Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area
Kern County Subbasin

Prepared by:
EKI Environment & Water, Inc.
for:
Wheeler Ridge-Maricopa Water Storage District

DRAFT – 28 August 2019
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<tbody>
<tr>
<td>AEWSD</td>
<td>Arvin-Edison Water Storage District</td>
</tr>
<tr>
<td>AF</td>
<td>acre-feet</td>
</tr>
<tr>
<td>AFY</td>
<td>acre-feet per year</td>
</tr>
<tr>
<td>AWMP</td>
<td>Agricultural Water Management Plan</td>
</tr>
<tr>
<td>BMP</td>
<td>Best Management Practice</td>
</tr>
<tr>
<td>BOS</td>
<td>bottom of screen</td>
</tr>
<tr>
<td>C2VSim</td>
<td>California Central Valley Groundwater-Surface Water Simulation Model</td>
</tr>
<tr>
<td>C2VSim-CG</td>
<td>California Central Valley Groundwater-Surface Water Simulation Model – Coarse Grid</td>
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<td>C2VSim-FG</td>
<td>California Central Valley Groundwater-Surface Water Simulation Model – Fine Grid</td>
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<td>Cal EPA</td>
<td>California Environmental Protection Agency</td>
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<td>CASGEM</td>
<td>California Statewide Groundwater Elevation Monitoring</td>
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<tr>
<td>CCR</td>
<td>California Code of Regulations</td>
</tr>
<tr>
<td>CDEC</td>
<td>California Data Exchange Center</td>
</tr>
<tr>
<td>CDMG</td>
<td>California Division of Mines and Geology</td>
</tr>
<tr>
<td>cfs</td>
<td>cubic feet per second</td>
</tr>
<tr>
<td>CGS</td>
<td>California Geological Survey</td>
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<tr>
<td>CIMIS</td>
<td>California Irrigation Management Information System</td>
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<td>CVHM</td>
<td>Central Valley Hydrologic Model</td>
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<td>Central Valley Project</td>
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<td>CVRWQCB</td>
<td>Central Valley Regional Water Quality Control Board</td>
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<td>CWC</td>
<td>California Water Code</td>
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<tr>
<td>DAC</td>
<td>Disadvantaged Community</td>
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<tr>
<td>DDW</td>
<td>Division of Drinking Water</td>
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<tr>
<td>DEM</td>
<td>Digital elevation model</td>
</tr>
<tr>
<td>DMS</td>
<td>Data Management System</td>
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<tr>
<td>DOGGR</td>
<td>Division of Oil, Gas and Geothermal Resources</td>
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<tr>
<td>DTSC</td>
<td>Department of Toxic Substances Control</td>
</tr>
<tr>
<td>DWR</td>
<td>California Department of Water Resources</td>
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<tr>
<td>EC</td>
<td>electrical conductance</td>
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<tr>
<td>EKI</td>
<td>EKI Environment &amp; Water, Inc.</td>
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<tr>
<td>ET</td>
<td>evapotranspiration</td>
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<tr>
<td>ETo</td>
<td>reference evapotranspiration</td>
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<tr>
<td>FKC</td>
<td>Friant-Kern Canal</td>
</tr>
<tr>
<td>ft</td>
<td>feet</td>
</tr>
<tr>
<td>ft bgs</td>
<td>feet below ground surface</td>
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ft msl  feet above mean sea level
ft/day  feet per day
ft²/day  feet squared per day
gal  gallons
GAMA  Groundwater Ambient Monitoring and Assessment
GDE  groundwater dependent ecosystem
GIS  Geographic Information System
gpd/ft  gallons per day per foot
gpd/ft²  gallons per day per foot squared
gpm  gallons per minute
GSA  Groundwater Sustainability Agency
GSP  Groundwater Sustainability Plan
GWMP  Groundwater Management Plan
HCM  Hydrogeologic Conceptual Model
ILRP  Irrigated Lands Regulatory Program
in  inches
in/hr  inches per hour
in/mo  inches per month
IRWMP  Integrated Regional Water Management Plan
ITRC  Irrigation Training & Research Center
JPA  Joint Powers Agreement
JPL  Jet Propulsion Laboratory
KCPHSD  Kern County Public Health Services Department
KCWA  Kern County Water Agency
KDWD  Kern Delta Water District
KGA  Kern Groundwater Authority
KRWCA  Kern River Watershed Coalition Authority
LUST  leaking underground storage tank
MCL  Maximum Contaminant Level
METRIC  Mapping EvapoTranspiration at high Resolution with Internalized Calibration
mg/L  milligrams per liter
M&I  municipal and industrial
NASA  National Aeronautics and Space Administration
NCCAG  Natural Communities Commonly Associated with Groundwater
ND  not detected
NLCD  National Land Cover Database
NRCS  Natural Resources Conservation Service
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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>PLSS</td>
<td>Public Land Survey System</td>
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<tr>
<td>P/MA</td>
<td>Project / Management Action</td>
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<tr>
<td>RMS</td>
<td>Representative Monitoring Site</td>
</tr>
<tr>
<td>RMSE</td>
<td>root mean squared error</td>
</tr>
<tr>
<td>SCEP</td>
<td>Stakeholder Communication and Engagement Plan</td>
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<tr>
<td>SDAC</td>
<td>Severely Disadvantaged Community</td>
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<td>SGMA</td>
<td>Sustainable Groundwater Management Act</td>
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<td>SSURGO</td>
<td>Soil Survey Geographic Database</td>
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<td>SWP</td>
<td>State Water Project</td>
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<td>SWRCB</td>
<td>State Water Resources Control Board</td>
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<td>SWSA</td>
<td>Surface Water Service Area</td>
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<tr>
<td>TCWD</td>
<td>Tejon Castac Water District</td>
</tr>
<tr>
<td>TDS</td>
<td>total dissolved solids</td>
</tr>
<tr>
<td>TNC</td>
<td>The Nature Conservancy</td>
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<td>TOS</td>
<td>top of screen</td>
</tr>
<tr>
<td>TRS</td>
<td>township-range-section</td>
</tr>
<tr>
<td>ug</td>
<td>micrograms</td>
</tr>
<tr>
<td>ug/L</td>
<td>micrograms per liter</td>
</tr>
<tr>
<td>umhos/cm</td>
<td>microsiemens per centimeter</td>
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<tr>
<td>USBR</td>
<td>United States Bureau of Reclamation</td>
</tr>
<tr>
<td>USCS</td>
<td>Unified Soil Classification System</td>
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<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
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<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
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<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
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<tr>
<td>WDRs</td>
<td>Waste Discharge Requirements</td>
</tr>
<tr>
<td>WKWD</td>
<td>West Kern Water District</td>
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<td>WRMWSD</td>
<td>Wheeler Ridge-Maricopa Water Storage District</td>
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EXECUTIVE SUMMARY

ES.1. Introduction

On 16 September 2014, the California legislature enacted the Sustainable Groundwater Management Act (SGMA) whose primary purpose is to achieve and/or maintain sustainability within the state’s high and medium priority groundwater basins. Key tenets of SGMA are the concept of local control, use of best available data and science, and active engagement and consideration of all beneficial uses and users of groundwater. As such, SGMA empowers certain local agencies to form Groundwater Sustainability Agencies (GSAs) whose purpose is to manage basins sustainably through the development and implementation of Groundwater Sustainability Plans (GSPs). Under SGMA, GSPs are required to contain certain elements, the most significant of which include: a Sustainability Goal; a description of the area covered by the GSP (“Plan Area”); a description of the Basin Setting, including hydrogeologic conceptual model, historical and current groundwater conditions, and a water budget; locally-defined sustainability criteria; monitoring networks and protocols for sustainability indicators; and a description of projects and/or management actions that will be implemented to achieve or maintain sustainability. SGMA also requires a significant element of stakeholder outreach to ensure that all beneficial uses and users of groundwater are given the opportunity to provide input into the GSP development and implementation process.

This GSP Management Area Plan (“MA Plan”) has been prepared by Wheeler Ridge-Maricopa Water Storage District (WRMWSD) and covers an area called the “Wheeler Ridge-Maricopa Management Area” or “Management Area” (see figure below). The Management Area underlies the WRMWSD service area, excluding the area (approximately 2,809 acres) also overlain by the West Kern Water District, and is located in the southern portion of the Kern County Subbasin of the San Joaquin Valley Groundwater Basin (Department of Water Resources [DWR] Basin No. 5-022.14; referred to herein as the “Kern Subbasin”). The Kern Subbasin is one of 21 basins and subbasins identified by the DWR as being critically overdrafted, a designation that triggers an accelerated timetable for GSP development by 2020 and achievement of sustainability by 2040.

The Kern Groundwater Authority (KGA) GSA, of which WRMWSD is a member, is the largest of the 11 GSAs that have been formed within the Kern Subbasin. The KGA GSA was formed in 2017 upon adoption of a Joint Powers Agreement by all members and is governed by a 16-member Board of Directors that includes...
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The KGA GSA is preparing an “Umbrella GSP” that, in addition to providing content for the entire KGA GSA area, includes individual Management Area Plans that contain more detailed information for each member agency’s service area. Areas of the Kern Subbasin that are outside of the KGA GSA GSP are covered under five separate, coordinated GSPs that have been developed by other GSAs.

The KGA Umbrella GSP and this MA Plan for the Wheeler Ridge-Maricopa Management Area have been developed to meet SGMA regulatory requirements1 while reflecting local needs and preserving local control over water resources. Together, these documents provide a path to maintain the long-term sustainability of locally-managed groundwater resources now and into the future.

ES.2. Sustainability Goal

The sustainability goal for the Wheeler Ridge-Maricopa Management Area is to maintain an economically-viable groundwater resource for the beneficial use of the Management Area’s landowners and water users by utilizing the area’s groundwater resources within the local sustainable yield. Long-term groundwater sustainability, i.e., the absence of undesirable results within 20 years of the applicable statutory deadline,

1 Regulations for GSP development are contained within Title 23 of the California Code of Regulations (CCR) Division 2 Chapter 1.5 Subchapter 2.
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will be achieved and maintained through the implementation of projects and management actions as described herein to both increase water supplies and reduce demands within the Management Area.

The local sustainability goal, above, is consistent with and in addition to the basin-wide sustainability goal being adopted by all GSAs in the Kern Subbasin.

**ES.3. Plan Area**

The Wheeler Ridge-Maricopa Management Area covers 91,430 acres in the southwestern portion of the Kern Subbasin. Located at the far southern end of the state’s Central Valley, the Kern Subbasin is the largest groundwater basin in the state and is bounded on the north by the Tulare Lake Subbasin, the Tule Subbasin, the Kettleman Plain Subbasin and on the south by the White Wolf Subbasin. The Wheeler Ridge-Maricopa Management Area is bordered on the north by the Kern Delta Water District and Henry Miller Water District, on the west by West Kern Water District, and on the east by (and overlapped with) the Arvin-Edison Water Storage District. To the south are “non-districted” lands, some of which have requested inclusion in this MA Plan and whose information is included in an Appendix hereto.

Most lands within the Wheeler Ridge-Maricopa Management Area are developed for irrigated agriculture, especially in the central and southern portions of the Management Area (see figure above). These agricultural lands use a combination of imported surface water provided by WRMWSD and groundwater from private wells for their water supply. WRMWSD has a water supply contract through Kern County Water Agency for State Water Project water which is obtained through turnouts off the California Aqueduct which runs through the District. WRMWSD has invested considerably over the years to import, convey, and distribute water to its customers within the Management Area (and also to customers in the portion of the District that is in the White Wolf Subbasin). Through its conjunctive management of water
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supplies, WRMWSD has provided a substantial net benefit to groundwater conditions within its service area.2

Two small public water systems exist within the Management Area, serving small populations of residents or workers at various commercial/agricultural facilities. Most of the Management Area is designated by the U.S. Census Bureau as either Disadvantaged Community (DAC) or Severely Disadvantaged Community (SDAC). In the preparation of this MA Plan the interests of DACs have been considered.

ES.4. Stakeholder Outreach Efforts

WRMWSD has developed and adopted a Stakeholder Communication and Engagement Plan (SCEP) for the Wheeler Ridge-Maricopa Management Area to fulfill notice and communication requirements and enable the interests of all beneficial users of groundwater within the Management Area during the development and implementation of the MA Plan. The goal of the outreach efforts described in the SCEP is to encourage open and transparent engagement by diverse stakeholders and gain knowledge and perspectives provided by basin stakeholders. Public participation has been welcomed throughout the MA Plan development process. Venues for public stakeholder engagement and input throughout the MA Plan development process have included: Wheeler Ridge-Maricopa Management Area SGMA Landowner Workshops, WRMWSD Board meetings, KGA GSA Board meetings, and KGA GSA Stakeholder Workshops and Meetings. Other outreach to Management Area stakeholders throughout the MA Plan development process has included: distribution and collection of a Stakeholder Survey and an Agricultural Stakeholder Survey, and various letters from WRMWSD and KGA to landowners. WRMWSD has also conducted extensive coordination with other KGA members and GSAs in the Kern Subbasin.

2 WRMWSD supplies surface water to certain lands with WRMWSD water supply contracts within the eastern portion of the Wheeler Ridge-Maricopa Management Area that overlaps with the Arvin-Edison Water Storage District (AEWSD) service area and Arvin-Edison Management Area. WRMWSD will continue to serve surface water to those lands within the overlap area that have contracts with and have historically received water from WRMWSD.
ES.5. Hydrogeologic Conceptual Model

The Wheeler Ridge-Maricopa Management Area is located in the southwestern portion of the Kern Subbasin, south of the Kern River. The Kern Subbasin occupies a large structural trough filled with thick sedimentary deposits of continental and marine origin. The local geology underlying the Management Area reflects its location near the edge of the basin, proximal to the San Emigdio Mountains which are a source for the sediments washed down into the basin.

The “principal aquifer” is defined in the Management Area as the aquifer materials encountered within the depths of production wells in the area (i.e., the top 2,600 feet) and is comprised of fluvial and alluvial deposits of Mio/Pliocene to Recent age. In the northeastern portion of the Management Area, a regionally-extensive clay layer (the “E”-Clay) is found at intermediate depths and creates more confined conditions in the underlying sediments. Aquifer conditions in general are more unconfined to semi-confined in the shallower zones and southern and western areas and more confined in the deeper zones and northern areas. The White Wolf Fault forms the southern boundary of the Kern Subbasin and has been demonstrated to be a significant impediment to groundwater flow as evidenced by higher groundwater levels on the upgradient (southern) side.

Due to its location near the edge of the basin, the southern half of the Management Area has fairly coarse and permeable soils that are conducive to recharge from precipitation and excess applied water. The northern half of the Management Area is underlain by finer soils with lower recharge potential, and in some locations perched groundwater is present due to low permeability soils and sediments close to the surface.

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3 Irrigation practices are generally highly efficient within the Wheeler Ridge-Maricopa Management area; however, recharge of applied water includes some irrigation inefficiency as well as water applied for leaching purposes and other non-consumptive operational uses.
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surface. The Management Area also receives recharge from percolation of natural surface water flows in several creeks that flow from the uplands in the south into the Management Area.

ES.6. Existing Groundwater Conditions

Information on groundwater conditions within the Management Area is presented in this MA Plan with respect to the six “Sustainability Indicators” defined under SGMA, which include the following:

• Chronic lowering of groundwater levels
• Reduction in groundwater storage
• Seawater intrusion
• Degraded water quality
• Land subsidence
• Depletion of interconnected surface water

Water Levels: Groundwater levels within the Management Area are presented using contour maps depicting recent (2015) seasonal high (spring) and seasonal low (fall) conditions, as well as hydrographs from 16 wells throughout the Management Area that have long records. The available data indicate groundwater flow directions are variable throughout the Management Area, with groundwater levels generally higher in the west and lower in the southern central and north central areas. Relative highs and lows appear to be controlled, at least in part, by the distribution of groundwater pumping versus surface

Spring 2015 Groundwater Elevations
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Water deliveries, with the exception of the south central where groundwater levels in 2015 were relatively low despite being within the District’s Surface Water Service Area. Depths to groundwater in Spring 2015 range from approximately 100 to 560 feet below ground surface (ft bgs). The fact that most groundwater levels are greater than 100 ft bgs indicates that connections to surface water and the existence of groundwater dependent ecosystems (GDEs) are unlikely. Hydrographs show the long-term positive effects of WRMWSD’s surface water importation in raising groundwater levels, tempered by the effects of the recent severe drought.

**Groundwater Storage:** Changes in groundwater storage over selected time periods of interest were analyzed by comparing water levels at the beginning and end of the period. The water levels show the positive impacts of water importation and the variability caused by wet and dry climate periods. Over the period from Fall 1994 through Fall 2014 (the KGA historical water budget period of interest), the average annual change in storage was +3,286 acre-feet per year (AFY), indicating sustainable conditions although annual changes in groundwater storage ranged from +83,000 AFY to -46,000 AFY. Spatially, the changes in storage (directly related to changes in water level) are more positive in the WRMWSD Surface Water Service Area compare to areas that rely solely on groundwater for supply.

**Water Quality:** Agricultural use is the dominant beneficial use within the Management Area, and groundwater quality is generally suitable for agricultural uses. That being said, in some instances concentrations of nitrate, arsenic, total dissolved solids (TDS), boron, iron, manganese and sulfate have been detected in groundwater within or near the Management Area above drinking water standards and/or agricultural water quality goals. Future monitoring efforts will include routine collection of water quality data throughout the Management Area; these data will be periodically reviewed and water quality trends will be evaluated as part of future GSP implementation efforts. Further, water quality issues related to potential constituents or concern are regulated separately under the Irrigated Lands Regulatory Program (ILRP), Central Valley-Salinity Alternatives for Long-term Sustainability (CV-SALTS), and the State Water Resources Control Board (SWRCB).

**Land Subsidence:** Some amount of land subsidence has been documented within the Wheeler Ridge-Maricopa Management Area over both historical (1949-2005) and recent (2015-2016) timeframes. Subsidence due to aquitard depressurization following groundwater withdrawal tends to be greater in the north central area, with some localized subsidence historically in the far western area and more recently in the south-central area. Subsidence has the potential to affect critical infrastructure including gravity-driven water conveyance systems (canals) and has been monitored and observed along the California Aqueduct. However, subsidence has been historically managed by DWR through maintenance and

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4 A perched groundwater zone exists along the northern boundary of the Management Area, where depth to groundwater has historically been encountered as shallow as 20 ft bgs. This perched zone is hydraulically disconnected from the underlying principal aquifer system and does not yield significant or economic quantities of groundwater to wells, springs, or surface water systems (see Section 8.1 Groundwater Elevations and Flow Direction).
improvements to its facilities and no reaches of the Aqueduct in this area have less than the minimum recommended freeboard.

**Interconnected Surface Waters:** Due to the great depth to groundwater in the principal aquifer (i.e., greater than 100 ft bgs in most places), it appears that there are no interconnection surface water systems within the Management Area. Similarly, while the DWR dataset of Natural Communities Commonly Associate with Groundwater (NCCAG) shows some areas along the northern boundary of the Management Area as NCCAG, due to the great depth to groundwater in the principal aquifer, these areas do not appear to be GDEs.

**Seawater Intrusion:** The Management Area is located far from coastal areas. As a result, seawater intrusion is not considered to be an issue for this area.

**ES.7. Water Budget**

For the Kern Subbasin as a whole, the basin GSAs coordinated in the development of a numerical model based on the California Central Valley Groundwater/Surface Water Simulation Model (C2VSim) to estimate the basin-wide water budget, as described in the KGA Umbrella GSP. In addition, on a local Management Area basis, a spreadsheet water budget model was developed and calibrated to observed water level/storage changes to provide locally-refined water budget information. The calibrated spreadsheet model is the basis for the historical and current water budget information presented herein (see figure below). The sustainable yield for the Management Area is conservatively estimated to be at a minimum approximately 60,300 AFY under current supply and demand conditions (approximately 0.65 AFY/acre over the 91,430-acre Management Area). This sustainable yield is consistent with the assumptions for “native yield” and effective precipitation being used basin-wide and also reflects the contribution to groundwater from return flow of applied imported surface water. Over the historical water budget time period (DWR water years [WY] 1995 through 2014; October 1994 through September 2014), the average annual change in groundwater storage in the Management Area was +3,286 AFY, indicating that the Management Area is **not in a condition of critical overdraft**.
Water budget information under projected (future) conditions was also developed using the calibrated spreadsheet water budget model, with DWR-provided inputs for climate variables (i.e., precipitation and evapotranspiration) and water supply assumptions (i.e., changes to imported water supplies). The projected water budget assesses the magnitude of the net water supply deficit under future conditions that would need to be addressed through Projects and Management Actions (P/MA) to prevent Undesirable Results and achieve the Sustainability Goal. Consistent with the basin-wide efforts, three projected water budget scenarios were developed for this analysis: a Baseline Scenario, a 2030 Climate Change Scenario, and a 2070 Climate Change Scenario. The results of this assessment were used as the basis to develop P/MA for the Management Area.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Estimated Annual Change in Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (No climate change)</td>
<td>-14,665 AFY</td>
</tr>
<tr>
<td>2030 Climate Change Conditions (Moderate climate change effects)</td>
<td>-21,429 AFY</td>
</tr>
<tr>
<td>2070 Climate Change Conditions (High climate change effects)</td>
<td>-33,326 AFY</td>
</tr>
</tbody>
</table>
ES.8. Sustainable Management Criteria

Sustainable Management Criteria (SMCs) are the metrics by which groundwater sustainability is judged under SGMA. Key terms related to SMCs under SGMA include the following:

**Undesirable Results**: Undesirable Results are the significant and unreasonable occurrence of conditions, for any of the six Sustainability Indicators defined under SGMA, that adversely affect groundwater use in the basin. Definitions of Undesirable Results for the basin have been developed through a coordinated effort of the basin GSAs and are described in the KGA GSA Umbrella GSP. The basin-wide definitions of Undesirable Results allow for local definition of Minimum Thresholds and the combination thereof that is considered significant and unreasonable. Therefore, the broad basin-wide Undesirable Results definitions were refined locally for the Wheeler Ridge-Maricopa Management Area to better reflect local groundwater conditions and beneficial uses.

**Minimum Thresholds**: Minimum Thresholds (MTs) are the numeric criteria for each Sustainability Indicator that, if exceeded in a locally-defined combination of monitoring sites, may constitute an Undesirable Results for that indicator. Where appropriate, the Minimum Thresholds for the Sustainability Indicators have been set using groundwater levels as a proxy.

**Measurable Objectives**: Measurable Objectives (MOs) are a specific set of quantifiable goals for the maintenance or improvement of groundwater conditions. Measurable Objectives use the same units and metrics as the Minimum Thresholds and are thus directly comparable.

**Interim Milestones**: Interim Milestones are a set of target values representing measurable groundwater conditions in increments of five years over the 20-year statutory deadline for achieving sustainability.

**Chronic Lowering of Groundwater Levels** is arguably the most fundamental Sustainability Indicator, as it influences several other key Sustainability Indicators, including Reduction of Groundwater Storage and Land Subsidence. MTs and MOs for Chronic Lowering of Groundwater Levels were developed through temporal analysis of long-term groundwater level data. Briefly, at each of 15 locations with long-term records, an initial MT estimate was calculated considering historical lows, recent groundwater level trends, and the variability or range in groundwater levels. Initial MOs were set based on fall 2015 levels. These initial individual estimates were then generalized into three Sustainability Zones to allow flexibility in the ultimate monitoring locations. An evaluation of these generalized MTs against known well construction information was performed to understand the potential impacts on wells (i.e., potential dewatering of shallow wells). MTs and MOs were presented on multiple occasions in public meetings to allow for stakeholder input.
Significant Groundwater Storage exists within the Wheeler Ridge-Maricopa Management Area, and it is estimated that it would take roughly 100 years of zero recharge to deplete the usable storage under current extraction rates. As such, it was determined to be sufficiently protective to define the SMCs for Reduction of Groundwater Storage based on the SMCs for Chronic Lowering of Groundwater Levels.

No SMCs for Degraded Water Quality are defined within the Wheeler Ridge-Maricopa Management Area because, based the existing beneficial uses and users of groundwater within, there are no Undesirable Results for Degraded Water Quality occurring, and the MTs for Chronic Lowering of Groundwater Levels are anticipated to be protective in terms of preventing migration of poor-quality water. Monitoring for water quality will continue to be conducted at a set of Representative Monitoring Sites, and if a nexus between these constituent concentrations and water levels and groundwater management actions is established, then the SMCs for water quality will be revisited.

The SMCs for Land Subsidence are based on observed rates of subsidence from ground-based surveys along the California Aqueduct between 1993 and 2013. Specifically, the MT is set as the maximum rate of subsidence that was observed during that period extended through the GSP implementation timeframe. The rationale for this MT rate of subsidence is that such subsidence has been historically managed by DWR through maintenance and improvements to its facilities and no reaches of the Aqueduct in this area have less than the minimum recommended freeboard. The MO is defined as half of the amount of land subsidence that would occur if the maximum observed subsidence rates (1993 – 2013) were to continue.

As discussed above, Depletion of Interconnected Surface Water has not been observed within the Wheeler Ridge-Maricopa Management Area and is not applicable due to the great depths to groundwater in the principal aquifer. Likewise, Seawater Intrusion does not exist within the Kern Subbasin. Therefore, no SMCs for these Sustainable Indicators are defined in this MA Plan.
ES.9. Monitoring Network

The objective of the Wheeler Ridge-Maricopa Management Area Monitoring Network is to collect sufficient data to allow for assessment of the Sustainability Indicators relevant to the Management Area, and potential impacts to the beneficial uses and users of groundwater. The proposed Monitoring Network was developed to ensure sufficient spatial distribution and spatial density. The network consists of 14 Representative Monitoring Sites for groundwater levels and (by proxy) groundwater storage, nine sites for monitoring groundwater quality (although as discussed above, no SMCs are defined for this Sustainability Indicator), and 40 sites along the California Aqueduct for monitoring land subsidence. The SGMA-compliance network for the Management Area supplements other monitoring networks and programs in the basin such as DWR California Statewide Groundwater Elevation Monitoring (CASGEM), Central Valley-Salinity Alternatives for Long-term Sustainability (CV-SALTS), Kern County Water Agency (KCWA) semiannual groundwater monitoring program, etc. and basin-wide monitoring networks related to SGMA compliance such as the KGA’s land subsidence network.

Data collected from the SGMA-compliant Monitoring Network will be uploaded to the Data Management System maintained for the basin and reported to the DWR in accordance with the Monitoring Protocols developed for the basin as described in the KGA Umbrella GSP. In addition, local data will be stored and managed in a Wheeler Ridge-Maricopa Management Area-specific DMS. Additional data collected as part of WRMWSD’s other regular monitoring programs may be used in conjunction with data collected from the SGMA-compliant Monitoring Network to meet compliance with GSP regulations regarding Annual Reporting or as otherwise deemed necessary for the Management Area.

ES.10. Project and Management Actions

Achieving sustainability in the Wheeler Ridge-Maricopa Management Area will require implementation of P/MAAs to address projected water budget deficits. As such, WRMWSD has developed a portfolio of P/MAAs,
each with specific expected benefits, implementation triggers, and costs. A preliminary “glide path” has been developed that results in closing of the currently identified “deficit”\textsuperscript{5} of approximately -21,400 AFY by 2040. Accelerated implementation of P/MAs will be triggered if observed groundwater conditions deteriorate, as measured against defined SMCs at the representative monitoring sites.

The Projects in WRMWSD’s P/MA portfolio have supply augmentation as their primary expected benefit, and are grouped into the following categories:

- Projects to Enhance Recharge/Banking;
- Projects to Increase Water Management Flexibility; and
- Projects to Develop New Supplies.

The Management Action in the P/MA portfolio have water demand reduction as their primary expected benefit and are grouped into the following categories:

- Management Actions to Raise Funds to Support SGMA Compliance; and
- Management Actions / Policies to Reduce Groundwater Pumping.

The supply augmentation and demand reduction P/MAs listed above comprise a diverse portfolio of options that can be implemented by WRMWSD to achieve sustainability from a water quantity perspective. Simulation results from the basin-wide numerical (C2VSim) model indicate that P/MA implementation along the planned glide path will successfully achieve sustainability and avoid Undesirable Results for Groundwater Levels (and by proxy for the other applicable Sustainability Indicators). The glide path provides a general guide to how quickly these benefits are to be realized. However, the exact schedule and order of implementation is not known, and further analysis will be conducted to prioritize the P/MAs in consideration of factors including permitting, engineering feasibility, cost effectiveness and other factors. In general, P/MAs being considered for implementation will be discussed during regular

\textsuperscript{5} The net deficit to be addressed by the 2040 GSP implementation deadline is the estimated deficit under the 2030 Climate Change scenario.
ES.11. GSP Implementation

Key GSP implementation activities to be undertaken over the next five years include:

- Monitoring and data collection;
- Projects & Management Action (P/MA) implementation, including policy development to support GSP implementation;
- Technical and non-technical coordination with other water management entities within the Kern County Subbasin (Kern Subbasin);
- Continued outreach and engagement with stakeholders;
- Annual reporting;
- Enforcement and response actions, as necessary; and
- Evaluation and updates, as necessary, of the Wheeler Ridge-Maricopa MA Plan as part of the required periodic evaluations (i.e., “five-year updates”).

ES.12. GSP Implementation Costs and Funding

Costs to implement this MA Plan can be divided into several groups, as follows:

- Costs of local groundwater management activities;
- WRMWSD’s proportional share of costs for basin-wide groundwater management activities; and
- Costs to implement P/MAs, including capital/one-time costs and ongoing costs.

The estimated costs to WRMWSD for local groundwater management activities is approximately $261,000 per year, the estimated proportional share of costs for basin-wide groundwater management activities is approximately $120,000 per year, and the estimated costs to implement P/MAs is approximately $3.5 million per year in the first five years, increasing to between approximately $4.5 million to $7.1 million per year in the subsequent 15 years.

Sources of funding for SGMA compliance activities will include primarily regular fees and assessments from customers and rate payers. This primary source of revenue will be supplement to the greatest extent possible through loans and grants, and possibly by additional fees imposed as an incentive to discourage unsustainable water use practices. All efforts by WRMWSD to raise revenue through fees and charges will be conducted pursuant to applicable laws and regulations (e.g., Proposition 218 and related laws).
ES.13. Conclusion

The passage of SGMA in 2014 ushered in a new era of mandatory groundwater management in California’s most intensively used groundwater basins. The law was followed by promulgation of a robust regulatory framework for GSA formation and GSP development and implementation. The law and regulations emphasize the use of best available science, local control and decision making, and active engagement of affected stakeholders. Because of the breadth and scope of the groundwater sustainability problem in California and the legislative and regulatory response to it, SGMA presents significant challenges both for local implementing agencies and groundwater users alike. Achieving and maintaining sustainability in the face of uncertain future water supply conditions while addressing and balancing the needs of all beneficial uses and users will require significant effort, creative solutions, and unprecedented collaboration. As the implemented agency within the Wheeler Ridge-Maricopa Management Area, WRMWSD is committed to facing these challenges in a manner that upholds the interests of its landowners and other beneficial uses and users of groundwater.
1. PURPOSE OF THIS GROUNDWATER SUSTAINABILITY PLAN

The purpose of this Groundwater Sustainability Plan (GSP) Management Area Plan (MA Plan) is to, in combination with the Kern Groundwater Authority (KGA) Groundwater Sustainability Agency (GSA) and the other GSAs in the Kern County Subbasin (Kern Subbasin), meet the regulatory requirements set forth in the three-bill legislative package consisting of Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley), and SB 1319 (Pavley), collectively known as the Sustainable Groundwater Management Act (SGMA)\(^6\). 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”. Undesirable results are defined by SGMA as any of the following effects caused by groundwater conditions occurring throughout the basin:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply;
- Significant and unreasonable reduction of groundwater storage;
- Significant and unreasonable seawater intrusion;
- Significant and unreasonable degraded water quality;
- Significant and unreasonable land subsidence; and/or
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

The Kern Subbasin has been identified by the California Department of Water Resources (DWR) as critically overdrafted. WRMWSD’s MA Plan has been developed in coordination with the KGA GSA to meet SGMA regulatory requirements by the January 31, 2020 deadline for critically-overdrafted basins while reflecting local needs and preserving local control over water resources. WRMWSD’s MA Plan, in coordination with the KGA Umbrella GSP and the other GSPs in the Kern Subbasin, provides a path to achieve and document sustainable groundwater management within 20 years following Plan adoption, and preserves the long-term sustainability of locally-managed groundwater resources now and into the future.

\(^6\) Nothing in this Management Area Plan or in the related Groundwater Sustainability Plan determines or alters surface water rights or groundwater rights under common law, any provision of law that determines or grants surface water rights, or otherwise (see, California Water Code section 10720.5(b)). This Management Area Plan and the related Groundwater Sustainability Plan shall be construed consistent with Section 2 of Article X of the California Constitution and nothing provided in this Chapter modifies rights or priorities to use or store groundwater except as expressly stated in California Water Code section 10720.5(a). The District reserves and retains all rights to the use of water to the extent provided by law.
2. SUSTAINABILITY GOAL

§ 354.24 Sustainability Goal

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.

The sustainability goal for the Wheeler Ridge-Maricopa Management Area is to maintain an economically-viable groundwater resource for the beneficial use of the Management Area’s landowners and water users by utilizing the area’s groundwater resources within the local sustainable yield. Long-term groundwater sustainability, i.e., the absence of undesirable results within 20 years of the applicable statutory deadline, will be achieved and maintained through the implementation of projects and management actions as described herein to both increase water supplies and reduce demands within the Management Area.

The local sustainability goal, above, is consistent with and in addition to the basin-wide sustainability goal being adopted by all GSAs in the Kern Subbasin, shown below (as of 9 August 2019).

“The sustainability goal of the Kern County Subbasin is to:

- Achieve sustainable groundwater management in the Kern County Subbasin through the implementation of projects and management actions at the member agency level of each GSA
- Maintain its groundwater use within the sustainable yield of the basin
- Operate within the established sustainable management criteria, which are based on the collective technical information presented in the GSPs in the Subbasin.
- Implement projects and management actions that include a variety of water supply development and demand management actions
- Collectively bring the Subbasin into sustainability and to maintain sustainability over the implementation and planning horizon.

Further, the Subbasin sustainability goal includes a commitment to monitor and report groundwater conditions, as required by SGMA, and to continue coordination among the KGA member agencies and all other GSA’s in the Subbasin to identify the potential for, or presence
of, undesirable results and actions to prevent undesirable results. The coordination process established in the development of this GSP and memorialized in the Coordination Agreement will ensure that the Subbasin is managed as a shared groundwater resource and that the districts within the Subbasin work collaboratively towards achieving and maintaining sustainable groundwater use.”
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3. AGENCY INFORMATION

§ 354.6. When submitting an adopted Plan to the Department, the Agency shall include a copy of the information provided pursuant to Water Code Section 10723.8, with any updates, if necessary, along with the following information:

(a) The name and mailing address of the Agency.
(b) The organization and management structure of the Agency, identifying persons with management authority for implementation of the Plan.
(c) The name and contact information, including the phone number, mailing address and electronic mail address, of the plan manager.
(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.
(e) An estimate of the cost of implementing the Plan and a general description of how the Agency plans to meet those costs.

3.1. Name and Mailing Address of the Agency

The Wheeler Ridge-Maricopa Water Storage District Management Area (Wheeler Ridge-Maricopa Management Area) is the portion of the Kern County Subbasin of the San Joaquin Valley Groundwater Basin (Department of Water Resources [DWR] Basin No. 5-022.14) that underlies the WRMWSD. WRMWSD is member of the Kern Groundwater Authority Groundwater Sustainability Agency (KGA GSA or Agency) per a Joint Power Agreement (JPA) executed on 22 March 2017. Information regarding the Agency’s mailing address is provided in the KGA “Umbrella” GSP.

The mailing address for the WRMWSD is:

12109 Highway 166
Bakersfield, California 93313-9630

The mailing address for the KGA GSA is:

Kern Groundwater Authority
(c/o Provost & Pritchard Consulting Group)

7 In this document, the term “Wheeler Ridge-Maricopa Management Area” is used in its entirety the first time the area is being referenced in each paragraph; subsequent references to this area in each paragraph use the term “Management Area”.

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3.2. Organization and Management Structure of the Agency

Per the JPA executed on 22 March 2017, the KGA GSA Board is composed of one representative from each of the general member agencies\(^8\), including: Arvin Community Services District (ACSD), Arvin-Edison Water Storage District (AEWSD), Cawelo Water District (CWD), Kern County Water Agency (KCWA), Kern-Tulare Water District (KTWD), Kern Water Bank Authority (KWBA), North Kern Water Storage District (NKWSD), Rosedale-Rio Bravo Water Storage District (RRBWSD), Semitropic Water Storage District (SWSD), Shafter-Wasco Irrigation District (SWID), Southern San Joaquin Municipal Utility District (SSJMUD), Tejon-Castac Water District (TCWD), West Kern Water District (WKWD), Westside District Water Authority (WDWA) and WRMWSD, and the City of Shafter.

To facilitate the implementation of the KGA GSA GSP, the Agency is divided into management areas formed by the portion of the Kern Subbasin that underlies the boundaries of each general member agency. Each general member agency will prepare a refined Management Area Plan for their management area.

The WRMWSD Board of Directors also represents the Wheeler Ridge-Maricopa Management Area and it is formed by nine directors, one for each division within the District:

- Jonathan N. Reiter (Division 1)
- Mark B. Valpredo (Division 2)
- Michael P. Blaine (Division 3)
- Colby Fry (Division 4)
- Kyle G. Richardson (Division 5)
- Jeffrey R. Mettler (Division 6)
- Jose B. Marin (Division 7)
- Dennis J. Atkinson (Division 8)
- Dennis Mullins (Division 9); WRMWSD representative on the KGA Board of Directors

The KGA GSA was formed by a resolution of the Board of Directors of the Kern Groundwater Authority on 26 April 2017. The KGA GSA is governed by a Board of Directors that includes a representative of each member agency. Information regarding current KGA GSA Board members can be found on the KGA’s website at http://www.kerngwa.com/. Current KGA GSA Board Members include:

\(^8\) See executed JPA for a full list of member agencies to the KGA.
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- Board Chairman – Dennis Mullins, Wheeler Ridge-Maricopa Water Storage District
- Vice Chairman – Vacant
- Bob Rodriguez, Arvin Community Services District
- Kevin Pascoe, Arvin-Edison Water Storage District
- John Gaugel, Cawelo Water District
- Chad Givins, City of Shafter
- Royce Fast, Kern County Water Agency
- Andrew Pandol, Kern-Tulare Water District
- Bill Taube, Kern Water Bank Authority
- Kevin Andrew, North Kern Water Storage District
- Jason Selvidge, Rosedale-Rio Bravo Water Storage District
- Rick Wegis, Semitropic Water Storage District
- Mark Franz, Shafter-Wasco Irrigation District
- Jim Regan, Southern San Joaquin Municipal Utility District
- Gary Morris, West Kern Water District
- Rob Goff, Westside Water Authority
- Ryan Fachin, Tejon-Castac Water District

3.3. MA Plan Manager

The Plan Manager for this MA Plan is Sheridan Nicholas, Engineer-Manager of the WRMWSD. Mr. Nicholas can be reached at:

Sheridan Nicholas  
Engineer-Manager  
Wheeler Ridge-Maricopa Water Storage District  
12109 Highway 166  
Bakersfield, California 93313-9630  
661-858-2281 office phone  
email: snicholas@wrmwsd.com

The KGA GSP Plan Manager is Patricia Poire. Ms. Poire can be reached at:
3.4. Legal Authority of the GSA

The KGA GSA applied for and was granted GSA status under SGMA Section 10723(c). Please refer to the KGA Umbrella GSP for further discussion of the legal authority of the KGA GSA, demonstrating that it has the legal authority to implement the GSP.

3.5. Estimated Cost of Implementing the GSP and the GSA’s Approach to Meet Costs

Information on estimated costs to implement the GSP within the Wheeler Ridge-Maricopa Management Area, and the WRMWSD’s plan to meet those costs is provided in Section 19 Plan Implementation Costs.
4. GSP ORGANIZATION

This MA Plan is organized as follows:

- Sections 1 through 4 comprise the Introduction, including the following sections:
  - Section 1. Purpose of this Groundwater Sustainability Plan
  - Section 2. Sustainability Goal
  - Section 3. Agency Information
  - Section 4. GSP Organization

- Section 5 provides the Description of the Plan Area.

- Sections 6 through 10 present the Basin Setting, including the following sections:
  - Section 6. Introduction to Basin Setting
  - Section 7. Hydrogeologic Conceptual Model
  - Section 8. Current and Historical Groundwater Conditions
  - Section 9. Water Budget Information
  - Section 10. Management Areas

- Sections 11 through 16 present the Sustainable Management Criteria, including the following sections:
  - Section 11. Introduction to Sustainable Management Criteria
  - Section 12. Sustainability Goal
  - Section 13. Undesirable Results
  - Section 14. Minimum Thresholds
  - Section 15. Measurable Objectives and Interim Milestones
  - Section 16. Monitoring Network

- Section 17 presents the Projects and Management Actions.

- Sections 18 through 20 present Plan Implementation, including the following sections:
  - Section 18. Plan Implementation Activities
  - Section 19. Plan Implementation Costs
  - Section 20. Plan Implementation Schedule
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- References and Technical Studies are included at the end of this document.
- Supporting information is provided in appendices as follows:
  - Appendix A. GSP Submittal Checklist
  - Appendix B. Stakeholder Communications and Engagement Plan
  - Appendix C. List of Public Meetings Specific to SGMA and WRMWSD’s MA Plan Development
  - Appendix D. Analysis of Temporal Characteristics of Available Groundwater Quality Data
  - Appendix E. Methods and Data Used in the Water Budget Spreadsheet Model Approach
  - Appendix F. WRMWSD Long-term Monitoring Access Agreement
  - Appendix G. DWR California Aqueduct Subsidence Study (June 2017), Plates 20 – 24
  - Appendix H. Parcels Outside of WRMWSD Covered by GSP
Plan Area
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

PLAN AREA
5. DESCRIPTION OF THE PLAN AREA

This section presents a description of the Plan Area for the Wheeler Ridge-Maricopa Management Area\(^9\), and a summary of the relevant jurisdictional boundaries and other key land use features potentially relevant to the sustainable management of groundwater in the Management Area. This section also describes the water monitoring programs, water management programs, and general plans relevant to the Management Area and their influence on the development and execution of this Groundwater Sustainability Plan (GSP) Management Area Plan (MA Plan).

5.1. Summary of Jurisdictional Areas and Other Features

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

(a) One or more maps of the basin that depict the following, as applicable:

(1) 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.

(2) Adjudicated areas, other Agencies within the basin, and areas covered by an Alternative.

(3) 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.

(4) Existing land use designations and the identification of water use sector and water source type.

(5) 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.

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

5.1.1. Plan Area Setting

As discussed previously in Section 3.2 Organization and Management Structure of the Agency, this MA Plan is a locally refined subcomponent of the “Umbrella” GSP prepared by the Kern Groundwater

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\(^9\) In this document, the term “Wheeler Ridge-Maricopa Management Area” is used in its entirety the first time the area is being referenced in each paragraph; subsequent references to this area in each paragraph use the term “Management Area”.

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Plan Area

Groundwater Sustainability Plan

Wheeler Ridge-Maricopa Management Area, Kern Subbasin

Authority (KGA) Groundwater Sustainability Agency (GSA). This MA Plan covers a portion of the KGA GSA area, specifically the portion underlying Wheeler Ridge-Maricopa Water Storage District (WRMWSD). The area covered by this MA Plan, referred to herein as the “Wheeler Ridge-Maricopa Management Area” and shown on Figure PA-1, includes all WRMWSD lands within the Kern County Subbasin (Department of Water Resources [DWR] Basin 5-022.14) (referred to herein as the Kern Subbasin or basin) excepting 2,809 acres that occur within the West Kern Water District (WKWD). Lands within the WRMWSD service area that are located in the White Wolf Subbasin are managed under a separate GSP being prepared by the White Wolf GSA. The Arvin-Edison Water Storage District (AEWSD) jurisdictional boundary also partially overlaps the Management Area, both in the Kern Subbasin and the White Wolf Subbasin; AEWSD is a participating member of the KGA GSA and is developing separate Management Area Plan for its jurisdictional area within the Kern Subbasin in close coordination with WRMWSD. For purposes of SGMA monitoring, WRMWSD and AEWSD have agreed that AEWSD will cover the overlap areas.

The Wheeler Ridge-Maricopa Management Area is in the southern-southeastern portion of the Kern Subbasin. The basin is bounded on the north by the Tulare Lake Subbasin (DWR Basin 5-022.12), the Tule Subbasin (DWR Basin 5-022.13), and the Kettleman Plain Subbasin (DWR Basin 5-022.17), and on the south by the White Wolf Subbasin (DWR Basin 5-022.18).

The Wheeler Ridge-Maricopa Management Area encompasses 91,430 acres of the KGA GSA. There are 10 other GSAs that are located within the Kern Subbasin: Buena Vista Water Storage District (BVWSD), Cawelo GSA, Greenfield County Water District, Henry Miller Water District (HMWD), Kern River GSA, McFarland GSA, Olcese GSA, Pioneer GSA, Semitropic Water Storage District, and West Kern Water District (WKWD). These GSAs were formed by several other GSA-eligible public agencies in the basin and in some cases are preparing separate GSP documents that will be coordinated with the GSP prepared by the KGA GSA. The rest of the basin is comprised of undistricted lands (i.e. “white lands”), some of which have executed management agreements with nearby water districts or other public agencies. The basin is not adjudicated, and no portion of the basin is being managed pursuant to an alternative.

5.1.2. Jurisdictional Boundaries

The Wheeler Ridge-Maricopa Management Area is entirely within Kern County and the Kern County Water Agency. As shown on Figure PA-1, water agencies that partially overlie the Management Area are AEWSD and the WKWD. Additional water agencies and public water systems in the vicinity of the Management Area include: BVWSD, HMWD, Kern Delta Water District (KDWD), Opal Fry and Son Water System, and Mettler County Water District (MCWD).

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11 WKWD overlaps a portion of WRMWSD, however, the GSA formed by this district (WKWD GSA) does not include such area.
Plan Area
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

According to the information made available by DWR in support of the development of GSPs, there are no tribal lands nor state lands within or in the vicinity of the Wheeler Ridge-Maricopa Management Area. Federal lands within the Management Area include approximately 500 acres of national public lands managed by the U.S. Bureau of Land Management, located in the northern portion of the District (see Figure PA-2). Tribal, federal and state lands within the KGA GSA are identified in the KGA Umbrella GSP.

DWR further presents information regarding U.S. Census Blocks, Tracts and Places that are defined as Disadvantaged Communities (DAC) or Severely Disadvantaged Communities (SDAC). Figure PA-3 shows DAC/SDAC areas within the Wheeler Ridge-Maricopa Management Area. As shown on Figure PA-3, a majority of the Management Area is considered either a severely disadvantaged or a disadvantaged community based on the Census Block Group and Census Tract characterizations (see Figure PA-3).

The Wheeler Ridge-Maricopa Management Area is located entirely within the Kern County General Plan area (see Figure PA-7). This plan is described in further detail below in Section 5.3 Land Use Elements or Topic Categories of Applicable General Plans.

5.1.3. Existing Land Use and Water Use

As shown on Figure PA-4, agriculture is the primary land use within the Wheeler Ridge-Maricopa Management Area, followed by idle/non-irrigated lands. As of Spring 2017, approximately 63,620 acres (71%) are classified as irrigated agricultural lands within the Management Area, ~23,950 acres (27%) are classified as non-irrigated agricultural/native lands, and ~2,260 acres (3%) are classified as urban areas and artificial channels.

Agricultural water demands are met with surface water and/or groundwater depending on location within the Wheeler Ridge-Maricopa Management Area. The District has a contract for 197,088 acre-feet per year (AFY) of Table A water from the State Water Project (SWP) through the Kern County Water Agency (KCWA) (WRMWSD, 2015). Figure PA-5 shows the parcels within the District’s surface water service area (SWSA). The reminder of the Management Area relies solely on groundwater to meet demands; surface water customers are not precluded from pumping underlying groundwater for beneficial use.

Imported surface water is served only to agricultural water users for irrigation. All municipal/industrial (M&I) and domestic demands are met by groundwater pumping. The potable consumption of groundwater in the Management Area is limited to domestic well owners.

Land use designations under the Kern County General Plan are discussed in Section 5.3.1 Kern County General Plan and shown on Figure PA-7.

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12 SGMA Data Viewer: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer
5.1.4. Well Density per Square Mile

Figure PA-6 shows the density of wells per square mile within the Wheeler Ridge-Maricopa Management Area, based on Well Completion Report records compiled by DWR and refined information on active domestic wells obtained from the Community Water Center. According to these records, approximately 121 production wells, 27 active domestic wells, and one public supply well have been installed within the Public Land Survey System (PLSS) sections that fall partially or entirely within the Management Area.

The WRMWSD Data Management System (DMS) identifies 559 wells within the Wheeler Ridge-Maricopa Management Area; 100 of these wells are known to be active, 49 inactive or abandoned, and the status of 410 wells is unknown. Of the active wells, 79 are production wells, 14 are domestic/Municipal & Industrial (M&I) wells, and seven are monitoring wells. As part of GSP preparation efforts, the District is attempting to reconcile the information in its DMS with the DWR records. These data reconciliation efforts are expected to continue as part of GSP implementation.

The closest urban communities to the Wheeler Ridge-Maricopa Management Area are Maricopa and Mettler but there are no communities dependent on groundwater within the Management Area. The only potable groundwater consumption comes from the domestic wells.

5.1.5. Lands Outside of District Covered by MA Plan

Under SGMA (CWC § 10724), counties are presumed to be the GSA for areas that are not otherwise covered by another GSA, unless the county specifically opts out of this GSA role. In the Kern Subbasin, the County of Kern opted out of this role in early 2019 which resulted in lands outside of the other GSA boundaries being “uncovered”. To address this, the KGA sent notices to these “undistricted” landowners offering an opportunity to sign an agreement for coverage under the Management Area Plans of nearby KGA members. Three landowners with a total of four parcels outside of the District totaling approximately 1,122 acres accepted the offer to gain coverage under the WRMWSD MA Plan. Given the late time at which these offers were made and accepted following the County’s withdrawal, KGA determined that it would not be possible to cover these undistricted lands in the KGA member’s Management Area Plans to the same degree of detail as lands that were covered by KGA members from the start; instead, KGA determined that it would be appropriate to include the lands in an appendix to the Management Area Plans, providing basic information about each parcel including the owner, APN, area, land/water use, and well information. As such, Appendix H includes a table of these lands with the above information as well.

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14 Community Water Center Drinking Water Vulnerability Tool, obtained 24 May 2019.
15 Each PLSS section represents approximately 1 square mile of area (i.e., 640 acres).
16 All four undistricted parcels included in Appendix H are unirrigated.
5.2. Water Resources Monitoring and Management Programs

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

(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.

(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.

(e) A description of conjunctive use programs in the basin.

5.2.1. Existing Monitoring and Management Programs

Existing Monitoring Programs

Existing groundwater monitoring in the Wheeler Ridge-Maricopa Management Area includes:

• The California Statewide Groundwater Elevation Monitoring (CASGEM) Program is a program that tracks long-term groundwater elevation trends in groundwater basins throughout California. The program’s mission is to establish a permanent, locally-managed program of regular and systematic monitoring in all of California's alluvial groundwater basins, including within the Management Area. In 2011, the District submitted to DWR an application to be the CASGEM Monitoring Entity for the District’s service area (except the overlap areas with AEWSD and WKWD), but a full CASGEM monitoring plan has not been completed. Therefore, all wells monitored within the District are designated as “voluntary wells” under the CASGEM program at this point.

• The Groundwater Ambient Monitoring and Assessment (GAMA) Program is California's comprehensive groundwater quality monitoring program that was created by the State Water Resources Control Board (SWRCB) in 2000. The GAMA Program monitors groundwater quality trends throughout California, including within the Management Area.17

• The Monitoring and Reporting Program (MRP) from the Irrigated Lands Regulatory Program (ILRP), establishes the specific surface and groundwater monitoring, reporting, and electronic data

17 GAMA Website: https://www.waterboards.ca.gov/water_issues/programs/gama/about.html.
deliverable requirements for irrigated lands used for commercial purposes within the Tulare Lake Basin Area (The ILRP is further described in the section below “Existing Management Programs”). The purpose of this MRP is to determine the effects of irrigated lands waste discharges on water quality and assess the effectiveness of ILRP management actions. Data collected and reports are available in the GAMA database (Central Valley Regional Water Quality Control Board [CVRWQCB], 2013).

- Central Valley-Salinity Alternatives for Long-term Sustainability (CV-SALTS) is a collaborative stakeholder driven and managed program to develop sustainable salinity and nitrate management planning for the Central Valley. The Kern Subbasin is a Priority 2 basin for nitrate management. Consequently, the nitrate control program schedule is set to begin in 2021 as described in the KGA Umbrella GSP.

- The District conducts periodic groundwater level monitoring and groundwater quality sampling in selected wells throughout the Management Area as part of its on-going water resources management efforts, including the AEWSD-WRMWSD overlap portion of the Management Area. CASGEM groundwater elevations (and groundwater elevations from wells in the WRMWSD and AEWSD monitoring networks) have been used to characterize groundwater level conditions (see Section 8.1 Groundwater Elevations and Flow Direction)\(^{18}\). Water quality data from the above sources have been used to assess groundwater quality conditions (see Section 8.4 Groundwater Quality Concerns).

Existing surface water monitoring in the Wheeler Ridge-Maricopa Management Area includes the following:

- The WRMWSD is establishing a network of five stream gauges in the San Emigdio mountains, three of which are on streams that flow into the Management Area and two of which flow into the White Wolf Subbasin.

- The California Data Exchange Center (CDEC) provides a centralized database to store, process, and exchange real-time hydrologic information gathered by various cooperators throughout the State\(^{19}\). The CDEC has three monitoring points within or in the vicinity of the Management Area.

Another surface water monitoring program in the basin is the United States Geological Survey (USGS) National Water Information System; however, there are not monitoring points within or in the vicinity of the Wheeler Ridge-Maricopa Management Area.

\(^{18}\) While they collect groundwater level data on a regular basis, WRMWSD is not an official CASGEM monitoring entity for the Kern Subbasin.

\(^{19}\) CDEC Website: http://cdec.water.ca.gov/cdecstation2/
Land subsidence data in the vicinity of WRMWSD is available through the following sources:

- University Navstar\textsuperscript{20} Consortium (UNAVCO) Plate Boundary Observatory’s continuous and conventional Global Positioning System (GPS) network; and

- Remote sensing studies by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL).

- USGS San Joaquin Valley Land Subsidence Network. A subsidence monitoring network in the San Joaquin Valley was implemented in the 1960s to help quantify the extent and magnitude of the subsidence that was first discovered in the 1950s. To identify existing and future subsidence, a new monitoring network is currently being developed\textsuperscript{21}.

- The DWR’s San Luis Field Division and the San Joaquin Field Division conducted a land subsidence study along the California Aqueduct (DWR, 2017) to understand the magnitude, location and effects of past and present land subsidence. For this study, data from 940 survey benchmarks along the California Aqueduct that have been monitored at 1-year and 7-year intervals by the San Luis Field Division, and 1,009 benchmarks monitored at 3-year and 7-year intervals by the San Joaquin Field Division was used.

The WRMWSD will incorporate information from these existing regional and local programs to inform GSP development and implementation. The Wheeler Ridge-Maricopa Management Area Monitoring Network is further described in Section 16 Monitoring Network.

**Existing Management Programs**

The Wheeler Ridge-Maricopa Management Area falls within the South County Subregion of the Kern County Integrated Regional Water Management Region (Kern Region) and is therefore included in the November 2011 Kern Integrated Regional Water Management Plan (Kern IRWMP; Kennedy/Jenks Consultants, 2011). The Kern Region covers approximately 5,690 square miles of Kern County and a small portion of southern Kings County. The Kern Region is separated into nine subregions, in acknowledgement of the variation in geography, agency boundaries, and water management strategies. These subregions are: (1) Greater Bakersfield, (2) Kern Fan, (3) Mountains/Foothills, (4) Kern River Valley, (5) North County, (6) South County, (7) West Side, (8) KCWA1 and (9) the County of Kern.

The key issues, needs, challenges, and priorities for the South County subregion, according to the Kern IRWMP (2011), include the following:

- Decreased Imported Water Supply;

\textsuperscript{20}Navstar is a network of U.S. satellites that provide GPS services.

\textsuperscript{21}From USGS California Water Science Center website: https://ca.water.usgs.gov/projects/central-valley/land-subsidence-san-joaquin-valley.html
• Water Quality/Groundwater Contamination;
• Urban Growth Encroachment on Key Recharge Areas; and
• Water Rights.

The WRMWSD has an existing Groundwater Management Plan (GWMP). Although this MA Plan extends and supersedes the groundwater management efforts outlined in the GWMP, a brief summary of this GWMP is included below for completeness.

The WRMWSD GWMP was developed in 2007 and aimed to increase reliability and sustainability of water supply by conjunctively integrating groundwater with imported surface water supply. Specifically, the WRMWSD GWMP (2007) set forth the following groundwater management objectives to guide future water management actions:

• Prevent a return to historical overdraft conditions;
• Maintain groundwater quality;
• Monitor water levels, water quality, and groundwater storage; and
• Estimate groundwater use and future groundwater demands on the basin.

The ILRP, initiated in 2003 and last modified in 2013 to include groundwater provisions, is a program whose objective is to protect both groundwater and surface water from irrigated agricultural waste dischargers throughout the Central Valley. The ILRP is implemented through CVRWQCB Orders, also called Waste Discharge Requirements (WDRs). Order R5-2013-0120 (Order) regulates discharges in the Tulare Lake Basin. Under this order, third parties are responsible for fulfilling regional requirements and conditions (e.g. surface and groundwater monitoring). WRMWSD is a member of the Kern River Watershed Coalition Authority (KRWCA) which is a third-party coalition that formed in 2014 to respond to the Order. Key elements of the ILRP are: Surface water/Groundwater Quality Monitoring Plan, Sediment and Erosion Control Plan, Nitrogen Management Plan and Mitigation Monitoring. The overall goals of the ILRP for the Tulare Lake Basin Area are:

• To restore and/or maintain the highest reasonable quality of state waters;
• Minimize waste discharge from irrigated agricultural lands that could degrade state waters quality;
• Maintain the economic viability of agriculture in California’s Central Valley; and
• Ensure that irrigated agricultural discharges do not impair access by Central Valley communities and residents to safe and reliable drinking water.

In accordance with these goals, the objectives are the following:

• Restore and/or maintain appropriate beneficial uses established in CVWQCB plans by ensuring that all state waters meet applicable water quality objectives; and
• Encourage implementation of management practices that improve water quality in keeping with the first objective, without jeopardizing the economic viability for all sizes of irrigated agricultural operations.

The District prepared an Agricultural Water Management Plan (AWMP) in accordance with the requirements of SBx7-7 and Governor’s Executive Order B-29-15 and it was last modified in December 2015. The purpose of this AWMP is to describe and document the District’s existing and proposed agricultural water management programs and activities aimed to provide reliable agricultural water supply for its landowners. The document provides a description and quantification of water supply sources for agricultural users (surface and groundwater), a water reliability assessment, and efficient water management practices (WRMWSD, 2015).

5.2.2. Operational Flexibility Limitations

The above water resource monitoring programs are not expected to limit operational flexibility in the basin. In fact, some of these management and monitoring programs will be integral to the on-going monitoring and reporting that will be conducted pursuant to this MA Plan (see Section 16 Monitoring Network).

For example, the IRWMP and GSP development are complimentary management processes. To the extent that the issues identified for the greater IRWMP region affect the Management Area, these issues will be discussed in the following sections of this MA Plan. The implementation of this MA Plan will contribute to the sustainable use of water supplies within the IRWMP region and the IRWMP is not expected to limit operational flexibility in the Wheeler Ridge-Maricopa Management Area.

Most of the groundwater management objectives identified in the GWMP are consistent with the issues and objectives identified in the following sections of this MA Plan. The implementation of this MA Plan will contribute to the sustainable groundwater use within the Wheeler Ridge-Maricopa Management Area. Therefore, this GSP compliments and supersedes the GWMP.

5.2.3. Conjunctive Use in the Wheeler Ridge-Maricopa Management Area

Since 1971, WRMWSD has imported SWP surface water, supporting the conjunctive use of surface water and groundwater resources within the Wheeler Ridge-Maricopa Management Area, which has been the primary cause of the recovery and stability of groundwater levels observed in the area (see Section 8 Current and Historical Groundwater Conditions). WRMWSD banks water in and returns it from out-of-District water banks (e.g., the Pioneer Water Bank; see Section 9.2.1 Surface Water Inflows and Outflows) through its own conveyance network and the California Aqueduct. As of December 2018, the District has a combined 200,700 acre-feet (AF) stored in its banking projects. The California Aqueduct is also used for intra-District conveyance, wherein delivered water supplies are blended with groundwater, the proportion of which varies depending on the season and the water year type.
5.3. Land Use Elements or Topic Categories of Applicable General Plans

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

(f) A plain language description of the land use elements or topic categories of applicable general plans that includes the following:

(1) A summary of general plans and other land use plans governing the basin.

(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.

(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.

(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.

(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.

5.3.1. Kern County General Plan

The Wheeler Ridge-Maricopa Management Area is located within the Kern County General Plan area (Kern County, 2009). The current Kern County General Plan was first adopted in 2004 and has undergone several amendments, the most recent amendment approved in 2009 (General Plan). The County is currently working to update its General Plan through 2040, with completion of the “2040 General Plan” expected in 2019. This section identifies relevant policies in the current General Plan that could: (1) affect water demands in the Management Area (e.g., due to population growth and development of the built environment), (2) influence the GSP’s ability to achieve sustainable groundwater use, and (3) affect implementation of General Plan land use policies.

Figure PA-7 shows the current General Plan land use designations within the Wheeler Ridge-Maricopa Management Area. The land use designations include primarily intensive and extensive agriculture, residential, mineral and petroleum, resource management, federal land, and seven other designations that account for less than 1% of the Management Area. These designations are generally consistent with the predominantly agricultural land use within the Management Area as shown in Figure PA-4.

The Land Use, Open Space, and Conservation Element (Chapter 1) of the General Plan includes the following goals, policies, and implementation measures that are related to groundwater or land use management, and that could potentially influence the implementation of this GSP.
Physical and Environmental Constrains

- **Implementation Measure C.** Cooperate with the Kern County Water Agency to classify lands in the County overlying groundwater according to groundwater quantity and quality limitations.

Public Facilities and Services

- **Goal 5.** Ensure that adequate supplies of quality (appropriate for intended use) water are available to residential, industrial, and agricultural users within Kern County.
- **Goal 7.** Facilitate the provision of reliable and cost-effective utility services to residents of Kern County.
- **Policy 2.** The efficient and cost-effective delivery of public services and facilities will be promoted by designating areas for urban development which occur within or adjacent to areas with adequate public service and facility capacity.
- **Policy 2.a.** Ensure that water quality standards are met for existing users and future development

Residential

- **Goal 6.** Promote the conservation of water quantity and quality in Kern County.
- **Goal 7.** Minimize land use conflicts between residential and resource, commercial, or industrial land uses.

Industrial

- **Goal 2.** Promote the future economic strength and well-being of Kern County and its residents without detriment to its environmental quality.

Resource

- **Policy 7.** Areas designated for agricultural use, which include Class I and II and other enhanced agricultural soils with surface delivery water systems, should be protected from incompatible residential, commercial, and industrial subdivision and development activities.
- **Policy 10.** To encourage effective groundwater resource management for the long-term economic benefit of the County the following shall be considered:
  - **Policy 10.a.** Promote groundwater recharge activities in various zone districts.
  - **Policy 10.c.** Support the development of groundwater management plans.
  - **Policy 10.d.** Support the development of future sources of additional surface water and groundwater, including conjunctive use, recycled water, conservation, additional storage of surface water and groundwater and desalination.
General Provisions

- **Goal 1.** Ensure that the County can accommodate anticipated future growth and development while maintaining a safe and healthful environment and a prosperous economy by preserving valuable natural resources, guiding development away from hazardous areas, and assuring the provision of adequate public services.

- **Policy 40.** Encourage utilization of community water systems rather than the reliance on individual wells.

- **Policy 41.** Review development proposals to ensure adequate water is available to accommodate projected growth.

- **Policy 45.** New high consumptive water uses, such as lakes and golf courses, should require evidence of additional verified sources of water other than local groundwater. Other sources may include recycled stormwater or wastewater.

- **Implementation Measure U.** The Kern County Environmental Health Services Department will develop guidelines for the protection of groundwater quality which will include comprehensive well construction standards and the promotion of groundwater protection for identified degraded watersheds.

The above goals, policies and implementation measures established by the General Plan are complementary to sustainable groundwater management of the Wheeler-Ridge Management Area relative to future land use development and conservation (i.e., the plan encourages development of the County’s groundwater supply to ensure that existing users have access to high quality water, and states that future growth should be accommodated only while ensuring that adequate high-quality water supplies are available to existing and future users). Successful implementation of this MA Plan will help to ensure that the Management Area groundwater supply is managed in a sustainable manner by avoiding undesirable results as defined under SGMA. Therefore, implementation of General Plan policies is not expected to affect the ability of the Management Area to achieve groundwater sustainability. Likewise, implementation of this MA Plan is not anticipated to significantly affect the water supply assumptions or land use plans over the planning horizon. Given that the General Plan is being updated concurrently with the development of this MA Plan, and the County is engaged in the process of GSP development through its participation in the KGA GSA, it is anticipated that the 2040 General Plan would take into account this MA Plan and utilize consistent water supply assumptions over the 2040 planning horizon.

**5.3.2. Well Permitting Process**

Well permits within the Wheeler Ridge-Maricopa Management Area are issued by the Kern County Public Health Services Department Water Well Program. The Water Well Program issues permits to construct, reconstruct and destroy water wells. All wells must be constructed in accordance with Kern County Ordinance Code, Section 14.08, and DWR Bulletins 74-81 and 74-90, except as modified by subsequent
revisions. The ordinance requires, among other things, that domestic and agricultural wells be installed a minimum distance from potential pollution and contaminant sources, water quality be tested for new and reconstructed wells, an NSF 61 approved flowmeter be installed, and the final well construction be inspected by County staff. It is expected that as part of GSP implementation, the Water Well Program may be more closely coordinated with KGA GSA activities to support long-term sustainability within the Management Area and the Basin at large. Recently, the Kern County Public Health Services Department (KCPHSD) released a supplemental well application for wells intended to be installed on overdrafted basins. This new form additionally requires water district and GSA information, granting GSAs review power. Starting in 2019, it is WRMWSD’s policy to provide a written response to KCPHSD and the well applicant when supplemental well application forms are received.

5.4. Additional GSP Elements

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

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

5.4.1. Other Elements

Per California Water Code (CWC) Section (§) 10727.4, a GSP shall include, where appropriate and in collaboration with the appropriate agencies, all of the following:

Control of Saline Water Intrusion

Because the Wheeler Ridge-Maricopa Management Area is located far from coastal areas, seawater intrusion is not considered to be an issue.

Wellhead Protection

The Kern County Public Health Services Department Water Well Program issues permits to construct, reconstruct and destroy water wells (see Section 5.3.2 Well Permitting Process).

Migration of Contaminated Groundwater

There are no known active contaminated groundwater sites within the Wheeler Ridge-Maricopa Management Area. The Central Valley Regional Water Quality Control Board’s (CVRWQCB) GeoTracker and California Department of Toxic Substances Control (DTSC) EnviroStor databases show two closed Cleanup Program sites, one closed Leaking Underground Storage Tank (LUST) site, and four sites listed as “inactive – Needs Evaluation”. These sites are discussed further in Section 8.4 Groundwater Quality Concerns below.
Well Abandonment and Well Destruction Program
The Kern County Public Health Services Department Water Well Program issues permits to construct, reconstruct and destroy water wells (see Section 5.3.2 Well Permitting Process).

Replenishment of Groundwater Extractions
The District actively manages the groundwater basin within its boundaries through conjunctive use and other programs (see Section 5.2.3 Conjunctive Use in the Wheeler Ridge-Maricopa Management Area).

Conjunctive Use and Underground Storage
The District actively manages the groundwater basin within its boundaries through conjunctive use and other programs (see Section 5.2.3 Conjunctive Use in the Wheeler Ridge-Maricopa Management Area).

Well Construction Policies
The Kern County Public Health Services Department Water Well Program issues permits to construct, reconstruct and destroy water wells (see Section 5.3.2 Well Permitting Process).

Groundwater Contamination Cleanup, Recharge, Diversions to Storage, Conservation, Water Recycling, Conveyance, and Extraction Projects
The District constantly pursues water conservation through its water management practices. Currently its efficient water management practices for agricultural users are described in the WRMWSD Agricultural Water Management Plan (WRMWSD, 2015). This plan is summarized in Section 5.2.1 Existing Monitoring and Management Programs.

The District also operates a “User Input pump-in program” to facilitate conveyance of groundwater pumped by landowners through its distribution system to other lands within the WRMWSD service area owned by that same landowner.

Efficient Water Management Practices
The District constantly pursues gaining efficiency through its water management practices. Currently its efficient water management practices for agricultural users are described in the WRMWSD Agricultural Water Management Plan (WRMWSD, 2015). This plan is summarized in Section 5.2.1 Existing Monitoring and Management Programs.

Relationships with State and Federal Regulatory Agencies
As described above, WRMWSD maintains a water supply contract with DWR for its SWP surface water supply that remains in effect until 2035. Currently, the Contractors and DWR are in the validation process of approving a contract extension to 2085.
Land Use Plans and Efforts to Coordinate with Land Use Planning Agencies to Assess Activities that Potentially Create Risks to Groundwater Quality or Quantity

Applicable land use planning documents and processes are discussed in Section 5.3 Land Use Elements or Topic Categories of Applicable General Plans.

Impacts on Groundwater Dependent Ecosystems

This topic discussed in Section 8.7 Groundwater Dependent Ecosystems.

5.5. Notice and Communication

§ 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) 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.

(b) A list of public meetings at which the Plan was discussed or considered by the Agency.

(c) Comments regarding the Plan received by the Agency and a summary of any responses by the Agency.

(d) A communication section of the Plan that includes the following:

   (1) An explanation of the Agency’s decision-making process.

   (2) Identification of opportunities for public engagement and a discussion of how public input and response will be used.

   (3) A description of how the Agency encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin.

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

The Wheeler Ridge-Maricopa Management Area adopted its Stakeholder Communication and Engagement Plan (SCEP) in August 2018 to fulfill notice and communication requirements. The SCEP is included herein as Appendix B.

5.5.1. Beneficial Uses and Users of Groundwater

As part of the SCEP, beneficial uses and users of groundwater in the basin were identified, including various holders of overlying groundwater rights (agricultural users, domestic users, commercial/industrial users, etc.), public water systems, local land use planning agencies, environmental users of groundwater, surface water users, the federal government, and DACs/SDACs (see SCEP Section 3). Additionally, a Stakeholder Constituency “Lay of the Land” exercise was developed which identified stakeholders in the
Wheeler Ridge-Maricopa Management Area, key interests and issues, and the level of engagement expected with each stakeholder (see SCEP Table 1). This exercise will be updated during select phases of GSP development and/or implementation.

5.5.2. Public Meetings Summary

The list below identifies public meetings, workshops, and direct outreach specific to SGMA and WRMWSD’s MA Plan development and progress.

WRMWSD Board Meetings

The WRMWSD Board meets every month at its offices. Regular SGMA and MA Plan development updates are provided by Staff and/or WRMWSD’s consultant, and stakeholders are provided the opportunity to provide input on the GSP development and implementation process. Appendix C includes a list of meeting dates where SGMA topics have been discussed at the WRMWSD Board Meeting. This information will be updated throughout MA Plan development and/or implementation.

Stakeholder Workshops

WRMWSD has hosted and/or participated in workshops intended to educate local landowners and other stakeholders within the Wheeler Ridge-Maricopa Management Area regarding SGMA, including:

- WRMWSD Sustainable Groundwater Management Act (SGMA) Landowner Workshop #1 – 05/24/2018
- Kern Subbasin Open House – 14 May 2019
- WRMWSD SGMA Landowner Workshop #2 – 12 June 2019

This list will be populated throughout MA Plan development and/or implementation. While stakeholders were very engaged during the workshops, no direct feedback was provided for input into the MA Plan.

Direct Outreach

Through the distribution of letters and surveys, WRMWSD has made numerous efforts to secure local stakeholder input during the SGMA process:

- KGA stakeholder survey distribution and respondence (May 2018 - July 2018);
- KGA agricultural stakeholder survey distribution and respondence (December 2018 – January 2019);
- Public water system data request (October 2018-January 2019); and
- KGA Landowner Letter (June 2019).
Results from these outreach efforts have been compiled and reviewed. Data and information received from respondents has been incorporated into the WRMWSD DMS and into this MA Plan, as appropriate. The list above will be updated throughout MA Plan development and/or implementation.

### 5.5.3. Public Comments on the MA Plan

Table PA-1 below summarizes the public comments received on the MA Plan and WRMWSD’s responses.

<table>
<thead>
<tr>
<th>Public Comment</th>
<th>WRMWSD Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letter from The Nature Conservancy (TNC) dated October 2018 regarding Groundwater Dependent Ecosystems (GDEs)</td>
<td>As recommended by TNC, reviewed the GDE Guidance Document for GSPs and the Groundwater Resource Hub and conducted analysis of the presence of GDEs, see Section 8.7 and Figure GWC-18.</td>
</tr>
<tr>
<td>Letter from The Leadership Counsel dated June 2019 entitled Concerns and Recommendations to Ensure that Kern Groundwater Authority GSA GSP Protects Vulnerable Drinking Water Users</td>
<td>WRMWSD has worked to understand water quality conditions within its service area (Section 8.4) and to ensure that the Sustainability Criteria are protective of water quality and beneficial users (Sections 13.4, 14.4, 15.4).</td>
</tr>
<tr>
<td>Letter from The Leadership Counsel dated December 2018 regarding the Kern Groundwater Authority (KGA) adoption of the Undesirable Results definitions</td>
<td>WRMWSD has worked closely with neighboring GSAs and KGA members and other stakeholders within its service area to develop its local definition of Undesirable Results that are protective of beneficial users (Section 14).</td>
</tr>
</tbody>
</table>

Table PA-1 will be updated as more comments are received during MA Plan development and/or implementation.

### 5.5.4. Communication

The SCEP outlines WRMWSD’s communication goals.

#### Decision-Making Process

The SCEP Section 2.2 outlines the WRMWSD decision-making process. Briefly, the process involves decision making by the WRMWSD Board of Directors during District Board meetings which are open to the public. In addition, the KGA GSA Board of Directions makes decisions of the KGA GSA at its public Board meetings. The KGA GSA Board is supported by a Coordination Committee composed of representatives of...
each KGA GSA board member, whose role is to provide recommendations to the KGA GSA Board on technical and other matters.

