field parameters are stable).

5.3 Representative Monitoring

23 CCR §354.36 *Each Agency may designate a subset of monitoring sites as representative of conditions in the basin or an area of the basin, as follows:*
(a) Representative monitoring sites may be designated by the Agency as the point at which sustainability indicators are monitored, and for which quantitative values for minimum thresholds, measurable objectives, and interim milestones are defined.
(b) Groundwater elevations may be used as a proxy for monitoring other sustainability indicators…
(c) The designation of a representative monitoring site shall be supported by adequate evidence demonstrating that the site reflects general conditions in the area.

DWR has referred to representative monitoring as utilizing a subset of sites in a management area. The GSP has developed a monitoring network of RMS wells where MOs, MTs, and interim milestones are defined in further detail in Section 4.3 and 4.4, *Minimum Thresholds* and *Measurable Objectives* alongside Sections 2 through 4 of the 2022 GSP Addendum. Groundwater conditions can vary substantially across the Subbasin and the use of a small number of representative wells in the Subbasin is not practical to cover such a large area with varying conditions. The network will strive to fill data gaps with existing wells that have well construction information and historical groundwater level data. Proposed monitoring sites may include clustered wells, if existing wells cannot be identified and used, that will be able to provide data for different aquifer zones at a single location.

The GSP does not plan to use groundwater elevations as a proxy for monitoring other sustainability indicators. As noted, groundwater elevations will be used as a critical component of groundwater storage change estimation, but the groundwater elevation monitoring will not replace or be used as a proxy for storage change estimations.

The GSAs will rely on the distribution of existing subsidence monitoring points coupled with the regional-based subsidence mapping to sufficiently cover the Subbasin, initially, and that the two CGPS stations (LEMA and CORC) are generally located in potentially viable subsidence RMS locations.

5.4 Assessment and Improvement of Monitoring Network

23 CCR §354.34(f) *The Agency shall determine the density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends based upon the following factors:*

1. *Amount of current and projected groundwater use.*
2. *Aquifer characteristics, including confined or unconfined aquifer conditions, or other physical characteristics that affect groundwater flow.*
3. *Impacts to beneficial uses and users of groundwater and land uses and property interests affected by groundwater production, and adjacent basins that could affect the ability of that basin to meet the sustainability goal.*
4. *Whether the Agency has adequate long-term existing monitoring results or other technical information to demonstrate an understanding of aquifer response.*

This section reviews and evaluates the adequacy of the monitoring network, identifies data gaps, and describes methods to fill data gaps.

5.4.1 Groundwater Levels

5.4.1.1 Monitoring Frequency and Density

The CASGEM Groundwater Elevation Monitoring Guidelines (DWR 2010) were used to estimate the density of RMS wells needed for the Subbasin per the DWR's Best Management Practices for the Sustainable Management of Groundwater - Monitoring Networks and Identification of Data Gaps (DWR 2016e). The Subbasin GSAs collect water level data from more wells than the density requirements for RMSs as discussed below. The density of RMS wells outlined here is meant to meet the density requirements in the DWR Best Management Practices for the Sustainable Management of Groundwater - Monitoring Networks and Identification of Data Gaps (DWR 2016e), but data may continue to be collected from the various networks at higher densities needed to prepare groundwater contour maps. As feasible, the GSAs will evaluate the RMS network and make adjustments as needed over time. Recent adjustments made are discussed in Chapter 2 of the 2022 GSP Addendum.

