2.3.3 Existing Land Subsidence Monitoring

Past, recent, and potential future monitoring of land subsidence in the Kaweah Subbasin are briefly summarized below in ***Table 6***. Details and results of recent and historical subsidence monitoring are discussed in ***Section 2.8.*** of this document.

Table 6: Summary of Land Subsidence Monitoring in the Kaweah Subbasin

Category	Monitoring Entity(s)	Period of Record
Historical Monitoring	• National Geodetic Survey of benchmarks (repeat level surveys)	• 1926-1970
Recent Monitoring	• National Geodetic Survey of benchmarks (repeat level surveys and installation and measurement of Deer Creek extensometer [8.5 miles south of subbasin]) • Local benchmark monitoring network (Kaweah Subbasin collaborators) • CGPS data from UNAVCO and CVSRN stations: P056, P566, CRCN, LEMA, and RAPT. • NASA including both InSAR and UAVSAR programs	• NGS – 1970 to Present • Tie into NGS and CGPS benchmarks • CGPS – ~2006 to Present (depending on station) • NASA – 2006 to 2017 (except from 2011-2014)
Future Data Availability	• National Geodetic Survey of benchmarks (repeat level surveys) • Deer Creek Extensometer to the South • CGPS data from UNAVCO and CVSRN stations: P056, P566, CRCN, LEMA, and RAPT • NASA including both InSAR and UAVSAR programs, potentially new extensometers in the Kaweah Subbasin	• 2018 through 2020 • 2018 to present • CGPS – continuous daily readings • Ongoing

Subsidence monitoring includes both land elevation surveying as well as groundwater level monitoring to consider the effects that the change in groundwater levels have on the rate and change of land subsidence over time. Land elevation survey monitoring includes National Geodetic Survey (NGS) benchmark repeat level surveys, remote sensing by Interferometric Synthetic Aperture Radar (InSAR), and in-situ compaction monitoring by an extensometer south of the Subbasin. Groundwater level monitoring, as briefly discussed in ***Section 2.3.1***, includes collecting data from representative monitoring wells throughout the Subbasin in all three aquifer systems: UAS, LAS, and SAS. In areas where the Corcoran Clay is present, preliminary monitoring results suggest that groundwater level decline in the lower aquifer system is contributing to increased land subsidence. The relationship between groundwater levels and land subsidence are discussed in ***Section 2.8.***

2.3.3.1 Future Data Availability

The effectiveness of future subsidence monitoring will require continued support by National Aeronautics and Space Administration/Jet Propulsion Laboratory (NASA/JPL), USGS, and Scripps Orbit and Permanent Array Center (SOPAC)/UNAVCO/California Department of Transportation (CalTrans) for InSAR and Global Positioning System (GPS) data processing and reporting. According to USGS, the European Space Agency's (ESA's) Sentinel satellites collect InSAR data at approximately weekly intervals, and data are available for download and use as necessary. These data require processing which has been performed by JPL at the request of DWR. Similarly, GPS data has been made available by UNAVCO, SOPAC/California Real Time Network (CRTN), and CalTrans. Although there are currently no extensometers within the Kaweah Subbasin, USGS has replaced extensometer 22S-27E-30D2 (Deer Creek south of Porterville and in the Tule Subbasin), and will provide data to interested parties (personal communication, USGS).

2.3.4 Existing Stream Flow Monitoring

At the upper reaches of the Kaweah River watershed, the U.S. Army Corps of Engineers measures and records inflow to Lake Kaweah. The Kaweah and St. Johns Rivers Association (KSJRA) measure data on a daily basis for the Kaweah River, Dry Creek, and Yokohl Creek. These data are summarized in annual reports and published by KSJRA.

The records of the stream groups impacting the facilities and stockholders of the ditch companies that they manage were acquired. Although data gaps exist, these may represent relatively small quantities of contributory flows. The records of the USGS are, for the most part, supplemental to the records of the Association and local agencies. The information that is published by the USGS, however, does fill some of the data gaps that exist in the information related to the local stream groups. *Figure 20* shows the locations of stream flow gauges monitored within the Subbasin.

Supplies made available from the Kings River impact the north, northwestern, and westerly areas of the Subbasin. Information as to the gross deliveries made available to these areas is available from the Kings River Water Association, as published in annual reports that contains the information necessary to document the gross delivery information. Specific information related to deliveries into areas in and adjacent to the Subbasin on the north, northwest, and westerly boundaries are available from records of the Corcoran Irrigation Company, the Corcoran Irrigation District, the Kings County Water District, the Lakeside Irrigation Water District, and the Melga Water District.

TID's main sources of surface water come from the San Joaquin and the Kaweah rivers. Surface water is provided from the San Joaquin River through a USBR contract which delivers water to TID from the Friant Dam via the Friant-Kern Canal. Kaweah River water is delivered to TID from KSJRA. TID can also obtain surface water from several small surface streams which pass through TID's service area.

Surface water quality is recorded by Friant Water Authority (FWA), USBR, and KSJRA to monitor long-term hydrology, water availability, and water quality changes. TID monitors published data from these agencies to ensure surface water quality does not affect groundwater quality.

2.4 Groundwater Elevation and Flow Conditions §354.16

This section describes available information to document current and historical groundwater elevation data, flow directions, lateral and vertical gradients, and regional pumping patterns in the Subbasin.

2.4.1 Current and Historical Groundwater Trends

Current and historical groundwater level trends are provided below. This section provides an overview of groundwater flow conditions by describing groundwater elevation maps and key well hydrographs.

2.4.1.1 Elevation and flow directions

Water level measurements and groundwater elevation data from over 1,300 wells within and adjacent to the Subbasin were used to generate water level contour maps and water level hydrographs for individual water wells throughout the Subbasin. Water level contour maps for spring seasons of years 2015 through 2017 and earlier key years - 1981, 1999, and 2011 - during the representative base period are provided as ***Figure 23*** through ***Figure 28***. Water level contour maps for the fall season of the four most recent years - 2014 through 2017 - are provided as ***Figure 29*** through ***Figure 32***.

Groundwater flow direction was calculated for the spring of every year from 1981 to 2017 for the entire Kaweah subbasin. Groundwater flow directions were generally similar for the majority of the Subbasin during the subsequent years of 2013 through 2017. Flow directions are further quantified through numerical groundwater model development. The approach and methods used for numerical groundwater model development and described in the technical memorandum included as ***Appendix A***.

Groundwater within the Kaweah Subbasin flows from the Sierra Nevada towards the southwest. The presence of Corcoran Clay in the western portion of the Subbasin and lack of well construction information available for the measured water wells has resulted in meager determination of water level conditions in the confined aquifers of the region.

Inflow of groundwater into the Kaweah Subbasin occurs both from the north (Kings Subbasin), from mountain front recharge along the eastern edge of the basin, and in some years, from the south in response to pumping. Outflow of groundwater from the Kaweah Subbasin occurs to the west generally into the Tulare Lake Subbasin, but also occurs to the south into the Tule Lake Subbasin. Large areas of lowered groundwater levels were present in most years of the current drought in the west and southwestern portion of the Kaweah Subbasin, near the cities of Hanford and Corcoran. Groundwater levels are directly affected by the distribution of groundwater pumping in the basin which is further addressed in **Section 2.4.1.3**.

2.4.1.2 Lateral and vertical gradients

Due to the inherent variability in aquifer properties and the complexity of the gradients, estimates of subsurface flow within the Kaweah Subbasin are considered approximations.

Lateral Gradients

The rates of groundwater flow are a function of the slope of the groundwater surface and the permeability of the water-bearing materials. In the Subbasin, groundwater flow rates are on the order of a several feet per day. However, in materials of low permeability, such rates may be reduced to as little as a few feet per year. The gradients of the groundwater in this Subbasin vary but are typically between 10 vertical feet per mile (0.002 feet per foot) to 16 feet per mile (0.003 feet per foot) outside of significant groundwater pumping depressions.

Groundwater flow in underlying confined aquifers Lower Aquifer System (LAS), is analogous to the flow of water in a pressure conduit and moves in response to pressure differentials created by pumping extractions from the confined aquifer or by a buildup in the water table in the unconfined groundwater body supplying the aquifer (Fugro West, 2007). Along the western portion of the Subbasin, where dynamic pumping depressions are present, gradients steepen and groundwater flow rates increase by an order of magnitude. In these areas, groundwater levels can show vertical differences of 100 feet within less than a mile due to localized pumping stresses.

Vertical Gradients

Many wells in the Kaweah Subbasin west of SR 99 penetrate aquifers above and below the Corcoran Clay and provide significant vertical leakage and hydraulic communication, which affects the pattern of groundwater movement and rates of regional recharge and discharge (Malcolm Pirnie, 2001).

The water level analysis included an attempt to correlate 1,300 wells included in the monitoring network to well construction details. It was determined that very few well construction details were available for the monitored wells, making it difficult to determine whether measured water levels were representative of upper or lower aquifer systems. As early as 1972, "…it was found that many of the wells measured drew from more than one aquifer system and water level measurements therein reflected a composite of the water levels" (B-E, 1972).

Even without certainty about the specific completion of most wells, it is believed that wells located east of the Corcoran Clay extent reflect water level conditions representative of the SAS, while wells located within the area of the Corcoran Clay are, for the most part, perforated in the confined aquifer system below the Corcoran Clay (Fugro West, 2007). Furthermore, the heterogeneity of aquifer properties in the Subbasin and known presence of many interbedded aquitards in the west part of the Subbasin complicate the separation of water level data representative of the confined versus unconfined aquifer systems. According to Bertoldi (1991), the many fine-grained lenses of overlapping, discontinuous clay beds within the Valley have a combined effect that controls vertical flow to a greater degree than the Corcoran Clay.

There are currently eight paired (shallow and deep) monitoring wells within or in close proximity to the Kaweah Subbasin. Four are monitored by KDWCD and four are monitored by TID. The locations of these wells are shown on ***Figure 33*** and ***Figure 34***. Each monitoring location has two paired (shallow and deep) monitoring wells; one screened above the Corcoran Clay and the other screened below the Corcoran Clay. This enables water level monitoring agencies to measure vertical gradients distinctly without inaccuracies caused by hydraulic communication in wells screened in multiple aquifer zones. Several of these wells were installed recently; thus, only a limited amount of data is available. The KDWCD wells were installed between 2005 and 2006 and have consistent water level data to present, but the TID wells were installed in 2016 and only have one distinct water level measurement each.

As discussed previously, not all wells screened below the Corcoran Clay exhibit truly confined groundwater conditions. However, it is widely accepted that "the degree of confinement in the continental deposits generally increases in a westerly direction and becomes greater as depth to the aquifer increases" (B-E, 1972). This generality is corroborated by the paired hydrographs presented on ***Figure 33*** and ***Figure 34***. The TID wells, which are relatively close to the eastern extent of the Corcoran Clay, show relatively small vertical gradients. Water level differences in the shallow and deep wells vary between approximately 35 feet and 7 feet. The KDWCD wells, which are further west (three of the four wells are outside the basin), show much greater vertical gradients than the TID wells. Water elevations differences in the KDWCD nested wells average from about 50 feet to 200 feet. The two wells furthest to the southwest exhibit higher vertical gradients on average than the two northernmost wells, which are closer to the eastern extent of the Corcoran Clay.

2.4.1.3 Regional patterns

Figure 23 through ***Figure 32*** illustrate the groundwater elevation contour maps of the following periods: Spring 1981, Spring 1999, Spring 2011, Spring 2015 through 2017, and Fall 2014 through 2017. Review of the contour maps indicate that the principal direction of groundwater flow is to the southwest in the unconfined groundwater of the Kaweah River alluvial fan and continental deposits. Subsurface inflow occurs in the unconfined aquifer system above the Corcoran Clay, and from the Tule River system to the south. Outflow of confined groundwater occurs to the west in the confined aquifer system below the Corcoran Clay (Fugro West, 2007).

The influence of water extraction from the Kings River occurs to lands generally west of the Kaweah Subbasin and can be seen by contours that reflect replenishment from various tributaries in that area. The contours also show pumping depressions, which have been created in southwest corner of the Kaweah Subbasin north of Corcoran and west of Visalia.

The groundwater contours presented in this report were mapped as a single homogenous unit. Ideally, the contours would have been mapped by the principal aquifer units (SAS, LAS, and UAS); however, this wasn't feasible given the lack of well completion information for most wells in the Subbasin.

Wells located east of the Corcoran Clay boundary are all considered to be representative of the SAS. The SAS is generally unconfined to semi-confined aquifer system in the eastern half of the basin. All wells within the extent of the Corocan Clay could be representative of either the LAS or the UAS, depending on their depth and screened intervals. To contour the LAS and UAS separately, water level data would be needed in numerous wells of known completion that are dispersed throughout the basin. There are a small number of wells with known completion in the Corcoran Clay extent, but not enough to create reliable contour maps. Additionally, water level data from any wells with multiple screen zones that span both aquifer systems are not eligible for contour mapping. Until more well completion information for wells in the Corcoran Clay extent is acquired, it will remain infeasible to create contours for the separate principal aquifer units in the Kaweah Subbasin.

Water level hydrographs were selected from several of the wells with a long-term period of record. These are the key wells referenced throughout the Basin Setting. The selected hydrographs, presented as ***Figure 35***, provide a baseline of groundwater conditions throughout the Subbasin. The hydrographs selected demonstrate appropriate geographic distribution within the Subbasin and generally provide excellent records of both Spring and Fall water level conditions and long-term trends in water levels, some of which extend back to the 1940s.

2.4.1.4 Water Year Type

Discussion of water level trends must include context with regard to hydrologic variations in historical wet-dry cycles, referred to by DWR as "water year type". Water levels vary in response to the cyclical nature of precipitation, surface water flows, and diversions from the Kaweah River system. ***Figure 36*** illustrates the changing hydrologic conditions within the Subbasin for rainfall recorded in Visalia from water year 1878 through 2017. Average rainfall in the basin is 10.1 inches per year. The bottom half of the chart shows the annual precipitation. The upper portion of the chart shows the climactic variability by stacking subsequent years, such that upward trending portions (blue areas) represent wet periods and downward trending portions (yellow areas) represent drought periods.

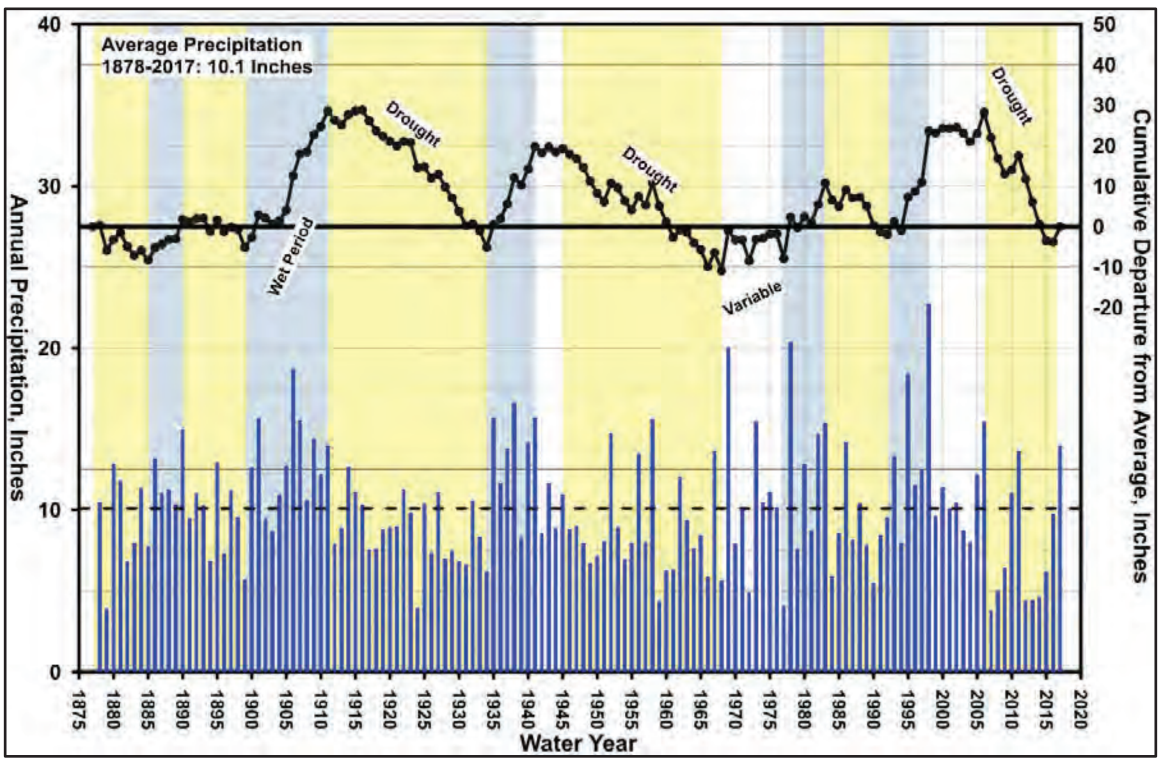


Figure 36: Cumulative Departure from Mean Precipitation – Visalia, California

Table 7: Historic Hydrologic Conditions (Water Year Types)

Period (Water Years)	Hydrologic Condition	Duration (No. of Years)	Precipitation Deviation (Inches)	Deviation Rate (Inches/year)
1878 to 1885	Drought	8	- 6	- 0.7
1886 to 1890	Wet	5	10	2.0
1891 to 1899	Drought	9	7	- 0.8
1900 to 1911	Wet	12	34	2.8
1912 to 1934	Drought	23	- 34	- 1.5
1935 to 1941	Wet	7	25	3.6
1942 to 1945	Variable	4	4	- 0.1
1946 to 1968	Drought	23	- 30	- 1.3
1969 to 1977	Variable	9	3	0.3
1978 to 1983	Wet	5	19	3.1
1984 to 1993	Drought	8	-10	-1.0
1994 to 1998	Wet	5	22	4.5
1999 to 2006	Variable	8	5	0.6
2007 to 2016	Drought	10	32	- 3.2

Precipitation data from Visalia California NOAA gauge.
Precipitation Deviation is the cumulative departure from average precipitation for the period
Deviation Rate provides a relative sense of the severity of the wet or dry periods.

Figure 36 and *Table 7* emphasize the highly variable climactic cycles common to the southern San Joaquin Valley consisting of prolonged periods of modest drought punctuated by short, intense wet periods. Notable aspects of this graph include:

> A 23-year drought including water years 1946 through 1968 received below-average precipitation, when an average of 1.5 inches below normal fell each year.
>
> A wet period from 1978 through 1983 received an annual average precipitation of 3.1 inches above normal each year.
>
> An eight-year drought period between 1984 and 1993 received an average of 1 inch below normal precipitation each year.
>
> A wet period from 1994 through 1998 which was recorded as wetter than the previous wet period. Annual rainfall averaged a full 4.5 inches above normal each year.

The most recent drought changed the long-term pattern of prolonged, but somewhat modest, droughts. During the period of ten years - water years 2007 to 2016 - the area received a total of 30 inches less rainfall than the long-term average, which is equal to an annual rainfall of 3 inches less than normal each year. During this decade, the Subbasin received 30 percent less rainfall than the long-term average; the most severe drought on record.

The water level hydrographs presented on ***Figure 35*** are color coded to show the varying climactic cycles (water year type) as above, where wet periods are shaded blue and dry periods (drought) are shaded yellow. White areas on the hydrographs represent variable conditions (alternating wet and dry years).

Throughout the Subbasin, water levels generally follow characteristic patterns following climactic cycles and availability of surface water to offset groundwater pumping. During wet periods water levels either remained relatively unchanged or rose moderately. During the wet periods between 1978 and 1983, and again during 1994 to 1998, water levels rose between 20 and 50 feet in most parts of the Subbasin.

During the eight-year drought of the late 1980s through mid-1990s, typical water levels declined by as much as 80 feet in the central and eastern portions of the basin. During this period, water levels in the southwestern portion of the basin declined more than 100 feet, within TID and near the Corcoran Irrigation District well field.

The most recent severe drought, which started in water year 2007, included an unprecedented multi-year period during between 2013 and 2015 when CVP deliveries were unavailable in the Subbasin. The combination of lack of precipitation and unavailability of CVP water reduced recharge and required local water demands to be met from groundwater pumping, collectively leading to lowered water levels throughout the basin. While in some areas, including north of Visalia, water level declines were limited to approximately 40 to 50 feet, other areas experienced water level declines of as much as 100 to 150 feet.

In many parts of the Subbasin, but particularly in the southern portion of EKGSA, west of the Cities of Lindsay and Strathmore and within MKGSA south of the city of Tulare, water levels in 2015 and 2016 declined to the lowest levels on record. Cumulatively, water levels declined since the record high levels of the (early 1940s or) early 1980s, by 50 to 150 feet. Notably, in one well south of the City of Tulare, the water level declined by more than 200 feet between the early 1980s through 2015. See ***Appendix B***.

Although the Subbasin experienced widespread water level declines, water levels in a few wells in the eastern portion of the basin along the Kaweah River experienced only limited declines. These wells are presumed to be both relatively shallow and to benefit from almost continual recharge from the flow of the Kaweah and St. Johns rivers. Since the 1960s, one well has experienced only 10 feet of decline with very limited seasonal fluctuations.

2.5 Kaweah Subbasin Water Budget §354.18

This section is provided for compliance with GSP Regulations § 354.18 which states that "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."

The GSP Regulations § 354.18(b) detail the required components for a water budget which are illustrated below in *Figure 37.* The Kaweah Subbasin water budget includes each of these required components and more.

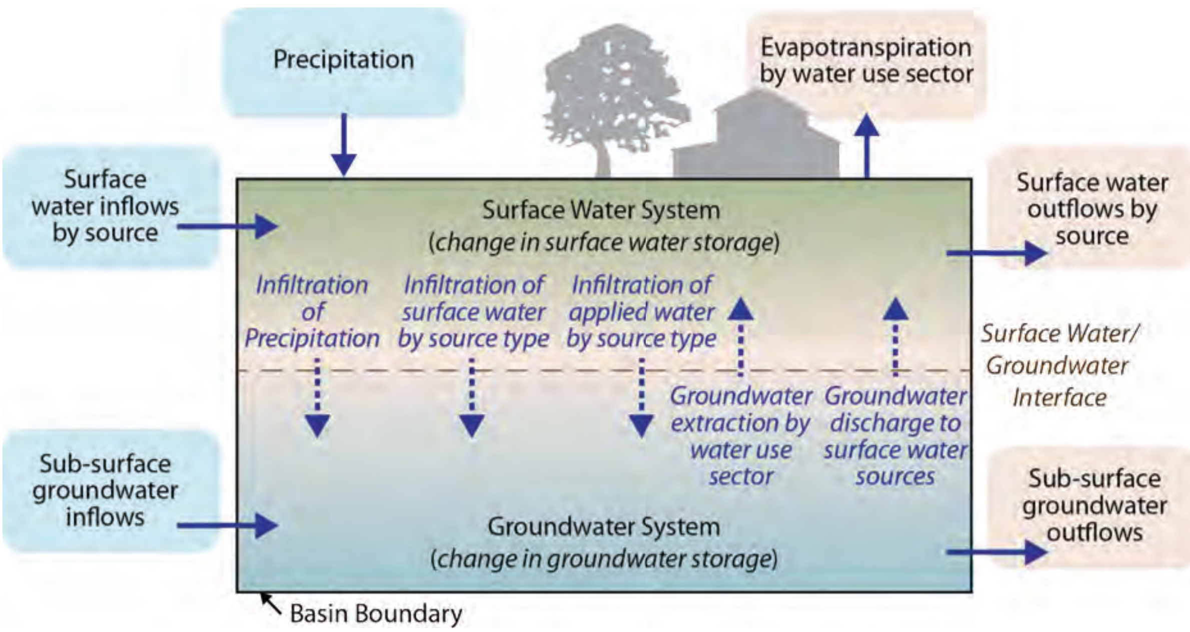


Figure 37: Water Budget Components (source, DWR)

The Kaweah Subbasin water budgets were created to quantify the inflows and outflows through the Subbasin based on a long period of hydrology, water supply availability, water demand, and land use information. The selected periods also include sufficient variability in these components to quantify and evaluate the aquifers' responses to these changes.

The historical and current water budgets for the Kaweah Subbasin are presented in *Section 2.5.1* below. The projected water budget is provided in *Section 2.5.2*.

2.5.1 Historical and Current Water Budget

Water budget information was compiled for the three GSAs within the Subbasin to evaluate the historic availability and reliability of past surface water supply deliveries and the aquifer response to water supply and demand trends relative to water year type (or hydrologic condition). All readily available data were collected, and water budget compiled in accordance with a coordination agreement between the three GSAs, "to ensure that the three plans are developed and implemented utilizing the same data and methodologies, and that the elements of the Plans necessary to achieve the sustainability goal for the basin are based upon consistent interpretations of the basin setting." (§354.4 (a))

Within the Kaweah Subbasin, the historical water budget period (base period) was selected to be between water years 1981 and 2017. The current water budget period was between water years 1997 and 2017. The projected water budget extends to 2070 (***Figure 38***).

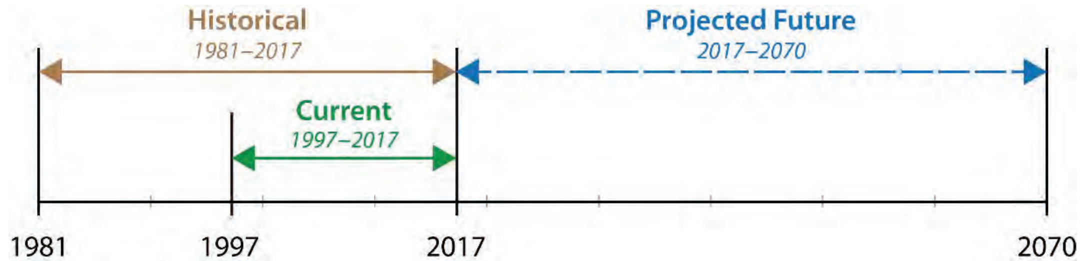


Figure 38: Historical, Current, and Projected Future Water Budget Periods for Kaweah Subbasin

2.5.1.1 Historical Water Budget Period Selection

The GSP Regulations describe the historical water budget as "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." The historical period selected also includes, "the most recently available information."

The selected representative period of the historical water budget for the Kaweah Subbasin, begins in water year 1981 and extends to the most-recent water year of 2017. The 37-year period selected for the historical water budget, includes two wet-dry hydrologic cycles; recent changes in water supply availability including an unprecedented lack of availability of imported water for several recent years; changes to water demand associated with new cropping patterns and associated land use.

The historical water budget (also referred to as the hydrologic base period) was used to define a specific time period over which elements of recharge and discharge to groundwater basin may be compared to the long-term average. This period allows the identification of long-term trends in groundwater basin supply and demand as well as water level trends, changes of groundwater in storage (both seasonal and long term), estimates of the annual components of inflow and outflow to the zone of saturation, safe yield estimates, and groundwater modeling.

The following summarizes the main considerations for base period selection:

> "The base period should be representative of long-term hydrologic conditions, encompassing dry, wet, and average years of precipitation. It must be contained within the historical record and should include recent cultural conditions to assist in determining projected basin operations. To minimize the amount of water in transit in the zone of aeration, the beginning and end of the base period should be preceded by comparatively similar rainfall quantities" (CDWR, 1962).

Determination of an appropriate period included consideration of data availability, surface water reservoir management, and the historical development of water supplies imported from outside the Subbasin.

Furthermore, the GSP Regulations require that the historical water budget provide a "quantitative evaluation of the availability or reliability of historical surface water supply deliveries" and are to start "with the most recently available information … extending back a minimum of 10 years (§ 354.18 (c)(2)."

This base periods selection also helps inform the projected water budget which is to "utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology (§ 354.18 (c)(3)." Notably, the selection of both the historical water budget, described in this section, and current water budget, which is described in the subsequent section, are based on this requirement and both closely approximate long-term hydrologic conditions based up both precipitation and streamflow patterns, which are significant components of the overall supply. A strong correlation exists between Kaweah River flow and precipitation for the historical and current periods.

Precipitation records for 15 stations in and adjacent to the Subbasin were reviewed, six of which are shown on *Table 8*. These six stations were selected as best representing the historical record of precipitation within and surrounding the Subbasin, based both on geographic distribution and period of record.

Table 8: Precipitation Stations Used for Base Period Analysis and Selection

Station Name	Elevation (feet, MSL)	Township/ Range/ Section	Start of Period*	Average for Period of Record (inches)	Average Precipitation 1945 to 2017 (inches)	Average Precipitation 1981 to 2017 (inches)	Average Precipitation 1999 to 2017 (inches)
Hanford 1 S	242	T18S/R21E-S31	1932	7.98	7.94	8.25	7.60
Corcoran Irrigation District	200	T21S/R22E-S15	1946	6.91	6.85	6.98	6.31
Visalia	325	T18S/R25E-S30	1878	10.14	10.21	10.08	8.90
Lindsay	420	T20S/R27E-S9	1932	11.65	11.53	11.67	10.68
Lemon Cove	513	T18S/R27E-S3	1932	13.77	13.68	14.07	13.00
Three Rivers Edison PH 1	1,140	T17S/R29E-S8	1949	21.69	21.69	22.47	18.46
Average				**12.02**	**11.98**	**12.25**	**10.83**

*Note: Period of Record extends through water year 2017

Generally, total precipitation is lower along the western portion of the Subbasin (Hanford and Corcoran Irrigation District stations), where at this lower elevation an average of less than 8 inches of precipitation per year are recorded. Along the eastern portion of Subbasin, at a relatively higher elevation (as represented by Lindsay and Lemon Cove), an average of 12 to 14 inches of precipitation is recorded. Outside of the Subbasin to the east, at a much higher elevation, greater precipitation occurs (as represented by the Three Rivers Edison gauge located in the foothills of the Sierra Nevada).

The key precipitation station for the Kaweah Subbasin is the Visalia station, because

it has a long period of record between 1878 and current,

is centrally located within the Subbasin, and

approximates the average rainfall in the Subbasin.

A graph presenting the variability of rainfall recorded at the Visalia station is presented as ***Figure 39***. Average rainfall at this station is 10.1 inches per year. The bottom half of the chart shows the annual precipitation. The upper portion of the chart shows the climactic variability by stacking subsequent years, such that upward trending portions (blue areas) represent wet periods and downward trending portions (yellow areas) represent drought periods.

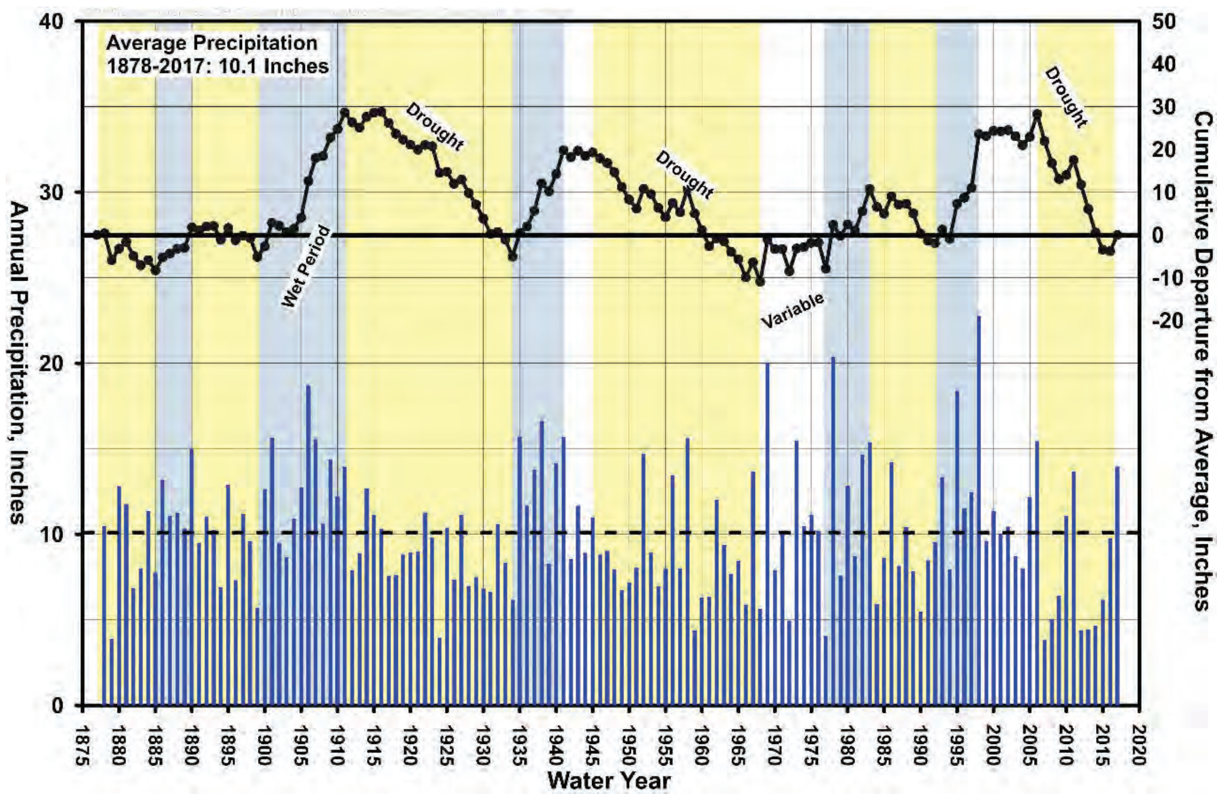


Figure 39: Cumulative Departure from Average Annual Precipitation, Visalia

Kaweah River flow records for the period of 1904 through 1989 were obtained from KDWCD staff and calculated as the summation of flow data from gauges at Kaweah River at Three Rivers and South Fork of Three Rivers. Flow records for the period of 1990 through 2017 were obtained from the U.S. Army Corps of Engineers' records of inflow to Lake Kaweah. Flow records at the Dry Creek gauging station and at the Kaweah River below McKay Point were similarly reviewed and are shown on ***Table 9***. As presented, Kaweah River flow as measured at Three Rivers (plus the South

Fork of Three Rivers) during the 37 year (inclusive) historical period of 1981 to 2017 closely approximates the long-term average during the period of record (within 3 percent).

Table 9: Surface Water Flow Stations Used for Base Period Analysis and Selection

Station Name	Elev. (feet, MSL)	Period of Record (Water Year)	Average for Period of Record (AFY)	Average for Historical Period 1981-2017 (AFY)	Range for Period of Record (AFY)
Kaweah River at Three Rivers + South Fork of Three Rivers (Full Natural Flow)	833	1904-Present	426,600	438,700	90,100 - 1,359,000
Dry Creek Near Lemon Cove	589	1962-Present	17,200	17,100	173 - 93,800
Kaweah River plus St. Johns River Below McKay Point	455	1962-Present	396,300	382,100	43,800 - 1,331,300

As presented on ***Figure 40***, variations in Kaweah River flow exhibit somewhat similar trends to climactic variations exhibited in the precipitation data.

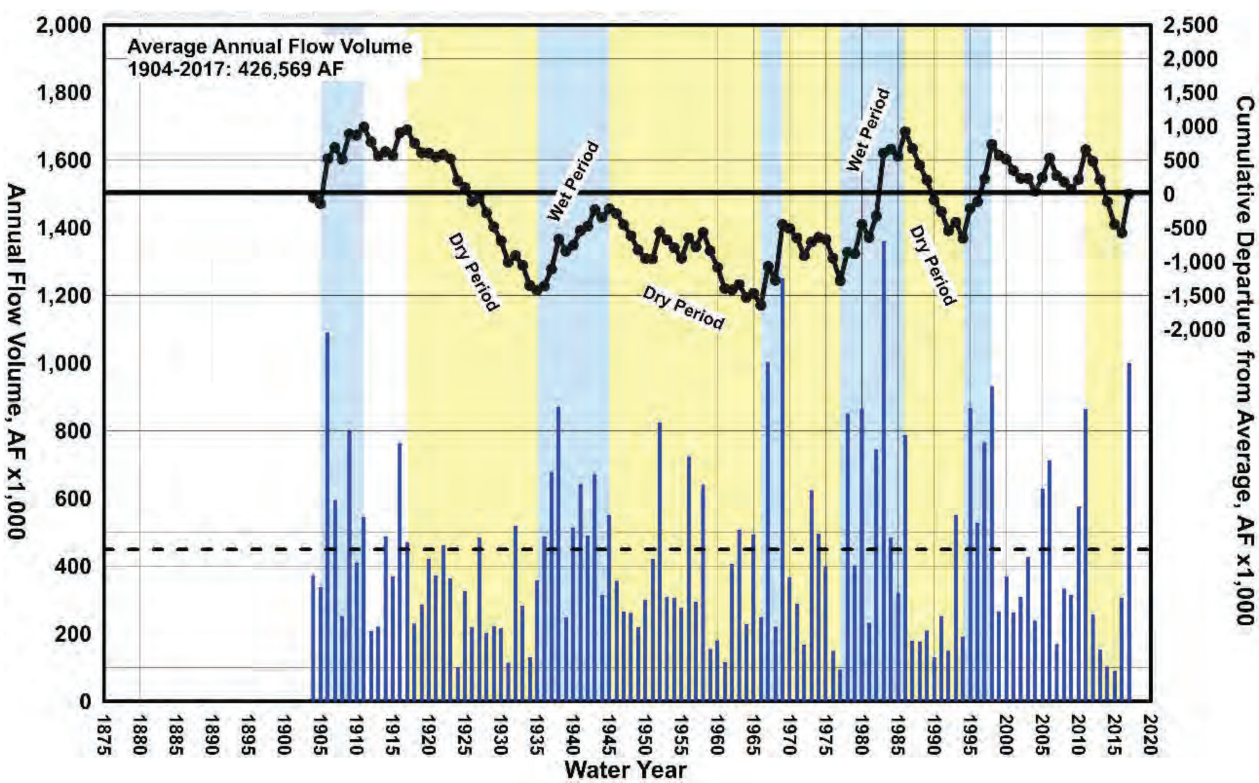


Figure 40: Cumulative Departure from Average Annual Flow, Kaweah River

An analysis of the statistical relationship between the composite precipitation and river flow data is presented as ***Figure 41***. The average composite precipitation and Kaweah River flow for the base period approximated the long-term average (within several percent).

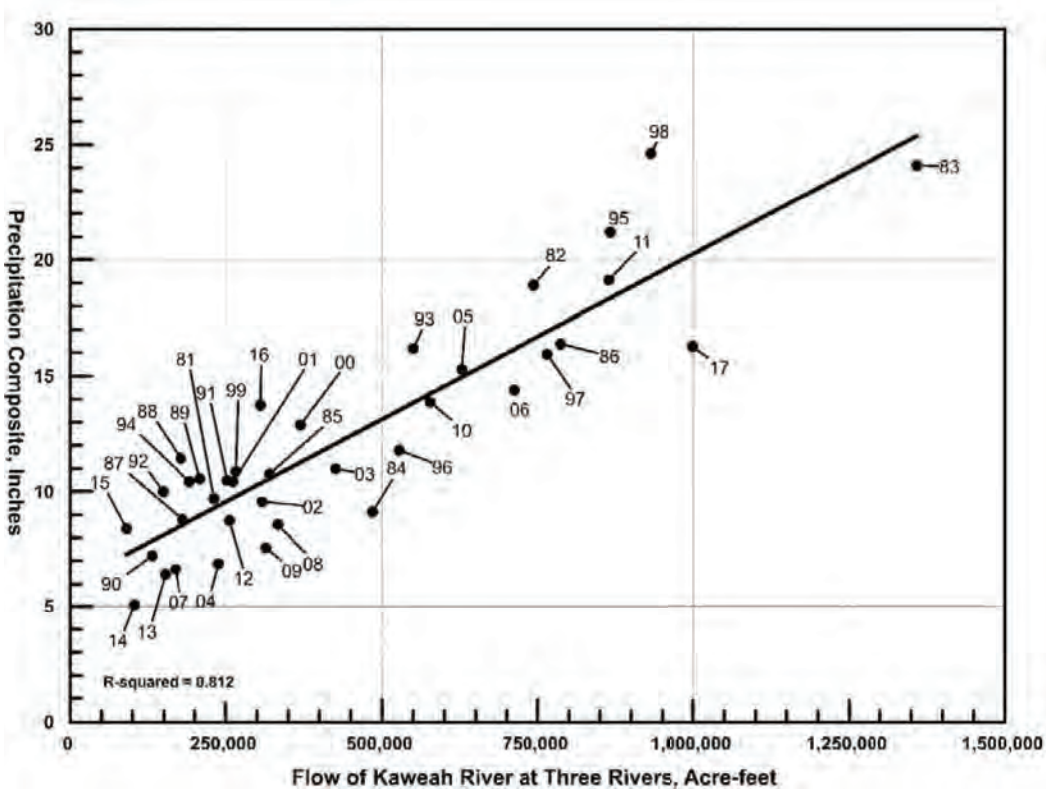


Figure 41: Kaweah River Runoff Versus Mean PrecipitationA review of the cumulative departure graphs for the precipitation station and Kaweah River flow identify candidate years for beginning the base period to include 1981, 1986, 1993 and 1999. The most recent water year (2017) was identified as a suitable year for ending the hydrologic base period. Importantly, 2017 is representative of current cultural conditions in the Subbasin relative to changes in land and water use. Precipitation totals in each year between 2012 and 2016 were below average, which would minimize significant amounts of water in transit through the unsaturated zone. A review of the differences in cumulative departure for these years is summarized in the following ***Table 10***.

Table 10: Historical Base Period Analysis (Relative to 1945 - 2017)

Station Number	Station Name	Difference in Cumulative Departure Between Base Period Years (inches)			
		1981-2017	1986-2017	1993-2017	1999-2017
43747	Hanford	0.38	0.38	0.57	-0.34
42012	Corcoran	0.06	0.06	0.38	-0.53
49367	Visalia	-0.22	-0.22	0.01	-1.31
44957	Lindsay	-0.14	-0.14	0.31	-0.85
44890	Lemon Cove	0.10	0.10	0.75	-0.68
48917	Three Rivers Edison	-0.70	-0.70	-0.52	-3.23
Average Cumulative Departure:		0.27	-0.09	0.25	-1.16

Based on comparison of precipitation averages, the most suitable candidates for a representative hydrologic base period are water years 1981 to 2017 and 1993 to 2017. Considering the availability of data, especially land use and California Irrigation Management Information System (CIMIS) data, the longer period of 1981 to 2017 is preferred. The relationship of surface water flow to precipitation was also considered in the selection of the base period by plotting flow at Three Rivers versus precipitation for various periods. For the most part, a strong correlation was obtained, showing a strong linear relationship, regardless of the period selected.

Based on the above, one appropriate base period was selected for use as the historical water budget: water years 1981 through 2017 (37 years inclusive). The average precipitation during both periods is within approximately 1 percent of each other and the long-term period. The position of the base period relative to historical wet-dry cycles is appropriate. If a smooth curve is fitted to the precipitation patterns, the base period includes two full cycles of wet and dry conditions. The base period ends in 2017, which incorporates recent cultural conditions, including an unprecedented lack of imported surface water availability between 2013 and 2015. The precipitation is similar for years leading into the beginning of the base period.

Compared to the long period of record from the Visalia station (130 years) average precipitation for the base period varies by less than 2 percent . Similarly, average flow for the base period varies by less than 3 percent compared to the long period of record of flow data from the Kaweah River at Three Rivers gauge (104 years), and by about 2 percent from the period of 1945 to 2017.

2.5.1.2 Current Water Budget

The GSP regulations state "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."

The period 1997 to 2017 was selected for the current water budget in the Kaweah Subbasin. This period was selected because it represents current water supply conditions in the subbasin including surface water supply availability under average, extremely dry and extremely wet conditions. This period also represents the current crop and municipal water demands which have remained consistent throughout this period. The average annual overdraft during this period is 77,600 AFY. This overdraft value will be used as the starting point for the development of projects and management actions to bring the subbasin into balance and achieve Sustainable Yield by 2040. Groundwater modeling accounting for projected future supplies and demands, i.e., the projected water budget, will be used to evaluate the benefits of our planned projects and management actions at arresting the overdraft in the subbasin.

2.5.1.3 Summary of Water Budget Components

This section provides a description of each of the water budget components quantified as part of the historic budget evaluation.

Surface Water

Water from both locally derived and imported surface water sources are distributed in the natural and constructed channels in the Subbasin. The natural channels are the streams, rivers and creeks that flow from the catchments in the Sierra Nevada Mountains and foothill regions along the eastern side of the Subbasin. The constructed channels (ditches) are a system of hydraulically inter-connected canals and channels that deliver surface water from the natural channels to the entitlement holders, and ultimately to individual land units. Some natural channels receive diversions of imported surface water, comingled with native (local) sources, and divert it via ditches to entitlement holders.

The Kaweah River flows westward into the subbasin from the Sierra Nevada Mountains, beginning at an elevation of over 12,000 feet and drains a watershed area of about 630 square miles above the foothill line. Terminus Reservoir, located in the foothills of the Sierra Nevada, has a tributary drainage area of about 560 square miles, which produces about 95 percent of the total runoff of the watershed (Fugro Consultants, 2016).

During the period of record from water years 1901 through 2017, the average annual flow within the Kaweah River at Three Rivers (plus the South Fork of Three Rivers) was 426,600 AF/WY, ranging from a minimum of 90,100 AF/WY in 2015 to a maximum of 1,360,000 AF/WY in 1983. The average annual flow for the historical (1981 to 2017) period of 435,500 AF/WY was 104 percent of the long-term average since 1901.

The principal local source of water, the Kaweah River, is divided equally at McKay Point between the Lower Kaweah and St. Johns rivers, which occurs each year until the flow has diminished in the late summer months (Fugro West, 2007). Thereafter, the entire entitlement flow, regardless of the amount, is diverted into the Lower Kaweah River. A schematic diagram of the Kaweah River system is presented as ***Figure 42***. As presented on ***Table 11*** an average of 336,710 AF/WY of AF/WY Kaweah River water (through the entire Kaweah River system) was diverted through headgates for agricultural purposes.

Table 11: Surface Water in Kaweah Subbasin (AF/WY)

Water Year	CVP Water	Kings Water	Total Imported	Kaweah Water Diversions (Local Sources)	Total of Surface Water (Headgate Diversions)
1981	153,960	11,117	165,077	192,814	357,891

Water Year	CVP Water	Kings Water	Total Imported	Kaweah Water Diversions (Local Sources)	Total of Surface Water (Headgate Diversions)
1982	324,038	3,217	327,255	594,413	921,668
1983	141,947	0	141,947	964,811	1,106,758
1984	224,960	42,685	267,645	446,364	714,009
1985	170,262	3,205	173,467	255,935	429,402
1986	273,525	18,068	291,593	568,236	859,829
1987	114,407	2,430	116,837	133,945	250,782
1988	141,865	1,996	143,861	140,009	283,870
1989	133,034	1,000	134,034	157,589	291,623
1990	69,224	0	69,224	96,294	165,518
1991	108,907	0	108,907	201,631	310,538
1992	108,785	1,226	110,011	105,851	215,862
1993	250,502	7,093	257,595	454,179	711,774
1994	106,309	1,392	107,701	136,046	243,747
1995	212,823	13,383	226,206	632,021	858,227
1996	255,721	33,753	289,474	401,832	691,306
1997	199,376	20,733	220,109	562,767	782,876
1998	169,292	13,919	183,211	698,203	881,414
1999	233,760	20,106	253,866	239,440	493,306
2000	224,684	2,575	227,259	297,865	525,124
2001	109,268	6,926	116,195	208,051	324,246
2002	133,824	2,341	136,165	230,074	366,238
2003	183,657	11,732	195,389	320,161	515,550
2004	123,718	5,562	129,279	175,451	304,730
2005	328,005	8,948	336,952	454,252	791,204
2006	239,266	15,723	254,990	531,308	786,298
2007	80,972	9,037	90,009	120,844	210,853
2008	107,908	0	107,908	264,142	372,050
2009	143,689	2,624	146,313	241,048	387,361
2010	240,826	3,223	244,050	440,838	684,887
2011	235,335	2,041	237,376	666,658	904,034
2012	98,102	2,688	100,789	198,608	299,397
2013	52,515	0	52,515	105,476	157,991
2014	24,169	0	24,169	72,652	96,821
2015	13,304	0	13,304	59,694	72,998
2016	97,606	0	97,606	231,650	329,256
2017	211,386	11,645	223,031	857,122	1,080,153
Maximum	**328,005**	**42,685**	**336,952**	**964,811**	**1,106,758**
Minimum	**13,304**	**0**	**13,304**	**59,694**	**72,998**
Average	**163,268**	**7,578**	**170,846**	**336,710**	**507,556**

During the historical period, an average of 170,846 AF/WY of water is imported annually, of which a majority (some 163,300 AF/WY) is imported from the CVP system. The remainder of the imported water, is directed into the Subbasin through the Kings River.

On average, for the historical base period, a total of 507,556 AF/WY of Kaweah River and imported water from both the CVP Friant Division system and Kings River system was diverted for irrigation within the Kaweah Subbasin. These local and imported water supplies are comingled during conveyance (**Table 11)**. The trend of deliveries of imported water is generally downward in recent years, with the exception of the wet years (e.g. 2005, 2011 and 2017). The gross irrigation demand is supplied by both surface and groundwater sources; of this an average of 685,400 AF/WY was extracted from the groundwater reservoir to satisfy crop demands (discussed later in this report). Conveyance losses related to the delivery of surface water is significant, and the estimated annual quantity of such a "loss" is discussed later in this section.

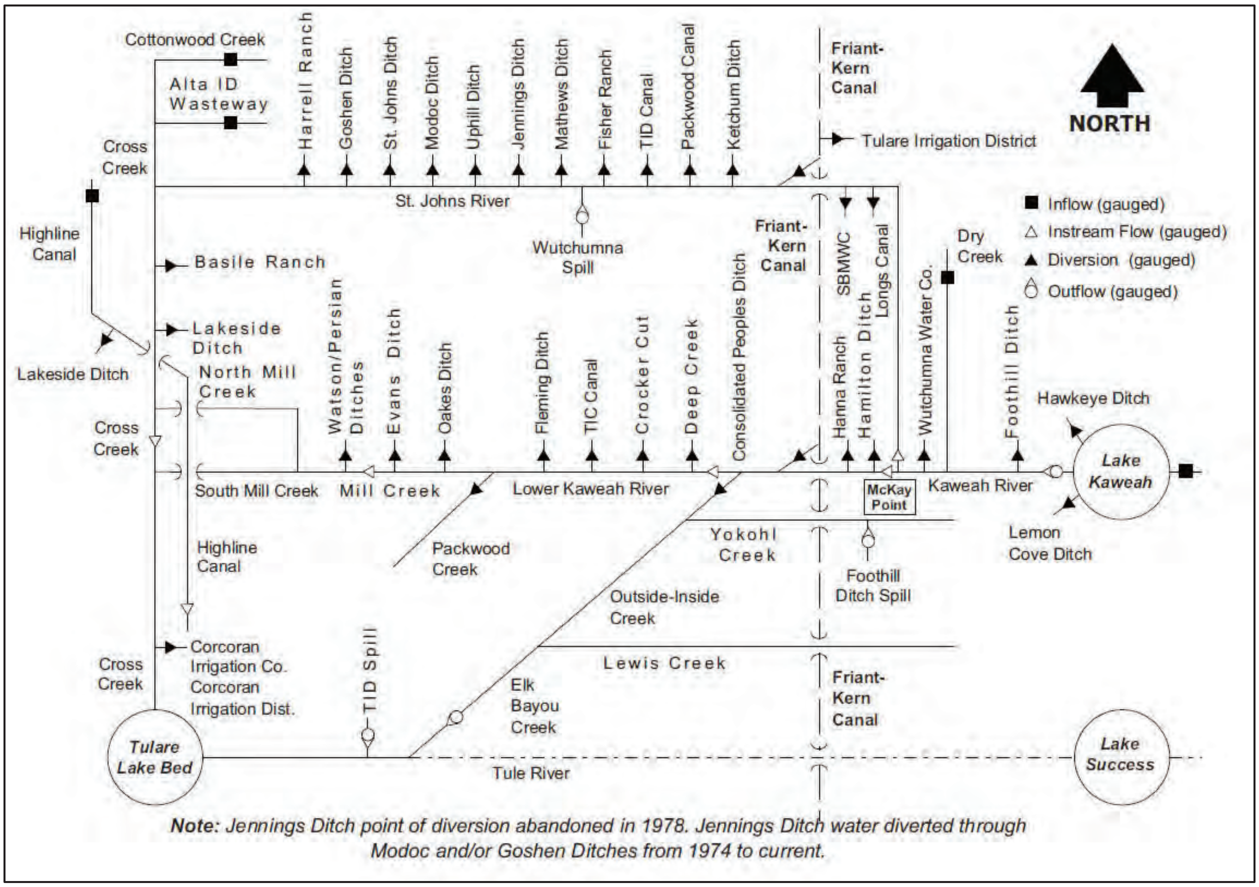


Figure 42: Schematic Diagram of Kaweah River System

Supplemental sources of water supply have been imported to the Subbasin for decades. Deliveries to lands within the boundaries of the Subbasin started in the late 1800s and were made available from the Kings River. An additional source of supplemental supply to lands located within the Subbasin in the early 1950s was made available from the CVP, with both long-term and short-term contract supplies. With the termination of short-term contracting procedures, supplemental supplies, in addition to the long-term CVP supplies, have been made available through temporary contracts.

The delivery of ample surface water by local and imported sources for agricultural irrigation is a key to avoiding several of the undesirable results in the Kaweah Subbasin. Within the historical base period, in the late 1980s, surplus water was available in the system beyond the needs of contractors.

During the 1987 to 1992 drought, when imported water was available and no significant contract limitations were in place, no significant water level declines were noted.

Beginning in the 2010s, surplus water began to be partially allocated to the San Joaquin River Restoration Program. In the recent 2012 to 2015 drought, CVP contract deliveries were severely limited, such that in 2012 only 50% Class 1 water was delivered. In 2013 only 62% was delivered. In both 2014 and 2015, none of the contracted water was delivered. During these dry years, TID did not receive Class 2 contract water. Meanwhile, groundwater levels reached record lows.

Surface Water Crop Delivery

Crop water demands constitute the largest portion of groundwater and surface water demand in the Subbasin. Therefore, the complete understanding of how much of these two sources of water are applied to crops is central to the groundwater budget calculations. This section summarizes the methodology used to determine the volumes of surface water delivered to crops, which will in turn be used to estimate the additional crop water demand, which is provided through un-metered groundwater pumpage.

Surface water in the Kaweah Subbasin is used primarily to satisfy the irrigated agricultural demands, which constitutes the majority of water use. The irrigation of the agricultural lands is satisfied by a combination of diverted surface water and pumped groundwater. The calculation of the volume of surface water delivered to fields to meet agricultural crop demands is described using the following equation adapted from previous methods (Fugro West, 2007; Fugro Consultants, 2016):

$$SW_C = HG_{DIV} + R_{DIV} + RW - TotDS_P - RB_{DIV} - S$$

Where:

SW_C	=	Surface water delivered to crops
HG_{DIV}	=	Headgate diversions
R_{DIV}	=	Riparian diversions
RW	=	Recycled water
$TotDS_P$	=	Total ditch system percolation
RB_{DIV}	=	Recharge basin diversions
S	=	Spills

The annual quantities of water associated with each of the components in the equation above are presented in subsequent sections with focus on "loss" of the water from the surface water system and subsequent inflow into the aquifer. The average volumes of water for each of the components of the above equation during the historical (base) period are:

$$SW_C = HG_{DIV} + R_{DIV} + RW - TotDS_P - RB_{DIV} - S$$

$$SW_C \cong 507{,}600 + 4{,}900 + 8{,}800 - 117{,}000 - 51{,}200 - 16{,}800$$

$$SW_C \cong 335{,}100$$

Based on the above calculation, the total volume of surface water delivered to crops averaged 335,100 AF/WY. This volume of surface water was used to offset groundwater pumpage for irrigated agriculture, the remainder of which was satisfied by groundwater pumpage. While this calculation was used for most areas of the Subbasin, in two limited cases the quantity of water delivered crops were reported directly and not calculated using this method.

These summaries of surface water flow components described in this section are provided to calculate the total amount of surface water delivered to crops. Several of these components will also be described further in a later section with regard to estimates of inflows to the groundwater system.

In general terms, the components of riparian diversions, recycled water applied to crops, total ditch system percolation, recharge basin diversions, and spills are presented in the following paragraphs.

Headgate Diversions (HG_{DIV})

Headgate diversions for each appropriator are an integral component into the water budget for the calculation of groundwater pumpage. Headgate diversions occur as surface water diverted from the natural channels into constructed canals and channels for delivery to entitlement holders for farm delivery. Data for these diversions were compiled from Kaweah and St. Johns Rivers Association records. Annual volumes of headgate diversions throughout the Subbasin are presented in ***Table 11***. Basin-wide, an average of 507,600 AF/WY was diverted through headgates from the surface water flow (from comingled local and imported sources). Such headgate diversions, in turn, experience seepage (ditch) losses, can be redistributed to artificial recharge basins, or in years of very high surface water flow, leave the District as "spill" or outflow.

Riparian Diversions (R_{DIV})

Annual quantities of surface water diverted by riparian users for agricultural use from the Lower Kaweah and St. Johns river systems were quantified in prior reports (Fugro West, 2007; Fugro Consultants, 2016). These riparian diversions were quantified in concert with the calculation of reach losses (natural channel percolation). The riparian diversions (located within GKGSA) are presented in ***Table 12***. On average, 4,922 AF/WY of surface water were diverted for riparian use.

Table 12: Riparian Diversions (AF/WY)

Water Year	Riparian Diversions
1981	**3,046**
1982	**9,971**
1983	**12,054**
1984	**8,729**
1985	**4,899**
1986	**9,789**
1987	**2,677**
1988	**1,388**
1989	**2,032**
1990	**696**
1991	**1,843**
1992	**815**
1993	**5,640**
1994	**2,271**
1995	**9,031**
1996	**7,466**
1997	**7,553**
1998	**11,040**
1999	**5,806**
2000	**5,522**
2001	**2,162**
2002	**2,332**
2003	**3,260**
2004	**2,038**
2005	**8,418**
2006	**9,796**
2007	**2,381**
2008	**3,423**
2009	**2,080**
2010	**5,854**
2011	**10,346**
2012	**3,543**
2013	**1,521**
2014	**618**
2015	**242**
2016	**1,994**
2017	**9,825**
Maximum	**12,054**
Minimum	**242**
Average	**4,922**

Recycled Water (RW)

The cities of Visalia and Tulare both produce recycled water for crop irrigation as a portion of the effluent from their wastewater treatment plants (WWTPs). The managers of each WWTP provided Annual Use Monitoring Reports for this analysis. Based on these records, the WWTP effluent applied to nearby crops is estimated to be on average 20 percent of the effluent flow for Visalia and an average of 70 percent of the Tulare's effluent flow[2] over the period of record. The results of the recycled water applied to crops are presented in *Table 13*. As presented, an average of 8,792 AF/WY of recycled water from the municipal wastewater treatment plants was delivered to crops on adjacent fields. There are no other applications of recycled water to crops within the Subbasin.

[2] Based on Annual Use Reports

Table 13: Recycled Water Delivered to Crops (AF/WY)

Water Year	Recycled Water
1981	**5,019**
1982	**5,199**
1983	**5,379**
1984	**5,558**
1985	**5,739**
1986	**5,919**
1987	**6,099**
1988	**6,279**
1989	**6,459**
1990	**6,595**
1991	**6,786**
1992	**6,414**
1993	**6,942**
1994	**7,516**
1995	**7,749**
1996	**7,733**
1997	**7,879**
1998	**7,996**
1999	**8,590**
2000	**8,928**
2001	**9,077**
2002	**9,791**
2003	**10,671**
2004	**10,915**
2005	**11,359**
2006	**11,599**
2007	**11,781**
2008	**11,441**
2009	**11,350**
2010	**11,566**
2011	**11,548**
2012	**12,079**
2013	**11,825**
2014	**11,651**
2015	**11,092**
2016	**11,144**
2017	**11,374**
Maximum	**12,079**
Minimum	**5,019**
Average	**8,792**

Total Ditch System Percolation ($TotDS_P$)

The volumes of total ditch system percolation are the portion of water that percolated through the bottom and sides of the ditch system between a headgate diversion point and a grower turnout for agricultural irrigation. These volumes are used to estimate how much of the water diverted at a headgate is ultimately delivered for agricultural irrigation. The results of the total ditch system percolation analysis are presented in ***Table 14***. Basin wide, the average annual volume of surface water that percolates through the ditch systems is 117,001 AF/WY.

Table 14: Ditch Percolation (AF/WY)

Water Year	Ditch Percolation
1981	**70,745**
1982	**243,470**
1983	**257,593**
1984	**149,426**
1985	**85,151**
1986	**226,874**
1987	**35,502**
1988	**50,098**
1989	**50,355**
1990	**19,649**
1991	**61,780**
1992	**32,401**
1993	**177,784**
1994	**46,311**
1995	**215,126**
1996	**161,633**
1997	**189,363**
1998	**216,275**
1999	**104,433**
2000	**114,612**
2001	**65,837**
2002	**76,638**
2003	**120,560**
2004	**58,082**
2005	**206,240**
2006	**207,682**
2007	**38,028**
2008	**80,803**
2009	**90,254**
2010	**151,862**
2011	**196,378**
2012	**65,852**
2013	**29,293**
2014	**26,177**
2015	**17,698**
2016	**78,869**
2017	**310,206**
Maximum	**310,206**
Minimum	**17,698**
Average	**117,001**

Recharge Basin Diversions (RB_{DIV})

The recharge basin diversions are the portions of water that percolate to groundwater via recharge basins subsequent to being diverted through a headgate. A summary of the recharge basin diversions is presented in ***Table 15***. Basin wide, an average of 51,191 AF/WY of the surface water is diverted to recharge basins. Total recharge basin inflow will be discussed below. There are no recharge basin diversions in EKGSA.

Table 15: Recharge Basin Percolation (AF/WY)

Water Year	Basin Recharge
1981	**16,706**
1982	**103,579**
1983	**74,439**
1984	**43,474**
1985	**35,435**
1986	**99,137**
1987	**8,318**
1988	**20,892**
1989	**14,332**
1990	**4,687**
1991	**12,270**
1992	**9,032**
1993	**95,849**
1994	**9,582**
1995	**123,637**
1996	**71,069**
1997	**114,110**
1998	**115,638**
1999	**42,075**
2000	**37,608**
2001	**14,373**
2002	**14,790**
2003	**53,149**
2004	**16,701**
2005	**111,102**
2006	**83,625**
2007	**15,835**
2008	**16,943**
2009	**22,761**
2010	**94,110**
2011	**155,756**
2012	**26,090**
2013	**7,695**
2014	**349**
2015	**382**
2016	**22,073**
2017	**186,458**
Maximum	**186,458**
Minimum	**349**
Average	**51,191**

Spills (S)

In years of significant surface water availability, the quantity of surface water can exceed the crop demands and recharge capacity of the conveyance systems and basins (Fugro Consultants, 2016). This occurred in 1983, 1995, 1997, 2006, 2011 and 2017. In such years, surface water flows out of the Subbasin in the form of surface water "spills"(***Figure 22***). Quantification of these spills is straightforward because these spill points are gauged and records are maintained by both KDWCD and TID. A summary of the surface water spills from the Subbasin is presented as ***Table 16***. Basin wide, an average of 16,767 AF/WY has been spilled from the Subbasin. Of these spills, only the Cross Creek spill occurs from the natural channels. There are no spills from the Subbasin from EKGSA.

Table 16: Spills from the Subbasin (AF/WY)

Water Year	Spills
1981	**3,277**
1982	**56,246**
1983	**204,315**
1984	**37,993**
1985	**2,879**
1986	**51,784**
1987	**804**
1988	**757**
1989	**556**
1990	**0**
1991	**633**
1992	**74**
1993	**5,674**
1994	**152**
1995	**23,124**
1996	**6,730**
1997	**50,994**
1998	**38,904**
1999	**4,318**
2000	**10,567**
2001	**3,468**
2002	**3,321**
2003	**14,380**
2004	**2,382**
2005	**6,593**
2006	**24,675**
2007	**773**
2008	**1,651**
2009	**1,274**
2010	**7,263**
2011	**34,805**
2012	**1,541**
2013	**0**
2014	**0**
2015	**0**
2016	**177**
2017	**18,313**
Maximum	**204,315**
Minimum	**0**
Average	**16,767**

Surface Water Delivered to Crops

The results of the calculations for the volume of surface water delivered to crops are summarized in ***Table 17***. As indicated, the average annual amount of surface water delivered to meet crop demand within the Subbasin is about 335,081 AF/WY over the base period (historical period). The deliveries show a clear correlation to the availability of surface water and ranged from about 65,799 AF/WY (2015) to 583,928 AF/WY (2017) just two years later. These values indicate that approximately two-thirds of the total water diverted through the headgates is ultimately delivered to the crops within the Subbasin.

Table 17: Surface Water Delivered to Crops (AF/WY)

Water Year	SW Delivered to Crops
1981	**278,671**
1982	**530,403**
1983	**587,280**
1984	**497,124**
1985	**316,088**
1986	**495,387**
1987	**214,159**
1988	**219,328**
1989	**234,313**
1990	**147,874**
1991	**243,654**
1992	**180,900**
1993	**443,681**
1994	**196,360**
1995	**511,710**
1996	**465,774**
1997	**442,074**
1998	**527,890**
1999	**356,181**
2000	**375,275**
2001	**250,475**
2002	**282,037**
2003	**339,763**
2004	**239,493**
2005	**485,483**
2006	**488,422**
2007	**169,232**
2008	**286,352**
2009	**285,166**
2010	**446,511**
2011	**536,716**
2012	**220,069**
2013	**133,663**
2014	**80,923**
2015	**65,799**
2016	**239,854**
2017	**583,928**
Maximum	**587,280**
Minimum	**65,799**
Average	**335,081**

Inflows to The Groundwater System

The inflow components to the groundwater system include the following:

Subsurface inflow

Percolation of precipitation

Streambed percolation in the natural and man-made channels

Artificial recharge

Percolation of irrigation water

Percolation of waste water

Each of these components and the method by which each was calculated is presented in this section.

Subsurface Inflow

Subsurface inflow is the flow of groundwater into and out of a groundwater basin. During the base period, subsurface inflow into the Kaweah Subbasin exceeded subsurface outflow from the Subbasin by 64,501 AF/WY (***Table 18***).

Annual estimates were prepared to determine the subsurface flow between the three GSAs within the Subbasin and both into and out of the Subbasin as a whole. These calculations were performed by two methods.

During the earlier period between 1981 and 1998, these calculations were performed using the Darcy flow equation, which requires input values of groundwater gradient and hydraulic conductivity. The gradient was calculated for every year of the base period using the groundwater contour maps prepared for this Basin Setting. Horizontal hydraulic conductivity values were used from the numerical groundwater model.

In this method, the rate of groundwater flow is expressed by the Darcy equation Q = PiA, where 'P' is the coefficient of aquifer permeability (horizontal hydraulic conductivity), 'i' is the average hydraulic gradient, and 'A' is the cross-sectional area of the saturated aquifer. Permeability data for the aquifers in the Kaweah Subbasin were discussed in **Section 2.2.5.2**, which were used in the numerical groundwater model. Hydraulic gradient data, derived from annual water level contour maps developed for this Basin Setting were analyzed on an annual basis over the base period. The cross-sectional areas of the aquifer at each groundwater flux line representing the boundaries of the Subbasin were estimated using GIS analysis. The general directions of which are presented in ***Figure 43***. From these, annual magnitudes of subsurface flow were tallied.

The second method used to compute groundwater flux along the Subbasin boundary was based on the numerical groundwater flow model. Groundwater flow into and out of the Subbasin were calculated as an output from the model. These estimates of groundwater flow are considered to be superior to the Darcian flux method.

These subsurface flow calculations include an estimate of mountain-front recharge, which is the contribution of water from the mountains to recharge the aquifers in the adjacent basins. For the Kaweah Subbasin, this flow enters the Subbasin from the Sierra Nevada on the east. Mountain front recharge is limited and most of the flow into the basin occurs principally as surface runoff, which subsequently percolates rapidly into alluvial valleys. Based on several sources, mountain-front recharge is estimated to contribute an average of 52,000 AF/WY to the Kaweah Subbasin. This volume of mountain-front recharge includes estimated percolation from minor streams along the eastern periphery of the Subbasin. For the purposes of this water budget, this estimation was varied based on water year type based on relative precipitation in any year.

A summary of the total estimated annual subsurface inflow and outflow is presented in ***Table 18***. The average total subsurface inflow into the Subbasin during the historical period was estimated to be 155,640 AF/WY. During this same period, average subsurface outflow was only 91,139 AF/WY, resulting in a net subsurface inflow into the basin of 64,501 AF/WY. A map of the typical subsurface flow within the Subbasin is presented as ***Figure 43***.

Table 18: Subsurface Flow (AF/WY)

Water Year	Subsurface Inflows	Subsurface Outflows	Net Subsurface Flows
1981	7,416	113,057	**-105,641**
1982	102,364	108,566	**-6,202**
1983	193,509	113,190	**80,319**
1984	71,758	112,636	**-40,878**
1985	35,970	50,210	**-14,240**
1986	110,886	53,331	**57,555**
1987	43,989	95,673	**-51,685**
1988	81,490	125,284	**-43,795**
1989	(15,488)	74,850	**-90,338**
1990	(4,763)	32,566	**-37,329**
1991	36,014	54,523	**-18,509**
1992	87,139	123,629	**-36,490**
1993	171,393	112,885	**58,508**
1994	76,131	116,379	**-40,248**
1995	135,459	109,653	**25,806**
1996	229,839	83,117	**146,722**
1997	238,893	96,499	**142,395**
1998	208,409	93,089	**115,320**
1999	194,083	35,425	**158,659**
2000	197,904	57,725	**140,178**
2001	192,026	79,952	**112,073**
2002	192,215	89,440	**102,775**
2003	187,739	96,878	**90,861**
2004	164,507	93,392	**71,116**
2005	246,894	74,913	**171,981**
2006	247,302	61,294	**186,008**
2007	154,061	101,444	**52,617**
2008	180,795	166,204	**14,590**
2009	186,598	153,981	**32,617**
2010	246,030	117,451	**128,579**
2011	288,083	62,978	**225,106**
2012	199,932	68,294	**131,638**
2013	187,277	107,638	**79,639**
2014	193,692	93,867	**99,825**
2015	191,677	82,095	**109,582**
2016	200,844	93,551	**107,293**
2017	296,623	66,478	**230,145**
Maximum	**296,623**	**166,204**	**230,145**
Minimum	**-15,488**	**32,566**	**-105,641**
Average	**155,640**	**91,139**	**64,501**

Percolation of Precipitation

The amount of rainfall that percolates deeply into the groundwater depends on many factors including the type and structure of the soil; density of the vegetation; the quantity, intensity and duration of rainfall; the vertical permeability of the soil; the relative saturation of the soil during rainfall episodes; and local topography. Deep percolation of rainfall does not occur until the initial soil moisture deficiency is exceeded. In most years, rainfall events do not produce sufficient quantities and timing of rainfall to penetrate beyond the root zone of native vegetation. However, in irrigated soils, because of the artificial application of water, the initial fall and winter moisture content is greater, and less annual rainfall is required to meet and exceed the soil moisture deficiency. Once the soil moisture deficiency within the root zone has been satisfied, continued precipitation (occurring prior to evapotranspiration) will percolate downward and eventually reach the groundwater reservoir.

Estimation of the deep percolation of precipitation was performed for the earlier period (prior to 2000) using an established method that incorporates the distribution of known crop types, rainfall distribution, reference evapotransporation (ET) data from the CIMIS, and soil data. From these data, the percolation of precipitation was calculated with the development of a monthly moisture model spreadsheet that accounted for immediate evaporation, effective rainfall, percolation of infiltrated rainfall, and percolation of rainfall runoff (Fugro West, 2007).

Since 2000, estimates of the percolation of precipitation were made by a different method, based on a combination of remote sensing (satellite) images and computer simulations, which relied on a daily root zone water balance model and crop ET. The method utilizes Davids Engineering's "Normalized Difference Vegetation Index" (NDVI) analysis methods, which were applied to the area of the KDWCD (Davids Engineering, 2013) and the entire Subbasin (Davids Engineering, 2018[*Appendix C*]).

The Davids Engineering analysis estimated percolation of precipitation applied to agricultural land. For the period of 2000 to 2017, the clipped irrigated fields GIS data was exported from GIS and imported into the Davids Engineering database model to develop an "irrigated fields" table. From this, the annual estimated percolation of precipitation on irrigated fields located within the Subbasin was calculated. The results were checked against previously calculated values (Fugro Consultants, 2016). Both the earlier DWR land use survey-based method and the Davids Engineering database-model method account for the agricultural land that has been converted to urban land use over time.

Percolation of precipitation on non-irrigated lands was estimated with published methods based on the distribution of annual precipitation with comparison parcel areas provided by Davids Engineering (Williamson et. al., 1989). Based on this method, an average of approximately 8 percent of the annual precipitation percolated into the groundwater during the base period. Within Visalia and Tulare, the principal urban areas, net percolation of precipitation directly on the urban areas is assumed to be negligible as these cities generally divert storm water into nearby channels that distribute it away from the city. However, the runoff amount from these areas is generally believed to be included in both the estimate of percolation into non-agricultural areas in the Kaweah Subbasin and streambed percolation.

Estimated percolation of precipitation is presented in *Table 19*. These results indicate that the percolation of precipitation onto the irrigated lands within the Subbasin averaged 89,197 AF/WY.

On non-agricultural areas, an average of 18,428 AF/WY percolated to the groundwater reservoir. In total, an annual average of 107,625 AF/WY of precipitation percolated during the base period.

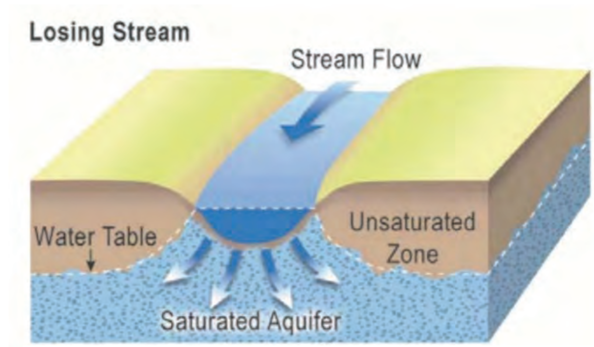
Table 19: Percolation of Precipitation (AF/WY)

Water Year	Precip on Ag Land	Precip on Non-Ag Land	Total Precip Percolation
1981	97,708	16,530	**114,238**
1982	107,397	25,860	**133,256**
1983	170,393	27,693	**198,086**
1984	26,301	12,071	**38,373**
1985	46,527	16,136	**62,664**
1986	133,058	25,011	**158,068**
1987	93,024	14,987	**108,011**
1988	78,888	18,779	**97,667**
1989	42,700	15,065	**57,765**
1990	65,033	11,440	**76,473**
1991	123,099	16,042	**139,140**
1992	67,582	17,417	**85,000**
1993	130,116	23,932	**154,049**
1994	73,708	15,729	**89,437**
1995	213,159	31,577	**244,736**
1996	100,127	20,371	**120,498**
1997	109,374	22,132	**131,507**
1998	258,852	29,960	**288,812**
1999	69,233	16,800	**86,034**
2000	82,482	19,653	**102,135**
2001	63,426	16,661	**80,087**
2002	67,840	16,451	**84,292**
2003	59,007	16,212	**75,220**
2004	48,927	12,831	**61,758**
2005	97,108	24,112	**121,220**
2006	129,634	25,387	**155,022**
2007	32,225	9,179	**41,404**
2008	52,943	13,801	**66,745**
2009	36,310	12,164	**48,474**
2010	72,084	19,666	**91,750**
2011	172,399	28,407	**200,807**
2012	50,752	13,618	**64,370**
2013	33,043	9,540	**42,583**
2014	25,505	8,047	**33,552**
2015	49,875	12,477	**62,352**
2016	88,100	20,329	**108,429**
2017	132,352	25,758	**158,111**
Maximum	**258,852**	**31,577**	**288,812**
Minimum	**25,505**	**8,047**	**33,552**
Average	**89,197**	**18,428**	**107,625**

Streambed Percolation and Delivered Water Conveyance Losses

Natural Channels

Percolation of water from flows in natural channels has been estimated for the entire Subbasin. Within the GKGSA and MKGSA area, streambed percolation was based on comparison of flow between the Terminus Reservoir and the appropriators' headgates. This percolation is often referred to as "conveyance loss" (or seepage loss) (***Figure 44***). Percolation through the riverbeds of the St. Johns and Lower Kaweah rivers has been calculated for specific lengths of each river and is referred to as individual "reach losses." Percolation in these natural channels was estimated based on the number of days that water flowed in each reach and the difference between an adjusted reach loss and any known riparian diversion within the reach (Fugro West, 2007; Fugro Consultants, 2016).



Source: DWR
Figure 44: Losing Stream Diagram

Within the EKGSA, reliable, long-term streamflow gauges do not exist for the four major tributaries flowing into the area from the Sierra Nevada foothills. A single streamflow gauge exists on Yokohl Creek. The other three creeks, Cottonwood Creek, Lewis Creek, Fraiser Creeks, are ungauged. Therefore, in the absence of empirical data, the streambed percolation for all four creeks were assumed to be included within the mountain-front recharge estimate for the Subbasin. The natural channel reaches (portions) within the Subbasin are presented on ***Table 20***. In total, natural channel percolation within the Subbasin averaged 79,080 AF/WY as presented on ***Table 21***.

Table 20: Stream Reaches within the Kaweah Subbasin

Reach	Total Length (feet)
Lower Kaweah Reach #2	15,767
Lower Kaweah Reach #3	5,666
Lower Kaweah Reach #4	8,129
Lower Kaweah Reach #5	9,325
Lower Kaweah Reach #6	39,731
St. Johns Reach #1	18,168
St. Johns Reach #2	31,545
St. Johns Reach #3	8,318
St. Johns Reach #4	6,601
St. Johns Reach #5	10,331
St. Johns Reach #6	31,878
St. Johns Reach #7	61,066
St. Johns Reach #8	64,580

Table 21: Streambed Percolation (AF/WY)

Water Year	Streambed Percolation
1981	**54,231**
1982	**126,001**
1983	**188,773**
1984	**138,378**
1985	**69,467**
1986	**125,734**
1987	**45,507**
1988	**34,888**
1989	**38,409**
1990	**32,199**
1991	**47,071**
1992	**38,473**
1993	**98,293**
1994	**46,885**
1995	**135,990**
1996	**84,356**
1997	**102,699**
1998	**122,161**
1999	**64,052**
2000	**68,501**
2001	**40,490**
2002	**61,508**
2003	**73,346**
2004	**46,977**
2005	**126,312**
2006	**109,920**
2007	**35,725**
2008	**60,114**
2009	**60,710**
2010	**112,106**
2011	**144,354**
2012	**50,429**
2013	**46,119**
2014	**23,790**
2015	**19,552**
2016	**73,309**
2017	**179,122**
Maximum	**188,773**
Minimum	**19,552**
Average	**79,080**

Ditches

Percolation of water from ditches within the Subbasin was estimated based on the best available data. Ditch system percolation was estimated by assigning a specified percentage of the water delivered to the appropriators' headgates as ditch percolation for each system for each year of the base period (Fugro West, 2007), which is described below.

The ditch system percolation analysis was calculated using a GIS analysis of the irrigated fields parcel data within each of the appropriators' service areas (Davids Engineering, 2018). The extents of the service areas were provided by agencies within the Subbasin including KDWCD and Lindsay-Strathmore Irrigation District, the areas of which are partially, or wholly, contained within Subbasin. A list of the names and irrigated field acreage within each of the service areas is presented in ***Table 22***, which cover a total of 259,059 acres within the approximately 443,000 acre Subbasin, or approximately 58 percent of the land area. Within the Subbasin the percolation within the ditches averaged 117,001 AF/WY, as presented on ***Table 23***.

Table 22: Appropriator Service Areas

Service Area	Acres
Consolidated Peoples D.C.	**15,770**
Evans D.C.	**4,369**
Exeter I.D.	**14,939**
Farmers D.C.	**13,202**
Fleming D.C.	**1,641**
Goshen D.C.	**5,586**
Hamilton D.C.	**350**
Ivanhoe I.D.	**10,466**
Lakeside Irrigation W.D.	**24,126**
Lemon Cove D.C.	**787**
Lewis Creek W.D.	**1,307**
Lindmore I.D.	**27,292**
Lindsay-Strathmore I.D.	**16,417**
Longs Canal Area	**952**
Mathews D.C.	**1,831**
Modoc D.C.	**6,486**
Oakes D.C.	**1,104**
Persian D.C.	**6,321**
Sentinel Butte	**815**
St. Johns W.D.	**13,355**
Stone Corral I.D.	**6,671**
Tulare I.D.	**70,446**
Tulare Irrigation Company	**7,887**
Uphill D.C.	**1,819**
Wutchumna W.C.	**5,218**
Total	**259,159**

Table 23: Total Ditch Percolation (AF/WY)

Water Year	All Conveyance Percolation
1981	70,745
1982	243,470
1983	257,593
1984	149,426
1985	85,151
1986	226,874
1987	35,502
1988	50,098
1989	50,355
1990	19,649
1991	61,780
1992	32,401
1993	177,784
1994	46,311
1995	215,126
1996	161,633
1997	189,363
1998	216,275
1999	104,433
2000	114,612
2001	65,837
2002	76,638
2003	120,560
2004	58,082
2005	206,240
2006	207,682
2007	38,028
2008	80,803
2009	90,254
2010	151,862
2011	196,378
2012	65,852
2013	29,293
2014	26,177
2015	17,698
2016	78,869
2017	310,206
Maximum	310,206
Minimum	17,698
Average	117,001
Total	**4,329,038**

Artificial Recharge

Artificial recharge basins receive surface water, which percolates directly to groundwater, the volumes of which were estimated for the entire Subbasin. The method of estimating these volumes was developed as part of the WRIs for KDWCD, which involved multiplying the number of days each recharge basin received water by the basin's known percolation rate (recharge factor) (Fugro West, 2007). Artificial recharge occurs throughout the GKGSA and EKGSA. The basin recharge factors were refined for the entire period of the WRI (Fugro Consultants, 2016), and were utilized for this analysis for the entire base period.

There are 42 recharge basins completely within the Kaweah Subbasin (refer to ***Table 24***), over a total of 1,916 acres. Within these, the recharge inflows were determined for each recharge basin, using the methodology described in the previous reports (Fugro West, 2007; Fugro Consultants, 2016). The results of the recharge basin inflow analysis are presented as ***Table 15***. As indicated, an average of 51,191 AF/WY of surface water was recharged to the groundwater by recharge basins. The volume of water recharged by this method varies widely and episodic recharge occurs principally during times of excess flow associated with wet years.

Table 24: Recharge Basins in the Kaweah Subbasin

Source	Basin ID	Source	Acres
Evans	Nelson Pit - 13	Evans	**25**
Farmers	Anderson - 24	Farmers	**130**
Farmers	Art Shannon - 1	Farmers	**27**
Farmers	Ellis - 27	Farmers	**9**
Farmers	Gary Shannon - 7	Farmers	**3**
Farmers	Gordon Shannon - 21	Farmers	**39**
Farmers	Nunes - 29	Farmers	**9**
Goshen Ditch	Doe-Goshen - 28	Goshen Ditch	**28**
Harrell No. 1	Harrell - 30	Harrell No. 1	**25**
Lakeside Ditch	Alcorn	Lakeside Ditch	**10**
Lakeside Ditch	Batti	Lakeside Ditch	**33**
Lakeside Ditch	Burr	Lakeside Ditch	**6**
Lakeside Ditch	Caeton	Lakeside Ditch	**4**
Lakeside Ditch	Green - 23	Lakeside Ditch	**4**
Lakeside Ditch	Guernsey	Lakeside Ditch	**4**
Lakeside Ditch	Howe - 15	Lakeside Ditch	**49**
Lakeside Ditch	Lakeside #2	Lakeside Ditch	**58**
Lakeside Ditch	Sousa	Lakeside Ditch	**6**
Lakeside Ditch	Youd	Lakeside Ditch	**6**
Modoc	Doe-Ritchie - 26	Modoc	**0**
Modoc	Goshen: Doe - 9	Modoc	**30**
Modoc	Shannon-Modoc - 22	Modoc	**8**
Modoc	Willow School - 5	Modoc	**14**
Peoples	Bill Clark - 32	Peoples	**1**
Peoples	Hammer - 31	Peoples	**1**
Peoples	Sunset - 95	Peoples	**95**
Persian	Packwood - 4	Persian	**147**
TID	Abercrombie - 14	TID	**17**
TID	Colpien - 3	TID	**144**
TID	Corcoran Hwy - 8	TID	**106**
TID	Creamline - 16	TID	**133**
TID	Doris - 25	TID	**26**
TID	Enterprise - 2	TID	**18**
TID	Franks - 17	TID	**33**
TID	Franks - 19	TID	**108**
TID	Guinn - 18	TID	**142**
TID	Liberty	TID	**29**
TID	Machado - 6	TID	**128**
TID	Martin	TID	**16**
TID	Swall	TID	**153**
TID	Tagus - 11	TID	**78**
TID	Watte - 20	TID	**14**
		Total	**1,916**

Percolation of Irrigation Return Water

Estimates for percolation of irrigation return water are presented in *Table 25.*

Table 25: Percolation of Irrigation Water and Additional Recharge (AF/WY)

Water Year	Irrigation Return Flow	Additional Recharge
1981	**285,574**	**18,416**
1982	**276,604**	**36,740**
1983	**253,708**	**39,055**
1984	**344,152**	**51,797**
1985	**313,508**	**14,930**
1986	**251,295**	**8,565**
1987	**271,198**	**6,311**
1988	**274,740**	**10,130**
1989	**290,799**	**0**
1990	**285,874**	**219**
1991	**246,574**	**0**
1992	**246,249**	**0**
1993	**245,247**	**8,190**
1994	**247,267**	**0**
1995	**218,632**	**12,491**
1996	**226,064**	**8,161**
1997	**226,793**	**4,342**
1998	**173,211**	**23,281**
1999	**234,804**	**24,943**
2000	**237,762**	**19,190**
2001	**213,593**	**0**
2002	**226,064**	**5,482**
2003	**228,157**	**0**
2004	**219,653**	**2,342**
2005	**208,530**	**34,807**
2006	**230,550**	**18,983**
2007	**236,599**	**6,039**
2008	**229,848**	**1,812**
2009	**220,352**	**1,501**
2010	**216,833**	**15,107**
2011	**243,286**	**33,094**
2012	**236,186**	**0**
2013	**236,137**	**412**
2014	**242,824**	**0**
2015	**225,281**	**0**
2016	**208,859**	**3,142**
2017	**231,809**	**74,633**
Maximum	**344,152**	**74,633**
Minimum	**173,211**	**0**
Average	**243,368**	**13,084**

Percolation of irrigation return water was estimated using two approaches, 1) the earlier (1981 to 1999) period, and 2) the later (2000 to 2017) period. Both approaches were based on the same analysis of "irrigated fields" used in the ditch system percolation analysis. A somewhat simplified version of this method was also utilized for the portion of the basin that are located outside of the KDWCD area.

Since 2000, GIS files of updated irrigated fields were acquired for the entire Subbasin. These were imported into the Davids Engineering database model for the calculation of the annual estimated percolation of irrigation return water for the irrigated fields as described by Davids Engineering (2013 and 2018).The Davids Engineering database model accounts for the agricultural land that has been converted to urban land use over time. The results of the analyses are presented in ***Table 25***. This principal form of groundwater recharge occurs within a relatively narrow range due to the continually-irrigated nature of the agricultural areas and near-constant recharge throughout the Subbasin. The average percolation of irrigation return water was 243,368 AF/WY during the historical (base) period ***Figures 45*** through ***49***, present the estimated distribution of groundwater pumping throughout the Subbasin.

In addition to the percolation calculated by the above method, some additional recharge occurs between the surface water headgate diversion and the fields calculated apart from ditch percolation. In some years, recharge occurs when excess water is delivered to the fields, which is beyond the requirements of the crop, either as additional ditch percolation or direct over-irrigation of the crops via on-farm recharge. On average, the volume of this recharge water is approximately 13,084 AF/WY, which occurs within the irrigated areas that receive surface water throughout the Subbasin.

Percolation of Wastewater

Several municipal WWTPs are operated within the Kaweah Subbasin, the principal ones of which are the cities of Visalia and Tulare, located entirely within MKGSA. Treated wastewater is discharged to holding ponds for percolation, evaporation, or agricultural reuse. Both WWTPs are regulated by Waste Discharge Requirements (WDRs) and Monitoring and Reporting Programs by the RWQCB (Fugro West, 2007). The managers of the two treatment plants were contacted by GSI and Annual Use Monitoring Reports for the City of Tulare were consulted during this analysis. Based on this research, on average, approximately 80 percent of the Visalia WWTP effluent percolates to groundwater while the other 20 percent is applied to adjacent crops. At the city of Tulare's WWTP, on average, 30 percent of the WWTP effluent percolates to groundwater while the other 70 percent is applied to nearby crops. The annual sums of wastewater that percolate to groundwater within MKGSA are presented in ***Table 26***. The table indicates that a total of 16,289 AF/WY of wastewater is recharged to the groundwater reservoir.

Table 26: Wastewater Percolation (AF/WY)

Water Year	Wastewater Percolation
1981	**11,082**
1982	**11,203**
1983	**11,588**
1984	**11,970**
1985	**12,375**
1986	**12,591**
1987	**13,159**
1988	**13,436**
1989	**13,874**
1990	**13,939**
1991	**14,231**
1992	**14,147**
1993	**14,519**
1994	**15,183**
1995	**15,655**
1996	**15,725**
1997	**16,133**
1998	**16,374**
1999	**16,982**
2000	**17,728**
2001	**18,063**
2002	**17,917**
2003	**18,645**
2004	**19,016**
2005	**19,172**
2006	**19,593**
2007	**19,440**
2008	**19,661**
2009	**19,434**
2010	**19,512**
2011	**19,409**
2012	**19,188**
2013	**18,975**
2014	**18,834**
2015	**18,025**
2016	**17,610**
2017	**18,299**
Maximum	**19,661**
Minimum	**11,082**
Average	**16,289**

Outflows from the groundwater system

Outflow from the groundwater system occurs through the following components:

Subsurface outflow,

Agricultural and municipal groundwater pumpage,

Phreatophyte evapotranspiration, and

Evaporation.

Each of these components and the method used for each calculation is presented in this section.

Subsurface Outflow

Subsurface outflow is the flow of groundwater at depth that passes beyond the downgradient boundary of a groundwater basin. As presented on **Table 18**, during the historical base period, a total of 91,139 AF/WY of groundwater flowed out of the Subbasin, while subsurface inflow exceeded subsurface outflow by an average of 64,501 AF/WY.

Agricultural Water Demand and Consumptive Use

Agricultural water demand is the principal component of water use within the Kaweah Subbasin. Similar to and associated with the analysis for percolation of precipitation and percolation of irrigation water, the calculation of the agricultural water demand was calculated using two different methods, each of which are described below.

For the earlier portion of the historical period prior to 2000, the agricultural water demand was based principally on periodic land surveys, which were separated by as many as 10 years (Fugro West, 2007). These methods were updated for the later (2000 to 2017) period, when remote sensing methods were adopted and which incorporated data from satellite images for the period from September 1998 to January 2011 (Davids Engineering, 2013) and again through the end of water year 2017 (Davids Engineering, 2018).

For the later period since 2000, the irrigated fields were input into the Davids Engineering database model (2018) and then queried from the full Subbasin irrigated fields table to return annual estimated gross applied irrigation water for the irrigated fields. Because of the magnitude and importance of this component of water use in the area, considerable database model error checking was performed to verify the accuracy and reasonableness of the data. The Davids Engineering database model accounts for the agricultural land that has been converted to urban land use over time. The results of the gross applied irrigation water analyses indicated that an average of 1,007,363 AF/WY of water, from a combination of surface and groundwater sources, were delivered to the agricultural lands within the Subbasin (***Table 27****Error! Reference source not found.****).***

Table 27: Gross Applied Water to Crops (Acre-Feet/WY)

Water Year	Crop Water Demand
1981	981,809
1982	933,059
1983	855,764
1984	1,160,572
1985	1,057,233
1986	909,899
1987	983,920
1988	997,082
1989	1,055,096
1990	1,037,574
1991	967,375
1992	968,204
1993	964,278
1994	971,984
1995	860,068
1996	965,166
1997	970,414
1998	741,888
1999	953,826
2000	1,013,101
2001	1,016,803
2002	1,072,721
2003	1,061,020
2004	1,087,721
2005	953,219
2006	981,903
2007	1,110,079
2008	1,101,383
2009	1,154,190
2010	1,022,157
2011	1,014,507
2012	1,103,581
2013	1,125,567
2014	1,146,453
2015	1,055,737
2016	964,415
2017	952,655
Maximum	**1,160,572**
Minimum	**741,888**
Average	**1,007,363**

Municipal and Industrial Demand

Municipal and industrial (M&I) pumping from the Subbasin was estimated using a variety of methods. The categories of water users included in this summarized component include:

Urban

Small public water system

Golf course

Dairy

Nursery

Rural domestic

The total M&I groundwater pumping estimate within the Subbasin is the sum of the individual groundwater demands estimated for the components discussed in the following sections. Data used in the M&I groundwater pumping estimate were collected from a variety of sources. Sources of these data include: metered municipal groundwater pumping records, demand estimates based on service connections and categories of facilities, population and dwelling unit density estimates, interviews with various industrial facility managers (nursery, food processing, and packing plants, etc.), and information provided by the County Agricultural Commissioner's Office and the Dairy Advisor. As presented on **Table 28,** M&I demand within the Subbasin averaged approximately 69,040 AF/WY, or 9 percent of the total groundwater pumpage.

Table 28: Municipal and Industrial Demand (AF/WY)

Water Year	Urban Demand	Small Water System Demand	Rural Demand	Golf Course Demand	Dairy Demand	Nursery Demand	Total M&I Demand
1981	26,875	2,824	1,591	1,350	4,545	0	**37,185**
1982	26,425	2,898	1,591	1,350	5,300	0	**37,564**
1983	27,643	2,973	1,591	1,350	6,054	0	**39,611**
1984	31,285	3,046	1,591	1,350	6,808	0	**44,081**
1985	31,951	3,120	1,591	1,350	7,562	0	**45,574**
1986	34,399	3,194	1,591	1,350	8,316	0	**48,850**
1987	35,629	3,268	1,591	1,350	9,071	0	**50,910**
1988	36,110	3,342	1,591	1,350	8,983	0	**51,376**
1989	35,599	3,416	1,591	1,350	10,761	0	**52,717**
1990	37,506	3,490	1,591	1,350	11,222	0	**55,160**
1991	35,415	3,554	1,591	1,350	11,721	500	**54,130**
1992	38,153	3,615	1,591	1,350	12,433	500	**57,641**
1993	38,392	3,680	1,591	1,350	12,354	500	**57,868**
1994	41,359	3,742	1,591	1,350	13,590	500	**62,132**
1995	42,355	3,805	1,591	1,350	15,360	500	**64,961**
1996	44,876	3,863	1,591	1,485	14,581	500	**66,896**
1997	46,368	3,925	1,591	1,485	16,613	500	**70,483**
1998	39,285	3,989	1,591	1,620	16,623	500	**63,607**
1999	46,556	4,051	1,591	1,620	16,632	500	**70,950**
2000	47,129	4,113	1,591	1,620	16,641	500	**71,593**
2001	51,137	4,185	1,591	1,620	16,650	500	**75,683**
2002	54,474	4,266	1,591	1,755	17,550	500	**80,136**
2003	55,696	4,349	1,591	1,755	18,449	500	**82,341**
2004	59,623	4,431	1,591	1,755	19,349	500	**87,250**
2005	57,390	4,515	1,591	1,755	20,249	500	**85,999**
2006	57,932	4,597	1,591	1,485	21,148	500	**87,253**
2007	61,707	4,680	1,591	1,485	22,048	500	**92,010**
2008	62,340	4,763	1,591	1,485	22,947	500	**93,626**
2009	61,376	4,845	1,591	1,485	23,840	500	**93,637**
2010	57,918	4,927	1,591	1,485	24,740	500	**91,161**
2011	56,461	4,953	1,591	1,485	23,463	500	**88,451**
2012	57,977	4,979	1,591	1,485	19,338	500	**85,870**
2013	60,484	5,005	1,591	1,485	20,138	500	**89,203**
2014	54,963	5,031	1,591	1,485	20,138	500	**83,707**
2015	47,889	5,067	1,591	1,215	20,138	500	**76,400**
2016	49,143	5,104	1,591	1,215	20,888	500	**78,440**
2017	51,447	5,177	1,591	1,215	20,088	500	**80,018**
Maximum	**62,340**	**5,177**	**1,591**	**1,755**	**24,740**	**500**	**93,637**
Minimum	**26,425**	**2,824**	**1,591**	**1,215**	**4,545**	**0**	**37,185**
Average	**45,980**	**4,075**	**1,591**	**1,452**	**15,576**	**365**	**69,040**

Urban Demand

Urban groundwater demand in the Subbasin is the demand occurs in the major cities:

Visalia and Tulare (in the MKGSA),

Exeter, Farmersville, Ivanhoe and Woodlake (within the GKGSA), and

Lindsay in the EKGSA, which relies only partially on groundwater to meet demands.

All other water demand in the unincorporated areas are met by small public water systems regulated by the local environmental health departments or by private domestic wells. A summary of annual urban groundwater pumping is presented in **Table 28***Error! Reference source not found.*. As indicated, urban demand increased from from about 26,875 (1981) to 60,484 (2013) AF/WY over the period. Since 2013, when statewide conservation measures were implemented, total urban water demand declined significantly through 2015 to 2017, by which time urban demands had declined to levels not seen since the late 1990s. Urban demand averaged about 45,980 AF/WY over the base period.

Small Water Systems Demand

Analysis of annual water demand for small, regulated public water systems in the Subbasin was accomplished based on data provided previous reports (Fugro West, 2007; Fugro Consultants, 2016) and an analysis of the types of water systems in the area available from the County of Tulare Health and Human Services Agency. The listings of water systems provided information such as the facility identification/name, general location within the respective counties, a code related to the approximate number of service connections for the facility, and a contact name and phone number for each facility. Typical groupings of facility types common to the lists included mutual water companies, schools, mobile home parks, county facilities (e.g. civic centers, road yards), motels, livestock sales yards, and miscellaneous industries such as nurseries, food processing facilities, packing houses, etc.

Approximately one-third of the groundwater pumped by small public water systems occurs in a rural setting. Of this groundwater pumping, approximately 70 percent of the pumped water is believed to return to groundwater via septic system percolation and landscape irrigation return flow, with the remainder being consumptively used (Dziegielewski and Kiefer, 2010). A summary of the net small water system groundwater pumping values is provided in ***Table 28***. Although small in the context of the overall water use, the increase in small water system groundwater demand over the base period was noted and commensurate with population changes within the Subbasin.

Rural Domestic Demand

Rural domestic water demand in the Subbasin consists of the demand of residences not served by a municipal connection, mutual water company, or other small public water system. Rural residential units can be described as "ranchette" type homes of several acres in size with an average of population per dwelling unit of about three people. Net water demand for such dwelling units is on the order of 2 AF/WY.

Unlike the small, public water system demand estimates that were indexed to population changes in Tulare County, the density of rural domestic dwellings has not changed significantly in the Subbasin over the base period, other than being replaced to a small degree by urban expansion. Similar to the rural small water system analysis above, a 70 percent portion of the pumped rural domestic water is assumed to return to groundwater via septic system percolation and irrigation return flows (Dziegielewski and Kiefer, 2010). Throughout the Subbasin, an annual total pumpage for rural users was 2,272 AF/WY on average, 30 percent of which returned to groundwater. Therefore, the net pumpage for rural users was 1,591 AF/WY. The rural domestic groundwater pumping calculations are included on ***Table 28***, and demonstrates demand from rural domestic users is very minor.

Golf Course Demand

Golf courses have operated within the Subbasin for the entire base period and the supply is believed to be groundwater pumping and recycled water from WWTPs. Based on this assumption, golf course demand was calculated using an estimated 300 AFY of demand per 18-holes water duty factor (Fugro West, 2007). It is estimated that 10 percent of the irrigation water applied on the golf courses returns to groundwater via deep percolation (Grismer, 1990; Cahn and Bali, 2015; Ayers and Westcot, 1985). A summary of the golf course groundwater pumping estimates is included in ***Table 28.*** During the base period, between 1,215 and 1,755 AF/WY were pumped, of which between 140 and 200 AF/WY returned to the groundwater reservoir. An average of 1,452 AF/WY of net pumping occurred to satisfy golf course demand.

Dairy Pumping

The dairy industry and related processing and distribution facilities requires a significant amount of water. Estimates of net water consumed by the dairy industry (farms) were based on cow census records maintained by the County and a per-cow based water use factor. Conversations with County personnel indicate the gross daily water use per cow is on the order of 125 gallons per day (gpd). Net water use (after consideration for the recycling of the water for irrigation on adjacent agricultural lands) is on the order of 75 gpd (Fugro West, 2007). Groundwater pumping by dairies in the Subbasin is an average of 15,576 AF/WY (**Table 28**). This volume of net pumping has increased significantly since the beginning of the period when 4,545 AF/WY was pumped (net). Notably, the groundwater demand is influenced directly to dairy cow populations, which are in turn directly affected by the market price for milk. The highest groundwater demand for dairy use was during 2010 when a total of 24,740 AF/WY of (net) groundwater was pumped for dairy uses.

Nursery Demand

The Kaweah Subbasin has a single relatively minor nursery-based agricultural operation that has extracted an estimated average of 500 AF/WY since 1991, which is included in ***Table 28***.

Total M&I Groundwater Pumping

The total M&I groundwater pumping was estimated as the sum of the total pumping for each of the individual components described in the preceding paragraphs. For several of the M&I components, such as small water systems, rural domestic users, and golf courses, a portion of the pumped groundwater deep percolates and returns to the groundwater reservoir. A summary of the total M&I groundwater pumping calculations is included in ***Table 28*** which indicates that total M&I demand, satisfied mainly by groundwater sources, averaged 69,040 AF/WY.

Agricultural Pumping

The principal groundwater outflow from the Subbasin is pumping to satisfy irrigated agriculture. 91 percent of the total groundwater pumpage is used to fulfill this demand.

The distribution of groundwater pumping in the Subbasin for the irrigation of agriculture has been determined based on the spatial distribution of crop water demand and annual surface water delivery to individual surface water appropriator service areas (***Figures 50 through 54***). Crop water demand was calculated using two different methods for the 37-year period of record, as discussed earlier. Briefly, the analysis for water years prior to 2000 using estimated crop water use based on DWR land use surveys and irrigation efficiency factors (Fugro West, 2007). The analysis for water years from 2000 onward was completed by Davids Engineering (2018) using satellite data to calculate the NDVI. A detailed spatial distribution of crop water demand is available from the NDVI analysis method.

Surface water deliveries to crops from a combination of local Kaweah River and imported (CVP and Kings River) water sources for the 37-year period of record have been calculated by appropriator service area. Because the spatial distributions of surface water deliveries within each service area are unknown, it is assumed that surface water deliveries are distributed evenly across the irrigated fields within each service area. The current extent of irrigated agricultural land and the establishment of surface water appropriators in the Kaweah Subbasin was fully developed well before the beginning of the historical base period (B-E, 1972 and Fugro West, 2007). The appropriator service areas have remained essentially unchanged since that time. The only minor changes that have taken place are isolated conversions of agricultural lands to urban development (Davids Engineering, 2018) and conversion of land use within each service area. These minor changes to appropriator service areas have been accounted for in the surface water delivery analysis.

To determine distributions of groundwater pumping in the Subbasin for irrigated agriculture, the surface water volumes distributed among the known-irrigated fields within each service area were subtracted from the spatially precise NDVI crop water demand dataset, using the following equation:

$$AP = CD - SWc$$

where: AP = Agricultural Pumping

CD = Agricultural Crop Demand

SWc = Surface Water Crop Delivery

On average, a total of 685,375 AF/WY was pumped from the groundwater reservoir as shown on **Table 29**. This ranged from a low of 237,278 AF/WY in 1998, which was the wettest year of the period, and a high of over 1,065,530 AF/WY in 2014 during the recent drought and associated lack of imported surface water.

Table 29: Groundwater Pumping for Irrigated Agriculture (AF/WY)

Water Year	Ag Irrigation Pumping
1981	**721,553**
1982	**439,395**
1983	**307,540**
1984	**715,245**
1985	**756,074**
1986	**423,077**
1987	**776,072**
1988	**787,884**
1989	**820,783**
1990	**889,919**
1991	**723,721**
1992	**787,119**
1993	**528,788**
1994	**775,625**
1995	**360,849**
1996	**507,553**
1997	**532,683**
1998	**237,278**
1999	**622,587**
2000	**657,015**
2001	**766,328**
2002	**796,166**
2003	**721,257**
2004	**850,570**
2005	**502,543**
2006	**512,464**
2007	**946,886**
2008	**816,843**
2009	**870,526**
2010	**590,752**
2011	**511,468**
2012	**883,485**
2013	**992,285**
2014	**1,065,530**
2015	**989,938**
2016	**727,703**
2017	**443,360**
Maximum	**1,065,530**
Minimum	**237,278**
Average	**685,375**

The results of the analysis for water years 1999, 2001, 2006, 2015 and 2016 are presented on *Error! Reference source not found.* through *Error! Reference source not found.*. As expected, the results of this analysis show a pattern of increased agricultural pumping during drought periods to compensate for a reduction in surface water deliveries to irrigated lands from both local and imported sources and a commensurate increase in crop water demand. Pronounced increases in agricultural pumping occurred during extended periods of drought, such as the 2011 to 2015 period when imported water supplies were limited or non-existent.

During the following three periods, notable groundwater pumping increases occurred to satisfy agricultural demand:

Between 1987 and 1992 when annual pumpage averaged 800,000 AF/WY;

Between 2007 and 2009, when average pumpage for agriculture averaged 878,000 AF/WY; and

Between 2012 and 2016 when average pumpage for agriculture exceeded 931,200 AF/WY.

Based upon this analysis and as shown on *Error! Reference source not found.* through *Error! Reference source not found.,* the following key observations regarding changes in water usage over the entire base period are noted:

Groundwater pumping for agricultural uses has varied with surface water availability, but has increased at an average of 0.8% per year (5,500 AF/WY on average);

crop water demand has increased modestly (at a rate of 0.3% or 2,800 AF/WY);

surface water deliveries have declined at a rate of 1% or (-3,000 AF/WY on average); and

since 1999, groundwater pumping has increased at a rate of 1.2% or 6,500 AF/WY.

Phreatophyte Extractions

Phreatophyte extraction refers to groundwater use by vegetation with roots extending into groundwater in riparian areas. Phreatophyte extractions within the Subbasin constitute a minor outflow component and were estimated in a manner constant with previous estimates (Fugro West, 2007). The results of phreatophyte extraction analysis are presented in*Error! Reference source not found.* **Table 30**, which indicate that this component constitutes a minor extraction from the groundwater reservoir (480 AF/WY).

Table 30: Phreatophyte Extractions (Acre-Feet/WY)

Water Year	Phreatophyte Extractions
1981	**411**
1982	**692**
1983	**727**
1984	**280**
1985	**406**
1986	**672**
1987	**385**
1988	**491**
1989	**370**
1990	**258**
1991	**400**
1992	**451**
1993	**630**
1994	**376**
1995	**870**
1996	**545**
1997	**589**
1998	**1,075**
1999	**455**
2000	**537**
2001	**478**
2002	**493**
2003	**412**
2004	**377**
2005	**575**
2006	**730**
2007	**178**
2008	**237**
2009	**303**
2010	**523**
2011	**645**
2012	**207**
2013	**209**
2014	**219**
2015	**291**
2016	**462**
2017	**660**
Maximum	**1,075**
Minimum	**178**
Average	**476**

2.5.1.4 Change in Storage §354.16 (b)

Annual variations in the volumes of groundwater in storage in the Subbasin were calculated for each year of the historical (base) period. The changes in storage for the 37-year period were used to evaluate conditions of water supply surplus and deficiency, and in identifying conditions of long-term overdraft.

As shown on **Table 31** and **Figure 55** below, there was an accumulated water supply deficiency of 2,428,487 AF over the 37-year study period, or an average deficit of 65,635 AF/WY.

Prior to 2000, a net surplus occurred throughout the Subbasin as calculated by this method, when inflows exceeded outflows by 323,000 AF, or an average of 17,900 AF/WY.

Between 1999 and 2017, when surface water supplies were occasionally unavailable and precipitation was low, the groundwater reservoir lost 2,176,000 AF, or an average of 143,000 AF/WY.