Public Engagement Opportunities

The SCEP Section 6 discusses public engagement opportunities and SCEP Sections 5 and 6 discuss how public input and responses will be handled. These opportunities include WRMWSD Board meetings, the planned public hearing at which the Draft MA Plan will be available for public comments, and the various stakeholder workshops and surveys, discussed below.

Stakeholder Involvement

The SCEP Section 5 outlines WRMWSD’s goals, including open and transparent engagement with diverse stakeholders. Additionally, SCEP Section 4 outlines describes the Stakeholder Survey which the District used to gain additional knowledge on stakeholders within the Management Area. Only three entities have responded to the survey to date.

District staff have made numerous outreach efforts to landowners within the District regarding well access for monitoring. This effort has represented a constructive effort to improve local knowledge of well conditions and to engage landowners in SGMA implementation efforts.

Public Notification

The SCEP Section 5 and 6 details the methodology that is being followed to inform the public regarding all MA Plan updates, status, and actions.

5.5.5. Interagency Coordination

WRMWSD has actively engaged in both intrabasin and interbasin coordination efforts through multiple avenues during the GSP development process, including:

KGA Board/Coordination Committee Meetings

Prior to enactment of the SGMA, the KGA was established to provide a framework for the active, comprehensive management of the groundwater basin underlying the valley portion of Kern County, to preserve and maintain local control of groundwater resources and provide long term surety for all basin users. With passage of the SGMA, the KGA seeks to coordinate local groundwater management efforts and is working with its members to determine the most cost effective and efficient way of meeting the new requirements of the SGMA. During 2016-2018 the KGA Board of Directors met monthly at the Kern County office in Bakersfield. These monthly meetings have continued into 2019, now at the Great Bakersfield Chamber. Meeting agendas and other information can be found at http://www.kerngwa.com.

The KGA Coordination Committee meets monthly at the Rosedale-Rio Bravo WSD office. Meeting agendas and other information can be found at http://www.kerngwa.com/.
Kern Managers Meetings

Managers of member agencies to the KGA as well as representatives from other Kern GSAs (Kern River GSA, HMWD, etc.) meet weekly at Rosedale-Rio Bravo WSD to discuss Basin-wide SGMA topics ranging from monitoring network coordination to Basin-wide modeling efforts and sustainable management criteria development.

South of Kern River Coordination Meetings

WRMWSD and neighboring agencies in the “south of Kern River” portion of the Basin have periodically convened to coordinate on major GSP development topics, including methodologies and data sources used to develop the Basin Setting, Water Budget, and Sustainability Criteria sections of their respective GSPs/Management Area Plans and the development of projects and management actions.

White Wolf Basin GSA

The White Wolf GSA was formed in 2017 by three water districts: WRMWSD, AEWSD, Tejon-Castac Water District (TCWD), as well as Kern County (as a non-voting member). Prior to that, the GSA parties coordinated in an effort to subdivide the Kern Subbasin into two separate subbasins and remove the critical-overdraft status from the newly formed White Wolf Subbasin. By December of 2016, both goals were accomplished, and the White Wolf GSA is currently in the process of developing a GSP. The White Wolf GSA meets quarterly at WRMWSD’s offices.

5.5.6. Interbasin Coordination

WRMWSD has actively participated in interbasin coordination with the neighboring White Wolf Subbasin (DWR 5-022.18), Tule Subbasin (DWR 5-022.13), and Tulare Lake Subbasin (DWR 5-022.12) throughout the GSP development process through its membership with the KGA. Coordination topics have included subsidence concerns along the California Aqueduct, delineation of the White Wolf Fault, and cross-boundary flows between subbasins.
Abbreviations

DWR = California Department of Water Resources
GSA = Groundwater Sustainability Agency
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. The WRMWSD Plan Area is the WRMWSD Management Area.
3. The pastel filled and labeled areas represent public and private water systems neighboring the WRMWSD Management Area.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 March 2019.
2. DWR groundwater basins are based on the boundaries released on 11 February 2019.
North Canal Spreading Works

Kern County, CA
March 2019
B70103.01
Figure PA-2

Legend
- WRMWSD Service Area
- Federal Lands - BLM
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)

Abbreviations
BLM = United States Bureau of Land Management
DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world aerial map, obtained 14 March 2019.
Disadvantaged Communities

Legend
- WRMWSD Service Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)

Disadvantaged Community Census Block Group
- Severely Disadvantaged Community
- Disadvantaged Community

Disadvantaged Community Census Tract
- Severely Disadvantaged Community
- Disadvantaged Community

Abbreviations
- BLM = United States Bureau of Land Management
- DWR = California Department of Water Resources
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world aerial map, obtained 14 March 2019.
Legend

**WRMWSD Service Area**

**Groundwater Subbasin**
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

**Spring 2017 Land Use**
- Pasture
- Deciduous Fruits and Nuts
- Truck, Nursery, and Berry Crops
- Citrus and Subtropical
- Field Crops
- Grain and Hay Crops
- Vineyards
- Idle

**Abbreviations**
- DWR = California Department of Water Resources
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

**Notes**
1. All locations are approximate.

**Sources**
1. Basemap is ESRI's ArcGIS Online world aerial map, obtained 14 March 2019.
2. Spring 2017 land use data received from WRMWSD staff on 21 November 2017.
Kern County, CA  
March 2018  
B70103.01  
Figure PA-5

Wheeler Ridge-Maricopa Water Storage District  

Path: X:\B70103\Maps\for_GSP\2019\03\Fig_PA-5_WaterSourceType.mxd

Abbreviations  

- WRMWSD = Wheeler Ridge-Maricopa Water Storage District  
- DWR = California Department of Water Resources  
- NHD = National Hydrography Dataset  
- SWSA = surface water service area

Legend

- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)

- WRMWSD Service Area
- Surface Water Feature
  - California Aqueduct
  - WRMWSD Surface Water Service Area

Abbreviations

Notes

1. All locations are approximate.
2. Users outside the SWSA rely exclusively on groundwater, however, users on the SWSA are not precluded of using groundwater.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 14 March 2019.
2. Surface water features and California Aqueduct location from NHD.
3. District infrastructure data and Surface Water Service Area acquired from WRMWSD staff on 21 November 2017.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 14 March 2019.
2. Surface water features and California Aqueduct location from NHD.
3. District infrastructure data and Surface Water Service Area acquired from WRMWSD staff on 21 November 2017.
Well Density by PLSS Section
from DWR Well Completion Reports

Sources:
1. Basemap is ESRI’s ArcGIS Online world topographic map, obtained 14 March 2019.
2. WRMWSD boundary is from DWR’s water agencies shapefile and updated based on input from WRMWSD staff on 12 April 2017.
3. Well Count per square mile (PLSS section) from Well Completion Report Map Application, obtained on 8 October 2018, website: https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=181078580a214096fe2da98f623637

Abbreviations:
DWR = California Department of Water Resources
MA = management area
PLSS = Public Land Survey System
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes:
1. All locations are approximate.
2. Potable water is supplied in the WRMWSD MA by private domestic wells, there is no public water supply, therefore, it is considered that there are not communities dependent on groundwater.
Legend

- WRMWSD Service Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)

Land Use Designation
- Extensive Agriculture; Extensive Agriculture (Min. 20 Acre Parcel Size)
- Heavy Industrial
- Intensive Agriculture; Intensive Agriculture (Min. 20 Acre Parcel Size)
- Light Industrial
- Low Medium Density Residential
- Mineral and Petroleum; Mineral and Petroleum (Min. 5 Acre Parcel Size)
- Residential/Other
- Resource Management
- Service Industrial
- Solid Waste Facilities
- State or Federal Land

Abbreviations
- DWR = California Department of Water Resources
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. The legend shows land use designations only within the Management Area.

Sources
1. Kern County General Plan information obtained on 16 August 2018 from the Kern County website.
Basin Setting
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

BASIN SETTING
6. INTRODUCTION TO BASIN SETTING

§ 354.12. Introduction to Basin Setting

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.

This section presents Basin Setting information for the Wheeler Ridge-Maricopa Management Area. As discussed previously in Section 5 Description of the Plan Area, the Management Area consists of the portion of the Wheeler Ridge-Maricopa Water Storage District (WRMWSD) service area within the Kern County Subbasin (Kern Subbasin) that is not overlapped by the West Kern Water District (WKWD) Groundwater Sustainability Agency (GSA; Figure HCM-1). In some cases, Basin Setting information for areas proximal to, but outside of, the Management Area is provided for context. Basin Setting information includes the Hydrogeologic Conceptual Model, Groundwater Conditions, and Water Budget.

\[22\] In this document, the term “Wheeler Ridge-Maricopa Management Area” is used in its entirety the first time the area is referenced in each paragraph; subsequent references to this area in each paragraph use the term “Management Area”. 47
7. HYDROGEOLOGIC CONCEPTUAL MODEL


(a) Each Plan shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin.

This section presents the hydrogeologic conceptual model (HCM) for the Wheeler Ridge-Maricopa Management Area. As described in the Hydrogeological Conceptual Model Best Management Practices (BMP) document (California Department of Water Resources [DWR], 2016), an HCM provides, through descriptive and graphical means, an understanding of the physical characteristics of an area that affect the occurrence and movement of groundwater, including geology, hydrology, land use, aquifers and aquitards, and water quality. This HCM serves as a foundation for subsequent Basin Setting analysis including water budgets and numerical models, monitoring network development, and the development of sustainable management criteria. The HCM information presented herein is supplemental to the HCM provided in the Kern Groundwater Authority (KGA) Umbrella Groundwater Sustainability Plan (GSP) and provides refined detail on HCM topics specific to the Management Area.
7.1. General Description

(b) The hydrogeologic conceptual model shall be summarized in a written description that includes the following:

(1) The regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.

(2) Lateral basin boundaries, including major geologic features that significantly affect groundwater flow.

(3) The definable bottom of the basin.

(4) Principal aquifers and aquitards, including the following information:
   (A) Formation names, if defined.
   (B) Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.
   (C) Structural properties of the basin that restrict groundwater flow within the principal aquifers, including information regarding stratigraphic changes, truncation of units, or other features.
   (D) General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.
   (E) Identification of the primary use or uses of each aquifer, such as domestic, irrigation, or municipal water supply.

(5) Identification of data gaps and uncertainty within the hydrogeologic conceptual model

7.1.1. Geological and Structural Setting
The Wheeler Ridge-Maricopa Management Area is located at the southern end of the San Joaquin Valley which is the portion of California’s Central Valley that is south of the San Joaquin/Sacramento River Delta. The San Joaquin Valley is a structural trough filled with tens of thousands of feet of Cenozoic continental and shallow marine sedimentary deposits shed from the surrounding mountains which include the Sierra Nevada Mountains to the east, the Temblor Range and Coast Range Mountains to the west, and the San Emigdio and Tehachapi Mountains to the south (Davis et al., 1959). The structural trough is asymmetric, with its axis located west of the valley’s centerline at land surface (Scheirer, 2013). Locally, to the north of the Management Area, the Maricopa Depocenter is a structural depression which has accumulated thicker deposits than the surrounding areas. The Buena Vista Hills are located to the northwest of the Management Area. The reader is referred to the Basin-wide geologic and structural setting discussion included in the KGA Umbrella GSP for additional information and map figures.
Due to its location near the North American and Pacific plate boundary, the southern San Joaquin Valley underwent complex patterns of tectonic evolution during the Cenozoic era, including phases of extension, uplift, subsidence, faulting, and flexure (Goodman and Malin, 1992). The White Wolf Fault cuts through the District and forms the boundary between the Kern Subbasin to the north and the White Wolf Subbasin to the south. The White Wolf Fault is a recently active southward-dipping high-angle reverse fault that has resulted in significant displacement of stratigraphic units on either side of the fault trace (California Division of Mines, 1955; Hagan, 2001).

The general geologic setting of the Wheeler Ridge-Maricopa Management Area consists of multiple alluvial fans derived from sediments washed into the basin from the surrounding highlands, coarser near their source and finer towards the basin interior. These fan deposits wash up against Quaternary lake and basin deposits that border the Management Area to the north. The basin deposits, including those beneath the Buena Vista Lake Bed, Kern Lake Bed, and the slough that connects them, are generally fine-grained due to the low energy depositional environment in which they were formed. The “E Clay”, a significant regional aquitard (Croft, 1972), underlies the western portion of the southern Central Valley including portions of the Management Area. The E Clay is several tens of feet thick in this area and becomes thinner and shallower towards the east, pinching out in the vicinity of the City of Arvin. On the northern edge of the Management Area, shallow clay layers and fine-grained soils create areas of perched groundwater that is separate from the main groundwater system. Two hydrogeologic cross-sections through the Management Area that further illustrate the subsurface structural relationships are discussed further in Section 7.2 Cross-Sections.

### 7.1.2. Lateral Basin Boundaries

This MA Plan covers only the Wheeler Ridge-Maricopa Management Area (see Figure HCM-1) which is within the larger Kern Subbasin. With the exception of its southeastern edge, the Management Area does not coincide with any part of the Kern Subbasin boundary, and therefore a complete discussion of the lateral basin boundaries is not provided herein, but rather in the KGA Umbrella GSP.

The southeastern edge of the Wheeler Ridge-Maricopa Management Area is coincident with the White Wolf Fault which is the boundary between the Kern Subbasin and the White Wolf Subbasin. As discussed above, the White Wolf Fault is a south-dipping reverse fault, with the northern block down-dropped relative to the southern block. There is also a component of left-lateral slip on the fault (California Division of Mines, 1955). The total vertical displacement is estimated to be over 10,000 feet and is greatest at the southwestern end and less to the northeast (California Division of Mines, 1955). As evidenced by surface rupture during the major earthquake of 21 July 1952, the White Wolf Fault is active, and its displacement plane extends to the ground surface, affecting the youngest sedimentary deposits.

Based on multiple lines of evidence, the fault acts as a significant barrier to groundwater flow, which is the basis for the Kern Subbasin boundary (Erler & Kalinowski, Inc., 2016). These lines of evidence include
substantial groundwater elevation differences across the fault (based on analysis of available water level data and reports prepared by others), aquifer testing data from wells close to the fault that showed boundary effects, and groundwater modeling studies.

7.1.3. **Bottom of the Basin**

As discussed above, the southern San Joaquin Valley is a deep structural trough filled with a thick sequence of Tertiary sediments including sandstone, siltstone, shale, and conglomerate. As described below, multiple sources of information can be relied on to define the “bottom of the basin” for purposes of the Sustainable Groundwater Management Act (SGMA), including elevation maps of the basement bedrock surface, information on the base of fresh water, the presence, location and depth of oil and gas fields, and depth of groundwater extraction. Each of these is discussed below, with depth information presented as feet below ground surface (ft bgs) or feet above mean sea level (ft msl), based on the original source information. A summary comparison, including a unit normalization, is included in Table HCM-1.

*Depth to Basement Bedrock*

The depth of pre-Tertiary basement rocks which form the impermeable floor of the San Joaquin Valley groundwater basin generally increases from east to west within the southern end of the San Joaquin Valley. Within the Wheeler Ridge-Maricopa Management Area, the elevation of the top of the basement rock surface ranges from between -21,000 to -22,000 ft msl in the western area and -16,000 to -20,000 ft msl in the eastern area (Scheirer, 2013). Given the land surface elevations, discussed further in Section 7.3 Physical Characteristics below, the depth to bedrock ranges from less than 16,500 ft bgs in the eastern area to approximately 23,000 ft bgs in the far western area.

*Base of Fresh Water*

Despite the substantial thickness of sedimentary strata overlying impermeable basement rock within this structural basin, in the case of the Central Valley it is more appropriate to consider geochemical properties (i.e., water quality) in determining the definable bottom of the basin (DWR, 2016). Documentation of the DWR’s C2VSim model states that “although the Central Valley sedimentary basins are very thick, the fresh water aquifer in each basin is very thin” (Brush et al., 2016).

Page (1973) mapped the elevation of the base of fresh water in the Kern Subbasin using a criterion for fresh water of specific conductance (also known as electrical conductivity or EC) of less than 3,000 micromhos per centimeter (umhos/cm). This EC is equivalent to a total dissolved solids (TDS) concentration of approximately 2,000 milligrams per liter (mg/L). The Page (1973) base of fresh water map only characterizes the northernmost portion of the Wheeler Ridge-Maricopa Management Area and is therefore less informative in this case. O’Bryan (1992) used the same criteria as Page to map the base of fresh water in areas farther south in the San Joaquin Valley, including most of the Management Area. O’Bryan shows that the base of fresh water ranges from -1,000 ft msl in the western portion of the Management Area to below -5,000 ft msl near the Rio Viejo oil field in the east-central portion of the
Basin Setting
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

Management Area (Figure HCM-2). These elevations translate to a range of depths of approximately 1,300 ft bgs to 5,600 ft bgs.

Base of Fresh Water from Oil Field Information
For over a century, oil and gas exploration and development has taken place throughout the Kern Subbasin, tapping various Tertiary sedimentary deposits. Such activity continues to this day and has resulted in the accumulation of a substantial body of knowledge concerning the regional geology, including stratigraphy, structural features, hydrocarbon occurrence, and the geochemical character of groundwater. Figure HCM-3 shows the locations of oil fields in and around the Wheeler Ridge-Maricopa Management Area, as mapped by the Division of Oil, Gas, and Geothermal Resources (DOGGR). The San Emidio Nose oil field, located in the central portion of the Management Area, contains two “pools” (subareas with distinct production characteristics and rules) – the Main Area and the Northwest Area. The base of fresh water indicated on the field data sheets for these pools ranges from 4,500 ft bgs to 5,000 ft bgs in the Main Area to 3,800 ft bgs to 5,000 ft bgs in the Northwest Area (DOGGR, 1998). The DOGGR base of fresh water determination is based primarily on salinity derived from borehole electric log (e-log) data. The Rio Viejo oil field, located just north of the San Emigdio Nose oil field, has a base of fresh water of 5,500 ft bgs. The Yowlumne oil field, located in the western portion of the Management Area, has a base of fresh water between 1,600 ft bgs and 4,000 ft bgs. The Los Lobos oil field overlies a small portion of the southwestern corner of the Management Area and has a base of fresh water between 500 and 3,000 ft bgs. The Midway-Sunset oil field overlies portions of the far western edge of the Management Area, and is largely in an area without fresh water, except in the far southeastern tip of the oil field near Santiago Creek where fresh water is found down to approximately 500 ft bgs.

Deepest Groundwater Extractions
The HCM BMP states that “the definable bottom of the basin should be at least as deep as the deepest groundwater extractions” (DWR, 2016). Based on well construction information from 191 wells within the Wheeler Ridge-Maricopa Management Area, all wells have depths less than 2,600 ft bgs and approximately 90% of wells have depths less than 1,800 ft bgs.

Another indication of the "bottom" of the basin in the Wheeler Ridge-Maricopa Management Area comes from the basin representation within groundwater flow models, specifically the Department of Water Resources C2VSim basin model (Brush et al., 2016).23 The C2VSim model (C2VSim-CG, version R374) divides the Central Valley alluvial basin vertically into three layers, the top two of which are pumped (i.e., could be considered to define the vertical extent of the basin). C2VSim-CG layer thickness data for 33 model nodes within and near the Management Area show that the combined thickness of Layers 1 and 2 (i.e., the unconfined and confined pumped layers) ranges from 1,252 ft to 3,910 ft, averaging 1,834 feet

23 http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/index_C2VSIM.cfm
The updated version of C2VSim\textsuperscript{24} which utilizes a finer grid (C2VSim-FG, Beta version) uses the same layering scheme, but has a refined grid/mesh, adjusts the thickness of Layers 1 through 3 and adds an additional deeper Layer 4. C2VSim-FG layer thickness data for 103 model nodes within the Management Area show a combined thickness of Layers 1 and 2 ranging from 597 ft to 1,807 ft, averaging 1,446 ft (see Figure HCM-4). These combined Layer 1 and 2 thicknesses correspond to the total depth of the pumped zone in this model.

Given the above information, the controlling factor for the definable “bottom of the basin” is determined to be the depth of the base of fresh water. Within the Wheeler Ridge-Maricopa Management Area, the bottom of the basin ranges in elevation from -1,000 ft msl in the western portion to below -5,000 ft msl near the Rio Viejo oil field in the east-central portion, corresponding to depths of approximately 1,300 ft bgs to 5,600 ft bgs. It is recognized, however, that the maximum depth of wells is only about 2,600 feet, with 90% of wells screened to depths of 1,800 feet or less, and therefore a substantial volume of groundwater above the “bottom of the basin” has not been tapped by water wells.

\textsuperscript{24} C2VSim-FG, Beta version is currently uncalibrated, and various potential concerns have been identified regarding this model’s parameterization of the Kern and White Wolf Subbasins, including representation of the White Wolf Fault (location and hydraulic properties), hydraulic properties of the aquifers, etc. as discussed in detail in the letter to DWR from the White Wolf GSA, of which WRMWSD is a member, on 9 July 2018.
### Table HCM-1. Information Relevant to Definition of the Bottom of the Basin

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Source(s)</th>
<th>Parameter Range within Wheeler Ridge-Maricopa Management Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Elevation Range (ft msl)</td>
</tr>
<tr>
<td>Bedrock Basement</td>
<td>Scheirer, 2013</td>
<td>Western Area: -22,000 to -21,000 Eastern area: -20,000 to -16,000</td>
</tr>
<tr>
<td>Composite Surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Western Area: -3,000 to -1,000 Eastern area: -5,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base of Fresh Water</td>
<td>O’Bryan, 1992</td>
<td>Western Area: -22,000 to -21,000 Eastern area: -20,000 to -16,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>OGGR, 1998</td>
<td>Western Area: -3,000 to -1,000 Eastern area: -5,000</td>
</tr>
<tr>
<td>Oil Field Base of Fresh Water Information</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Western Area: -3,000 to -1,000 Eastern area: -5,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deepest GW Extractions from</td>
<td>WRMWSD Well Database</td>
<td>90% of wells BOS elevation &gt; -1,400 100% of wells BOS elevation &gt; -2,000</td>
</tr>
<tr>
<td>Well Construction Information</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brush et al., 2016; DWR,</td>
<td>C2VSim-CG (R374): -357 to -1,447 C2VSim-FG (Beta): -129 to -1,342</td>
</tr>
<tr>
<td></td>
<td>2018</td>
<td></td>
</tr>
</tbody>
</table>

Note:  
1. Shaded cells indicate estimated values based on approximate ground surface elevation.
7.1.4. Principal Aquifer(s) and Aquitard(s)

Principal aquifers are defined in the GSP Emergency Regulations (23-CCR Division 2 Chapter 1.5 Subchapter 2) as “aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems” (23-CCR § 351(aa)). In an area with significant groundwater development, such as the Wheeler Ridge-Maricopa Management Area, it is therefore reasonable to equate the principal aquifer(s) with the aquifer(s) from which wells pump water. This in turn can be deduced through examination of the depths of production wells.

As discussed previously and shown on Figure HCM-5, well construction information from 191 wells within the Wheeler Ridge-Maricopa Management Area indicates that all wells have depths less than 2,600 ft bgs, and approximately 90% of wells have depths less than 1,800 ft bgs. Therefore, the principal aquifer is considered to be the aquifer materials encountered within the top 2,600 ft bgs. The surficial geology within the Management Area is discussed further below in Section 7.3 Physical Characteristics, and the stratigraphic relations and well log information along the lines of section are presented on cross-sections A-A′-A″ and G-G′, discussed further below in Section 7.2 Cross-Sections.

Formation Names and Occurrence

The stratigraphy within the depth zone of the principal aquifer includes (from shallowest to deepest; youngest to oldest): Quaternary (Recent to Pleistocene) Alluvium deposits and the late Tertiary (Pliocene/Pleistocene) Tulare Formation. Underlying the Tulare Formation (and generally well below the depth of the principal aquifer) are Miocene and Pliocene marine sedimentary rocks of the San Joaquin and Etchegoin Formations. Owing to their similar continental origin and fluvial mode of deposition, the Quaternary Alluvium and Plio/Pleistocene Tulare Formation can be difficult to distinguish from one another. The Alluvium and Tulare Formations are generally unconsolidated, although consolidation increases with age and depth.

The Alluvium unit, sometimes divided into Younger (Recent) and Older (Pleistocene) units (e.g., Wood and Dale, 1964), is composed generally of unconsolidated sands and gravels of fluvial origin, coarser towards its base, and is somewhat coarser than the underlying deposits (Croft, 1972). The Tulare Formation is correlative to and interfingers with the Kern River Formation which underlies the Quaternary Alluvium on much the eastern side of the Kern Subbasin. In the vicinity of the southwestern border of the San Joaquin Valley, the Tulare Formation is exposed in the foothills and is folded or tilted. It consists of poorly sorted lenticular beds of sand and conglomerate with interbeds of siltstone and mudstone. The fluvial origin of the Tulare Formation results in channel-like bodies of coarse-grained materials which can provide anisotropic hydraulic connections, although these channels are largely unmapped. Underlying the Tulare

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25 The depth of wells is determined from well construction information using the following data, in order of preference (if data are available): bottom of screen depth, completed depth, or total depth.
Formation (generally well below the depth of the principal aquifer) are the Etchegoin Formation and, towards the east, the Miocene Chanac to the east of the Wheeler Ridge-Maricopa Management Area.

A significant regional aquitard within the Tulare Formation, the Pleistocene E Clay (Croft, 1972), underlies the northern portion of the center of the Wheeler Ridge-Maricopa Management Area (Figure HCM-6). The E Clay, correlative with and sometimes referred to as the “Corcoran Clay”, is one of several flood-basin, lacustrine and marsh deposits within the southern San Joaquin Valley. It is often described as “blue clay” in well driller logs (Croft, 1972). The E Clay dips generally southwestward, and beneath the Management Area the base of the E Clay ranges in elevation from approximately -200 ft msl in the northeastern portion to -400 ft msl in the north-central portion. The depth to top of the E Clay ranges is approximately 250 ft bgs in its most southwestern extent beneath the Management Area (DWR, 2008). The E Clay, where present, acts as a confining unit for the underlying groundwater; above the E Clay (and where it does not exist) groundwater occurs under unconfined conditions (Croft, 1972). As shown on Figure HCM-6, the E Clay is not known to extend all the way underneath the Management Area to the western or southern extents, and thus is not known to consistently confine the underlying aquifer. Another similar regional aquitard unit, the “A Clay”, exists at shallower depths to the north of the Management Area but does not underlie it. The A Clay may be the cause of perched groundwater conditions observed in this area (Croft, 1972).

It should be noted that despite the variably confined conditions in this area, it is not deemed appropriate to define separate unconfined and confined principal aquifers because (1) the regional aquitards are not extensive throughout the Wheeler Ridge-Maricopa Management Area; and (2) many wells are screened over large vertical intervals including above and below the regional aquitard (where it is present), thus creating a vertical hydraulic connection.

Physical Properties of Aquifer(s) and Aquitard(s)

Given the range of lithologies and grain sizes within the formations that comprise the principal aquifer (i.e., ranging from gravels and sands, to silts and clays, generally poorly-sorted and interbedded), the physical properties of the aquifer vary widely both laterally and with depth. In general, wells drilled into the principal aquifer tap into sufficient coarse-grained material to be productive enough to support overlying agricultural demands. Wood and Dale (1964) developed a map of “yield factors” for the Edison-Maricopa area. The yield factor is defined as the specific capacity (gallons per minute per foot of drawdown) per 100 feet of aquifer screened by a well (i.e., units of gpm/100ft²). The Wood and Dale (1964) map (Figure HCM-7) shows that most of the central portion of the Wheeler Ridge-Maricopa Management Area has yield factors between 1 and 5 gpm/100ft², with some areas to the west having lower yield factors, and some areas to the east having higher yield factors of 6 to 10 gpm/100ft². Well testing data collected in 2017 from 19 wells located in the north-central portion of the Management Area indicates specific capacity ranging from 10.8 gallons per minute per foot of drawdown (gpm/ft) to 61.4 gpm/ft, averaging 28.1 gpm/ft.
While the yield factors of Wood and Dale (1964) provide insight into the relative productivity of wells, they do not directly translate into aquifer hydraulic properties. Multiple-well aquifer pumping test data, which is necessary to accurately determine hydraulic conductivity and storage parameters, is generally not available. Another potential source of information regarding hydraulic properties is extraction of parameters from calibrated numerical groundwater models, although this information must be used with caution, particularly in areas such as Wheeler Ridge-Maricopa Management Area where the model parameters are not based on local calibration. As mentioned previously, the DWR’s C2VSim model covers the Management Area and is therefore one such source of hydraulic property information. Table HCM-2, below, shows a summary of hydraulic property information for C2VSim nodes in Layers 1 and 2 within the Management Area, based on the R374 version of the coarse grid (CG) model and the “beta” version of the fine grid (FG) model. Figure HCM-8 shows selected hydraulic property values for the 103 C2VSim-FG nodes within the Management Area, including hydraulic conductivity for Layers 1 and 2, specific yield for Layer 1, and specific storage for Layer 2.

Table HCM-2. Hydraulic Properties Extracted from C2VSim Models

<table>
<thead>
<tr>
<th>Parameter</th>
<th>C2VSim-CG (R374)</th>
<th>C2VSim-FG (Beta version)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Nodes within Wheeler</td>
<td>9</td>
<td>103</td>
</tr>
<tr>
<td>Ridge-Maricopa Management Area</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Layer 1 Node Properties: Average (Min to Max)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average (Min to Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic Conductivity (ft/d)</td>
<td>33.6 (30.0 to 41.4)</td>
</tr>
<tr>
<td>Specific Yield (-)</td>
<td>0.27 (0.11 to 0.40)</td>
</tr>
<tr>
<td>Specific Storage (-)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Layer 2 Node Properties: Average (Min to Max)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average (Min to Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic Conductivity (ft/day)</td>
<td>20.7 (8.7 to 49.9)</td>
</tr>
<tr>
<td>Specific Yield (-)</td>
<td>0.122 (0.122 to 0.123)</td>
</tr>
<tr>
<td>Specific Storage (-)</td>
<td>1.8E-05 (9E-06 to 4.6E-05)</td>
</tr>
</tbody>
</table>

Abbreviations:
- ft/d = feet per day
- N/A = not applicable

26 Numerical models that are regional (i.e., large scale) in extent should be assumed to possess a high degree of uncertainty with respect to local parameter values. Nonetheless, where local measurements are not available, such model parameters can serve as an approximation for unknown values.
As shown in the table above, the upper unconfined zone, represented by Layer 1 in both the coarse-grid and (uncalibrated) fine-grid versions of C2VSim, is somewhat more permeable than the confined zone represented by Layer 2. The specific yield of Layer 1 is much greater in the Wheeler Ridge-Maricopa Management Area in C2VSim-CG than in C2VSim-FG; however, these values may change in C2VSim-FG upon completion of model calibration.

Another numerical groundwater model that covers the entire Central Valley is the U.S. Geological Survey’s (USGS’s) Central Valley Hydrologic Model (CVHM) (Faunt, ed., 2009). The CVHM model is based on the USGS MODFLOW software package and simulates integrated subsurface and surface water flow processes, including agricultural water demand based on climate and land use information, for the period from October 1961 through September 2003. Hydraulic properties for each 1 square mile model grid cell were assigned based on the spatially interpolated (using kriging) distribution of coarse-grained deposits that was ascertained through review and lithologic coding of thousands of well logs. Figure HCM-9 shows the horizontal hydraulic conductivity of active cells of CVHM model layers 3, 4, 6, and 8 which correspond, respectively and approximately, to (Layer 3) the upper unconfined, saturated portion of the principal aquifer, (Layer 4) the Corcoran Clay, and (Layers 6 and 8), the confined portion of the principal aquifer. As shown on Figure HCM-9, the hydraulic conductivity of Layer 3 is high (generally in the 250 feet per day [ft/d] to 500 ft/d range), which is much higher than in C2VSim. For the confined aquifer represented in CVHM by Layers 6 and 8, hydraulic conductivity ranges from 5 ft/d to 50 ft/d.

From the information discussed above, it is clear that considerable uncertainty exists in the values for aquifer properties including hydraulic conductivity and specific yield. This is not unexpected, given the heterogeneous nature of the Tulare Formation. As a further indication of the variability in these parameters, Dale et al. (1966) provided estimates of permeability (analogous to hydraulic conductivity) of the various types of continental deposits in the Kern River alluvial fan area, and they range over several orders of magnitude. Permeability for gravel and clay is stated in Dale et al. (1966) to range between 10 and 100 gallons per day per foot squared (gpd/ft²)²⁷, for fine sand and silt from 0.001 to 10 gpd/ft², for medium and coarse sand from 100 to 1,000 gpd/ft², and for the gravel (dominated) lentil from 1,000 to 10,000 gpd/ft². As such, an accurate spatial distribution of hydraulic properties remains a significant data gap, although one that may be filled via further local investigation and/or model calibration.

**Structural Properties of the Basin that Restrict Groundwater Flow Within the Principal Aquifer(s)**

The White Wolf Fault that forms the southeastern border of the Wheeler Ridge-Maricopa Management Area and the Kern Subbasin is known to act as a significant barrier to (lateral) groundwater flow from the White Wolf Subbasin northwards into the Kern Subbasin, especially at lower groundwater levels (Erler &

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²⁷ One gpd/ft² is equal to 0.133 ft/day.
Basin Setting
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

Kalinowski, Inc., 2016). As discussed above, the E Clay acts as a regional aquitard that limits vertical flow to some extent between the unconfined and confined portions of the aquifer in the northern portion of the Management Area. It should be noted, however, that many wells are screened through this aquitard and therefore serve as a hydraulic connection between the two zones. The Plieto Fault is a southward dipping thrust fault located roughly two to six miles south of the Management Area that separates Miocene and older rocks on the south from Pliocene and Quaternary rocks on the north. The fault is active in Recent times and is roughly coincident with the southern boundary of the Kern Subbasin (as defined in 2016).

**General Water Quality of the Principal Aquifer(s)**

General groundwater quality within most of the Wheeler Ridge-Maricopa Management Area is categorized by Wood and Dale (1964) as “west-side waters” (see Figure HCM-10). Small areas on the far eastern side are categorized as “transition waters” and “axial waters”. The Wood and Dale (1964) groundwater quality categories reflect differences in the chemical characteristics of streams that recharge groundwater and differences in the rock types through which groundwater moves. The “west-side waters” have sulfate as the predominant anion and with intermediate cation composition. Total ionic concentrations, indicated by the size of the pie charts on Figure HCM-10, are highest in the west, which reflects that the source of water is marine rocks of the Coast Range Mountains. The “transition” waters represent the transition from water emanating chiefly from the Sierra Nevada Mountains to the east and “axial” and “west-side” waters whose chemical composition reflects geochemical processes occurring in the central and western San Joaquin Valley, respectively. The “transition” waters have bicarbonate as the predominant anion and an intermediate cation composition. Further discussion of specific constituents of particular relevance to the beneficial uses within the Management Area, including maps of the distribution of these constituents, is provided in Section 8.4 *Groundwater Quality Concerns*.

**Primary Uses of Each Aquifer**

The predominant use of groundwater from the principal aquifer in the Wheeler Ridge-Maricopa Management Area is for irrigated agriculture. This includes groundwater pumped by individual landowners for use on their crops, as well as groundwater pumped by WRMWSD and subsequently distributed to WRMWSD customers. There are also several domestic wells in the Management Area, mostly in the east-central portion. WRMWSD also supplies small quantities of water (approximately 1% of total water deliveries) to several industrial entities. Figure HCM-11 shows the distribution of wells within the Management Area by well type (i.e., agricultural, domestic, industrial, monitoring, and unknown). As shown on Figure HCM-11, the density of wells is much lower in the western half of the Management Area, presumably due to the relatively lower yields and poorer water quality in that area.
7.1.5. Data Gaps

Key data gaps and uncertainties identified during development of this HCM for the Wheeler Ridge-Maricopa Management Area include:

- Uncertainty in hydraulic properties (hydraulic conductivity, specific yield) of the principal aquifer;
- Uncertainty in the degree of hydraulic connection between the unconfined and confined zones of the principal aquifer where the E Clay is present;
- Uncertainty about well construction details, including well screen intervals, for many in-District wells (i.e., many available well logs are old and no longer legible, or the well logs cannot be accurately mapped to the correct well location); and
- Uncertainty about well status (i.e., whether or not certain wells are active).

7.2. Cross-Sections

Two hydrogeologic cross-sections (A-A’-A” and G-G’) were developed for this HCM (see Figure HCM-12 and Figure HCM-14, respectively). The locations of the cross-sections with respect to the surficial geology are shown on Figure HCM-12. The cross-sections extend laterally slightly beyond the boundaries of the Wheeler Ridge-Maricopa Management Area and extend vertically down to an elevation of -15,000 ft msl. As such the cross-sections include the entire thickness of aquifer materials that are or could reasonably be tapped for groundwater supply purposes (i.e., down through the Pliocene and younger continental/alluvial deposits of the Tulare Formation) and include the entire zone above the Page (1973) and O’Bryan (1992) base of fresh water surfaces. The cross-sections include the following:

- Land surface elevation extracted from the USGS 10-meter digital elevation model (DEM);
- Surficial geologic units after Chapman and Saleeby (2012), Bartow and McDougall (1984), and Wood and Dale (1964), and other geologic references, discussed further below;
- The locations and State Well IDs of water wells proximal to the cross-section lines, that were used to infer lithology based on inspection of well logs. The locations of water supply wells included on the cross-sections are also shown on Figure HCM-12;
Basin Setting
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

- The locations an American Petroleum Institute (API) ID numbers of DOGGR oil wells proximal to the cross-section lines from which the elevations of various stratigraphic markers were extracted from well records;

- Subsurface geologic units, after Chapman and Saleeby (2012), Bartow and McDougall (1984), Wood and Dale (1964), and other geologic references (i.e., lithologic information from water well and DOGGR oil well records);

- Base of fresh water, after O’Bryan (1992);

- Locations of relevant boundaries and landmarks, including the WRMWSD jurisdictional boundary, the Kern Subbasin boundary, the centerlines of various roadways, etc.; and

- The Spring and Fall 2015 groundwater elevations as measured in wells screened in the principal aquifer.

As shown on the cross-sections and discussed previously, all groundwater supply wells with known construction information within the Wheeler Ridge-Maricopa Management Area are less than 2,800 feet in total depth, whereas the Tulare Formation extends significantly deeper. The base of fresh groundwater (after O’Bryan, 1992) is generally deeper than groundwater supply wells in the Management Area. Wells are typically not drilled deeper than needed to obtain the desired quantity of water. Therefore, while usable groundwater may be present below the depths currently tapped by groundwater wells, it may not be economical to do so, especially given that water quality tends to be poorer at greater depths, even above the nominal base of fresh water.

Cross-Section A-A’-A’’

Cross-sections A-A’-A’’ extends for approximately 37 miles in a west-east direction through the center and extending out of the Wheeler Ridge-Maricopa Management Area. The cross-section starts between the bases of the Little Signal Hills and Buena Vista Hills to the west of the Management Area, where the ground surface is highest in elevation (approximately 1,000 ft msl). The cross-section then crosses through Maricopa Flat in the center of the Management Area, passes through the south-central portion of the Arvin-Edison Management Area, and ends near the southeastern boundary of the Kern Subbasin and the northeastern corner of the White Wolf Subbasin. After declining in elevation from the hills in the west, the ground surface along the cross-section remains approximately constant near 400 to 500 ft msl.

The surficial geologic unit traversed by the cross-section is “Qa”, Undifferentiated Surficial Deposits (Pleistocene/Holocene). This deposit is approximately 500 to 700 feet in thickness within the Wheeler Ridge-Maricopa Management Area. Underlying the Qa unit is the Plio-Pleistocene Tulare Formation, which thickens from west to east and extends down to approximately 5,000 feet in the eastern portion of the Management Area. The contact with the Kern River Formation on the east is approximated and gradational. Underlying the Tulare Formation are the Pliocene San Joaquin Formation, the Miocene/Pliocene Etchegoin Formation, and the Miocene Monterey Formation.
The groundwater elevation in Spring and Fall 2015 is shown to be several hundred feet below the land surface which is within the Pleistocene/Holocene surficial deposits. The base of fresh water is shown to increase in depth from west to east, roughly in line with the base of the Tulare Formation.

**Cross-Section G-G’**

Cross-section G-G’ extends for approximately 26 miles in a north-south direction through the center of the Wheeler Ridge-Maricopa Management Area. The northern end of the cross-section is roughly seven miles north of the Management Area within the Kern Delta Water District (KDWD) service area at an elevation of approximately 300 ft msl. Moving southward the land surface elevation rises through the Management Area and then more steeply as it nears the Plieto Fault Zone and the southern boundary of the Kern Subbasin. Further south, the cross-section extends up into the San Emigdio Mountains, reaching an elevation at its southern end of approximately 5,000 ft msl. The portion of the cross-section within the Management Area has similar stratigraphy as in cross-section A-A’, including the Undifferentiated Surficial Deposits, underlain by the Tulare, San Joaquin, Etchegoin, and the Monterey Formations. The groundwater levels in Spring and Fall 2015 are relatively flat, showing a slight decrease to the south. The base of fresh water is found at elevations between -4,000 and -5,000 ft msl. On the southern end of the cross-section, outside of the Management Area and Subbasin, the structural regime is dominated by the Plieto Fault which has raised older (Miocene and older) marine sedimentary units upwards on the south relative to the younger continental rocks on the north side. Another prominent feature in this area is the Devil’s Kitchen Syncline.

### 7.3. Physical Characteristics


(d) Physical characteristics of the basin shall be represented on one or more maps that depict the following:

1. Topographic information derived from the U.S. Geological Survey or another reliable source.
2. Surficial geology derived from a qualified map including the locations of cross-sections required by this Section.
3. Soil characteristics as described by the appropriate Natural Resources Conservation Service soil survey or other applicable studies.
4. Delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.
5. Surface water bodies that are significant to the management of the basin.
6. The source and point of delivery for imported water supplies.
7.3.1. Topographic Information
Figure HCM-15 shows the topography within the Wheeler Ridge-Maricopa Management Area. Topography generally slopes to the north in the western and central portions of the Management Area and to the northwest in the eastern portion. Elevations within the Management Area range from approximately 300 ft msl in the central low spot to 1,000 ft msl in the southern highlands of the San Emigdio Mountains.

7.3.2. Surficial Geology
Figure HCM-12 shows the surficial geology within the Wheeler Ridge-Maricopa Management Area, based on the Geologic Map of California, Bakersfield Sheet (CDMG, 1964) and associated map explanation. The predominant surficial geologic unit of Management Area is “Qf” (i.e., Recent alluvial fan deposits in the Great Valley). These deposits were deposited by streams entering the San Joaquin Valley from the uplands to the south and west. A small portion of Cross-Section A-A’-A’’ cuts through “Qs” (Recent dune sand) in the northeastern extent of the Management Area and just south of the Kern Lake Bed.

Along the northern boundary of the Wheeler Ridge-Maricopa Management Area, “Qf” alluvial fan deposits transition to fine-grained “Qb” Quaternary basin deposits that connect two areas of “Ql” Quaternary lake deposits associated with the Buena Vista Lake Bed and Kern Lake Bed. These recent “Basin” deposits (“Qb”) are relatively less permeable and were deposited under lower-energy floodplain or marsh environments. The basin and lake deposits may contribute to local perched water conditions in that area in the very shallow subsurface (i.e., approximately the top 20 feet). These perched zones are often composed of poor-quality water (Central Valley Regional Water Quality Control Board [CVRWQCB], 2009) and do not yield significant or economic quantities of water to wells, springs, or surface water systems, and therefore are not considered part of the principal aquifer.

Just south of the Wheeler Ridge-Maricopa Management Area and along the boundary of the Kern Subbasin, “Qc”, Quaternary (Pleistocene) non-marine deposits, and “QP”, Quaternary (Pliocene-Pleistocene) non-marine deposits are prevalent. The “Qc” deposits consist of older alluvium, including slightly consolidated and dissected fan deposits. The “QP” deposits underlie the Recent Alluvium throughout the Management Area.

7.3.3. Soil Characteristics
Soils within the Wheeler Ridge-Maricopa Management Area are shown on Figure HCM-16, based on the U.S Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic Database (SSURGO) for western Kern County. Soils are generally of intermediate texture, with the predominant type being loam with lesser amounts of fine sandy loam, sandy loam, loamy sand, and other. As shown on Figure HCM-16, saturated hydraulic conductivity of soils is generally in the range of 2 to 4 inches per hour (4 to 8 ft/d) in the southern area, decreasing towards the north. As shown on Figure HCM-17, soils are predominantly in the B Hydrologic Soil Group in the south and the C Hydrologic Soil Group in the north. These B and C Hydrologic Soil Groups indicate moderate and slow infiltration rates,
respectively, and moderately low and moderately high runoff potential, respectively. The northernmost portion of the Management Area, where the “Qf” alluvial fan deposits transition to fine-grained “Qb” Quaternary basin deposits, has soils belonging to the D Hydrologic Soil Group, with very slow infiltration rates and high runoff potential.

7.3.4. Recharge and Discharge Areas

Figure HCM-18 shows the existing and potential recharge and discharge areas within the Wheeler Ridge-Maricopa Management Area. The groundwater system underlying the Management Area is recharged from several sources, including deep percolation of excess irrigation water applied to agricultural lands (i.e., due to inherent irrigation inefficiency), and seepage/shallow subsurface inflow from natural surface water channels entering the Management Area from the uplands. Recharge of precipitation via deep percolation likely occurs primarily during particularly wet time periods and rarely if ever during normal and dry periods. Discharge of groundwater is predominantly through groundwater pumping from wells. Because water levels are far below the land surface, no significant springs, seeps, or wetlands exist within the Management Area. Outside of the Management Area, recharge areas include spreading grounds associated with other water banking operations and agricultural lands, and discharge areas are primarily to groundwater supply and recovery wells.

SAGBI Soil Recharge Potential

Figure HCM-19 shows groundwater recharge suitability on agricultural lands within the Wheeler Ridge-Maricopa Management Area based on the UC Davis California Soil Resource Lab’s Soil Agricultural Groundwater Banking Index (SAGBI) dataset. This dataset ranks agricultural lands for groundwater recharge suitability based on soil types and five key factors: deep percolation potential, root zone residence time, topography, chemical limitations, and soil surface conditions. The SAGBI dataset ranks a majority of lands within the southern two thirds of the Management Area as having “Good” suitability for groundwater recharge, whereas areas in the northern third are classified as “Moderately Good” or “Very Poor”. As discussed in Section 17 Projects and Management Actions, WRMWSD plans to study and pursue in-District banking and recharge efforts as part of its portfolio approach to supply augmentation projects. Any additional future groundwater recharge facilities proposed within the Management Area will be screened against the SAGBI dataset along with other local sources of information to determine their potential suitability for groundwater recharge operations.

7.3.5. Surface Water Bodies

Surface water bodies significant to the management of the Wheeler Ridge-Maricopa Management Area include both natural surface water features as well as man-made features. Figure HCM-20 shows the natural surface water features in the vicinity of the Management Area.

To the south of the Wheeler Ridge-Maricopa Management Area, approximately 309 square miles of upland watershed area drains into the area, providing occasional surface water inflows and likely some shallow subsurface inflow. Several creeks whose headwaters are in the Tehachapi and San Emigdio...
mountains drain northward into the Management Area, including (from west to east) Bitterwater Creek, Cienega Creek, Bitter Creek, Santiago Creek, Muddy Creek, Los Lobos Creek, San Emigdio, and Pleito Creeks. Several smaller unnamed watersheds along the southern valley margin also drain into the Management Area. In addition, several other watersheds and creeks, including El Paso Creek, Pastoria Creek, Grapevine Creek, and Tecuya Creek drain into the White Wolf Subbasin which ultimately drains into the Kern Subbasin. The mapped extents of these creeks mostly terminate along the southern edge of the Management Area, implying that channelized flow does not continue further into the basin, but rather seeps out into the subsurface. The mountain watersheds that drain into the Management Area receive substantially greater precipitation than the Management Area itself and therefore surface/shallow subsurface inflows from these watersheds are likely a considerable source of recharge.

The USGS historically operated a stream gauge on San Emigdio Creek\(^{28}\), south of the Wheeler Ridge-Maricopa Management Area but the gauge has not been in operation since 1981. WRMWSD is establishing a network of five stream gauges in the San Emigdio mountains, three of which are on streams that flow into the Management Area and two of which flow into the White Wolf Subbasin. No streamflow data are yet available from these gauges.

**7.3.6. Source and Point of Delivery for Imported Water Supplies**

WRMWSD conjunctively manages its surface water and groundwater supplies. The District imports State Water Project (SWP) water through a contract with Kern County Water Agency (KCWA) for 197,088 acre-feet per year (AFY) of Table A Allocation (WRMWSD, 2015). During wet years, the District also receives “Article 21” wet period, surplus water from the SWP. Pursuant to transfer agreements with partner agencies (e.g., Buena Vista Water Storage District, Tehachapi-Cummings Community Water District, etc.), the District has also obtained additional imported water from the SWP, the Central Valley Project (CVP), and other sources. Additionally, the District banks water with the Kern Water Bank, Pioneer Project, and Berrenda Mesa Project in wet years and recovers banked water during dry years.\(^{29}\) Figure PA-5 shows the District’s facilities and infrastructure used for the conveyance and distribution of imported water supplies. The California Aqueduct runs through the District from west to southeast, and the District has approximately twenty pump stations along the Aqueduct that feed SWP water into the District pipelines, distributing water to the District’s Surface Water Service Area.

\(^{28}\) [https://waterdata.usgs.gov/nwis/inventory/?site_no=11195500](https://waterdata.usgs.gov/nwis/inventory/?site_no=11195500)

\(^{29}\) Table 28 of the WRMWSD Agricultural Water Management Plan provides a complete listing of water transfer and exchange partners.
Abbreviations

DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. DWR groundwater basins are based on the boundaries defined in California’s Groundwater, Bulletin 119 - 2016 Update.
3. WRMWSD Management Area boundary was received by WRMWSD staff on 3 July 2018 and excludes overlap area with West Kern Water District Groundwater Sustainability Agency.

Legend
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- County Boundary
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)
Base of Fresh Groundwater, Based on Page, 1973 (USGS) and O'Bryan, 1992

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
Legend
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- DOGGR Oil Field

XX Base of Fresh Groundwater (ft bgs)

Abbreviations
- DOGGR = California Division of Oil, Gas, and Geothermal Resources
- DWR = California Department of Water Resources
- ft bgs = feet below ground surface
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. Base of Fresh Groundwater according to DOGGR field data sheets.

Sources
1. Basemap is ESRI’s ArcGIS Online world topographic map, obtained 18 July 2019.
2. Oil fields map obtained from DOGGR website (ftp://ftp.consrv.ca.gov/pub/oil/maps/dist4/Dist4_fields.pdf)

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
July 2019
B70103.01
Figure HCM-3
Thickness of Layers 1 and 2 in C2VSim-FG Model (Beta Version)

**Legend**
- WRMWSD Management Area
- WRMWSD Service Area
- Outside of Management Area

**Groundwater Subbasin**
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

**Depth to Bottom of Layer 2 (ft bgs)**
- <1,100
- 1,100 - 1,200
- 1,200 - 1,300
- 1,300 - 1,400
- 1,400 - 1,500
- 1,500 - 1,600
- 1,600 - 1,700
- >1,700

**Abbreviations**
- C2VSim-FG = California Central Valley Groundwater-Surface Water Simulation Model-Fine Grid
- CNRA = California Natural Resources Agency
- DWR = California Department of Water Resources
- ft bgs = feet below ground surface
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

**Notes**
1. All locations are approximate.
2. Total thickness of Layers 1 and 2 of C2VSim-FG Beta Model are shown.
3. Layer 1 and 2 total depths range from 597 to 1,807 ft bgs in C2VSim-FG Model within WRMWSD Management Area.

**Sources**
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. C2VSim-FG Model data obtained from CNRA website: https://data.cnra.ca.gov/dataset/c2vsimfg-beta-model

---

North Canal
North Canal Spreading Works

(Scale in Miles)

Kern County, California
July 2019
B70103.01
Figure HCM-4
Notes
1. Well screen data is based on digitized well records of 167 wells in the Wheeler Ridge-Maricopa Management Area.
2. When BOS depth was not available, completed depth was used.
Contour Map of Base Elevation of “E Clay” Layer

Abbreviations

- DWR = California Department of Water Resources
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Overlay map shows elevation contours (red lines) of the base of the “E Clay”. The contour interval is 100 feet and the datum is mean sea level.

Sources

1. Basemap is ESRI’s ArcGIS Online world topographic map, obtained 18 July 2019.
Yield Factors after Wood and Dale (1964)

**Legend**
- WRMWSD Management Area
- WRMWSD Service Area
- Outside of Management Area

**Groundwater Subbasin**
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

**Legend**
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

**Abbreviations**
- DWR = California Department of Water Resources
- gpm/ft = gallons per minute per foot

**Notes**
1. All locations are approximate.
2. Yield factor is in gallons per minute per foot of drawdown per 100 feet of saturated materials penetrated by irrigation wells.

**Sources**
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
Abbreviations

- C2VSim-FG = California Central Valley Groundwater-Surface Water Simulation Model - Fine Grid
- CNRA = California Natural Resources Agency
- ft bgs = feet below ground surface
- ft/d = feet per day
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Layers 1 and 2 are the representative "pumped layers" of C2VSim-FG Beta Model.
3. Layer 1 and 2 total depths range from 600 to 1,810 ft bgs in C2VSim-FG Beta Model within WRMWSD Management Area.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. C2VSim-FG Model data obtained from CNRA website: https://data.cnra.ca.gov/dataset/c2vsimfg-beta-model
Abbreviations
CVHM = Central Valley Hydrologic Model
DWR = California Department of Water Resources
ft/d = feet per day
USGS = United States Geological Survey
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. Percent coarse is used to approximate hydrogeologic properties of each layer in the CVHM model.

Sources
1. Basemap is ESRI’s ArcGIS Online world topographic map, obtained 18 July 2019.
2. CVHM aquifer properties were acquired from Faunt, C.C., ed., 2009, Groundwater Availability of the Central Valley Aquifer, California: USGS Professional Paper 1766, 225 p.

Legend
WRMWSD Management Area
WRMWSD Service Area Outside of Management Area
Groundwater Subbasin
Kern County (DWR 5-022.14)
White Wolf (DWR 5-022.18)

Horizontal Hydraulic Conductivity (ft/d)

(a) Layer 3 Horizontal Hydraulic Conductivity
(b) Layer 4 Horizontal Hydraulic Conductivity (Corcoran Clay)
(c) Layer 6 Horizontal Hydraulic Conductivity
(d) Layer 8 Horizontal Hydraulic Conductivity

< 0.5
0.5 - 5.0
5.0 - 25
25 - 50
50 - 100
100 - 250
250 - 500
500 - 1,000
> 1,000

CVHM Horizontal Hydraulic Conductivity, Layers 3, 4, 6, 8

DRAFT
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
July 2019
B70103.01
Figure HCM-9
General Groundwater Quality

Legend
- WRMWSD Management Area
- WRMWD Service Area Outside of Management Area

Groundwater Subbasin
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Area of circle indicates mineral concentration (excluding silica), in parts per million

Notes
1. All locations are approximate.
2. Map shows areas of different water quality (shading, hatching, and stippling), as shown by labels, and chemical composition of major ions (pie charts) the sizes of which are scaled by the total mineral concentration (excluding silica).

Abbreviations
- DWR = California Department of Water Resources
- USGS = The United States Geological Survey
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
North Canal Spreading Works

Kern County, California
July 2019
B70103.01

Figure HCM-11

In-District Well Locations, Type, and Status

Well Type/Status
- Active Agricultural
- Active Domestic
- Active Industrial
- Active WRMWSD Production Well
- Monitoring Well
- Abandoned
- Dry Well
- Other

Legend
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. Well type data received from WRMWSD on 20 November 2017.

Abbreviations
- DWR = California Department of Water Resources
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District
Notes
1. All locations are approximate.

Sources
1. DWR groundwater basins are based on the boundaries defined in California’s Groundwater, Bulletin 118 - 2016 Update.
2. WRMWSD cross section locations and data type provided by WRMWSD staff on 25 January 2018 (A-A’-A’’) and 9 March 2018 (G-G’).
North Canal
North Canal Spreading Works
0
5
10
(Scale in Miles)
±
Kern County, California
July 2019
B70103.01
Figure HCM-15
Wheeler Ridge-Maricopa Water Storage District

Abbreviations
DWR = California Department of Water Resources
ft msl = feet above mean sea level
NED = National Elevation Dataset
USGS = United States Geological Survey
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 16 July 2019.
2. Surface elevation data obtained from USGS NED (https://viewer.nationalmap.gov/basic/).

Legend
WRMWSD Management Area
WRMWSD Service Area Outside of Management Area
Elevation Contour (100-ft interval)
Groundwater Subbasin
Kern County (DWR 5-022.14)
White Wolf (DWR 5-022.18)

Low : 330
High : 1100

Land Surface Elevation (ft msl)

Topography
Legend

(a) Soil Map Units

(b) Soil Saturated Hydraulic Conductivity

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.

Notes

1. All locations are approximate.
2. Map units extracted from SSURGO data.
3. Only the soil units of greatest extent are included in their own category. Additional soil units grouped as "Other".

Abbreviations

DWR = California Department of Water Resources
in/hr = inches/hour
NRCS = Natural Resources Conservation Service
SSURGO = Soil Survey Geographic Database
WWMWSD = Wheeler Ridge-Maricopa Water Storage District

Soil Saturated Hydraulic Conductivity (in/hr)

- 1
- 2
- 3
- 4

0 4 8
(Scale in Miles)

Soil Texture

- Fine Sandy Loam
- Loam
- Loamy Sand
- Sandy Clay Loam
- Sandy Loam
- Other

Soil Map Units and Saturated Hydraulic Conductivity

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
July 2019
8/0/03/DT
Figure HCM-16
Legend

WRMWSD Management Area

Groundwater Subbasin

Kern County (DWR 5-022.14)

White Wolf (DWR 5-022.18)

Hydrologic Soil Groups

A
B
C
D

Hydrologic Soil Group

Abbreviations

DWR = California Department of Water Resources
SSURGO = Soil Survey Geographic Database
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Hydrologic soil groups extracted from SSURGO data.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. Soil data from SSURGO (https://gdg.sc.egov.usda.gov/GDGOrder.aspx#).
Abbreviations

DWR = California Department of Water Resources
NHD = National Hydrography Dataset
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. Surface water features and California Aqueduct location from NHD (https://viewer.nationalmap.gov/basic/).
3. Surface Water Service Area and well type and status data acquired from WRMWSD staff on 21 November 2017.
Soil Recharge Potential Based on SAGBI Dataset

Legend
- WRMWSI Management Area
- WRMWSI Service Area Outside of Management Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)

SAGBI Rating
- Excellent
- Good
- Moderately Good
- Moderately Poor
- Poor
- Very Poor

Abbreviations
- DWR = California Department of Water Resources
- SAGBI = Soil Agricultural Groundwater Banking Index
- WRMWSI = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. The SAGBI dataset is a spatial mapping of a suitability index for groundwater recharge on agricultural land, based on five key factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition.

Sources
1. Basemap is ESRI’s ArcGIS Online world topographic map, obtained 18 July 2019.
2. SAGBI data from https://casoilresource.lawr.ucdavis.edu/sagbi/
Abbreviations
DWR = California Department of Water Resources
NHD = National Hydrography Dataset
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. Pastel filled areas are watersheds draining into the Wheeler Ridge-Maricopa Management Area, and gray filled areas are watersheds draining into WRMWSD's area in the White Wolf Subbasin.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. Surface water features and watersheds from NHD (https://viewer.nationalmap.gov/basic/).
8. CURRENT AND HISTORICAL GROUNDWATER CONDITIONS

This section presents information on historical and current groundwater conditions within the Wheeler Ridge-Maricopa Management Area based on available data. Sources of data used to inform this current conditions assessment are described within each data topic section and include data from District records, various state and federal databases, and other reports.

For the purposes of this assessment, “current conditions” refers to conditions in calendar year 2015 (i.e., the effective date of SGMA), which is consistent with how “current” is defined by the KGA in the KGA Umbrella GSP. For historical conditions, two periods are relevant. The first is DWR Water Years (WY) 1995 through 2015 (i.e., October 1994 through September 2015) which is the period being used by KGA and its member entities for historical water budget development. As discussed further below, this period is climatically close to normal/average, but includes a significantly dry (drought) period between 2012 and 2015, as well as other years that were drier or wetter than normal. The second historical period discussed herein is the period from 1971 through 2017/2018 which corresponds to the period since WRMWSD began its water importation operations. Consideration of this longer period allows assessment of the long-term effects of District operations and various sustainability indicators (i.e., groundwater levels, storage, and water quality). In some cases, certain other historical periods are also discussed in this section when either (a) the discussion is constrained by the time periods of available datasets (e.g., for land subsidence), or (b) the groundwater conditions characterization is improved by incorporation of data from other time periods.
Groundwater elevation data have been collected and compiled from WRMWSD monitoring records, datasets from other neighboring entities (i.e., Arvin-Edison Water Storage District [AEWSD], Kern Delta Water District [KDWD], and Kern County Water Agency [KCWA]), and the DWR’s California Statewide Groundwater Elevation Monitoring (CASGEM) database. The multiple datasets were reconciled and processed for quality assurance/quality control prior to analysis for groundwater conditions. These data cleaning efforts included removal of erroneous data points identified through examination of hydrographs and removal of very shallow depth-to-water data points (less than 20 ft bgs) suspected of being affected by perched conditions along the northern boundary and to the north of the Wheeler Ridge-Maricopa Management Area. The resulting dataset used to inform this discussion of groundwater elevation conditions consists of over 100,000 groundwater elevation data points from over 1,600 wells over the period from 1936 to spring 2018 throughout the Kern Subbasin. For the purposes of this analysis the periods of Spring and Fall 2015 are used to represent seasonal high and low conditions under current land and water use, which is consistent with how other Management Area Plans under the KGA Umbrella GSP and other GSPs within the Kern Subbasin (i.e., Kern River GSA’s GSP) are being prepared.

Lateral Gradients

Lateral gradients are discussed below in the context of groundwater elevation contour maps.

Vertical Gradients

Vertical gradients between the different zones within the principal aquifer (i.e., the unconfined zone above the E Clay versus the confined zone below the E Clay, where it exists) may develop due to variability in proximity to recharge sources and the intensity of pumping. Vertical gradients may also vary in time as the stresses affecting water levels are also temporally variable. Evaluation of vertical gradients can be accomplished by examination of water levels in well pairs where one well is representative of the upper,
unconfined zone and the other well is representative of the lower, confined zone. This approach requires water level information from wells that: (a) have known well construction information, (b) are screened in different depth zones, (c) have contemporaneous measurements (i.e., water levels measured at least in the same year and season), and (d) are in close spatial proximity to each other (i.e., to minimize the influence of lateral gradients in water level). At this time, data that meets all of the above criteria are limited. Available data indicate that vertical gradients within the District are generally downwards but vary and between years and seasons. Compiling additional well screen interval information for associated groundwater elevation data would help fill to better define vertical gradients between different zones of the principal aquifer.

Groundwater Elevation Contour Maps

Groundwater elevation contour maps for “current conditions” – Spring 2015 and Fall 2015 – are presented on Figure GWC-1 and Figure GWC-2, respectively. The following generalities can be made based on groundwater elevation data compiled for wells within the Wheeler Ridge-Maricopa Management Area.

- Groundwater levels are consistently lowest in the southern central portion of the Management Area near the California Aqueduct, in the northernmost portion between the Buena Vista Lake Bed and Kern Lake Bed, and in the far eastern portion just north of the White Wolf Fault.
- Groundwater levels are highest in the western portion of the Management Area and just south of the Kern Lake Bed.
- The barrier effects of White Wolf Fault tend to cause higher groundwater levels on the upgradient (South) side just outside of the Management Area, due to "backing up" of water.
- Assuming groundwater flow is perpendicular to groundwater elevation contours, flow directions are highly variable throughout the Management Area. Generally, groundwater flows into the Management Area across the White Wolf Fault at a relatively low rate due to low transmissivity. Flow across the northern boundary is variable and may result in net inflow or outflow from season to season.
- Average lateral groundwater gradients across the northern boundary of the Management Area under current conditions were extracted from the Spring and Fall 2015 groundwater elevation contour maps (Figure GWC-1 and Figure GWC-2) using GIS analysis. This boundary was divided into three sections – northwest (where data are very limited and gradients therefore uncertain), north-central, and northeast. The estimated lateral gradients across these three northern boundary sections in Spring 2015 were 0.005 feet per foot (ft/ft) 0.0016 ft/ft, and 0.0022 ft/ft, all in a northerly (outflow) direction. In Fall 2015, the gradients for these sections were 0.0049 ft/ft, 0.0033 ft/ft, and 0.0039 ft/ft, respectively, also all in an outflow direction. Average lateral gradients across the White Wolf Fault in Spring and Fall 2015 were approximately 0.01 ft/ft.
An area of relatively high groundwater levels exists to the northeast of the Management Area, which may potentially be due to the impact of finer-grained “basin” deposits.

The relative highs and lows within the Wheeler Ridge-Maricopa Management Area appear to be controlled, at least in part, by the distribution of groundwater pumping versus surface water deliveries; with the notable exception of the south-central area with low groundwater elevations mentioned in the first bullet above, areas within the District’s Surface Water Service Area (SWSA) (see Figure GWC-3) tend to exhibit higher groundwater elevations than areas outside of the SWSA that rely exclusively on groundwater.

**Depth to Groundwater**

As shown on Figure GWC-4, depth to groundwater for “current conditions” in Spring 2015 within the Wheeler Ridge-Maricopa Management Area varies from about 23 ft bgs to 559 ft bgs within the principal aquifer. Most of the Management Area had depths to water of between 100 and 350 ft bgs, with shallower depths interspersed in the northern portion and deeper depths concentrated in the south-central portion. The shallowest depths to water (i.e., less than 50 ft bgs), were measured in wells along the far northern portion of the Management Area near the Kern Lake Bed and Buena Vista Lake Bed and may be indicative of perched groundwater atop the fine-grained “basin” deposits in that area. It appears that these shallow measurements are representative of perched water that is not connected to the principal aquifer system. The fact that depth to water in the principal aquifer system is in most cases more than 100 ft bgs indicates that interconnected surface water and groundwater-dependent ecosystems are unlikely to occur with respect to the principal aquifer in the Management Area. These topics are discussed further below in Section 8.6 *Interconnected Surface Water Systems* and Section 8.7 *Groundwater Dependent Ecosystems*, respectively.

**Long-Term Groundwater Elevation Trends**

Long-term trends in groundwater levels were evaluated based on examination of hydrographs for 16 wells throughout the Wheeler Ridge-Maricopa Management Area. Wells were selected for hydrograph analysis based on the length of record, their distribution throughout the Management Area, and their representativeness of conditions in their area. Hydrographs were developed for two periods: a long-term period from 1955 through February 2018 which captures the entire operational history of the District through the most recent available data (Figure GWC-5), and the more recent period from October 1994 through September 2015 which is consistent with the KGA period of interest (Figure GWC-6). As shown on Figure GWC-5, a majority of the wells with long-term records in the Management Area have shown increased groundwater levels over the long-term, reflecting the increased storage resulting from the WRMWSD’s importation of surface water starting in 1971. Prior to 1971, groundwater levels in many wells were experiencing steep declines. Wells in the far eastern and northwestern portions of the Management Area show more moderate long-term increases or slight declines in groundwater level. The effects of drought cycles (e.g., late 1980s/early 1990s) are apparent in some but not all wells, with greater declines
during dry periods and recovery during wet periods. As shown on Figure GWC-6, over the more recent period from October 1994 to September 2015, the same general behavior and spatial patterns are apparent, except that the long-term increase in water levels due to surface water importation is tempered by recent declines due to drought, especially in the central portion of the Management Area.

To evaluate long-term water level trends, linear regression of the water level data was used (recognizing that this method can be slightly biased by the data’s temporal frequency and distribution). Over the period from 1971 (i.e., the start of surface water imports) through February 2018, trends ranged from -1.38 feet per year to +4.06 feet per year, with 12 out of 16 wells showing positive trends greater than 0.5 feet per year, and only two wells with negative trends. Over the period from Fall 1994 through Fall 2015 (i.e., the KGA period of interest), trends ranged from -2.06 feet per year to +3.86 feet per year, with 9 out of 16 wells showing positive trends greater than 0.5 feet per year, and six wells with negative trends.

Table GWC-1 below shows the DWR Water Year Hydrologic Classification Index for the San Joaquin Valley (i.e., water year type)\textsuperscript{31,32}. Based on the DWR San Joaquin Valley Water Year Index for the 21 Water Years from 1995 through 2015, the period included five "critical" (dry) years, four dry years, two below normal years, three above normal year, and seven wet years. The first third of this period was relatively wet, the middle third was a mix of wet and dry years, and the last third of the period was extremely dry. This climatic factor is reflected in the hydrographs which tend to exhibit water level increases in the 1990s, relative stability in the early 2000s, and then greater decreases starting in the late 2000s.

\textsuperscript{31} http://cdec.water.ca.gov/reportapp/javareports?name=WSIHHIST
\textsuperscript{32} DWR defines a Water Year as extending from October 1 of the previous year to September 30 of the year in question. For example, Water Year 2005 extends from October 1, 2004 through September 30, 2005.
Table GWC-1. Summary of DWR Water Year Types, 1995 - 2015

<table>
<thead>
<tr>
<th>Water Year</th>
<th>WY Index</th>
<th>Water Year</th>
<th>WY Index</th>
<th>Water Year</th>
<th>WY Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>Wet</td>
<td>2002</td>
<td>Dry</td>
<td>2009</td>
<td>Below Normal</td>
</tr>
<tr>
<td>1996</td>
<td>Wet</td>
<td>2003</td>
<td>Below Normal</td>
<td>2010</td>
<td>Above Normal</td>
</tr>
<tr>
<td>1997</td>
<td>Wet</td>
<td>2004</td>
<td>Dry</td>
<td>2011</td>
<td>Wet</td>
</tr>
<tr>
<td>1998</td>
<td>Wet</td>
<td>2005</td>
<td>Wet</td>
<td>2012</td>
<td>Dry</td>
</tr>
<tr>
<td>1999</td>
<td>Above Normal</td>
<td>2006</td>
<td>Wet</td>
<td>2013</td>
<td>Critical</td>
</tr>
<tr>
<td>2001</td>
<td>Dry</td>
<td>2008</td>
<td>Critical</td>
<td>2015</td>
<td>Critical</td>
</tr>
</tbody>
</table>

**Groundwater Levels Relative to Well Screens**

One factor to consider when setting minimum thresholds for chronic lowering of groundwater levels is the potential for dewatering of wells or well screens\(^{33}\). Based on available well construction information, the elevation of the top of well screen (TOS) varies substantially across the Wheeler Ridge-Maricopa Management Area, with differences of several hundred feet between neighboring wells (Figure GWC-7). In order to understand how wells may have been historically or currently impacted, groundwater levels were compared to known TOS elevation information.

Under the assumption that historical low water levels occurred in fall 1971, just prior to the start of surface water imports by WRMWSD (which is generally supported by the long-term hydrographs shown on Figure GWC-5), historic groundwater elevation lows from fall 1971 were compared to TOS data (Figure GWC-8 (a))\(^{34}\). Wells in the western and northern portions of the Wheeler Ridge-Maricopa Management Area tended to be less impacted (i.e., not dewatered) than wells in the central portion of the Management Area.

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\(^{34}\) Groundwater elevation data used are interpolated values in order to include all wells for which the District has well screen data in the analysis, as opposed to only those with both well screen and fall 1971 groundwater elevation records.
To assess potential vulnerability due to drought under the current water supply regime (i.e., since surface water imports have been in effect), groundwater levels from Fall 2016\(^35\) were compared to the TOS data (Figure GWC-8(b)). As this analysis was focused on assessing recent and future potential impact, only wells known to be active are shown.

Of the four active domestic wells for which the District has well screen data, one showed groundwater elevations more than 100 ft below the TOS elevation, two showed groundwater elevations between 50 and 100 feet below the TOS, and one showed groundwater elevations between 100 and 200 feet above the TOS. Of the 30 active agricultural production wells (including 28 private wells and two District-owned wells) for which the District has well screen data, groundwater levels were below the TOS for 10 wells and were within 50 ft of the TOS for four other wells.

Lack of complete well screen data\(^36\) currently prevents a comprehensive analysis of impacts of lowering groundwater levels on wells in the Wheeler Ridge-Maricopa Management Area. To better understand the potential impacts of groundwater level changes on active wells in the Management Area, it would be necessary to acquire and compile data on well screen interval information for additional domestic, agricultural, and industrial wells. Additionally, it would be necessary to update data on well status (i.e., whether or not the well is active) to determine potential impacts to existing wells, as District data show that the status of some wells was most recently assessed in January 1991.

### 8.2. Change in Groundwater Storage

Change in groundwater storage was estimated based on data for selected periods of interest. The method used to estimate storage change for these periods used water level data collected at the start and end of

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\(^{35}\) Data from Fall 2016, near the end of the recent historic drought, were used to understand the extent of drought impacts.

\(^{36}\) District records indicate that there are thirteen active domestic wells in the Wheeler Ridge-Maricopa Management Area; the District has well screen data compiled for four of these wells. There are 74 active agricultural production wells within the Management Area, not including the District’s own production wells, and the District has well screen data for 28 of these and is lacking well screen data for 46. There are three active District production wells in the Management Area (the District has thirteen additional active production wells in its area within the White Wolf Basin), and the District has well screen information for two of these wells. The District also lacks well screen information for the one active industrial well in the Management Area.
each period, spatially-variable specific yield information, and the following relationship, applied in a distributed manner:

\[
\text{Change in Storage} = [\text{Ending Water Level} - \text{Starting Water Level}] \times \text{Specific Yield} \times \text{Area}
\]

Specifically, this approach was implemented by: (1) interpolating groundwater elevations for both years onto a 100-ft grid of pixels using the geostatistical spatial interpolation method known as kriging, (2) similarly interpolating the specific yield values from C2VSim-FG node data\(^{37}\), (3) calculating the water level difference at each pixel, (4) multiplying the water level difference from (3) by the specific yield at each pixel, (5) multiplying the result from (4) by the area of each pixel (i.e., 100 ft x 100 ft = 10,000 ft\(^2\)), and (5) summing all calculated values over the area of the Wheeler Ridge-Maricopa Management Area. To avoid errors caused by comparison of interpolated data that is based on different well points, a paired-well approach was used, wherein wells were selected for inclusion only if they were present in both datasets or if they were in close proximity (less than 1 mile) to a well in the other dataset.

Table GWC-2, below, presents the results of this storage change estimation for selected time periods of interest. As shown in Table GWC-2, the total change in storage from 1971 through 2016 (i.e., since the start of District water imports through the latest available data) was 77,180 AF or approximately 1,715 AFY. The total change in storage from Fall 1994 through Fall 2015 (i.e., the recent KGA period of interest) was 27,180 AF or approximately 1,294 AFY. To put this annual change in storage value into context, it represents approximately 2.3% of the average annual rate of groundwater pumping within the Wheeler Ridge-Maricopa Management Area over that same period (approximately 57,000 AFY; discussed further below in Section 9.3.2 *Historical Water Budget*). This indicates that groundwater storage over the Management Area has shown long-term stability over the WY 1994 – 2015 period.\(^{38}\)

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\(^{37}\) As discussed previously, specific yield values in the C2VSim-FG model used in this calculation may change upon completion of the model calibration.

