2 Basin Setting

2.1 Overview

The three Kaweah Subbasin GSAs (EKGSA, GKGSA, and MKGSA) jointly developed a Subbasin Basin Setting document through their coordinated efforts. The Kaweah Subbasin Basin Setting document is included with this EKGSA GSP in **Appendix 2-A**. The focus of this Basin Setting Chapter will be on the EKGSA and how it fits within the Kaweah Subbasin. The EKGSA is located on the eastern side of the Kaweah Subbasin and covers approximately a quarter of the Subbasin acreage. The EKGSA is made up of two areas bisected by the Kaweah River. The major land use in the EKGSA is agriculture.

2.2 Hydrogeologic Conceptual Model

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

The purpose of a Hydrogeologic Conceptual Model (HCM) is to provide an easy to understand description of the general physical characteristics of the regional hydrology, land use, geology, geologic structure, water quality, principal aquifers, and principle aquitards in the basin setting. Once developed, an HCM is useful in providing the context to develop water budgets, monitoring networks, and identification of data gaps.

An HCM is not a numerical groundwater model or a water budget model. An HCM is a written and graphical description of the hydrologic and hydrogeologic conditions that lay the foundation for future water budget models. This HCM has been written by adhering to the requirements set forth by the SGMA legislation in the California Code of Regulations. Several topics are touched on in the HCM, including groundwater quality, groundwater flow, and groundwater budget which are discussed in greater detail in Groundwater Conditions (Section 2.4) and Water Budget (Section 2.5).

The narrative HCM description provided in this chapter is accompanied by graphical representations of the EKGSA portion of the Kaweah Subbasin that attempt to clearly portray the geographic setting, regional geology, basin geometry, and general water quality. This HCM has been prepared utilizing published studies and resources and will be periodically updated as data gaps are addressed when new information is available.

2.2.1 Information Sources

The Subbasin HCM is based largely on data compiled from two recent Water Resources Investigations (WRIs) within the Subbasin (Fugro, 2007; Fugro, 2016), as well as additional data and analyses derived from well completion reports, geophysical electric logs, pumping test data, and monitoring well data collected from DWR, KDWCD, and other GSA member agencies within the Subbasin. This information is provided in detail in the Kaweah Subbasin Basin Setting document located in **Appendix 2-A**. Additional sources of information were used for further development of the HCM and Basin Setting for the EKGSA area. These sources include:

- Geologic Study of the Lindmore Irrigation District, U.S. Bureau of Reclamation, 1948.
- Technical Studies in Support of Factual Report: Exeter ID, Ivanhoe ID, and Stone Corral ID, U.S. Bureau of Reclamation, 1948 – 1950.
- Groundwater Conditions and Storage Capacity in the San Joaquin Valley, CA. U.S. Geological Survey, 1964.

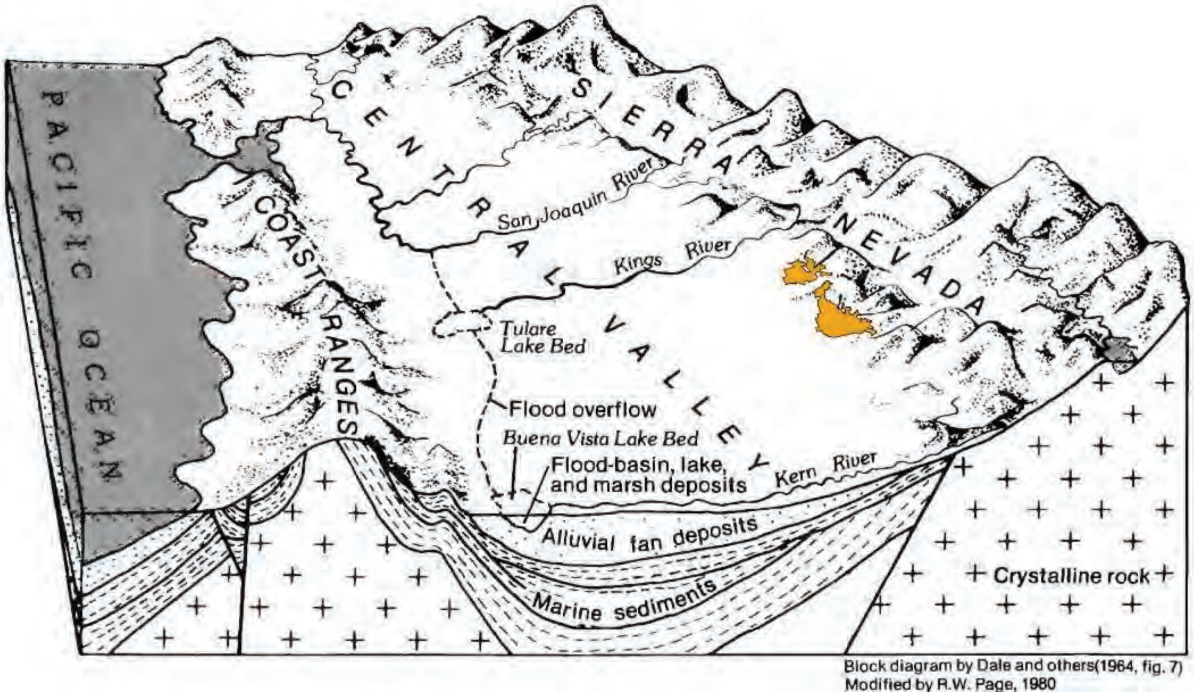
- Geology, hydrology, and quality of water in the Hanford-Visalia area, San Joaquin Valley, California; Croft & Gordon, 1968.