CASGEM guidelines (DWR 2012) reference the Hopkins and Anderson (Hopkins 2016) approach which incorporates a relative well density based on the amount of groundwater used within a given area (DWR 2016e). The densities range from 1 well per 100 square miles to 1 well per 25 square miles, based on the quantity of groundwater pumped. A minimum density of 1 well per 25 square miles is recommended for basins pumping over 10,000 AF of groundwater per year per 100 square miles. Groundwater use varies throughout the Subbasin with many areas currently exceeding 10,000 AF/year per 100 square miles. As a result, a well density of approximately 1 RMS well per 25 square miles will be used. For this evaluation, well density istracked per 36-square mile Township, which results in about 1.5 wells per Township. A more practical value of 2 wells per Township per aquifer zone is adopted resulting in a density of about 1 RMS well per 18 square miles. The RMS well density above the A-Clay and in areas of shallow groundwater outside of the A-Clay is recommended to be 1 well per Township because groundwater use is estimated to be less than the amount needed for a 2 well per Township density. Areas that have little to no pumping (de-designated areas or poor strata for groundwater production in the Tulare Lakebed area; reference Section 3.1.7.2, *Water Quality Method*, for more information), may have 0 to 1 well per Township. In general, each proposed RMS monitoring site, assuming a dedicated monitoring well is constructed if an existing well cannot be found for a given aquifer zone, will include monitoring above the A-Clay (where it is present and is used as a major water source), and above and below the Corcoran Clay where it is present. When economically feasible and practical, and existing wells cannot be identified for use, dedicated monitoring wells will be installed. Use of dataloggers will be evaluated by the GSAs on a case by case bases. It should be noted that the use of data loggers in areas of the Subbasin that have poor groundwater quality can be problematic and, as mentioned above, use of data loggers will be evaluated on a case-by-case basis by the GSAs.

Monitoring sites include RMS wells, which are defined as wells with reliable access during semi-annual water levels readings each year, known information on the well depth and perforated interval (or the GSA is reasonably certain of which aquifer zone a given wells is perforated in), and have adequate depth to accommodate seasonal fluctuations. Wells that do not meet these guidelines may be maintained in the network as monitoring locations, as they can still provide useful information. Well construction information on these wells may be obtained in the future, and assigned to a specific aquifer zone, if applicable. Regardless of the how these wells are constructed, water level data will continue to be collected in them to continue the record and provide valuable operational information for the well owner.

If more frequent data collection is required to demonstrate progress toward sustainability, monitor impacts to beneficial use of groundwater, monitor groundwater levels more closely, and/or quantify annual or seasonal changes in groundwater conditions, then the GSAs will re-evaluate the monitoring network and make changes as appropriate. Use of data loggers will be on a case-by-case basis as evaluated by the GSA. Data loggers, when they work successfully, can provide valuable data to evaluate short-term, seasonal, and long-term trends.

Groundwater levels will be measured in October for seasonal low conditions and in February to April for the seasonal high conditions depending on the GSA. The February through April water level measurements are designed to capture the recovery of groundwater levels after a seasonal period of minimal demand. The October measurement would capture a period after peak irrigation and summertime peak urban demands have declined, thereby showing the cumulative impacts on the groundwater basin before the seasonal winter and spring recovery has taken place.

5.4.1.2 Identification of Data Gaps

23 CCR §354.38 *(b) Each Agency shall identify data gaps wherever the basin does not contain a sufficient number of monitoring sites, does not monitor sites at a sufficient frequency, or utilizes monitoring sites that are unreliable, including those that do not satisfy minimum standards of the monitoring network adopted by the Agency.*
(c) If the monitoring network contains data gaps, the Plan shall include a description of the following:
The location and reason for data gaps in the monitoring network.
Local issues and circumstances that limit or prevent monitoring.

Lack of Pumping Data

Most groundwater users have not kept track of how much water they have pumped or have not disclosed how much they have pumped. The GSA boards are considering direct measurement of groundwater options which may include flow meters.

Temporal Data Gaps

Some of the current wells used for data collection have not been measured consistently year after year, and therefore, temporal data gaps exist ranging from one year to over a decade. The GSAs designed a data collection program that assures semi-annual data collection. The GSAs' future monitoring efforts will increase the reliability of groundwater level readings given their importance to active management and compliance documentation. If a water level reading cannot be taken at a given well, the reason will be documented. The individual GSAs will determine if or when additional attempts will be made to collect that data. Temporal adjustments may be made for the different aquifer zones or in certain areas. For example, semi-annual water level readings in above the A-Clay wells is probably sufficient to capture seasonal and long-term trends in most of that aquifer zone because water levels in the aquifer are relatively stable in most of the area. Near the Kings River it may be desirable to collect more frequent data from above the A-Clay to better understand the relationship between the river and shallow groundwater. As well, in areas where there is more pumping from below the E-Clay, it may be desirable to collect data more frequently due to relatively rapid changes in head pressure in confined aquifers. More frequent data may also be needed from the aquifer above the E-Clay in areas where it is the main aquifer in which wells are perforated. The need to collect more frequent data and from which aquifer zone will be evaluated by the individual GSA.