\(^{38}\) Results from the basin-wide numerical modeling indicated a negative average annual storage change of approximately 7,900 AFY between Fall 1994 and Fall 2014. However, that estimate is considered less accurate than the locally-derived storage change estimates presented here because the basin-wide model has not undergone calibration of subsurface parameters on a local scale against actual local water level data.
Table GWC-2. Change in Storage for Selected Time Periods

<table>
<thead>
<tr>
<th>Period</th>
<th>Relevance of Time Period</th>
<th>Total Change in Storage (AF)</th>
<th>Annual Rate of Change in Storage (AFY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 1971 – Spring 2016</td>
<td>Entire period of District Operations</td>
<td>77,180</td>
<td>1,715</td>
</tr>
<tr>
<td>Fall 1971 – Fall 1990</td>
<td>Entire Bookman-Edmonston Water Budget Period</td>
<td>358,993</td>
<td>18,894</td>
</tr>
<tr>
<td>Fall 1994 – Fall 2015</td>
<td>KGA water budget period of interest</td>
<td>27,180</td>
<td>1,294</td>
</tr>
<tr>
<td>Spring 2003 – Spring 2015</td>
<td>Longer normal/dry period</td>
<td>-80,939</td>
<td>-6,745</td>
</tr>
<tr>
<td>Spring 2003 – Spring 2012</td>
<td>Longer normal/wet period</td>
<td>81,839</td>
<td>9,093</td>
</tr>
<tr>
<td>Fall 2014 – Fall 2015</td>
<td>Short dry period</td>
<td>-76,197</td>
<td>-76,197</td>
</tr>
</tbody>
</table>

Figure GWC-9 shows the distribution of groundwater elevation change throughout the Wheeler Ridge-Maricopa Management Area for the periods from Spring 1971 through Spring 2016, Fall 1994 through Fall 2015, and Fall 2014 through Fall 2015 (groundwater elevation change is directly related to storage change). As shown on Figure GWC-9, from Spring 1971 through Spring 2016 groundwater levels increased throughout most of the Management Area, with the exception of the south-central portion and a small area along the west/central portion of the northern border. The area in the south-central portion appears to have been influenced by several low water level measurements that may be indicate short-term pumping-related levels rather than static levels, but because they were observed in several wells they were not considered outliers. Over the recent period from Fall 1994 through Fall 2015, changes in groundwater elevation were variable, with slight increases in the west, north-central, and east portions of the Management Area, and slight decreases along the southern central and northeastern areas. Over the period from Fall 2014 to Fall 2015, groundwater elevation changes were slightly positive in most areas, but negative in the south-central area.

Determination of the change in storage on a yearly basis using the method described above is more difficult due to a lack of consistent water level monitoring data. To address this issue, annual change in
storage estimates were extracted from the output of the water budget model, described further in Section 9 Water Budget Information below. A graph of estimated annual change in storage between seasonal water level highs (i.e., from March of each year to March of the following year), is presented on Figure GWC-10. Also shown on Figure GWC-10 is the Water Year type based on DWR’s San Joaquin Valley Water Year Index. As shown on Figure GWC-10, annual change in storage within the Wheeler Ridge-Maricopa Management Area ranged from an increase of 83,000 AF for the period from March 1998 – February 1999 to a decrease of 46,000 AF for the period between March 2013 and February 2014. Change in storage tends to be more negative during dry Water Years and more positive during wet Water Years. Change in groundwater storage is discussed further below in Section 9.3.2 Historical Water Budget.

8.3. Seawater Intrusion

Because the Wheeler Ridge-Maricopa Management Area is located far from coastal areas, seawater intrusion is not considered to be an issue.

8.4. Groundwater Quality Concerns

Groundwater quality constituents that may affect the supply and beneficial uses of groundwater in the Wheeler Ridge-Maricopa Management Area were identified by comparing the highest measured concentrations detected at an individual well for each constituent between 2012 and 2016 to applicable screening levels for the various beneficial uses (i.e., Maximum Contaminant Levels [MCLs]) for

Groundwater Quality Constituents of Concern

Groundwater quality constituents that may affect the supply and beneficial uses of groundwater in the Wheeler Ridge-Maricopa Management Area were identified by comparing the highest measured concentrations detected at an individual well for each constituent between 2012 and 2016 to applicable screening levels for the various beneficial uses (i.e., Maximum Contaminant Levels [MCLs]) for

39 The seasonal high groundwater condition occurs typically in late winter or spring and for the purposes of Figure GWC-10 is assumed to occur in March. March groundwater levels are affected by both the amount of pumping during the prior summer (i.e., previous DWR Water Year) as well as the amount of precipitation during the winter months of the current DWR Water Year. In Figure GWC-10, the color of each bar is based on the Water Year type for the year the begins in the October between the March and February represented by the bar.
domestic/Municipal & Industrial (M&I) use and various thresholds for irrigated agricultural use). Constituents for which at least 15% of samples exceeded the applicable screening level include TDS, nitrate, arsenic, boron, iron, manganese, and sulfate, as discussed below. Of the seven constituents mentioned above, only nitrate and arsenic are regulated with a primary (i.e., health risk-based) MCL\textsuperscript{40}, while TDS, iron, manganese, and sulfate have secondary (i.e., aesthetically-based) MCLs\textsuperscript{41}. Boron does not have a primary nor secondary MCL, but levels exceeding 0.50 mg/L can be harmful to sensitive crops (including oranges and grapes) and thus may cause a slight to moderate restriction of use to prevalent crops in the Management Area (United Nations Food and Agriculture Organization, 1985).

- Nitrate was detected above the primary MCL of 10 mg/L (as N) or 45 mg/L (as NO\textsubscript{3}) in zero of 37 wells sampled between 2012 and 2016. Higher concentrations were measured in locations along the southeastern edge of the Management Area, near the White Wolf Fault, and several wells just southeast of the Management Area across the White Wolf Fault show nitrate exceedances (Figure GWC-11).

- Arsenic was detected above the primary MCL of 10 micrograms per liter (ug/L) in six (38%) of 16 wells sampled between 2012 and 2016, with most MCL exceedances in the northern and central portions of the Management Area (Figure GWC-11). Arsenic concentration varies over short distances, with relatively high values in close proximity to “non-detect” values. Arsenic is naturally-occurring in this area, derived from the granitic source rocks whose eroded sediments are present within the alluvial Tulare Formation (Thiros, 2010).

- Boron was detected at levels that may restrict a water’s use for irrigation for common crops (i.e., above 0.5 mg/L; Ayers and Westcot, 1985) in 13 (87%) of 15 wells sampled between 2012 and 2016. Boron is commonly detected throughout the central portion of the Management Area (Figure GWC-12). Boron was also cited as the cause of a base of fresh water determination for nearby oil field pools (Jeppi, Main Area of the Edison oil field) (DOGGR, 1988).

- Sulfate is detected above the recommended secondary MCL of 250 mg/L throughout the Management Area; 34 (92%) of 37 wells sampled between 2012 and 2016 show sulfate concentrations above 250 mg/L. In many cases (41%, or 15 of 37 wells), the sulfate concentration exceeds the upper secondary MCL of 500 mg/L.

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\textsuperscript{40} Primary MCLs are drinking water standards set by the USEPA and California Environmental Protection and Agency (CalEPA) based on human health considerations.

\textsuperscript{41} Secondary MCLs are non-health related standards set by the State Water Resources Control Board based on aesthetic characteristics of drinking water such as taste, odor, and color. For four common constituents – TDS, specific conductance, chloride and sulfate – the SWRCB sets three levels of secondary MCLs for consumer acceptance, referred to as (lowest to highest concentration): “recommended”, “upper”, and “short term”.
• TDS was detected above the recommended secondary MCL of 500 mg/L in 35 (95%) of 37 wells sampled between 2012 and 2016 and was present throughout the Management Area (Figure GWC-13). TDS exceeded the upper secondary MCL of 1,000 mg/L in 10 (27%) of 37 wells sampled between 2012 and 2016, primarily in the northern central portion of the Management Area. As shown on Figure GWC-13, recent water quality sampling has not occurred in the western portion of the Management Area, as groundwater use and monitoring have mostly ceased in this area due to a combination of poor water quality and relatively low yield. Historical water quality sampling from the 1960s shows high concentrations of TDS in the western portion of the Management Area, with TDS detected in most wells above the upper secondary MCL.

• Both iron and manganese exceeded their respective secondary MCLs (300 ug/L and 50 ug/L, respectively) in some locations. Iron exceeded its secondary MCL in eight (33%) of 24 wells sampled between 2012 and 2016, and manganese exceeded its secondary MCL in six (25%) of 24 wells sampled between 2012 and 2016. Though these naturally-occurring constituents can impair the aesthetic quality of drinking water and at high enough concentrations can result in staining of fixtures or clothes washed therein, they are not likely to significantly affect beneficial uses of groundwater in the Management Area.

• The District has indicated that chloride and Uranium may be of concern; groundwater sample data collected between 2012 to 2016 showed no exceedances of MCLs (primary for Uranium and secondary for chloride) for either constituent. Because chloride can negatively affect crop health, recent (2012-2016) groundwater quality sample data were screened against a lower concentration threshold associated with sensitive rootstocks and cultivars for major tree and berry crops (Ayers and Westcot, 1985). Only one of 43 samples exceeded the lowest (most conservative) threshold concentration of 117 mg/L (3.3 milliequivalents per liter of chloride).

Recent District sampling has included primarily inorganic constituents such as major ions and metals, as well as volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). VOCs and SVOCs constituents are typically not a concern for agricultural beneficial uses, but some are harmful to humans if consumed at high enough concentrations (often at parts per million or parts per billion concentrations) and are thus regulated by the U.S. Environmental Protection Agency (EPA) and California EPA (specifically the State Water Resources Control Board [SWRCB]) in drinking water sources. Some of these compounds are, or have been historically, used in agriculture as pesticides, herbicides, fungicides, and can be transported to groundwater by deep percolation of excess applied water, although this is more of a concern for the older “legacy” chemicals and less so for the current generation of chemicals that are designed to avoid deep percolation. One compound in particular, 1,2,3-trichloropropane (1,2,3-TCP), which is an industrial solvent that was also historically a component in a soil fumigant, was recognized in 2006 as a “constituent of special interest” in Kern County (Shelton et al., 2006), and was recently assigned
a (primary) MCL of 0.005 ug/L (five parts per trillion) by the California EPA\textsuperscript{42}, effective 14 December 2017. Limited data from the District’s water quality sampling (43 samples since 2000) indicate that 1,2,3-TCP has not been detected in the Wheeler Ridge-Maricopa Management Area. Additionally, limited data from the USGS Groundwater Ambient Monitoring and Assessment (GAMA) program (Shelton et al., 2006) showed that 1,2,3-TCP was not detected in wells within the Management Area but was detected in 2006 in one location in the adjacent Arvin-Edison Management Area at a concentration of 0.40 ug/L, 80 times the MCL.

8.4.1. Temporal Characteristics of Groundwater Quality

Historical water quality sampling data are limited both in spatial extent and temporal frequency within the Wheeler Ridge-Maricopa Management Area, thus making analysis of water quality trends and their potential nexus to groundwater elevations difficult. The most regularly monitored constituents of concern within the District include TDS, Arsenic, and Nitrate. For these constituents, time-series water quality data were plotted relative to groundwater level measurements for all wells with at least five historical water quality and groundwater level records (see Appendix D). For each constituent, there was no discernable relationship between groundwater levels and groundwater quality trends that could be consistently identified. Thus, additional data collection and analysis will be needed to further evaluate this potential relationship.

8.4.2. Point-Source Contamination Sites

In addition to the relatively widespread non-point source groundwater quality constituents of concern, there are a small number of point-source contamination sites that historically or currently affect shallow (possibly perched) groundwater within the Wheeler Ridge-Maricopa Management Area. These sites, shown on Figure GWC-14, are typically associated with certain industrial or commercial land uses (e.g., gas stations).

As shown on Figure GWC-14, there are a total of two closed Cleanup Program sites and one closed Leaking Underground Storage Tank (LUST) Cleanup site. The LUST Cleanup site was managed by Kern County and the two of the Cleanup Program sites were managed under the oversight of the CVRWQCB. There are no active cleanup sites within the Wheeler Ridge-Maricopa Management Area. The LUST Cleanup site has gasoline listed as a potential contaminant of concern and one of the Cleanup Program sites has crude oil listed as a contaminant of concern. Table GWC-3 below summarizes these three closed sites within the Management Area.

As shown on Figure GWC-14, there are five inactive sites that need evaluation listed in the Department of Toxic Substances Control EnviroStor database within the Wheeler Ridge-Maricopa Management Area. Four of these are military sites, and one is a firing range that has been identified for State Response.

\textsuperscript{42} https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/123-tcp/2017_1115_01S_app.pdf
In addition to the closed and inactive sites discussed above, there are several open and closed Cleanup Program Sites, several closed LUST Cleanup sites, a few active Corrective Action and State Response Sites, and Certified Voluntary Cleanup Sites just outside of the Wheeler Ridge-Maricopa Management Area. Given the lack of open sites and the fact that groundwater is generally hundreds of feet below the surface and separated from near-surface contamination by numerous thin low permeability layers, the threat to groundwater from the closed sites is likely minor.

Table GWC-3. Summary of Active Point-Source Contamination Sites

<table>
<thead>
<tr>
<th>Site ID (see Figure GWC-14)</th>
<th>Site Name</th>
<th>Site Type</th>
<th>Regulatory Oversight Agency</th>
<th>Potential Contaminants of Concern</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tenneco - Rancho Loma Farm</td>
<td>Cleanup Program Site</td>
<td>CVRWQCB</td>
<td>None Listed</td>
<td>Completed - Case Closed</td>
</tr>
<tr>
<td>2</td>
<td>Robert Andrews Farms</td>
<td>LUST Cleanup Site</td>
<td>Kern County</td>
<td>Gasoline</td>
<td>Completed - Case Closed</td>
</tr>
<tr>
<td>3</td>
<td>Four Corners Pipeline Company</td>
<td>Cleanup Program Site</td>
<td>CVRWQCB</td>
<td>Crude Oil</td>
<td>Completed - Case Closed</td>
</tr>
</tbody>
</table>

8.4.3. Oil Field Injection Wells and Produced Water Ponds

As described in Section 7.1.3 Bottom of the Basin, there are five oil fields that overlap the Wheeler Ridge-Maricopa Management Area – the San Emidio Nose, Yowlumne, Rio Viejo, Los Lobos, and Midway-Sunset oil fields. Figure GWC-15 shows the locations of active underground injection wells (based on DOGGR data) and produced water ponds (based on data from the SWRCB’s GeoTracker website) used for oil field operations in these areas. Within the Management Area there are 12 active injection wells, all but one of which are in the Yowlumne oil field (the other being in the Rio Viejo oil field). There are also a large number of injection wells in the Midway-Sunset oil field to the west of the Management Area. There are no produced water ponds within the Management Area, but there are many in the Midway-Sunset oil field.

Underground injection wells used to dispose of wastewater from oil and gas development are regulated in California by the USEPA, DOGGR, and SWRCB (see CA Health and Safety Code § 25159.10 et seq). Produced water discharges to ponds are under the purview of SWRCB and CVRWQCB regulatory oversight and are subject to regulation under individual and general Waste Discharge Requirements (WDRs) amongst other requirements to ensure adequate protection against impacts to underlying groundwater resources.
8.5. Land Subsidence

The Kern Subbasin has a documented history of land subsidence, including historical and recent subsidence in the southern portion of the Kern Subbasin, south of the Kern River, which includes the Wheeler Ridge-Maricopa Management Area (Lofgren, 1975; DWR, 2014). Subsidence in this area has been caused primarily by withdrawal of groundwater, with some areas also affected by hydrocompaction (Lofgren, 1975). Subsidence due to oil and gas production has also occurred in some areas but is minor in importance. Figure GWC-16 depicts maps of areas of hydrocompaction and historical (1949-2005) and recent (2015-2016) subsidence, which are discussed below. The KGA Umbrella GSP provides additional information on subsidence throughout the Kern Subbasin and over time, and with particular reference to critical delivery system infrastructure such as the California Aqueduct and the Friant-Kern Canal.

**Historical Subsidence**

During the mid-20th century, when groundwater levels were declining rapidly before the importation of surface water supplies by WRMWSD and others began, subsidence was widespread throughout the area, with the greatest amounts – over nine feet between 1926 and 1970 – occurring just south of Kern Lake Bed northwest of Mettler (Lofgren, 1975). Subsidence amounts tended to decrease in all directions from this central “hot spot”. This area of historical subsidence generally coincides with the presence of the regional E Clay aquitard and other shallower regional aquitards, which is also presumably an area that includes a greater proportion of other unnamed fine-grained compactible materials.

Between 1957 and 1965, the estimated rate of subsidence as a function of groundwater level decline varied widely from approximately 0.01 to 0.4 feet of subsidence per foot of head decline in the Wheeler Ridge-Maricopa Management Area (Lofgren, 1975).

Extending the historical record further into recent times, DWR has mapped subsidence in this portion of the Kern Subbasin between 1949 and 2005. The southern and northwestern areas of the Wheeler Ridge-Maricopa Management Area are shown in this dataset as having subsidence over that period of between zero and five feet and the northern central areas having subsidence between five and 15 feet (see Figure GWC-16).

**Recent Subsidence**

Subsidence due to water level decline has continued in recent times of groundwater level decline associated with dry climatic conditions; between May 2015 and September 2016 most areas within the
Wheeler Ridge-Maricopa Management Area experienced between one and eight inches of subsidence, with some small areas between eight and twelve inches (see Figure GWC-16; based on Farr et al., 2016). The continued recent subsidence, occurring at a time when groundwater levels are not necessarily below their historic minima, demonstrates that subsidence can continue to occur even after water levels are partially recovered. This continued subsidence could be elastic or could be inelastic subsidence resulting from the temporally-lagged, continued slow depressurization of compactible fine-grained materials (Lofgren, 1975).

As discussed further in Section 13 _Undesirable Results_ the localized areas of increased subsidence in the near-vicinity of the alignment of the California Aqueduct within the Wheeler Ridge-Maricopa Management Area highlights the potential impacts of subsidence on critical infrastructure. Approximately 22 miles of the California Aqueduct runs through the Management Area, from approximately Milepost 256.14 (Check No. 31) to Milepost 278.13 (Teerink Pumping Plant). This portion of the California Aqueduct includes pools 32-35. DWR has documented subsidence by milepost of the California Aqueduct with a baseline of 1967 or 1969 ground surface elevation and estimated hydraulic impacts of differential settling (DWR, 2017). Within this section of the Aqueduct, measured values for survey benchmark locations within the Management Area show up to approximately 1.7 feet of settlement from the 1967/1969 baseline through 2013 (DWR, 2017), and up to approximately 9 inches of additional settlement between 2013 and 2017 (Walker, 2017). Subsidence measurements based on InSAR data between April 2014 and June 2016 indicate a localized area of subsidence in the south-central portion of the Management Area in close proximity to the California Aqueduct (Figure GWC-17).

### 8.6. Interconnected Surface Water Systems

> **§ 354.16. Groundwater Conditions**
> *(f)* Identification of interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems, utilizing data available from the Department, as specified in Section 353.2, or the best available information.

As discussed above, groundwater levels in the principal aquifer are far below the ground surface within the Wheeler Ridge-Maricopa Management Area. Depths to groundwater are generally 100 or more feet below ground surface, and even deeper (greater than 350 ft bgs) in the southern areas where surface water streams enter the Management Area from the south. (see Figure GWC-4). The few water level data that show shallower groundwater in the northern portion of the Management Area are from wells that

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43 It should be noted that subsidence estimates based on interferometric synthetic aperture radar (InSAR) methods can be subject to errors when the period of time between measurements is short and when the land is subject to surface disturbance, as is typical in agricultural areas (personal communication, Michelle Sneed, USGS, 27 June 2018).
are not screened in the principal aquifer, but rather shallow monitoring wells monitoring perched conditions. Therefore, with respect to the principal aquifer, it is assumed there is no interconnected surface water. As such, depletion of interconnected surface water is not considered to be an issue in this area.

8.7. Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are those natural communities that depend on near-surface groundwater as a source of water. As discussed above, depths to groundwater in the principal aquifer are several hundred feet below ground surface, and it is therefore highly unlikely that any ecosystems depend on groundwater from this aquifer system.

DWR has developed a map of “Natural Communities Commonly Associated with Groundwater” (NCCAG) for use by GSAs in identifying potential GDEs. Figure GWC-18 shows the distribution of NCCAG within the Wheeler Ridge-Maricopa Management Area. As shown on Figure GWC-18, the primary area where NCCAG were identified is along the northern boundary of the Management Area near the Kern Lake Bed. These wetlands and vegetation may be connected to perched groundwater atop the fine-grained “basin” deposits in that area, where depth to groundwater is generally encountered at less than 20 ft bgs. This perched zone is not used for groundwater production within the Management Area. Water level data collected from monitoring wells screening the principal aquifer in the area indicate depth to water of approximately 120-200 ft bgs in the area as of Spring 2015, suggesting that the perched zone is fully disconnected from the underlying principal aquifer. Due to the great depth to the principal aquifer, these vegetation communities (i.e., mostly areas of iodine bush, quailbush, and tamarisk) are likely not dependent on groundwater from the principal aquifer system. Other potential GDE features identified by the NCCAG within the north-central portions of the Wheeler Ridge-Maricopa Management Area are vegetation communities that generally line artificial reservoirs, ditches, or other small open water bodies within the District. Based on groundwater level data collected from surrounding monitoring wells, depth to water is generally encountered at 140-300 ft bgs in these areas, indicating that these vegetation communities are not connected to the principal aquifer system and are therefore not considered to be GDEs.
Groundwater Elevations
Spring 2015
Kern County, CA
July 2019

Figure GWC-1

Source: 1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 7 August 2019. 2. Water level data provided by Arvin-Edison Water Storage District, Kern Delta Water District, and WRMWS.

Legend
- WRMWS Management Area
- WRMWS Service Area Outside of Management Area
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Spring 2015 Groundwater Elevation (50 ft interval)

Abbreviations:
- DWR = California Department of Water Resources
- ft = feet
- msl = feet above mean sea level
- WRMWS = Wheeler Ridge-Maricopa Water Storage District

Notes:
1. All locations are approximate.
2. Groundwater elevation contours were created using an interpolation process called kriging and are less certain in areas with sparse data.

Sources:
1. Water level data provided by Arvin-Edison Water Storage District, Kern Delta Water District, and WRMWS.
Groundwater Elevations
Fall 2015
Kern County, CA
July 2019
B70103.01
Figure GWC-2

Legend
- WRMWSI Management Area
- WRMWSI Service Area Outside of Management Area
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- Fall 2015 Groundwater Elevation (50 ft interval)

Fall 2015 Groundwater Elevation (ft msl)
- <0
- 0 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- >250

Abbreviations
- DWR = California Department of Water Resources
- ft = foot
- ft msl = feet above mean sea level
- WRMWSI = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. Groundwater elevation contours were created using an interpolation process called kriging and are less certain in areas with sparse data.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 7 August 2019.
2. Water level data provided by Arvin-Edison Water Storage District, Kern Delta Water District, and WRMWSI.

= California Department of Water Resources
= feet
= feet above mean sea level
= Wheeler Ridge-Maricopa Water Storage District
North Canal
North Canal Spreading Works

**Abbreviations**
- DWR = California Department of Water Resources
- NHD = National Hydrography Dataset
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

**Notes**
1. All locations are approximate.

**Sources**
1. Basemap is ESRI’s ArcGIS Online world topographic map, obtained 18 July 2019.
2. Surface water features and California Aqueduct location from NHD (https://viewer.nationalmap.gov/basic/).
Depth to Groundwater
Spring 2015

Legend
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)
- Stream into WRMWSD

Spring 2015 Depth to Groundwater (ft bgs)
- 0 - 50
- 50 - 100
- 100 - 200
- 200 - 350
- > 350

Abbreviations
- DWR = California Department of Water Resources
- ft bgs = ft below ground surface
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 7 August 2019.
2. Depth to groundwater data provided by WRMWSD on 8 December 2017.
**Legend**
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)
- Groundwater Monitoring Well
- Groundwater Elevation Measurement
- Groundwater Elevation Measurement, Apparent Outlier

**Abbreviations**
- DWR = California Department of Water Resources
- ft = feet
- msl = mean sea level
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

**Notes**
1. All locations are approximate.
2. The water level trend was calculated using linear regression on all non-outlier data between 1 January 1971 and 1 August 2018.

**Sources**
1. Basemap is ESRI’s ArcGIS Online world topographic map, obtained 18 July 2019.
2. DWR groundwater basins are based on the boundaries defined in California’s Groundwater, Bulletin 118 - 2016 Update.
3. Groundwater elevation data provided by WRMWSD on 8 December 2017.

**Bulletin 118 - 2016 Update**

**Historical (1955-2018) Groundwater Elevation Hydrographs**

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
July 2019

Figure GWC-5
Groundwater Subbasin

Groundwater Elevation (ft msl)

-100
300
500
600
100
200
300
400
500
600

Trendline Slope (ft/year)

1.156
1.409
1.260
1.132
1.639
1.614
2.060
0.413
0.712

Groundwater Elevation Measurement, Apparent Outlier

Groundwater Monitoring Well

White Wolf (DWR 5-022.18)
Kern County (DWR 5-022.14)

WRMWSD Service Area Outside of Management Area

WRMWSD Management Area

Notes

1. All locations are approximate.
2. The water level trend was calculated using linear regression on all non-outlier data between 1 October 1994 and 30 September 2015.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
3. Groundwater elevation data provided by WRMWSD on 8 December 2017.

Abbreviations

DWR = California Department of Water Resources
ft msl = feet above mean sea level
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Recent (1994-2015) Groundwater Elevation Hydrographs

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA

Figure GWC-6

DRAFT
Elevation of Top of Well Screen

Depth of Top of Well Screen (ft bgs)
- <100
- 100 - 200
- 201 - 300
- 301 - 400
- >400

Abbreviations
DWR = California Department of Water Resources
ft bgs = feet below ground surface
ft msl = feet above mean sea level
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. All data is approximate.

Sources
1. Basemap is ESRI’s ArcGIS Online world topographic map, obtained 18 July 2019.
2. Well screen data provided by WRMWSD staff on 20 November 2017.
Legend

- WRMWSD Management
- WRMWSD Service Area Outside of Management Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)

<table>
<thead>
<tr>
<th>Difference between Groundwater Elevation and Top of Well Screen (ft)</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100</td>
<td>■</td>
</tr>
<tr>
<td>100 - 0</td>
<td>●</td>
</tr>
<tr>
<td>0 - 50</td>
<td>□</td>
</tr>
<tr>
<td>50 - 100</td>
<td>△</td>
</tr>
<tr>
<td>100 - 200</td>
<td>▽</td>
</tr>
<tr>
<td>&gt; 200</td>
<td>⌐</td>
</tr>
</tbody>
</table>

Notes

1. All locations are approximate.
2. Only active wells with available Fall 2016 groundwater elevation data are displayed for panel (b).

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 7 August 2019.
2. Groundwater elevation and well screen data provided by WRMWSD staff on 20 November 2017.
Groundwater Elevation Change

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 7 August 2019.
2. Groundwater elevation data provided by WRMWSD staff on 8 December 2017.

Notes
1. All locations are approximate.
2. Groundwater elevation change shown as feet change in each 100 ft by 100 ft cell. Groundwater elevation data were interpolated using kriging for each year, and the difference was calculated using GIS tools.

Abbreviations
DWR = California Department of Water Resources
USGS = United States Geological Survey
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Groundwater Subbasin
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Legend
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Starting Groundwater Elevation
- Ending Groundwater Elevation

Groundwater Elevation Change (ft)
-270
-200
-100
0
100
200
270

(a) Change in Groundwater Elevation, Spring 1971 - 2016

(b) Change in Groundwater Elevation, Fall 1994 - 2015

(c) Change in Groundwater Elevation, Fall 2014 - 2015
Legend

**DWR Water Year Type**

- **= Wet**
- **= Above Normal**
- **= Below Normal**
- **= Dry**
- **= Critical**

**Abbreviations**

AFY = acre-feet per year

**Notes**

1. “Seasonal high” condition is defined as March – February of the following year.
2. The color of each bar is based on the Water Year type for the Water Year the begins in the October between the March and February represented by the bar.
**Groundwater Quality – Nitrate and Arsenic Concentrations (2012 - 2016)**

**Notes**
1. All locations are approximate.
2. Constituent concentration is the maximum observed for each well between 2012 and 2016.
3. CCR 22-4 Table 64431-A lists primary MCL for nitrate as nitrogen at 10 mg/L, equivalent to 45 mg/L nitrate as NO₃.
4. CCR 22-4 Table 64431-A lists Primary MCL for Arsenic at 10 ug/L.

**Sources**
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. Groundwater quality data was provided by WRMWSD staff on 20 November 2017.

**Legend**
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

**Nitrate (as NO₃) Concentration (mg/L)**
- ND
- 0.1 - 9
- 9 - 22.5
- 22.5 - 45
- > 45

**Dissolved Arsenic Concentration (ug/L)**
- ND (< 7.8)
- 7.8 - 10
- > 10
Notes:
1. All locations are approximate.
2. Constituent concentration is the maximum observed for each well between 2012 and 2016.
3. Boron levels >0.5 mg/L can exhibit slight to moderate restrictions on agricultural productivity, depending on crop type.
4. CCR 22-4 Table 64449-B lists "Upper" Secondary MCL for sulfate at 500 mg/L.

Sources:
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. Groundwater quality data was provided by WRMWSD staff on 20 November 2017.
(a) Recent (2012-2016) Groundwater Quality - Total Dissolved Solids

(b) Historical (1960s) Groundwater Quality - Total Dissolved Solids

**Legend**
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Kern County (DWR S-022.14)
- White Wolf (DWR S-022.18)

**Groundwater Subbasin**
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

**Total Dissolved Solids Concentration (mg/L)**
- <300
- 300 - 500
- 500 - 1,000
- >1,000

**Abbreviations**
- CCR = California Code of Regulations
- DWR = California Department of Water Resources
- MCL = Maximum Contaminant Level
- mg/L = milligrams per liter
- TDS = Total Dissolved Solids
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

**Notes**
1. All locations are approximate.
2. Constituent concentration is the maximum observed for each well between 2012 and 2016 (Figure GWC-13(a)) and between 1960 and 1969 (Figure GWC-13(b)).
3. CCR 22-4 Table 64449-B lists "upper" Secondary MCL for TDS at 1,000 mg/L and "lower" Secondary MCL for TDS at 500 mg/L.

**Sources**
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
2. Groundwater quality data was provided by WRMWSD staff on 20 November 2017.
Legend
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area

Groundwater Subbasin
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

GeoTracker Sites
- Cleanup Program Site, Open
- Cleanup Program Site, Closed
- LUST Cleanup Site, Closed

EnviroStor Sites
- Active Corrective Action
- Active Federal Superfund
- Active State Response
- Corrective Action, Refer: EPA
- Inactive - Needs Evaluation
- Certified Voluntary Cleanup
- School Investigation, No Action or No Further Action
- Closed Hazardous Waste Site
- Hazardous Waste Site Undergoing Closure

Abbreviations
- DWR = California Department of Water Resources
- LUST = Leaking Underground Storage Tank
- SWRCB = State Water Resources Control Board
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 18 July 2019.
Locations of Oil Fields, Active Injection Wells, and Produced Water Ponds

Kern County, CA
July 2019
B70103.01

Figure GWC-15

Abbreviations
DWR = California Department of Water Resources
DOGGR = Division of Oil, Gas, and Geothermal Resources
WMRWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. Wells shown are listed as "Active" and include injection (INJ), Cyclic Steam (SC), Steam Flood (SF), and Multi (injection and production).

Sources
1. Base map is ESRI’s ArcGIS Online world topographic map, obtained 18 July 2019.
2. DOGGR well data obtained 4 June 2019.

Legend
WWMRWSD Management Area
WWMRWSD Service Area Outside of Management Area
Groundwater Subbasin
Kern County (DWR 5-022.14)
White Wolf (DWR 5-022.18)
DOGGR Oil & Gas Fields
Produced Water Ponds
Active
Inactive
Injection Well Type (see Note 2)
INJ
Multi
SC
SF
Historical (1949-2005) and Recent (2015-2016) Land Subsidence and Hydrocompaction

(a) Subsidence and Hydrocompaction

(b) Historical (1949-2005) Land Subsidence

(c) Recent (May 2015 - September 2016) Land Subsidence

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)

Subsidence Type

- Subsidence Monitoring Station
- Area of subsidence due to hydrocompaction
- Area with subsidence due to water level decline of >1 foot
- Outline of valley

Subsidence (1949 - 2005)

- -30 to -25 feet
- -25 to -20 feet
- -20 to -15 feet
- -15 to -10 feet
- -10 to -5 feet
- -5 to 0 feet

Subsidence (May 2015 - Sept. 2016)

- -8 to -4 inches
- -4 to 1 inches
- 1 to 1 inches
- California Aqueduct
- Highway

Abbreviations

- DWR = California Department of Water Resources
- USGS = United States Geological Survey
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

3. California Aqueduct location is from the National Hydrography Dataset.
4. Subsidence monitoring locations are from UNAVCO's Plate Boundary Observatory database.
5. Subsidence data is from DWR's Estimated Subsidence in the San Joaquin Valley between 1949-2005.

Figure GWC-16
Recent (April 2014 - June 2016) Land Subsidence Along the California Aqueduct within the District

Notes
1. All locations are approximate.
2. Inset map shows the area of highest widespread subsidence observed along the southern portion of the California Aqueduct from April 2014 to June 2016. See Source 4.

Sources
1. Basemap is ESRI’s ArcGIS Online world topographic map, obtained 18 July 2019.

Abbreviations
CASGEM = California Statewide Groundwater Elevation Monitoring Program
DWR = California Department of Water Resources
WMWSD = Wheeler Ridge-Maricopa Water Storage District

Legends
- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- California Aqueduct
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- State Well 11N21W08A001S

Groundwater Subbasin

Recent Land Subsidence
Along the California Aqueduct
With Groundwater Elevation Hydrograph
Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
July 2019
B70103.D1
Figure GWC-17
Natural Communities Commonly Associated with Groundwater (DWR)

Kern County, CA
July 2019

B70103.01
Figure GWC-18

Legend

- WRMWSD Management Area
- WRMWSD Service Area Outside of Management Area
- Groundwater Subbasin
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)
- NCCAG Wetland
- NCCAG Vegetation
- Removed NCCAG Vegetation or Wetland
- Stream into WRMWSD

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 7 August 2019.
2. DWR NCCAG dataset was obtained from NC Dataset Viewer (https://gis.water.ca.gov/app/NCDatasetViewer/

Abbreviations
DTW = Depth to Water
DWR = California Department of Water Resources
ft bgs = feet below ground surface
NCCAG = Natural Communities Commonly Associated with Groundwater
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Spring 2015 Depth to Groundwater (ft bgs)

- 0 - 50
- 50 - 100
- 100 - 200
- 200 - 350
- > 350

NCCAG features line artificial channels and open surface water bodies. DTW encountered at 140 - 300 ft bgs.

NCCAG features are in perched groundwater area, where DTW < 20 ft bgs. DTW of principal aquifer is 120 - 200 ft bgs.
9. WATER BUDGET INFORMATION

As described in the KGA Umbrella GSP, member agencies of the KGA as well as other Kern GSAs have participated in multiple coordinated, Basin-scale water budgeting efforts, including:

1. Development of a **numerical groundwater flow model** for the Kern County Subbasin based on DWR’s California Central Valley Groundwater-Surface Water Simulation beta fine-grid model (C2VSim-FG); and

2. Creation of a “**checkbook**” accounting approach that attempts to quantify a Basin-wide “natural safe yield” and document GSA-specific contributions to groundwater recharge within the Basin (see Appendix E-7 for WRMWSD-specific water budget values derived for the KGA “checkbook”).

These basin-level water budgeting efforts are complimented by the water budget information presented in this section for the Wheeler Ridge-Maricopa Management Area. Consistent with DWR’s GSP Regulations (23-CCR Division 2 Chapter 1.5 Subchapter 2) and DWR’s Water Budget BMP (DWR, 2016b), this water budget provides an accounting of the total annual volume of water entering and leaving the Management Area, for historical, current, and projected future conditions.
9.1. Water Budget Methods and Data Sources

§ 354.18. Water Budget

(d) The Agency shall utilize the following information provided, as available, by the Department pursuant to Section 353.2, or other data of comparable quality, to develop the water budget:

1. Historical water budget information for mean annual temperature, mean annual precipitation, water year type, and land use.
2. Current water budget information for temperature, water year type, evapotranspiration, and land use.
3. Projected water budget information for population, population growth, climate change, and sea level rise.

(e) Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, climate change, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow. If a numerical groundwater and surface water model is not used to quantify and evaluate the projected water budget conditions and the potential impacts to beneficial uses and users of groundwater, the Plan shall identify and describe an equally effective method, tool, or analytical model to evaluate projected water budget conditions.

(f) The Department shall provide the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) and the Integrated Water Flow Model (IWFM) for use by Agencies in developing the water budget. Each Agency may choose to use a different groundwater and surface water model, pursuant to Section 352.4.

This District-level water budget uses a spreadsheet model approach that quantifies each flow component and enforces mass balance principles for each “subdomain” that collectively comprise the water budget domain (i.e., the Wheeler Ridge-Maricopa Management Area). Details of this approach and the corresponding data sources employed within the water budget model are described further below.

9.1.1. Spreadsheet Model Approach

The spreadsheet model approach was developed for WRMWSD to serve as an independent estimate of the local historical, current, and projected water budget conditions within the Wheeler Ridge-Maricopa Management Area. The spreadsheet model approach uses a variety of data and analytical methods to quantify each water budget flow component. Processes and groups of processes are grouped into “subdomains” and “flow components”. These water budget flow components are quantified on a monthly timestep for the period from January 1994 through December 2015.
Water Budget Subdomains

The water budget is divided into five internal subdomains, each influenced by a number of flow components and within which mass-balance is enforced (i.e., the sum of inflow components is balanced by the sum of outflow components and/or a change in storage component). Figure WB-1 shows the water budget domain, and the following internal subdomains:

1. Artificial Channels and Pipelines
2. Agricultural Lands
3. Urban Lands
4. Natural Channels, and
5. Groundwater System

In addition to the five internal subdomains, several external subdomains are incorporated into the spreadsheet model. These include the watersheds that contribute streamflow to streams entering the Wheeler Ridge-Maricopa Management Area, the atmosphere which is a source of precipitation and sink for evapotranspiration, the adjacent and connected portions of the groundwater basin, and the external surface water sources including out-of-basin and in-basin (but outside of the District) storage “accounts”. The spreadsheet model does not explicitly account for the vadose (unsaturated) zone between the land surface and the (saturated) groundwater system, but instead incorporates temporal lag factors to account for the movement of water through this zone. An implicit assumption in this approach, therefore, is that the vadose zone does not experience any change in storage over time.

Water Budget Flow Components

Within and between each subdomain are 31 water budget flow components that route water through the Wheeler Ridge-Maricopa Management Area. Figure WB-2 shows a conceptual diagram of the individual water budget flow components between subdomains as well as flow components that are external to the overall water budget domain (i.e., serve only as an inflow or outflow to the entire system, rather than a flow between subdomains).

Certain components are based on “raw” data which are directly measured and based on historical records. These “raw” components are considered to have a relatively high degree of certainty. Other components are estimated using a variety of analytical methods (e.g., Darcy’s Law to calculated subsurface flows across the domain’s external boundaries) and are thus subject to uncertainty based on the parameters used in their estimation. Some components (i.e., groundwater pumping for agricultural use) constitute major proportions of the overall water budget and have thus been given significant attention. Others are relatively minor in magnitude (e.g., seepage from artificial channels) and are, to some degree, less significant to the overall water budget and less well defined. Details of the methods and data used in the spreadsheet model approach are provided in Appendix E.
Wheeler Ridge-Maricopa / Arvin-Edison Overlap Lands

The District also supplies surface water to certain lands within the portion of its service area that overlaps with the AEWSD service area. The total acreage of overlap lands within the Kern Subbasin is approximately 5,318 acres, and WRMWSD serves surface water to approximately 3,186 acres in this area. Although the overlap lands are being covered by AEWSD for SGMA monitoring and management purposes, WRMWSD will continue in the future to serve surface water to those lands within the overlap area that have historically received District supplies in accordance with the District’s water delivery contracts with landowners. The water budget presented herein is quantified for the entire Wheeler Ridge-Maricopa Management Area, but also specifically identifies inflow and outflow quantities associated with these overlap lands. For the projected water budget “checkbook” accounting exercise conducted by all entities within the Kern Subbasin, the demands for the overlap lands are only included in the Arvin-Edison Management Area “checkbook” and the supplies for those lands include WRMWSD-provided surface water (included as an import to the Arvin-Edison “checkbook”) and groundwater.

9.1.2. Data Sources

Per 23-CCR § 354.18(e), the best-available data were used to evaluate the water budget for the Wheeler Ridge-Maricopa Management Area and include the following:

- **Precipitation Records** from the various local climate stations including:
  - Two additional climate stations (Lebec and Tejon Rancho) maintained by the National Oceanic and Atmospheric Administration (NOAA)\(^{44}\); *Monthly resolution, January 1971 – December 2015 (data availability varies by station)*

- **Satellite Evapotranspiration (ET) Data** from the California Polytechnic Institute’s Irrigation Training and Research Center’s “Mapping Evapotranspiration at High Resolution with Internalized Calibration” (ITRC-METRIC) Study, funded by the KGA\(^{45}\); *Monthly, January 1993 -December 2015*\(^{46}\)

\(^{44}\) See Appendix E for a detailed description of how climate stations are used to estimate precipitation on District lands and surrounding watersheds.


\(^{46}\) There is no ITRC satellite ET data for calendar year 2012, as the LANDSAT satellite system employed in the ITRC-METRIC analysis was non-operational during this period. See Appendix E for further details.
Basin Setting
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

- **WRMWSD Land Use Surveys** from the District’s internal land use records; *Seasonal, Spring 2001 – Spring 2017* (data availability varies by season)
- **WRMWSD Surface Water Delivery Records** from the District’s internal operations records; *Monthly resolution, January 1999 – December 2016*
- **Historical Groundwater Level Records** from selected wells within the District; *Seasonal resolution, Spring 1936 – Fall 2017* (data availability varies by well)
- **Streamflow Records** for San Emigdio Creek (USGS stream gauge 11195500), *Monthly, April 1959 – September 1981*

9.2. Water Budget Results

§ 354.18. Water Budget

(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.

(b) The water budget shall quantify the following, either through direct measurements or estimates based on data:

1. Total surface water entering and leaving a basin by water source type.
2. Inflow to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.
3. Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow.
4. The change in the annual volume of groundwater in storage between seasonal high conditions.
5. If overdraft conditions occur, as defined in Bulletin 118, the water budget shall include a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.
6. The water year type associated with the annual supply, demand, and change in groundwater stored.
7. An estimate of sustainable yield for the basin.
Results are presented below in terms of both annual values during the historical water budget period (DWR Water Years [WY] 1995 – 2014)\textsuperscript{47}, as well as long-term averages over that period. As such, some information presented here aligns with the requirements of the historical water budget described under Section 9.3 \textit{Current and Historical Water Budget} below, and is not repeated there.

\textbf{9.2.1. Surface Water Inflows and Outflows}

Per 23-CCR § 354.18(b)(1), Table WB-1 presents an annual summary of the total surface water inflows to and outflows from the Wheeler Ridge-Maricopa Management Area between WY 1995 – 2014. These inflows include imported surface water, natural streamflow into the area, and precipitation. Figure WB-3 shows the total surface water inflows by type. Total surface water inflows to the Management Area average approximately 166,000 AFY over WY 1995 – 2014 but have varied widely from year to year. On average, 68\% of surface water inflows are from imported water supplies, and 30\% are from direct precipitation, and 2\% are from intermittent streamflow from surrounding watersheds.

\textit{Imported Water Supplies}

WRMWSD has been importing surface water into its service area since 1971. Annual surface water imports (District-wide) from 1971 through WY 2015 have ranged from approximately 41,000 AFY to over 250,000 AFY, and cumulatively a total of 7.49 million AF have been imported through September 2015 (see Figure WB-4)\textsuperscript{48}. WRMWSD’s primary source of imported water is the State Water Project (SWP), delivered via the California Aqueduct which runs through the District. WRMWSD has a contract with the Kern County Water Agency for 197,088 AFY of Table A water from the SWP. In addition to its Table A water allocation, in the District has access to Article 21 water when it is available (primarily during wet years). When surplus supplies are available, the District banks water in several out-of-District water banks\textsuperscript{49}. Recovery of banked water during dry years is used to supplement SWP allocations. The District also actively and regularly pursues additional water supplies through banking programs, water transfers, and purchases. Imported surface water supplies have averaged approximately 113,000 AFY over WY 1995 – 2014 but vary substantially from year to year.

\textit{Natural Streamflow}

As discussed in Section 7.3.5 \textit{Surface Water Bodies}, several creeks drain into the Wheeler Ridge-Maricopa Management Area from watersheds to the south and west (see Figure HCM-20). There are no stream gauges on these creeks that have data during the historical water budget period (WY 1995 – 2014). However, in 2018 the District installed gauges on five streams and will be establishing rating curves for

\textsuperscript{47} DWR Water Years run from October of the previous year to September of the current year (e.g. DWR Water Year 2015 is October 2014 – September 2015.

\textsuperscript{48} Through 11 July 2019, WRMWSD has imported and delivered a total of 7,974,462 AF.

\textsuperscript{49} WRMWSD has participated in the following groundwater banking and recovery projects: Kern Water Bank, 2800 Acres, Pioneer Project, and Berrenda Mesa Project (WRMWSD, 2015).
these gauges over the next few years. Between April 1959 and September 1981, the USGS operated a stream gauge on San Emigdio Creek (USGS stream gauge 11195500)\(^{50}\), located approximately four miles south of the District boundary. Data from this gauge were used as a proxy for all contributing watersheds (i.e., runoff as a function of precipitation was upscaled for the remaining watersheds by proportional area). During this gauge’s period of record, average monthly discharge at this location ranged from 2.2 cubic feet per second (cfs) in October to 3.5 cfs in May. Annual average discharge ranged from 0.71 cfs in 1966 to 9.87 cfs in 1978. Annual peak flows ranged from a minimum of 16.0 cfs in 1968 to a maximum of 6,690 cfs in 1961. These data indicate a mildly seasonal pattern in streamflow at this location with substantial variability from year to year.

**Precipitation**

Precipitation on lands within the Wheeler Ridge-Maricopa Management Area contributes some water to the overall water budget and is grouped herein with “surface water inflows”. WRMWSD operates six rainfall measurement stations, four of them are within the Management Area. Data from the District’s rain gauges are similar in magnitude and temporal pattern. Annual rainfall over the period of WY 1995 – 2014 ranged from approximately 1.5 inches in WY 2014 to over 16 inches in WY 1998, with an average of 6.5 inches per year. Overall, an average of approximately 49,700 AFY of precipitation fell on lands within the Management Area during this period. This water serves to wet the near surface soil and then either evaporates, contributes to crop water demand, or (when a rainfall event is intense enough or long enough) percolates through the root zone to eventually recharge groundwater. “Effective precipitation”, i.e. the volume of precipitation that ultimately contributes to meeting evapotranspiration demands within the root zone, is estimated to be approximately 24,100 AFY (or 49% of total precipitation) within the Management Area.\(^{51}\)

**Surface Water Outflows**

As shown in Table WB-1, natural surface water outflows from the Wheeler Ridge-Maricopa Management Area are essentially zero. This is because there are no natural stream channels that flow through the District to the north; any natural stream inflows percolate into the ground before reaching the northern District boundary.

The District uses its network of canals and pipelines to convey and deliver not only imported surface water, but also groundwater pumped by the District, and by District customers participating in its “User Input” groundwater pump-in program. These deliveries are made to customers throughout the WRMWSD service area, including some customers in the White Wolf Subbasin. At times, the District also uses the California Aqueduct for intra-District conveyance. Some of these conveyance facilities, including the

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\(^{50}\) https://waterdata.usgs.gov/ca/nwis/inventory/?site_no=11195500; upstream catchment area = 48.8 square miles.

\(^{51}\) Based on application of the U.S. Department of Agriculture-Soil Conservation Service method (USDA-SCS, 1970); see Appendix E.
California Aqueduct, cross the basin boundary between the Kern Subbasin and the White Wolf Subbasin. Therefore, outflows leaving the Wheeler Ridge-Maricopa Management Area through these conveyance facilities have been blended upstream and may include a variable percentage of groundwater depending on the given season and Water Year type.

**Out-of-District Groundwater Storage**

As described in Section 5.2.3 Conjoint Use in the Wheeler Ridge-Maricopa Management Area, AEWSD also participates in several out-of-District groundwater storage and recovery programs both within and outside the Kern Subbasin. As of December 2018, the District has a combined 200,774 acre-feet (AF) stored and available to withdraw in its various banking projects outside the Management Area, including:

- 160,564 AF in the Kern Water Bank;
- 29,288 AF in the Pioneer Project; and
- 10,922 AF in the Berrenda Mesa water bank.

These banked imported water supplies are **not included** in the quantification of total surface water inflows into the Wheeler Ridge-Maricopa Management Area or in the subsequent determination of change in groundwater storage, as they are currently being physically stored outside the Management Area boundaries. However, WRMWSD maintains rights to recover these banked supplies in the future per the contract terms specified in the individual agreements with the entities mentioned above.

**9.2.2. Groundwater Inflows and Outflows**

Per 23-CCR § 354.18(b)(2) and (b)(3), Table WB-2 and Figure WB-5 provide an annual summary of inflows to and outflows from the groundwater system by water source type for WY 1995 – 2014. As evident from these two exhibits (as well as the groundwater hydrographs shown in Figure GWC-5 and Figure GWC-6), the groundwater system is highly sensitive to climatic conditions and WRMWSD operations. As such, annual inflows and outflows vary widely depending on availability of surface water supplies to meet irrigation demands. Sources of inflow to the groundwater system include:

- Subsurface inflows across the District’s northern boundary (from north to south), across its southern boundary (from southern foothills to north), and across the White Wolf Fault (from southeast to northwest);
- Infiltration of a portion of applied irrigation water;
- Infiltration of precipitation; and
- Infiltration from surface water systems (e.g., seepage from streams and channels).

Figure WB-6 provides a summary of long-term (WY 1995 – 2014) annual average inflows to and outflows from the groundwater system. Total inflows to the groundwater system averaged approximately 60,300 AFY. Approximately 20% of total inflows to the groundwater system came from subsurface
groundwater inflows, 66% from infiltration of applied water, 6% from infiltration from surface water systems, and 9% from infiltration of precipitation.

Due to the District’s position at the southern edge of the Kern Subbasin (near pre-development discharge areas) and the resulting low hydraulic heads which are further drawn down by pumping, there are virtually no subsurface outflows, losses to surface water systems, or evapotranspiration losses occurring from the groundwater system (see Figure GWC-1). As shown on Figure WB-6, total outflows from the groundwater system averaged approximately 57,000 AFY over WY 1995 – 2014 and were entirely related to groundwater extraction. Of this value, approximately 94% of groundwater extraction can be attributed to private agricultural pumpage, 5% to pumpage from private wells related to its “User Input” pump-in program, and the remaining 1% to pumpage from District wells.

9.2.3. Change in Groundwater Storage

Per 23-CCR § 354.18(b)(4), Figure WB-7, Figure WB-8, and Table WB-3 present the annual and cumulative change in groundwater storage between seasonal high conditions, which are defined in this chapter to be March through February of the following year. Note that this time window is distinct from DWR’s definition of the Water Year, which runs from October of the previous year to September of the current year (e.g. DWR WY 2014 is October 2013 – September 2014); thus the values presented in Table WB-3 are slightly different than the annual and cumulative change in storage estimates provided for DWR WY 1995 – 2014 in Table WB-2, Table WB-4, and Table WB-5.

Annual change in groundwater storage under the Wheeler Ridge-Maricopa Management Area averaged approximately +2,300 AFY between seasonal high conditions for the period of March 1994 – February 2015, with a cumulative change in storage of +47,700 AF over the same period. However, as seen in Figure WB-7 and Figure WB-8, change in storage varied widely between years, from a -29,400 AF decrease in storage to a +51,000 AF increase in storage.

Figure WB-9, Figure WB-10, and Table WB-4 compare the annual and cumulative change in storage in the Wheeler Ridge-Maricopa Management Area associated with each DWR Water Year from WY 1995 – 2014 to the water year type based on DWR’s San Joaquin Valley Water Year Index. Annual change in groundwater storage under the Management Area averaged approximately +3,300 AFY from DWR WY 1995 – 2014, with a cumulative change in storage amounting to +65,700 AF over this period. These exhibits depict a clear relationship between change in groundwater storage to WY type, whereby change in storage becomes more positive with an increasing “wet” condition and more negative with an increasing “dry” condition. The net benefit of a “wet” period on groundwater conditions is especially evident in WYs 1995 – 2000, whereas the impact of a severe multi-year drought becomes increasingly evident in WYs 2012 – 2015.

Section 8.2 Change in Groundwater Storage, of the Groundwater Conditions section of this MA Plan, reported values for change in storage based on interpolated groundwater levels and specific yield values (see Table GWC-2). Some of those water level-based change in storage values were used in the calibration
of the water budget spreadsheet model\textsuperscript{52}. Figure WB-11 shows a comparison of the spreadsheet model-based transient change in storage against the water level-based change in storage values for the entire District service area as well as for the Wheeler Ridge-Maricopa Management Area. As shown on Figure WB-11, the spreadsheet model matches the water level-based estimates well; the root-mean squared error (RMSE) for the annual rate of change for the three long-term periods (Fall 1994 – Fall 2015, Spring 2003 – Spring 2012, and Spring 2003 – Spring 2015) over the Management Area is approximately 4,300 AFY, which is a relatively small fraction (<4\%) of the overall groundwater subdomain water budget magnitude (e.g., average annual groundwater inflows and outflows of approximately 60,300 AFY and 57,000 AFY, respectively).

### 9.2.4. Overdraft Conditions

The Kern Subbasin is designated by DWR in its latest version of \textit{Bulletin 118 – California’s Groundwater} as being in a condition of critical overdraft (DWR, 2016c). With respect to overdraft conditions and basins subject to those conditions, DWR has made the following statements:

- “A basin 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, 1980)

- Groundwater overdraft is “… the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions. Overdraft can be characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years. If overdraft continues for a number of years, significant adverse impacts may occur, including increased extraction costs, costs of well deepening or replacement, land subsidence, water quality degradation, and environmental impacts.” (DWR, 2003)

- “Overdraft occurs where the average annual amount of groundwater extraction exceeds the long-term average annual supply of water to the basin. Effects of overdraft result can include seawater intrusion, land subsidence, groundwater depletion, and/or chronic lowering of groundwater levels”.\textsuperscript{53}

In evaluating basins for critical overdraft conditions in its most recent Bulletin 118 update, DWR considered the time period from WY 1989 – 2009. This period excludes the recent drought which began

\textsuperscript{52} The water budget spreadsheet model calibration was completed for the entire WRMWSD service area, inclusive of the area within the White Wolf Subbasin.

in 2012, includes both wet and dry periods, is at least 10 years in length, and includes precipitation close to the long-term average; these were all criteria used in selecting the time period.

The historical water budget information discussed herein covers the period from WY 1995 through 2014\textsuperscript{54} (i.e., it does not cover the entire period used in DWR’s evaluation). However, within the period covered by this water budget, the timeframe between WYs 1997 and 2009 (October 1996 through September 2009) meets all of the same criteria. During this 13-year period, the cumulative departure in statewide average precipitation increased by approximately 9\% (DWR, 2016c Figure 1), indicating that, on average, each year was less than 1\% wetter than the long-term average. Over this time period, the cumulative change in storage within the Wheeler Ridge-Maricopa Management Area increased by approximately 48,100 AF, averaging 3,700 AFY. Therefore, by this metric, and DWR’s description of overdraft on their website (see footnote 53), the Management Area as a whole is not in a condition of critical overdraft\textsuperscript{55}.

9.2.5. Sustainable Yield

SGMA defines sustainable yield as “the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result” (CWC § 10721(w)). DWR’s Water Budget BMP (DWR, 2016b), further states that “Water budget accounting information should directly support the estimate of sustainable yield for the basin and include an explanation of how the estimate of sustainable yield will allow the basin to be operated to avoid locally defined undesirable results. The explanation should include a discussion of the relationship or linkage between the estimated sustainable yield for the basin and local determination of the sustainable management criteria (sustainability goal, undesirable results, minimum thresholds, and measurable objectives).”

A key part of the codified definition and the BMP statement is the avoidance of Undesirable Results, defined as “significant and unreasonable” effects for any of the six SGMA sustainability indicators. For example, in regard to groundwater levels, declining levels during a drought do not constitute and Undesirable Result for Chronic Lowering of Groundwater Levels if extractions and groundwater recharge are managed as necessary to ensure that reduction in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods (CWC § 10721(x)(1)). Therefore, while the water budget should provide support for sustainable yield, determination of the

\textsuperscript{54} This timeframe is consistent with the water budgeting timeframes incorporated into basin-level modeling efforts for the Kern Subbasin.

\textsuperscript{55} It should be noted that groundwater conditions vary spatially through the Kern Subbasin and even within the WRMWSD Management Area, and broad generalizations over large areas can lead to mischaracterization of conditions on a local scale. For this reason, its imperative (and SGMA requires) that conditions be evaluated locally on a management area or representative monitoring location basis. Results from the basin-wide numerical modeling indicated a negative average annual storage change of approximately 7,900 AFY between Fall 1994 and Fall 2014. However, that estimate is considered less accurate than the locally-derived storage change estimates presented here because the basin-wide model has not undergone calibration of subsurface parameters on a local scale against actual local water level data.
sustainable yield for the Wheeler Ridge-Maricopa Management Area ultimately depends upon whether Undesirable Results are avoided within the time-frames required by SGMA.

A conservative estimate of the sustainable yield of the groundwater system underlying the Wheeler Ridge-Maricopa Management Area can be made by adding the average annual change in storage to the average annual groundwater extraction. This simplified approach provides a sustainable yield number corresponding to the volume of groundwater that, if pumped over the water budget period of interest, would have resulted in zero change in storage – a reasonable metric for sustainability. Based on the average annual change in groundwater storage over the water budget period from WY 1995 – 2014 (i.e., +3,300 AFY) and the average annual groundwater extraction (i.e., 57,000 AFY), using this simple method the sustainable yield is conservatively estimated to be at a minimum approximately 60,300 AFY under current supply and demand conditions. This equates to an acreage-normalized sustainable yield of approximately 0.65 AFY/acre over the (92,343 acre) Wheeler Ridge-Maricopa Management Area.56

This number is conservative because SGMA itself does not require that the basin or any particular management area to be balanced at any particular point in time, as discussed above. As mentioned above, the sustainable yield estimate does not factor in the additional ~200,700 AF of imported District supplies currently stored within other groundwater banking facilities outside the District but within the Kern Basin (see Section 9.2.1).

Moreover, as described earlier in this section, WRMWSD has also participated in a Basin-wide numerical modeling effort in addition to developing a more refined local water budget for their Management Area. Results from the C2VSim-FG historical water budget model, extracted for model elements corresponding approximately to the Management Area, indicate an average annual groundwater extraction rate of approximately 107,200 AFY for the historical period of WY 1995 – 2014, and an average annual change in storage of -7,900 AFY during that same period. Under the same approach as described above, the C2VSim-FG historical water budget results indicate a sustainable yield estimate of 99,300 AFY within the Management Area, or 1.08 AFY/acre. It is important to note that this model is intended to be a Basin-wide assessment of groundwater conditions and, unlike the local water budget described above, is not specifically calibrated to the WRMWSD service area. Additional reconciliation of basin water budgeting efforts is a high priority for basin GSAs as part of GSP implementation.

56 The acreage-normalized sustainable yield values presented herein should not be viewed as an “allocation” but rather is presented herein to facilitate comparisons to commonly-used agronomic quantities (e.g., crop water demands in AFY/ac).
9.3. Current and Historical Water Budget

§ 354.18. Water Budget

(d) Each Plan shall quantify the current, historical, and projected water budget for the basin as follows:

(1) Current water budget information shall quantify current inflows and outflows for the basin using the most recent hydrology, water supply, water demand, and land use information.

(2) Historical water budget information shall be used to evaluate availability or reliability of past surface water supply deliveries and aquifer response to water supply and demand trends relative to water year type. The historical water budget shall include the following:

(A) A quantitative evaluation of the availability or reliability of historical surface water supply deliveries as a function of the historical planned versus actual annual surface water deliveries, by surface water source and water year type, and based on the most recent ten years of surface water supply information.

(B) A quantitative assessment of the historical water budget, starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the tools and methods used to estimate and project future water budget information and future aquifer response to proposed sustainable groundwater management practices over the planning and implementation horizon.

(C) A description of how historical conditions concerning hydrology, water demand, and surface water supply availability or reliability have impacted the ability of the Agency to operate the basin within sustainable yield. Basin hydrology may be characterized and evaluated using water year type.

9.3.1. Current Water Budget

This section presents results for the “current” water budget, based on values extracted from the spreadsheet model for WY 2015. This is consistent with how “current” is being defined by the KGA in the KGA Umbrella GSP.

WY 2015 was classified as the third consecutive “Critical” (dry) Water Year and fourth consecutive “Dry” or “Critical” Water Year within the San Joaquin Valley and is thus representative of perhaps the worst drought condition in recent history within the region.

Per 23-CCR § 354.18(d)(1), Table WB-5 and Figure WB-12 provide a summary of total inflows and outflows to the Wheeler Ridge-Maricopa Management Area for WY 2015, while Table WB-2 and Figure WB-13 provide a summary of groundwater inflows and outflows.
Total inflows to the Wheeler Ridge-Maricopa Management Area amounted to approximately 150,000 AF in WY 2015, comprised of 36% precipitation, 56% surface water imports, 6% subsurface inflows, and 2% natural surface water inflows. This resulted in a total inflow to the groundwater system of approximately 57,600 AF, comprised of 15% subsurface inflow, 70% infiltration of applied water, 6% infiltration from surface water systems, and 9% infiltration of precipitation.

Total outflows from the Wheeler Ridge-Maricopa Management Area amounted to approximately 187,000 AF in WY 2015, comprised entirely (100%) of evapotranspiration (consumptive use by vegetation). This resulted in a total outflow from the groundwater system of approximately 103,000 AF, 100% of which is due to groundwater extraction.

As evident from these water budget values, the Wheeler Ridge-Maricopa Management Area (like nearly all areas in the Kern Subbasin and San Joaquin Valley as a whole) was impacted significantly by the extreme drought condition of WY 2015, resulting in a net loss of approximately -42,900 AF of groundwater storage during this timeframe. However, as evidenced by the recovery of water levels and storage following previous dry periods, the groundwater system is resilient, and the “current” (WY 2015) conditions are not indicative of a normal condition but rather represent the late stages of a major drought period from which the groundwater system has already started to recover (see Figure GWC-6).

9.3.2. Historical Water Budget

Water budget results are presented for the historical water budget period in Section 9.2 Water Budget Results, including associated figures and tables, and are not repeated here. Rather, this section focuses on providing: (a) a quantitative evaluation of historical surface water availability and reliability (23-CCR § 354.18(d)(2)(A)), (b) a quantitative assessment of the historical water budget (23-CCR § 354.18(d)(2)(B)), and (c) a description of how historical conditions have impacted the ability of the Wheeler Ridge-Maricopa Management Area to be operated within its sustainable yield (23-CCR § 354.18(d)(2)(C)).

**Historical Surface Water Availability and Reliability**

As described above, WRMWSD’s only contracted source of surface water supply is its SWP supply contract with KCWA for 197,088 AFY of Table 1 water. Between WY 1995 – 2014, WRMWSD received an average allocation (entitlement) of approximately 73% of this contractual amount. Figure WB-14 presents an annual breakdown of total imported SWP supplies relative to the District’s existing SWP contract volumes.

This large inter-annual variability in supply indicates that, while SWP water remains the primary and most important source to the District, its reliability is not iron-clad, and has been impacted significantly in recent years due to natural drought, and by federal court rulings and other regulatory measures which have served to limit pumping of northern California supplies through the Delta to the southern part of the state. For this reason, the District actively and regularly pursues additional water supplies through transfers, purchases, exchanges, and banking programs.
Quantitative Assessment of Historical Water Budget

Based on the DWR San Joaquin Valley Water Year Index for the 20-year period from WY 1995 through 2014, this period included four "critical" (dry) years, four dry years, two below normal years, three above normal year, and seven wet years. The first third of this period was relatively wet, the middle third was a mix of wet and dry years, and the last third of the period was extremely dry. This climatic factor is clearly reflected in the water budget for the Wheeler Ridge-Maricopa Management Area, whereby the groundwater system shows consistent increases in storage with wetter conditions and decreases in storage under “drier” conditions (see Figure WB-9, Figure WB-10, and Table WB-4).

Table WB-5 and Figure WB-15 provide a tabular and graphical breakdown of total inflows and outflows to the Wheeler Ridge-Maricopa Management Area for WY 1995 – 2014, with a summary of average annual total inflows and outflows provided in Figure WB-16. Table WB-2 and Figure WB-5 provide a tabular breakdown of inflows and outflows to the groundwater system underlying the Management Area for WY 1995–2014, with a summary of average annual groundwater inflows and outflows provided in Figure WB-6.

Total inflows to the Wheeler Ridge-Maricopa Management Area amounted to an average of 178,000 AFY for WY 1995 – 2014, including 64% from surface water imports, 28% from precipitation, 7% from subsurface inflows, and 2% from natural surface water inflows. This resulted in an average net inflow to the groundwater system of approximately 60,300 AFY, comprised of 66% of infiltration of applied water, 20% of subsurface inflow, 6% of infiltration from surface water systems, and 9% of infiltration of precipitation.

Total annual outflows from the Wheeler Ridge-Maricopa Management Area amounted to 175,000 AFY for WY 1995 – 2014, comprised nearly entirely (99.99%) of evapotranspiration (consumptive use by vegetation). This resulted in a net outflow from the groundwater system of approximately 57,000 AF, 100% of which comes from groundwater extraction.

Operation within Sustainable Yield

Average annual change in groundwater storage under the Wheeler Ridge-Maricopa Management Area amounted to approximately +3,300 AFY between WY 1995 – 2014, resulting in a cumulative change in groundwater storage of 65,700 AF during this period. This cumulative storage change over a 20-year historical record, that includes the recent severe drought, indicates that the groundwater system is in a state of relative balance, and NOT a state of significant overdraft. Although some years in this period showed negative changes in storage as much as -34,000 AF, the calculated transient change in storage and water levels measured in wells within the Management Area (see Figure WB-18, Figure GWC-5, and Figure GWC-6) demonstrate that the groundwater system is sensitive to climatic variability and WRMWSD operations, with decreases in storage during drought followed by increases in storage during wet periods.

As discussed previously, through September 2015 WRMWSD has imported nearly 7.5 million AF of water into its service area since it began imports in 1971. Since that time, the groundwater system has
experienced a long-term increase in storage of approximately 77,100 AF (see Table GWC-2) and groundwater elevations have increased in areas where imported surface water is delivered (see Figure GWC-5). Clearly District operations have resulted in a net benefit to the groundwater supply beneath the Wheeler Ridge-Maricopa Management Area, demonstrating successful groundwater management.

9.4. Projected Water Budget

§ 354.18. Water Budget

(e) Each Plan shall quantify the current, historical, and projected water budget for the basin as follows:

(2) Projected water budgets shall be used to estimate future baseline conditions of supply, demand, and aquifer response to Plan implementation, and to identify the uncertainties of these projected water budget components. The projected water budget shall utilize the following methodologies and assumptions to estimate future baseline conditions concerning hydrology, water demand and surface water supply availability or reliability over the planning and implementation horizon:

(A) Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology. The projected hydrology information shall also be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.

(B) Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand. The projected water demand information shall also be applied as the baseline condition used to evaluate future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate.

(C) Projected surface water supply shall utilize the most recent water supply information as the baseline condition for estimating future surface water supply. The projected surface water supply shall also be applied as the baseline condition used to evaluate future scenarios of surface water supply availability and reliability as a function of the historical surface water supply identified in Section 354.18(c)(2)(A), and the projected changes in local land use planning, population growth, and climate.

Per 23-CCR § 354.18(e)(2), projected water budgets are required as a way to estimate future conditions of water supply and demand within a basin, as well as the aquifer response to implementation of the Plan over the planning and implementation horizon. To develop the projected water budget, the same tools and methodologies that were used for the historical and current water budget were used, with updated inputs for climate variables (i.e., precipitation and ET) and water supply assumptions (i.e., imported water supplies). The chief purpose of this projected water budget analysis is to assess the magnitude of the net
water supply deficit that would need to be addressed through Projects and Management Actions to prevent Undesirable Results (discussed further in Section 13 Undesirable Results and Section 17 Projects and Management Actions) and achieve the Sustainability Goal. This section describes the development and results of the projected water budget for the Wheeler Ridge-Maricopa Management Area.

9.4.1. Development of 50-Year Analog Period

Per 23-CRR § 354.18(e)(2)(A), the projected water budgets must use 50 years of historical precipitation, evapotranspiration, and streamflow information as the basis for evaluating future conditions under baseline and climate-modified scenarios. The process by which a 50-year period of precipitation, evapotranspiration and streamflow information was developed is based on the process adopted by all GSAs within the Basin, as described in the KGA Umbrella GSP and the Coordination Agreement. That process is briefly summarized here.

To develop the required 50 years-worth of hydrologic input information, first an “analog period” was created from the 20 years-worth of historical information (WY 1995-2014) by combining the years in a specific way that, on average, maintained the long-term average hydrologic conditions. This approach, which was used for both the spreadsheet water budget model approach and the basin-wide C2VSim-FG modeling approach, allowed for the creation of a complete 50-year period to inform the projected water budget analysis, even when certain component datasets were not available for that length of time. The sequence of actual years that were combined to create the 50-year analog period is as follows:

- Analog Years 1-12: Based on actual years 2003-2014
- Analog Years 13-32: Based on actual years 1995-2014
- Analog Years: 33-50: Based on actual years 1995-2012

The above mapping of actual years to analog years within the required 50-year projected water budget period applies to precipitation and ET datasets. It also applies to imported surface water datasets with some additional modifications as described in the following section.

9.4.2. Development of Projected Water Budget Scenarios

Using the 50-year analog period, three projected water budget scenarios were developed for this analysis: a baseline scenario, and 2030 climate change scenario, and a 2070 climate change scenario. Development of the three scenarios was done consistent with the agreed-upon process being used basin-wide. Details of the scenario development are contained within in the KGA Umbrella GSP and the Coordination Agreement and are briefly summarized here.

Baseline Scenario

Per 23-CRR § 354.18(e)(2)(C), the projected water budgets must use “the most recent water supply information as the baseline condition for estimating future surface water supply”. Consistent with the process applied basin-wide, the information used to inform the baseline conditions for SWP supplies is
Basin Setting
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

Based on information published by and/or obtained from DWR, including data from DWR’s CalSim water resources planning model, historical SWP operations data, and impacts from new operations regulations pursuant to the 2008/2009 Long-Term Operations Criteria and Plan (OCAP) Biological Opinion (BO).57,58

As part of the basin-wide approach to Baseline Scenario development, certain substitutions and/or adjustments to years were made to the 50-year analog period for certain water supplies because the available datasets did not cover the entire historical water budget time period (WY 1995-2014). These substitutions included the following:

- Adjusting years 2004-2007 for SWP supplies to account for the recent regulatory changes to SWP operations made effective in 2008 and 2009 (i.e., the OCAP BO59); and
- Replacing years 1995-2003 for SWP supplies with values from DWR’s 2030-level CalSim study60, increased by 3.03%, again to account for the OCAP BO.

The above substitutions and adjustments were made by KGA GSA consultants based upon their analysis of the DWR studies and were provided to all Districts as a basis for development of projected water budgets. As such, the information used for this analysis is consistent with the basin-wide approach.

2030 Climate Change Scenario

In order to estimate the potential effects on the projected water budget of climate change during the GSP implementation period (i.e., between 2020 and 2040), a water budget scenario based on 2030 climate change factors published by DWR was developed. For this scenario, precipitation and ET were both adjusted based on the change factors published by DWR. SWP supply projections were taken from the DWR 2030-Level CalSim studies, except for years 2004-2007 which were taken as the actual SWP data, adjusted for the OCAP BO and reduced by 3.03%, and years 2008-2014 which were taken as the actual


58 The District has a long history of actively striving to achieve sustainable groundwater use within the District. In fact, the District was specifically formed to contract for a substantial surface water supply because of declining groundwater levels. Since that time, groundwater levels within the District have stabilized, and in many areas have risen. In the 1990s, with regulatory shifts in the State Water Project, the District invested in groundwater storage facilities in order to capture and recharge wet year supplies to augment the District’s contractual supplies. The Wenger decision in 2008, and the subsequent Biological Opinions, had a dramatic negative impact on the availability of the District’s contractual supplies. Although the District does not agree with the decision nor the subsequent Biological Opinions, it has been forced to adapt to those negative impacts.


60 Consistent set of CALSIM operations studies at current, 2030 and 2070 climate levels for Bay Delta Conservation Plan evaluation provided by DWR Bay Delta Office staff.
Basin Setting
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

SWP data, reduced by 3.03%. Again, the assumptions upon which this scenario was based are from the KGA consultant’s analysis of DWR information and are therefore consistent with the basin-wide approach.

2070 Climate Change Scenario
In order to estimate the potential effects on the projected water budget of climate change towards the end of the planning and implementation horizon (i.e., 50 years out into the future), a water budget scenario based on 2070 “central tendency” climate change factors for the published by DWR was developed. It should be noted that estimates of climate change impacts on water supplies this far into the future have significant uncertainty. For this scenario, precipitation and ET were both adjusted based on the 2070 “central tendency” change factors published by DWR. SWP supply projections were taken from the DWR 2070-Level CalSim studies, except for years 2004-2007 which were taken as the actual SWP data, adjusted for the OCAP BO and reduced by 8.09%, and years 2008-2014 which were taken as the actual SWP data, reduced by 8.09%. Again, the assumptions upon which this scenario was based are from the KGA consultant’s analysis of DWR (CalSim) information and are therefore consistent with the basin-wide approach.

9.4.3. Projected Water Budget Results
Results of the projected water budget analysis are summarized in Table WB-6 for both the entire water budget domain and for the groundwater subdomain, as well as in Figure WB-19. As shown in Table WB-6, water budget components are presented as averages over the 20-year historical period and averages over the 50-year analog period for the Baseline, 2030 Climate Change, and 2070 Climate Change scenarios. Water budget components are grouped into inflows and outflows, relative to the domain or subdomain they pertain to (also see Figure WB-2). Also shown in Table WB-6 is the average annual change in groundwater storage for the historical period and each projected scenario. Results from Table WB-6 were subsequently used to inform the development of Projects and Management Actions (P/MAs) as further described in Section 17 Projects and Management Actions. Implementation of the P/MAs described in Section 17 were then input into the 2030 and 2070 projected water budget model scenarios to assess their estimated impacts to the groundwater balance within the Wheeler Ridge-Maricopa Management Area. Results of this exercise are presented in Table WB-7 and briefly mentioned below.