2.2.2 Regional Geologic and Structural Setting

Legal Requirements
§354.14(b)(1) The hydrogeologic conceptual model shall be summarized in a written description that includes the regional geologic and structural setting of the basin including the immediate surrounding area, as necessary for geologic consistency.

The San Joaquin Valley is a structural trough up to 200 miles long and 70 miles wide that comprises the southern portion of the Great Central Valley of California. The Sierra Nevada rises along its eastern boundary, the coast ranges hem it in to the west, and the Tehachapi mountains rise to the south. Continental deposits shed from the mountains form an alluvial wedge that thickens from the valley edges toward the axis of the structural trough. This process, in addition to periodic inundation by the Pacific Ocean, has resulted in an accumulation of sediments up to 32,000 feet thick. The depositional axis is slightly west of the series of rivers, lakes, sloughs, and marshes which mark the current and historic axis of surface drainage in the San Joaquin Valley (CDWR, 2016), as illustrated by **Figure 2-1**. South of the San Joaquin River the valley is currently a basin of interior drainage. Water flows to several depressions in the valley trough. The largest of these is the Tulare Lakebed, which receives runoff from the Kaweah, Tule, and Kings Rivers (Croft and Gordon, 1968).

The geologic structure of the EKGSA area is divided between the sedimentary deposits of the surface and near-surface, and a basement complex beneath. The sedimentary deposits dip gently to west on the uptilted western slope of the Sierra Nevada. En echelon faulting (i.e., faulting that occurs as a series of small parallel to sub-parallel faults oblique to the overall structural trend) is inferred to parallel the Sierra Nevada, which likely accounts for steep contacts between the sedimentary deposits and bedrock units. Bedrock outcrops within the sedimentary deposits are inferred to be the result of upfaulting, as no such outcrops occur to the west of the inferred fault zone (Croft and Gordon, 1968).



Block diagram by Dale and others(1964, fig. 7)
Modified by R.W. Page, 1980

Figure 2-1 Isometric Block Diagram of the Central San Joaquin Valley

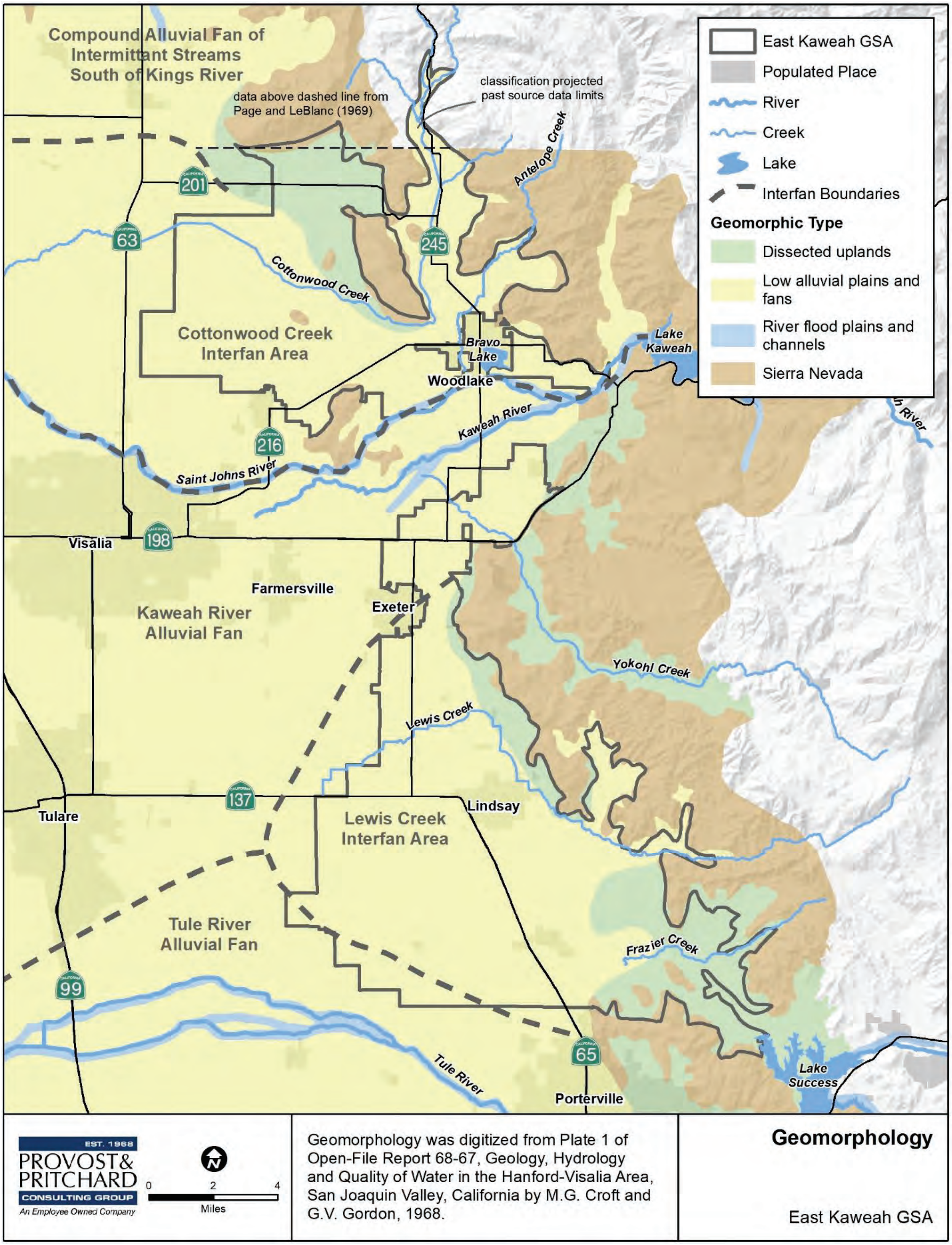
2.2.2.1 Subbasin Features and Topographic Information