Spatial Data Gaps

Currently, there are spatial data gaps throughout the Subbasin. Spatial data gaps are primarily in the southern/southwestern region of the Subbasin where groundwater is not used due to poor water quality, and in the lakebed area due to lack of productive strata and poor water quality. These areas are delineated as Secondary Management Area A and Secondary Management Area B (Figures 5-1 to 5-5). Consequently, groundwater levels are unknown for most of this area and minimal monitoring sites are proposed there to fill this data gap, since groundwater is not a resource that needs to be managed in this area to the benefit of the overlaying landowners. There are active wells east of the Tulare lake area clay plug, and RMS wells are located in these areas. In other areas of the Subbasin, data gaps are primarily due to the lack of known well construction. There are also spatial data gaps in the northern portion of the Subbasin, primarily related to well distribution in the various aquifer zones (Figures 5-1 to 5-3). Since the aquifer above the A-Clay (the A zone) is not used as a primary water source in most of the Subbasin, the spatial coverage does not have to be as dense as the more heavily pumped portions of the aquifer; i.e., the B zone above the Corcoran Clay and the C zone below the Corcoran Clay).

Insufficient Quality of Data

Currently, most of the wells monitored in unincorporated areas are privately owned. Specific well construction information, including depth and perforated interval, are not programmed into the model for most of these wells. While these wells may not provide ideal data points, they will continue to be monitored even if well construction data is collected which indicates the well is a composite well (perforated across multiple aquifer zones, in the Subbasin usually across the Corcoran Clay). Many well owners and water management agencies find this data relevant to their operations, and while these wells may not be compliant for SGMA reporting, data may continue to be collected from them as decided by the GSAs. Collecting well construction information is especially important throughout the Subbasin which is underlain, to a large extent, by the Corcoran Clay layer and other smaller aquitards. It is still desirable to know wells construction information, and if a Well Completion Report (WCR) is not available, other methods, including television (TV)/video surveys or sonic logs can be used to determine well construction. Once a well's construction is known, the aquifer zone(s) it is perforated in can be confirmed. When funding allows and an existing well cannot be found to monitor a specific aquifer zone, dedicated monitoring wells may be installed at targeted depths and perforated intervals to fill spatial data gaps.

Additional data gaps are discussed in Sections 2-7of the 2022 GSP Addendum.

5.4.1.3 Plans to Fill Data Gaps

23 CCR §354.38(d) *Each Agency shall describe steps that will be taken to fill data gaps before the next five-year assessment, including the location and purpose of newly added or installed monitoring sites.*

The RMS groundwater level network has data gaps, such as missing construction or partial construction information for some RMS wells. The goal is to have accurate well construction information for RMS wells monitored for groundwater level that currently lack construction information within 5 years of plan implementation if possible. Well construction information will be needed for at least 5 existing A-zone wells, 1 existing B-zone well, and 7 existing C-zone wells. As well, as shown on Figures 5-1 to 5-3, there are 3 A-zone areas with data gaps, 12 B-zone areas with data gaps, and 18 C-zone areas with data gaps that need to be filled to achieve the RMS well density of 2 wells per Township for the B and C aquifer zones, and one well per Township density in the A zone. The GSAs prefer to fill the areas with data gaps with existing wells, if possible, but will construct dedicated monitoring wells as funding becomes available. One B-zone well data gap has been filled since implementation of the 2020 GSP. These data gaps can be filled using the four alternatives below:

- **Collect Well Completion Reports.** WCRs will provide the needed information if a WCR can be positively linked to a well. These could be collected from the landowner or DWR;

however, several challenges exist since so many have been drilled in the area and location information in the reports can be inaccurate. However, WCRs for private wells may not always be available to the GSAs.