Baseline Scenario
In the Baseline Scenario, the water budget components that are not dependent on surface water imports differ only slightly from the historical period. The percent difference from the historical average period to the Baseline Scenario ranges from approximately -4.0% for M&I consumptive use (including evapotranspiration from urban lands) to natural surface water inflows to -1.2% for precipitation. This demonstrates that the 50-year analog period is a good representation of the historical conditions.

The water budget components that are dependent on surface water imports differ more significantly from the historical averages, due to the different assumptions about imported surface water availability under the Baseline Scenario, as discussed above. In particular, the surface water imports component is
approximately 17.7% lower under the Baseline Scenario than it is under the historical period, due to a projected decrease in SWP supplies due to factors including the OCAP BO.

**Overall, the Baseline Scenario indicates a net “deficit” (i.e., outflows greater than inflows) of approximately -14,700 AFY.**

**2030 Climate Change Scenario**

Under the 2030 Climate Change Scenario, changes in precipitation, natural surface water inflows, and M&I consumptive use relative to the Baseline Scenario are all relatively small (i.e., relative changes of 1.1% to 2.9% and absolute changes of approximately 0 AFY to 550 AFY). The most significant changes relative to the Baseline Scenario are a reduction in surface water imports of approximately -2,800 AFY (-3.0%) and an increase in evapotranspiration of approximately 4,700 AFY (+2.8%).

**Overall, the 2030 Climate Change Scenario indicates a net deficit of approximately -21,400 AFY.** Consistent with the approach being used by all KGA GSA members (and other GSAs in the basin), this estimated net deficit under the 2030 Climate Change Scenario is the amount that the Projects and Management Actions are targeted to address by the GSP implementation deadline (i.e., January 2040). As shown on Table WB-7 and further described in Section 17.1.4 Implementation Glide Path and in Table PMA-2, WRMWSD has proposed to address approximately 60% of the projected deficit of -21,400 AFY by the GSP implementation deadline (i.e. January 2040) through adoption of supply augmentation projects (i.e., ~12,900 AFY), and the remaining 40% of the projected deficit through adoption of demand reduction management actions (i.e., ~8,600 AFY).

**2070 Climate Change Scenario**

Under the 2070 Climate Change Scenario, changes in precipitation, natural surface water inflows, and M&I consumptive use relative to the Baseline Scenario are somewhat greater than in the 2030 Climate Change Scenario, but still not significant (i.e., relative changes of -1.3% to 6.8% and absolute changes of approximately 0 AFY to -700 AFY). Surface water imports are lower by approximately -7,200 AFY (-7.7%) and evapotranspiration is greater by approximately +10,700 AFY (+6.2%).

**Overall, the 2070 Climate Change Scenario indicates a net deficit of approximately -33,300 AFY.** As shown on Table WB-7 and further described in Section 17.1.4 Implementation Glide Path and in Table PMA-2, WRMWSD has proposed to address approximately 56% of the projected deficit of -33,300 AFY by the end of the 50-year GSP planning and implementation horizon (i.e. January 2070) through adoption of supply augmentation projects (i.e., ~18,800 AFY), and the remaining 44% of the projected deficit through adoption of demand reduction management actions (i.e., ~14,600 AFY).

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61 The District, as required by law, is planning on implementing Projects and Management Actions to address the potential impacts due to climate change. The District does note that making planning decisions based on models has real and substantial economic impacts on District landowners and residents and does not agree with this exercise.
TABLE WB-1
Annual Surface Water Inflows and Outflows by Source Type
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

<table>
<thead>
<tr>
<th>Year</th>
<th>Natural Inflows</th>
<th>TOTAL SURFACE WATER INFLOWS</th>
<th>Natural Outflows</th>
<th>TOTAL SURFACE WATER OUTFLOWS</th>
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</thead>
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<td>OUTFLOWS [AFY]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direct Precipitation</td>
<td>Streamflow into District</td>
<td>Surface Water Exports</td>
<td>Streamflow out of District</td>
</tr>
<tr>
<td></td>
<td>Non-Overlap Lands</td>
<td>Overlap Lands</td>
<td>TOTAL</td>
<td>Non-Overlap Lands</td>
</tr>
<tr>
<td>1995</td>
<td>120,977</td>
<td>67,393</td>
<td>4,118</td>
<td>71,511</td>
</tr>
<tr>
<td>1996</td>
<td>150,040</td>
<td>61,041</td>
<td>3,730</td>
<td>64,771</td>
</tr>
<tr>
<td>1997</td>
<td>147,817</td>
<td>46,179</td>
<td>2,822</td>
<td>49,001</td>
</tr>
<tr>
<td>1998</td>
<td>108,888</td>
<td>118,987</td>
<td>7,271</td>
<td>126,258</td>
</tr>
<tr>
<td>1999</td>
<td>126,098</td>
<td>50,787</td>
<td>3,103</td>
<td>53,890</td>
</tr>
<tr>
<td>2000</td>
<td>108,888</td>
<td>34,843</td>
<td>2,129</td>
<td>36,972</td>
</tr>
<tr>
<td>2001</td>
<td>95,287</td>
<td>49,374</td>
<td>3,017</td>
<td>52,391</td>
</tr>
<tr>
<td>2002</td>
<td>93,727</td>
<td>27,223</td>
<td>1,664</td>
<td>30,887</td>
</tr>
<tr>
<td>2003</td>
<td>86,002</td>
<td>57,801</td>
<td>3,532</td>
<td>61,333</td>
</tr>
<tr>
<td>2004</td>
<td>97,212</td>
<td>34,477</td>
<td>2,107</td>
<td>36,583</td>
</tr>
<tr>
<td>2005</td>
<td>91,378</td>
<td>61,076</td>
<td>7,192</td>
<td>64,808</td>
</tr>
<tr>
<td>2006</td>
<td>104,769</td>
<td>43,555</td>
<td>2,662</td>
<td>46,216</td>
</tr>
<tr>
<td>2007</td>
<td>120,260</td>
<td>30,176</td>
<td>1,844</td>
<td>32,020</td>
</tr>
<tr>
<td>2008</td>
<td>121,328</td>
<td>16,782</td>
<td>1,026</td>
<td>17,808</td>
</tr>
<tr>
<td>2009</td>
<td>109,427</td>
<td>35,367</td>
<td>2,161</td>
<td>37,529</td>
</tr>
<tr>
<td>2010</td>
<td>110,195</td>
<td>49,311</td>
<td>3,013</td>
<td>52,324</td>
</tr>
<tr>
<td>2011</td>
<td>111,698</td>
<td>77,100</td>
<td>4,711</td>
<td>81,811</td>
</tr>
<tr>
<td>2012</td>
<td>123,256</td>
<td>35,585</td>
<td>2,175</td>
<td>37,760</td>
</tr>
<tr>
<td>2013</td>
<td>120,138</td>
<td>29,627</td>
<td>1,810</td>
<td>31,438</td>
</tr>
<tr>
<td>2014</td>
<td>96,394</td>
<td>10,560</td>
<td>645</td>
<td>11,205</td>
</tr>
<tr>
<td>2015</td>
<td>83,710</td>
<td>51,321</td>
<td>3,136</td>
<td>54,457</td>
</tr>
<tr>
<td></td>
<td>TOTAL AFY</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviations**

- AFY = acre-feet per year
- DWR = California Department of Water Resources
- Precip. = precipitation
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District
- WY = Water Year

**Notes**

(a) All values reported in acre-feet per year (AFY).
(b) Surface water import sources include State Water Project water, as well as recovered groundwater from out-of-district banking operations, including (1) Kern Water Bank, (2) Pioneer Project, (3) Berrenda Mesa Project, and (4) 2800 Acres. These sources are blended into the California Aqueduct prior to delivery to WRMWSD customers and thus cannot be independently quantified.
## TABLE WB-2
Annual Inflows to and Outflows from the Groundwater System, and Change in Groundwater Storage

Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

### Historical Water Budget (DWR WY 1995 - 2014)

<table>
<thead>
<tr>
<th>Year</th>
<th>INFLOWS [AFY]</th>
<th>OUTFLOWS [AFY]</th>
<th>CHANGE IN STORAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>22,957</td>
<td>50,181</td>
<td>27,224</td>
</tr>
<tr>
<td>1996</td>
<td>10,578</td>
<td>46,181</td>
<td>35,603</td>
</tr>
<tr>
<td>1997</td>
<td>11,239</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>1998</td>
<td>13,423</td>
<td>64,204</td>
<td>111,638</td>
</tr>
<tr>
<td>1999</td>
<td>15,652</td>
<td>65,929</td>
<td>110,277</td>
</tr>
<tr>
<td>2000</td>
<td>16,259</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2001</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2002</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2003</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2004</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2005</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2006</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2007</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2008</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2009</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2010</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2011</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2012</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2013</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
<tr>
<td>2014</td>
<td>15,881</td>
<td>7,844</td>
<td>99,629</td>
</tr>
</tbody>
</table>

### Current Water Budget (DWR WY 2015)

<table>
<thead>
<tr>
<th>Year</th>
<th>INFLOWS [AFY]</th>
<th>OUTFLOWS [AFY]</th>
<th>CHANGE IN STORAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>8,640</td>
<td>5,044</td>
<td>2,708</td>
</tr>
</tbody>
</table>

### Abbreviations

- AF = acre-feet
- AFY = acre-feet per year
- DWR = California Department of Water Resources
- ITRC = Cal Poly Irrigation Training & Research Center
- WY = Water Year

### Notes

(a) All values reported in acre-feet per year (AFY), except cumulative change in storage (reported in acre-feet).
(b) This value includes all groundwater extractions from WRMWSD wells for its long-term groundwater banking and recovery program. On certain years, this value also includes minor groundwater inputs to the District delivery system from private wells that have elected to participate in the District’s groundwater “pump-in” program to augment delivery supplies in times of drought.
(c) There are years for which ITRC-measured evapotranspiration from non-irrigated lands exceeds the total measured rainfall to these lands. In these cases, residual water demands on non-irrigated lands are accounted for as a reduction in total infiltration (“inflows”) rather than an explicit groundwater “outflow” due to evapotranspiration. This is based on the understanding that the groundwater table is fully disconnected from the root zone under the District. The ITRC-measured residual water demands on non-irrigated lands are likely caused in part by evaporation from local surface water bodies (e.g., storage ponds) and/or are met by a reduction of root zone soil moisture, which is not explicitly accounted for in the water budget spreadsheet model.
<table>
<thead>
<tr>
<th>Period of Reference [m/yy]</th>
<th>Annual Change in Groundwater Storage [AFY]</th>
<th>Cumulative Change in Groundwater Storage [AF]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/94 - 2/95</td>
<td>676</td>
<td>676</td>
</tr>
<tr>
<td>3/95 - 2/96</td>
<td>2,314</td>
<td>2,989</td>
</tr>
<tr>
<td>3/96 - 2/97</td>
<td>4,749</td>
<td>7,738</td>
</tr>
<tr>
<td>3/97 - 2/98</td>
<td>12,156</td>
<td>19,894</td>
</tr>
<tr>
<td>3/98 - 2/99</td>
<td>49,356</td>
<td>69,251</td>
</tr>
<tr>
<td>3/99 - 2/00</td>
<td>4,753</td>
<td>74,004</td>
</tr>
<tr>
<td>3/00 - 2/01</td>
<td>5,654</td>
<td>79,658</td>
</tr>
<tr>
<td>3/01 - 2/02</td>
<td>-12,446</td>
<td>67,212</td>
</tr>
<tr>
<td>3/02 - 2/03</td>
<td>-27,481</td>
<td>39,732</td>
</tr>
<tr>
<td>3/03 - 2/04</td>
<td>-10,773</td>
<td>28,959</td>
</tr>
<tr>
<td>3/04 - 2/05</td>
<td>-8,647</td>
<td>20,312</td>
</tr>
<tr>
<td>3/05 - 2/06</td>
<td>19,552</td>
<td>39,864</td>
</tr>
<tr>
<td>3/06 - 2/07</td>
<td>21,652</td>
<td>61,517</td>
</tr>
<tr>
<td>3/07 - 2/08</td>
<td>-11,478</td>
<td>50,038</td>
</tr>
<tr>
<td>3/08 - 2/09</td>
<td>-12,299</td>
<td>37,740</td>
</tr>
<tr>
<td>3/09 - 2/10</td>
<td>-2,415</td>
<td>35,325</td>
</tr>
<tr>
<td>3/10 - 2/11</td>
<td>26,890</td>
<td>62,215</td>
</tr>
<tr>
<td>3/11 - 2/12</td>
<td>50,964</td>
<td>113,180</td>
</tr>
<tr>
<td>3/12 - 2/13</td>
<td>-8,233</td>
<td>104,946</td>
</tr>
<tr>
<td>3/13 - 2/14</td>
<td>-29,420</td>
<td>75,526</td>
</tr>
<tr>
<td>3/14 - 2/15</td>
<td>-27,863</td>
<td>47,664</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>47,664</strong></td>
<td><strong>47,664</strong></td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td><strong>2,270</strong></td>
<td><strong>-</strong></td>
</tr>
</tbody>
</table>
TABLE WB-4
Annual Change in Groundwater Storage vs. DWR Water Year Type
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

<table>
<thead>
<tr>
<th>DWR Water Year (Oct - Sept)</th>
<th>DWR Water Year Type (a)</th>
<th>Annual Change in Groundwater Storage [AFY]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical Water Budget (DWR WY 1995 - 2014)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>W</td>
<td>15,125</td>
</tr>
<tr>
<td>1996</td>
<td>W</td>
<td>-4,020</td>
</tr>
<tr>
<td>1997</td>
<td>W</td>
<td>4,946</td>
</tr>
<tr>
<td>1998</td>
<td>W</td>
<td>49,878</td>
</tr>
<tr>
<td>1999</td>
<td>AN</td>
<td>22,381</td>
</tr>
<tr>
<td>2000</td>
<td>AN</td>
<td>51</td>
</tr>
<tr>
<td>2001</td>
<td>D</td>
<td>862</td>
</tr>
<tr>
<td>2002</td>
<td>D</td>
<td>-31,814</td>
</tr>
<tr>
<td>2003</td>
<td>BN</td>
<td>-6,413</td>
</tr>
<tr>
<td>2004</td>
<td>D</td>
<td>-21,726</td>
</tr>
<tr>
<td>2005</td>
<td>W</td>
<td>27,419</td>
</tr>
<tr>
<td>2006</td>
<td>W</td>
<td>18,718</td>
</tr>
<tr>
<td>2007</td>
<td>C</td>
<td>446</td>
</tr>
<tr>
<td>2008</td>
<td>C</td>
<td>-14,703</td>
</tr>
<tr>
<td>2009</td>
<td>BN</td>
<td>-1,949</td>
</tr>
<tr>
<td>2010</td>
<td>AN</td>
<td>6,846</td>
</tr>
<tr>
<td>2011</td>
<td>W</td>
<td>53,698</td>
</tr>
<tr>
<td>2012</td>
<td>D</td>
<td>3,863</td>
</tr>
<tr>
<td>2013</td>
<td>C</td>
<td>-24,061</td>
</tr>
<tr>
<td>2014</td>
<td>C</td>
<td>-33,839</td>
</tr>
<tr>
<td>Current Water Budget (DWR WY 2015)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>C</td>
<td>-42,898</td>
</tr>
</tbody>
</table>

**Abbreviations**

AFY = acre-feet per year
DWR = California Department of Water Resources

**Notes:**

(a) DWR Water Year Types are as follows: W = wet,
    AN = above normal, BN = below normal, D = dry, C = critical

**Sources:**

(1) DWR Water Year Type is from DWR’s Water Year Hydrologic
    Classification Indices for the San Joaquin Valley
    <http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST>. 

Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin GSP Chapter
**TABLE WB-5**

**Annual Total Inflows, Outflows, and Change in Groundwater Storage**

Wheeler Ridge-Maricopa Water Storage District

Kern Subbasin Management Area

<table>
<thead>
<tr>
<th>Historical Water Budget (DWR WY 1995 - 2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INFLOWS [AFY]</strong></td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td><strong>Non-Overlap Lands</strong></td>
</tr>
<tr>
<td><strong>Non-Overlap Lands</strong></td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td><strong>Municipal &amp; Industrial</strong></td>
</tr>
<tr>
<td><strong>Subsurface Groundwater</strong></td>
</tr>
<tr>
<td><strong>Inflow</strong></td>
</tr>
<tr>
<td><strong>Change in storage</strong></td>
</tr>
<tr>
<td><strong>(b)</strong></td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td><strong>Total Inflows</strong></td>
</tr>
<tr>
<td><strong>Outflows</strong></td>
</tr>
<tr>
<td><strong>Deliveries to Overlap</strong></td>
</tr>
<tr>
<td><strong>Lands</strong></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td><strong>Groudwater Inflow</strong></td>
</tr>
<tr>
<td><strong>Lands</strong></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
</tr>
<tr>
<td><strong>INFLOWS</strong></td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
</tr>
<tr>
<td><strong>AFY</strong></td>
</tr>
<tr>
<td><strong>AF</strong></td>
</tr>
</tbody>
</table>

**Annual Change in Groundwater Storage Since WY 1995 [AF]**

- **2015**: 8,640
- **2016**: 51,321
- **2017**: 3,136
- **2018**: 54,457
- **2019**: 83,710
- **2020**: 2,676
- **2021**: 149,483
- **2022**: 175,651
- **2023**: 10,734
- **2024**: 186,384
- **2025**: 4,478
- **2026**: 102
- **2027**: 187,527
- **2028**: 42,898

**Abbreviations**

- **AFY** = acre-feet per year
- **AF** = acre-feet
- **M&I** = municipal & industrial
- **DWR** = California Department of Water Resources

**Notes**

(a) All values reported in acre-feet per year (AFY), except cumulative change in storage (reported in acre-feet).

(b) "Evapotranspiration" includes all estimated crop and vegetative evapotranspirative demands as well as evaporation of excess rainfall and from open water bodies within the District.

(c) Apparent residual of water-budget calculated change in groundwater storage to [Total Inflows - Total Outflows] can be attributed to the deep percolation lag effect in the water budget spreadsheet model, which serves to delay infiltration from reaching the groundwater system. See "Appendix A - Methods & Data Used in the Water Budget Spreadsheet Model Approach" for further details on how monthly storage change is calculated within the water budget spreadsheet model.

**Footnotes**

- Percentages may not sum to 100 due to rounding.
- wed = water year ending December 31.
### TABLE WB-6
Summary of Projected Water Budget Results without Project & Management Action Implementation
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

#### Total Water Budget Domain

<table>
<thead>
<tr>
<th>Water Budget Category</th>
<th>Water Budget Component</th>
<th>Historical Period (WY 1995-2014)</th>
<th>Baseline (50-year Synthetic Hydrologic Period)</th>
<th>Projected 2030 Climate (scaled from Baseline Period)</th>
<th>Projected 2070 Climate (scaled from Baseline Period)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inflows</strong></td>
<td>(Net) Subsurface Inflow</td>
<td>11,779</td>
<td>11,551</td>
<td>11,704</td>
<td>11,485</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precipitation</td>
<td>49,726</td>
<td>49,144</td>
<td>49,707</td>
<td>48,485</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface Water Imports</td>
<td>113,431</td>
<td>93,328</td>
<td>90,541</td>
<td>86,119</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural Surface Water Inflows</td>
<td>3,104</td>
<td>3,044</td>
<td>3,095</td>
<td>3,022</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL INFLOWS</td>
<td>178,041</td>
<td>157,067</td>
<td>155,046</td>
<td>149,111</td>
</tr>
<tr>
<td><strong>Outflows</strong></td>
<td>Evapotranspiration</td>
<td>173,847</td>
<td>171,023</td>
<td>175,767</td>
<td>181,702</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M&amp;I Consumptive Use</td>
<td>902</td>
<td>866</td>
<td>891</td>
<td>925</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface Water Exports</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural Surface Water Outflows</td>
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<td>0</td>
<td>0</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subsurface Groundwater Outflow</td>
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<td>0</td>
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<td>0</td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL OUTFLOWS</td>
<td>174,749</td>
<td>171,888</td>
<td>176,658</td>
<td>182,627</td>
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<tr>
<td><strong>Change in Groundwater Storage</strong></td>
<td>Equivalent to &quot;Deficit&quot;</td>
<td>3,286</td>
<td>-14,665</td>
<td>-21,429</td>
<td>-33,326</td>
</tr>
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</table>

#### Groundwater Subdomain

<table>
<thead>
<tr>
<th>Water Budget Category</th>
<th>Water Budget Component</th>
<th>Historical Period (WY 1995-2014)</th>
<th>Baseline (50-year Synthetic Hydrologic Period)</th>
<th>Projected 2030 Climate (scaled from Baseline Period)</th>
<th>Projected 2070 Climate (scaled from Baseline Period)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inflows</strong></td>
<td>(Net) Subsurface Inflow</td>
<td>11,779</td>
<td>11,551</td>
<td>11,704</td>
<td>11,485</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td>Infiltration of Precipitation</td>
<td>5,307</td>
<td>4,997</td>
<td>4,974</td>
<td>4,678</td>
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<tr>
<td></td>
<td>Infiltration from Surface Water Systems</td>
<td>3,552</td>
<td>3,443</td>
<td>3,450</td>
<td>3,308</td>
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<tr>
<td></td>
<td>Infiltration of Applied Water</td>
<td>39,608</td>
<td>33,132</td>
<td>32,618</td>
<td>30,935</td>
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<td></td>
<td>TOTAL GW INFLOWS</td>
<td>60,247</td>
<td>53,123</td>
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<td><strong>Outflows</strong></td>
<td>Pumpage from District Wells</td>
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<td>463</td>
<td>463</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>Pumpage from Private Wells - User Input Program</td>
<td>2,705</td>
<td>2,563</td>
<td>2,563</td>
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</tr>
<tr>
<td></td>
<td>Pumpage from Private Wells - Private Use</td>
<td>53,777</td>
<td>64,918</td>
<td>71,330</td>
<td>80,894</td>
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<td>TOTAL GW OUTFLOWS</td>
<td>56,955</td>
<td>67,944</td>
<td>74,357</td>
<td>83,921</td>
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<td><strong>Change in Groundwater Storage</strong></td>
<td>Equivalent to &quot;Deficit&quot;</td>
<td>3,286</td>
<td>-14,665</td>
<td>-21,429</td>
<td>-33,326</td>
</tr>
</tbody>
</table>

**Notes**

(a) All values reported in acre-feet per year (AFY).
(b) Projected GW Inflow terms based on Estimated Net Groundwater Inflows from Calibrated Historical Water Budget
(c) Evapotranspiration includes all estimated crop and vegetative evapotranspirative demands as well as evaporation of excess rainfall and from open water bodies within the District.
(d) M&I Consumptive Use includes evapotranspiration on Urban Lands (no other consumptive uses specified within the District), which is in part met by precipitation.
(e) Apparent residual of water-budget calculated change in groundwater storage to "Total Inflows - Total Outflows" can be attributed to the deep percolation lag effect in the water budget spreadsheet model, which serves to delay infiltration from reaching the groundwater system. See "Appendix E - Methods & Data Used in the Water Budget Spreadsheet Model Approach" for further details on how monthly storage change is calculated within the water budget spreadsheet model.
### Summary of Projected Water Budget Results with Project & Management Action Implementation

#### Wheeler Ridge-Maricopa Water Storage District

#### Kern Subbasin Management Area

<table>
<thead>
<tr>
<th>Water Budget Category</th>
<th>Historical Period (WY 1995-2014)</th>
<th>Baseline (50-year Synthetic Hydrologic Period)</th>
<th>2030 Climate (scaled from Baseline Period)</th>
<th>2070 Climate (scaled from Baseline Period)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inflows</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Net) Subsurface Inflow (b)</td>
<td>11,779</td>
<td>11,551</td>
<td>11,704</td>
<td>11,485</td>
</tr>
<tr>
<td>Precipitation</td>
<td>49,726</td>
<td>49,144</td>
<td>49,707</td>
<td>48,485</td>
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<tr>
<td>Surface Water Imports</td>
<td>113,431</td>
<td>93,328</td>
<td>90,541</td>
<td>86,119</td>
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<td>P&amp;MA Augmented Supplies</td>
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<td>0</td>
<td>12,900</td>
<td>18,800</td>
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<tr>
<td>Natural Surface Water Inflows</td>
<td>3,104</td>
<td>3,044</td>
<td>3,095</td>
<td>3,022</td>
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<td><strong>TOTAL INFLOWS</strong></td>
<td>178,041</td>
<td>157,067</td>
<td>167,946</td>
<td>167,911</td>
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<td><strong>Outflows</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Evapotranspiration (c)</td>
<td>173,847</td>
<td>171,023</td>
<td>175,767</td>
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<td>P&amp;MA Demand Reduction</td>
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<td>-8,600</td>
<td>-14,600</td>
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<tr>
<td>M&amp;I Consumptive Use (d)</td>
<td>902</td>
<td>866</td>
<td>891</td>
<td>925</td>
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<tr>
<td>Surface Water Exports</td>
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<td>Natural Surface Water Outflows</td>
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<td>Subsurface Groundwater Outflow</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td><strong>TOTAL OUTFLOWS</strong></td>
<td>174,749</td>
<td>171,888</td>
<td>168,058</td>
<td>168,027</td>
</tr>
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<td><strong>Change in Groundwater Storage</strong></td>
<td>3,286</td>
<td>-14,665</td>
<td>53</td>
<td>47</td>
</tr>
</tbody>
</table>

#### Notes

(a) All values reported in acre-feet per year (AFY).
(b) Projected GW Inflow terms based on Estimated Net Groundwater Inflows from Calibrated Historical Water Budget
(c) Evapotranspiration includes all estimated crop and vegetative evapotranspirative demands as well as evaporation of excess rainfall and from open water bodies within the District.
(d) M&I Consumptive Use includes evapotranspiration on Urban Lands (no other consumptive uses specified within the District), which is in part met by precipitation.
(e) Apparent residual of water-budget calculated change in groundwater storage to [Total Inflows - Total Outflows] can be attributed to the deep percolation lag effect in the water budget spreadsheet model, which serves to delay infiltration from reaching the groundwater system. See "Appendix E - Methods & Data Used in the Water Budget Spreadsheet Model Approach" for further details on how monthly storage change is calculated within the water budget spreadsheet model.
Water Budget Domains and Subdomains

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
August 2019
EKI B70103.01

Figure WB-1
Notes:
1. Components 4-28 are further parsed into their respective contributions to the Kern and White Wolf Subbasins within the water budget.
Annual Surface Water Inflows by Source

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01
Figure WB-3
Abbreviations
AF = acre-feet
DWR = California Department of Water Resources

Notes
1. Annual volumes reported by DWR Water Year, which extends October (of the previous year) – September.
Legend

**Groundwater Inflows**
- Subsurface GW Inflow
- Infiltration of Applied Water
- Infiltration of Precipitation
- Infiltration from Surface Water Systems
- Recharge from Spreading Basins

**Groundwater Outflows**
- Groundwater Extraction
- Subsurface GW Outflow

**Change in Groundwater Storage**
- Gain in GW Storage
- Reduction in GW Storage

**Abbreviations**
- DWR = California Department of Water Resources
- GW = groundwater

**Notes**
1. “Groundwater Extraction” includes all District, private, and municipal & industrial groundwater pumping.

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Annual Groundwater Inflows and Outflows

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01
Figure WB-5
**Summary of Groundwater Inflows & Outflows, WY 1995 - 2014**

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01

**Figure WB-6**

**Legend**

- **Groundwater Inflows**
  - = Subsurface GW Inflow
  - = Infiltration of Applied Water
  - = Infiltration of Precipitation
  - = Infiltration from Surface Water Systems
  - = Recharge from Spreading Basins

- **Groundwater Outflows**
  - = Groundwater Extraction
  - = Subsurface GW Outflow

- **Change in Groundwater Storage**
  - = Gain in GW Storage
  - = Reduction in GW Storage

**Abbreviations**

- AFY = acre-feet per year
- GW = groundwater
- WY = Water Year

**Notes**

1. All values reported in acre-feet per year (AFY).
2. “Groundwater Extraction” includes all District and private groundwater pumping.

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**Total Average Annual Inflows: 60,247 AFY**

- Subsurface Groundwater Inflow: 11,779 (19%)
- Infiltration of Precipitation: 5,307 (9%)
- Infiltration from Surface Water Systems: 3,552 (6%)
- Infiltration of Applied Water: 39,608 (66%)

**Total Average Annual Outflows: 56,955 AFY**

- Pumpage from District Wells: 474 (1%)
- Pumpage from Private Wells - for User Input Program: 2,705 (5%)
- Pumpage from Private Wells - for Private Use: 53,777 (94%)
- Discharge to Surface Water Sources: 0 (0%)
- Evapotranspiration: 0 (0%)
Abbreviations
AFY = acre-feet per year

Notes
1. “Seasonal high” condition is defined as March – February of the following year.
Abbreviations
AF = acre-feet

Notes
1. Values represent cumulative change in storage since the “seasonal high” condition of March 1994.
Abbreviations

AFY = acre-feet per year

Sources

1. DWR Water Year Type is from DWR’s Water Year Hydrologic Classification Indices for the San Joaquin Valley
   <http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST>.
Abbreviations
AF = acre-feet

Sources
1. DWR Water Year Type is from DWR’s Water Year Hydrologic Classification Indices for the San Joaquin Valley
   <http://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST>.
Comparison of Modeled & Water Level-Based Estimated Change in Storage

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01
Figure WB-11

Notes
1. Calibration of the water budget spreadsheet model was performed for the District’s entire service area, including the portion within the White Wolf Subbasin.
Summary of Total Inflows & Outflows, WY 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01

Figure WB-12

Legend

Inflows
- = Subsurface GW Inflows
- = Surface Water Imports
- = Precipitation
- = Natural Surface Water Inflows

Outflows
- = Subsurface GW Outflows
- = Evapotranspiration

Abbreviations
AFY = acre-feet per year
GW = groundwater
M&I = municipal & industrial
WY = Water Year

Notes
1. All values reported in acre-feet per year (AFY).

Total Inflows: 149,483 AF

- Subsurface Groundwater Inflow: 8,640 AF (6%)
- Precipitation: 54,457 AF (36%)
- Surface Water Imports: 83,710 AF (56%)
- Natural Surface Water Inflows: 2,676 AF (2%)

Total Outflows: 187,327 AF

- Evapotranspiration: 187,224 AF (100%)
- Subsurface Groundwater Outflow: 102 AF (0%)
- M&I Consumptive Use: 0 AF (0%)
- Surface Water Exports + Losses: 0 AF (0%)
- Natural Surface Water Outflow: 0 AF (0%)
**Legend**

Groundwater Inflows

- **Subsurface GW Inflow**
- **Infiltration of Applied Water**
- **Infiltration of Precipitation**
- **Infiltration from Surface Water Systems**
- **Recharge from Spreading Basins**

Groundwater Outflows

- **Groundwater Extraction**
- **Subsurface GW Outflow**
- **Gain in GW Storage**
- **Reduction in GW Storage**

**Change in Groundwater Storage**

- **Gain in GW Storage**
- **Reduction in GW Storage**

**Abbreviations**

- **AF** = acre-feet
- **GW** = groundwater
- **WY** = Water Year

**Notes**

1. All values reported in acre-feet (AF).
2. “Groundwater Extraction” includes all District and private groundwater pumping.

---

**Summary of Groundwater Inflows & Outflows, WY 2015**

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01
Figure WB-13
Legend

- SWP Annual Entitlement
- SWP Table A Contract

Abbreviations

AFY = acre-feet per year
SWP = State Water Project

Notes

1. WRMWSD’s Table A SWP Contract is 197,088 AFY
Legend

**Inflows**
- = Subsurface GW Inflow
- = Surface Water Imports
- = Precipitation
- = Natural Surface Water Inflows

**Outflows**
- = Subsurface Outflows
- = Evapotranspiration

**Change in Groundwater Storage**
- = Gain in GW Storage
- = Reduction in GW Storage

**Abbreviations**
DWR = California Department of Water Resources
GW = groundwater

**Annual Inflows & Outflows**
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01
Figure WB-15
Summary of Inflows & Outflows to Groundwater System, WY 1995 - 2014
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01

<table>
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<th><strong>Legend</strong></th>
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<tr>
<td><strong>Inflows</strong></td>
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<td><img src="image" alt="Subsurface GW Inflows" /></td>
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<tr>
<td><img src="image" alt="Surface Water Imports" /></td>
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<td><img src="image" alt="Precipitation" /></td>
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<tr>
<td><img src="image" alt="Natural Surface Water Inflows" /></td>
</tr>
<tr>
<td><strong>Outflows</strong></td>
</tr>
<tr>
<td><img src="image" alt="Subsurface GW Outflows" /></td>
</tr>
<tr>
<td><img src="image" alt="Evapotranspiration" /></td>
</tr>
</tbody>
</table>

**Abbreviations**
- **AFY** = acre-feet per year
- **GW** = groundwater
- **M&I** = municipal & industrial
- **WY** = Water Year

**Notes**
1. All values reported in acre-feet per year (AFY).

**Average Total Annual Inflows:** 178,041 AFY

- **Natural Surface Water Inflows:** 3,104 AFY (2%)
- **Subsurface Groundwater Inflow:** 11,779 AFY (6%)
- **Precipitation:** 49,726 AFY (28%)
- **Surface Water Imports:** 113,431 AFY (64%)

**Average Total Annual Outflows:** 174,749 AFY

- **Evapotranspiration:** 174,738 AFY (100%)
- **M&I Consumptive Use:** 11 AFY (0%)
- **Surface Water Exports + Losses:** 0 AFY (0%)
- **Natural Surface Water Outflow:** 0 AFY (0%)
Legend

- Precipitation
- Surface Water Imports
- District Pumpage
- Private Pumpage - User Input Program
- Private Pumpage - Private Use

Abbreviations

AFY = acre-feet per year
WY = Water Year

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Water Supply Portfolio and Annual Precipitation, WY 1995 - 2015
Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01
Figure WB-17
Observed vs. Modeled Change in Water Levels, WY 1995 - 2015

Legend
- Measured Water Level (ft msl)
- Water Budget Spreadsheet
- Model-Calculated Change In Water Level (ft)

Abbreviations
- ft = feet
- ft msl = feet above mean sea level
- WY = Water Year

DRAFT

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
March 2019
EKI B70103.01
Figure WB-18
Projected Water Budget Supplies, Demands, and Shortfall Before Project & Management Action Implementation

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
May 2019
EKI B70103.00

Figure WB-19
10. MANAGEMENT AREAS

§ 354.20. Management Areas
(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.

(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.

The information presented in the Basin Setting sections of this GSP (i.e., Section 7 Hydrogeologic Conceptual Model, Section 8 Current and Historical Groundwater Conditions and Section 9 Water Budget Information) is specific to and describes conditions within the Wheeler Ridge-Maricopa Management Area. As discussed in Section 5.1.5 Lands Outside of District Covered by MA Plan, information regarding the undistricted lands (i.e., “White Lands”) covered by this MA Plan is presented in Appendix H.

10.1. Description and Justification

§ 354.20. Management Areas
(b) A 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.

As discussed previously in Section 5.1.1 Plan Area Setting, the Kern Subbasin is overlain by a large number of entities with water or land use management authority. A subset of these entities formed the Kern Groundwater Authority GSA. WRMWSD is a member of the KGA GSA but is locally responsible for SGMA compliance within a specific portion of the KGA GSA -- the Wheeler Ridge-Maricopa Management Area. This Management Area includes all of WRMWSD’s service area within the Kern Subbasin except for small portions on the far western side (see Figure HCM-1).

The reason for creation of the Wheeler Ridge-Maricopa Management Area is to ensure that WRMWSD maintains maximum flexibility and control over sustainable groundwater management within the portion of its service area where land and water use is predominantly agricultural, and where there is a strong nexus between WRMWSD management decisions and groundwater conditions.
10.2. Minimum Thresholds and Measurable Objectives

The Sustainable Management Criteria developed for the Wheeler Ridge-Maricopa Management Area, including the rationale for their selection, are described in detail in Section 14 Minimum Thresholds and Section 15 Measurable Objectives and Interim Milestones.

10.3. Monitoring

Monitoring networks for each applicable Sustainability Indicator, including a discussion of the level of monitoring an analysis appropriate for the Wheeler Ridge-Maricopa Management Area, are described in detail in Section 16 Monitoring Network.
SUSTAINABLE MANAGEMENT CRITERIA
11. INTRODUCTION TO SUSTAINABLE MANAGEMENT CRITERIA

The Sustainable Groundwater Management Act (SGMA) legislation defines “Sustainability Goal” as “the existence and implementation of one or more groundwater sustainability plans that achieve sustainable groundwater management by identifying and causing the implementation of measures targeted to ensure that the applicable basin is operated within its sustainable yield” (California Water Code [CWC] § 10721(u)). SGMA requires Groundwater Sustainability Plans (GSPs) to develop and implement plans to meet the Sustainability Goal (CWC § 10727(a)) and defines terms related to achievement of the Sustainability Goal, including:

- Interim Milestone - a target value representing measurable groundwater conditions, in increments of five years, set by an Agency as part of a plan (23-CCR § 351(q));
- Measurable Objective - specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted plan to achieve the sustainability goal for the basin (23-CCR § 351(s)); and
- Minimum Threshold - a numeric value for each sustainability indicator used to define undesirable results (23-CCR § 351(t)).

Collectively, the Sustainability Goal, Interim Milestones, Measurable Objectives, and Minimum Thresholds are referred to herein as Sustainable Management Criteria (SMCs).

The GSP Emergency Regulations (23-CCR Division 2 Chapter 1.5 Subchapter 2) specify how Groundwater Sustainability Agencies (GSAs) must establish SMCs for each applicable Sustainability Indicator. Sections 12, 13, 14, and 15 of this GSP describe the Sustainability Goal, Undesirable Results, Minimum Thresholds, and Measurable Objectives and Interim Milestones, respectively, developed as part of this MA Plan.
SGMA requires that a Sustainability Goal be defined for the basin (CWC § 10727(a)). The sustainability goal for the Wheeler Ridge-Maricopa Management Area is to maintain an economically-viable groundwater resource for the beneficial use of the Management Area’s landowners and water users by utilizing the area’s groundwater resources within the local sustainable yield. Long-term groundwater sustainability, i.e., the absence of undesirable results within 20 years of the applicable statutory deadline, will be achieved and maintained through the implementation of projects and management actions as described herein to both increase water supplies and reduce demands within the Management Area.

The local sustainability goal, above, is consistent with and in addition to the basin-wide sustainability goal being adopted by all GSAs in the Kern Subbasin, shown below (as of 9 August 2019).

“The sustainability goal of the Kern County Subbasin is to:

- Achieve sustainable groundwater management in the Kern County Subbasin through the implementation of projects and management actions at the member agency level of each GSA
- Maintain its groundwater use within the sustainable yield of the basin
- Operate within the established sustainable management criteria, which are based on the collective technical information presented in the GSPs in the Subbasin.
- Implement projects and management actions that include a variety of water supply development and demand management actions
- Collectively bring the Subbasin into sustainability and to maintain sustainability over the implementation and planning horizon.

Further, the Subbasin sustainability goal includes a commitment to monitor and report groundwater conditions, as required by SGMA, and to continue coordination among the KGA member agencies and all other GSA’s in the Subbasin to identify the potential for, or presence
of, undesirable results and actions to prevent undesirable results. The coordination process established in the development of this GSP and memorialized in the Coordination Agreement will ensure that the Subbasin is managed as a shared groundwater resource and that the districts within the Subbasin work collaboratively towards achieving and maintaining sustainable groundwater use.”
13. UNDESIRABLE RESULTS

§ 354.26. Undesirable Results

(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.

(b) The description of undesirable results shall include the following:

(1) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.

(2) The criteria used to define when and where the effects of the groundwater conditions cause undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.

(3) Potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results.

(c) The Agency may need to evaluate multiple minimum thresholds to determine whether an undesirable result is occurring in the basin. The determination that undesirable results are occurring may depend upon measurements from multiple monitoring sites, rather than a single monitoring site.

(d) An Agency that is able to demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin shall not be required to establish criteria for undesirable results related to those sustainability indicators.

This section describes the Undesirable Results defined for the Wheeler Ridge-Maricopa Management Area. Pursuant to the GSP Emergency Regulations, which state that Undesirable Results are to be defined consistently throughout the basin (23-CCR § 354.20), definitions of Undesirable Results have been developed through a coordinated effort of the Kern Subbasin GSAs and are described in the KGA Umbrella GSP.

As discussed below for each Sustainability Indicator, the Undesirable Results definitions for the Basin refer to and rely on Minimum Thresholds established at the local management area level. Specifically, Undesirable Results for the Basin occur when Minimum Thresholds for a certain percentage (by acreage) _____________________

62 In this document, the term “Wheeler Ridge-Maricopa Management Area” is used in its entirety the first time the area is being referenced in each paragraph; subsequent references to this area in each paragraph use the term “Management Area”.

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of management areas are exceeded. Each management area determines what the local Minimum Thresholds values are and what combination of local exceedances constitutes a local Undesirable Result. If a local Undesirable Result manifests in a management area, that area counts towards the basin-wide Undesirable Results definition.

In the following sections, the Undesirable Results statements adopted by the Kern Groundwater Authority (KGA) GSA and other Basin GSAs for each Sustainability Indicator are presented, along with a description of the local Wheeler Ridge-Maricopa Management Area definition of Undesirable Results (i.e., what combination of Minimum Threshold exceedances, if any, constitutes a local Undesirable Result).

13.1. Undesirable Results for Chronic Lowering of Groundwater Levels

The basin-wide definition of Undesirable Results for Chronic Lowering of Groundwater Levels is as follows:

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

This is determined when the minimum threshold for groundwater levels are exceeded in at least three (3) adjacent management areas which represent at least 15% of the sub-basin or greater than 30% of the subbasin (as measured by each Management Area). Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.”

The above basin-wide definition requires local definition within each management area of the Minimum Thresholds and combination of exceedances that constitute a significant and unreasonable impact to the reasonable and beneficial use of, and access to, groundwater by overlying users. As such, it is necessary to consider local conditions and beneficial uses and users within each management area.

13.1.1. Potential Causes of Undesirable Results

Potential causes of Undesirable Results due to Chronic Lowering of Groundwater Levels in the Wheeler Ridge-Maricopa Management Area include increased pumping and/or reduced recharge. Because the primary use of groundwater from the principal aquifer in the Management Area is for agricultural purposes, increased pumping from the principal aquifer could occur if new land is put into agricultural production or if water use per acre on existing irrigated land increases. Pumping from the principal aquifer for potable domestic use is relatively small and unlikely to substantially increase. Reduced recharge could occur due to increased agricultural irrigation efficiency, reduced surface water imports, reduced groundwater inflows, or due to climate change that results in decreased precipitation and increased evapotranspiration (ET), as discussed in Section 9.4 Projected Water Budget.
13.1.2. Criteria Used to Define Undesirable Results

Per Section 354.26(b)(2) of the GSP Emergency Regulations, the description of Undesirable Results must include a quantitative description of the number of Minimum Threshold exceedances that constitute an Undesirable Result. As discussed further below in Section 14 Minimum Thresholds and in Section 16 Monitoring Network, within the Wheeler Ridge-Maricopa Management Area Minimum Thresholds for groundwater levels are set at 15 representative monitoring sites by considering groundwater levels and trends, well depths, and proximity to critical infrastructure. In a similar manner to how Undesirable Results are defined at the basin level, at the local Management Area level it is considered an Undesirable Result for Chronic Lowering of Groundwater Levels if Minimum Thresholds are exceeded in 40% or more of the representative monitoring sites (i.e., 6 or more out of 14 sites) over four consecutive seasonal measurements (i.e., two measurements at the seasonal high condition and two measurements at the seasonal low condition).

13.1.3. Potential Effects of Undesirable Results

The primary potential effects of Undesirable Results caused by Chronic Lowering of Groundwater Levels on beneficial uses and users of groundwater in the Wheeler Ridge-Maricopa Management Area include groundwater well dewatering, increased pumping lift, and potential land subsidence. Well dewatering is detrimental to wells as it can lead to increased maintenance costs (i.e., well rehabilitation/redevelopment, pump lowering) and reduced well lifespan due to corrosion of well casing and screen. Increased pumping lift results in more energy use per unit volume of groundwater pumped and greater pumping costs and can cause increased wear and tear on well pumps/motors. Land subsidence can affect critical infrastructure as discussed further below in Section 13.5.3 Potential Effects of Undesirable Results.

13.2. Undesirable Results for Reduction of Groundwater Storage

The basin-wide definition of Undesirable Results for Reduction of Groundwater Storage is as follows:

“The point at which significant and unreasonable impacts, as determined by the amount of groundwater in the basin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users over an extended drought period. (10-years?)

This is determined when the volume of storage (above the groundwater level minimum thresholds) is depleted to an elevation lower than the groundwater level minimum threshold in at least three (3) adjacent management areas that represent at least 15% of the subbasin or greater than 30% of the subbasin (as measured by the acreage of each Management Area).

Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.”
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The above basin-wide definition ties the Undesirable Result for Reduction of Groundwater Storage directly to the Minimum Thresholds for Chronic Lowering of Groundwater Levels which, as stated above, are defined locally within each management area of the Kern Subbasin.

13.2.1. Potential Causes of Undesirable Results

Reduction of Groundwater Storage is generally correlated to Chronic Lowering of Groundwater Levels. Therefore, the potential causes of Undesirable Results due to Reduction in Groundwater Storage are generally the same as the potential causes listed above for Undesirable Results due to Chronic Lowering of Groundwater Levels (i.e., increased groundwater pumping and reduced recharge).

13.2.2. Criteria Used to Define Undesirable Results

The criteria used to define Undesirable Results for Reduction of Groundwater Storage in the basin-wide definition above are the Minimum Thresholds established at a local management area level for Chronic Lowering of Groundwater Levels. Furthermore, Minimum Thresholds set related to Subsidence protect against excessive loss of aquifer storage (and resulting reduction of Groundwater Storage). Extending this definition to the local Wheeler Ridge-Maricopa Management Area level, it would be considered an Undesirable Result if groundwater storage were to be reduced by an amount that would cause the groundwater levels in 40% or more of representative monitoring sites to exceed their Minimum Thresholds for Chronic Lowering of Groundwater Levels over four consecutive seasonal measurements. As discussed below in Section 14 Minimum Thresholds, due to the great depth of fresh water and wells able to access it, there is significant usable groundwater storage within the Management Area even below the elevation of the Minimum Thresholds. As such, on a local level it is not necessary to define unique SMCs for Reduction of Groundwater Storage; the criteria set for Chronic Lowering of Groundwater Levels are “protective” and a reasonable proxy.

13.2.3. Potential Effects of Undesirable Results

The primary potential effect of Undesirable Results caused by Reduction of Groundwater Storage on beneficial uses and users of groundwater in the Wheeler Ridge-Maricopa Management Area is reduced groundwater supply reliability. The effect of reduced groundwater supply reliability would be most significant during periods of reduced surface water supply availability due to, for example, natural drought conditions, regulatory restrictions, natural disasters, or other causes. However, as discussed below in Section 14 Minimum Thresholds, there is significant groundwater storage within the Management Area, and so these effects are unlikely to occur.

13.3. Undesirable Results for Seawater Intrusion

The GSP Emergency Regulations state that “An Agency that is able to demonstrate that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin shall not be required to establish criteria for undesirable results related to those sustainability indicators” (23-CCR § 354.26(d)). Because the Kern Subbasin is not located near any saline water bodies, seawater
intrusion is not present and not likely to occur. Therefore, the Seawater Intrusion Sustainability Indicator is not applicable to the Kern Subbasin and no Undesirable Results for this Sustainability Indicator are defined.

13.4. Undesirable Results for Degraded Water Quality

The basin-wide definition of Undesirable Results for Degraded Water Quality is as follows:

“The point at which significant and unreasonable impacts over the planning and implementation horizon, as caused by water management actions, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.

This is determined when the minimum threshold for a groundwater quality constituent of concern is exceeded in at least three (3) adjacent management areas which represent at least 15% of the subbasin or greater than 30% of the designated monitoring points within the basin. Minimum thresholds shall be set by each of the management areas through their respective Groundwater Sustainability Plans.”

As with Chronic Lowering of Groundwater Levels, the above basin-wide definition allows for local definition, within each Management Area of the Kern Subbasin, of the Minimum Thresholds that constitute a significant and unreasonable impact to the reasonable and beneficial use of, and access to, groundwater by overlying users. Key to the basin-wide definition is the phrase “as caused by water management actions”. This phrase rightfully distinguishes between water quality impacts that are due to human actions and those that are the result of natural conditions. Because impacts due to natural conditions are not caused by (and in some cases, cannot be remedied by) human action, those impacts are not considered to be Undesirable Results subject to SGMA compliance.

13.4.1. Potential Causes of Undesirable Results

Potential causes of Undesirable Results due to Degraded Water Quality within the Wheeler Ridge-Maricopa Management Area include the addition of constituents of concern (COCs) to groundwater in the principal aquifer through processes that are causatively related to water management or land use activities. These potential processes include:

- Deep percolation of precipitation, seepage from various natural and man-made channels, and recharge from reservoirs and spreading basins;
- Irrigation system backflow into wells and flow through well gravel pack and screens from one formation to another\(^{63}\),

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\(^{63}\) Kern County's existing well destruction programs are designed to help minimize cross-connection between aquifer zones and prevent groundwater quality impairments that can result from cross-contamination of aquifer zones
13.4.2. Criteria Used to Define Undesirable Results

The basin-wide definition of Undesirable Results provides for local definition of the combination of Minimum Threshold exceedances that constitute and Undesirable Result in a Management Area. As described in Section 8.4 Groundwater Quality Concerns, agricultural use is the dominant beneficial use within the Wheeler Ridge-Maricopa Management Area, and groundwater quality is generally suitable for agricultural uses, with the exception of groundwater on the western side of the District which has poorer quality (i.e., higher TDS and sulfate) due to natural geologic conditions. Water quality issues related to deep percolation of agricultural chemicals such as nitrate are regulated separately under the ILRP and CV-SALTS. Therefore, based on the existing and potential beneficial uses and users of groundwater within the Management Area, Undesirable Results for Degraded Water Quality are not defined on a local level. It should be noted, however, that monitoring for water quality will be conducted at a set of Representative Monitoring Site locations, as discussed further in Section 16.1.4 Monitoring Network for Degraded Water Quality.
13.4.3. Potential Effects of Undesirable Results

Per Section 354.26(b)(3) of the GSP Emergency Regulations, potential effects of Undesirable Results must be identified. As discussed above, because the dominant beneficial use is agricultural, and water quality is generally suitable for agricultural uses within the Wheeler Ridge-Maricopa Management Area, Undesirable Results are not defined for this Sustainability Indicator.

The above notwithstanding, more generally the potential effects of Undesirable Results caused by Degraded Water Quality on beneficial uses and users of groundwater may include: increased costs to treat groundwater to drinking water standards if it is to be used as a potable supply source; increased costs to blend relatively poor-quality groundwater with higher quality sources for agricultural and non-agricultural uses; limitations on viable crop types or crop yield depending on crop sensitivity and tolerance to COCs in groundwater used for irrigation; and potential reduction in “usable storage” volume of groundwater in the basin if large areas of aquifer are impacted to the point that they cannot be used to support beneficial uses and users.

As discussed in Section 5.2.1 Existing Monitoring and Management Programs, the District conducts groundwater quality sampling and monitoring for its own agricultural water management program, as does the State Water Resources Control Board (SWRCB) through its Groundwater Ambient Monitoring and Assessment (GAMA) program. These groundwater quality monitoring programs are expected to continue during the SMGA implementation horizon and will be incorporated into future SGMA reporting and analysis.

13.5. Undesirable Results for Land Subsidence

The basin-wide definition of Undesirable Results for Land Subsidence is as follows:

“The point at which significant and unreasonable impacts, as determined by a subsidence rate and extent in the basin, that affects the surface land uses or critical infrastructure. This is determined when subsidence results in significant and unreasonable impacts to critical infrastructure as indicated by monitoring points established by a basin wide coordinated GSP subsidence monitoring plan.”

Critical infrastructure is defined in the adopted Undesirable Results definition document as:

“facilities which are utilized to provide public services such as water, utilities, and or transportation service for a region”

Unlike the Undesirable Results definitions for Chronic Lowering of Groundwater Levels, Reduction in Groundwater Storage, and Degraded Water Quality, the above basin-wide definition for Undesirable Results for Land Subsidence does not look towards a local definition of Minimum Thresholds on a management area level, but instead refers to a basin-wide coordinated GSP subsidence monitoring plan.
and affected water, utilities, and transportation service “for a region”. Thus, the definition is focused on regional impacts, rather than local impacts.

13.5.1. Potential Causes of Undesirable Results

Land subsidence can be caused by several mechanisms, but the mechanism most relevant to sustainable groundwater management is the depressurization of aquifers and aquitards due to lowering of groundwater levels, which can lead to compaction of compressible strata and lowering of the ground surface. Therefore, the potential causes of Undesirable Results due to Land Subsidence are generally the same as the potential causes listed above for Undesirable Results due to Chronic Lowering of Groundwater Levels.

13.5.2. Criteria Used to Define Undesirable Results

The basin-wide definition of Undesirable Results refers to significant and unreasonable impacts to critical infrastructure which, as noted above, is defined with a regional emphasis. Within the Wheeler Ridge-Maricopa Management Area, the only critical infrastructure is the California Aqueduct. The California Aqueduct is the backbone of the State Water Project and is vital to the movement of water from northern California to the south. As such, the aqueduct is subject to ongoing subsidence monitoring by the DWR, which is anticipated to continue during the SGMA implementation period.

Recent monitoring has shown some land subsidence impacts to the section of the Aqueduct within the Wheeler Ridge-Maricopa Management Area. Recognizing the importance of the California Aqueduct to regional and statewide water infrastructure, it is considered an Undesirable Result for land subsidence to continue indefinitely in the vicinity of the Aqueduct. That being said, it is also recognized that due to the inherent time lag of the aquitard depressurization process, there may still be some “built-in” subsidence potential that has yet to manifest. It is therefore unrealistic to define the Undesirable Result as “any further land subsidence”, as such an outcome would almost certainly be unavoidable, and therefore would prevent achievement of the Sustainability Goal. Therefore, the Undesirable Result for land subsidence is defined based on exceedance of a Minimum Threshold rate of subsidence which is based on historical observations of subsidence along the California Aqueduct.

Given the variability in subsidence throughout the Wheeler Ridge-Maricopa Management Area, it is appropriate to incorporate a fraction of monitoring sites in the definition of Undesirable Results, similar to how the Undesirable Results definition for Chronic Lowering of Groundwater Levels states that it occurs when Minimum Thresholds for that indicator are exceeded in 40% of Representative Monitoring Sites. For Land Subsidence, it is considered an Undesirable Result if the Minimum Threshold rate is exceeded in 40% or more (i.e., 16 out of 40) of the DWR survey benchmark locations64 between Mileposts 256.14 (Check

__________________________

64 The DWR surveyed benchmark locations at which the Undesirable Results are defined are those within Pools 32 through 35 presented in Table 6-7 of DWR (2017).
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No. 31) and 278.13 (Teerink Pumping Plant). The Minimum Threshold rate is described in Section 14.5 Minimum Threshold for Land Subsidence

13.5.3. Potential Effects of Undesirable Results
Potential effects of Undesirable Results caused by land subsidence on beneficial uses and users of groundwater and overlying land uses within the Wheeler Ridge-Maricopa Management Area would include damage to gravity-driven water conveyance infrastructure (i.e., the California Aqueduct) which could impair its ability to move water to points further south. Land subsidence could also affect non-critical infrastructure such as local water conveyance systems (e.g., the District’s pressure pipeline distribution system) and groundwater well casings, but those land uses are not considered critical infrastructure per the basin-wide definition which emphasizes regional impacts.

13.6. Undesirable Results for Depletions of Interconnected Surface Water
No basin-wide definition of Undesirable Results for Depletions of Interconnected Surface Water has been developed by the Kern Subbasin GSAs. Based on available data and information, depletion of interconnected surface water has not been observed within the Wheeler Ridge-Maricopa Management Area.

13.6.1. Potential Causes of Undesirable Results
Depletion of Interconnected Surface Water is generally correlated to Chronic Lowering of Groundwater Levels in an interconnected groundwater aquifer system. Therefore, the potential causes of Undesirable Results due to Depletion of Interconnected Surface Water are generally the same as the potential causes listed above for Undesirable Results due to Chronic Lowering of Groundwater Levels (i.e., increased groundwater pumping and reduced recharge). However, as discussed above, the degree of hydraulic connection between the principal aquifer and surface water within the Wheeler Ridge-Maricopa Management Area is unknown but suspected to be small based on available water level information. Therefore, there does not appear to be any active potential causes for Undesirable Results due to Depletion of Interconnected Surface Water.

13.6.2. Criteria Used to Define Undesirable Results
As described in Section 8.6 Interconnected Surface Water Systems, there are no major surface water systems that are believed to be interconnected to the underlying groundwater table within the Wheeler Ridge-Maricopa Management Area. Because there is little to no interconnected surface water, no Undesirable Result for Depletion of Interconnected Surface Water is defined within the Management Area.

13.6.3. Potential Effects of Undesirable Results
Potential effects of Undesirable Results of Depletion of Interconnected Surface Water may include reduced surface water flows to support downstream or in-stream uses. As discussed above, there is little
to no interconnected surface water within the Wheeler Ridge-Maricopa Management Area, and therefore no effects from Undesirable Results for this indicator have occurred or are expected to occur within the Management Area.

13.7. Undesirable Results Summary

Table SMC-1 below provides a summary of the local definitions of Undesirable Results for each Sustainability Indicator.

**Table SMC-1. Summary of Undesirable Results Definitions within the Wheeler Ridge-Maricopa Management Area**

<table>
<thead>
<tr>
<th>Sustainability Indicator</th>
<th>Undesirable Results Definition within the Wheeler Ridge-Maricopa Management Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Lowering of Groundwater Levels</td>
<td>Minimum Threshold exceedance in at least 40% (i.e., 6 or more out of 14) of Representative Monitoring Sites over four consecutive seasonal (bi-annual) measurements</td>
</tr>
<tr>
<td>Reduction of Groundwater Storage</td>
<td>No local Undesirable Results definition; Chronic Lowering of Groundwater Levels used as a proxy.</td>
</tr>
<tr>
<td>Seawater Intrusion</td>
<td>No local Undesirable Results definition; Sustainability Indicator not applicable within the Kern Subbasin</td>
</tr>
<tr>
<td>Degraded Water Quality</td>
<td>No local Undesirable Results definition</td>
</tr>
<tr>
<td>Land Subsidence</td>
<td>Subsidence at rates exceeding the Minimum Threshold rate throughout the SGMA implementation period in at least 40% (16 of 40) of subsidence monitoring locations</td>
</tr>
<tr>
<td>Depletion of Interconnected Surface Water</td>
<td>No local Undesirable Results definition; Sustainability Indicator not applicable within the Wheeler Ridge-Maricopa Management Area</td>
</tr>
</tbody>
</table>
14. MINIMUM THRESHOLDS

§ 354.28. Minimum Thresholds

(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.

(b) The description of minimum thresholds shall include the following:

1. The information and criteria relied upon to establish and justify the minimum thresholds for each sustainability indicator. The justification for the minimum threshold shall be supported by information provided in the basin setting, and other data or models as appropriate, and qualified by uncertainty in the understanding of the basin setting.

2. The relationship between the minimum thresholds for each sustainability indicator, including an explanation of how the Agency has determined that basin conditions at each minimum threshold will avoid undesirable results for each of the sustainability indicators.

3. How minimum thresholds have been selected to avoid causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals.

4. How minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests.

5. How state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the Agency shall explain the nature of and basis for the difference.

6. How each minimum threshold will be quantitatively measured, consistent with the monitoring network requirements described in Subarticle 4.

... 

(d) An Agency may establish a representative minimum threshold for groundwater elevation to serve as the value for multiple sustainability indicators, where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence.

(e) An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators.

Minimum Thresholds are the numeric criteria for each Sustainability Indicator that, if exceeded, may cause Undesirable Results. This section describes the Minimum Thresholds that have been developed to avoid Undesirable Results for each applicable Sustainability Indicator in the Wheeler Ridge-Maricopa Management Area, Kern Subbasin.
Management Area. These Minimum Thresholds have been developed in coordination with other KGA members and GSAs within the “south of Kern River” portion of the Kern Subbasin (e.g., Arvin-Edison Water Storage District and the Kern River GSA).

As shown in Table SMC-2, Minimum Thresholds within the Wheeler Ridge-Maricopa Management Area are defined at different spatial scales and locations, or not at all, depending on the Sustainability Indicator. Where appropriate, the Minimum Thresholds for the Sustainability Indicators have been set using groundwater levels as a proxy, based on demonstration “that there is a significant correlation between groundwater levels and the other metrics” (California Department of Water Resources [DWR] Sustainable Management Criteria Best Management Criteria [BMP] document; DWR, 2018).

Table SMC-2. Spatial Scale of Minimum Threshold Definition

<table>
<thead>
<tr>
<th>Sustainability Indicator</th>
<th>Spatial Scale of Minimum Threshold Definition</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Lowering of Groundwater Levels</td>
<td>Sustainability Criteria Zones</td>
<td>There are three Sustainability Criteria Zones defined; Groundwater levels will be measured at 14 Representative Monitoring Sites (i.e., wells)</td>
</tr>
<tr>
<td>Reduction of Groundwater Storage</td>
<td>No Minimum Threshold defined</td>
<td>Chronic Lowering of Groundwater Levels will be used as a proxy</td>
</tr>
<tr>
<td>Seawater Intrusion</td>
<td>No Minimum Threshold defined</td>
<td>Sustainability Indicator not applicable within the Kern Subbasin</td>
</tr>
<tr>
<td>Degraded Water Quality</td>
<td>No Minimum Thresholds defined</td>
<td>Monitoring for groundwater quality at selected locations will continue as part of District agricultural water management and as part of compliance with other regulatory programs</td>
</tr>
<tr>
<td>Land Subsidence</td>
<td>Basin-wide coordinated subsidence monitoring network</td>
<td>Surface elevations will be monitored at a network of benchmarks along the California Aqueduct by DWR and others</td>
</tr>
<tr>
<td>Depletion of Interconnected Surface Water</td>
<td>No Minimum Thresholds defined</td>
<td>Sustainability Indicator not applicable within the Wheeler-Ridge Maricopa Management Area</td>
</tr>
</tbody>
</table>
Sustainable Management Criteria
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14.1. Minimum Threshold for Chronic Lowering of Groundwater Levels

§ 354.28. Minimum Thresholds
(c) Minimum thresholds for each sustainability indicator shall be defined as follows:

(1) Chronic Lowering of Groundwater Levels. The minimum threshold for chronic lowering of groundwater levels shall be the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results. Minimum thresholds for chronic lowering of groundwater levels shall be supported by the following:

(A) The rate of groundwater elevation decline based on historical trends, water year type, and projected water use in the basin.
(B) Potential effects on other sustainability indicators.

Chronic Lowering of Groundwater Levels is arguably the most fundamental Sustainability Indicator, as it influences several other key Sustainability Indicators, including Reduction of Groundwater Storage, Land Subsidence, and in certain ways, Degraded Water Quality. Groundwater levels are also the most readily available and measurable metrics of groundwater conditions, which allows for a systematic, data-driven approach to development of Minimum Thresholds to be applied. There are no state, federal, or local standards that relate to this Sustainability Indicator.

14.1.1. Minimum Threshold Development

Consistent with the GSP Emergency Regulations (23-CCR § 354.28(c)), the definition of Minimum Thresholds for Chronic Lowering of Groundwater Levels in the Wheeler Ridge-Maricopa Management Area is based on consideration of trends in historical groundwater levels, water year types, projected water use in the management area, and the relationship to other Sustainability Indicators. Specifically, the information and criteria relied on to establish the Minimum Thresholds for Chronic Lowering of Groundwater Levels includes:

- Historical water level data from selected wells with long-term representative water level records;
- The proximity to critical infrastructure (i.e., for consideration of potential land subsidence impacts); and
- Well construction information.

65 The representativeness of the wells with long-term hydrograph records is illustrated on Figure SMC-1, which shows the Fall 2015 groundwater level at each well compared to the average groundwater elevation by Public Land Survey System (PLSS) section for all sections “associated with” (i.e., closest to) each long-term hydrograph location. The figure shows that the percent difference in water level in the local area around each well is small in most cases, indicating that the well is representative of that local area.
This information was used to develop initial Minimum Threshold estimates using a quantitative algorithm that accounted for trends, historical lows, and water level variability (discussed below) and then these initial estimates were mapped and generalized spatially to create three “Sustainability Criteria Zones” within the Wheeler Ridge-Maricopa Management Area. This approach allowed for the most complete and representative historical water level information to inform the Minimum Thresholds, while also allowing for potentially different wells (i.e., other than those with the best historical records) to be used as Representative Monitoring Sites.

**Minimum Threshold Algorithm**

The initial Minimum Threshold estimates for Chronic Lowering of Groundwater Levels were developed for each long-term hydrograph well location through development and application of an algorithm that considers the above information, as follows:

- **Historical low water levels** over a relevant time period are used as a starting point for Minimum Thresholds based on the fact that significant and unreasonable impacts to beneficial uses and users of groundwater due to groundwater levels are not known to have occurred since the time when water levels were at their historical low. The relevant time period for historical low determination is defined as Water Year (WY) 1966 - 2018 for the following reasons:
  - The assumed upper-end usable lifespan of groundwater wells is approximately 50 years, and therefore most wells would likely not have experienced conditions prior to about 50 years ago;
  - The WRMWSD started surface water importation in 1971, and AEWSD (which overlaps WRMWSD in the eastern portion of the management area) began importing water in 1966. These actions represented a significant change to water management in this part of the Kern Subbasin; and
  - The relevant time period includes conditions observed up to “present” (Fall 2018).

- **Variability in groundwater levels** is accounted for by calculating a Variability Correction Factor as the product of the observed water level range over a relevant time period and a “Range Fraction”. This Variability Correction Factor is applied to the historical low (as discussed below) and acknowledges the fact that different locations within the Wheeler Ridge-Maricopa Management Area have experienced different amounts of water level variability.
  - The time period for water level range determination is defined as WY 1995 – 2015 for the following reasons:
    - The 21-year length of this period is roughly the same as the 20-yr SGMA implementation period, and therefore the SGMA implementation period is expected to include a similar range of variability as the groundwater level range period;
The period includes a mix of wet and dry years and so variability in groundwater levels during this time should be reflective of variable climate;

- The period is climatically close to the long-term average for precipitation and Kern River Flow (Todd Groundwater, 2016); and

- This period is the same as the historical and current water budget period of interest defined by KGA and its member agencies, and therefore water budget and model results are available for this period.

  - The Range Fraction is set at 25% as a conservative allowance for water level fluctuation within a well.

- Recent trends in groundwater levels and projected water use are accounted for by extending the trend for a certain amount of time (the “Trend Extension Period”) to determine a Trend Continuation Factor. This factor is also applied to historical low water levels (as discussed below) in order to avoid rapid disruption to land uses and allow time for implementation of any Projects and/or Management Actions needed to eliminate declining trends.

  - The time period for water level trend calculation is defined as WY 2009 – 2018 for the following reasons:

    - This period reflects the effects of changes to SWP/CVP deliveries resulting from Delta-related federal District Court rulings; and

    - The period includes the recent significant drought, and therefore allows the Trend Continuation Factor to incorporate the possibility of another long-term drought in the future (e.g., potentially exacerbated by climate change), consistent with the basin-level Undesirable Results definition for Reduction in Groundwater Storage.

  - The Trend Extension Period was set to ten years for the following reasons:

    - This length of time is considered reasonable and necessary to implement the various Projects & Management Actions that may be required to reverse declining groundwater level trends, in consideration of the potential regulatory, environmental, logistical, engineering, socioeconomic and other challenges that the various Projects & Management Actions may entail, as well as the time that such measures would likely take to manifest in observed groundwater level conditions; and

    - This length of time is half the duration of the SGMA implementation period, suggesting that by the halfway point, the Wheeler Ridge-Maricopa Management Area should be on a trajectory towards achieving the Sustainability Goal.
Using the above values (i.e., the Historical Low, the Variability Correction Factor, and the Trend Continuation Factor), the initial Minimum Threshold estimates for Chronic Lowering of Groundwater Levels at each long-term hydrograph location are calculations as the lower of: (a) the historic low groundwater level minus the Variability Correction Factor, and (b) the recent (Fall 2015) groundwater level minus the greater of either the Variability Correction Factor or the Trend Continuation Factor. In mathematical terms, the algorithm for defining the initial Minimum Threshold estimates for Chronic Lowering of Groundwater Levels at each long-term hydrograph location is as follows:

\[
MT = \min \left\{ HL - VCF, \text{Recent} - \max \{VCF, TCF\} \right\}
\]

\[
VCF = Range \times 25\%
\]

\[
TCF = Trend \times 10 \text{ yrs}
\]

where:

- \(MT\) is the initial Minimum Threshold estimate (ft msl),
- \(HL\) is the historical low groundwater level over the WY 1965 – 2018 period (ft msl),
- \(VCF\) is the Variability Correction Factor (ft),
- \(TCF\) is the Trend Continuation Factor (ft),
- \(Recent\) is the Fall 2015 groundwater level (ft msl),
- \(Range\) is the water level range over the WY 1995 – 2015 period, and
- \(Trend\) is the groundwater level trend over the 2009 – 2015 period (ft/yr).

**Adjustment in Areas Proximal to Critical Infrastructure**

In areas proximal to critical infrastructure that may be particularly sensitive to significant and unreasonable effects from land subsidence (discussed further below), an adjustment to the initial Minimum Threshold estimates was applied in the algorithm to keep the values at historical low groundwater levels. Specifically, for long-term hydrograph locations that were within one mile of critical infrastructure, the initial Minimum Threshold estimates were set to their historical low groundwater levels, as this theoretically prevents any further subsidence from occurring. Results from the initial Minimum Threshold estimation exercise described above are shown on Figure SMC-2. Also shown on this figure are the proposed Sustainability Criteria Zones defined within the Wheeler Ridge-Maricopa Management Area which are discussed below.
Spatial Generalization into Sustainability Criteria Zones

Once the initial Minimum Threshold estimates for the long-term hydrograph locations were calculated using the algorithm described above, they were plotted on a map and examined for spatial patterns that could be used to generalize the values into zones. The purpose of this step was to allow flexibility in the selection of Representative Monitoring Sites for this Sustainability Indicator, recognizing that not all of the wells with long-term hydrograph data are available for use in the monitoring network. It was determined that the Wheeler Ridge-Maricopa Management Area could be divided into three zones, referred to as the Western, Northeastern, and Southeastern zones, as shown on Figure SMC-2. The Minimum Threshold Values for each Sustainability Criteria Zone is shown on Figure SMC-3.

As part of the delineation of Sustainability Criteria Zones within the Wheeler Ridge-Maricopa Management Area, an analysis was performed regarding potential well impacts associated with various Minimum Threshold values. Using available well construction information for domestic, production (agricultural), and public supply wells, an assessment was made of the number of wells which would be dewatered at different generalized Minimum Threshold levels. Through this analysis which was performed iteratively with different Minimum Threshold levels, it was determined that the final Minimum Thresholds would not likely have unreasonable impacts on wells (i.e., only seven wells would potentially be dewatered, throughout the Management Area). Results from this well impact analysis of Minimum Thresholds are shown on Figure SMC-4 and Figure SMC-5 for the Sustainability Criteria Zones and the PLSS sections, respectively.

The final Minimum Thresholds for Chronic Lowering of Groundwater Levels in each Sustainability Criteria Zone and at each Representative Monitoring Site are shown in Table SMC-3 and on Figure SMC-3.

14.2. Minimum Threshold for Reduction of Groundwater Storage

As discussed above, the Undesirable Results definition for Reduction of Groundwater Storage at the basin level refers to a decrease in storage that would cause water levels to decline below Minimum Thresholds established in each management area for Chronic Lowering of Groundwater Levels. It is logical to tie these two Sustainability Indicators together, as the amount of groundwater in storage is directly, if not linearly,
related to groundwater levels. Because of the close relationship between these two Sustainability Indicators, and because the Minimum Thresholds for Chronic Lowering of Groundwater Levels (discussed above) are protective of the beneficial uses and users of groundwater, it is not necessary to set a unique Minimum Threshold for Reduction of Groundwater Storage. Rather, Minimum Thresholds for Chronic Lowering of Groundwater Levels will be used as a proxy for the Reduction of Groundwater Storage Sustainability Indicator. There are no state, federal, or local standards that relate to this Sustainability Indicator.

14.2.1. Usable Storage

To support the use of Minimum Thresholds for Chronic Lowering of Groundwater Levels as a proxy for Reduction of Groundwater Storage, it is informative to define an actual volume of “usable storage” above the median bottom depth of wells. This volume is calculated based on the following data and assumptions:

- Area of Wheeler Ridge-Maricopa Management Area (92,343 acres)
- Storage coefficient (0.08)\(^{66}\)
- Average depth to groundwater in Fall 2015 (approximately 303 ft)
- Depth corresponding to the 50% cumulative bottom depth of wells (approximately 1,100 ft)

The volume of usable storage is approximately 5.9 million AF. This volume corresponds to the volume that would be pumped in roughly 100 years of pumping at the average rate pumped from WY 1995 through 2015 (i.e., 59,152 AFY).

14.2.2. Use of Groundwater Levels as Proxy

Pursuant to the GSP Emergency Regulations (23-CCR § 354.28(d)) and as further described in the DWR Sustainable Management Criteria BMP, Minimum Thresholds for Reduction of Groundwater Storage may be set by using groundwater levels as a proxy if it is demonstrated that a correlation exists between the two metrics. One approach to using groundwater levels as a proxy, described in the DWR Sustainable Management Criteria BMP, is to demonstrate that Minimum Thresholds for Chronic Lowering of Groundwater Levels are sufficiently protective to ensure prevention of significant and unreasonable occurrences of the Sustainability Indicator in question.

To demonstrate that the Minimum Thresholds for Chronic Lowering of Groundwater Levels are sufficiently protective, a calculation was performed to determine the volume of groundwater that would be removed from the primary aquifer if groundwater levels were to decline from current (Fall 2015) levels to their respective Minimum Thresholds for Chronic Lowering of Groundwater Level. This volume is then compared to the volume of usable storage, and it is shown that there is more usable storage is greater, \(^{66}\)There is uncertainty in the value for the storage coefficient used in the above calculations, as discussed in Section 7.1.4 Principal Aquifers and Aquitards. However, the value of 0.08 is considered conservative.
and therefore, the Minimum Thresholds for Chronic Lowering of Groundwater Levels are protective for the Reduction of Groundwater Storage Sustainability Indicator.