Legal Requirements:
§354.14(d)(1) Physical characteristics of the basin shall be represented on one or more maps that depict topographic information derived from the U.S. Geological Survey or another reliable source.

The east side of the San Joaquin Valley is a broad plain formed by large coalescing alluvial fans of streams draining the western slope of the Sierra Nevada. The EKGSA is located entirely in this geomorphic setting. Croft & Gordon (1968) mapped the geomorphic features of the EKGSA and surrounding areas, as shown in **Figure 2-2**. The Kaweah River and Tule River alluvial fans account for significant contributions to the area's geomorphology. The Lewis Creek Interfan Area between these two fans comprises most of the southern lobe of the EKGSA. The northern lobe of the EKGSA is dominated by the Cottonwood Creek Interfan Area between the Kaweah River fan and the compound alluvial fan of intermittent streams south of the Kings River as mapped by Page and LeBlanc (1969).

The Kaweah River fan is the most prominent fan complex in the Kaweah watershed and is characterized by a surface of low topographic relief. As is illustrated in **Figure 2-3**, the fan generally slopes in a west-southwesterly direction at about 10 feet per mile, with the slope lessening further away from the mountains. The Kaweah River fan is characterized by a network of natural channels of the Kaweah River and its distributaries (Fugro, 2016).

Figure 2-3 shows that in the intermontane valleys of the southern lobe of the EKGSA, the topography climbs to elevations exceeding 800 feet above sea level. On the eastern edge of the valley floor the topography reaches heights of about 520 feet and gently slopes toward the center of the valley, descending to 320 feet above sea level on the far western edge of the EKGSA. In the northern lobe the topographic relief is less extreme. The highest contour is at 720 feet to the northeast of Colvin Mountain. Topography descends to 480 feet on Colvin Mountain's eastern flank. On the western side of Colvin Mountain, the topography begins at heights of about 460 feet above sea level and slopes gently westward, so that the western edge of the EKGSA is 340 feet above sea level.



Geomorphology was digitized from Plate 1 of Open-File Report 68-67, Geology, Hydrology and Quality of Water in the Hanford-Visalia Area, San Joaquin Valley, California by M.G. Croft and G.V. Gordon, 1968.