- **Perform a video inspection of wells to obtain construction information.** A video inspection or TV survey can be performed on desired wells to determine the total depth and perforated interval. Video inspections can be performed when the pump is pulled for other reasons. As well, the GSAs can work with well owners to obtain existing videos or TV surveys. Recognize that video inspection would not provide information on the aquifer material.
- **Replace monitor point with an alternate private well:** Private wells without construction information could be replaced with another existing well with available well construction information. This may be simpler and less costly than a video inspection. However, changing monitoring well locations is not always desirable, since it is preferred to continue measurements in wells that have a long period of record (i.e., many years of groundwater level data).
- **Construct a dedicated monitoring well:** Dedicated monitoring wells are relatively expensive to construct, and their installation will depend on available funding. Dedicated monitoring wells will only be constructed if an existing private well cannot be found.

For those GSAs that do not have known construction for some of the wells in their RMS monitoring networks, they will either collect construction information on wells lacking well construction information by 2025, or will fill the gaps with monitoring sites with complete data.

The proposed dedicated monitoring wells, if an existing well cannot be found, will be nested (multiple casings installed in a single borehole) or clustered monitoring wells (multiple wells located close together). It is probable that with the recommended casing diameters, most multi-depth zone monitoring wells will need to be clustered as opposed to nested. This allows for monitoring groundwater levels at different aquifer zones at a single location or in close proximity to each other for clustered wells.

In the event that an existing RMS well becomes unavailable for water level monitoring, existing wells that monitor the same aquifer zone will need to be found and added to the network, or a dedicated monitoring well will need to be constructed. As well, an individual GSA may decide to continue to collect well construction information and allow monitoring of additional wells so that the water level monitoring network has redundant wells that meet the criteria for an RMS well. GSAs that develop and maintain a working list or an inventory of wells available for monitoring may choose to add these as RMS wells to increase RMS density. Water levels will be collected in these wells during the semi-annual water level monitoring events so that if an existing RMS well is no longer available for monitoring, an alternate well is readily available for use in the RMS water level network. Developing an inventory of wells additional to the RMS wells, and whether or when to add these wells to the RMS water level network will be decided by the individual GSAs.

5.4.1.4 Site Selection

23 CCR §354.34(g) *Each Plan shall describe the following information about the monitoring network:*
(1) Scientific rationale for the monitoring site selection process.

The scientific rationale for the groundwater level monitoring network includes the following:

- Existing wells with known construction information were preferentially selected for RMS wells.
- Other wells have over 20 years of water level data and are useful for long-term evaluations even though they may reflect multiple aquifer zones. These wells will continue to be monitored as this information is important to users of groundwater.
- The RMS network density follows the guidelines from DWRs' Best Management Practices for the Sustainable Management of Groundwater - Monitoring Networks and Identification of Data Gaps (DWR 2016e) to determine the RMS density.

The following scientific rationale will be used to add new RMS wells:

- Add wells, whenever necessary to maintain a minimum RMS monitoring well density.
- Avoid wells perforated across multiple aquifer zones for RMS wells, especially wells penetrating the Corcoran Clay and/or the A-Clay.
- Select wells that have access during semi-annual water level readings, preferably wells that do not have gates or access issues.
- Select sites for dedicated monitoring wells as far as possible from existing active wells.
- Active wells are preferred over idle or unused wells.
- Select wells with available construction information (i.e., depth, perforated interval).
- Select existing wells over constructing monitoring wells where feasible.

If data for a specific monitoring site is lacking, other wells in the vicinity which have the desired attributes, if available, can be added to increase the monitoring network's scope and breadth.

Figures 5-1 through 5-3 show the former RMS network and areas that need additional RMS wells to fill data gap areas while Figure 2-10 of the 2022 GSP Addendum shows the current RMS network. As mentioned above, the GSAs will endeavor to fill data gaps with existing wells that meet the criteria above for an RMS monitoring point or will construct dedicated monitoring wells if funding is available.

5.4.2 Groundwater Storage

Groundwater storage change will be calculated using groundwater level contour maps from seasonal high groundwater conditions of successive years. Groundwater storage calculations are largely dependent on the groundwater level monitoring network. Collection of well attribute information described above will also benefit groundwater storage change evaluations. In addition, groundwater released from clays due to subsidence will also be evaluated annually from data collected from the land subsidence monitoring network.