Table 31: Change of Groundwater in Storage (Acre-Feet/WY)

Water Year	Total Inflow	Total Outflow	Inflow - Outflow	Cumulative Change in Storage
1981	578,407	875,019	(296,613)	**(296,613)**
1982	1,033,218	590,880	442,338	**145,725**
1983	1,216,750	464,621	752,129	**897,854**
1984	849,328	873,998	(24,670)	**873,184**
1985	629,499	854,223	(224,724)	**648,461**
1986	993,150	529,801	463,349	**1,111,809**
1987	531,995	925,272	(393,277)	**718,533**
1988	583,340	966,953	(383,613)	**334,919**
1989	450,046	950,735	(500,689)	**(165,770)**
1990	428,276	979,969	(551,692)	**(717,462)**
1991	557,081	835,059	(277,978)	**(995,440)**
1992	512,440	971,114	(458,674)	**(1,454,115)**
1993	965,324	702,939	262,385	**(1,191,730)**
1994	530,796	956,997	(426,201)	**(1,617,930)**
1995	1,101,727	539,252	562,475	**(1,055,455)**
1996	917,345	660,958	256,386	**(799,069)**
1997	1,023,840	703,536	320,304	**(478,765)**
1998	1,164,159	398,369	765,791	**287,026**
1999	767,406	731,503	35,903	**322,929**
2000	795,440	789,818	5,622	**328,550**
2001	624,469	925,262	(300,793)	**27,758**
2002	678,906	969,061	(290,155)	**(262,397)**
2003	756,815	903,916	(147,101)	**(409,498)**
2004	589,036	1,034,025	(444,990)	**(854,487)**
2005	1,074,278	667,099	407,179	**(447,309)**
2006	1,072,676	666,545	406,131	**(41,178)**
2007	547,132	1,143,054	(595,922)	**(637,100)**
2008	656,721	1,079,896	(423,174)	**(1,060,274)**
2009	650,083	1,121,433	(471,350)	**(1,531,624)**
2010	947,309	803,915	143,394	**(1,388,230)**
2011	1,281,167	667,375	613,792	**(774,438)**
2012	662,047	1,040,730	(378,682)	**(1,153,120)**
2013	568,489	1,191,559	(623,070)	**(1,776,190)**
2014	539,217	1,246,520	(707,303)	**(2,483,494)**
2015	534,967	1,150,819	(615,852)	**(3,099,346)**
2016	713,134	903,004	(189,870)	**(3,289,216)**
2017	1,455,261	594,532	860,729	**(2,428,487)**
Maximum	**1,455,261**	**1,246,520**	**860,729**	
Minimum	**428,276**	**398,369**	**-707,303**	
Average	**783,278**	**848,912**	**-65,635**	

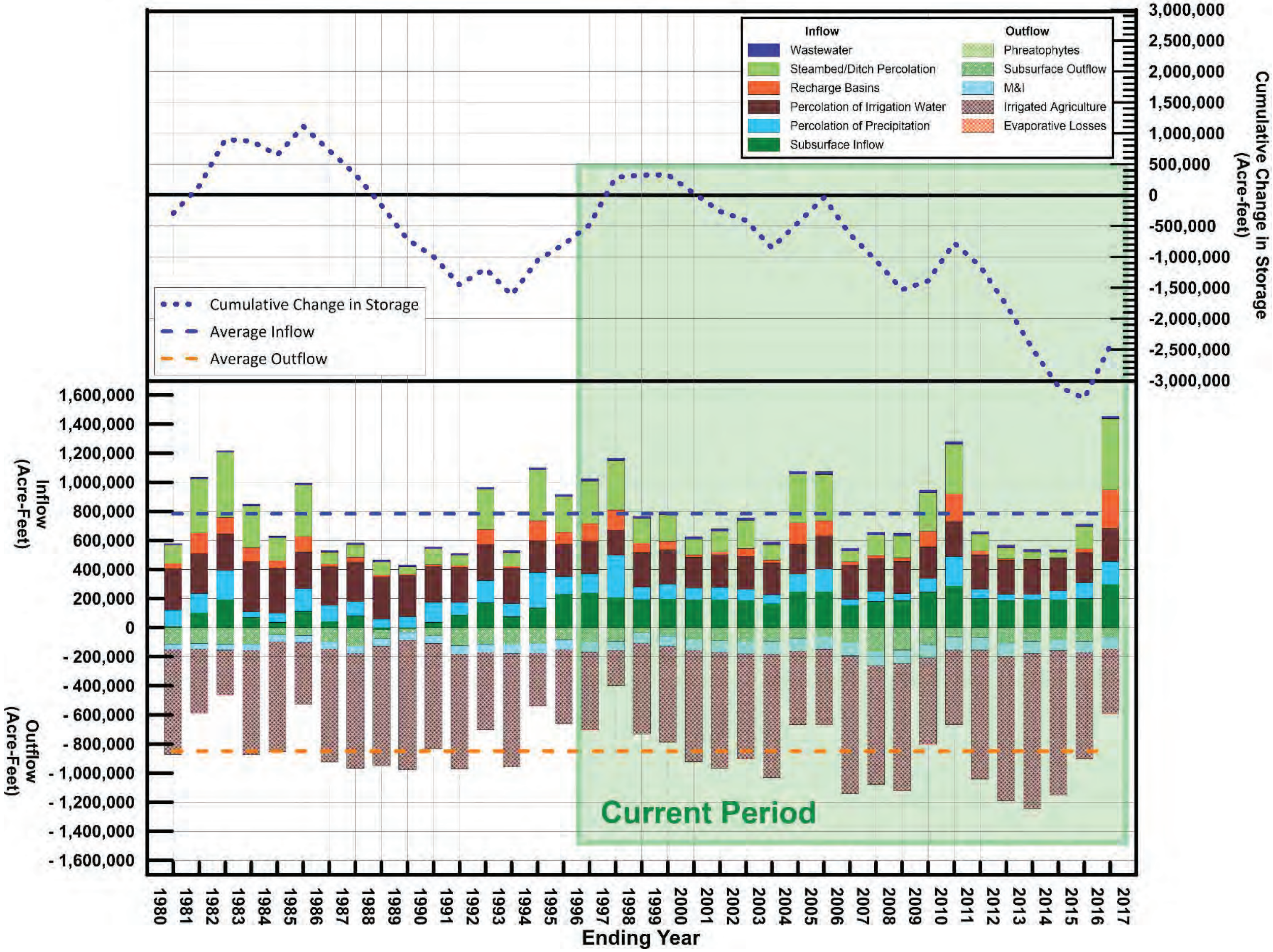


Figure 55: Kaweah Subbasin Hydrologic Budget Summary, Historical and Current Periods

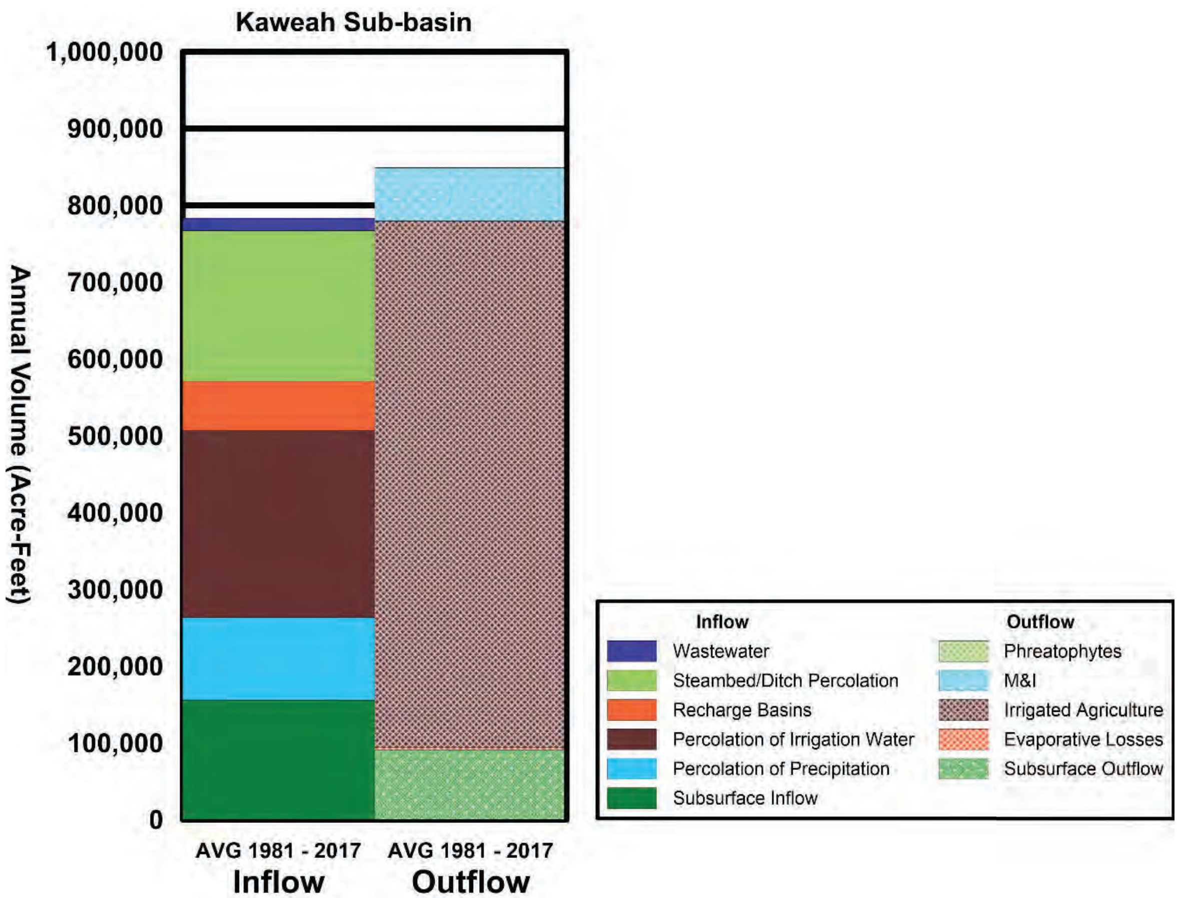


Figure 56: Kaweah Subbasin Hydrologic Budget Average, Historical Period

Figure 56 presents the annual amounts of each component of deep percolation and extractions within the Subbasin as computed using the hydrologic equilibrium equation (the "inventory method"). The results of the water budget show that the Kaweah Subbasin is in a severe overdraft during the historical period of water years 1981 to 2017. The magnitude of the overdraft for the Kaweah Subbasin during the overall base period was 65,600 AF/WY on average, which increased to 142,900 AF/WY since 1999.

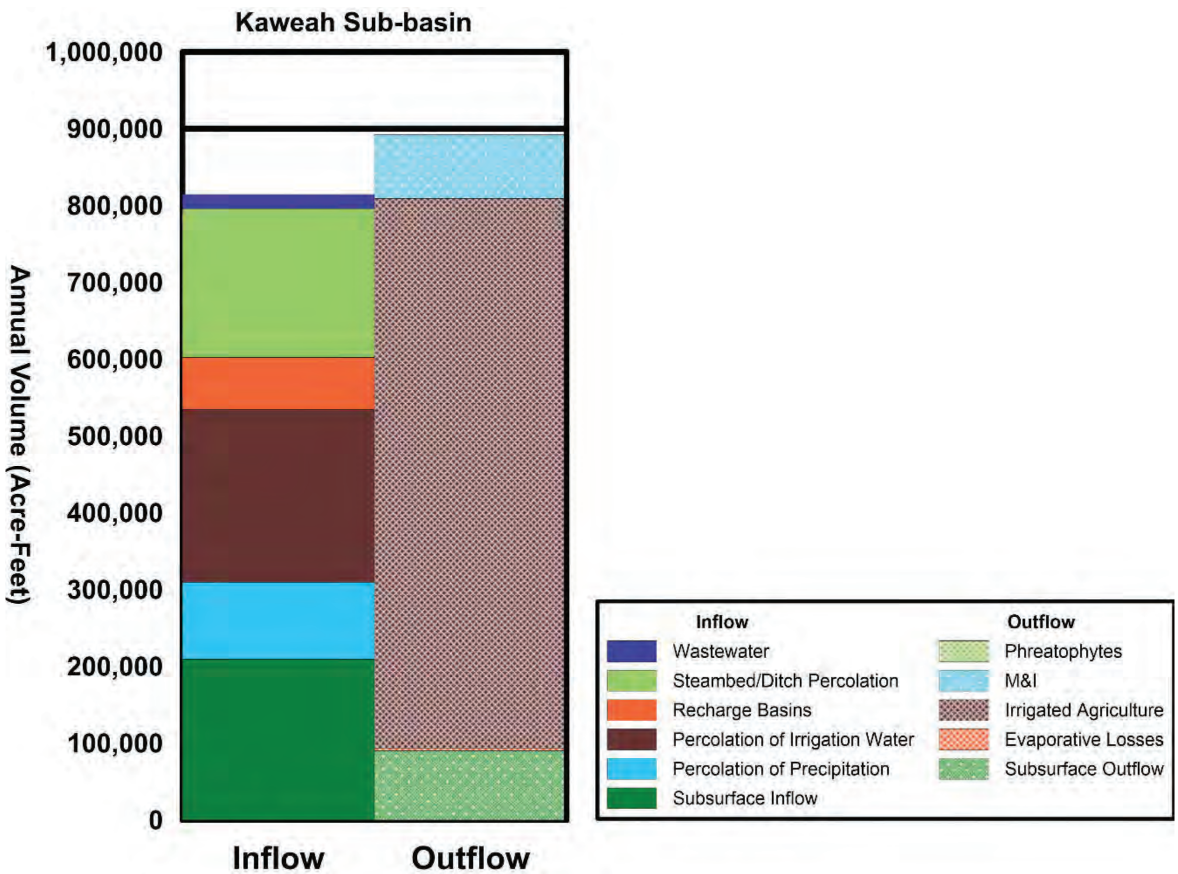


Figure 54: Kaweah Subbasin Hydrologic Budget Average, Current Period

Figure 57 summarizes the current water budget components. The results of the water budget for the current water budget show the magnitude of the overdraft for the Kaweah Subbasin during the overall base period was is 77,600 AF/WY on average for the period 1997 to 2017. **Table 32** summarizes each component of the current water budget by year and shows a total decrease in storage during the period of 1.630 MAF.

Table 32: Current Period - Estimated Deep Percolation, Extractions and Change in Storage - Kaweah Subbasin (values in 1,000s AF)

Water Year	Rainfall: Inches	Rainfall: % of Average	Components of Inflow: Subsurface Inflow	Components of Inflow: Wastewater Inflow	Components of Inflow: Steambed Percolation and Conveyance Losses	Components of Inflow: Percolation of Recharge Basins	Components of Inflow: Percolation of Irrigation Water	Components of Inflow: Percolation of Precipitation (Crop and Non-Ag Land)	Components of Outflow: Groundwater Pumpage: M & I	Components of Outflow: Groundwater Pumpage: Gross Applied Irrigation Water (Crop Water Demand)	Components of Outflow: Groundwater Pumpage: Delivered Surface Water	Components of Outflow: Groundwater Pumpage: *GW Pumping for Irrigated Agriculture*	Components of Outflow: Groundwater Pumpage: *Total Net Extraction*	Components of Outflow: Extraction by Phreatophytes	Components of Outflow: Evaporative Losses	Components of Outflow: Subsurface Outflow	*Total Inflow*	*Total Outflow*	Change in Storage: *Inventory Method*	Cumulative Change in Storage: *Inventory Method*
1997	12.5	128%	238.9	16.1	292.1	118.5	226.8	131.5	70.5	970.4	442.1	*532.7*	*603.2*	0.6	3.3	96.5	*1,023.8*	*703.5*	*320.3*	*320.3*
1998	22.8	234%	208.4	16.4	338.4	138.9	173.2	288.8	63.6	741.9	527.9	*237.3*	*300.9*	1.1	3.3	93.1	*1,164.2*	*398.4*	*765.8*	*1,086.1*
1999	9.6	99%	194.1	17.0	168.5	67.0	234.8	86.0	70.9	953.8	356.2	*622.6*	*693.5*	0.5	2.1	35.4	*767.4*	*731.5*	*35.9*	*1,122.0*
2000	11.4	117%	197.9	17.7	183.1	56.8	237.8	102.1	71.6	1,013.1	375.3	*657.0*	*728.6*	0.5	2.9	57.7	*795.4*	*789.8*	*5.6*	*1,127.6*
2001	10.1	103%	192.0	18.1	106.3	14.4	213.6	80.1	75.7	1,016.8	250.5	*766.3*	*842.0*	0.5	2.8	80.0	*624.5*	*925.3*	*-300.8*	*826.8*
2002	10.4	107%	192.2	17.9	138.1	20.3	226.1	84.3	80.1	1,072.7	282.0	*796.2*	*876.3*	0.5	2.8	89.4	*678.9*	*969.1*	*-290.2*	*536.7*
2003	8.7	90%	187.7	18.6	193.9	53.1	228.2	75.2	82.3	1,061.0	339.8	*721.3*	*803.6*	0.4	3.0	96.9	*756.8*	*903.9*	*-147.1*	*389.6*
2004	8.0	82%	164.5	19.0	105.1	19.0	219.7	61.8	87.3	1,087.7	239.5	*850.6*	*937.8*	0.4	2.4	93.4	*589.0*	*1,034.0*	*-445.0*	*-55.4*
2005	12.2	125%	246.9	19.2	332.6	145.9	208.5	121.2	86.0	953.2	485.5	*502.5*	*588.5*	0.6	3.1	74.9	*1,074.3*	*667.1*	*407.2*	*351.8*
2006	15.4	159%	247.3	19.6	317.6	102.6	230.5	155.0	87.3	981.9	488.4	*512.5*	*599.7*	0.7	4.8	61.3	*1,072.7*	*666.5*	*406.1*	*757.9*
2007	3.8	39%	154.1	19.4	73.8	21.9	236.6	41.4	92.0	1,110.1	169.2	*946.9*	*1,038.9*	0.2	2.5	101.4	*547.1*	*1,143.1*	*-595.9*	*162.0*
2008	5.0	52%	180.8	19.7	140.9	18.8	229.8	66.7	93.6	1,101.4	286.4	*816.8*	*910.5*	0.2	3.0	166.2	*656.7*	*1,079.9*	*-423.2*	*-261.2*
2009	6.4	66%	186.6	19.4	151.0	24.3	220.4	48.5	93.6	1,154.2	285.2	*870.5*	*964.2*	0.3	3.0	154.0	*650.1*	*1,121.4*	*-471.4*	*-732.6*
2010	11.1	114%	246.0	19.5	264.0	109.2	216.8	91.7	91.2	1,022.2	446.5	*590.8*	*681.9*	0.5	4.0	117.5	*947.3*	*803.9*	*143.4*	*-589.2*
2011	13.7	140%	288.1	19.4	340.7	188.9	243.3	200.8	88.5	1,014.5	536.7	*511.5*	*599.9*	0.6	3.8	63.0	*1,281.2*	*667.4*	*613.8*	*24.6*
2012	4.4	45%	199.9	19.2	116.3	26.1	236.2	64.4	85.9	1,103.6	220.1	*883.5*	*969.4*	0.2	2.9	68.3	*662.0*	*1,040.7*	*-378.7*	*-354.1*
2013	4.4	45%	187.3	19.0	75.4	8.1	236.1	42.6	89.2	1,125.6	133.7	*992.3*	*1,081.5*	0.2	2.2	107.6	*568.5*	*1,191.6*	*-623.1*	*-977.1*
2014	4.7	48%	193.7	18.8	50.0	0.3	242.8	33.6	83.7	1,146.5	80.9	*1,065.5*	*1,149.2*	0.2	3.2	93.9	*539.2*	*1,246.5*	*-707.3*	*-1,684.4*
2015	6.2	63%	191.7	18.0	37.2	0.4	225.3	62.4	76.4	1,055.7	65.8	*989.9*	*1,066.3*	0.3	2.1	82.1	*535.0*	*1,150.8*	*-615.9*	*-2,300.3*
2016	9.8	100%	200.8	17.6	152.2	25.2	208.9	108.4	78.4	964.4	239.9	*727.7*	*806.1*	0.5	2.8	93.6	*713.1*	*903.0*	*-189.9*	*-2,490.1*
2017	14.0	143%	296.6	18.3	489.3	261.1	231.8	158.1	80.0	952.7	583.9	*443.4*	*523.4*	0.7	4.0	66.5	*1,455.3*	*594.5*	*860.7*	*-1,629.4*
Maximum	22.8	234%	296.6	19.7	489.3	261.1	243.3	288.8	93.6	1,154.2	583.9	1,065.5	1,149.2	1.1	4.8	166.2	1,455.3	1,246.5	860.7	-81470.9
Minimum	3.8	39%	154.1	16.1	37.2	0.3	173.2	33.6	63.6	741.9	65.8	237.3	300.9	0.2	2.1	35.4	535.0	398.4	-707.3	
Average	**9.7**	**100%**	**209.3**	**18.5**	**193.6**	**67.7**	**225.1**	**100.2**	**82.3**	**1,028.7**	**325.5**	**716.1**	**798.4**	**0.5**	**3.1**	**90.1**	**814.4**	**892.0**	**-77.6**	
% of Total			26%	2%	24%	8%	28%	12%	9%			80%		0.05%	0.34%	10%				
			100%						100%											

Italic = Calculation
= Component of Inflow
= Component of Outflow

Specific Yield

One additional method of determining the annual change of groundwater in storage involves use of the specific yield method, which is based on water level contour maps created for key years throughout the Subbasin. To that end, groundwater contour maps were prepared for every year of the historical period by plotting water level data and accurately contouring the water surfaces. The contours of the water level surfaces represent spring conditions, based on as many as 655 wells evenly distributed throughout the Subbasin.

The storage calculations involved creating automated routines in GIS to develop a gridded surface, which were used to calculate the changes in water levels between the spring period of three key years of 1981, 1999 and 2017. The water surface changes were then integrated with the specific yield data available for the basin and described in Section 2.1.6.2 Physical Characteristics to calculate total change in basin storage.

Results of the analysis indicated that water levels declined by a total of 74 feet during the 37-year historic period on average throughout the Subbasin. During this period, a water supply deficiency of 3,127,300 AF has occurred, which is equal to an average rate of decline of 84,500 AF/WY. During the more recent (modeling) period since 2000, the water supply deficiency was approximately 2,948,600 AF, which is equal to a higher average rate of decline of 163,800 AF/WY. During this modeling period, water levels declined by a total of 70 feet on average throughout the subbasin. The results indicate that the water budget and specific yield methods are in general agreement, indicating that water supply deficiency in the Subbasin during the historical period was between 2,430,000 AF (water budget method) and 3,127,000 AF (specific yield method). During the more-recent modeling period since 2000, when water budget (inventory method) data quality is higher and thought to be more reliable, the agreement between the two methods is much better. During this modeling period the total water supply deficit was between 2,660,000 and 2,950,000 AF, or roughly 148,000 to 155,000 AF/WY.

Safe Yield

The safe or perennial yield of a groundwater basin, when discussed in SGMA, is defined as the volume of groundwater that can be pumped on a long-term average basis without producing an undesirable result. Long-term withdrawals in excess of safe yield is considered overdraft. While the definition of "undesirable results" mentioned in the definition have changed in recent years and have now been codified in SGMA regulations, they are recognized to include not only the depletion of groundwater reserves, but also deterioration in water quality, unreasonable and uneconomic pumping lifts, creation of conflicts in water rights, land subsidence, and depletion of streamflow by induced infiltration (Freeze and Cherry, 1979). It should be recognized that the concepts of safe yield and overdraft imply conditions of water supply and use over a long-term period. Given the importance of the conjunctive use of both surface water and groundwater in the Subbasin, short-term water supply differences are satisfied by groundwater pumpage, which in any given year, often exceed the safe yield of the Subbasin. The Subbasin, however, has a very large amount of groundwater in storage that can be used as carryover storage during years when there is little natural recharge, and replaced in future years by reduced pumping (when surface water is available instead or from various types of projects, including, for instance, artificial recharge), or by groundwater recharge projects.

While safe yield of the Subbasin is difficult to estimate due to the inherent uncertainties in the estimates of recharge and discharge, there are several methods available to estimate the safe yield under the conditions of water supply and use that prevailed during the 37-year historical base period. Use of these methods requires acknowledgement of the inherent uncertainties in the estimates of recharge and discharge as well as the challenges associated with calculating the changes of groundwater in storage in the confined "pressure" area of the Subbasin.

The first methods assumes that the safe yield is equal to the long-term recharge inflow, calculated as the total inflow minus the annual overdraft. Although there are considerable assumptions used to estimate each component of inflow in the hydrologic equation, the results of this method suggest that the safe yield of the Subbasin would be approximately 717,800 AF/WY (summation of the components of inflow, that is 783,300 AF/WY, less the average annual overdraft, which is about 65,600 AF/WY). This average is approximate and does not encompass the non-uniformity in safe yield application across the entire basin. Based on the water budget for the historical period, discharge from the Subbasin exceeded recharge by some 65,600 AF/WY, resulting in a decline in water levels. Imbalances of pumping demand related to patterns of land use over the base period are apparent, which created a progressive lowering of water levels.

A second method to estimate the safe yield is to compare the annual extractions over the base period to the net changes of groundwater in storage. The resulting graphs provide the rate of extraction in which there is a zero-net change of groundwater in storage. This method, the so-called "practical rate of withdrawal," is a useful method so long as the coefficient of correlation between annual pumpage and storage changes is sufficiently robust and the calculated annual values of inflow and outflow are relatively accurate. Estimates compiled for this GSP are believed to be reasonably accurate in the estimates of annual groundwater extractions. Likewise, annual storage change estimates are also believed to be reasonably accurate, based on the distribution of wells and frequency of water level measurements. As presented on **Figure 58**, the intercept of zero storage change occurs at an annual pumpage of about 723,000 AFY, implying that net annual groundwater extractions at this approximate amount would produce no change of groundwater in storage.

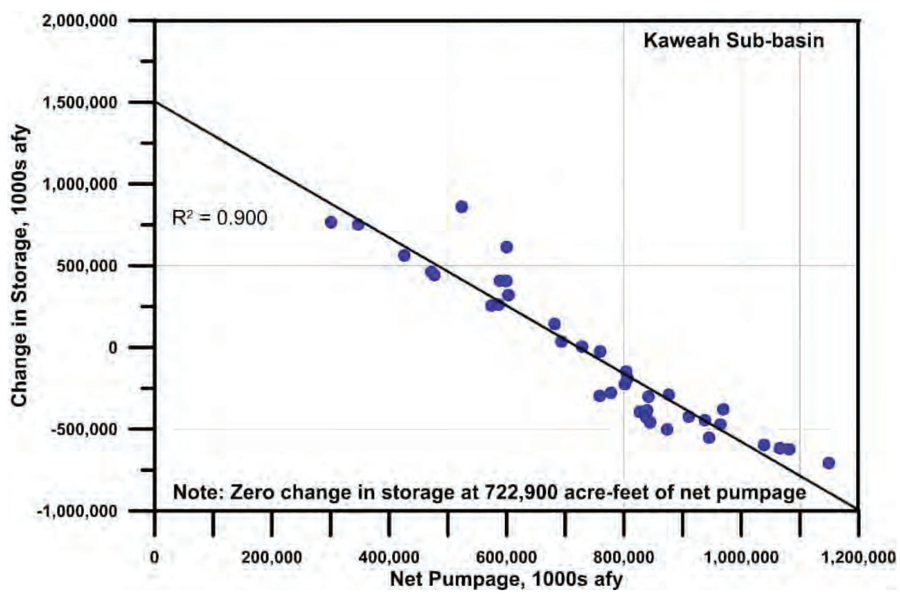


Figure 58. Practical Rate of Withdrawal

A summary of the safe yield estimates is provided in **Table 33**, which indicates that the safe yield of the Kaweah Subbasin is approximately 720,000 AFY. Based on the above, under the current conditions of development and water supply, it is apparent that the Subbasin is in a condition of overdraft.

Table 33: Estimated Safe Yield, Historical Period (AFY)

Method	Safe Yield
Long-term Recharge	717,800
Practical Rate of Withdrawal	722,900

The estimates of safe yield will be refined with the forthcoming predictive numerical model runs with the Kaweah Subbasin groundwater model and will then will also be re-visited through the planning and implementation phase of the SGMA process. Furthermore, the safe yield estimate will likely be superseded by forthcoming sustainable yield values for the basins to avoid undesirable results and achieve measurable objectives.

2.5.2 Projected/Future Water Budget

The GSP regulations require the following regarding Projected water budgets:

> "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."
>
> "Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology…"
>
> "Projected water demand shall utilize the most recent land use, evapotranspiration, and crop coefficient information as the baseline condition for estimating future water demand…"
>
> "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."

The subsurface inflow and outflow components of the future water budget in the Kaweah Subbasin will be estimated through application of the numerical groundwater model. Alternative future water supply and demand scenarios will be developed in coordination with the GSA managers as input to the numerical groundwater model. This section briefly describes the estimated components of the future water budget impacted by climate change and legal/environmental water reallocations on supply availability and projected water demands.

2.5.2.1 Climate Change Analysis and Results

SGMA requires local agencies developing and implementing GSPs to include water budgets which assess the current, historical, and projected water budgets for the basin, including the effects of climate change. Additional clarification can be found in DWR's Water Budget and Modeling BMPs which describe the use of climate change data to compute projected water budgets and simulate related actions in groundwater/surface water models. DWR has also provided SGMA Climate Change Data and published a Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development (Guidance Document) as the primary source of technical guidance.

The DWR-provided climate change data are based on the California Water Commission's Water Storage Investment Program (WSIP) climate change analysis results which used global climate models and radiative forcing scenarios recommended for hydrologic studies in California by the Climate Change Technical Advisory Group (CCTAG). Climate data from the recommended GCM models and scenarios have also been downscaled and aggregated to generate an ensemble time series of change factors which describe the projected change in precipitation and evapotranspiration values for climate conditions that are expected to prevail at mid-century and late-century, centered around 2030 and 2070, respectively. The DWR dataset also includes two additional simulation results for extreme climate scenarios under 2070 conditions. Use of the extreme scenarios which represent Drier/Extreme Warming (2070DEW) and Wetter/Moderate Warming (2070WMW) conditions in GSPs is optional.

This section describes the retrieval, processing, and analysis of DWR-provided climate change data to project the impact of climate change on precipitation, evapotranspiration, upstream inflow, and imported flows in the Kaweah Subbasin under 2030 and 2070 conditions. The precipitation and evapotranspiration change projections are computed relative to a baseline period of 1981 to 2010 and are summarized for the EKGSA, GKGSA and MKGSA areas. For upstream inflow into Kaweah Lake and imported water from the Friant-Kern Canal, change projections are computed using a baseline period of 1981 to 2003. The choice of baseline periods was selected based on the baseline analysis period for the Basin Settings report (which includes water years from 1981 to 2017), and the available of concurrent climate projections (calendar years 1915 to 2011) and derived hydrologic simulations (water years 1922 to 2011) from the SGMA Data Viewer.

Data Processing

The 2030 and 2070 precipitation and ET data are available on 6 km resolution grids. The climate datasets have also been run through a soil moisture accounting model known as the Variable Infiltration Capacity (VIC) hydrology model and routed to the outlet of subbasins defined by 8-digit Hydrologic Unit Codes (HUCs). The resulting downscaled hydrologic time series are available also on the SGMA Data Viewer hosted by DWR. Precipitation and ET data used in this analysis were downloaded from the SGMA Data Viewer for 69 climate grid cells covering the Kaweah Subbasin. Separate monthly time series of change factors were developed for each of the three Kaweah Subbasin GSAs by averaging grid cell values covering each GSA area. Monthly time series of change factors for inflow into Kaweah Lake and flow diversions from the Friant-Kern Canal were similarly retrieved from the SGMA Data Viewer. Mean monthly and annual values were computed from the subbasin time series to show projected patterns of change under 2030 and 2070 conditions.

Projected Future Changes in Evapotranspiration

Crops require more water to sustain growth in a warmer climate, and this increased water requirement is characterized in climate models using the rate of evapotranspiration. Under 2030 conditions, all three GSAs in the Kaweah Subbasin are projected to experience annual increases of 3.2% relative to the baseline period. ***Table 34; Figures 59 and 60*** signify the largest monthly changes would occur in Winter and early Summer with projected increases of 4.3% to 4.8% in January and 3.8% to 4% in June. Under 2070 conditions, annual evapotranspiration is projected to increase by 8.2% relative to the baseline period in all three GSA areas. The largest monthly changes would occur in December with projected increases of between 12.8% to 13.5%. Summer increases peak approximately 8% in May and June.

Table 34: Summary of Projected Changes in Evapotranspiration

	East Kaweah	Greater Kaweah	Mid-Kaweah	Largest Monthly Change	Month of Largest Change
Projected ET Change 2030	103.2%	103.2%	103.2%	4.6%	Jan
Projected ET Change 2070	108.2%	108.2%	108.2%	13.5%	Dec

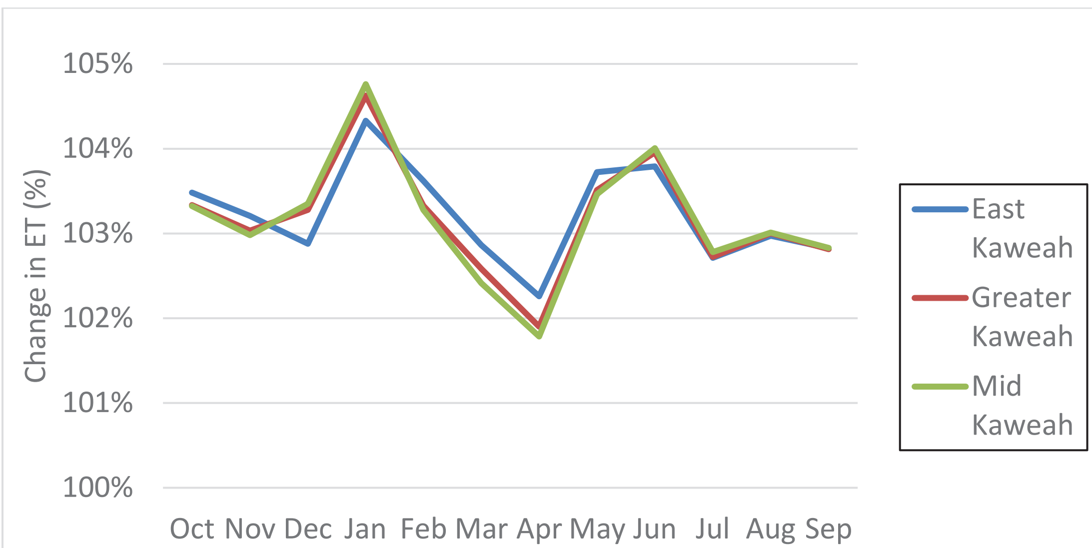


Figure 59: Evapotranspiration Projections under 2030 Conditions

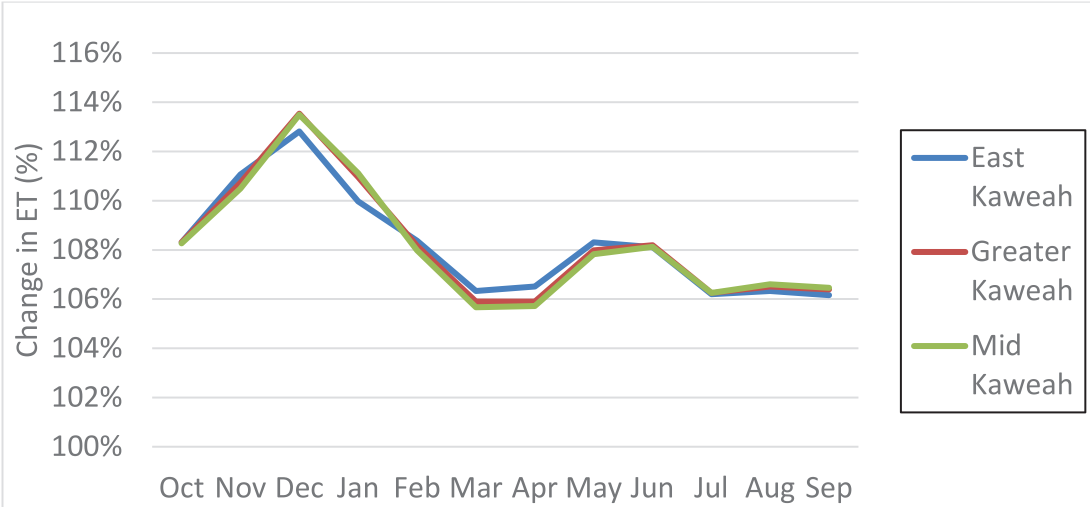


Figure 60: Evapotranspiration Projections under 2070 Conditions

Projected Future Changes in Precipitation

The seasonal timing of precipitation in the Kaweah Subbasin is projected to change. Sharp decreases are projected early Fall and late Spring precipitation accompanied by increases in Winter and Summer precipitation. ***Table 35; Figures 61 and 62*** display that under 2030 conditions, the largest monthly changes would occur in May with projected decreases of 14% while increases of approximately 9% and 10% are projected in March and August, respectively. Under 2070 conditions, decreases of up to 31% are projected in May while the largest increases are projected to occur in September (25%) and January (17%). All three GSA areas are projected to experience minimal changes in total annual precipitation. Annual increases in annual precipitation of 0.8% or less under 2030 conditions relative to the baseline period. Under 2070 conditions, small decreases in annual precipitation are projected with changes ranging from 0.6% in East Kaweah to 1.7% in Greater Kaweah and 1.9% in Mid-Kaweah.

Table 35: Summary of Projected Changes in Precipitation

	East Kaweah	Greater Kaweah	Mid-Kaweah	Largest Monthly Change	Month of Largest Change
Projected Precipitation Change 2030	100.4%	100.8%	100.8%	-14%	May
Projected Precipitation Change 2070	99.4%	98.3%	98.1%	25%	Sep

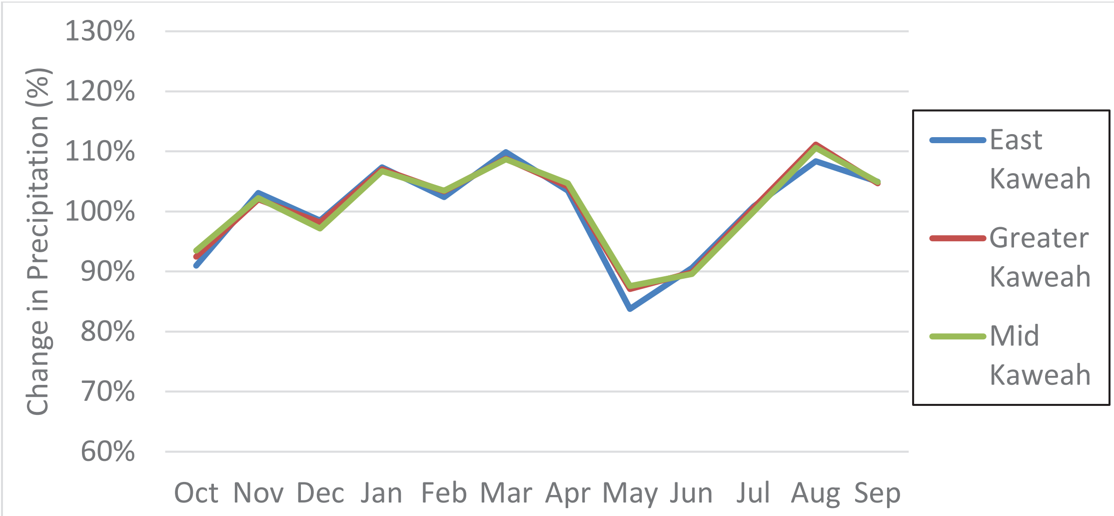


Figure 61: Precipitation Projections under 2030 Conditions

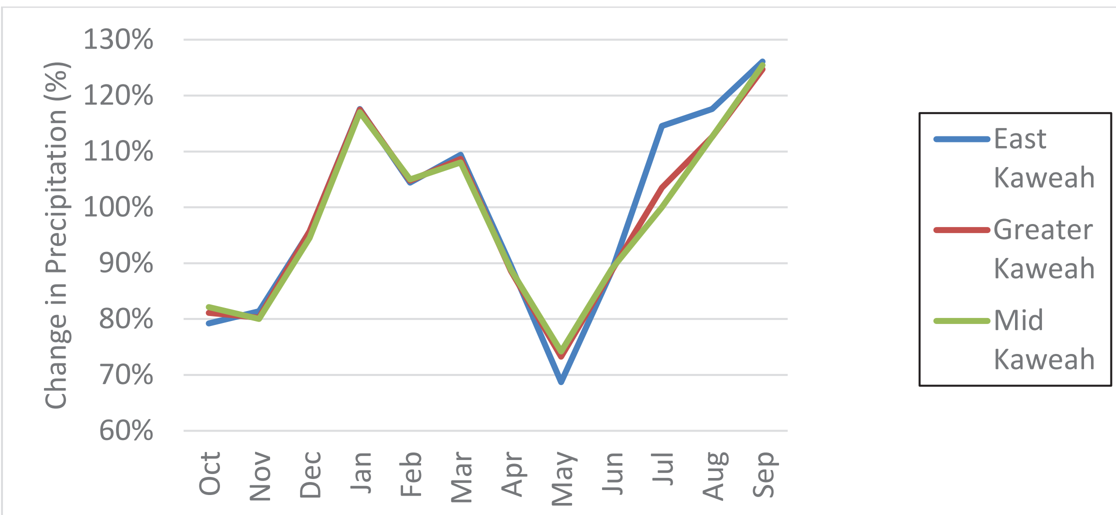


Figure 62: Precipitation Projections under 2070 Conditions

Projected Future Changes in Full Natural Flow

The quantity of inflows into Kaweah Lake, which is the main source of local water, are projected to decrease from 465 trillion acre-feet (TAF) per year under current climate conditions to 442 TAF under both 2030 and 2070 conditions. ***Figure 63*** shows peak flows are similarly projected to decrease from monthly peaks of 102 TAF under current climate conditions to 82 TAF by 2030 followed by a minimal decline to 81 TAF under 2070 conditions. However, significant changes in the seasonal timing of flows are expected. Under current and 2030 conditions, the monthly inflows into the reservoir are projected to peak in May. By 2070, inflows are projected to occur much earlier in the water year, with peak monthly inflows occurring in March.

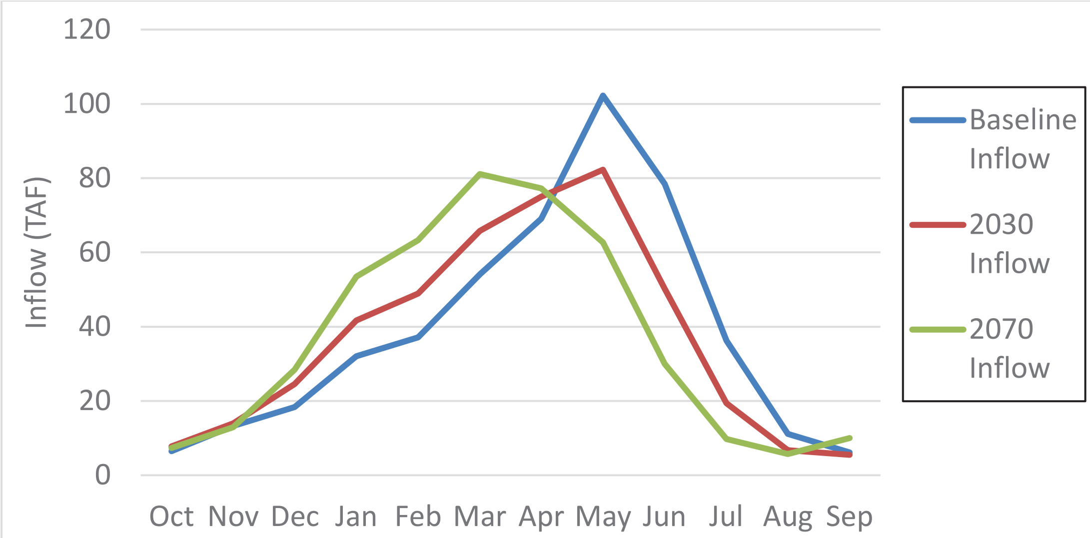


Figure 63: Projected Average Inflow into Kaweah Lake

Projected Future Changes in Imported Flow Diversions

Climate change could also impact the quantity and timing of imported water delivered to the Kaweah Subbasin from the CVP and the Kings River Basin. The Friant Water Authority has developed an analysis documented in a spreadsheet and a technical memorandum (***Appendix D***) showing the impact of climate change and the San Joaquin River Restoration Program (SJRRP) on water deliveries to the Friant-Kern Canal. The memorandum which is intended for use by water contractors preparing estimates of future Friant Division supplies in their groundwater sustainability plans summarizes results for five climate change conditions including:

> 2015 Conditions which represents a historical hydrology modified to match climate and sea level conditions for a thirty-year period centered at 1995 with a reference climate period of 1981 – 2010,
>
> Near-Future 2030 Central Tendency which represents a 2030 future hydrology with projected climate and sea level conditions for a thirty-year period centered at 2030 with a reference climate period of 2016 – 2045,
>
> Late-Future 2070 Central Tendency which represents a 2070 future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 with a reference climate period of 2056 – 2085,
>
> Late-Future 2070 Drier/Extreme Warming Conditions (DEW) which represents a 2070 DEW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 with a reference climate period of 2056 – 2085, and
>
> Late-Future 2070 Wetter/Moderate Warming Conditions (WMW) which represents a 2070 WMW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 with a reference climate period of 2056 – 2085.

The five scenarios analyzed also reflect progressive changes in implementation of the SJRRS Restoration and Water Management Goals which also have a direct effect on Friant Division water supplies. Under the 2015 scenario, implementation of the SJRRS Restoration Goal is limited because of capacity restrictions in the San Joaquin River below Friant Dam, and the need for further buildout of groundwater infiltration facilities to take full advantage wet year supplies limits implementation of the SJRRS Water Management Goals. Restrictions on implementation are expected to remain in place until 2025. The 2030 and 2070 scenarios assume full implementation of the Reclamation's Funding Constrained Framework of the SJRRS.

Table 36 shows future projections of water deliveries to the Kaweah Subbasin from Friant with climate change and SJRRP implementation. The results indicate that relative to baseline conditions, the central tendency of water deliveries from the Friant-Kern system to the Kaweah Subbasin would decrease by 8.5% to 154.4 TAF under 2030 conditions and by 16.8% to 140.4 TAF under 2070 conditions. The two extreme climate conditions for 2070 would results in a 37.9% decrease to 104.7 TAF for the Drier/Extreme Warming Conditions and a 10.4% increase to 186.3 TAF for the Wetter/Moderate Warming Conditions, respectively. These projections suggest that the Kaweah subbasin needs to prepare for decreasing water deliveries from Friant in the Near-Future and under most scenarios in the Far-Future.

Table 36: Future Projections of Water Deliveries to the Kaweah Subbasin from Friant with Climate Change and SJRRP Implementation

Future Projections of Kaweah Imports from Friant with SJRRP					
Model Run	**Scenario Description**	**Class 1 (TAF/yr)**	**Class 2 / Other (TAF/yr)**	**16B and Recapture (TAF/yr)**	**Total Delivery (TAF/yr)**
2015.c	Applies 2015 Climate Conditions and assumes implementation of SJRRS is limited by downstream capacity limitations.	**105.5**	**37.5**	**25.6**	**168.7**
2030.c	Applies the Near-Future 2030 Central Tendency climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).	**101.6**	**22.6**	**30.1**	**154.4**
2070.c	Applies the Late-Future 2070 Central Tendency climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).	**95.9**	**13.7**	**30.8**	**140.4**
2070 DEW.c	Applies the Late-Future 2070 Drier/Extreme Warming climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).	**76.7**	**3.1**	**24.8**	**104.7**
2070 WMW.c	Applies the Late-Future 2070 Wetter/Moderate Warming climate conditions and assumes Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).	**109.9**	**30.0**	**46.4**	**186.3**

Full natural flow of the Kings River at Pine Flat Dam is projected to decrease from 1,751 TAF under baseline conditions to 1,733 TAF under 2030 conditions and 1,731 TAF by 2070. The relative change in water supply is so small that Kings River water deliveries to Kaweah Subbasin would be assumed to remain unchanged at 13 TAF under both 2030 and 2070 conditions (*Table 37*).

Table 37. Summary of Projected Water Balance under 2030 and 2070 Conditions

	Annual Water Supply and Demand (TAF/yr)		
Changes in Primary Water Sources	Baseline	2030	2070
Upstream Inflow into Kaweah Lake	465	442	442
Total CVP Friant-Kern Canal Diversions	1200	1093	991
Total Kings River Full Natural Flow	1751	1733	1731
Surface Water Supply in Kaweah			
Rain Percolation (Cropland + Non-Ag)	118	119	116
Upstream Inflow Available for Kaweah	365	347	347
Imported Water CVP Friant-Kern Canal	169	154	140
Imported Water Kings River	13	13	13
Total Surface Water Supply in Kaweah	672	625	603
Water Demand in Kaweah			
Crop Water Demand	1004	1036	1086
Municipal & Industrial Demand	69	69	69
Total Water Demand in Kaweah	1073	1105	1155
Total Water Deficit in Kaweah	408	472	539

2.5.2.2 Projected Future Demand Estimates

Based upon the historical and current water budget, the total water demands within the Subbasin were estimated for the future demand period extending 50 years into the future through 2070. To estimate total demand for this period, two components of demand were considered. These components include extraction from the groundwater reservoir and agriculture and M&I pumping.

Projected Future Agricultural Demand

For the base period, irrigated agriculture demand averaged 1,055,700 AF/WY, which was satisfied by a combination of surface water and groundwater. Recent crop survey data indicate that this demand is from a variety of crops including almonds, alfalfa, citrus, cotton, grapes, olives, truck crops, walnuts, wheat and several others (Davids Engineering, 2018). Crop ET was derived for each of these crops for each year during the recent period of 1999 to 2017, based upon trends in water use for each crop. During the period, total water demand related to the growing of almonds has increased by 14 percent, while total water demand to satisfy miscellaneous field crops has declined by 18 percent. By considering all of the trends for a total of 16 crop categories on a net basis, the average change in crop water ET demand has been relatively unchanged, increasing modestly each year between 1999 and 2018.

Future projection of crop demand to 2040 and 2070 indicates that agricultural demand will increase to 1,138,200 AF/WY in 2030 and 1,239,500 AF/WY in 2070, which includes projected climate change affects.

Projected Future M&I and Other Demands

This section briefly summarizes future M&I demands as well as other demands not included in M&I. These other demands include dairies, small water systems, rural domestic, golf courses and nursery users. To estimate future M&I demands, GEI reviewed the 2015 Urban Water Management Plans for the Cities of Visalia, Tulare, along with California Department of Finance population projections.

Table 38 demonstrates future M&I and other demands in the Kaweah Subbasin. As shown, 76,400 AF/WY in 2015 was met with groundwater pumping. M&I and other demand is projected to increase to 126,421 AF/WY in 2030 and 186,445 AF/WY in 2070.

Table 38: Projected Water Demand (AF/WY)

	2015 Demand	Estimated 2040 Demand	Estimated 2070 Demand
Irrigation Demand	1,055,737	1,138,249	1,239,447
Tulare	9,055	20,372	33,952
Visalia	27,453	54,987	88,028
Exeter	1,825	2,336	2,949
Farmersville	822	1,052	1,328
Ivanhoe	694	888	1,122
Woodlake	1,688	2,161	2,728
Lindsay	518	663	837
Other Demand 2	34,345	43,961	55,501
Total M&I and Other	76,400	126,421	186,445
Total	**1,132,137**	**1,264,670**	**1,425,892**
Change	**--**	**132,533**	**293,755**

Notes: 1. This period selected for consistency with climate change datasets provided by DWR (DWR, 2018)
2. Other demand includes dairies, small water systems, rural domestic, golf courses, and nursery users

Figure 64 shows the increase in total Agricultural and M&I demand from 1,132,137 AF/WY in 2015, to 1,425,892 AF/WY in 2070, a 26% increase over the 50-year period. This increased demand results from increases in all three categories of users: agricultural, M&I and other demands.

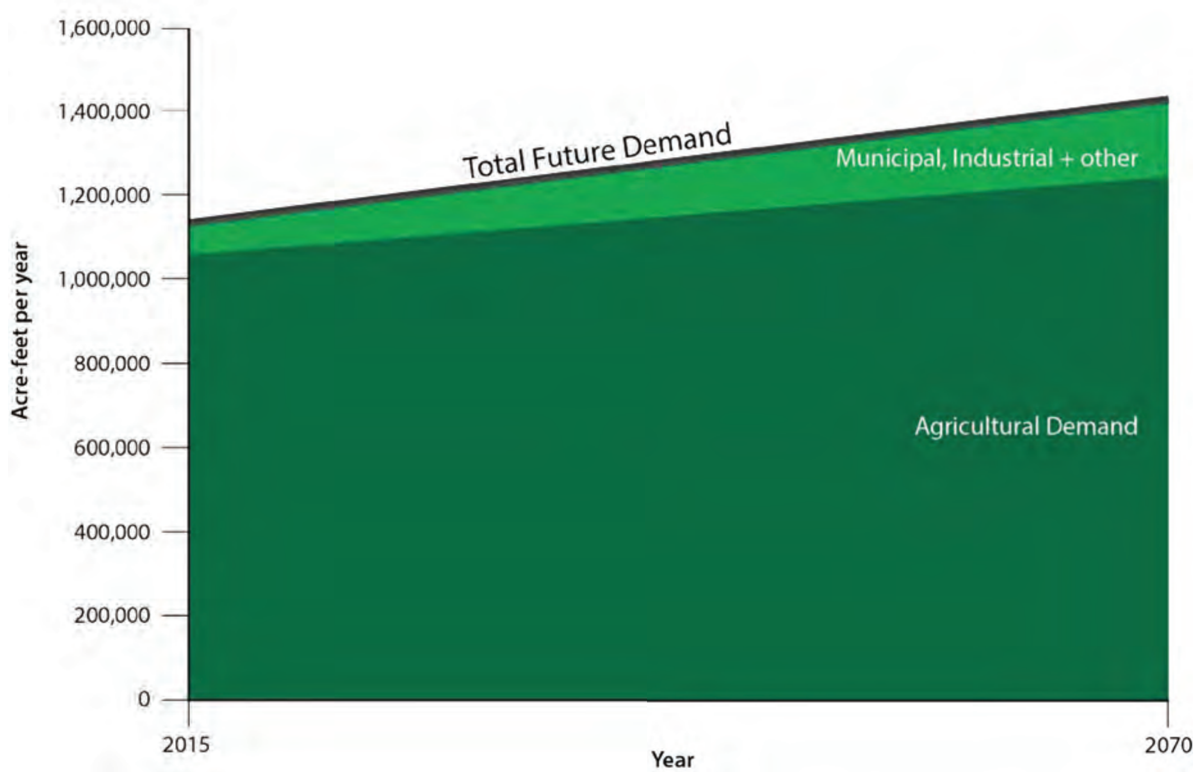


Figure 64: Kaweah Subbasin Projected Future Water Demand

During the projected future period, water supply availability is projected to slightly decrease in response to climate change and because of restoration of flows on the San Joaquin River. *Figures*

65 and 66 illustrate the gap between forecast water supply and forecast demand. This gap between future supply and demand will be met by groundwater supply produced at a sustainable yield that does not cause undesirable results. This sustainable yield will be established once measurable objectives are agreed upon throughout the basin. Groundwater modeling will be used to estimate the sustainable yield once initial thresholds and objectives are established.

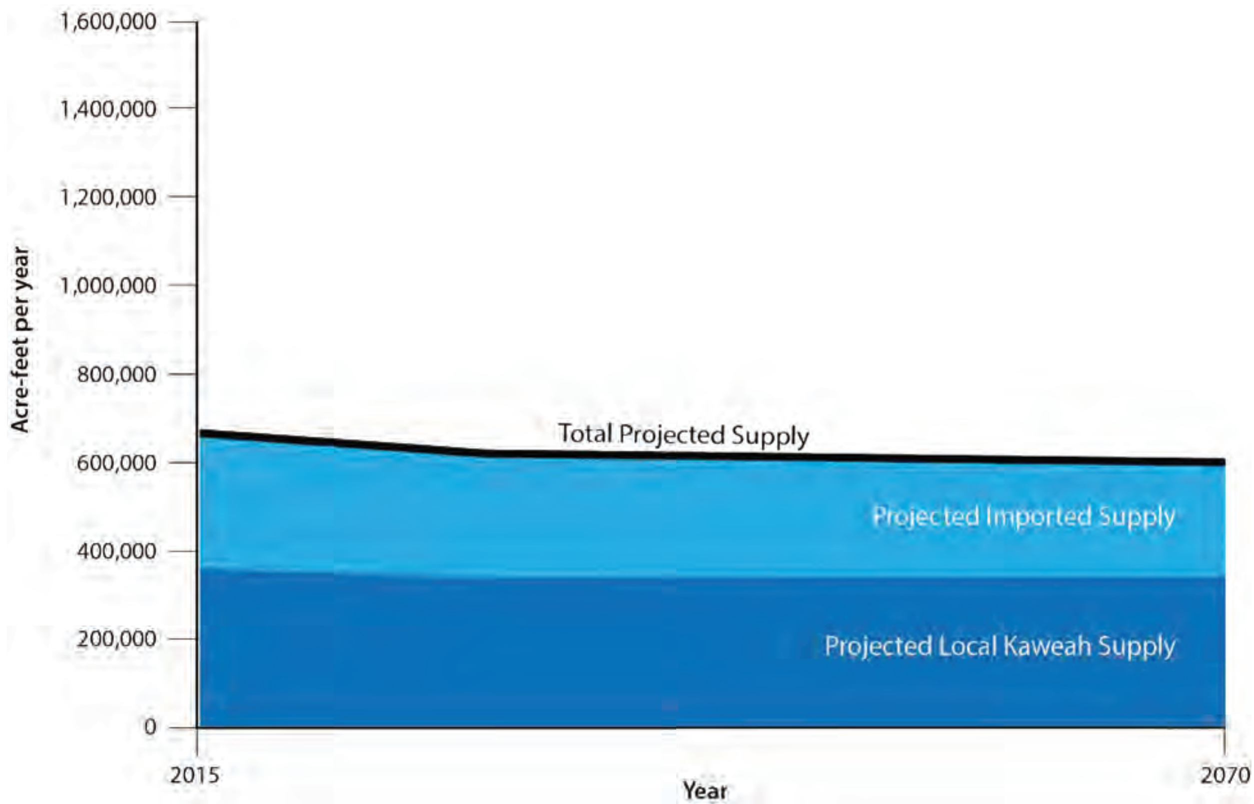


Figure 65: Kaweah Subbasin Projected Future Water Supply

Impacts of Climate Change Projections on Future Water Balance

The impacts of climate change on the water balance of the Kaweah Subbasin is presented in ***Table 37***. The first section of the table shows baseline conditions and project changes under 2030 and 2070 conditions for the Subbasin's primary water sources including Kaweah Lake, CVP Friant-Kern Canal Diversions, and full natural flow of the Kings River. The second section of the table shows estimated impacts of changes at primary water sources on surface water supplies delivered to the Kaweah Subbasin. Rain percolation is assumed to change in direct proportion to projected changes in local precipitation. To estimate future changes in water deliveries from upstream inflows and imported sources, Kaweah Subbasin's share (expressed as a percentage) of source water available is assumed to remain unchanged. Imported water deliveries consequently change in direction proportion to projected changes at the respective sources. Annual crop water demands are projected to similarly change in direct proportion to changes in evapotranspiration.

Overall, total surface water supply in Kaweah Subbasin is projected to decrease from 665 TAF under baseline conditions to 633 TAF under 2030 conditions and 616 TAF by 2070, as shown on **Figure 66**. Conversely, total water demand is projected to increase from 1,073 TAF under baseline conditions to 1,105 TAF under 2030 conditions and 1,155 TAF under 2070 conditions. The combined effect of these changes is that total water deficit in the Subbasin will increase from 408 TAF under baseline conditions to 472 TAF under 2030 conditions and 539 TAF by 2070 unless measures are implemented to increase supply or reduce demand.

Figure 66 demonstrates that a widening future shortfall in supply is anticipated. Future projects and management actions will be developed and presented in subsequent chapters of this GSP. These projects and management actions will address the shortfall through either demand reduction (i.e. water use efficiency, reduction in crop acreage) or supply augmentation (i.e. increases in artificial recharge during wet periods, increased surface water delivery).

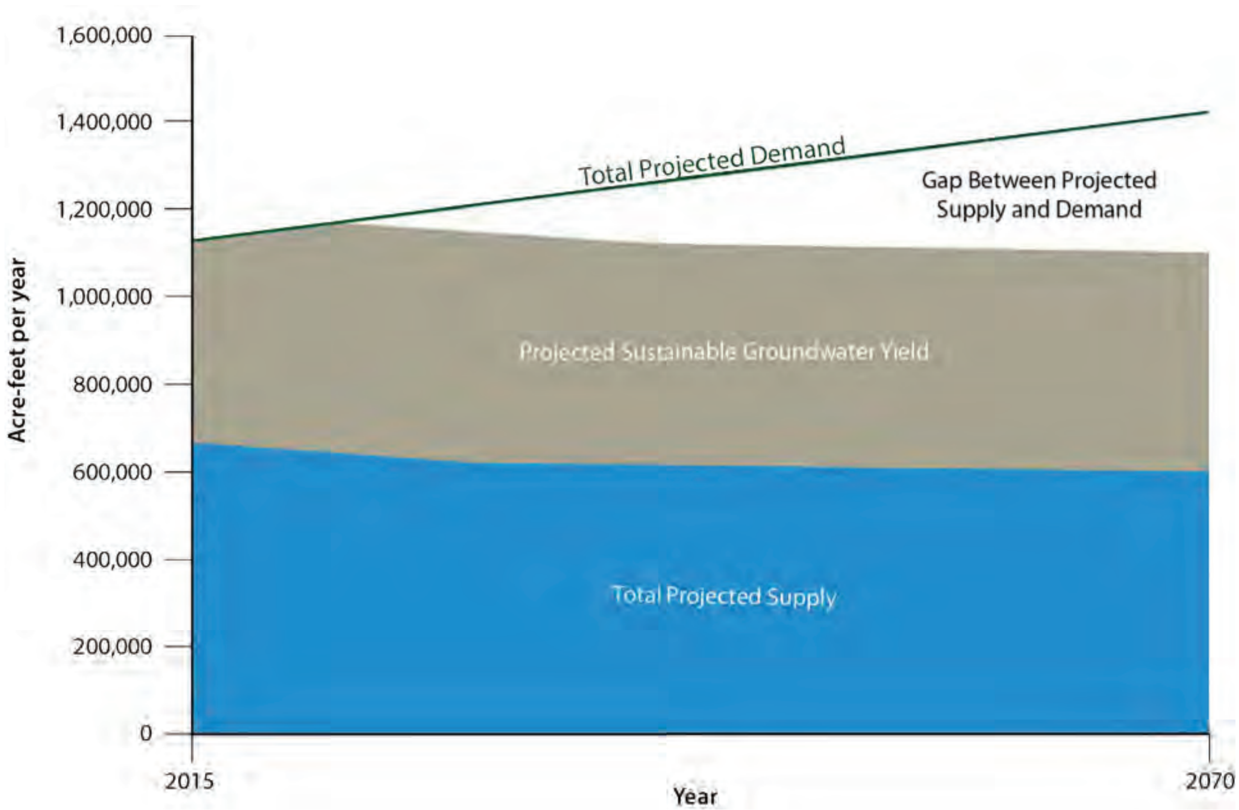


Figure 66: Kaweah Subbasin Projected Water Supply and Demand

2.6 Seawater Intrusion §354.16 (c)

Seawater intrusion is not an issue in the Kaweah Subbasin because the subbasin does not have a coastal boundary. Seawater intrusion is an issue in coastal basins that may be induced by creating a landward gradient through lowering of the groundwater table. Once seawater reaches the area of groundwater production, the production wells will not be suitable for drinking or irrigation use and it will likely take decades and significant changes in water supply and use patterns to restore an aquifer's productivity. Maintaining a "wedge" of freshwater in coastal areas, between the ocean and the freshwater aquifers, may prevent undesirable results. Knowledge of the aquifer system, groundwater levels, and water gradients are needed to manage seawater intrusion.

2.7 Groundwater Quality Conditions §354.16 (d)

This groundwater quality discussion is largely generalized, although constituents of concern are identified geographically. In 2007, Fugro conducted a Water Resources Investigation for the Kaweah Delta Water Conservation District. This report is referenced along with USGS studies and data collected from a wide variety of sources including state agencies, federal agencies, and county and city water departments. The Fugro study was limited by the volume of groundwater quality data that was available (Fugro West, 2007). At the time of this report, available groundwater quality data was confirmed to be insufficient to represent a large portion of the Subbasin. The primary source of data referenced for this characterization was obtained from the SDWIS which collects sample results from all State regulated public water systems.

2.7.1 Data Sources

There are 47 public water systems with data available in SDWIS. These systems are generally representative of the basin as they're located throughout the Subbasin. ***Figure 67*** shows the Kaweah Subbasin boundary, as well as the locations and density of wells with available water quality data. Between all 47 active public water systems, 174 wells were evaluated. In addition to SDWIS, GeoTracker and EnviroStor were searched to identify contaminant plumes, and the SWRCB's Human Right to Water Portal was searched to identify contaminants that commonly violate drinking water standards.

A limited amount of data are available for private domestic wells within the Subbasin; the State Water Board's GAMA Domestic Well Project provided insight to some private wells. Through their Groundwater Protection Section, the State Water Board offered voluntary groundwater monitoring to provide private well owners with information about their water quality. Groundwater samples were analyzed for bacteria, inorganic parameters, volatile organic compounds, and non-routine analytes. Select groundwater samples were also analyzed for stable isotopes of oxygen and hydrogen in water and stable isotopes of nitrogen and oxygen in nitrate. The State Board's GAMA report of the Domestic Well Project conducted for private well owners in Tulare County analyzed 29 of the 181 domestic well samples collected by the SWRCB for stable isotopes of nitrogen and oxygen in nitrate. The study found that nitrate isotopic composition varies with land use (dairies, agricultural/residential, and natural settings). Dairy site nitrate-N isotopic data are isotopically consistent with a manure source. While nitrate-O isotopic data are isotopically consistent with local nitrification of ammonium (from manure, septic effluent, or synthetic ammonium fertilizer).

The 29 samples that were analyzed for stable isotopes of nitrogen and oxygen were wells with higher nitrate concentration (median of 5 ppm and mean of 11 ppm nitrate as nitrogen). For a majority of the heavily impacted wells, the nitrate isotopic compositions indicate a dairy manure or septic effluent source, except for one well with a high nitrate concentration and an isotopic composition indicative of a synthetic fertilizer. Their study acknowledged that the data is under-represented by domestic wells with no potential anthropogenic sources within 500 meters of the well and that land uses were assigned on a high level.

2.7.2 Approach to Characterizing Groundwater Quality

Characterizing groundwater quality was conducted to comply with California Code of Regulations – Title 23 – Waters; Subarticle 2 §354.16(d) – Groundwater Conditions: groundwater quality issues that may affect the supply and beneficial uses of groundwater, including a description and map of the location of known groundwater contamination sites and plumes. Constituents evaluated and the methodology used were consistent with guidance provided in Assembly Bill 1249 (AB 1249) which states that "if the Integrated Regional Water Management (IRWM) region has areas of nitrate, arsenic, perchlorate, or hexavalent chromium contamination, the (IRWM) Plan must include a description of location, extent, and impacts of the contamination; actions undertaken to address the contamination, and a description of any additional actions needed to address the contamination" (Water Code §10541.(e)(14)). This approach of incorporating guidance from both programs was used to consider all major constituents of concern and characterize groundwater in a manner that is consistent with current water quality focused programs.

2.7.3 Results

While all regulated drinking water constituents were considered, findings from this evaluation show that the most common water quality issues within the Subbasin are: nitrate, arsenic, tetrachloroethylene (PCE), dibromochloropropane (DBCP), 1,2,3-trichloropropane (TCP), sodium, and chloride. This water quality discussion is divided by constituent to explain the drinking water standard, agricultural standard (sodium and chloride), and how these constituents impact beneficial uses in the different regions of the Subbasin. *Table 39* provides a summary of the range of these constituents within the Kaweah Subbasin referenced to the MCL.

Table 39: Summary of Water Quality Constituents in Kaweah Subbasin

Constituent	Units	Drinking Water Limits (MCL/SMCL)	Agricultural Water Quality Goal	Range in Kaweah Subbasin
Arsenic	ppb	10	100	ND - 20
Nitrate as N	ppm	10	n/a	ND - 27
Hexavalent Chromium	ppb	previously 10 ppb, currently under evaluation	n/a	ND - 14
Dibromochloropropane (DBCP)	ppb	0.2	n/a	ND - 0.31
1,2,3-Trichloropropane	ppt	5	n/a	ND - 230
Tetrachloroethylene (PCE)	ppb	5	n/a	ND - 270
Chloride	ppm	250	106	2 - 940
Sodium	ppm	n/a	69	1 - 270

2.7.3.1 Arsenic

Arsenic has a primary drinking water MCL of 10 ppb and an Agricultural Water Quality Goal of 100 ppb. Based on review of the Department of Pesticide Regulation studies and the hydrogeology of the Kaweah Subbasin, the major source of arsenic in this groundwater appears to be naturally occurring from erosion of natural deposits. Throughout the southern San Joaquin Valley, arsenic-rich minerals are present, including arsenopyrite, a common constituent of shales and apatite, a common constituent of phosphorites and the most common source of arsenic leaching materials in the aquifer (Burton, et. al., 2012). Data from public water systems shows that arsenic detections around 5-10 ppb are more prevalent in the western portion of the Subbasin, generally within the Corcoran clay. ***Figure 68*** shows the areas where arsenic is between 5- 10 ppb and/or shows an increasing trend to 10 ppb. The eastern boundary of the Corcoran clay generally follows the boundary of St. Johns River on the north till it crosses Highway 63 and extends south of Highway 63, where it continues south through the Subbasin and extends to the westerns portion of the Kaweah Subbasin.

USGS found that when arsenic is naturally occurring in the Kaweah Subbasin aquifer, concentrations tend to increase as pH increases due to desorption from aquifer sediments. Burton, et.al. (2012) report that almost all wells with moderate (5-10 ppb) or high (>10 ppb) arsenic concentrations were in samples with pH values greater than 7.6 units. This correlation between arsenic and pH is consistent in the public water wells evaluated. Wells with arsenic detections are located generally west of Highway 63 and Road 124.

When comparing the data from the municipal wells within the western portion of the Subbasin that have the Corcoran Clay present to the area east of Highway 63 where the aquifer is predominately alluvium, the pH levels were slightly lower than the western portion. This is further evidenced by the two wells located in the western portion of the Subbasin, west of Highway 63 and Road 124 that consistently have arsenic levels above 10 ppb, and pH levels that range from 9.1 – 9.6 units. Wells with arsenic levels less than 5 ppb typically have pH ranges from 7.0 – 8.6 units.

USGS also identified that arsenic concentrations were significantly higher in older and deeper groundwater. USGS assessed depth dependent arsenic concentrations by evaluating both the lateral and vertical extents of arsenic concentrations. Their conclusion is that higher arsenic concentrations directly correlate to well construction (completed depth and top of the perforations). Almost all detections with arsenic concentrations greater than 5 ppb were in wells deeper than 250-ft. These findings were compared with data obtained for this report. While the data is limited, there are two wells consistent with findings from the USGS Report. ***Figure 69*** shows that Well A with a total depth of 284 feet has historically had no arsenic detections. However, in Well B with a total depth of 760 feet also located in the same area has higher arsenic levels and at times exceeds 10 ppb.

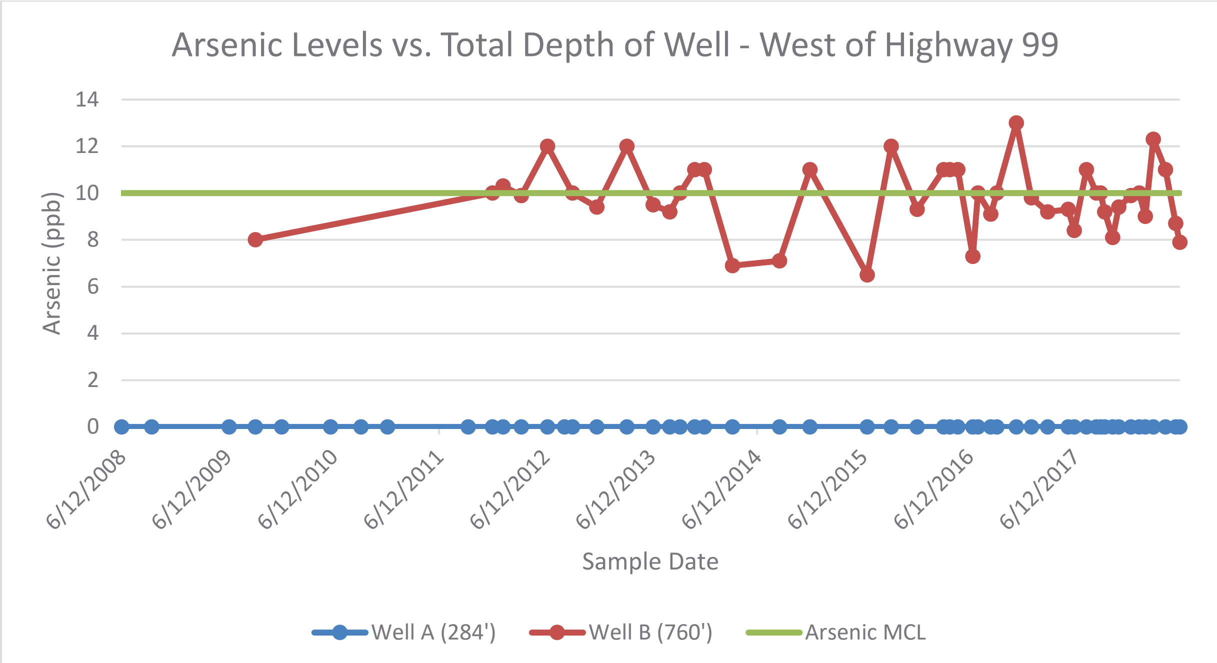


Figure 69: Hydrogeologic Zone 2 – Arsenic Levels vs. Total Depth of Well

2.7.3.2 Nitrate

Nitrate has an acute drinking water MCL of 10 ppm (as N). There is no Agricultural Water Quality Goal for nitrate. Nitrate predominately comes from runoff leaching from fertilizer use, leaching from septic systems and sewage, and small concentrations from erosion of natural deposits. Characterizing nitrate contamination in the Kaweah Subbasin includes identifying known and estimated sources of nitrate contamination, identifying public water system wells with nitrate concentrations above the MCL, and correlating the concentrations with land uses and water level trends.

Public water systems with high nitrate levels or increasing nitrate trends are common throughout the Subbasin. ***Figure 70*** provides a spatial observation of where the public water system wells with nitrate issues are generally located. Most nitrate concentrations greater than 5 ppm were detected in the eastern part of the studied area. In areas east of Highway 63 and Road 152 to the eastern extent of the Subbasin, nitrate tends to be higher than 5 ppm with increasing trends. All other areas of the Subbasin have nitrate levels ranging from non-detect to 5 ppm.

While Burton et. al. (2012) report that nitrate contaminations correlates to orchard and vineyard land uses, USGS finds that these regions also have medium to high density septic systems. ***Table 40*** shows the percentages of orchard and vineyard land uses and septic system density for each hydrogeologic zone (Tulare County 2007 land use data and Kings County 2003 land use data were used to create this table). Greater than 50 percent of the land use in this region are orchards or vineyards.

Septic-system density greater than the median value of 5 septic systems in a 500-meter radius around each selected GAMA well occurred throughout the Subbasin, with very high density of 9.4 septic systems within 500 meters of the selected well(s) between Highway 63 and Highways 245 and 65.

Figure 71 shows the location of wells selected by USGS to evaluate septic system density. Well locations are overlaid with land uses and public water system wells with high nitrate levels.

USGS data was used for this evaluation to develop a clearer understanding of potential sources of nitrate contamination. While previous reports point towards orchard and vineyard land uses, septic system density is an unquantified source of contamination. Data gathered by USGS was determined from housing characteristics data from the 1990 U.S. Census. The density of septic systems in each housing census block was calculated from the number of tanks and block area. The density of systems around each well was calculated from the area-weighted mean of the block densities for blocks within a 500-m buffer around the well location. To more precisely identify the nitrate sources, current data should be compiled and evaluated with proximity to domestic water wells. This effort is being made through the Disadvantaged Community Involvement Program to identify septic system density and condition in the Tulare-Kern Funding Area.

Table 40: Percentages of Nitrate Contributing Land Uses

Geographic Description	Orchard Percent	Vineyard Percent	Septic System Density (per 500 meters)
West of Hwy 63	8.91%	1.33%	5.5
Between Hwy 63 and Hwy 245 and Hwy 65	50.88%	3.19%	9.4
East of Friant-Kern Canal	45.64%	0.19%	5.5

It is well understood that nitrate is a surface contaminant and predominately impacts shallower wells, particularly wells with minimum sanitary features (i.e. the required 50-ft sanitary seal). Nitrate impacts based on well construction is demonstrated by the 3 wells with varied construction that are all located within the City of Tulare, Wells B and C are relatively close in proximity of each other but shows significantly different trends. While each of these wells are influenced by similar land uses and aquifer conditions, they each have varying levels of nitrate contamination. *Table 41* summarizes nitrate concentration and well construction for each of these wells. *Figure 72* graphically displays the nitrate trends.

Table 41: Comparison of Nitrate Concentrations and Well Construction

	Well A	Well B	Well C
Completed Depth	710	800	800
Sanitary Seal	280	260	370
Highest Perforations	320	280	400
Nitrate as N (ppm) current median value	8.2	14	3

While each of these wells show nitrate contamination related to land uses, vulnerability is substantially lower in Well C, which has a 370-ft sanitary seal. Both wells A and B have increasing trends, with the highest concentrations and steepest increasing trend found in Well B which has a sanitary seal of only 260-ft. Well B also shows significant variation in nitrate concentration that is likely associated with pumping duration at the time of sampling. Typically, shallow wells that are vulnerable to surface contamination will show the highest contaminant concentration with low pumping hours. Increased pumping hours will show lower contaminant concentrations. Regardless of contaminant/pumping correlations, this well has an increasing nitrate trend over time. Well A shows similar trends and pumping correlation, but the variation is less severe. Whereas Well C doesn't appear to be impacted by pumping or showing a significant increasing trend.

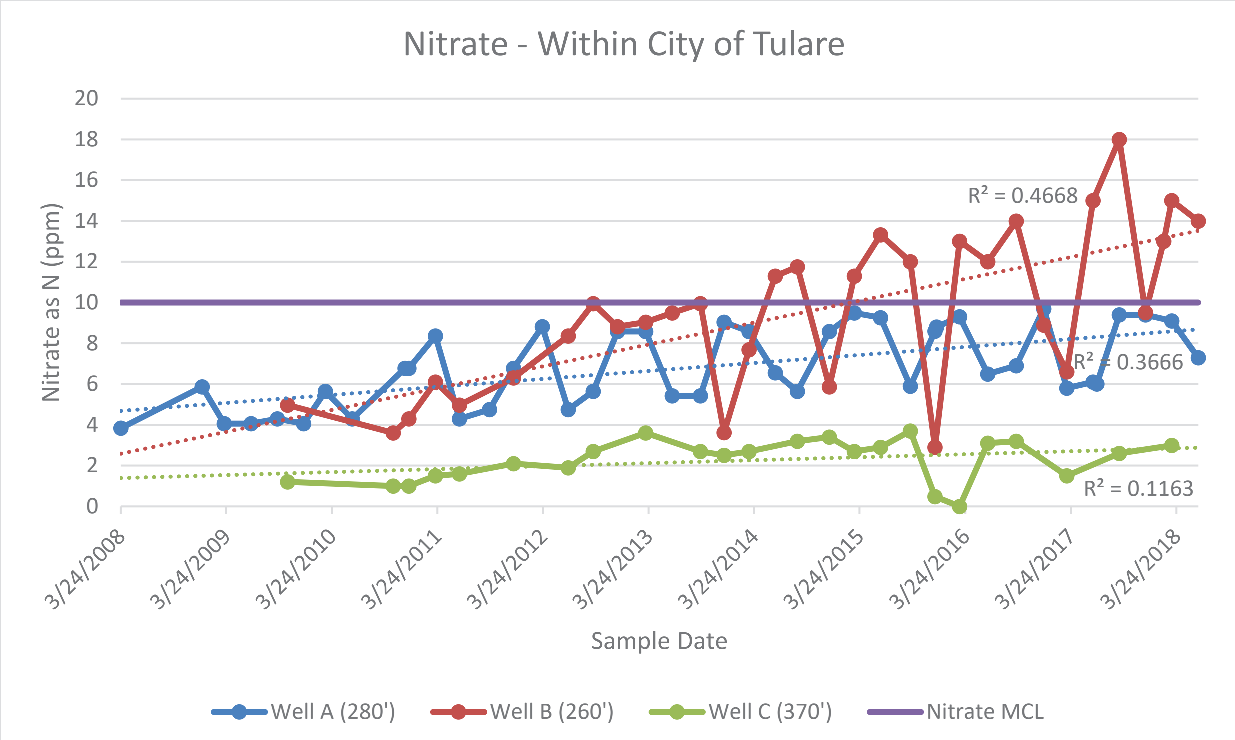


Figure 72: Nitrate Levels in Relation to Well Construction

In an effort to evaluate the extent of nitrate contamination basin-wide, a comparison was made between the general depth to water and nitrate concentrations. Since there was no well specific depth to water level data available, the use of the generalized depth to water levels of the Subbasin from DWR modeling database was used to determine if there is correlation between nitrate levels and changing water levels. In some of the wells located in the central portion of the Subbasin, there is no apparent correlation; however, in some wells located within the same area, it appears that nitrate levels are influenced by changing water levels. An evaluation of the wells between Highway 65 and Yokohl Creek shows that it does not appear that the declining water levels were causing nitrate to migrate deeper into the aquifer. See ***Figure 73*** as an example.

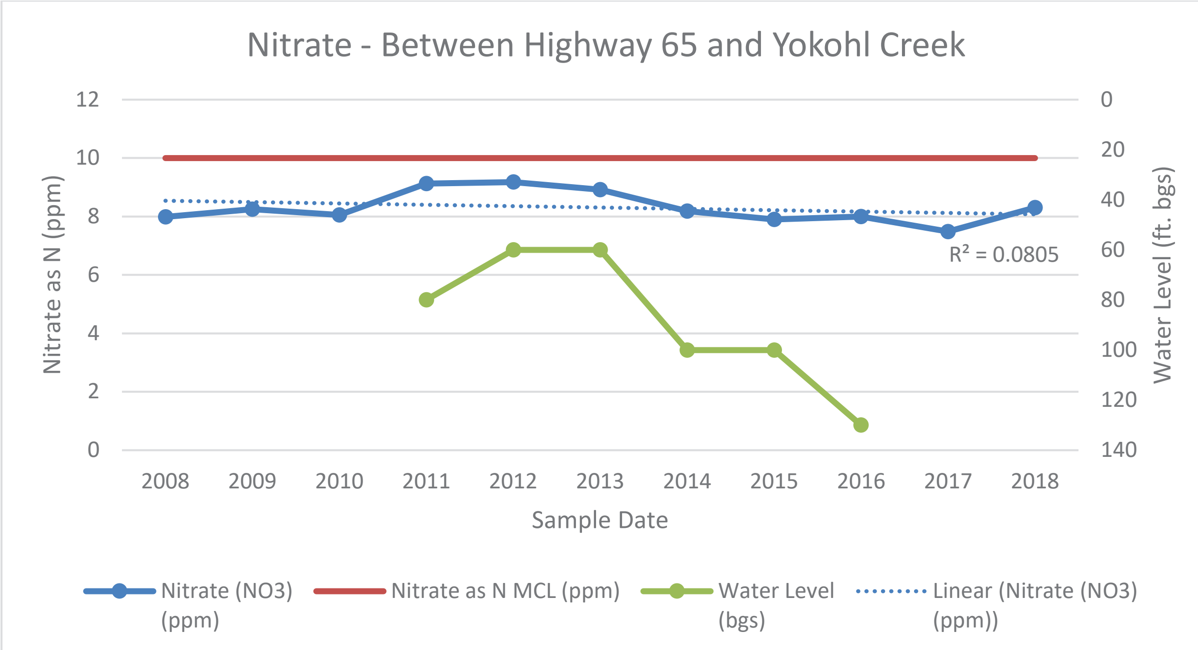


Figure 73: Nitrate Levels Remain Consistent Between Hwy 65 and Yokohl Creek

In contrast, the area south of Highway 137 between Roads 124 and 152, as shown in ***Figure 74***, there appears to be a correlation between declining water levels and increasing nitrate concentrations. This trend indicates that nitrate is migrating deeper into the aquifer and is within the pumping zone of the domestic wells evaluated in this region. This preliminary assessment is based on the limited amount of data available. To confirm accuracy of this trend, further studies are needed.

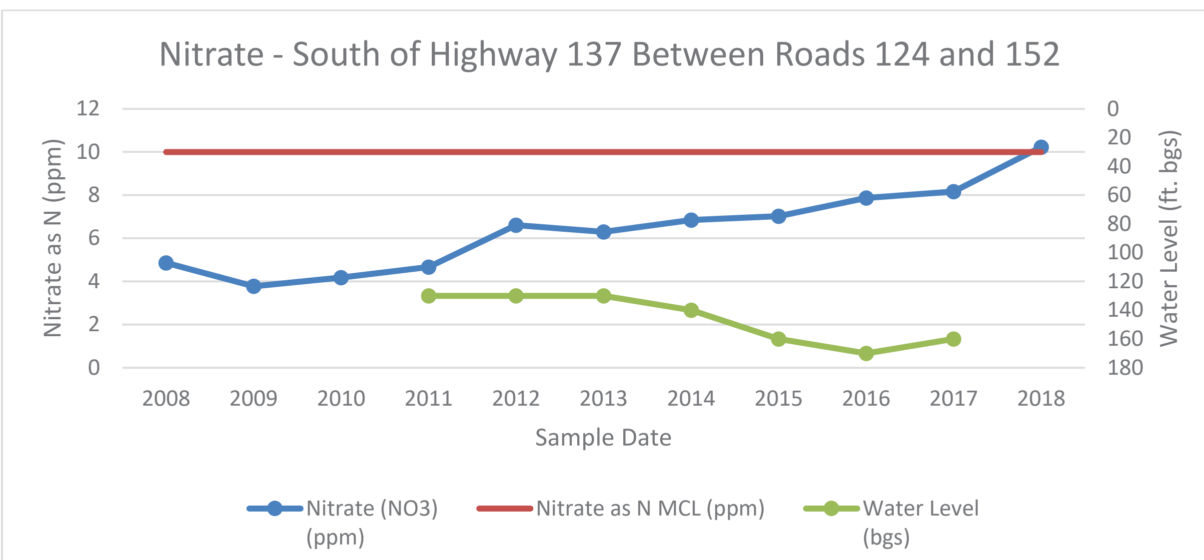


Figure 74: Nitrate levels increase south of Hwy 137

Figure 75 shows the nitrate trend that is representative of wells north of Highway 137 between Highway 99 and 63. The nitrate and water level trends that follow a parallel pattern indicate that nitrate is not migrating deeper into the aquifer. Nitrate in this well has decreased from its maximum concentration of 6 ppm to non-detect levels. This type of trend indicates that there are confining layers in the aquifer preventing nitrate from migrating with the water levels.

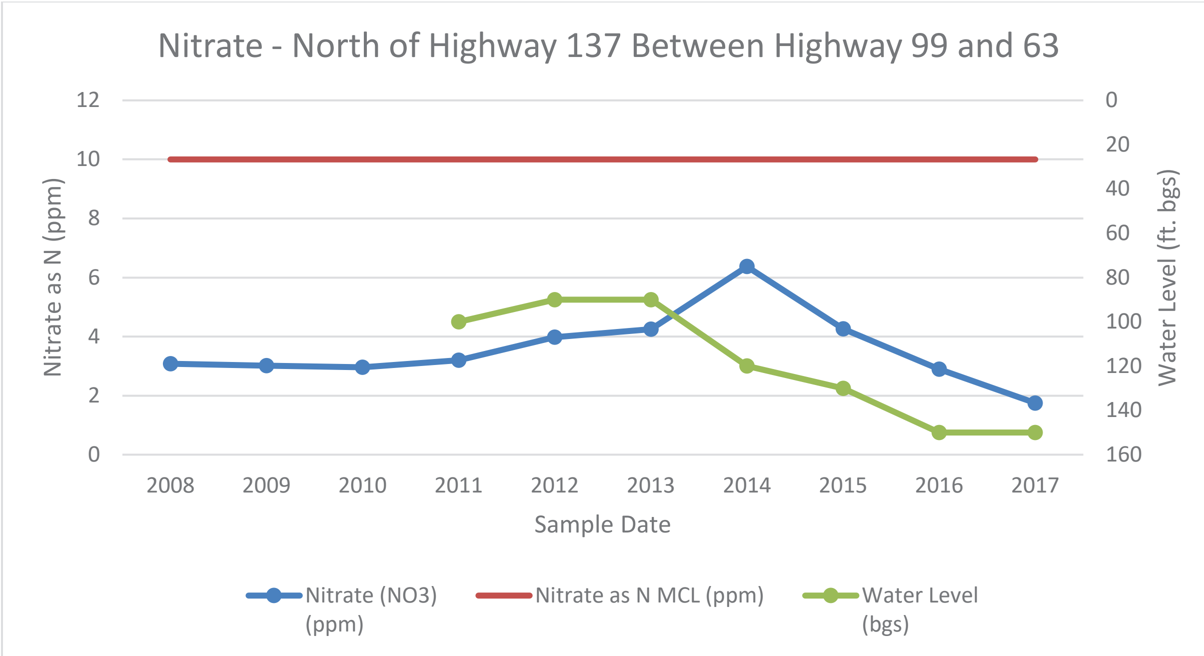


Figure 75: Nitrate levels decrease north of Hwy 137

2.7.3.3 Hexavalent Chromium

Hexavalent chromium is not commonly found in concentrations greater than 10 ppb in the Kaweah Subbasin. An evaluation of hexavalent chromium results indicates that only one well has historic levels with a maximum result of 14 ppb and an increasing trend. This well is located on the eastern border of the Subbasin, near the Friant-Kern Canal in hydrogeologic zone eight.

The federal MCL for total chromium (which includes chromium-3 and chromium -6) is 100 ppb, a specific federal MCL for chromium-6 has not been established. In California, the MCL for chromium-6 is currently 50 ppb. This MCL is a reversion from the July 2014 establishment of a primary MCL of 10 ppb. While DDW repeats the regulatory process for adopting the new MCL, the federal MCL of 50 ppb for total chromium applies. There is no Agricultural Water Quality Goal for hexavalent chromium.

2.7.3.4 Dibromochloropropane (DBCP)

Dibromochloropropane (DBCP) is a synthetic organic contaminant with a drinking water MCL of 0.2 ppb. There is no Agricultural Water Quality Goal. DBCP is a banned nematicide that is still present in soils and groundwater due to runoff or leaching from former use on soybeans, cotton, vineyards, tomatoes, and tree fruit.

Since the use of this pesticide was banned in 1977, concentrations of DBCP detected in the public water system wells have been either steady or decreasing trends. Presently, detections are found in 7 of the 47 public water systems, at concentrations below the MCL of 0.2 ppb.

Studies on the half-life of DBCP in groundwater estimate it will last from 3 to 400 years depending on ambient conditions. In 2008 the Department of Public Health (transferred to State Water Board as DDW in July 2014) estimated the median half-life of DBCP in the Central Valley is 20 years. This is consistent with the data that's been evaluated for this Subbasin since the levels are steady or decreasing.

2.7.3.5 1,2,3-Trichloropropane (TCP)

TCP is a semi-volatile organic compound with a primary drinking water MCL of 5 ppt. There is currently no federal MCL and no Agricultural Water Quality Goal. The majority of TCP in California's Central Valley is believed to be from an impurity in certain 1,3-D soil fumigants used to kill nematodes. When applied to land, TCP passes through soil and bonds to water, then sinks into the aquifer. It is a highly stable compound, meaning that it is resistant to degradation and has a half-life of hundreds of years[3].

Large public water systems began sampling their wells for TCP using a low-level analytical method around 2003, as a requirement of the Unregulated Chemical Monitoring Rule. From this data, DDW determined that the most impacted counties are Kern, Fresno, Tulare, Merced and Los Angeles. All water systems are required to test their wells quarterly beginning January 2018. Since only a few of the 47-public water system had data available in SDWIS at the time data was extracted for this report, the majority of detections were located in the central portion of the Subbasin. ***Figure 78*** shows wells with historical TCP detections in the Kaweah Subbasin.

2.7.3.6 Tetrachloroethylene (PCE) / Contamination Plumes

PCE is a volatile organic compound with a primary drinking water MCL of 5 ppb. There is no Agricultural Water Quality Goal for PCE. Sources of PCE include discharges related to dry cleaning operations and metal degreasing processes. An evaluation of contamination plumes in the Subbasin was identified through the SWRCB – GeoTracker and Department of Toxic Substances (DTSC) – EnviroStor databases. There is a total of 21 sites identified within the Kaweah Subbasin.

The largest PCE contamination plume involves nine sites in the city of Visalia, which are all dry cleaners. DTSC is leading this case and it's considered a city-wide investigation. According to the DTSC Fact Sheet dated January 2009, this investigation began after DTSC identified 25 public drinking water wells having detection of PCE. It is believed that the PCE plume is related to solvent releases from dry cleaning facilities in the city of Visalia. Soil and groundwater samples were first collected in 2007. Currently, the database indicates that from the nine sites identified there are three municipal drinking water wells that are within 1,500 feet of the plume vicinity. The three wells are located within the Cal Water area. One of the wells was shut down in 2000 due to PCE detection over the MCL. The well is now back online with PCE treatment.

Cal Water and DTSC entered into their first agreement in May 2007. One of the agreements identified between the two parties was for Cal Water to assist in preventing groundwater wells from spreading the PCE plume by early identification of problem areas or determination of appropriate remedial actions such as continued monitoring, pumping, not pumping, treatment, or well

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[3] Transformation and biodegradation of 1,2,3-trichloropropane (TCP) 2012. https://link.springer.com/content/pdf/10.1007%2Fs11356-012-0859-3.pdf

destruction. The agreement was amended in June 2009 and again in March 2013. The most recent agreement stated for Cal Water to evaluate the effects of pumping groundwater at two specific well locations. Subsequently the evaluation was focused to one well and based on a report completed in November 2015 of that well, it showed that the well resides in a dynamic geohydrologic environment. When the well is not pumping or under ambient condition, fresh water displaces PCE contaminated water from the shallow part of the aquifer near the well. When the well is pumping, it draws in the water from deep and shallow sources, including upper aquifer contaminated water. ***Figure 76*** shows the increasing PCE levels of the Cal Water well, with it peaking at 270 ppb in July 2014. Levels have significantly decreased but intermittently show increasing trends.

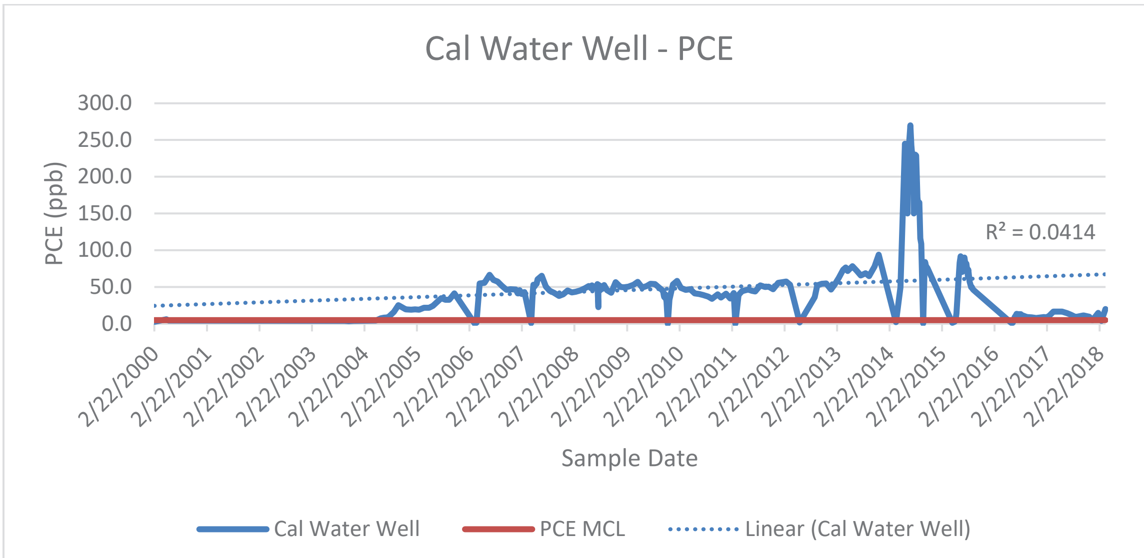

Figure 76: Historical PCE Levels of Cal Water Well Impacted by PCE Plume

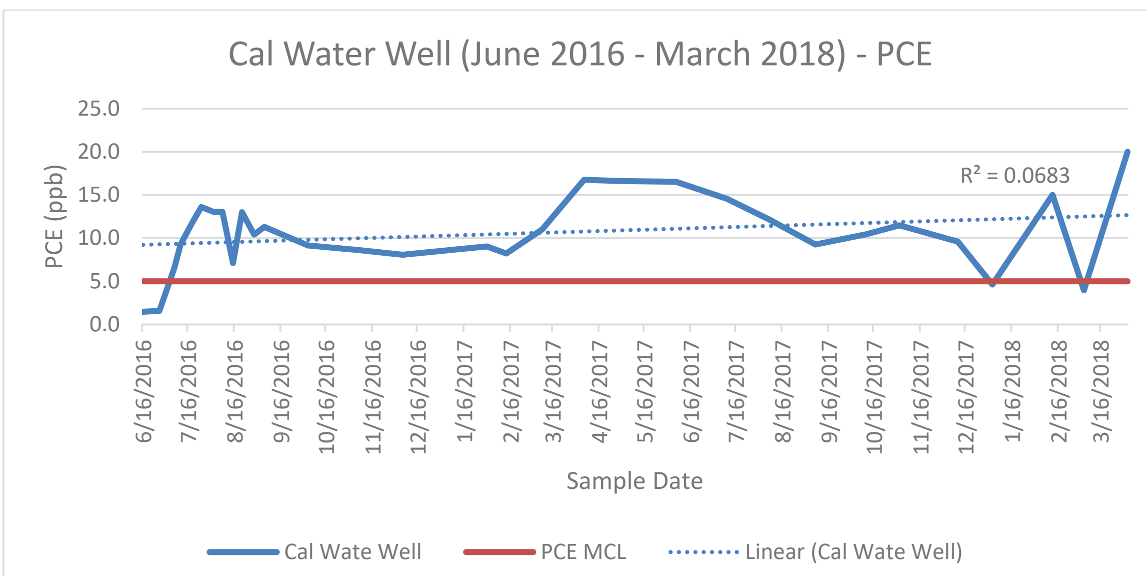

Figure 77: PCE Levels of Cal Water Well Impacted by PCE Plume from June 2016 – March 2018

This city-wide PCE investigation is still underway and each of the nine sites are in varying stages of investigation with work plans approved by DTSC. Monitoring wells that have been installed with screens about 100 feet below ground surface (bgs) have detected PCE levels above 5 ppb. The size of the plume has not been determined and is still under investigation. *Figure 79* shows the nine sites in relation to the municipal drinking water wells.

Other contamination sites were identified within the Subbasin. These other sites are summarized in *Table 42* An extensive summary for each of the contamination sites is not presented since most did not have more recent information or reports on the ongoing investigation of these sites. From reviewing the available reports, none of the sites listed have been determined to have an impact on the aquifer.

Table 42: Summary of Active Contamination Sites Not Part of PCE City-Wide Investigation

Global ID# / EnviroStor ID#	Lead Agency	Potential Contaminants of Concern	DDW Wells within 1500 Feet of Site	Status
SLT5FR184373 / 54270005	DTSC	VOC	No	Open – Remediation as of 5/12/10
SLT5FT344509	Regional Board	TCA, DCE, other inorganic/salt	Yes, but well inactivated in 2014	Open – Site Assessment as of 4/18/16
SL0610711757	Regional Board	Gasoline, MTBE, TBA, other fuel oxygenates, Diesel	Yes, but well was destroyed in 1995	Open – Inactive as of 4/28/16
T0610700032	Regional Board	Gasoline	No	Open – Eligible for closure as of 8/30/17
T0610700138	Regional Board	Gasoline	Yes	Open – Assessment & interim remedial action as of 1/29/17
T0610700075	Regional Board	Gasoline	Yes	Open – Site assessment as of 8/1/17
T10000011363	Regional Board	Polychlorinated biphenyls (PCBs), insecticides, pesticides, herbicides, arsenic, lead, mercury, total petroleum hydrocarbons (TPH) After testing, focus is arsenic	Yes – 4 total, but 3 have been inactivated in 1984 due to water system inactivation	Open – Site assessment as of 3/5/18
SL205194270	Regional Board	PCE, TCE, other chlorinated hydrocarbons	None identified, but reports indicate impacts to wells	Open – Verification monitoring as of 4/18/16

Global ID# / EnviroStor ID#	Lead Agency	Potential Contaminants of Concern	DDW Wells within 1500 Feet of Site	Status
SLT5FT424517	DTSC	Pesticides/ Herbicides	No	Open – Site assessment as of 1/22/87
SLT5S3483663	Regional Board	Pesticides, herbicides	No	Open – Inactive as of 5/21/09
80001396	DTSC	Soil - Lead, Sulfuric acid, TPH	No	Open – Active as of 1/1/08
80001510	DTSC	Cadmium, copper, lead, and zinc	Unknown	Open – Active as of 3/1/17

Out of all the contamination sites identified, there are 16 contamination sites that will need to be monitored to determine the extent of impact to the groundwater (*Figure 80*). Sites that have no information at all or eligible for closure is not counted towards the 16 contamination sites that needs further monitoring. The 9 PCE sites that are not listed in the table are also included in the count of 16 sites. In some of the sites, shallow monitoring wells went dry due to the water table levels dropping and deeper monitoring wells had to be drilled to continue the investigations. Currently, there is not enough information to determine if the contaminants are sinking with the groundwater levels. The main constituents of concern due to contamination plumes in this Subbasin are volatile organic compounds (VOCs), more specifically PCE and TCE, and gasoline related constituents. The two pesticide/herbicide plumes that were identified in the GeoTracker database have no information or data available.

2.7.3.7 Sodium and Chloride

Based on drinking water standards, the recommended secondary maximum contaminant level (SMCL) of chloride is 250 parts per million (ppm) with an upper limit of 500 ppm. There is no primary drinking water standard for sodium, however Water Quality Goals for Agriculture, published by the Food and Agriculture Organization of the United Nations in 1985, has set Agricultural Water Quality Goals for sodium and chloride at 69 ppm and 106 ppm, respectively. The criteria identified are protective of various agricultural uses of water, including irrigation of various types of crops and stock watering. These levels are used as a baseline to compare against and are not intended to represent an acceptable maximum value for the Subbasin. Since a majority of the land use in the Subbasin is irrigated lands, the Agricultural Water Quality Goals for sodium and chloride are used for this portion of the water quality evaluation.

There are four primary sources of sodium: agriculture, municipal, industrial, and natural. Agriculture practices result in evaporation of irrigation water which removes water and leaves the salts behind. Plants may also naturally increase soil salinity as they uptake water and exclude the salts. Application of synthetic fertilizers and manure from confined animal facilities are also other means by agriculture. A municipal source of sodium occurs through the use of detergents, water softeners, and industrial processes. Wastewater discharged to Publicly Owned Treatment Works (POTWs) and septic systems can increase salinity levels. An industrial source is by industrial processes such as cooling towers, power plants, food processors, and canning facilities. The last source is naturally from the groundwater, which contains naturally-occurring salts from dissolving rocks and organic material.

Only a few wells within the Kaweah Subbasin that have increasing or elevated sodium and chloride levels. However, there are small pockets within the Subbasin that have increasing or elevated sodium and chloride levels. ***Figure 81*** identifies where those wells are located. Sodium and chloride levels are increasing and, in some cases, already over the Agricultural Water Quality goals.

Figure 82 shows trends from two wells in a public water system located between Highway 65 and the Friant-Kern Canal with increasing chloride trends that have exceeded the Agricultural Water Quality goals and in one well, also exceeding the secondary drinking water standard. ***Figure 83*** also shows trends from wells within the City of Lindsay, where the chloride levels show a similar trend.

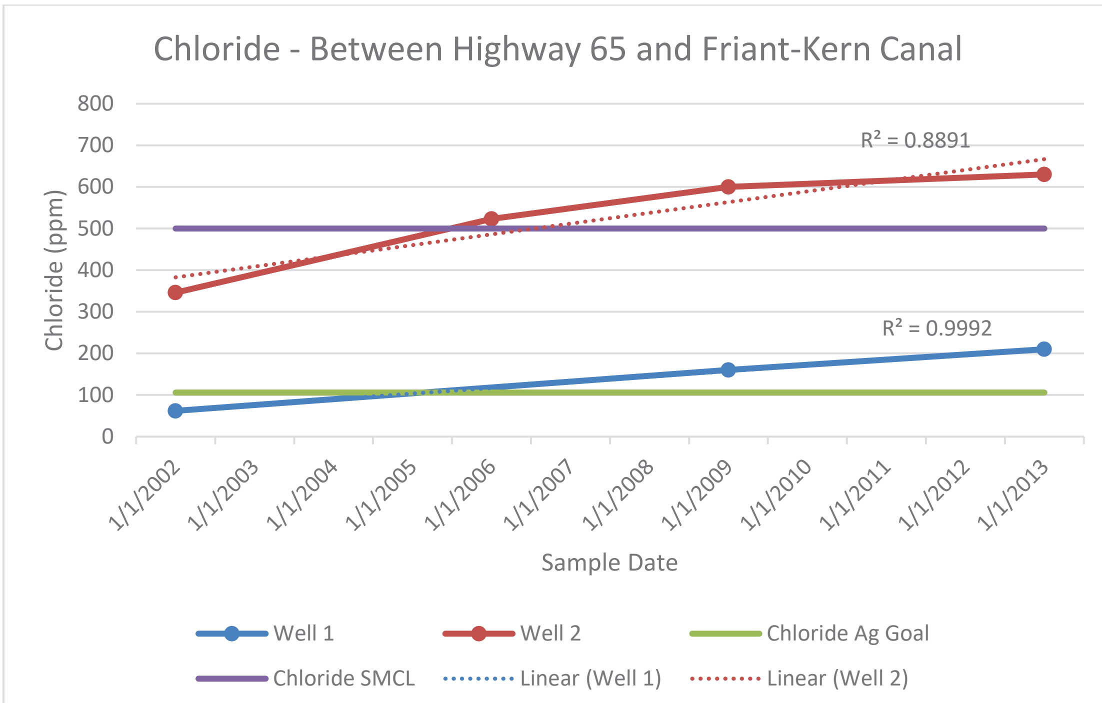

Figure 82: Chloride Trend of Two Wells Located Between Highway 65 and Friant-Kern Canal

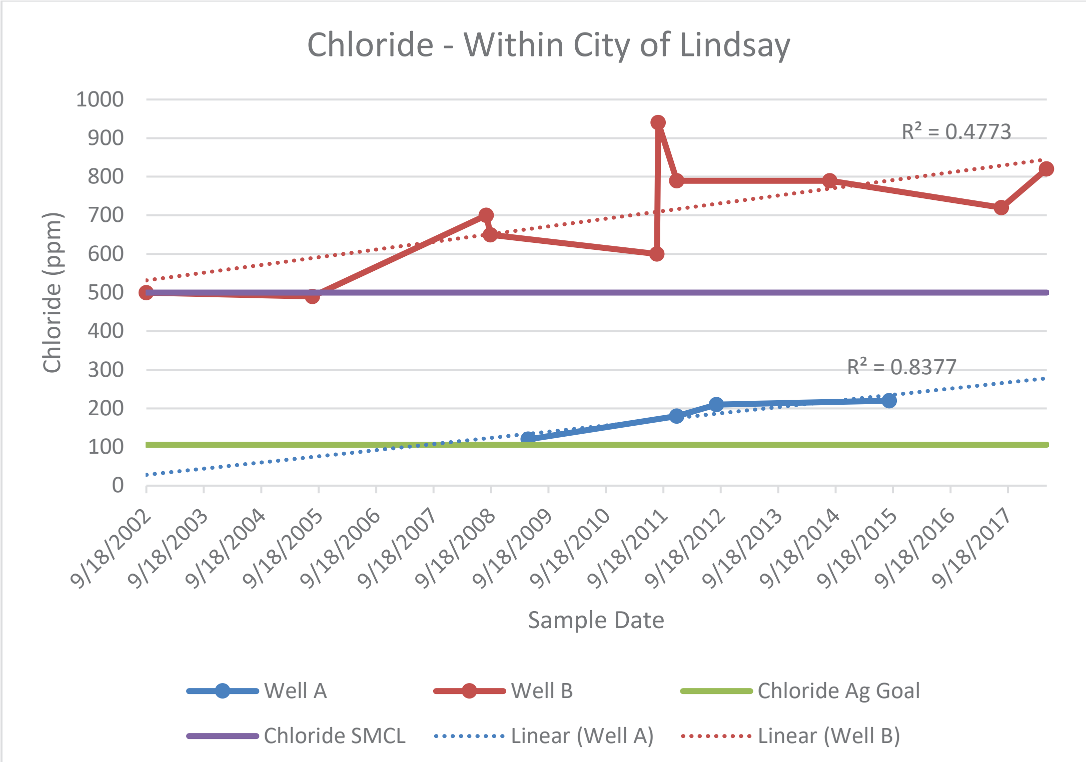

Figure 83: Chloride Trends of a Public Water System with Wells Within City of Lindsay

Findings from this evaluation show that the most common water quality issues within the Subbasin are: nitrate, arsenic, and PCE. Wells with high arsenic correlates with deeper, older water that is associated with the Corcoran Clay. The pH levels were also higher with wells having arsenic levels over 10 ppb. Nitrate is prevalent throughout the Subbasin with higher concentrations from east of Highway 63 to Highway 245 in the north and from Road 152 to the eastern extent of the Subbasin. These zones had greater than 50% of the land use as orchard and vineyards. Also, septic system density is greater in these areas compared to the rest of the Subbasin. Well construction also plays a factor in both elevated arsenic and nitrate levels. Deeper wells, greater than 250 ft., tend to have higher arsenic levels. On the other hand, shallow wells or wells with sanitary seals less than 250 ft. tend to have higher nitrate levels. The city-wide PCE plume in Visalia is something that needs to be monitored since it is an ongoing investigation. All other constituents that were evaluated are not a Subbasin-wide issue.