This volume is calculated for each PLSS section by subtracting the Minimum Threshold from the associated Sustainability Criteria Zone from the “current” (Fall 2015) gridded groundwater elevation data, multiplying the difference by the storage coefficient, and then summing the values for each PLSS section to arrive at a total volume for the entire Wheeler Ridge-Maricopa Management Area. This calculation is shown in the equation below:

\[
MT\_\text{Stor} = \sum_{k=1}^{n} (GW_{L_i} - MT\_GW_{L_i}) \times A_k \times S_k
\]

where:

- \(MT\_\text{Stor}\) is the Minimum Threshold for Reduction of Groundwater Storage (AF),
- \(GW\_L\) is the current groundwater elevation (ft msl),
- \(MT\_GW\_L\) is the Minimum Threshold for Chronic Lowering of Groundwater Levels within the Sustainability Criteria Zone (subscript \(i\)) (ft msl),
- \(A\) is the area (acres), and
- \(S\) is the storage coefficient (dimensionless). The subscript \(k\) refers to each PLSS section (a total of \(n\) sections within the Wheeler Ridge-Maricopa Management Area).

The resulting volume is approximately 1.08 million AF which is much less than the 5.9 million AF of “usable storage”. Therefore, the Minimum Thresholds for Chronic Lowering of Groundwater Levels are sufficiently protective to ensure prevention of significant and unreasonable occurrences of Reduction of Groundwater Storage. Therefore, no Minimum Threshold for Reduction of Groundwater Storage is set within the Wheeler Ridge-Maricopa Management Area.
14.3. Minimum Threshold for Seawater Intrusion

§ 354.28. Minimum Thresholds

(c) Minimum thresholds for each sustainability indicator shall be defined as follows:

(3) Seawater Intrusion. The minimum threshold for seawater intrusion shall be defined by a chloride concentration isocontour for each principal aquifer where seawater intrusion may lead to undesirable results. Minimum thresholds for seawater intrusion shall be supported by the following:

(A) Maps and cross-sections of the chloride concentration isocontour that defines the minimum threshold and measurable objective for each principal aquifer.

(B) A description of how the seawater intrusion minimum threshold considers the effects of current and projected sea levels.

The GSP Emergency Regulations state that “An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators” (23-CCR § 354.28(e)). Because the Kern Subbasin is not located near any saline water bodies, seawater intrusion is not present and not likely to occur. Therefore, the Seawater Intrusion Sustainability Indicator is not applicable to the Kern Subbasin and no SMCs for this Sustainability Indicator are defined in the Wheeler Ridge-Maricopa Management Area.

14.4. Minimum Threshold for Degraded Water Quality

§ 354.28. Minimum Thresholds

(c) Minimum thresholds for each sustainability indicator shall be defined as follows:

(4) Degraded Water Quality. The minimum threshold for degraded water quality shall be the degradation of water quality, including the migration of contaminant plumes that impair water supplies or other indicator of water quality as determined by the Agency that may lead to undesirable results. The minimum threshold shall be based on the number of supply wells, a volume of water, or a location of an isocontour that exceeds concentrations of constituents determined by the Agency to be of concern for the basin. In setting minimum thresholds for degraded water quality, the Agency shall consider local, state, and federal water quality standards applicable to the basin.

The GSP Emergency Regulations state that “An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators” (23-CCR § 354.28(e)). As discussed above, based on the existing beneficial uses
and users of groundwater within the Wheeler Ridge-Maricopa Management Area, there are not Undesirable Results for Degraded Water Quality occurring and the Minimum Thresholds for Chronic Lowering of Groundwater Level are anticipated to be protective in terms of preventing migration of poor-quality water. Therefore, no unique Minimum Thresholds are set for this Sustainability Indicator. It should be noted, however, that monitoring for water quality will be conducted at a set of Representative Monitoring Site locations, as discussed further in Section 16.1.4 Monitoring Network for Degraded Water Quality.

14.5. Minimum Threshold for Land Subsidence

Minimum Thresholds for Land Subsidence are defined herein as levels of land subsidence that, if they occurred, would result in significant and unreasonable impacts to critical infrastructure and surface land uses. There are no state, federal, or local standards that relate to this Sustainability Indicator.

Within the Wheeler Ridge-Maricopa Management Area, the critical infrastructure that has the potential to be significantly and unreasonably impacted by land subsidence includes the California Aqueduct. While certain other land uses exist within the Management Area that are potentially affected by land subsidence (see Section 13.5 Undesirable Results for Land Subsidence), the Aqueduct is considered the most critical to avoid Undesirable Results from land subsidence in the Management Area because it is associated with the regional water supply system as well as the central mission of WRMWSD which is the importation and delivery of surface water.

14.5.1. Minimum Threshold Development

Historical and recent rates of subsidence measured within the Wheeler Ridge-Maricopa Management Area in proximity to the sensitive land uses listed above are discussed in Section 8.5 Land Subsidence. The Minimum Threshold rate for Land Subsidence is defined herein based on the maximum rate of subsidence.
observed through ground-based surveys between 1993 and 2013 at survey benchmarks along the California Aqueduct. The Minimum Threshold amount of subsidence is defined as the amount that would occur if the Minimum Threshold rate were extended forward until the end of the SGMA implementation timeline (i.e., to 2040). Specifically, the Minimum Threshold for Land Subsidence is calculated as follows:

$$MT_{Sub} = Max\_rate\_Aqueduct \times t\_impl$$

where:

- $MT_{Sub}$ is the Minimum Threshold for Land Subsidence as a cumulative amount (in),
- $Max\_rate\_Aqueduct$ is the maximum average rate of subsidence between 1993 and 2013 observed at any survey benchmark along the California Aqueduct between Mileposts 256.14 (Check No. 31) and 278.13 (Teerink Pumping Plant), equal to 0.42 inches per year, and
- $t\_impl$ is time from 2019 until the end of the SGMA GSP implementation timeframe (2040), equal to 22 years.

The rationale for this Minimum Threshold rate of subsidence is that such subsidence has been historically managed by DWR through maintenance and improvements to its facilities. Within the Wheeler Ridge-Maricopa Management Area, as of 2013 there are no reaches of the Aqueduct that have less than the minimum recommended freeboard (2.5 ft); the minimum freeboard is approximately 3.9 ft in one location around milepost 256.56, and along most other portions of these reaches the freeboard is between 6 and 8 feet (DWR, 2017).

### 14.5.2. Final Minimum Thresholds

The final Minimum Thresholds for Land Subsidence are shown in Table SMC-4 below. The Minimum Threshold applies to all 40 DWR survey benchmark locations between Mileposts 256.56 (Check No. 31) and 278.13 (Teerink Pumping Plant). Additional information about the representative monitoring sites for this Sustainability Indicator is provided in Section 16 Monitoring Network.

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67 Satellite-based land subsidence measurements (i.e., InSAR data) indicate recent subsidence of 1 to 4 inches between May 2015 and September 2016, with localized amounts of between 4 and 8 inches (see Figure GWC-15). However, this data collected method, while useful for spatial understanding of subsidence patterns, is considered less accurate at any given location than ground-based survey methods, and for purposes of subsidence monitoring near critical infrastructure, ground-based survey methods will be used. Therefore, the ground-based survey data collected by DWR along the California Aqueduct are used herein to define Minimum Thresholds for Land Subsidence in the vicinity of critical infrastructure.

68 The maximum rate of subsidence between 1993 and 2013 of 0.42 inches per year was observed at Milepost 257.63.
Table SMC-4. Minimum Thresholds for Land Subsidence

<table>
<thead>
<tr>
<th>Minimum Threshold Component</th>
<th>Minimum Threshold Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsidence Rate</td>
<td>0.42 inches per year</td>
<td></td>
</tr>
<tr>
<td>Total Subsidence Amount</td>
<td>9.24 inches</td>
<td>From 2019 through 2040</td>
</tr>
</tbody>
</table>

It should be noted that the Minimum Thresholds for Chronic Lowering of Groundwater Levels include consideration of land subsidence by limiting the Minimum Thresholds to the historical low groundwater levels in those representative monitoring sites that are within one mile of critical infrastructure (see Section 14.1 Minimum Threshold for Chronic Lowering of Groundwater Levels). While groundwater level measurements are not being used as a proxy for land subsidence measurements in these areas (i.e., the land subsidence monitoring network will consist of survey benchmark locations maintained and measured by DWR), these Minimum Thresholds for Chronic Lowering of Groundwater Levels are set conservatively to avoid further land subsidence.

14.6. Minimum Threshold for Depletion of Interconnected Surface Water

§ 354.28. Minimum Thresholds

(c) Minimum thresholds for each sustainability indicator shall be defined as follows:

(6) Depletions of Interconnected Surface Water. The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results. The minimum threshold established for depletions of interconnected surface water shall be supported by the following:

(A) The location, quantity, and timing of depletions of interconnected surface water.

(B) A description of the groundwater and surface water model used to quantify surface water depletion. If a numerical groundwater and surface water model is not used to quantify surface water depletion, the Plan shall identify and describe an equally effective method, tool, or analytical model to accomplish the requirements of this Paragraph.

The GSP Emergency Regulations state that “An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators” (23-CCR § 354.28(e)). As discussed above, based on available data and information, Depletion of Interconnected Surface Water has not been observed within the Wheeler Ridge-
Maricopa Management Area. Therefore, there are no Undesirable Results and no Minimum Thresholds defined for this Sustainability Indicator.
15. MEASURABLE OBJECTIVES AND INTERIM MILESTONES

§ 354.30. Measurable Objectives

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

(b) Measurable objectives shall be established for each sustainability indicator, based on quantitative values using the same metrics and monitoring sites as are used to define the minimum thresholds.

(c) Measurable objectives shall provide a reasonable margin of operational flexibility under adverse conditions which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty.

(d) An Agency may establish a representative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence.

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

(f) Each Plan may include measurable objectives and interim milestones for additional Plan elements described in Water Code Section 10727.4 where the Agency determines such measures are appropriate for sustainable groundwater management in the basin.

(g) An Agency may establish measurable objectives that exceed the reasonable margin of operational flexibility for the purpose of improving overall conditions in the basin, but failure to achieve those objectives shall not be grounds for a finding of inadequacy of the Plan.

15.1. Measurable Objective and Interim Milestones for Chronic Lowering of Groundwater Levels

Initial estimates for Measurable Objectives for Chronic Lowering of Groundwater Levels were developed based on the groundwater levels that were observed in the 16 long-term hydrograph locations in or around Fall 2015. As with the Minimum Thresholds, the initial Measurable Objective estimates were then adjusted and generalized into values for each Sustainability Criteria Zone. The adjustments and generalizations generally entail decreasing the Measurable Objective for the zone relative to the fall 2015 levels. The downward adjustments were made in recognition of the fact that in most cases groundwater
levels in 2015 were not near their historical low, and therefore an ample Margin of Operational Flexibility could be achieved even with levels lower than they were in 2015. Also, considering the potential for reduced surface water imports in the future and potentially increased groundwater use, it was considered appropriate to set the Measurable Objectives to allow for some decrease from 2015 levels. Measurable Objectives for Chronic Lowering of Groundwater Levels for each Sustainability Criteria Zone and at each Representative Monitoring Site are shown in Table SMC-3 and Figure SMC-6.

15.1.1. Interim Milestones for Chronic Lowering of Groundwater Levels

Interim Milestones for Chronic Lowering of Groundwater Levels are defined herein based on a trajectory for groundwater levels informed by the current (Fall 2018) levels, the Minimum Thresholds, and the Measurable Objectives. This trajectory allows for and assumes a continuation of current groundwater level trends for the first 5-year period, a deviation from that trend over the second 5-year period, a recovery to the 5-year Interim Milestone in the third 5-year period, and recovery towards the Measurable Objectives over the fourth (last) 5-year period. Specifically, the trajectory for groundwater levels prescribed in the Interim Milestones is as follows:

Table SMC-5. Interim Milestone Trajectory for Chronic Lowering of Groundwater Levels

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>Interim Milestone for Chronic Lowering of Groundwater Levels</th>
<th>Basis for Interim Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>2025</td>
<td>IM-5</td>
<td>( \frac{1}{2} \times (GWL_{F2018} + MT_{GWL}) )</td>
</tr>
<tr>
<td>2030</td>
<td>IM-10</td>
<td>( \frac{1}{2} \times (IM-5 + MT_{GWL}) )</td>
</tr>
<tr>
<td>2035</td>
<td>IM-15</td>
<td>( \frac{1}{2} \times (IM-10 + MO_{GWL}) )</td>
</tr>
<tr>
<td>2040</td>
<td>Not applicable (Measurable Objective)</td>
<td>Not applicable (Measurable Objective)</td>
</tr>
</tbody>
</table>

where:

IM-5, IM-10, and IM-15 are the Interim Milestones for Chronic Lowering of Groundwater Levels after 5 years, 10 years and 15 years, respectively;

\( GWL_{F2018} \) is the groundwater elevation measured in Fall 2018;

\( MT_{GWL} \) is the Minimum Threshold for Chronic Lowering of Groundwater Levels (defined previously; see Table SMC-3); and

\( MO_{GWL} \) is the Measurable Objective for Chronic Lowering of Groundwater Levels (defined previously; see Table SMC-3)
15.2. Measurable Objective for Reduction of Groundwater Storage

As discussed above, the Undesirable Results definition for Reduction of Groundwater Storage at the basin level refers to a decrease in storage that would cause water levels to decline below Minimum Thresholds established in each management area for Chronic Lowering of Groundwater Levels. It is logical to tie these two Sustainability Indicators together, as the amount of groundwater in storage is directly, if not linearly, related to groundwater levels. Because of the close relationship between these two Sustainability Indicators, it is not necessary to set a unique Measurable Objective for Reduction of Groundwater Storage. As stated above, the Measurable Objectives for Chronic Lowering of Groundwater Levels provide an adequate Margin of Operational Flexibility.

15.3. Measurable Objective for Seawater Intrusion

The GSP Emergency Regulations state that “An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators” (23-CCR § 354.28(e)). Because the Kern Subbasin is not located near any saline water bodies, and seawater intrusion is not present and not likely to occur, the Seawater Intrusion Sustainability Indicator is not applicable to the Kern Subbasin, and therefore no SMCs for this Sustainability Indicator are defined.

15.4. Measurable Objective for Degraded Water Quality

As discussed above, based on the existing beneficial uses and users of groundwater within the Wheeler Ridge-Maricopa Management Area, there are not Undesirable Results for Degraded Water Quality occurring and the Minimum Thresholds for Chronic Lowering of Groundwater Level are anticipated to be protective. Therefore, no unique Minimum Thresholds or Measurable Objectives are set for this Sustainability Indicator.

15.5. Measurable Objective for Land Subsidence

The Measurable Objective for Land Subsidence is defined as half of the amount of land subsidence that would be observed if historical subsidence rates were to continue. This corresponds to a total amount of subsidence by 2040 of no more than 4.62 inches in no more than 40% of the Representative Monitoring Sites. While ideally there would be no further land subsidence along the Aqueduct, as stated above, due to the inherent time lag of the aquitard depressurization process, there may still be some “built-in” subsidence potential that has yet to manifest. Therefore, it is not considered reasonable to expect an immediate and complete cessation to the historic subsidence rates. Rather, it is considered a reasonable
and potentially achievable goal to reduce the historical rate by half over the SGMA implementation period (i.e., by 2040).

15.6. Measurable Objective for Depletions of Interconnected Surface Water

As discussed above, based on available data and information, Depletion of Interconnected Surface Water has not been observed within the Wheeler Ridge-Maricopa Management Area. Therefore, there are no SMCs defined for this Sustainability Indicator.
### TABLE SMC-3
Summary of Minimum Thresholds, Interim Milestones, and Measurable Objectives for Chronic Lowering of Groundwater Levels

Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

<table>
<thead>
<tr>
<th>Representative Monitoring Site ID</th>
<th>Sustainability Criteria Zone</th>
<th>Minimum Threshold (ft msl)</th>
<th>Interim Milestones (ft msl)</th>
<th>Measurable Objective (ft msl)</th>
<th>Margin of Operational Flexibility (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11N22W06H001S</td>
<td>Western</td>
<td>100</td>
<td>184 142 171 200</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>32S25E29Q001M</td>
<td>Western</td>
<td>100</td>
<td>195 147 174 200</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>32S26E20G001M</td>
<td>Northeastern</td>
<td>-50</td>
<td>33  -8  -4  0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>32S26E24K001M</td>
<td>Northeastern</td>
<td>-50</td>
<td>33  -8  -4  0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>32S27E30N001M</td>
<td>Northeastern</td>
<td>-50</td>
<td>93  21  11  0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>32S27E35R001M</td>
<td>Northeastern</td>
<td>-50</td>
<td>49  -1  0  0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>32S26E34P001M</td>
<td>Northeastern</td>
<td>-50</td>
<td>68  9  4  0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>32S26E36P002M</td>
<td>Northeastern</td>
<td>-50</td>
<td>63  6  3  0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>32S28E16P001M</td>
<td>Northeastern</td>
<td>-50</td>
<td>111 30 15 0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>11N22W01D001S</td>
<td>Southeastern</td>
<td>0</td>
<td>93  47 61 75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>11N21W16E001S</td>
<td>Southeastern</td>
<td>0</td>
<td>3  2  38 75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>12N21W36N001S</td>
<td>Southeastern</td>
<td>0</td>
<td>100 50 62 75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>12N21W34Q001S</td>
<td>Southeastern</td>
<td>0</td>
<td>62  31 53 75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>11N21W09C001S</td>
<td>Southeastern</td>
<td>0</td>
<td>80  40 58 75</td>
<td>75</td>
<td>75</td>
</tr>
</tbody>
</table>

**Abbreviations:**
- ft = feet
- ft msl = feet above mean sea level
Legend

- WRMWSD Service Area
- Long-Term Hydrograph Well
- Representative Coverage Area

Groundwater Subbasin

- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Normalized Difference (% of GWE Range)

Factors:

- Groundwater Subbasin
- Groundwater Elevation (ft msl)

Notes

1. All locations are approximate.
2. "Normalized Difference" is defined herein as the difference between the Fall 2015 GWE at the RML and the average Fall 2015 GWE within each section, divided by the total range of Fall 2015 GWE within the WRMWSD Kern Management Area.
3. Negative normalized differences (i.e. where the GWE at RML is less than the average Fall 2015 GWE within the section), are represented in green as these sections have an RML that is considered "overprotective" of local water level conditions.

Abbreviations

- GWE = Groundwater Elevation
- DWR = California Department of Water Resources
- ft msl = feet above mean sea level
- PLSS = Public Land Survey System
- RML = Representative Monitoring Location
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 19 March 2019.

Representativeness of Long-Term Hydrograph Locations

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
March 2019
DRAFT

Figure SMC-1
Groundwater Subbasin
Kern County (DWR 5-022.14)
White Wolf (DWR 5-022.18)

Abbreviations
DWR = California Department of Water Resources
ft Igs = feet below ground surface
ft msal = feet above mean sea level
MO = Measurable Objective
MT = Minimum Threshold
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. Water levels that showed a rate of change between consecutive measurements greater than 50 ft in 60 days, or a significant change without a reasonable hydrological explanation, were removed from the hydrographs.

Sources
1. Base map is ESRI's ArcGIS Online world topographic map, obtained 8 August 2019.
2. Groundwater elevation data provided by WRMWSD on 8 December 2017.

Groundwater Level (ft msl)
-100 0 100 200 300 400
Western Zone
Northeastern Zone
Kern County (DWR 5-022.14)
WRMWSD Service Area
MO
MT
Trend Period (1/09 - 11/15)
Range Period (10/94 - 9/15)

Figure SMC-2
Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
August 2019
B70103.01
Figure SMC-2
Legend:
- WRMWSD Service Area
- Long-Term Hydrograph Well
- Groundwater Subbasin
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Sustainability Criteria Zones:
- Northeastern Zone
- Southeastern Zone
- Western Zone

<table>
<thead>
<tr>
<th>Zone</th>
<th>Water Level</th>
<th># of Wells Dewatered</th>
<th>% of Wells Dewatered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western</td>
<td>MO</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>MT</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>Northeastern</td>
<td>MO</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>MT</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>Southeastern</td>
<td>MO</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>MT</td>
<td>3</td>
<td>5%</td>
</tr>
</tbody>
</table>

Abbreviations:
- DWR = California Department of Water Resources
- ft bgs = feet below ground surface
- KGA = Kern Groundwater Authority
- MO = Minimum Objective
- MT = Maximum Threshold
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes:
1. All locations are approximate.
2. FTs and MOs are defined as elevations, and are displayed on the bar graphs as their average depth (ft bgs) within all representative sections.
3. A "dewatered well" is considered to be a well whose total depth is less than the MT specified for the given sustainability criteria zone.
4. Wells displayed in grey were already dewatered relative to Fall 2015 groundwater conditions and are thus not included in the count of dewatered wells.

Sources:
2. Well info obtained from KGA on 21 November 2018.
Preliminary Well Impact Analysis by PLSS Section

Legend

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRMWSD Service Area</td>
<td></td>
</tr>
<tr>
<td>Sustainability Criteria Zones</td>
<td></td>
</tr>
<tr>
<td>Kern County (DWR 5-022.14)</td>
<td></td>
</tr>
<tr>
<td>White Wolf (DWR 5-022.18)</td>
<td></td>
</tr>
</tbody>
</table>

**Groundwater Subbasin**

Kern County (DWR 5-022.14)

White Wolf (DWR 5-022.18)

**Count of Wells Dewatered at Minimum Threshold**

<table>
<thead>
<tr>
<th>Category</th>
<th>Total Dewatered</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Supply Wells</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Domestic Wells</td>
<td>3 (11%)</td>
<td></td>
</tr>
<tr>
<td>Production Wells</td>
<td>2 (2%)</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**

1. All locations are approximate.
2. A "dewatered well" is considered to be a well whose total depth is less than the MT specified for the given sustainability criteria zone.
3. Wells that were already dewatered relative to Fall 2015 groundwater conditions are not included in the count of dewatered wells.

**Abbreviations**

DWR = California Department of Water Resources
MT = Minimum Threshold
N/A = Not Applicable
PLSS = Public Land Survey System
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

**Sources**

1. Well count and depth statistics from Well Completion Report Map Application, obtained on 19 October 2018, website: https://dwr.maps.arcgis.com/apps/webappviewer/index.html?id=18107858a214c0986e2da28f8623b37
2. Basemap is ESRI's ArcGIS Online world topographic map, obtained 19 March 2019.

**Figure SMC-5**
North Canal Spreading Works

Abbreviations
- DWR = California Department of Water Resources
- ft msl = feet above mean sea level
- MO = Measurable Objective
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 12 August 2019.

Legend
- Representative Monitoring Site
- WRMWSD Service Area
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Groundwater Subbasin
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Sustainability Criteria Zones
- Northeastern Zone
- Southeastern Zone
- Western Zone
Figure SMC-7

Legend
- Representative Monitoring Well
- WRMWSD Service Area

Groundwater Subbasin
- Kern County (DWR 5-022.14)
- White Wolf (DWR 5-022.18)

Sustainability Criteria Zones
- Northeastern Zone
- Southeastern Zone
- Western Zone

Hydrograph
Groundwater Level (ft msl)
- 100
- 200
- 300
- 400
- 500
- 600
- -100

Notes
1. Elevations are approximate.
2. Representative Monitoring Well 32S28E16P001M does not have a historical water level record and is thus not displayed on the map.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 12 August 2019.
2. Groundwater elevation data provided by WRMWSD on 26 September 2018.

Abbreviations
- DWR = California Department of Water Resources
- ft = foot
- IM = Interim Milestone
- MO = Measurable Objective
- MT = Minimum Threshold
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Water Level
- Interim Milestones

Wheeler Ridge-Maricopa Water Storage District
Kern County, CA
August 2019
B70103.01
Figure SMC-7
MONITORING NETWORK
This section describes the monitoring network designed for the Wheeler Ridge-Maricopa Management Area, subsequently referred to as the “SGMA Monitoring Network”. Pursuant to the GSP Emergency Regulations (23-CCR Division 2 Chapter 1.5 Subchapter 2), the SGMA Monitoring Network objective is to collect sufficient data for the correct assessment of the Sustainability Indicators relevant to the Management Area (see Section 13 Undesirable Results), and the impacts to the beneficial users of groundwater. Per 23-CCR § 354.32(e), the SGMA Monitoring Network incorporates elements from the existing monitoring programs occurring within the Management Area (see Section 5.2.1 Existing Monitoring and Management Programs) and includes additional components to comply with the GSP Emergency Regulations. All monitoring will be performed in accordance with the protocols agreed upon for the Basin, as described the KGA Umbrella GSP.
16.1. Description of Monitoring Network

§ 354.34. Monitoring Network

(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.

(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.

... 

(d) The monitoring network shall be designed to ensure adequate coverage of sustainability indicators. If management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the basin setting and sustainable management criteria specific to that area.

(e) A Plan may utilize site information and monitoring data from existing sources as part of the monitoring network.

(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.
Pursuant to 23-CCR § 354.32(a)-(b), the objective of the Wheeler Ridge-Maricopa Management Area SGMA Monitoring Network is to collect data with sufficient temporal frequency and spatial density necessary to evaluate Plan implementation as it relates to:

- Monitoring short-term, seasonal, and long-term trends in groundwater and related surface water conditions (see Section 8 Current and Historical Groundwater Conditions);
- Demonstrating progress toward achieving measurable objectives described in the Plan (see Section 15 Measurable Objectives and Interim Milestones);
- Monitoring impacts to the beneficial uses and users of groundwater (see Section 5.5.1 Beneficial Uses and Users of Groundwater);
- Monitoring changes in groundwater conditions relative to Measurable Objectives (see Section 15 Measurable Objectives and Interim Milestones) and Minimum Thresholds (see Section 14 Minimum Thresholds); and
- Quantifying annual changes in water budget components (see Section 9 Water Budget Information).
Pursuant to 23-CCR § 354.32(d) and § 354.32(j), the Representative Monitoring Network consists of a series of Representative Monitoring Sites that: (1) were selected from the existing monitoring programs that are active within the Wheeler Ridge-Maricopa Management Area (see Section 5.2.1 Existing Monitoring and Management Programs), (2) have been demonstrated to be representative of groundwater conditions within the Management Area (see Figure SMC-1, for example), and (3) where Sustainability Criteria (Minimum Thresholds, Measurable Objectives, and Interim Milestones) have been defined for at least one of the relevant Sustainability Indicators to the Basin (see Section 13 Undesirable Results):

- Chronic Lowering of Groundwater Levels;
- Reduction of Groundwater Storage;
- Degraded Water Quality\(^{69}\); and
- Land Subsidence\(^{70}\).

Per 23-CCR § 354.32(e), the selection of Representative Monitoring Sites was informed by the existing local monitoring programs (see Section 5.2.1 Existing Monitoring and Management Programs) and leverages historical data wherever possible to help assess and quantify Basin response to Plan implementation relative to historical groundwater conditions (see Section 8 Current and Historical Groundwater Conditions). Pursuant to 23-CCR § 354.32(f), the spatial distribution, spatial density, and temporal frequency of measurements collected from Representative Monitoring Sites is determined for each Sustainability Indicator based on considerations of:

- Amount of current and projected groundwater use;
- Aquifer characteristics, including any vertical and/or lateral barriers to groundwater flow;
- Potential impacts to beneficial uses and users of groundwater, land uses, and property interests affected by groundwater production, and other adjacent basins (and GSAs within the Basin); and
- Availability of historical data to evaluate long-term trends in groundwater conditions associated with the above factors.

Per 23-CCR § 354.32(g), other factors considered in the selection of Representative Monitoring Sites include:

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\(^{69}\) No Sustainability Criteria are defined for Degraded Water Quality within the Wheeler Ridge-Maricopa Management Area. Representative Monitoring Sites for Degraded Water Quality are included in the SGMA Monitoring Network for use in collecting supplemental data to allow for continued evaluation of groundwater quality trends within the Management Area (see Section 16.1.4).

\(^{70}\) WRMWSD will leverage DWR’s existing regional subsidence monitoring program along the California Aqueduct for use in evaluating land subsidence conditions within the Management Area (see Section 16.1.5).
Monitoring Network
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

- Availability of existing technical information about the Representative Monitoring Site (e.g., well location, construction information, condition, status, etc.);
- Quality and reliability of historical data at the Representative Monitoring Site;
- “Representativeness” to local groundwater conditions and nearby well populations (per 23-CCR § 354.36); and
- Projected availability of long-term access to the Representative Monitoring Site.

Table MN-1 summarizes the site type, site count, measured constituent(s), measurement frequency, and spatial density of the Monitoring Network for each of the relevant Sustainability Indicators mentioned above. Further details about the SGMA Monitoring Network for each Sustainability Indicator can be found in Sections 16.1.1 through 16.1.6.

### Table MN-1. Summary of SGMA Monitoring Network

<table>
<thead>
<tr>
<th>Sustainability Indicator</th>
<th>Site Type</th>
<th>Site Count</th>
<th>Measured Constituent(s)</th>
<th>Measurement Frequency</th>
<th>Spatial Density (# sites / 100 mi²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Lowering of Groundwater Levels</td>
<td>Well</td>
<td>14</td>
<td>Water Level</td>
<td>Semiannually</td>
<td>10.4</td>
</tr>
<tr>
<td>Reduction of Groundwater Storage</td>
<td>Well</td>
<td>15</td>
<td>Water Level</td>
<td>Semiannually</td>
<td>10.4</td>
</tr>
<tr>
<td>Degraded Water Quality&lt;sup&gt;71&lt;/sup&gt;</td>
<td>Well</td>
<td>9</td>
<td>see list in Section 16.1.4</td>
<td>Annually</td>
<td>6.7</td>
</tr>
<tr>
<td>Land Subsidence</td>
<td>Stationary GPS</td>
<td>40</td>
<td>Ground Surface Elevation</td>
<td>Annually, or per DWR schedule</td>
<td>27.7</td>
</tr>
</tbody>
</table>

**Note:**
1. Spatial density of monitoring sites is calculated based on only the area of the Wheeler Ridge-Maricopa Management Area that is not overlapped by AEWSD (86,112 acres), as WRMWSD and AEWSD have agreed that AEWSD will cover the overlap lands for SGMA monitoring purposes.

<sup>71</sup> Ibid [49].
Pursuant to 23-CCR § 354.32(i), in all cases the SGMA Monitoring Network will adhere to the monitoring protocols specified for the Basin as described in Section 16.2 and in the KGA Umbrella GSP.

16.1.1. Monitoring Network for Chronic Lowering of Groundwater Levels

The SGMA Monitoring Network for Chronic Lowering of Groundwater Levels consists of 14 wells distributed across the Wheeler Ridge-Maricopa Management Area (spatial density of 10.4 wells / 100 mi².) for which water level Sustainability Criteria have been defined within this MA Plan (see Section 14.1 Minimum Threshold for Chronic Lowering of Groundwater Levels and Section 15.1 Measurable Objective and Interim Milestones for Chronic Lowering of Groundwater Levels). As described in Section 14.1 Minimum Threshold for Chronic Lowering of Groundwater Levels, a series of 15 wells with long-term groundwater level records were initially selected to analyze historical and current groundwater conditions across the Management Area and to inform the development of Sustainability Criteria for Chronic Lowering of Groundwater Levels (see Sections 14.1 and 15.1). These wells were included in the selection of Representative Monitoring Sites wherever possible; however, in WRMWSD’s recent stakeholder outreach efforts, it became clear that there were several instances in which the “long-term hydrograph” wells would not be available for continued monitoring. In these cases, alternative Representative Monitoring Sites were identified in areas proximate to the long-term hydrograph well locations such that the SGMA Monitoring Network achieves a comparable spatial density, distribution, and “representativeness” to local groundwater conditions. Specific details regarding each of the Representative Monitoring Sites are listed in Table MN-2. The site locations and their spatial distribution are displayed on Figure MN-1. These Representative Monitoring Sites were selected based on the following considerations:
Monitoring Network
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

- **Current and projected groundwater use** – The Monitoring Network includes ten wells located within or immediately adjacent to WRMWSD’s surface water service area and four wells located in the “groundwater only” portion of the Management Area.

- **Aquifer characteristics** – All 14 wells included in the Monitoring Network screen the Tulare Formation, which is the only principal aquifer defined within this portion of the Basin.

- **Potential impacts to beneficial uses and users of groundwater, land uses or property interests, and adjacent Basins (or GSAs)** – The Monitoring Network includes three wells situated within one mile of the California Aqueduct (11N22W06H001S, 11N22W01D001S, and 11N21W09C001S), which is defined as “critical infrastructure” to the Management Area (see Section 13.5 *Undesirable Results for Land Subsidence*). The Monitoring Network also includes one well situated within half a mile of San Emigdio Creek (11N21W16E001S), which will be used to monitor hydraulic gradients between the creek and underlying principal aquifer. Finally, the Monitoring Network includes three wells near the WRMWSD-KDWD boundary (32S26E20G001M, 32S26E24K001M, and 32S29E16P001M) and two wells near the WRMWSD-AEWSD boundary (32S28E16P001M and 32S27E35R001M), which will be used to assess hydraulic gradients between the Management Area, the KDWD portion of the Kern River GSA, and AEWSD.

- **Availability of historical data** – Eight of the 14 Representative Monitoring Sites have associated water level records spanning back through at least 1971, the year that WRMWSD began importing surface water and coincident to the general period of historical low groundwater elevations within the Wheeler Ridge-Maricopa Management Area (see Section 8 *Current and Historical Groundwater Conditions*). Thirteen out of 14 Representative Monitoring Sites have associated water level records spanning back through at least October 1994, coincident with the start of the historical water budget period (see Section 9.3.2 *Historical Water Budget*).

- **Availability of site-specific technical information** – As shown in Table MN-2, each of the 14 Representative Monitoring Sites have known geographic coordinates, ground surface elevations, and reference point elevations. Ten of the 14 sites contain known well depths, and 12 of the 14 sites contain known well screen intervals. Five of the 14 wells are presumed to still be active and in use for irrigation or production purposes, while the other nine are inactive wells which will be used for dedicated monitoring purposes only. All 14 wells are confirmed to be in suitable condition for recording water level measurements. For the sites where well construction information is incomplete or currently unavailable, WRMWSD has developed a plan to fill these data gaps in

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72 There are no interconnected surface water features presumed to occur within the Management Area as the water table is encountered well below the ground surface (i.e., depth to water greater than 100 ft. bgs) throughout WRMWSD (see Section 8.6 *Interconnected Surface Water Systems*).
Monitoring Network
Groundwater Sustainability Plan
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accordance with 23-CCR § 354.38 (see Section 16.4 Assessment and Improvement of Monitoring Network).

- **Quality and reliability of historical data** – Twelve of the 14 Representative Monitoring Sites contain at least 35 water level records, and 13 of 14 have at least one record in the last five years (i.e., since January 2014). Ten of the 14 sites are included in WRMWSD’s voluntary CASGEM network, and most sites have been monitored biannually for at least the past 10 years as part of WRMWSD’s routine water level monitoring program.

- **“Representativeness” to local groundwater conditions** – As described above, Representative Monitoring Sites were selected from the list of “long-term hydrograph” wells demonstrated to be representative of local groundwater conditions (see Figure SMC-1) wherever possible; however, there were several cases where the long-term hydrograph wells would not be available for continued monitoring going forward. In these cases, alternative Representative Monitoring Sites were identified in areas proximate to the long-term hydrograph well locations such that the SGMA Monitoring Network achieves a comparable spatial density, distribution, and “representativeness” to local groundwater conditions.

- **Long-term access** – For each of the 14 Representative Monitoring Sites, a preliminary agreement has been reached with associated landowners/well owners allowing WRMWSD long-term access to the site to conduct monitoring for SGMA compliance purposes. A copy of the long-term access agreement can be found in Appendix F.

All Representative Monitoring Sites will be monitored semiannually in accordance with the monitoring protocol described in Section 16.2 Monitoring Protocols for Data Collection and Monitoring. All data will be reported to DWR per the requirements specified under Section 16.5 Reporting Monitoring Data to the Department.

### 16.1.2. Monitoring Network for Reduction of Groundwater Storage

§ 354.34. Monitoring Network
(c) Each monitoring network shall be designed to accomplish the following for each sustainability indicator:
(2) Reduction of Groundwater Storage. Provide an estimate of the change in annual groundwater in storage.

As described in Section 13.2.2 Criteria Used to Define Undesirable Results and in Section 14.2.2 Use of Groundwater Levels as Proxy, the criteria used to define Undesirable Results for Reduction of Groundwater Storage are the Minimum Thresholds established at a local management area level for Chronic Lowering of Groundwater Levels. As such, the SGMA Monitoring Network for Reduction of Groundwater Storage will be comprised of the same Representative Monitoring Sites described in Section
16.1.1 Monitoring Network for Chronic Lowering of Groundwater Levels. The information collected from this SGMA Monitoring Network will be sufficient to estimate the change in annual groundwater in storage.

16.1.3. Monitoring Network for Seawater Intrusion

As described in Section 13.3 Undesirable Results for Seawater Intrusion, seawater intrusion is not present and not likely to occur within the Kern Subbasin. Therefore, the Seawater Intrusion Sustainability Indicator is not applicable to the basin and no Undesirable Results for this Sustainability Indicator are defined for the basin. As such, per the stipulations defined under 23-CCR § 354.32(j), a monitoring network has not been defined for the Seawater Intrusion Sustainability Indicator as it is demonstrated to not be applicable to the Basin.

16.1.4. Monitoring Network for Degraded Water Quality

As described in Section 14.4 Minimum Threshold for Degraded Water Quality, based on the existing beneficial uses and users of groundwater within the Wheeler Ridge-Maricopa Management Area, Undesirable Results for Degraded Water Quality are not likely to occur and no unique Minimum Thresholds are currently defined for this Sustainability Indicator. However, WRMWSD has historically conducted routine monitoring of groundwater quality conditions (see Section 5.2.1 Existing Monitoring and Management Programs), and has elected to develop a SGMA Monitoring Network for Degraded
Water Quality to facilitate continued monitoring and evaluation of groundwater quality trends within the Wheeler Ridge-Maricopa Management Area throughout Plan implementation.

The SGMA Monitoring Network for Degraded Water Quality includes nine Representative Monitoring Sites selected from WRMWSD’s existing water quality sampling program. Specific details regarding each of the Representative Monitoring Sites are listed in Table MN-2. The site locations are displayed on Figure MN-2. These Representative Monitoring Sites were selected based on the following considerations:

- **Current and projected groundwater use** – The Monitoring Network includes five wells located within WRMWSD’s surface water service area and four wells located in the “groundwater only” portion of the Management Area.

- **Aquifer characteristics** – All nine wells included in the Monitoring Network screen the Tulare Formation, which is the only principal aquifer defined within this portion of the Basin.

- **Potential impacts to beneficial uses and users of groundwater, land uses or property interests, and adjacent Basins (or GSAs)** – The Monitoring Network is spread generally evenly across the Management Area and includes Representative Monitoring Sites in the areas of groundwater quality concern identified in Section 8.4 Groundwater Quality Concerns.

- **Availability of historical data** – All nine Representative Monitoring Sites have been sampled for groundwater quality constituents (including the constituents of concern [COCs] identified in Section 8.4 Groundwater Quality Concerns) at least three times, and six of nine at least 15 times. Eight of the nine sites have been sampled at least once since the year 2000, and seven sites have sampling records extending back through at least 1981.

- **Availability of site-specific technical information** – As shown in Table MN-2, each of the nine Representative Monitoring Sites have known geographic coordinates, ground surface elevations, and reference point elevations. Three of the nine sites contain known well depths, and five of the nine sites contain known well screen intervals. Four of the nine wells are presumed to still be active and in use for irrigation purposes, while the other five will be used for dedicated for monitoring purposes only. All nine wells are confirmed to be in suitable condition for collecting water quality samples. For the sites where well construction information is incomplete or currently unavailable, WRMWSD has developed a plan to fill these data gaps in accordance with 23-CCR § 354.38 (see Section 16.4 Assessment and Improvement of Monitoring Network).

- **Quality and reliability of historical data** – Each of the nine Representative Monitoring Sites contains at least three water quality sampling records, and eight of nine contain at least one record since 2000, and four of nine contain at least one record in the last five years (i.e., since January 2014). Most sites have been monitored regularly for at least the past ten years as part of WRMWSD’s routine water quality sampling program.
“Representativeness” to local groundwater conditions — As described above, the nine sites are spread generally evenly across the Management Area, including some wells in the areas of groundwater quality concern identified in Section 8.4 Groundwater Quality Concerns.

Long-term access — For each of the nine Representative Monitoring Sites, a preliminary agreement has been reached with associated landowners/well owners allowing WRMWSD long-term access to the site to conduct monitoring for SGMA compliance purposes. A copy of the long-term access agreement can be found in Appendix F.

All Representative Monitoring Sites will be sampled annually in accordance with the monitoring protocol described in Section 16.2 Monitoring Protocols for Data Collection and Monitoring. Representative Monitoring Sites will be sampled for the COCs identified in Section 8.4 Groundwater Quality Concerns, namely:

- Total Dissolved Solids
- Nitrate
- Arsenic
- Boron
- Iron
- Manganese
- Sulfate
- Chloride
- Uranium

In addition, Representative Monitoring Sites will be monitored for other relevant groundwater quality constituents as identified in Stanford University’s “A Guide to Water Quality Requirements under the Sustainable Groundwater Management Act” (Moran & Belin, 2019).

73 As identified in Stanford University’s “A Guide to Water Quality Requirements under the Sustainable Groundwater Management Act” (Moran & Belin, 2019).
Monitoring Network
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

- Microbes

All data will be reported to DWR per the requirements specified under Section 16.5 Reporting Monitoring Data to the Department.

16.1.5. Monitoring Network for Land Subsidence

As described in Section 14.5 Minimum Threshold for Land Subsidence, the California Aqueduct is considered the most critical infrastructure to avoid Undesirable Results from Land Subsidence in the Management Area. As such, WRMWSD intends to utilize DWR’s existing land subsidence monitoring program along the California Aqueduct for its local SGMA Monitoring Network for Land Subsidence (see Appendix G).

DWR maintains 40 ground surface elevation survey benchmark locations within the Wheeler Ridge-Maricopa Management Area, between Mileposts 251.50 (Check No. 31) and 278.13 (Teerink Pumping Plant) of the California Aqueduct. These benchmarks have been surveyed intermittently since 1967, including the most recent surveys completed in 2013 and 2017. WRMWSD will coordinate with DWR to obtain access to future survey data collected between Pools 31 – 35 (i.e., Mileposts 251.50 – 278.13) from this regional monitoring program, and will use these publicly-available data to evaluate changes in ground surface elevation along the local reaches of the California Aqueduct within the Management Area, and to assess Plan Implementation relative to the Sustainability Criteria for Land Subsidence defined under Sections 14.5 and 15.5 of this MA Plan.

§ 354.34. Monitoring Network
(c) Each monitoring network shall be designed to accomplish the following for each sustainability indicator:

(5) Land Subsidence. Identify the rate and extent of land subsidence, which may be measured by extensometers, surveying, remote sensing technology, or other appropriate method.

DWR survey information along the California Aqueduct through 2013 are presented in DWR (2017), several plates of which are included as Appendix G. Data from 2017 are not available as of the date of this MA Plan, but the survey is known to have occurred based on an updated plate found in a November 2017 meeting agenda packet.
16.1.6. Monitoring Network for Depletions of Interconnected Surface Water

§ 354.34. Monitoring Network

(c) Each monitoring network shall be designed to accomplish the following for each sustainability indicator:

(6) Depletions of Interconnected Surface Water. Monitor surface water and groundwater, where interconnected surface water conditions exist, to characterize the spatial and temporal exchanges between surface water and groundwater, and to calibrate and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. The monitoring network shall be able to characterize the following:

(A) Flow conditions including surface water discharge, surface water head, and baseflow contribution.

(B) Identifying the approximate date and location where ephemeral or intermittent flowing streams and rivers cease to flow, if applicable.

(C) Temporal change in conditions due to variations in stream discharge and regional groundwater extraction.

(D) Other factors that may be necessary to identify adverse impacts on beneficial uses of the surface water.

As described in Section 13.6 Undesirable Results for Depletions of Interconnected Surface Water, no basin-wide definition of Undesirable Results for Depletions of Interconnected Surface Water has been developed and, based on available data and information, depletion of interconnected surface water has not been observed within the Wheeler Ridge-Maricopa Management Area. As such, per the stipulations defined under 23-CCR § 354.32(j), a monitoring network has not been defined for the Depletion of Interconnected Surface Water Sustainability Indicator as it is demonstrated to not be applicable.
16.2. Monitoring Protocols for Data Collection and Monitoring

§ 352.2. Monitoring Protocols
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.

Pursuant to 23-CCR § 354.32(i), in all cases the Wheeler Ridge-Maricopa Management Area SGMA Monitoring Network will adhere to the monitoring protocols specified for the Basin as described in the KGA Umbrella GSP.

16.3. Representative Monitoring

§ 354.36. Representative Monitoring
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 if the Agency demonstrates the following:

(1) Significant correlation exists between groundwater elevations and the sustainability indicators for which groundwater elevation measurements serve as a proxy.

(2) Measurable objectives established for groundwater elevation shall include a reasonable margin of operational flexibility taking into consideration the basin setting to avoid undesirable results for the sustainability indicators for which groundwater elevation measurements serve as a proxy.

(c) The designation of a Representative Monitoring Site shall be supported by adequate evidence demonstrating that the site reflects general conditions in the area.

As described in Section 16.1 Description of Monitoring Network, WRMWSD has defined a SGMA Monitoring Network for each relevant Sustainability Indicator in the Management Area that will be used
Monitoring Network
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

for SGMA reporting purposes to evaluate Plan implementation with respect to meeting the Sustainability Goal defined for the Basin through compliance with the Minimum Thresholds and Measurable Objectives described in the Plan. The rationale for selecting Representative Monitoring Sites are described for each Sustainability Indicator in Sections 16.1.1 - 16.1.6 of this MA Plan.

As described in Section 16.1.2 Monitoring Network for Reduction of Groundwater Storage, the Monitoring Network for Chronic Lowering of Groundwater Levels will be used as a proxy to monitor Reduction in Groundwater Storage. As described in Section 14.2 Minimum Threshold for Reduction of Groundwater Storage, groundwater levels are considered sufficiently protective of Reduction in Groundwater Storage, and thus no Sustainability Criteria have been defined for this Sustainability Indicator. There are no other Sustainability Indicators for which groundwater levels will be used as a proxy for representative monitoring.
16.4. Assessment and Improvement of Monitoring Network

§ 354.38. Assessment and Improvement of Monitoring Network

(a) Each Agency shall review the monitoring network and include an evaluation in the Plan and each five-year assessment, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin.

(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:

(1) The location and reason for data gaps in the monitoring network.

(2) Local issues and circumstances that limit or prevent monitoring.

(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.

(e) Each Agency shall adjust the monitoring frequency and density of monitoring sites to provide an adequate level of detail about site-specific surface water and groundwater conditions and to assess the effectiveness of management actions under circumstances that include the following:

(1) Minimum threshold exceedances.

(2) Highly variable spatial or temporal conditions.

(3) Adverse impacts to beneficial uses and users of groundwater.

(4) The potential to adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of sustainability goals in an adjacent basin.

As described above and in the Basin-wide Monitoring Protocols (see the KGA Umbrella GSP), the Wheeler Ridge-Maricopa SGMA Monitoring Network for the Kern Subbasin will be reevaluated in each five-year GSP update, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the Sustainability Goal for the Basin.

In all cases, the SGMA Monitoring Network developed for each Sustainability Indicator includes a sufficient density and spatial distribution of monitoring sites to meet the monitoring objectives outlined in Section 16.1 Description of Monitoring Network. In most cases, the existing Representative Monitoring Sites selected for each Sustainability Indicator conform to the best management practices for monitoring networks outlined in DWR’s BMP 2 – Monitoring Networks and Identification of Data Gaps. As identified in Sections 16.1.1 - 16.1.6, there are a few notable exceptions:
Regarding the Monitoring Network for Chronic Lowering of Groundwater Levels

- Four of the 14 sites are missing well depth information (wells 32S26E24K001M, 11N22W01D001S, 11N22W06H001S, and 32S28E16P001M);
- Two of the 14 sites are missing perforation interval information (wells 32S26E24K001M and 11N22W06H001S); and
- Five of the 14 wells are presumed to still be active and in use for irrigation or production purposes (wells 11N21W16E001S, 32S27E35R001M, 12N21W36N001S, 32S26E34P001M, and 32S25E29Q001M).

Regarding the Monitoring Network for Degraded Water Quality

- Six of the nine sites are missing well depth information (wells 32S28E16P001M, 32S26E17H001M, 11N21W12N002S, 11N22W09A001S, 12N21W31P001S, and 32S26E14J001M);
- Four of the nine sites are missing perforation interval information (wells 11N21W12N002S, 11N22W09A001S, 12N21W31P001S, and 32S26E14J001M); and
- Four of the nine wells are presumed to still be active and in use for irrigation or municipal and industrial purposes (wells 32S25E29Q001M, 11N21W12N002S, 12N21W31P001S, and 32S26E14J001M).

For the Representative Monitoring Sites currently missing well information and well screen information, WRMWSD has developed a plan to fill these data gaps by conducting video-logging on the identified wells (see Section 18 Plan Implementation Activities). In the event these data gaps cannot be readily filled, WRMWSD will identify alternative sites or develop plans to construct new Representative Monitoring Sites for Chronic Lowering of Groundwater Levels and Degraded Water Quality as deemed necessary by the District.

For the Representative Monitoring Sites still under active use, WRMWSD will work to convert these sites to dedicated monitoring sites or will otherwise identify or develop alternative sites by the GSP implementation deadline (i.e., by January 2040).

16.5. Reporting Monitoring Data to the Department

§ 354.40. Reporting Monitoring Data to the Department

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.
Data collected from the SGMA Monitoring Network will be uploaded to the Data Management System maintained for the Kern Subbasin and reported to the DWR in accordance with the Monitoring Protocols developed for the Basin as described in the KGA Umbrella GSP. Additional data collected as part of WRMWSD’s other regular monitoring programs (see Section 5.2.1 Existing Monitoring and Management Programs) may be used in conjunction with data collected from the SGMA Monitoring Network to meet compliance with GSP regulations regarding Annual Reporting (23-CCR § 356.2) or as otherwise deemed necessary by the District.
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### TABLE MN-2
Summary of Representative Monitoring Sites
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

**Abbreviations**
- **amsl** = above mean sea level
- **bgs** = below ground surface
- **CASGEM** = California Statewide Groundwater Elevation Monitoring
- **DWR** = California Department of Water Resources
- **ft** = feet
- **gpm** = gallons per minute
- **in** = inches
- **KRF** = Kern River Formation
- **N/A** = not applicable
- **WGS** = World Geodetic System

**Notes**
1. Seawater intrusion is not considered to be a sustainability indicator of concern to the WRMWS Kern Management Area and is thus not monitored for SGMA compliance.
2. Wells included in the Land Subsidence monitoring network use water levels as a proxy risk indicator and are thus monitored to their respective water level minimum thresholds.
3. Depletion of interconnected surface water is not considered to be a sustainability indicator of concern to the WRMWS Kern Management Area and is thus not monitored for SGMA compliance.
4. Only one Principal Aquifer is defined for the WRMWS Kern Management Area - the "Kern River Formation Principal Aquifer".
Figure MN-1
SGMA Water Level Monitoring Network

Legend
- WRMWSD Service Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)
- Representative Monitoring Sites

Abbreviations
- DWR = California Department of Water Resources
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 12 August 2019.
2. Well type data received from WRMWSD on 20 November 2017.
Abbreviations
DWR = California Department of Water Resources
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 12 August 2019.
2. Well type data received from WRMWSD on 20 November 2017.
PROJECTS AND MANAGEMENT ACTIONS
17. PROJECTS AND MANAGEMENT ACTIONS

Pursuant to the GSP Regulations, this section presents the Projects and Management Actions (P/MAs) proposed to support achievement of the sustainability goal within the Wheeler Ridge-Maricopa Management Area. The P/MAs were developed using a portfolio approach whereby individual P/MAs were identified and grouped into categories based on their expected benefits. Implementation of P/MAs within those benefit categories is estimated to occur along a “glide path” that will result in closing of the currently identified “deficit” under the 2030 Climate Change Scenario by the January 2040 GSP implementation deadline (see Section 9.4.3 Projected Water Budget Results), as well as in response to observed groundwater conditions relative to the associated Sustainability Indicators. This approach allows for flexible implementation of P/MAs as needed to address future conditions throughout the 50-year GSP planning and implementation horizon (i.e., out to 2070). The P/MAs presented herein were developed with consideration of costs and benefits and preliminary feasibility analysis; however, each P/MA will require significant further evaluation (i.e., engineering, economic, legal, etc.) prior to implementation.

This section first presents the goals and objectives of the P/MAs, including the relevant Sustainability Indicators, the spatial “focus areas” within the Wheeler Ridge-Maricopa Management Area, the categories of expected benefits and the implementation glide path. Next, a list of specific P/MAs grouped by benefit category and type is presented, information which is also provided in. Following this list is a discussion of how the P/MAs address overdraft conditions or other Undesirable Results (i.e., water quality); a description of the various potentially applicable permitting and regulatory requirements; a discussion of the P/MA status and implementation timeline; a discussion of how the expected benefits will be evaluated; a description of sources of outside water that are relied upon; a discussion of the legal authority required to implement the P/MAs; a summary of estimated costs and how the Wheeler Ridge-Maricopa Water Storage District (WRMWSD) plans to meet those costs; and a discussion of how recharge and extraction will be managed to avoid depletion of groundwater levels and storage.

75 In this document, the term “Wheeler Ridge-Maricopa Management Area” is used in its entirety the first time the area is being referenced in each paragraph; subsequent references to this area in each paragraph use the term “Management Area”.

§ 354.42. Introduction to Projects and Management Actions

This Subarticle describes the criteria for projects and management actions to be included in a Plan to meet the sustainability goal for the basin in a manner that can be maintained over the planning and implementation horizon.
17.1. Goals and Objectives of Projects and Management Actions

17.1.1. Relevant Sustainability Indicators
Per the Groundwater Sustainability Plan (GSP) Regulations (23-CCR Division 2 Chapter 1.5 Subchapter 2), GSPs must include P/MAs to address any existing or potential future Undesirable Results for the identified relevant Sustainability Indicators. As discussed in Section 13 Undesirable Results, the relevant Sustainability Indicators in the Wheeler Ridge-Maricopa Management Area for which Undesirable Results and Sustainable Management Criteria (SMCs) have been defined include: (1) Chronic Lowering of Groundwater Levels, (2) Reduction of Groundwater Storage, and (3) Land Subsidence. Because groundwater levels and storage area directly correlated, P/MAs that address groundwater levels also address groundwater storage, and the two Sustainability Indicators are considered together in this discussion of P/MAs. Each of these relevant Sustainability Indicators is further associated with specific areas within the Management Area. Therefore, the goal of the P/MAs discussed herein is to address significant and unreasonable effects related to the relevant Sustainability Indicators in the relevant areas.

17.1.2. Focus Areas
As discussed in Section 8.1 Groundwater Elevations and Flow Direction, groundwater levels in 2015 were lowest in the southern central portion and the far northernmost portion of the Wheeler Ridge-Maricopa Management Area, and the patterns likely reflect, in part, the distribution of groundwater pumping (the latter of these two areas is outside of the Surface Water Service Area [SWSA] and therefore relies exclusively on groundwater) (see Figure GWC-1, Figure GWC-2, and Figure GWC-5). For that reason, the proposed P/MAs that address groundwater levels and storage are focused on those areas. Land Subsidence is also closely tied to groundwater levels but is only relevant where there is critical infrastructure (defined with an emphasis on regional infrastructure, as discussed in Section 13.5 Undesirable Results for Land Subsidence above). The area most relevant to the Land Subsidence Sustainability Indicator is along the California Aqueduct, which is also within the SWSA. Groundwater quality is generally suitable for agricultural uses within the Management Area, except for the far western portion of the Management Area where naturally-occurring salinity affects groundwater quality, and therefore no SMCs are defined, and no P/MAs are proposed to address effects related to this Sustainability Indicator.

17.1.3. Benefit Categories
The primary water management “tools” (i.e., authorities) by which Groundwater Sustainability Agencies (GSAs) can address conditions that may lead to Undesirable Results associated with water quantity (i.e., Chronic Lowering of Groundwater Levels and Reduction of Groundwater Storage) pertain to management of inflows (supplies) and outflows (demands). Therefore, the primary categories of expected benefits for these water quantity-related P/MAs are:

1. Water supply augmentation, including
Projects and Management Actions
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

a. Wet year supplies
b. Other (i.e. all year) new supplies; and

2. Water demand reduction.

All of the P/MAs have a water quantity-related benefit relating to at least one of those two primary categories. In addition, some P/MAs also have secondary benefits, including:

3. Water quality improvement; and

17.1.4. Implementation Glide Path

As stated above, the goals and objectives of the P/MAs presented herein are to address any existing or potential Undesirable Results by the GSP implementation deadline for the Kern County Subbasin (Kern Subbasin) (i.e., by January 2040). As such, P/MAs will be implemented incrementally on an as-needed basis to achieve this goal. While the exact schedule and timetable for implementation of individual P/MAs is not known at this time, a general implementation schedule, also known as a “glide path”, has been developed and is summarized in Table PMA-2. This preliminary “glide path” aims to address a certain percentage of the projected deficit during each five-year period through 2040, which in turn will affect conditions of the relevant Sustainability Indicators based on the assumption that those conditions are directly related to the balance of supplies and demands within the Wheeler Ridge-Maricopa Management Area. The “glide path” also includes a preliminary estimate of the supply augmentation and demand reduction measures necessary to address the projected deficit specified under the 2070 Climate Change Scenario by the end of the 50-year GSP planning and implementation horizon (i.e., January 2070).
## Table PMA-2. General Project and Management Actions Implementation Schedule (“Glide Path”)

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<tr>
<td>Target Deficit Reduction (AFY)</td>
<td>3,200</td>
</tr>
</tbody>
</table>

**P/MA Benefits, by Type (AFY)**

<table>
<thead>
<tr>
<th>Water Supply Augmentation</th>
<th>Wet Year Supplies</th>
<th>896</th>
<th>2,688</th>
<th>4,508</th>
<th>5,992</th>
<th>5,992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other New Supplies</td>
<td></td>
<td>1,024</td>
<td>3,072</td>
<td>5,152</td>
<td>6,848</td>
<td>12,798</td>
</tr>
<tr>
<td>Demand Reduction</td>
<td></td>
<td>1,280</td>
<td>3,840</td>
<td>6,440</td>
<td>8,560</td>
<td>14,510</td>
</tr>
<tr>
<td><strong>Total P/MA Benefits</strong></td>
<td></td>
<td>3,200</td>
<td>9,600</td>
<td>16,100</td>
<td>21,400</td>
<td>33,300</td>
</tr>
</tbody>
</table>

**Abbreviations:**

AFY = acre-feet per year  
P/MA = Project / Management Action

**Notes:**

1. Projected Deficit to be addressed by implementation of P/MAs up to 2040 is the net water supply shortfall based on the 2030 Climate Change Scenario. Projected Deficit to be addressed by future P/MA implementation beyond 2040 (i.e., up to 2070) is the net water supply shortfall based on the 2070 Climate Change Scenario.

2. In the 2025 through 2040 periods, 60% of the target deficit reduction is met by Water Supply Augmentation P/MAs and 40% is met by Demand Reduction P/MAs. In the period from 2040 through 2070, the additional target deficit reduction is met with 50% each from Water Supply Augmentation P/MAs and Demand Reduction P/MAs.
17.2. List of Projects and Management Actions

This section provides a list of the P/MAs identified by WRMWSD, divided into the two primary benefit categories discussed above, both of which address the Chronic Lowering of Groundwater and Reduction of Groundwater Storage Sustainability Indicators. Within these two categories, the P/MAs are further classified into five types based on the mechanism by which the primary benefit is achieved. Details of the P/MAs are provided in Table PMA-1.

17.2.1. Water Supply Augmentation Projects

The Projects listed below have supply augmentation as their primary expected benefit, and include Projects to Enhance Recharge/Banking, Projects to Increase Water Management Flexibility, and Projects to Develop New Supplies.

Projects to Enhance Recharge/Banking

1. On-Farm Recharge
2. In-District District Banking Facilities
3. Increase Out-of-District Banking Operations

76 As discussed in Section 7.3.4 Recharge and Discharge Areas, much of the District, especially the southern portion, has surface conditions deemed suitable for recharge (see Figure HCM-19).
Projects and Management Actions
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

Projects to Increase Water Management Flexibility

4. Expand District Distribution System

Projects to Develop New Supplies

5. Purchase Additional Supplies
6. Desalination Facilities
7. “Thru Delta” Facility

17.2.2. Water Demand Reduction Management Actions

The Management Actions listed below have water demand reduction as their primary expected benefit and include Management Actions / Policies to Raise Funds to Support Sustainable Groundwater Management Act (SGMA) Compliance and Management Actions / Policies to Reduce Groundwater Pumping.

Management Actions to Raise Funds to Support SGMA Compliance

8. Acreage Assessment

Management Actions / Policies to Reduce Groundwater Pumping

9. Groundwater Allocation and Market
10. Voluntary Pumping Limitations
11. Mandatory Pumping Limitations
12. Land Retirement

17.3. Circumstances for Implementation

Using the portfolio approach, P/MAs will be selected for implementation based on further consideration of the magnitude of expected benefit, the relative cost and ease of implementation, and other factors. Some P/MAs will be implemented immediately upon adoption of the GSP. Others will be implemented when grant funds are obtained or upon completion of feasibility studies, economic evaluations, and/or other necessary planning studies. A key precursor to implementing some of the P/MAs will be renegotiation and modification to the contracts between the District and landowners to allow for certain funding and assessment provisions, and to allow greater flexibility in the types of water supplies that the District can purchase. Renegotiation of the contracts will be pursued by the District’s Board immediately upon adoption of the GSP.

As discussed above, an overall P/MA implementation schedule, or “glide path” has been developed that serves as a framework to guide the level of benefits that are planned to be achieved over the GSP implementation period (i.e., until 2040), and further through the SGMA planning and implementation...
horizon (i.e., through 2070). Accelerated implementation of P/MAs (i.e., at expected benefit accrual rates faster than those shown in Table PMA-2 above) will be triggered if Minimum Thresholds for Chronic Lowering of Groundwater Levels are exceeded in more than 20% of (i.e., at least 3 out of 14) of Representative Monitoring Sites.

17.4. Public Notice Process

Public notice requirements vary for the different P/MAs listed above. Some projects that involve infrastructure improvements only may not require specific public noticing (other than that related to construction), whereas certain other management actions that involve, for example, imposition of fees by WRMWSD, may require public noticing pursuant to Proposition 218 or Proposition 26. In general, P/MAs being considered for implementation will be discussed during regular WRMWSD Board Meetings which are open to the public. Additional stakeholder outreach efforts will be conducted prior to and during P/MA implementation, as required by law.

17.5. Addressing Overdraft Conditions

As discussed in Section 9.2.4 Overdraft Conditions, the Wheeler Ridge-Maricopa Management Area as a whole is not in an overdraft condition (i.e., based on the Management Area-specific spreadsheet water budget model, there is not a net water budget deficit over the historical period). However, groundwater levels in some areas, both inside and outside of the SWSA, have shown decreasing trends in recent years, suggesting a local imbalance of supplies versus pumping over this period (which includes a significant drought period). Furthermore, the projected water budget indicates that under the 2030 Climate Change Scenario, imported water supplies to the Management Area may be reduced, resulting in a net deficit of approximately -21,400 AFY. The P/MAs presented herein are expected to result in benefits (discussed below) that will address the projected deficit so as to avoid Undesirable Results and achieve sustainability.

77 Prior to the start of water importation into the WRMWSD area in 1971, groundwater levels were in a state of chronic decline, indicating overdraft.
17.6. Permitting and Regulatory Process

Permitting and regulatory requirements vary for the different P/MAs depending on whether they are infrastructure projects, recharge projects, demand reduction management actions, and so forth. The various types of permitting and regulatory requirements (not all applicable to every P/MA) include the following:

- **Federal**
  - National Environmental Policy Act (NEPA) documentation, if federal grant funds are used;
  - National Pollution Discharge Elimination System (NPDES) stormwater program permit (administered by the California State Water Resources Control Board [SWRCB]);

- **State**
  - California Environmental Quality Act (CEQA) documentation, including one or more of the following: Initial Study (IS), Categorical Exemption (CE), Negative Declaration (ND), Mitigated Negative Declaration (MND), Environmental Impact Report (EIR);

- **Regional**
  - San Joaquin Valley Air Pollution Control District (SJVAPCD) permit and regulations;

- **County/Local**
  - Encroachment permits – Kern County, Caltrans, and others;
  - Kern County grading permit.

Specific currently-identified permitting and regulatory requirements for each P/MA are listed in Table PMA-1. Upon implementation of any P/MA, the regulatory and permitting requirements of the P/MA will be re-examined.
Projects and Management Actions  
Groundwater Sustainability Plan  
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

17.7. Status and Implementation Timetable

§ 354.44. Projects and Management Actions  
(b) Each Plan shall include a description of the projects and management actions that include the following:  
…  
(4) The status of each project and management action, including a timetable for expected initiation and completion, and the accrual of expected benefits.

With a few exceptions, the current status of P/MAs listed in Table PMA-1 is “not yet initiated”. As discussed above in Section 17.3 Circumstances for Implementation, P/MAs related to water quantity will be initiated in a manner and sequence that achieves the “glide path” level of expected benefits shown in Table PMA-2, with accelerated implementation if Minimum Thresholds for Chronic Lowering of Groundwater Levels are exceeded in more than 20% (i.e., at least 3 out of 14) of Representative Monitoring Sites. Table PMA-1 presents preliminary estimates of the time required to complete/implement each P/MA and a timetable for accrual of expected benefits. These estimates will be refined, as necessary, upon further evaluation of the P/MAs.

17.8. Expected Benefits

§ 354.44. Projects and Management Actions  
(b) Each Plan shall include a description of the projects and management actions that include the following:  
…  
(5) An explanation of the benefits that are expected to be realized from the project or management action, and how those benefits will be evaluated.

The different categories of expected benefits are presented above in Section 17.1.3 Benefit Categories, and the specific expected benefits of each P/MA are presented in Table PMA-1. Below is a discussion of how the expected benefits will be evaluated.

17.8.1. Evaluation of Benefits

Each of the P/MAs has expected benefits related to water quantity. Once a P/MA is implemented, it is important for there to be a way to evaluate, ideally to quantify, the benefits resulting from that P/MA. The way in which P/MA benefits are evaluated/quantified depends on the P/MA type. For those P/MAs that involve direct supply augmentation, the benefit is quantified directly through measurement of those
flows and corresponding response in water levels. For P/MAs that involve indirect supply augmentation through, for example, increased delivery flexibility, quantification of the benefit will require a comparison of the observed water supply condition (e.g., total imported water) For P/MAs that involve water demand reduction the benefit will be evaluated by comparison of the observed water demand condition (e.g., irrigated acreage) against a hypothetical condition where the P/MA was not in place. Because it is not possible to determine with certainty what the condition without the P/MA would be like, quantification of the benefits is inherently uncertain.

As discussed above, although the P/MAs described herein are laid out along a general timetable defined by incremental elimination of water budget deficits (i.e., the “glide path”), the goals and objectives of P/MA implementation are not necessarily to achieve a certain water budget outcome, but rather to ensure that Undesirable Results for relevant Sustainability Indicators are avoided by the end of the SGMA implementation period (i.e., by 2040). For this reason, ultimately the success of the collective implementation of P/MAs will be determined by whether the Sustainability Goal is achieved.

17.8.2. Evaluation Relative to Water Level Sustainability Criteria

As mentioned in Section 9 Water Budget Information, as part of its involvement in the KGA GSA, WRMWSD is participating in the development of a numerical groundwater water flow model for the Kern Subbasin based on DWR’s California Central Valley Groundwater-Surface Water Simulation beta fine-grid model (C2VSim-FG). As part of this process, all Basin GSAs were asked to input their proposed P/MAs into the Baseline and 2030 Climate Change C2VSim-FG projected model scenarios to assess water level responses to GSP implementation relative to proposed Water Level Sustainability Criteria defined for each GSA/Management Area (see Sections 14.1 and 15.1). As demonstrated in Figure PMA-1, for each of the fifteen water level Representative Monitoring Sites within the Wheeler Ridge-Maricopa Management Area, groundwater elevations are expected to meet their Minimum Thresholds under P/MA implementation in both the Baseline and 2030 Climate Change Scenarios. In almost all cases, water levels are also maintained at or above the Measurable Objectives upon full P/MA implementation. The results of this Basin-wide projected modeling exercise thus further support the notion that the proposed P/MA implementation strategy is expected to result in sustainable management of groundwater levels within the Wheeler Ridge-Maricopa Management Area.
17.9. Source and Reliability of Water from Outside WRMWSD

Several of the P/MAs discussed below and shown in Table PMA-1 rely on additional water supplies from outside of the WRMWSD area. Specifically, certain P/MAs rely on the availability of water during wet years to conduct managed recharge, banking inside and outside of the District, and offset groundwater pumping. As discussed in Section 9.4 *Projected Water Budget*, the volume of SWP supplies is anticipated to decrease under the 2030 Climate Change Scenario relative to the historical water budget period (Water Year [WY] 1995 – 2014) and the Baseline Scenario, and that decrease is the main cause of the projected deficit. However, the District understands that additional wet year supplies may be available, if sufficient infrastructure is developed to take it in (within or outside of the District). Furthermore, the District is an active participant in the various surface water transfer, exchange and purchase markets in the Central Valley and will continue those efforts.

The District is also participating in efforts to develop several new surface water supplies that would provide a more regular (i.e., year to year) source of supply, to be conveyed through the California Aqueduct. These potential additional sources of supply include the following:

- Sites Reservoir Project, and
- Water Fix and Eco Restore (formerly known as the Bay Delta Conservation Plan, referred to in Table PMA-1 as the “Thru Delta” Facility).

17.10. Legal Authority Required

§ 354.44. Projects and Management Actions

(b) Each Plan shall include a description of the projects and management actions that include the following:

... (6) An explanation of how the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.

§ 354.44. Projects and Management Actions

(b) Each Plan shall include a description of the projects and management actions that include the following:

... (7) A description of the legal authority required for each project and management action, and the basis for that authority within the Agency.
WRMWSD is a Participating Member of the KGA GSA, which is organized as a joint powers authority. WRMWSD, as a water storage district, possesses the legal authority to implement the supply augmentation P/MA's discussed herein. As a GSA, per California Water Code (CWC) § 10725 through 10726.8, the KGA GSA possesses the legal authority outlined in necessary to implement the demand management P/MA's described herein and will either act upon WRMWSD's behalf to enforce these P/MA's as necessary or will delegate authority to WRMWSD itself to enforce the GSP within the Wheeler Ridge-Maricopa Management Area. As mentioned above, the District will pursue renegotiation of landowner contracts as one of the initial steps of GSP implementation.

17.11. Estimated Costs and Plans to Meet Them

§ 354.44. Projects and Management Actions
(b) Each Plan shall include a description of the projects and management actions that include the following:

(8) A description of the estimated cost for each project and management action and a description of how the Agency plans to meet those costs.

Estimated costs for each P/MA are presented in Table PMA-1. Given the uncertainty in the scope and timing of these P/MA's, in some cases the costs are presented as ranges, and in all cases are considered approximate subject to refinement. These costs include “one-time” costs and ongoing costs. The one-time costs may include capital costs associated with construction, feasibility studies, permitting, environmental (CEQA) compliance, or any other costs required to initiate a given P/MA. The ongoing costs are associated with operations and maintenance (O&M) of facilities, costs for purchased water supplies, and/or costs to otherwise continue implementing a given P/MA. It should be noted that depending on the source and nature of funding for the P/MA's, the one-time costs may or may not be incurred entirely at the beginning of the P/MA; in some instances, loans or other financing options may allow for spreading out of “one-time” costs over time.

Potential sources of funding for the various P/MA's are also presented in Table PMA-1, and include the following:

- WRMWSD funds, generally supported by fees charged to landowners within WRMWSD, including potentially the following:
  - General fund
  - SGMA compliance subaccount
- Partnering agencies for certain P/MA's
Projects and Management Actions
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

- Grant funding from sources including DWR and others
- Other

Upon implementation of any given P/MA, the available funding sources for that P/MA will be re-examined.

17.12. Management of Recharge and Groundwater Extractions

As stated previously in Section 9 Water Budget Information, under historical conditions (WY 1995 – 2014), the Wheeler-Ridge Maricopa Management Area is in a state of approximate water supply/demand balance (i.e., with a moderate net surplus of approximately 3,300 AFY, based on the Management Area-specific spreadsheet water budget model). Under the Baseline and 2030 (and 2070) Climate Change Scenarios, however, a net water supply deficit is projected to occur. That projected deficit is due, in large part, to a projected reduction in imported water supplies. However, as discussed above, one of the primary means by which the deficit will be addressed is through the implementation of P/MAs that obtain additional outside sources of water, in particular during normal to wet years. Most of the supply augmentation projects discussed herein and shown on Table PMA-1 take advantage of additional wet year supplies that are assumed to be available once demands increase. These P/MAs include various direct recharge projects and projects that increase storage capacity and delivery flexibility.