5.4.2.1 *Monitoring Frequency and Density*

Annual groundwater storage changes by each GSA will be calculated so individual GSAs can evaluate progress towards meeting MOs. The data used to estimate storage change will be the water level data collected from the water level networks. This data will be collected, as mentioned above, at a minimum every October and February through April. In addition, also as discussed above, the GSAs will continue to collect data at more wells than the RMSs. This additional data will be used in conjunction with data from the RMSs to prepare groundwater contour maps which are then used to estimate storage change. The individual GSA storage change information will be aggregated for reporting to the DWR for the Subbasin as a whole.

5.4.2.2 *Identification of Data Gaps*

The most significant data gaps in the groundwater storage change monitoring network include:

- Information on well construction related to understanding groundwater pumping from the different aquifer zones;
- Aquifer characteristics of storativity, specific yield, and hydraulic conductivity/ transmissivity to better define the amount of groundwater in saturated aquifers, annual storage change, and boundary flows;
- Shallow groundwater level data near rivers, creeks, and canal systems to characterize recharge;
- Groundwater levels from wells with known construction along the Subbasin boundary that could better characterize groundwater flows in and out of the Subbasin, especially in the B and C zones;
- The amount of groundwater being released through subsidence and how that relates to changes in groundwater storage; and
- The amount of water released from clays due to subsidence.

Other data gaps in the groundwater storage network are the same as in the groundwater level monitoring network, as described above, since storage change is dependent on changes in groundwater levels.

5.4.2.3 Plans to Fill Data Gaps

Data gaps in the storage change monitoring network will be filled as data gaps in the groundwater level network, as discussed in Section 5.2, *Monitoring Protocols for Data Collection and Monitoring*, are filled.

- **Groundwater Pumping.** There are areas of the Subbasin where not all wells have flow meters and, therefore, no record of the amount of groundwater pumping exists. The estimates of groundwater pumping included in this GSP, in many areas, are developed based on assumptions of how much crops require for ideal irrigation and then subtracting out effective precipitation and applied surface water. GSAs in the Subbasin plan to monitor groundwater pumping directly in the future to better understand this key water balance component. Also, the lack of construction information on many wells has led to a gap in understanding how much water is being pumped from each aquifer zone. Some actual pumping data plus estimates are being used for modelling purposes. Only after the construction of wells in the Subbasin is better understood, then the amounts being pumped from each aquifer zone can begin to be managed.
- **Coordination with Adjacent Subbasins.** The Subbasin is surrounded by five other critically overdrafted subbasins. Coordination with adjacent subbasins and the development of additional groundwater level monitoring facilities will be needed along the edge of the Subbasin to more accurately estimate the amount of groundwater flow in and out of the subbasins. From the groundwater modeling evaluations, it is clear that if conditions in adjacent subbasins don't improve, it will impact the ability of the Subbasin to achieve sustainability.
- **Recharge/Conveyance Loss Measurements.** There are many surface water right holders in the Subbasin that are partnering with local GSAs. The current measuring facilities on rivers, creeks and canals have been developed for surface water delivery and flood control purposes. Developing new measuring locations in order to refine information on recharge and conveyance losses will be important for water budgets and change in storage estimates. Local GSAs will work with their partners to develop new facilities as needed.
- **Aquifer Characteristics.** Estimates are currently being made about the specific yield or storativity of aquifers in the Subbasin. The GSAs will implement requirements relating to the development of new wells to develop a broader understanding of the variability of aquifer parameters throughout the Subbasin. This broader understanding will over time help refine estimates of groundwater in storage and groundwater flows.
- **Geology.** The current hydrogeologic conceptual model (HCM) for the Subbasin is based on the most current scientific information, but that information is limited. Much of the work that USGS and others have done on mapping the most significant geologic/ hydrogeologic features in the Subbasin are from evaluations of oil wells or water wells. Data from these wells, especially electric logs, are useful in developing an understanding

of the subsurface at that location, but this data may not be available at a sufficient density to fill gaps in the HCM for an area of over half a million acres. New technologies may be able to fill in some of the missing information and provide a more accurate or complete HCM for the Subbasin. It is hoped that grant funding may be available for this type of effort or that the state develops this information on behalf of its groundwater basins to improve its understanding of this important resource.