2.8 Land Surface Subsidence §354.16 (e)

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

2.8.1 Cause of Land Subsidence

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

Inelastic compaction (subsidence) typically occurs in the fine-grained beds of the aquifers and in the aquitards due to the one-time release of water from the inelastic specific storage of clay layers caused by groundwater pumping. When long-term groundwater pumping and overdraft occurs, the aquifer system can become depressurized, and water originally deposited within the fine-grained units can be released from the clay layers. This depressurization allows for the permanent collapse and rearrangement of the structure, or matrix, of particles in fine-grained layers. Groundwater cannot re-enter the clay structure after it has inelastically collapsed. This condition represents a permanent loss of the water storage volume in fine-grained layers due to a reduction of porosity and specific storage in the clay layers. Although space within the overall aquifer is reduced by subsidence of the land surface and reduced thickness of the clay layers, this storage reduction does not substantially decrease usable storage for groundwater because the clay layers do not typically store significant amounts of recoverable, usable groundwater (LSCE, 2014). However, this one-time release of water from compaction has been substantial in some areas of the San Joaquin Valley. Although the largest regional clay unit in and adjacent to the Kaweah Subbasin is the Corcoran Clay, a relatively insignificant volume of water has been released from storage from it (Faunt et al., 2009). This is likely because of its large thickness and low permeability. However, the groundwater quality of the aquifers, however, could be impacted by the lower quality of groundwater emanating from the depressurized clay layers.

2.8.2 Regional Cause and Effect of Subsidence

Figure 84 through *Figure 88* of this section present land subsidence at a subbasin scale; however, the data also show that subsidence occurs regionally where the Corcoran Clay and other associated fine-grained units are present in the subsurface. Areas where greater groundwater pumping has occurred coupled with newly installed deeper well screen intervals below the Corcoran Clay may contribute to land subsidence from dewatered clays in previously unpumped depth intervals of the aquifer system. This topic is further discussed in the sustainable management criteria section of this report. These pumping intervals occur in the Kaweah Subbasin as well as in neighboring subbasins to the Northwest, West, Southwest, and South of the Subbasin. Additional data and coordination between subbasins are recommended to better understand the effects of groundwater management on the mitigation of land subsidence.

2.8.3 Past Land Subsidence

Historical documentation of subsidence within the Central Valley has relied on various types of data, including topographic mapping and ground surveys (including the remote sensing NASA JPL InSAR data), declining groundwater levels, borehole extensometers, and continuous GPS station information. Within the Subbasin, subsidence has been documented by the National Geodetic Survey at up to 8 feet from 1926 to 1970, as shown on ***Figure 84***. Groundwater overdraft (when there is a lack of surface water supply for irrigation) is considered to be the primary driver for historical land subsidence in the Central Valley (Faunt et. al., 2009). USGS estimates that about 75 percent of historical subsidence in the Central Valley occurred in the 1950s and 1960s, corresponding to extensive groundwater development. Time-series charts of historical water levels were compared with the DWR water year indices corresponding to above normal, below normal, and normal climatic conditions. In general, water levels declined during below normal water year indices (critical, dry, or below normal), while water levels were more stable or recovering during high water year indices (wet, above normal).

2.8.4 Recent Land Subsidence

Recent subsidence studies of the Central Valley, including the Subbasin, have utilized satellite-based, remote sensing data from the InSAR and aircraft-based L-band SAR or Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) programs, led by NASA/JPL, as well as other international researchers. These datasets, shown on ***Figure 85*** and ***Figure 86***, provide a continuous estimate of subsidence over a large portion of the Subbasin. The annual rate of subsidence for these datasets are shown on ***Figure 87*** through ***Figure 88***.

Recent subsidence in the Subbasin and in the Tule Subbasin (immediately to the south) can also be observed at two continuous GPS (CGPS) stations, shown on ***Figure 85*** through ***Figure 88***. These monitoring points are located to the northwest of Farmersville (station P566), and southwest of Porterville (P056) and provide recent, localized subsidence data from November 2005 to present. These CGPS stations are monitored as a part of UNAVCO's Plate Boundary Observation (PBO), the California Real Time Network (CRTN) and California Spatial Reference Center (CSRC) of the Scripps Orbit and Permanent Array Center (SOPAC). Daily CGPS position time-series data with 6 month moving averages are plotted and displayed with InSAR data for comparative purposes on ***Figure 85*** through ***Figure 88***. The quality of these datasets is deemed "reproducible" by UNAVCO, and cumulative rates of subsidence were calculated by taking annual water year averages of the dataset. Annual averages of CGPS or future extensometer data may permit a more meaningful comparison with InSAR data in future calculations and analyses. Another dataset to be used in the future for comparing InSAR and CGPS data, are level surveying data from local subsidence monitoring benchmarks. These benchmarks represent a piece of the subsidence monitoring network as described in the monitoring section of this report.

Time-series charts of subsidence data are included on ***Figure 85*** and ***Figure 86***, and are compared with the DWR water year indices. Greater rates of compaction/subsidence generally correlate with below normal water year indices (critical, dry, or below normal), while lower rates of subsidence are observed during high water year indices (wet, above normal). The inserted hydrographs show that, in recent times, nearby water levels do not consistently correspond with DWR water year indices, likely due to changes in groundwater management practices and improved surface water supplies since the 1960's. Upon further examination of time-series data for the Corcoran Station, water levels in the lower aquifer (deep) better correlate with the water year indices and changes in subsidence rates, in contrast to the water levels in the upper aquifer (shallow), which do not correlate as readily with changes in subsidence rates.

Recent and historical subsidence data are summarized in *Table 43*. It includes a summary of InSAR data published in a subsidence study commissioned by the California Water Foundation (LSCE, 2014), and by JPL. The InSAR data were collected from a group of satellites (Japanese PALSAR, Canadian Radarsat-2, and ESA's satellite-borne Sentinel-1A and -1B), from 2006 to 2017, with a data gap from 2011 to 2014 because there was a gap in satellite data collection until the ESA Sentinel satellites were launched in 2014.

According to the California Water Foundation study (LSCE, 2014), subsidence is on-going and leading to significant impairment of water deliveries from the Friant-Kern Canal south of the Kaweah Subbasin. According to DWR (2014), the Kaweah Subbasin was rated at a high risk for future subsidence due to 1) a significant number of wells with water levels at or below historical lows; 2) documented historical subsidence; and 3) documented current subsidence. Moreover, greater amounts of subsidence are occurring to the west, southwest, and south of Kaweah in adjacent subbasins. The amount of future subsidence will depend on whether future water level elevations decline below previous lows and remain at these levels for years. Maintaining water at a suitable water level elevation (threshold) may limit future subsidence caused by groundwater pumping within the Kaweah Subbasin.

2.8.5 Subsidence Locations

Historical subsidence within the Subbasin, as determined by the data sources discussed above, are presented on *Figure 84* through *Figure 88*. Hydrographs for selected wells are plotted with subsidence data for comparison purposes. Although undesirable results due to subsidence are dependent up on declines in groundwater elevations and potentiometric surfaces for deeper aquifers, the presence of regional fine-grained stratigraphic units, such as the Corcoran Clay, and localized areas of substantial thicknesses of fine-grained layers is also a major factor. Likewise, key infrastructure that may be impacted by land subsidence should also be considered to determine areas that are sensitive to impacts from subsidence.

In general, groundwater levels lowered by pumping correspond with observed land subsidence, as seen on *Figure 84*. The groundwater elevation declines shown on this figure can also be compared to the subsidence trends shown on other subsidence maps. The magnitude and annual rate of subsidence increases toward the west and southwest within the Kaweah Subbasin, and progressively increase to the south and west of the Subbasin boundaries, according to InSAR data as well as CGPS data and historical data from the Deer Creek Extensometer and surveying information along the Friant-Kern Canal.

Cumulative and annual rates of recent subsidence (Spring 2015 through 2017) are presented in *Figure 86* and *Figure 88*, respectively. When compared to the cumulative and annual rates of subsidence shown for January 2007 through May 2011, shown on *Figure 85* and *Figure 87*, it is apparent that land subsidence has increased in recent years, in response to drought conditions and increased groundwater demand. This trend is also reinforced by regional extensometer and CGPS data. Overall the limited CGPS data presented in the figures reasonably corresponds with the estimated magnitude of subsidence estimated by the InSAR data.

2.8.6 Measured Subsidence

The following tabulated data includes cumulative inches of subsidence within Kaweah, and approximate annual rates for various data collection periods.

Table 43: Land Subsidence Data

Subbasin Area	Date Range	Cumulative Subsidence (inches)	Calculated Annual Rate of Subsidence (inches/year)	Source
Kaweah Subbasin	1926 - 1970	~0 - 96	0 – 2.2	Ireland, 1984. Topographic Maps and Leveling Data.
North of Farmersville	2007 - 2017	4.9	0.5	CGPS PBO (P566). Data are averaged by water year 2007 to 2017
South of Porterville (just outside of Subbasin)	2007 - 2017	21.3	2.1	CGPS PBO (P056 just south of Subbasin). Data are averaged by water year 2007 to 2017
Deer Creek. South of Porterville	1970 – 1982	15.8	1.3	Extensometer Data from USGS CA Water Science Center
Corcoran[4]	Sep. 2010 – May. 2017	76.35	11.4	Corcoran CGPS Station (CRCN). Central Valley Spatial Reference Network (CVSRN) Caltrans via California Real Time Network (CRTN) at SOPAC.
West and central Kaweah Subbasin *(Highest values in SW near Corcoran)*	Jan. 2007 – Mar. 2011	0 – 33.9	0 - 8	LSCE, 2014. Compiled from InSAR.
Kaweah Subbasin *(Highest values in SW near Corcoran)*	2015 - 2017	0 – 26.7	0 – 13.4	InSAR. Downloaded from DWR SGMA Viewer.
Mile Post 88. Friant-Kern Canal (FKC). Between Lindsay and Strathmore	1945/1951 to 2017	~4.6	~0.07	USBR FKC Subsidence Monitoring Surveys. NGVD29 to NAVD88
Mile Post 92 FKC. South of Subbasin	1945/1951 to 2017	~6.7	~0.1	
Mile Post 95 FKC. Tule River Siphon	1945/1951 to 2017	~21.6	~0.3	

[4] Cumulative Subsidence calculated from Annual Rate Value of 11.4 inches per year.

Subbasin Area	Date Range	Cumulative Subsidence (inches)	Calculated Annual Rate of Subsidence (inches/year)	Source
	1959 to 2017	~20.3	~0.4	
Mile Post 96 FKC. South of Tule River.	1945/1951 to 2017	~27.4	~0.4	
	1959 to 2017	~25.2	~0.4	
Mile Post 99 FKC. West of CGPS P056	1945/1951 to 2017	~78.9	~1.1	

Although the highest rates of subsidence occur outside of the Kaweah Subbasin; to the west and south in the Tulare Lake and Tule subbasins, respectively; there has been significant subsidence within the Subbasin, largely focused in the western and southwest portions. It is apparent that this subsidence is coincident with both a decline in water levels from pumping near Corcoran, as well as pumping within the Kaweah and the Tule subbasins. Higher levels of subsidence have also been estimated southeast of Tulare and appear to correlate with neighboring subsidence in the Tule Subbasin. Overall, annual subsidence rates vary spatially but have increased in magnitude during the recent drought conditions, as groundwater supplied a higher percentage of agricultural demand.

2.8.7 Release of Water from Compression of Fine-Grained Units

Long-term overdraft conditions from groundwater pumping can lead to depressurization of the aquifer system and corresponding dewatering of fine-grained units (or dewatering of clays). The one-time release of water from dewatered clays may represent a one-time principle source of groundwater released from storage to the aquifer system, because fine-grained deposits constitute more than half of the unconsolidated sediments in the Central Valley (Faunt et. al., 2009). The 1989 USGS model (CV-RASA) and other studies attributed most of this one-time release of water to the aquifer system to dewatering of fine grained interbeds of clays and not from regional confining beds such as the Corcoran Clay (Ireland and others, 1984; Williamson and others, 1989; and Faunt et. al., 2009). It is further postulated that “a relatively significant volume of water has not yet been released from storage in the Corcoran Clay” (Faunt et. al., 2009).

2.8.7.1 Water Volume Calculation

The dewatering of clays may lead to measurable land subsidence, in which case, a rudimentary estimate of the volume of water contributing to the aquifer system by the dewatering of clays can be calculated. The land subsidence is a proxy for estimating one-time release of water from clays to aquifer system. A rough estimate of the volume water is calculated herein, by taking the land surface area multiplied by the measured change in vertical elevation of land surface, mostly attributed to land subsidence. Ideally, extensometers would provide depth-specific measurements of compaction of specific zones, instead of using changes in land surface; however, CGPS measuring points were used in the absence of extensometer data for this calculation. In addition, reliable InSAR data are not available for this time period, or for the entire Subbasin, to use as a control for this calculation. For a preliminary volume calculation of one-time water release from the clay layers to the aquifer system, the Subbasin was divided into relative zones of decreasing subsidence starting from the Southwest of the basin to the East-Northeast. These zones were approximated by using the 2015 to 2017 InSAR data as a qualitative tool to identify regimes or different zones of cumulative subsidence.

Figure 77, illustrates the zones which were chosen to correspond with nearby areas of subsidence that have a CGPS station. The Southwest zone corresponds with the 1. CRCN Corcoran station, the adjacent area to the Northeast corresponds with the 2. P056 Porterville station, the next adjacent area corresponds with the 3. P566 Visalia station which is situated in this zone, and the 4. Eastern-most area where negligible to zero subsidence has historically been recorded is not assigned to a CGPS station but is estimated as zero for this calculation. These areas or regimes of subsidence are base only on InSAR data and would require further refinement by additional data for better accuracy. It is likely that the Southwestern-most zone is overestimating the amount of water contributed to the system due to clay dewatering because the Corcoran station reports very high values of subsidence, which decreases rapidly toward the Northeast. The date range of analysis was chosen from September 30, 2011 to September 30, 2017, for the CGPS Stations as presented in *Table 44*.

Table 44: Preliminary Estimate of Volume of Water (AF) by Land Subsidence (2011 to 2017)

	1. CRCN	2. P056	3. P566	4. East
Year	**(Mean Vertical Change (inches))**			
2011	-0.8	-5.2	-2.4	--
2012	-3.7	-6.1	-2.7	--
2013	-15.5	-7.4	-3.1	--
2014	-27.2	-9.5	-3.5	--
2015	-38.9	-12.5	-4.0	--
2016	-52.4	-16.9	-4.6	--
2017	-62.1	-22.1	-5.3	--
Cumulative Total (inches) (9/30/11 to 9/30/17)	-61.3 (-5.1 ft)	-16.9 (-1.4 ft)	-2.9 (-0.2 ft)	-- (0 ft)
Rate (inches/year) (9/30/11 to 9/30/17)	-10	-2.8	-0.2	--
Acreage for each Subsidence Area	98,100	156,000	127,700	64,300
Preliminary Estimate of Volume of Water (AF) by Land Subsidence (2011 to 2017)	500,600	219,300	31,700	0

2.9 Interconnected Surface Water

Both the loss of streamflow to groundwater (losing streams) and the loss of groundwater to surface streams (gaining streams) are part of the natural hydrologic system. The direction of flow depends on the relative elevation of these inter-connected waters, and the rate of flow depends on the properties of the aquifer matrix and the gradients of the water sources. Many surface water-groundwater systems reverse the flow direction seasonally in response to either groundwater extraction or significant groundwater recharge related to spring and early summer runoff.

The flow rate between interconnected surface water-groundwater systems will generally increase as groundwater levels are pumped below the bottom of the surface channel and the flow gradient steepens. While not altogether common in the southern San Joaquin Valley, in many areas, the depth-to-groundwater results in a nearly vertical gradient from the surface stream, and depletion of streamflow becomes nearly constant, varying only with the wetted area of the stream channel.

Declining groundwater levels may decrease the discharge to surface streams and result in reduced instream flow and supply to wetland, estuary areas, and other groundwater dependent ecosystems. Loss of streamflow may reduce the supply available for downstream diverters or require additional releases to be made from surface water reservoirs to meet required instream and downstream needs.

An analysis of baseline conditions has been performed, which considered both local knowledge of natural streamflow within the Kaweah River system including timing and flow regimes (gaining and losing stretches) and gaged streamflow compared to groundwater-level information. Based on this, an estimate of streamflow contribution to the groundwater supply is included in the water budget for the period between water years 1981 and 2017.

Because the streamflow data has been compiled from continuous monitors (Parshall flumes) located throughout a majority of the Subbasin and compiled for every month of the base period, the cumulative effects of both wet year and drought year impacts are well-understood. Furthermore, semiannual groundwater-level measurements collected within Subbasin wells support the understanding of the variability of the relative proximity and/or separation of the surface water from the groundwater in both wet and drought conditions.

In general, the vast majority of the natural streams and manmade ditches (channels) throughout the Subbasin are considered losing channels throughout the year with considerable vertical separation between the channels and groundwater. This vertical separation and disconnection between surface and groundwater throughout much of the San Joaquin Valley floor is recognized by DWR and USGS in the conceptualizations for their regional numerical groundwater models CVHM and C2VSim. Streams located in the eastern portion of the Subbasin, generally between the Friant Kern Canal eastward to McKay Point (See ***Figure 20***), are more likely to be relatively neutral to gaining stream reaches during limited times of year.

2.10 Groundwater Dependent Ecosystems

Where groundwater and surface water are separated by significant distances, as is the case with most of the Kaweah Subbasin, the groundwater does not interact with the natural streams or manmade ditches. In these areas, therefore, no possibility exists for the presence of Groundwater Dependent Ecosystems to exist. However, where the base of the aquifer is relatively shallow, as is the case along the eastern boundary of the Subbasin adjacent the Sierra Nevada, groundwater levels are closer to the surface.

As presented on ***Figure 19***, areas where groundwater is within 50 feet of the ground surface are located along the Kaweah River (Greater Kaweah GSA) and in two areas within the East Kaweah GSA. Notably, these represent areas where groundwater elevations as of the Spring of 2015 has risen to within 50 feet of the ground surface. The indicated areas are preliminary and subject to review of the local GSAs, who know better which areas can be considered Potential GDEs. This can be addressed as part of a further study.

2.11 Conditions as of January 1, 2015

Groundwater levels measured in the spring and fall of each year by the DWR and member agencies provide the data required to document groundwater conditions January 1, 2015, as required. To document the groundwater conditions as of January 1, 2015 when SGMA was enacted, we are using the first round of groundwater level measurements that occurred after that date as the "baseline" condition against which future conditions will be compared. Groundwater levels at that time are presented as ***Figure 30***, along with the water level hydrographs presented as ***Figure 35***.

Review of the map and hydrograph indicate that water levels were near the lowest levels on record. In the spring of 2015 groundwater elevations varied from as low below sea level in the western portion of the basin near the cities of Hanford and Corcoran, to a high of over 400 feet above in the East Kaweah GSA area. As discussed, the exceptionally high pumpage was due in part to the severe drought coupled with a complete lack of delivery of imported CVP water for two years leading up to this period.

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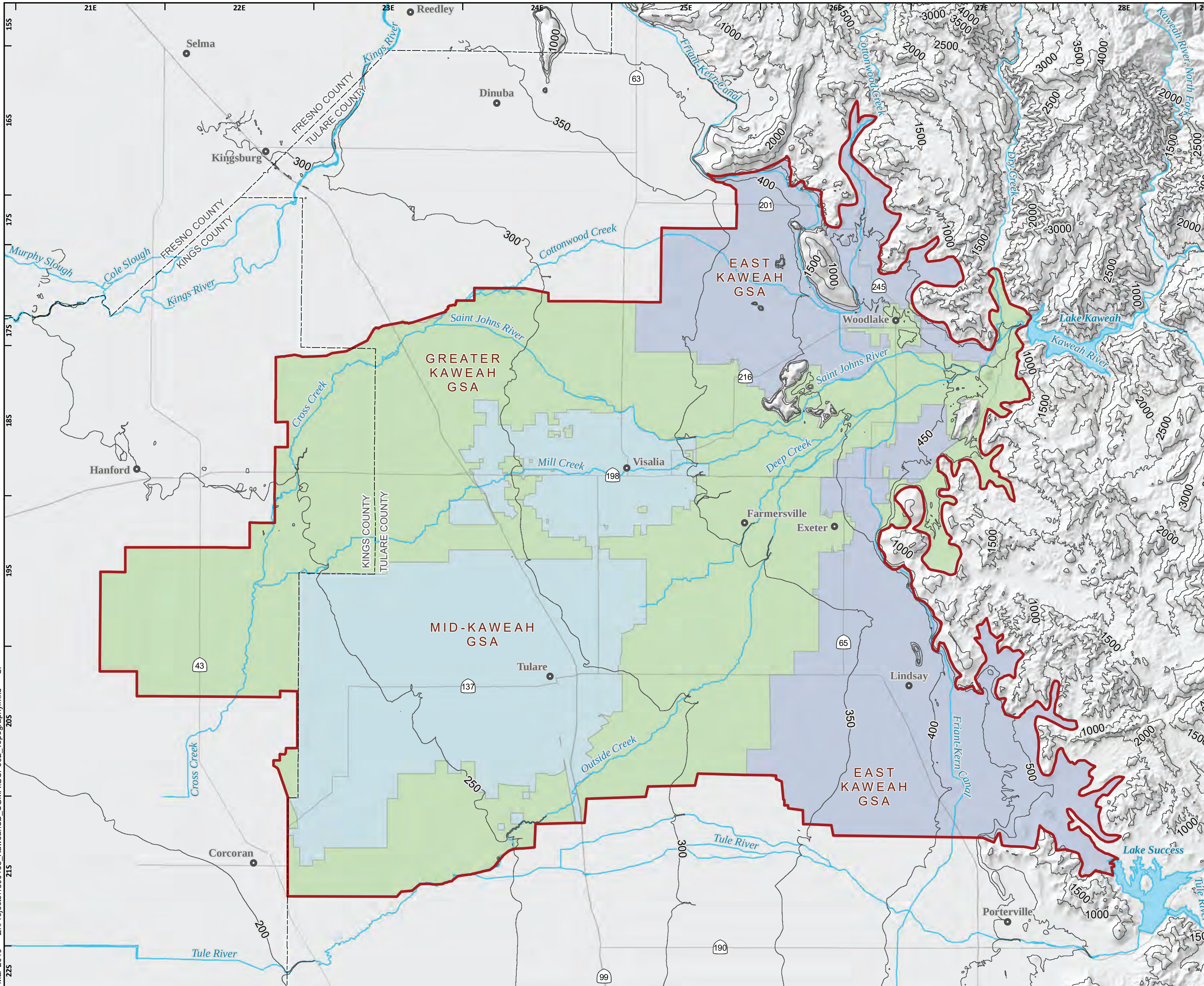
Large Format Figures

TOPOGRAPHIC MAP



Topographic Elevation Contours

Ground Surface Elevation Contours (500-ft interval at greater than 500 ft msl; 50-ft interval at less than 500 ft msl)

GSA Boundaries

East Kaweah GSA

Greater Kaweah GSA

Mid-Kaweah GSA

Kaweah Subbasin Boundary

All Other Features

Highway

Waterway

Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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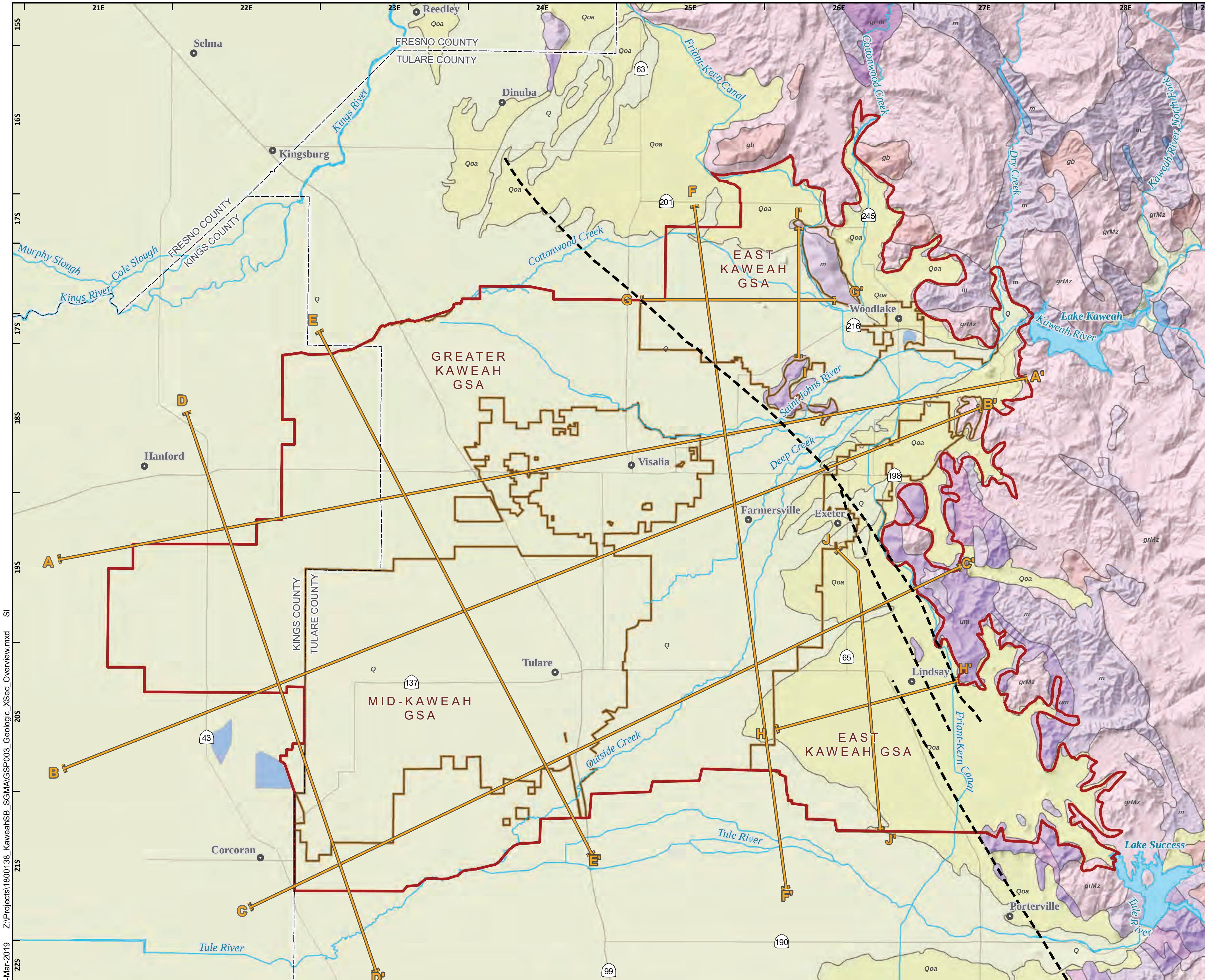
FIGURE 1

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP002_Topography.mxd SI



GEOLOGIC AND CROSS SECTION LOCATION MAP

Rocky Hill Fault Zone
Cross Section Line

Surficial Geology

- Alluvium (Q)
- Older Alluvium (Qoa)
- Marine Sedimentary Rocks (ls)
- Mixed Granitic and Metamorphic Rocks (gr-m)
- Metavolcanic Rocks (mv)
- Granite (grMz)
- Ultramafic Plutonic Rocks (um)
- Gabbro (gb)
- Undated Granitic Rocks (gr)
- Mixed Rocks (m)
- Water

Kaweah Subbasin Boundary
Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lakes

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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MARCH 2019 FIGURE 3

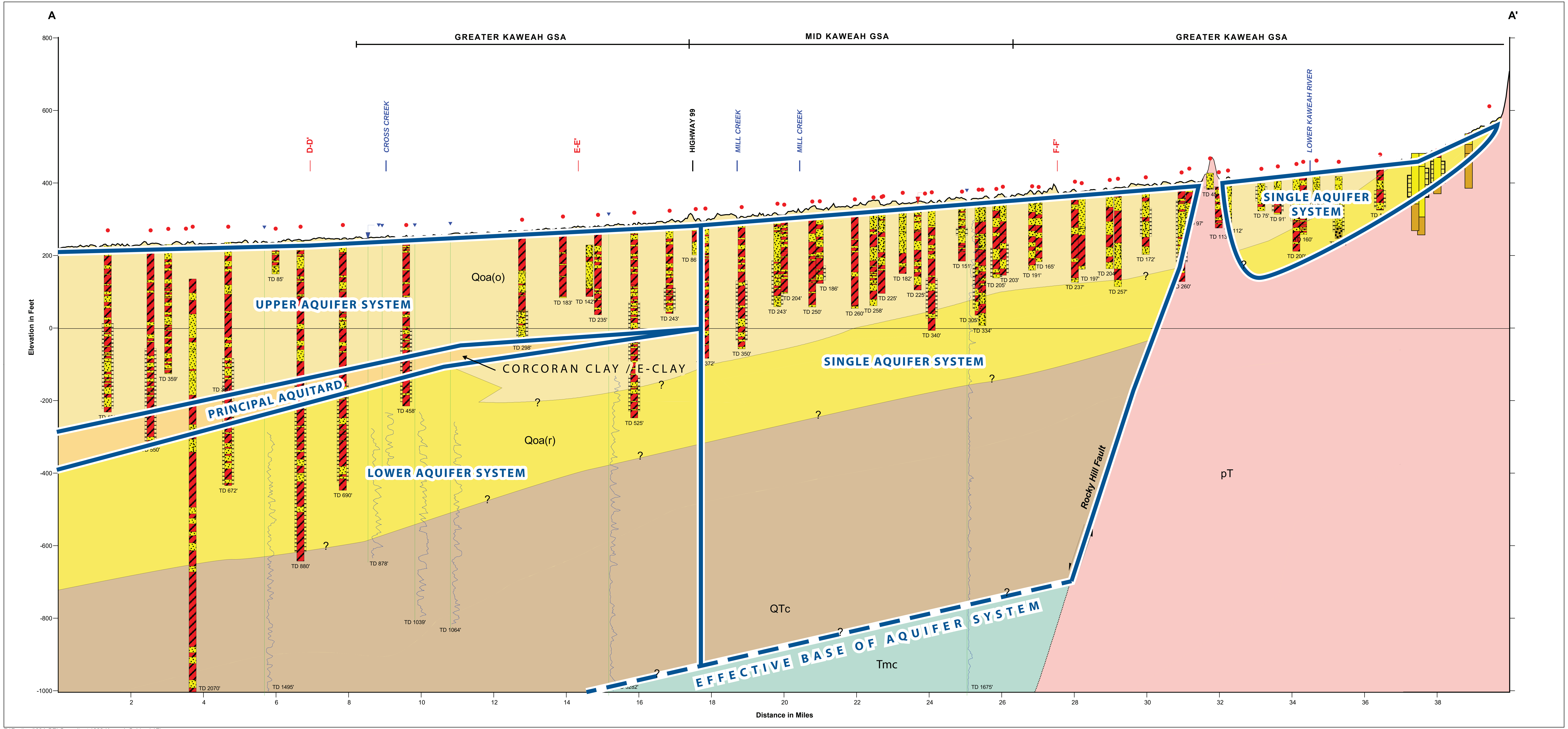


FIGURE 4

Cross Section A

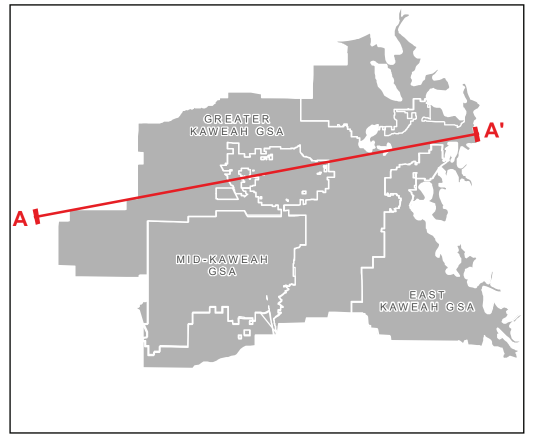
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 14, Geologic Cross Section A

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

0 2 mi

VERTICAL EXAGGERATION: 52.8X

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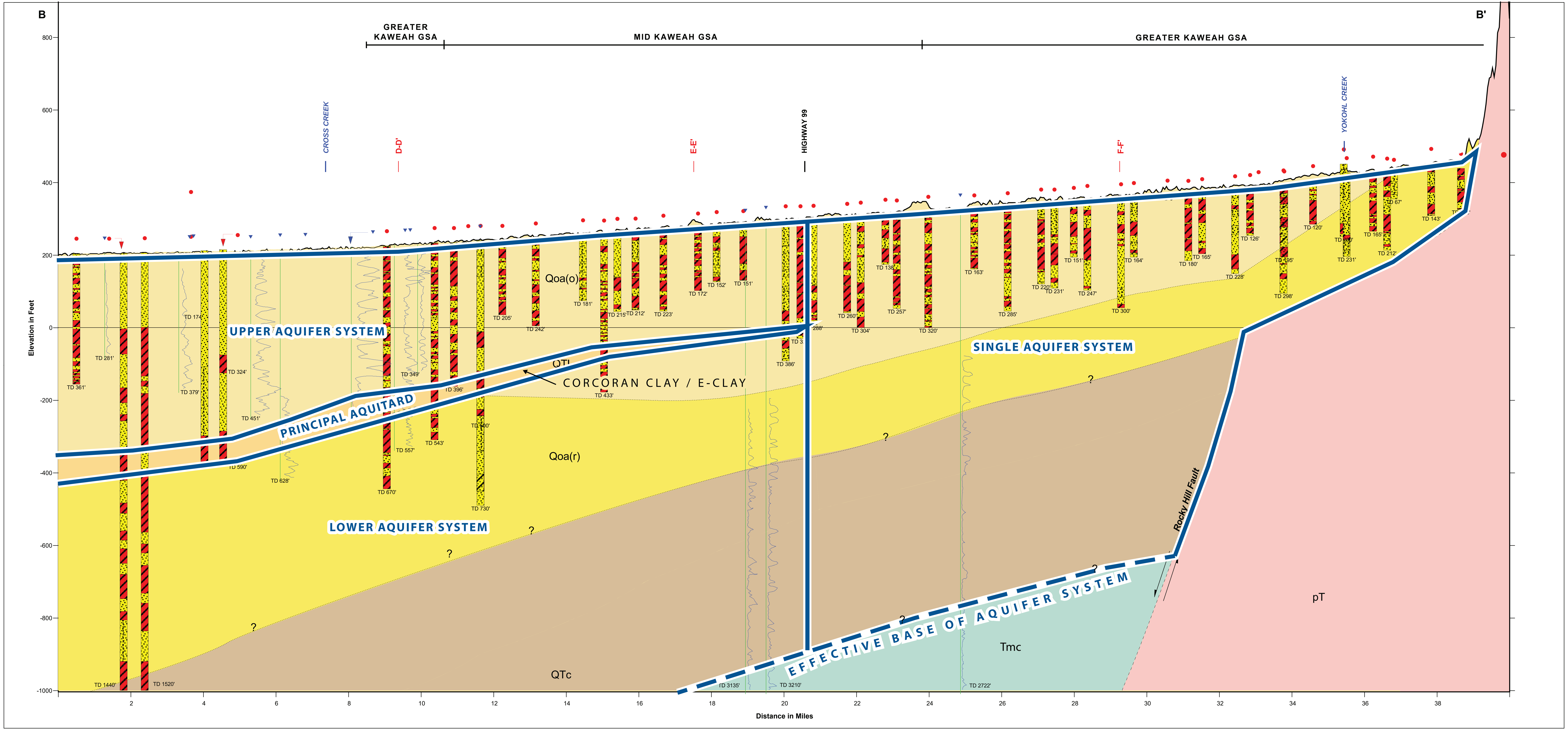

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FIGURE 5

Cross Section B

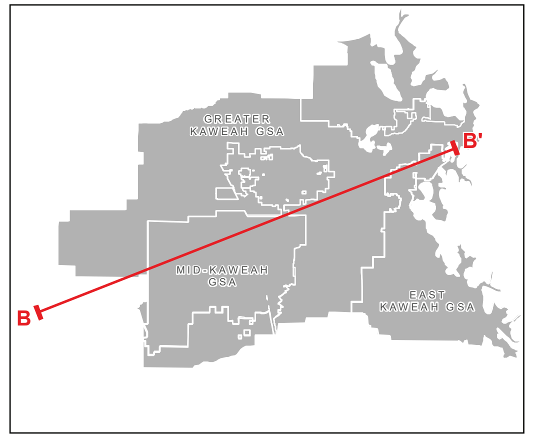
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 15, Geologic Cross Section B

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft | 0 | 2 mi

VERTICAL EXAGGERATION: 52.8X

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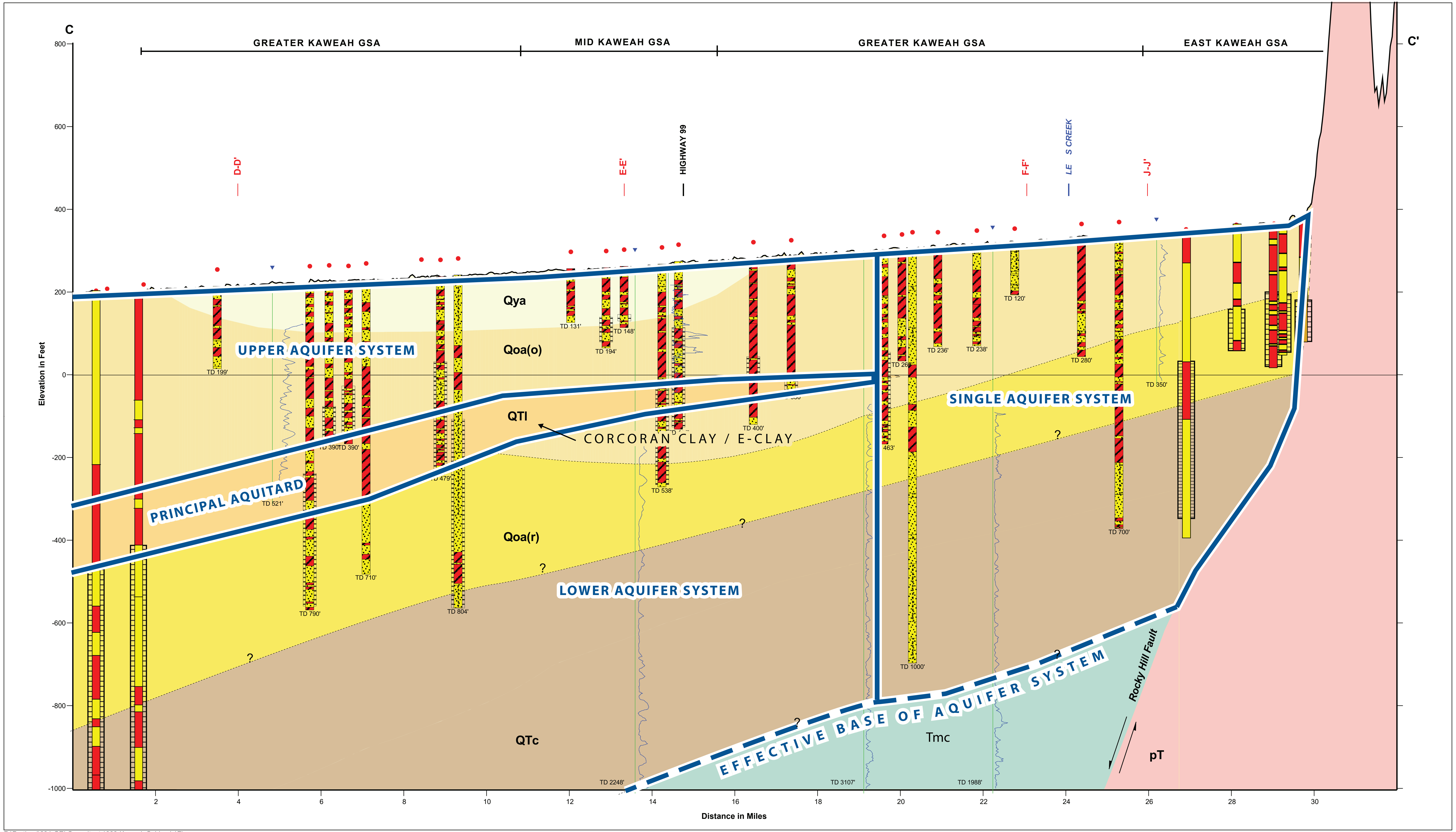

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FIGURE 6

Cross Section C

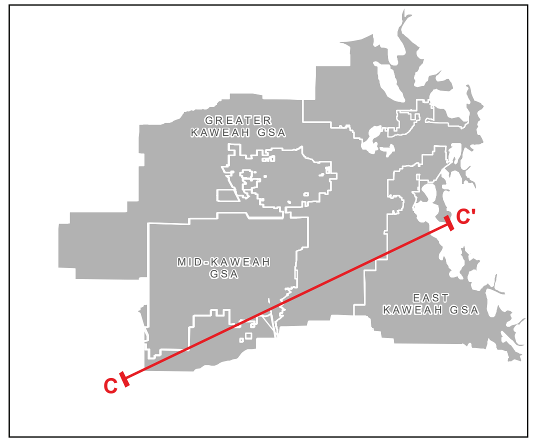
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 16, Geologic Cross Section C

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

0 — 2 mi

VERTICAL EXAGGERATION: 52.8X

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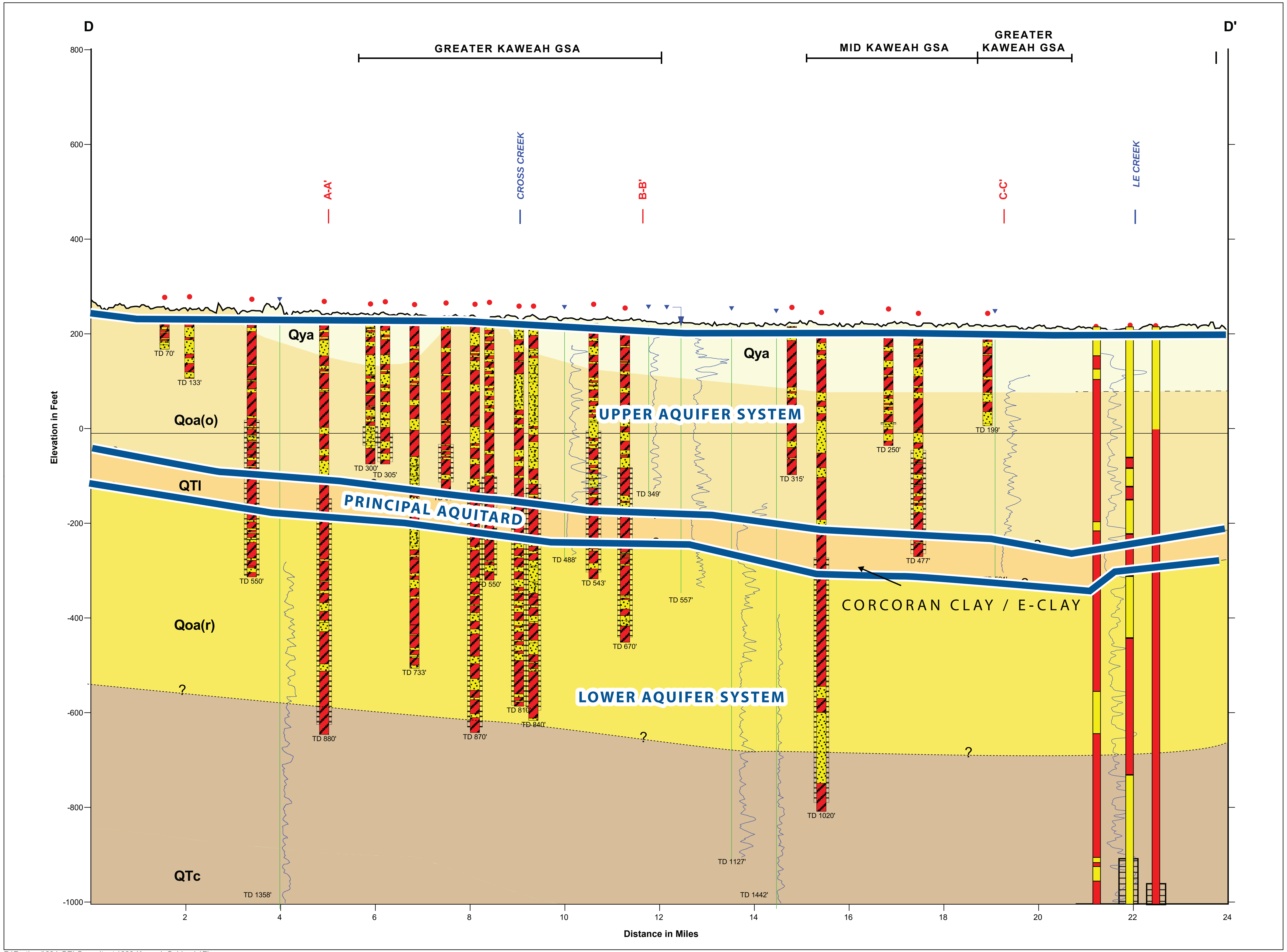

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FIGURE 7

Cross Section D

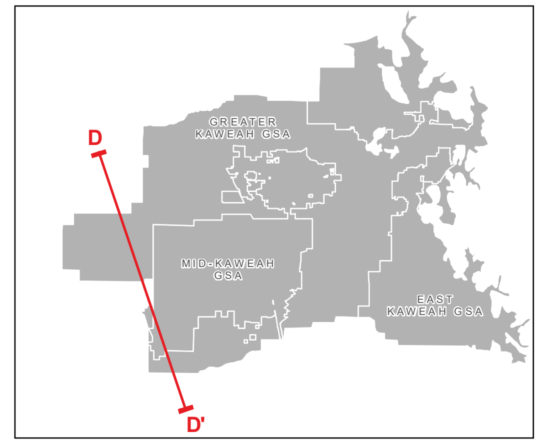
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 14, Geologic Cross Section D

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.
4. Effective Base of Aquifer System is base of continental deposits (Tulare Formation)

SCALE

200 ft

VERTICAL EXAGGERATION: 52.8X

0 2 mi

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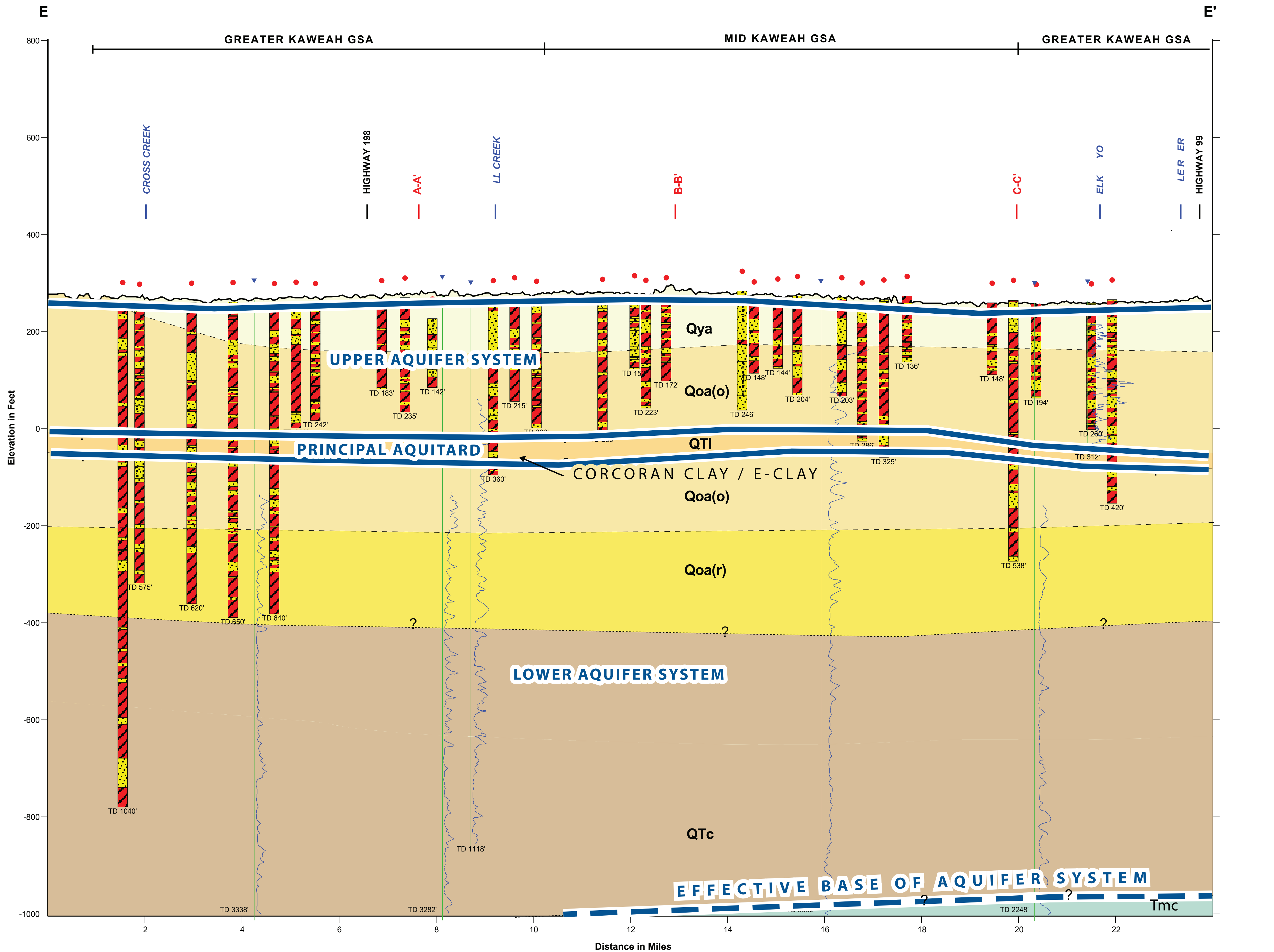


FIGURE 8

Cross Section E

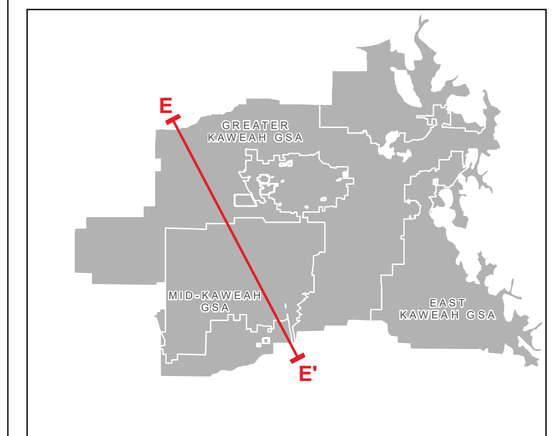
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 18, Geologic Cross Section E

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft — 0 — 2 mi

VERTICAL EXAGGERATION: 52.8X

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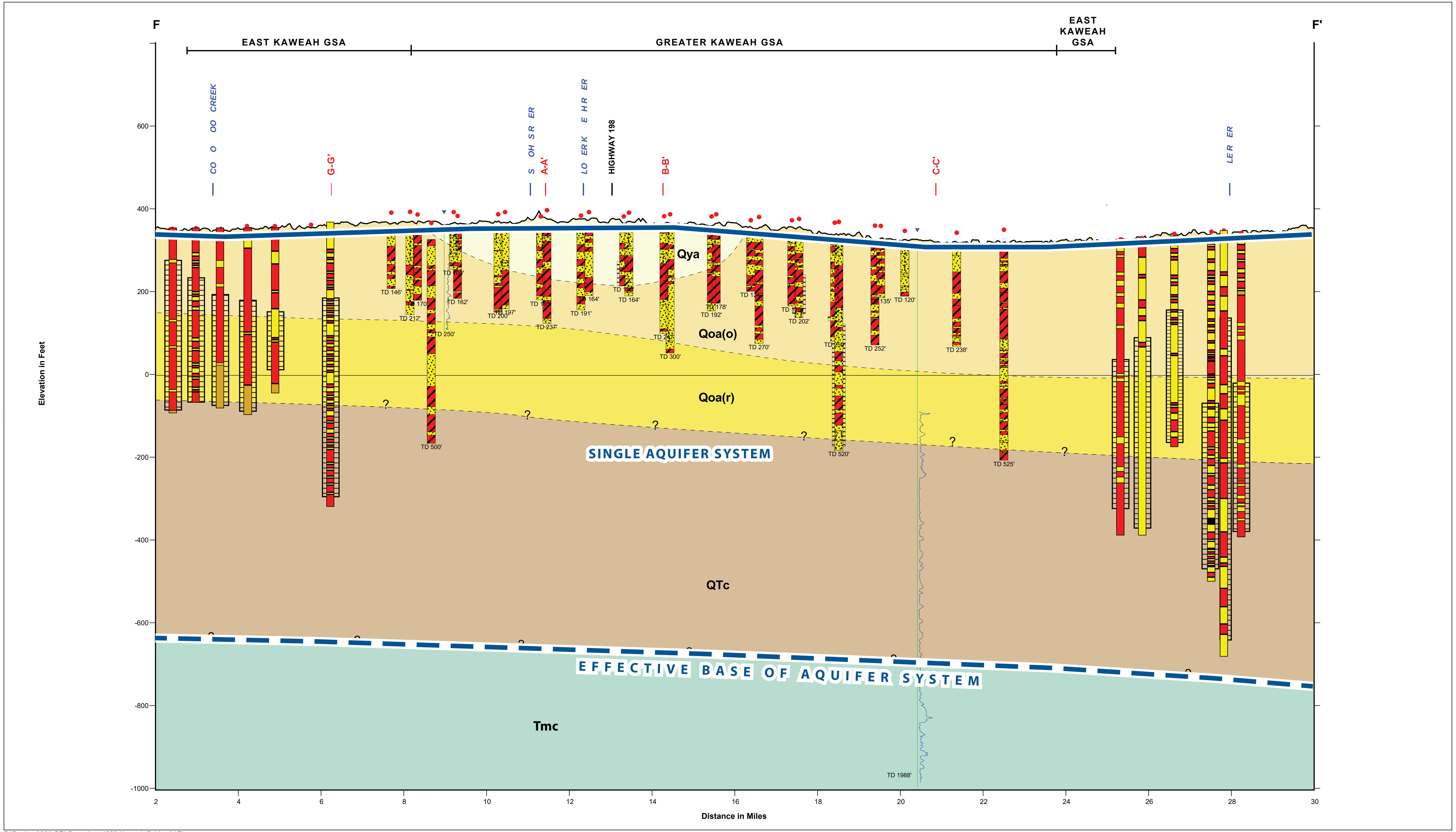

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FIGURE 9

Cross Section F

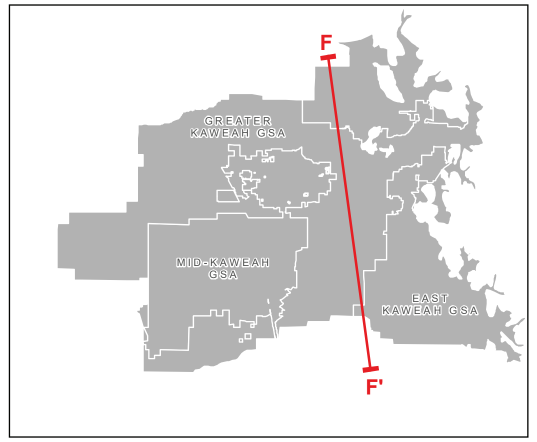
Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System

Boring

- Clay
- Sand
- Sandstone/Rock



NOTES:

Cross section modified from Fugro, 2007, Plate 19, Geologic Cross Section F

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

0 — 2 mi

VERTICAL EXAGGERATION: 52.8X

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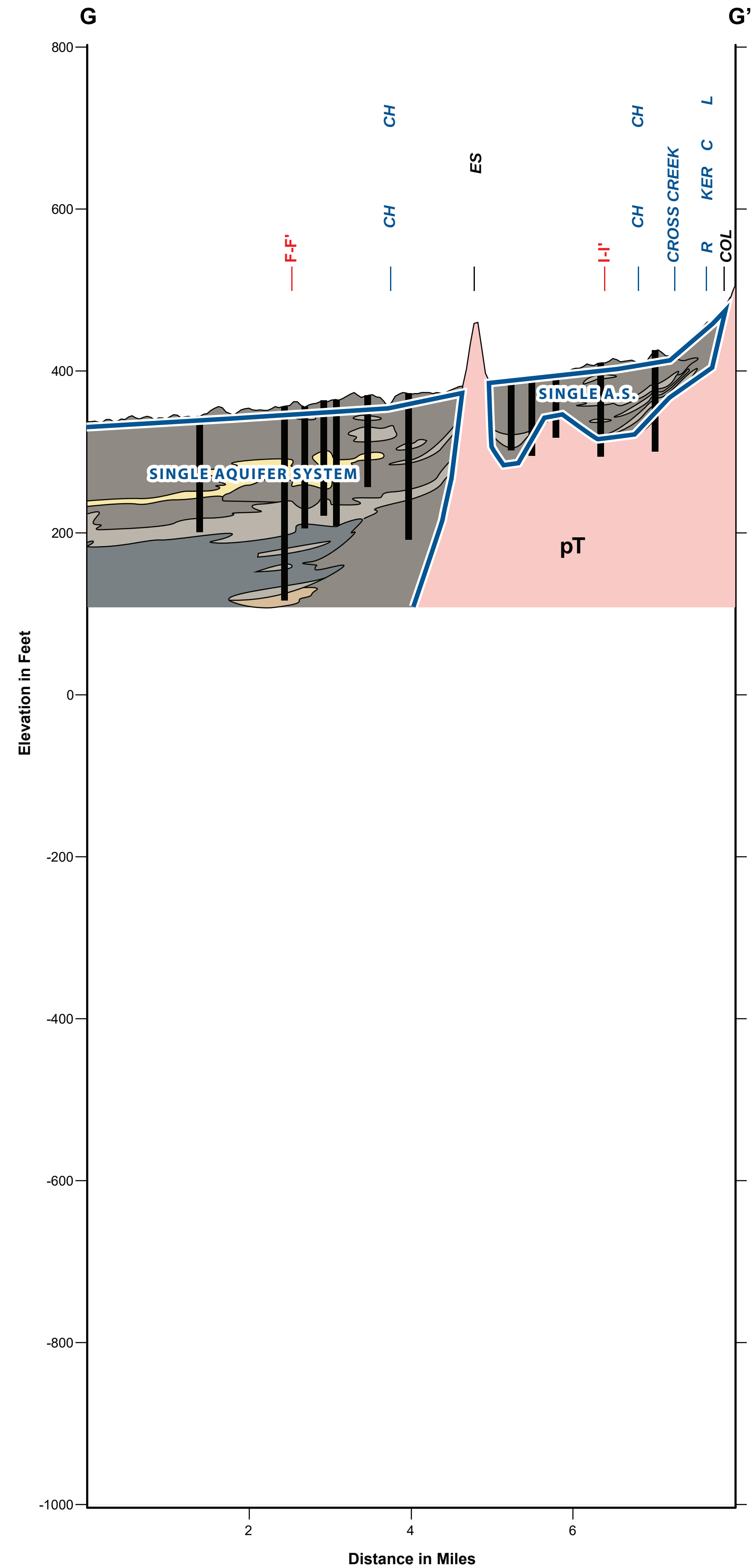


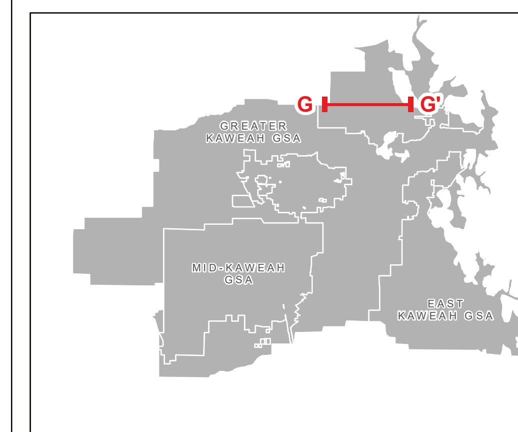
FIGURE 10

Cross Section G

Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Gravel
- Sand
- Silt
- Sandy Clay
- Clay
- pT - Basement Complex
- Generalized Boundaries of Aquifer System



NOTES:

Cross section modified from U.S. Bureau of Rec. (1949), Geologic Cross Section A

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.
4. Effective Base of Aquifer System is base of continental deposits (Tulare Formation)

SCALE

200 ft

VERTICAL EXAGGERATION: 52.8X

0 2 mi

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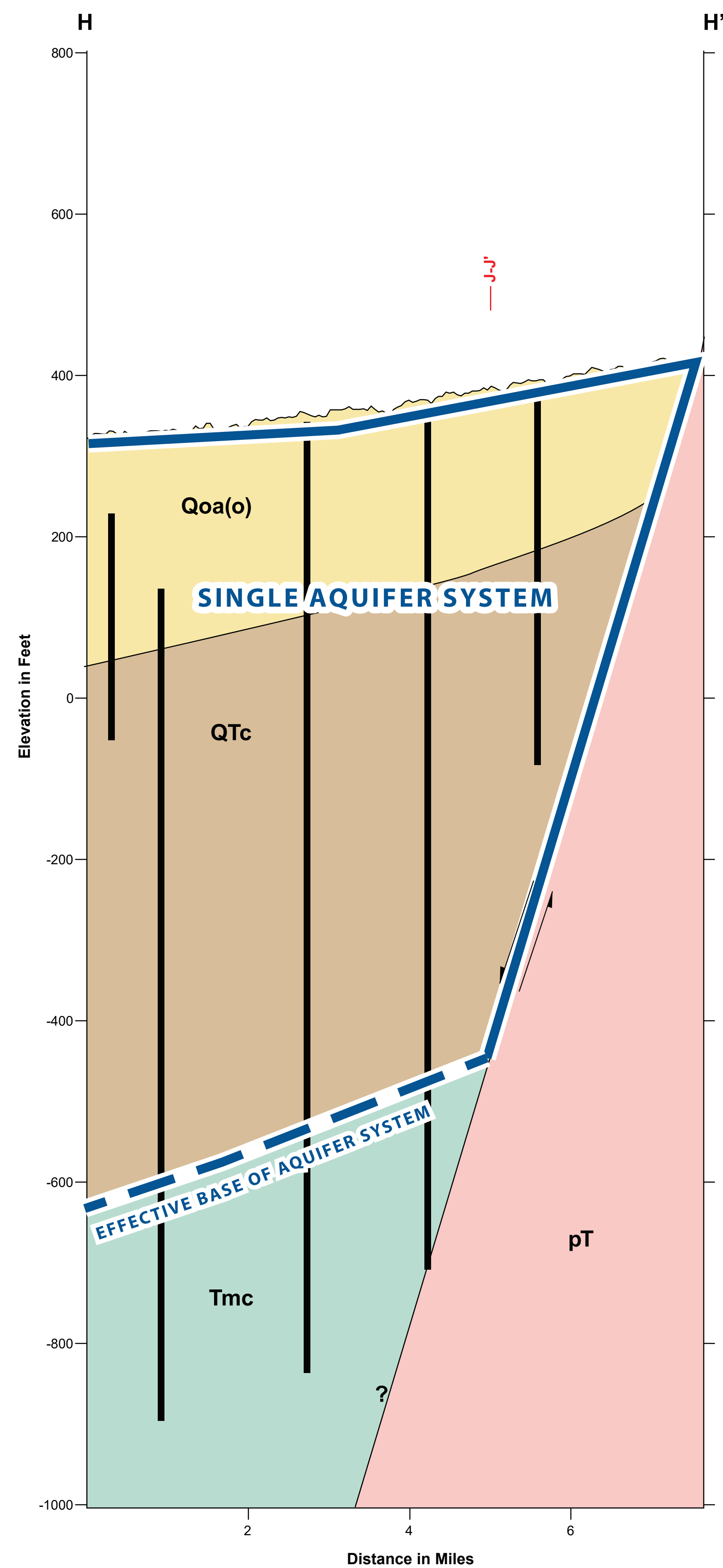


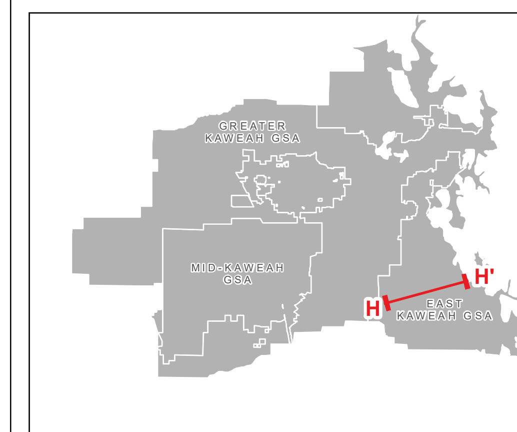
FIGURE 11

Cross Section H

Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System



NOTES:

Cross section modified from Davis et al. (1959), Geologic Cross Section G

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

VERTICAL EXAGGERATION: 52.8X

0 2 mi

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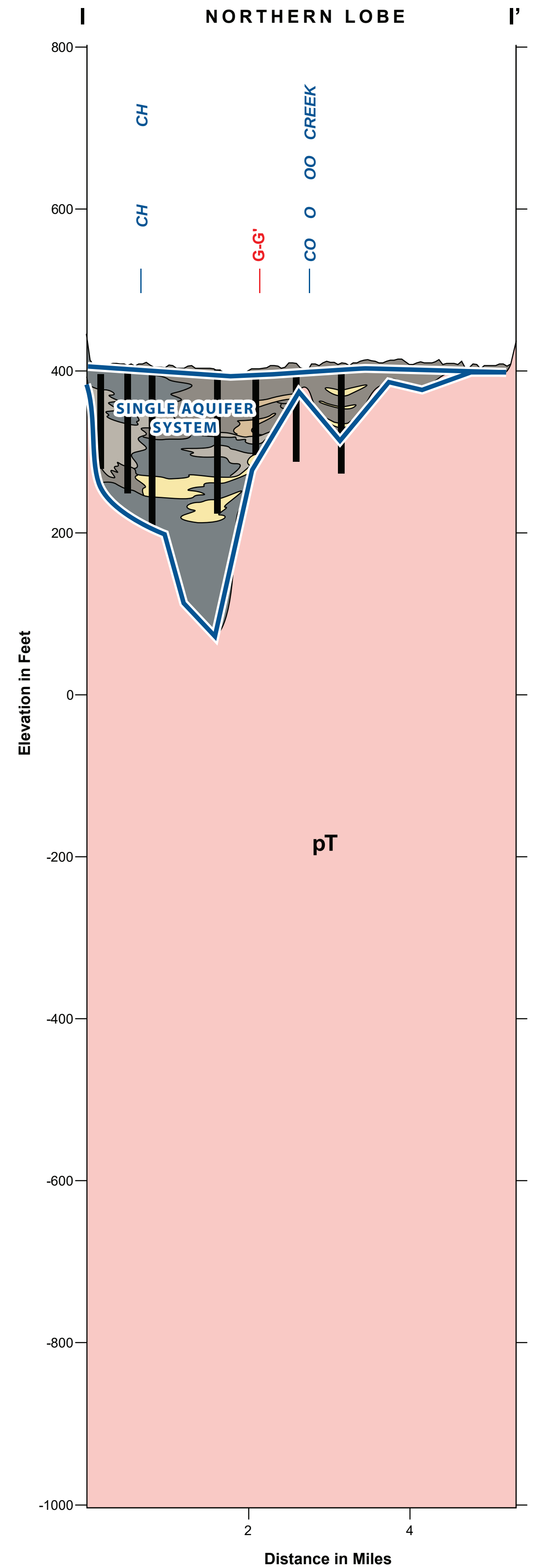
FIGURE 12

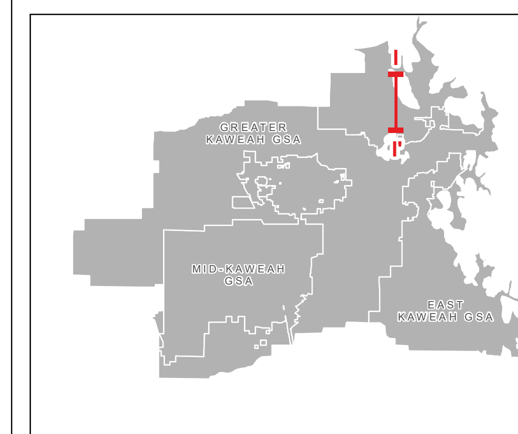
Cross Section I

Kaweah Subbasin
Groundwater Sustainability Plan



LEGEND

- Gravel
- Sand
- Silt
- Sandy Clay
- Clay
- pT - Basement Complex
- Generalized Boundaries of Aquifer System



NOTES:

Cross section modified from U.S. Bureau of Rec. (1949), Geologic Cross Section D

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.
4. Effective Base of Aquifer System is base of continental deposits (Tulare Formation)

SCALE

200 ft

0 2 mi

VERTICAL EXAGGERATION: 52.8X

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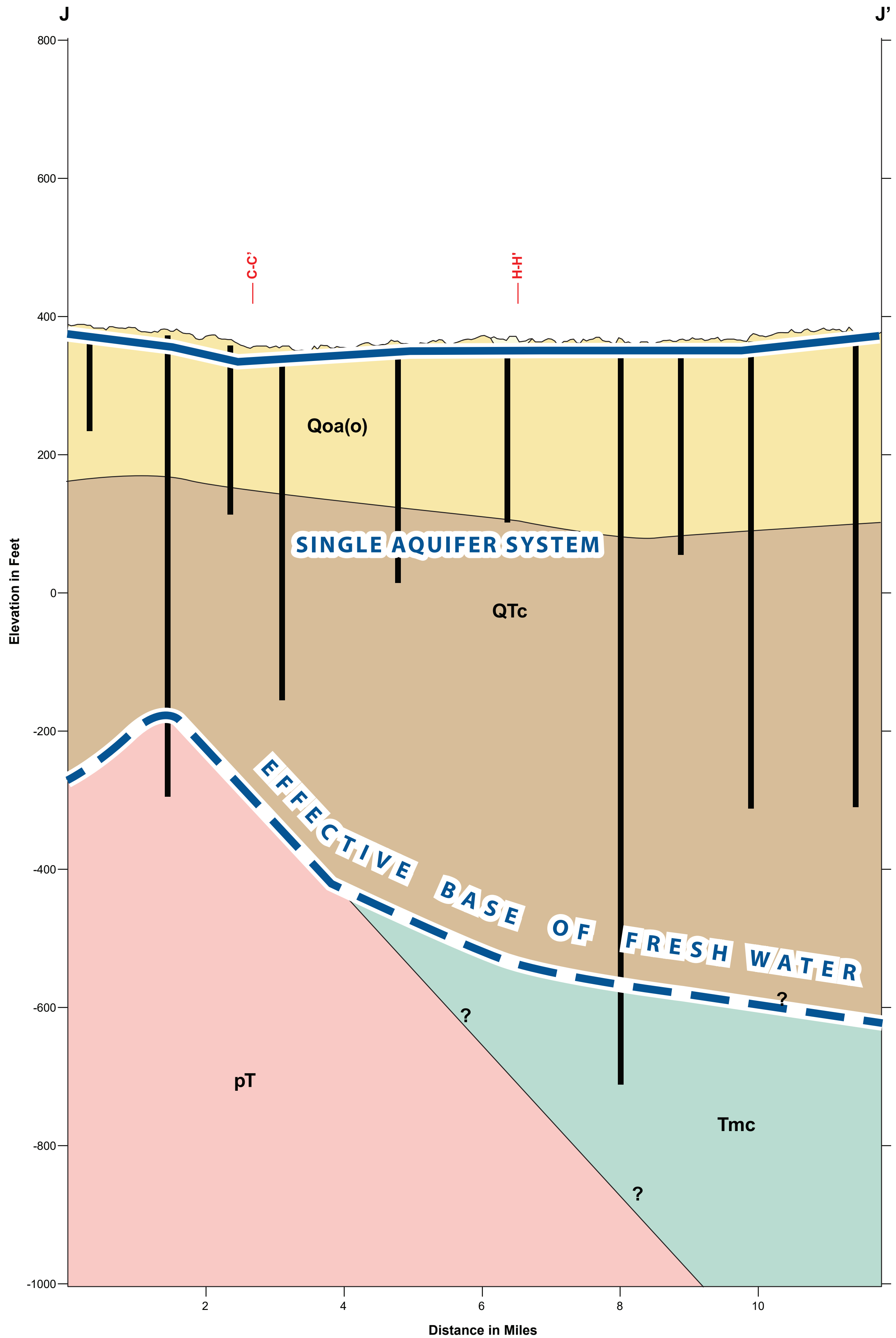


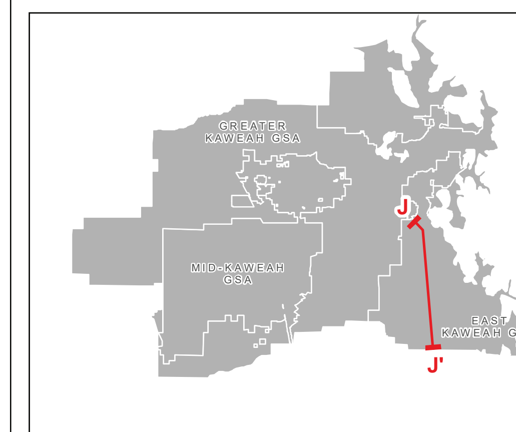
FIGURE 13

Cross Section J

Kaweah Subbasin
Groundwater Sustainability Plan

LEGEND

- Qya - Younger Alluvium
- Qoa(o) - Older Alluvium (oxidized)
- QTl - Corcoran Clay (E-Clay, lacustrine)
- Qoa(r) - Older Alluvium (reduced)
- QTc - Continental Deposits
- Tmc - Marine and Continental Rocks
- pT - Basement Complex
- Generalized Boundaries of Aquifer System



NOTES:

Cross section modified from Croft and Gordon (1968), Geologic Cross Section E

1. Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2. Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
3. Effective base of aquifer system is based on review of recent well logs, professional judgment based on collaboration with adjoining subbasins, and USGS base of fresh water contacts.

SCALE

200 ft

VERTICAL EXAGGERATION: 52.8X

0 2 mi

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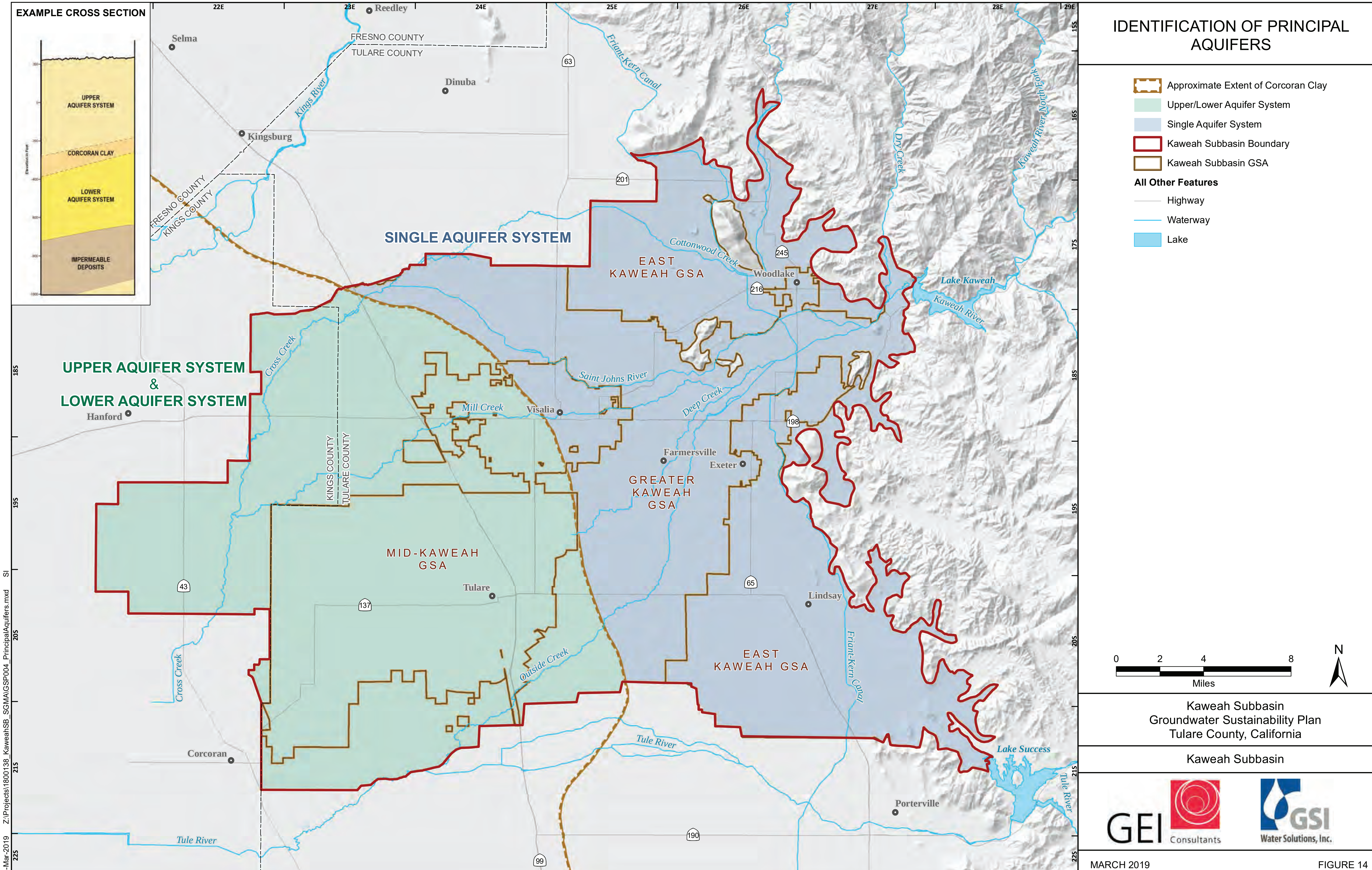
IDENTIFICATION OF PRINCIPAL AQUIFERS



Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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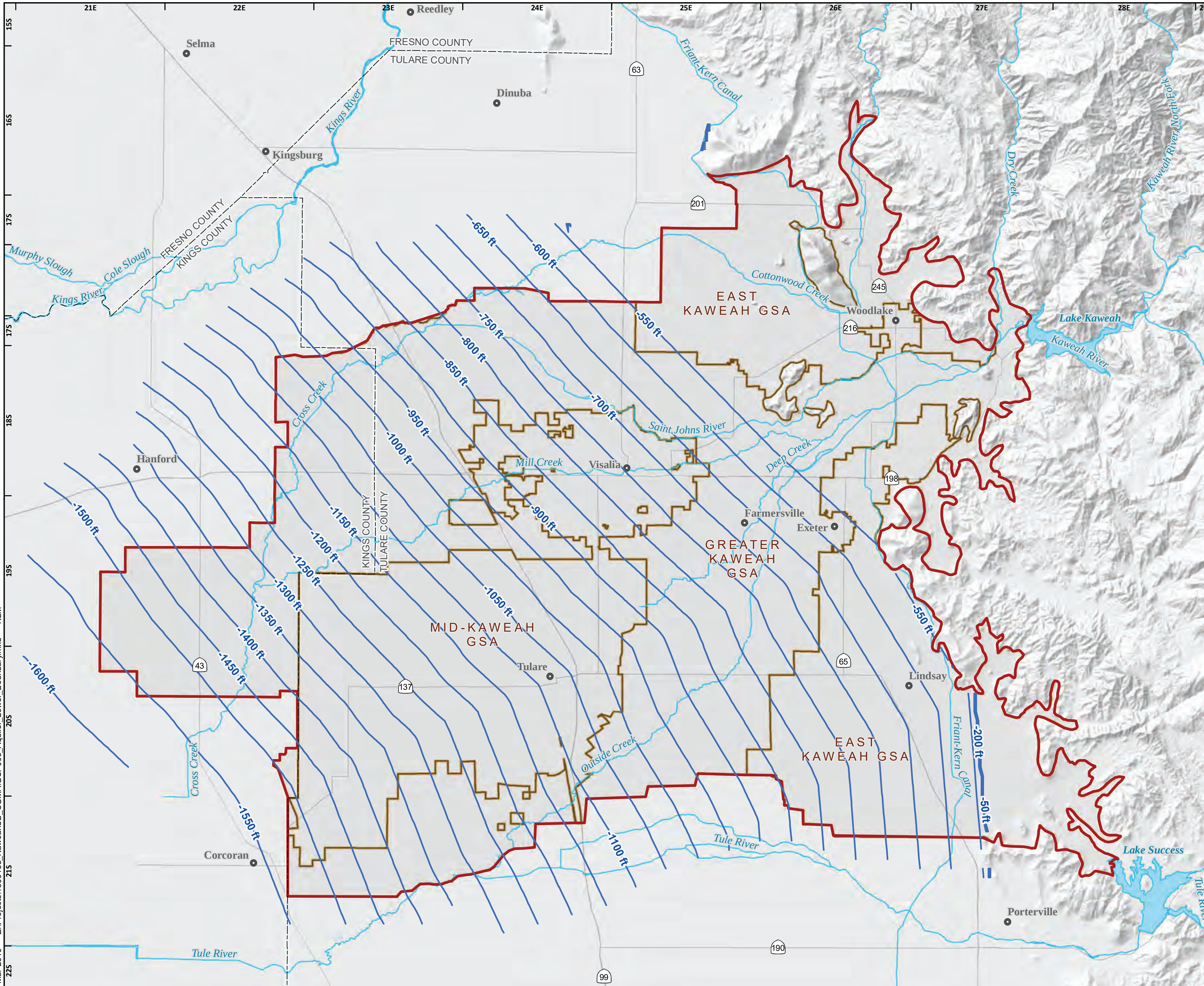
FIGURE 14

APPROXIMATE ELEVATION OF EFFECTIVE BASE OF FRESHWATER SYSTEM



Approx. Elevation of Effective Base of Freshwater System (ft MSL)

Kaweah Subbasin Boundary

Kaweah Subbasin GSA

All Other Features

Highway

Waterway

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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FIGURE 15

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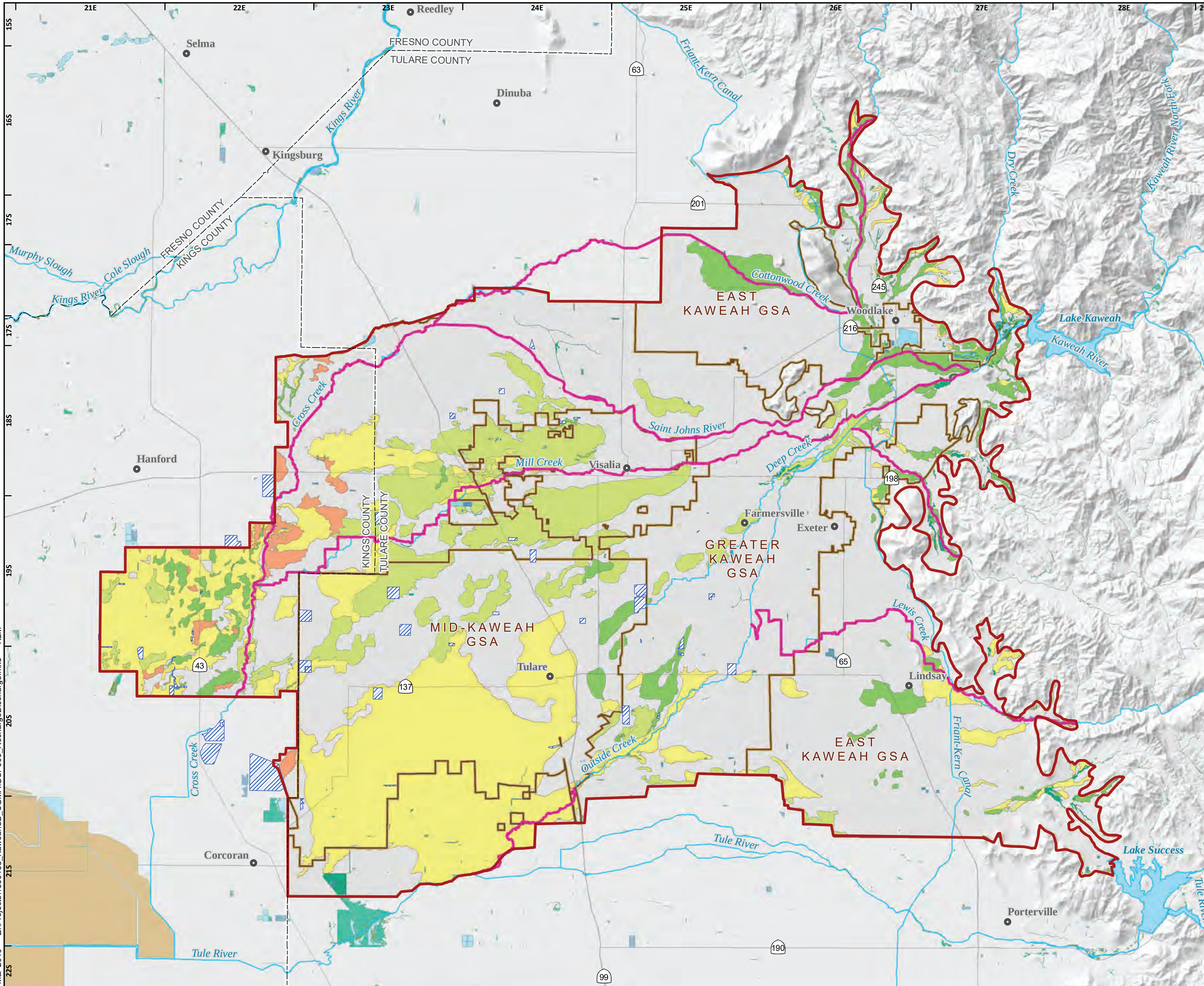
18-Mar-2019

GROUNDWATER RECHARGE AND DISCHARGE AREAS AND WETLANDS



Wetland Type (National Wetland Inventory, 2018)
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater/Recharge/Irrigation Pond
- Lake
- Farmed Wetland

Soil Agricultural Groundwater Banking Index (2015)

Rating Class
- Excellent
- Good
- Moderately Good
- Moderately Poor
- Recharge Basin
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features
- Highway
- Waterway
- Losing Stream Reach
- Lake

Note: Data is preliminary and subject to field verification for accuracy.

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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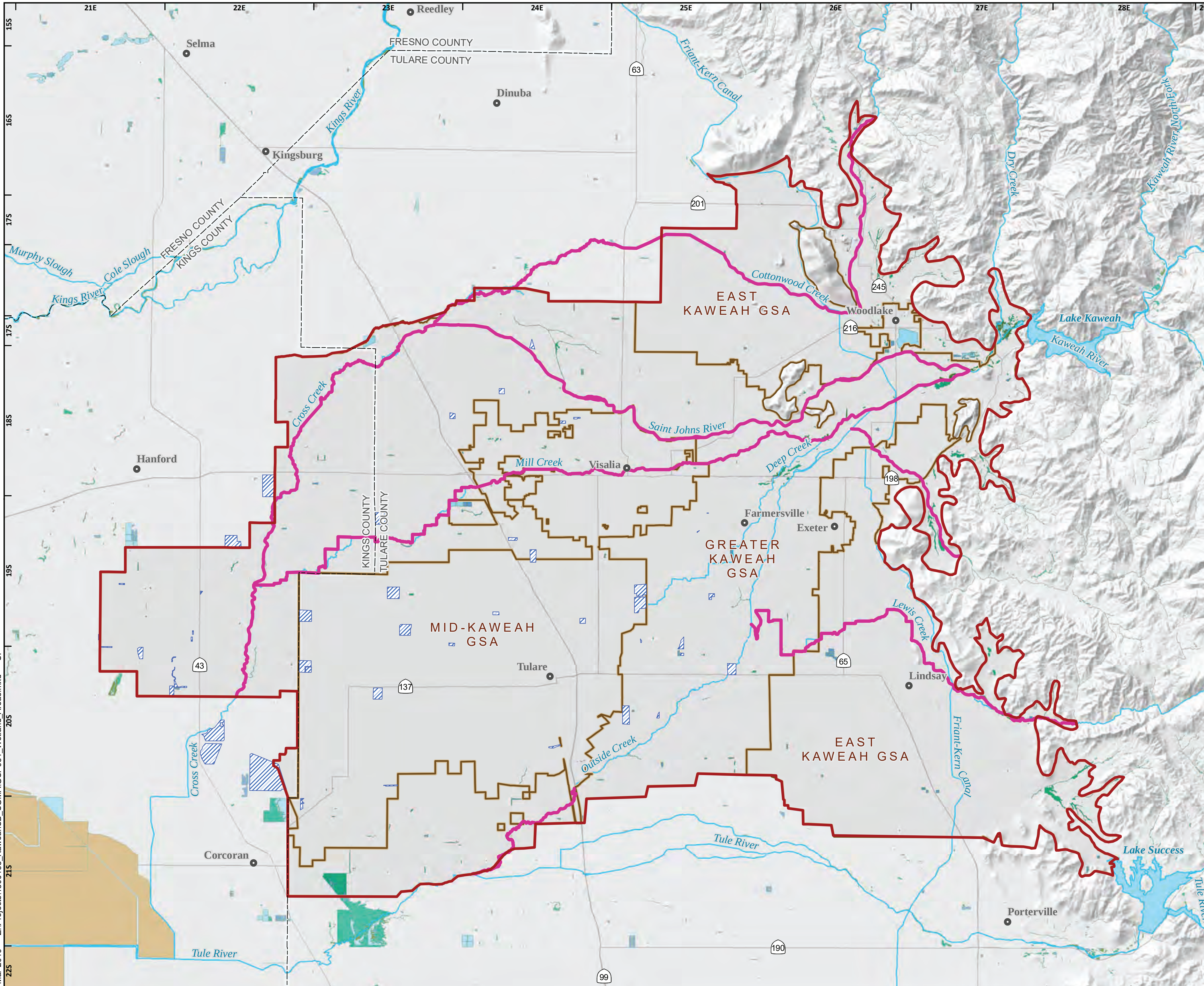
MARCH 2019

FIGURE 16

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP006_RechargeDischarge.mxd KLM



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WETLAND AREAS

Wetland Type (National Wetland Inventory, 2018)

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater/Recharge/Irrigation Pond
- Lake
- Farmed Wetland
- Recharge Basin
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Losing Stream Reach
- Lake

Note: Data is preliminary and subject to field verification for accuracy.

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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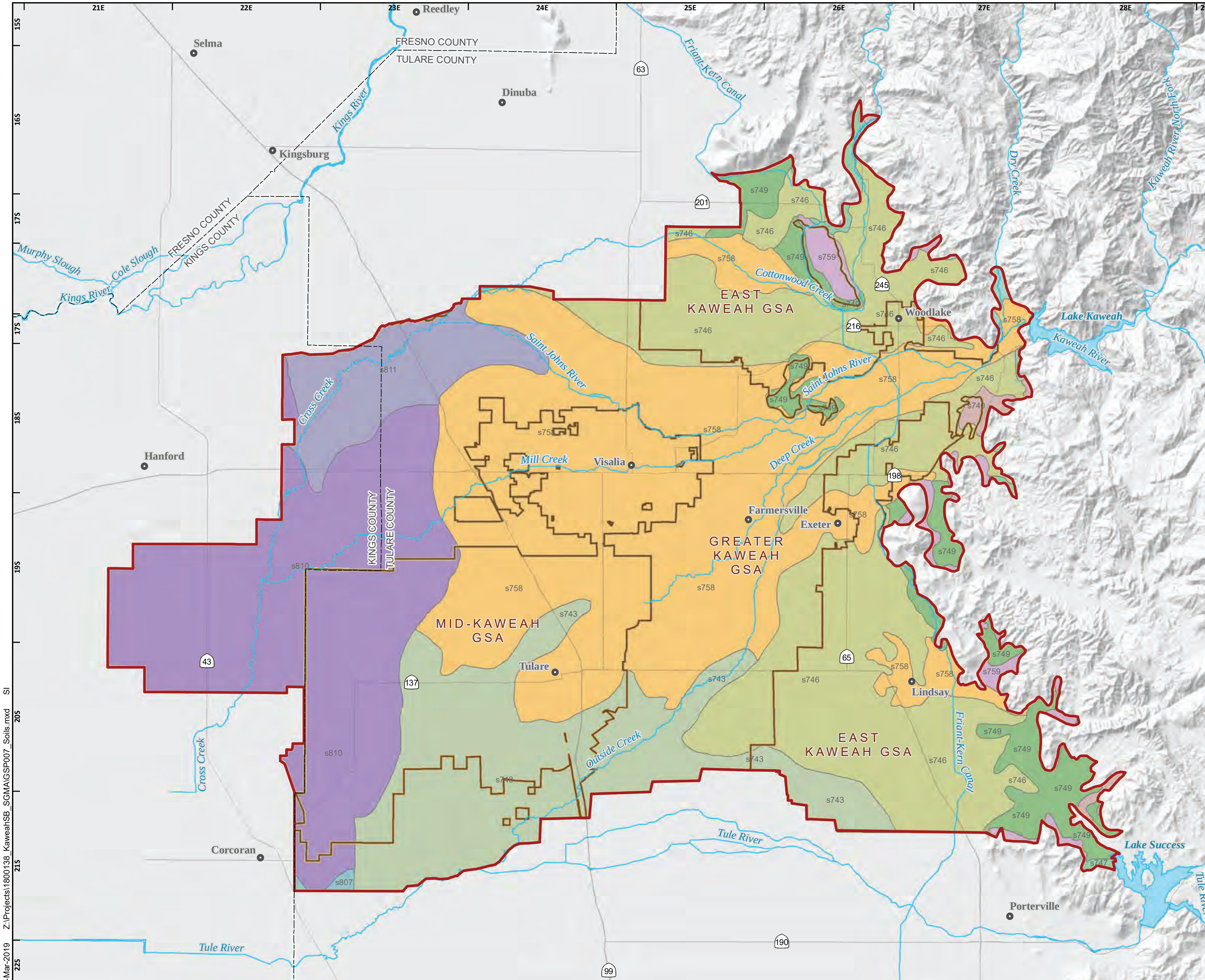
MARCH 2019

FIGURE 17



SOILS MAP

National Resource Conservation Service Soils Categories (STATSGO)

- Hanford-Delhi (s745)
- Lakeside-Kimberlina-Garces (s810)
- Lewis-Fresno-Dinuba (s742)
- Nord-Grangeville-Chino (s744)
- Porterville-Centerville (s749)
- Rock outcrop-Friant-Coarsegold (s751)
- Rock outcrop-Las Posas-Cibo (s759)
- San Joaquin-Madera-Cometa (s746)
- Sheephead-Rock outcrop-Holland-Crouch (s752)
- Tulare (s808)
- Vista-Rock outcrop-Auberry-Ahwahnee (s740)
- Vista-Rock outcrop-Cieneba (s747)
- Water (s8369)
- Waukena-Temple-Pond (s743)
- Westcamp-Houser-Gepford-Armona (s807)
- Woolstalf-Rock outcrop-Jocal-Hotaw-Chaix (s1072)
- Yettem-San Emigdio-Honcut (s758)
- Youd-Remnoy-Melga-Kimberlina (s811)
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

GEI Consultants
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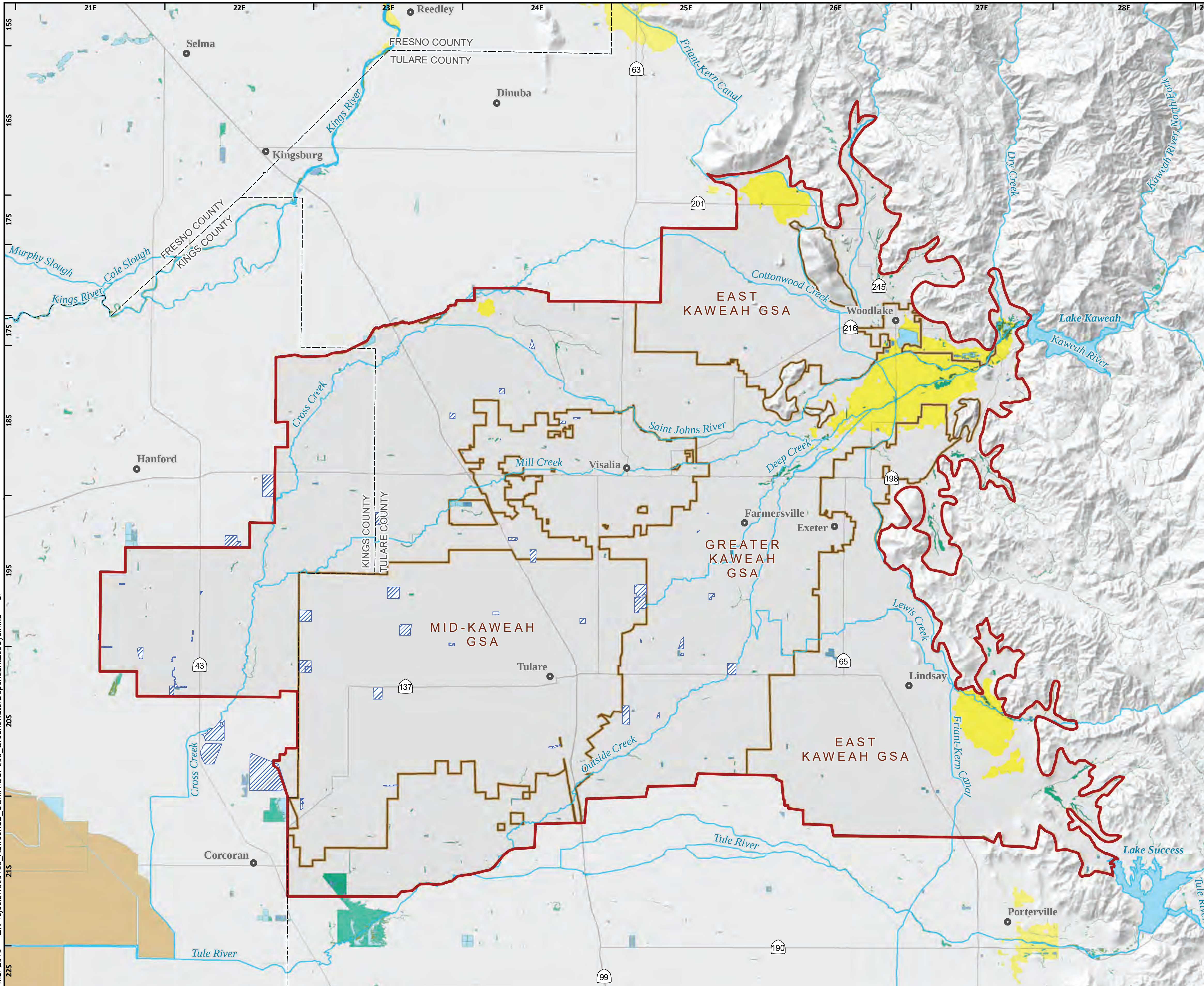
MARCH 2019 FIGURE 18

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP007_Soils.mxd SI



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POTENTIAL GROUNDWATER DEPENDENT ECOSYSTEMS

Potential Groundwater Dependant Ecosystem

- Spring 2015 Groundwater Surface within 50 feet of Ground Surface

Wetland Type (National Wetland Inventory, 2018)

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater/Recharge/Irrigation Pond
- Lake
- Farmed Wetland
- Recharge Basin
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

Note: Data is preliminary and subject to field verification for accuracy.