Geomorphology

East Kaweah GSA

Figure 2-2 Geomorphic Features

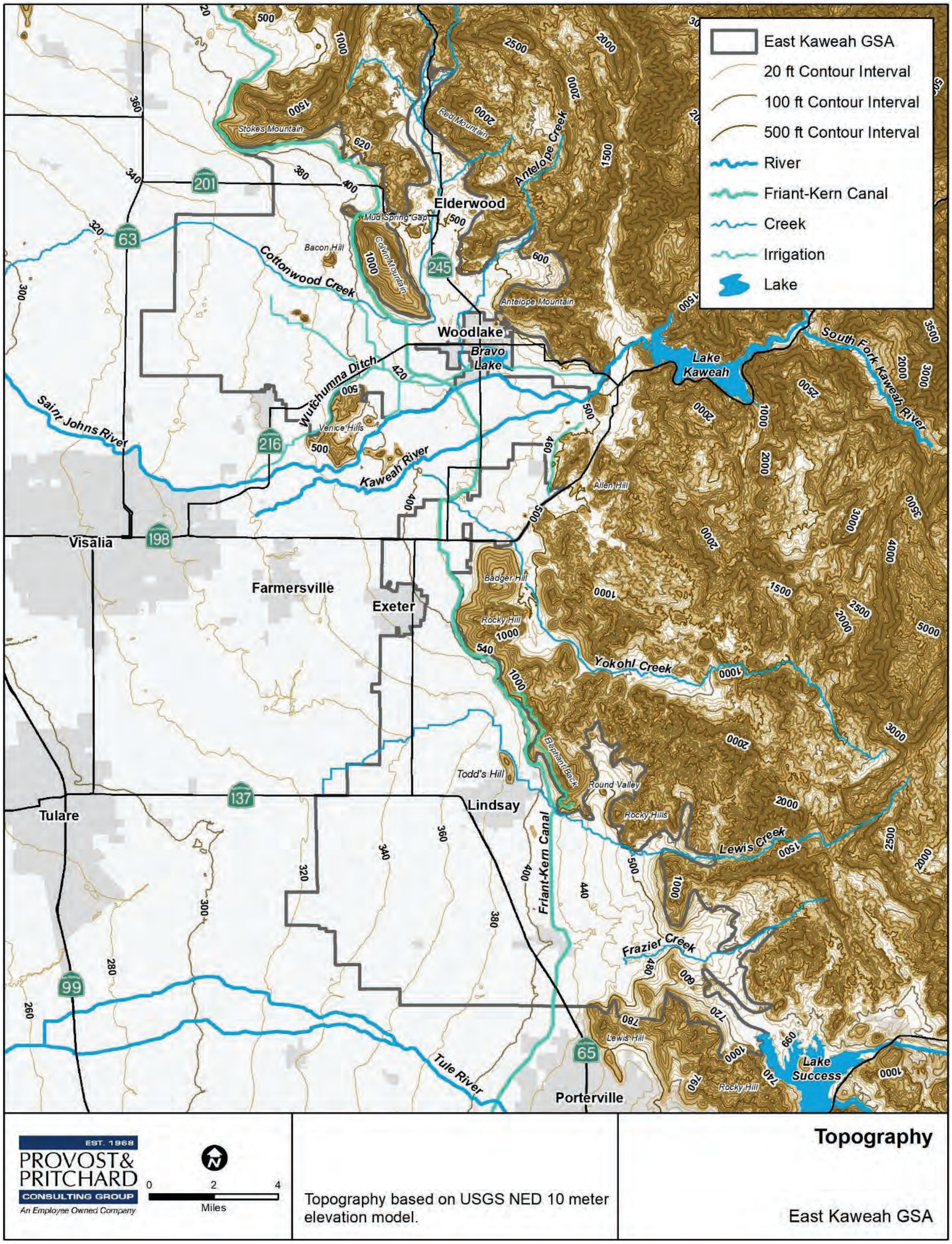


Figure 2-3 Topography

2.2.2.2 Regional Geologic Conditions

The generalized regional subsurface geologic conditions with corresponding hydrologic units is described below in **Table 2-1**. This table, adapted from Page, 1986 and Bertoldi et. al., 1991, provides a general overview of geologic deposits in the region within the context of regional hydrologic units. Flood plain and river deposits from recent fluvial processes overlie older lacustrine, marsh, and other continental deposits. Below the continental deposits are Tertiary marine deposits and pre-Tertiary crystalline basement rock. More detailed discussion is included in the Kaweah Subbasin Basin Setting document in **Appendix 2-A**.

Table 2-1 Generalized Regional Geologic & Hydrologic Units of the San Joaquin Valley

	Generalized Regional Geology (adapted from Page, 1986, table 2 and Bertoldi et. al. 1991).	Generalized Regional Hydrologic Units
Quaternary	Flood basin deposits (0 to 100 ft thick) – Primarily clay, silt, and some sand; including muck, peat, and other organic soils in Delta area. These restrict yield to wells and impede vertical movement of water. River deposits (0 to 100 ft thick) – Primarily gravel, sand, and silt; include minor amounts of clay. Among the more permeable deposits in valley.	Undifferentiated upper water-bearing zone; unconfined to semiconfined. Principal confining unit (modified E Clay)
Tertiary and Quaternary	Lacustrine and marsh deposits (up to 3,600± ft thick) – Primarily clay and silt; include some sand. Thickest beneath Tulare Lakebed. Include three widespread clay units – A, C, and modified E clay. Modified E clay includes the Corcoran Clay Member of the Tulare Formation. These impede vertical movement of water. Continental rocks and deposits (15,000± ft thick) – Heterogeneous mix of poorly sorted clay, silt, sand, and gravel; includes some beds of mudstone, claystone, shale, siltstone, and conglomerate. They form the major aquifer system in the valley.	Undifferentiated lower water-bearing zone; semiconfined to confined. Extends to base of freshwater which is variable.
Tertiary	Marine rocks and deposits – Primarily sand, clay, silt, sandstone, shale, mudstone, and siltstone. Locally they yield fresh water to wells, mainly on the southeast side of the valley but also on the west side near Kettleman Hills.	Below the base of freshwater and depth of water wells. In many areas, post-Eocene deposits contain saline water.
Pre-Tertiary	Crystalline basement rocks – Non-water-bearing granitic and metamorphic rocks, except where fractured.	

2.2.2.3 Kaweah Subbasin Geology

Legal Requirements:
§354.14(b)(4)(a) Formation names, if defined.

The geology underlying the Kaweah Subbasin is generally consistent with the regional geology. Details of the local geology, as it affects the occurrence and movement of groundwater, are provided below based on previous investigations in the area (i.e. USBR Technical Studies and Fugro WRI). The following units are presented from the ground surface downward (roughly youngest to oldest):

- **Alluvium (Q), unconsolidated deposits:** Non-marine, water-bearing material comprised of the Tulare Formation and equivalent units. Alluvium is generally mapped in the Subbasin except where the following specific units are provided.
    - **Flood basin deposits (Qb):** Clay, silt, and some sand on the lateral edges of fanned sediment distal of Kaweah River.
    - **Younger alluvium (Qya), oxidized older alluvium (Qoa[o]) and reduced older alluvium (Qoa[r]):** Coarse-grained, water-bearing alluvial fan and stream deposits.