5.4.2.4 Site Selection

The site selection process for wells in the storage change monitoring network used the same criteria as the groundwater levels monitoring network. The same criteria as outlined in Section 5.1.3, *Design Criteria*, may be used to add additional wells into the storage change monitoring network as the water level monitoring network is the same.

5.4.3 Groundwater Quality

Several programs already operate with the directive of groundwater quality standards. Groundwater quality associated with projects and management actions will be monitored appropriately. A more detailed groundwater quality assessment for the Subbasin is provided in Section 3.2.5, *Groundwater Quality* and Section 4 of the 2022 GSP Addendum

5.4.3.1 Monitoring Frequency and Density

The GSAs desire to use existing groundwater quality sampling programs for tracking of groundwater quality. Figure 5-5 shows the relative density of groundwater quality well locations for the original 2020 GSP. Figure 4-10 of the 2022 GSP Addendum highlights new RMS locations. The monitoring frequency is dependent on those existing monitoring schedules. In general city/municipal wells are sampled quarterly but the frequency of sampling can vary significantly for different constituents and can also vary considerably from well to well. Sampling schedules for city/municipal and other community system wells are determined by the SWRCB Division of Drinking Water. The KRWQC-ILRP samples annually. Data, reports, and/or pertinent evaluations from the various programs will be retrieved annually.

5.4.3.2 Identification of Data Gaps

There are currently no data gaps in monitoring groundwater quality within the Subbasin. Additional monitoring will be triggered through evaluation of the existing data from the agencies and coalitions, and in conjunction and collaboration with the agencies or coalitions, on a case-by-case case basis. Further discussion of groundwater quality network data gaps are presented in Section 4.8 of the 2022 GSP Addendum

5.4.3.3 Site Selection

Groundwater quality monitoring site selection is driven, in part, by the location of city/municipal and other community well locations. As well, the KRWQC-ILRP has several well locations north of the clay plug. At this time, the Subbasin GSAs are proposing not to sample for groundwater quality in de-designated areas which includes Secondary Management Areas A and B. Locations of future groundwater quality sampling will likely be from monitoring wells that are constructed with funds from state or federal programs in data gap areas. As described above, the Subbasin GSAs would like to work collaboratively with the agencies currently performing groundwater quality monitoring.

5.4.4 Land Subsidence

The Subbasin land subsidence monitoring network will utilize data and subsidence evaluations from a variety of agencies including USGS, NASA, UNAVCO, CVSRN, KRCD, and KDWCD to verify areas of subsidence. Current DWR subsidence monitoring along the California Aqueduct is in cooperation with the USGS (Sneed, Brandt, and Solt 2018). If data from these sources becomes unavailable in the future, a new or expanded monitoring network may be established to monitor land subsidence. The agencies and methods used for measuring subsidence are discussed below

5.4.4.1 USGS Monitoring Network

A land subsidence monitoring network consisting of 31 extensometers was installed in the 1950s to quantify subsidence occurring in the San Joaquin Valley. This monitoring did not target the Tulare Lake bed area. By the 1980s, the land subsidence monitoring efforts decreased. Since then, a new monitoring network has been developed. The new network includes refurbished extensometers from the old network, CGPS stations, and use of Interferometric Synthetic Aperture Radar (InSAR). The USGS network does not have an extensometer in the Subbasin. Below is a description of the various methods used in the USGS Monitoring Network.

- **Extensometers.** Extensometers measure changes in the length of an object. As the surrounding soils move, or in the case of land subsidence fine grained soils compact, the distances between reference points change, which allows for continuous measurement of subsidence. Extensometers provide data for specific depth intervals in the subsurface where compaction of clays is occurring as well as the amount. These data are considered necessary to enable future predictions and mitigation of land subsidence. Extensometers are costly to install and require frequent maintenance and calibration.
- **InSAR.** During the last decade, the USGS and other groups have been using data from radar emitting satellites referred to as InSAR. This form of remote sensing compares radar images from each pass of an InSAR satellite over a study area to determine changes in the elevation of the land surface (USGS, 2017). InSAR has a relative accuracy

within fractions of an inch.

- **LiDAR.** DWR and USBR utilize LiDAR coupled with land elevation surveys to monitor subsidence. LiDAR utilizes a laser device that is flown above the Earth's surface. The accuracy of LIDAR is known to be less than a tenth (1/10th) of a foot as measured in root-mean-square deviation and very similar to that of surveying.