0 2 4 8
Miles

N

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Tulare County, California

Kaweah Subbasin

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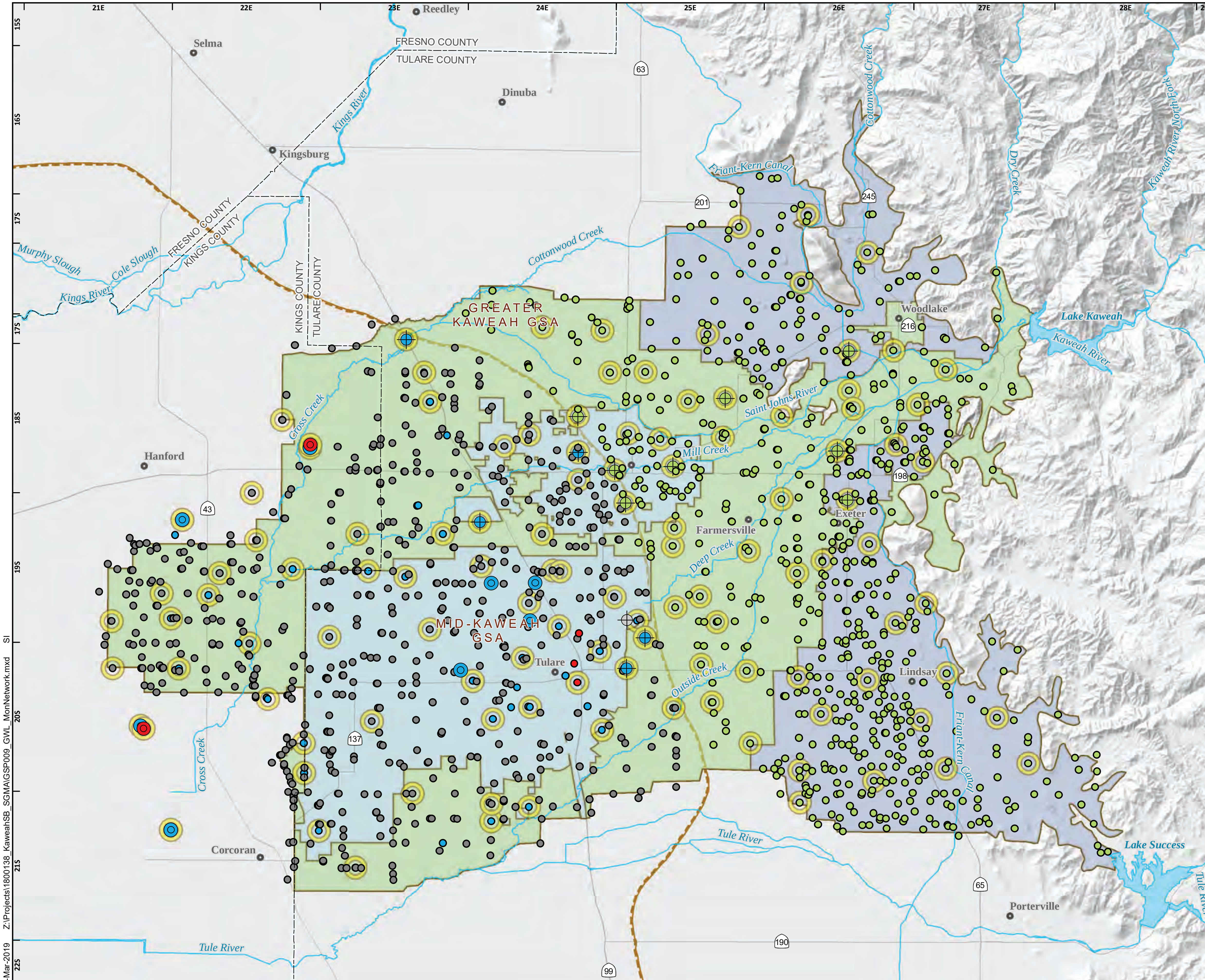
FIGURE 19



GROUNDWATER LEVEL MONITORING NETWORK

Well Types

- Lower Aquifer
- Upper Aquifer
- Single Aquifer
- Unknown
- Dedicated Monitoring Well
- Dual Completion Well
- Monitoring Well
- Key Well

Approximate Extent of Corcoran Clay

GSA Boundaries

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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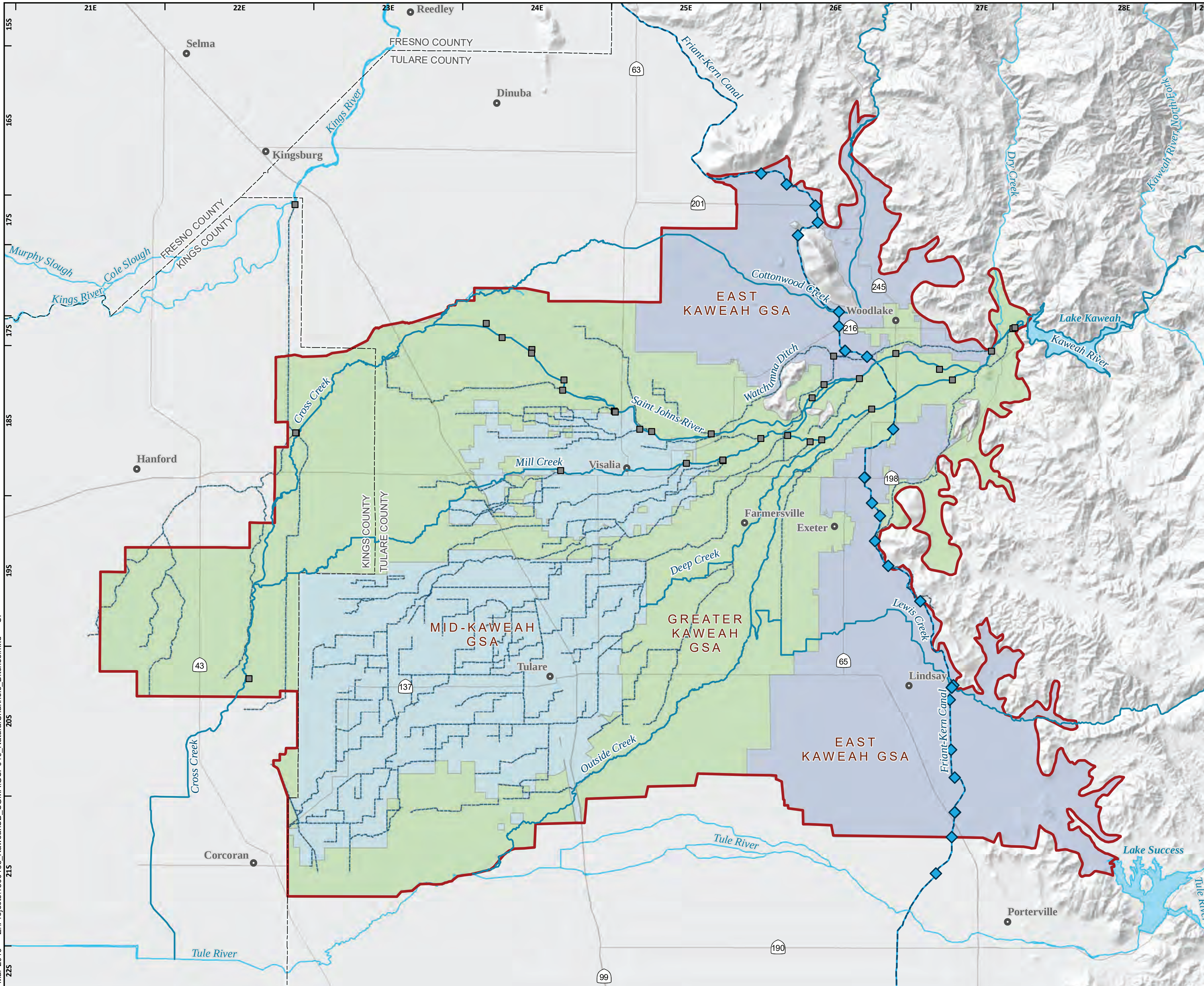
NATURAL AND MAN-MADE CHANNELS



- Friant-Kern Turnout
- Headgate
- Principal KSB Natural Channel
- Friant-Kern Canal
- Other Natural Channel
- Man-Made Channel

GSA Boundaries

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin Boundary

All Other Features

- Highway
- Lake

0 2 4 8
Miles

N

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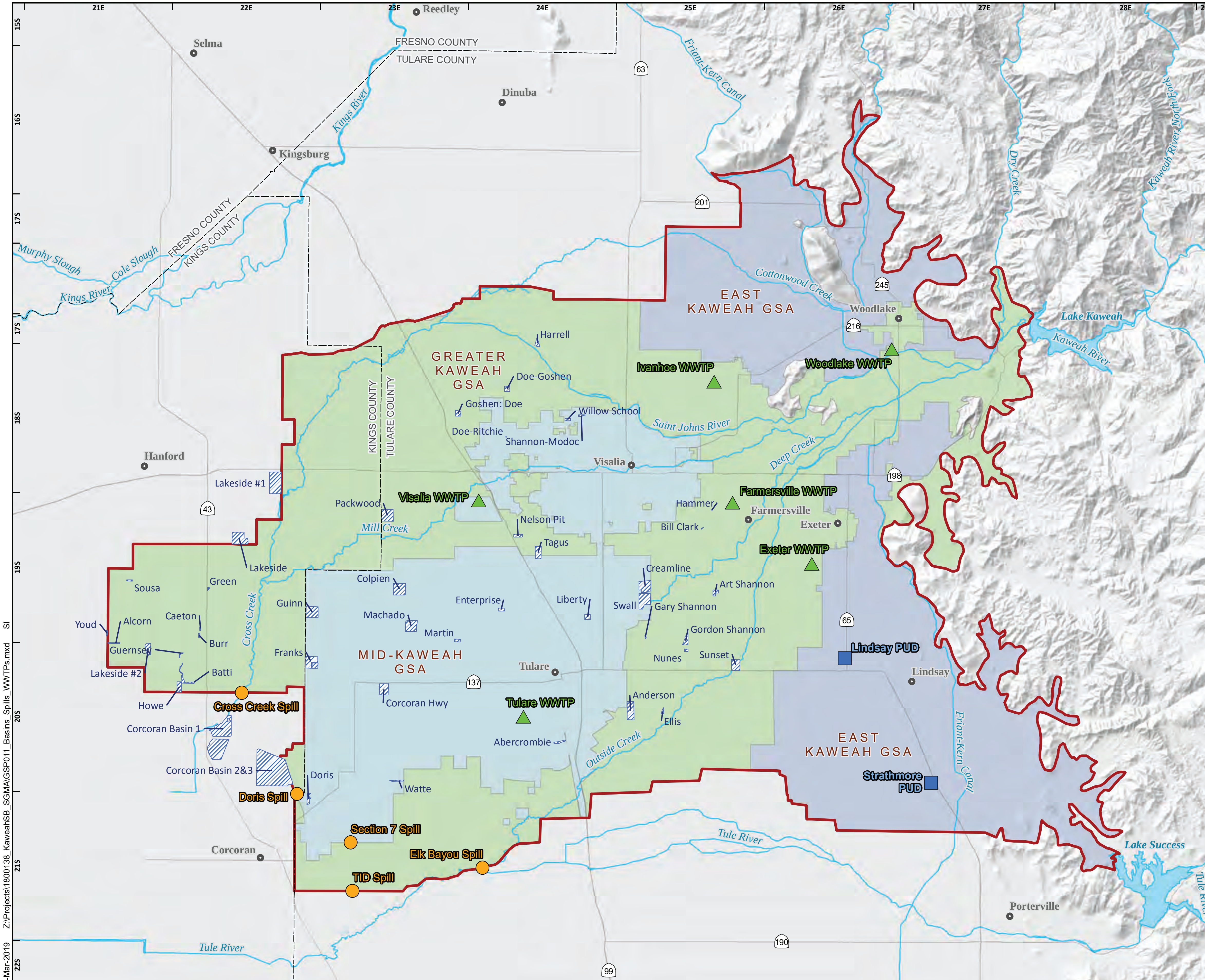
FIGURE 21

18-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP010_NaturalChannels_Ditches.mxd SI



RECHARGE BASINS, SPILLS AND WASTEWATER TREATMENT PLANTS

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Tulare County, California

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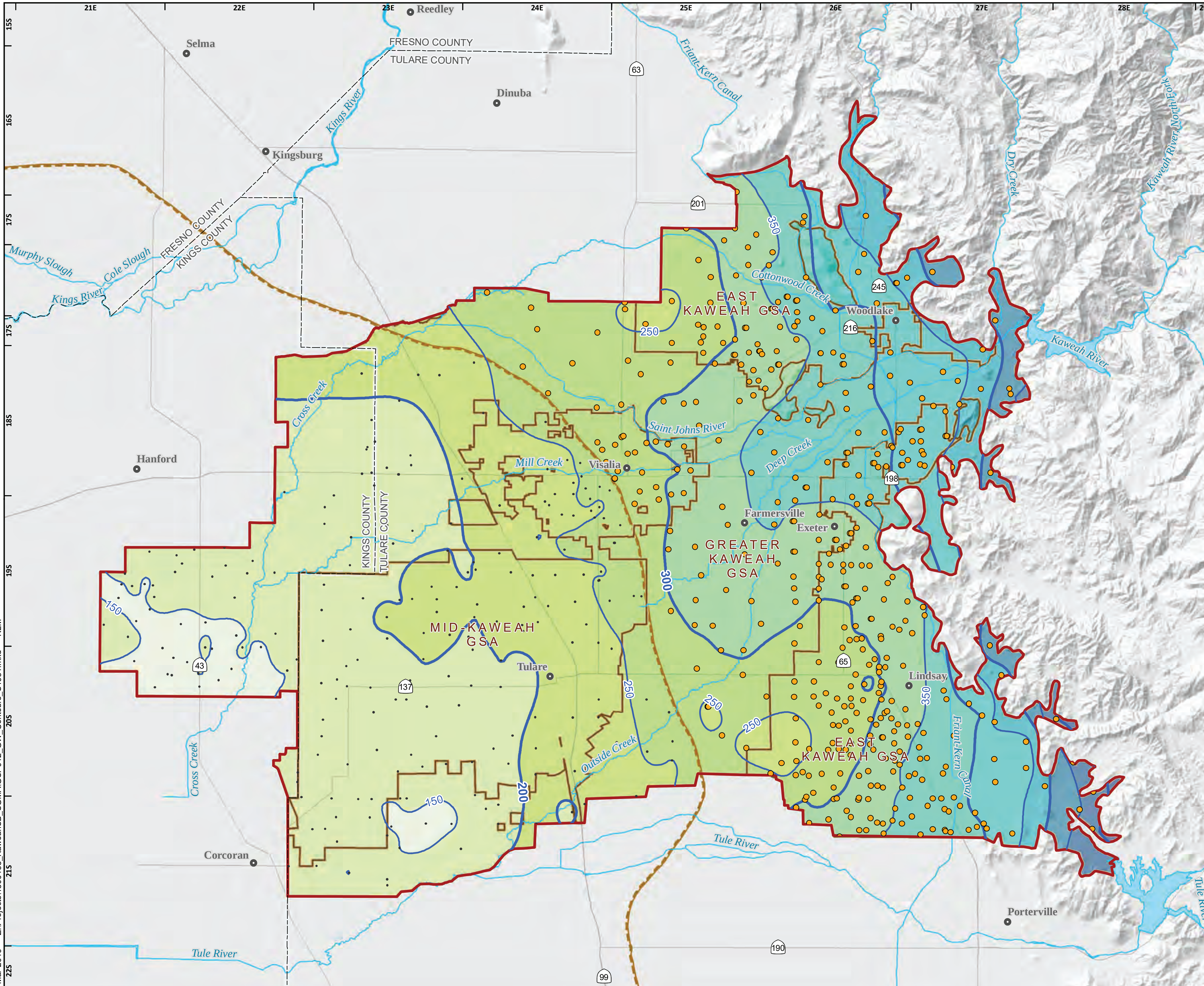
FIGURE 22

SPRING 1981 GROUNDWATER ELEVATION CONTOURS



- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Spring 1981 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- 123 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- 601 - 650
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
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MARCH 2019 FIGURE 23

Z:\Projects\1800138_KaweahSB_SGMA\GSP012_GW_Contours_S1981.mxd KLM
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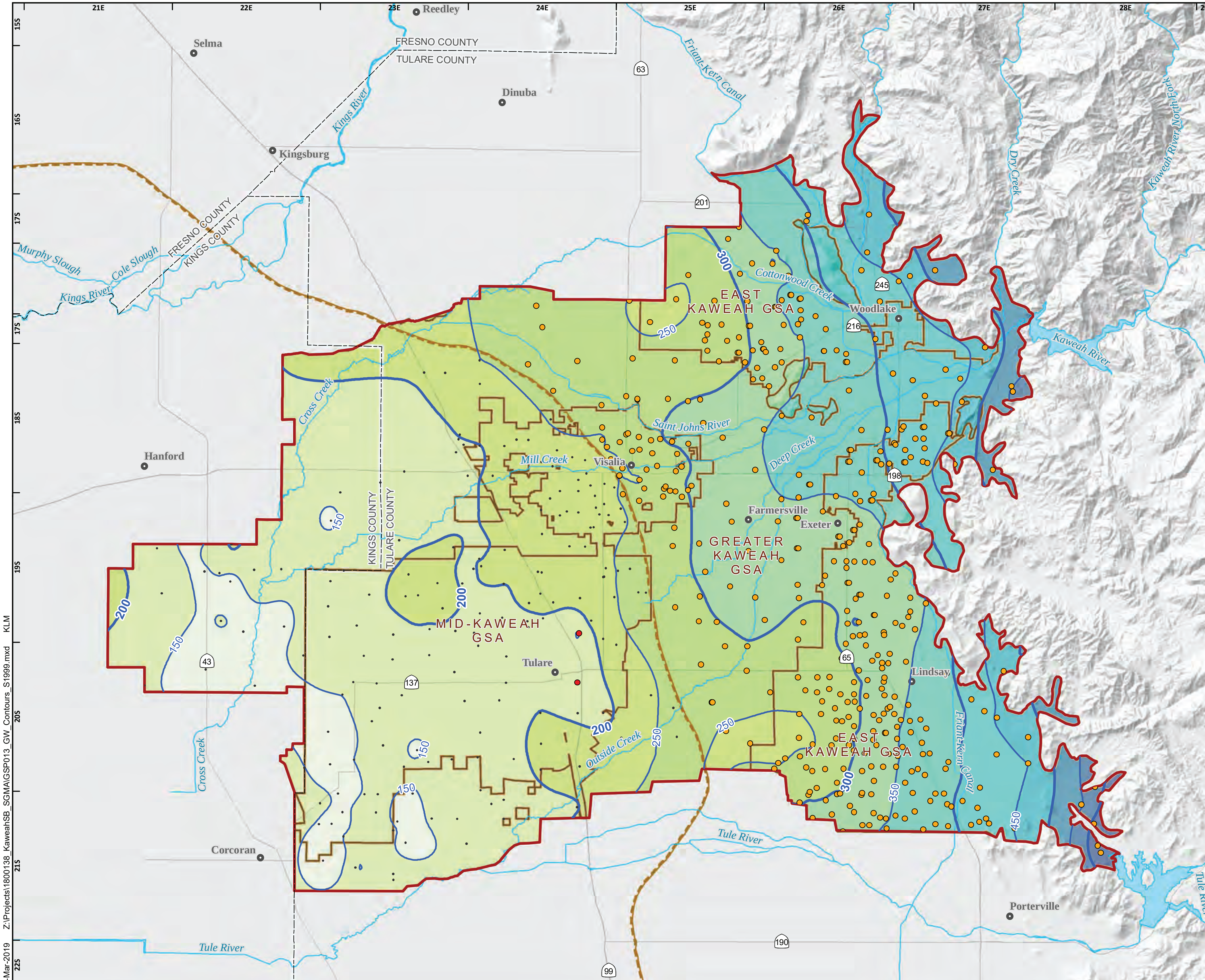
SPRING 1999 GROUNDWATER ELEVATION CONTOURS



Lower Aquifer System, Dedicated Monitoring Well
Single Aquifer System, Dedicated Monitoring Well
Lower Aquifer System Well
Single Aquifer System Well
Well Construction Details Unknown

Groundwater Elevation Contours, Spring 1999 (GWE ft msl)

Major (100-foot interval)
Minor (50-foot interval)
120 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
501 - 550
551 - 600
601 - 650
Approximate Extent of Corcoran Clay
Kaweah Subbasin Boundary
Kaweah Subbasin GSA

All Other Features

Highway
Waterway
Lake

0 2 4 8
Miles

N

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Tulare County, California

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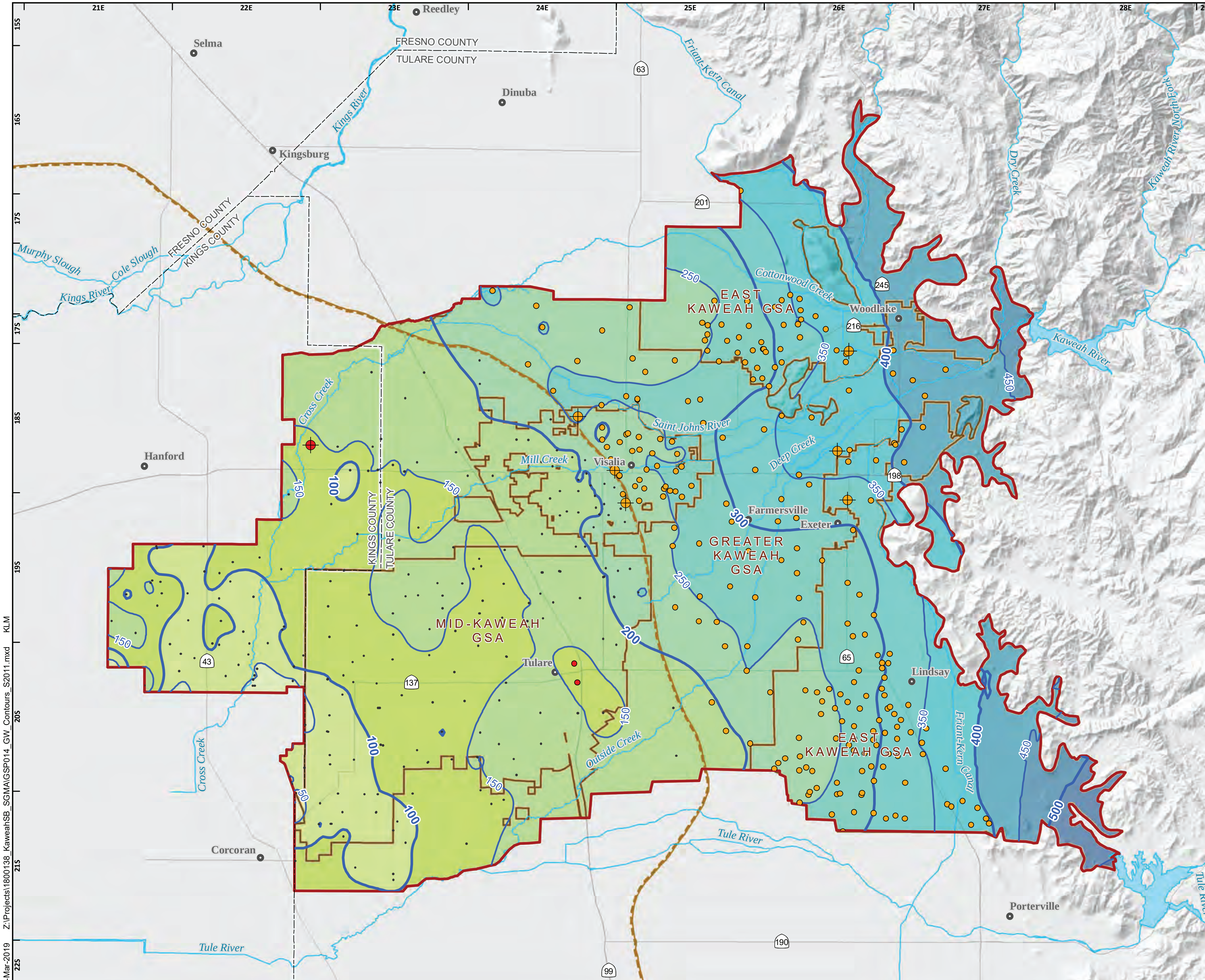
MARCH 2019 FIGURE 24

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP013_GW_Contours_S1999.mxd KLM



SPRING 2011 GROUNDWATER ELEVATION CONTOURS

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Spring 2011 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -40 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
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Tulare County, California

Kaweah Subbasin

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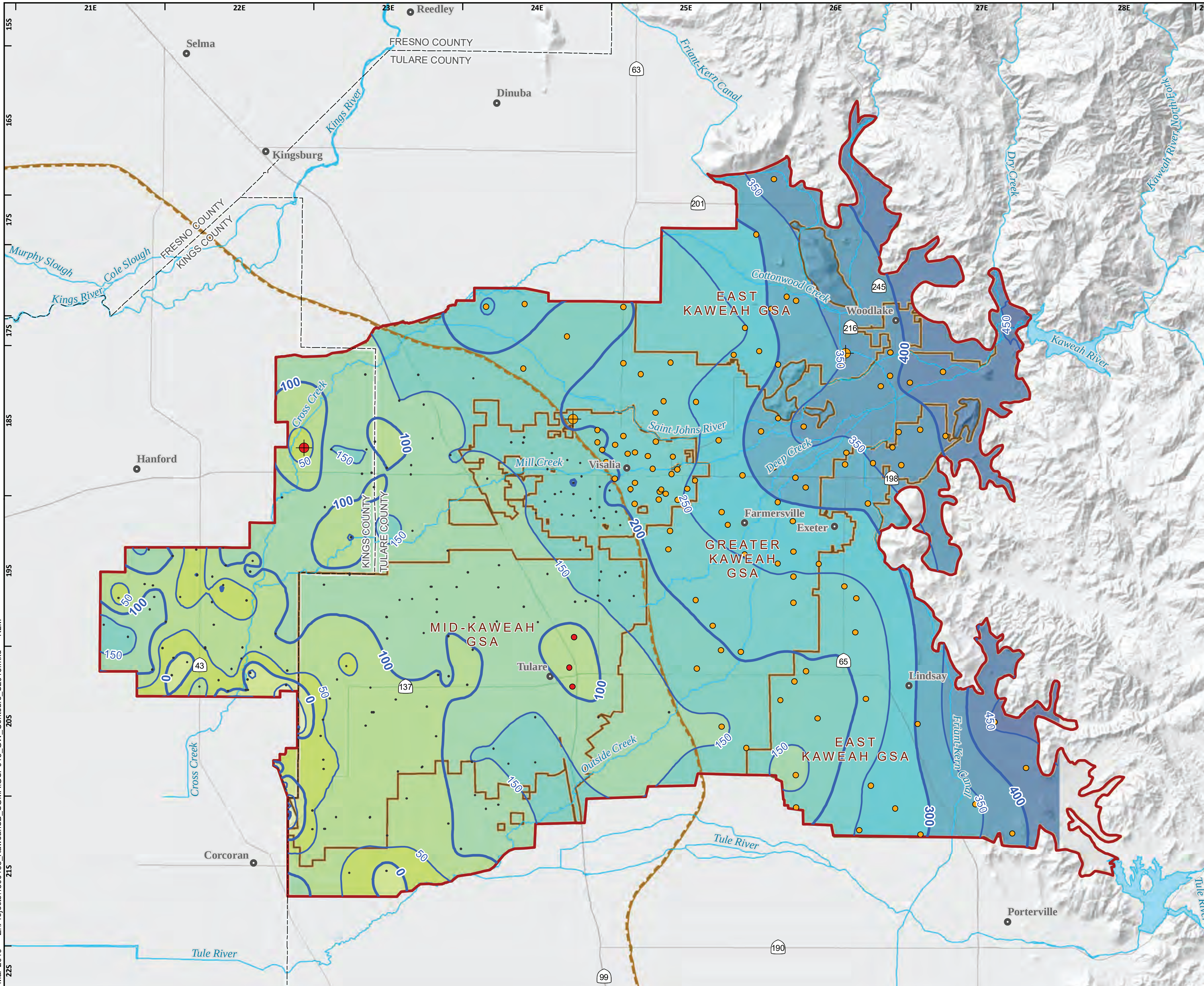
FIGURE 25

SPRING 2015 GROUNDWATER ELEVATION CONTOURS



- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Spring 2015 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -112 - -100
- -99 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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Tulare County, California

Kaweah Subbasin

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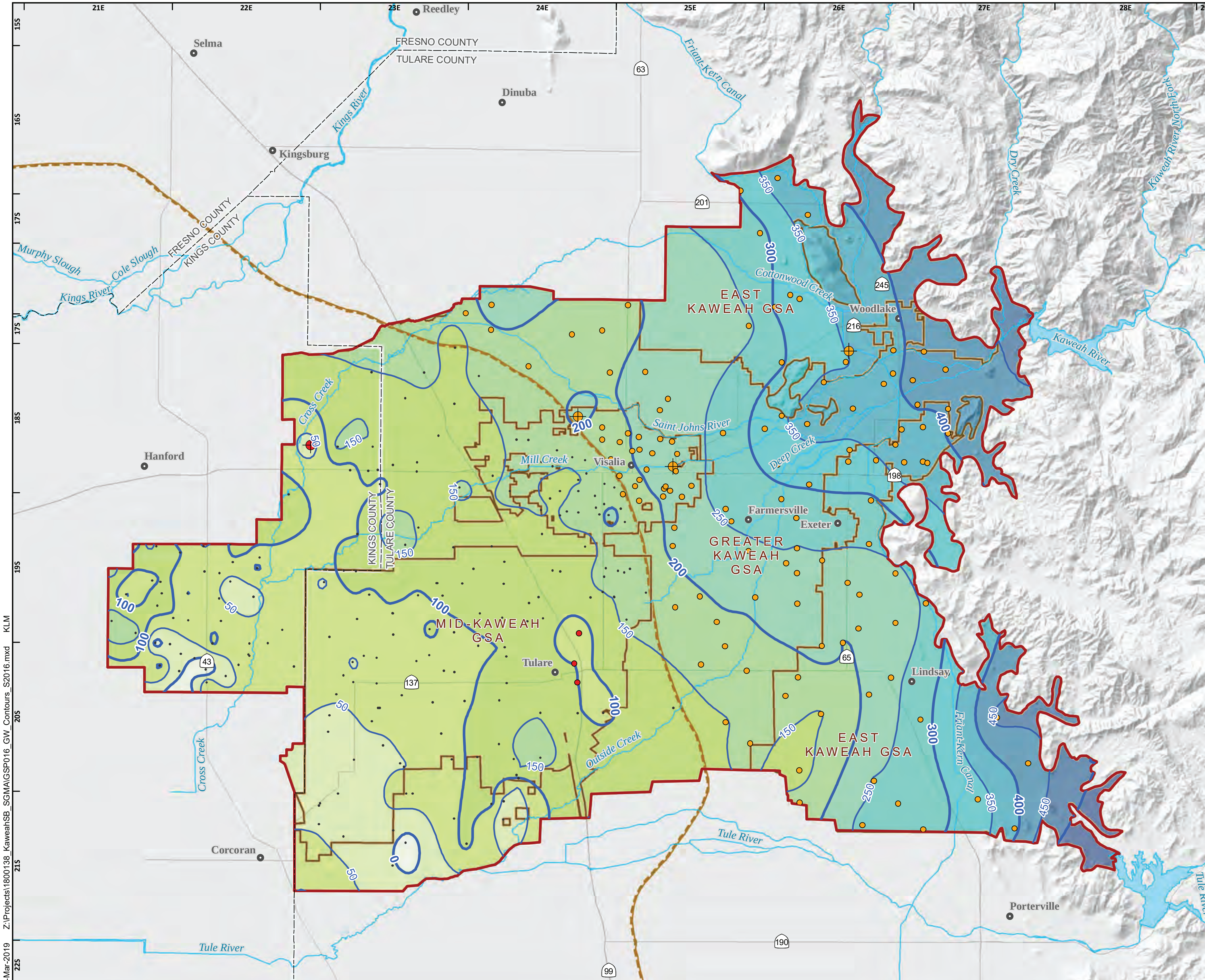
FIGURE 26



SPRING 2016 GROUNDWATER ELEVATION CONTOURS

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Spring 2016 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -46 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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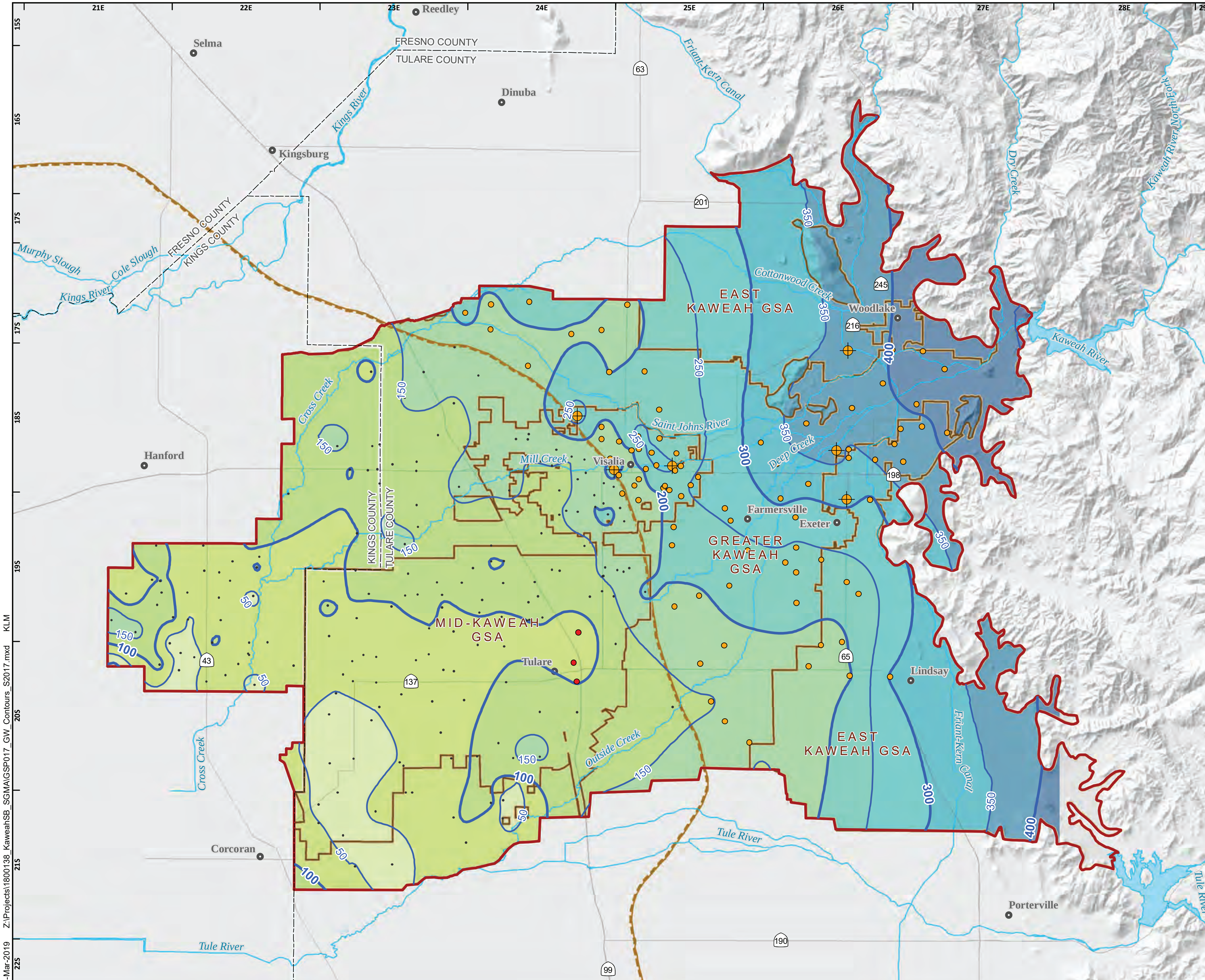
FIGURE 27

SPRING 2017 GROUNDWATER ELEVATION CONTOURS



Lower Aquifer System, Dedicated Monitoring Well

Single Aquifer System, Dedicated Monitoring Well

Lower Aquifer System Well

Single Aquifer System Well

Well Construction Details Unknown

Groundwater Elevation Contours, Spring 2017 (GWE ft msl)

Major (100-foot interval)

Minor (50-foot interval)

-6 - 0

1 - 50

51 - 100

101 - 150

151 - 200

201 - 250

251 - 300

301 - 350

351 - 400

401 - 450

451 - 500

Approximate Extent of Corcoran Clay

Kaweah Subbasin Boundary

Kaweah Subbasin GSA

All Other Features

Highway

Waterway

Lake

0 2 4 8

Miles

N

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Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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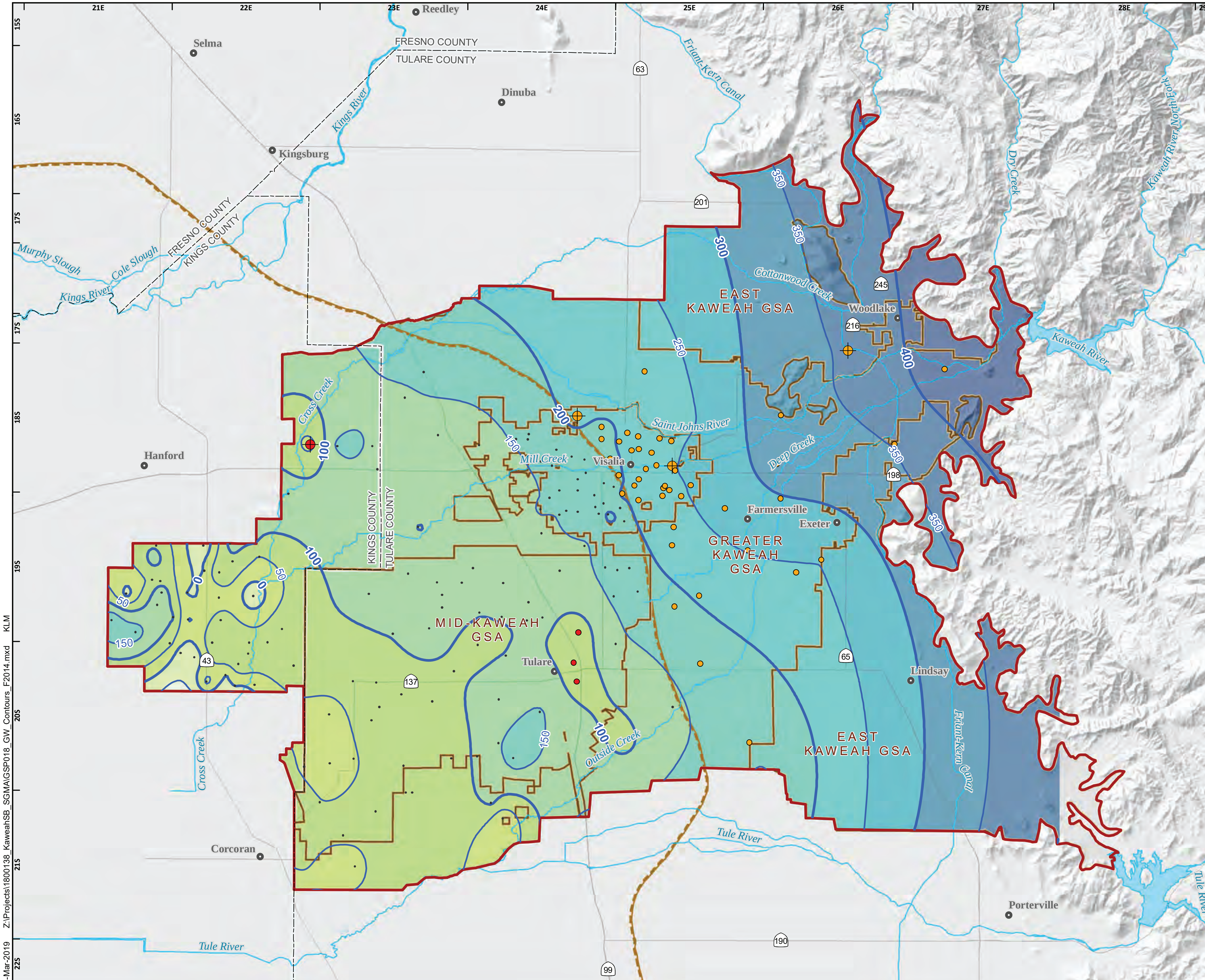
FIGURE 28



FALL 2014 GROUNDWATER ELEVATION CONTOURS

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Fall 2014 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -75 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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Tulare County, California

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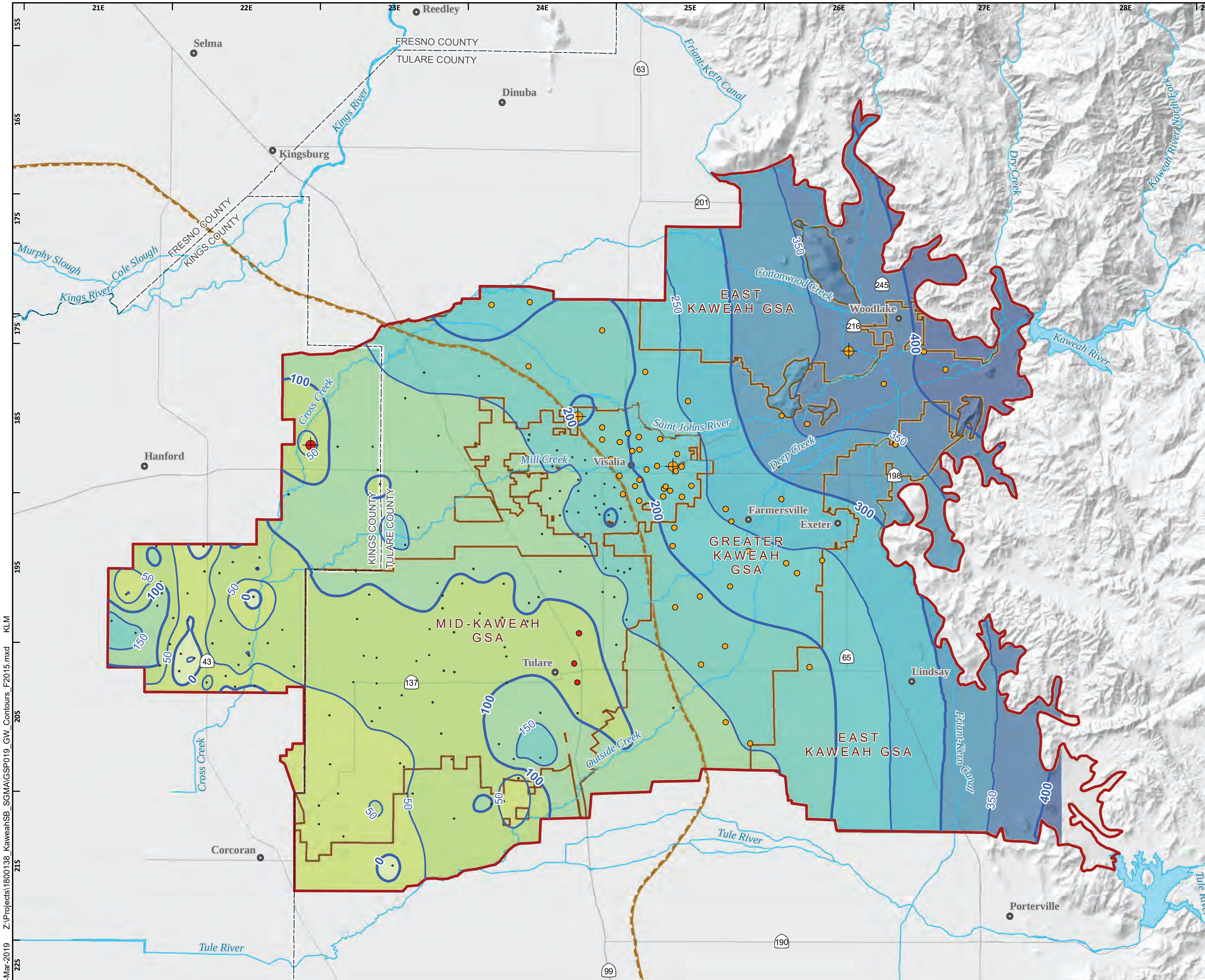
FIGURE 29

FALL 2015 GROUNDWATER ELEVATION CONTOURS



- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Fall 2015 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -52 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles
N

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FIGURE 30

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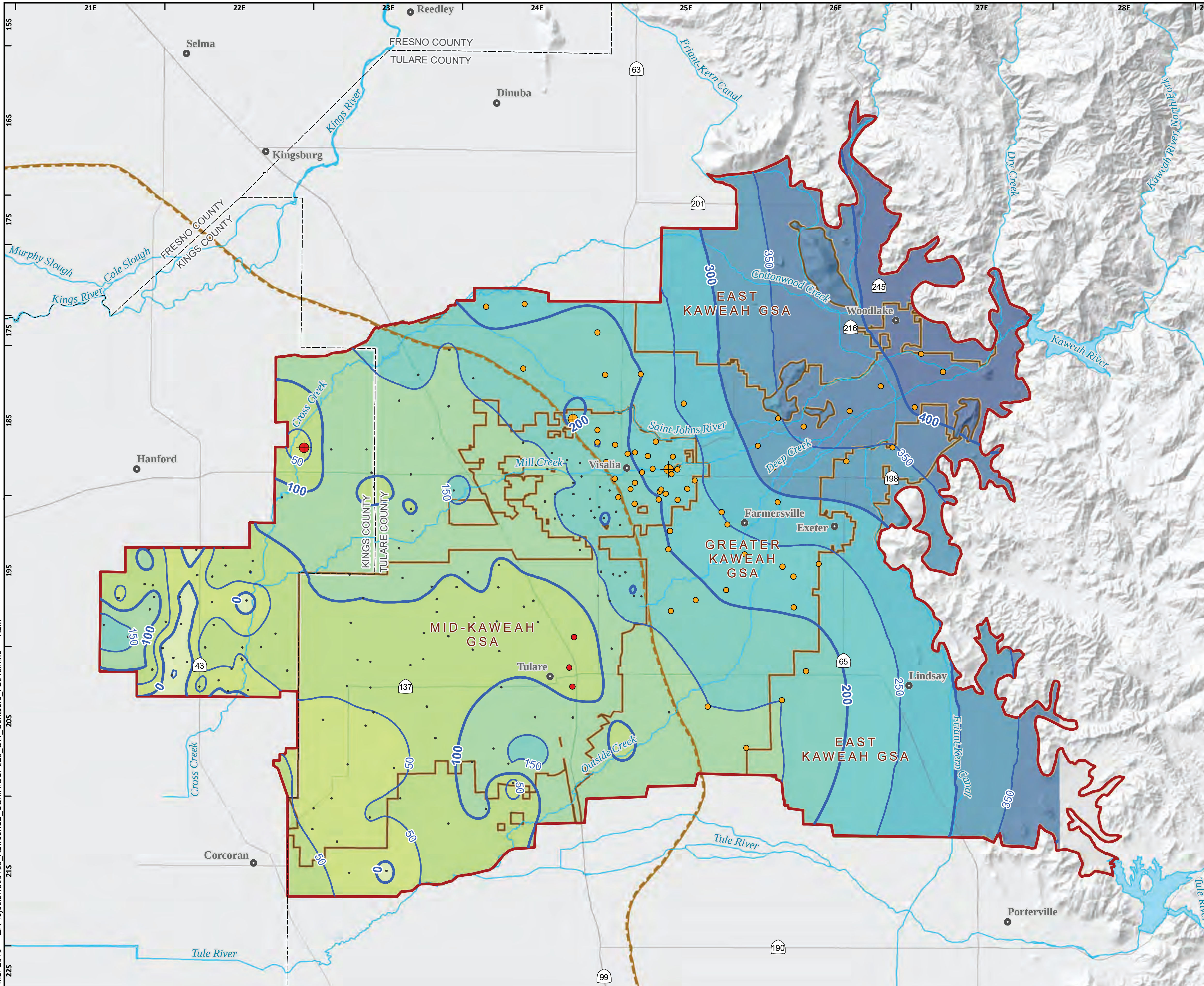
FALL 2016 GROUNDWATER ELEVATION CONTOURS



Legend

- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Fall 2016 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -56 - -50
- -49 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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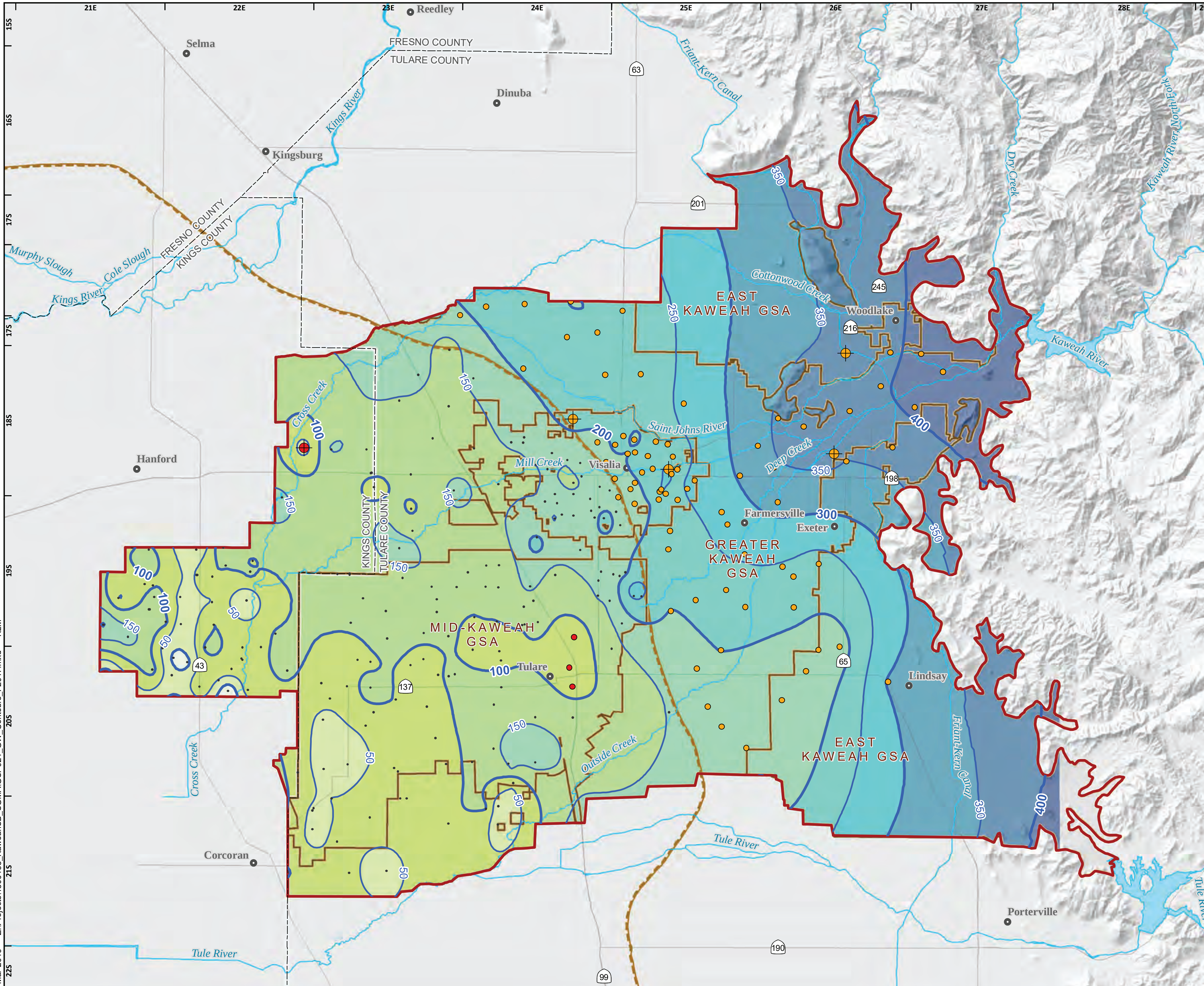
FIGURE 31

Z:\Projects\1800138_KaweahSB_SGMA\GSP020_GW_Contours_F2016.mxd KLM
11-Mar-2019

FALL 2017 GROUNDWATER ELEVATION CONTOURS



- Lower Aquifer System, Dedicated Monitoring Well
- Single Aquifer System, Dedicated Monitoring Well
- Lower Aquifer System Well
- Single Aquifer System Well
- Well Construction Details Unknown

Groundwater Elevation Contours, Fall 2017 (GWE ft msl)

- Major (100-foot interval)
- Minor (50-foot interval)
- -44 - 0
- 1 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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Tulare County, California

Kaweah Subbasin

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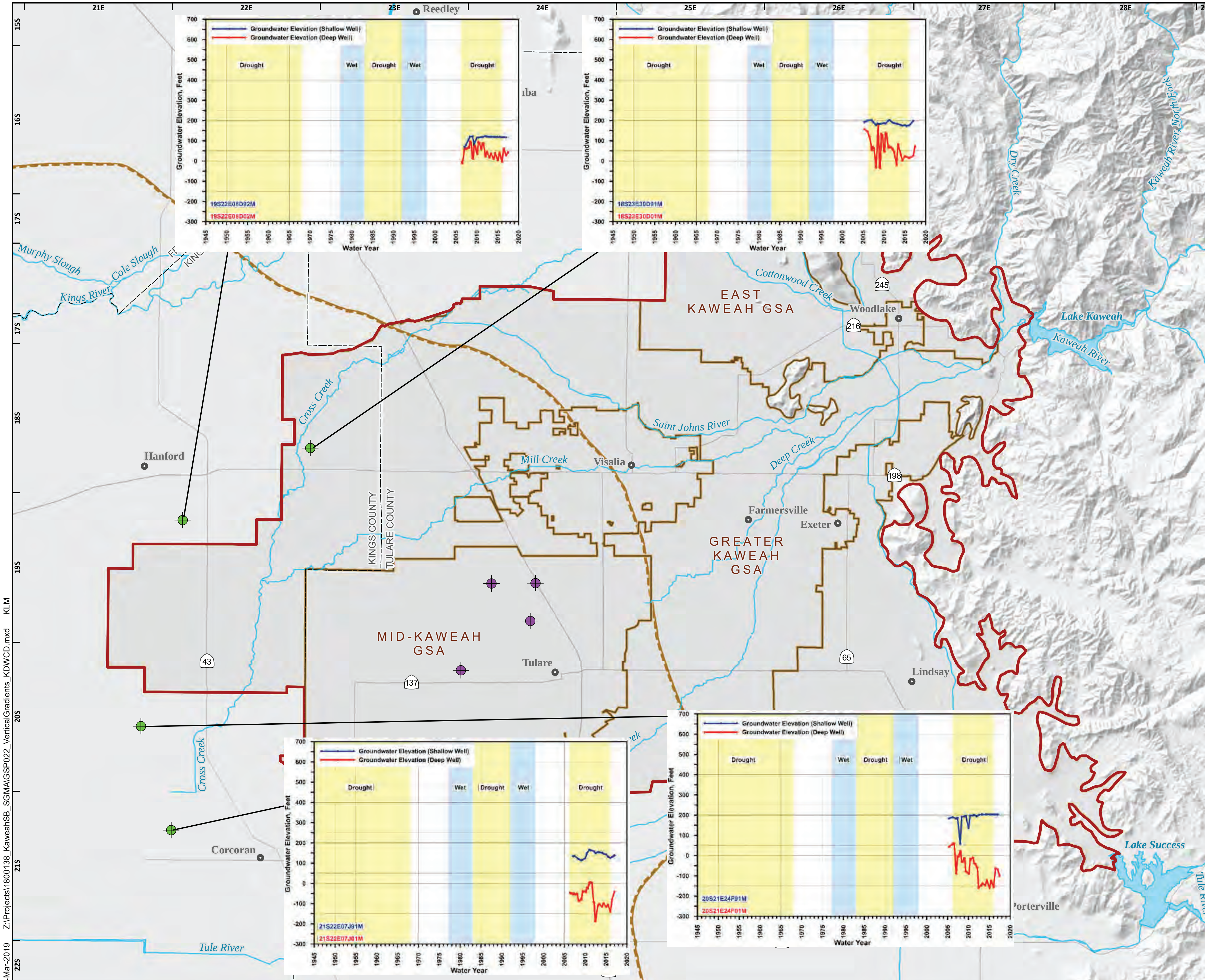
MARCH 2019 FIGURE 32

VERTICAL GRADIENTS KAWEAH DELTA WATER CONSERVATION DISTRICT WELLS



Dual Completion Monitoring Wells

- KDWCD Dual Completion Wells
- TID Dual Completion Wells
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
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Tulare County, California

Kaweah Subbasin

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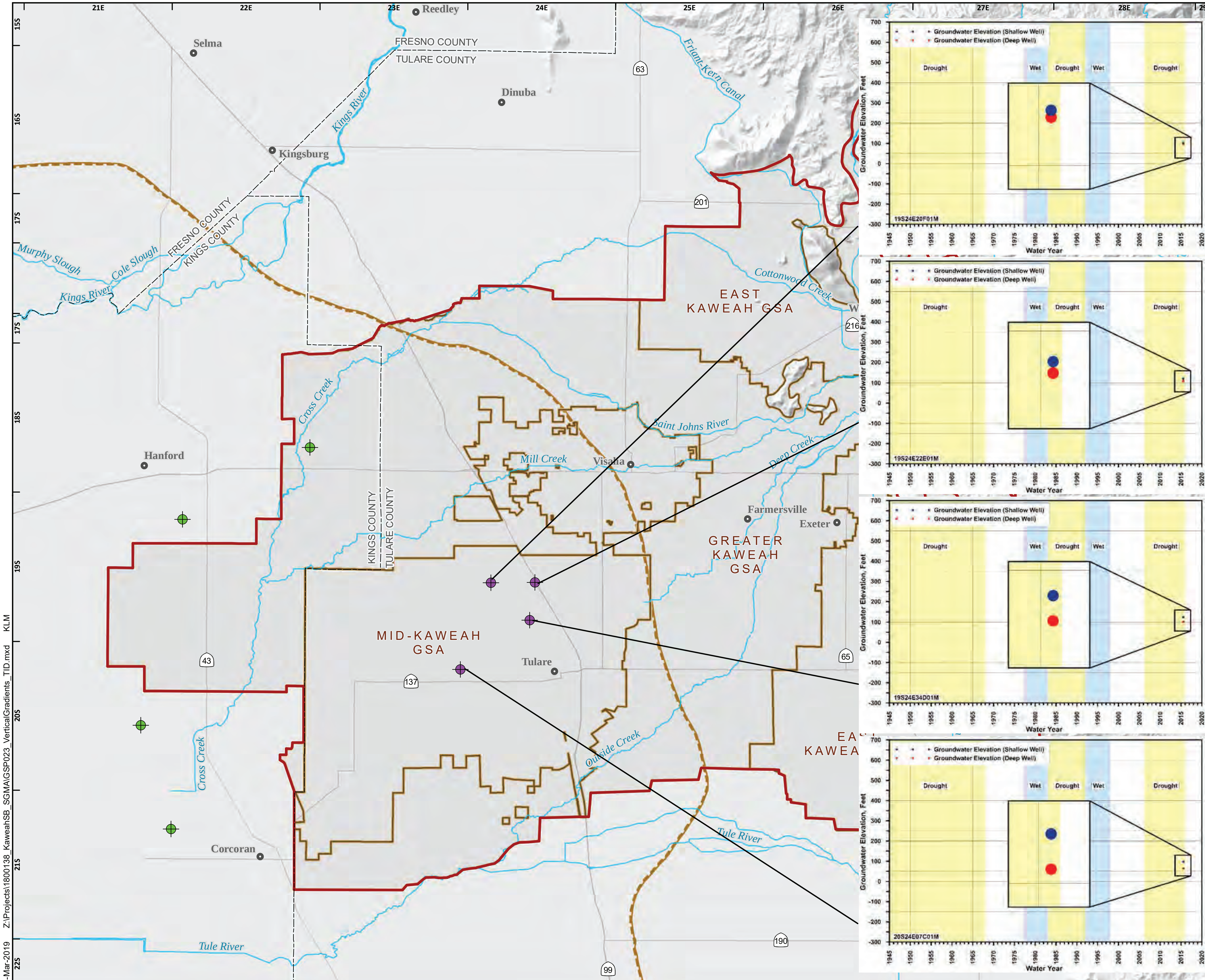
FIGURE 33

VERTICAL GRADIENTS TULARE IRRIGATION DISTRICTWELLS



Dual Completion Monitoring Wells

- KDWCD Dual Completion Wells
- TID Dual Completion Wells
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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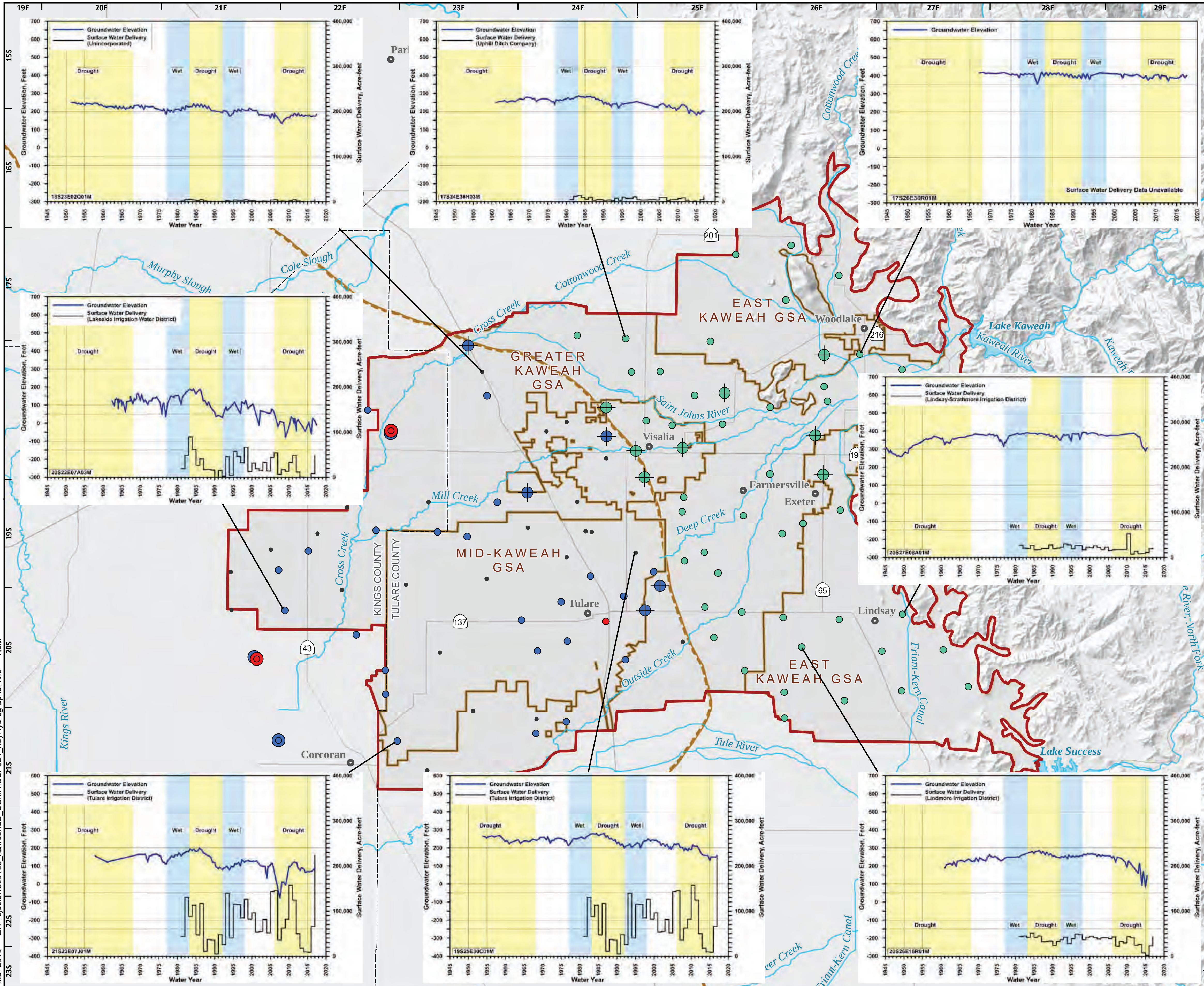
FIGURE 34



SELECT KEY WELL HYDROGRAPHS

- Lower Aquifer System Dual Completion Well
- Lower Aquifer System Well
- Single Aquifer System Dedicated Monitoring Well
- Single Aquifer System Well
- Upper Aquifer System Dedicated Monitoring Well
- Upper Aquifer System Dual Completion Well
- Upper Aquifer System Well
- Well Construction Details Unknown
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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Kaweah Subbasin

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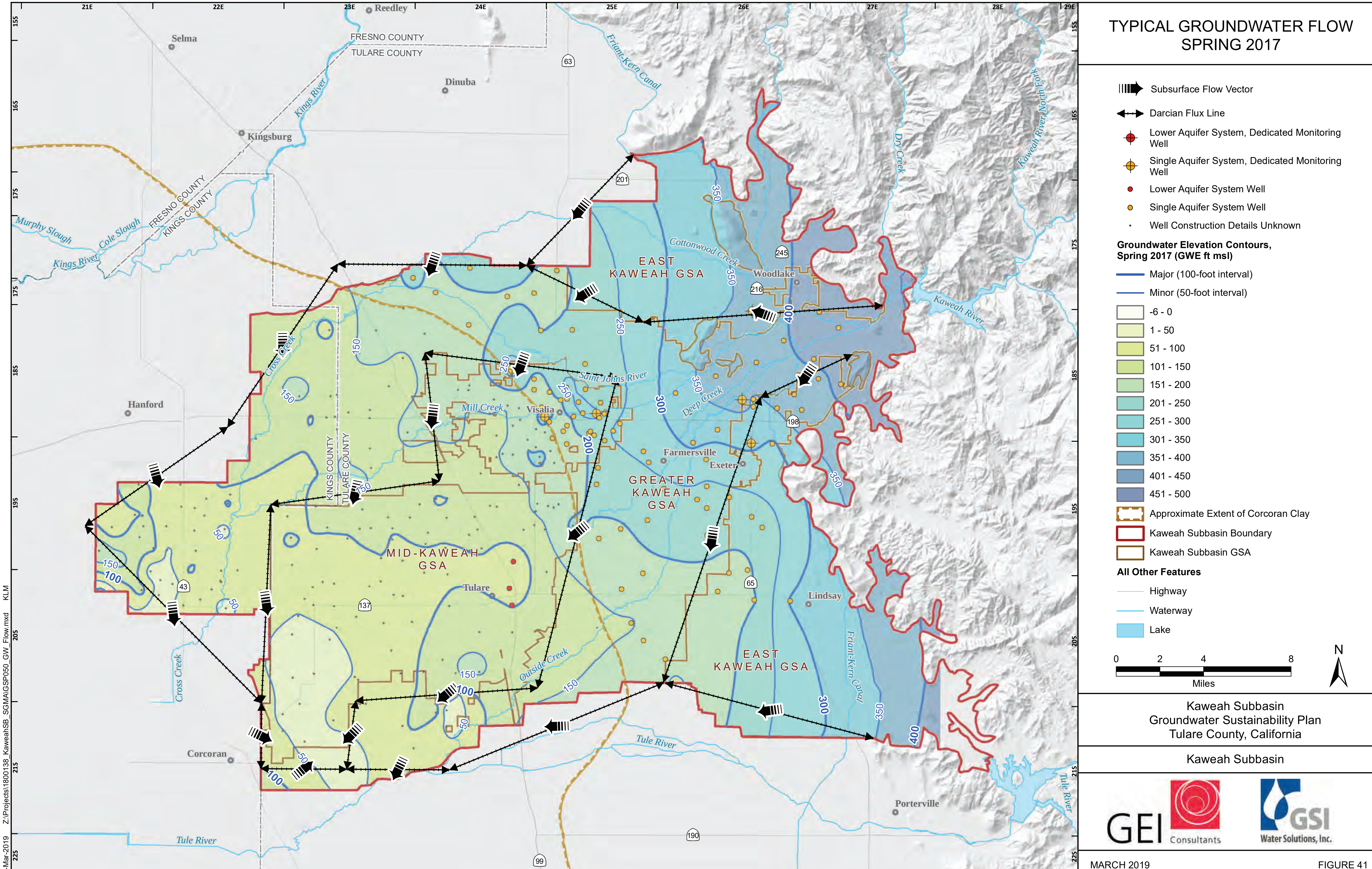
FIGURE 35

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP024_KeyHydrographs.mxd KLM

TYPICAL GROUNDWATER FLOW SPRING 2017



Z:\Projects\1800138_KaweahSB_SGMA\GSP050_GW_Flow.mxd KLM 11-Mar-2019

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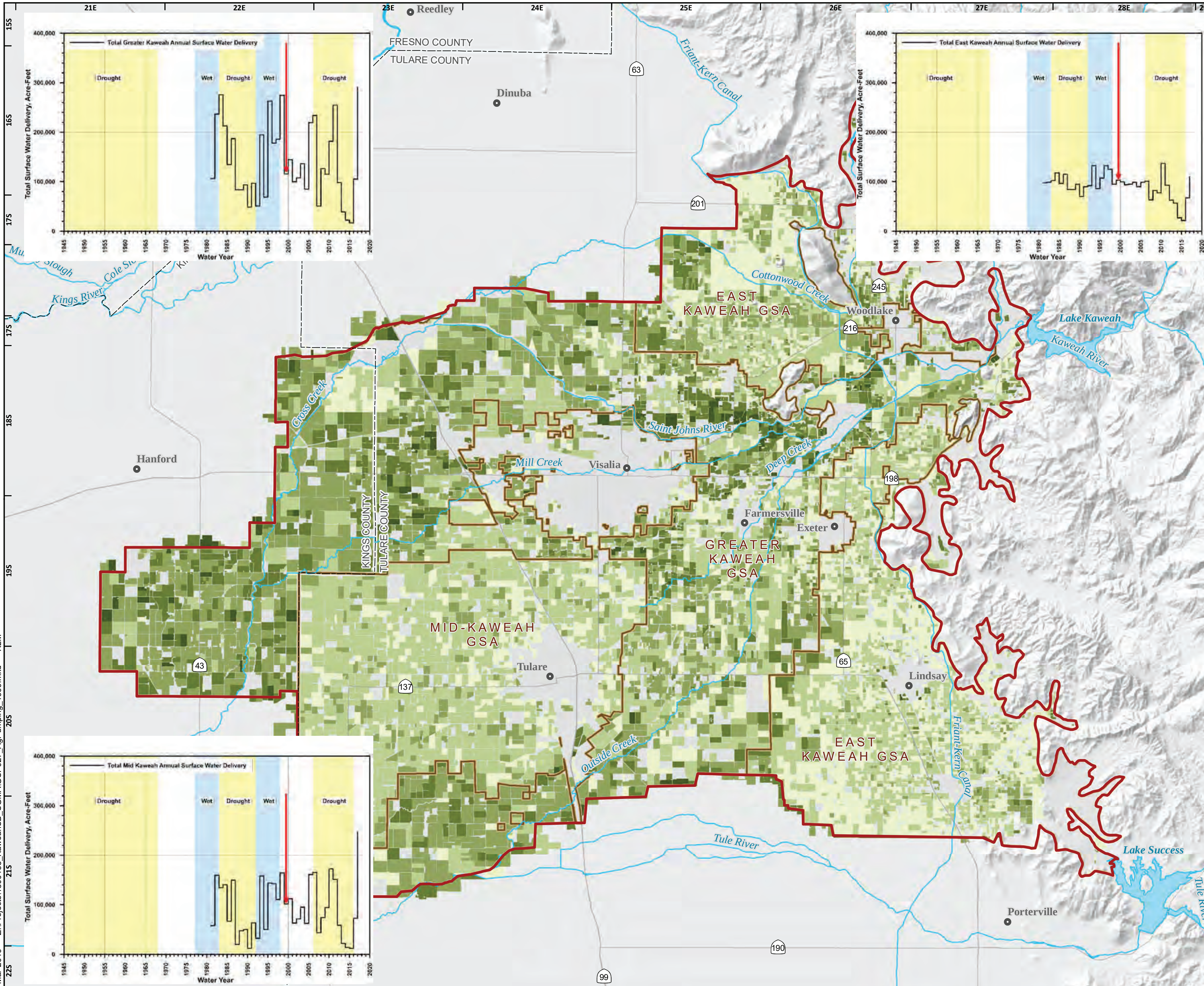

11-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP027_AgPumping_1999.mxd KLM

ANNUAL AGRICULTURAL PUMPING WATER YEAR 1999

Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
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Tulare County, California

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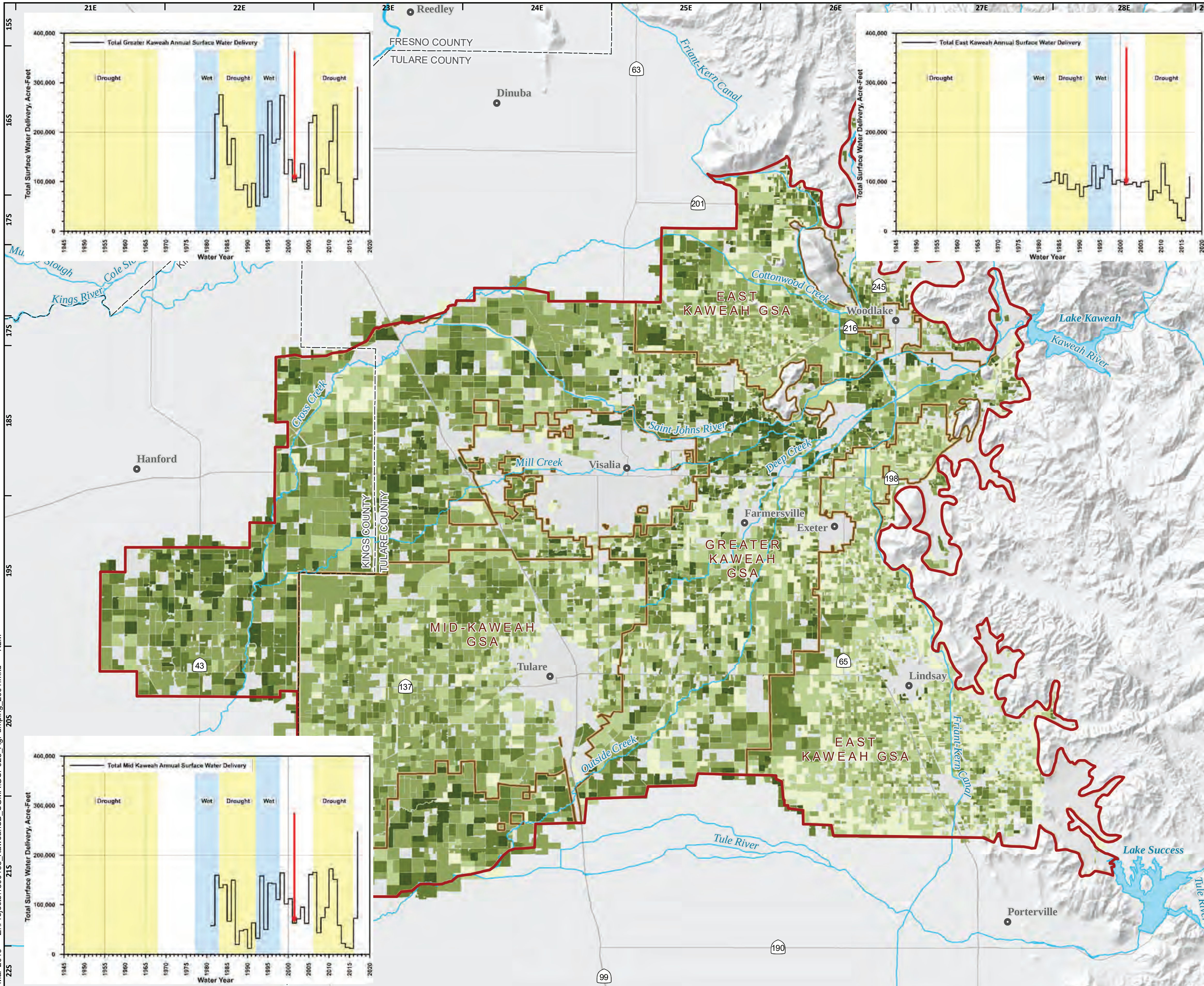
MARCH 2019 FIGURE 42

ANNUAL AGRICULTURAL PUMPING WATER YEAR 2001



Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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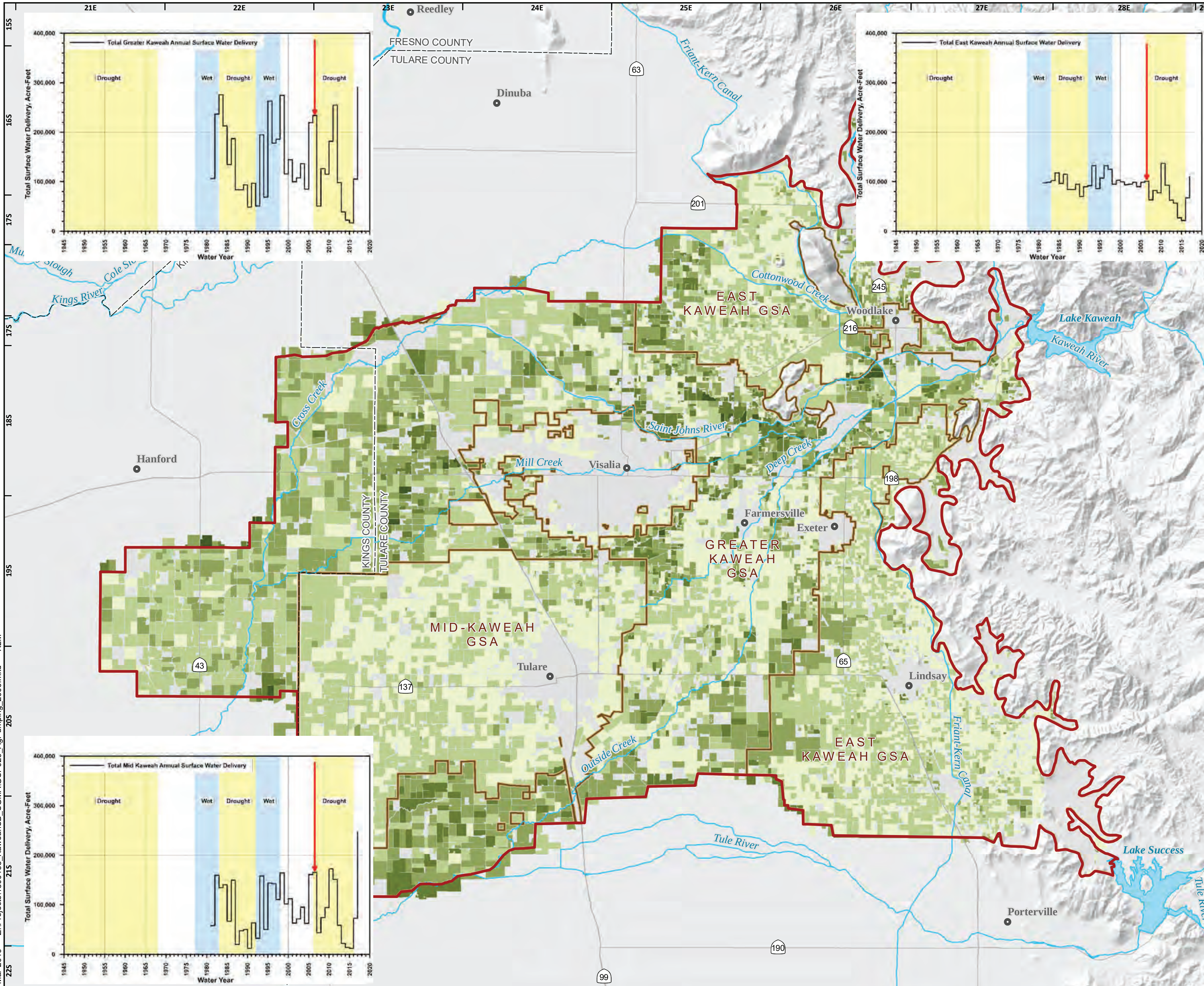
FIGURE 43

Z:\Projects\1800138_KaweahSB_SGMA\GSP028_AgPumping_2001.mxd KLM
11-Mar-2019

ANNUAL AGRICULTURAL PUMPING WATER YEAR 2006



Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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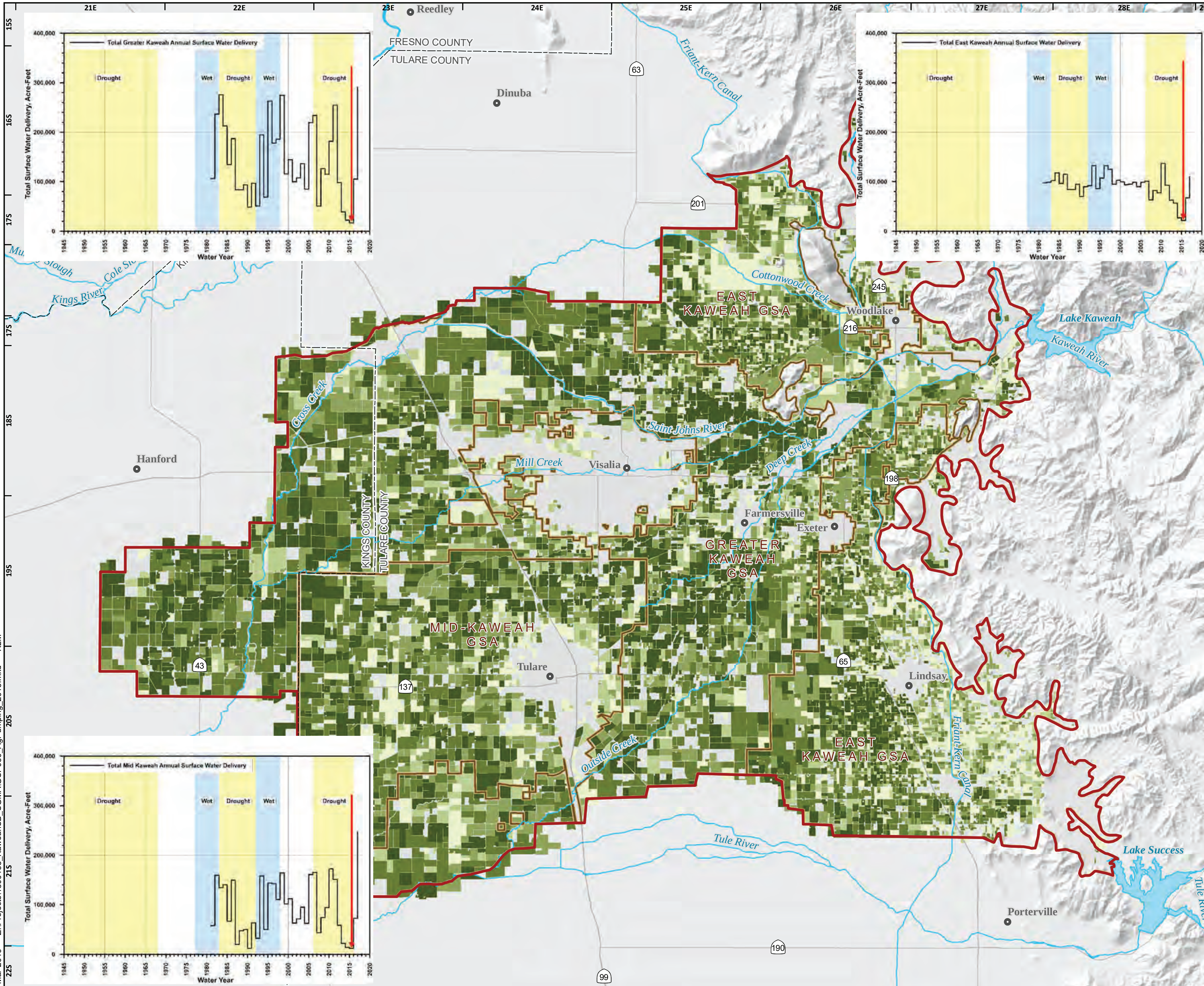
MARCH 2019 FIGURE 44

ANNUAL AGRICULTURAL PUMPING WATER YEAR 2015



Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
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Tulare County, California

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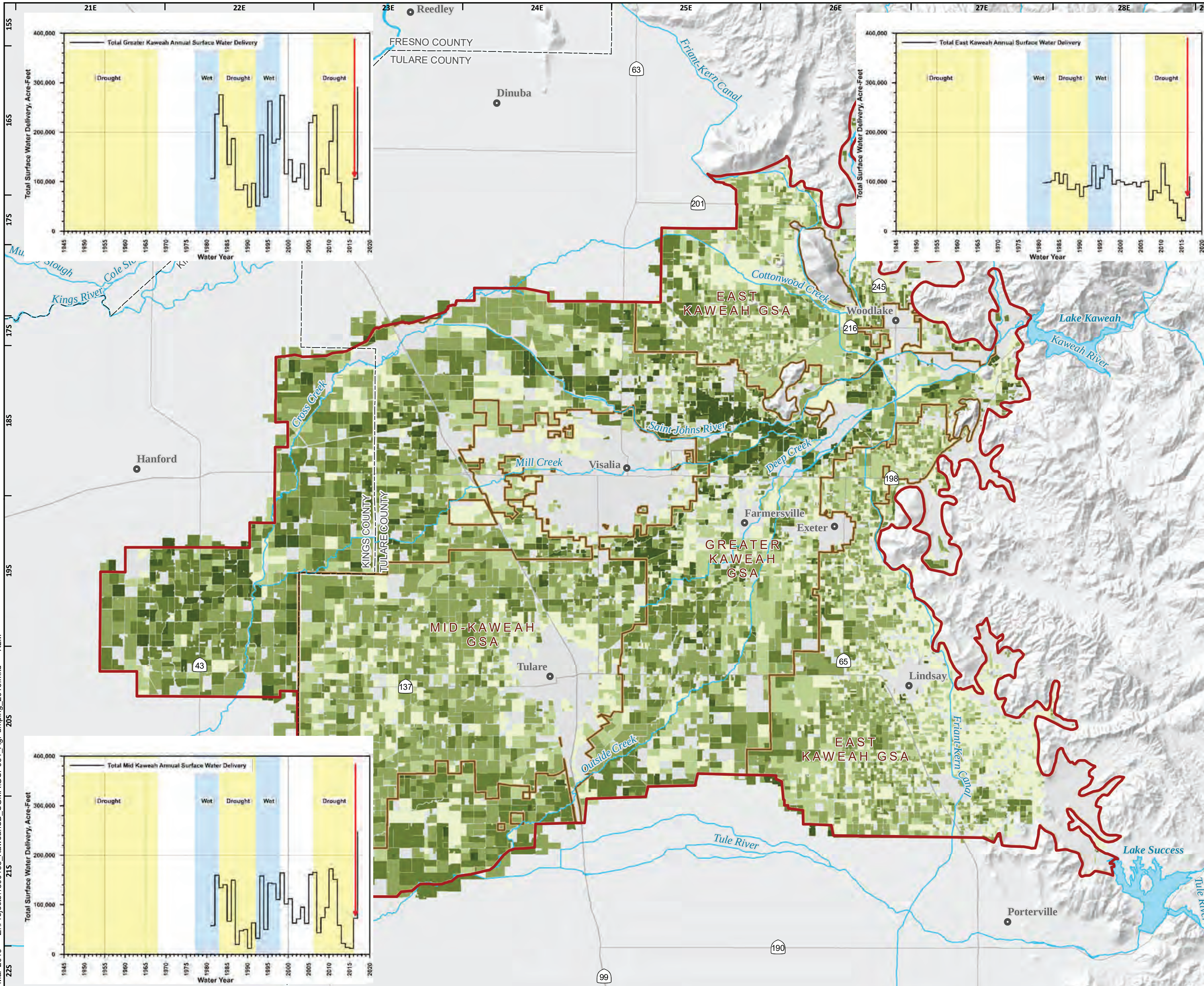
MARCH 2019 FIGURE 45

Z:\Projects\1800138_KaweahSB_SGMA\GSP030_AgPumping_2015.mxd KLM
11-Mar-2019



ANNUAL AGRICULTURAL PUMPING WATER YEAR 2016

Agricultural Pumping, acre-feet/acre

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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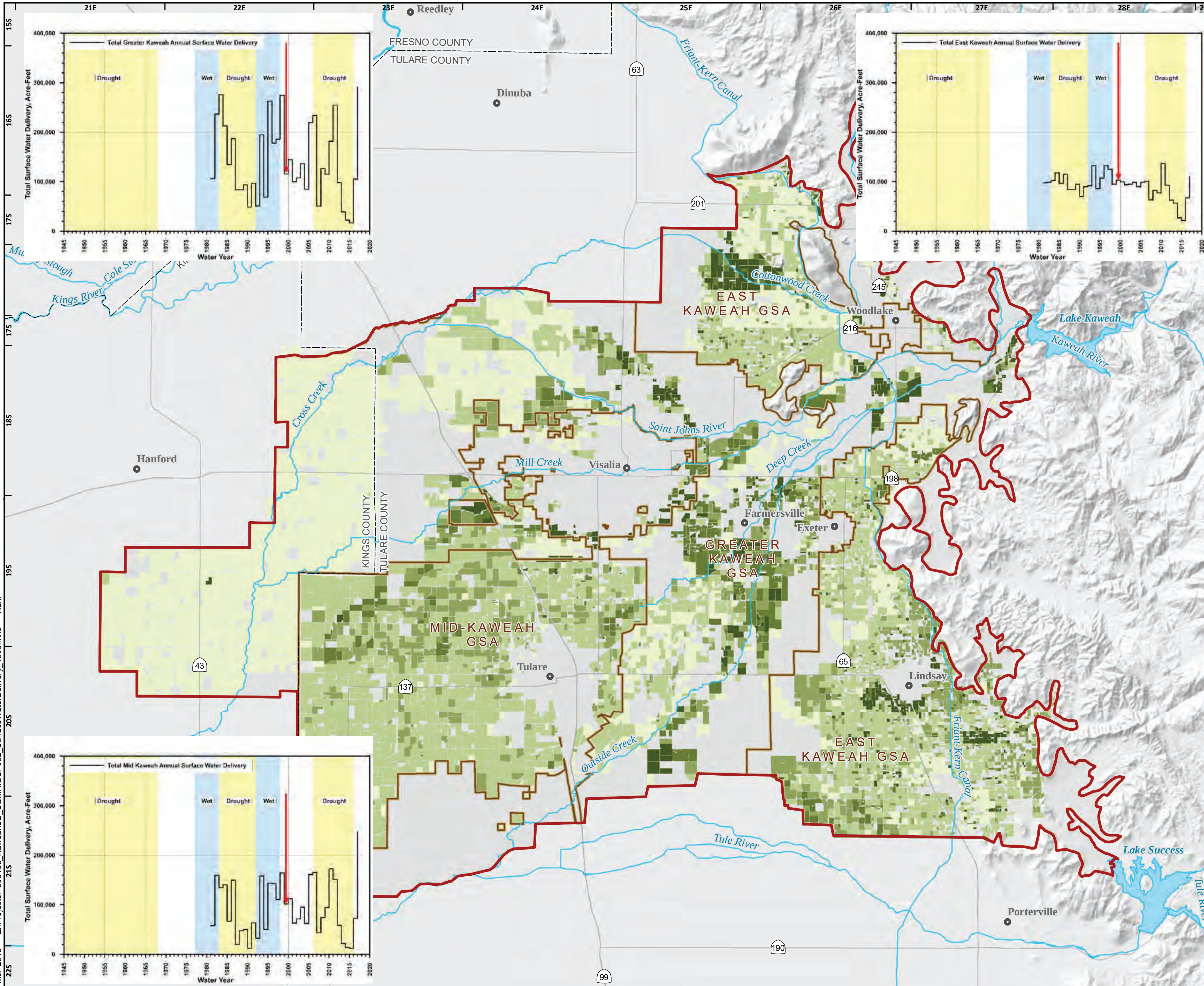
FIGURE 46

ANNUAL SURFACE WATER DELIVERY WATER YEAR 1999



Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

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Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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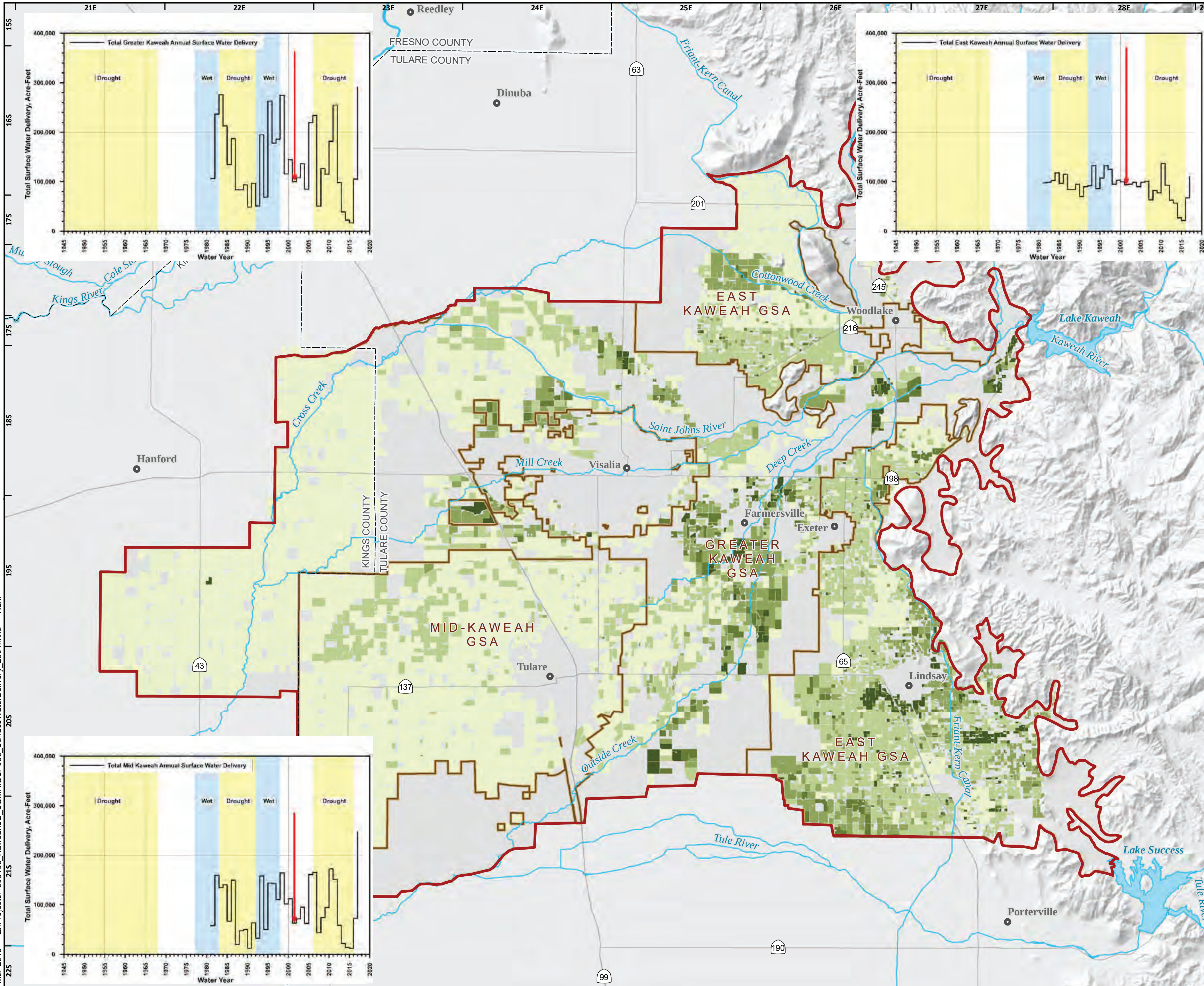
FIGURE 47

ANNUAL SURFACE WATER DELIVERY WATER YEAR 2001



Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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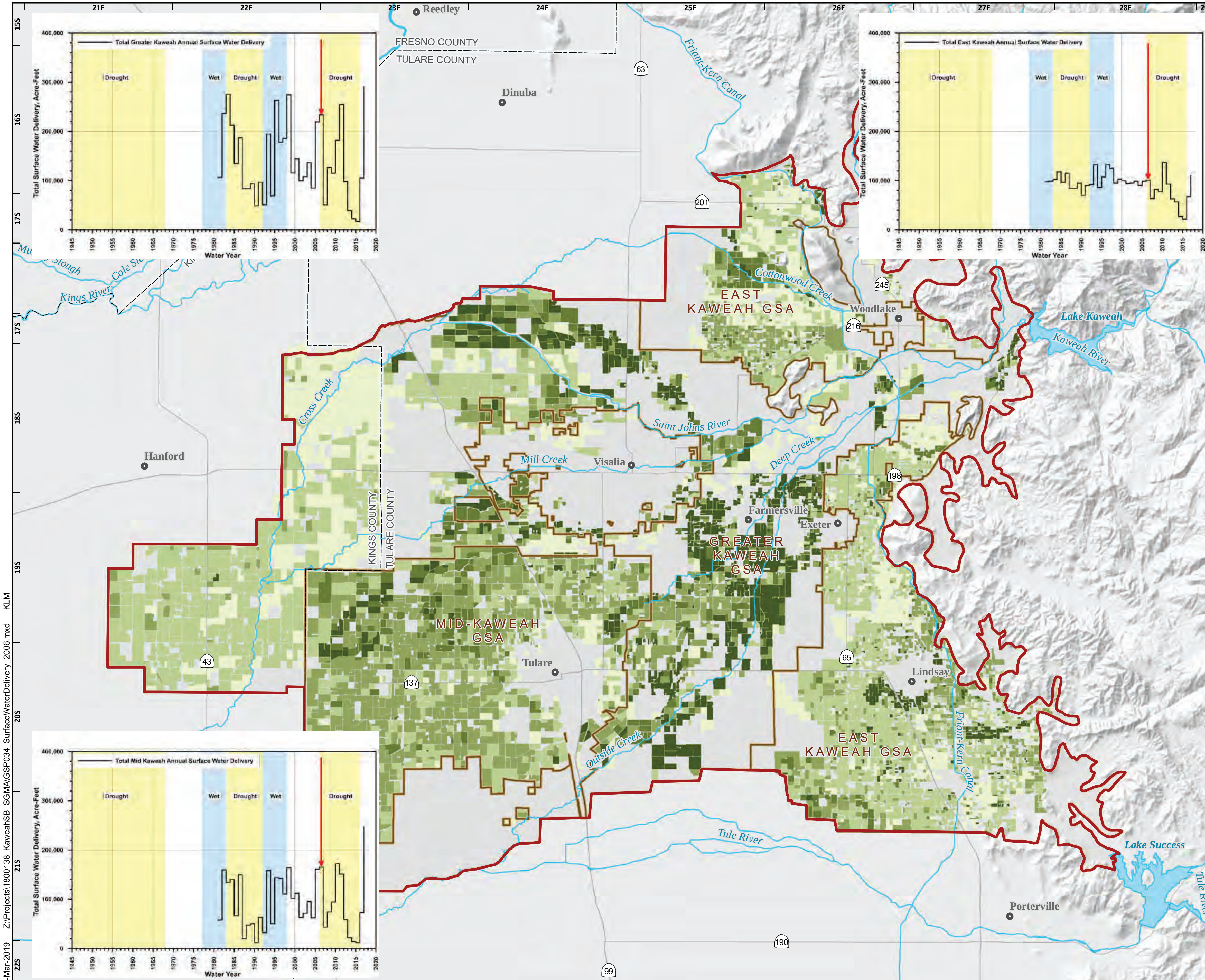
FIGURE 48

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP033_SurfaceWaterDelivery_2001.mxd KLM



ANNUAL SURFACE WATER DELIVERY WATER YEAR 2006

Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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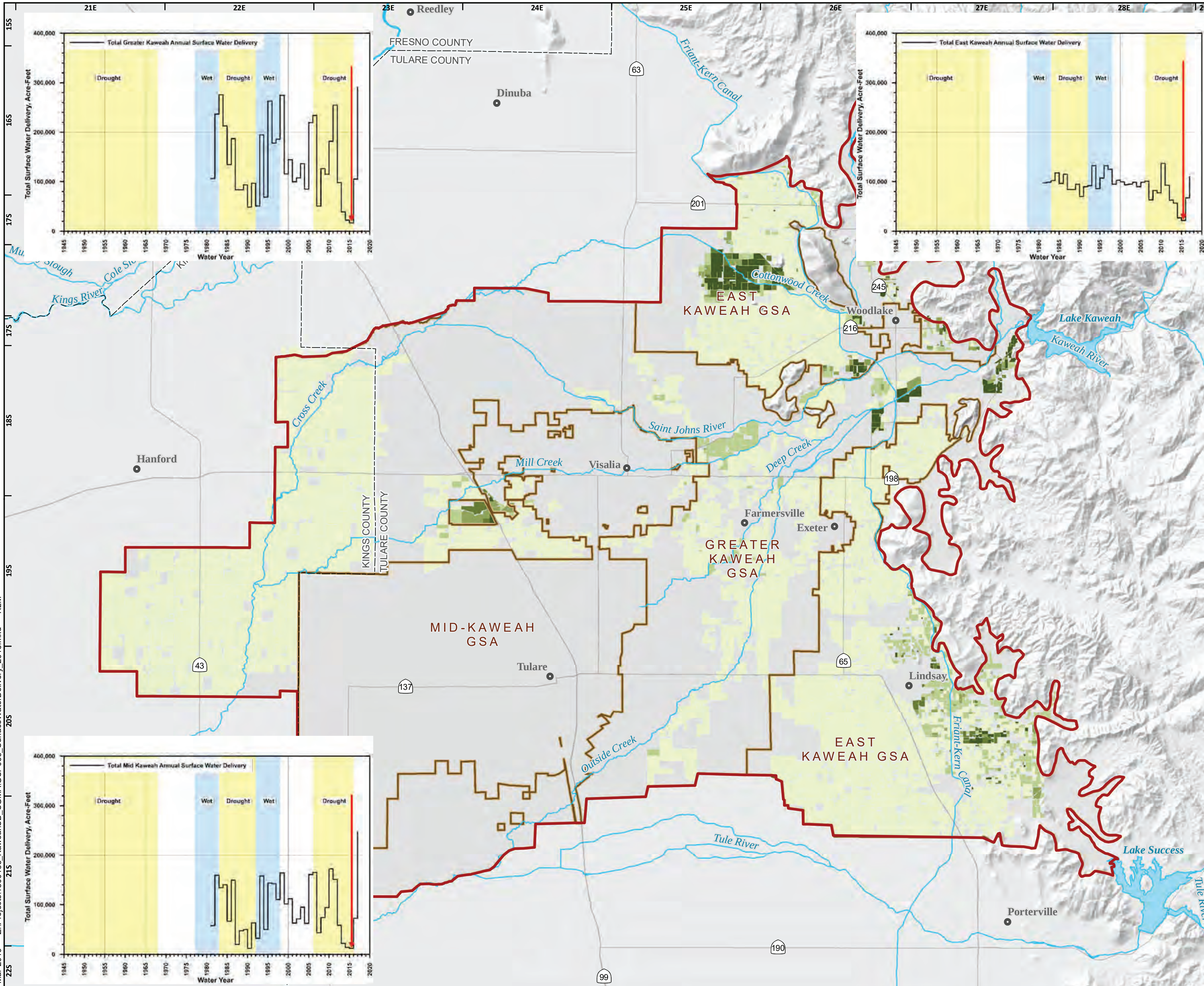
FIGURE 49

ANNUAL SURFACE WATER DELIVERY WATER YEAR 2015



Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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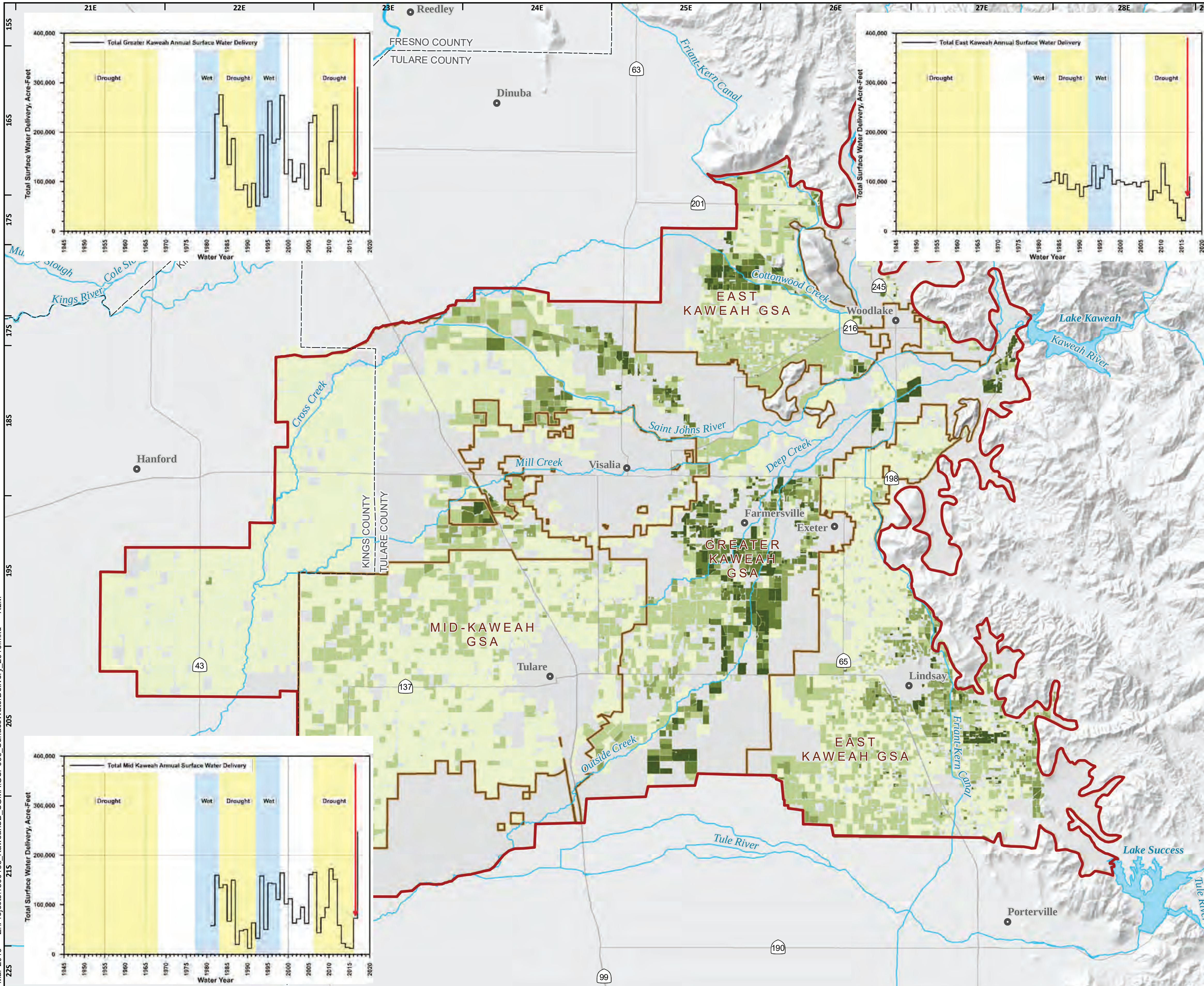
FIGURE 50

Z:\Projects\1800138_KaweahSB_SGMA\GSP035_SurfaceWaterDelivery_2015.mxd KLM 12-Mar-2019



ANNUAL SURFACE WATER DELIVERY WATER YEAR 2016

Surface Water Delivery, acre-feet/acre

- < 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- > 4.0
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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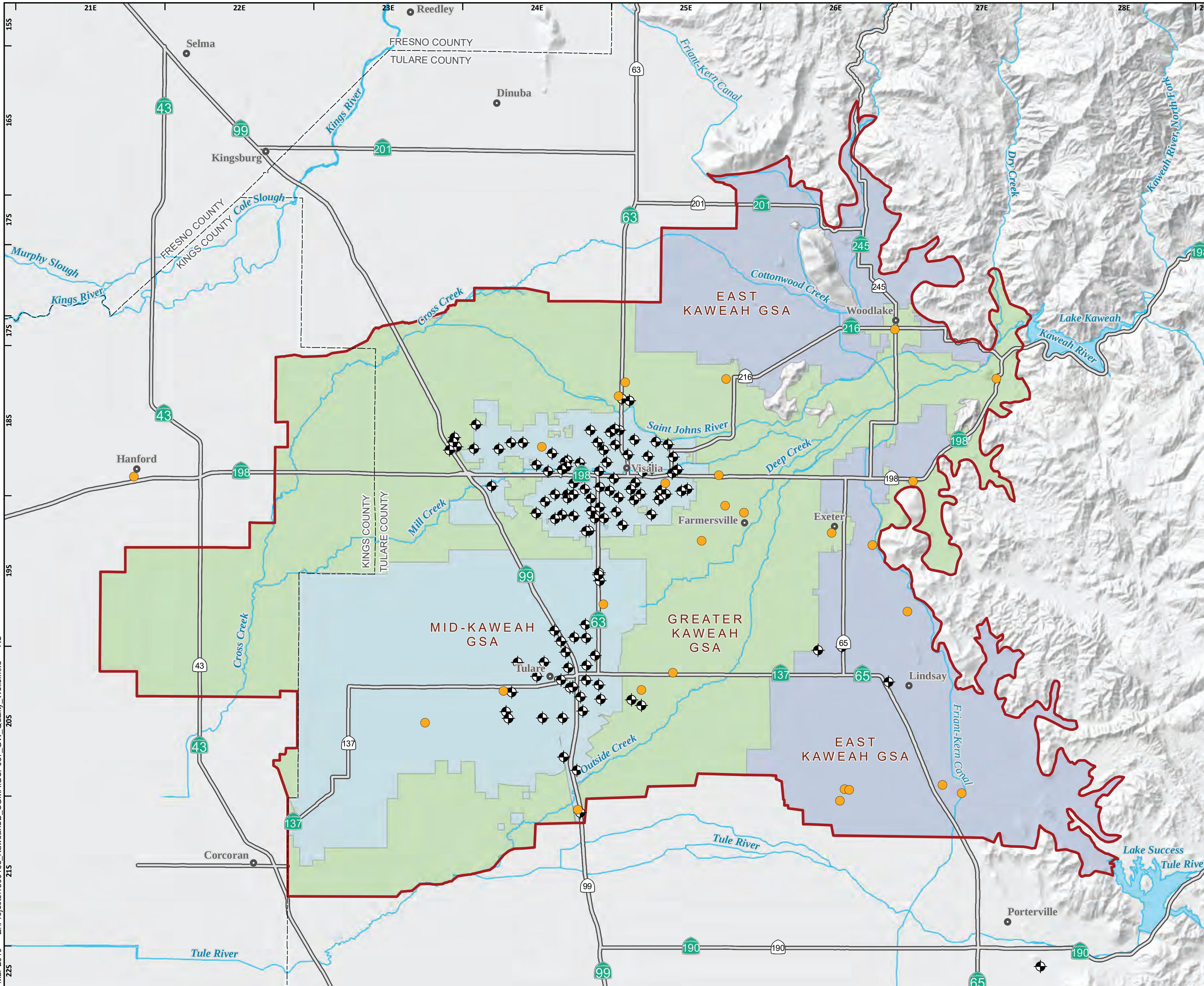
FIGURE 51

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP036_SurfaceWaterDelivery_2016.mxd KLM



KAWEAH SUBBASIN GROUNDWATER QUALITY WELL LOCATIONS

Representation of PWS with unknown Well Locations

Approximate Well Location

GSA Boundaries

East Kaweah GSA

Greater Kaweah GSA

Mid-Kaweah GSA

Kaweah Subbasin Boundary

All Other Features

Highway

Waterway

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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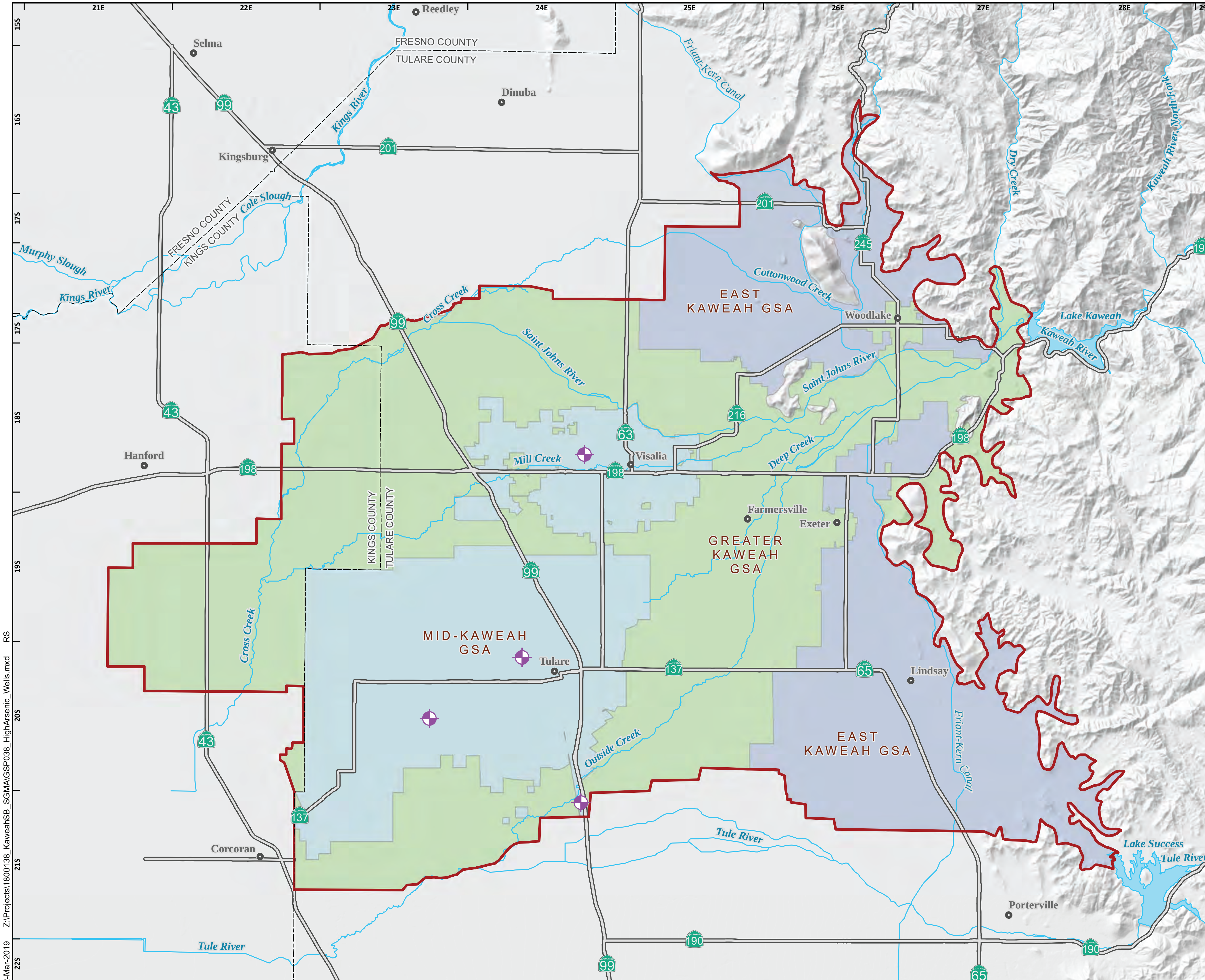
FIGURE 58