  - **Lacustrine and Marsh Deposits – (QTl):** Fine-grained sediments representing a lake and marsh phase of equivalent continental and alluvial fan deposition. Includes the Tulare Formation and Corcoran Clay Member.
- **Continental Deposits (QTc):** Heterogeneous mix of water-bearing poorly sorted clay, silt, sand, and gravel.
- **Marine Rocks – (Tmc):** Non-water-bearing marine sediments including the San Joaquin Formation. Historically, the top contact of Tmc marked the effective base of the Kaweah aquifer system because of the low permeability of Tmc and the general occurrence of brackish to saline water (B-E, 1972).
- **Basement Rocks – (pT):** Insignificant water-bearing granitic and metamorphic rocks, except where highly fractured near the foothills on the eastern side of the Subbasin.

The listed units correlate to the geologic units listed in **Table 2-1**. Discussion of key units in the EKGSA is provided below. A more detailed discussion is included in the Kaweah Subbasin Basin Setting document in **Appendix 2-A**. Additional discussion and figures are provided in **Section 2.2.2.5** (Subsurface Geologic Cross-Sections).

Unconsolidated Deposits (Q). The unconsolidated deposits include undifferentiated Alluvium (Q), younger alluvium (Qya), older alluvium (Qoa), lacustrine and marsh deposits (QTl), and unconsolidated continental (QTc) deposits. Unconsolidated deposits were eroded from the adjacent mountains, transported by streams and mudflows, and deposited in lakes, swamps, or on alluvial fans (Fugro West, 2007). The base of the unconsolidated deposits within the Kaweah Subbasin is projected by electric log correlation from the top of the marine rocks (Tmc) (Woodring et al., 1940). The unconsolidated deposits gradually thicken from along the western front of the Sierra Nevada to a maximum of at least 1,800 feet at the western boundary of the EKGSA.

Younger Alluvium - Qya. The Younger Alluvium is generally above the water table and does not constitute a major water-bearing unit. It consists of gravelly sand, silty sand, silt, and clay deposited along stream channels (Fugro West, 2007). The deposits are moderately sorted and generally loose. The deepest Younger Alluvium deposit is found along the Kaweah fan axis, where it is unlikely to exceed 100 feet of thickness (Ivanhoe USBR Report, 1949). The younger alluvium interfingers and/or grades laterally into the flood basin deposits (Qb) and undifferentiated alluvium. It overlies the older alluvium (Fugro West, 2007).

Older Alluvium – Qoa. The older alluvium is subdivided into "oxidized" and "reduced" variants based on environment of deposition (Fugro West, 2007). Oxidized deposits generally represent subaerial deposition, and reduced deposits generally represent subaqueous deposition (Davis et al., 1957). Oxidized deposits are red, yellow, and brown, consist of gravel, sand, silt and clay, and generally have well-developed soil profiles. Groundwater in oxidized deposits is typically aerobic (citation needed). Reduced deposits are typically black, gray, green, and blue. Anaerobic bacteria present in organic matter beneath the water table may further contribute to the reduction of iron compounds (Davis et al., 1957).

The older alluvium unconformably overlies the continental deposits. The contact of the older alluvium with the underlying oxidized continental deposits is well defined in electric logs. It thickens irregularly from east to west, and probably has filled gorges cut by the ancient Tule River in the underlying oxidized continental deposits near the city of Porterville. The older alluvium and continental deposits interfinger and/or grade laterally into the lacustrine and marsh deposits or into undifferentiated alluvium. (Fugro West, 2007).

Oxidized Older Alluvium - Qoa(o). The oxidized older alluvium is unconfined in the EKGSA. It underlies the younger alluvium, though it dominates the surficial deposits within the interfan areas. They are 200 to 500 feet thick (Croft, 1968) and consist mainly of deeply weathered, reddish brown, calcareous sandy silts and clays. Beds of coarse sand and gravel are rare, but, where present, they commonly contain significant silt and clay. The highly oxidized character of the deposits is the result of deep and prolonged weathering. Many of the easily weathered minerals have altered to clay and are therefore poorly permeable (Fugro West, 2007). The beds consist of fine to very coarse sand, gravel, silt, and clay derived primarily from granitic rocks of the Sierra Nevada. Beneath the channels of the Kaweah and Tule rivers, electric logs indicate that the beds are very coarse. In the inter-fan areas, metamorphic rocks and older sedimentary units locally contributed to the deposits and, in those areas, the beds are typically not as coarse as the beds beneath the rivers (Fugro West, 2007). The base of the deposits occurs approximately 195 feet below land surface near the City Exeter (Fugro West, 2007).

Reduced Older Alluvium - Qoa(r). The reduced older alluvium consists mainly of fine to coarse sand, silty sand, and clay. It was likely deposited in a flood plain or similar subaqueous low-energy environment. Gravel such as occurs in the oxidized older alluvium is generally absent. The deposits are sporadically cemented with calcium carbonate, but less prevalently than is found in the underlying reduced continental deposits (Fugro West, 2007).

Continental Deposits – QTc. The continental deposits are poorly sorted clays, silts, sands, gravels, claystones, shales, siltstones, and conglomerates that grade into and/or underlie the older alluvium. These continental deposits are underlain by the Tertiary marine rocks (Tmc) (Fugro West, 2007). The Porterville Clays are a subset of QTc that occupy distinctive smooth concave slopes at the base of the foothills. They consist of weathered outwash from the Sierra Nevada, transported by "creep" and slope-wash, and veneer the other materials at shallow depths. The clays interfinger with both the younger and older alluvial units, indicating they have likely been accumulating during most of Quaternary time (Ivanhoe USBR Report, 1949).