5.4.4.2 NASA Monitoring Network

NASA obtains subsidence data by comparing satellite images of Earth's surface over time. For the last few years, InSAR observations from satellite and aircraft have been used to produce the subsidence maps (NASA n.d.). More information can be found on the California Open Data Portal under NASA JPL InSAR Subsidence Data (California Open Data Portal 2019).

5.4.4.3 Continuous Global Positioning System Stations

The CGPS stations provide daily horizontal and vertical data, with records starting as early as 2004. One CGPS station is located south of Kettleman City. The Plate Boundary Observatory (PBO) and the Scripps Orbit and Permanent Array Center (SOPAC) upload and process data from the network of CGPS stations and produce graphs depicting the horizontal and vertical change in a point's location through time. More Information on CGPS stations can be found at the UNAVCO website (UNAVCO 2019).

5.4.4.4 Central Valley Spatial Reference Network

The California Department of Transportation's Central Region has developed a network that is comprised of CGPS stations that are permanently in place and operate continuously. These stations are known as the CVSRN. The network has stations along highway corridors to provide real time corrections for surveyors and data that can also be post-processed as well. Two CVSRN stations are located within the Subbasin near Corcoran and Highway 43, and Lemoore and Highway 198. In addition, PBO CGPS stations will be included in the CVSRN network in the future. The network was not designed to monitor subsidence, but the network is used by a variety of disciplines which benefit from the data collected at the stations (Caltrans 2019). Subsidence RMS wells are shown on Figure 3-11 of the 2022 GSP Addendum.

5.4.4.5 Kings River Conservation District

KRCD monitors a network of new and existing benchmarks, targeting a density of approximately 7 miles, where possible. Figure 3-11 of the 2022 GSP Addendum shows the locations of the benchmarks in their monitoring system that are added during the development of the 2022 GSP Addendum(Thiede 2016). Monitoring locations are further discussed in Section 3 of the 2022 GSP Addendum.

5.4.4.6 *Kaweah Delta Water Conservation District*

KDWCD has a subsidence monitoring program with one benchmark monument in the Subbasin in the MKR GSA (Figure 5-4). KDWCD surveys the benchmark monuments twice a year in February and September.

5.4.5 Monitoring Frequency and Density

The subsidence monitoring network is surveyed annually in the Subbasin. Subsidence change will generally be reported by GSA. Subsidence occurs on a regional scale with varying degrees occurring throughout the Subbasin.

5.4.6 Identification of Data Gaps

There is presently no known depth-discrete subsidence monitoring facilities (i.e., extensometers which can measure subsidence in specific portions of the aquifer) within the Subbasin. It is believed that the majority of subsidence occurs from compaction of clays. Extensometers would provide the data needed to differentiate subsidence at specific depth intervals. This data would be used to validate which portions of the aquifer are experiencing the most subsidence. In addition to the regional-based LiDAR/InSAR subsidence maps, the groundwater model developed for the Subbasin has previously been used as a tool to estimate where subsidence may occur in future as the GSAs determine where projects will be implemented and if pumping patterns change in the future. Westside, Kern County, and Tule subbasins have extensometers that are monitored by the USGS. Extensometers have a relative accuracy of approximately 1/100th of a foot and can provide information on which part of the aquifer is subsiding. When funding permits, proposed depth-discrete subsidence monitoring extensometers, in the vicinity of the greatest subsidence would be useful to evaluate depth-discrete subsidence. If and when depth-discrete monitoring becomes possible, the GSAs will pursue information on surface subsidence, groundwater pumping per well, surveys of well head elevations as needed, aquifer characteristics, and well construction to develop a scientific view of the zones and areas that can be managed to avoid subsidence. Additional discussion of the land subsidence network data gaps can be found in Section 3.4 of the 2022 GSP Addendum.

5.4.7 Site Selection

Land subsidence in the Subbasin is monitored through agency and government land subsidence surveying programs. The data generated by these programs are considered adequate both spatially and temporally as InSAR/LiDAR mapping covers the entire Subbasin, and because the area is closely monitored due to existing subsidence. However, individual GSAs may develop