KAWEAH SUBBASIN
HIGH ARSENIC WELLS

Arsenic Concentrations 5-10 ppb, or Increasing Trends

GSA Boundaries

East Kaweah GSA

Greater Kaweah GSA

Mid-Kaweah GSA

Kaweah Subbasin Boundary

All Other Features

Highway

Waterway

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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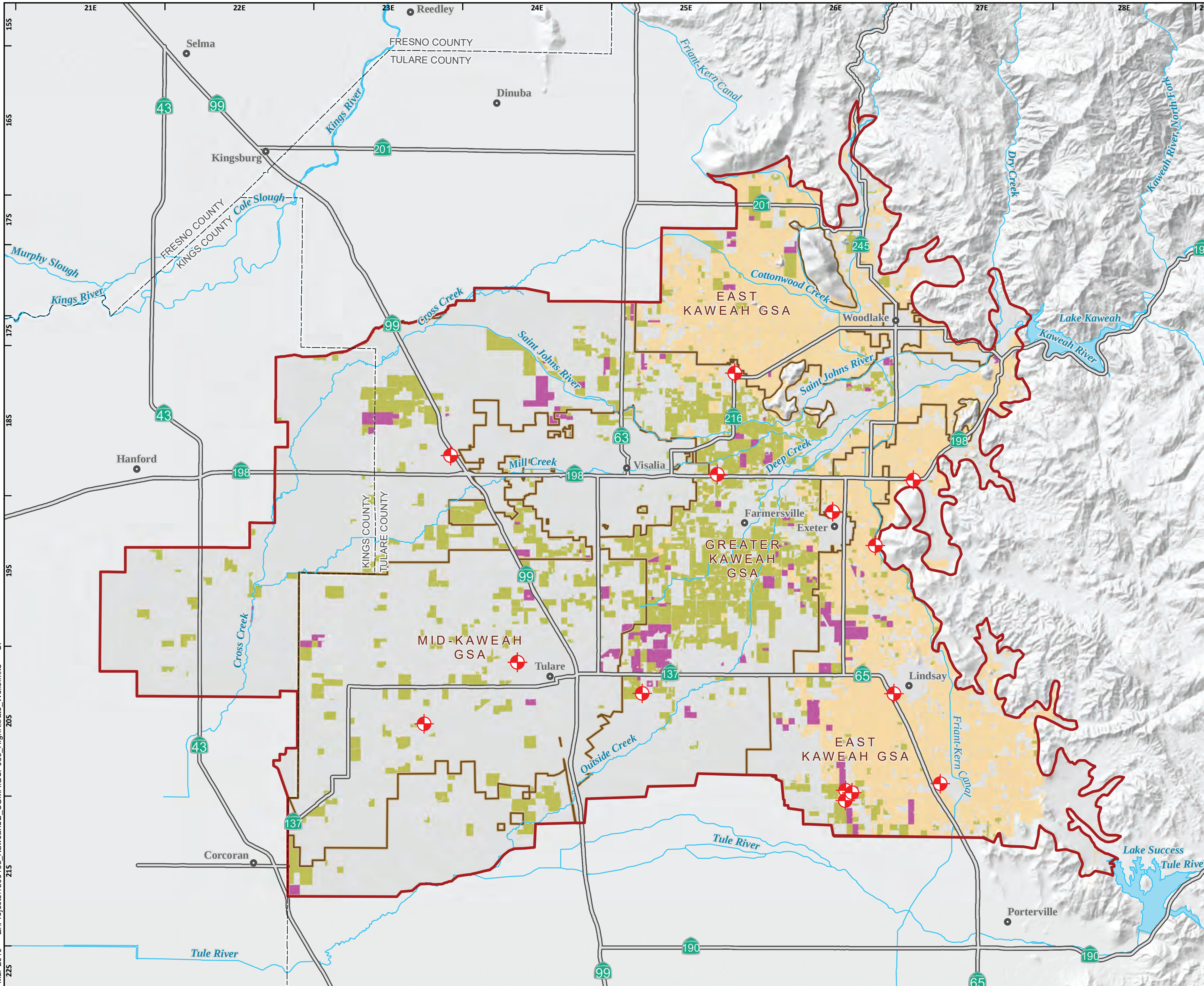
FIGURE 59

KAWEAH SUBBASIN HIGH NITRATE WELLS



- Nitrate Concentrations 5-10 ppm, or Increasing Trends
- Kaweah Subbasin GSA
- Kaweah Subbasin Boundary

Land Use

- Citrus and Subtropical
- Deciduous Fruits and Nuts
- Vineyard

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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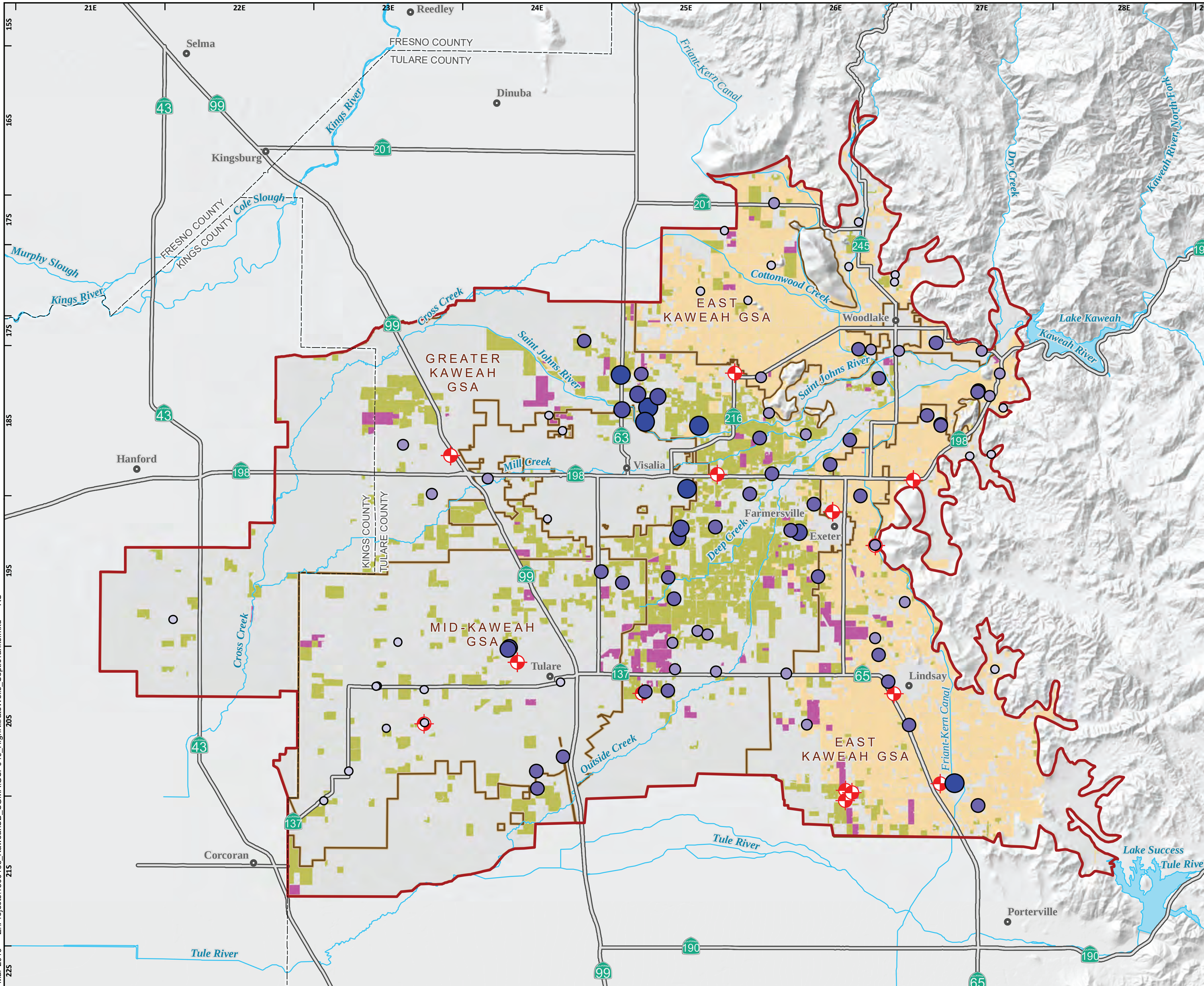
FIGURE 61

KAWEAH SUBBASIN HIGH NITRATE WELLS AND SEPTIC TANKS



Nitrate Concentrations 5-10 ppm, or Increasing Trends
Kaweah Subbasin GSA
Kaweah Subbasin Boundary

USGS Study Septic Tank Density per 500 meters

- 0.9 to 3.7
- >3.7 to 6.4
- > 6.4 to 10.6
- >10.6 to 15.4
- >15.4 to 35.9

Land Use

- Citrus and Subtropical
- Deciduous Fruits and Nuts
- Vineyard

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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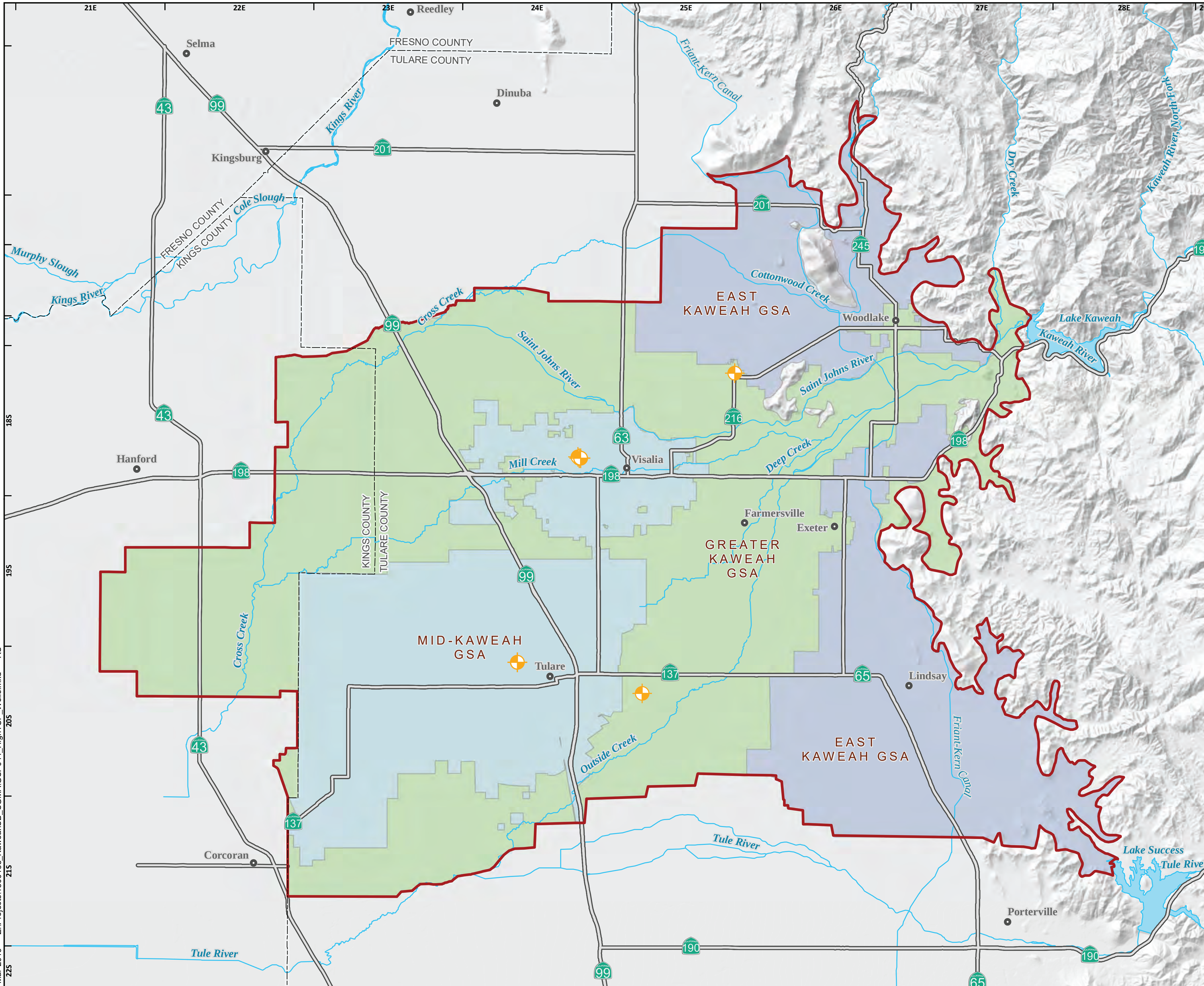
MARCH 2019 FIGURE 62

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP040_HighNitrateWells_SepticTanks.mxd RS

KAWEAH SUBBASIN
HIGH TCP WELLS



Areas of TCP Levels Greater Than 5 ppt

GSA Boundaries

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin Boundary

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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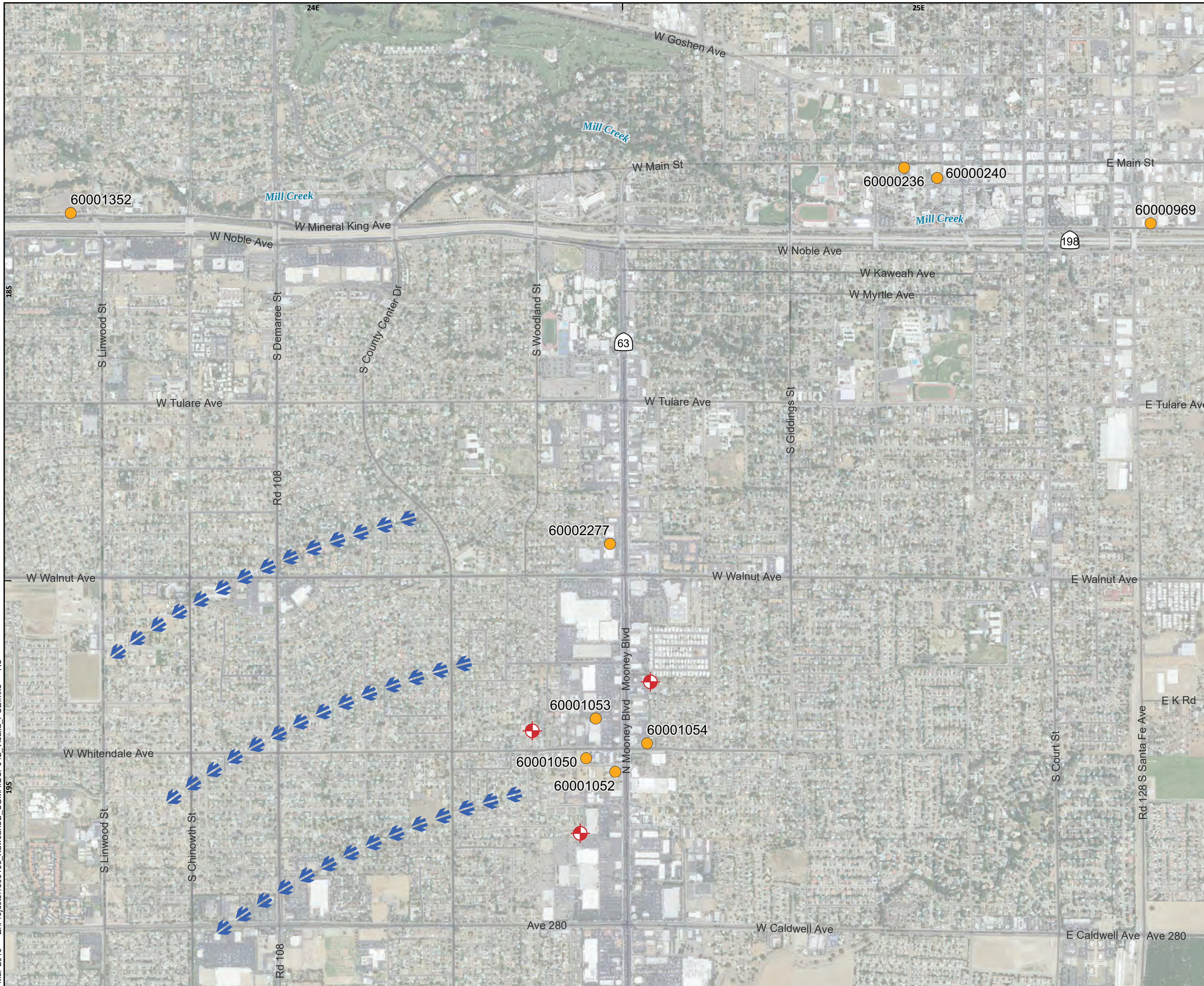
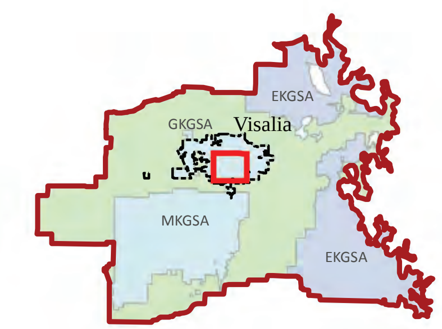
FIGURE 78

Z:\Projects\1800138_KaweahSB_SGMA\GSP041_HighTCP_Wells.mxd RS
12-Mar-2019

KAWEAH SUBBASIN
VISALIA CITYWIDE PCE PLUME



PCE Contamination Site
Municipal Well
General GW Flow Direction



0 1,500 3,000
Feet
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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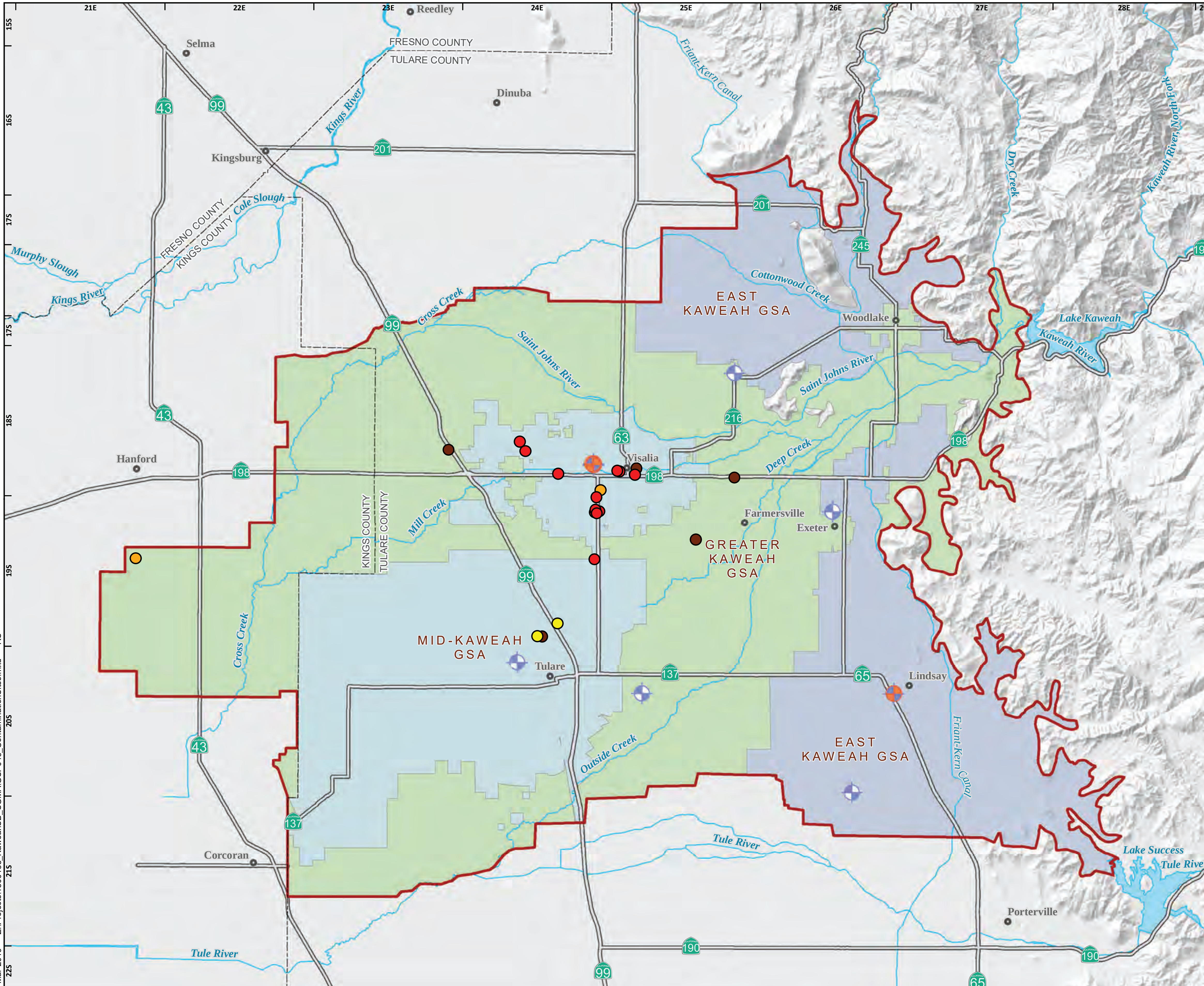
MARCH 2019 FIGURE 70

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP042_Visalia_PCE.mxd RS

KAWEAH SUBBASIN CONTAMINATION SITES



Increased or Elevated PCE Area

Well with DBCP Detected

Contamination Site

- Gasoline
- Arsenic
- Pesticide/Herbicide
- VOC

GSA Boundaries

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA
- Kaweah Subbasin Boundary

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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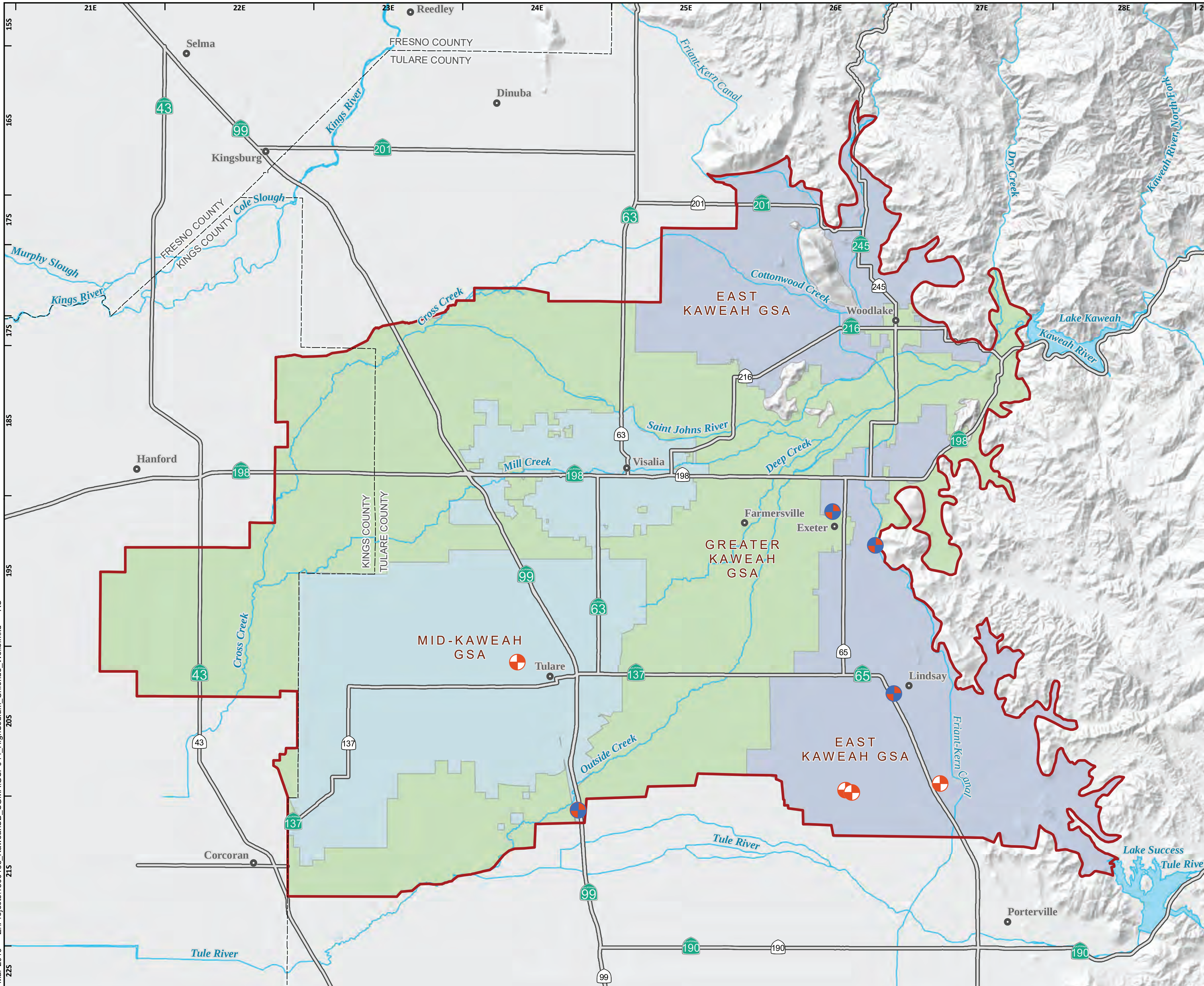
FIGURE 71

KAWEAH SUBBASIN
HIGH SODIUM AND CHLORIDE WELLS



Increasing or Elevated Chloride Area

Increasing or Elevated Sodium Area

GSA Boundaries

East Kaweah GSA

Greater Kaweah GSA

Mid-Kaweah GSA

Kaweah Subbasin Boundary

All Other Features

Highway

Waterway

Lake

0 2 4 8

Miles

N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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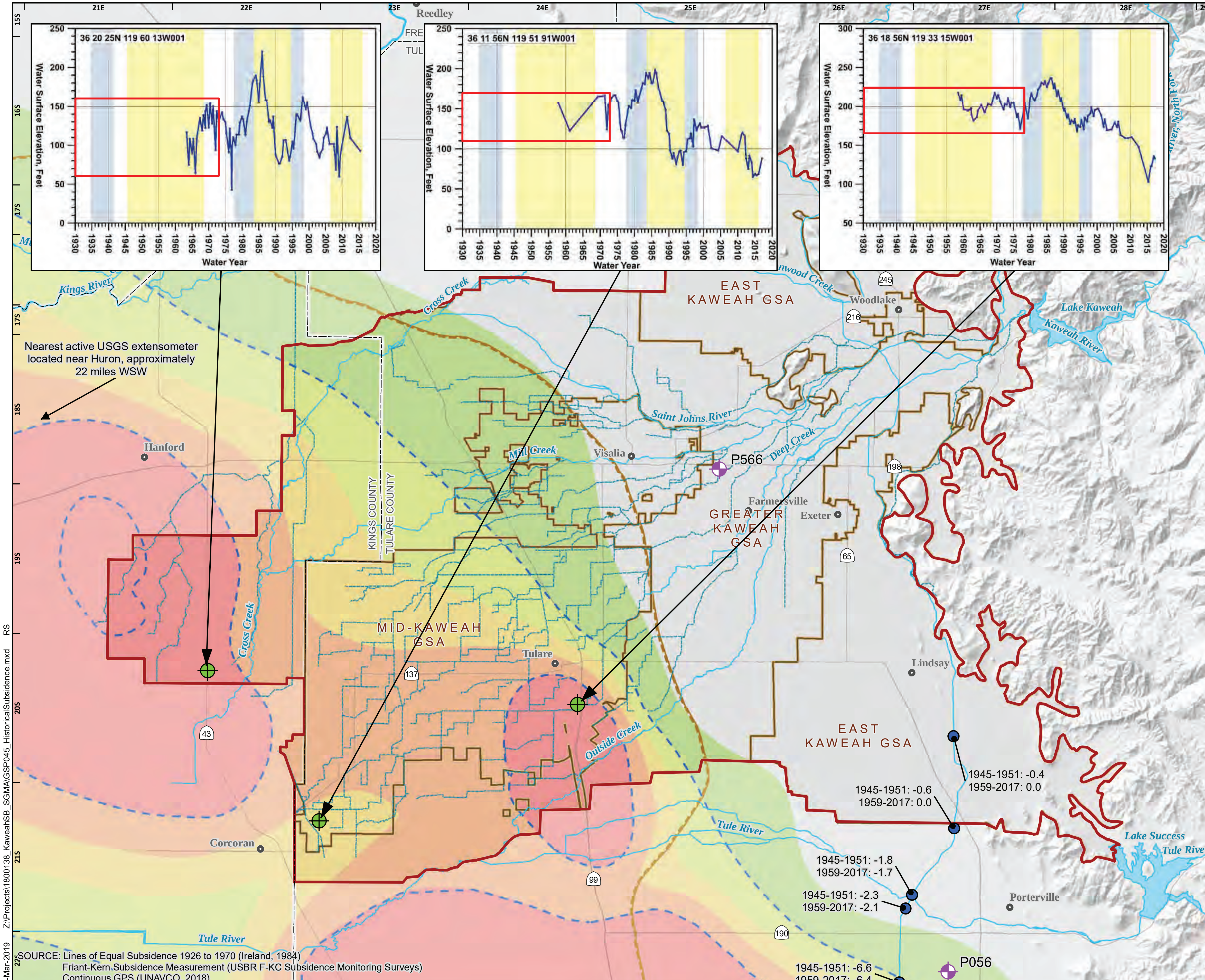
FIGURE 72

12-Mar-2019 Z:\Projects\1800138_KaweahSB_SGMA\GSP044_HighSodium_Chloride_Wells.mxd RS



Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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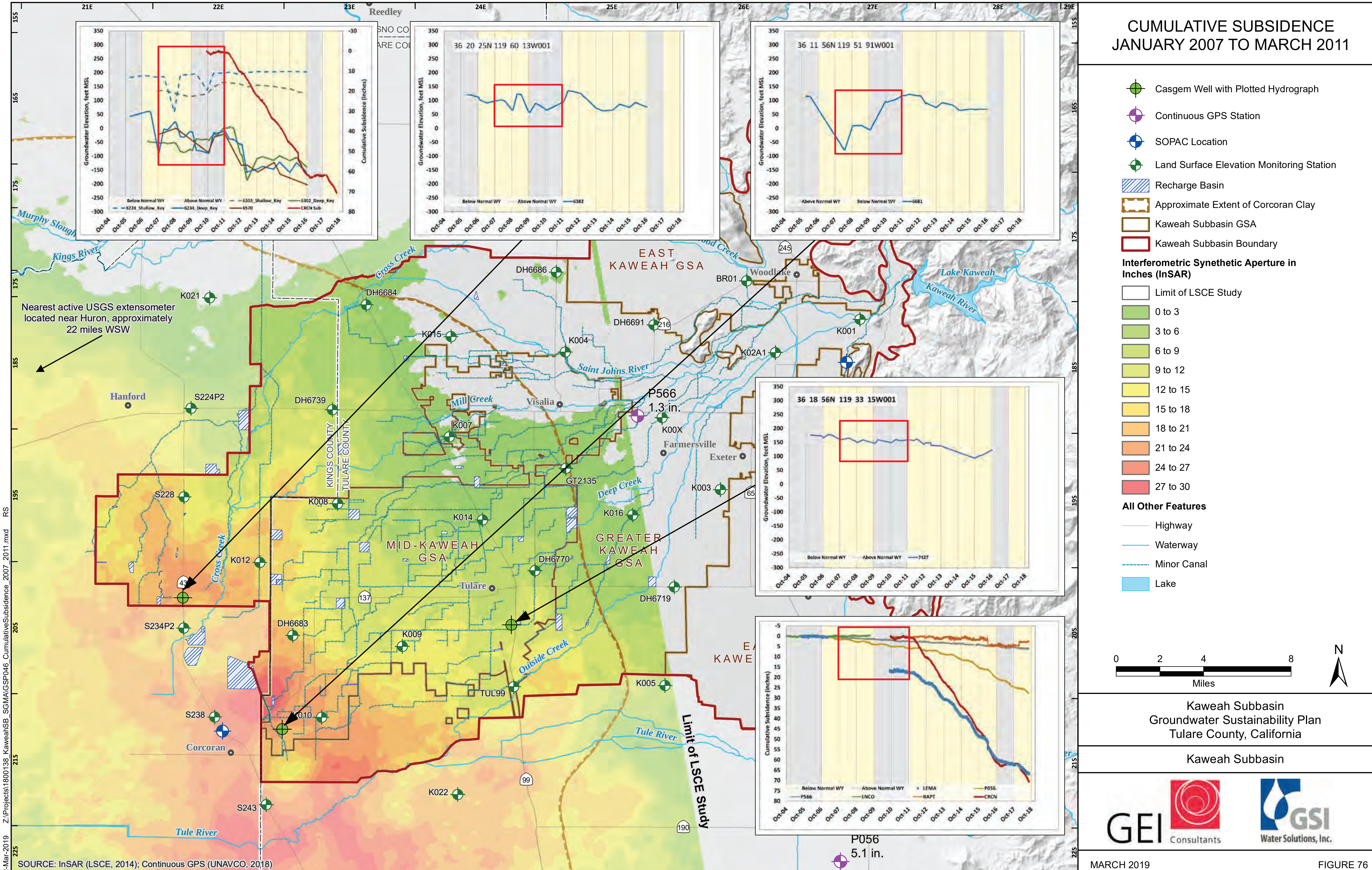
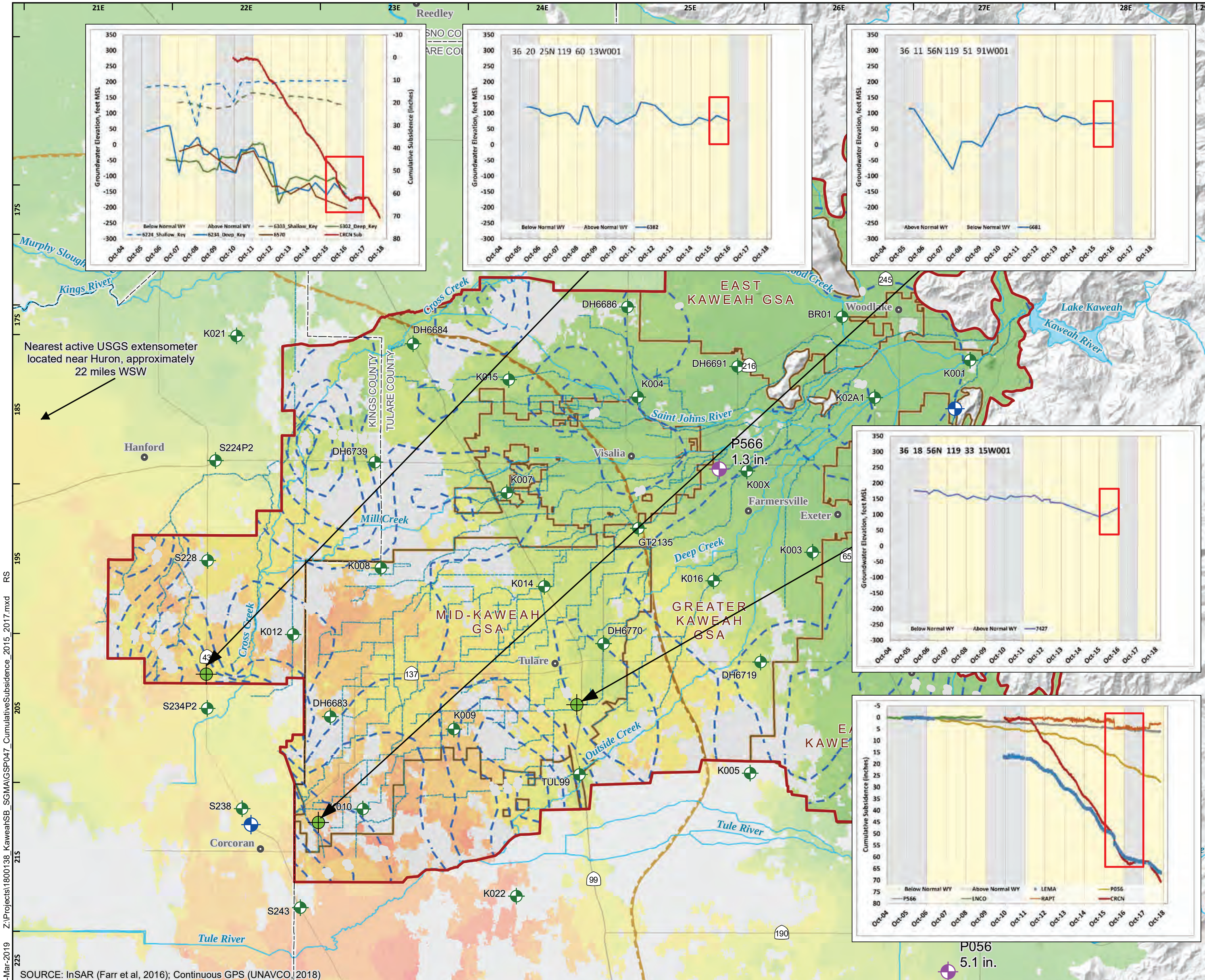
FIGURE 75


CUMULATIVE SUBSIDENCE
JANUARY 2007 TO MARCH 2011
Casgem Well with Plotted Hydrograph
Continuous GPS Station
SOPAC Location
Land Surface Elevation Monitoring Station
Recharge Basin
Approximate Extent of Corcoran Clay
Kaweah Subbasin GSA
Kaweah Subbasin Boundary
Interferometric Synthetic Aperture in Inches (InSAR)
Limit of LSCE Study
0 to 3
3 to 6
6 to 9
9 to 12
12 to 15
15 to 18
18 to 21
21 to 24
24 to 27
27 to 30
All Other Features
Highway
Waterway
Minor Canal
Lake
0 2 4 8
Miles
N
Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California
Kaweah Subbasin
GEI Consultants
GSI Water Solutions, Inc.
MARCH 2019
FIGURE 76
EAST KAWEAH GSA
MID-KAWEAH GSA
GREATER KAWEAH GSA
KINGS COUNTY
TULARE COUNTY
Nearest active USGS extensometer located near Huron, approximately 22 miles WSW
P566
1.3 in.
P056
5.1 in.
Limit of LSCE Study
Hanford
Visalia
Farmersville
Exeter
Tulare
Corcoran
Reedley
Woodlake
Lake Kaweah
Kaweah River
Kings River
Murphy Slough
Cross Creek
Saint Johns River
Mill Creek
Deep Creek
Outside Creek
Tule River
36 20 25N 119 60 13W001
36 11 56N 119 51 91W001
36 18 56N 119 33 15W001
Groundwater Elevation, feet MSL
Cumulative Subsidence (inches)
Below Normal WY
Above Normal WY
SOURCE: InSAR (LSCE, 2014); Continuous GPS (UNAVCO, 2018)
Z:\Projects\1800138_KaweahSB_SGMA\GSP046_CumulativeSubsidence_2007_2011.mxd RS
12-Mar-2019

CUMULATIVE SUBSIDENCE GROUNDWATER LEVEL DECLINE SPRING 2015 TO SPRING 2017



Casgem Well with Plotted Hydrograph
Continuous GPS Station
Land Surface Elevation Monitoring Station
SOPAC Location
Groundwater Elevation Decline Contour (20-foot Interval)
Approximate Extent of Corcoran Clay
Kaweah Subbasin GSA
Kaweah Subbasin Boundary

Subsidence in Inches (NASA JPL InSAR Dataset)

- 0 to 3
- 3 to 6
- 6 to 9
- 9 to 12
- 12 to 15
- 15 to 18
- 18 to 21
- 21 to 24
- 24 to 27
- 27 to 30

All Other Features

Highway
Waterway
Minor Canal
Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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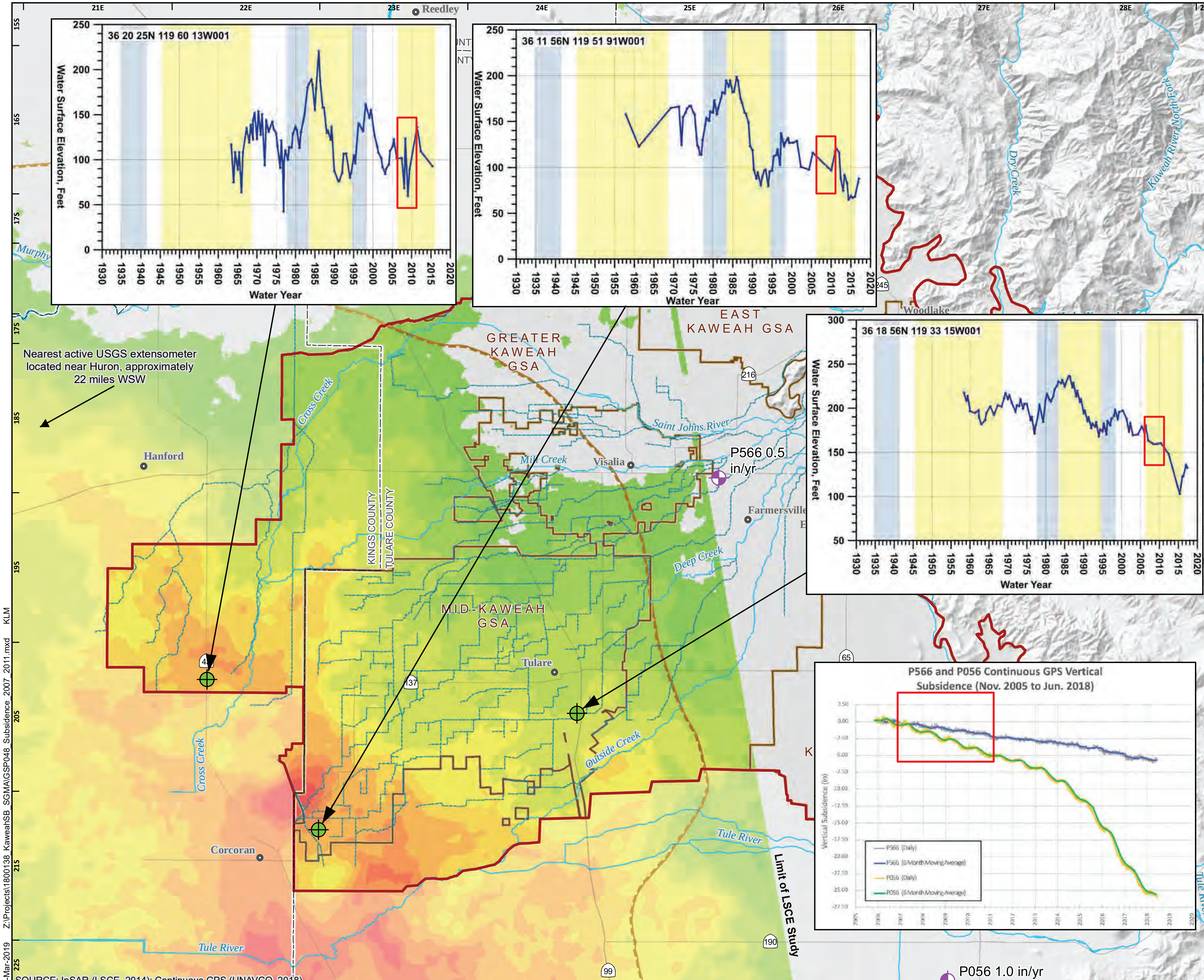
MARCH 2019

FIGURE 77



ANNUAL RATE OF SUBSIDENCE (JANUARY 2007 TO MARCH 2011)

- Continuous GPS Station
- Casgem Wells with Plotted Hydrograph
- Approximate Extent of Corcoran Clay
- Kaweah Subbasin Boundary
- Kaweah Subbasin GSA

Interferometric Synthetic Aperture in Inches per Year (InSAR)

- Limit of LSCE Study
- 0 to 0.75
- .75 to 1.5
- 1.5 to 2.25
- 2.25 to 3
- 3 to 3.75
- 3.75 to 4.5
- 4.5 to 5.25
- 5.25 to 6
- 6 to 6.75
- 6.75 to 7.5

All Other Features

- Highway
- Waterway
- Minor Canals
- Lake

0 2 4 8
Miles
N

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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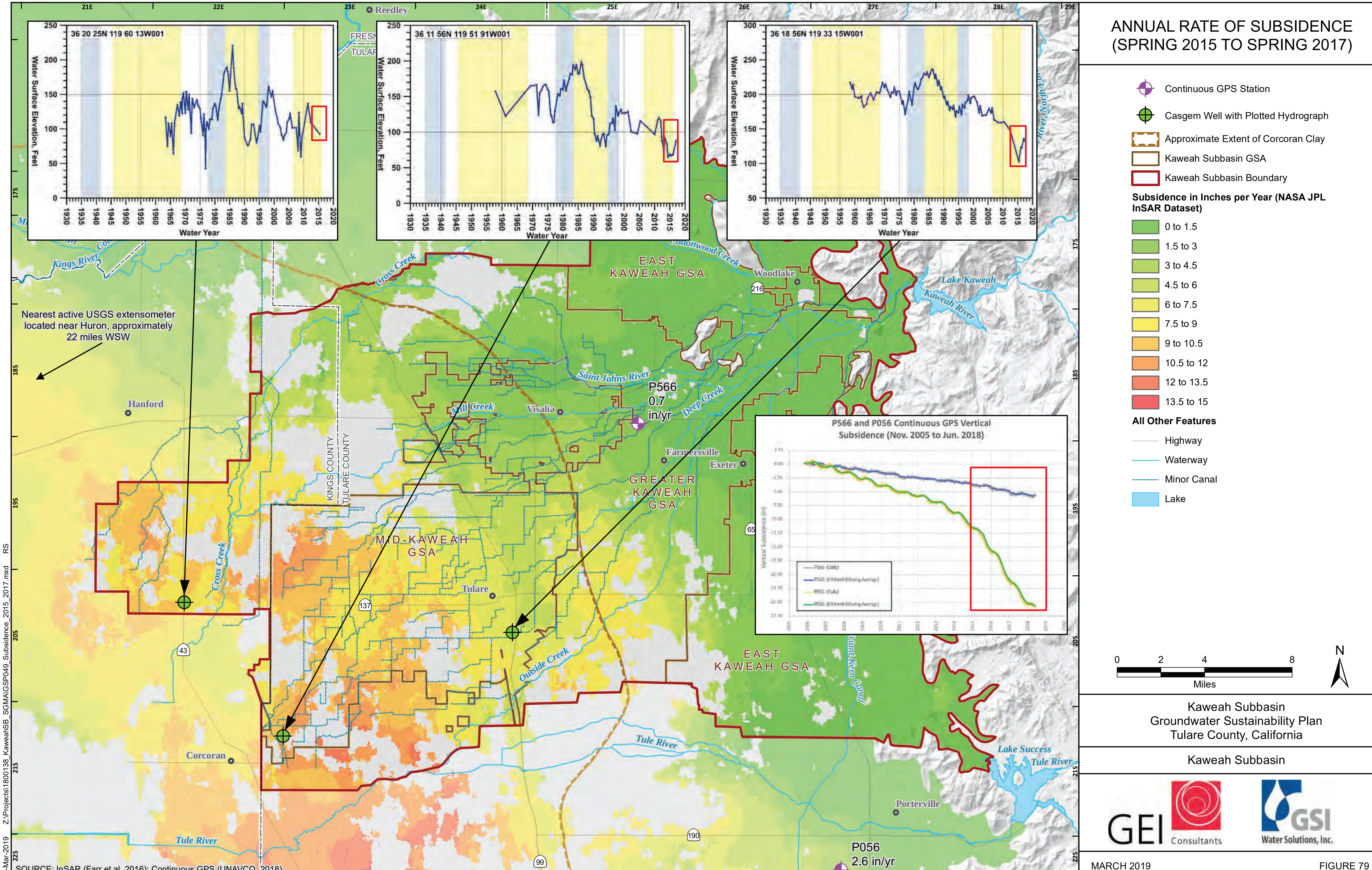
MARCH 2019

FIGURE 78

ANNUAL RATE OF SUBSIDENCE (SPRING 2015 TO SPRING 2017)



SOURCE: InSAR (Farr et al, 2016); Continuous GPS (UNAVCO, 2018)

Z:\Projects\1800138_KaweahSB_SGMA\GSP049_Subsidence_2015_2017.mxd RS 12-Mar-2019

Kaweah Subbasin
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

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MARCH 2019

FIGURE 79

Appendix A

Groundwater Modeling Technical Memorandum

Consulting Engineers and Scientists

D R A F T

T E C H N I C A L   M E M O R A N D U M

TO: Kaweah Sub-Basin Management Team

FROM: GEI Consultants, Inc.; GSI Water Solutions, Inc.

DATE: August 24, 2018

RE: TASK 1 – REVIEW OF EXISTING KAWEAH SUB-BASIN GROUNDWATER MODELS AND APPROACH FOR MODEL DEVELOPMENT TO SUPPORT GSPs

Introduction

Early in 2017, the GEI Consultants, Inc. (GEI) and GSI Water Solutions, Inc. (GSI) teams prepared a Technical Memorandum (TM) to evaluate the groundwater models available for use in development of the Groundwater Sustainability Plans (GSP) for the three Groundwater Sustainability Agencies (GSA) in the Kaweah Sub-Basin (Sub-Basin). That TM, dated March 8, 2017, presented the significant comparative details of three numerical groundwater flow models that cover the Sub-Basin, including:

- Kaweah Delta Water Conservation District (KDWCD) Groundwater Model,
- Central Valley Hydrologic Model (CVHM), and
- California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) coarse grid and fine grid variants.

The March 2107 TM identified the water budget from the most recent update of the KDWCD Water Resources Investigation (WRI) as an accounting "model", but it is essentially a water accounting analysis that uses water consumption and soil moisture models. It is not a three-dimensional, numerical groundwater flow model, but is a valuable analysis that will be used as primary inputs to the groundwater model. The March 2017 TM recommended use of the KDWCD Groundwater Model as the preferred tool for Sustainable Groundwater Management Act (SGMA) applications based upon its relative ability to address the potential model needs cited in SGMA regulations. Model selection criteria used in the TM included: model availability; cost of development and implementation; regulatory acceptance; suitability for GSP-specific analyses; and relative abilities to assess Sub-Basin water budget components, future undesirable results, and impacts of future management actions and projects.

More recently, the Kaweah Management Team, consisting of the East Kaweah, Greater Kaweah, and Mid-Kaweah Groundwater Sustainability Agencies (EKGSA, GKGSA, and MKGSA) approved a scope of work to develop a Sub-Basin wide numerical groundwater model to support GSP development and implementation. Efforts related to groundwater model development and use of the calibrated tool were generally defined within three tasks, as follows:

1. Task 1 – Perform a technical assessment of existing groundwater models that cover the Kaweah Sub-Basin, with emphasis on the KDWCD Model, and develop an approach to update and revise the selected source model as required to support the objectives of the GSP.
2. Task 2 – Perform model revisions and updates for the selected groundwater model as documented in Task 1, with a focus on supporting GSP objectives.
3. Task 3 – Apply the updated model predictively for each GSA and cumulatively for the entire Sub-Basin to simulate future conditions, with and without potential management actions and projects proposed to support GSP implementation.

This TM documents the results of Task 1. GEI and GSI (the Modeling Team), as part of supporting Sub-Basin SGMA compliance, have evaluated the existing KDWCD Groundwater Model for update to simulate the entire Sub-Basin and relevant adjacent areas. The following presents technical details and performance aspects of the KDWCD Model and proposes a general approach for utilizing the model to support development of the GSP. Specifics of this approach may change over the course of model development as dictated by data constraints and improved conceptualization provided by the updated Sub-Basin Basin Setting developed through the Management Team. This TM and associated analyses satisfies Task 1 requirements, including:

- Perform a detailed evaluation of the existing KDWCD groundwater model inputs and outputs, including test runs and simulations, comparisons with water budget data, and a general comparison with regional C2VSim and CVHM models.
- Develop a plan to move forward with the model update, including assessment of status of required hydrogeologic data, updates to model area, parameters, fluxes, spatial framework, stress periods, validation periods, and calibration periods and general approach for the model domain.
- Prepare a TM summarizing the path forward for modeling support of the GSP, including technical coordination with adjacent basin GSA representatives regarding groundwater modeling methods and assumptions.

Additionally, the Modeling Team will present the key findings of this TM in a workshop for representatives of the Sub-Basin GSAs. This working session will allow GSA representatives to better understand the model design and capabilities as well as provide a forum for discussion of current, future, and outstanding data as well as planning needs for model development and predictive simulations.

After submittal of this proposed modeling approach and path forward, the Modeling Team will execute the recommended actions described in this document. Once updated, the Modeling Team is recommending adoption of the name Kaweah Sub-Basin Hydrologic Model (KSHM) for this new SGMA tool to differentiate it from the previous modeling efforts and to reflect the fact that it includes complex hydrologic analyses in addition to groundwater flow.

Comparison with Regional Modeling Tools

The Modeling Team previously performed a cursory review of pertinent aspects affecting the efficient use of the three major groundwater modeling tools that cover the Sub-Basin. This TM is built upon that analysis and includes a more in-depth assessment of the newly released beta version of the C2VSim model provided by the California Department of Water Resources (DWR). Although the results of the March 2017 analysis were reinforced with findings from this review, the Modeling Team also looked at the datasets contained within these valuable, regional modeling tools to see if they may be of use in the development of the KSHM.

Central Valley Hydrologic Model

CVHM is an 11-layer model that covers the entire Central Valley. It has a spatial resolution of one square mile and includes both a coupled lithologic model and Farm Process module (model) that are used to estimate hydraulic parameters and agricultural groundwater demand and recharge, respectively. The CVHM was previously deemed not to be a viable modeling alternative for the Sub-Basin analyses by the Modeling Team due to several factors. Most significant of these is the fact that the model data is only current to 2009, well before the SGMA-specified accountability date of 2015. The model resolution is also not suitable to reflect all water budget components at the precision required to assess past and current groundwater responses to water management within each GSA. The CVHM is also not suitably calibrated nor reflective of the hydrostratigraphy in the Sub-Basin and does not match the higher resolution and more accurate crop and related groundwater pumping estimates produced by Davids Engineering, Inc. (Davids Engineering) time-series analysis of evaporation and applied water estimates for the KDWCD; soon to be provided for the entire Sub-Basin through water year 2017. Lastly, the use of the Farm Process is cost prohibitive, given the fact that it would have to be rigorously calibrated to the evapotranspiration and deep percolation estimates already provided by the Davids Engineering analysis.

California Central Valley Groundwater-Surface Water Simulation Model (C2VSim)

The DWR-supported C2VSim Fine Mesh Beta Version was assessed in greater detail as part of the development of this modeling approach. Like CVHM, the C2VSim fine mesh does not include the high resolution of crop demands and surface water deliveries that are in the existing KDWCD model and can be easily updated with the KSHM. It also does not have the element resolution, flexibility to change fluxes, cost savings, and GSA-level accuracy of a sub-regional model designed to incorporate the highest resolution and locally accurate consumptive use and recharge information available. The Modeling Team assessed model layering, significant water budget components, storage change, and groundwater level elevation changes used in C2VSim relative to KDWCD monitoring well locations. The previous KDWCD model produced a better match for the data and estimates from the WRI, and at a significantly higher resolution. Simulated storage change within the Sub-Basin was greater than that estimated by C2VSim by over 20,000 acre-feet per year (AFY); without documentation of how the quantification of water budget components was performed. Calibration of regional flow directions and gradients were reasonable but not as accurate nor locally refined as that observed with the KDWCD modeling efforts.

The beta version of the C2VSim model is not currently considered to be calibrated in a quantitative sense, and no documentation is publicly available to assess the resolution or accuracy of the model inputs for the Sub-Basin. Because of our analysis and comparison of the C2VSim Fine Mesh Beta Model with the water budget and groundwater conditions from the WRI and the draft Basin Setting; the C2VSim was deemed to be a viable source of regional information to supplement development of the KSHM. However, relative to a modeling approach using the KSHM, the C2VSIM model would not provide a more accurate or cost-efficient option for satisfying SGMA regulations.

KDWCD Model Assessment and Review with Respect to an Updated Model

The KDWCD Groundwater Model was originally developed by Fugro Consultants, Inc. (Fugro) under the direction and sponsorship by KDWCD. Model development was documented in the report "*Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District, Final Report*" (April 2005). The objective of the model was to simulate the water budget estimates as refined under the WRI in 2003 and evaluate calibrated groundwater elevations, and modeled fluxes to and from adjacent sub-basins.

In May 2012, the KDWCD model was expanded to the east and southeast by Fugro to include the service areas of the Cities of Lindsay and Exeter, and adjacent irrigation districts, including: the Lewis Creek Water District; some unincorporated land and significant portions of Exeter Irrigation District, Lindmore Irrigation District, and Lindsay-Strathmore Irrigation District. The purpose of this effort was to update only the geographic extent, and it did not include updates to the simulation period or the calibration. The model was intended to be updated, refined, and improved in the coming years to provide a rigorously calibrated model over this larger extent, but this proposed work was not performed prior to initiation of SGMA and GSP development efforts.

Modeling Code and Packages

The KDWCD model was developed using MODFLOW 2000. MODFLOW, developed and maintained by the United States Geological Survey (USGS), is one of the most commonly used groundwater modeling codes in the world and is considered an industry standard. The pre- and post-processing of groundwater model data was performed using Groundwater Vistas, a third-party graphical user interface (GUI) that is among the most commonly used software in the groundwater industry to facilitate the use of MODFLOW.

The previous two KDWCD model variants used the following MODFLOW modules, or "packages":

- Well Package (WELL)
- Recharge Package (RCH)
- General Head Boundary (GHB) Package

MODFLOW utilizes large text files of numerical values as input files that provide the model with the values of various physical parameters and fluxes; all incorporated into the three-dimensional (3D) model structure. Much of the pre-processing and spatial organization of the data used to develop the MODFLOW input files was accomplished by Fugro using customized FORTRAN routines, as well as a geographic information system (GIS). Because of more recently available evapotranspiration and applied water estimates from Davids Engineering, the use of these FORTRAN routines is no longer necessary; providing a significant cost and time savings.

A summary of the construction and implementation of various water budget components into these model packages is discussed in following sections.

Model Extent and Discretization

The spatial extent of the current KDWCD model is presented in Figure 1. The figure displays the original model extent as well as the expanded extent to the east from the 2012 update. The model extends approximately twelve miles from east to west and 7.5 miles from north to south. It is composed of uniform 1,000 foot by 1,000-foot model cells for each layer.

There are some areas of the Sub-Basin that are not currently within the model domain (Figure 1), including much of what is now the EKGSA area. To evaluate the entire Sub-Basin area, in support of SGMA, it will be necessary to expand the model area to include all of the areas within the Sub-Basin. The updated model must also have shared boundaries and shared buffer zones with all adjacent groundwater sub-basins, as well as an evaluation of subsurface inflow and outflow (underflow) between the sub-basins. Figure 2 shows the proposed, expanded model grid for the new KSHM extent.

Model Layers

The KDWCD model is vertically discretized into three layers as shown on hydrogeologic cross sections shown on Figures 3, 4, and 5. These hydrogeologic cross sections show the principal aquifers, aquitard, and associated geologic units located throughout the Sub-Basin. Layer 1 represents the unconfined, basin sediments from the ground surface down to the Corcoran Clay in the western portion of the model domain or deeper; also including some older Quaternary alluvial deposits in the eastern portion of the domain. Layer 2 represents the Corcoran Clay, which is the primary aquitard in the Sub-Basin, where it is present in the western portion of the domain. In the eastern portion of the model area, where the Corcoran Clay pinches out, Layer 2 is simply represented with a minimal thickness and hydraulic parameters comparable to those of Layer 1. Layer 3 represents the largely confined basin sediments below the Corcoran Clay, where it is present, and deeper unconsolidated sediments to the east of the occurrence of this regional confining unit.

Although some of the regional models covering large areas of the Central Valley (i.e., CVHM and C2VSim) have a more highly discretized vertical layering, the Modeling Team believes that the three-layer conceptual model represented in the KDWCD model is likely suitable for the primary modeling objectives that support GSP development.

Model Simulation Time Periods

The KDWCD model was originally set up with 38 6-month stress periods to simulate the 19-year (calendar) calibration period of 1981 through 1999. Water budget components as documented in the 2003 WRI were used as input into the model and spatially distributed to the degree feasible given the spatial resolution and precision of the data sources and model grid.

It is likely that, after any recommended changes to the KDWCD model are implemented into the KSHM, the Modeling Team will calibrate the model through water year 2017 and perform validation simulations to confirm that the previous calibration developed with the historic WRI information is a suitable starting point the new simulation period. After validation, additional model refinements and updates can proceed to further improve the predictive capabilities of the KSHM using the aforementioned recent, high-resolution datasets as well as updated Basin Setting information.

Model Parameters

- **Hydraulic Conductivity/Transmissivity.** Hydraulic conductivity values are documented in the 2005 Model Report as well as in previous iterations of the WRI and conform with industry-standard literature values for the types of aquifer materials encountered at these depth intervals. Calibrated, horizontal hydraulic conductivities for Layer 1 (upper, unconfined aquifer) range from 50 feet/day (ft/d) to 235 ft/d, with the highest values in the southwest portion of the model area. Horizontal hydraulic conductivities for the portion of Layer 2 representing the Corcoran Clay were set at 0.024 ft/d. In the eastern area of Layer 2, where the Corcoran Clay pinches out, hydraulic conductivity values range from 50 to 150 ft/d and are essentially equal to the values assigned to the same area in Layer 1. Horizontal hydraulic conductivities for Layer 3 range from 25 ft/d to 125 ft/d. This distribution of hydraulic conductivity is consistent with previously published estimates from both the WRI and industry-standard literature estimates for the lithologies encountered.
- **Vertical hydraulic conductivity.** Vertical hydraulic conductivity in the model is set to a ratio of the estimated horizontal hydraulic conductivity, or an anisotropy ratio of 1:1. This essentially means that the vertical hydraulic conductivity of the Corcoran Clay was assumed to be equal to its horizontal conductivity and was apparently based upon the extensive perforation of the Corcoran Clay and other aquifer units by fully penetrating wells. This perforation of the regional aquitard allows for greater hydraulic connection between the upper and lower aquifer units. The Modeling Team will assess the validity of this anisotropy ratio during the validation simulation and adjust where merited.
- **Storage Parameters.** Specific yields in the unconfined aquifer (Layer 1) range from approximately 8% to 14%. Storage coefficients for the confined areas were set at an order of magnitude of approximately 1×10^{-4}. The storage coefficients used for the unconfined and the confined portions of the model are typical of those found in the basin and documented in the WRI as well as other commonly referenced literature for large basin fill valleys.

Current Model Boundary Packages and WRI Water Budget Components

As mentioned previously, the current KDWCD model uses three MODFLOW packages: WELL, RCH, and GHBs. A discussion of how those packages are used follows below.

- **Well Package (WELL).** As currently constructed, the KCWCD model represents the following WRI water budget components; which were calculated outside of the model Groundwater Vistas graphical user interface (GUI) using GIS and a FORTRAN routine that are unavailable to the Modeling Team. The flux values specified in the WELL package input files are essentially "lumped" fluxes representing the sum of the following water budget components:

    - Well pumpage (outflow)
    - Rainfall-based recharge (inflow)
    - Irrigation return flows (inflow)
    - Ditch loss (inflow)
    - Recharge basins (inflow)

The compilation of multiple water budget components into a single MODFLOW package makes tracking and assessment of the individual water budget components from model simulations difficult. Additionally, this model flux accounting approach and design makes evaluation of possible changes in the water budget because of management actions, changes in water demand or availability, and groundwater projects problematic. Because of this lumping of separate water budget components, every cell in Layer 1 is represented in the WELL Package. This makes the exact validation of the test runs and verification of the calibration with the WRI challenging. Without access to the spatial and temporal distributions of all water budget components utilized by Fugro, it is not possible to re-create the exact WELL package input file. However, the gross water budget inflow, outflow and storage values from the earlier WRI's match those simulated by the model and were reproduced by the Modeling Team.

- **Recharge Package (RCH).** The natural stream channels of the St. John's and the Lower Kaweah Rivers are represented in the model using the MODFLOW RCH Package. The RCH package applies a flux (ft/yr) in the surficial (shallowest) cells at the location where applied. The natural seepage flux values (or groundwater recharge) applied to the model correspond to the values of stream infiltration spatially estimated for these rivers and documented in the WRI.
- **General Head Boundaries (GHB).** The KDWCD model has GHBs assigned to all cells on the exterior perimeter of the model, as seen on Figure 1. GHBs are commonly used to represent the edges of a model domain within a larger aquifer extent. Reference heads (groundwater elevations) and "conductance" terms for adjacent aquifers just outside the model domain are used by this package to calculate fluxes in and out across the boundary. The Modeling Team generally agrees with the use of GHBs in the north, south, and west portions of the Sub-Basin. However, we propose the removal of the GHBs along the eastern portion of the sub-basin at the Sierra Nevada mountain front. Conceptually, the eastern model boundary, especially with the expansion and inclusion of the EKGSA area, is not a head-dependent boundary, but a flux-dependent one based on mountain front recharge and seepage from natural drainages and streams adjacent to relatively impermeable material. Thus, this boundary will be better represented using a no-flow condition coupled with a recharge or prescribed underflow component.

Previous WRIs have included estimates of inflow and outflow across the study boundaries, and comparisons between modeled and calculated values vary significantly both spatially and by magnitude. However, there are several variables that directly impact estimated underflow values that have not been sufficiently constrained, due to the focus of previous work being on the interior of the KDWCD area. Recently updated basin conditions, improved understanding of appropriate regional groundwater conditions adjacent to the Sub-Basin and use of an expanded model area will significantly improve the certainty of these underflow estimates.

Model Calibration. Calibration of the KDWCD model for the historic simulation period of 1981-1999 is discussed in the April 2005 model report. These include charts of observed versus modeled water levels for three different time periods and transient hydrographs for 30 target well locations. The density of calibration targets was deemed adequate by the Modeling Team for a model of this area and with the resolution of the model input datasets. Detailed calibration statistics are not documented in the report, but qualitative inspection of the hydrographs indicates that the calibration is adequate for future use in predictive simulations. Additionally, an open-source and industry-standard parameter estimation and optimization algorithm and code (PEST) was used to enhance model calibration. This is a common and robust industry practice that typically improves model calibration statistics.

Adequacy of the KDWCD Groundwater Model for GSP Development

Layering scheme. The 3-layer model layering scheme incorporated into the KDWCD model was deemed adequate by the Modeling Team for use in GSP analyses, and likely does not need significant revision prior to use. This decision was based upon the agreement of the model layers with the hydrogeologic conceptual model for the Sub-Basin as well as the ability of the previous model to simulate historic fluctuations in groundwater elevations over an extensive spatial extent and temporal period. However, should the refinement of the lithologic and stratigraphic understanding of the basin and identification of specific pumping intervals require additional vertical resolution, both Layer 1 and Layer 2 can be split into two layers to improve the model's ability to match and describe key vertical gradients and changes in groundwater level elevations and pressures near prominent pumping centers. At present, this vertical refinement is not required nor supported by data.

Model area. The model area will need to be expanded so that the entire Sub-Basin is included in the model. In addition, at the request of and in coordination with the technical groups for both Kaweah and adjacent sub-basins, a buffer zone will be included outside the defined Sub-Basin boundaries so that adjacent models will overlap and share model input and monitoring data. This overlap will assist in reconciling differences between the direction and magnitude of groundwater gradients along sub-basin boundaries. The preliminary extent of this buffer zone is proposed to be approximately 3 miles; however, this value will be revised in areas based on of the estimated locations of pervasive groundwater divides or apparent hydrologic boundaries.

Cell size. The 1,000 feet square cell size appears to be adequate for the data density for most model inputs. However, due to improvements in computing speed and power, the Modeling Team recommends initially using a smaller cell size of 500 feet square to 1) accommodate improvements in assigning real world boundaries to the model grid, and 2) leverage the improved resolution of crop demand and evapotranspiration data available for this effort.

Parameters. Hydraulic conductivity and storage parameters will remain unchanged at the start of model revisions and calibration scenarios. These will be adjusted if the Modeling Team determines it is necessary during the model validation run or if model calibration standards require parameter refinements.

Stress Periods. The previous temporal discretization of the model incorporated 6-month stress periods. To appropriately characterize seasonal rainfall, surface water delivery and pumping patterns; one-month stress periods should be adopted for predictive simulations. This decision will be finalized after review and conditioning of the input groundwater demand and recharge datasets.

With these revisions to the model framework and geometry of the KDWCD model to support the development of the KSHM will be adequate for use to support GSP analyses. The following section summarizes additional, recommended revisions to the organization of the model inputs, parameters, boundary conditions, and MODLFOW packages.

Proposed Revisions to KDWCD Groundwater Model and Model Approach

The Modeling Team concludes that the KDWCD model is suitable to support GSP development if the following revisions and refinements to the model are performed to develop the KSHM. As mentioned above, once updated, the Modeling Team is recommending adoption of the name Kaweah Sub-Basin Hydrologic Model for this new SGMA tool. This nomenclature is based upon that fact that this model incorporates more than simply a groundwater model in the final analysis. It also incorporates crop demand/evapotranspiration (with precipitation modeling) and applied water models.

The Modeling Team recommends that the relationships between the water budget components, as defined in the WRI (December 2003, revised July 2007), and the MODFLOW modeling packages currently available, be re-organized such that lumping of different water budget components within single MODFLOW packages is minimized. Some degree of aggregation may be unavoidable, but efforts will be made to apply unique water budget components from the updated WRIs and associated water budget components to more appropriate and recent MODFLOW packages. Additionally, we will utilize features of MODFLOW and Groundwater Vistas that allow for tracking of unique components within a single model package when possible. The current and proposed revised conceptual assignments of water budget components to MODFLOW packages are summarized below.

A major change and advantage of this effort relative to previous modeling work involves the availability and use of time-series evapotranspiration and applied water estimates from 1999 through water year 2017, provided by Davids Engineering. This data set uses remote sensing imagery from Landsat satellites to estimate agricultural water demand throughout the Sub-Basin at a very high resolution (approximately 30 meters). This information was not available for previous model builds, and its use will not only improve the understanding and accuracy of agricultural water requirements relative to the previous land use and soil moisture balance calculations that have been used, but also enhance the spatial calibration and predictive capability of the updated and expanded KSHM. The Davids Engineering dataset also includes estimates of deep percolation of applied water and precipitation. During the review of the KDWCD model and development of this modeling approach, the Modeling Team performed testing of the use of this dataset and was able to readily develop crop requirements and associated pumping estimates at a resolution even finer than the proposed model resolution.

Well Pumping. Groundwater pumpage will be the dominant water budget component represented in the WELL package. Other, more limited fluxes may also be used to represent mountain front fluxes or other unforeseen fluxes that are specified but do not have a specific package that is appropriate. All pumpage will be coded within the WELL package input files to identify the pumping by source, use, or entity. Municipal wells will be specifically located and simulated when well permits and required data reports are accessible and provide data specific to each well. Agricultural well pumpage will likely be spatially averaged, or "spread across", irrigated areas because of the uncertainty associated with irrigation well location, construction, and monthly or seasonal pumping rates.

Precipitation-based recharge. The Modeling Team proposes to represent this water budget component using the Recharge package.

Natural channel infiltration. Infiltration of surface water in the natural stream channels of the St. John's and the Lower Kaweah Rivers is currently assigned to the Recharge Package. The Modeling Team proposes to maintain this data in the recharge package along the spatial location of the courses of the rivers. If deemed appropriate and more beneficial the latest version of the Stream Package (SFR2) may be used for localized reaches of continuously flowing water, where gages do not adequately monitor seepage that can be applied directly as recharge. The Stream package calculates infiltration (inflow) to the aquifer based on defined parameters regarding bed geometry and vertical conductivity, and this will likely involve some iterative re-definition of STREAM package components to accurately portray the calculated water budget component flux. Native evapotranspiration (ET), where relevant, will be subtracted from either the precipitation or natural channel infiltration modules. The inclusion of natural, riparian ET will be addressed specifically upon finalization of the water budget for the Sub-Basin.

Man-made channel recharge. (i.e., ditch and canal loss). This is currently incorporated with four other water budget components as a single summed value in the Well Package. The Modeling Team proposes to represent this water budget component using either the Recharge package or another Type 3 boundary condition type, such as a prescribed stage above land surface. Should another more advanced MODFLOW module prove to more effective in simulating this flux, it will be utilized, and the reasoning documented in the model development log.

Irrigation Return Flows. Irrigation return flows are the component of the water budget that infiltrates into the subsurface due to over-watering of crops. This is currently incorporated with four other water budget components as a single summed value in the WELL Package. The Modeling Team proposes to represent this water budget component using the Recharge package, but to differentiate it from precipitation-based recharge within Groundwater Vistas by assigning zone identifiers that are different from the rainfall-based recharge.

Artificial Recharge Basins. This is currently incorporated with four other water budget components as a single summed value in the WELL Package. Recharge basins are likely to be a common management strategy to help achieve sustainability in the Sub-Basin. As such, the model should be able to individually represent each recharge basin. These could be represented in the Recharge Package or other more sophisticated module if specifically merited.

Lateral Model Boundaries. These are currently simulated using the GHB Package. We will maintain this concept, but the locations of the GHBs will be moved to locations beyond the edge of the Sub-Basin up to the extent of the expanded model area. Assigned reference heads for the GHB cells will be based on observed groundwater elevations from historic groundwater elevation maps. GHB head assignments for predictive runs may be lowered over time if current trends indicate declining water levels over the next 20-40 years. These head assignments will be finalized in consultation and coordination with adjacent sub-basin technical groups as well as any regional modeling or State-derived predictive information.

Mountain Front Recharge. Currently, a GHB is assigned to the eastern edge of the Sub-Basin, along the front of the Sierra Nevada foothills. The modeling team will remove this GHB and represent mountain front recharge using the Recharge Package. Conceptually, mountain front recharge is not a head-dependent boundary, but a specified flux-dependent boundary.

Calibration Period and Validation Period. As discussed previously, the original model was calibrated to a 19-year calibration period using 6-month stress periods. The Modeling Team suggests that upon completion of the KSHM model, a validation run simulating the time period of 1999-2017 be made to assess that the model is still adequately calibrated. Upon assessment of the validation simulation, the KSHM will undergo the calibration process using both qualitative and quantitative measures, such as parameter estimation software (PEST), to produce the final calibrated simulation modeling tool to be used to refine the Sub-Basin water budget and be used for predictive simulations. Moving forward, the updated groundwater model for the Kaweah Sub-Basin will begin in 1999 and continue to be updated as new GSP updates are required and deemed necessary by the GSAs. This new start date is due to the substantially increased accuracy and spatial resolution of water budget features, primarily crop demand and surface water deliveries that result in agricultural pumping estimates, beginning with the first year that high quality satellite imagery and associated evapotranspiration/soil moisture balance models were provided by Davids Engineering. This modeling effort can be updated in the future with newer and more accurate local and regional data from neighboring GSAs to benefit required SGMA reporting, refinements, and optimization of the GSPs within the Sub-Basin.

Predictive Simulations. Predictive simulations through the SGMA timeframe of 2040 and beyond will be performed using the same monthly stress period interval and will be developed using the projected climate dataset provided by DWR. Correlations between this climatic projection and previously quantified groundwater demands and surface water deliveries will be developed to produce a suitable baseline predictive simulation that will serve as a starting point for assessing the impacts of various adaptive management actions and groundwater projects. Simulations will be performed for individual GSAs, but also the cumulative effects of future groundwater management in the Sub-Basin will be assessed relative to the baseline predictive simulation.

Collaboration with Neighboring Sub-Basins

The Modeling Team will be collaborating with neighboring sub-basin technical representatives during the update and application of the KSHM, with permission from the Kaweah Sub-Basin GSAs. The purpose for this coordination is to accomplish the following objectives:

- Receive input from GSAs' representatives on modeling tools and approaches in adjacent basins.
- Exchange data and information for consistency between tools.
- Agree on boundary conditions including both gradients and heads located at and outside of the boundaries of the Sub-Basin.
- Ensure that the KSHM integrates well, to the extent possible, with adjacent tools that our approaches for Kaweah Sub-Basin will not result in conflicting boundary conditions or water budgets.

The Modeling Team recommends that inter-basin model coordination meetings begin in August of 2018 and continue until the simulations required for use in developing the draft GSP is are completed. We anticipate the need for four (4) focused meetings on this approximate schedule:

1. KSHM Approach Meeting – Mid September 2018
2. KSHM Update Meeting – Late October 2018
3. KSHM Model Baseline Run and Boundary Flux Meeting – Late November 2018
4. KSHM Model Simulation Results Meeting – January 2019

The Modeling Team attended one meeting with the Tulare Lake Sub-Basin modeling group on June 15th, 2018 to facilitate data transfer between the two modeling efforts and improve agreement and conceptual consistency between the Sub-Basins. Upon request from the Kaweah Sub-Basin managers and committees, the Modeling Team will continue to collaborate and improve consensus with adjacent modeling groups to improve model agreement and sub-regional consistency between calibrated and predictive simulations. The Modeling Team is also prepared to develop and share baseline predictive simulation results with neighboring basins and accept in-kind data sharing to further improve predictive accuracy and understanding on adaptive management and project options and collaboration. These activities will be approved by GSA representatives prior to the Modeling Team sharing any information or data.

Conclusions and Recommendations Regarding Model Updates

In general, the Modeling Team believes that the KDWCD model provides an adequate precursor model that will be suitable for use in GSP development if the following revisions and updates are incorporated.

Groundwater Vistas Version 7 will be the processing software package utilized. We will maintain MODFLOW as the basic code and will update to MODFLOW-USG or MODFLOW-NWT to take advantage of advances in numerical solution techniques that are available in these updated MODFLOW revisions.

1. **Extent**. The model will need to be expanded to fill the area between the general head boundary of the current model and the Sub-Basin boundary shown in Figure 1 to include the entire area of the Kaweah Sub-Basin.
2. **Layers.** The model layering scheme depicting two water-bearing layers above and below the Corcoran Clay is suitable for the objective of supporting the GSP development.
3. **Historical Simulations.** The KDWCD model has been calibrated to the 1981-1999 hydrologic period. Based on inspection of the hydrographs presented in the 2005 modeling report and the 2012 Model update report, observed water levels are adequately simulated to consider this model effectively calibrated. The objective is to have a model suitable to simulate projected management actions through the entire Sub-Basin. No changes will be made to the inputs to the 1981-1999 run. Therefore, it is already calibrated to that period. We are just re-organizing the assignment of water budget components to different MODFLOW packages from 1999-2017, and beyond. Monthly stress periods will be used.
4. **Assignment of water budget components to MODFLOW Packages.** The Modeling Team proposes to revise the conventions used in the current KDWCD model. This will be the most involved part of the model revision. The updated water budget values that have been generated by the GSA will continue to be the primary input as far as flux values go. However, we propose to organize them into more readily identifiable currently available MODFLOW packages to help with the analyses of potential water budget changes that may correspond to management actions in the future.
5. **Recharge Components.** Spatial distribution of such water budget components as percolation of precipitation, irrigation return flow, recharge basins, etc., will be updated based on the most currently available data.
6. **Model Parameters**. Hydraulic conductivity (horizontal and vertical) and storage coefficient will initially stay unchanged during the validation period simulation. If the calibration target hydrographs for the validation period indicate that a suitable match is retained between observed and modeled water levels, the existing parameters will be retained.
7. **Flow Boundaries.** In areas where the current GHB boundaries are within the Kaweah Sub-Basin, they will be expanded approximately 1-2 miles, or at locations of any likely groundwater divides from the Sub-Basin boundary on the north, south, and west sides of the Sub-Basin. The assigned heads for these GHBs for the 1999-2017 verification run will be based on published groundwater elevations in the vicinity as depicted in contour maps published by DWR. Seasonal variability in assigned GHB heads can be incorporated.
8. **No-Flow Boundaries.** The eastern GHB along the base of the Sierra foothills will be removed. Instead, the flux in the Recharge Package will be increased along this boundary to represent mountain front recharge. The flux volume from the GHB will be evaluated, and this flux volume will be approximated using the Recharge Package.

Estimated Schedule of Model Update Activities

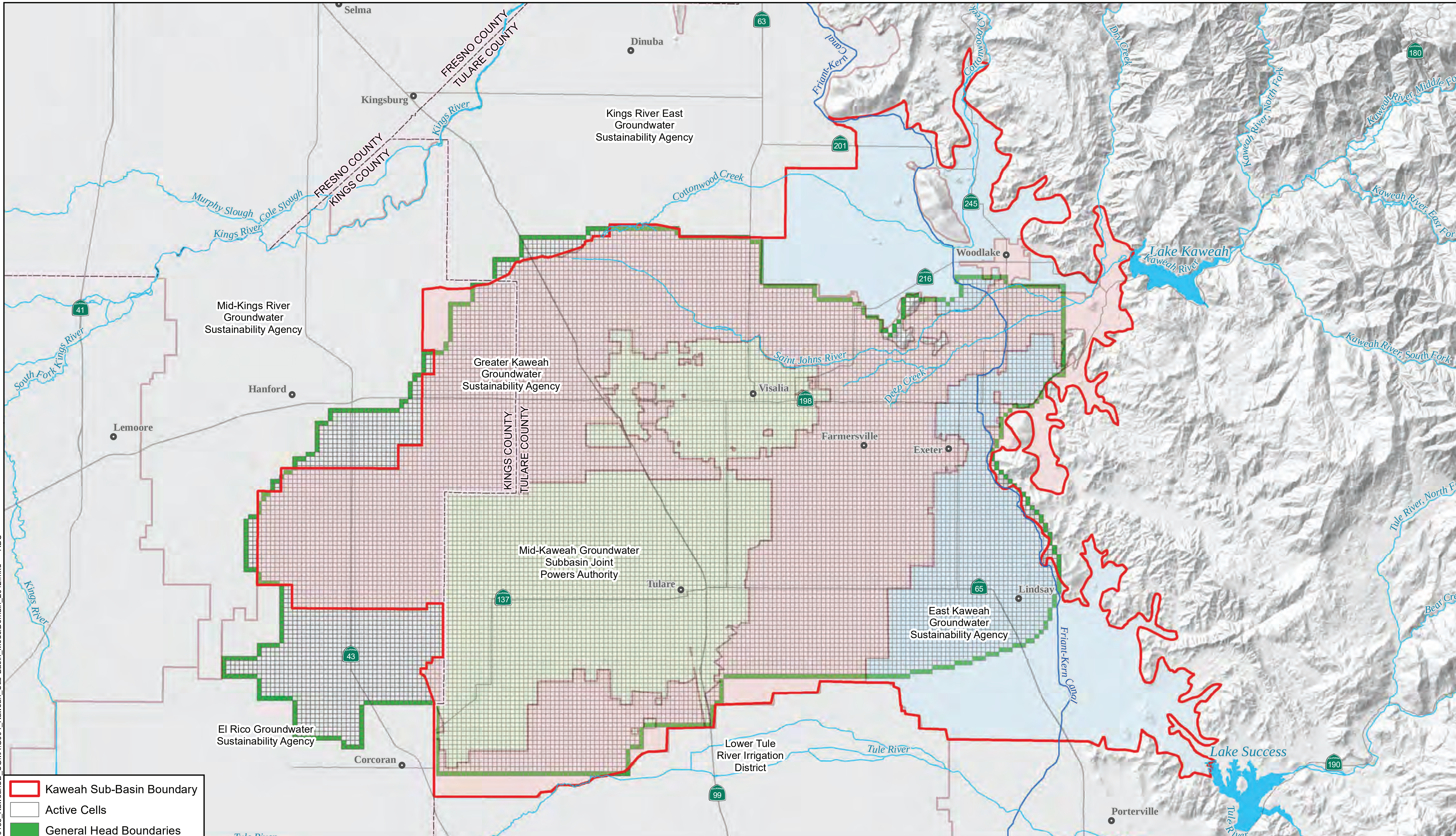
The Modeling Team proposes the following schedule for the major groundwater model update activities. Estimated timeframes for key inter-basin model coordination meetings and updates are also included in the following table to provide a more comprehensive schedule and to facilitate meeting planning. Specific model development and simulation tasks may shift to earlier or later timeframes, but it is the intention of the Modeling Team to comply with the overall schedule and satisfy deadlines for the final deliverable of the calibrated modeling tool and associated predictive scenarios. Should information not be available to the Modeling Team in time to use them in development of the calibrated model simulation or predictive simulations, the data will either not be included, or the schedule may be adjusted to accommodate their inclusion, per guidance from Sub-Basin GSA leadership.

Updates and presentations on the status of the groundwater modeling efforts will occur at regular intervals during Coordinated Sub-Basin and individual GSA meetings, per the scope of work for the groundwater modeling task order.

Table 1: Anticipated Schedule of Groundwater Model Update Activities

Modeling Activity	Estimated Completion Timeframe
Refinement and expansion of model domain and boundary conditions	Early September 2018
Update water budget with Davids Engineering and EKGSA data	Early September 2018
Development of calibration targets	Mid-September 2018
Parameterization of model layers	Mid-September 2018
Refinement of groundwater fluxes	Mid-September 2018
Inter-basin KSHM Approach Meeting (inter-basin)	Mid-September 2018
Adjust boundary conditions, fluxes, and parameters using any new adjacent basin data	Late September 2018
Initiate Formal Calibration Process	Early October 2018
Inter-basin KSHM Update Meeting	Late October 2018
Complete initial calibration process	Early November 2018
Calibration and model refinements and preparation for predictive simulations	Late November 2018
Inter-basin KSHM Calibrated Model and Boundary Flux Meeting	Late November 2018
Develop predictive baseline scenario – Sub-Basin level –	Early December 2018
Develop GSA specific predictive simulations	Mid December 2018
Cumulative Sub-Basin simulations	Early January 2019

LIST OF FIGURES



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Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California

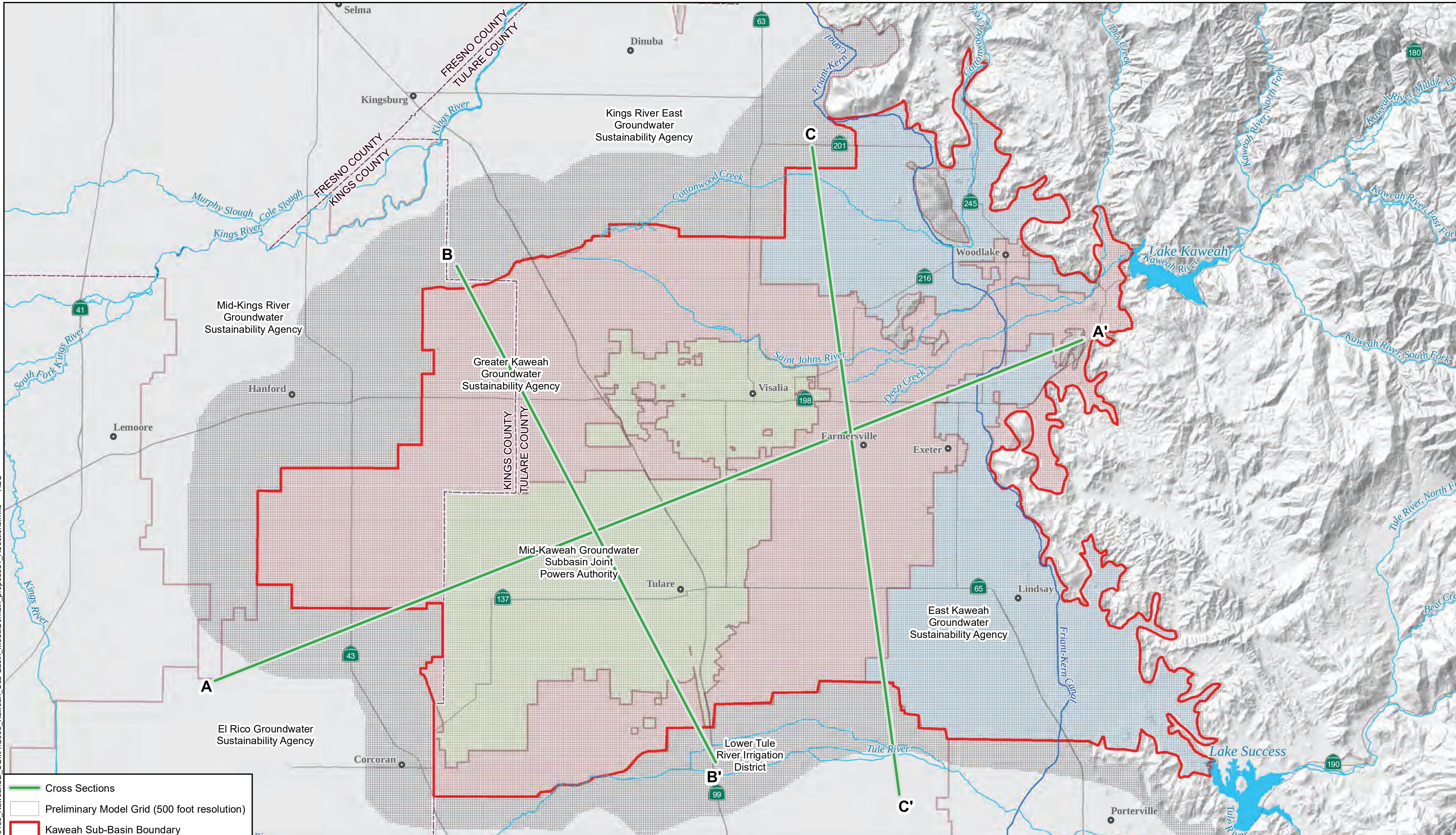
Kaweah Sub-Basin

GSI Water Solutions, Inc.

GEI Consultants

2012 KDWCD EXPANDED MODEL DOMAIN
WITH GENERAL HEAD BOUNDARIES

AUGUST 2018 DRAFT FIGURE 1



Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California

Kaweah Sub-Basin

GEI Consultants

GSI Water Solutions, Inc.

PRELIMINARY KSHM GRID EXTENT AND RESOLUTION INCLUDING BUFFER ZONES AND CROSS SECTION LOCATIONS

AUGUST 2018 | DRAFT | FIGURE 2

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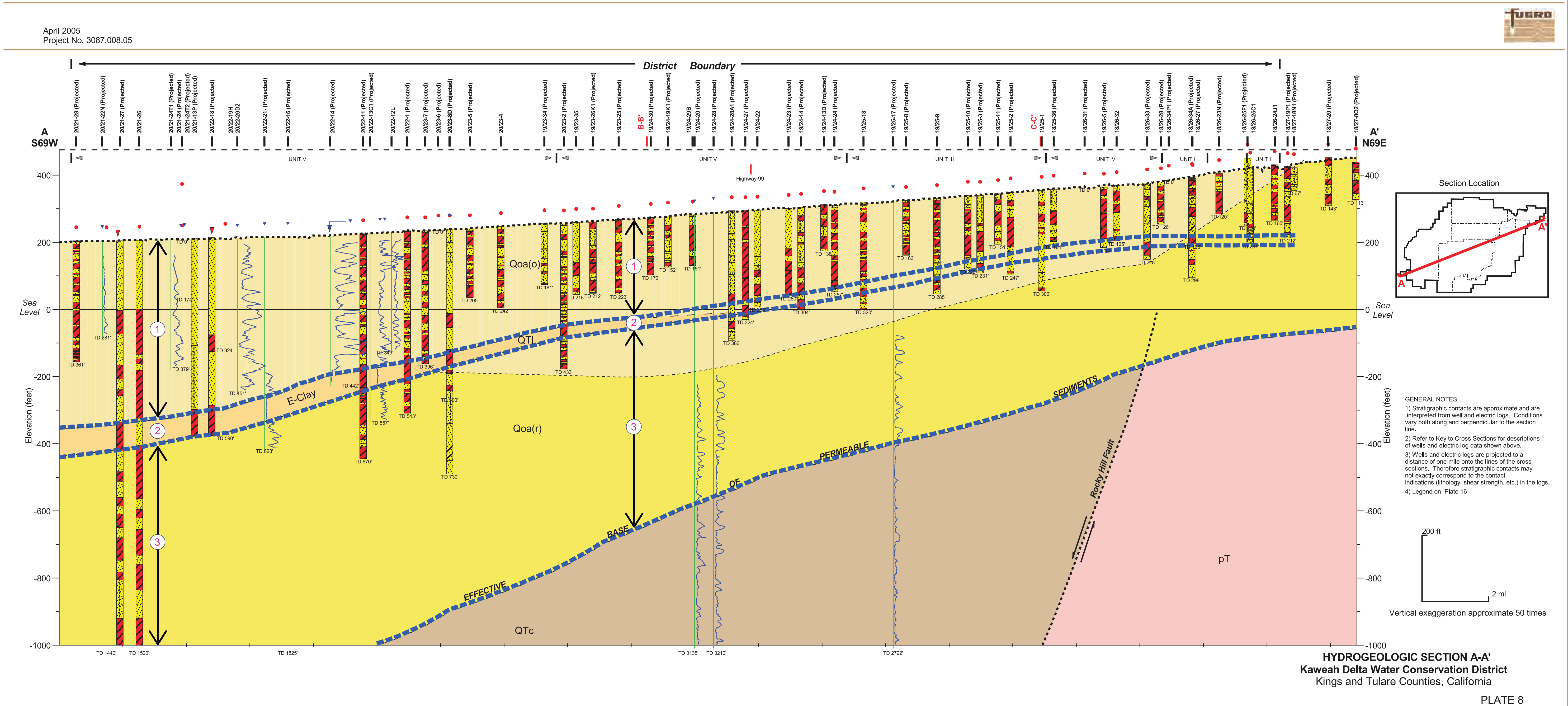


Qoa(o)	Principal Aquifer A (Model Layer 1)
E-Clay/QTl	Principal Aquitard (E/Corcoran Clay) (Model Layer 2)
Qoa(o) / Qoa(r)	Principal Aquifer B (Model Layer 3)
▬ ▬ ▬	Model Layer Boundary

SOURCE: Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District (April 2005) Prepared for: Kaweah Delta Water Conservation District by Fugro West, Inc.

2 1 0 2
Miles

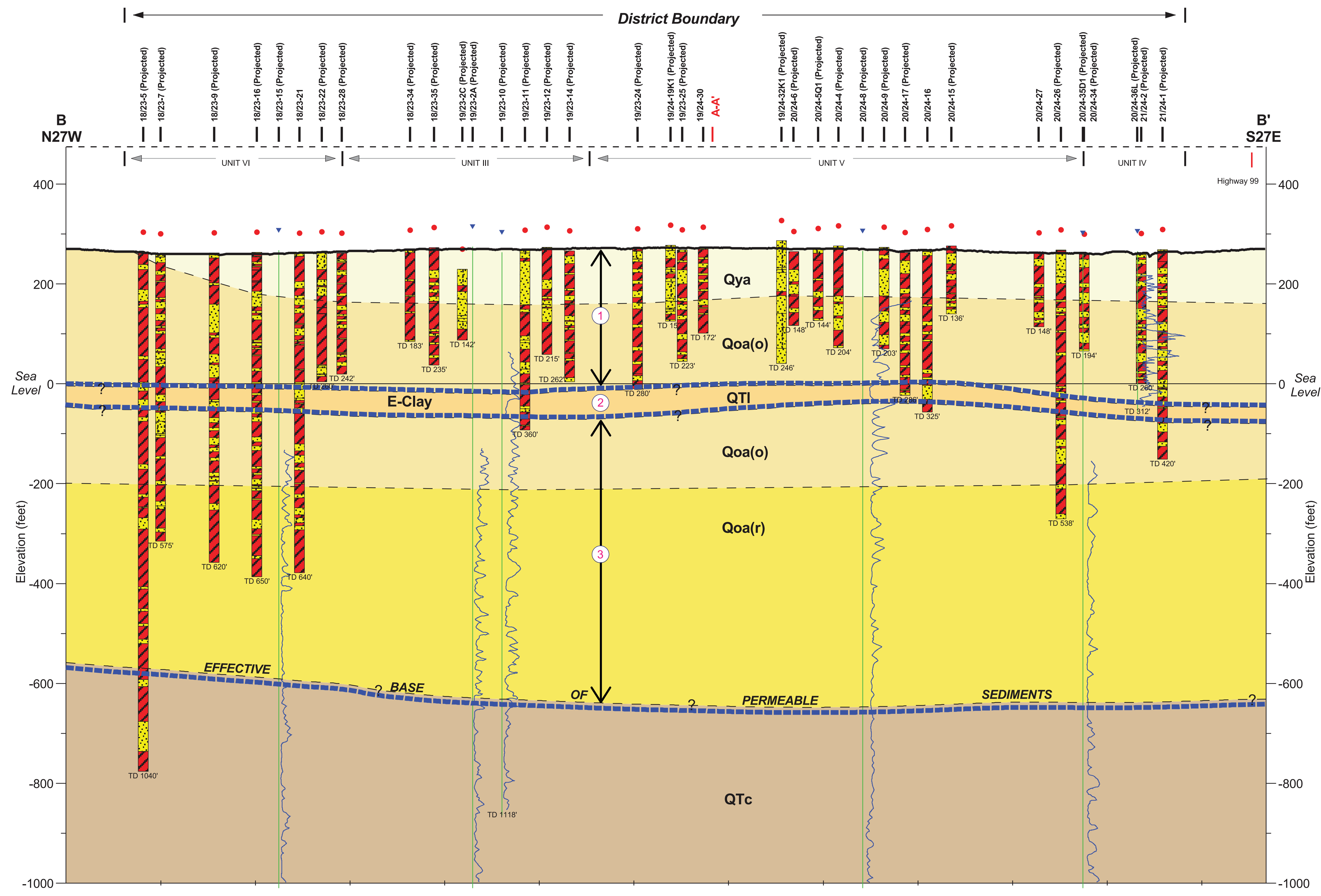
Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California

Kaweah Sub-Basin

Model Layering Scheme along Hydrogeologic Cross Section A-A'

AUGUST 2018 | **DRAFT** | FIGURE 3

April 2005
Project No. 3087.008.05



GENERAL NOTES:

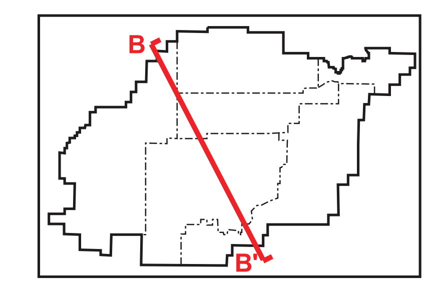
1) Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.

2) Refer to Key to Cross Sections for descriptions of wells and electric log data shown above.

3) Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.

4) Legend on Plate 16

Section Location



Model Layer Boundary

Principal Aquifer A (Model Layer 1)

Principal Aquitard (E/Corcoran Clay) (Model Layer 2)

Principal Aquifer B (Model Layer 3)

200 ft

2 mi

Vertical exaggeration approximate 50 times

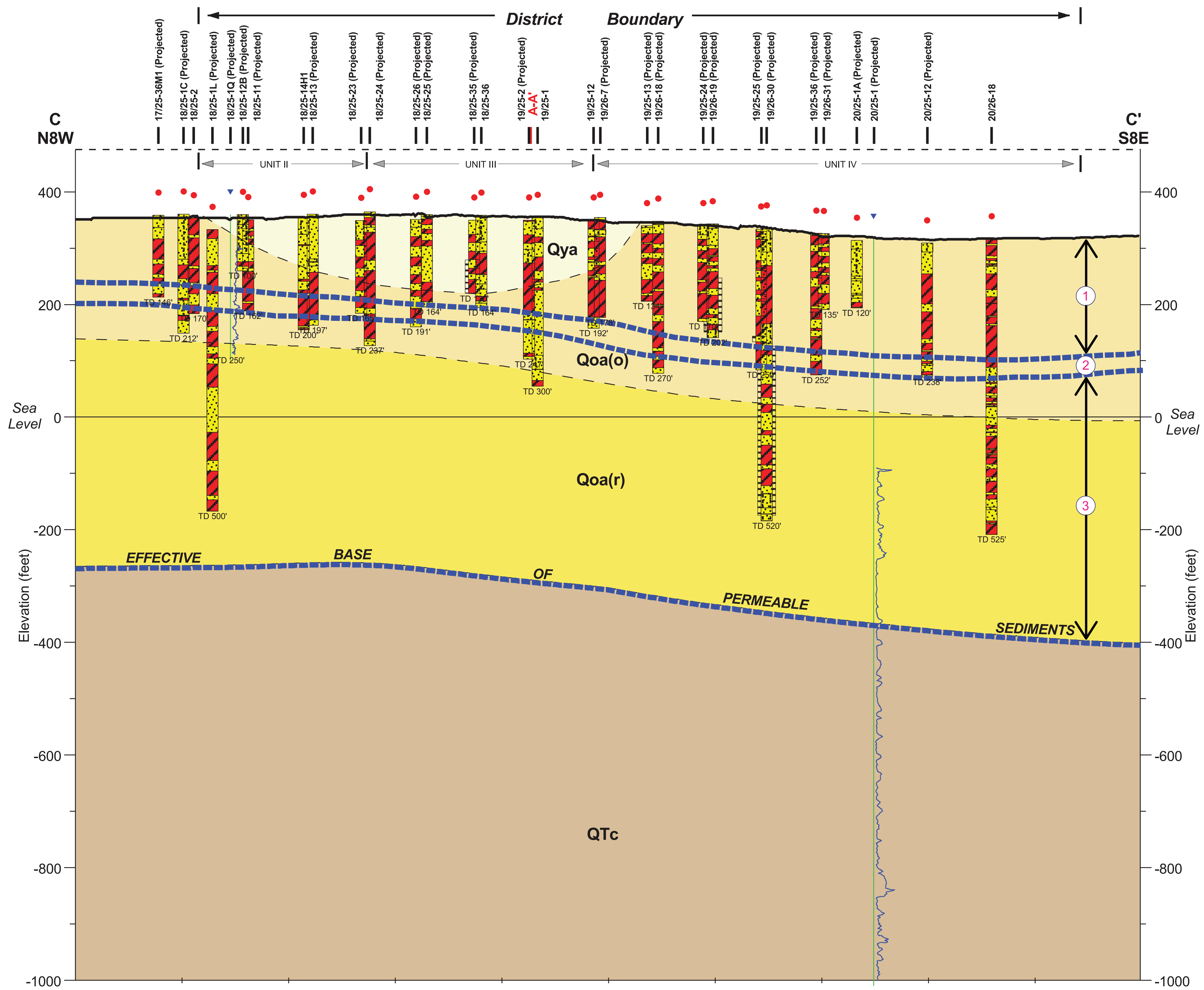
HYDROGEOLOGIC SECTION B-B'
Kaweah Delta Water Conservation District
Kings and Tulare Counties, California

PLATE 9

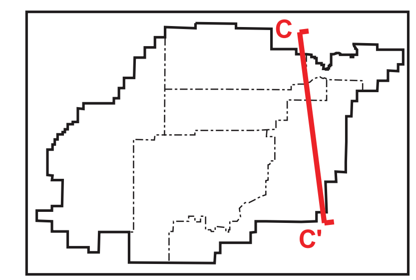
SOURCE: Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District (April 2005) Prepared for: Kaweah Delta Water Conservation District by Fugro West, Inc.

2 1 0 2 Miles	Kaweah Sub-Basin Groundwater Modeling Task 1 Tulare County, California	Model Layering Scheme along Hydrogeologic Cross Section B-B'
	Kaweah Sub-Basin	AUGUST 2018 DRAFT FIGURE 4

April 2005
Project No. 3087.008.05



Section Location



GENERAL NOTES:
1) Stratigraphic contacts are approximate and are interpreted from well and electric logs. Conditions vary both along and perpendicular to the section line.
2) Refer to Key to Cross Sections for descriptions of wells and electric log data shown above.
3) Wells and electric logs are projected to a distance of one mile onto the lines of the cross sections. Therefore stratigraphic contacts may not exactly correspond to the contact indications (lithology, shear strength, etc.) in the logs.
4) Legend on Plate 16

Model Layer Boundary

Qya / Qoa(o) — Principal Aquifer A (Model Layer 1)

Qoa(o) — Principal Aquifer A (Model Layer 2)

Qoa(o) / Qoa(r) — Principal Aquifer B (Model Layer 3)

200 ft
2 mi
Vertical exaggeration approximate 50 times

HYDROGEOLOGIC SECTION C-C'
Kaweah Delta Water Conservation District
Kings and Tulare Counties, California

PLATE 10

SOURCE: Numerical Groundwater Flow Model for the Kaweah Delta Water Conservation District (April 2005) Prepared for: Kaweah Delta Water Conservation District by Fugro West, Inc.

2 1 0 2
Miles

Kaweah Sub-Basin
Groundwater Modeling Task 1
Tulare County, California

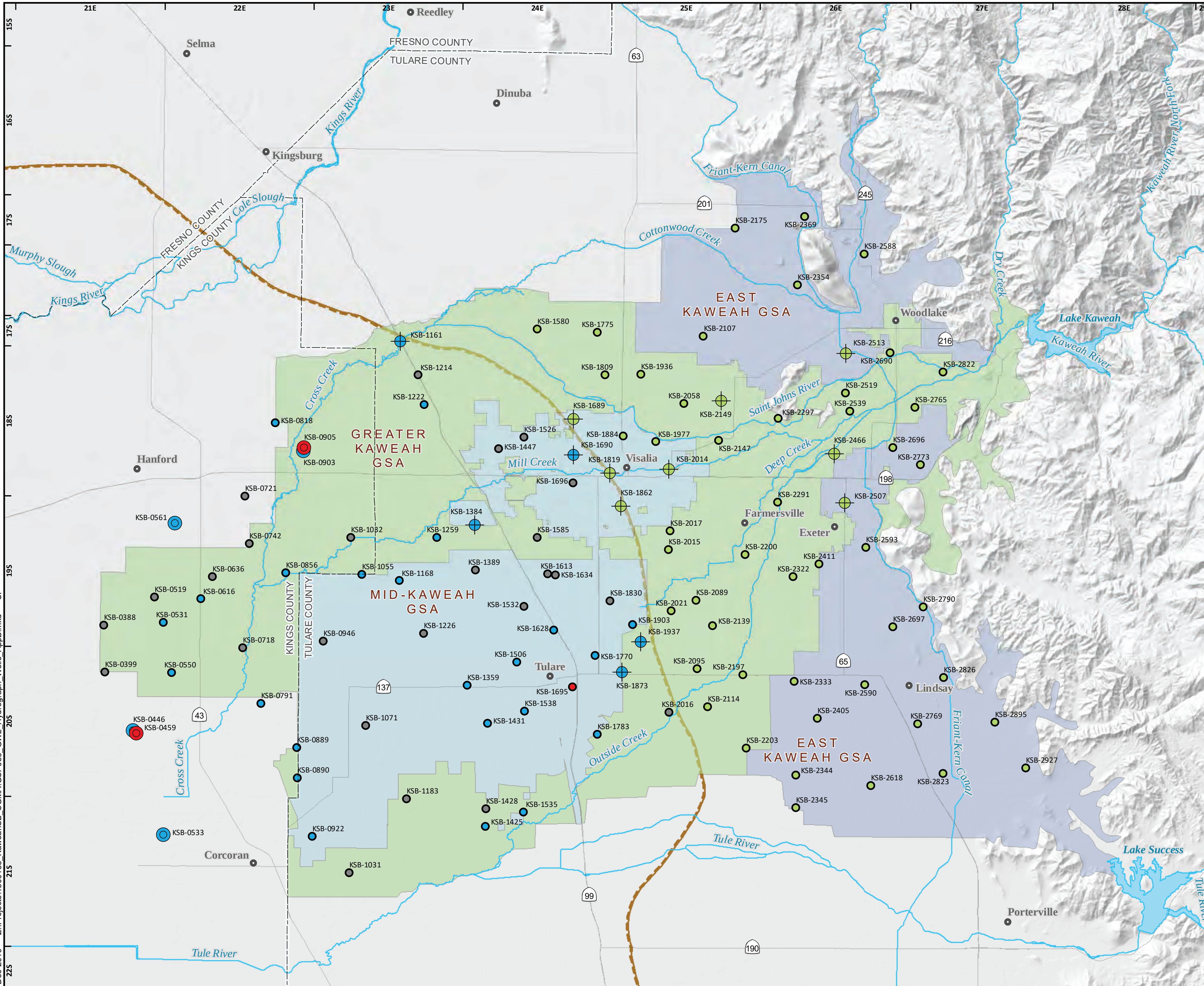
Kaweah Sub-Basin

Model Layering Scheme along Hydrogeologic Cross Section C-C'

AUGUST 2018 DRAFT FIGURE 5

Appendix B

Key Well Information



KEY WELLS WITH HYDROGRAPHS

Well Types

- Lower Aquifer
- Upper Aquifer
- Single Aquifer
- Unknown
- Dedicated Monitoring Well
- Dual Completion Well
- Monitoring Well

Approximate Extent of Corcoran Clay

GSA Boundaries

- East Kaweah GSA
- Greater Kaweah GSA
- Mid-Kaweah GSA

All Other Features

- Highway
- Waterway
- Lake

0 2 4 8
Miles

N

Kaweah Subbasin Managers
Groundwater Sustainability Plan
Tulare County, California

Kaweah Subbasin

GEI Consultants

GSI Water Solutions, Inc.