Marine Rocks (non-water bearing) - Tmc. Tertiary rocks of mainly marine origin underlie the unconsolidated deposits and overlie the basement complex. This unit may locally include beds of continental origin in its upper strata (Croft, 1968). The marine rocks do not outcrop in the EKGSA. They range in age from Eocene to late Pliocene and consist of consolidated to semi-consolidated sandstone, siltstone, and shale. They generally contain brackish and saline connate or dilute connate water unsuitable for most uses (Fugro West, 2007). The top contact of Tmc marks the effective base of the Kaweah aquifer system due to its low permeability and the degraded quality of its (B-E, 1972).

Basement Complex (essentially non-water bearing) – pT. The basement complex consists of metamorphic and igneous rocks which are predominantly Triassic or Late Jurassic in age (Ivanhoe USBR Report, 1949). These rocks outcrop as resistant inliers in the alluvium and as linear ridges in the foothills in the EKGSA. In the subsurface, the basement slopes westward from the Sierra Nevada beneath the deposits of Cretaceous and younger rocks and sediment that compose the Valley fill. Escarpments interpreted as buried fault scarps are associated with the Rocky Hill fault. West of the escarpments, the slope of the basement complex steepens (Fugro West, 2007).

The basement complex is considered to be non-water bearing in most areas, as it is composed of impermeable crystalline rock. However, fractures within the basement frequently contain fresh water of useful quantities. In the areas of Lindsay, Strathmore, Ivanhoe, and in the intermontane valleys these fractured rock aquifers are tapped by many water wells. Near Farmersville and Exeter, the basement complex forms a broad, gently westward-sloping shelf overlain by 100 to 1,000 feet of unconsolidated deposits (Fugro West, 2007).

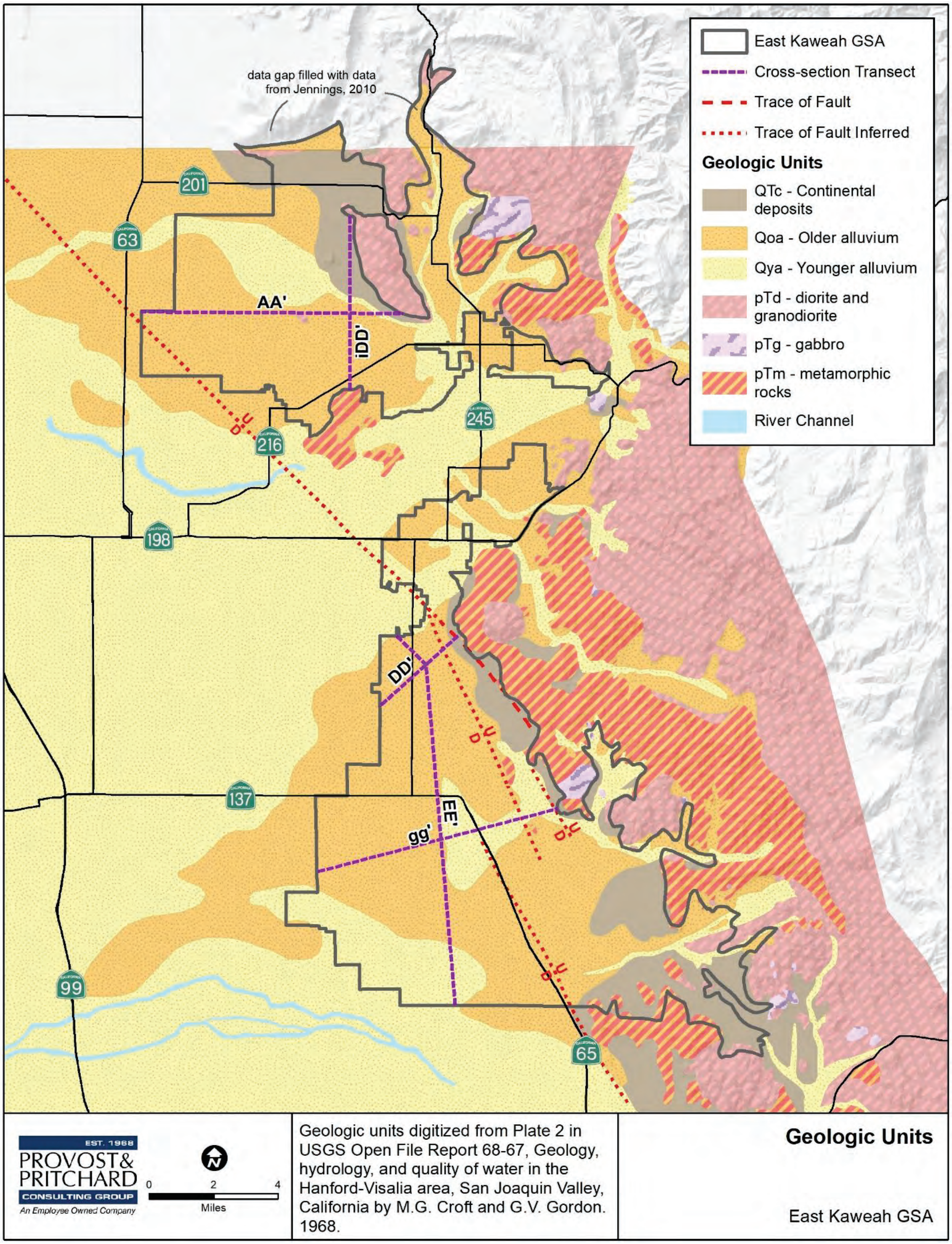
2.2.2.4 Surficial Geology

Legal Requirements:
§354.14(d)(2) Physical characteristics of the basin shall be represented on one or more maps that depict surficial geology derived from a qualified map including the locations of cross-sections required by this Section.