In addition to these supply augmentation projects, the portfolio also includes policy-based management actions aimed at demand reduction. Some of these management actions aim to reduce overall water demand, and others are more specifically focused on reducing groundwater pumping. These management actions will rely initially on financial incentives (e.g., tiered pricing and/or fees) to drive voluntary demand reduction, but also include setting of mandatory groundwater pumping allocations, if necessary. A groundwater allocation program would likely include mechanisms to allow for trading or exchange of pumping allocations, subject to constraints dictated by groundwater conditions observed within the Monitoring Network and policies developed by the WRMWSD Board. Through this combination of increased recharge during wet years and demand reduction, WRMWSD’s P/MA efforts will ensure that chronic lowering of groundwater levels and storage during drought will be offset by increases in groundwater levels and storage during other periods.
## Details of Projects and Management Actions

**Wheeler Ridge-Maricopa Water Storage District, Kern County, California**

<table>
<thead>
<tr>
<th>P/MA Number</th>
<th>P/MA Name</th>
<th>Summary Description</th>
<th>Relevant Sustainability Indicators Affected</th>
<th>Timetable / Circumstances for Initiation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Projects to Enhance Recharge / Banking</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>On-Farm Recharge</td>
<td>Study and implement on-farm recharge where viable.</td>
<td>●  ●  ● To be implemented upon adoption of WRMWSD GSP Chapter</td>
<td>Regular District Board meetings CEQA Not yet initiated 2020</td>
</tr>
<tr>
<td>2</td>
<td>In-District Banking Facilities</td>
<td>Program to promote private and/or District-owned banking facilities within the District.</td>
<td>●  ●  ● To be implemented upon adoption of WRMWSD GSP Chapter</td>
<td>Regular District Board meetings CEQA Not yet initiated 2020</td>
</tr>
<tr>
<td>3</td>
<td>Increase Out-of-District Banking Operations</td>
<td>Increase size/participation in out-of-District banking facilities (i.e., Kern Water Bank and Pioneer Project). Increased banking of wet year supplies outside of the District would support deliveries of imported water into the District in normal/dry years.</td>
<td>●  ●  ● To be implemented upon adoption of WRMWSD GSP Chapter</td>
<td>Regular District Board meetings CEQA Not yet initiated 2020</td>
</tr>
<tr>
<td><strong>Projects to Increase Water Management Flexibility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Expand District Distribution System</td>
<td>Project to expand District distribution system into area currently using only private groundwater.</td>
<td>●  ●  ●  ● upon modification of water service contracts</td>
<td>Regular District Board meetings CEQA Not yet initiated TBD</td>
</tr>
<tr>
<td><strong>Projects to Develop New Supplies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Purchase Additional Supplies</td>
<td>Continue purchase of additional supplies, as available, for banking outside of the District or direct delivery within the District.</td>
<td>●  ●  ●  ● Ongoing</td>
<td>Regular District Board meetings CEQA Ongoing Ongoing</td>
</tr>
<tr>
<td>6</td>
<td>Desalination Facilities</td>
<td>Desalination facilities to allow for use of additional poor quality groundwater for agricultural use, easing demand on principal aquifer.</td>
<td>●  ●  ● Localized pumping lowering GW levels near MT</td>
<td>Regular District Board meetings CEQA Not yet initiated TBD</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Thru Delta&quot; Facility</td>
<td>Participation of some sort of &quot;Thru Delta&quot; Facility to increase access to contracted (SWP) supplies.</td>
<td>●  ●  ● State-led effort underway</td>
<td>Prop 218 CEQA State-led effort underway Underway</td>
</tr>
<tr>
<td><strong>Management Actions to Raise Funds to Support SGMA Compliance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Acreage Assessment</td>
<td>Set policy to implement an acreage assessment to fund purchase of additional supplies, purchase of land for fallowing, and other investments to support SGMA compliance.</td>
<td>●  ●  ● To be implemented upon adoption of WRMWSD GSP Chapter</td>
<td>Prop 218 CEQA Not yet initiated 2020</td>
</tr>
</tbody>
</table>
### Projects to Enhance Recharge

<table>
<thead>
<tr>
<th>P/MA Number</th>
<th>P/MA Name</th>
<th>Timetable for Completion</th>
<th>Timetable for Accrual of Expected Benefits</th>
<th>Water Supply</th>
<th>Water Demand</th>
<th>Water Quality</th>
<th>Water Management Flexibility / Efficiency</th>
<th>Source(s) of Water, if applicable</th>
<th>Legal Authority Required</th>
<th>One-time Costs</th>
<th>Ongoing Costs (per year)</th>
<th>Potential Funding Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>On-Farm Recharge</td>
<td>TBD; depending on grower interest</td>
<td>First wet year after construction</td>
<td>approx. 2,000 AFY (10,000 AF every five years)</td>
<td>●  ●</td>
<td>Additional wet-year imported water supplies</td>
<td>None</td>
<td>CEQA Costs &lt;$50K</td>
<td>Costs tied to water purchases plus pumping costs (~ $50/AF)</td>
<td>WRMWSD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>In-District Banking Facilities</td>
<td>construction duration: TBD</td>
<td>First wet year after construction</td>
<td>approx. 2,000 AFY (10,000 AF every five years)</td>
<td>approx. 2.75 AFY per acre of land converted to basins</td>
<td>●  ●</td>
<td>Additional wet-year imported water supplies</td>
<td>None</td>
<td>Approx. $40K per acre for land purchase and recharge basin construction</td>
<td>Costs tied to water purchases plus pumping costs (~ $50/AF)</td>
<td>WRMWSD</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Increase Out-of-District Banking Operations</td>
<td>construction duration: TBD</td>
<td>First wet year after construction</td>
<td>TBD; depends on recharge basin area</td>
<td>●  ●</td>
<td>Additional wet-year imported water supplies</td>
<td>None</td>
<td>Approx. $40K per acre for land purchase and recharge basin construction</td>
<td>Costs tied to water purchases plus pumping costs (~ $50/AF)</td>
<td>WRMWSD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Projects to Increase Water Management Flexibility

<table>
<thead>
<tr>
<th>P/MA Number</th>
<th>P/MA Name</th>
<th>Timetable for Completion</th>
<th>Timetable for Accrual of Expected Benefits</th>
<th>Water Supply</th>
<th>Water Demand</th>
<th>Water Quality</th>
<th>Water Management Flexibility / Efficiency</th>
<th>Source(s) of Water, if applicable</th>
<th>Legal Authority Required</th>
<th>Water Management Flexibility / Efficiency</th>
<th>Source(s) of Water, if applicable</th>
<th>Estimated Costs</th>
<th>Potential Funding Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Expand District Distribution System</td>
<td>construction duration: TBD</td>
<td>First wet year after construction</td>
<td>approx. 2,000 AFY</td>
<td>●  ●</td>
<td>Additional wet-year imported water supplies</td>
<td>District authority as a Water Storage District</td>
<td>approx. $18M for 2,000 acre SWSA expansion</td>
<td>Costs tied to water purchases plus pumping costs (~ $50/AF)</td>
<td>WRMWSD; grants</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Projects to Develop New Supplies

<table>
<thead>
<tr>
<th>P/MA Number</th>
<th>P/MA Name</th>
<th>Timetable for Completion</th>
<th>Timetable for Accrual of Expected Benefits</th>
<th>Water Supply</th>
<th>Water Demand</th>
<th>Water Quality</th>
<th>Water Management Flexibility / Efficiency</th>
<th>Source(s) of Water, if applicable</th>
<th>Legal Authority Required</th>
<th>Estimated Costs</th>
<th>Potential Funding Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Purchase Additional Supplies</td>
<td>Ongoing</td>
<td>Immediately</td>
<td>Increase purchases by 5,000 AFY</td>
<td>●  ●</td>
<td>Additional imported water supplies</td>
<td>District authority as a Water Storage District</td>
<td>NA</td>
<td>District has been an active purchaser of additional supplies for some time. Average costs are approx. $500/AF.</td>
<td>WRMWSD</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Desalination Facilities</td>
<td>construction duration: 1-3 years</td>
<td>Immediately upon completion of construction</td>
<td>No-net supply augmentation, but minimizes local GW pumping impacts</td>
<td>●  ●</td>
<td>Poor-quality (currently unused) groundwater</td>
<td>None</td>
<td>NA</td>
<td>Annual costs approximately $600/AF</td>
<td>WRMWSD; grants</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>“Thru Delta” Facility</td>
<td>2035</td>
<td>1 year after completion</td>
<td>up to 25,000 AFY</td>
<td>●  ●</td>
<td>State Water Project</td>
<td>None</td>
<td>NA, as this Project would be bonded through SWP, costs would occur on annual bills</td>
<td>TBD; estimates of Cal WaterFix Project were &gt;$600/AF</td>
<td>WRMWSD</td>
<td></td>
</tr>
</tbody>
</table>

### Management Actions / Policies to Reduce Overall Water Demand

<table>
<thead>
<tr>
<th>P/MA Number</th>
<th>P/MA Name</th>
<th>Timetable for Completion</th>
<th>Timetable for Accrual of Expected Benefits</th>
<th>Water Supply</th>
<th>Water Demand</th>
<th>Water Quality</th>
<th>Water Management Flexibility / Efficiency</th>
<th>Source(s) of Water, if applicable</th>
<th>Legal Authority Required</th>
<th>Estimated Costs</th>
<th>Potential Funding Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Acreage Assessment</td>
<td>upon modification of water service contracts</td>
<td>1-3 years after completion</td>
<td>●  ●</td>
<td>NA</td>
<td>District authority as a Water Storage District</td>
<td>approx. $50,000 to set up program</td>
<td>This management action would be used to fund other P/MA</td>
<td>WRMWSD; grants</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table PMA-1  
Details of Projects and Management Actions  
Wheeler Ridge-Maricopa Water Storage District, Kern County, California

<table>
<thead>
<tr>
<th>P/MA Number</th>
<th>P/MA Name</th>
<th>Summary Description</th>
<th>Relevant Sustainability Indicators Affected</th>
<th>Circumstances for Implementation</th>
<th>Public Noticing Process</th>
<th>Permitting and Regulatory Process Requirements</th>
<th>Status</th>
<th>Timetable / Circumstances for Initiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Groundwater Allocation and Market</td>
<td>Develop a groundwater pumping allocation methodology, including a market system for trading and/or transferring of allocations.</td>
<td>●</td>
<td>To be implemented upon adoption of WRMWSD GSP Chapter</td>
<td>Regular District Board meetings</td>
<td>CEQA</td>
<td>Not yet initiated</td>
<td>2020</td>
</tr>
<tr>
<td>10</td>
<td>Voluntary Pumping Limitations</td>
<td>Set non-binding pumping limitations in conjunction with a fee for pumping above limits.</td>
<td>●</td>
<td>To be implemented upon adoption of WRMWSD GSP Chapter</td>
<td>Prop 218</td>
<td>CEQA</td>
<td>Not yet initiated</td>
<td>2020</td>
</tr>
<tr>
<td>11</td>
<td>Mandatory Pumping Limitations</td>
<td>Set binding pumping limitations in conjunction with a fee for pumping above limits.</td>
<td>●</td>
<td>If other PMAAs are insufficient</td>
<td>Prop 218</td>
<td>CEQA</td>
<td>Not yet initiated</td>
<td>2030</td>
</tr>
<tr>
<td>12</td>
<td>Land Retirement</td>
<td>Purchase and permanently fallow previously irrigated acreage within District to reduce overall water demand and groundwater extractions.</td>
<td>●</td>
<td>If other PMAAs are insufficient</td>
<td>Prop 218</td>
<td>CEQA</td>
<td>Not yet initiated</td>
<td>2035</td>
</tr>
<tr>
<td>P/MA Number</td>
<td>P/MA Name</td>
<td>Timetable for Completion</td>
<td>Timetable for Accrual of Expected Benefits</td>
<td>Expected Benefits</td>
<td>Source(s) of Water, if applicable</td>
<td>Legal Authority Required</td>
<td>One-time Costs</td>
<td>Ongoing Costs (per year)</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------------------------</td>
<td>--------------------------</td>
<td>-------------------------------------------</td>
<td>-------------------</td>
<td>----------------------------------</td>
<td>---------------------------</td>
<td>----------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>9</td>
<td>Groundwater Allocation and Market</td>
<td>upon modification of water service contracts</td>
<td>1 year after completion</td>
<td>Primary</td>
<td>NA</td>
<td>District authority as a GSA (KGA Member)</td>
<td>approx. $50,000 to set up program</td>
<td>Minimal</td>
</tr>
<tr>
<td>10</td>
<td>Voluntary Pumping Limitations</td>
<td>upon modification of water service contracts</td>
<td>1-3 years after completion</td>
<td>Primary</td>
<td>NA</td>
<td>District authority as a Water Storage District</td>
<td>approx. $100,000 to set up program</td>
<td>approx. $100,000/yr for monitoring costs; this management action would be used to fund other P/MA</td>
</tr>
<tr>
<td>11</td>
<td>Mandatory Pumping Limitations</td>
<td>2030</td>
<td>1-3 years after completion</td>
<td>Primary</td>
<td>NA</td>
<td>District authority as a GSA (KGA Member)</td>
<td>Minimal additional cost beyond Voluntary Pumping Limitations P/MA</td>
<td>Minimal additional cost beyond Voluntary Pumping Limitations P/MA</td>
</tr>
<tr>
<td>12</td>
<td>Land Retirement</td>
<td>TBD; depending on landowner interest</td>
<td>1 year after completion</td>
<td>Primary</td>
<td>NA</td>
<td>District authority as a GSA (KGA Member)</td>
<td>approx. $40,000 per acre for land purchase (incl. interest); 30 yrs of water savings at 2.75 AFY/ac gives net cost of ~$500 per AF</td>
<td>$250/yr per acre for maintenance</td>
</tr>
</tbody>
</table>

**Management Actions / Policies to Reduce Groundwater Pumping**

**Abbreviations:**
- AFY = acre-feet per year
- SWP = State Water Project
- CEQA = California Environmental Quality Act
- GW = groundwater
- GSA = Groundwater Sustainability Agency
- GSP = Groundwater Sustainability Plan
- KGA = Kern Groundwater Authority
- NA = Not Applicable
- P/MA = Project/Management Action
- SGMA = Sustainable Groundwater Management Act
- TBD = to be determined
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

**Notes:**
C2VSim-FG Projected Hydrographs with and without P/MA Implementation

Kern County, California
August 2019

Wheeler Ridge-Maricopa Water Storage District (WRMWSD)

Legend
- WRMWSD Service Area
- Groundwater Subbasin
  - Kern County (DWR 5-022.14)
  - White Wolf (DWR 5-022.18)
- Minimum Threshold
- Measurable Objective
- 2030 Baseline
- 2030 with Projects
- Baseline
- Baseline with Projects

Abbreviations
- C2VSim-FG: California Central Valley Groundwater-Surface Water Simulation Model, beta fine-grid version
- DWR: California Department of Water Resources
- ft: feet
- P/MA: Project / Management Action
- RMW: Representative Monitoring Well
- SGMA: Sustainable Groundwater Management Act
- WRMWSD: Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.
2. Projected hydrographs are output from C2VSim-FG model, which is currently uncalibrated, and are thus subject to change upon further revision of model.
3. Simulated hydrograph locations do not correspond in all cases to the final water level RMWs to be used for SGMA compliance in the WRMWSD Management Area.

Sources
1. Projected hydrographs obtained from GEI on 5 August 2019.
2. Basemap of RMW locations obtained from GEI on 4 April 2019.
Plan Implementation
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

PLAN IMPLEMENTATION
18. PLAN IMPLEMENTATION ACTIVITIES

Per the Groundwater Sustainability Plan (GSP) Regulations, “plan implementation” refers to “an Agency’s exercise of the powers and authorities described in the Act, which commences after an Agency adopts and submits a Plan or Alternative to the Department and begins exercising such powers and authorities” (California Code of Regulations [23-CCR] § 351(y)). This section describes the activities that will be performed by Wheeler Ridge-Maricopa Water Storage District (WRMWSD or District) as part of GSP implementation within the Wheeler Ridge-Maricopa Management Area, with a focus on the first five years. This section does not address any actions by other entities with potential management authority in the Management Area – i.e., the Kern Groundwater Authority (KGA) Groundwater Sustainability Agency (GSA).

Key GSP implementation activities to be undertaken by the District over the next five years include:

- Monitoring and data collection;
- Data gap filling;
- Projects & Management Action (P/MA) implementation, including policy development to support GSP implementation;
- Technical and non-technical coordination with other water management entities within the Kern County Subbasin (Kern Subbasin);
- Continued outreach and engagement with stakeholders;
- Annual reporting;
- Enforcement and response actions, as necessary; and
- Evaluation and updates, as necessary, of the District’s MA Plan as part of the required periodic evaluations (i.e., “five-year updates”).

Each of these activities is discussed in more detail below.
18.1. Monitoring and Data Collection

As discussed in Section 16 Monitoring Network, successful sustainable groundwater management relies on a foundation of data to support decision making. As such, collection of data within the Wheeler Ridge-Maricopa Management Area will be a key part of GSP implementation. These data collection efforts include data on applicable sustainability indicators to be collected from the networks of Representative Monitoring Sites (RMS), as well as other data and information required for management and reporting under the Sustainable Groundwater Management Act (SGMA), as described below.

**Monitoring of Applicable Sustainability Indicators**

Section 16 Monitoring Network discusses the monitoring networks (i.e., Representative Monitoring Sites) and protocols that will be used for the applicable sustainability indicators within the Wheeler Ridge-Maricopa Management Area, including Chronic Lowering of Groundwater Levels, Reduction of Groundwater Storage (using groundwater levels as a proxy), and Land Subsidence. Those protocols will be followed in the defined networks as part of GSP implementation. Data collected will be incorporated into the District’s own Data Management System (DMS) for subsequent inclusion in the basin-wide DMS. These data will be used to support coordination efforts within the KGA GSA and the Kern Subbasin (e.g., as part of Annual Reports; see Section 18.5 Annual Reporting).

Monitoring results will be evaluated against applicable Sustainable Management Criteria (SMCs; i.e., Undesirable Results, Minimum Thresholds, and Measurable Objectives) to support local management efforts. In addition, although no SMCs are defined at this time for Degraded Water Quality, a network of water quality monitoring sites and sampling protocols have been established within the Wheeler Ridge-Maricopa Management Area. Those data collection activities will also be conducted to support improved local understanding and groundwater management decisions. If it is determined in the future that SMCs are warranted for this Sustainability Indicator, the MA Plan will be amended as such.

The District anticipates that within the first five years of GSP implementation (i.e., in the 2020 – 2025 timeframe), the following efforts related to monitoring will be performed:

- Refinement of the local DMS to comply with the basin-wide DMS;
- Refinement of the Monitoring Network, including potentially adding, replacing or drilling new wells and/or video-logging to collect missing screen/depth info of Representative Monitoring Sites with data existing data gaps (see Section 16.4 Assessment and Improvement of Monitoring Network);
- Semi-annual monitoring for water levels at the RMS, with the potential for more frequent (i.e., monthly) monitoring and/or monitoring of additional well sites;
- Annual monitoring for water quality at the RMS, with the potential for monitoring of additional well sites; and
- Compilation and review of publicly available subsidence data.
Collection of Other Required Information

Besides the data on Sustainability Indicators described above, collection and reporting of other types of information is required under SGMA (see further discussion below in Section 18.5 Annual Reporting). These other types of information include:

- Groundwater extraction information; and
- Surface water supply data

Groundwater extraction information will be quantified for inclusion in the Annual Reports through methods described in the Coordination Agreement.

Surface water supply data will be based on metered diversions at each of the turnouts off the California Aqueduct. All surface water delivered into the Wheeler Ridge-Maricopa Management Area will have a source/type (e.g., State Water Project [SWP], Kern River, Central Valley Project [CVP], or other) assigned to it to facilitate basin-wide accounting of these supply sources.  

Data Gap Filling

The District will prioritize and begin to fill the key data gaps identified in this MA Plan related to the hydrogeologic conceptual model, groundwater conditions, and water budgets, among other things. Such efforts will include, but not be limited to, validating the status of existing wells, refining the water budget parameters based on additional data and modeling, and collecting additional data related to aquifer conditions and properties.

18.2. Project and Management Action Implementation

A main part of GSP implementation will be the implementation of P/MAs to address and prevent potential Undesirable Results. As described in Section 17 Projects and Management Actions, a portfolio of P/MAs has been developed with the goal of addressing the relevant Sustainability Indicators in the specific areas of concern within the Wheeler Ridge-Maricopa Management Area, and each P/MA in the portfolio has certain expected benefits. Table PMA-1 provides the required details about each P/MA, including the circumstances under which they will be implemented.

For many of the P/MAs shown in Table PMA-1, initial steps in implementation will include performing various studies or analyses to refine the concepts into actionable projects and/or policies. Studies and work efforts may include, but are not limited to, the following:

- White papers exploring policy options;

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78 The District’s sole contractual source for imported water supplies is for SWP supplies through the Kern County Water Agency (KCWA). However, the District also obtains water through various exchanges, transfers and sales of water from other sources from time to time.
Plan Implementation
Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

- California Environmental Quality Act (CEQA) studies and documentation;
- Engineering feasibility studies and preliminary design reports;
- Financial and/or economic analysis such as Proposition 218 studies; and
- Legal analyses.

Once the necessary initial studies are completed, P/MAs will undergo, as necessary, final engineering design (in the case of infrastructure projects) and final drafting (in the case of policy-based actions). At that point, construction of projects and/or adoption of policies will occur, followed by ongoing operations and maintenance (O&M), as necessary. It is anticipated that each implemented P/MA will have its own set of monitoring or data collection components to allow for P/MA assessment and, if necessary, modification.

The District anticipates that within the first five years of GSP implementation (i.e., in the 2020 – 2025 timeframe), the following efforts related to P/MA implementation will be performed:

- Initiate study, permitting (i.e., CEQA), and implementation of on-farm recharge (P/MA #1);
- Initiate program to promote private and/or District-owned banking facilities within the District (P/MA #2);
- Explore options to increase size/participation in out-of-District banking facilities (P/MA #3);
- Initiate feasibility and engineering studies to expand the District’s distribution system to areas currently using only private groundwater (P/MA #4);
- Actively participate in the local, regional and state-wide water market(s) to secure additional short- and long-term surface water supplies through exchanges, trades, and sales (P/MA #5);
- Actively participate in the efforts supporting the “Thru-Delta” facility (P/MA #7);
- Initiate re-negotiation of the District’s landowner contracts to provide, among other things, greater flexibility to the District in terms of water purchase and delivery (in support of P/MA #4 and others) and revenue to support other P/MAs (P/MA #8);
- Initiate study of potential groundwater allocation and market system (P/MA #9); and/or
- Develop policies to implement voluntary pumping limitations (P/MA #10).

18.3. Intrabasin Coordination

Just as this MA Plan has been developed as part of a coordinated GSP process in the Kern Subbasin, coordination amongst all water management entities involved in SGMA in the Kern Subbasin will continue during GSP implementation. This coordination will include both technical and non-technical matters, as discussed below.
18.3.1. Technical Coordination

Continued technical coordination will be critical to ensure that all entities in the Kern Subbasin as a whole approach local groundwater management using a robust shared framework of data, information, and technical assumptions. WRMWSD will coordinate with other water management entities on technical matters including, but not limited to, the following:

- DMS development and maintenance;
- Groundwater model refinement and updates;
- Water budget refinement and collection of supporting data; and
- Basin-wide monitoring and reporting efforts.

18.3.2. Non-Technical Coordination

Non-technical coordination will involve matters related to policy, advocacy, governance, and the like. The District will continue to actively participate in coordination meetings with and amongst fellow KGA members and the other Kern Subbasin GSAs. Specific additional non-technical coordination activities will be pursued, as necessary.

18.4. Stakeholder Engagement

The District’s Stakeholder Communication and Engagement Plan (SCEP; Appendix B) is a key part of the MA Plan, and will continue to be refined, updated and executed during GSP implementation. Anticipated stakeholder engagement activities include, but are not limited to:

- Regular SGMA updates during District Board meetings;
- Hosting stakeholder workshops, as needed;
- Posting of relevant announcements and information on the District website; and
- Conducting informational discussions and meetings, as necessary, with interested stakeholders.
18.5. Annual Reporting

§ 356.2. Annual Reports

Each Agency shall submit an annual report to the Department by April 1 of each year following the adoption of the Plan. The annual report shall include the following components for the preceding water year:

(b) A detailed description and graphical representation of the following conditions of the basin managed in the Plan:

(1) Groundwater elevation data from monitoring wells identified in the monitoring network shall be analyzed and displayed as follows:

(A) Groundwater elevation contour maps for each principal aquifer in the basin illustrating, at a minimum, the seasonal high and seasonal low groundwater conditions.

(B) Hydrographs of groundwater elevations and water year type using historical data to the greatest extent available, including from January 1, 2015, to current reporting year.

(2) Groundwater extraction for the preceding water year. Data shall be collected using the best available measurement methods and shall be presented in a table that summarizes groundwater extractions by water use sector, and identifies the method of measurement (direct or estimate) and accuracy of measurements, and a map that illustrates the general location and volume of groundwater extractions.

(3) Surface water supply used or available for use, for groundwater recharge or in-lieu use shall be reported based on quantitative data that describes the annual volume and sources for the preceding water year.

Per the GSP Regulations, an annual report on basin conditions and GSP implementation status is required to be submitted to the Department of Water Resources (DWR) by April 1 of each year following GSP adoption. These annual reports will be prepared on the basin-level but will require input from each local entity, including from WRMWSD. Activities required at the District level and the Basin level are described below.
18.5.1. District-Level Activities

In support of the annual reporting requirements, the District will provide to the basin-level entity preparing the reports all monitoring data from the RMS in its designated monitoring networks, as well as the other required information discussed in Section 0 Collection of Other Required Information above. The District will also provide review and comment on the draft reports to ensure that local information is properly incorporated into the basin-level reports.

18.5.2. Basin-Level Activities

An entity will be designated at the basin level to compile and consolidate all of the local information into annual reports that meet the requirements of the GSP Regulations (23-CCR § 356.2).

18.6. Enforcement and Response Actions

Part of successful management involves the ability to adapt and respond to unforeseen or uncertain circumstances. To the extent possible, methods to address foreseeable problems should be developed before those problems arise. It is anticipated that there may need to be actions taken to enforce compliance with the GSP and any policies adopted thereunder. Such actions, if necessary, will be taken in accordance with applicable laws and authorities.

18.6.1. Impacted Well Mitigation Program

In other cases, a response action may be needed that is driven not by a non-compliance concern (e.g., an Undesirable Result), but rather by a physical, social or economic condition that falls outside of the six Sustainability Indicators defined under SGMA. One such condition that may arise is that of wells being impacted by low groundwater levels. Impacts could include dewatering of pumps or dewatering of well screens to the point of significant reduction in production. To address this potential occurrence, an Impacted Well Mitigation Program will be developed whereby a potential remedy will be provided to owners of wells that are demonstrably impacted by groundwater conditions, as defined within the policy. Funding for such a program may be sourced from the WRMWSD general fund or from a dedicated fund supported by a fee on owners of commercial (i.e., agricultural or industrial) supply wells. The program may be modeled after similar programs developed elsewhere in the basin or around the state (e.g., the Kern Water Bank’s program).
18.7. Periodic Evaluations of GSP

§ 356.4. Periodic Evaluation by Agency

Each Agency shall evaluate its Plan at least every five years and whenever the Plan is amended, and provide a written assessment to the Department. The assessment shall describe whether the Plan implementation, including implementation of projects and management actions, are meeting the sustainability goal in the basin, and shall include the following:

(a) A description of current groundwater conditions for each applicable sustainability indicator relative to measurable objectives, interim milestones and minimum thresholds.

(b) A description of the implementation of any projects or management actions, and the effect on groundwater conditions resulting from those projects or management actions.

(c) Elements of the Plan, including the basin setting, management areas, or the identification of undesirable results and the setting of minimum thresholds and measurable objectives, shall be reconsidered and revisions proposed, if necessary.

(d) An evaluation of the basin setting in light of significant new information or changes in water use, and an explanation of any significant changes. If the Agency’s evaluation shows that the basin is experiencing overdraft conditions, the Agency shall include an assessment of measures to mitigate that overdraft.

(e) A description of the monitoring network within the basin, including whether data gaps exist, or any areas within the basin are represented by data that does not satisfy the requirements of Sections 352.4 and 354.34(c). The description shall include the following:

(1) An assessment of monitoring network function with an analysis of data collected to date, identification of data gaps, and the actions necessary to improve the monitoring network, consistent with the requirements of Section 354.38.

(2) If the Agency identifies data gaps, the Plan shall describe a program for the acquisition of additional data sources, including an estimate of the timing of that acquisition, and for incorporation of newly obtained information into the Plan.

(3) The Plan shall prioritize the installation of new data collection facilities and analysis of new data based on the needs of the basin.

(f) A description of significant new information that has been made available since Plan adoption or amendment, or the last five-year assessment. The description shall also include whether new information warrants changes to any aspect of the Plan, including the evaluation of the basin setting, measurable objectives, minimum thresholds, or the criteria defining undesirable results.

(g) A description of relevant actions taken by the Agency, including a summary of regulations or ordinances related to the Plan.

(h) Information describing any enforcement or legal actions taken by the Agency in furtherance of the sustainability goal for the basin.

(i) A description of completed or proposed Plan amendments.
Per the GSP Regulations (23-CCR § 356.4), the District will conduct a periodic evaluation of its MA Plan, at least every five years, and will modify the MA Plan as necessary to ensure that the Sustainability Goal defined for the Kern Subbasin (see Section 12 Sustainability Goal) is achieved within the Wheeler Ridge-Maricopa Management Area. The GSP elements that will be covered in the periodic evaluation are described below. It is anticipated that the 2025 plan will require substantial revision, especially on matters related to the water budget, P/MAs and sustainability criteria.

18.7.1. Sustainability Evaluation
This section will evaluate the current groundwater conditions for each applicable sustainability indicator within the Wheeler Ridge-Maricopa Management Area, including progress toward achieving Interim Milestones and Measurable Objectives.

18.7.2. Plan Implementation Progress
This section will evaluate the current implementation status of P/MAs, along with an updated project implementation schedules and any new projects that are not included in this MA Plan.

18.7.3. Reconsideration of GSP Elements
Per 23-CCR § 356.4 (c), elements of the MA Plan, including the Basin Setting, Management Areas, Undesirable Results, Minimum Thresholds, and Measurable Objective, will be reviewed and revised if necessary.

18.7.4. Monitoring Network Description
This section will provide a description of the Monitoring Network, including identification of data gaps, assessment of monitoring network function with an analysis of data collected to date, identification of actions that are necessary to improve the monitoring network, and development of plans or programs to fill data gaps.
18.7.5. **New Information**
This section will provide a description of significant new information that has been made available since the adoption or amendment of the MA Plan, or the last five-year assessment, including data obtained to fill identified data gaps. As discussed in Section 18.7.3 *Reconsideration of GSP Elements*, if evaluation of the Basin Setting, Measurable Objective, Minimum Threshold, or Undesirable Results definition warrant changes to any aspect of the MA Plan, these new information would also be included.

18.7.6. **Regulations or Ordinances**
WRMWSD possesses the legal authority to implement regulations or ordinances related to the MA Plan. This section will provide a description of relevant actions taken by WRMWSD, including a summary of related regulations or ordinances.

18.7.7. **Legal or Enforcement Actions**
This section will summarize legal or enforcement actions taken by WRMWSD or the KGA GSA in relation to the MA Plan, along with how such actions support sustainability in the Wheeler Ridge-Maricopa Management Area.

18.7.8. **Plan Amendments**
This section will provide a description of proposed or complete amendments to the MA Plan.

18.7.9. **Coordination**
This section will describe coordination activities relevant to the Wheeler Ridge-Maricopa Management Area.
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Groundwater Sustainability Plan
Wheeler Ridge-Maricopa Management Area, Kern Subbasin

19. PLAN IMPLEMENTATION COSTS

Per the GSP Regulations (23-CCR § 354.6(e) and 354.44(b)(8)), this section provides estimates of the costs to WRMWSD to implement this MA Plan and potential sources of funding to meet those costs.\(^79\)

19.1. Estimated Costs

Costs to the District to implement this MA Plan can be divided into several groups, as follows:

- Costs of local groundwater management activities;
- District’s proportional share of costs for basin-wide groundwater management activities; and
- Costs to implement P/MAs, including capital/one-time costs and ongoing costs.

Table PI-1 provides an estimate of the costs for each of the above groups. Costs to implement P/MAs are shown in Table PI-1 for each main P/MA category; estimated costs for individual P/MAs are provided in Table PMA-1.

19.2. Sources of Funding to Meet Costs

As shown in Table PI-1, costs for GSP implementation are estimated to be significant – i.e., ranging from approximately $3.8 million to $7.5 million per year on average over the next 20 years. To meet these costs, the District will need to establish new funding sources or increase existing funding sources. SGMA grants GSAs certain financial authorities (California Water Code [CWC] § 10725.4 and 10730 through 10731), including to raise revenue through use of fees, assessments, pump taxes, and other methods to pay for the costs incurred by the GSA for SGMA compliance. The District will likely meet the estimated costs through a combination of the following:

\(^79\) Implementation of this MA Plan is likely to result in additional costs to landowners and stakeholders within the Wheeler Ridge-Maricopa Management Area; however, this section does not attempt to quantify those potential costs, but rather focuses on the costs, and funding sources to meet those costs, for the District.
Plan Implementation

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- District revenue from assessments/fees;
- Special assessments/fees for specific projects;
- Grant funding or other financing options; and/or
- Penalties levied on prohibited activities.
20. PLAN IMPLEMENTATION SCHEDULE

This section discusses a general estimated schedule for GSP implementation. The GSP Regulations do not specifically require that a schedule for GSP implementation over the 20-year implementation period (i.e., 2020 through 2040) be provided, and any such schedule would be subject to considerable uncertainty. However, the following factors and constraints inherent to the GSP process guide the schedule for GSP implementation:

- The GSP Regulations require achievement of the Sustainability Goal (i.e., avoidance of Undesirable Results) within 20 years of GSP adoption, which in the case of the Kern Subbasin means by 2040.
- The P/MA implementation glide path discussed in Section 17.1.4 Implementation Glide Path above spells out the general schedule for when expected benefits from P/MAs will accrue between 2020 and 2040.
- Annual reports are due on April 1 of the following year.
- Periodic evaluations are required at least every five years, meaning this MA Plan will be updated no later than 31 January 2025.
### TABLE P1-1
Estimated Costs for Plan Implementation
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

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**Part 1. Costs of Local Groundwater Management Activities**

<table>
<thead>
<tr>
<th>Local Groundwater Management Activity</th>
<th>2020 - 2025</th>
<th>2025 - 2030</th>
<th>2030 - 2035</th>
<th>2035 - 2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring and Data Collection</td>
<td>$38,150</td>
<td>$38,150</td>
<td>$38,150</td>
<td>$38,150</td>
</tr>
<tr>
<td>Monitoring of Applicable Sustainability Indicators</td>
<td>$12,400</td>
<td>$12,400</td>
<td>$12,400</td>
<td>$12,400</td>
</tr>
<tr>
<td>Voluntary Monitoring of Groundwater Quality at Selected Sites</td>
<td>$19,000</td>
<td>$19,000</td>
<td>$19,000</td>
<td>$19,000</td>
</tr>
<tr>
<td>Collection of Other Required Information</td>
<td>$6,750</td>
<td>$6,750</td>
<td>$6,750</td>
<td>$6,750</td>
</tr>
<tr>
<td>Enforcement and Response Actions</td>
<td>$20,300</td>
<td>$20,100</td>
<td>$20,100</td>
<td>$20,100</td>
</tr>
<tr>
<td>Enforcement Actions</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Impacted Well Mitigation Program</td>
<td>$26,100</td>
<td>$20,100</td>
<td>$20,100</td>
<td>$20,100</td>
</tr>
<tr>
<td>Local Stakeholder Engagement</td>
<td>$40,000</td>
<td>$40,000</td>
<td>$40,000</td>
<td>$40,000</td>
</tr>
<tr>
<td>Data Gap Filling</td>
<td>$50,000</td>
<td>$50,000</td>
<td>$50,000</td>
<td>$50,000</td>
</tr>
<tr>
<td>Annual Reporting - District-Level Activities</td>
<td>$12,500</td>
<td>$12,500</td>
<td>$12,500</td>
<td>$12,500</td>
</tr>
<tr>
<td>Periodic Evaluation of GSP - District-Level Activities</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$100,000</td>
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<td><strong>TOTAL Annual Costs of Local Groundwater Management Activities</strong></td>
<td><strong>$260,750</strong></td>
<td><strong>$260,750</strong></td>
<td><strong>$260,750</strong></td>
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**Part 2. Costs for Basin-Wide Groundwater Management Activities**

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<th>2020 - 2025</th>
<th>2025 - 2030</th>
<th>2030 - 2035</th>
<th>2035 - 2040</th>
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TABLE PI-1
Estimated Costs for Plan Implementation
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

Part 3. Costs to Implement Projects and Management Actions

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<td>Capital Costs</td>
<td>Annual O&amp;M Costs</td>
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<td>$8,988</td>
<td>$18,988</td>
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<td>Increase Out-of-District Banking Operations</td>
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<td>Acreage Assessment</td>
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<td>Management Actions / Policies to Reduce Groundwater Pumping</td>
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<td>Voluntary Pumping Limitations</td>
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<td>Mandatory Pumping Limitations</td>
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<td>TOTAL Costs to Implement P/MAs</td>
<td>$14,581,818</td>
<td>$534,090</td>
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Grant Total Costs of GSP Implementation

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<td>$120,000</td>
<td>$120,000</td>
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<td>$4,875,444</td>
<td>$6,255,744</td>
<td>$7,498,014</td>
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REFERENCES AND TECHNICAL STUDIES


Central Valley Regional Water Quality Control Board (CVRWQCB), 2000, *Order No. R5-00-093, Waste Discharge Requirements for City of Arvin and United States Filter Corporation Arvin Wastewater Treatment Facility, Kern County*.

Central Valley Regional Water Quality Control Board (CVRWQCB), 2009, *Order No. R5-2009-0122, Waste Discharge Requirements for City of Bakersfield Wastewater Treatment Plant No. 2, Kern County*. 184
Central Valley Regional Water Quality Control Board (CVRWQCB), 2013, Order No. R5-2013-0120, Waste Discharge Requirements General Order for Growers within the Tulare Lake Basin Area that are Members of a Third-Party Group, Kern County.


Diepenbrock, A., 1933, Mount Poso oil field: California Division of Oil and Gas Summary of Operations – California Oil Fields, v. 19, no. 2.


References and Technical Studies

Groundwater Sustainability Plan

Wheeler Ridge-Maricopa Management Area, Kern Subbasin


Smith, R., Knight, R., and Fendorf, S., 2018, Overpumping leads to California groundwater arsenic threat, Nature Communications, DOI: 10.1038/s41467-018-04475-3


# APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
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<tbody>
<tr>
<td>A</td>
<td>GSP Submittal Checklist</td>
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<tr>
<td>B</td>
<td>Stakeholder Communications and Engagement Plan</td>
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<tr>
<td>C</td>
<td>List of Public Meetings Specific to SGMA and WRMWSD’s MA Plan Development</td>
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<td>D</td>
<td>Analysis of Temporal Characteristics of Available Groundwater Quality Data</td>
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<td>E</td>
<td>Methods and Data Used in the Water Budget Spreadsheet Model Approach</td>
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<td>F</td>
<td>WRMWSD Long-term Monitoring Access Agreement</td>
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<td>G</td>
<td>DWR California Aqueduct Subsidence Study (June 2017), Plates 20 – 24</td>
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<td>H</td>
<td>Parcels Outside of WRMWSD Covered by GSP</td>
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Appendix A

GSP Chapter Submittal Checklist
Table 1. Preparation Checklist for GSP Submittal

<table>
<thead>
<tr>
<th>GSP Regulations Section</th>
<th>Water Code Section</th>
<th>Requirement</th>
<th>Description</th>
<th>Section(s) or Page Number(s) in the GSP</th>
<th>Figures</th>
<th>Tables</th>
<th>Appendices</th>
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<tbody>
<tr>
<td>Article 3. Technical and Reporting Standards</td>
<td>352.2</td>
<td>Monitoring Protocols</td>
<td>- Monitoring protocols adopted by the GSA for data collection and management</td>
<td>16.2</td>
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<td></td>
<td></td>
<td></td>
<td>- Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin</td>
<td>16.1</td>
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<tr>
<td>Article 5. Plan Contents, Subarticle 1. Administrative Information</td>
<td>354.4</td>
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<td>- Executive Summary</td>
<td>ES</td>
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<td>- Organization and management structure</td>
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<tr>
<td></td>
<td>354.8(a)</td>
<td>Map(s)</td>
<td>- Contact information of Plan Manager</td>
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<td>10727.2(a)(4)</td>
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<td>- Legal authority of GSA</td>
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<td>- Estimate of implementation costs</td>
<td>3.5</td>
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<td>354.8(b)</td>
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<td>- Area covered by GSP</td>
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<tr>
<td></td>
<td></td>
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<td>- Adjudicated areas, other agencies within the basin, and areas covered by an Alternative</td>
<td>5.1.1</td>
<td>PA-1</td>
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<td>10727.2(g)</td>
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<td>- Jurisdictional boundaries of federal or State land</td>
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<td></td>
<td></td>
<td>- Existing land use designations</td>
<td>5.1.3</td>
<td>PA-4, PA-5, PA-7</td>
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<td></td>
<td></td>
<td></td>
<td>- Density of wells per square mile</td>
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<td>354.8(c)</td>
<td>Description of water resources monitoring and management programs</td>
<td>- Description of water resources monitoring and management programs</td>
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<td>354.8(d)</td>
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<td>- Description of how the monitoring networks of those plans will be incorporated into the GSP</td>
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<td>354.8(e)</td>
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<td>- Description of conjunctive use programs</td>
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<td>GSP Regulations Section</td>
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| 354.8(f)                | 10727.2(g)         | Land Use Elements or Topic Categories of Applicable General Plans | - Summary of general plans and other land use plans  
- Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects  
- Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans  
- Summary of the process for permitting new or replacement wells in the basin  
- Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management | 5.3.1  
5.3.1  
5.3.1  
5.3.2  
NS |        |        |            |
| 354.8(g)                | 10727.4           | Additional GSP Contents | Description of Actions related to:  
- Control of saline water intrusion  
- Wellhead protection  
- Migration of contaminated groundwater  
- Well abandonment and well destruction program  
- Replenishment of groundwater extractions  
- Conjunctive use and underground storage  
- Well construction policies  
- Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects  
- Efficient water management practices  
- Relationships with State and federal regulatory agencies  
- Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity  
- Impacts on groundwater dependent ecosystems | 5.4  
5.4  
5.4  
5.4  
5.4  
5.4  
5.4  
5.4  
8.7 |        |        |            |
| 354.10                  |                    | Notice and Communication | Description of beneficial uses and users  
- List of public meetings  
- GSP comments and responses  
- Decision-making process  
- Public engagement  
- Encouraging active involvement  
- Informing the public on GSP implementation progress | 5.5.1  
5.5.2  
5.5.3  
PA-1  
5.5.4  
5.5.4  
5.5.4 | B  
C  
B  
B  
B  
B |
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<td>- Two scaled cross-sections</td>
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<td>- Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies</td>
<td>7.3.1, 7.3.2, 7.3.3, 7.3.5</td>
<td>HCM-14 to HCM-20</td>
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<td>354.14(c)(4)</td>
<td>10727.2(a)(5)</td>
<td>Map of Recharge Areas</td>
<td>- Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas</td>
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<td>Current and Historical Groundwater Conditions</td>
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<td>354.20</td>
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<td>Management Areas</td>
<td>- Reason for creation of each management area</td>
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<td>- Minimum thresholds and measurable objectives for each management area</td>
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**Table 1. Preparation Checklist for GSP Submittal**

**Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria**

<p>| 354.24                  | Sustainability Goal | - Description of the sustainability goal                                      | NS 12                                    |         |        |            |
| 354.26                  | Undesirable Results | - Description of undesirable results                                          | 13                                       |         |        |            |
|                         |                    | - Cause of groundwater conditions that would lead to undesirable results      | 13                                       |         |        |            |
|                         |                    | - Criteria used to define undesirable results for each sustainability indicator | 13                                       | 1       |        |            |
|                         |                    | - Potential effects of undesirable results on beneficial uses and users of groundwater | 13                                       |         |        |            |
| 354.28                  | Minimum Thresholds | - Description of each minimum threshold and how they were established for each sustainability indicator | 14                                       |         |        |            |
| 10727.2(d)(1)           |                    | - Relationship for each sustainability indicator                              | 14                                       |         |        |            |
| 10727.2(d)(2)           |                    | - Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater | 14                                       |         |        |            |
|                         |                    | - Standards related to sustainability indicators                              | 14                                       |         |        |            |
|                         |                    | - How each minimum threshold will be quantitatively measured                  | 14                                       |         |        |            |
| 354.30                  | Measurable Objectives| - Description of establishment of the measurable objectives for each sustainability indicator | 15                                       |         |        |            |
| 10727.2(b)(1)           |                    | - Description of how a reasonable margin of safety was established for each measurable objective | 15                                       |         |        |            |
| 10727.2(b)(2)           |                    | - Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones | 15                                       |         |        |            |
| 10727.2(d)(1)           |                    |                                                                                  |                                           |         |        |            |
| 10727.2(d)(2)           |                                                                                  |                                                                                  |                                           |         |        |            |</p>
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<td>10727.2(d)(1)</td>
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<td>- Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions</td>
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<td>- Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends</td>
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<td>- Scientific rational (or reason) for site selection</td>
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<td>- Consistency with data and reporting standards</td>
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<td>- Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone</td>
<td>14, 15</td>
<td>MN-2, SMC-3</td>
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<td>- Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used</td>
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<td>MN-1, MN-2</td>
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<td>- Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies</td>
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<td>- Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators</td>
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<td>- How the Agencies have used the same data and methodologies to coordinate GSPs</td>
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<td>- How the GSPs implemented together satisfy the requirements of SGMA</td>
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<td>- Process for submitting all Plans, Plan amendments, supporting information, all monitoring data and other pertinent information, along with annual reports and periodic evaluations</td>
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<td>- A coordinated data management system for the basin</td>
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<td>- Coordination agreements shall identify adjudicated areas within the basin, and any local agencies that have adopted an Alternative that has been accepted by the Department</td>
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**Status Key**
- **NS** = Not started
- **DIP** = Draft in Prep
- **CR** = Client reviewing
- **FIP** = Final in Prep
- **FA** = Final Approved

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August 2019  
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Wheeler Ridge-Maricopa Water Storage District  
Kern Subbasin GSP Chapter
Appendix B

Stakeholder Communications and Engagement Plan
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<td>CASGEM</td>
<td>California Statewide Groundwater Elevation Monitoring</td>
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<td>Coordination Committee</td>
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<td>Communications and Engagement</td>
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<td>DWR</td>
<td>California Department of Water Resources</td>
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<td>GSA</td>
<td>Groundwater Sustainability Agency</td>
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<td>GSP</td>
<td>Groundwater Sustainability Plan</td>
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<td>HCM</td>
<td>Hydrogeologic Conceptual Model</td>
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<td>JPA</td>
<td>Joint Powers Agreement</td>
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<td>Kern County Water Agency</td>
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<td>Kern Groundwater Authority</td>
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1. INTRODUCTION

§ 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) 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.
(b) A list of public meetings at which the Plan was discussed or considered by the Agency.
(c) Comments regarding the Plan received by the Agency and a summary of any responses by the Agency.
(d) A communication section of the Plan that includes the following:
   (1) An explanation of the Agency’s decision-making process.
   (2) Identification of opportunities for public engagement and a discussion of how public input and response will be used.
   (3) A description of how the Agency encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin.
   (4) The method the Agency shall follow to inform the public about progress implementing the Plan, including the status of projects and actions.

The Wheeler Ridge-Maricopa Water Storage District (WRMWSD or District) has developed this Stakeholder Communication and Engagement Plan (SCEP) to describe its approach to communication and engagement throughout the Groundwater Sustainability Plan (GSP) Chapter development process. This SCEP was prepared in accordance with California Water Code (CWC), the GSP Regulations (Title 23 of the California Code of Regulations [CCR] §354.10 [see above]), and the California Department of Water Resources (DWR) Guidance Document for Groundwater Sustainability Plan Stakeholder Communication and Engagement (DWR, 2018), as well as additional reference documents recommended by DWR for guidance.

Communication and engagement efforts carried out as described in this SCEP will help to ensure that local beneficial uses and users of groundwater are adequately considered in the GSP Chapter development process as required by GSP Regulations (23-CCR §354.10). Specifically, in this SCEP:

- **Section 2** describes the District and Groundwater Sustainability Agency (GSA) decision-making process (23-CCR §354.10(d)(1));
- **Section 3** identifies stakeholders;
- **Section 4** describes how the District intends to build upon its current understanding of stakeholders in the Management Area (23-CCR §354.10(d)(3) and CWC §10723.4);
- **Section 5** describes the key messages for communication and engagement efforts, and anticipated questions as well as possible responses (23-CCR §354.10(d)(4));
- **Section 6** identifies opportunities for public engagement and how public input an response will be used (23-CCR §354.10(d)(2));
• **Section 7** describes the Communications and Engagement (C&E) implementation timeline, including when this SCEP will be updated to inform the public about GSP Chapter implementation progress, including the status of projects and actions (23 CCR §354.10(d)(4));

• **Section 8** describes SCEP assessment and evaluation during the GSP Chapter development process.
2. OBJECTIVES AND DECISION-MAKING

This SCEP is designed to effectively engage a variety of relevant stakeholders in the development of a GSP Chapter that will guide the District, in coordination with the Kern Groundwater Authority (KGA) GSA, to demonstrate sustainability by 31 January 2040 and maintain sustainability through the Sustainable Groundwater Management Act (SGMA)’s 50-year planning timeline.

2.1. GSA and Management Area Description and Boundary

The WRMWSD is a public agency whose jurisdiction encompasses about 147,000 acres of land in Kern County, California, at the southern end of the San Joaquin Valley. The WRMWSD is one of the member agencies of the KGA GSA. The KGA GSA overlies a portion of the Kern County Subbasin (Basin; DWR 5-022.18) of the San Joaquin Valley Basin.

The Wheeler Ridge-Maricopa Management Area (Management Area) comprises approximately 91,000 acres of the KGA GSA, as shown in Figure 1. The remainder of the WRMWSD service area is located outside of the Management Area and within the White Wolf Subbasin. The Basin is a high priority basin that has been designated as being in critical groundwater overdraft condition and has a GSP submission deadline of 31 January 2020.

2.2. WRMWSD Structure and Decision-Making Process

Key GSP Chapter development and implementation decisions are made by the WRMWSD Board of Directors (District Board). The WRMWSD staff help to guide the GSP Chapter development technical consultant team and provide feedback on draft work products.

2.2.1. WRMWSD Board Structure and Meetings

The District is governed by an elected nine-member Board of Directors. District Board meetings are held on the second Wednesday of the month (unless otherwise noticed) and are open to the public. District Board meeting agendas and packets are posted to the WRMWSD website (https://wrmwsd.com) at least 72 hours before each Board meeting.

An ad-hoc committee of the District Board has been formed that will support more detailed engagement with the GSP Chapter development process. The ad-hoc committee will meet on an as-needed basis.

2.2.2. KGA Board Structure and Meetings

Per the Joint Powers Agreement (JPA) executed on 22 March 2017, the KGA GSA Board is composed of one representative from each of the general member agencies (Arvin Community Services District [ACSD], Arvin-Edison Water Storage District [AEWSD], Cawelo Water District [CWD], Kern County Water Agency [KCWA], Kern-Tulare Water District [KTWD], Kern Water Bank Authority [KWBA], North Kern Water Storage District [NKWSD], Rosedale-Rio Bravo Water Storage District [RRBWSD], Semitropic Water Storage District [SWSD], Shafter-Wasco Irrigation District [SWID], Southern San Joaquin Municipal Utility District [SSJMUD], Tejon-Castac Water District [TCWD], West Kern Water District [WKWD], Westside District Water Authority [WDWA], and WRMWSD plus one representative from the County as well as the City of Shafter).
The KGA GSA Board meetings are held on the fourth Wednesday of every month and are open to the public. The KGA GSA Board meeting agendas and packets are posted to the KGA website (www.kerngwa.com/board-of-directors.html).

The KGA GSA Board is supported by a Coordination Committee (CC) that is composed of one to two (1-2) representatives from each voting party of the KGA GSA and encompasses residential, agricultural, environmental, rural, domestic well, and municipal interests\(^1\). The specific role of the KGA’s CC is to make recommendations to the KGA GSA Board regarding technical and other matters (e.g., stakeholder outreach) related to GSP development.

The CC meetings are held the first Monday of each month, and they are open to the public. Meeting agendas and packets are posted to the KGA website (www.kerngwa.com/committees.html).

**2.3. Desired Outcome**

The WRMWSD aims to develop a GSP Chapter that sets its Management Area on a path to maintain sustainability through SGMA’s 50-year planning timeline.

\(^1\) Kern Groundwater Authority Communication & Engagement Plan (http://www.kerngwa.com/assets/kga-communication---engagement-plan---may-2018.pdf)
2.4. Communication Objectives to Support the GSP Chapter

The WRMWSD SCEP efforts aim to support development of a GSP Chapter that meets the needs of beneficial uses and users of groundwater in the Management Area and reflects and incorporates stakeholder input as appropriate. The WRMWSD aims to be knowledgeable about and anticipate stakeholder interests and concerns.

2.5. Challenges for the Plan Area

The WRMWSD is aware of and plans to address the following challenges:

- Several large landowners in the District overlie both the Basin and the White Wolf Subbasin (White Wolf Basin; DWR 5-022.18). The WRMWSD will need to coordinate with entities and landowners in the White Wolf Basin to ensure that communication and engagement efforts conducted by the District and the KGA GSA align with communication and engagement efforts in the White Wolf Basin. Should substantially different groundwater management decisions be made in each basin, WRMWSD will communicate with stakeholders near and straddling the basin boundary to help them understand how GSP implementation in each basin will impact them.

- Irrigated agriculture is the primary land use in the District. It is anticipated that there will be concerns regarding how SGMA compliance could impact that land and water use. The District will be open and transparent in decisions that will have a substantial impact on beneficial users of groundwater, and will engage stakeholders early in the decision-making process to consider their interests and concerns.
3. STAKEHOLDER IDENTIFICATION

The KGA GSA identified current beneficial uses and users of groundwater in the Basin in its formation Notice submitted on 30 May 2017 in accordance with the interests listed in CWC §10723.2. The following are the identified beneficial uses and users of groundwater within the Management Area. Representatives of specific organizations on this list form the basis of the District’s list of interested parties, as required by CWC §10723.2.

3.1. Holders of overlying groundwater rights

3.1.1. Agricultural Users
The primary land use in the Management Area is irrigated agriculture. The WRMWSD provides water service to agricultural water users within its service area.

3.1.2. Domestic Well Owners
There are several known domestic wells scattered throughout the Management Area, but the full extent and distribution of active domestic wells within the Management Area is currently unknown.

3.2. Municipal Well Operators
There are currently no identified municipal well operators within the Management Area.

3.3. Public Water Systems
The WRMWSD provides untreated water for irrigation and industrial purposes. However, there are some small public water systems that provide treated groundwater for domestic uses\(^2\), including:

1. Andrews Ag – Non-community water system that serves a residential population of two (2) and a transient population of 50.
2. Opal Fry and Son – Community water system that serves a residential population of 40.
3. Wheeler Farms Headquarters – Non-Transient Non-Community water system that serves a non-transient population of 25.

While publicly available data have been examined to identify Public Water Systems in the Management Area\(^3\), WRMWSD acknowledges that these datasets are known to be incomplete.

3.4. Local Land Use Planning Agencies
The Management Area is comprised of unincorporated County land, for which the Kern County Planning and Community Development is responsible for land use planning. The County will be involved in the


\(^3\) Including the California Environmental Health Tracking Program Water System Map Viewer (http://www.cehtp.org/page/water/water_system_map_viewer).
development and implementation of the KGA GSP (which includes the District’s GSP Chapter) through its participation in the KGA GSA.

3.5. Environmental Users of Groundwater

There is minimal interaction between groundwater and surface water in the Management Area, except in the area of known perched groundwater along the northern boundary. While this perched groundwater appears to support localized wetlands areas, as mapped by DWR\(^4\), this system is disconnected from and not part of the principal aquifer. In most of the Management Area, the groundwater table is encountered more than 200 feet below ground surface and thus there is no groundwater contribution to streamflow or other surface water features.

Wind Wolves Preserve is a nature preserve that is adjacent to the Management Area.

3.6. Surface Water Users

Surface water features in the Basin include ephemeral streams draining the San Emigdio Mountains, several small lakes and ponds, the California Aqueduct, and a network of irrigation canals and ditches.

The US Bureau of Land Management holds appropriative water rights, Wildlands Conservancy holds diversion water rights, and CalMat Co. holds both appropriative and diversion water rights on San Emigdio Creek\(^5\). There are also several entities with diversion rights from springs near the boundary of the Basin. These include inactive rights held by Dole Dried Fruit & Nut Company and active federal claims held by USDA – Los Padres National Forest.

3.7. The Federal Government

Two parcels located south of the Rim Ditch within the Management Area, Southeast ¼ of Section 20 and South ½ of Section 22 within Township 32 South, Range 26 East, are identified as federal lands owned by the US Bureau of Land Management.

3.8. California Native American Tribes

There are no identified California Native American tribal lands within the Management Area.

3.9. Disadvantaged Communities

There were no Disadvantaged Community Places identified within the Management Area (U.S. Census, 2015). A portion of US Census Tracts 33.04, 33.06, and 62.02, which overlie almost the entire Management Area, was identified as a Disadvantaged Community Census Tract based on an average household income less than 80% of the State median (U.S. Census, 2015). Census Tract 33.06 includes a Severely Disadvantaged Community Census Block Group (Block Group 1 of Census Tract 33.05) in the southern portion of the Management Area.

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\(^4\) DWR NC Dataset Viewer (https://gis.water.ca.gov/app/NCDatasetViewer/).
\(^5\) According to the SWRCB Electronic Water Rights Information Management System (eWRIMS), accessed 26 July 2018.
As described in the KGA GSA Community & Engagement Plan to engage residents of disadvantage communities/areas, the KGA GSA is coordinating with Self-Help Enterprises (SHE) to identify convenient times and locations for public outreach meetings and to distribute meeting notices.

3.10. Groundwater Monitoring Entities

The WRMWSD submitted a notice to become a monitoring entity for its service area under the California Statewide Groundwater Elevation Monitoring (CASGEM) Program in 2011. The current status for this application process is under review and pending development of the CASGEM monitoring network. However, AEWSD is a Monitoring Entity in the Basin and overlaps with the Management Area. AEWSD is a member of the KGA GSA and will be involved in coordinating GSP Chapter development.

Additionally, Kern River Fan Group (comprised of Kern Delta Water District, Henry Miller Water District, and Buena Vista Water Storage District) is a Monitoring Entity just north of the Management Area. Henry Miller Water District and Buena Vista Water Storage District have formed their own GSAs, and Kern Delta Water District is part of the Kern River GSA. Monitoring coordination will be included in a coordination agreement as required by the GSP Regulations (23-CCR §357.4).
4. STAKEHOLDER SURVEY AND MAPPING

The WRMWSD intends to update its list of stakeholders based on new information as appropriate. To learn more about its stakeholders, WRMWSD has coordinated with the KGA GSA to distribute a stakeholder survey (Appendix A) by:

- Posting the survey on WRMWSD website (https://wr mwsd.com/);
- Having copies of the survey available at WRMWSD Board meetings and stakeholder workshops;
- Sending the survey in water bill mailings or special mailings; and
- Coordinating with the community organizations (e.g., Kern County Farmers Bureau, Self-Help Enterprises, etc.) to distribute the survey to diverse members of the population that may not be otherwise be reached.

Based on current knowledge of stakeholders, WRMWSD has completed a “Lay of the Land” exercise in Table 1, identifying specific stakeholder organizations/individuals, stakeholder type, key interests and issues, the sections of the GSP Chapter likely to be relevant to this stakeholder, and the level of engagement (e.g., inform, consult, involve) expected with each stakeholder organization/individual.

Given that WRMWSD will gain more knowledge of the interests, issues, and challenges of stakeholders over the course of GSP Chapter development, Table 1 will be updated as part of GSP Chapter development. Should WRMWSD need to learn more about specific stakeholders, individual meetings will be arranged to find out more about their issues, interests, and challenges.

In addition to the more detailed stakeholder survey, WRMWSD intends to maintain a simple form or an e-mail request link on its webpage for individuals to enroll in WRMWSD interested parties list and provide their contact information.
5. MESSAGES

The WRMWSD aims to convey consistent high-level messaging to stakeholders throughout GSP Chapter development and implementation. The following are the key messages that will form the foundation for communication and engagement efforts:

1. WRMWSD aims to engage with diverse stakeholders to best represent their interests in the GSP Chapter development process;
2. Key GSP Chapter development decisions will be made in an open and transparent fashion during public District Board meetings; and
3. Technical GSP Chapter development progress will be communicated in an accessible manner to support stakeholder understanding and input.

Additionally, the GSA has developed Table 2 to document anticipated questions as well as possible responses. Table 2 will be updated, as needed, to add additional, frequently received questions as well as to build upon responses based on GSP Chapter development progress.

Table 2 Likely Questions and Responses

<table>
<thead>
<tr>
<th>Likely Questions</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>How can I participate in the GSP Chapter development and implementation process?</td>
<td>District Board meetings are open to the public and held at 8:30 AM on the second Wednesday of the month unless otherwise noticed in the District Headquarters, 12109 Highway166, Bakersfield CA 93313. Stakeholder workshops will be held throughout the GSP Chapter development process, and will be publicized on WRMWSD website (<a href="https://wrmwsd.com/">https://wrmwsd.com/</a>).</td>
</tr>
<tr>
<td>Will I have to fallow my land?</td>
<td>We are currently in the initial phases of GSP Chapter development. Projects and management actions to achieve sustainability will be discussed later in the process, with opportunity for stakeholder input.</td>
</tr>
<tr>
<td>What types of management actions or projects are going to occur in my area?</td>
<td>We are currently in the initial phases of GSP Chapter development. Projects and management actions to achieve sustainability will be discussed later in the process, with opportunity for stakeholder input.</td>
</tr>
<tr>
<td>Are pump meters going to be required? Who will pay for meters?</td>
<td>We are currently in the initial phases of GSP Chapter development. Projects and management actions to achieve sustainability will be discussed later in the process, with opportunity for stakeholder input.</td>
</tr>
<tr>
<td>Who is paying for GSP Chapter development and implementation?</td>
<td>Agencies in the Basin have obtained state funding to support specific efforts related to GSP development (<a href="https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Sustainable-Groundwater">https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Sustainable-Groundwater</a>). The WRMWSD will pay for GSP Chapter development and will contribute to the development of a GSP Umbrella by the KGA GSA. The actual cost to the landowner has yet to be determined.</td>
</tr>
</tbody>
</table>
6. VENUES FOR ENGAGING

The WRMWSD intends to provide a variety of opportunities for engagement with stakeholders. Stakeholder input received will inform and be incorporated into corresponding sections of the GSP Chapter as appropriate.

6.1. District Board Meetings

As described in Section 2.2.1, District Board meetings are open to the public and are a consistent venue for public engagement.

The WRMWSD understands that Basin-wide public outreach meetings will direct residents to the member agency in whose management area they reside, and welcomes residents within its Management Area, including the overlying DAC areas, to attend its public board meetings.

6.2. Stakeholder Workshops

Stakeholder workshops will be held to communicate progress on GSP technical components to stakeholders and to receive input on upcoming decisions and work efforts. At least two stakeholder workshops and one public hearing will be held during GSP Chapter development:

- **Stakeholder Workshop #1** – held 24 May 2018 – SGMA Overview, draft results of Basin Setting Information, Preliminary Undesirable Results, and Key Policy Decisions
- **Stakeholder Workshop #2** – to be held in Winter 2018/2019 – Draft Sustainable Management Criteria and Discussion of Projects and Management Actions.
- **Public Hearing** – Review of the draft GSP Chapter.

The WRMWSD will publicize all stakeholder workshops on its website (https://rmwsd.com/) and to its list of interested parties and will coordinate with community organizations (e.g., Kern County Farmers Bureau, Self-Help Enterprises, etc.) to send out emails and mailings as appropriate.

The KGA GSA is holding a series of stakeholder workshops focused on Basin-wide GSP development. The WRMWSD will coordinate with the KGA GSA as appropriate about their respective stakeholder workshops.

Additional stakeholder workshops may be held during GSP Chapter implementation. The timing and content of these stakeholder workshops will be determined when the GSP Implementation Plan is developed shortly before GSP Chapter submission.

6.3. Website Communication

The WRMWSD will update its website with WRMWSD Board meeting materials as described in Section 2.2.1, and will additionally update the website with key GSP Chapter updates.
6.4. Stakeholder Surveys

The WRMWSD intends to learn about stakeholder interests using surveys that will be distributed as discussed in Section 4. This stakeholder survey is included as Appendix A.
7. IMPLEMENTATION TIMELINE

The GSA’s C&E implementation timeline aligns with a four phase GSP Chapter development timeline, as described in Table 3 below.

Table 3 GSP Development and C&E Efforts by Phase

<table>
<thead>
<tr>
<th>Phase</th>
<th>Timeframe</th>
<th>Overall GSP Efforts (led by technical consultant team)</th>
<th>C&amp;E Efforts (led by the WRMWSD staff)</th>
</tr>
</thead>
</table>
| GSP Foundation         | May 2018 – September 2018| • Select and design a Data Management System (DMS)  
• Conduct data gaps assessment  
• Evaluate numerical groundwater model options                                                                 | • Develop SCEP  
• Distribute Stakeholder Survey  
• Update Stakeholder Constituency Table                                                                 |
| Basin Characterization and Analysis | May 2018 – October 2018  | • Implement plan for filling data gaps  
• Develop Hydrogeologic Conceptual Model (HCM) and definition of groundwater conditions  
• Develop water budget  
• Assess existing monitoring programs                                                                 | • Conduct Stakeholder Workshop #1  
• Update Stakeholder Constituency Table                                                                 |
| Sustainability Planning | August 2018 – December 2018 | • Evaluate potential management areas  
• Develop sustainable management criteria  
• Identify projects and management actions  
• Create GSP implementation plan  
• Finalize monitoring network and protocols                                                                 | • Conduct Stakeholder Workshop #2  
• Update Stakeholder Constituency Table  
• Update SCEP to reflect plan for C&E efforts during GSP Implementation |
| GSP Preparation and Submittal | December 2018 – January 2020 | • Compile complete draft GSP  
• Revise draft GSP (if necessary) per stakeholder feedback  
• Finalize GSP and submit to DWR                                                                 | • Distribute draft GSP  
• Hold Public Hearing on draft GSP  
• Assess C&E progress and plan for C&E related to GSP Implementation  
• Update Stakeholder Constituency Table |

The WRMWSD will update this SCEP while creating a GSP Chapter implementation plan. This update will focus on informing the public about GSP implementation progress, including the status of projects and actions (23-CCR §354.10(d)(4)).
8. EVALUATION AND ASSESSMENT

The WRMWSD intends to assess its SCEP during GSP Chapter development, as shown in Table 3. The WRMWSD staff will present brief summaries of SCEP implementation progress at District Board meetings and will lead a discussion about lessons learned and what can be improved as part of GSP implementation. The following questions will guide SCEP evaluation:

- What worked well?
  - What allowed us insight into stakeholder concerns?
  - What types of materials best communicated GSP development to stakeholders?
- What didn’t work as planned?
  - Could materials (e.g., presentation slides, website pages) have been improved to better communicate GSP development progress?
  - Are certain stakeholder groups less represented in the GSP development process than they should be?
- What do we plan on doing differently during the next phase based on what we have learned?
- How much of our communication and engagement budget have we spent relative to work completed? Do we have enough remaining budget to complete our SCEP?
REFERENCES AND TECHNICAL STUDIES


DWR, 2018. NC Dataset Viewer.
https://gis.water.ca.gov/app/NCDatasetViewer/


https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystems.jsp?PointOfContactType=none&number=&name=&county=Kern

https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=1413&tinwsys_st_code=CA&wsnumber=CA1502004.

https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=1267&tinwsys_st_code=CA&wsnumber=CA1500216.

https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=1417&tinwsys_st_code=CA&wsnumber=CA1502017.

# Stakeholder Communication and Engagement Plan
## Wheeler Ridge-Maricopa Management Area

### Table 1
**Stakeholder Constituency – “Lay of the Land” Exercise**

<table>
<thead>
<tr>
<th>Organization/Individual</th>
<th>Type of Stakeholder (a)</th>
<th>Anticipated Key Interests</th>
<th>Anticipated Key Issues (b)</th>
<th>Relevant GSP Sections</th>
<th>Level of Engagement and Rationale (c)</th>
</tr>
</thead>
</table>
| Agricultural Water Users | Agricultural Users       | Preserving access to high quality groundwater for irrigation | • Potential curtailment of pumping  
• GSP development and implementation costs | • Sustainable Management Criteria  
• Projects and Management Actions | Collaborate to ensure sustainable management of groundwater |
| Domestic Well Users      | Domestic Well Owners    | Preserving access to high quality groundwater for domestic users | • Water quality degradation  
• Declining water levels  
• Potential curtailment of pumping  
• GSP development and implementation costs | • Sustainable Management Criteria  
• Projects and Management Actions | Inform and involve to avoid negative impact to these users |
| Kern County Planning and Community Development | Local Land Use Planning Agency | Managing County-wide land use |  
*Need to identify* |  
*Need to identify* | Consult and involve to ensure land use policies are supporting GSPs |
| Active oil field operators | Industrial Users | Continue to operate oil fields |  
• Definition of vertical extent of the groundwater basin based on salinity |  
• Basin Setting  
• Sustainable Management Criteria  
• Projects and Management Actions | Inform and involve to avoid negative impact to these users |
| Andrews Ag               | Public Water System     |  
*Need to identify* |  
*Need to identify* |  
*Need to identify* |  
*Need to identify* |
| Opal Fry and Son         | Public Water System     |  
*Need to identify* |  
*Need to identify* |  
*Need to identify* |  
*Need to identify* |
| Wheeler Farms Headquarter | Public Water System     |  
*Need to identify* |  
*Need to identify* |  
*Need to identify* |  
*Need to identify* |
| Arvin-Edison Water Storage District | Agricultural Users, Groundwater Monitoring Entity | Preserve access to high quality groundwater for irrigation |  
• Potential curtailment of pumping  
• GSP development and implementation costs  
• Operation of recharge basins |  
• Basin Setting  
• Sustainable Management Criteria  
• Projects and Management Actions | Collaborate to ensure sustainable management of groundwater |
| Wheeler Ridge-Maricopa Water Storage District | Agricultural Users, Groundwater Monitoring Entity | Preserve access to high quality groundwater for irrigation |  
• Potential curtailment of pumping  
• GSP development and implementation costs |  
• Basin Setting  
• Sustainable Management Criteria  
• Projects and Management Actions | Collaborate to ensure sustainable management of groundwater |
<table>
<thead>
<tr>
<th>Organization/ Individual</th>
<th>Type of Stakeholder (a)</th>
<th>Anticipated Key Interests</th>
<th>Anticipated Key Issues (b)</th>
<th>Relevant GSP Sections</th>
<th>Level of Engagement and Rationale (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Wolves Preserve</td>
<td>Environmental Users</td>
<td>Preserve ecosystem</td>
<td>Analyzing potential groundwater dependence of ecosystems</td>
<td>Basin Setting, Sustainable Management Criteria, Projects and Management Actions</td>
<td>Inform and involve to sustain ecosystem</td>
</tr>
<tr>
<td>The US Bureau of Land Management</td>
<td>Surface Water Users</td>
<td>Need to identify</td>
<td>Need to identify</td>
<td>Need to identify</td>
<td>Need to identify</td>
</tr>
<tr>
<td>CalMat Co.</td>
<td>Surface Water Users</td>
<td>Need to identify</td>
<td>Need to identify</td>
<td>Need to identify</td>
<td>Need to identify</td>
</tr>
<tr>
<td>Wildlands Conservancy</td>
<td>Surface Water Users</td>
<td>Need to identify</td>
<td>Need to identify</td>
<td>Need to identify</td>
<td>Need to identify</td>
</tr>
<tr>
<td>U.S. Bureau of Land Management</td>
<td>The Federal Government</td>
<td>Need to identify</td>
<td>Need to identify</td>
<td>Need to identify</td>
<td>Need to identify</td>
</tr>
</tbody>
</table>

**Abbreviations:**

CWC = California Water Code  
DWR = California Department of Water Resources  
GSA = Groundwater Sustainability Agency  
GSP = Groundwater Sustainability Plan  
SGMA = Sustainable Groundwater Management Act

**Notes:**

(a) Type of stakeholder based on CWC §10723.2 (e.g., agricultural groundwater users, municipal well operators, etc.).

(b) Any documented issues (media coverage, statements, reports, etc.), specific issues such as past events, or issues that have been otherwise communicated to or are anticipated by the GSA.

(c) Level of engagement based on the International Association of Public Participation Spectrum of Public Participation, as referenced in DWR’s Guidance Document for Groundwater Sustainability Plan Stakeholder Communication and Engagement (DWR, 2018).
Abbreviations
DWR = California Department of Water Resources
KGA GSA = Kern Groundwater Authority Groundwater Sustainability Agency
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 9 August 2018.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
3. WRMWSD Management Area boundary was received by WRMWSD staff on 3 July 2018 and excludes overlap area with West Kern Water District Groundwater Sustainability Agency.
4. KGA GSA boundary was extracted from the SGMA portal on 12 October 2017.
APPENDIX A – STAKEHOLDER SURVEY
Stakeholder Survey

Date: ____________________________

Stakeholder Type (check all that apply):

<table>
<thead>
<tr>
<th>Agricultural User</th>
<th>Domestic Well Owner/User</th>
<th>Municipal Well Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Water Systems</td>
<td>Local Land Use Planning Agency</td>
<td>Environmental User</td>
</tr>
<tr>
<td>Surface Water User</td>
<td>Native American Tribe</td>
<td>Disadvantaged/Rural Community Resident</td>
</tr>
<tr>
<td>City Resident</td>
<td>Food Processor</td>
<td>Industrial User/Oil Producer</td>
</tr>
<tr>
<td>Entity monitoring and reporting groundwater elevations in all or part of the groundwater basin</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Please complete your name and contact information if you’d like to be added to the GSA’s email and mailing list for future updates and information regarding Sustainable Groundwater Management Act (SGMA) and the Kern Groundwater Authority.

Name: __________________________________________________________

Address: _________________________________________________________

City: ___________________________________ State: _______ Zip: __________

Email: __________________________________ Telephone: ___________________

1. Are you familiar with Sustainable Groundwater Management Act (SGMA) regulations?  
   □ Yes  □ No

2. Are you currently working on or discussing groundwater management in this region?  
   □ Yes  □ No

3. Do you own or manage/operate land in this region?  
   □ Yes  □ No

4. Where are you getting your water supply?  
   □ City or Community Water System  □ Surface  □ Groundwater  
   □ Both Groundwater & Surface Water  □ Unknown

5. Agriculture & Domestic Well Users: What is your well(s) depth?  
   ________________________________________________________________

6. Agriculture & Domestic Well Users: Has your well(s) ever gone dry?  
   □ Yes  □ No  
   If yes, when (month/year)? _______________________________________

7. If you are an Agricultural User, do you:  
   □ Irrigate  □ Dry Farm  □ Graze Livestock  
   □ Other: ______________________________________________________

8. How reliable is your current groundwater supply?  
   ________________________________________________________________

9. If you grow crops, do you use irrigation for frost protection?  
   □ Yes  □ No

10. Do you manage water resources?  
    □ Yes  □ No  
    If yes, what is your role? ________________________________________
11. What is your primary interest in land or water resources management? ____________________________________________

_______________________________________________________________________________________________________

_______________________________________________________________________________________________________

12. Do you have concerns about groundwater management?  ☐ Yes  ☐ No

If so, what are they? ____________________________________________

_______________________________________________________________________________________________________

_______________________________________________________________________________________________________

_______________________________________________________________________________________________________

13. Do you have requests or recommendations regarding groundwater management?  ☐ Yes  ☐ No

If so, what are they? ____________________________________________

_______________________________________________________________________________________________________

_______________________________________________________________________________________________________

_______________________________________________________________________________________________________

14. Any other information the Kern Groundwater Authority should be aware of or take into consideration while developing the Groundwater Sustainability Plan (GSP)?