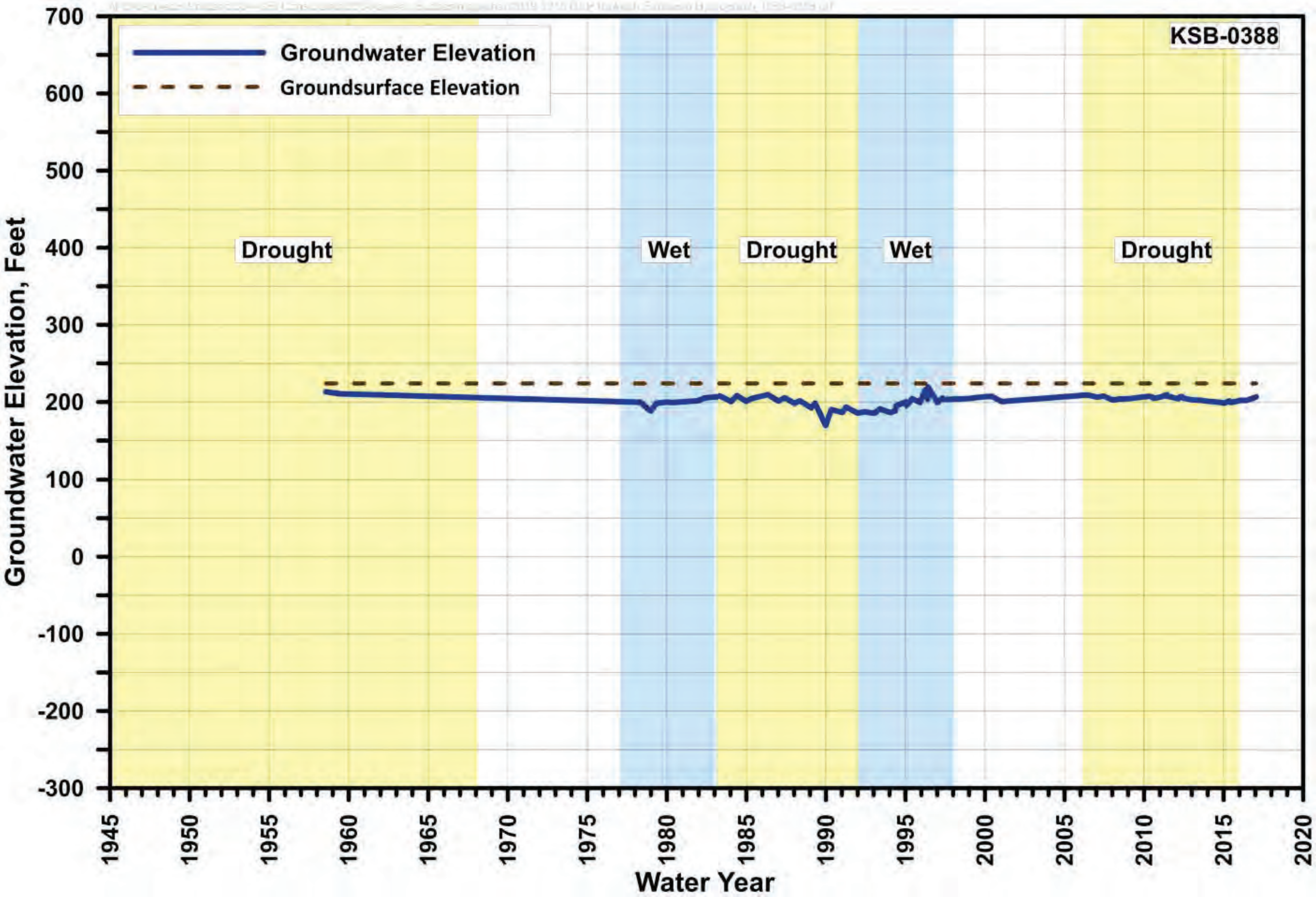
DECEMBER 2018 **DRAFT** FIGURE B-1

Table _ - Kaweah Sub-basin Key Well Information

KSB ID	State Well #	CASGEM SITE_CODE	Common Name Well	Water Level Measurement Organization	Water Supply Service Area	GSA	Count of Water Level Measurements	Earliest Measurement Date on Record	Latest Measurement Date on Record	Known Construction? (Y/N)	Dedicated Monitoring Well (Y/N)	Dual Completion Well (Y/N)	Total Depth (Feet)	Top of Screen (Feet)	Bottom of Screen (Feet)	Within the Corcoran Clay? (Y/N)	Reported Ground Surface Elevation (Feet)	Aquifer Screened	LATITUDE	LONGITUDE
KSB-0388	19S21E35D001M	362383N1196704W001		Department of Water Resources	Lakeside Irrigation W.D.	Greater Kaweah GSA	80	Apr-59	Oct-17	N	N	N				y	227	UNK	36.2383	-119.67
KSB-0399	20S21E11D001M	362106N1196685W001		Bureau of Reclamation			52	Sep-76	Oct-17	N	N	N				y	217	UNK	36.2106	-119.669
KSB-0446	20S21E24F901M			Kaweah Delta Water Conservation District	Melga W.D.		23	Feb-06	Oct-17	Y	Y	Y	186	170	186	y	213	UAS	36.176661	-119.648219
KSB-0459	20S21E24F001M	361753N1196460W001		Kaweah Delta Water Conservation District	Melga W.D.		42	Feb-06	Mar-18	Y	Y	Y	700	650	690	y	213	LAS	36.1753	-119.646
KSB-0519	19S22E30D001M	362547N1196341W001		Kaweah Delta Water Conservation District	Lakeside Irrigation W.D.	Greater Kaweah GSA	119	Feb-63	Oct-17	N	N	N				y	230	UNK	36.2547	-119.634
KSB-0531	19S22E31B002M	362400N1196274W001		Bureau of Reclamation	Lakeside Irrigation W.D.	Greater Kaweah GSA	200	Feb-63	Oct-13	Y	N	N		247	271	y	226	UAS	36.24	-119.627
KSB-0532	21S22E07J001M	361158N1196258W001		Kaweah Delta Water Conservation District	Corcoran I.D.		40	Feb-07	Oct-17	Y	Y	Y	775	735	775	y	204	LAS	36.1158	-119.626
KSB-0533	21S22E07J901M			Kaweah Delta Water Conservation District	Corcoran I.D.		20	Oct-07	Oct-17	Y	Y	Y	314	274	314	y	204	UAS	36.115798	-119.625828
KSB-0550	20S22E07A003M	362106N1196216W001		Kings River Conservation District	Lakeside Irrigation W.D.	Greater Kaweah GSA	120	Feb-63	Mar-18	Y	N	N	421	181	421	y	220	UAS	36.2106	-119.622
KSB-0560	19S22E08D002M	362981N1196189W001		Kaweah Delta Water Conservation District	Lakeside Irrigation W.D.		40	Feb-07	Mar-18	Y	Y	Y	700	625	665	y	243	LAS	36.2981	-119.619
KSB-0561	19S22E08D902M			Kaweah Delta Water Conservation District	Lakeside Irrigation W.D.		21	Oct-07	Oct-17	Y	Y	Y	355	315	355	y	244	UAS	36.298133	-119.618932
KSB-0616	19S22E28D001M	362539N1196004W001		Bureau of Reclamation	Lakeside Irrigation W.D.	Greater Kaweah GSA	198	Feb-63	Mar-18	Y	N	N	362	190	360	y	232	UAS	36.2539	-119.6
KSB-0636	19S22E21C001M	362669N1195924W001		Kings County Water District	Lakeside Irrigation W.D.	Greater Kaweah GSA	117	Feb-63	Oct-17	N	N	N				y	237	UNK	36.2669	-119.592
KSB-0718	20S22E03B001M	362256N1195702W001		Department of Water Resources	Lakeside Irrigation W.D.	Greater Kaweah GSA	104	Feb-66	Oct-17	N	N	N				y	232	UNK	36.2256	-119.57
KSB-0721	18S22E34R001M	363142N1195685W001		Bureau of Reclamation	Lakeside Irrigation W.D.		81	Jan-72	Mar-18	N	N	N				y	245	UNK	36.3142	-119.569
KSB-0742	19S22E10R002M	362864N1195654W002		Bureau of Reclamation	Lakeside Irrigation W.D.		85	Oct-61	Oct-17	N	N	N				y	244	UNK	36.2864	-119.565
KSB-0791	20S22E14C001M	361928N1195563W001		Kaweah Delta Water Conservation District	Corcoran I.D.		23	Oct-88	Oct-13	Y	N	N		323	1600	y	225	UAS	36.1928	-119.556
KSB-0818	18S22E24D001M	363572N1195468W001		Department of Water Resources	Kings County W.D.		138	Oct-49	Oct-17	Y	N	N		240	340	y	258	UAS	36.3572	-119.547
KSB-0856	19S22E24B001M	362694N1195393W001		Kaweah Delta Water Conservation District	Kings County W.D.	Greater Kaweah GSA	77	Sep-69	Mar-18	N	N	N	160			y	244	UAS	36.2694	-119.539
KSB-0889	20S22E24R001M	361672N1195299W001		Bureau of Reclamation	Corcoran I.D.	Greater Kaweah GSA	37	Sep-87	Mar-18	Y	N	N	332	196	204	y	227	UAS	36.1672	-119.53
KSB-0890	20S22E36A001M	361497N1195296W001		Bureau of Reclamation	Unincorporated	Greater Kaweah GSA	143	Oct-75	Oct-17	Y	N	N	210	155	206	y	222	UAS	36.1497	-119.53
KSB-0903	18S23E30D901M			Kaweah Delta Water Conservation District	Kings County W.D.	Greater Kaweah GSA	22	Feb-06	Oct-17	Y	Y	Y	154	114	154	y	255	UAS	36.340824	-119.526639
KSB-0905	18S23E30D001M	363426N1195264W001		Kaweah Delta Water Conservation District	Kings County W.D.	Greater Kaweah GSA	39	Feb-06	Mar-18	Y	Y	Y	440	400	440	y	255	LAS	36.3426	-119.526
KSB-0922	21S23E07J001M	361156N1195191W001		Bureau of Reclamation	Tulare I.D.	Mid-Kaweah GSA	171	Aug-58	Oct-17	Y	N	N	428	322	420	y	221	UAS	36.1156	-119.519
KSB-0946	19S23E31R001M	362297N1195121W001		Department of Water Resources	Tulare I.D.	Mid-Kaweah GSA	148	Oct-45	Mar-17	N	N	N				y	245	UNK	36.2297	-119.512
KSB-1031	21S23E21C003M	360942N1194921W001		Department of Water Resources	Unincorporated	Greater Kaweah GSA	82	Feb-63	Oct-17	N	N	N				y	219	UNK	36.0942	-119.492
KSB-1032	19S23E08J001M	362903N1194927W001		Department of Water Resources	Kings County W.D.	Greater Kaweah GSA	146	Oct-49	Mar-17	N	N	N				y	256	UNK	36.2903	-119.493
KSB-1055	19S23E21C001M	362686N1194846W001		Kaweah Delta Water Conservation District	Tulare I.D.	Mid-Kaweah GSA	83	Feb-64	Oct-13	Y	N	N		168	195	y	255	UAS	36.2686	-119.485
KSB-1071	20S23E21B001M	361803N1194813W001		Department of Water Resources	Tulare I.D.	Mid-Kaweah GSA	100	Oct-60	Oct-17	N	N	N				y	241	UNK	36.1803	-119.481
KSB-1161	17S23E34J001M	364049N1194573W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	38	Apr-07	Mar-18	Y	Y	N	126	96	126	y	275	UAS	36.4049	-119.457
KSB-1168	19S23E22H001M	362653N1194571W001		Bureau of Reclamation	Tulare I.D.	Mid-Kaweah GSA	129	Oct-52	Mar-16	Y	N	N	331	178	190	y	265	UAS	36.2653	-119.457
KSB-1183	21S23E02A001M	361378N1194513W001		Kaweah Delta Water Conservation District	Elk Bayou D.C.	Greater Kaweah GSA	100	Sep-63	Oct-17	N	N	N				y	238	UNK	36.1378	-119.451
KSB-1214	18S23E02Q001M	363856N1194443W001		Kings County Water District	Unincorporated	Greater Kaweah GSA	144	Feb-52	Mar-18	N	N	N				y	278	UNK	36.3856	-119.444
KSB-1222	18S23E14A001M	363683N1194399W001		Bureau of Reclamation	Goshen D.C.	Greater Kaweah GSA	160	Oct-69	Oct-14	Y	N	N		115	330	y	280	UAS	36.3683	-119.44
KSB-1226	19S23E35H001M	362344N1194396W001		Tulare Irrigation District	Tulare I.D.	Mid-Kaweah GSA	142	Oct-53	Jan-18	N	N	N				y	264	UNK	36.2344	-119.44
KSB-1259	19S23E12L001M	362906N1194304W001		Department of Water Resources	Persian D.C.	Greater Kaweah GSA	144	Sep-69	Oct-13	Y	N	N		192	600	y	275	UAS	36.2906	-119.43
KSB-1359	20S24E07G001M	362042N1194082W001		Tulare Irrigation District	Tulare I.D.	Mid-Kaweah GSA	75	Feb-55	Mar-15	Y	N	N	456	216	456	y	264	UAS	36.2042	-119.408
KSB-1384	19S24E08D002M	362979N1194028W001		Kaweah Delta Water Conservation District	Persian D.C.	Greater Kaweah GSA	29	Apr-07	Mar-18	Y	Y	N	121	91	121	y	287	UAS	36.2979	-119.403
KSB-1389	19S24E17N001M			Tulare Irrigation District	Tulare I.D.	Mid-Kaweah GSA	115	Feb-54	Oct-14	N	N	N				y	287	UNK	36.27166667	-119.4016667
KSB-1425	21S24E08A001M	361219N1193946W001		Kaweah Delta Water Conservation District	Elk Bayou D.C.	Greater Kaweah GSA	109	Oct-51	Mar-18	Y	N	N	520	144	356	y	247	UAS	36.1219	-119.395
KSB-1428	21S24E05H002M	361319N1193938W001		Kaweah Delta Water Conservation District	Elk Bayou D.C.	Greater Kaweah GSA	108	Jan-70	Mar-18	N	N	N				y	250	UNK	36.1319	-119.394
KSB-1431	20S24E17P001M	361819N1193935W001		Department of Water Resources	Tulare I.D.	Mid-Kaweah GSA	128	Feb-56	Oct-17	Y	N	N	229	170	210	y	257	UAS	36.1819	-119.394
KSB-1447			075-01		Unincorporated	Mid-Kaweah GSA	120	Sep-93	Dec-10	N	N	N				y		UNK	36.34244882	-119.3853457
KSB-1506	20S24E04K01M		Well 26		Unincorporated	Mid-Kaweah GSA	114	Mar-92	Feb-18	Y	N	N	720	300	720	y	280	UAS	36.21798677	-119.371617
KSB-1526	18S24E22E001M			Kaweah Delta Water Conservation District	St. Johns W.D.	Mid-Kaweah GSA	9	Mar-12	Oct-17	N	N	N				y	307	UNK	36.34930676	-119.3671998
KSB-1532	19S24E28H001M	362503N1193677W001		Department of Water Resources	Tulare I.D.	Mid-Kaweah GSA	127	Oct-54	Oct-17	N	N	N				y	292	UNK	36.2503	-119.368
KSB-1535	21S24E03L001M	361303N1193665W001		Bureau of Reclamation	Elk Bayou D.C.	Greater Kaweah GSA	126	Feb-53	Oct-17	Y	N	N	325	200	317	y	257	UAS	36.1303	-119.367
KSB-1538	20S24E16H001M	361892N1193667W001		Department of Water Resources	Tulare I.D.	Mid-Kaweah GSA	182	Oct-53	Jan-18	Y	N	N		157	357	y	265	UAS	36.1892	-119.367
KSB-1580	17S24E34B001M	364125N1193588W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	208	Sep-30	Mar-14	N	N	N				n	298	SAS	36.4125	-119.359
KSB-1585	19S24E10G001M	362911N1193579W001		Department of Water Resources	Tulare Irrigation Company	Greater Kaweah GSA	115	Oct-56	Oct-17	N	N	N				y	304	UNK	36.2911	-119.358
KSB-1613	19S24E15R001M			Kaweah Delta Water Conservation District	Tulare I.D.	Mid-Kaweah GSA	7	Mar-14	Mar-17	N	N	N				y	306	UNK	36.26949556	-119.3497664
KSB-1628	19S24E35E01M		Well 27		Tulare I.D.	Mid-Kaweah GSA	104	Jul-93	Feb-18	Y	N	N	720	320	720	y	293	UAS	36.23653948	-119.345132
KSB-1634	19S24E23D001M	362689N1193445W001		Department of Water Resources	Tulare I.D.	Mid-Kaweah GSA	139	Oct-36	Jan-18	N	N	N				y	307	UNK	36.2689	-119.345
KSB-1689	18S24E13N001M	363601N1193320W001		Kaweah Delta Water Conservation District	Modoc D.C.	Mid-Kaweah GSA	34	May-08	Mar-18	Y	Y	N	110	70	110	n	321	SAS	36.3601	-119.332
KSB-1690	18S24E25D001M	363391N1193316W001		Kaweah Delta Water Conservation District	Modoc D.C.	Mid-Kaweah GSA	32	May-08	Mar-18	Y	Y	N	123	83	123	y	317	UAS	36.3391	-119.332
KSB-1695	20S24E11J02M		Well 11		Unincorporated	Mid-Kaweah GSA	121	Mar-92	Feb-18	Y	N	N	774	348	756	y	288	LAS	36.20362572	-119.3315452
KSB-1696			025-01		Unincorporated	Mid-Kaweah GSA	393	Jan-71	Apr-18	N	N	N				y		UNK	36.32262819	-119.3314731
KSB-1770	20S24E01H02M		Well 15		Unincorporated	Mid-Kaweah GSA	115	Mar-92	Feb-18	Y	N	N	715	300	700	y	112	UAS	36.22191281	-119.3154621
KSB-1775	17S24E36H003M	364106N1193145W001		Kaweah Delta Water Conservation District	Uphill D.C.	Greater Kaweah GSA	128	Oct-61	Oct-17	N	N	N				n	314	SAS	36.4106	-119.315
KSB-1783	20S24E24H001M	361756N1193140W001		Bureau of Reclamation	Farmers D.C.	Greater Kaweah GSA	160	Feb-69	Oct-16	Y	N	N	355	178	182	y	281	UAS	36.1756	-119.314
KSB-1809	18S25E06P001M			Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	4	Mar-16	Oct-17	N	N	N				n	323	SAS	36.386016	-119.308785
KSB-1819	18S25E30Q001M	363286N1193054W001		Kaweah Delta Water Conservation District	Unincorporated	Mid-Kaweah GSA	23	May-08	Mar-17	Y	Y	N	123	83	123	n	326	SAS	36.3286	-119.305
KSB-1830	19S25E30C001M	362539N1193051W001		Department of Water Resources	Tulare I.D.	Mid-Kaweah GSA	167	Oct-54	Oct-17	N	N	N				y	313	UNK	36.2539	-119.305
KSB-1862	19S25E06A001M	363094N1192974W001		Kaweah Delta Water Conservation District	Evans D.C.	Mid-Kaweah GSA	21	May-08	Mar-14	Y	Y	N	124	84	124	n	327	SAS	36.3094	-119.297
KSB-1873	20S25E06R002M	362122N1192962W001		Kaweah Delta Water Conservation District	Farmers D.C.	Greater Kaweah GSA	18	Apr-07	Oct-13	Y	Y	N	125	95	125	y	299	UAS	36.2122	-119.296
KSB-1884			036-01		Unincorporated	Mid-Kaweah GSA	368	Jul-71	Apr-18	N	N	N				n		SAS	36.35027811	-119.2954358
KSB-1903	19S24E36C002M		Well 36		Farmers D.C.	Mid-Kaweah GSA	27	Oct-04	Feb-18	Y	N	N	620	320	620	y	302	UAS	36.24008	-119.2882

Table _ - Kaweah Sub-basin Key Well Information

KSB ID	State Well #	CASGEM SITE_CODE	Common Name Well	Water Level Measurement Organization	Water Supply Service Area	GSA	Count of Water Level Measurements	Earliest Measurement Date on Record	Latest Measurement Date on Record	Known Construction? (Y/N)	Dedicated Monitoring Well (Y/N)	Dual Completion Well (Y/N)	Total Depth (Feet)	Top of Screen (Feet)	Bottom of Screen (Feet)	Within the Corcoran Clay? (Y/N)	Reported Ground Surface Elevation (Feet)	Aquifer Screened	LATITUDE	LONGITUDE
KSB-1936	18S25E05Q001M	363864N1192834W001		Kaweah Delta Water Conservation District	Mathews D.C.	Greater Kaweah GSA	140	Feb-64	Mar-18	N	N	N	278			n	333	SAS	36.3864	-119.283
KSB-1937	19S25E32J001M	362301N1192828W001		Kaweah Delta Water Conservation District	Farmers D.C.	Greater Kaweah GSA	20	Apr-07	Oct-13	Y	Y	N	115	85	115	y	312	UAS	36.2301	-119.283
KSB-1977			053-01		Unincorporated	Mid-Kaweah GSA	276	Mar-80	Apr-18	N	N	N				n		SAS	36.34705864	-119.2719874
KSB-2014	18S25E28R001M	363309N1192627W001		Kaweah Delta Water Conservation District	Unincorporated	Mid-Kaweah GSA	21	Oct-11	Oct-17	Y	Y	N	100	60	100	n	342	SAS	36.3309	-119.263
KSB-2015	19S25E16A002M	362839N1192634W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	140	Oct-50	Mar-18	N	N	N				n	335	SAS	36.2839	-119.263
KSB-2016	20S25E16J002M	361889N1192620W001		Kaweah Delta Water Conservation District	Farmers D.C.	Greater Kaweah GSA	138	Feb-67	Oct-17	N	N	N				y	299	UNK	36.1889	-119.262
KSB-2017	19S25E09H001M	362947N1192617W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	133	Oct-61	Oct-17	N	N	N				n	338	SAS	36.2947	-119.262
KSB-2021	19S25E28H001M	362481N1192609W001		Kaweah Delta Water Conservation District	Farmers D.C.	Greater Kaweah GSA	135	Feb-68	Oct-17	N	N	N				n	322	SAS	36.2481	-119.261
KSB-2058	18S25E15C001M	363692N1192520W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	175	Oct-41	Oct-17	N	N	N	90			n	348	SAS	36.3692	-119.252
KSB-2089	19S25E27A001M	362544N1192431W001		Kaweah Delta Water Conservation District	Farmers D.C.	Greater Kaweah GSA	137	Feb-68	Oct-17	N	N	N				n	332	SAS	36.2544	-119.243
KSB-2095	20S25E03R001M			Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	97	Feb-63	Oct-17	N	N	N				n	308	SAS	36.214539	-119.24285
KSB-2107	17S25E35E001M	364086N1192381W001		Ivanhoe Irrigation District	Ivanhoe I.D.	East Kaweah GSA	169	Mar-53	Mar-14	N	N	N				n	354	SAS	36.4086	-119.238
KSB-2114	20S25E14F004M	361922N1192337W003		Kaweah Delta Water Conservation District	Consolidated Peoples D.C.	Greater Kaweah GSA	118	Feb-68	Oct-17	N	N	N				n	306	SAS	36.1922	-119.234
KSB-2139	19S25E35B002M	362394N1192309W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	133	Sep-63	Oct-16	N	N	N				n	327	SAS	36.2394	-119.231
KSB-2147	18S25E23J001M	363478N1192267W001		Kaweah Delta Water Conservation District	Fleming D.C.	Greater Kaweah GSA	136	Sep-63	Mar-15	N	N	N				n	360	SAS	36.3478	-119.227
KSB-2149	18S25E12N001M	363711N1192250W001		Kaweah Delta Water Conservation District	Wutchumna W.C.	Greater Kaweah GSA	21	Apr-07	Mar-13	Y	Y	N	82	52	82	n	397	SAS	36.3711	-119.225
KSB-2175	17S25E01P001M	364718N1192151W001		Bureau of Reclamation	Unincorporated	East Kaweah GSA	355	Dec-31	Oct-10	N	N	N				n	356	SAS	36.4718	-119.215
KSB-2197	20S25E12A001M	362108N1192092W001		Kaweah Delta Water Conservation District	Consolidated Peoples D.C.	Greater Kaweah GSA	130	Feb-66	Oct-16	N	N	N				n	316	SAS	36.2108	-119.209
KSB-2200	19S25E13A002M	362811N1192076W001		Kaweah Delta Water Conservation District	Consolidated Peoples D.C.	Greater Kaweah GSA	156	Oct-61	Mar-18	N	N	N				n	350	SAS	36.2811	-119.208
KSB-2203	20S25E24R001M	361681N1192067W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	151	Oct-45	Oct-17	N	N	N	170			n	315	SAS	36.1681	-119.207
KSB-2291	19S26E05C001M	363117N1191842W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	143	Sep-63	Oct-17	N	N	N				n	367	SAS	36.3117	-119.184
KSB-2297	18S26E17L001M	363606N1191837W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	166	Oct-50	Mar-18	N	N	N				n	385	SAS	36.3606	-119.184
KSB-2322	19S26E20A001M	362683N1191728W001		Bureau of Reclamation	Unincorporated	Greater Kaweah GSA	195	Nov-48	Oct-17	N	N	N				n	353	SAS	36.2683	-119.173
KSB-2333	20S26E08H001M	362069N1191723W001		Lindmore Irrigation District	Lindmore ID	East Kaweah GSA	102	Feb-54	Mar-16	N	N	N				n	329	SAS	36.2069	-119.172
KSB-2344	20S26E32A001M	361522N1191706W001		Bureau of Reclamation	Lindmore ID	East Kaweah GSA	270	Oct-45	Mar-16	N	N	N	340			n	335	SAS	36.1522	-119.171
KSB-2345	21S26E04F001M	361333N1191703W001		Bureau of Reclamation	Lower Tule ID	East Kaweah GSA	132	Oct-61	Mar-16	N	N	N				n	343	SAS	36.1333	-119.17
KSB-2354	17S26E21E001M	364388N1191703W001		Bureau of Reclamation	Ivanhoe I.D.	East Kaweah GSA	179	Jan-61	Mar-14	N	N	N				n	397	SAS	36.4388	-119.17
KSB-2369	17S26E04F002M	364788N1191653W001		Stone Corral Irrigation District	Stone Corral I.D.	East Kaweah GSA	98	Feb-62	Mar-16	N	N	N				n	406	SAS	36.4788	-119.165
KSB-2405	20S26E16R001M	361853N1191551W001		Bureau of Reclamation	Lindmore ID	East Kaweah GSA	182	Sep-61	Mar-16	Y	N	N	492	210	485	n	338	SAS	36.1853	-119.155
KSB-2411	19S26E16J002M	362756N1191545W001		Bureau of Reclamation	Unincorporated	East Kaweah GSA	186	Oct-61	Mar-18	N	N	N	131			n	366	SAS	36.2756	-119.154
KSB-2466	18S26E27B001M	363403N1191434W001		Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	30	Apr-07	Mar-18	Y	Y	N	29	9	29	n	394	SAS	36.3403	-119.143
KSB-2507	19S26E03A001M	363115N1191358W001		Kaweah Delta Water Conservation District	Exeter I.D.	East Kaweah GSA	28	Apr-07	Mar-18	Y	Y	N	90	60	90	n	402	SAS	36.3115	-119.136
KSB-2513	18S26E02D002M	363990N1191352W001		Kaweah Delta Water Conservation District	Ivanhoe I.D.	East Kaweah GSA	38	Apr-07	Oct-17	Y	Y	N	69	39	69	n	422	SAS	36.399	-119.135
KSB-2519	18S26E10J001M	363755N1191353W001		Department of Water Resources	Unincorporated	Greater Kaweah GSA	233	Oct-51	Mar-13	Y	N	N	140	57	87	n	408	SAS	36.3755	-119.135
KSB-2539	18S26E14E001M	363649N1191318W001		Kaweah Delta Water Conservation District	Lindsay-Strathmore I.D.	Greater Kaweah GSA	9	Mar-16	Mar-18	N	N	N				n	404	SAS	36.3649	-119.132
KSB-2588	17S26E14B001M	364568N1191217W001		Bureau of Reclamation	Unincorporated	East Kaweah GSA	115	Nov-48	Mar-07	N	N	N				n	489	SAS	36.4568	-119.122
KSB-2590	20S26E11H001M	362053N1191217W001		Kaweah Delta Water Conservation District	Lindmore ID	East Kaweah GSA	99	Feb-54	Mar-13	N	N	N				n	359	SAS	36.2053	-119.122
KSB-2593	19S26E11R001M	362853N1191209W001		Exeter Irrigation District	Exeter I.D.	East Kaweah GSA	107	Oct-50	Mar-16	N	N	N				n	394	SAS	36.2853	-119.121
KSB-2618	20S26E35H001M	361461N1191165W001		Lindmore Irrigation District	Lindmore ID	East Kaweah GSA	148	Feb-54	Mar-16	N	N	N				n	364	SAS	36.1461	-119.117
KSB-2690	17S26E36R001M	363993N1191028W001		Kaweah Delta Water Conservation District	Sweeney Ditch Area	Greater Kaweah GSA	121	Feb-68	Mar-18	N	N	N				n	427	SAS	36.3993	-119.103
KSB-2696	18S26E24J003M	363438N1191012W001		Bureau of Reclamation	Exeter I.D.	East Kaweah GSA	141	Oct-61	Mar-18	N	N	N				n	432	SAS	36.3438	-119.101
KSB-2697	19S26E25R001M	362389N1191009W001		Bureau of Reclamation	Lewis Creek WD	East Kaweah GSA	178	Jan-70	Mar-16	Y	N	N	290	96	226	n	358	SAS	36.2389	-119.101
KSB-2765	18S27E18A001M			Kaweah Delta Water Conservation District	Unincorporated	Greater Kaweah GSA	4	Mar-16	Oct-17	N	N	N				n	429	SAS	36.367412	-119.084864
KSB-2769	20S27E18R001M	361822N1190831W001		Lindmore Irrigation District	Lindmore ID	East Kaweah GSA	113	Nov-52	Mar-16	N	N	N				n	412	SAS	36.1822	-119.083
KSB-2773	18S27E30H001M	363338N1190817W001		Exeter Irrigation District	Exeter I.D.	East Kaweah GSA	82	Feb-62	Mar-16	N	N	N	213			n	456	SAS	36.3338	-119.082
KSB-2790	19S27E29D001M	362506N1190795W001		Lindsay-Strathmore Irrigation District	Lindsay-Strathmore ID	East Kaweah GSA	99	Oct-49	Mar-16	N	N	N	200			n	388	SAS	36.2506	-119.08
KSB-2822	18S27E05J001M	363880N1190651W001		Bureau of Reclamation	Unincorporated	Greater Kaweah GSA	237	Oct-61	Mar-18	Y	N	N	98	24	79	n	447	SAS	36.388	-119.065
KSB-2823	20S27E29R001M	361533N1190645W001		Lindmore Irrigation District	Lindmore ID	East Kaweah GSA	125	Oct-61	Oct-11	N	N	N				n	403	SAS	36.1533	-119.065
KSB-2826	20S27E08A001M	362094N1190645W001		Lindsay-Strathmore Irrigation District	Lindsay-Strathmore ID	East Kaweah GSA	130	Oct-36	Mar-16	N	N	N				n	403	SAS	36.2094	-119.065
KSB-2895	20S27E15R001M	361833N1190278W001		Lindsay-Strathmore Irrigation District	Lindsay-Strathmore ID	East Kaweah GSA	108	Feb-52	Mar-16	N	N	N	200			n	468	SAS	36.1833	-119.028
KSB-2927	20S27E25N001M	361564N1190048W001		Lindsay-Strathmore Irrigation District	Lindsay-Strathmore ID	East Kaweah GSA	139	Feb-52	Mar-16	N	N	N				n	478	SAS	36.1564	-119.005


KSB-0388
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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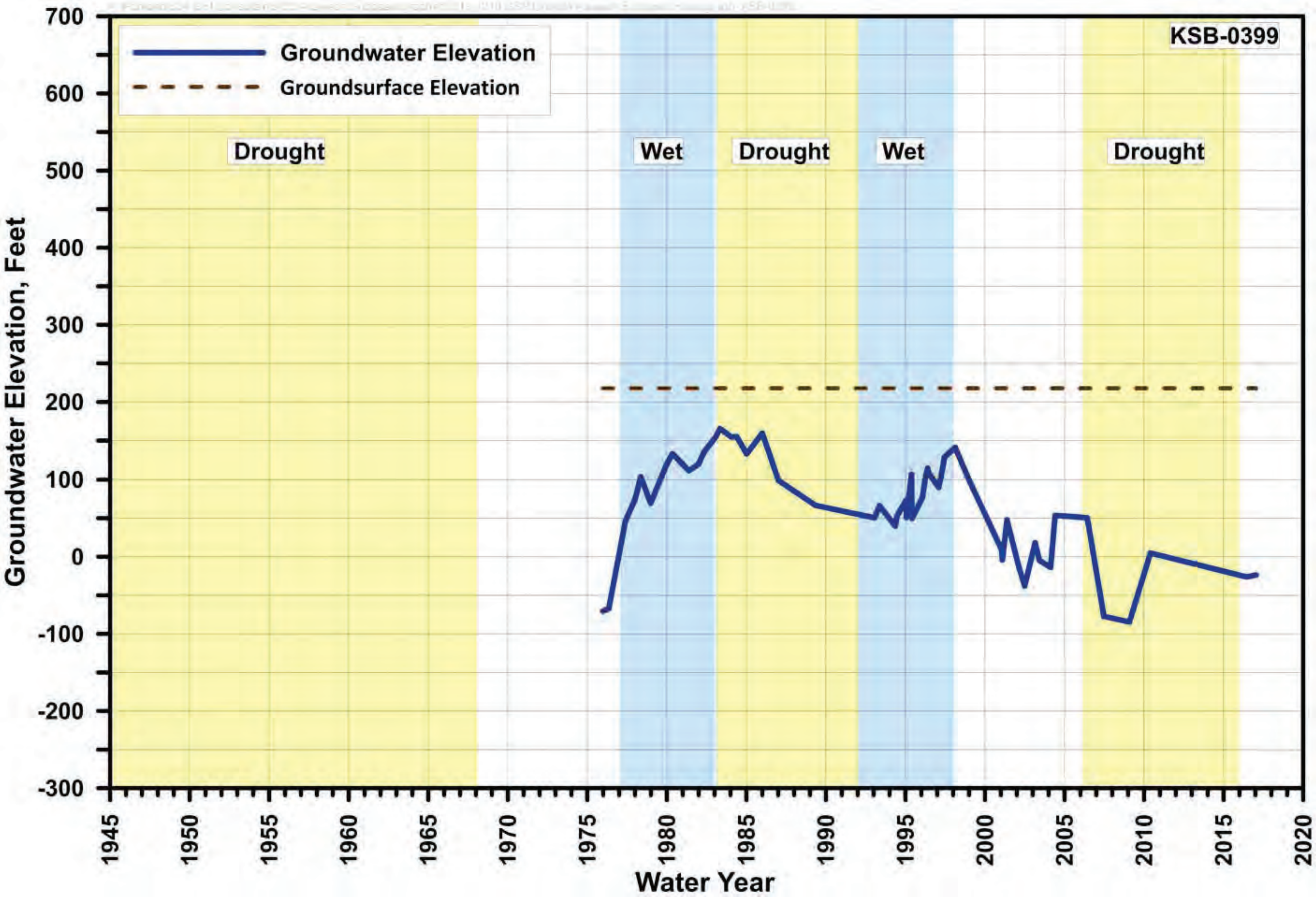
2015
2020
Water Year



KSB-0399
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
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-100
-200
-300
1945
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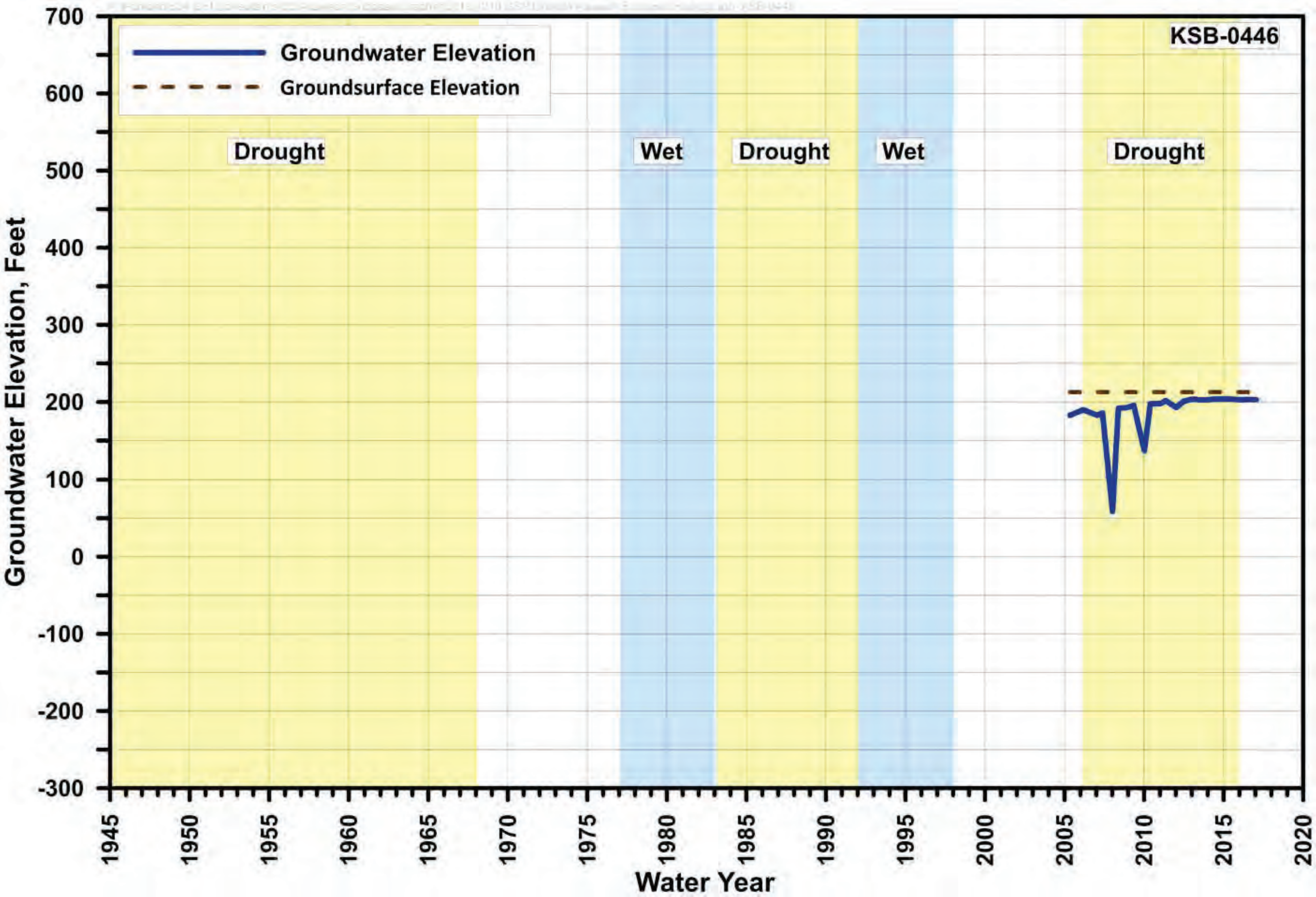
2020
Water Year



KSB-0446
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
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-100
-200
-300
1945
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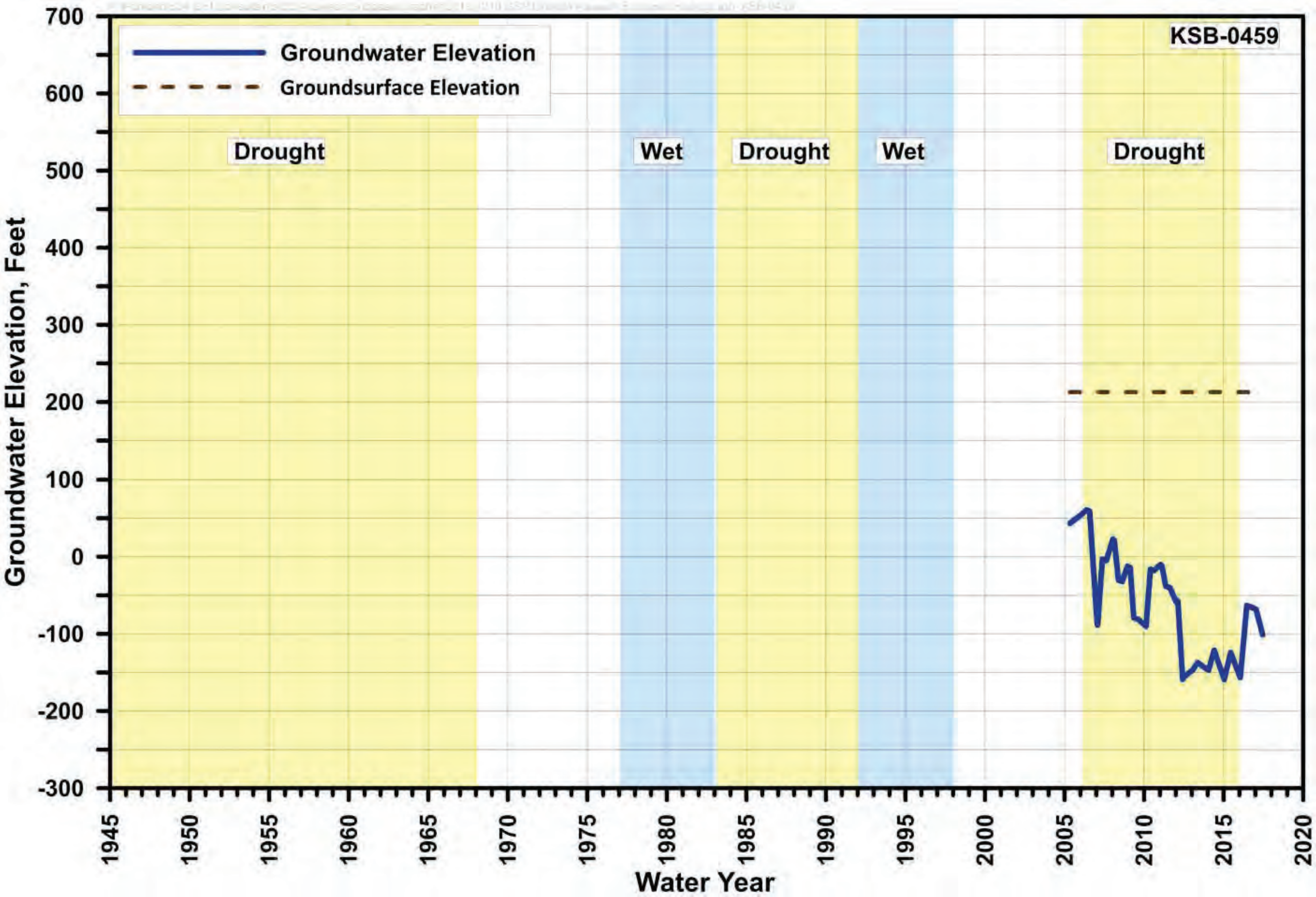
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-0459
Drought
Wet
Drought
Wet
Drought
700
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200
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-100
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Groundwater Elevation, Feet
1945
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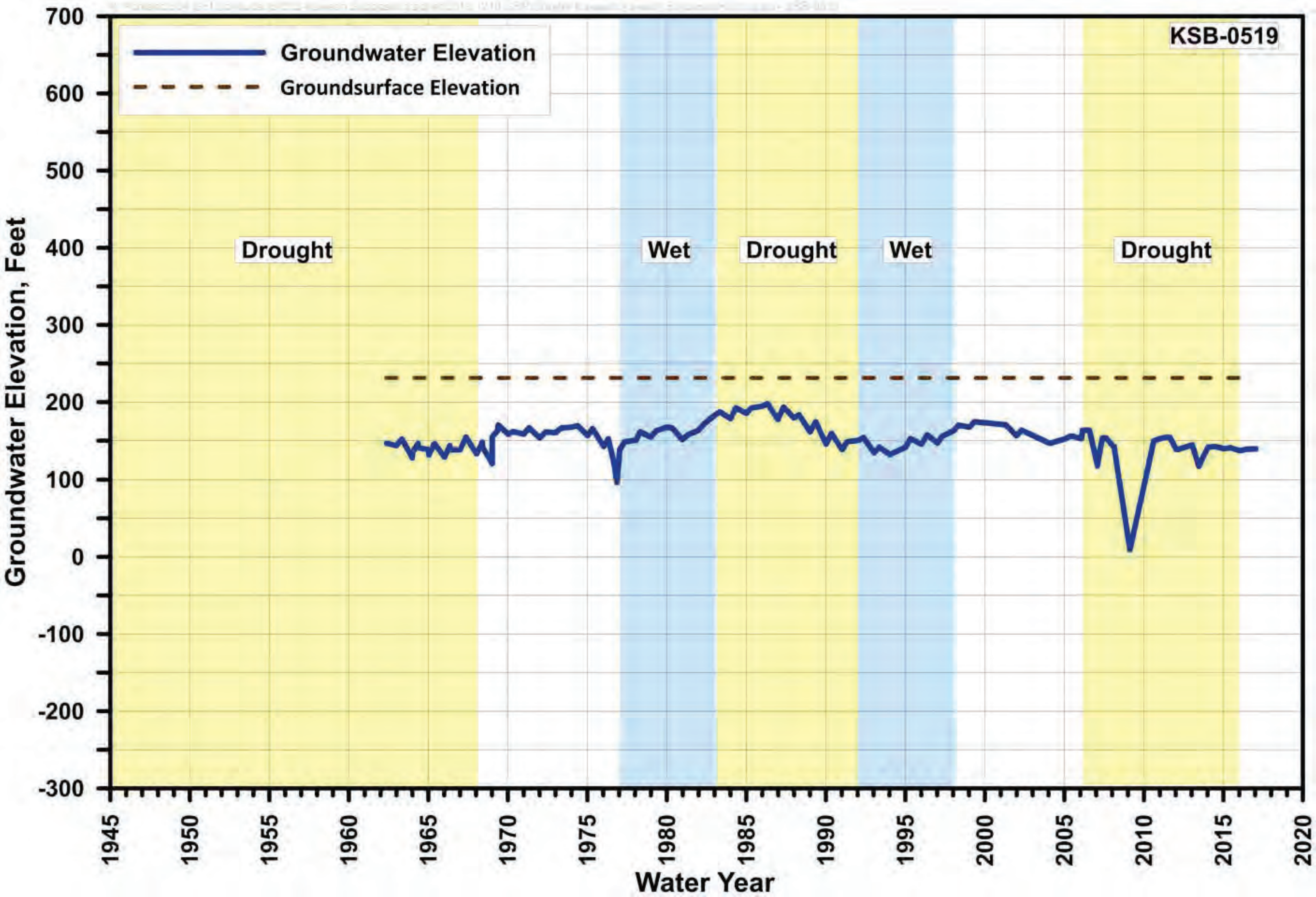
2015
2020
Water Year



KSB-0519
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
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1945
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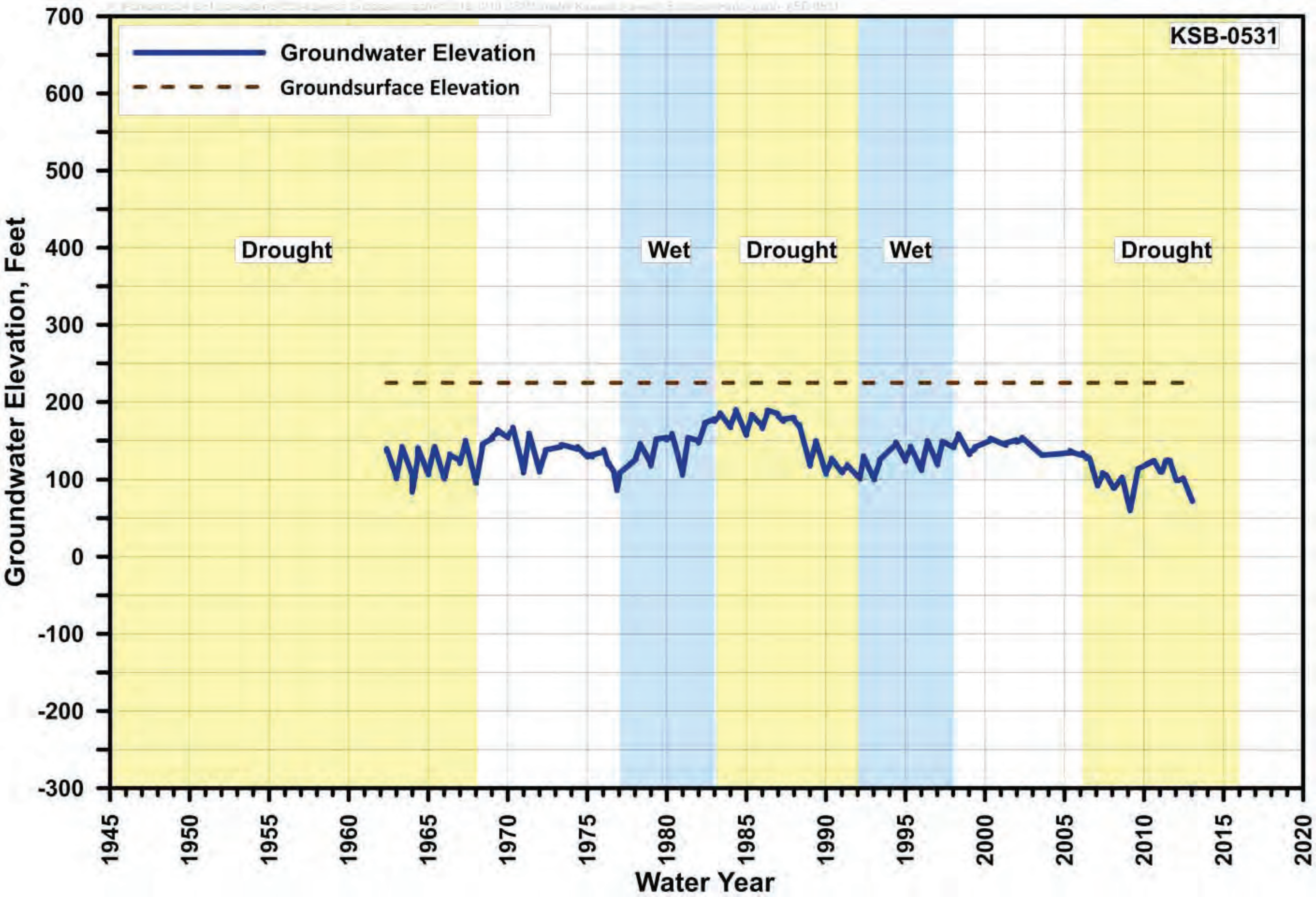

KSB-0531
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
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1945
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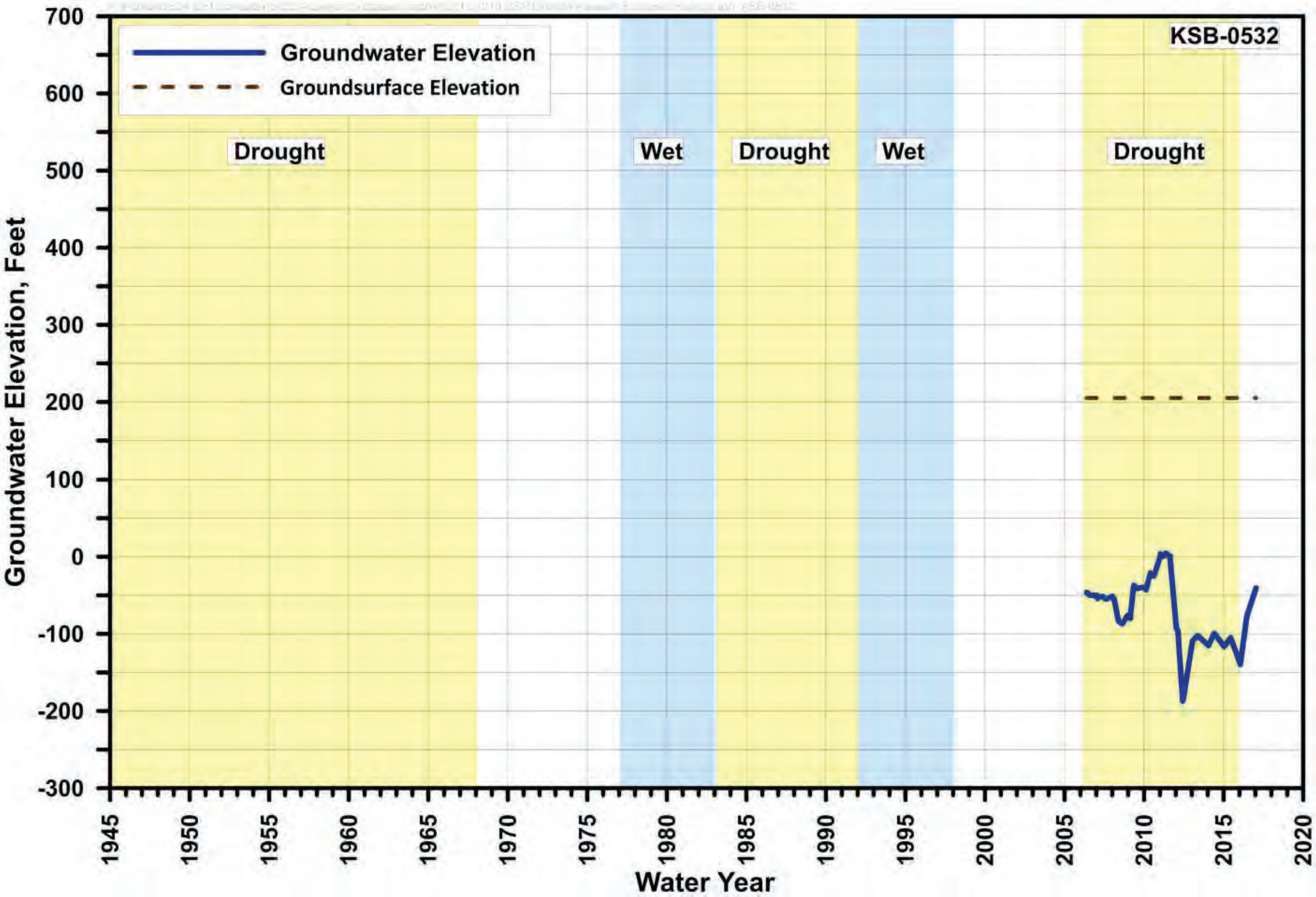
Water Year


KSB-0532
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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300
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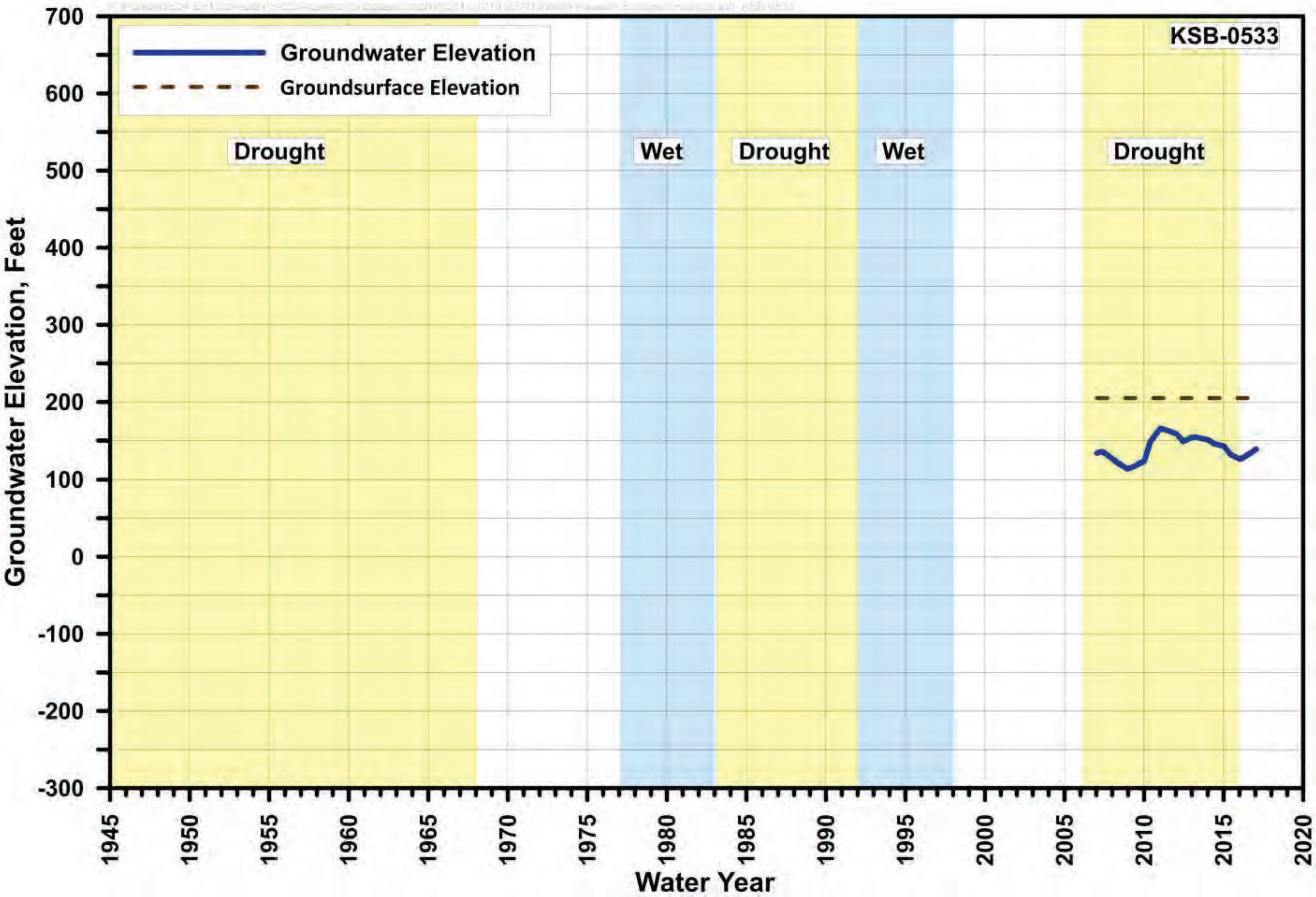
2020
Water Year


KSB-0533
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
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500
400
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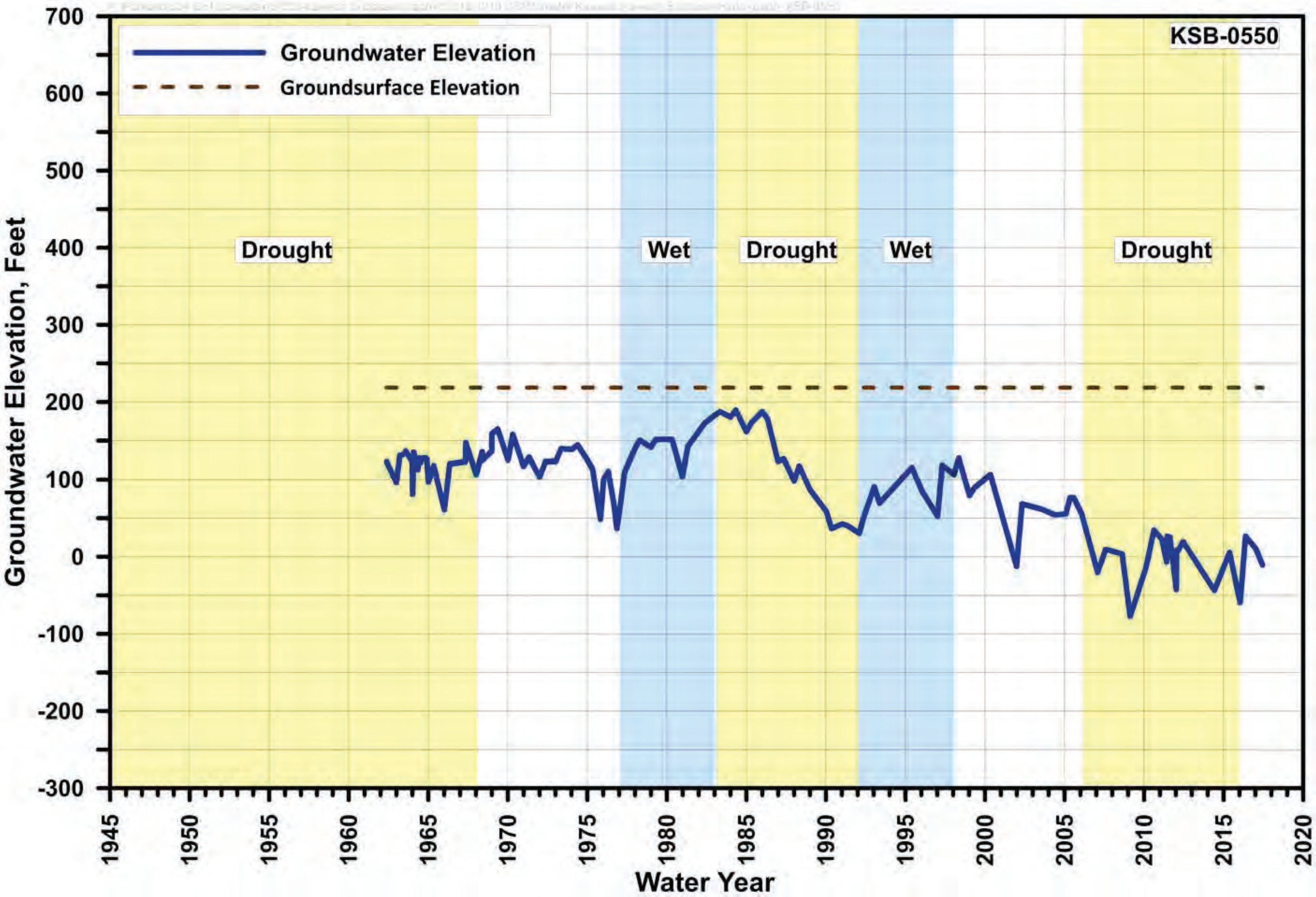
KSB-0550
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
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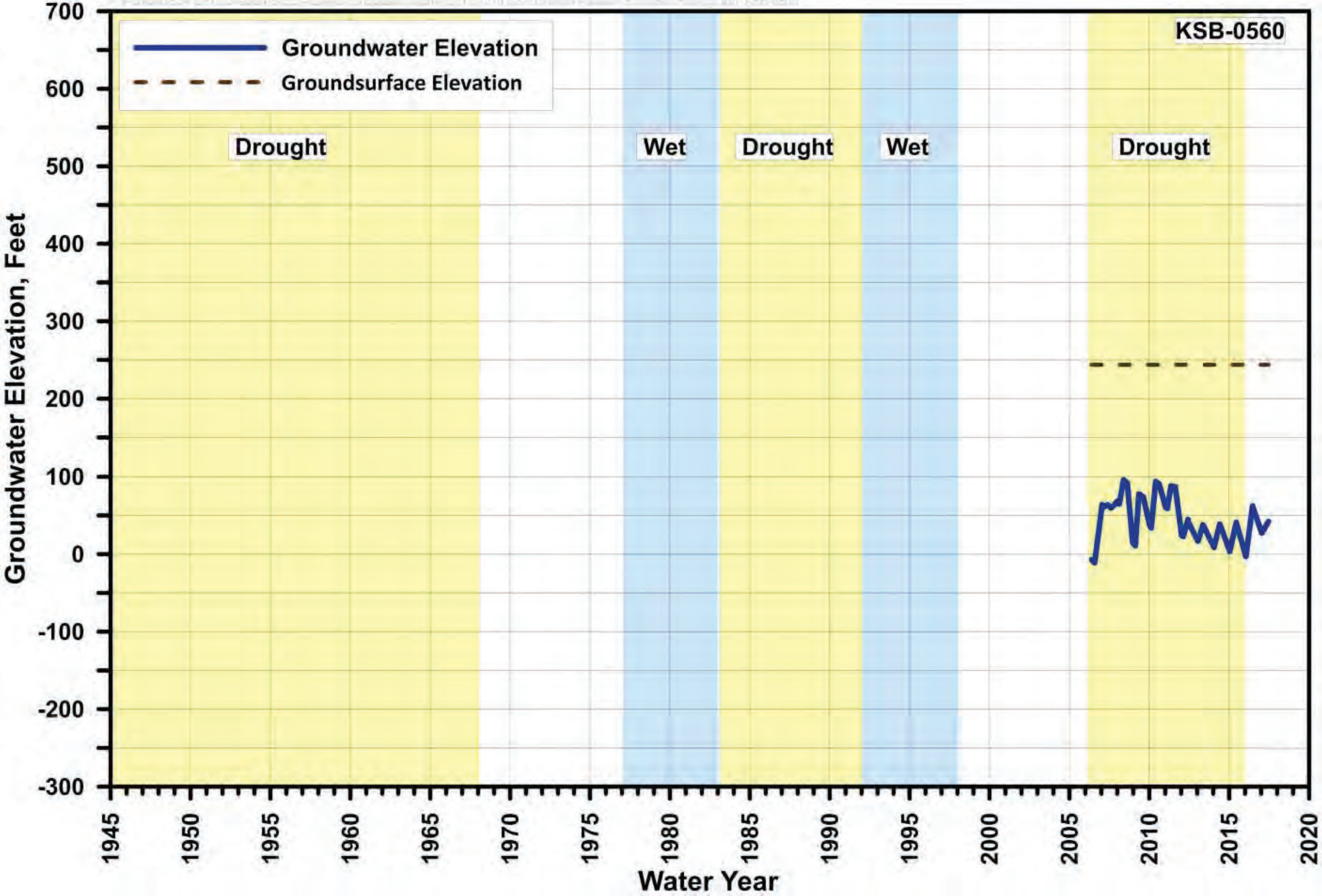
KSB-0560
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
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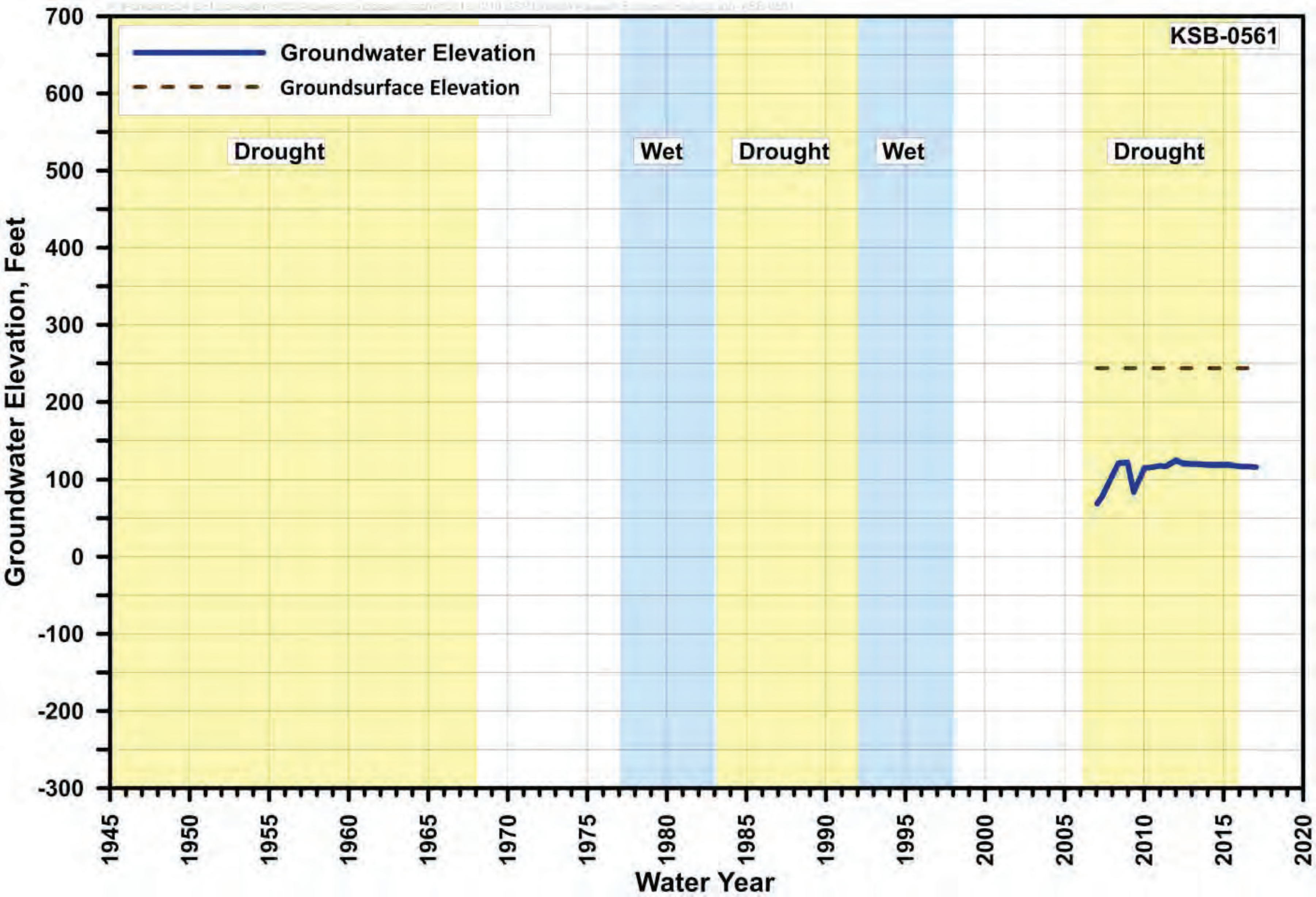
Water Year


KSB-0561
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
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400
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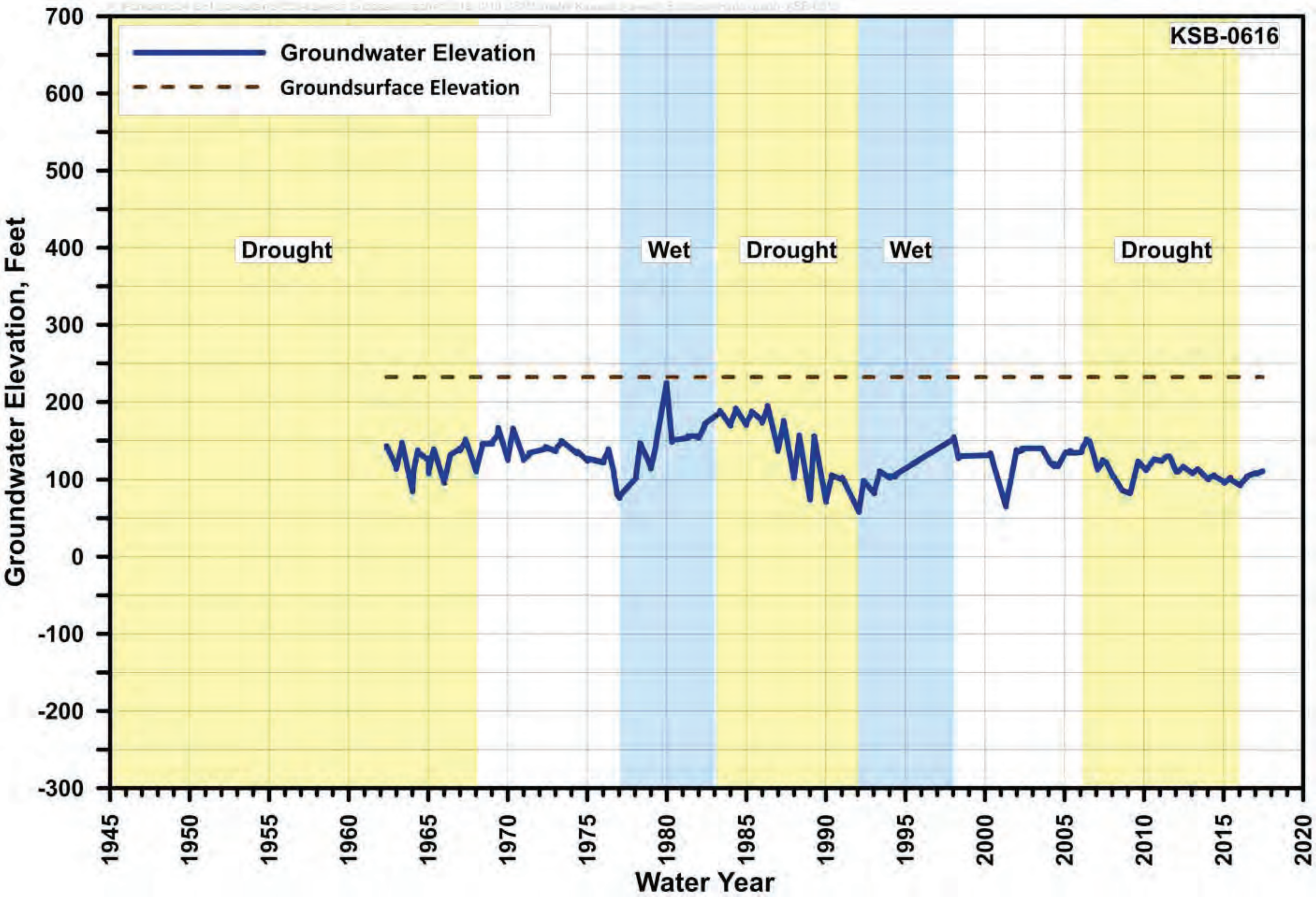
KSB-0616
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
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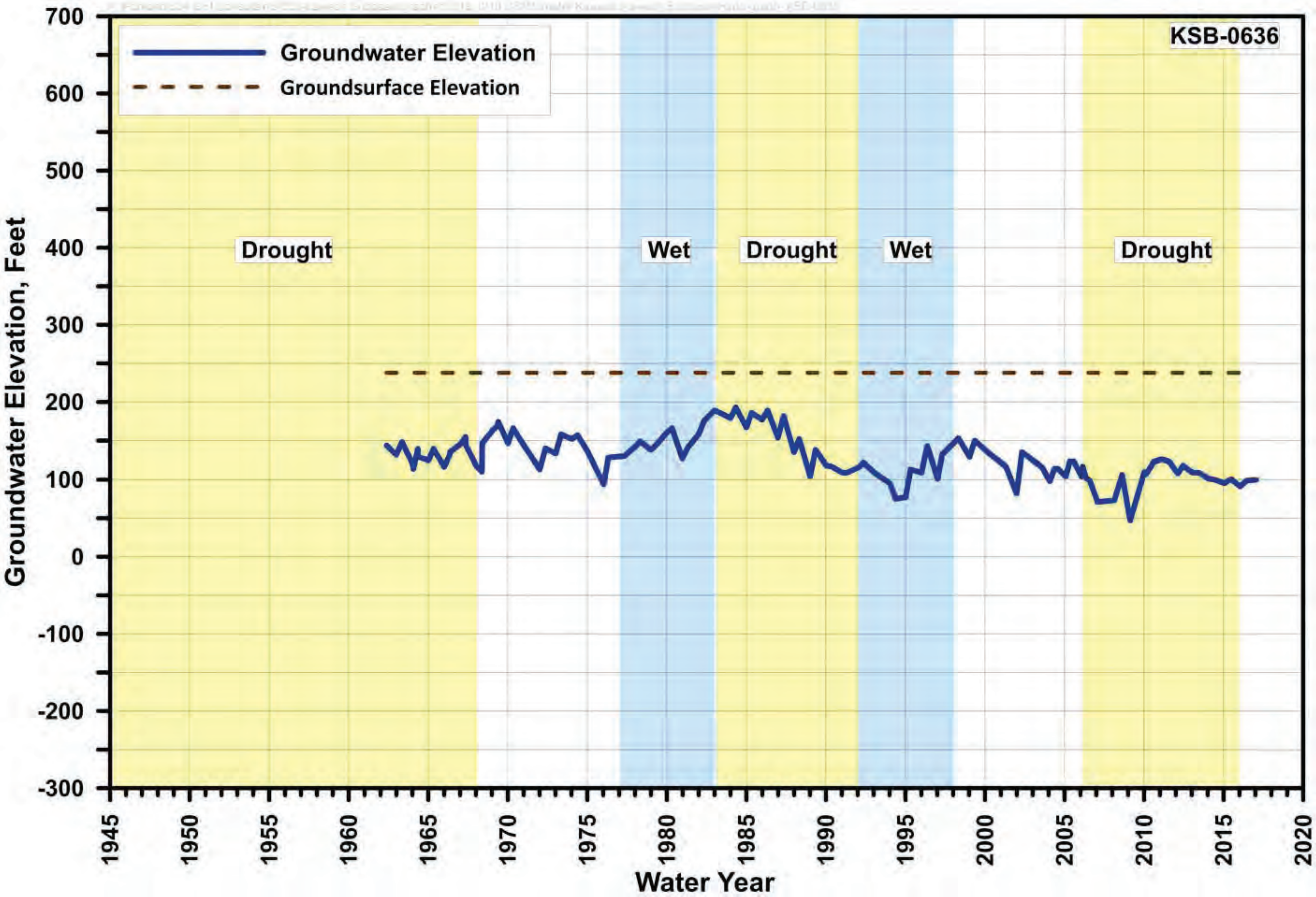
Water Year


KSB-0636
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
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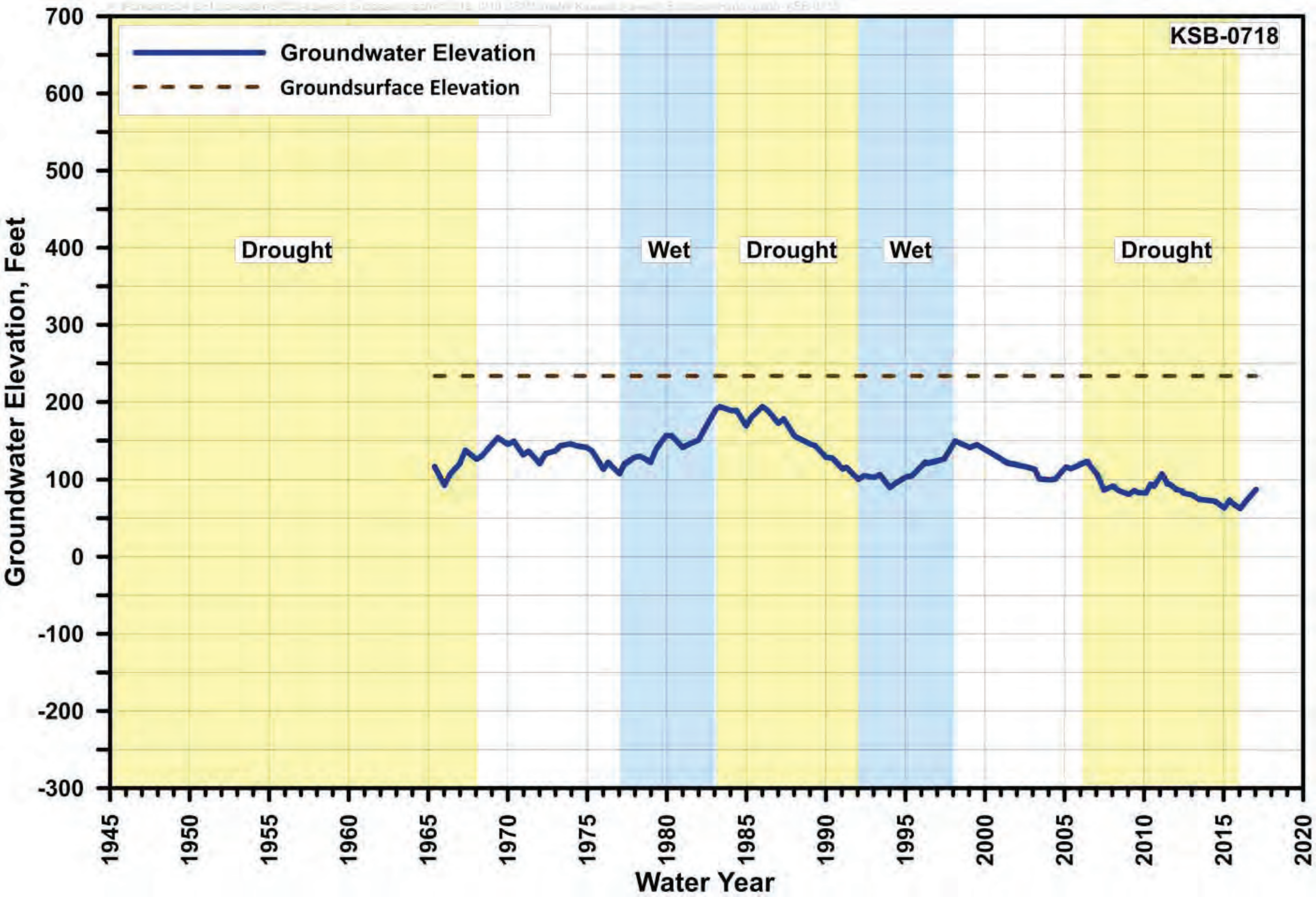
Water Year



KSB-0718
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
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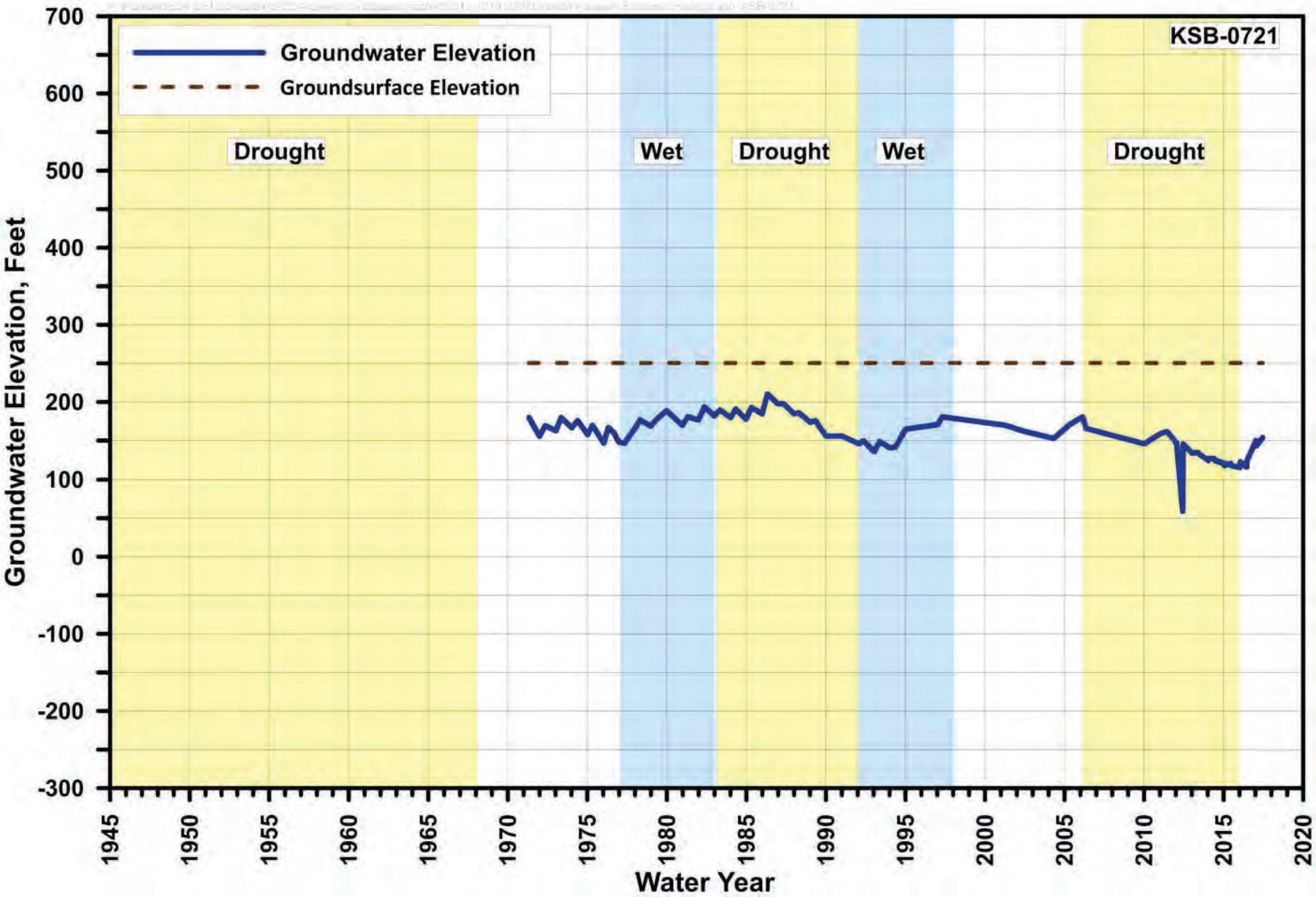
Water Year



KSB-0721
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
700
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Groundwater Elevation, Feet
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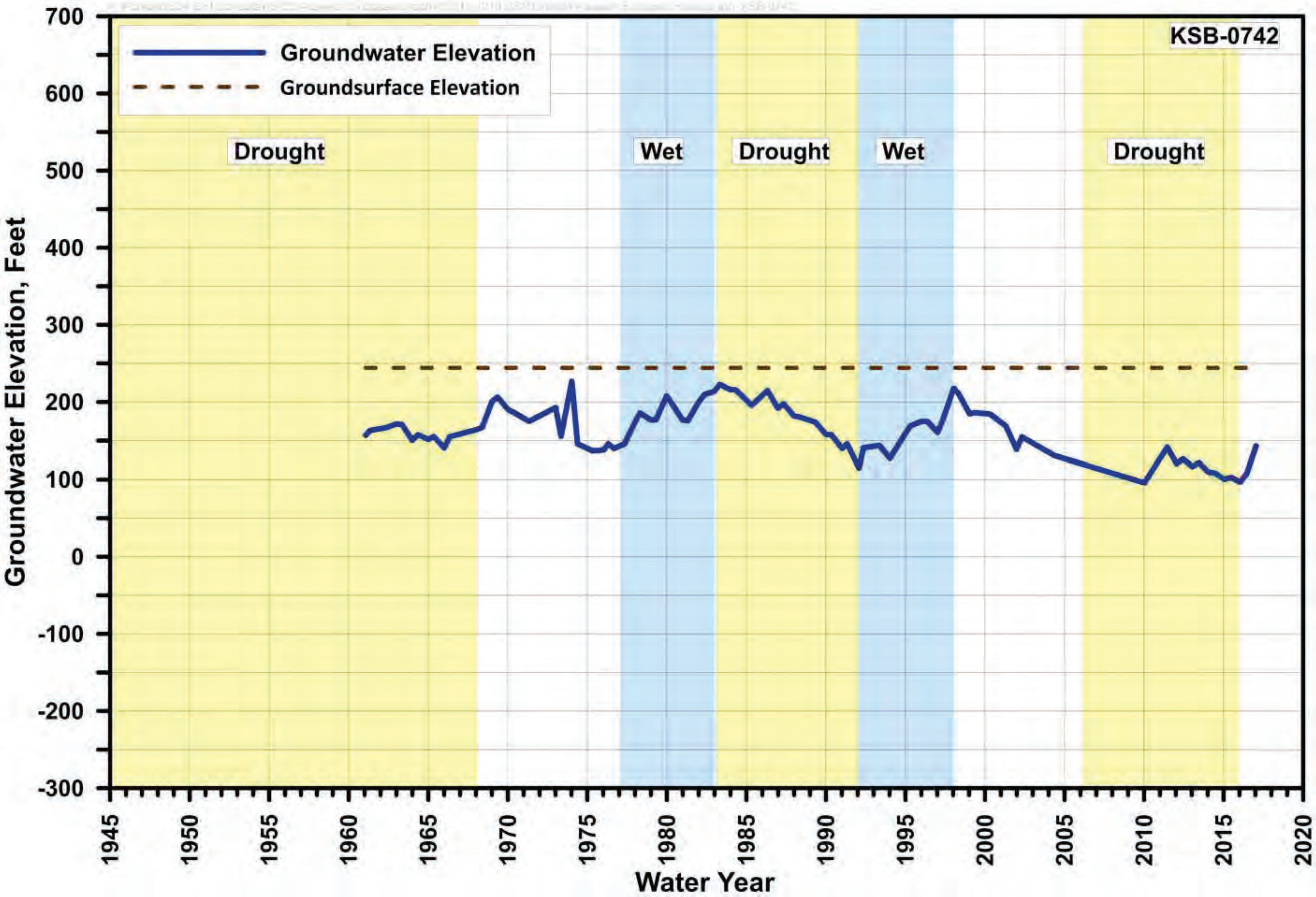
Water Year


Groundwater Elevation
Groundsurface Elevation
KSB-0742
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
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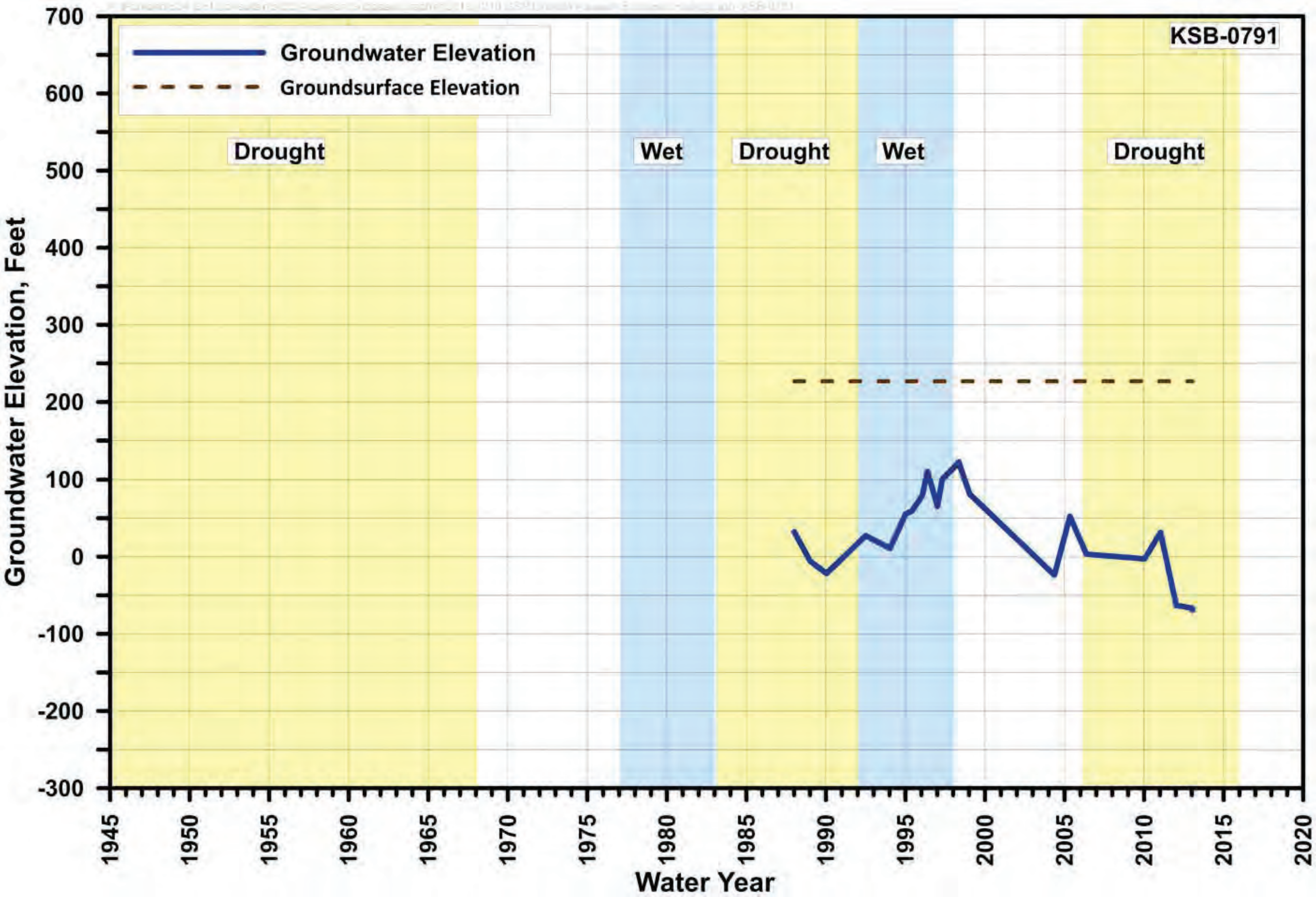
Water Year



KSB-0791
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
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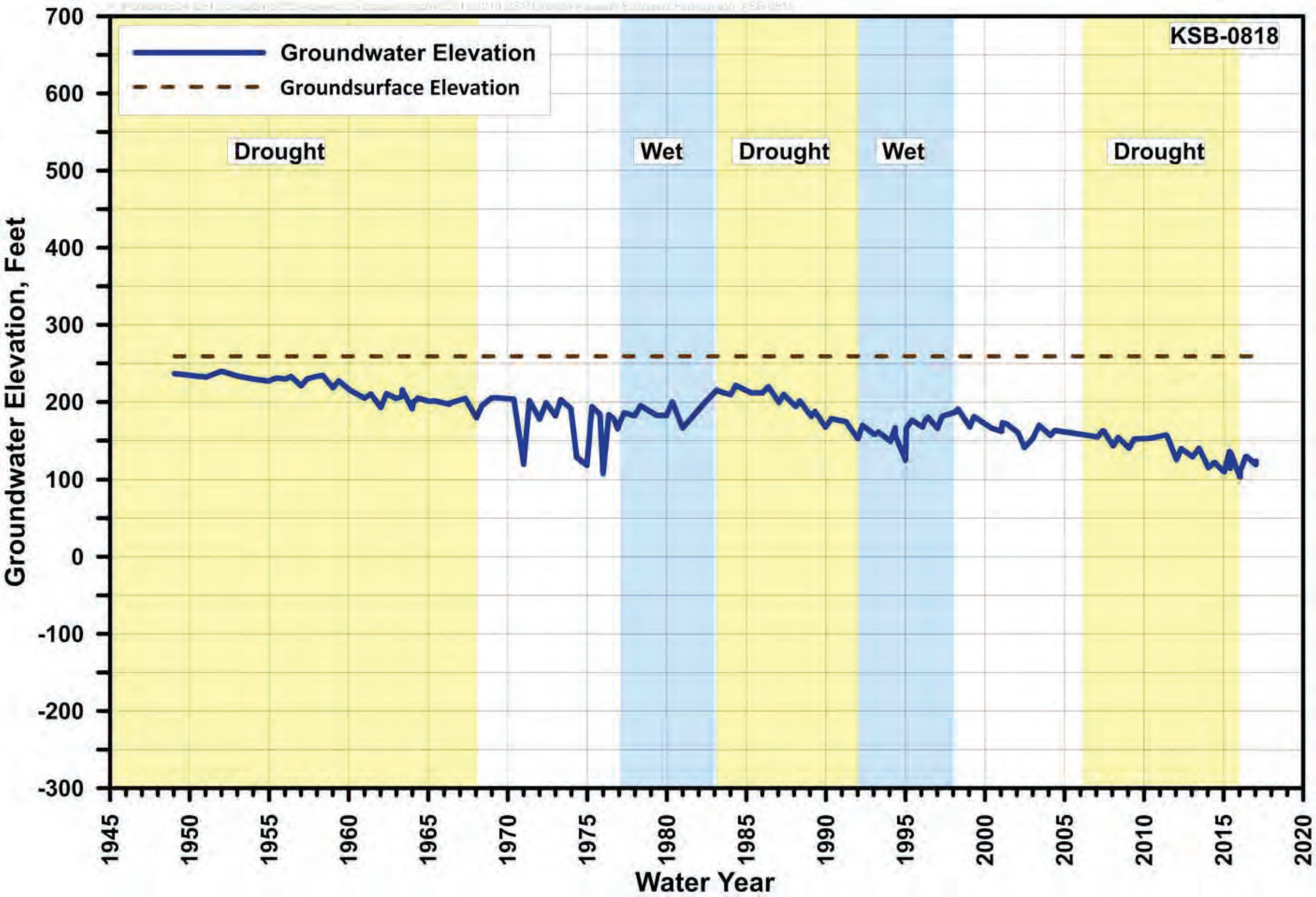
Water Year



KSB-0818
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
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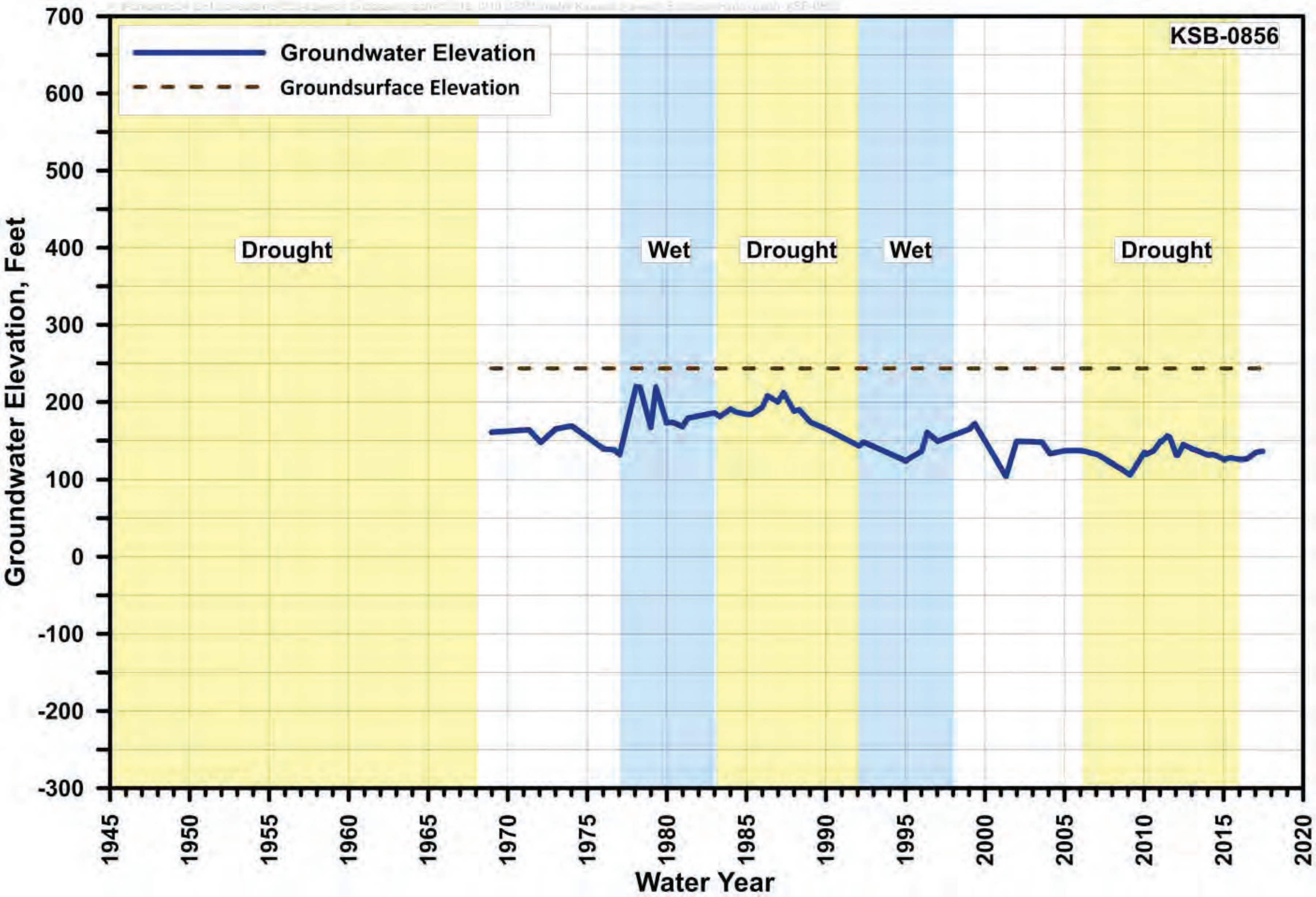
Water Year



KSB-0856
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
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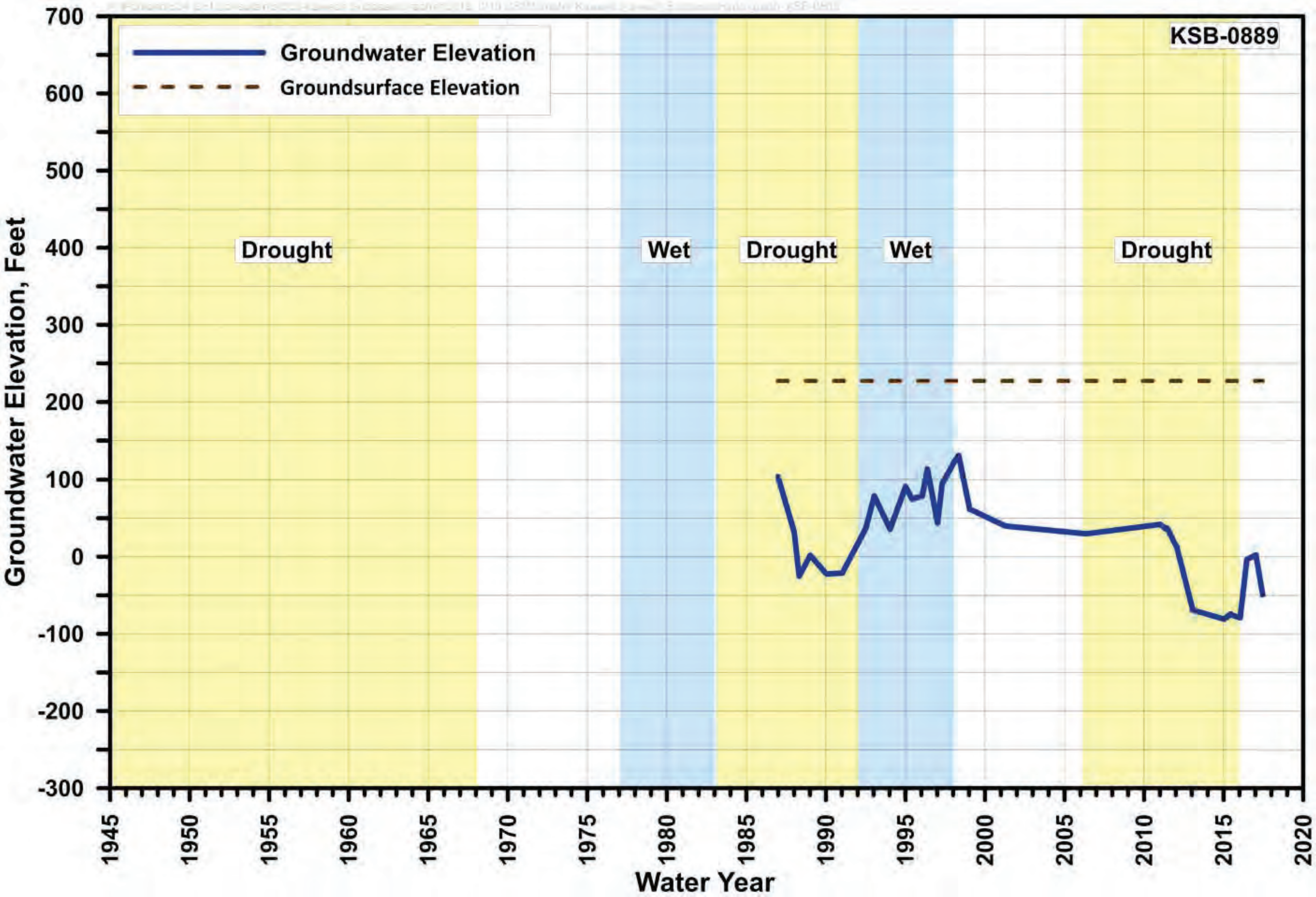
2020
Water Year



KSB-0889
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
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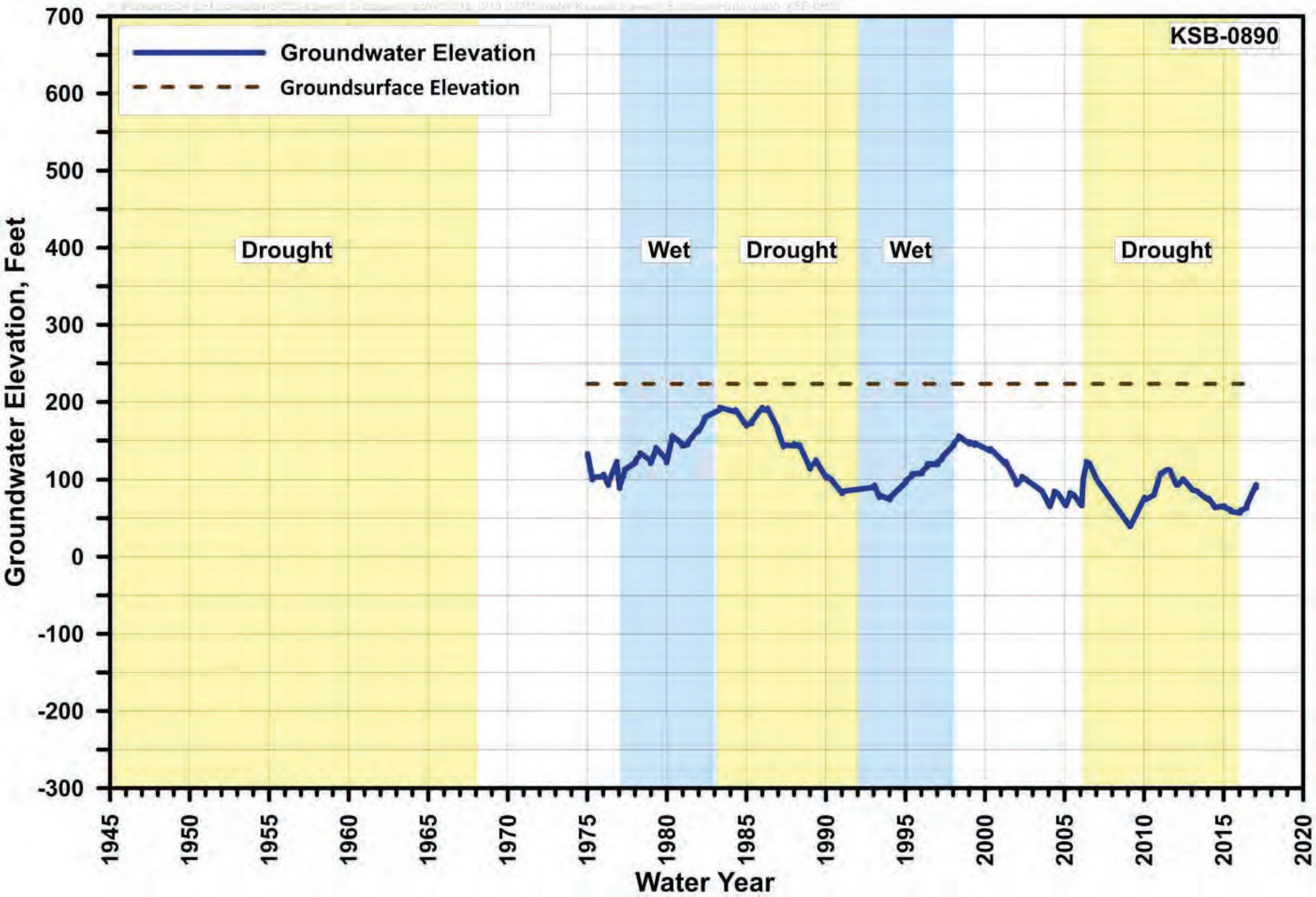
Water Year