With the exception of scattered inliers of the basement complex, the surficial geology in the EKGSA is comprised of unconsolidated Quaternary deposits as represented in **Figure 2-4** (Croft & Gordon, 1968). Data gaps in the northern section of the map were filled with data from the California Geological Survey 2010

Geologic Map of California (Jennings, 2010). The major units are the Young Alluvium, Old Alluvium, and Continental Deposits (also known as the Porterville Clays) (Ivanhoe USBR Report, 1949).

The Young Alluvium is extensively developed in areas that have regularly experienced recent flow, primarily in the alluvial fans, and overlies the Old Alluvium (Ivanhoe USBR Report, 1949). The Old Alluvium crops out in the interfan areas, where recent deposition is not as common as on the active fans (Exeter and Stone Corral USBR Report, 1949). The Porterville clays occur in a discontinuous belt between the basement complex outcrops of the foothills and the alluvium of the valley floor. The clays consist of weathered outwash from the Basement Complex and have been observed interfingering with both alluvial units, indicating they have likely been accumulating during most of Quaternary time (Ivanhoe USBR Report, 1949).



Geologic units digitized from Plate 2 in USGS Open File Report 68-67, Geology, hydrology, and quality of water in the Hanford-Visalia area, San Joaquin Valley, California by M.G. Croft and G.V. Gordon. 1968.

Figure 2-4 Geologic Units and Cross-Section Locations

2.2.2.5 Geologic Cross-Sections

Legal Requirements:
§354.14(c) The hydrogeologic conceptual model shall be represented graphically by at least two scaled cross-sections that display the information required by this section and are sufficient to depict major stratigraphic and structural features in the basin.

Cross sections that transverse the EKGSA area are presented as **Figure 2-5** through **Figure 2-9**. Cross section locations are shown on the Surficial Deposits Map (**Figure 2-4**). They include two cross sections parallel, and three cross sections perpendicular, to the structural grain of the San Joaquin Valley.

No single data source provided ample coverage of the EKGSA, so cross sections were selected from several sources to provide the best available coverage. As such, they provide varying degrees of detail. Cross sections AA' and iDD' are from the Ivanhoe USBR Technical Report (1949). Sections DD' and EE' are from Croft & Gordon (1968), with section gg' from USGS Water Supply Paper 1469 (Davis et. al. 1959). The cross sections presented herein represent a portion of the original regional geologic cross sections, to more prominently display the subsurface conditions within the EKGSA.

Ivanhoe section AA' traverses west-east through the northern lobe of the EKGSA and is presented in **Figure 2-5**. Ivanhoe section iDD' traverses south-north through the northern lobe and is presented in **Figure 2-6**. These sections do not differentiate between sedimentary units (i.e. Young Alluvium or Old Alluvium). Clay is shown in frequent proximity to the rocks of the Sierra Nevada Batholith (a batholith being a mass of igneous rock formed deep within the crust and being larger than 40 square miles), interfingering with the alluvial sediments. The basement is depicted within 100 feet of the ground surface across most of the eastern side of this area. West of the plutonic outcropping of Twin Buttes the surface of the batholith dips steeply to the west.

Section DD' from Croft & Gordon (1968) traverses southwest-northeast through the EKGSA in the vicinity of Exeter as presented in **Figure 2-7**. Section EE', from the same publication, traverses the southern lobe of the EKGSA from north to south, entering the GSA just south of Exeter as presented in **Figure 2-8**. The Basement Complex (pTu) is shown to dip steeply beneath the sediments of the valley, which is exacerbated by the presence of a fault. The fault appears to cut the QTc (Continental deposits) but does not extend into the alluvial units. By the base of the foothills in the far east of cross section DD' is an approximate 300-foot wedge of QTc, presumably representing (at least in part) the Porterville Clays. The Qoao (Older Alluvium) constitutes the upper 200 feet of the alluvial wedge dipping west from the mountains. In the western half of cross section DD' consolidated marine and continental rocks are shown resting on the batholith at a depth of 600-700 feet below the ground surface. Croft & Gordon inferred that the presence of the marine rocks within a few hundred feet of the surface was likely the result of upfaulting. The foothills are much closer to the trace of section EE' in the northern part of its transect than in the southern. In the subsurface this can be seen in the way the pTu (Basement complex) "peaks" in the vicinity of Exeter, where the cross section is closest to the hills. To the south of this peak the basement plunges to depths not fully defined in the cross section. Lenses of Qya (Younger Alluvium) indicate recent deposition, and particularly thicken towards the south where alluvium from the Tule River has been depositing. Between 500 to 700 feet beneath the ground surface is where the authors estimated the top of the brackish water to begin in the northern two-thirds of the cross-section, a depth that increased to be in excess of 900 feet towards the far south of the EKGSA.