_______________________________________________________________________________________________________

_______________________________________________________________________________________________________

_______________________________________________________________________________________________________

_______________________________________________________________________________________________________

Please return completed surveys to the Kern Groundwater Authority by emailing tbarton@ppeng.com, faxing to (661) 479-7172, or mail to Kern Groundwater Authority, 1800 30th Street, Suite 280, Bakersfield, CA 93301. Stakeholder Surveys may also be completed online by visiting www.kerngwa.com.
Appendix C

List of Public Meetings Specific to SGMA and WRMWSD’s GSP Chapter Development
Meetings at which WRMWSD SGMA/GSP Topics Were Discussed

WRMWSD Board Meetings
14 February 2018  
24 May 2018  
12 September 2018  
14 November 2018  
11 March 2019  
10 April 2019  
14 May 2019  
10 July 2019

GSP Stakeholder Workshops
12 June 2019

Basin-wide Stakeholder Open House
14 May 2019
Appendix D

Analysis of Temporal Characteristics of Available Groundwater Quality Data
Appendix D - 1

Analysis of Temporal Characteristics of Available Groundwater Quality Data - Total Dissolved Solids vs. Groundwater Elevation
TDS
Appendix D -2

Analysis of Temporal Characteristics of Available Groundwater Quality Data - Nitrate (as NO3) vs. Groundwater Elevation
Nitrate
Appendix D -3

Analysis of Temporal Characteristics of Available Groundwater Quality Data -
Total Recoverable Arsenic vs. Groundwater Elevation
Arsenic
Appendix E

Methods and Data Used in the Water Budget Spreadsheet Model Approach
Appendix E-1

Water Budget Model Overview
A water budget is an accounting of all water inflows to and outflows from a given spatial domain, and enforces the principle of mass balance through use of a change in water storage term. A water budget is expressed by the following simple equation:

\[
\text{Inflows} - \text{Outflows} = \text{Change in Storage}
\]

The above fundamental equation holds true for any defined domain (e.g., parcel, watershed, basin, etc.) and length of time (e.g., day, month, year, etc.) and, when properly constructed using process- and/or physics-based components, serves as a powerful tool for understanding water flow through a system.

**Figure E-1-1: DWR Water Budget Schematic (Fig. 7 from DWR's SGMA BMP #4, pg. 30)**

### Description of Water Budget Framework

A water budget “framework” has been developed to inform the development of a water budget model for the District’s service area that is consistent with the requirements of the Sustainable Groundwater Management Act (SGMA) and aligns with the historical, current, and future water budget periods as specified by the Kern Groundwater Authority GSA (KGA GSA) and further described below. The conceptual water budget model is depicted on **Figures WB-1 and WB-2** of the Wheeler Ridge-Maricopa Water Storage District (WRMWSD) Kern Subbasin Management Area Plan, and is further described below.

**Water Budget Subdomains**

The water budget is divided into five internal subdomains, each influenced by a number of flow components and within which mass-balance is enforced (i.e., the sum of inflow components is balanced by the sum of outflow components and/or a change in storage component). **Figure WB-1** shows the water budget domain, and the following internal subdomains:
In addition to the five internal subdomains, several external subdomains are incorporated into the spreadsheet model. These include the watersheds that contribute streamflow to streams entering the District, and the atmosphere which is a source of precipitation and sink for evapotranspiration. The spreadsheet model does not explicitly account for the vadose (unsaturated) zone between the land surface and the (saturated) groundwater system, but instead incorporates temporal lag factors to account for the movement of water through this zone. An implicit assumption in this approach, therefore, is that the vadose zone does not experience any change in storage over time.

**Water Budget Flow Components**

Within and between each subdomain are 31 water budget flow components that route water through WRMWSD. Figure WB-2 shows a conceptual diagram of the individual water budget flow components between subdomains as well as flow components that are external to the overall water budget domain (i.e., serve only as an inflow or outflow to the entire system, rather than a flow between subdomains). The 31 conceptual water budget flow components are listed in Table E-1-1, along with an overview of their estimation methods. The general relationship between water budget subdomains, associated flow components, and mass balance relationships is further depicted in Table E-1-2.

Certain components are based on “raw” data which are directly measured and based on historical records. These “raw” components are considered to have a relatively high degree of certainty. Other components are estimated using a variety of analytical methods (e.g., Darcy’s Law to calculate subsurface flows across the domain’s external boundaries) and are thus subject to greater uncertainty based on the parameters used in their estimation. Some components (i.e., groundwater pumping for agricultural use) constitute major proportions of the overall water budget and have thus been given significant attention. Others are relatively minor in magnitude (e.g., seepage from artificial channels) and are, to some degree, less significant to the overall water budget and less well defined.

While the various subdomains and linkages shown on Figures WB-1 and WB-2 and in Table E-1-1 and Table E-1-2 indicate a highly complex system, the use of such a component-based bottom-up approach allows each component to be considered separately which can benefit model development and application. For example, if new data or methods become available for a certain component, they can be easily plugged into the appropriate component without disturbing the rest of the model.

**Water Budget Time Periods**

As mentioned above, the water budget spreadsheet model was developed to estimate the magnitude of water budget flow components and the resulting change in groundwater storage to the local aquifer system underlying WRMWSD for three distinct time-periods as defined by the KGA GSA:

- **Historical** – DWR Water Years 1995 – 2014 (i.e., October 1994 – September 2014);
- **Current** – DWR Water Year 2015 (i.e., October 2014 – September 2015); and
- **Future** – 50-year projection of DWR Water Years 2016 – 2065 (see Appendix E-6).
Water Budget Spreadsheet Model Functionality

The water budget spreadsheet model was developed using Microsoft Excel. The complete model consists of one Excel (.xlsx) workbook with several individual spreadsheet tabs which can generally be grouped into four categories:

- “Master” Models
- “User Input Parameters” and Model Calibration
- Presentation and Reporting
- “Backend” Data and Calculations

“Master” Models

The final calculations for all historical and current (1994 - 2015) water budget components occur within the following three “master” tabs of the spreadsheet:

- “Kern_monthly_WB”
- “WWB_monthly_WB”
- “Combined_monthly_WB”

These tabs contain the fully populated monthly historical and current water budgets for (1) the District’s SGMA management area within the Kern Subbasin\(^1\), (2) the District’s SGMA management area within the White Wolf Subbasin, and (3) District’s entire SGMA management area, respectively.

Results of the historical and current water budget efforts for the Kern Subbasin were subsequently used to inform the development of three projected (i.e. future) water budget scenarios for the WRMWSD Kern Subbasin Management Area, which are described in greater detail in Appendix E-6. The projected water budget “master” spreadsheet models include:

- “Kern_PROJECTED_baseline”
- “Kern_PROJECTED_2030”
- “Kern_PROJECTED_2070”

All master spreadsheets are denoted in green within the Excel workbook. Each column of the master spreadsheets represents an individual water budget flow component or associated calculation. Flow components are grouped by Water Budget Domain/Subdomain, and main flow components are listed by number (1 through 31) near the top of each master tab. Each row of the master spreadsheets (apart from the header rows) represents a single month in the model period, as defined in columns E-F. All values are listed in acre-feet (AF). Monthly values are subsequently summarized by water year at the bottom of each master spreadsheet. The master spreadsheets have been fully populated with data via linkages with the “backend” data and calculation spreadsheets (described in further detail below) and/or through calculations made directly within the master spreadsheet, and in all cases should not be directly edited.

---

\(^1\) This area includes the District’s overlap lands with Arvin-Edison Water Storage District (AEWSD) within the Kern Subbasin. Select water budget components are reported for the overlap and non-overlap areas in Tables WB-1 – WB-5 of the Management Area Plan. WRMWSD is actively coordinating with AEWSD regarding management responsibilities of the overlap lands under SGMA implementation, and associated water budget models will be updated accordingly going forward.
unless intending to override the existing data with updated inputs. Raw data inputs are denoted in blue shaded cells, whereas unshaded cells are calculated inputs.

“User Input Parameters” and Model Calibration

As further described in Appendix E-5, various “User Input Parameters” are included to assist in calibration of the historical and current water budgets. These are listed above the header rows of the master tabs, including:

- Irrigation Efficiency Coefficients (for micro-drip, micro-sprinkler, sprinkler, center-pivot sprinkler, and gravity-based irrigation types; see Appendix E-4)
- Deep Percolation Lag Period (i.e., approximate time delay for deep percolation to reach groundwater table; see Appendix E-4)
- White Wolf Fault Hydraulic Conductivity and Thickness (to estimate transmissivity along the fault; see Appendix E-3)
- Kern Subbasin Groundwater to Streamflow Inflow Ratio (to estimate groundwater inflows to the Kern Management Area as a residual to the groundwater subdomain; see Appendix E-3)
- Leachate Water Electrical Conductivity (to estimate leaching demands; see Appendix E-4)
- Additional Operational Demands (to estimate additional applied water demands [in terms of AFY/irrigated acre] from cultural practices and other operation requirements, e.g. dust abatement, frost control, etc.; see Appendix E-4)
- Ineffective Precipitation Deep Percolation Coefficient (to estimate deep percolation from ineffective precipitation; see Appendix E-4)
- Kern & White Wolf Watershed Consumptive Use Fractions (to estimate residual streamflows into the District; see Appendix E-2)
- Kern & White Wolf Watershed Precipitation Thresholds for Runoff (to estimate residual streamflows into the District, see Appendix E-2)
- Municipal & Industrial Consumptive Use Fraction
- Artificial Canals Seepage Rate
- Natural Channels Seepage Fraction (see Appendix E-2)

Many of these “User Input Parameters” have been adjusted within the model to reflect best available information and/or calibrated to optimize model response, but can be adjusted manually to reflect updated information or to test model response. Adjustments to the User Input Parameters are made within the “Calibration” tab of the model, and the listed values within the master tabs will update automatically.

As further described in Appendix E-5, The “Calibration” tab is the active module used to qualitatively calibrate the water budget by aligning the historical change in storage calculated in the master model tabs to change in storage values estimated via historical water level records collected within the model domain. This is principally done via adjustment of select “User Input Parameters” specified above, and subsequent
assessment of the resulting fit of the model-calculated change in storage to analogous estimates made from water level records collected at two “bookend” periods in time within the model period. The water level-calculated change in storage estimates used for this analysis are listed in the “WL_storage_change” spreadsheet of the Excel workbook. All calibration-related spreadsheets are denoted in yellow.

Presentation and Reporting

Live tables and figures that have been developed for inclusion in the Kern Management Area Plan, as well as several associated presentation & reporting related tabs, can be found in the blue shaded tabs within the water budget Excel workbook. These include:

- Exhibits used in the Kern Management Area Plan, including:
  - “Table WB-1_Kern” – Annual Surface Water Inflows and Outflows by Source Type
  - “Table WB-2_Kern” – Annual Inflows to and Outflows from the Groundwater System, and Change in Storage
  - “Table WB-3_Kern” – Annual and Cumulative Change in Groundwater Storage between Seasonal Highs
  - “Table WB-4_Kern” – Annual Change in Groundwater Storage vs. DWR Water Year Type
  - “Table WB-5_Kern” – Annual Total Inflows, Outflows, and Change in Groundwater Storage
  - “Table WB-6_Kern” – Summary of Projected Water Budget Results (with/without) Project & Management Action Implementation
  - “Table E-1-1_WB_Components” – Summary of Analytical Water Budget Components
  - “WB_graphs_Kern” – includes all graphs used to develop Figures WB-1 through WB-20 of Kern Management Area Plan
  - “Fig WB-18” – Figure WB-18 of Kern Management Area Plan
  - “Fig E-4-2” – Agricultural Subdomain Water Budget Schematic

- Spreadsheets supporting development of Management Area Plan exhibits, including:
  - “horiz_bar_chart” – used to summarize water budget components for reporting in Tables WB-1 through WB-5
  - “horiz_bar_chart_proj” – used to summarize projected water budget components for reporting in Table WB-6
  - “change_storage_figs” – used to develop Figures WB-10 through WB-14, GWC-8
  - “SW_cum_import_71_15” – used to help develop Figure WB-4
  - “data_as_values_for_combined_hyd” – used to help develop Figure WB-18

“Backend” Data and Calculations

All other tabs within the Excel workbook contain various input data and calculations used to support water budget calculations in the master water balance tabs and should not be edited. Uncolored tabs correspond to various raw input data that are directly linked to the historical and current master model tabs. These include:

• “M_I_deliveries” – records of annual WRMWSD deliveries to Municipal and Industrial (M&I) customers (1994 – 2015)
• “C2VSim_FG_Boundary_Params” – average transmissivity and depths of C2VSim-FG Layers 1 and 2 extracted along WRMWSD boundary lines, for use in approximating groundwater flux (see Appendix E-3)
• “raster_based_gradients” – average groundwater elevations along boundary gradient lines extracted from historical groundwater elevation raster data (see Appendix E-3)
• “S1b. SWP Historic” – record of annual historical SWP contract versus total imports, maintained by WRMWSD

Raw input data inputs to the water budget model also include spreadsheets imported directly from the R processing software, which was used predominantly to process land use and ITRC-METRIC data for integration into the Agricultural Lands subdomain (see Appendix E-4). These are denoted as light grey tabs in the Excel workbook, and include:

• “monthly_ITRC_CROPS_R” – WRMWSD monthly ITRC data by irrigation type, 2001 - 2015
• “monthly_ITRC_CROPS_pre2k_R” – WRMWSD monthly ITRC data by irrigation type, 1993 - 2000
• “monthly_ITRC_channels_R” – monthly ITRC data along California Aqueduct and 850 Canal, 1993 - 2015
• “monthly_ITRC_Basin_unadj_R” – monthly ITRC within WRMWSD by Basin, un-adjusted for non-coverage areas (see Appendix E-4), 1993 - 2015

Dark grey tabs represent spreadsheets involving a calculation or series of calculations for incorporation into the historical & current master model tabs. These include:

• “climate_parser_master_WR” – used to estimate precipitation on District lands and within surrounding watersheds (see Appendix E-2)
• “GW_Fluxes” – used to estimate subsurface fluxes across District boundaries (see Appendix E-3)
• Various tabs used to calculate components within the Agricultural Lands subdomain (see Appendix E-4), including:
  o “Monthly_adjusted_ET_by_zone” – parses monthly ITRC data into different land use subdomains and estimates ET for the in-District areas outside ITRC coverage
  o “Monthly_acreages” – parses seasonal crop data into different land use subdomains
  o “Monthly_irr_eff” – calculates monthly irrigation efficiency coefficients based on seasonal irrigation types
  o “leaching_master” – calculates monthly leaching volumes based on seasonal crop types
  o “operational demands” – calculates monthly operational demands based on irrigated acreage
  o “effective_precip” – calculates monthly effective precipitation using raw precipitation, ET data
  o “2012_AgDomain” – estimates monthly ET for calendar year 2012, where ITRC-METRIC data was unavailable
  o “pre2k_operations” – estimates monthly surface water deliveries, District groundwater pumping rates based on annual data from FAA Table IV records for 1994 - 2000
“native yield” – used for KGA “native yield” discussions (no impact on water budget functionality)

Purple shaded tabs correspond to raw data inputs and calculations used to delineate select water budget components in the overlap and non-overlap areas of the Kern and White Wolf portions of the District. These tabs do not effect the water budget functionality, and are used for reporting purposes in Tables WB-1 – WB-5 of the Management Area Plan only. They include:

- “ET_total_v_non-overlap” – compares monthly ITRC ET signal for the full District and the non-overlap area only
- “WRMWSD_Overlap_Deliveries_AE” – monthly WRMWSD surface water delivery records to the WRMWSD-AEWSD overlap area
- “Monthly_ET_by_zone_WR_no_overla” – parses monthly ITRC data on the non-overlap area into different land use subdomains
- “Monthly_acreages_WR_no_overlap” – parses seasonal crop data in the non-overlap area into different land use subdomains
- “2012_AgDomain_WR_no_ove” – estimates monthly ET in the non-overlap area for calendar year 2012, where ITRC-METRIC data was unavailable
- “MONTHLY_ITRC_Basin_WR_no_ove” – monthly ITRC within non-overlap area by Basin, unadjusted for non-coverage areas (see Appendix E-4), 1993 - 2015
- “MONTHLY_ITRC_CROPS_no_overlap” – WRMWSD monthly ITRC data in non-overlap area by irrigation type, 2001 - 2015
- “MONTHLY_ITRC_CROPS_pre2k_no_ove” – WRMWSD monthly ITRC data in non-overlap area by irrigation type, 1993 - 2000
- “leaching_master_WR_no_overlap” – calculates monthly leaching volumes in non-overlap area based on seasonal crop types
- “operational_demands_WR_no_over” – calculates monthly operational demands in non-overlap area based on irrigated acreage

Finally, brown shaded tabs correspond to raw data inputs and calculations used to inform development of three projected model scenarios (see Appendix E-6). These include:

- KGA climate change factors and surface water delivery assumptions for projected water budget scenarios, including:
  - “SWP Baseline” – Projected State Water Project supply change factors under “baseline” scenario
  - “SWP 2030” – Projected State Water Project supply change factors under “2030 Climate Change” scenario
  - “SWP 2070” – Projected State Water Project supply change factors under “2070 Climate Change” scenario
  - “Precipitation 2030 SR 21” – Projected precipitation change factors under “2030 Climate Change” scenario
  - “Precipitation 2070 SR 21” – Projected precipitation change factors under “2070 Climate Change” scenario
  - “ET 2030 SR 21” – Projected evapotranspiration change factors under “2030 Climate Change” scenario
- “ET 2070 SR 21” – Projected precipitation change factors under “2070 Climate Change” scenario
- “KernPROJECTED_analog” – Kern master water budget under 50-yr analog period (no adjustments to supplies, climate assumptions) – not used as a unique projected scenario, only to assist in calculations for baseline/2030/2070 projected scenarios
- “P&MA_scenarios” – used to input P&MA supply augmentation and demand reduction targets for 2030 and 2070 climate change scenarios to assess impacts on projected change in storage under full SGMA implementation
Water Budget Domains and Subdomains

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
August 2019
EKI B70103.01

Figure WB-1
Water Budget Flow Components

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
August 2019
EKI B70109.01
Figure WB-2

Legend

- "Raw"
- Likely Negligible
- External
- Inflow to WB Domain
- Internal
- Outflow from WB Domain
- Currently Not Estimated in WB

Abbreviations:

Agricultural
Cons. = consumptive
Evap. = evaporation
ET = evapotranspiration
GW = groundwater
Infiltr. = infiltration
M&I = municipal & industrial
Precip. = precipitation
WB = water budget

Notes:

1. Components 4-28 are further parsed into their respective contributions to the Kern and White Wolf Subbasins within the water budget.
# TABLE E-1-1
## Conceptual Water Budget Flow Components
### Wheeler Ridge-Maricopa Water Storage District
#### Kern Subbasin Management Area

<table>
<thead>
<tr>
<th>#</th>
<th>Water Balance Component</th>
<th>Component’s Role in Overall Water Budget Domain</th>
<th>&quot;Raw&quot; Component</th>
<th>Likely Negligible</th>
<th>Water Budget Subdomain</th>
<th>Component Estimation Method in Water Budget Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>State Water Project Allocation</td>
<td>External</td>
<td>Yes</td>
<td>In/Out</td>
<td>Natural Channels</td>
<td>Not currently quantified in water budget (contribution reflected in total imports)</td>
</tr>
<tr>
<td>2</td>
<td>Out-of-District Water Banks</td>
<td>External</td>
<td>Yes</td>
<td>In/Out</td>
<td>Natural Channels</td>
<td>Not currently quantified in water budget (contribution reflected in total imports)</td>
</tr>
<tr>
<td>3</td>
<td>Out-of-District Transfers/Exchanges</td>
<td>External</td>
<td>Yes</td>
<td>In/Out</td>
<td>Natural Channels</td>
<td>Not currently quantified in water budget (contribution reflected in total imports)</td>
</tr>
<tr>
<td>5</td>
<td>Rainfall onto Artificial Channels</td>
<td>Inflow</td>
<td>Yes</td>
<td>In/Out</td>
<td>Natural Channels</td>
<td>Precip Rate * CA Aqueduct area</td>
</tr>
<tr>
<td>6</td>
<td>District Groundwater Pumping Inputs to Artificial Channels</td>
<td>Internal Linkage</td>
<td>Yes</td>
<td>In</td>
<td>Natural Channels</td>
<td>From &quot;WRM_Wells_Production_2001-2016_ver_2017-07-18e.xls&quot;</td>
</tr>
<tr>
<td>7</td>
<td>Private Groundwater Pumping Inputs to Artificial Channels</td>
<td>Internal Linkage</td>
<td>Yes</td>
<td>In</td>
<td>Natural Channels</td>
<td>From &quot;AFUSRINPUT&quot; column of WLEDGER records, or from FAA (Table IV) Sheets; monthly distribution estimated from District GW Pump-in records</td>
</tr>
<tr>
<td>8</td>
<td>Evaporation from Artificial Channels</td>
<td>Outflow</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>Observed ITRC-METRIC ET along CA Aqueduct * CA Aqueduct area</td>
</tr>
<tr>
<td>9</td>
<td>Seepage from Artificial Channels</td>
<td>Internal Linkage</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>Seepage Rate * CA Aqueduct area</td>
</tr>
<tr>
<td>10</td>
<td>District Deliveries to Agricultural Lands</td>
<td>Internal Linkage</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>Total deliveries from &quot;WLEDGER&quot; monthly records - M&amp;I Deliveries [11]</td>
</tr>
<tr>
<td>11</td>
<td>District Deliveries to Municipal &amp; Industrial Customers</td>
<td>Internal Linkage</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>Annual M&amp;I deliveries from FAA Table IV records; assumed constant monthly distribution</td>
</tr>
<tr>
<td>12</td>
<td>Surface Water Exports / Unused Water</td>
<td>Outflow</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>No export data provided; assumed negligible</td>
</tr>
<tr>
<td>13</td>
<td>Rainfall on Agricultural Lands</td>
<td>Inflow</td>
<td>Yes</td>
<td>In/Out</td>
<td>Natural Channels</td>
<td>Precip Rate * Ag. Lands area</td>
</tr>
<tr>
<td>14</td>
<td>Agricultural Groundwater Pumping</td>
<td>Internal Linkage</td>
<td>Yes</td>
<td>In/Out</td>
<td>Natural Channels</td>
<td>Calculated as the residual of the Ag. Lands subdomain (see Appendix E.4)</td>
</tr>
<tr>
<td>15</td>
<td>Total Evapotranspiration from Agricultural Lands</td>
<td>Outflow</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>Observed ITRC-METRIC ET on Ag. Lands + Evap of Ineffective Precip (see Appendix E.4)</td>
</tr>
<tr>
<td>16</td>
<td>Infiltration from Agricultural Lands</td>
<td>Internal Linkage</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>Total Applied Water - Total ET on Ag. Lands [15] + Deep Perc. of Ineffective Precip (see Appendix E.4)</td>
</tr>
<tr>
<td>17</td>
<td>Rainfall onto Surrounding Watersheds</td>
<td>External</td>
<td>Yes</td>
<td>In</td>
<td>Natural Channels</td>
<td>Precip. Rate * Surrounding Watershed area (see Appendix E.2)</td>
</tr>
<tr>
<td>18</td>
<td>Consumptive Use from Surrounding Watersheds</td>
<td>External</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>Rainfall onto Surrounding Watersheds [17] * CU Fraction</td>
</tr>
<tr>
<td>19</td>
<td>Streamflow into District</td>
<td>Inflow</td>
<td>Yes</td>
<td>In/Out</td>
<td>Natural Channels</td>
<td>Rainfall onto Surrounding Watersheds [17] - CU from Surrounding Watersheds [18]</td>
</tr>
<tr>
<td>20</td>
<td>Rainfall onto Natural Channels</td>
<td>Inflow</td>
<td>Yes</td>
<td>In/Out</td>
<td>Natural Channels</td>
<td>Assumed negligible due to small stream area, and included in estimate of Rainfall on Ag. Lands [13]</td>
</tr>
<tr>
<td>21</td>
<td>Evaporation from Natural Channels</td>
<td>Outflow</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>Assumed negligible due to small stream area, and included in estimate of Evap. from Ag. Lands [13]</td>
</tr>
<tr>
<td>22</td>
<td>Seepage from Natural Channels</td>
<td>Internal Linkage</td>
<td>Yes</td>
<td>Out</td>
<td>Natural Channels</td>
<td>Streamflow into District [19] * Natural Channels Seepage Fraction</td>
</tr>
<tr>
<td>#</td>
<td>Water Balance Component</td>
<td>Component’s Role in Overall Water Budget Domain</td>
<td>&quot;Raw&quot; Component</td>
<td>Likely Negligible</td>
<td>Water Budget Subdomain</td>
<td>Component Estimation Method in Water Budget Model</td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------</td>
<td>-------------------</td>
<td>------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>24</td>
<td>Rainfall onto Urban Areas</td>
<td>Inflow</td>
<td></td>
<td></td>
<td></td>
<td>Precip Rate * Urban Lands area</td>
</tr>
<tr>
<td>26</td>
<td>Evapotranspiration &amp; Consumptive Use</td>
<td>Outflow</td>
<td>Yes</td>
<td></td>
<td></td>
<td>ET directly observed from ITRC-METRIC data (see Appendix D); CU = M&amp;I Deliveries * M&amp;I CU Fraction</td>
</tr>
<tr>
<td>27</td>
<td>Subsurface Groundwater Inflows</td>
<td>Inflow</td>
<td></td>
<td></td>
<td></td>
<td>Estimated by applying Darcy’s Law to groundwater head gradients derived from interpolated groundwater elevation maps, or via calibration (see Appendix E-3)</td>
</tr>
<tr>
<td>28</td>
<td>Subsurface Groundwater Outflows</td>
<td>Outflow</td>
<td></td>
<td></td>
<td></td>
<td>Estimated by applying Darcy’s Law to groundwater head gradients derived from interpolated groundwater elevation maps, or via calibration (see Appendix E-3)</td>
</tr>
<tr>
<td>29</td>
<td>Kern/White Wolf Groundwater Exchange</td>
<td>Internal Linkage</td>
<td></td>
<td></td>
<td></td>
<td>Estimated by applying Darcy’s Law to groundwater head gradients derived from interpolated groundwater elevation maps (see Appendix E-3)</td>
</tr>
<tr>
<td>30</td>
<td>Kern Basin Reduction in Groundwater Storage</td>
<td>Accumulation Term</td>
<td></td>
<td></td>
<td></td>
<td>Calculated as Residual of Groundwater Basin subdomain within the Kern monthly budget</td>
</tr>
<tr>
<td>31</td>
<td>White Wolf Basin Reduction in Groundwater Storage</td>
<td>Accumulation Term</td>
<td></td>
<td></td>
<td></td>
<td>Calculated as Residual of Groundwater Basin subdomain within the White Wolf monthly budget</td>
</tr>
</tbody>
</table>

**Abbreviations:**
Ag. = agricultural  
AFY = acre-feet per year  
CU = consumptive use  
ET = evapotranspiration  
Evap. = evaporation  
GW = groundwater  
M&I = municipal and industrial  
Precip. = precipitation  
WB = water budget

**Notes:**
1. Water budget subdomains outlined in dashed line are considered part of the overall water budget domain.  
2. "Raw" components are those that generally are best quantified based on actual data.  
3. The Artificial Channels Subdomain includes the CA Aqueduct, 850 Canal, and the District’s delivery pipeline network  
4. "Evapotranspiration" includes all estimated crop and vegetative evapotranspirative demands as well as evaporation of excess rainfall and from open water bodies within the District.
## TABLE E-1-2
Summary of Water Budget Domains, Flow Components, and Mass Balance Equations

Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

<table>
<thead>
<tr>
<th>EXTERNAL DOMAINS</th>
<th>MAJOR LAND-USE SUBDOMAINS</th>
<th>MINOR LAND-USE SUBDOMAINS</th>
<th>SUBSURFACE SUBDOMAINS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FROM</strong></td>
<td>Outside of Water Budget Domain</td>
<td>Atmosphere</td>
<td>Irrigated Ag Lands (SW and GW)</td>
</tr>
<tr>
<td><strong>TO</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside of Water Budget Domain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atmosphere</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated Ag Lands (SW and GW)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated Ag Lands (GW only)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Irrigated Ag Lands (dry farming)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native Lands</td>
<td></td>
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<tr>
<td>Urban Lands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Channels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial Channels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep (Production) Aquifer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater Bank &quot;Account&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mass Balance Equations**

- **Domains that Must "Balance"** (i.e., inflows = outflows), external fluxes shown in blue [inflow] or pink [outflow] text; internal fluxes shown in black text
- **Domains that can have a non-zero balance**

**Subdomains that Most “Balance”** (i.e., inflows = outflows), external fluxes shown in blue [inflow] or pink [outflow] text; internal fluxes shown in black text


**Subdomains that are not required to “Balance”** (i.e., can have a change in storage), external fluxes shown in blue [inflow] or pink [outflow] text; internal fluxes shown in black text

- **Deep (Production) Aquifer**
  - Groundwater Bank "Account"
    - Inflows (Banking "Deposits") = **Outflows** (Banking Loss) + Change in Storage


**Notes:**
- Inflows + precipitation (total) + Streamflow from Adjacent Uplands + GW inflows from Adjacent Areas + Imports
- Outflows = ET (consumptive use) + Streamflows to Adjacent Lowlands + GW Outflows to Adjacent Areas + Exports

*(Terms in italics are natural; these could be considered to make up the “native yield” supplies)*

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Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area Plan
Appendix E-2

Description of Precipitation and Contributing Streamflow Estimates
APPENDIX E-2
DESCRIPTION OF PRECIPITATION AND CONTRIBUTING STREAMFLOW ESTIMATES

This appendix documents the process used to derive estimates of precipitation on Wheeler Ridge-Maricopa Water Storage District (WRMWD or District) lands and the surrounding watersheds contributing to streamflow within the District.

Selection of Climate Stations

Precipitation on District lands and to surrounding watersheds is estimated from the six local climate stations maintained by and located within the District, and two additional climate stations located outside of the District maintained by the National Oceanic and Atmospheric Administration (NOAA). Each of these stations report measurements of monthly precipitation (inches per month [in/mo]) during the water budget period of interest (1993 – 2015), although data availability varies by station and includes sporadic missing monthly values which were filled with estimated values, as described below.

The six local climate stations maintained by the District include:

- **Greenlee’s Pasture** *(January 1971 – December 2017)*
- **District Headquarters** *(January 1978 – December 2017)*
- **WRM-2 Pumping Plant** *(January 1978 – December 2017)*
- **SP-P2 Pumping Plant** *(January 1978 – December 2017)*
- **PA-2 Pumping Plant** *(January 1978 – December 2017)*
- **Spillway Basin** *(January 1978 – December 2017)*

The additional climate stations maintained by NOAA employed for this analysis include:

- **Tejon Rancho, CA [NOAA Coop. ID #48839]** *(January 1895 – December 2017)*\(^1\)
- **Lebec, CA [NOAA Coop. ID #44863]** *(July 1948 – December 2017)*\(^2\)

NOAA stations were incorporated into this analysis because there is significant topographic difference (i.e., nearly 8,000-foot elevation difference) between the District lands and the peaks of the surrounding watersheds in the San Emidio and Tehachapi mountains to the southwest and southeast, respectively, that contribute to streamflow within the District. This elevation difference results in an orographic effect whereby precipitation in the surrounding watersheds is significantly greater than precipitation measured at the six local climate stations within the District. In order to account for this precipitation difference, data from the two additional NOAA climate stations were used. NOAA climate stations were selected based on the following criteria:

1) Data availability & continuity within the time-period of interest (1993 – 2015);
2) Location within the District’s surrounding watersheds; and
3) Ground surface elevation (relative to the elevation range within surrounding watersheds).

---

\(^1\) Data retrieved from NOAA’s National Climatic Data Center (NCDC) online portal [https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND:USC00048839/detail](https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND:USC00048839/detail)

\(^2\) Data retrieved from NOAA’s National Climatic Data Center (NCDC) online portal [https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND:USC00044863/detail](https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND:USC00044863/detail)
Interpolation of Missing Monthly Precipitation Data

NOAA stations employed in this analysis contained several missing monthly values within the period of interest. For these months, precipitation was estimated based on a linear correlation model developed with a District-operated climate station. The District-operated climate station that most directly aligned with both the Tejon Rancho and Lebec stations was the Spillway Basin (elevation ~840 feet above mean sea level [ft msl]). As shown on Figure E-2-1 below, over the entire period of record (1978-2017), monthly precipitation records collected from the Spillway Basin station showed an 85% correlation \((R^2 = 0.72)\) with data collected from the Tejon Rancho station (elevation ~1,370 ft. msl), and a 72% correlation \((R^2 = 0.52)\) with data collected from the Lebec station (elevation ~3,600 ft. msl).

Figure E-2-1. Long-term Correlation between Spillway Basin Station and NOAA Stations

As such, monthly precipitation values for months with missing precipitation data within the Tejon Rancho and Lebec records were estimated using the linear regression models derived for each station with respect to the Spillway Basin station.

Spatial Representation of Precipitation Data

Precipitation is a spatially variable phenomenon and can usually only be directly observed at discrete points within a domain (i.e., at climate station locations). Additionally, precipitation is affected by surrounding topography, and the orographic effect must be considered when deriving rainfall estimates over watershed areas with significant elevation range. As mentioned previously, the nearly 8,000 ft difference in elevation between District lands and the peaks of the surrounding watersheds in the San Emigdio and Tehachapi mountains results in an orographic effect. As such, it is practical to employ
precipitation data from higher-elevation climate stations to estimate precipitation within these surrounding watersheds contributing to streamflow into the District.

Table E-2-1 presents the approximate elevation of each climate station used in this analysis, as derived from the U.S. Geological Survey National Elevation Dataset (NED):

<table>
<thead>
<tr>
<th>Climate Station</th>
<th>Operator</th>
<th>Ground Surface Elevation (ft msl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenlee’s Pasture</td>
<td>WRMWSD</td>
<td>400</td>
</tr>
<tr>
<td>District Headquarters</td>
<td>WRMWSD</td>
<td>490</td>
</tr>
<tr>
<td>WRM-2 Pumping Plant</td>
<td>WRMWSD</td>
<td>500</td>
</tr>
<tr>
<td>5P-P2 Pumping Plant</td>
<td>WRMWSD</td>
<td>590</td>
</tr>
<tr>
<td>Spillway Basin</td>
<td>WRMWSD</td>
<td>840</td>
</tr>
<tr>
<td>PA-2 Pumping Plant</td>
<td>WRMWSD</td>
<td>940</td>
</tr>
<tr>
<td>Tejon Rancho</td>
<td>NOAA</td>
<td>1,370</td>
</tr>
<tr>
<td>Lebec</td>
<td>NOAA</td>
<td>3,590</td>
</tr>
</tbody>
</table>

Based on the distribution of locations and elevations from the eight climate stations employed for this analysis, a two-fold approach was employed to represent precipitation on District lands and from surrounding watersheds:

1) **Theisen polygons** were used to delineate the representative area for each of the six District-operated climate stations within the District.

2) **Elevation cutoffs** were used to delineate the representative area for the higher-elevation NOAA climate stations.

This analysis is based on the following assumptions:

- The six District-operated climate stations are located within the floor of the Central Valley at relatively similar elevations; thus, precipitation within the District is best represented spatially using the closest climate station to each point within the District.

- The two NOAA climate stations are located within surrounding watersheds to the District or near the southern boundary of the White Wolf portion of the District, and at significantly higher elevations than the District climate stations (see Table E-2-1 above); thus, precipitation on the surrounding watersheds (and the southern-most portion of the District) is best represented by the NOAA climate station at the nearest elevation to each point within the surrounding watershed area.
Figure E-2-2 (attached) shows the location and coverage area represented by each climate station within the District and its surrounding watersheds. The following elevation cutoffs were used to determine which NOAA station (if any) would be employed in these areas:

- Elevations less than 1,155 ft msl are represented by the District climate station network (i.e., delineated by the Theisen polygon lines);
- Elevations between 1,115 ft msl and 2,480 ft msl are represented by the Tejon Rancho climate station; and
- Elevations greater than or equal to 2,480 ft msl are represented by the Lebec climate station.

**Calculation of Rainfall and Contributing Streamflow**

Following the spatial delineation process described above, total areas represented by each climate station were calculated for in-District lands (in both the Kern and White Wolf Subbasins), as well as for the surrounding watershed area.

The volume of monthly rainfall (acre-feet per month; [AF/mo]) on the District and on surrounding watersheds is then estimated as follows:

\[ R = \sum_{12} \frac{p_{\text{station}}}{A_{\text{station}}} \]  

(1)

where \( p_{\text{station}} \) = monthly precipitation [in/mo] and \( A_{\text{station}} \) = total area represented by the station [acres].

Contributing streamflow into the District is then calculated from the Rainfall on Watersheds using a linear equation with two parameters: a “Precipitation Threshold for Runoff Initiation” and a “Watershed Consumptive Use Fraction”. These parameters are defined in the “User Input Parameters” of the water budget model (see Appendix E-1). Contributing streamflow into the District is calculated as:

\[ S = \max (0, R - \frac{p_{\text{threshold}}}{A_{\text{watershed}}}) \times (1 - CU_{\text{watershed}}) \]  

(2)

where \( p_{\text{threshold}} \) = Precipitation Threshold for Runoff Initiation [in], \( CU_{\text{watershed}} \) = Watershed Consumptive Use Fraction [dimensionless], and \( A_{\text{watershed}} \) = total area of surrounding watersheds [acres].

Ultimately, based on water budget calibration, Watershed Consumptive Use Fractions of 98% and 95% and Precipitation Thresholds of 0.5 inches were used to estimate contributing streamflow into the Kern Subbasin and White Wolf Subbasin portions of the District, respectively. This resulted in contributing streamflow estimates of 3,104 AFY and 8,416 AFY for the Kern and White Wolf portions of the District, respectively, over the historical water budget period (DWR WY 1995 – 2014). These estimates align very closely with the United States Geological Survey’s Basin Characterization Model\(^3\) (USGS-BCM) estimates for the same contributing watersheds (3,480 AFY and 9,730 AFY for the Kern and White Wolf areas) over 1981 – 2010. See Appendix E-5 for further details regarding the water budget calibration process.

---

Legend
- WRMWSD Service Area
- Groundwater Subbasin
- White Wolf
- Kern County
- Stream/River
- Climate Stations included in WB Analysis

Representative Climate Station
- 5P-P2 Pumping Plant
- District Headquarters
- Greenele's Pasture
- PA-2 Pumping Plant
- Spillway Basin
- WRM-2 Pumping Plant
- Tejon Rancho (NOAA)
- Lebec (NOAA)

Abbreviations
DWR = California Department of Water Resources
ft msl = feet above mean sea level
WB = Water Budget
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes
1. All locations are approximate.

Sources
1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 August 2019.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
3. WRMWSD boundary is from DWR's water agencies shapefile and updated based on input from WRMWSD staff on 12 April 2017.
4. Watershed boundaries obtained from the National Hydrography Dataset.

Climate Stations included in WB Analysis
- Lebec (NOAA)
- Spillway Basin
- WRM-2 Pumping Plant
- Tejon Rancho (NOAA)
- PA-2 Pumping Plant
- Greenlee's Pasture
- District Headquarters
- 5P-P2 Pumping Plant

Notes
1. All locations are approximate.
Appendix E-3

Description of Subsurface Cross Boundary Flow Estimates
This appendix documents the process used to estimate subsurface cross-boundary flows as a means of quantifying groundwater inflows and outflows to the aquifer system underlying Wheeler Ridge-Maricopa Water Storage District (WRMWSD or District) lands. As shown in Figure E-3-1, cross-boundary groundwater fluxes were calculated for three segments along the District perimeter:

- **White Wolf Fault Boundary (Exchange with AEWSD)** – to represent groundwater flux across the fault into Arvin Edison Water Storage District (AEWSD) lands in the Kern Subbasin;
- **White Wolf Fault Boundary (Internal Exchange)** – to represent groundwater flux across the fault into WRMWSD’s lands in the Kern Subbasin; and
- **Kern Boundaries (Net Exchange)** – to represent net groundwater fluxes to/from the Kern Subbasin portion of the WRMWSD service area (i.e. the “Kern Management Area”) resulting from (1) subsurface recharge from surrounding watersheds to the south of the Kern Management Area, and (2) groundwater exchange between WRMWSD and Kern Delta Water District (KDWD) lands and the Buena Vista Lake Bed area.

As further described below, estimates of subsurface cross-boundary flows across the White Wolf Fault were calculated using Darcy’s Law, while estimates of net groundwater inflows to the Kern Management Area were calculated as a residual to the groundwater subdomain during the water budget calibration process (see Appendix E-5 for more details).

**Estimation of Groundwater Fluxes Across the White Wolf Fault**

Monthly groundwater fluxes across the two segments of the White Wolf fault described above were calculated using Darcy’s Law, which states that:

\[
Q = T \times i \times L
\]

where \( Q \) = groundwater flowrate [feet cubed per day; ft³/d], \( T \) = aquifer transmissivity [feet squared per day; ft²/d], \( i \) = hydraulic gradient [dimensionless], and \( L \) = length of boundary perimeter used to calculate groundwater flux [feet; ft].

Methods used to derive values for \( T, i, \) and \( L \) along each boundary segment are further documented below.

**Estimation of Aquifer Transmissivity**

Aquifer transmissivity (\( T \)) is calculated as the product of aquifer hydraulic conductivity (\( K \)) [feet per day; ft/d] and aquifer thickness (\( b \)) [ft]:

\[
T = K \times b
\]
Final aquifer hydraulic conductivity and depth values were subsequently determined through water budget calibration. See Table E-3-1 below for initial and final (calibrated) estimates of $K$ and $b$ along the Kern Northern Boundary and White Wolf Fault.

### Table E-3-1. Aquifer Hydraulic Conductivity and Depth Estimates

<table>
<thead>
<tr>
<th>Boundary Segment</th>
<th>Initial $K$ [ft/d]</th>
<th>Calibrated $K$ [ft/d]</th>
<th>Initial $b$ [ft]</th>
<th>Calibrated $b$ [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Wolf Fault (to AEWSD)</td>
<td>1</td>
<td>3</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>White Wolf Fault (to WRMWSD)</td>
<td>1</td>
<td>3</td>
<td>1,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

**Estimation of Aquifer Gradients and Perimeter Length**

As mentioned previously, cross-boundary groundwater fluxes across the White Wolf fault were separated into two segments:

- White Wolf Fault Boundary (Exchange with AEWSD)
- White Wolf Fault Boundary (Internal Exchange)
To calculate boundary lengths \( (L) \) and hydraulic gradients \( (i) \), a GIS-based methodology was employed that uses interpolated groundwater elevation rasters, polylines representing the District boundaries, and the “Zonal Statistics” toolbox to estimate average hydraulic heads across each boundary.

Groundwater elevation rasters for various seasons within the period of interest were generated through Kriging interpolation of water level data contained in the District’s “WL” Access database. Based on data availability and quality, water levels from wells within the District and in the nearby area north of the District boundary were interpolated to produce groundwater elevation rasters for the following seasons:

- Spring 2003
- Fall 2005
- Spring 2006
- Fall 2006
- Spring 2009
- Fall 2009
- Spring 2011
- Fall 2011
- Spring 2013
- Fall 2013
- Spring 2014
- Fall 2014
- Spring 2015
- Fall 2015

A simplified set of “gradient line” polylines were then drawn in GIS that generally traced both sides of the two White Wolf Fault boundary segments described above (four polylines in total, see Figure E-3-1). The distance between polylines for each pair was 10,000 feet, and lengths were set consistently for each polyline in a pair to deduce the approximate boundary length \( (L) \) for the two boundary segments listed above.

Subsequently, for a given season and year, an average groundwater elevation (in feet above mean sea level [ft msl]) was deduced for each polyline on either side of the District boundary segment using the Zonal Statistics raster processing toolbox. Finally, the dimensionless hydraulic gradient \( (i) \) across the boundary segment for each season and year was calculated as follows:

\[
i = \frac{\text{GWE}_2 - \text{GWE}_1}{10,000 \text{ ft}}
\]

where \( \text{GWE}_1 \) and \( \text{GWE}_2 \) are the average groundwater elevations along the two polylines for each boundary segment.

**Estimation of Monthly Groundwater Flux in the Water Budget Model**

After deducing aquifer transmissivity \( (T) \), boundary length \( (L) \) and gradient parameters for a given season and year, groundwater flux was calculated using Darcy’s Law (see equation 1). Fluxes were converted from \( \text{ft}^3/\text{d} \) to acre-feet per month (AF/mo) to provide a representative “monthly” flux estimate associated with that season and year.
To populate the water budget model with a monthly groundwater flux for the entire period of interest (1994 – 2015), the “monthly” groundwater fluxes calculated for the season and year closest to the month in question within the model were used. Groundwater elevation rasters created for “Spring” seasons represent water level measurements collected in between January 15 – April 15; therefore, March 1 is used as the representative date for “Spring” groundwater flux calculations. Groundwater elevation rasters created for “Fall” seasons represent water level measurements collected in between August 15 – November 15; therefore, October 1 is used as the representative date for “Fall” groundwater flux calculations.

As an example, groundwater fluxes reported in the water budget for the month of May 2015 were represented by the calculated fluxes from the “Spring 2015” raster, whereas groundwater fluxes reported for the month of August 2015 were represented by the calculated fluxes from the “Fall 2015” raster. This allows the water budget to provide a continuous (monthly) estimate of cross-boundary groundwater fluxes that is most representative of current conditions as estimated from actual groundwater elevation data included in the District’s records.

**Estimation of Net Groundwater Fluxes to the Kern Management Area**

Use of raster-based gradients and Darcy’s law to estimate groundwater fluxes, as described above, is well suited for approximating fluxes across the White Wolf Fault, as this hydrogeologic barrier to flow is considerably well-defined and groundwater flow moves in a generally consistent southeast-to-northwest direction perpendicular to the fault line (see White Wolf Fault studies mentioned above for further details). This allows for reasonably straight-forward estimation of groundwater gradients across the fault, as the “gradient lines” can be drawn parallel to the fault line and consistent with the general direction of groundwater flow in the area.

As evident in Figure E-3-1 and in the local groundwater elevation surfaces derived for earlier dates within the historical water budget timeframe, groundwater flow directions are much more variable along the District perimeter within the Kern Subbasin, with certain sections indicating an inflow gradient, others an outflow gradient, and still others indicating a gradient that is nearly parallel to the boundary line. Another complicating factor is that very little groundwater elevation data exists for the regions to the south and west of the WRMWSD boundary, making it challenging to accurately estimate average groundwater elevations immediately outside the District. Consequently, the average groundwater gradient across each major boundary of the WRMWSD Kern Management Area is much harder to define. Furthermore, the WRMWSD Kern Management Area boundary is highly complex in geometry, making the use of generalized “gradient lines” to approximate fluxes across each boundary segment less applicable to this particular scenario.

Given the constraints mentioned above, an approach was used that approximates net groundwater fluxes to/from the Kern Management Area as a residual in the groundwater subdomain deduced via calibration of the water budget model. After constraining all other groundwater inflow and outflow variables within the model (e.g., infiltration, pumping, etc.), a monthly groundwater flux rate was calculated that resulted in the closest fit to change in groundwater storage calibration targets developed via comparison of observed water levels between “bookend” dates within the water budget timeframe (see Appendix E-5).

Ultimately, it was found that the modeled change in groundwater storage achieved a closest fit to all calibration targets when net monthly groundwater fluxes to the Management Area were tied to the
estimated streamflow signal into Management Area. Specifically, it was determined that setting a
“Groundwater to Streamflow Inflow” ratio of 3:1 within the Kern Management Area resulted in the best
overall calibration of the water budget model (see Appendix E-5) and produced net groundwater inflow
volumes on the order of 9,300 AFY on average through the historical water budget period (DWR WY 1995
– 2014). This net inflow estimate is conservative relative to how the C2VSim-FG Kern Subbasin numerical
model (developed by KGA and other Basin GSAs, see Section 9 of the Management Area Plan) quantifies
net groundwater inflows to the Management Area (31,200 AFY) over the same historical period.

This observed correlation between groundwater inflows and streamflow behavior could be in part due to
the fact that the southern border of WRMWSD abuts several alluvial fans receiving recharge from various
ephemeral creeks draining into the Kern Subbasin from the San Emigdio mountains to the south. Given
the variable gradients observed along the northern and western boundaries of the Management Area,
this subsurface recharge mechanism from the south may be the dominant groundwater flow component
along the WRMWSD Kern Subbasin boundaries and would thus result in a net groundwater inflow to the
Management Area. Further quantification of subsurface inflows across the southern boundary would
necessitate the collection of additional groundwater elevation data to the south of the District, where
very little historical data currently exist. See Appendix E-5 for further details regarding the water budget
model calibration process and results.
Abbreviations

DWR = California Department of Water Resources
ft msl = feet above mean sea level
GWEL = Groundwater Elevation
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.
2. Gradient line pairs placed 10,000 feet apart along each boundary with substantial subsurface flow.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 August 2019.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2018 Update.
3. Groundwater elevation data provided by District staff.
Appendix E-4

Description of the Agricultural Lands Water Budget Subdomain
This appendix describes the process for calculating water budget components within the Agricultural Lands subdomain of the Wheeler Ridge-Maricopa Water Storage District (WRMWSD or “District”) Long-term Water Budget (currently populated for 2001–2015). This analysis was based on the following data sources:

- **Satellite Evapotranspiration (ET) Data** from the Irrigation Training & Research Center (ITRC)\(^1\)
  “Mapping Evapotranspiration at High Resolution with Internalized Calibration” (ITRC-METRIC) Study, funded by the Kern Groundwater Authority (KGA)\(^2\)
  - *monthly resolution, January 1993 – December 2015* \(^3\)

- **WRMWSD Land Use Surveys** from the District’s “CROPS.shp” shapefile
  - *seasonal (spring and fall) resolution, Spring 2001 – Spring 2017*

- **WRMWSD Surface Water Delivery Records** from the District’s “WRM_DataMDB” Access databases (i.e., “WLEDGER” tables)
  - *monthly resolution, January 1999 – December 2016*

- **Precipitation Records** from the six local climate stations maintained by and located within the District, and two additional climate stations located outside of the District maintained by the National Oceanic and Atmospheric Administration (NOAA)\(^4\)
  - *monthly resolution, January 1971 – December 2017 (data availability varies by station)*

**Description of ITRC-METRIC ET Dataset**

The ITRC-METRIC ET Dataset uses satellite-based remote sensing of radiant energy and the METRIC energy balance theory to quantify actual water flux to the atmosphere from the land surface (including ET and evaporation from bare soil and open water). This approach differs from other commonly-used methods that estimate ET based on land use (i.e., cropping) patterns and reference ET data and/or crop water use coefficients. There are several advantages of the ITRC-METRIC approach over conventional crop coefficient methods:

- ITRC-METRIC provides the ability to measure actual ET over large areas without any previous knowledge of land use or climate variables, whereas crop coefficients will estimate ET based on known cropping acreages and assumed crop water use properties.

\(^1\) The Irrigation Training & Research Center is part of the California Polytechnic State University, San Luis Obispo.

\(^2\) Howes, D., 2018, 1993-2015 ITRC-METRIC ETc for Kern County, prepared for the Kern Groundwater Authority on behalf of the Cal Poly Irrigation Training & Research Center. (see Attachment E-4-1)

\(^3\) There is no ITRC satellite ET data for calendar year 2012, as the Landsat satellite system employed in the METRIC analysis was out of order during this period. See Attachment E-4-1 for further details.

\(^4\) See Appendix E-2 for a detailed description of how climate stations are used to estimate precipitation on District lands and surrounding watersheds.
ITRC-METRIC provides semi-continuous (i.e., rasterized) ET data at a high spatial resolution (satellite image pixel size of 30 x 30 meters) for an area of study, whereas crop coefficient-based ET estimates are limited to the resolution of the land use dataset being employed.

ITRC-METRIC allows for ET measurement at a relatively frequent temporal resolution (e.g., approximately every 10 days), whereas crop coefficient methods are typically only available on a seasonal, or at best monthly, basis.

Due to these advantages, ET data developed using the ITRC-METRIC method will intrinsically reflect spatial and temporal variabilities in ET due to factors that cannot be fully accounted for using conventional crop coefficient methods. For example, the ITRC-METRIC ET rasters (image files) will reflect impacts on ET due to crop stresses from drought conditions, ET for crops at various stages of growth, ET for land parcels with multiple growing seasons (i.e., double cropping) and/or interbedded crops, and evaporation from surface water features (such as canals, reservoirs, spreading basins, etc.).

However, the ITRC-METRIC dataset has a significant limitation for water-budgeting purposes in that it does not provide an estimate of total applied water, only actual (observed) ET. Total applied water is a term used by water resource engineers to estimate how much water is actually being applied to the land. This differs from ET in that it includes not only water applied to satisfy crop water demand, but also unintentional over-irrigation due to irrigation inefficiency and water intentionally applied for other operational requirements or cultural practices (e.g., leaching, dust abatement, field preparation, frost control). During the main growing season from spring through fall, when precipitation is minimal and ET is greatest, total applied water is nearly always greater than evapotranspiration for any irrigated land, as no irrigation method is 100 percent efficient. Calculation of total applied water must also consider water added to the land surface via precipitation, as this will reduce the irrigation demand for a given area. Figure E-4-1 illustrates the difference between actual (crop) ET (ETc) and total applied water.

---

5 Irrigation efficiency is defined as the fraction of total applied water that is used by the crop to satisfy its vegetative water demand.
Land Surface Processes within the Water Budget

From a holistic water budgeting perspective, total applied water that does not go towards satisfying crop ET will be subject to four main processes once it is applied to the land surface:

1) Evaporation to the atmosphere
2) Land surface runoff
3) Infiltration and accumulation in the root zone
4) Deep percolation below the root zone to the groundwater table (i.e., return flows)

Although this water budget model allows for temporary carry-over storage of excess effective precipitation in the root zone for subsequent uptake by crops (see below), it is assumed that there is no net long-term accumulation of water within the root zone. Accurate simulation of soil moisture changes would require detailed spatial information on soil properties and root zone depth, as well as data for precipitation, irrigation, and ET on the timescale of hours to days. As the current water budget is designed to reflect monthly changes on a District scale, this level of detail is beyond the current scope of the effort. Furthermore, assuming quasi-steady state conditions within the root zone mimics the approach of the
MODFLOW Farm Process package, which has proven that “simulated inflows into the root zone converged to outflows after time intervals of several days”\(^6\). Therefore, the assumption of steady-state soil moisture within the root zone is justified.

Similarly, as this water budget was developed on a District scale, and given the generally low topographic slope and lack of significant permanent streams along District boundaries, we have assumed that land surface runoff of applied water is negligible for the purposes of this water budget. Though runoff may occur between parcels within the District service area, there is no continuous receiving water body (i.e., “Natural Channels” such as streams) that could transport surface water runoff outside of the District in any significant volume. Therefore, we have assumed that all land surface runoff occurring between parcels within the District will either (1) evaporate or (2) infiltrate into the subsurface before leaving District boundaries.

Under the above assumptions, excess water applied to the ground surface on District lands will predominantly either (1) evaporate from the wetted bare soil or (2) percolate below the root zone into the deeper subsurface (eventually recharging groundwater) before leaving District boundaries. Considering that landowners within WRMWSD generally employ highly efficient irrigation techniques (such as micro-drip irrigation) and follow irrigation schedules designed to minimize evaporation of excess irrigation water, it is further assumed that evaporation of excess irrigation water is considered to be a negligible flux component of the ITRC-METRIC ET signal, and thus all “inefficient irrigation” of these lands will infiltrate through the root zone and eventually make its way down into the underlying principal aquifer.

**Building the Agricultural Lands Subdomain Water Budget**

As mentioned above, deep percolation is the only major component of total applied water not measured by the ITRC-METRIC dataset within the agricultural lands subdomain. Deep percolation is likely to result from three main applications of excess water to the ground surface:

1) Intentional operational and/or cultural processes, such as soil leaching and dust abatement
2) Irrigation inefficiencies
3) Excess (i.e. “ineffective”) precipitation

Excess water from operational processes and irrigation inefficiencies are only relevant to the irrigated portion of the District, whereas precipitation in excess of crop water demands must be considered across the entire District area. Therefore, for purposes of this water budget, we have separated the irrigated portion of the District from the non-irrigated portion of the District (i.e., including agricultural and native vegetation lands as well as urban lands) before estimating deep percolation and total applied water.

Determining Irrigated vs. Non-Irrigated and Urban Lands

As mentioned above, historical land use data for parcels within the WRMWSD service area were provided by the District for Spring and Fall, 1994 – 2015 in a shapefile entitled “CROPS.shp”. Land use for each parcel was classified on a biannual “seasonal” (i.e., Spring/Fall) basis using crop categories defined in the District’s “BAL_XREF” and “CROP_XREF” spreadsheets within the “WRMData_MDB” access database. For the Fall seasons, parcels without crop category information were assumed to have the same crop as was indicated in the Spring season of that same water year (per direction from the District’s GIS technician). Parcels were then classified into Irrigated, Non-Irrigated, and Urban categories for each season as follows:

- **“Non-Irrigated”** – land parcels marked as:
  - “NV” – Native Vegetation
  - “DEF” – Idle Lands
  - “FAL” – Fallowed Lands
  - “EUC” – Eucalyptus (not irrigated)
  - “WHD” – Wheat (dry farmed)
  - N/A (i.e., Spring parcels with blank entries)
- **“Urban”** – land parcels marked as “OTH” – Other Lands
- **“Irrigated”** – all other land parcels included in the CROPS.shp

This analysis was performed in R software to facilitate data processing and reproducibility of results.

Determining Irrigation Methods and Irrigation Efficiency Coefficients

As mentioned above, the contribution of “unintentional overwatering” resulting from irrigation inefficiency must be accounted for in estimating total applied water and deep percolation within the agricultural lands subdomain. As such, a representative irrigation efficiency coefficient must be associated with each irrigation type listed in the land use records.

In addition to providing seasonal crop categories, the WRMWSD “CROPS.shp” shapefile also included information on parcel-specific irrigation methods for the years 2011, 2012, and 2013. Irrigation methods listed in this shapefile included:

- “MD” – Micro-Drip
- “MS” – Micro-Sprinkler
- “SP” – Sprinkler
- “CP” – Center-Pivot Sprinkler
- “Fur” – Furrow (Gravity)
- “NON” – Not Irrigated

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7 Before the year 2001, the “CROPS.shp” shapefile only contained cropping information for Spring/Fall 1995 and 1997. These were used to infer general land use categories (e.g. “irrigated”, “non-irrigated”, “urban”) for all years before 2001, where Spring/Fall 1995 crops were used to infer land use for Spring/Fall 1994 – 1996, and Spring/Fall 1997 were used to infer land use for Spring/Fall 1997 – 2000.

8 “OTH” parcels were classified as “urban lands” based on observations from Google Earth, in which most cases “OTH” parcels were recognized as built structures or paved surfaces.
For parcels marked as “irrigated” based on the reclassification procedure described above, irrigation methods were assigned as follows:

- For year 2012, Irrigation Method = “IRR_METH_12” (2012 irrigation data)
- For years 2013—2015, Irrigation Method = “IR_METH_13” (2013 irrigation data)

This analysis was performed in R software to facilitate data processing and reproducibility of results.

From here, an area-weighted average irrigation efficiency coefficient was calculated for each season in the record within each basin, which was then later incorporated into the calculation of deep percolation on irrigated lands. Irrigation efficiencies were initially estimated for each irrigation method based on representative values reported by the Food and Agricultural Organization of the United Nations (FAO)\(^9\) and other commonly used resources, as follows:

- Micro-Drip (MD) – 85%
- Micro-Sprinkler (MS) – 80%
- Sprinkler (S) – 75%
- Center-Pivot Sprinkler (CS) – 70%
- Furrow (Gravity) (F) – 65%

These values were included as “User Input Parameters” in the budget to facilitate easy adjustment, but were ultimately left unchanged during the calibration process. Parcels marked “NON” (Not Irrigated) in 2011 – 2013 almost always fell into the “Not Irrigated” category based on the crop category classification as described above. However, for years where irrigation methods were not explicitly reported in the data, various parcels may have been irrigated for that year (based on the crop type information) and attributed a “NON” irrigation type if they were not irrigated during 2011 – 2013. For these parcels, the irrigation efficiency coefficient of “NON” was determined as the long-term (2011-2016), acreage-weighted average irrigation efficiency coefficient across the District for all known irrigation types. This weighted average was calculated as 83% based on the given data, reflecting a dominance of micro-drip irrigation systems within the District.

The resulting irrigation efficiency coefficient \(e_{IRR}^i\) for agricultural lands in any month \(i\) in the water budget period is then calculated as:

\[
e_{IRR}^i = \frac{\sum (0.85 \times \text{Acreage}_{MD}^i + 0.80 \times \text{Acreage}_{MS}^i + 0.75 \times \text{Acreage}_{S}^i + 0.70 \times \text{Acreage}_{CS}^i + 0.65 \times \text{Acreage}_{F}^i + 0.83 \times \text{Acreage}_{NON}^i)}{\text{Acreage}_{Irrigated \ Lands}}
\]

where \(\text{Acreage}_x^i\) = acreage of irrigated lands supplied by \(x\) irrigation type for month \(i\), and where \(x =\) micro-drip (MD), micro-sprinkler (MS), sprinkler (S), center-pivot sprinkler (CS), furrow (F), and NON (unknown type) irrigation types.

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Monthly ITRC-METRIC data was processed using a GIS model (i.e., automated procedure) that sums observed ET values for each parcel based on its geometry as mapped in the District’s “CROPS.shp” shapefile. The GIS model employs a Spatial Analyst tool known as “Zonal Statistics” to sum the ET values from each 30 x 30 meter raster pixel within a parcel to determine the total ET value (in inches per month; [in/mo]) for each parcel included “CROPS.shp.” This is then multiplied by the raster resolution (900 m²) and converted into acre-feet per month (AF/mo) to provide a volumetric estimate of ET (in AF/mo) for each parcel on a given month. This process was iterated for the entire set of monthly ITRC-METRIC ET rasters (265 in total) resulting in monthly ET values for each for the entire period of record of the ITRC-METRIC dataset (1993 – 2011, 2013 – 2015). These values were then joined to the reclassified crop information using a unique parcel-based key incorporated into both datasets. Because the crop classification data is reported biannually, whereas the ITRC data is collected monthly, the following time periods were employed to link reclassified land use data to the ITRC-METRIC dataset:

- **“Spring”** – March through August of the calendar year
- **“Fall”** – September through February of the following calendar year

As an example, under this scenario an ITRC raster developed for July 2003 would be linked to the “Spring 2003” land use dataset, whereas an ITRC raster developed for February 2003 would be linked to the “Fall 2002” dataset.

The result of this process is an aggregated monthly dataset containing parcel-based information on:

- Basin location (i.e., Kern Basin or White Wolf Basin)
- Acreage
- Crop type
- Irrigation type (irrigated, not irrigated, urban)
- Irrigation method (if irrigated)
- Monthly ET

A complicating factor in this process is that the ITRC rasters do not cover the entire District area, leaving approximately 1,012 acres of land (~0.6%) without associated ET data. To account for this gap in coverage, a value for “unused acreage” by parcel was developed based on the difference in acreages of the original and joined datasets. ET was then estimated for the area of each parcel outside of ITRC coverage (if any) by applying the average per-acre ITRC ET rate for each of the three irrigation types (irrigated, not irrigated urban) from the covered area. This ensured that the entirety of the District contained an ET estimate for each month.

**Determining Additional Irrigation Demands**

As mentioned above, ITRC-METRIC data provides a reasonable estimate of actual ET occurring within the District but should not be considered to represent total applied water on District lands. In addition to accounting for irrigation inefficiencies, estimates of total applied water must also consider the additional irrigation demands associated with crop leaching and other operational water requirements, as well as account for any contributions of effective precipitation in meeting the ET demand measured by ITRC-
METRIC. The following subsections detail how additional irrigation demands are estimated within the analytical water budget model.

_Crop Leaching Requirements_

As mentioned above, soil leaching is a common practice that can significantly increase the volume of applied water required for long-term operations beyond the ET demands estimated by ITRC-METRIC data. As no specific information on leaching practices (i.e., amounts, locations, timing) was available from the District, a conventional approach outlined by the FAO was used to determine leaching requirements based on crop-specific salinity thresholds and estimates of leaching water salinity\(^{10}\). For a given crop, the “leaching fraction” (i.e. the incremental portion of irrigation water in excess of crop ET demands required to maintain the soil salinity at ideal conditions for crop yield) is defined as follows:

\[
LF = \frac{EC_w}{S(EC_e) - EC_w}
\]

where \(LF\) = leaching fraction [dimensionless], \(EC_w\) = electrical conductivity of the irrigation water [deciSiemens per meter; dS/m], and \(EC_e\) = crop salinity threshold [dS/m].

From here, the volumetric “leaching requirement” can be calculated as the incremental volume of water needed to satisfy the leaching demand:

\[
LR = \frac{ET_c \cdot LF}{1 - LF}
\]

where \(LR\) = leaching requirement [AF] and \(ET_c\) = crop evapotranspiration [AF].

For the purposes of this analysis, leaching demands are calculated for the entire irrigated lands portion of the agricultural lands subdomain for each month. To achieve this, an area-weighted crop-salinity threshold is calculated for the irrigated lands area for each basin based on the relative acreages of each crop category included in “CROPS.shp.” (see Attachment E-4-2 for the list of indicative crop salinity thresholds used in this methodology). A leaching fraction (\(LF\)) is then calculated per equation (2) above within the water budget based on the area-weighted crop salinity threshold and an assumed electrical conductivity of irrigation water (\(EC_w\)). The \(EC_w\) is implemented as a user-adjustable input parameter within the water budget spreadsheet, and was ultimately set at 500 microsiemens per centimeter (µS/cm) in line with the general water quality profile of WRMWSD’s imported surface water supplies. Crop evapotranspiration (\(ET_c\)) is estimated from the monthly ITRC-METRIC ET data for irrigated lands, and a monthly leaching requirement (\(LR\)) is calculated using equation (3) above.

_Other Operational Demands_

As mentioned above, in addition to soil leaching, other operational practices that require additional applied water are commonly employed for purposes such as pre-irrigation requirements, harvesting, pest control, frost control, crop uniformity, germination, and dust control. As no specific information on specific operational water uses (i.e., amounts, locations, timing) was available from the District, these additional “operational demands” are estimated from JMLord, Inc.’s historical agricultural demand

reports provided for the District’s neighbor, Arvin-Edison Water Storage District (AEWSD), who is known to have a similar land use profile and distribution to WRMWSD.

Based on the JMLord, Inc. reports, it was determined that on a District scale, agricultural water users were historically applying an additional 0.16 AFY/acre to their lands on average (over Water Years 1994 – 2015) to meet additional operational demands beyond leaching. This value was employed for the “Additional Operational Demands” User Input Parameter within the analytical water budget model to estimate operational water demands within the District for any given month:

\[ OD_i = \frac{0.16}{12} \times \text{Acreage}_{\text{Irrigated Lands}} \]  

where \( OD_i \) = operational demands for month \( i \) [AF] and \( \text{Acreage}_{\text{Irrigated Lands}} \) = irrigated acreage for month \( i \).

**Processing Precipitation Data**

As mentioned above, estimates of total applied water should also take into account any contribution of effective precipitation in meeting ET demands on District lands. The residual “ineffective precipitation” (i.e., the portion of precipitation which is not considered available to meet ET demands) may also contribute to groundwater recharge to a certain degree and should thus be quantified and routed to appropriate subdomains within the analytical water budget to ensure mass balance is fully conserved within the model.

**Calculating Effective Precipitation**

Effective precipitation as defined as “the part of rainfall that can be used to meet the evapotranspiration of growing crops. It does not include surface runoff or percolation below the crop root zone.” (USDA-SCS, 1970) Since limited data exists to quantify historical rates of effective precipitation within the District, we have chosen to employ an empirical equation developed by the United States Department of Agricultural Soil Conservation Service (USDA-SCS) which factors in measurements of monthly rainfall, evapotranspiration (i.e. crop consumptive use), and estimated depth of application (or “usable soil water storage” depths) to approximate effective rainfall (in inches) for any given month. The resulting equation for estimating monthly effective precipitation [in] is:

\[ p_e = f \times (0.70917 \times p_t^{0.82416} - 0.1156) \times 10^{0.02426\times ET_c} \]  

where \( p_e \) = effective precipitation [in], \( p_t \) = total precipitation [in], \( ET_c \) = crop evapotranspiration [in], and \( f \) = correction factor for irrigation application depths different from 3 inches, where:

3 Ibid [17].
4 “SCS scientists analyzed 50 years of rainfall records at 22 locations throughout the United States to develop a technique to predict [monthly] effective precipitation (USDA 1970). A daily soil moisture balance incorporating crop [ET], rainfall, and irrigation was used to determine the ET effectiveness.” (USDA-SCS, 1993).
\[ f = (0.531747 + 0.295164 \times D - 0.057697 \times D^2 + 0.003804 \times D^3) \]  

where \( D \) = net depth of application during irrigation [in].

Effective precipitation \( (p_e) \) was calculated for each month for both irrigated and non-irrigated lands, where \( D \) was set to the default value of 3 inches for irrigated lands and set to zero inches for non-irrigated lands. These normalized values were subsequently converted into volumetric effective precipitation rates (in AF per month) using the acreages of irrigated and non-irrigated lands for the given month. For example:

\[
p_e^{i\text{Irrigated Lands}} = \frac{p_e^{i\text{Irrigated Lands}}}{12} \times \text{Acreage}_{\text{Irrigated Lands}}^i
\]

where \( p_e^{i\text{Irrigated Lands}} \) = effective precipitation on irrigated lands for month \( i \) [AF]. A similar calculation was used for the non-irrigated lands.

**Effective Precipitation Carryover Term**

While a soil moisture balance is not explicitly modeled in this analytical water budget, it is recognized that excess effective precipitation in the rainy winter months of the year may be retained temporarily in the root zone and can help contribute to meeting ET demands in the early growing season, thus reducing the irrigation demand during these months. To account for this phenomenon, we have included an effective precipitation “carryover” term to allow for any residual effective precipitation in excess of ITRC-METRIC ET signal to remain available for meeting ET demands in the following month(s) throughout the model period. This effective precipitation carryover term is defined as:

\[
p_e^{i\text{Carryover}} = \max(0, p_e^i - ET^i)
\]

where \( p_e^{i\text{Carryover}} \) = carryover of excess effective precipitation from month \( i \) [AF], \( p_e^i \) = effective precipitation for month \( i \) [AF], and \( ET^i \) = ITRC-METRIC measured ET for month \( i \) [AF].

This effective precipitation carryover term is subsequently added to the effective precipitation value calculated for the following month:

\[
p_e^{i+1} = p_e^{i+1} + p_e^{i\text{Carryover}}
\]

where \( p_e^{i+1} \) = adjusted effective precipitation for month \( i + 1 \) [AF], \( p_e^{i+1} \) = initial effective precipitation for month \( i + 1 \) (calculated from equations 5 – 7) [AF], and \( p_e^{i\text{Carryover}} \) = effective precipitation carryover term from month \( i \) [AF] (calculated from equation 8).

**Parsing Ineffective Precipitation**

As mentioned above, “ineffective precipitation” is defined as the portion of total (direct) precipitation that is not considered available to meet ET demands:

\[
p_{\text{ineff}}^i = p_i^i - p_{e\text{initial}}^i
\]
where \( P_{\text{ineff}} \) = ineffective precipitation for month \( i \) [AF], \( P^i \) = total precipitation for month \( i \) [AF], and \( P_e^i \) = initial effective precipitation for month \( i \) [AF] (calculated from equations 5 – 7).

Ineffective precipitation can either (1) runoff as a surface outflow from the water budget domain; (2) evaporate from the land surface before infiltrating into the root zone; or (3) percolate from the root zone into the vadose zone, where it eventually becomes groundwater recharge. As mentioned above, (1) surface runoff outside of the District is considered negligible in this water budget, leaving (2) evaporation and (3) deep percolation as the only pathways for parsing ineffective precipitation. Very little historical data or reference information exists for quantifying the proportions of evaporation versus deep percolation for ineffective precipitation, so we have chosen to define an “ineffective precipitation deep percolation coefficient” \( f_{DP} \) user input parameter to apportion these flux components within the model. Here, the portion of ineffective precipitation contributing to deep percolation for a given month \( P_{DP}^i \) is defined as:

\[
P_{DP}^i = P_{\text{ineff}}^i \times f_{DP}
\]

where \( P_{\text{ineff}} \) = ineffective precipitation for month \( i \) [AF], and \( f_{DP} \) = ineffective precipitation deep percolation coefficient [-].

Consequently, the portion of ineffective precipitation that will evaporate from the land surface for a given month \( P_{evap}^i \) is defined as:

\[
P_{evap}^i = P_{\text{ineff}}^i \times (1 - f_{DP})
\]

Notably, \( P_{evap}^i \) is included as a unique evaporative flux component from the water budget domain in addition to ITRC-METERIC derived ET, as opposed to assuming that evaporation of ineffective precipitation was included in the ITRC-METERIC signal. Though the ITRC-METERIC method is considered a generally reliable estimator of actual ET over large spatial domains, it faces certain limitations, particularly in the winter months where usable LANDSAT satellite imagery may not be available due to the presence of clouds, etc., and/or satellite imagery may not adequately capture the evaporation occurring from wetted soils immediately following a precipitation event\(^{15}\). With this constraint in mind, and under the observation that ITRC-METERIC measured ET in the winter months (i.e., November – February) was usually significantly lower than pan evaporation measured at the District’s nearby (5P-P2 Pumping Plant, District Headquarters, and PA-2 Pumping Plant) climate stations for the same months, it was determined that an additional “evaporation of ineffective precipitation” term \( P_{evap}^i \) was warranted for estimating evaporation of ineffective rainfall during the winter months when it is likely to be underestimated by the ITRC-METERIC method. Inclusion of \( P_{evap}^i \) also results in a more reasonably conservative estimate of groundwater recharge from ineffective precipitation \( P_{DP}^i \) during the wet season.

The ineffective precipitation deep percolation coefficient \( f_{DP} \) user input parameter was ultimately determined via calibration of the water budget model, as described further in Appendix H-5. A constant

\(^{15}\) Ibid [2]. See full ITRC-METERIC report for further details.
value of $f_{DP} = 0.5$ (i.e., 50% deep percolation of ineffective precipitation) was used for the WRMWSD analytical water budget model.

**Calculating the Total Irrigation Demand and Agricultural Groundwater Pumping**

Following the above methodologies to calculate the monthly ET demand, irrigation efficiency, leaching and other operational demands, and contributions of effective precipitation, the total irrigation demand within the District can be determined. After accounting for the volume of District surface water deliveries to irrigated lands from the District’s “WLEDGER” tables, the volume of groundwater pumping for irrigation (otherwise termed “agricultural groundwater pumping”) can also be estimated for any given month during the water budget period.

For any given month $(i)$, the unadjusted irrigation demand is defined as the ET demand on irrigated lands minus any contributions of effective precipitation:

$$I_{\text{demand}}^{i} = \max(0, ET_{\text{Irrigated Lands}}^{i} - P_{\text{eIrrigated Lands}}^{i})$$  \hspace{0.5cm} (13)

where $I_{\text{demand}}^{i}$ = unadjusted irrigation demand [AF], $ET_{\text{Irrigated Lands}}^{i}$ = ITRC-METRIC ET on irrigated lands [AF], and $P_{\text{eIrrigated Lands}}^{i}$ = effective precipitation on irrigated lands [AF] (equation 9) for month $i$.