KSB-0890
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
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500
400
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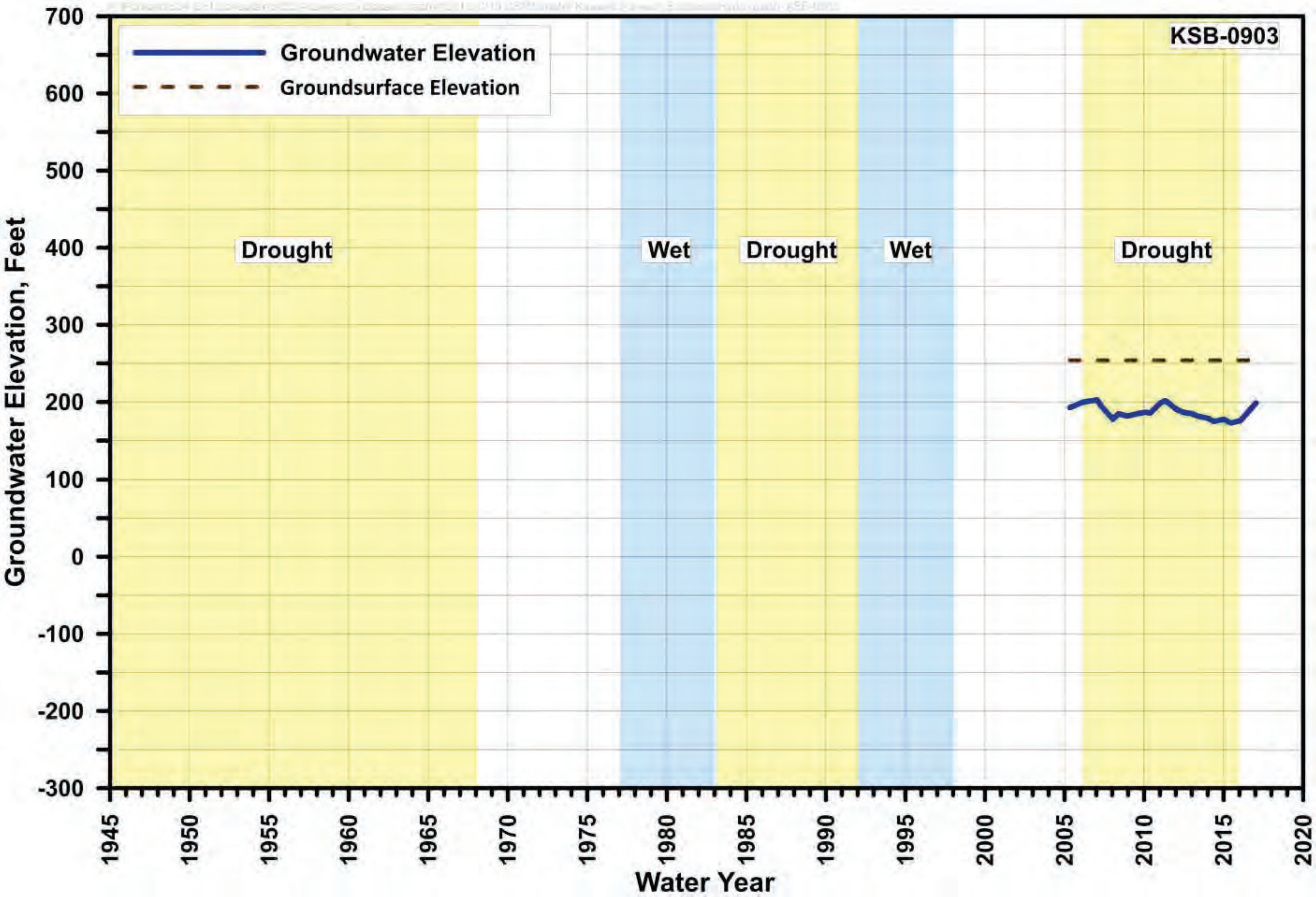
KSB-0903
Groundwater Elevation
Groundsurface Elevation
Drought
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Drought
Wet
Drought
Groundwater Elevation, Feet
700
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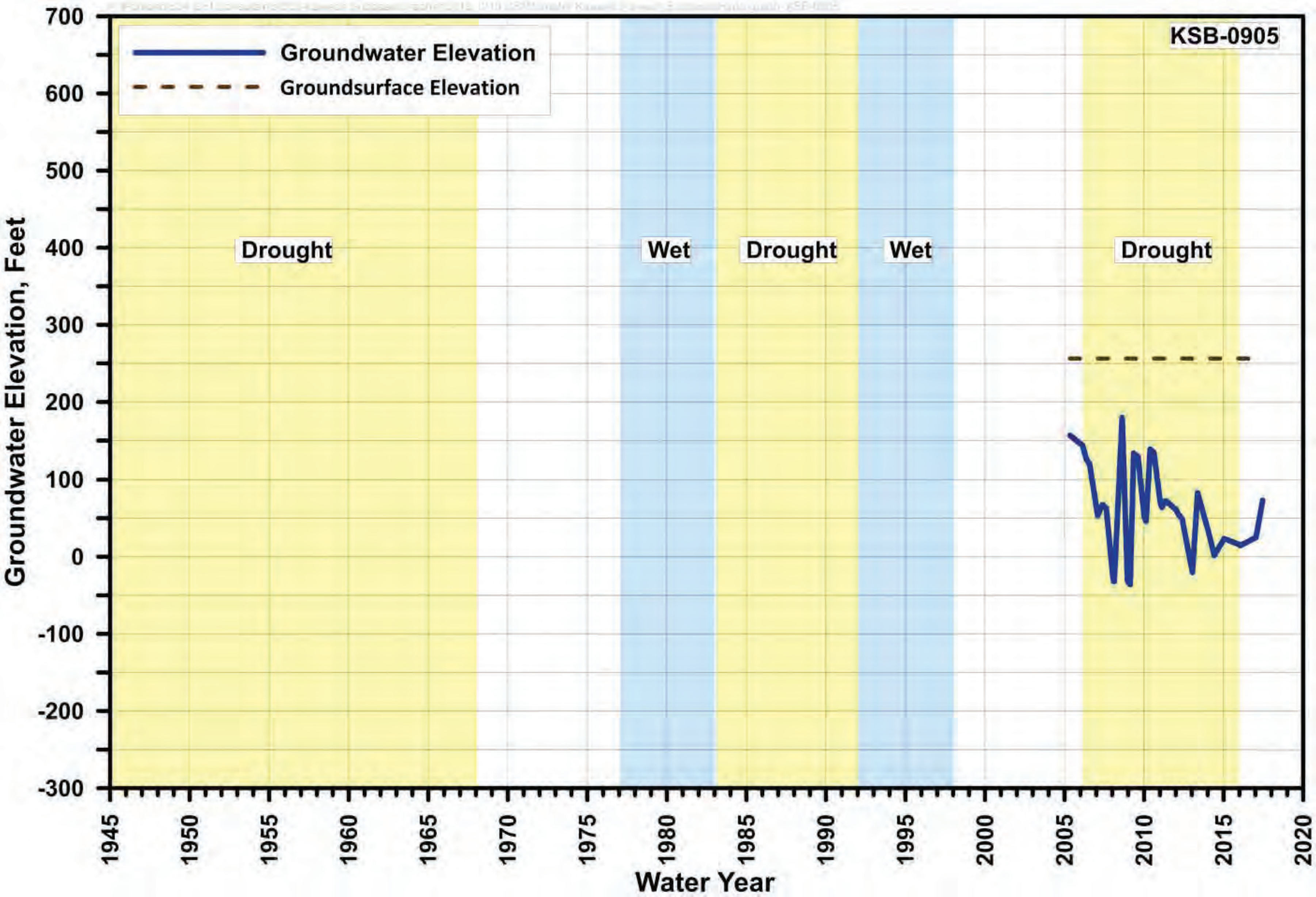
Water Year



KSB-0905
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
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400
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200
100
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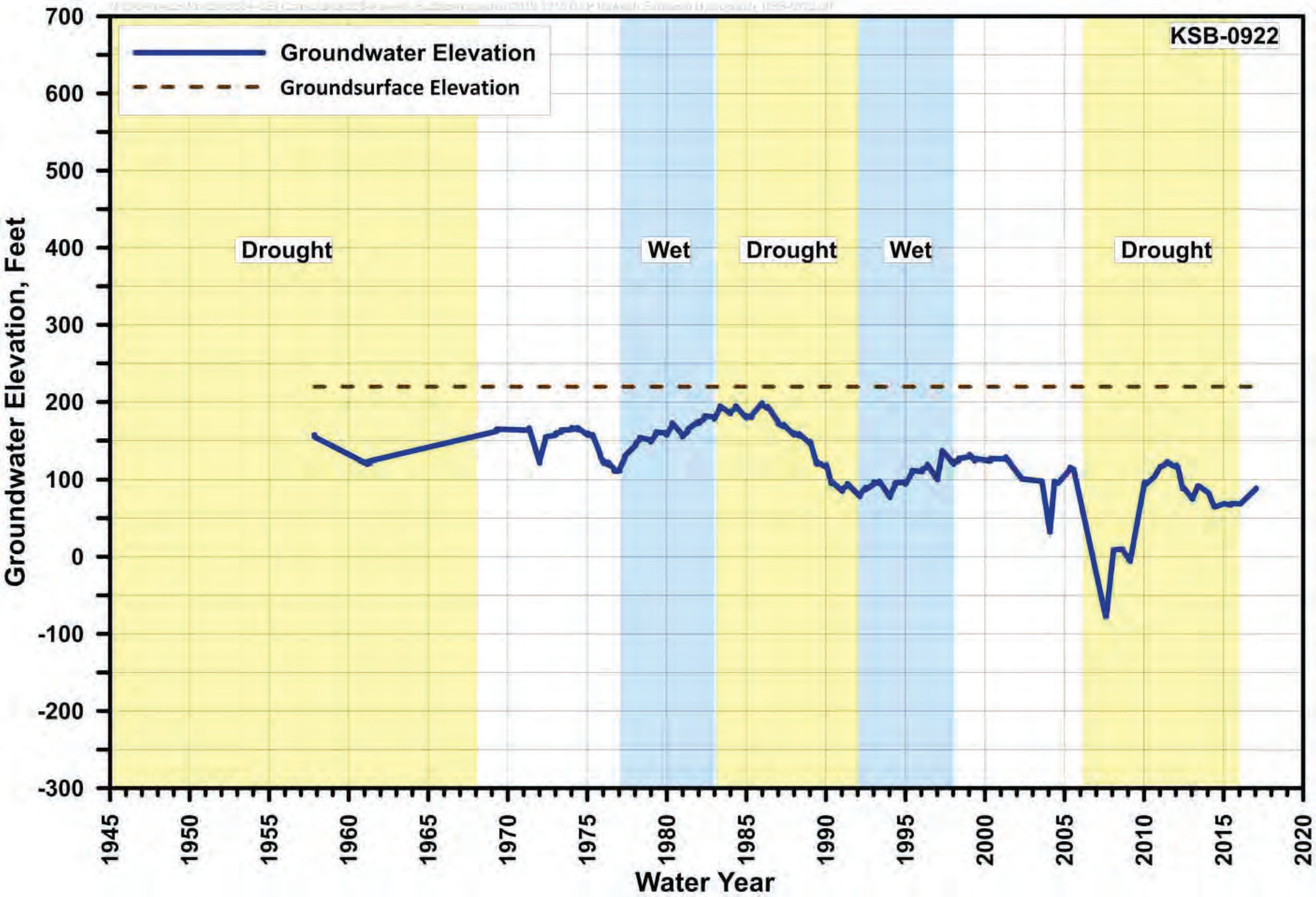

KSB-0922
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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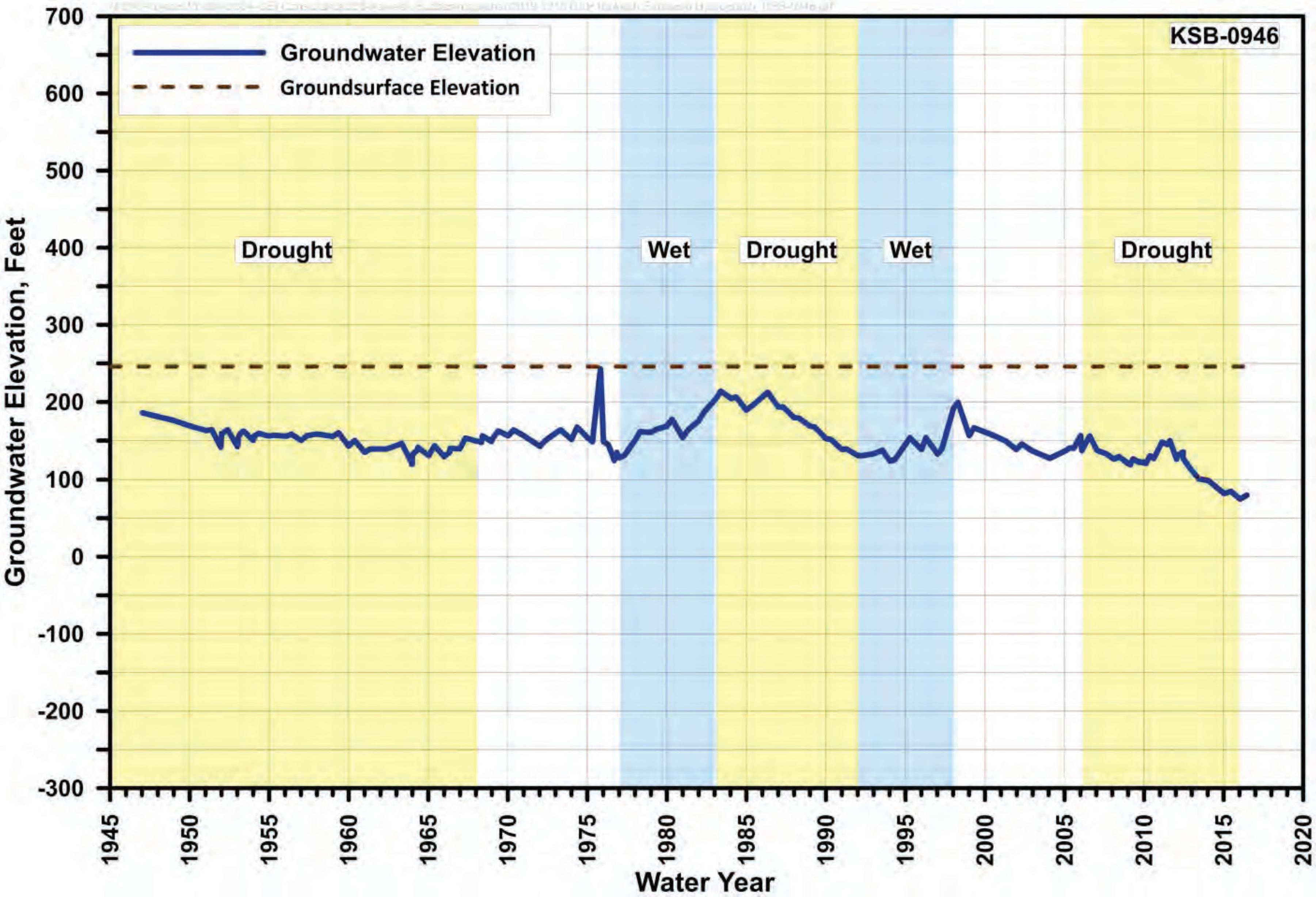
2015
2020



KSB-0946
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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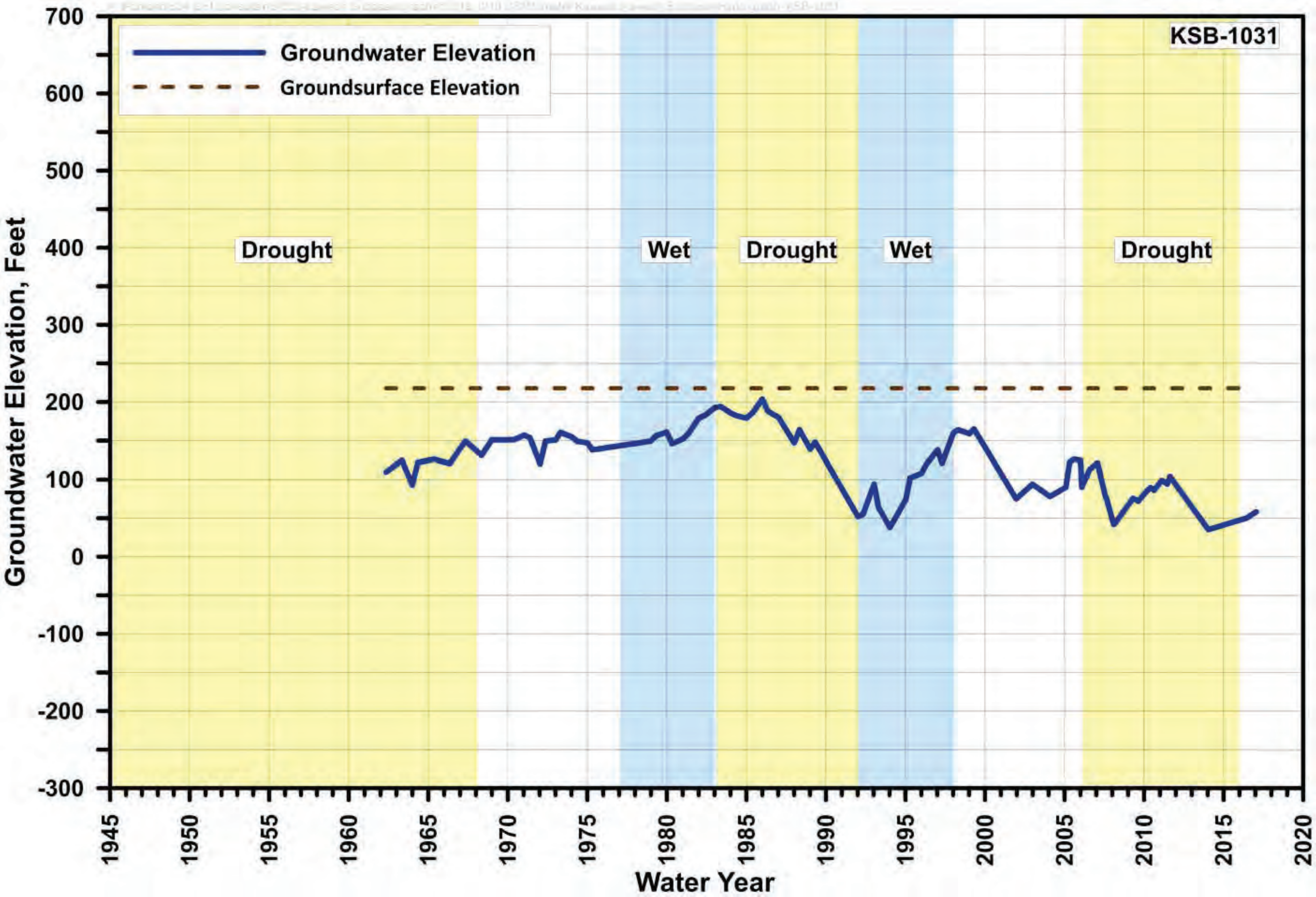
KSB-1031
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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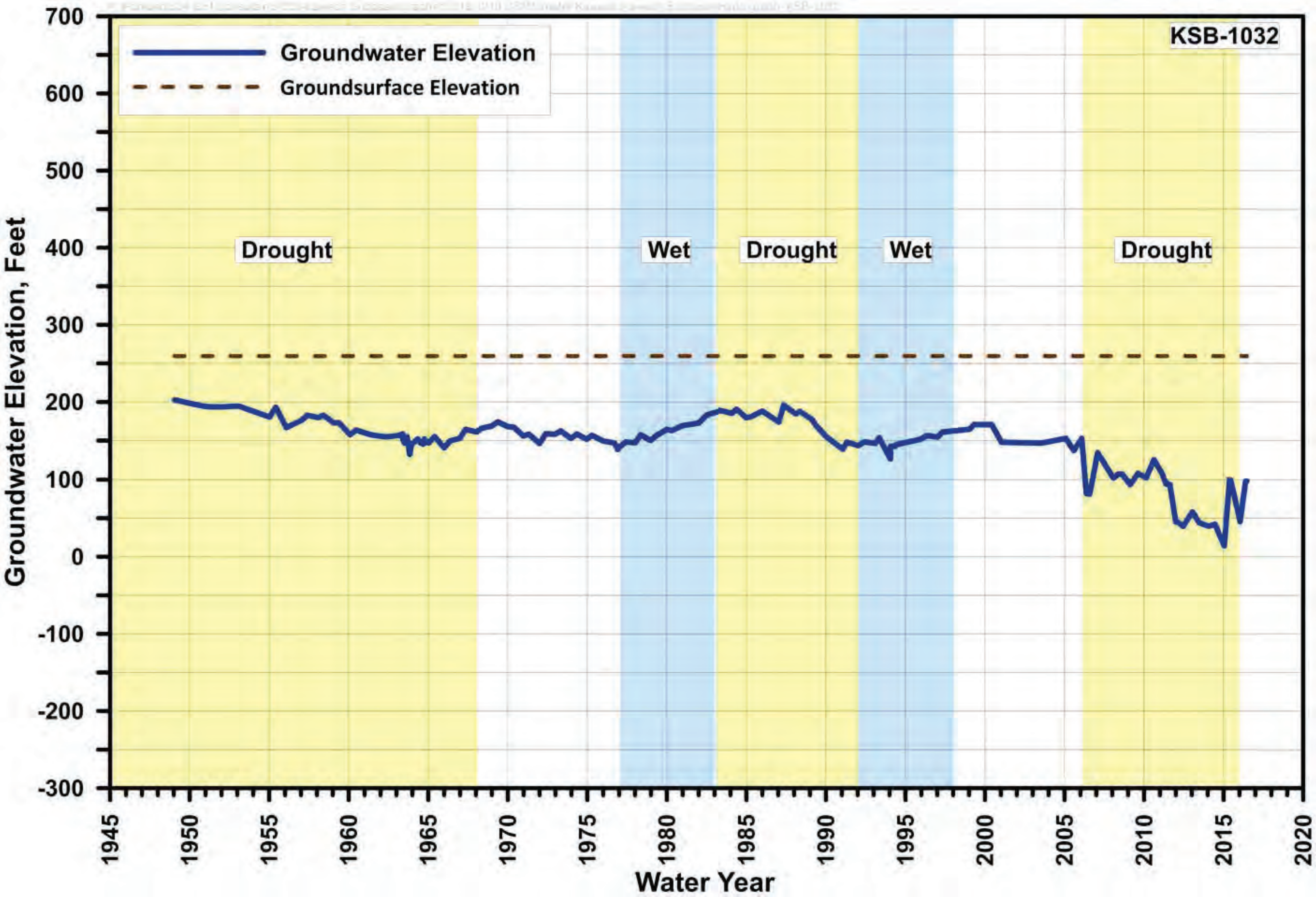
2020



KSB-1032
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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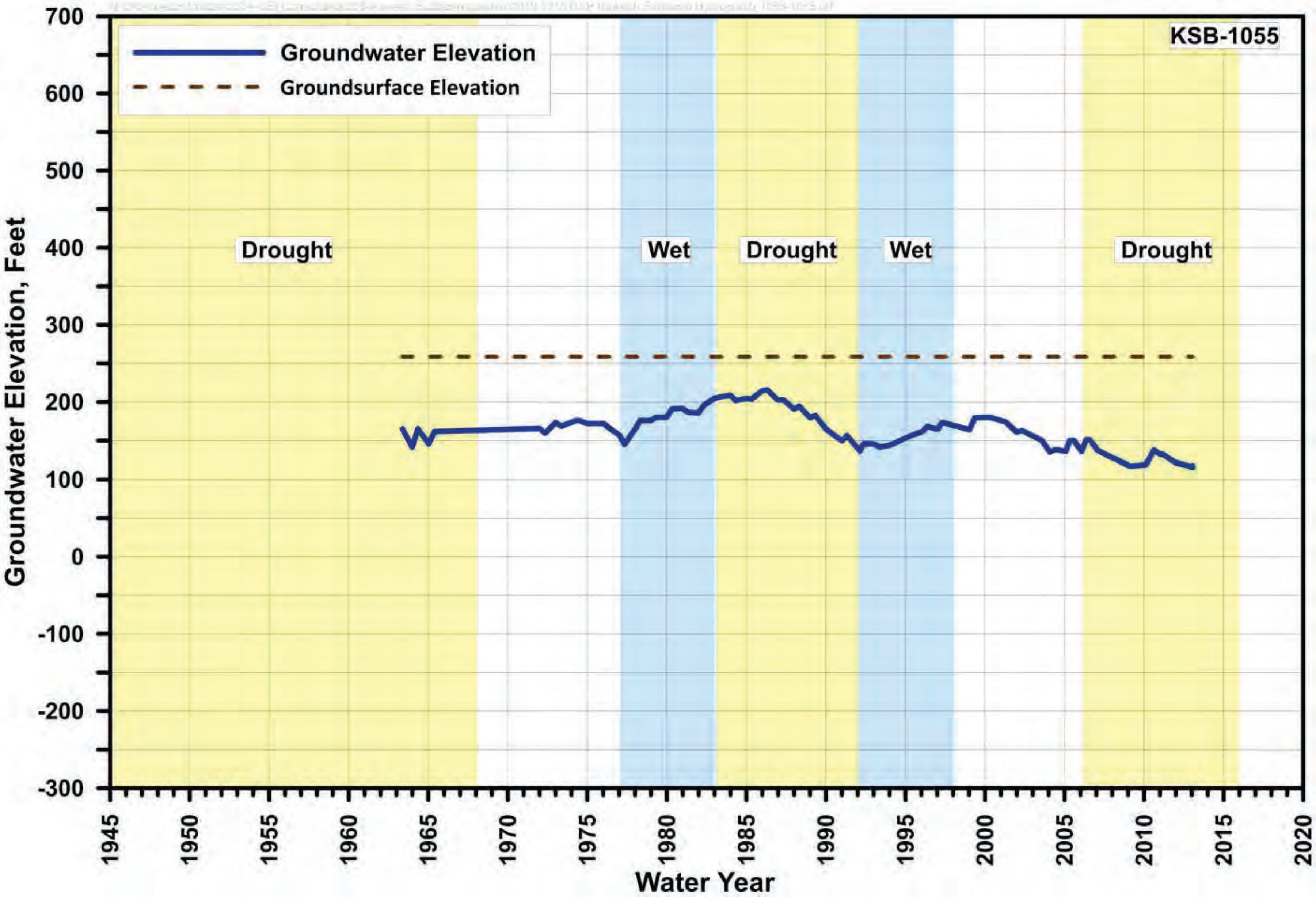

KSB-1055
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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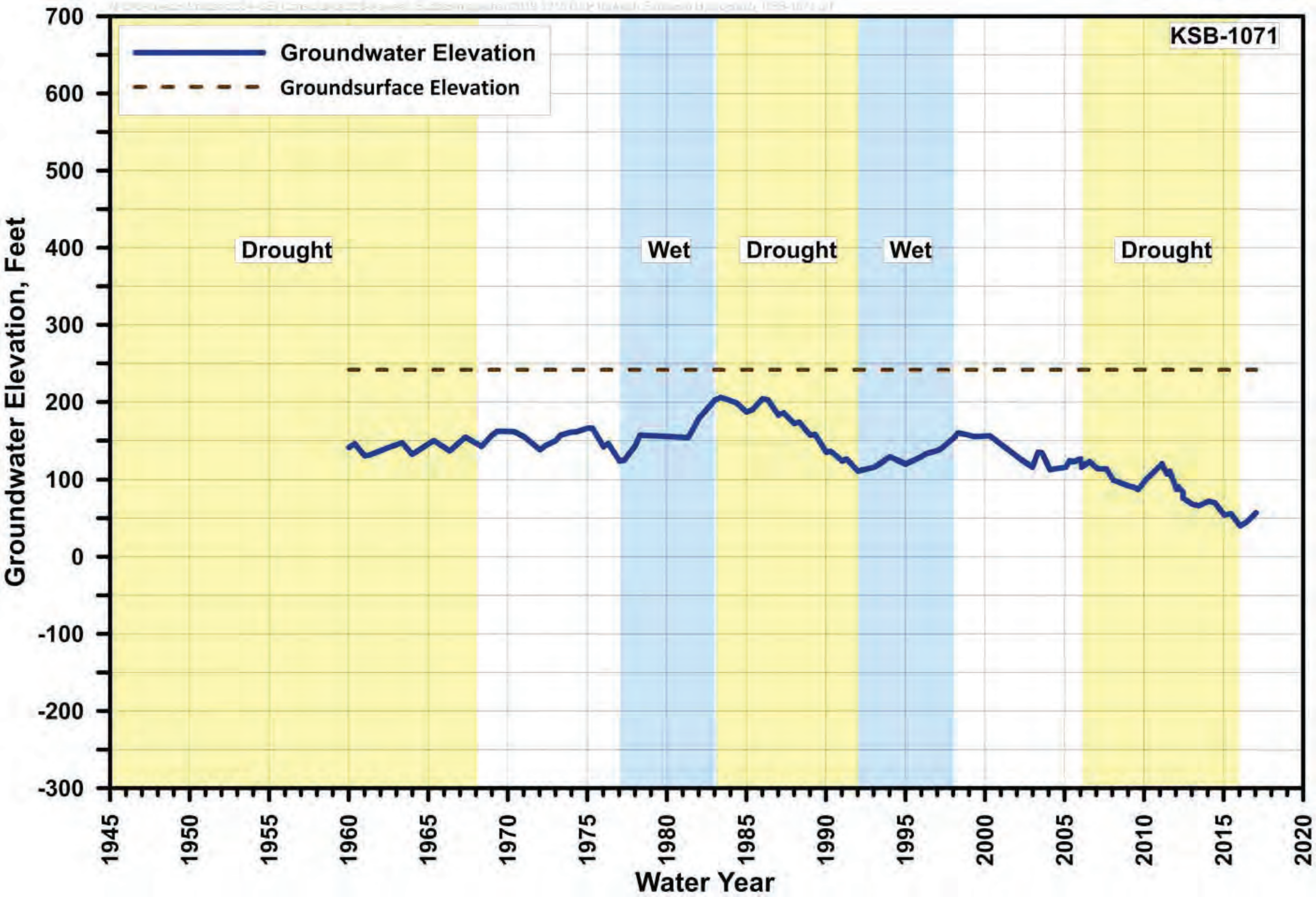
2010
2015
2020
Water Year



KSB-1071
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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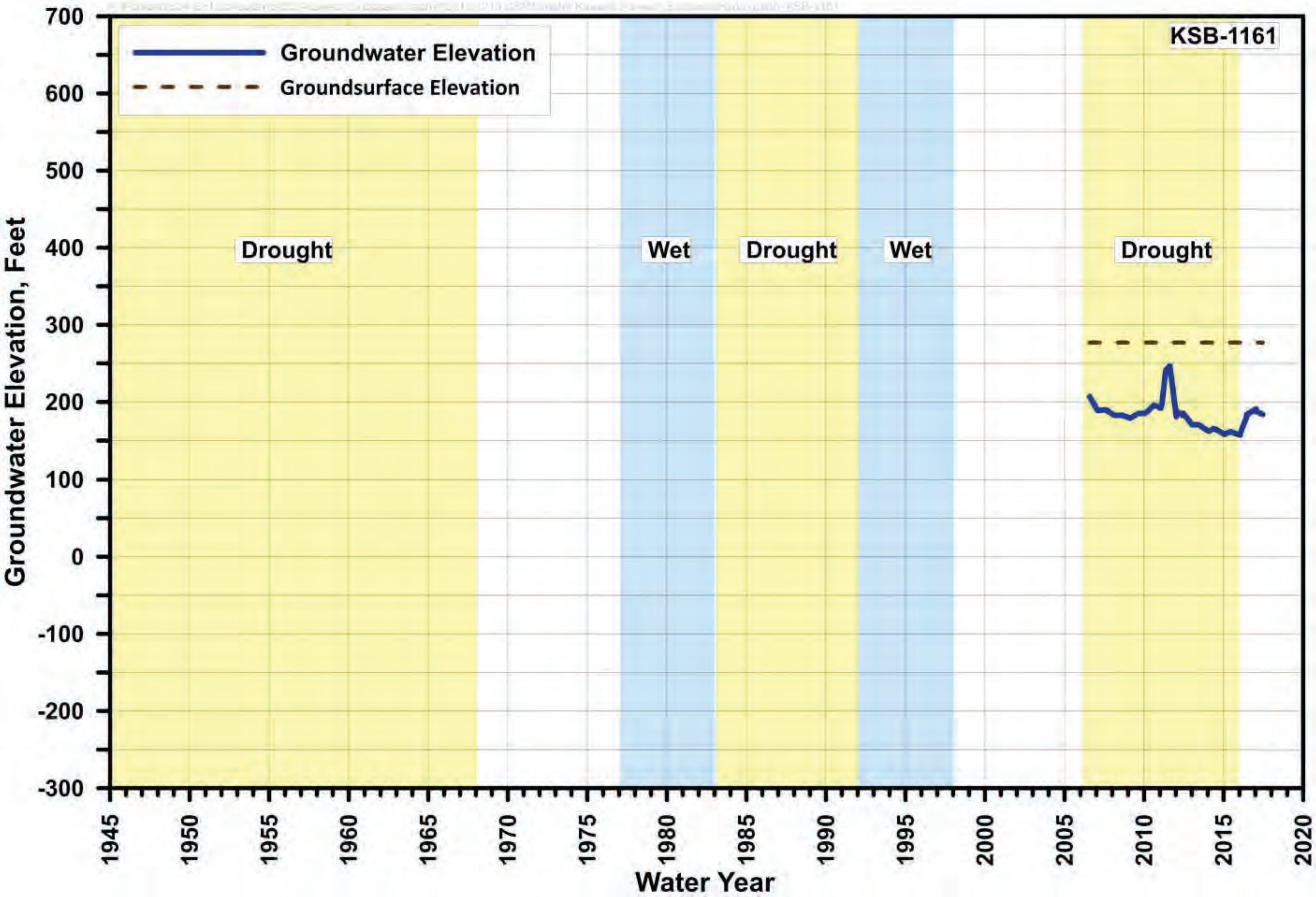
KSB-1161
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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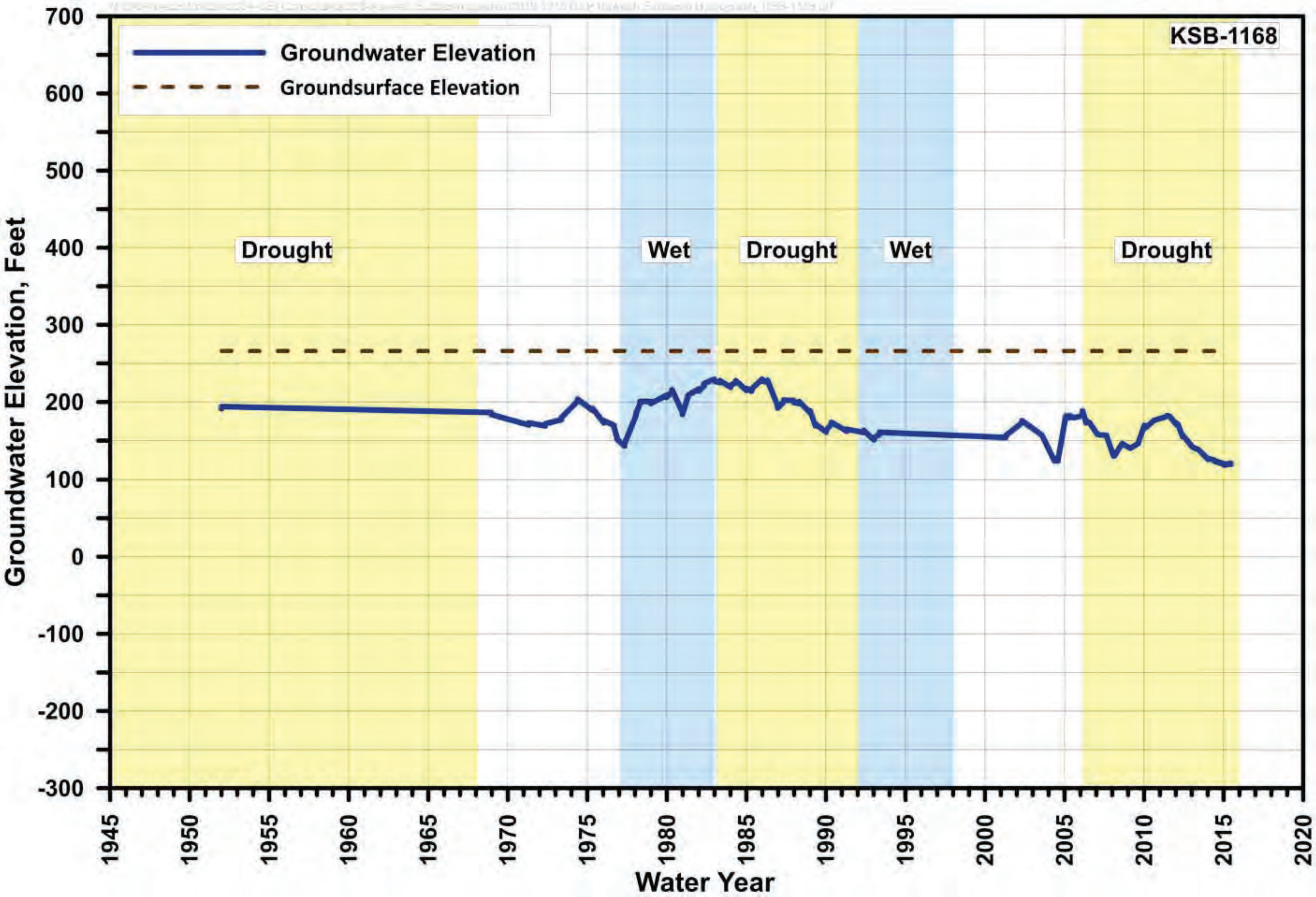
2015
2020
Water Year


KSB-1168
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
-200
-300
1945
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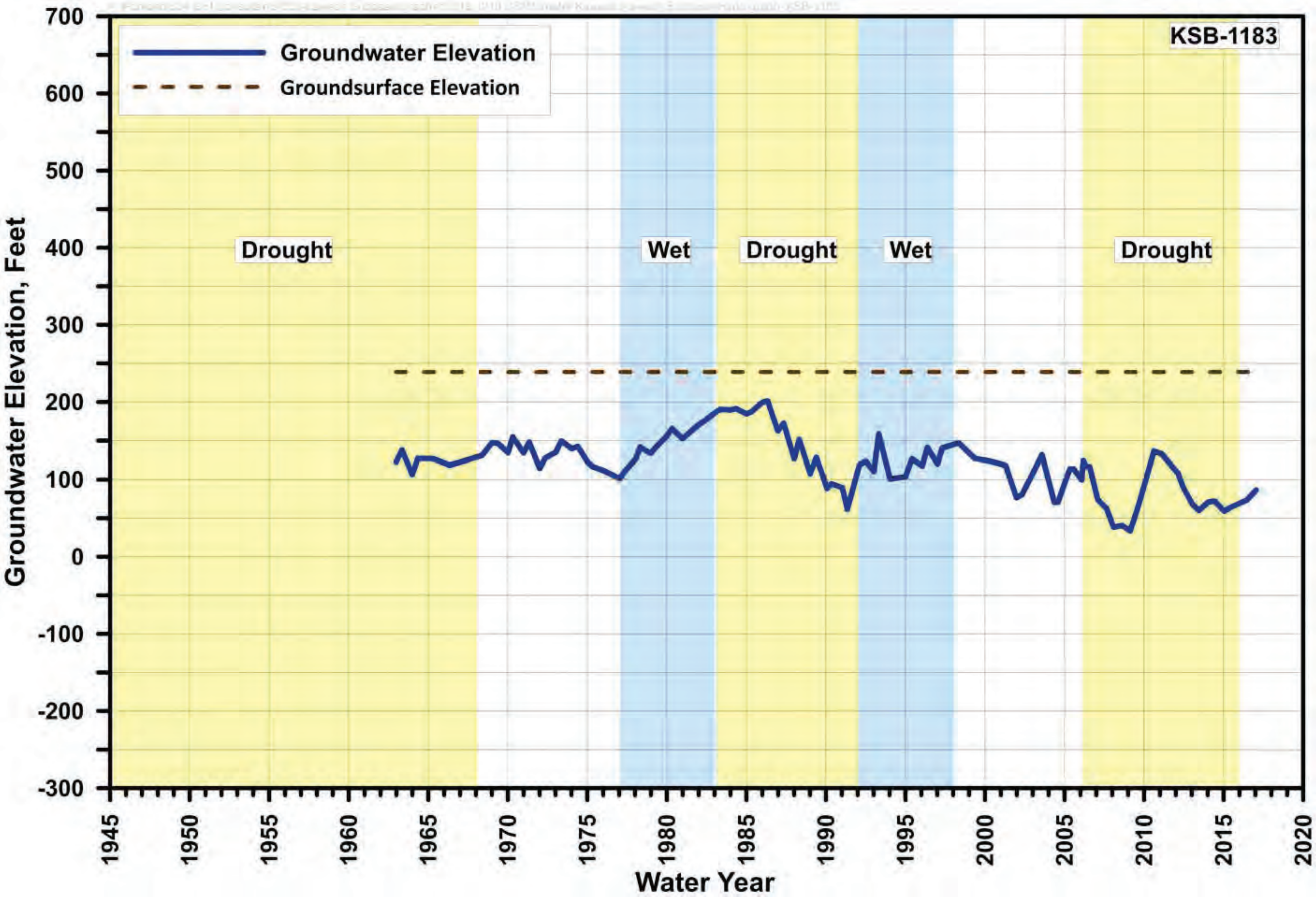
Groundwater Elevation
Groundsurface Elevation
KSB-1183
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
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-200
-300
1945
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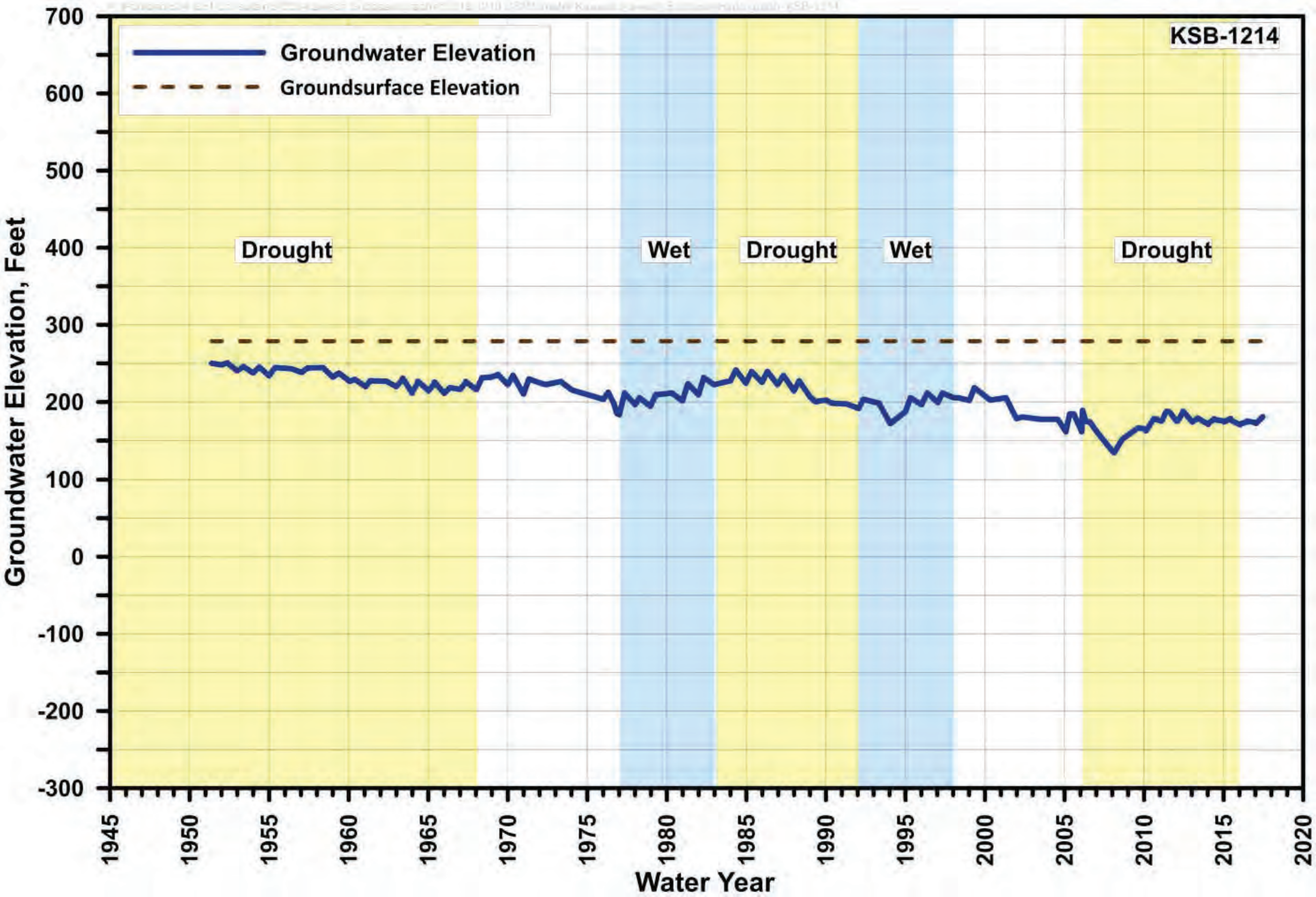

KSB-1214
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
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-100
-200
-300
1945
1950
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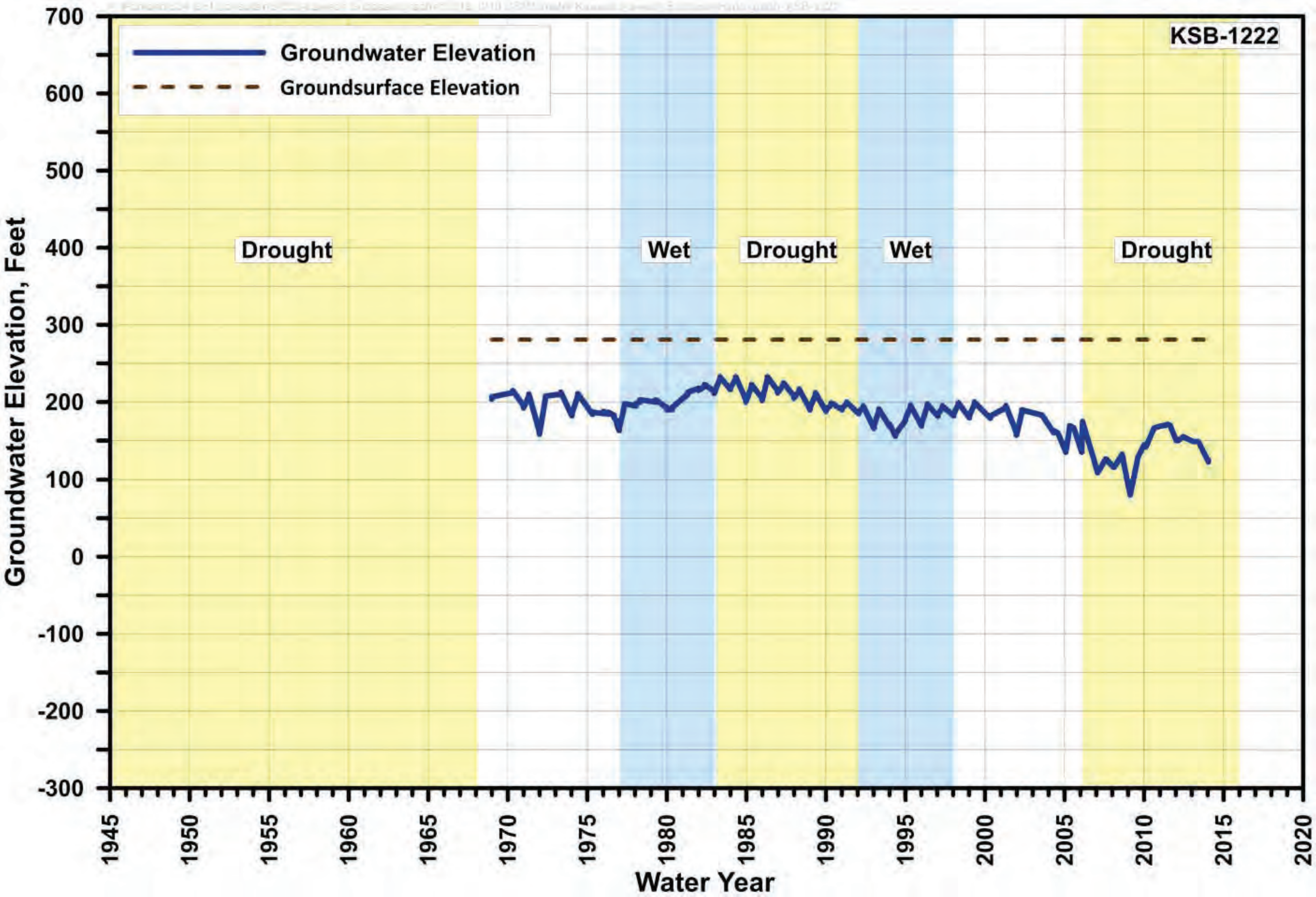
2010
2015
2020
Water Year



KSB-1222
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
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-100
-200
-300
1945
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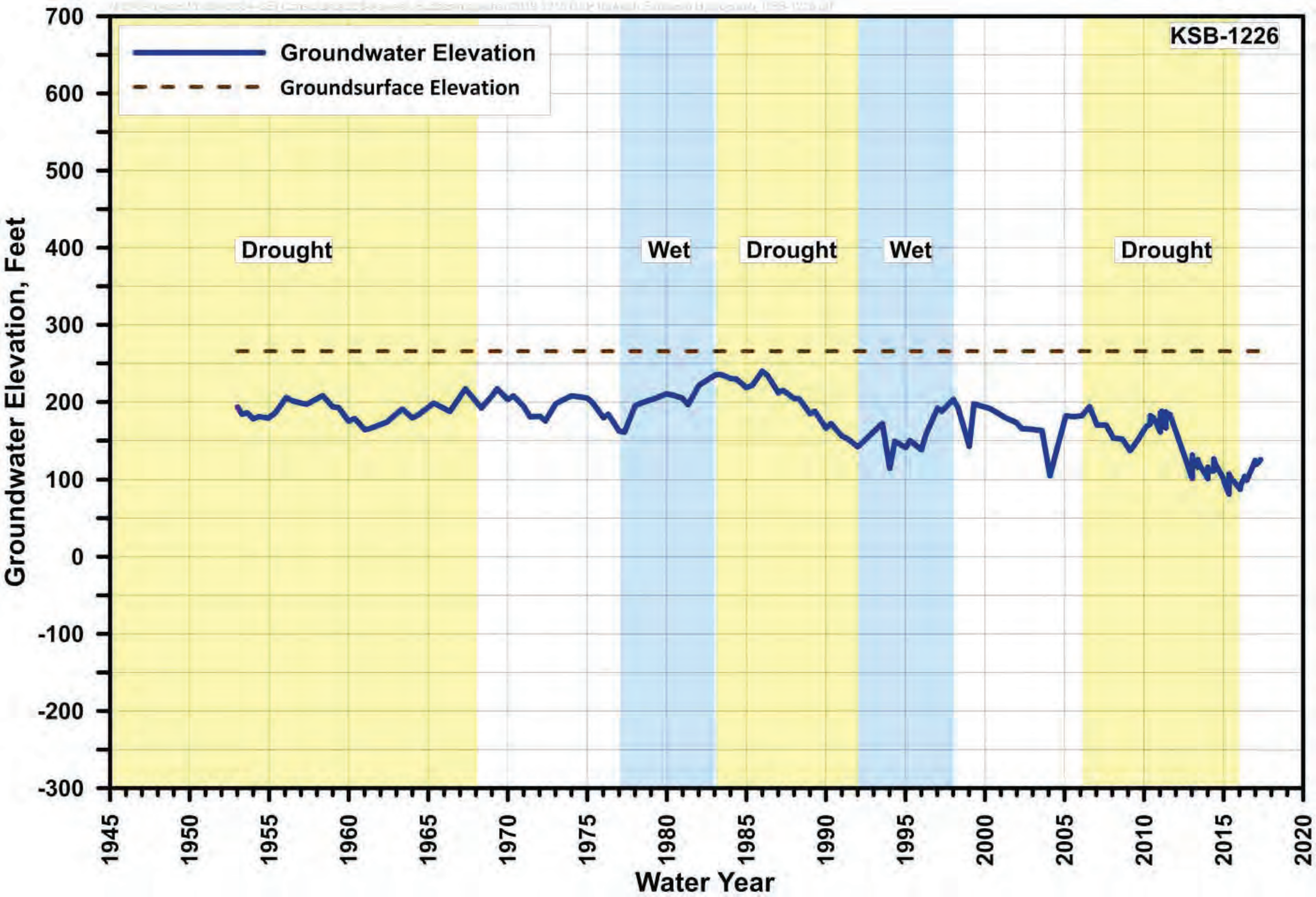
2010
2015
2020
Water Year



KSB-1226
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
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1945
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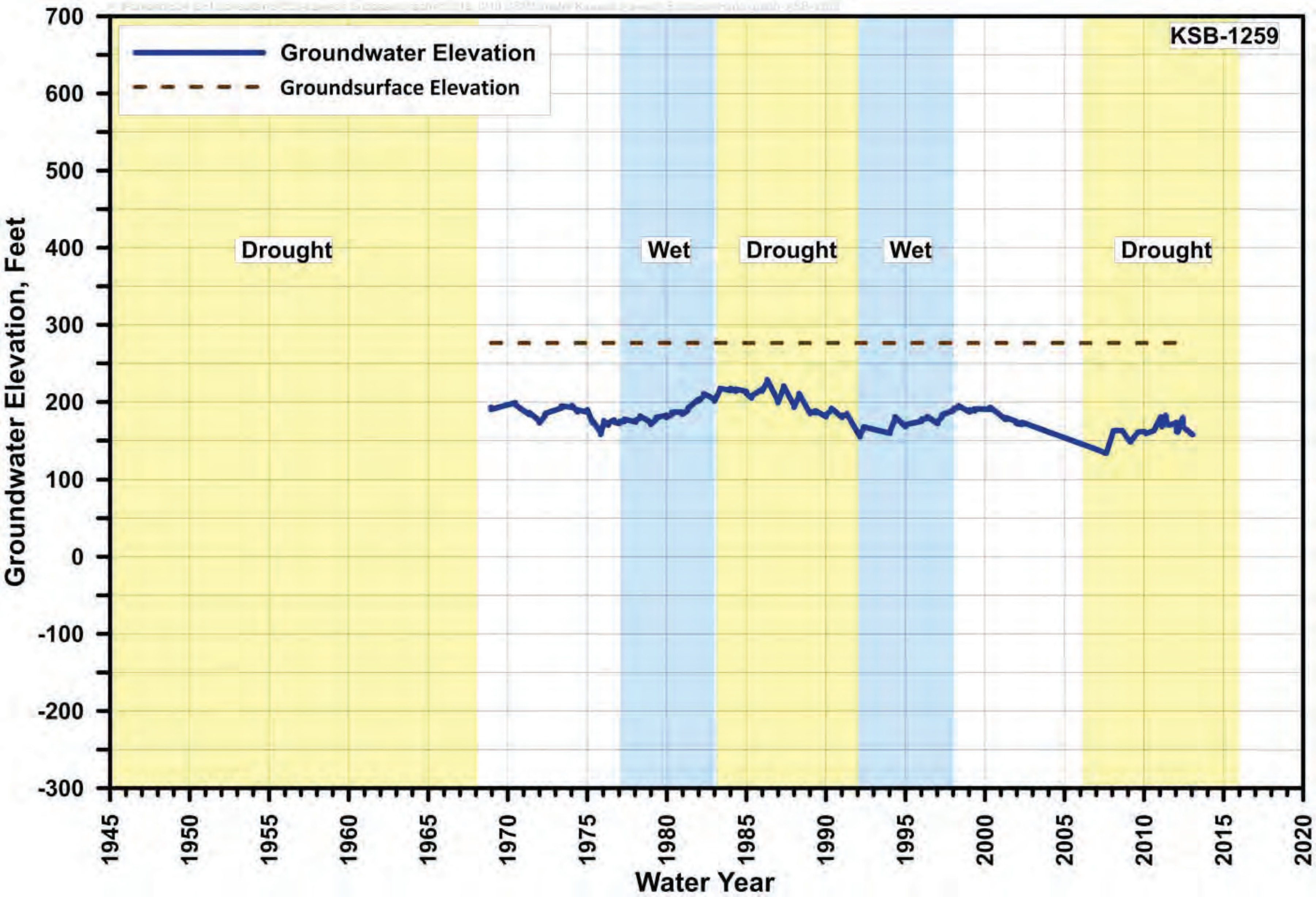
2015
2020
Water Year


KSB-1259
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
-200
-300
1945
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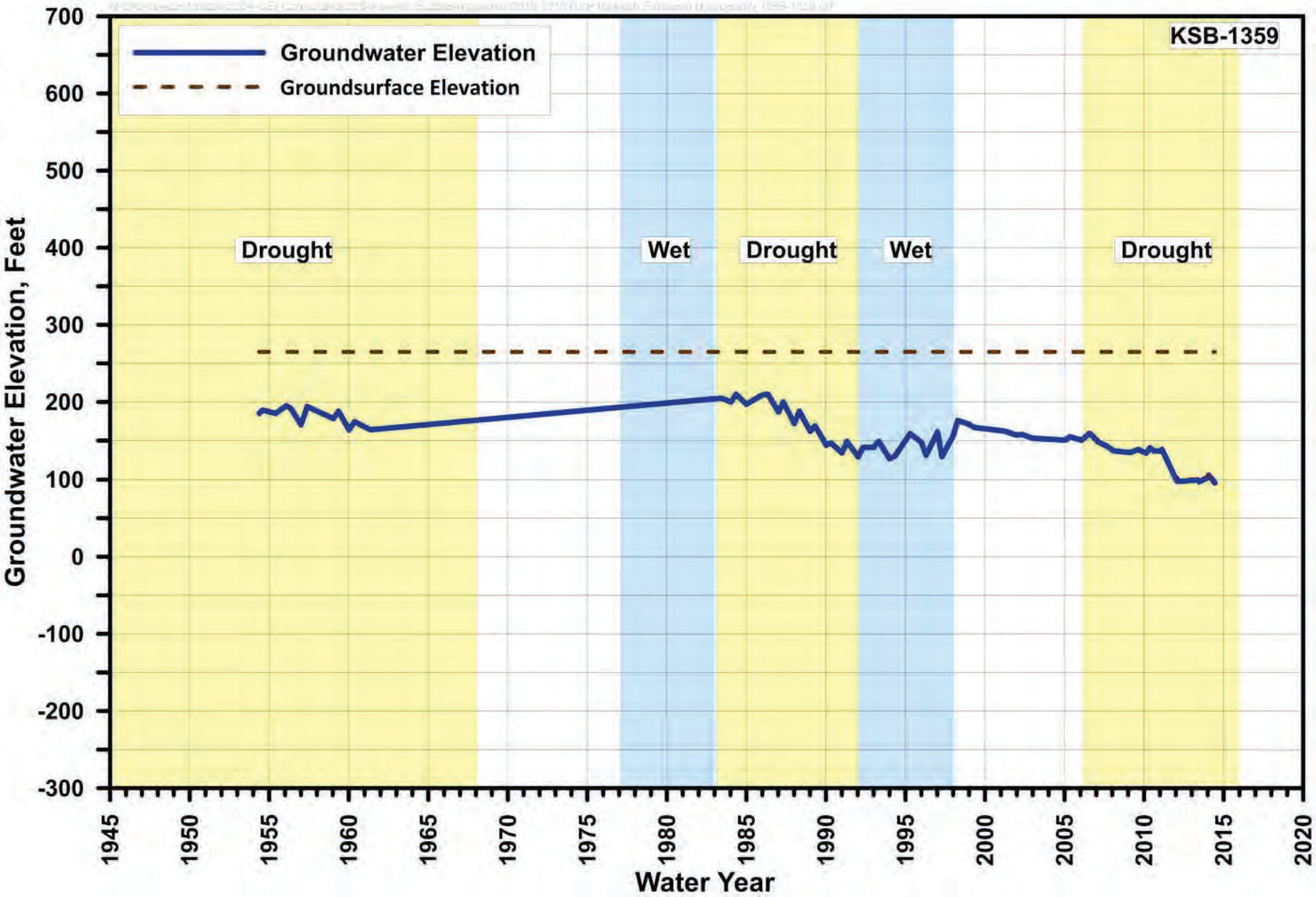

KSB-1359
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
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-100
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1945
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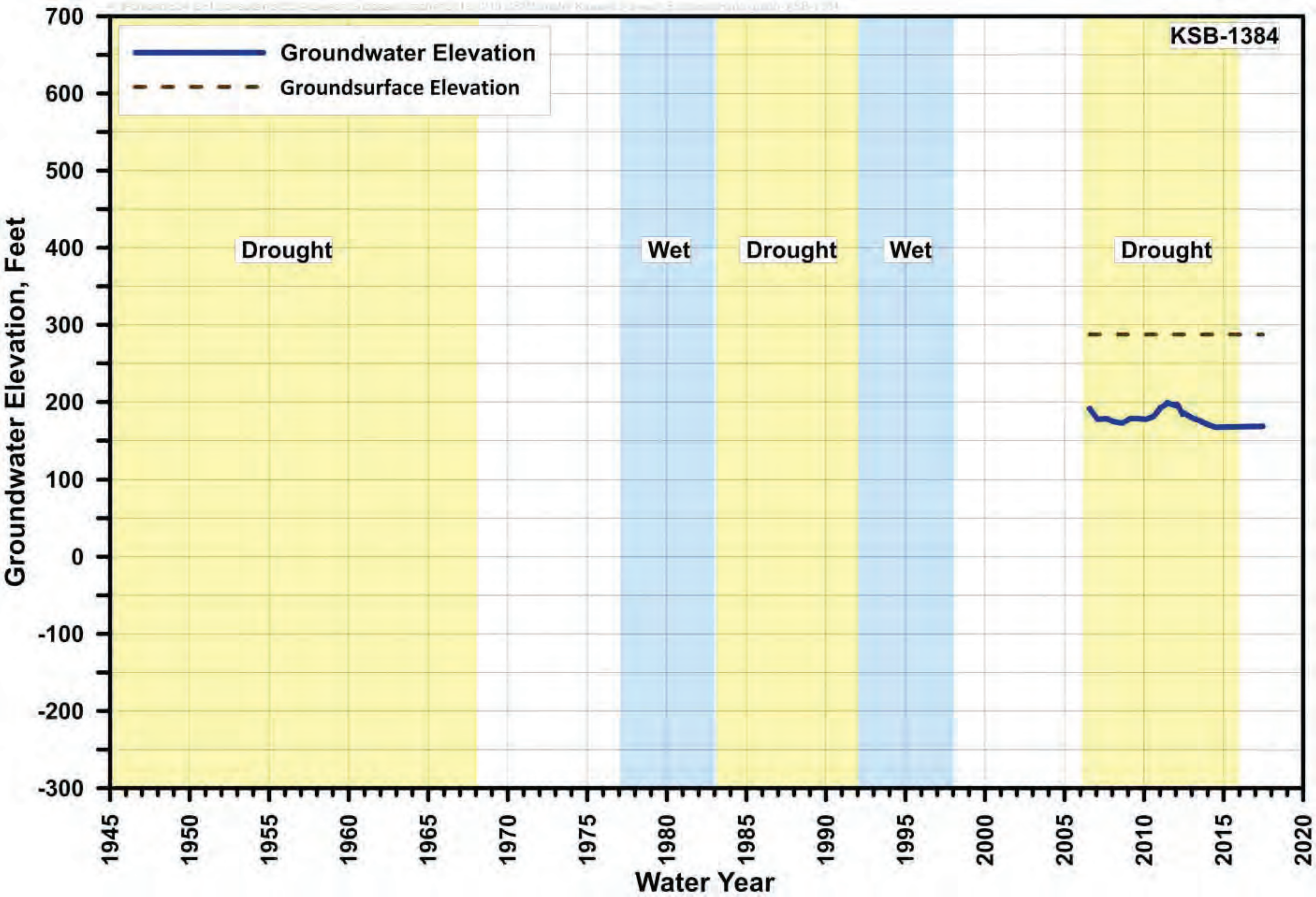
2015
2020
Water Year



KSB-1384
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
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-100
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1945
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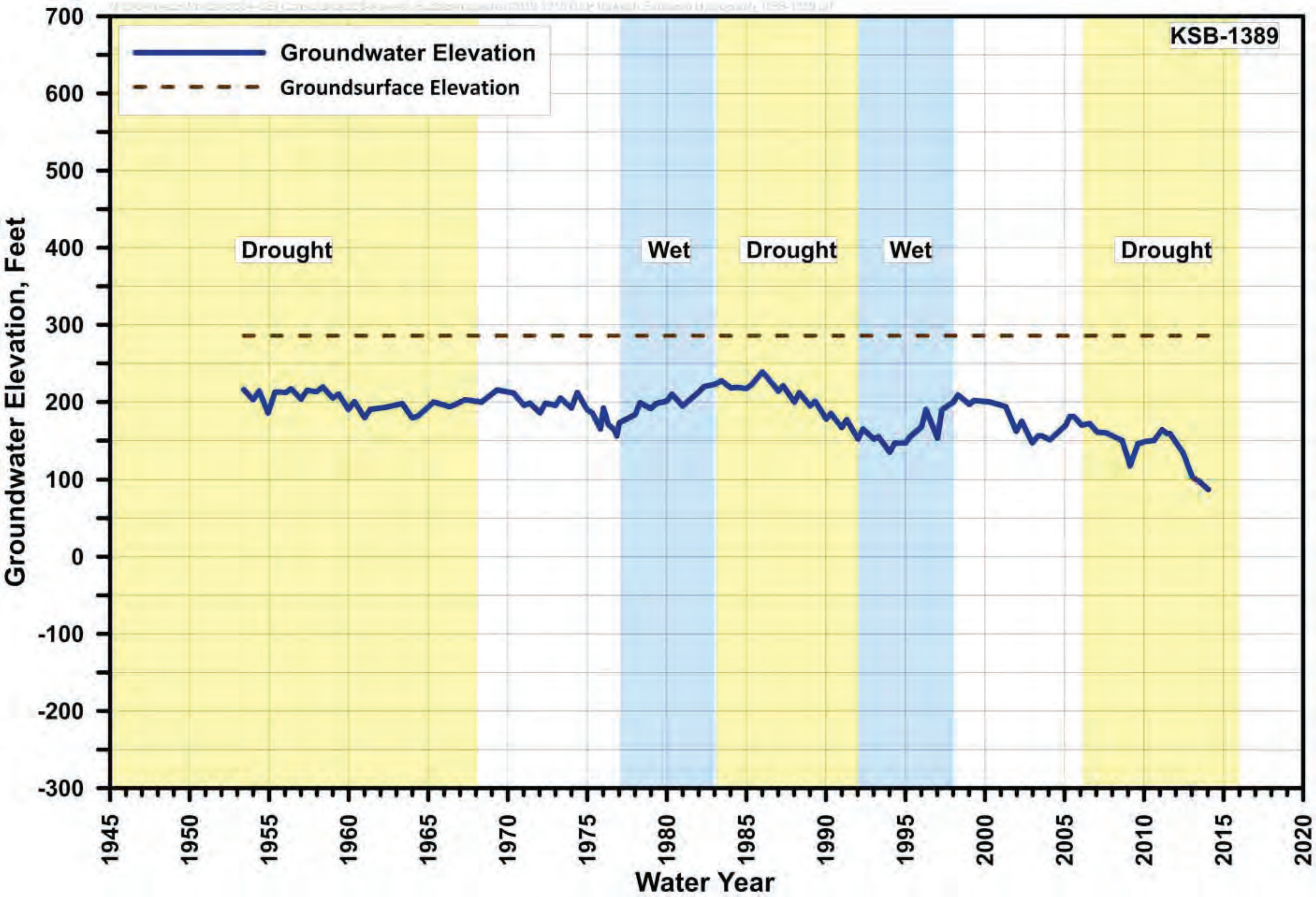

KSB-1389
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
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1945
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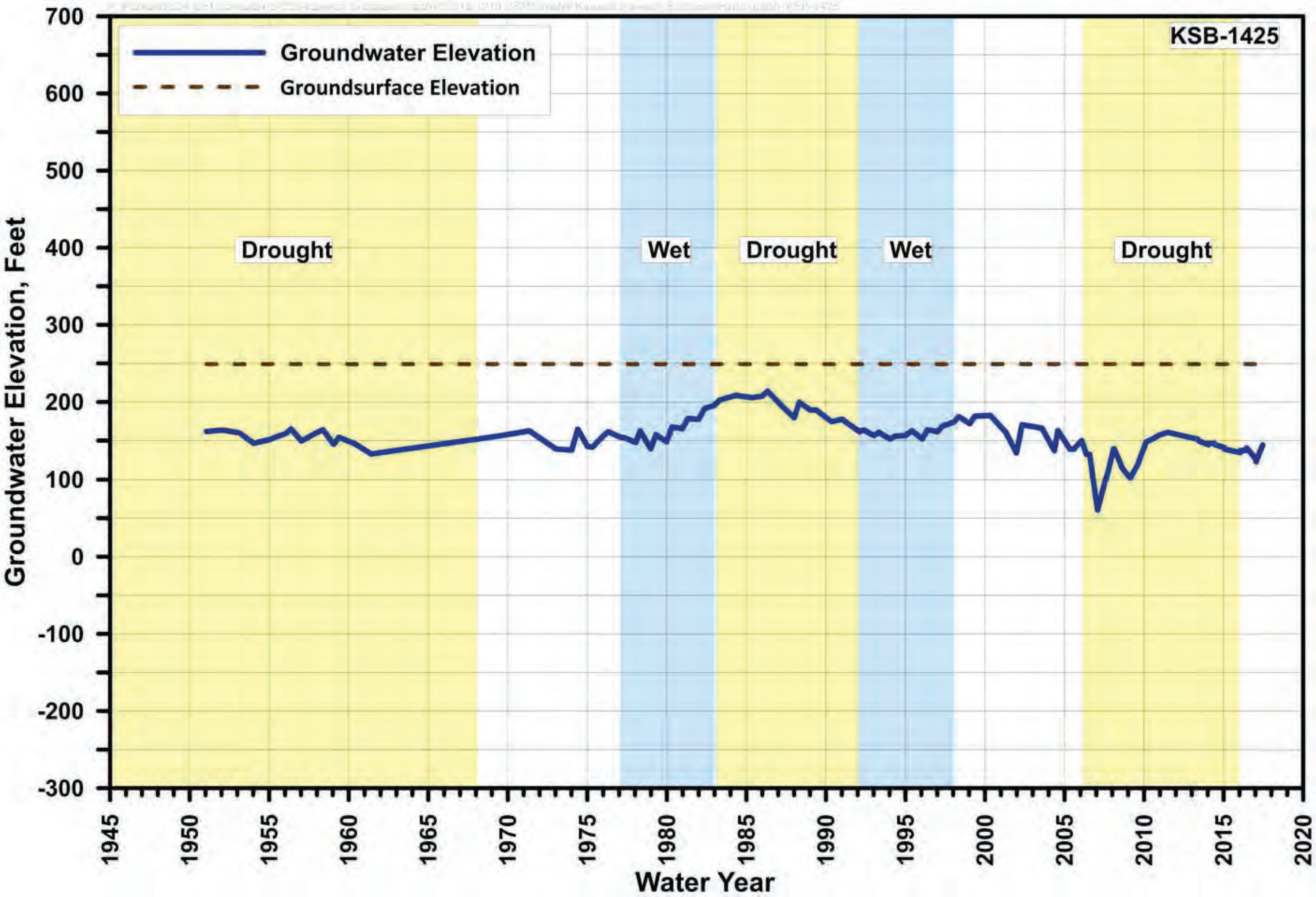
KSB-1425
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
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-100
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1945
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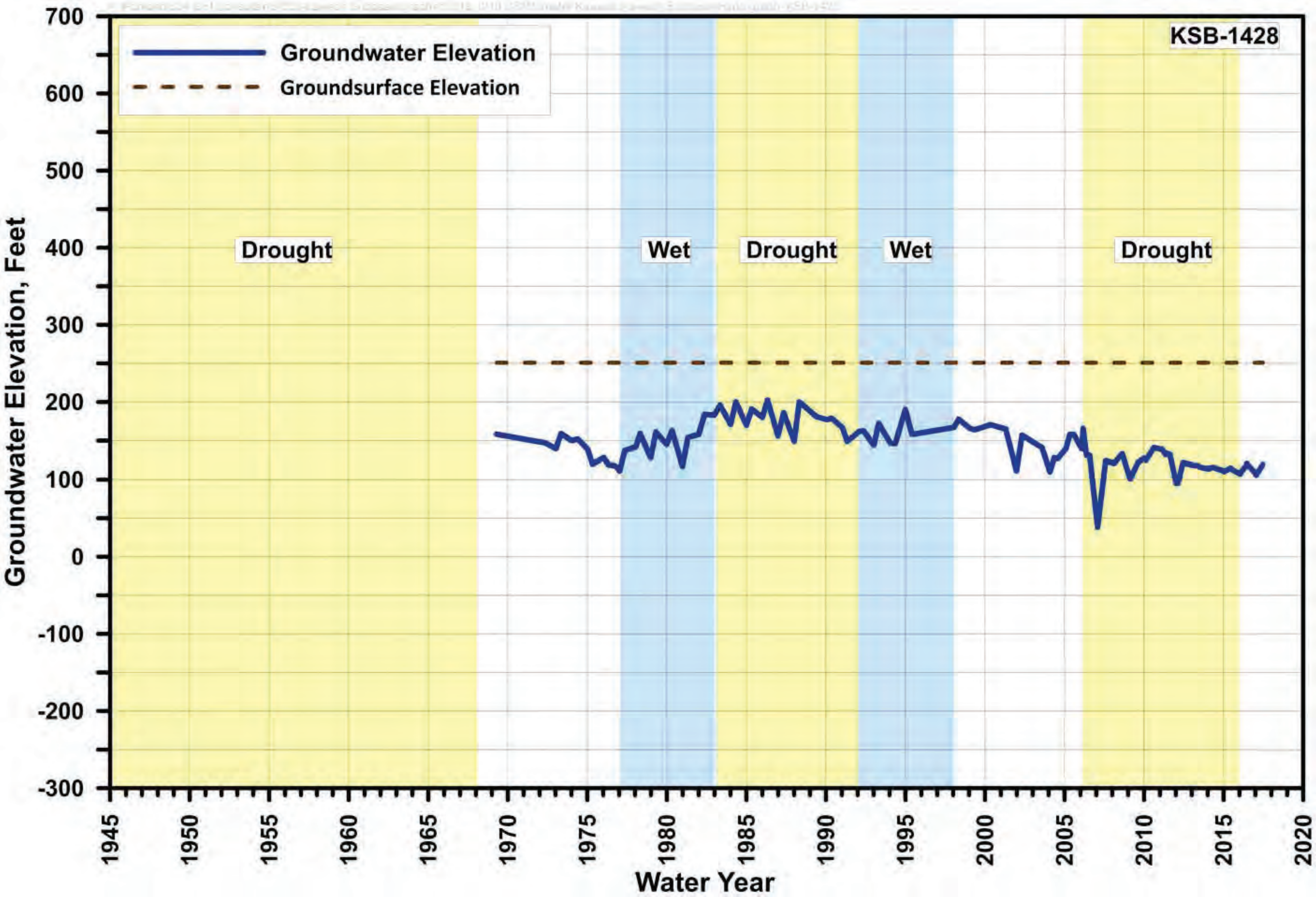

KSB-1428
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
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100
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1945
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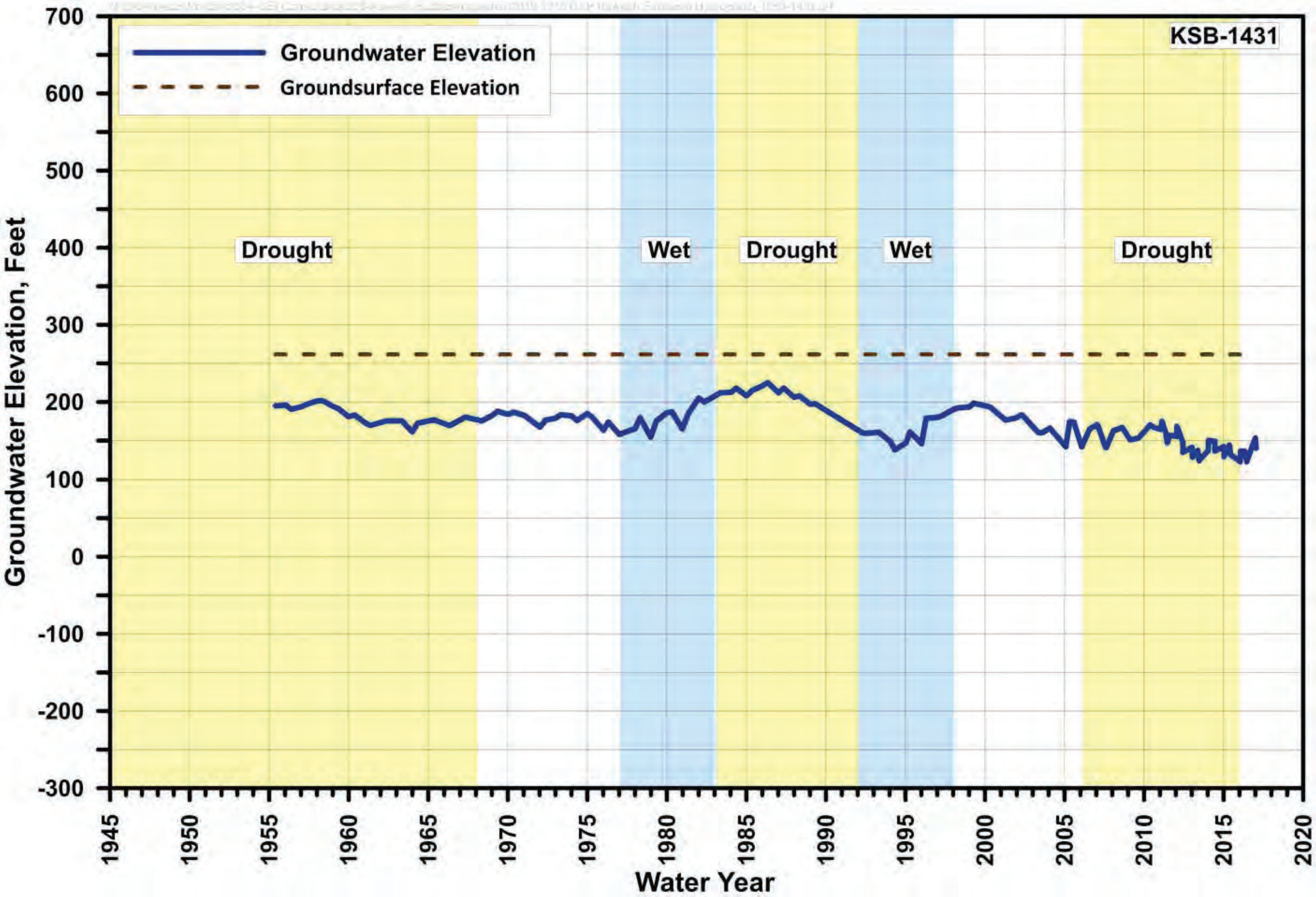
2015
2020
Water Year



KSB-1431
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
700
600
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400
300
200
100
0
-100
-200
-300
Groundwater Elevation, Feet
1945
1950
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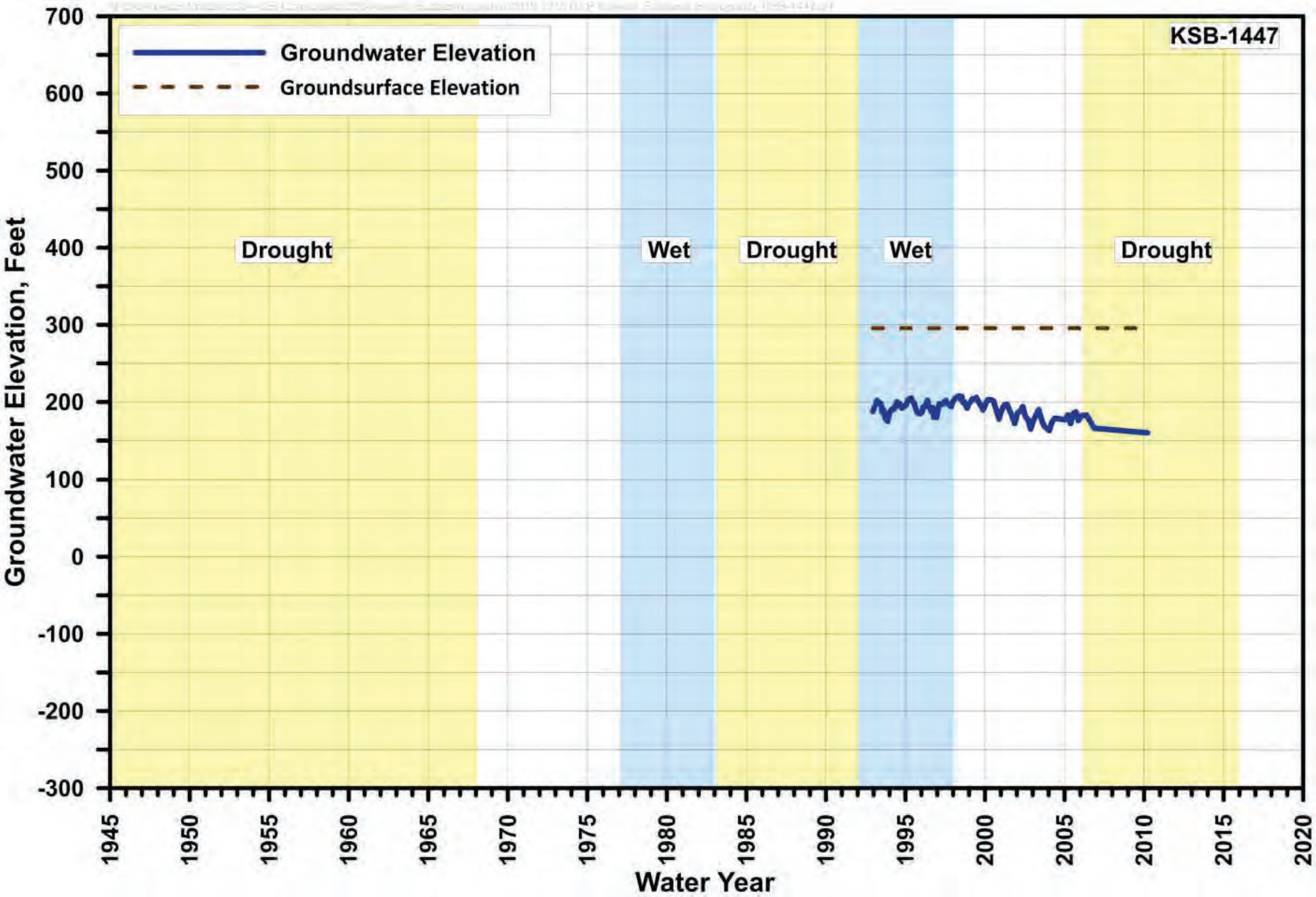
2010
2015
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-1447
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
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300
200
100
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-100
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-300
1945
1950
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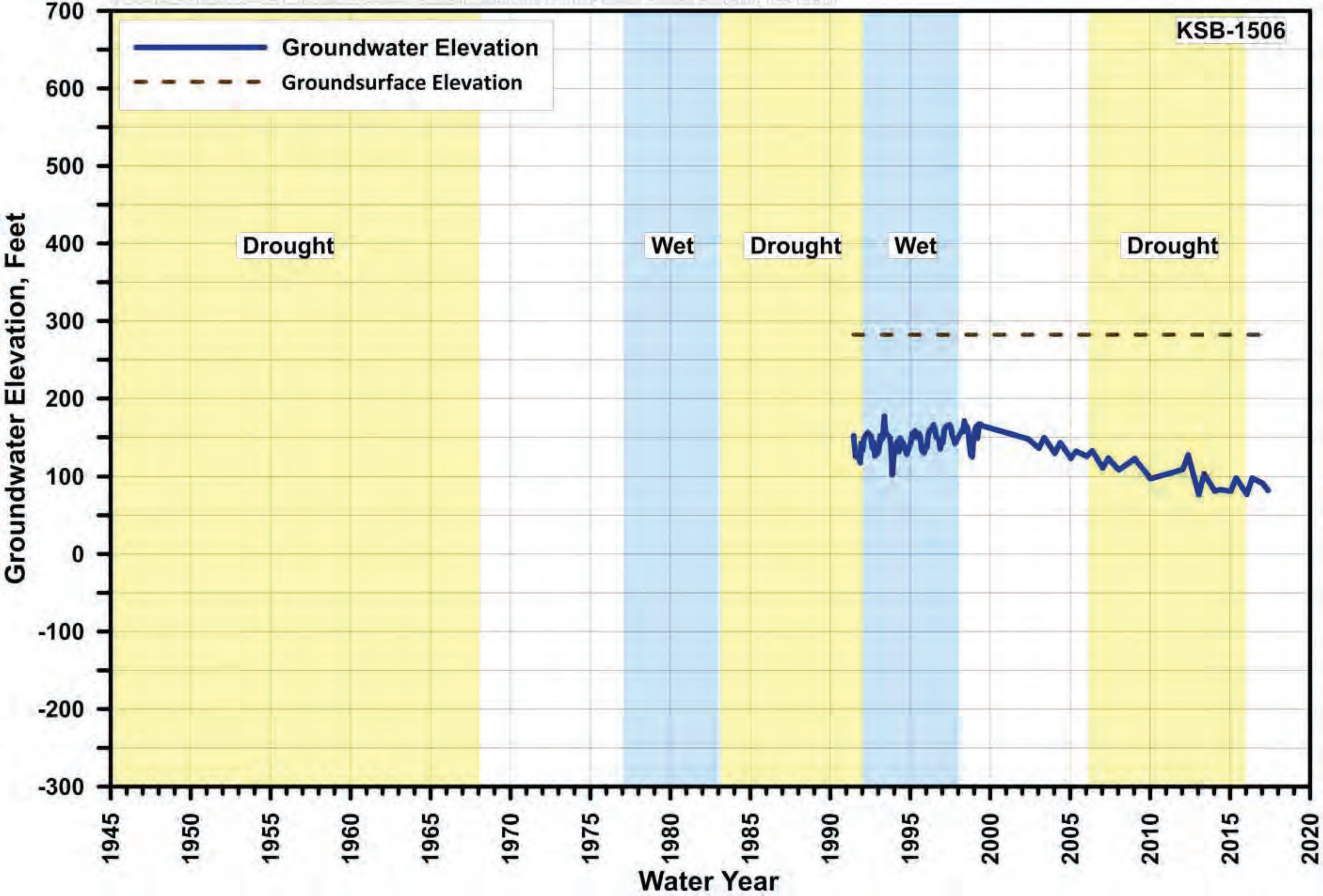
2015
2020
Water Year



KSB-1506
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
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1945
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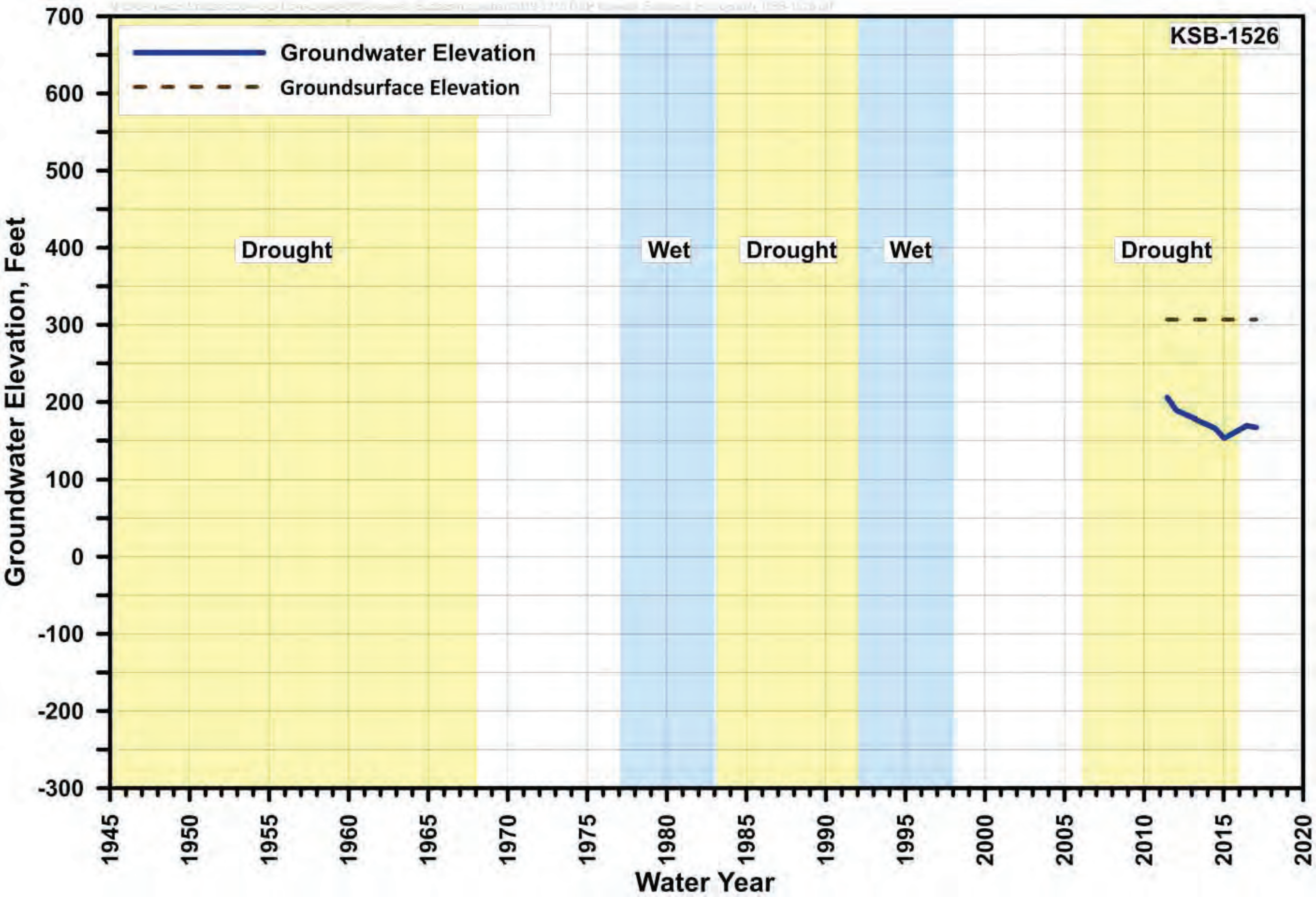
KSB-1526
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
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1945
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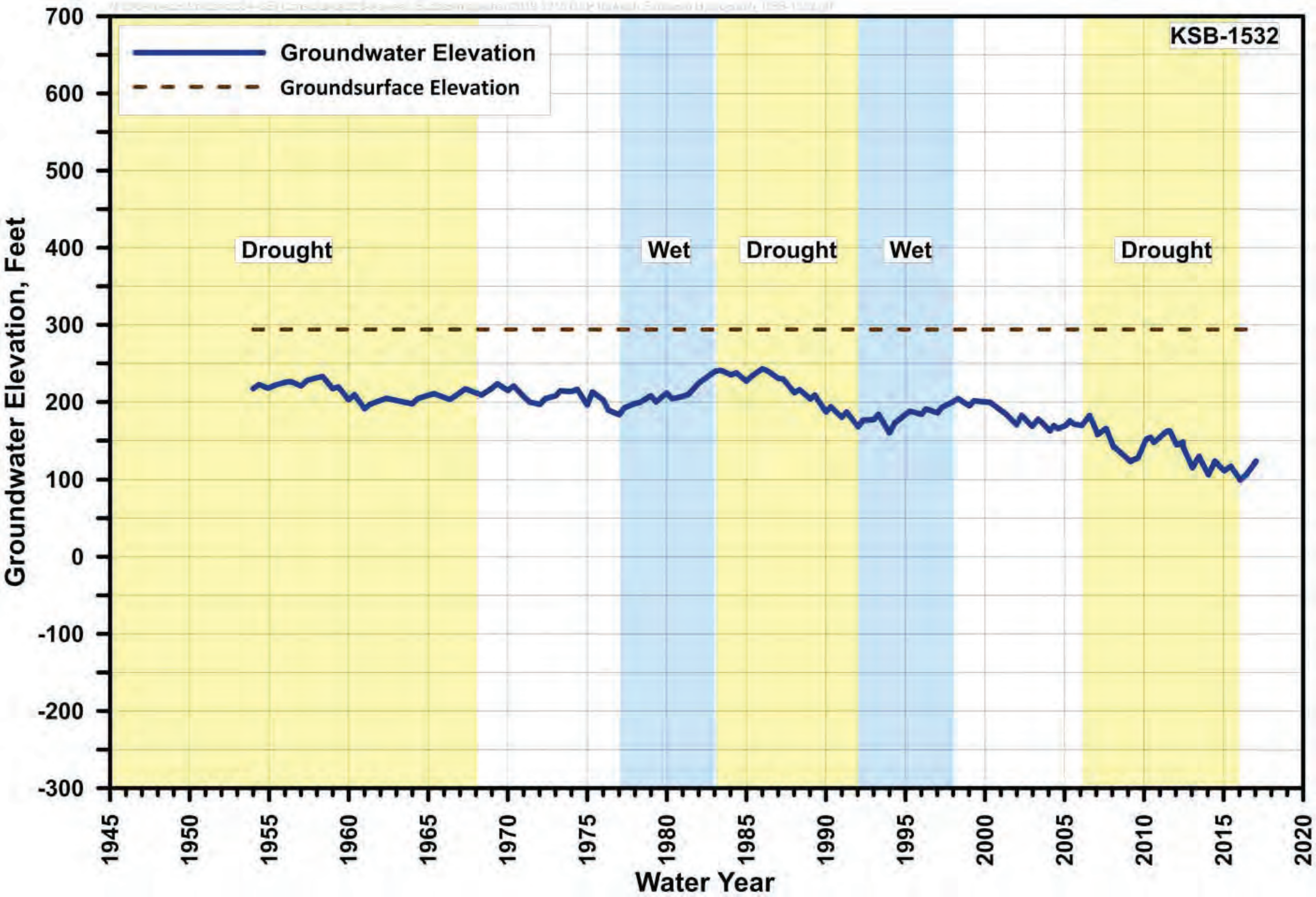
KSB-1532
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
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300
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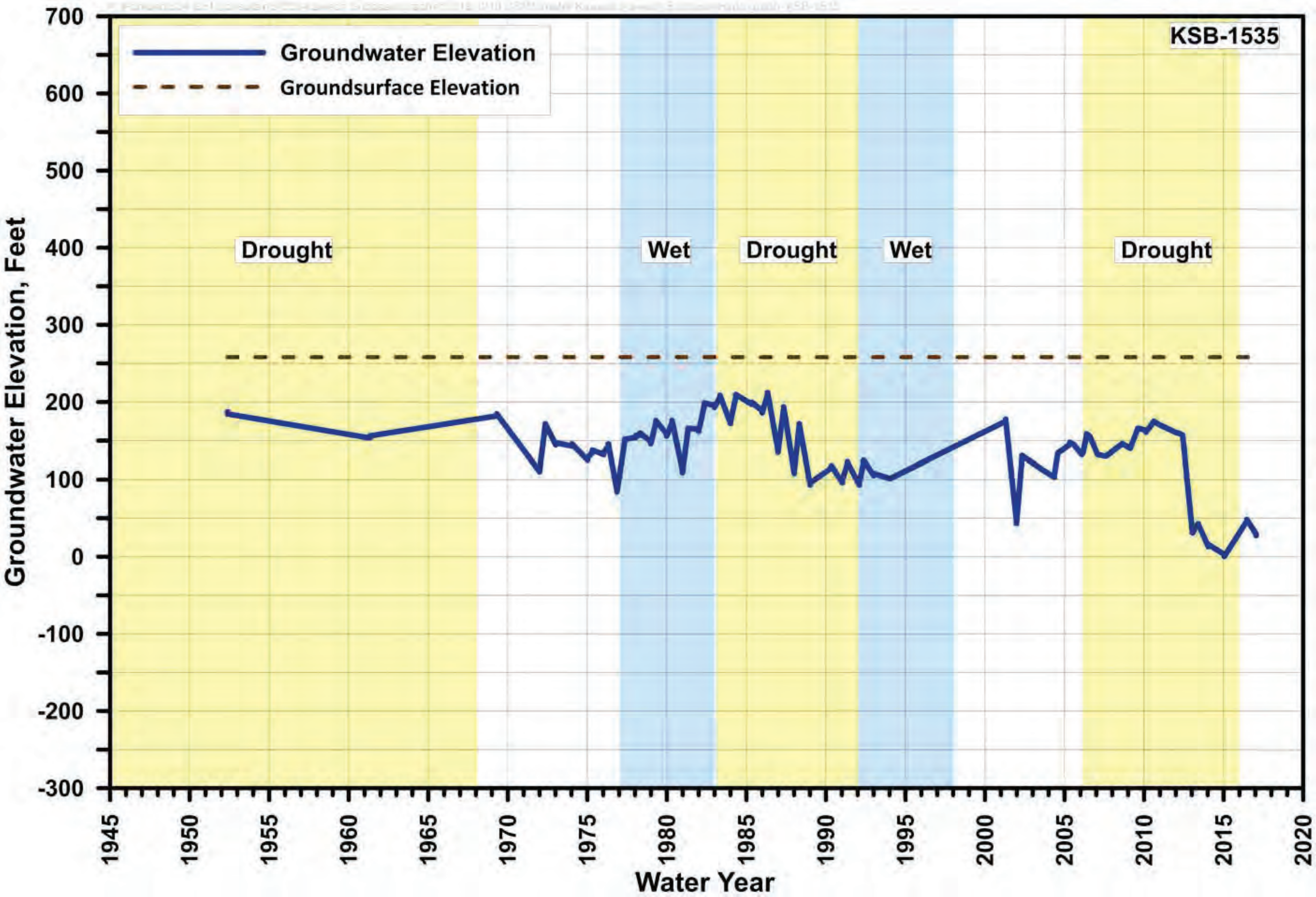
Water Year



KSB-1535
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
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100
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1945
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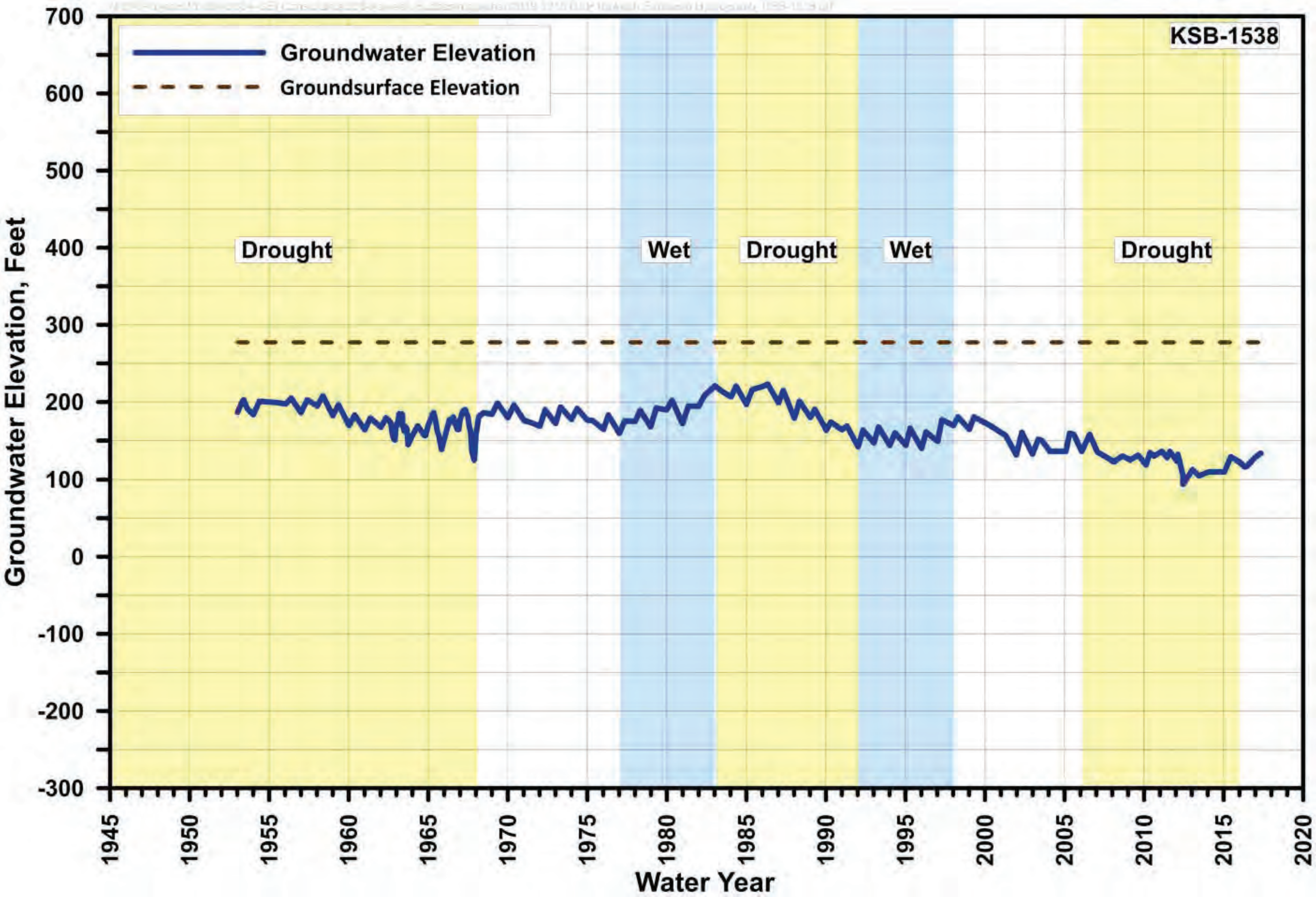
KSB-1538
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
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200
100
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-100
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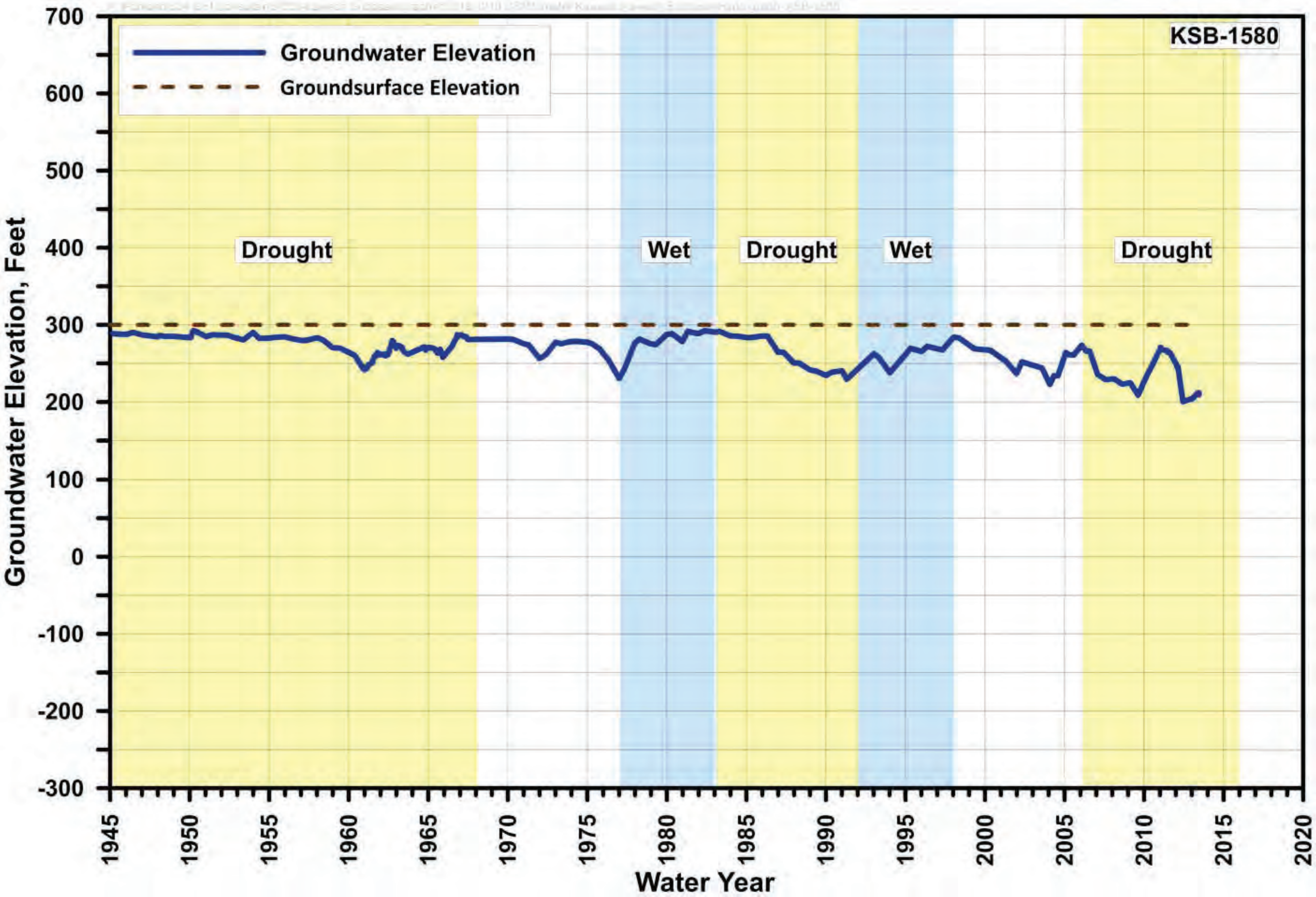
2020
Water Year



KSB-1580
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
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1945
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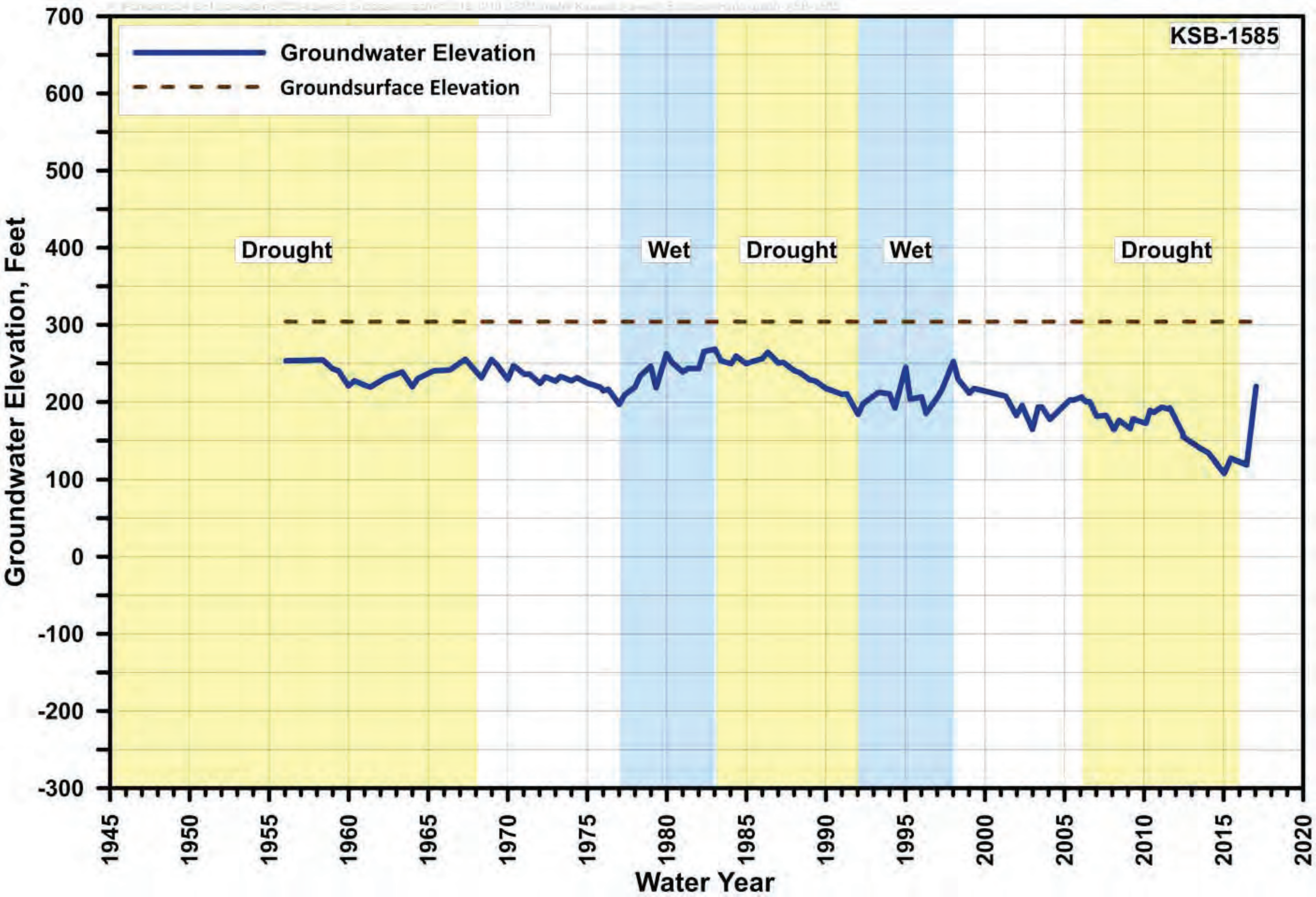
2020
Water Year



KSB-1585
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
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300
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1945
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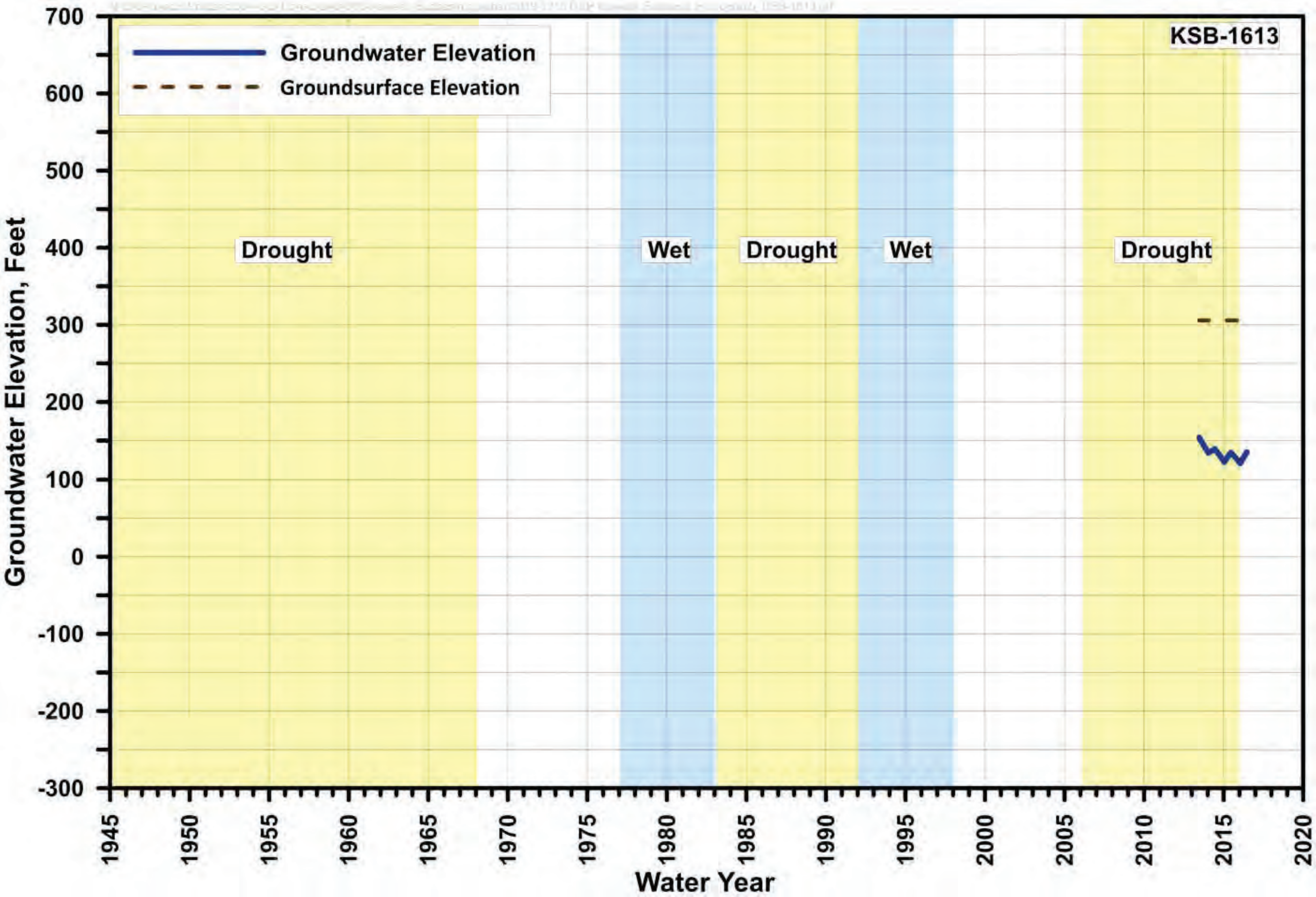
2020
Water Year


KSB-1613
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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400
300
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Water Year
1945
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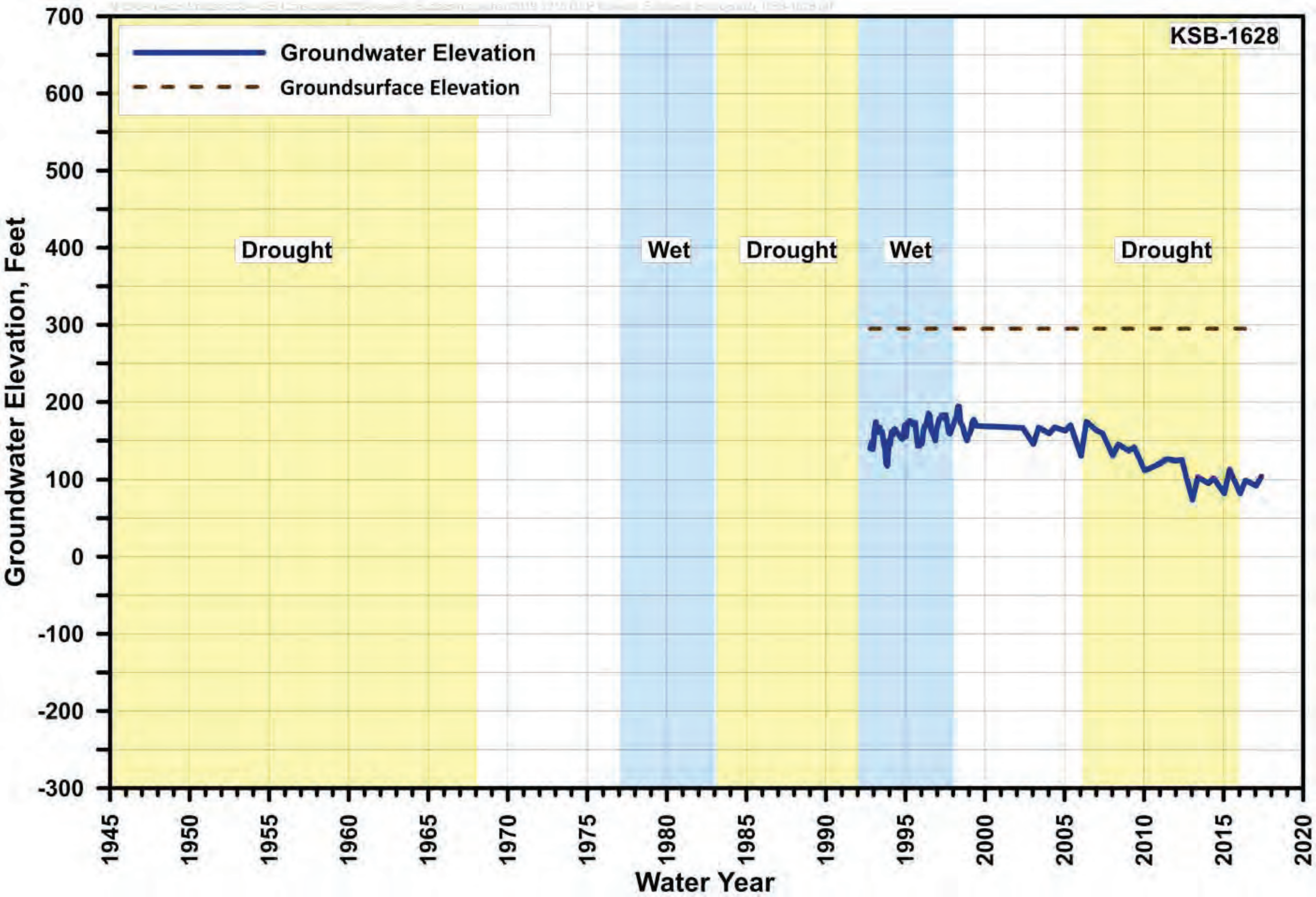

Groundwater Elevation
Groundsurface Elevation
KSB-1628
Drought
Wet
Drought
Wet
Drought
700
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500
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200
100
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-100
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-300
Groundwater Elevation, Feet
1945
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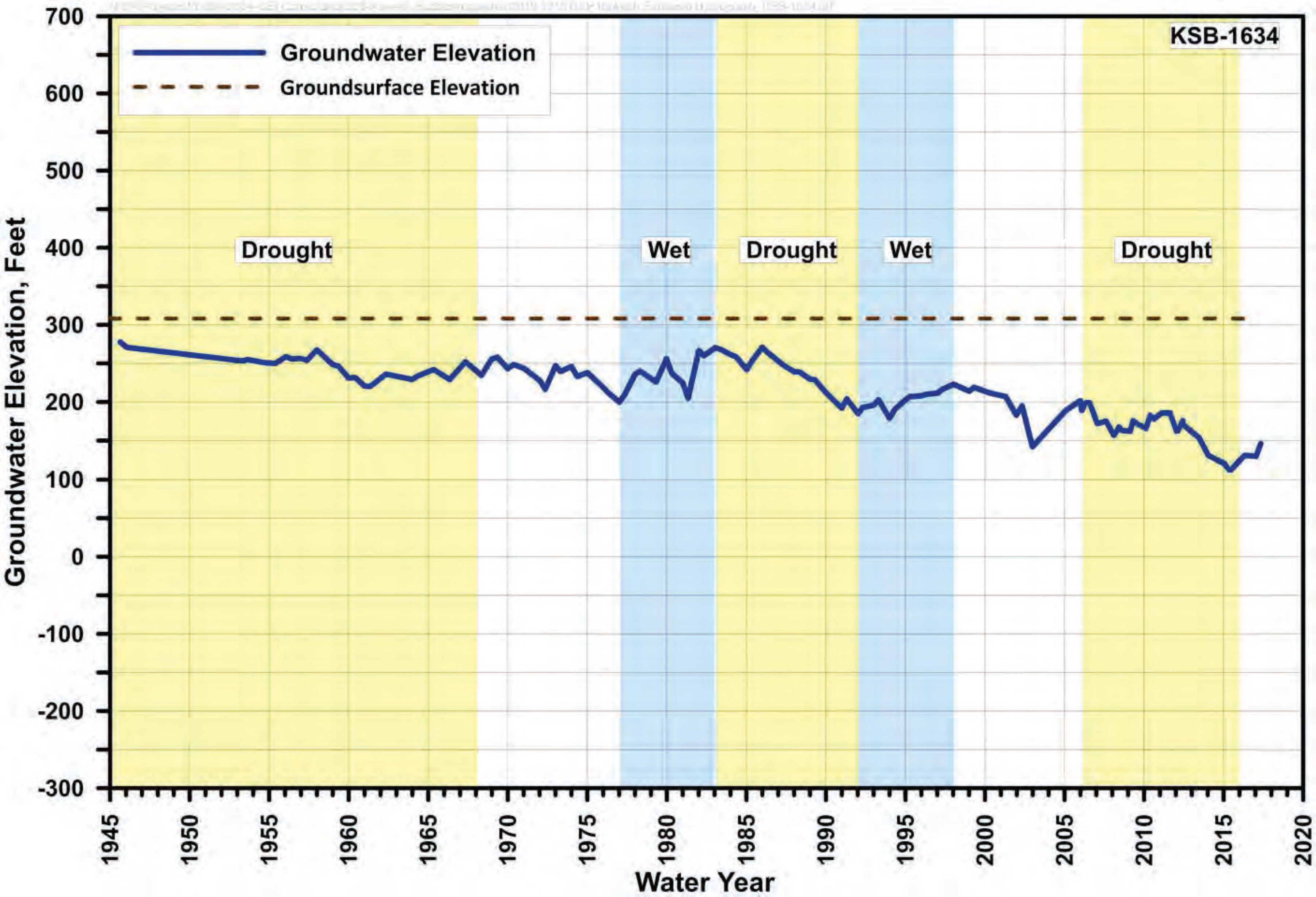
2015
2020
Water Year


KSB-1634
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
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1945
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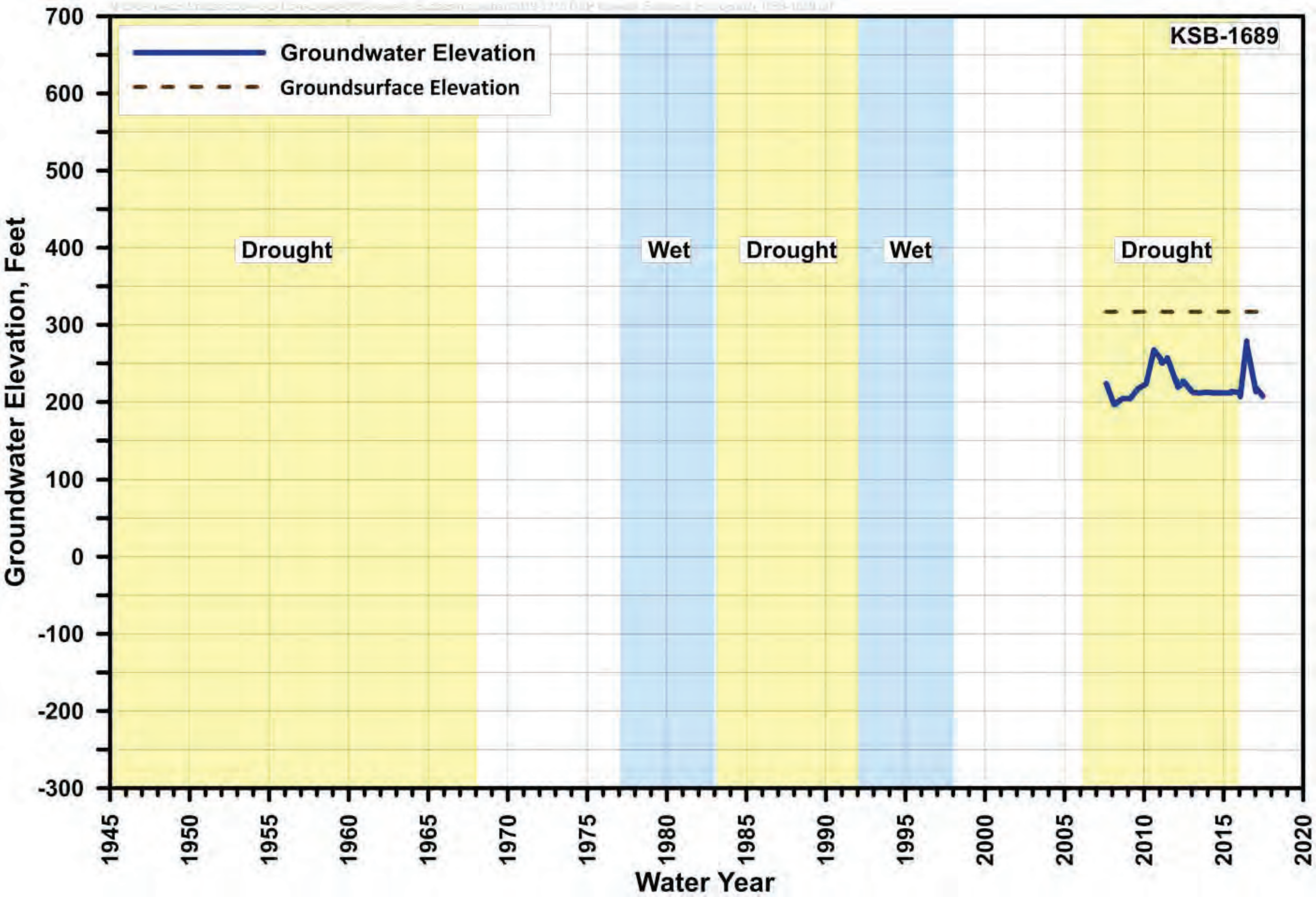

KSB-1689
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
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-100
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-300
1945
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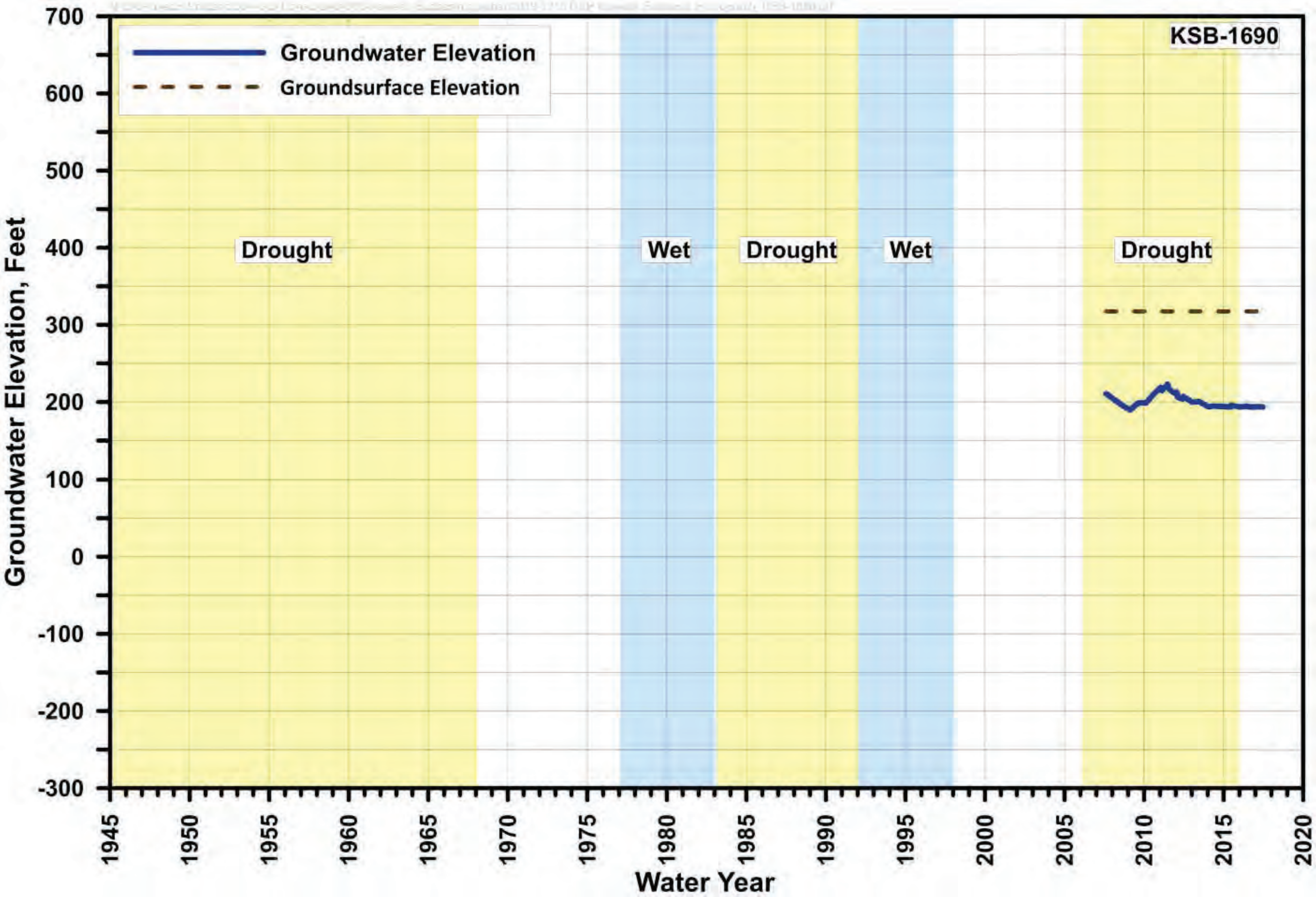
2020
Water Year



KSB-1690
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
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400
300
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1945
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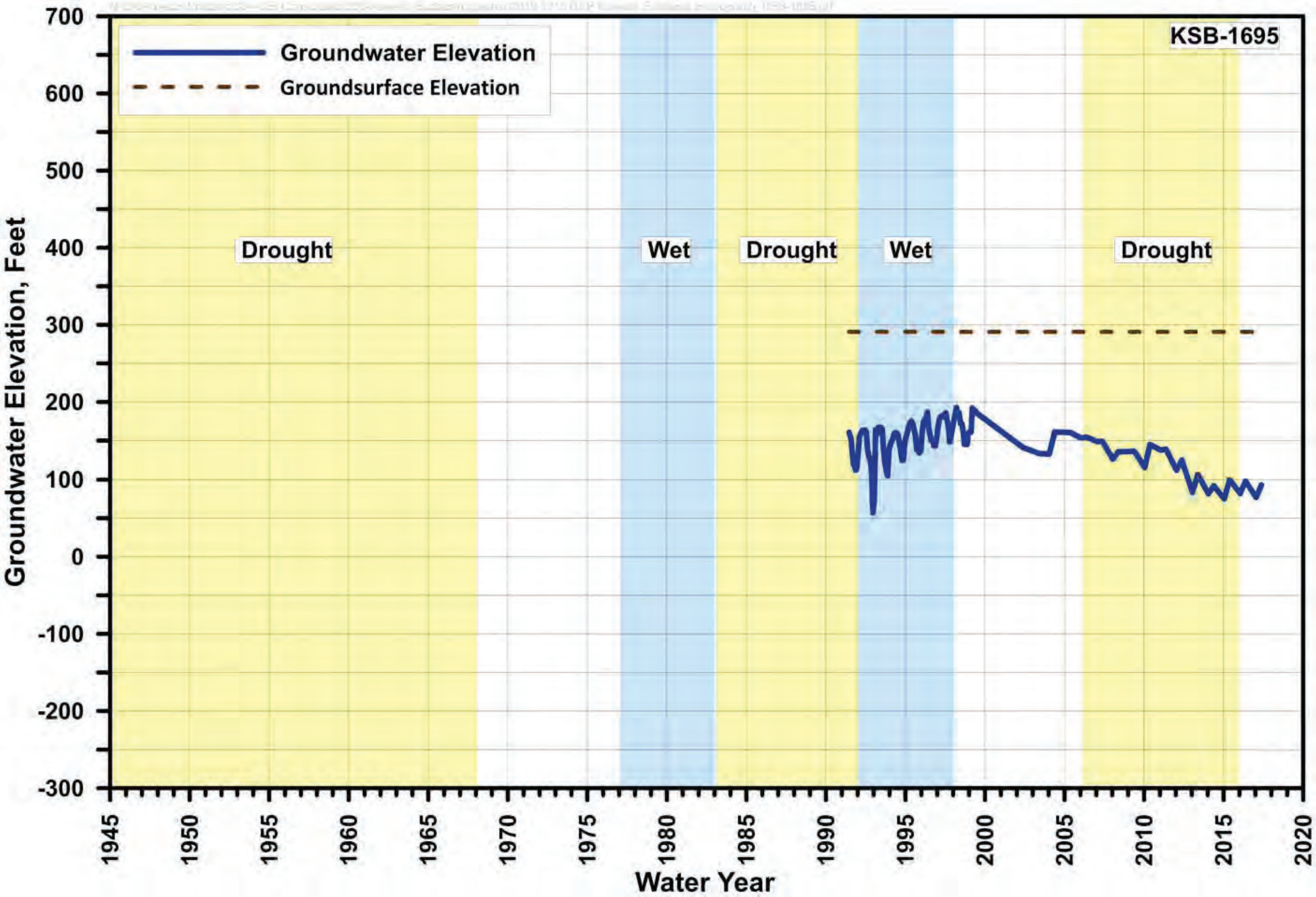
2020
Water Year


KSB-1695
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
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1945
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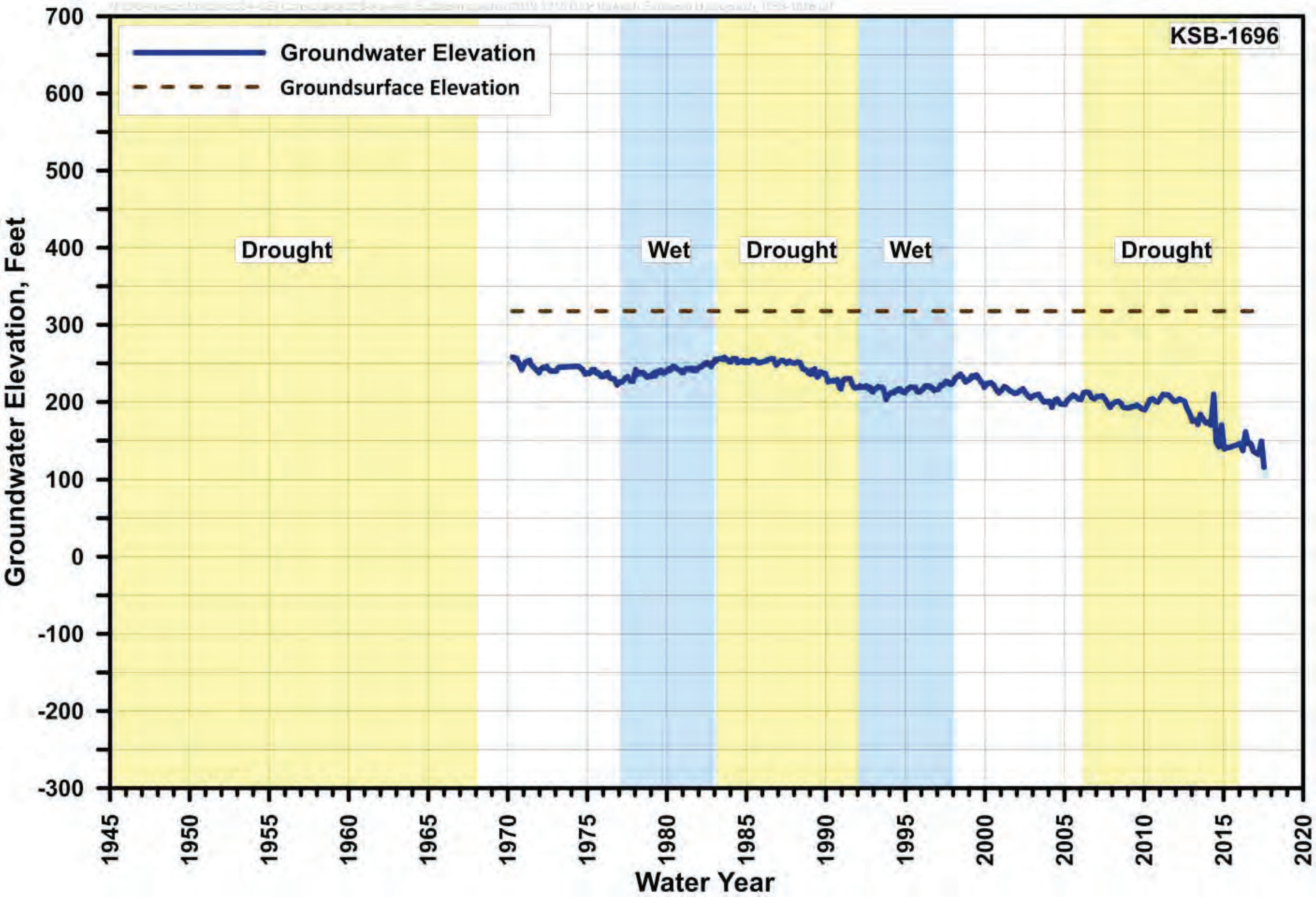

KSB-1696
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
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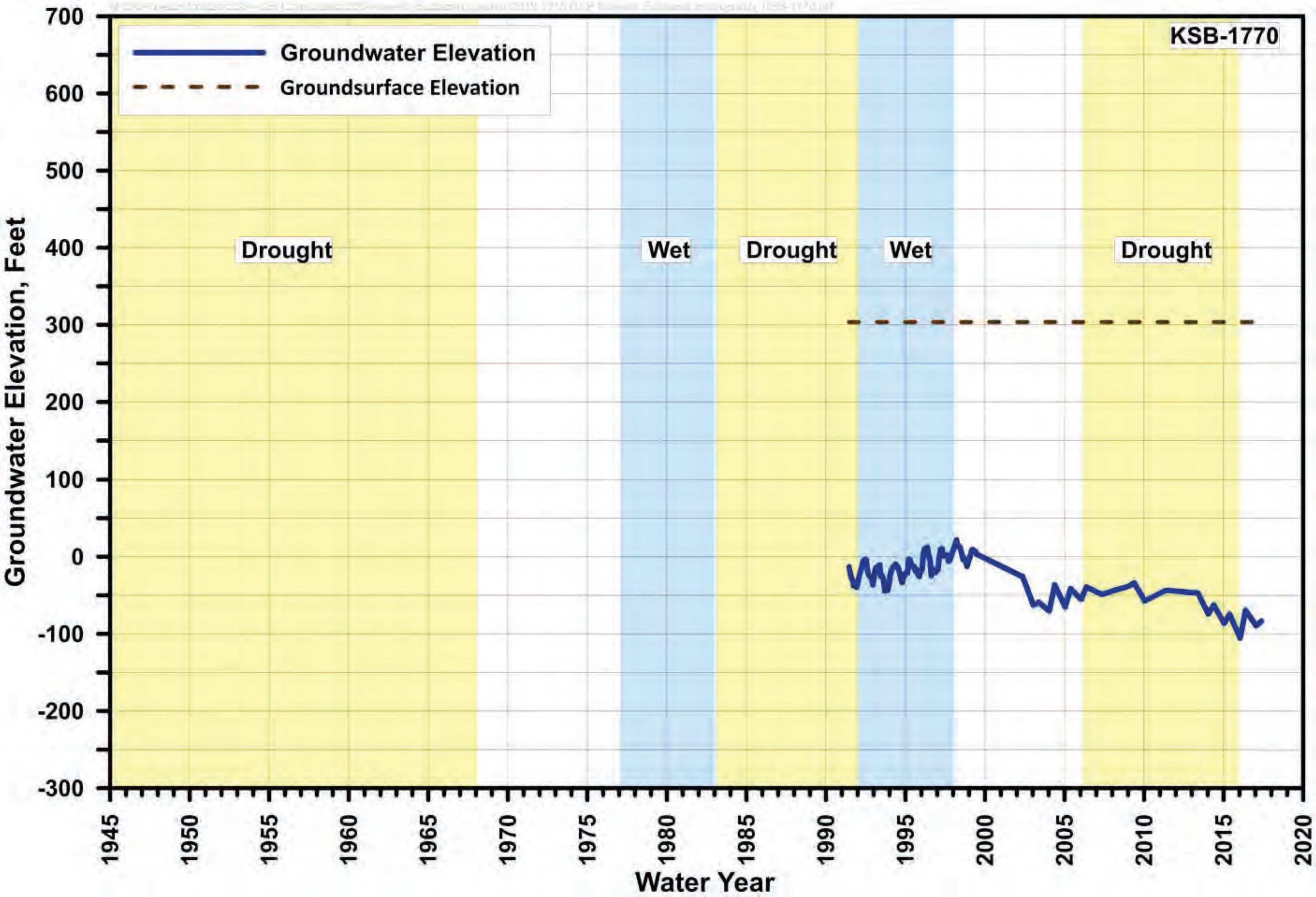
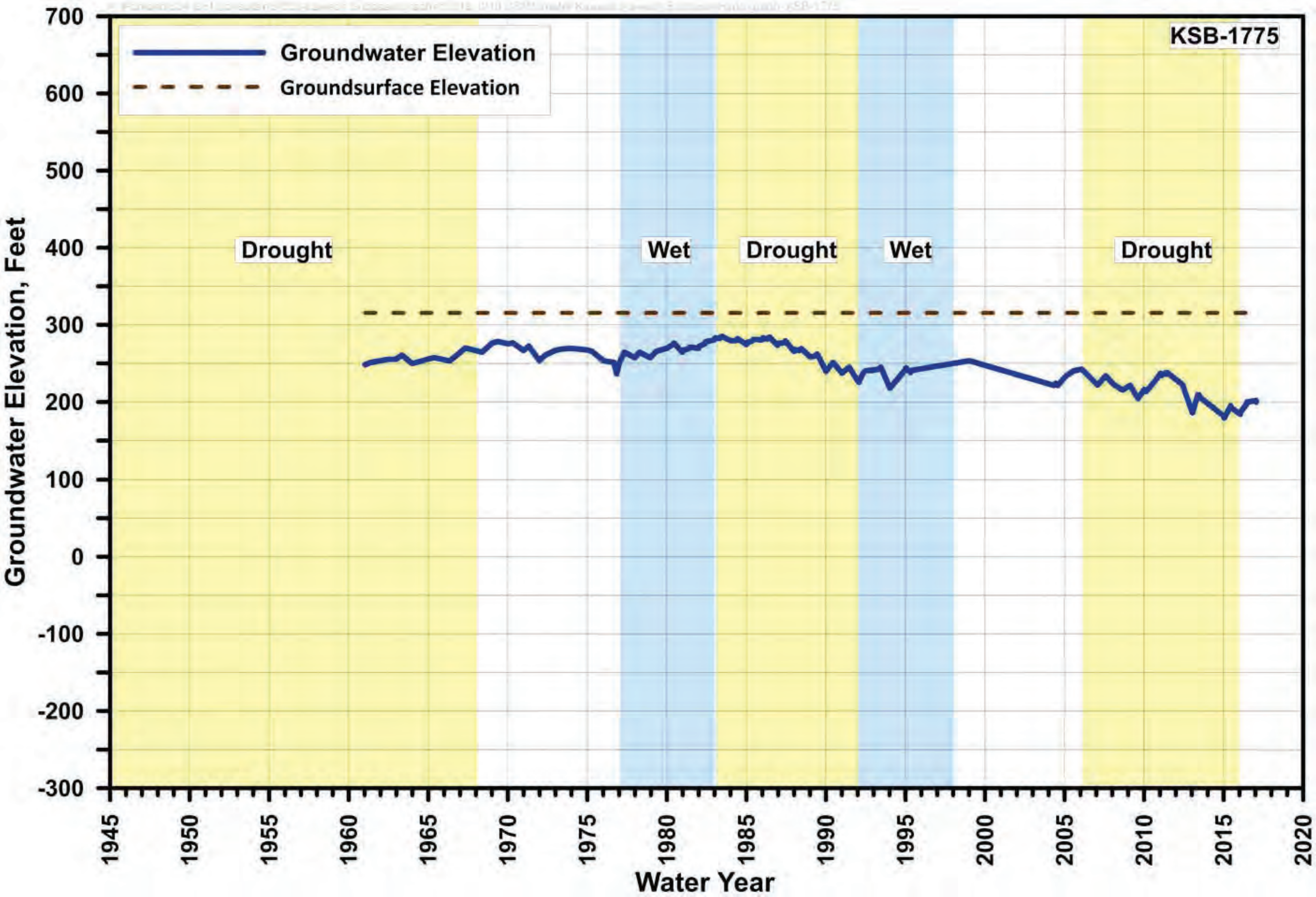
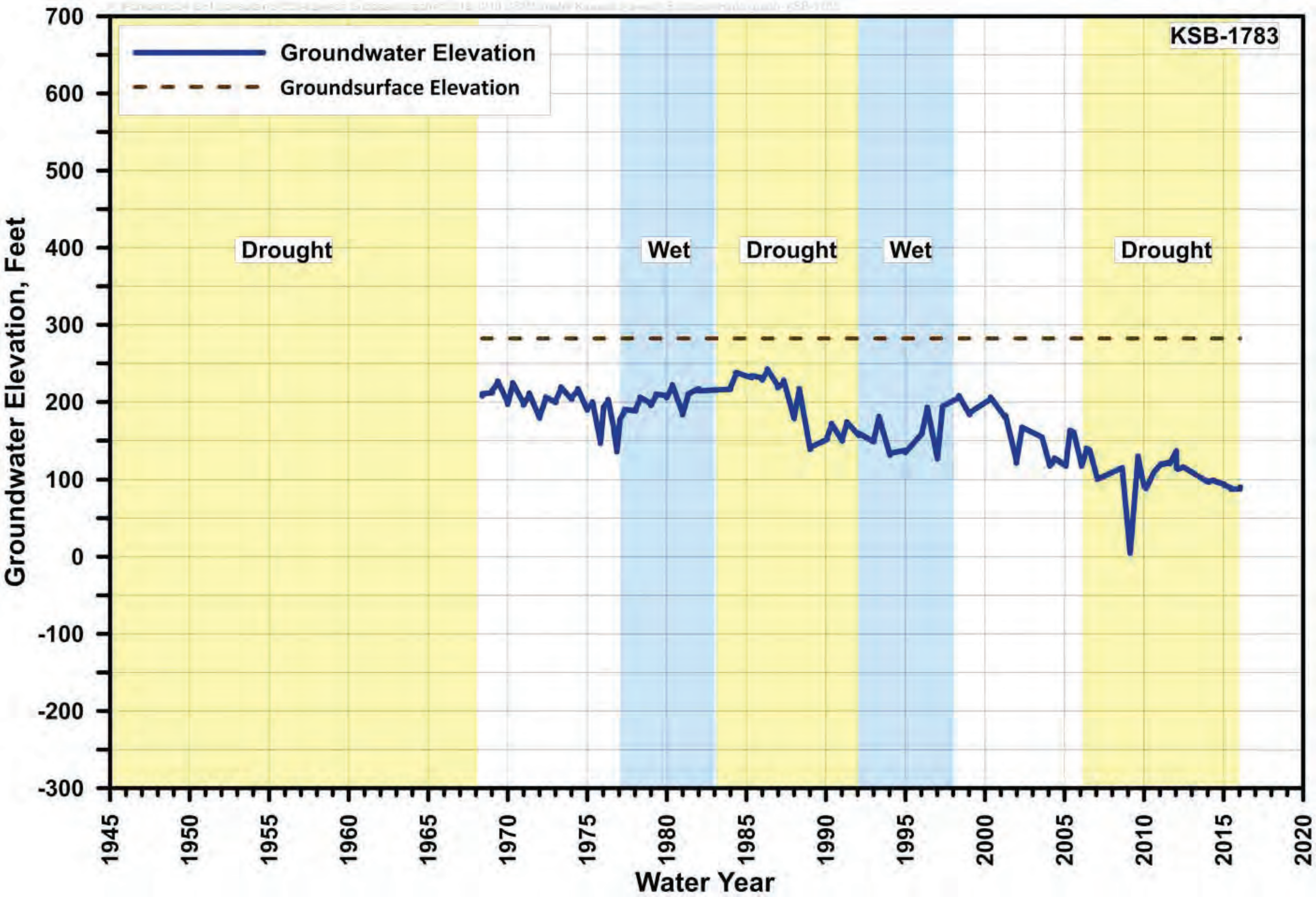
2020
Water Year



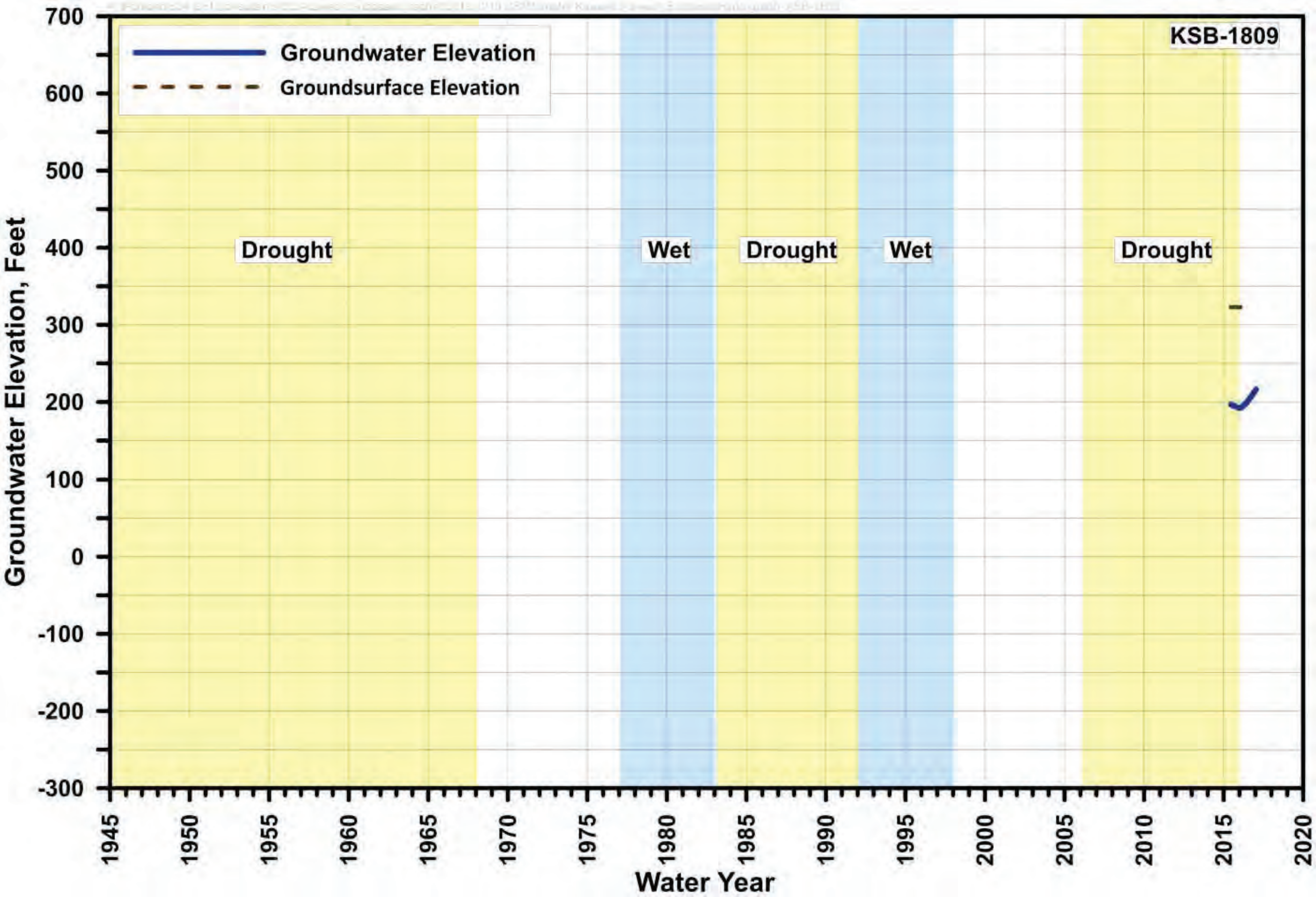
KSB-1770
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



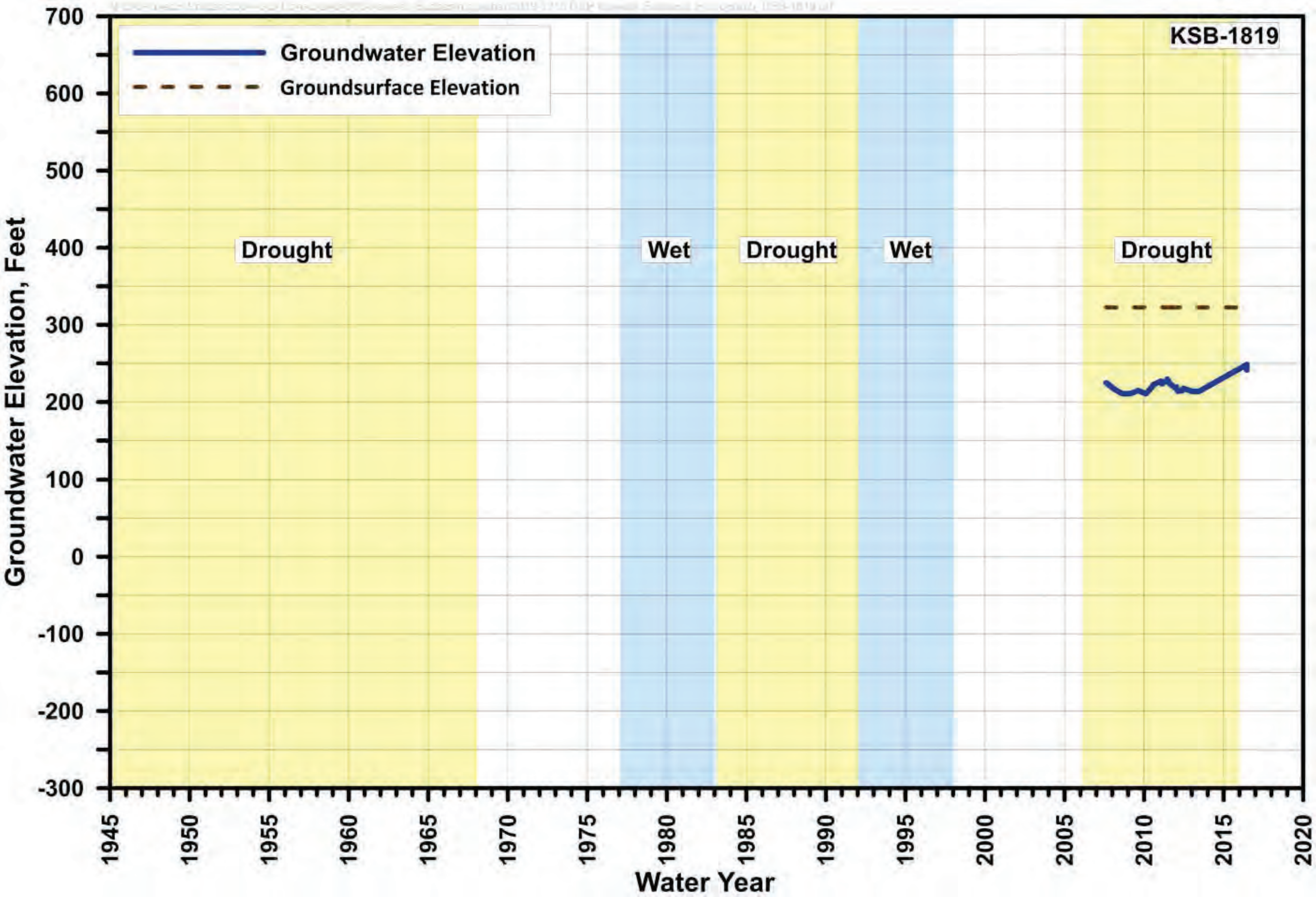
KSB-1775
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



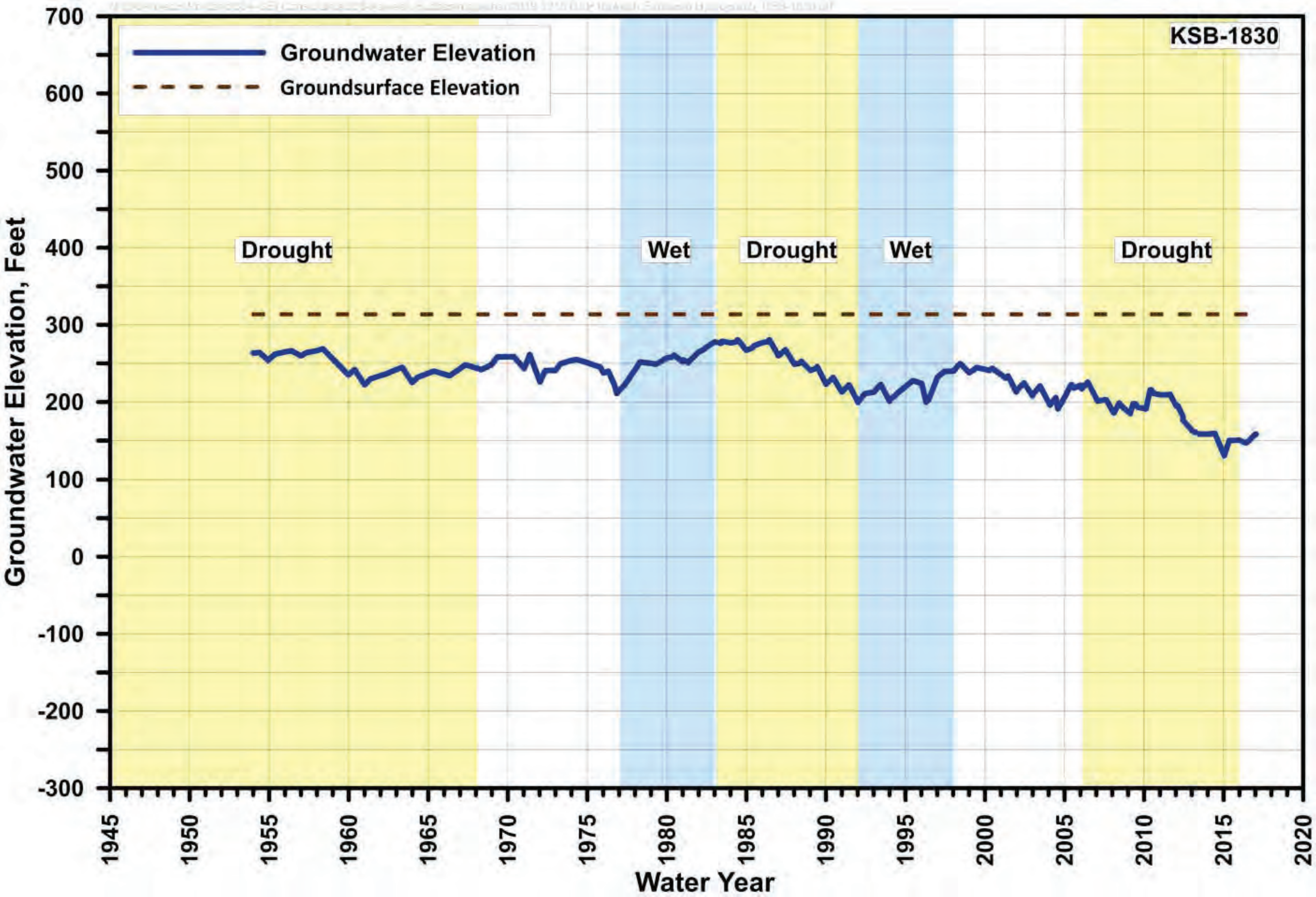
KSB-1783
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



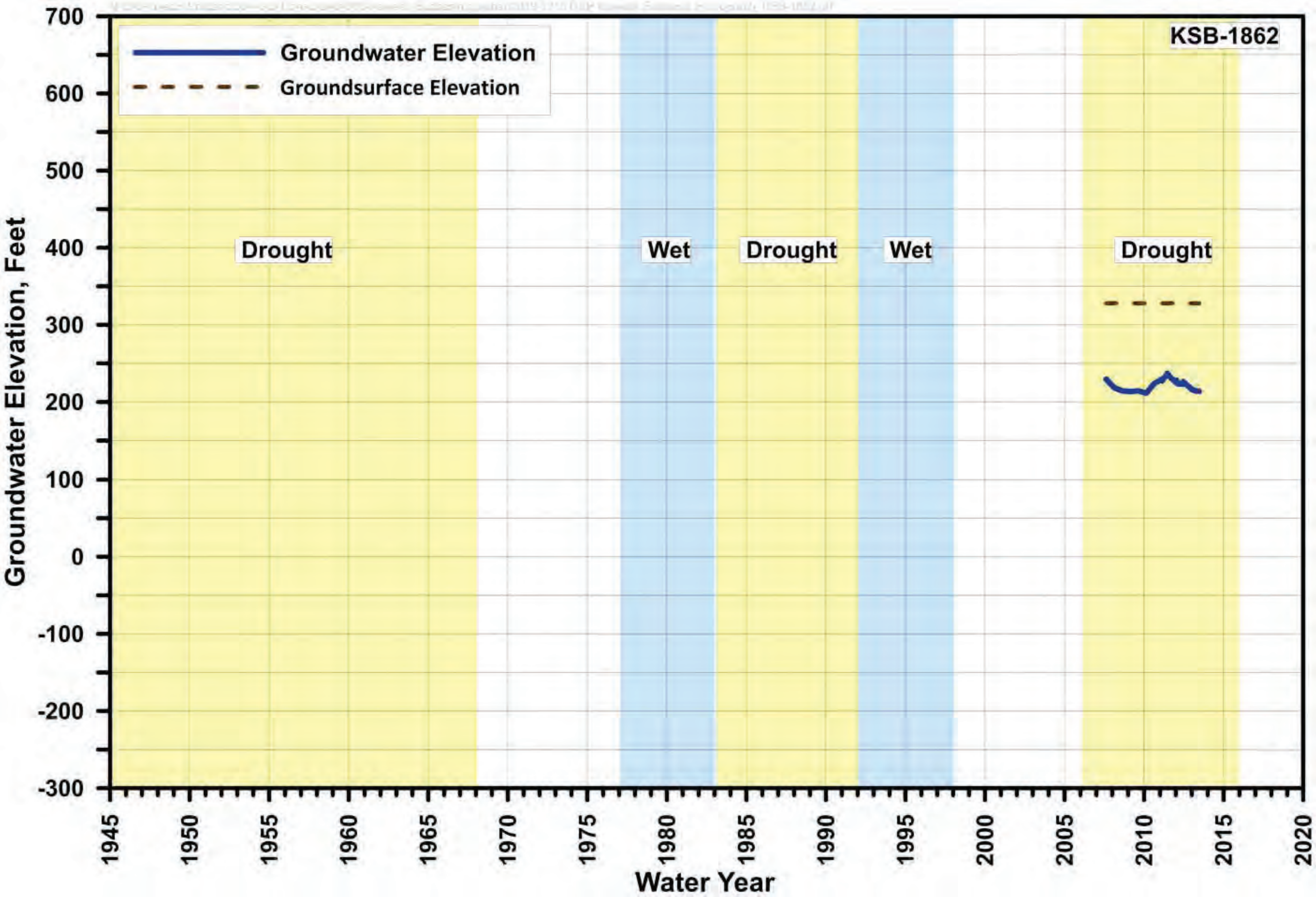
KSB-1809
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



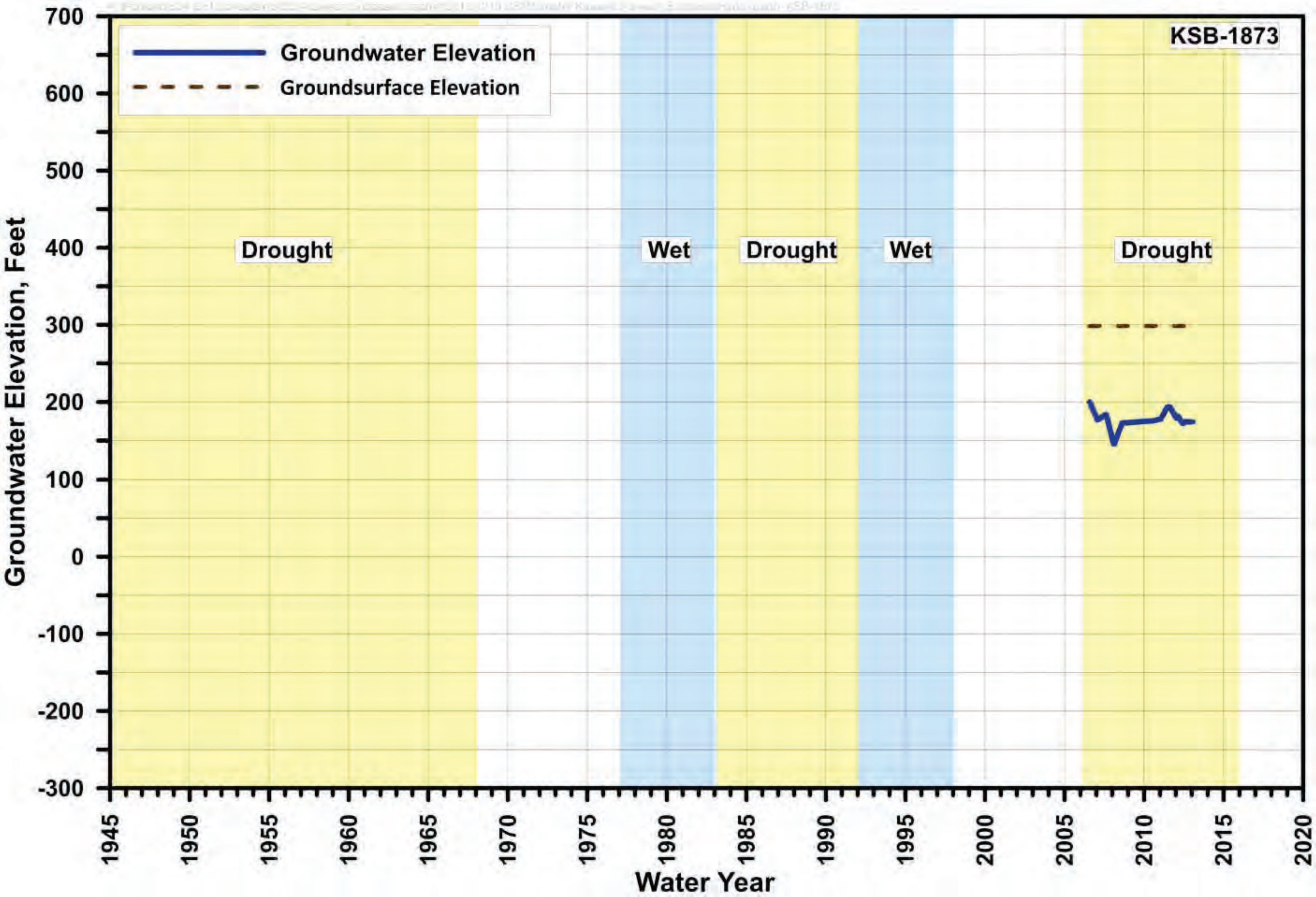
KSB-1819
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-1830
Drought
Wet
Drought
Wet
Drought
700
600
500
400
300
200
100
0
-100
-200
-300
Groundwater Elevation, Feet
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year



KSB-1862
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020



KSB-1873
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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1995
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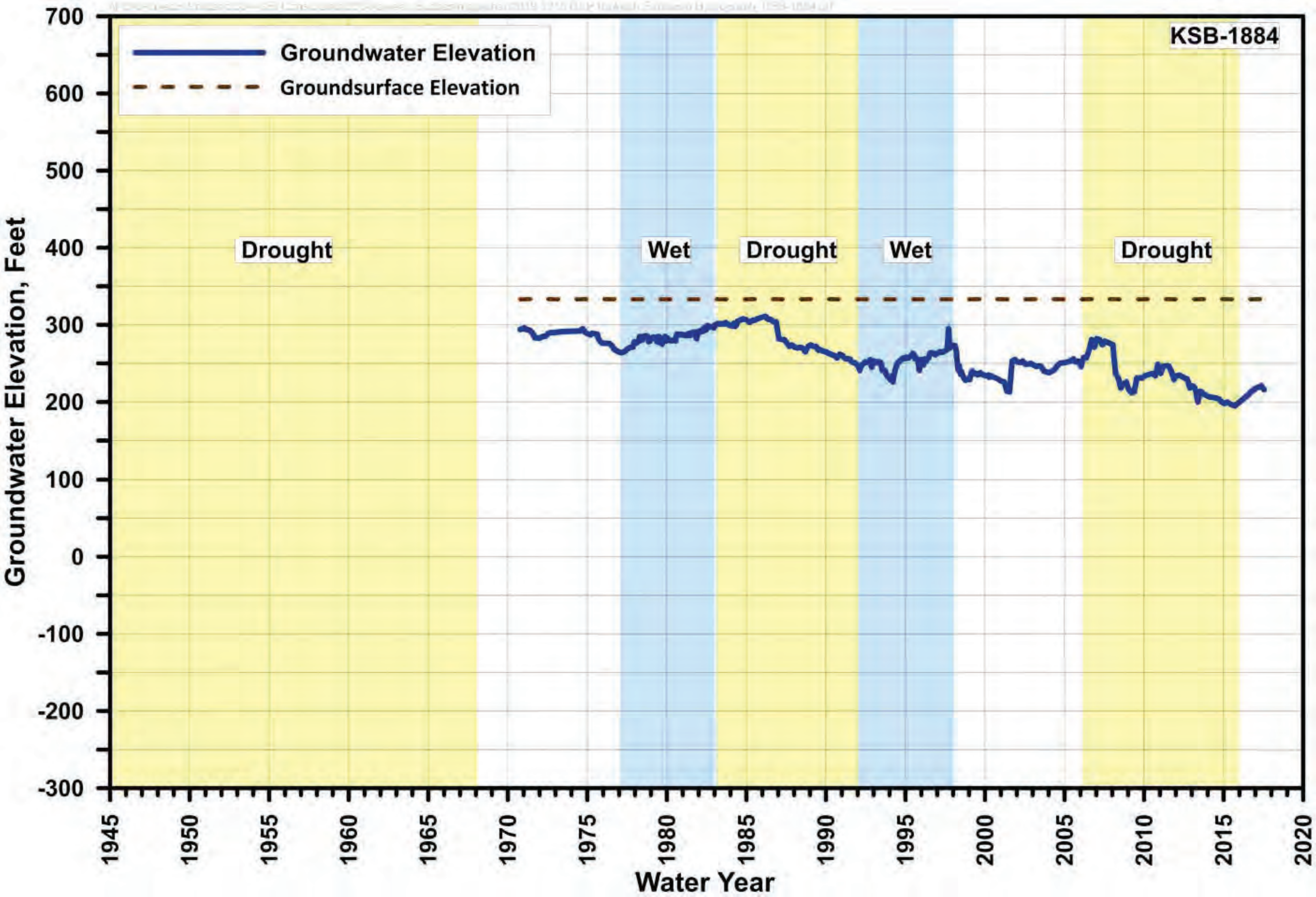
2005
2010
2015
2020
Water Year



KSB-1884
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
-200
-300
1945
1950
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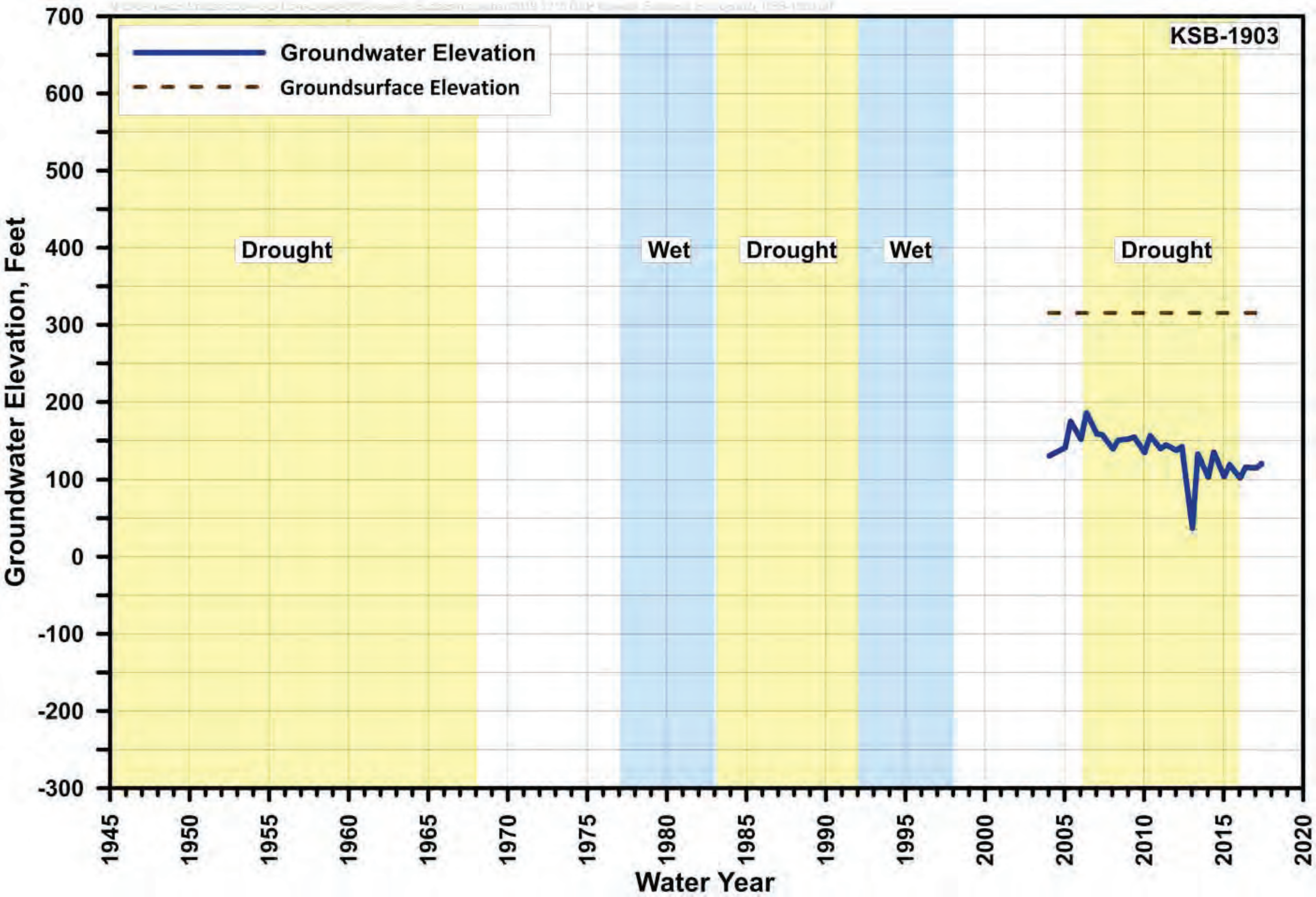
2015
2020


Groundwater Elevation
Groundsurface Elevation
KSB-1903
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
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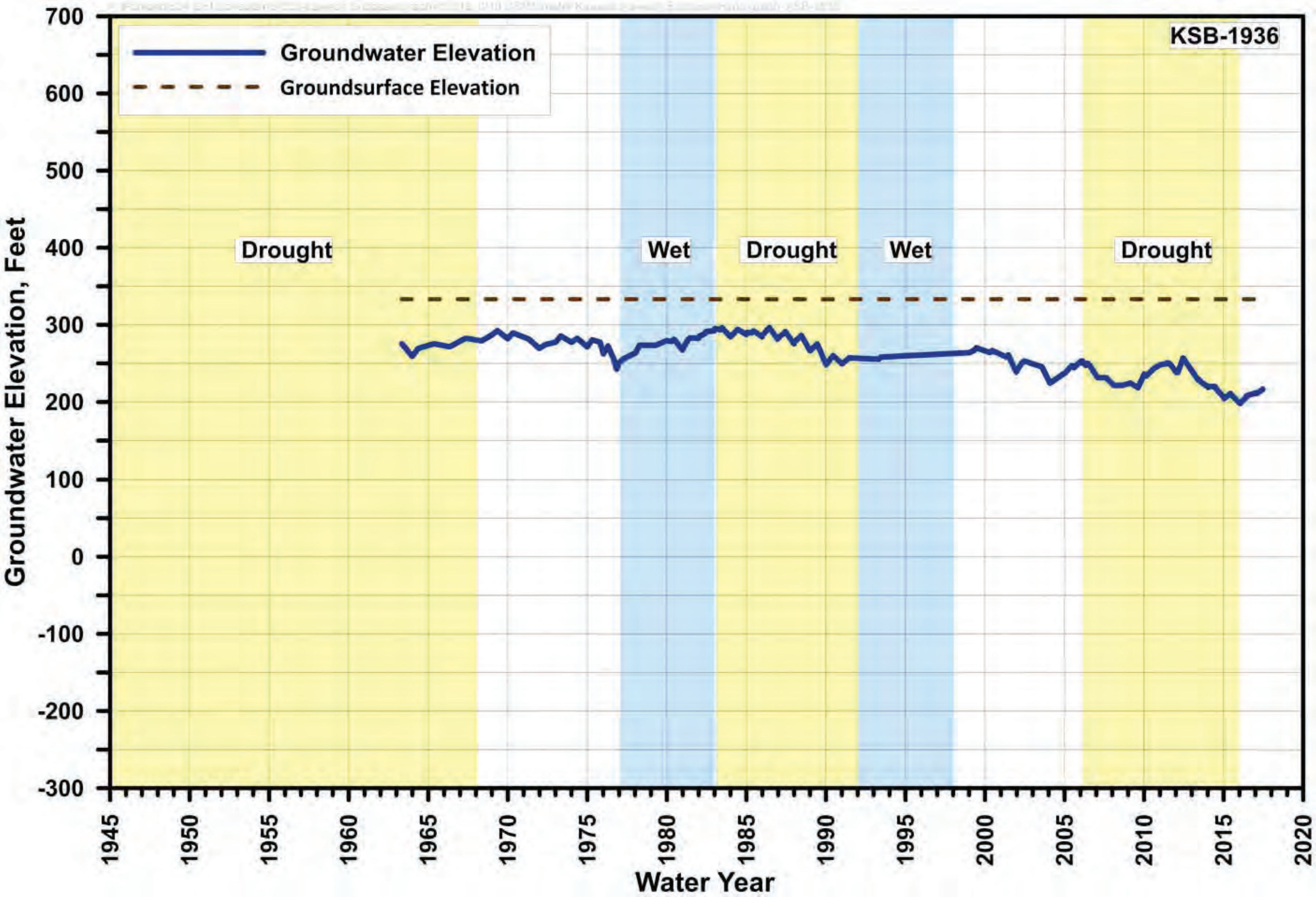
2005
2010
2015
2020
Water Year



Groundwater Elevation
Groundsurface Elevation
KSB-1936
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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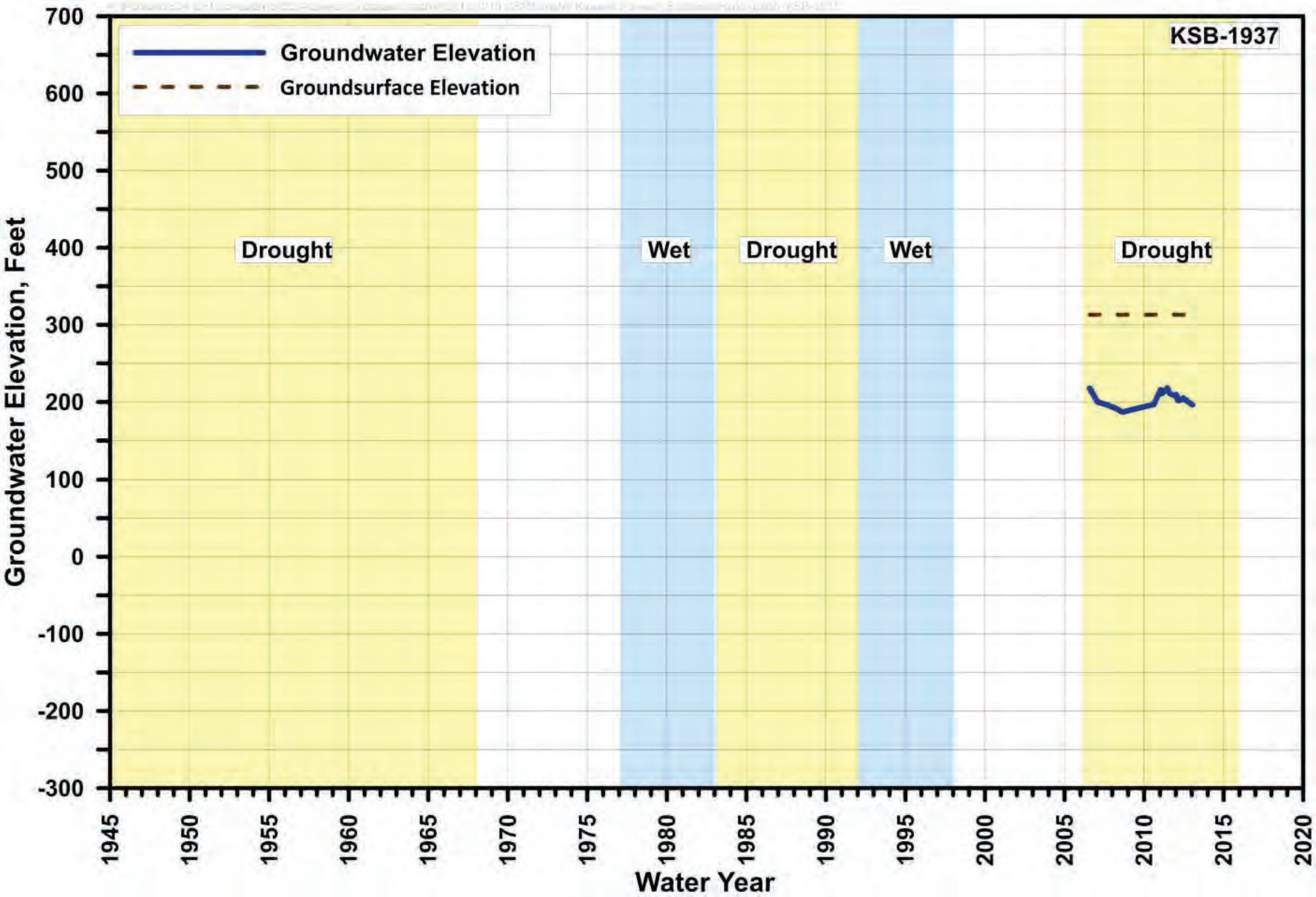
2010
2015
2020
Water Year


KSB-1937
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
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-100
-200
-300
1945
1950
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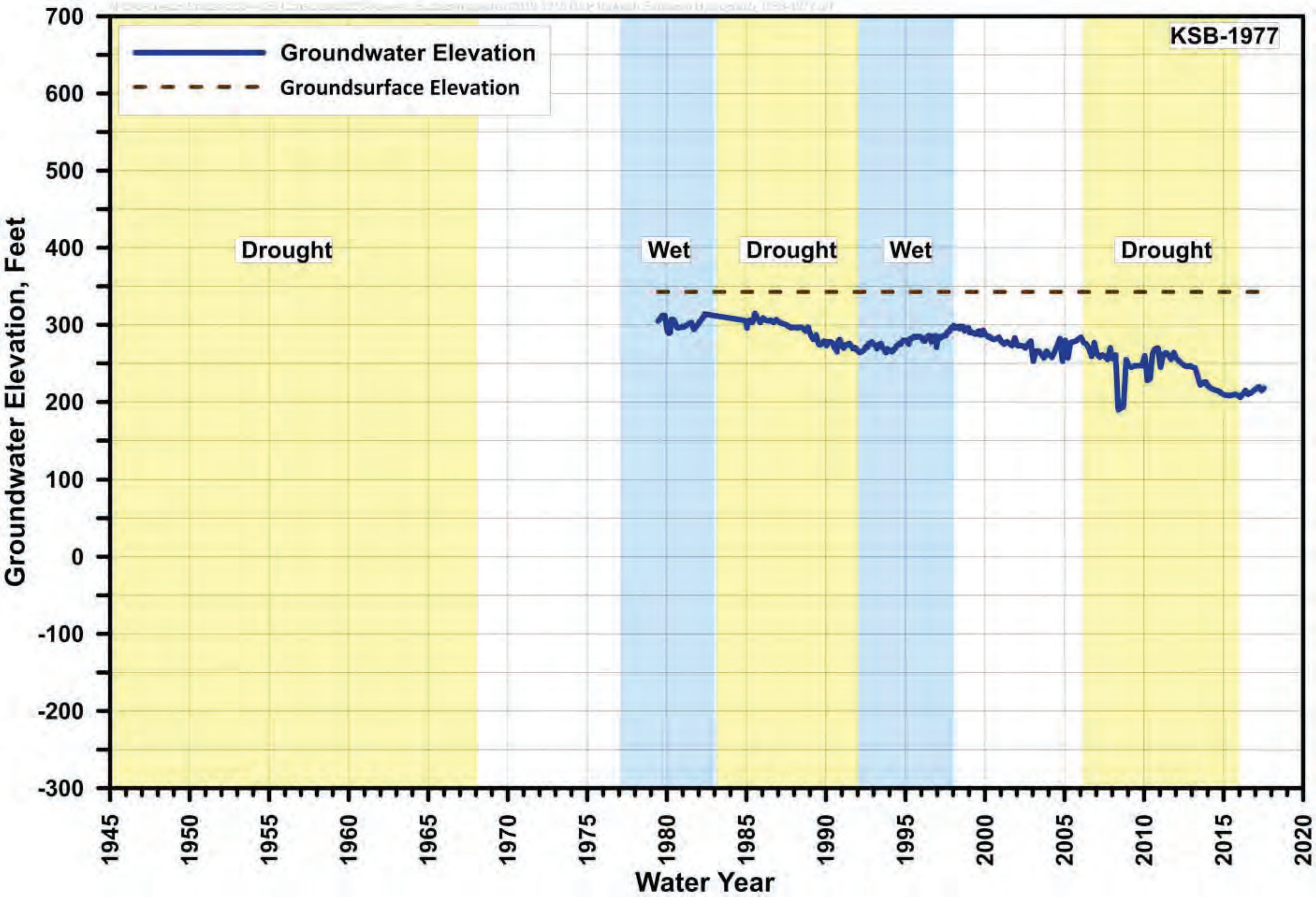
2015
2020
Water Year


KSB-1977
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
700
600
500
400
300
200
100
0
-100
-200
-300
Groundwater Elevation, Feet
1945
1950
1955
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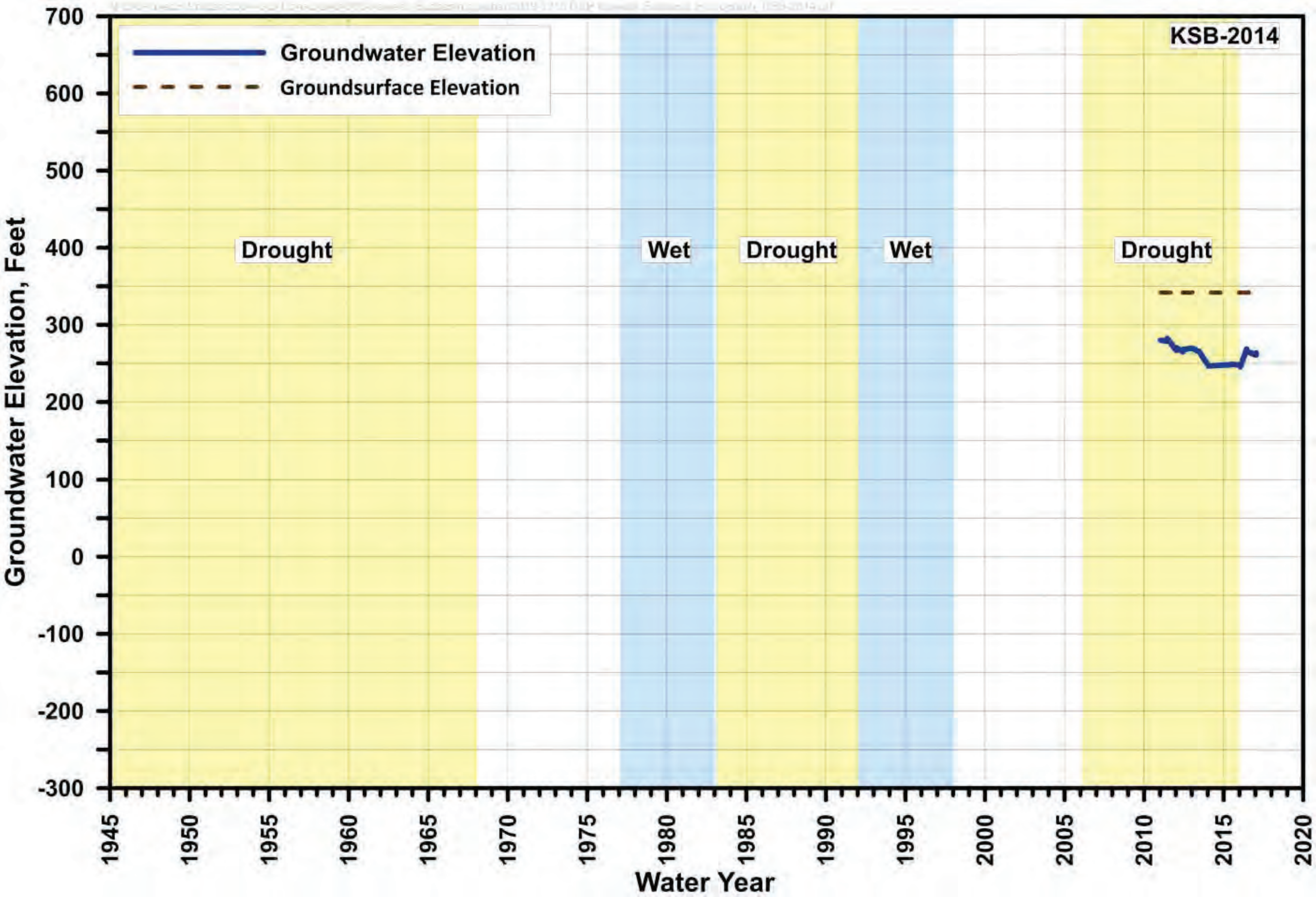
2005
2010
2015
2020
Water Year



KSB-2014
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
-200
-300
1945
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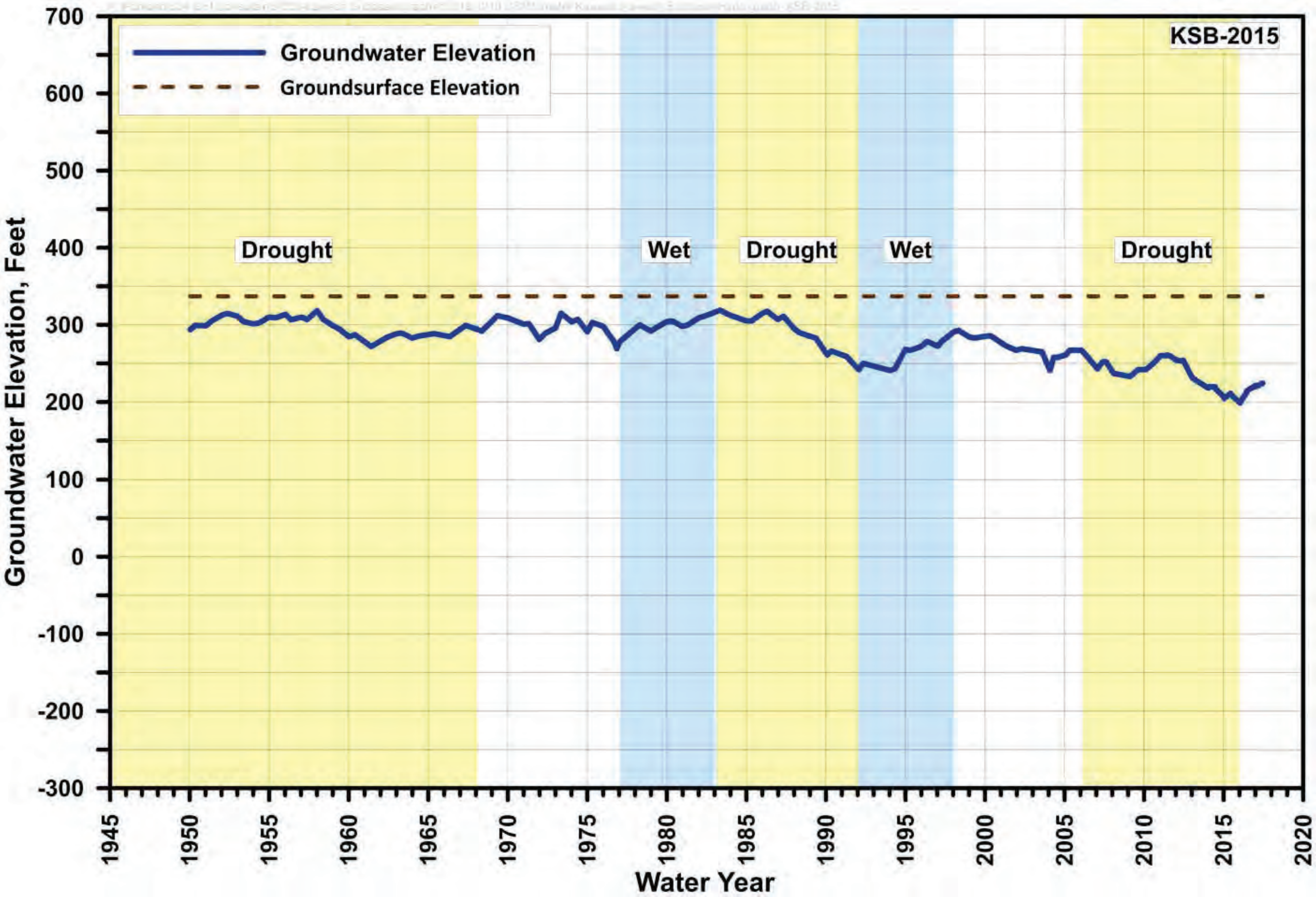
2020



KSB-2015
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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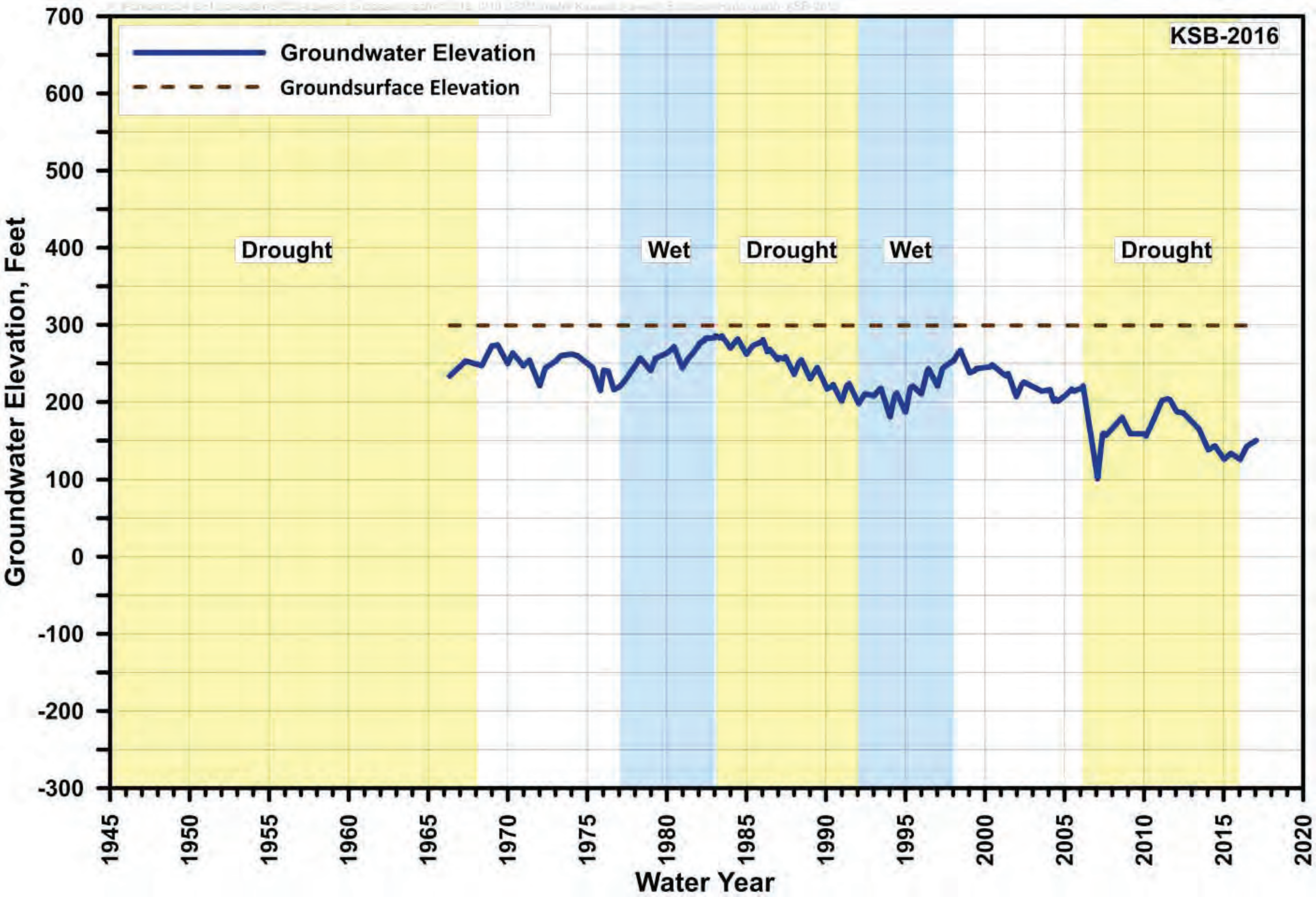
2010
2015
2020
Water Year



KSB-2016
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
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-100
-200
-300
1945
1950
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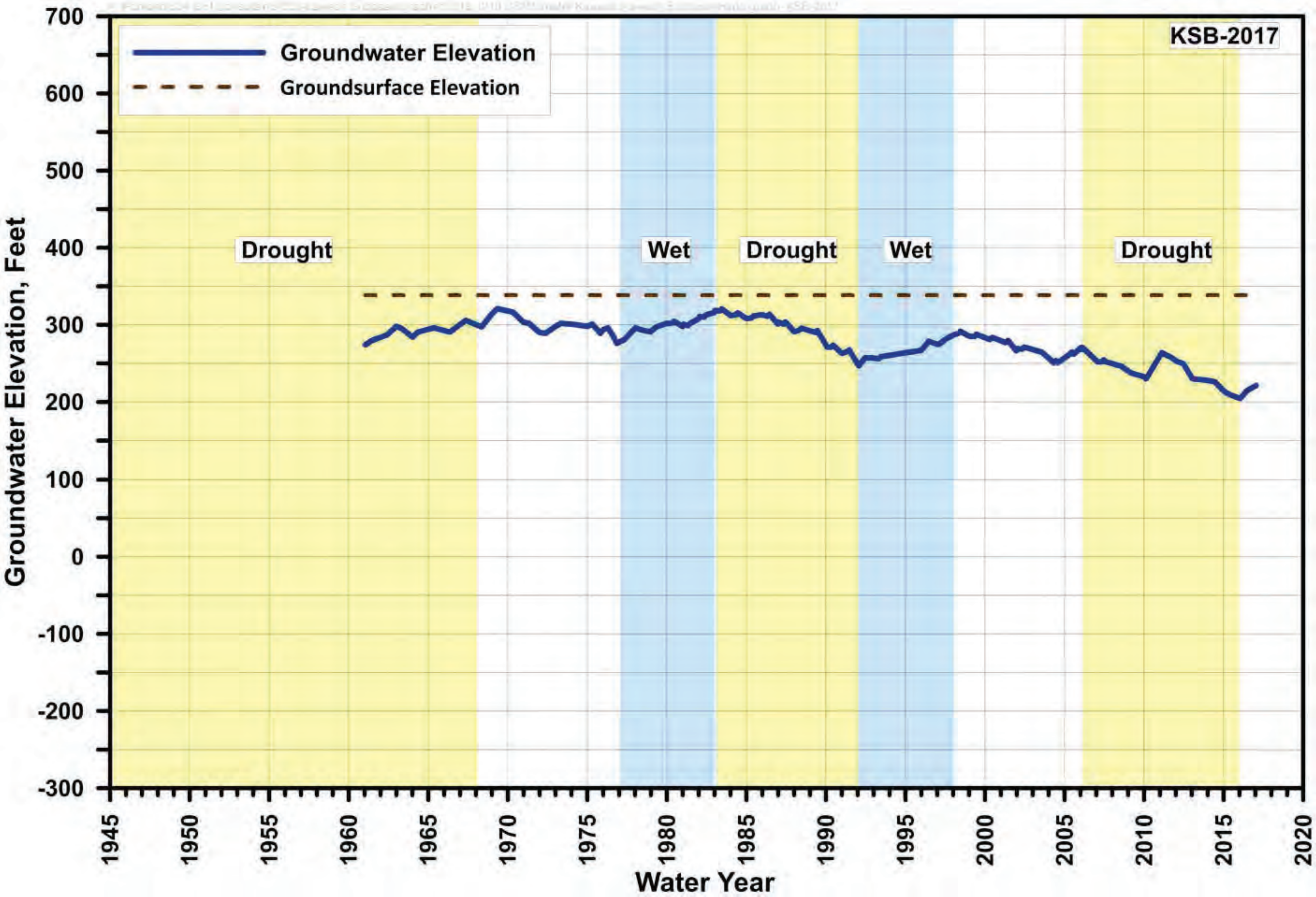
2015
2020
Water Year



KSB-2017
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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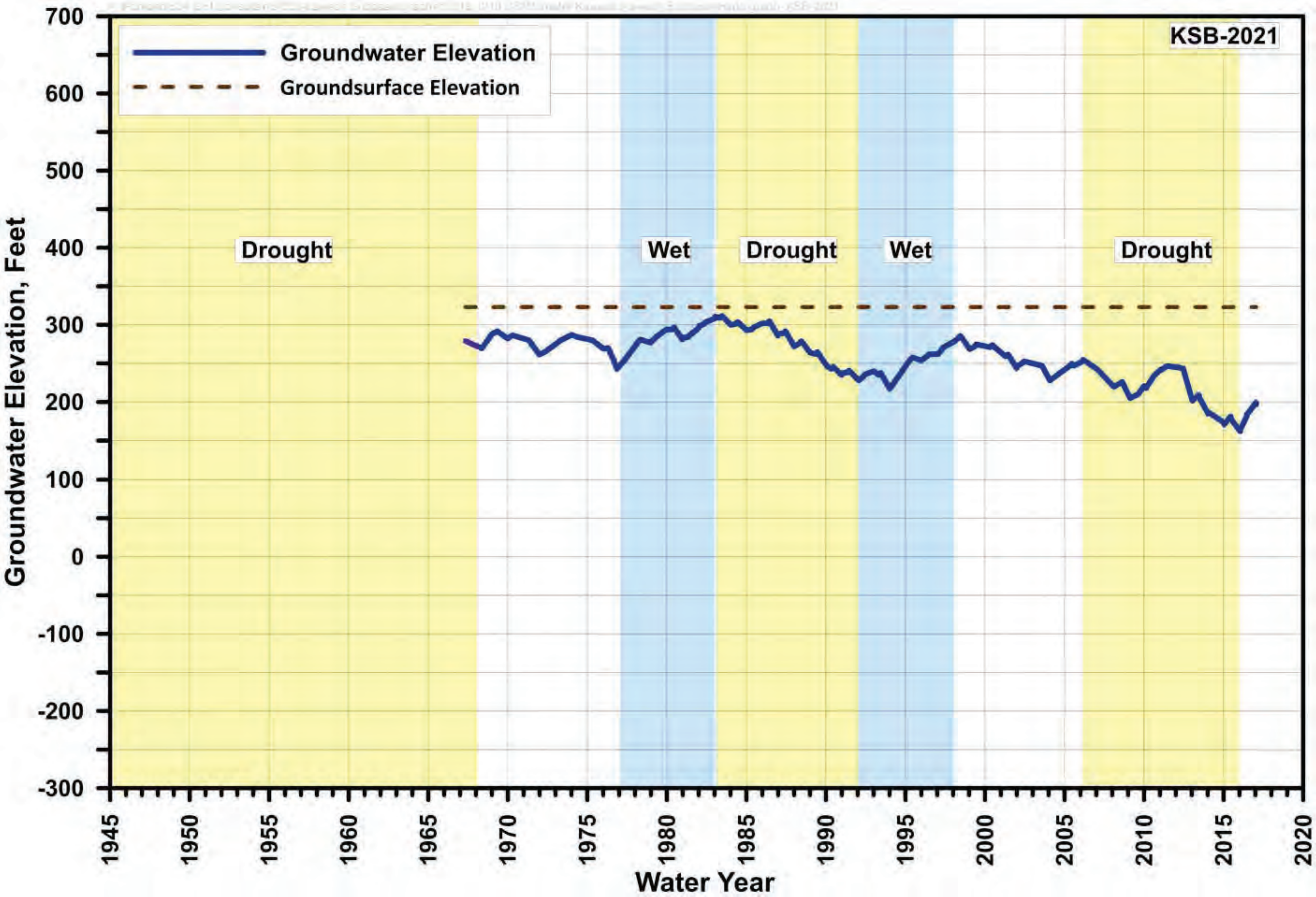
2010
2015
2020
Water Year



KSB-2021
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
-200
-300
1945
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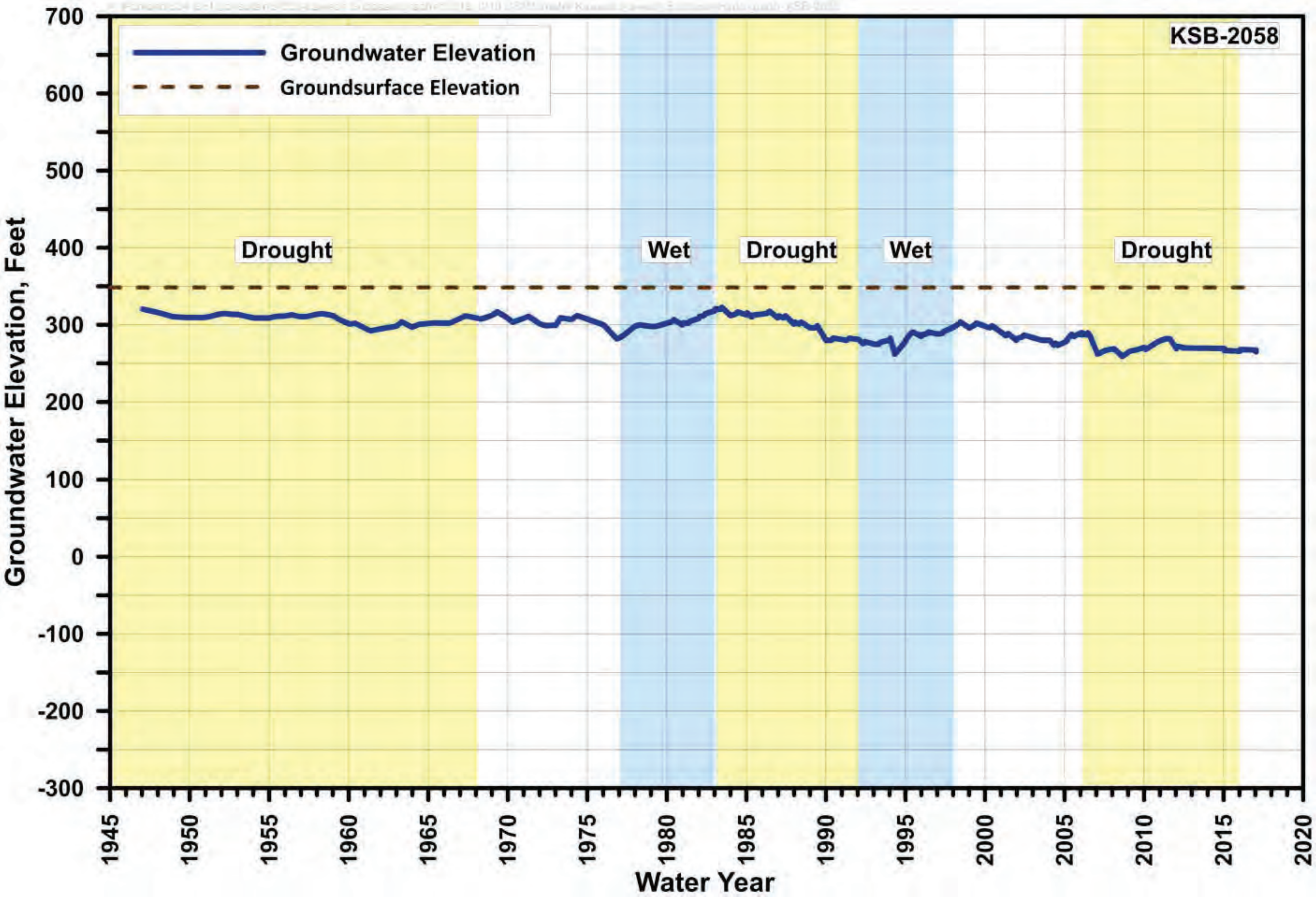
2020



KSB-2058
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
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-100
-200
-300
1945
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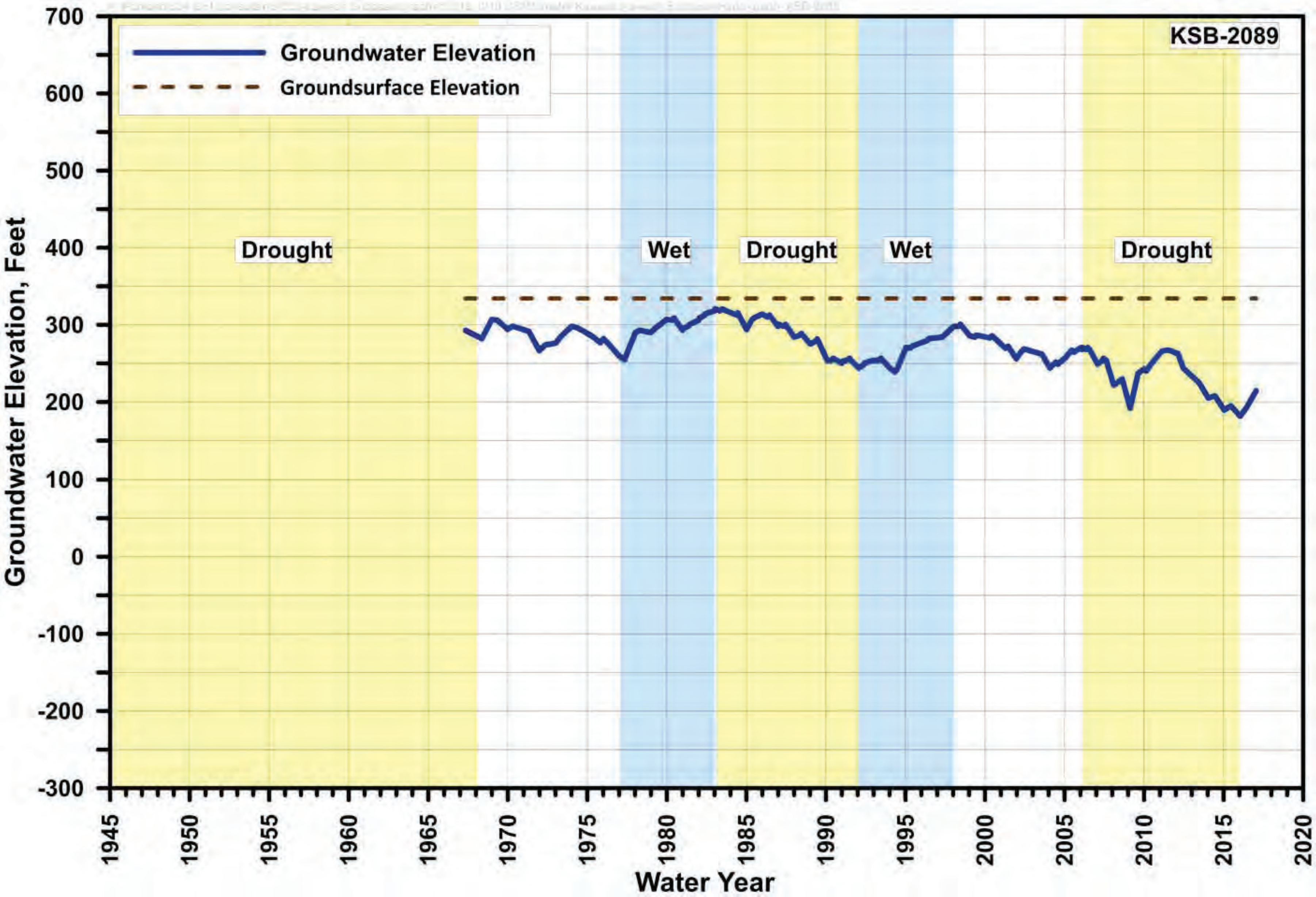

KSB-2089
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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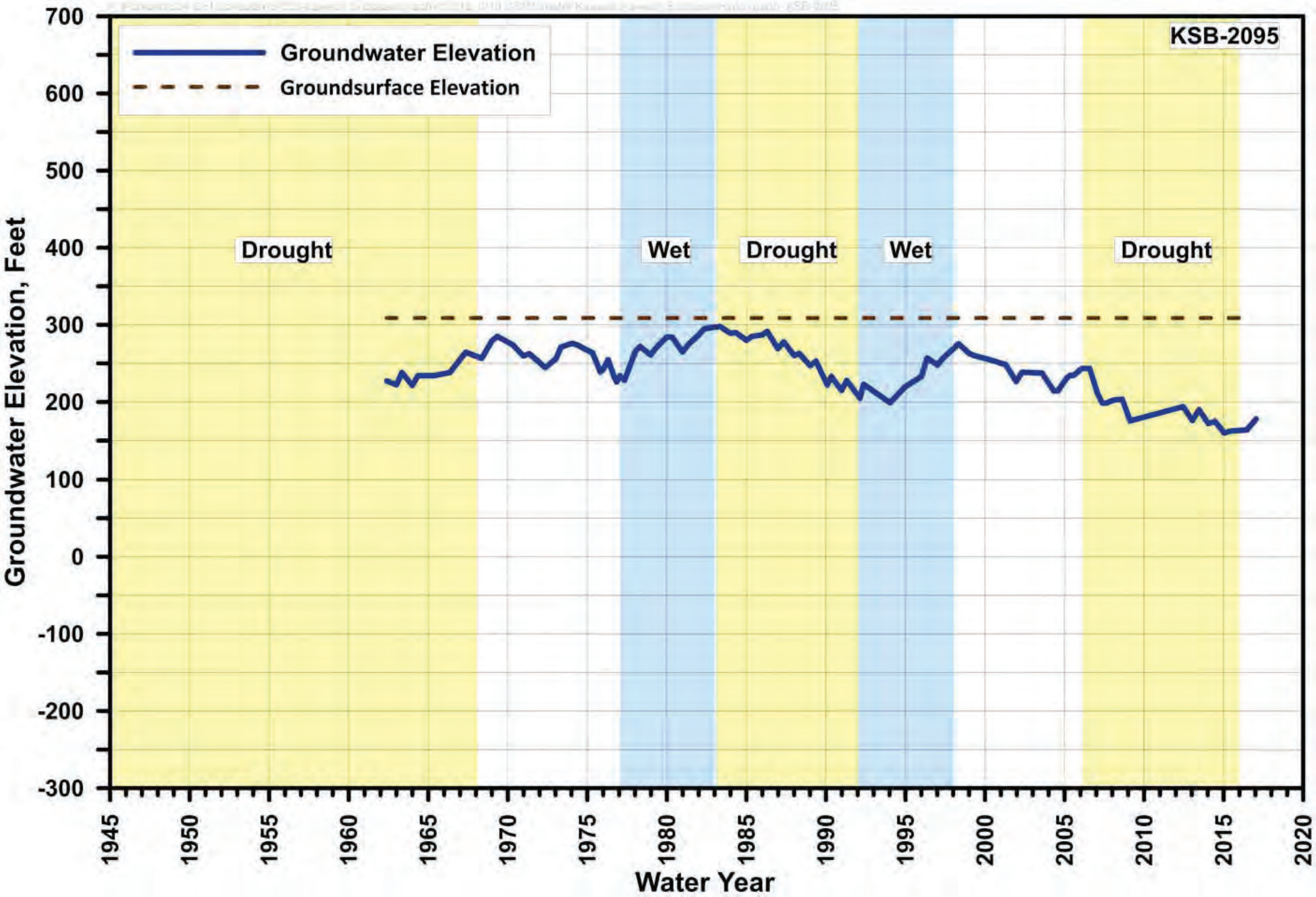
2015
2020
Water Year



KSB-2095
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
Water Year
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
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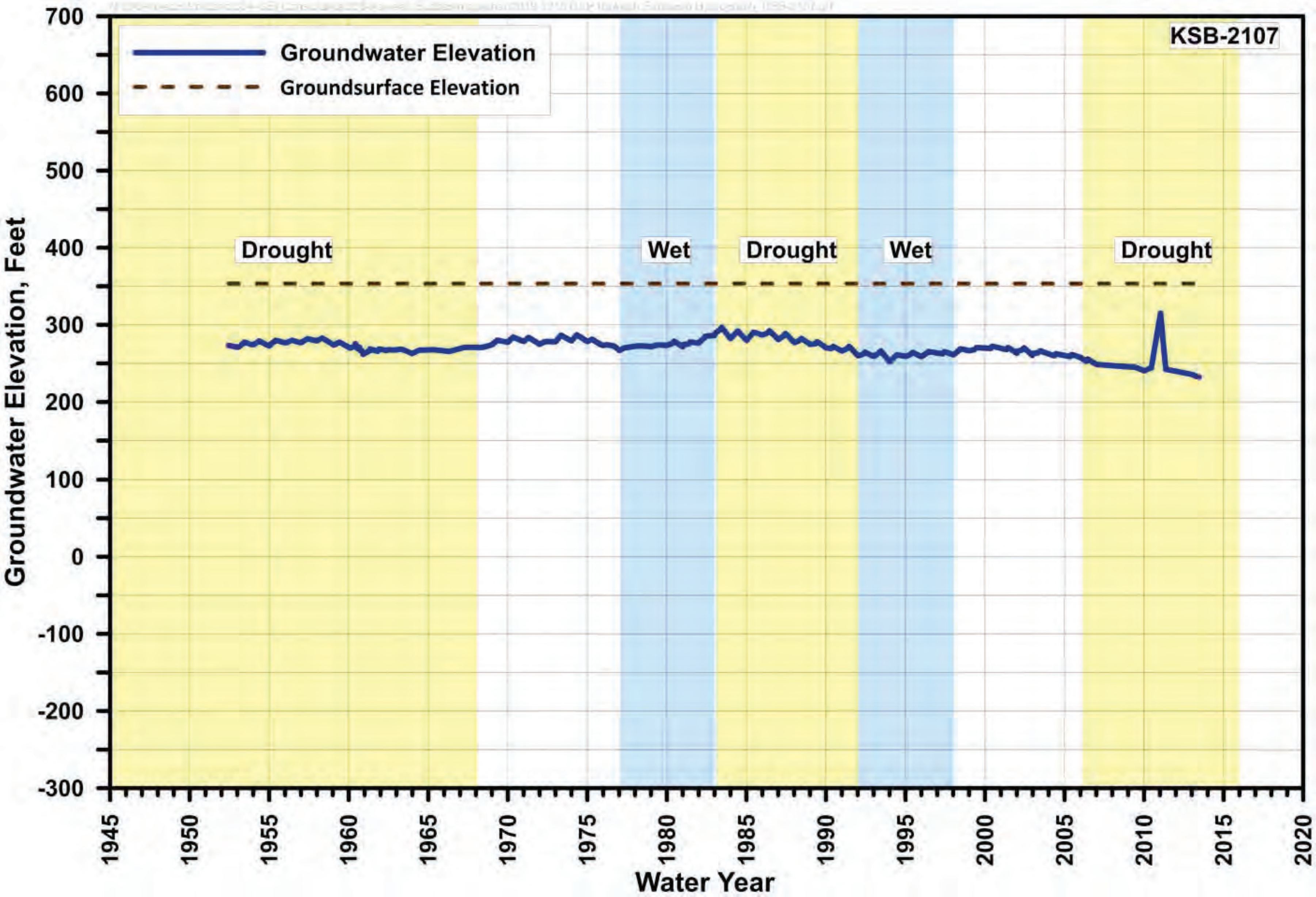
2015
2020


KSB-2107
Groundwater Elevation
Groundsurface Elevation
Drought
Wet
Drought
Wet
Drought
Groundwater Elevation, Feet
700
600
500
400
300
200
100
0
-100
-200
-300
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
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2010
2015
2020
Water Year