The adjusted irrigation demand is then computed as follows:

$$I_{\text{demand,adj}}^{i} = I_{\text{demand}}^{i} \times (1 + (1 - e_{\text{IRR}}^{i})) + LR^{i} + OD^{i}$$  \hspace{0.5cm} (14)

where $e_{\text{IRR}}^{i}$ = irrigation efficiency coefficient (equation 1), $LR^{i}$ = leaching requirement (equation 3), and $OD^{i}$ = operational demands (equation 4) for month $i$.

As seen in equations (13) and (14), if the unadjusted irrigation demand ($I_{\text{demand}}^{i}$) is less than zero (i.e., if there is effective precipitation in excess of the measured ET on irrigated lands) then $I_{\text{demand}}^{i}$ is set to zero and the adjusted irrigation demand only includes the leaching requirements & operational demands for that given month.

From here, we can calculate agricultural groundwater pumping ($GW_{\text{pumping}}^{i}$) for month $i$ as the residual of the surface water deliveries to irrigated lands and the adjusted irrigation demand:

$$GW_{\text{pumping}}^{i} = \max(0, I_{\text{demand,adj}}^{i} - SW_{\text{deliveries}}^{i})$$  \hspace{0.5cm} (15)

where $SW_{\text{deliveries}}^{i}$ = surface water deliveries\(^\text{16}\) [AF] for month $i$.

If surface water deliveries to irrigated lands are greater than the adjusted irrigation demand, then there is no additional need for irrigation water and agricultural groundwater pumping is thus set to zero.

\(^{16}\) The term “surface water deliveries” is used here to refer to deliveries by the District to its customers within the Surface Water Service Area through the District’s conveyance system. These deliveries may in fact include some groundwater recovered from storage by the District’s recovery wells.
Calculating Instantaneous and Time-Averaged Deep Percolation

Using the above methodology, total applied water \((TAW)\) [AF], is intrinsically calculated within the water budget as follows:

\[
TAW^i = SW^i_{\text{deliveries}} + GW^i_{\text{pumping}}
\]  \(16\)

For the irrigated lands, \(TAW\) includes groundwater pumping and surface water deliveries after accounting for effective precipitation on the irrigated portion of the District (see equation 13). The \(TAW\) term therefore inherently reflects all assumptions about irrigation efficiency, leaching, operational requirements, and effective precipitation, as these values are included in the calculation of groundwater pumping within the irrigated portion of the District. \(TAW\) reduces to zero for non-irrigated lands, while for urban lands \(TAW\) will only include surface water deliveries to municipal & industrial (M&I) customers, and/or any M&I groundwater pumpage.

From here, the total instantaneous deep percolation on irrigated lands \((DP_{\text{inst,Irrigated lands}}})\) [AF] for month \(i\) is calculated as:

\[
DP_{\text{inst,Irrigated lands}}^i = TAW^i - ET_{\text{Irrigated lands}}^i + P_{DP_{\text{Irrigated lands}}}^i
\]  \(17\)

where \(ET_{\text{Irrigated lands}}^i = \text{ITRC-METRIC ET on irrigated lands [AF]}\) and \(P_{DP_{\text{Irrigated lands}}}^i = \text{portion of ineffective precipitation contributing to deep percolation on irrigated lands (equation 11) [AF]}\).

For the irrigated lands, this term will reflect all deep percolation resulting from inefficient precipitation, irrigation inefficiency, leaching demands and any other operational water uses.

For the non-irrigated lands, \(TAW\) is, by definition, zero and the total instantaneous deep percolation on non-irrigated lands \((DP_{\text{inst,Non-Irrigated Lands}})\) can be re-written as:

\[
DP_{\text{inst,Non-Irrigated Lands}}^i = P_{e_{\text{Non-Irrigated Lands}}}^i - ET_{\text{Non-Irrigated Lands}}^i + P_{DP_{\text{Non-Irrigated Lands}}}^i
\]  \(18\)

Note that in equation 18 deep percolation includes a contribution from effective precipitation on non-irrigated lands \((P_{e_{\text{Non-Irrigated Lands}}}^i)\). This term is included in equation 18 as a mass-balance closure term, since it is not intrinsically considered in the calculation of \(TAW\) as it is for the irrigated lands subdomain. By definition of \(P_{e}^i\) in equation 9, this term should include all carryover effective precipitation from previous months where \(P_{e_{\text{Non-Irrigated Lands}}}^i > ET_{\text{Non-Irrigated Lands}}^i\) so as to prevent any effective precipitation from percolating below the root zone, thus reducing equation (18) to only include \(P_{DP_{\text{Non-Irrigated Lands}}}^i\). However, it has been noted that the ITRC-METRIC measured \(ET_{\text{Non-Irrigated Lands}}\) routinely exceeds \(P_{e_{\text{Non-Irrigated Lands}}}\) estimates during the dry season, thus resulting in a negative \(DP_{\text{inst,Non-Irrigated Lands}}^i\) during the summer months. Whether or not this high ET signal in the non-irrigated portions of the District is an artifact of the ITRC-METRIC method or is in fact a
real signal, for the purposes of this water budget a negative $DP_{inst,\text{Non-Irrigated Lands}}$ value results in a net reduction of groundwater storage from the non-irrigated subdomain for the given month.\(^\text{17}\)

Though the instantaneous deep percolation value serves as a closure term within the irrigated and non-irrigated lands water budget subdomains, in reality, because the groundwater table can occur several hundred feet below the ground surface, it may take a considerable time for deep percolation to travel through the thick vadose zone before it actually reaches the groundwater table and adds to groundwater storage. For the purposes of this water budget, this “lag effect” is represented by including a “Deep Percolation Lag Period” as a user input parameter within the water budget. This allows the user to specify an estimated time (in months) that it would take for any deep percolation water to travel through the vadose zone and reach the groundwater table. The resulting “time-averaged” deep percolation, $DP_{\text{avg}} [AF]$, is thus calculated as a moving average as follows:

$$DP_{\text{avg}} = \frac{\sum_{i=N}^{y} DP_{\text{inst}}^i}{N+1} \quad (19)$$

where $N =$ the deep percolation lag period [months].

This value represents the estimated volume of “deep percolation” that actually reaches the groundwater table on a given month. For the WRMWSD water budget, a final deep percolation lag period of 11 months was selected, so the amount of deep percolation recharging the groundwater basin for a given month would equal the time-averaged deep percolation ($DP_{\text{avg}}$) percolation for the past 11 months up to the present. Use of this time-averaged deep percolation (i.e., use of a moving average) results in a smoothed-out time series of recharge. This method was also applied to the recharge from stream flows into the District, seepage from man-made channels (negligible), and return flows from urban water use.

\(^{17}\) It should be noted that the excess non-irrigated demand likely does not come from groundwater storage depletion, but is rather made up by a combination of local runoff from adjacent irrigated lands, contributions from streamflows, and/or seepage from natural and artificial water systems. Functionally, it is justified to attribute this demand to groundwater storage depletion, because if it were to come from surface water it would then reduce the amount of surface water available for delivery to agricultural lands which would increase the demand for pumping, and so the same result is achieved.
Conclusions

The result of the above processing steps is a water budget for the agricultural lands subdomain that:

- Incorporates direct measurements of ET from the land surface using ITRC-METRIC data as well as estimates of direct precipitation from local climate stations;
- Links monthly ITRC-ET data to seasonal, parcel-based land use details;
- Parses ET into buckets of (1) irrigated lands, (2) non-irrigated lands, and (3) urban lands;
- Calculates estimates of agricultural pumping and deep percolation on irrigated lands due to ineffective precipitation, irrigation inefficiencies, leaching, and operational demands;
- Calculates estimates of deep percolation on non-irrigated lands due to ineffective precipitation;
- Factors in a user-defined lag period to represent the time lag effect of vadose-zone flow on groundwater recharge due to deep percolation; and
- Accounts for evaporation of ineffective precipitation in the winter months where ITRC-METRIC ET data may not fully capture evaporation after rain events due to gaps in imaging frequency and/or less-reliable interpolations between imaging dates.

The attached Figure E-4-2 provides a schematic of the irrigated agricultural lands subdomain equations and their interrelationships as described above.
For Irrigated Lands:

\[ DP_{irr} (17) \]

\[ TAW (16) \]

\[ SW_{delivers} \]

\[ GW_{pumping} (15) \]

\[ l_{demand,adj} (14) \]

\[ l_{demand} (13) \]

\[ l_{demand}^{*}(1-e_{al}) (1) \]

\[ OD (4) \]

\[ LR (3) \]

\[ P_{irr} \]

\[ P_{evap} (12) \]

\[ P_{D} (11) \]

\[ P_{E} (7) \]

\[ ET_{irr} \]

Legend

- Raw Data
- Quantity of Interest
- Calculated by Sum
- Calculated by Difference
- Calculated using Multiplication by a Calibration Factor or other constant
- Corresponding equation in Appendix E-4-2

Abbreviations

- ft = feet
- ft msl = feet above mean sea level

DRAFT

Irrigated Agricultural Lands
Equations & Interrelationships

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
August 2019
EKI B70103.01

Figure E-4-2
Attachment E-4-1

2015 ITRC-METRIC ET Study Report (GEI)
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Introduction

The Irrigation Training & Research Center (ITRC) at California Polytechnic State University, San Luis Obispo was contracted by the Kern Groundwater Authority (KGA) to compute actual evapotranspiration (ETc) from the Southern San Joaquin Valley within and near the Kern Groundwater Basin. The area of interest is shown in Figure 1 with a “natural color” image in the background.

ITRC uses a modified Mapping of EvapoTranspiration with Internal Calibration (METRIC™) procedure to compute actual evapotranspiration using LandSAT Thematic Mapper (LandSAT) data. The original METRIC procedure was developed by Dr. Richard Allen (University of Idaho). ITRC has made a number of modifications to the original procedures including using a grass reference evapotranspiration instead of alfalfa, a semi-automated calibration procedure, spatially interpolated ETo, modifications to the aerodynamic resistance and albedo computations for certain crops, improved open water evaporation algorithm, etc.

Figure 1. Aerial image of the area of interest within which actual evapotranspiration was provided to KGA

This report will describe the general process and some results of the modeling over the timeframe. The monthly and annual results of ITRC-METRIC for this project have been transmitted to KGA (care of Eric Averett, General Manager, Rosedale-Rio Bravo WSD).
ITRC- METRIC Procedures

This *Procedures* section will discuss the information that was gathered and used to compute the actual crop evapotranspiration (ET) in the Delta. The ITRC-METRIC process is based on a surface energy balance and includes corrections for aerodynamic resistance. It depends upon both accurate and frequent LandSAT satellite thermal images and understanding of the cropping systems within a region. The METRIC programs have gradually evolved from research in the US and other countries with the objective of being able to directly estimate actual ET over large areas with limited data availability (such as crop type, irrigation method, irrigation practices, etc.). The image processing is relatively fast; however, the collection of significant background data (besides the satellite images) that are necessary to start the processing in a new area can be somewhat time-consuming. Proper use of METRIC also requires expert input/interpretation by those who run the program.

LandSAT 5, 7, and 8 image pixel resolution is 30 meters by 30 meters for all but the thermal band. The thermal band pixel resolution is 120 meters by 120 meters for LandSAT 5, 60 meters by 60 meters for LandSAT 7, and 100 meters by 100 meters for LandSAT 8. For this project, the thermal band was sharpened to 30 meter by 30 meter resolution using the nominal cubic spline that is provided in the raw images by USGS. ITRC has a more advanced thermal sharpening process, but that was not used because of time and budget constraints for this project. Inputs into the ITRC-METRIC model included:

- LandSAT imagery
- Digital elevation maps
- NASS CropScape data
- Corrected weather station data (hourly and daily)
- Corrected spatial grass reference evapotranspiration (ETo) maps (daily)
- Spreadsheet calculated values
- Tabulated constants

A critical benefit of using ITRC-METRIC to determine actual evapotranspiration is that land use/crop type information is not needed. Therefore, inaccuracies of determining land use are not part of the uncertainty in ETc output. General land use information (row crop, orchard, etc.) is used to correct for aerodynamic influences on ETc. The information provided through the NASS CropScape is of sufficient accuracy for this piece of the process.

**Satellite Images**

LandSAT 5, LandSAT 7, and LandSAT 8 images available from the United States Geological Survey (USGS) on sixteen-day intervals were used for the METRIC process. Table 1 shows the time frame of available images from each satellite.

<table>
<thead>
<tr>
<th>LandSAT 5</th>
<th>LandSAT 7**</th>
<th>LandSAT 8</th>
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</table>

**After May 2003, LandSAT 7 began producing images with missing data, or “bandgaps” because of a defective sensor/mirror. LandSAT 7 is only used as a backup if other LandSAT data is missing. Bandgaps are filled using interpolation techniques in GIS as described in the METRIC Application Manual Version 2.0.7 (Allen et al. 2010)**
The area of interest is covered by the LandSAT image path 42, rows 35 and 36. Each path identifies a path, or single trip the LandSAT takes, and the rows are different portions of that path. The rows along the same path are taken on the same day and the center of the row image is taken at approximately the same time of the day (approximately 11 a.m. Pacific Standard Time).

The METRIC modeling process relies on surface temperature data from the LandSAT thermal band. Actual ETc cannot be computed for the regions covered by clouds or fog. Figure 2 compares a non-clouded image with a cloud-covered LandSAT image. The best quality (minimal clouds and fog) LandSAT images were selected for processing. Every LandSAT image available throughout the study period was evaluated manually.

All relatively cloud-free available images were used for the modeling process. Table 2 lists the images processed from late 1992 through early 2016. A total of 234 images were used to cover the study period.

If a cloud-free image was not available during a month, the image with the fewest clouds was selected or LandSAT 7 imagery was used. If an image with clouds had to be used, the clouds were masked out of the results and replaced with interpolated results from images processed before and after the image date. For the cloud masking interpolation, the two previous and three subsequent processed images were used to estimate the actual crop coefficient for the cloudy region.

Some months (generally during winter) had no usable images because of significant cloud cover. Available images, before and after the month with no data, were selected to be used to interpolate the missing image.

For those cases when three or more consecutive months did not have usable images, the closest available image was used in combination with a correction factor, to get an average estimated Kc map for the missing month. Those correction factors were established based on data from years with usable winter images. Because this process was used only for winter months, which have low ET, the overall accuracy should not be influenced significantly. However, users should understand that the uncertainty of the data for these months is greater than if LandSAT images were available. The months when this process was used can be seen in Table 3.
Table 2. Chosen image dates for 1993-2016 Kern County METRIC process

|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|

Table 3. Months with data estimated by the factor process

|------|-------|-------|------|------|------|------|------|------|------|-------|

Note: * indicates Landsat 7, ** indicates Landsat 8, and no asterisk indicates Landsat 5 images
Weather Data

ITRC-METRIC utilizes daily spatially varied grass reference ETo for interpolation between image dates. SpatialCIMIS is a product provided by the California Irrigation Management Information System (CIMIS) maintained by the California Department of Water Resources (DWR). Spatially varied ETo is developed by interpolating ETo between CIMIS weather stations, which measure and compute the ETo on an hourly basis. However, the collected data could have errors. Therefore, ITRC quality controls the hourly weather data at each weather station in the Central Valley (Redding to south of Bakersfield) and corrects the daily Spatial CIMIS data.

ITRC-METRIC also relies on hourly weather data from a station within the area of interest for processing the instantaneous images (prior to interpolation). The Shafter and Famoso CIMIS stations were utilized as the “primary” weather stations. These stations were selected because of their centralized locations within the primary area of interest. Shafter was used from 1992-1997 and Famoso was used from 1998-2015. The same quality control procedure was used at all weather stations, as will be described.

Hourly weather data for the project time frame was collected from CIMIS weather stations located throughout the project area. Forty-nine weather stations were used for the METRIC modeling process. Figure 3 shows the majority of weather stations used in this project. Not all stations were available during the entire analysis period. Each station is listed in Table 4 showing the approximate range of time that the station was utilized. A station may have become active or inactive within this timeframe.

The weather component data collected from the weather stations included:

1. Solar radiation (W/m²)
2. Vapor pressure (kPa)
3. Air temperature (°C)
4. Wind speed (m/s)
5. Precipitation (mm)
6. Relative humidity (%)
7. Dew point temperature (°C)
8. PM ETo (mm)
Figure 3. Locations of the CIMIS weather stations used in this evaluation
### Table 4. Weather stations used for the METRIC modeling process

<table>
<thead>
<tr>
<th>1993-2004 CIMIS Station</th>
<th>2005-2015 CIMIS Station</th>
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<tr>
<td>Arvin-Edison</td>
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<td>Famoso*</td>
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<td>Five Points SW</td>
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* “Primary” stations
All collected hourly weather data from the stations went through a quality control check and correction procedure. A detailed procedure on the quality control conducted can be found in FAO Irrigation and Drainage Paper No. 56\(^1\) along with correction procedures. The main variable needing correction to accurately compute the hourly ETo is solar radiation. However, relative humidity was also examined using the procedures described in Allen et al. (1998). Figure 4 contains a graph of the corrected solar radiation for the Famoso CIMIS station for 2010-2014. This weather parameter is often in error if a pyranometer becomes covered with dust or debris, or if it loses calibration. This can be identified by comparing the daily incoming solar radiation with the maximum potential solar radiation (computed based on elevation, latitude, and time of year). If the measured value does not approach or become equal to the maximum potential over a time frame of several weeks, this could indicate an error in the measurement. Day-to-day variability is expected, but during a clear day, the measured should approach the potential. High values of solar radiation can be caused by incorrect sensor calibration.

![Figure 4. Example of solar adjustments made on Famoso CIMIS Station for 2010-2014. The same analysis was conducted for all weather stations in the Central Valley.](image)

For missing data, or if an error was flagged on the CIMIS station signifying missing, incomplete, or odd data results, data were examined for general consistency. Missing data and data believed to be in error were corrected. The correction procedure used in this analysis replaced the missing or flawed data with the averages from nearby weather stations. Once all hourly data was corrected, the data was input into REF-ET\(^TM\) (Dr. Richard Allen, University of Idaho) to compute the corrected hourly ASCE Standardized ETo that was used in this study.

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ETo and individual weather data are used within the ITRC-METRIC process to compute inputs into the software. METRIC computes the instantaneous ETc for every pixel within the LandSAT image at the instant the image is taken. Knowing the ETo at that instant from the local weather station, a crop coefficient (Kc) can be computed (Kc = ETc/ETo). It has been shown that this instantaneous actual Kc at the time of image acquisition (approximately 11 a.m.) is a very good representation of the Kc for that entire day. These instantaneous Kc results are interpolated using a cubic spline procedure between image dates. The interpolated pixel Kc for each day is then multiplied by the daily corrected spatial ETo discussed in the next section.

Corrected Spatial ETo

Spatial CIMIS ETo is a relatively new resource available through the DWR. A specialized algorithm uses weather station data, elevations and other inputs to interpolate ETo between stations. However, Spatial CIMIS ETo rasters rely on CIMIS weather data that could have errors. In order to improve accuracy, ITRC incorporated the corrected CIMIS weather data into the Spatial CIMIS ETo raster images using a model we developed for ArcGIS 10.1.

The basic correction procedure first included adding the locations of all 49 stations into GIS. The uncorrected Spatial ETo at the weather station location was extracted for each day over the time frame investigated. The difference between the corrected daily ETo for each station and the uncorrected Spatial ETo was computed. These differences were used to generate a difference raster using Inverse Distance Weighting (IDW) interpolation. The difference raster was combined with the uncorrected Spatial ETo to generate the corrected Spatial ETo image.

Figure 5 shows a comparison of the uncorrected Spatial CIMIS ETo and the corrected Spatial ETo for July 15, 2015. The corrected Spatial ETo represents the combination of our corrected ETo data blended with the original Spatial CIMIS ETo.

Figure 5. Example of uncorrected Spatial CIMIS ETo compared to corrected Spatial ETo for July 15, 2015
Calibration near Primary Weather Station

The METRIC process requires calibration of the hot and cold pixel for each image processed. The calibration should be conducted near a primary weather station within the image. Therefore, a primary weather station was selected for each image path. The stations selected (Shafter (1993-1997) and Famoso (1998-2015)) were chosen on the basis of the stations’ history of reliable, relatively error-free data. Other reasons for choosing primary stations included:

- The location within intensive agricultural areas.
- Relatively representative of weather throughout the agricultural regions in the path.

Shafter was used as a primary station for the years 1993 through 1997. Famoso was used as a primary station for the remainder of the study period.

For the semi-automated calibration process, an area of interest (AOI) is created around the primary weather station. This AOI is generally within a 5 to 10 mile radius of the primary station and urban areas, or large non-agricultural areas are avoided. Figure 6 shows the calibration AOI for the Famoso CIMIS station.

Elevation Data

A Digital Elevation Model (DEM) obtained from the USGS was used to adjust the model outputs based on the surface elevation throughout the area of interest. The DEM used had a resolution of 10m (1/3 arc second) which was then re-projected into a 30m × 30m pixel size to match the resolution of the LandsAT images.
Land Use Map

As previously mentioned, accurate land use/crop types are not necessary for ITRC-METRIC. General information on whether land is natural vegetation, row/field crops, orchards, or vineyards is used to adjust for aerodynamic resistance of the canopy, and is also a function of leaf area index. NASS CropScape provides sufficient accuracy for this information.

Land Use Data 2007 to Present

For years 2007 to present, only the land use data from the NASS annual rasters were used. While this information is sufficient for METRIC, there are issues with consistency within fields. Land use surveys were conducted by the California DWR on a field-by-field basis for all of the counties located in the Central Valley. DWR land use survey shapefiles were downloaded for each county, some of which may have last been surveyed in the 1990s. The shapefiles contain field boundaries or in some cases boundaries of the same crop that cover multiple fields. All non-agricultural areas in the DWR land use surveys were removed from the shapefile. Using the zonal statistics tool in ArcGIS, the NASS land use was summarized for each DWR agricultural field boundary in the Central Valley. The crop that made up the majority of the field area was assumed to cover the entire field area.

The final corrected land use maps went through a quality control check to ensure that a single land use value was uniform across an entire field. Figure 7 shows an example of the original uncorrected NASS land use compared to the land use used in this analysis, which is much more consistent. The inconsistent “pixelated” areas in the corrected land use were identified as non-cropped areas in the DWR land use survey. Therefore, these non-ag areas use the original NASS data.

Figure 7. Example original NASS land use (left) compared to corrected land use based on the majority crop type within each agricultural field (right). Each color identifies a different land use type (i.e., almonds, alfalfa, developed, etc.)
**Land Use Data 1997 to 2006**

The earliest NASS land use raster available for California is from 2007. The County of Kern Agriculture and Measurement Standards provides land use shapefiles only for agricultural fields in the county from 1997 to present. The shapefiles did not provide land use data outside of the agricultural fields. Therefore, information from the last available NASS land use raster (2007) was used to fill in the missing background. The following process was used to combine the two sources to create land use maps for 1997 through 2006:

1. The crop data for each individual field from the Kern County data was converted to a specific value to match the crop identification value used by NASS. For example, a field containing alfalfa in the Kern County data was converted to the NASS crop value of 16.
2. The Kern County shapefile, with the added NASS crop value, was then converted to a raster image to represent the crop value.
3. The DWR survey shapefile was used to quality control the 2007 NASS land use raster so that the raster values within the field boundaries were all uniform.
4. The new Kern County raster was then mosaicked with the corrected 2007 NASS raster. The land use values from the Kern County raster had top priority over the 2007 NASS values and therefore were utilized in the final land use raster. Then 2007 NASS values were used in the non-agricultural areas as well as the background portion of the image.

**Land Use Data 1993-1996**

No land use data was available prior to 1997. Therefore, the final quality controlled 1997 land map was used for 1993 through 1996.
**Interpolation between Image Dates**

The selected images were processed, resulting in instantaneous actual crop coefficients (Actual Kc) on those dates for each pixel. The crop coefficient has been shown to remain constant during the majority of the daylight hours. Therefore, the instantaneous actual Kc was used as a surrogate for the daily actual Kc. In order to estimate the actual ETc between dates that images are available, actual Kc's are interpolated between image dates. A modified cubic spline approach is used to examine images within the month to be computed, prior to that month, and after that month. For example, to interpolate the ETc in the month of July, the July image(s) would be used along with May and June, and August and September. Cubic spline interpolation provides a smooth, non-linear interpolation between image dates. The interpolation takes place for every pixel in the image and the results are temporary Kc images for every day in the month. The daily pixel actual Kc values are then multiplied by the daily corrected Spatial ETo previously discussed to compute the daily actual ETc for each pixel. These daily ETc images are summed together for each month. Finally, the corrected Spatial ETo is summed for each month and the monthly ETc is divided by the ETo to generate the final monthly Kc image.

Monthly actual Kc and actual ETc results for Kern County for the period 1993-2016 have been provided to the Kern Groundwater Authority in GIS raster (image) format.

**Accuracy of ITRC-METRIC ETc Estimates**

Uncertainty is the quantification of accuracy in measurements and estimates. The most accurate method to estimate ETc is using a weighing lysimeter (correctly) but this is not feasible except in research situations. There are various methods that can be used to estimate ETc, each with different levels of uncertainty:

1. Traditional crop coefficient models (not used here but common in groundwater modeling) have uncertainty due to the assumptions that ETc is constant within a field and between fields in a region. Additionally, errors in land use determination (acreage of each crop), planting and harvest dates (or budbreak and dormancy for permanent crops), and crop management (irrigation, pruning, etc.) all impact the ETc uncertainty. Errors in weather data collection to determine grass reference ETo also impact the uncertainty. As a reference, uncertainties with crop coefficient methods are in the range of 20-25%.

2. Sensor-based measurements such as eddy covariance and surface renewal only measure a small footprint in a field and have potential for sensor errors due to improper calibration, loss of calibration over time, or sensor fouling. Additionally, the sensors must be adjusted, installed correctly, and some (e.g., surface renewal) depend on assumptions that may not hold. Data management and technical support make these infeasible when examining ETc over many fields.

3. NDVI-based ETc estimates have some advantages over (1) and (2) in that they provide spatial variation over a field and field to field. But these still rely on accurate crop surveys. Additionally, this method does not account for crop stress, unless that stress is so severe that it impacts the vegetative index. As with (1) above, the ETo errors translate to ETc uncertainty.

4. ITRC-METRIC ETc overcomes many of the issues with other methods, which is why it was developed. This method does not rely on accurate crop surveys. It also accounts for crop stress before it impacts the vegetation. Spatial variation in ETc throughout a field and between fields is accounted for. ETo continues to be an important part of ITRC-METRIC, which is why quality control of the data is important. In order to limit errors in ETo, ITRC conducts an extensive quality control of the weather station data and utilize spatially varied ETo to account for different climates within a region. As with other methods, it is imperative that the person doing the processing understands agronomic aspects
within the region being evaluated. Errors in processing will generate errors in ETc estimation. All ITRC-METRIC images are reviewed by project managers with many years of experience in farming, irrigation, and crop water use estimation to ensure that the outputs are correct. This overcomes potential errors in LandSAT sensor data since each image is calibrated independently.

ITRC-METRIC uncertainty is estimated to be +/-7 to 10% in this study. On a large scale (GSA or county-wide ETc volumes) the error is on the lower end of this range. On a field scale, it may be on the upper end currently. We have continued to make improvements to our methodology and feel that in the future field-scale ETc will be on the lower end of the range provided. Additionally, the launch of LandSAT 9 (planned for December 2020) will improve the temporal resolution, providing images every 16 days, offset by 8 days from LandSAT 8 (potential for images on an 8 day interval). There are no other ETc computational methods available with uncertainties on both a large scale and field scale within these ranges.
Summary of Results

The annual results have been summarized for the Kern County Valley floor and the field boundaries (majority) within the Valley floor of Kern County. Figure 9 shows the boundaries used for the data extraction for the summaries discussed in this section. Average annual ITRC-METRIC ETc was extracted using the Zonal Statistics tool in ArcGIS. The average ETc from the extracted area was multiplied by the area within the boundaries (overall boundary or each field boundary for the fields) to compute volumes. Over the 23-year period, the field boundaries and overall boundary were the same.

Figure 9. 2008 ETc image with Valley floor and field boundaries used for the summary analysis

The volume of actual ETc for the overall area and only within fields is shown in Figure 10. For reference, the grass reference evapotranspiration (ETo) and precipitation from the Shafter CIMIS station (1992-1997) and Famoso CIMIS (1998-2015) are also shown. ETo provides an idea of the weather conditions that drive evapotranspiration. Hotter, drier years have a higher ETo.

Figure 11 shows the volume of ETc for all water districts in Kern County and Kern Groundwater Authority members. The acreage of all districts is greater than the “Valley Floor Area” because of district boundaries covering areas outside of the valley floor (e.g., West Kern W.D.). Some districts with
substantial overlap of other districts were removed from the evaluation to limit double counting. However, some minor overlap may cause the estimates to be slightly higher than the actual volume of ETc.

Figure 10. Annual volume of ETc for the Kern County Valley floor and within fields in Kern County. Grass reference ETo and precipitation depths are shown for each year as a reference.

Figure 11. Annual volume of ETc for irrigation/water districts in Kern County and just Kern Groundwater Authority member districts
Evaluation of ETc Variation

In general, there is an overall decline in ETc volume from the Valley floor starting over the 23 years that the ET analysis covers. The field ETc decline is not as significant but does trend downward. The difference between the Valley floor and field ETc is due to ET and evaporation occurring outside of field boundaries. Year to year variability in ETc volume might be explained by weather differences between years. To examine this, the data was normalized to exclude weather variation by examining the annual crop coefficient (Kc), computed as the actual ETc divided by ETo (ETo is computed based on weather data, not including precipitation). Annual Kc values are shown in Figure 12 for the study period (bar graphs) for the entire Kern valley floor area (includes urban, streets, undeveloped areas, etc.) and within fields only (only agricultural fields in the same area).

![Figure 12. Annual crop coefficient (Kc) for the Kern County Valley floor and within fields in Kern County.](image)

As expected, the Kc is higher when only looking within field boundaries compared to the entire Valley floor of Kern County. Areas outside of the fields are in large part reliant on precipitation or are a mix of landscape and residential areas. Urban areas and open water are also included. As with the volume, there seems to be a general decline in overall Kc over the 23 years.

In the mid-2000s the Kc increases. Figure 12 also includes the Kern County Ag Commissioners total harvested acres over the 23 year period for reference and to possibly explain some of the variation. Interestingly, the Ag Commissioners’ total harvested acreage increases from 1993 to 2016. While there are some general trends indicating that the annual Kc increases as the acreage increases, the trends do not follow as closely as one might expect. This could be due to the types of crops harvested over the period or the age of permanent crops being grown. It is important to restate that crop types are not used to determine ETc using ITRC-METRIC. They are only shown here as a reference to potentially explain the variation in ETc.
To delve further into the theory that crop type shifts may explain ETc variation, crop acreages of the major crops in Kern County (Kern County Agricultural Commissioner Reports) are shown in Figure 13. The higher ETc and Kc values in the mid-2000s are likely due to the increase in alfalfa acreage during this period in combination with the higher almond acreage. However, the higher ETc and Kc values in the mid-1990s are more challenging to explain. Obviously there is more cotton acreage and likely more double cropping of different row crops (although cotton is not commonly double cropped). Other crops in the cotton rotations likely include double cropping, such as corn and grain hay, which are not shown.

Figure 13. Crop acreage for major crops in Kern County from 1993-2016 (top) and total harvested acres (bottom) from Ag Commissioner Reports

As previously discussed, the Kern County Ag Commissioner reports showed an overall increase in harvested acreage from 1993 to 2015. The Ag Commissioner reports showed the 1993 total harvested acres at approximately 809,700 compared to the 2015 harvested acreage of 881,000. Year-to-year variations are shown in Figure 12.
There are also some unexplainable anomalies in the Ag Commissioner data, such as the increase in almond acreage from 2013 to 2014. Figure 13 shows that total acres (bearing and non-bearing) for almonds increased by over 50,000 acres from 2013-2014. The bearing acreage showed the most significant increase from 2013 to 2014 even though only 1,600 acres of non-bearing trees were reported for 2013. The bottom line is that over 50,000 acres of bearing almonds showed up in 2014 without explanation. This could be due to an error in the Ag Commissioner’s reporting or a shifting methodology of accounting for certain crops.

The annual Kc by field in Kern County from ITRC-METRIC was plotted from lowest to highest Kc for four selected years (Figure 14). The fields with the lowest Kc would be fallow or young orchards/vineyards. Notice that there are more fields with Kc values below 0.2 in 2008 and 2015 than in 1993 or 1996. Of these, 1996 has the fewest low Kc fields while 2015 has the most. Different fields have different Kc values each of these years. The key point is that the lower Kc values in 2014 and 2015 (Figure 12) are likely driven down by increased fallowing or young orchards. Additionally, Figure 14 indicates that the overall field acreage was probably lower in 2015 than in 1993. While field acreage is not the same as harvested acreage because it does not account for double-cropping, it is unlikely that double cropping accounts for the full difference in reported acreage.

Visually, significantly more non-cropped fields can be seen in 2015 than in 1993 (Figure 15). Portions of Kern County (red circles which include portions of Lost Hills Water District, Buena Vista WSD, and Henry Miller WD) show much lower ET in 2015 than 1993. These areas were fallowed or not cropped during the drought. In other areas, new permanent crop plantings may be the cause of lower ET. Additionally, the Kern Lake and areas south of Bakersfield have much lower ET values indicating new permanent crops or fallowing.
Figure 15. Annual ITRC METRIC ET in 1993 (top) and 2015 (bottom) with field boundaries
Conclusion

Over the 1993-2016 period, the volume of evapotranspiration from fields within the valley floor of Kern County ranged from approximately 2-2.5 million acre-feet. Evapotranspiration varies year to year in the valley floor portion of Kern County. This is caused by several factors including weather, crop mix, water availability, precipitation, and land falling. It was beyond the scope of this study to investigate exactly why evapotranspiration varied. However, the previous figures indicate that there seems to be increased falling or young orchards and vineyards planted in more recent years, resulting in lower evapotranspiration in this period. This acreage reduction does not coincide with Kern County Ag Commissioner’s reported harvest acreage changes over the period.

The monthly and annual evapotranspiration and Kc imagery in GIS format has been transmitted to Kern Groundwater Authority.

Future Work

Net To/From Groundwater (NTFGW)

ITRC has developed a process to examine net groundwater use without the need to monitor groundwater pumping. This process is called the Net To and From Groundwater (NTFGW) and can be conducted at various scales from the farm/field, GSA, and Basin. This method incorporates surface water diversions, turnout deliveries (for farm/field scale), surface outflows, and precipitation with the monthly ETc to determine net groundwater use. Basically, if precipitation and surface water deliveries exceed ETc, the excess water would be stored in the root zone or moves to the groundwater (net to groundwater). If ETc exceed surface supplies, there is a net extraction from the groundwater to make up the difference. Results are provided spatially at the 30 meter pixel resolution. NTFGW is being used for two purposes:

1. Using historical data, to assist in calibration/verification of groundwater models. Equally important, the results provide a directly computed future ETc with net zero extraction.
2. For future management and regulation of groundwater use within the GSA. Monthly results will be provided to each GSA participant in near real-time (approximately 15 days after surface delivery information is provided to ITRC). Some GSAs are planning on providing this to farmers via a web mapping portal.

The benefits of NTFGW include:

- No groundwater metering program with meters at each well is needed. DWR has approved the method as a best-available science alternative.
- No estimates on irrigation efficiency are needed. Irrigation efficiency estimates have a high level of uncertainty, vary from field to field, and will change over time. NTFGW simplifies the evaluation of sustainable yield because inherently sustainable yield is a net value of how much groundwater can be consumed in a GSA. There is no need to estimate leaching requirements or other non-consumptive uses of groundwater. Comparing net values eliminates many uncertainties.
- It offers the ability to track net canal seepage and net recharge basin recharge by basin.
- It offers the ability to continuously track banked or over-drafted groundwater on a farm, district, and GSA level.
- It is cost-effective: the anticipated cost will be $30,000-$50,000 per year per district/GSA. Actual cost will depend on the district/GSA size and the level of evaluation.
ITRC-METRIC ETc

There are several options moving forward. ITRC-METRIC ETc will be an important tool. Over the past several years there have been lessons learned which will impact the process in the future:

1. Thermal sharpening has not been extensively used because it is time-consuming. However, ITRC is working on expediting this process. Currently, the thermal sharpening process increases the overall processing cost by a factor of 50%. It is expected that this cost will be reduced in the future. On a larger scale it is not important because the overall ETc is not increased or decreased. On a field level, it may be more important.

2. In the past we used at least 1 image per month to compute ETc. ITRC now uses all available good-quality images (mostly cloud/fog free, some cloud coverage is okay). Again, on a large scale (over a district for example) it is not as critical, but for individual fields, especially for row and field crops, it is critical to have images at least on a 16-day interval to capture harvests appropriately.

Future implementation of continuous ETc will be important for groundwater management in the Kern subbasin. The historical data generated as part of this project is being implemented in the groundwater modeling efforts in the subbasin. The next steps are towards monitoring sustainable use of the groundwater into the future. ITRC believes that NTFGW is the best methodology to monitor groundwater use since net groundwater use is more important than gross groundwater pumping. Pilot projects using NTFGW compared to groundwater pumping have been successfully implemented in a subbasin just north of Kern. ITRC would be pleased to share these results with interested parties.
Attachment A

Annual ITRC-METRIC ETc

Kern Groundwater Agency
ITRC-METRIC Actual ETc

1993 Annual ET (inches)
High: 50
Low: 10

1994 Annual ET (inches)
High: 30
Low: 10
Attachment E-4-2

List of Crop Salinity Thresholds Used for Leaching Estimate (JMLord)
## Crop Salinity Thresholds for Various Crops

<table>
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<th>Crop</th>
<th>Salinity Threshold (dS/m)</th>
<th>Crop</th>
<th>Salinity Threshold (dS/m)</th>
<th>Crop</th>
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Appendix E-5

Water Budget Model Calibration
APPENDIX E-5
WATER BUDGET MODEL CALIBRATION

This appendix documents the processes used to calibrate the Wheeler Ridge-Maricopa Water Storage District (WRMWSD) long-term water budget spreadsheet model and reports the final water budget calibration results.

Calibration Process

As described in Appendix E-1, the water budget model is a spreadsheet-based tool that quantifies 31 individual hydrologic flow “components” and then uses mass balance principles to link components and calculate a residual change in storage from the groundwater system at a monthly timestep.

Included in the water budget spreadsheet model are various “User Input Parameters” that can be adjusted to improve model performance. Values for these adjustable parameters were initially set to reasonable values based on review of previous relevant studies and local information, where possible (see Appendices E-1 through E-4), and were subsequently adjusted to minimize the difference between model-calculated change in storage and the change in storage derived from rasterized groundwater elevation monitoring data.

Development of Groundwater Storage Change Rasters

The change in groundwater storage was estimated within the District’s SGMA jurisdictional area1 between various time periods using local groundwater elevation data provided by the District2 along with data downloaded from the DWR’s “CASGEM” portal. Local groundwater level data within and proximate to the District boundaries were interpolated using kriging3 to create continuous groundwater elevation surfaces (rasters) for several “bookend” years of interest within the water budget period4. Interpolated water level surfaces were subsequently compared between bookend years to calculate the change in storage, as follows:

\[ \text{GW Storage Change}_{t1 \rightarrow t2} = \left( \text{GWEL}_{t2} - \text{GWEL}_{t1} \right) \times \text{Specific Yield} \]

1 WRMWSD’s “SGMA jurisdictional area” includes the portions of the District within the Kern Groundwater Authority Groundwater Sustainability Agency (KGA GSA) area within the Kern Subbasin and all portions of the District within the White Wolf Subbasin.

2 Local groundwater level data also included records from Arvin-Edison Water Storage District (AEWSD) for wells located in the AEWSD-WRMWSD “overlap area”.

3 Data were interpolated using kriging, a geostatistical method commonly used to interpolate groundwater elevation data, in the software package Surfer. The output of this interpolation process is a raster file with 100-ft by 100-ft pixels, which can be subtracted from or multiplied by other raster files covering the same area, and for which total volume can be calculated.

4 The interpolated surfaces vary significantly depending on which well data sets are used. Based on significant analysis, we have more confidence in the change in storage estimates generated from surfaces constructed using groundwater elevation data from paired and/or “nearby” wells within a 1-mile buffer radius between each other between datasets (i.e., when groundwater elevation data from each season and year were only selected if the same well or a “nearby” well also had a measurement for the other season and year used for the storage change analysis). Use of the full dataset would allow for greater data density in each bookend year, but, because of historically variable groundwater monitoring patterns, the groundwater storage change estimates are then impacted by changes in monitoring locations.
where $GWEL$ is the groundwater elevation and the subscripts $t_1$ and $t_2$ refer to the beginning and ending bookend years, respectively. For the purposes of this analysis, a uniform specific yield value of 0.08 was used to calculate groundwater storage change from the rasterized water level data, in line with the representative average specific yield value of the unconfined aquifer (i.e., Layer 1) within the District used in DWR’s California Central Valley Groundwater-Surface Water Simulation model, “fine-grid” Beta version (C2VSim-FG).

Using this approach, groundwater storage change was calculated within the District’s SGMA jurisdictional area for the following four periods, each of which representing unique timescales and/or climatic conditions within the historical/current water budget time period:

- Fall 1994 – Fall 2015 (entire KGA water budget period)
- Spring 2003 – Spring 2012: (representative long-term “wet” period)
- Spring 2003 – Spring 2015: (representative long-term “dry” period)
- Fall 2014 – Fall 2015: (representative short-term “dry” period)

**Water Budget Calibration to Change in Storage Rasters**

User input parameters specified within the water budget spreadsheet model (see Appendix E-1) were subsequently adjusted within reasonable limits to improve the fit between the water budget-calculated change in storage and the water level-based change in storage estimates for each of the four time periods mentioned above.

First, a sensitivity analysis was conducted to determine the most “critical” user input parameters (i.e., those that have the greatest effect on the water budget) for adjustment during model calibration. The most “critical” input parameters identified were those related to subsurface inflows and outflows, streamflow, and contributing precipitation to the District, including:

- **Kern Groundwater to Streamflow Inflow Ratio**, which controls the residual groundwater inflow term into the Kern Management Area (see Appendix E-3);
- **Hydraulic conductivity of the aquifer near the White Wolf Fault**, which controls the rate of groundwater flux across the fault (see Appendix E-3);
- **Watershed Consumptive Use Fraction and Watershed Precipitation Threshold for Runoff**. These parameters determine the amount of precipitation on contributing watersheds that runs off and becomes streamflow recharge within the District service area (see Appendix E-2);
- **Ineffective Precipitation Deep Percolation Coefficient**. This parameter controls how much ineffective precipitation is expected to percolate back into the groundwater subdomain, with the remainder assumed to evaporate from the wetted land surface (see Appendix E-4).

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5 C2VSim-FG beta is the latest release of C2VSim from DWR and is currently being used for SGMA planning and GSP development within the Kern Subbasin. Note, this model is currently uncalibrated. C2VSim input files downloaded 13 June 2018 from: [https://data.cnra.ca.gov/dataset/c2vsimfg-beta-model](https://data.cnra.ca.gov/dataset/c2vsimfg-beta-model)

6 March 1st was chosen as the representative date for which to compare “Spring” water level data to within the water budget model spreadsheet.
The above parameters were used as the primary calibration parameters to achieve an acceptable fit with the storage change estimated using the water level change method. Calibration was conducted by systematically adjusting the values of these key parameters to try to minimize the difference (in terms of root-mean-squared error [RMSE]) between the “observed” (i.e., based on water level records) change in storage for a given time period and the water budget model-calculated change in storage. Other user input parameters are less sensitive and were therefore left at their initial values in the final calibration.

**Calibration Results**

Table E-5-1 below reports the final calibrated values of each “User Input Parameter” included in the water budget model spreadsheet. Parameters listed in **bold** are those whose values were adjusted during the calibration process; all other parameters were held at their initial values during calibration.

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<thead>
<tr>
<th>User Input Parameter</th>
<th>Calibrated Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kern Groundwater to Streamflow Inflow Ratio (-) ^1</td>
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<tr>
<td>White Wolf Fault Hydraulic Conductivity (ft/day) ^1</td>
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**Abbreviations:**
- AFY = acre-feet per year; EC = electrical conductivity; ft/day = feet per day; in = inches; M&I = municipal and industrial; uS/cm = microSiemens per centimeter;

**Notes:**
1. The hydraulic conductivity values for the Wolf Fault were adjusted as calibration parameters for the groundwater inflow/outflow components. Other factors affecting this component (i.e., vertical saturated thickness of the inflow/outflow boundary) are assumed to be fixed for the purposes of calibration.
Table E-5-2 and Figure E-5-1 (attached) present the results of the water budget model calibration in terms of the water budget spreadsheet model-calculated change in storage compared to the change in storage estimated using the water level change method for all four calibration periods mentioned above.

### Table E-5-2. Water Budget Calibration Results to Raster-Based Storage Change Estimates

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Rationale for Selection of Time Period Employed for Model Calibration</th>
<th>Average Annual Groundwater Storage Change from Water Level Rasters (AFY)$^{2,3}$</th>
<th>Average Annual Groundwater Storage Change from Water Budget Model (AFY)$^{2,3}$</th>
<th>Difference (Relative to Water Level Raster Method) (AFY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 1994 – Fall 2015</td>
<td>Entire KGA Water Budget Period</td>
<td>-2,500</td>
<td>-1,300</td>
<td>1,200</td>
</tr>
<tr>
<td>Spring 2003 – Spring 2012</td>
<td>A representative long-term “wet” period</td>
<td>8,500</td>
<td>1,900</td>
<td>-6,600</td>
</tr>
<tr>
<td>Spring 2003 – Spring 2015</td>
<td>A representative long-term “dry” period</td>
<td>-20,700</td>
<td>-12,100</td>
<td>8,600</td>
</tr>
<tr>
<td>Fall 2014 – Fall 2015</td>
<td>A representative short-term “dry” period</td>
<td>-63,700</td>
<td>-76,900</td>
<td>-13,100</td>
</tr>
</tbody>
</table>

Notes:
1. March 1st was chosen as the representative date for which to compare “Spring” water level data to within the water budget model spreadsheet.
2. Results shown are rounded to the nearest 100 AFY.
3. Storage change estimates are calculated assuming a uniform storage coefficient of 0.08.

Table E-5-2 and Figure E-5-1 demonstrate the successful calibration of the water budget spreadsheet model to change in storage estimates deduced from the water level change method. Adjustment of the “critical” user input parameters resulted in a model calibration with a RMSE between “observed” and model-calculated annual change in storage of 8,500 AFY when considering all four calibration targets, and 6,300 AFY when only considering the three long-term calibration targets (i.e., Fall 1994 – 2015, Spring 2003 – 2012, and Spring 2003 – 2015). For context, the residuals in calculated vs. “observed” change in storage estimates for the three long-term periods (approximately -13,100 to 8,600 AFY) represent 0.67% to 7.36% of the total annual average inflows into the District, thus demonstrating the spreadsheet model’s accuracy in simulating long-term changes in groundwater storage relative to the total magnitude of the water budget domain.

Figure E-5-2 (attached) demonstrates the water budget-calculated change in water levels relative to a set of long-term hydrographs compiled from the District’s local groundwater elevation records. This figure
further demonstrates the general agreement between observed and model-calculated changes in water levels, both in terms of magnitude and directionality, throughout the 22-year water budget timeframe.
Comparison of Modeled & Water Level-Based Estimated Change in Storage

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
August 2019
EKI B70103.01
Figure E-5-1

Legend
= Raster-Based Estimated Change In Storage (AF)
= Water Budget Spreadsheet Model-Calculated Change In Storage (AF)

Abbreviations
AF = acre-feet

Notes
1. Calibration of the water budget spreadsheet model was performed for the District’s entire service area, including the portion within the White Wolf Subbasin.
Observed vs. Modeled Change in Water Levels, WY 1995 - 2015

Wheeler Ridge-Maricopa Water Storage District
Kern County, California
August 2019
EKI B70103.01
Figure E-5-2
Appendix E-6

Overview of Projected Water Budget Models
As described in Appendix E-1, results from the historical and current (California Department of Water Resources [DWR] Water Years 1994 – 2015) analytical water budget were subsequently used to inform development of three projected (i.e. future) water budget scenarios for the Wheeler Ridge-Maricopa Water District (WRMWSD) Kern Subbasin Management Area. These scenarios are consistent with the Kern Subbasin-wide projected water budget modelling effort that WRMWSD is participating in as a member of the KGA. A basic description of the projected water budget model assumptions and framework is provided below.

**Description of Projected Water Budget Timeline**

As described in Section 9.4.1. of the WRMWSD Management Area Plan, per 23-CCR § 354.18(e)(2)(A), the projected water budgets must use 50 years of historical precipitation, evapotranspiration, and streamflow information as the basis for evaluating future conditions under baseline and climate-modified scenarios. The process by which a 50-year period of precipitation, evapotranspiration and streamflow information was developed is based on the process adopted by all GSAs within the Basin, as described in the KGA Umbrella GSP and Appendix XX of the Coordination Agreement. That process is briefly summarized here.

To develop the required 50 years-worth of hydrologic input information, first an “analog period” was created from the 20 years-worth of historical information (DWR Water Years 1995-2014) by combining the years in a specific way that, on average, maintained the long-term average hydrologic conditions. This approach, which was used for both the spreadsheet water budget model approach and the basin-wide C2VSim-FG modeling approach, allowed for the creation of a complete 50-year period to inform the projected water budget analysis, even when certain component datasets were not available for that length of time. The sequence of actual years that were combined to create the 50-year analog period is as follows:

- **Analog Years 1-12:** Based on actual years 2003-2014
- **Analog Years 13-32:** Based on actual years 1995-2014
- **Analog Years: 33-50:** Based on actual years 1995-2012

The above mapping of actual years to analog years within the required 50-year projected water budget period applies to precipitation and ET datasets. It also applies to datasets of imported surface water with some additional modifications as described in the following section.

**Description of Projected Water Budget Scenarios**

As described in Section 9.4.2. of the WRMWSD Management Area Plan, using the 50-year analog period, three projected water budget scenarios were developed for this analysis:

- **Baseline Scenario** – uses “the most recent water supply information as the baseline condition for estimating future water supply”, per 23-CCR § 354.18(e)(2)(C);
- **2030 Climate Change Scenario** – uses 2030 climate change factors developed by DWR and the Friant Water Authority to estimate future water supplies, changes to precipitation and evapotranspiration; and
• **2070 Climate Change Scenario** – uses 2070 climate change factors developed by DWR and the Friant Water Authority to estimate future water supplies, changes to precipitation and evapotranspiration.

Development of the three scenarios was done consistent with the agreed-upon process being used basin-wide. Further details of the scenario development are contained within Section 9.4.2 of the WRMWSD Management Area Plan, in the KGA Umbrella GSP, and in Appendix XX of the Coordination Agreement.

**Description of Projected Water Budget Model Framework**

A projected water budget was developed for each of the three scenarios described above under the same framework and methodologies used to develop the historical and current water budget model. Given the scope of this effort was limited to completion of water budget requirements for the WRMWSD Management Area Plan, projected scenarios were only developed for the portion of WRMWSD contained within the Kern Subbasin.

**Building the 50-year Analog Period**

As described above, a 50-year “analog” period was first created using partial repeats of the 20-year historical WRMWSD water budget model (DWR Water Years 1995 – 2014) for the development of projected water budget scenarios. This was accomplished in the “master” projected water budget tabs of the spreadsheet model (see Appendix E-1) by creating a 50-year monthly sequence (i.e., 600 months) where, for any given month, each water budget component within the spreadsheet model directly referenced the analogous “analog” month of the historical Kern budget.

**Applying Change Factors**

After the 50-year “analog period” was replicated in the projected water budget “master” tabs, monthly change factors were applied to selected water budget components to incorporate projected changes to surface water supply availability, as well as precipitation and evapotranspiration intensity under each of the (3) projected water budget scenarios. These monthly change factors were provided directly from the KGA and are being used for the Basin-wide C2Sim-FG projected water budget effort¹. In summary, the following change factors were applied to the WRMWSD projected water budget model:

- Changes to State Water Project (SWP) imports, based on data from DWR’s CalSim water resources planning model and the 2008/2009 Long-Term Operations Criteria and Plan (OCAP) Biological Opinion²;

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¹ For more information see Section 9.4.2 of the WRMWSD Management Area Plan, the KGA Umbrella GSP, and in Appendix XX of the Coordination Agreement

Changes to precipitation and evapotranspiration, based on DWR’s “gridded change factors for precipitation and reference evapotranspiration” for 2030 and 2070 climate change projections³.

Change factors were provided by KGA as a monthly multiplier to each analog month within the projected water budget period. These change factors were applied to their respective water budget components within the WRMWSD projected water budget models to evaluate the projected impacts to groundwater storage underlying the District given the estimated changes to surface water supply availability and climate under each projected scenario.

**Modeling Projects & Management Actions**

After developing the projected water budget scenarios through the methodologies described above, the approximate groundwater storage deficits resulting from each projected scenario (see Table WB-6) were used to inform the development of Projects and Management Actions (P&MA) for the WRMWSD Kern Subbasin Management Area. These proposed P&MA were subsequently simulated under the 2030 and 2070 projected water budgets to assess how proposed P&MA implementation would address the groundwater storage change deficits identified from the model (see Table WB-7).

P&MA were incorporated in the model as either (1) increases in surface water deliveries to the irrigated portion of the District, to simulate supply augmentation benefits, or (2) reductions in evapotranspiration from irrigated lands, to simulate demand reduction benefits. Both surface water supply augmentation and demand reduction P&MA were applied uniformly for each year of the projected water budget model scenarios, so as to simulate the projected impacts of “full P&MA implementation” under each scenario. For each year, additional surface water supplies were delivered on a monthly basis according to WRMWSD’s average historical monthly delivery patterns, whereas reductions in evapotranspiration were performed in line with the average historical breakdown of monthly ET within the irrigated portion of the District.

³ [https://data.cnra.ca.gov/dataset/sgma-climate-change-resources/resource/f86f75e8-0de6-4232-968d-83521116496e](https://data.cnra.ca.gov/dataset/sgma-climate-change-resources/resource/f86f75e8-0de6-4232-968d-83521116496e)
Appendix E-7

Comparison of EKI and KGA Projected Water Budget Components
# Table E-7
Comparison of EKI and KGA Projected Water Budget Components

**Wheeler Ridge-Maricopa Water Storage District**
**Kern Subbasin Management Area**

## EKI Table WB-7 (expanded version) (see Note 1)

<table>
<thead>
<tr>
<th>Water Budget Category</th>
<th>Water Budget Component</th>
<th>Baseline (no P&amp;MA)</th>
<th>2030 Climate Change (w/ P&amp;MA)</th>
<th>Term ID used for calculation descriptions in checkbook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflows</td>
<td>(Net) Subsurface Inflow ¹⁾</td>
<td>11,551</td>
<td>11,704</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Precipitation</td>
<td>49,144</td>
<td>49,707</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effective Precipitation (to ET)</td>
<td>24,141</td>
<td>24,435</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ineffective Precipitation (to evaporation)</td>
<td>12,420</td>
<td>12,553</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ineffective Precipitation (to deep percolation)</td>
<td>12,584</td>
<td>12,719</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface Water Imports</td>
<td>93,328</td>
<td>90,541</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SWP Imports to Non-Overlap Lands</td>
<td>87,815</td>
<td>85,190</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>SWP Imports to Overlap Lands</td>
<td>5,513</td>
<td>5,350</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P&amp;MA Augmented Supplies</td>
<td>0</td>
<td>12,900</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural Surface Water Inflows</td>
<td>3,044</td>
<td>3,095</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL INFLOWS</td>
<td>157,067</td>
<td>167,946</td>
<td></td>
</tr>
<tr>
<td>Outflows</td>
<td>Evapotranspiration ²⁾</td>
<td>171,023</td>
<td>175,767</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ET on Non-Overlap Ag Lands (from ITRC)</td>
<td>148,427</td>
<td>152,742</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ET on Overlap Ag Lands (from ITRC)</td>
<td>10,176</td>
<td>10,472</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evaporation of Ineffective Precipitation</td>
<td>12,420</td>
<td>12,553</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P&amp;MA Demand Reduction</td>
<td>0</td>
<td>-8,600</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M&amp;I Consumptive Use ³⁾</td>
<td>866</td>
<td>891</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural Surface Water Exports &amp; Deliveries to White Wolf Subbasin</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subsurface Groundwater Outflow</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL OUTFLOWS</td>
<td>171,888</td>
<td>168,058</td>
<td></td>
</tr>
</tbody>
</table>

| Change in GW Storage | Equivalent to “Deficit” | -14,665 | 53 |

### Abbreviations

- **AFY** = acre-foot per year
- **AFY/ac** = acre-foot per year / acre
- **ET** = Evapotranspiration
- **GW** = Groundwater
- **ITRC** = Cal Poly Irrigation Training & Research Center
- **M&I** = Municipal and Industrial
- **MWD** = Metropolitan Water District
- **P&MA** = Project & Management Action
- **SWP** = State Water Project
- **WWB** = White Wolf Basin

### Notes

1. All values reported in acre-feet per year (AFY).
2. Projected GW Inflow terms based on Estimated Net Groundwater Inflows from Calibrated Historical Water Budget
3. "Evapotranspiration" includes all estimated crop and vegetative evapotranspirative demands as well as evaporation of excess rainfall and from open water bodies within the District.
4. M&I Consumptive Use includes evapotranspiration on Urban Lands (no other consumptive uses specified within the District), which is in part met by precipitation.
5. Apparent residual of water-budget calculated change in groundwater storage to [Total Inflows - Total Outflows] can be attributed to the deep percolation lag effect in the water budget spreadsheet model, which serves to delay infiltration from reaching the groundwater system. See “Appendix E - Methods & Data Used in the Water Budget Spreadsheet Model Approach” for further details on how monthly storage change is calculated within the water budget spreadsheet model.
### Table E-7
Comparison of EKI and KGA Projected Water Budget Components
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

#### KGA Checkbook Table (as of 7/10) (see Note 1)

| Scenario | Total Water Demand | SWP Average Annual Supply | CVP Average Annual Supply | Kern River Average Annual Supply | Native Yield Estimate | Precipitation | Alternative Water Supply | Total Water Supply | Net Water Budget |
|----------|--------------------|---------------------------|---------------------------|---------------------------------|-----------------------|---------------|--------------------------|------------------|----------------|---|---|
|          | Table "A" | Article 21 | "OTHER" SWP | TOTAL SWP SUPPLY | Class I | Class II | FK 235 | "OTHER" CVP | TOTAL CVP SUPPLY | Kern River Rights (1st Point/Lo wer River etc.) | "Flood" | "OTHER" KR Water | TOTAL KR SUPPLY | Gross Acres | Native Yield (.25-.75) | TOTAL NATIVE YIELD | Effective Precip | TOTAL EFFECTIVE PRECIP | NY + PRECIP | OF/ac | Oilfield Produce | Water Banking Etc. |
| Current Conditions | 154,305 | 93,328 | 93,328 | 0 | 0 | 87,026 | 0.3 | 26,108 | 87,026 | 0.24 | 20,705 | 0.54 | 140,321 | 14,465 |
| 2040 (see Note 3) | 150,423 | 103,381 | 103,381 | 0 | 0 | 87,026 | 0.3 | 26,108 | 87,026 | 0.24 | 20,987 | 0.54 | 150,475 | 53 |

#### Notes:
1. KGA-checkbook reports water budget components only for the portion of WRMWSD that does not overlap AEWSD (i.e., 87,026 acres), whereas EKI water budget reports water budget components for the entire WRMWSD Kern Management Area (i.e., 92,343 acres).
This distinction was made to avoid "double counting" of water budget components for the AEWSD-WRMWSD overlap area in the KGA-wide checkbook water budget.

2. The portion of ineffective precipitation that evaporates from the land surface is included both as an inflow term (C, as a component of Total Precip) and outflow term (K, as a component of Total ET) in the EKI water budget. This value is not included in the KGA-checkbook tabulation of Total Water Demands because, by definition, this "demand" is being met by ineffective precipitation, which is not considered to be a supply source in the KGA checkbook water budget.

3. Total Water Demands include deliveries of imported SWP supplies to the WRMWSD-AEWSD overlap lands, which are functionally treated as an export outside of WRMWSD's KGA-checkbook water budget domain (see Note 2).

4. Table A supplies include SWP imports to the entire WRMWSD Kern Management Area. Imports to the AEWSD-WRMWSD overlap lands are subsequently treated as an export under Total Water Demands (see Note 3).

5. NSY calculated from EKI water budget tables is ~0.295 AFY/acre. A value of 0.3 AFY/acre is employed in the KGA table, consistent with KGA definition.

6. Effective Precip reported in EKI table is calculated from USDA-SCS (1970) method. This value is then adjusted in KGA table to (1) remove the AEWSD-WRMWSD overlap area from the calculation (87,026 non-overlap acres / 92,343 total acres = 0.942); and (2) to account for the discrepancy between EKI-calculated NSY (0.3 AFY/acre) and KGA-defined NSY (0.5 AFY/acre), in order to align projected change in storage (Q) between EKI and KGA tables.

7. 2040 KGA scenario uses 2030 Climate Change scenario outputs under full P&M Action implementation (12,900 AFY supply augmentation, 8,600 AFY demand reduction).

#### Abbreviations:
- AEWSD = Arvin-Edison Water Storage District
- AFY = acre-foot per year
- AFY/ac = acre-foot per year / acre
- ET = Evapotranspiration
- ITRC = Cal Poly Irrigation Training & Research Center
- KGA = Kern Groundwater Authority
- NSY = Native Safe Yield
- P&M/A = Project & Management Action
- USDA-SCS = United States Department of Agriculture Soil Conservation Service
- WRMWSD = Wheeler Ridge-Maricopa Water Storage District

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**August 2019 Page 2 of 3**
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area Plan
## Table E-7
Comparison of EKI and KGA Projected Water Budget Components
Wheeler Ridge-Maricopa Water Storage District
Kern Subbasin Management Area

<table>
<thead>
<tr>
<th>Water Budget Term</th>
<th>EKI Historical Water Budget Model Result (AFY)</th>
<th>TODD Historical C2VSim-FG Model Result (AFY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private and M&amp;I Groundwater Pumping</td>
<td>57,000</td>
<td>107,200</td>
</tr>
<tr>
<td>Change in Groundwater Storage</td>
<td>3,300</td>
<td>-7,900</td>
</tr>
<tr>
<td><strong>Sustainable Yield (AFY)</strong></td>
<td><strong>60,300</strong></td>
<td><strong>99,300</strong></td>
</tr>
<tr>
<td><strong>(AFY/acre)</strong>[2]</td>
<td><strong>0.65</strong></td>
<td><strong>1.08</strong></td>
</tr>
</tbody>
</table>

**Abbreviations**

AF = acre-feet  
AFY = acre-feet per ear  
C2VSim-FG = California Central Valley Groundwater-Surface Water Simulation Model Fine Grid Version  
DWR = California Department of Water Resources

**Notes**

(1) Based on the WRMWSD Management Area acreage of 92,343 acres.
Appendix F

WRMWSD Long-Term Monitoring Access Agreement
MONITORING WELL ACCESS AGREEMENT

This Monitoring Well Access Agreement (“Agreement”) is made and entered into by and between the Wheeler Ridge-Maricopa Water Storage District (hereafter “District”) and ________________ (hereafter “Landowner”), both of whom shall be referred to individually as a “Party” to this Agreement and collectively as the “Parties” to this Agreement.

RECITALS

WHEREAS, the District is a member of the Kern Groundwater Authority (“KGA”) which has adopted or will adopt a Groundwater Sustainability Plan (“GSP”) to comply with the Sustainable Groundwater Management Act (“SGMA”); and

WHEREAS, the District has developed and is responsible for implementing a chapter of the KGA GSP; and

WHEREAS, SGMA requires the long-term monitoring of static groundwater levels and water quality; and

WHEREAS, to comply with this requirement, the District may need access rights from Landowners within its service area to monitor groundwater elevations and water quality; and

WHEREAS, Landowner’s Land (as described and depicted in Exhibit A) contains one or more groundwater wells (“Monitoring Well(s)”) in the District GSP chapter area for which the District is required to monitor for groundwater elevation and water quality monitoring activities; and

WHEREAS, Landowner has agreed to grant the District limited access onto Landowner’s Land, subject to the terms and conditions as set forth in this Agreement.

NOW, THEREFORE, the Parties have entered into this Agreement to allow the District to access to Landowner’s Land under the following terms and conditions:

TERMS AND CONDITIONS

1. Incorporation of Recitals. The foregoing recitals are incorporated herein as terms and conditions of this Agreement.

2. Right of Entry. Landowner grants to the District and its employees, agents, consultants, and contractors a non-exclusive year-round license to enter onto Landowner’s Land (as described and depicted in Exhibit A) to obtain groundwater elevation and water quality data from Landowner’s Monitoring Well(s). Unless otherwise agreed to by the Parties in a written amendment to this Agreement, the Parties agree that the District’s access to Landowner’s Land shall be limited to wells described in Exhibit A’s “Monitoring Well Locations” and in compliance with any conditions listed under “Access Instructions.”

3. Access and Control. Except as otherwise provided in this Agreement, Landowner retains the exclusive right of access to and control over the Landowner’s Land. Nothing contained in
this Agreement shall be construed as affording the public a right of access to any portion of the Landowner’s Land or precluding Landowner’s right to grant access to third parties across the Landowner’s Land, provided that such access is not inconsistent with this Agreement.

4. **Duration of Right.** The Parties agree that this Agreement shall remain in effect until either of the following occurs: (a) Termination of the Agreement by either Party, or (b) Change in Ownership of Landowner’s Land.

   a. **Termination by a Party.** The Parties agree that this Agreement may be terminated at any time, with or without cause, by either Party upon sixty (60) days written notice to the other Party.

   b. **Landowner’s Land: Change in Ownership.** The Parties agree that this agreement shall terminate upon any change in ownership of Landowner’s Land. Thereafter, the District acknowledges that it will need to enter into a new access agreement with the new owner(s) of Landowner’s Land.

5. **No Easement.** The Parties agree that this Agreement does not grant the District a possessory right, easement, or other land interest with respect to Landowner’s Land.

6. **Costs.** The Parties agree that all groundwater elevation and water quality monitoring performed by the District under this Agreement shall be funded by the District. The Landowner shall continue to be responsible for County well inspection fees. District agrees to provide a small concrete pad, a welded water-tight cover, and a locking cap at the Monitoring Well site if the wellhead is not already provided with a water-tight cover or pump head. The District also agrees to repair any defects in the integrity of the well collar, cap, lock, and pad above the ground surface, excepting damage caused by the sole negligence or intentional misconduct of the landowner, so long as this Agreement is in effect.

7. **No Storage.** The right of entry does not include permission to store soil, groundwater, or measurement apparatus on the Landowner’s Land. District shall remove its materials and tools from the Landowner’s Land at the end of each working day.

8. **Maintenance of Landowner’s Land.** The Parties acknowledge that this Agreement grants the District a non-exclusive year-round license to access Landowner’s Land for the limited purpose of obtaining groundwater elevation and water quality data from Landowner’s Monitoring Well(s). Accordingly, except as provided in section 5 of this Agreement below (“Damage/Restoration”), the Parties agree that the District (including its employees, agents, consultants, and contractors) is under no obligation to maintain or otherwise repair the Landowner’s Land.

9. **Damage/Restoration.** The District (including its employees, agents, consultants, and contractors) shall take all reasonable precautions to avoid damaging Landowner’s Land. If any
damage is caused to Landowner’s Land by the District in the course of performance of this Agreement, the District shall notify the Landowner immediately. In addition, the District will, at its sole cost and expense and with the Landowner’s consent, take all action reasonably necessary to repair the damage and restore Landowner’s Land to the condition that existed immediately prior to the damage caused by the District. It is understood and agreed that the District shall not be responsible for maintenance of the Monitoring Well(s) below the ground surface. The Parties agree that the District shall not be liable in the event that groundwater contamination or unauthorized waste disposal is eventually attributed to the well(s), or in the event that destruction of the well(s) (e.g., by grouting) is ultimately required.

10. **Schedule or Notice of Access.** The District may develop a schedule of dates/times it will access Landowner’s Land for the purposes of well monitoring. Upon reasonable notice, the Landowner shall endeavor to refrain from pumping from the Monitoring Well(s) for at least 48 hours prior to the scheduled access date. If the District does not provide a schedule, it shall undertake reasonable efforts to notify the Landowner at least twenty-four (24) hours in advance of accessing Landowner’s Land pursuant the access rights granted under this Agreement.

11. **Indemnity.** The District agrees to defend, indemnify, and hold harmless Landowner for any costs, claims, damages, losses or other liabilities arising out of the District’s (including any employees, agents, consultants, and contractors) actions on Landowner’s Land under this Agreement, with the exception that the District shall not be responsible for defending, indemnifying, or holding harmless Landowner with regard to costs, claims, damages, losses, or other liabilities arising out of the sole negligence or intentional misconduct of Landowner.

12. **Insurance.** Prior to entering onto Landowner’s Land, District shall provide to Landowner a certificate that the District or District’s consultant a certificate evidencing general liability insurance in the amount of at least $1,000,000 Dollars aggregate limit.

13. **Written Notices.** Written notices between the Parties shall be sent via U.S. mail to the addresses listed below:

   [District Name]  [Landowner’s Name]
   [Address]       [Address]
   [City,] CA [zip code]   [City,] CA [zip code]

14. **Entire Agreement.** This Agreement contains the entire understanding of the Parties and supersedes all prior agreements and understandings among the Parties related to the subject matter of this Agreement.

15. **Amendment.** Amendments to this Agreement shall become effective upon execution of a written amendment signed by both Parties.
16. **Severability.** If any provision of this Agreement is held to be unenforceable for any reason, it shall be adjusted, rather than voided, if possible, to achieve the intent of the Parties, and the balance of the Agreement shall remain in full force and effect.

17. **Governing Law.** This Agreement shall be interpreted and enforced pursuant to the laws of the state of California.

18. **Effective Date.** This Agreement shall become effective as of the latest date of execution below.

19. **Confidentiality.** By executing this Agreement, the Landowner authorizes the District to release the location and construction details of Landowner’s Monitoring Well(s) together with any and all groundwater elevation and water quality data obtained pursuant to this Agreement to the Kern Groundwater Authority, the State of California, and their agents. It is understood and agreed that data obtained from Landowner’s Monitoring Well(s) pursuant to this Agreement may be published from time to time in the District’s GSP chapter, in GSP updates, or in other forms, written and electronic, that will be available to the general public.

<table>
<thead>
<tr>
<th>[District]</th>
<th>[Landowner]</th>
</tr>
</thead>
<tbody>
<tr>
<td>By_____________________</td>
<td>By_____________________</td>
</tr>
<tr>
<td>[Name, title]</td>
<td>[Name, title]</td>
</tr>
<tr>
<td>Date: _________________</td>
<td>Date: _________________</td>
</tr>
</tbody>
</table>

**EXHIBIT A**

<table>
<thead>
<tr>
<th>Parcel (Referenced in the attached Agreement as “Landowner’s Land”)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Landowner Name, Contact Name</strong></td>
</tr>
<tr>
<td><strong>APN(s): XXX-XXX-XX</strong></td>
</tr>
</tbody>
</table>

**Monitoring Well Locations**

[Insert directions to where (on Landowner’s Land) the monitoring well(s) subject to this Agreement are located.]

**Access Instructions**

[Insert Landowner’s Land access instructions here. Examples include parking restrictions, gate codes, animals to be aware of etc.]
Appendix G

DWR California Aqueduct Subsidence Study (June 2017), Plates 20 – 24
### Subsidence Profile

<table>
<thead>
<tr>
<th>Mile Post (mi.)</th>
<th>Total Settlement (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250.5</td>
<td>-0.15</td>
</tr>
<tr>
<td>251</td>
<td>-0.13</td>
</tr>
<tr>
<td>251.5</td>
<td>-0.11</td>
</tr>
<tr>
<td>252</td>
<td>-0.09</td>
</tr>
<tr>
<td>252.5</td>
<td>-0.07</td>
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<tr>
<td>253</td>
<td>-0.05</td>
</tr>
<tr>
<td>253.5</td>
<td>-0.03</td>
</tr>
<tr>
<td>254</td>
<td>-0.01</td>
</tr>
<tr>
<td>254.5</td>
<td>0.01</td>
</tr>
<tr>
<td>255</td>
<td>0.03</td>
</tr>
<tr>
<td>255.5</td>
<td>0.05</td>
</tr>
<tr>
<td>256</td>
<td>0.07</td>
</tr>
</tbody>
</table>

### Geologic Profile

- **Ground Surface**
- **Tertiary Contact**

### Significant Subsidence Due to Ponds (DWR, 1971)

#### Preconsolidation Ponds

- Sandy Creek Siphon

#### Mile Post (mi.)

- 250.99
- 251.16
- 251.35
- 251.43
- 251.54
- 251.66
- 251.73
- 251.84
- 252.01
- 252.03
- 252.36
- 252.63
- 252.95
- 253.19
- 253.26
- 253.49

#### Elevation (ft)

- -2400
- -2000
- -1600
- -1200
- -800
- -400
- 0
- 400

### Structures

- Buena Vista Pumping Plant
- Pipeline Crossing
- Culvert Crossing
- Phone Line Crossing
- Sump Pump
- Structures
Appendix H

Parcels Outside of WRMWSD Covered by GSP
<table>
<thead>
<tr>
<th>Property Owner Name</th>
<th>APN</th>
<th>Acreage</th>
<th>Land Use</th>
<th>Well Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun Pacific</td>
<td>239-102-130</td>
<td>241.42</td>
<td>Unirrigated</td>
<td>No wells, per DWR well completion report database</td>
</tr>
<tr>
<td>Sun Pacific</td>
<td>239-102-189</td>
<td>160.9</td>
<td>Unirrigated</td>
<td>No wells, per DWR well completion report database</td>
</tr>
<tr>
<td>Maricopa Orchards</td>
<td>239-150-11</td>
<td>640</td>
<td>Unirrigated</td>
<td>No wells, per DWR well completion report database</td>
</tr>
<tr>
<td>Wonderful Citrus</td>
<td>239-030-36</td>
<td>80.9</td>
<td>Unirrigated</td>
<td>No wells, per DWR well completion report database</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1123.22</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviations:**
- APN = Assessor’s Parcel Number
- DWR = California Department of Water Resources
- GSP = Groundwater Sustainability Plan
Abbreviations

APN = Assessor's Parcel Number
DWR = California Department of Water Resources
GSP = Groundwater Sustainability Plan
WRMWSD = Wheeler Ridge-Maricopa Water Storage District

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 13 August 2019.
2. Parcel boundaries are from Kern County Assessor, obtained in June 2018.
3. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2016 Update.
4. WRMWSC Management Area boundary was received by WRMWSC staff on 3 July 2018 and excludes overlap area with West Kern Water District Groundwater Sustainability Agency.