The final cross section is Davis et al. (1959) gg', depicted in **Figure 2-9**. This section was created as part of a regional study and lacks the detail found in the previous cross-sections, but it is useful in extending the information reported above to the large southern lobe of the EKGSA. The Sierra Nevada hardrock plunges from the near surface in the east to deeper than 1,300 feet below the ground surface in the west. The marine sedimentary rocks overlie the basement beginning at approximately 1,000 feet below the surface towards the center of the southern EKGSA lobe.

Despite the differences in detail and format between geologic cross sections from these reports, it is possible to use the knowledge gleaned from one to help inform interpretations of another. The outcrops of pTu (Twin

Buttes, Colvin Mountain, and the Venice Hills) apparent in the Ivanhoe cross sections could be attributed to the presence of the fault indicated in Croft & Gordon section DD'. Cross section gg', while lacking detail, nevertheless corroborates the interpretations of Croft & Gordon sections DD' and EE' in showing the steepness of the basement complex and the presence of consolidated marine deposits at depth.

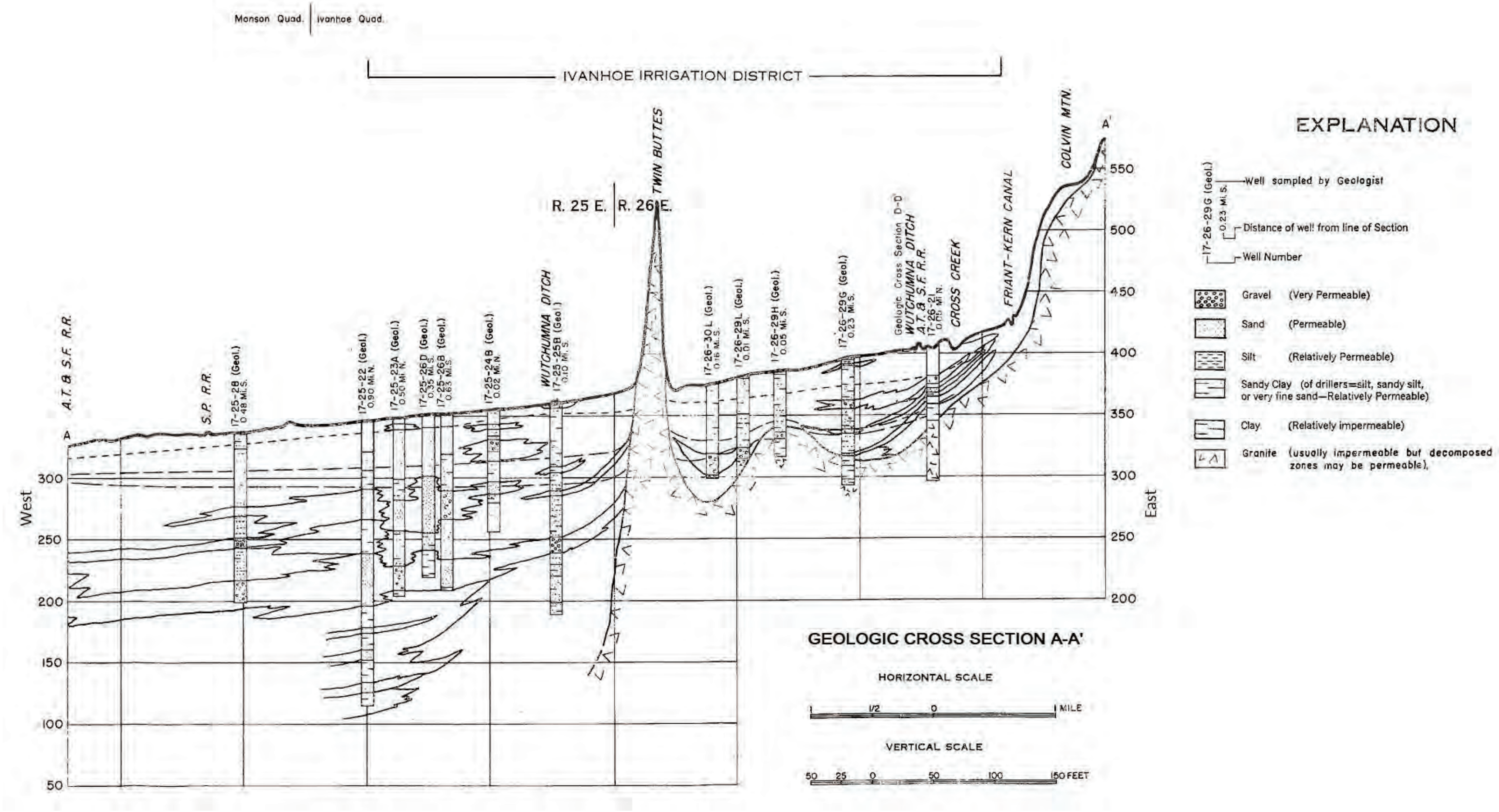


Figure 2-5 Regional Cross-Section AA', modified from Ivanhoe USBR Technical Report (1949)

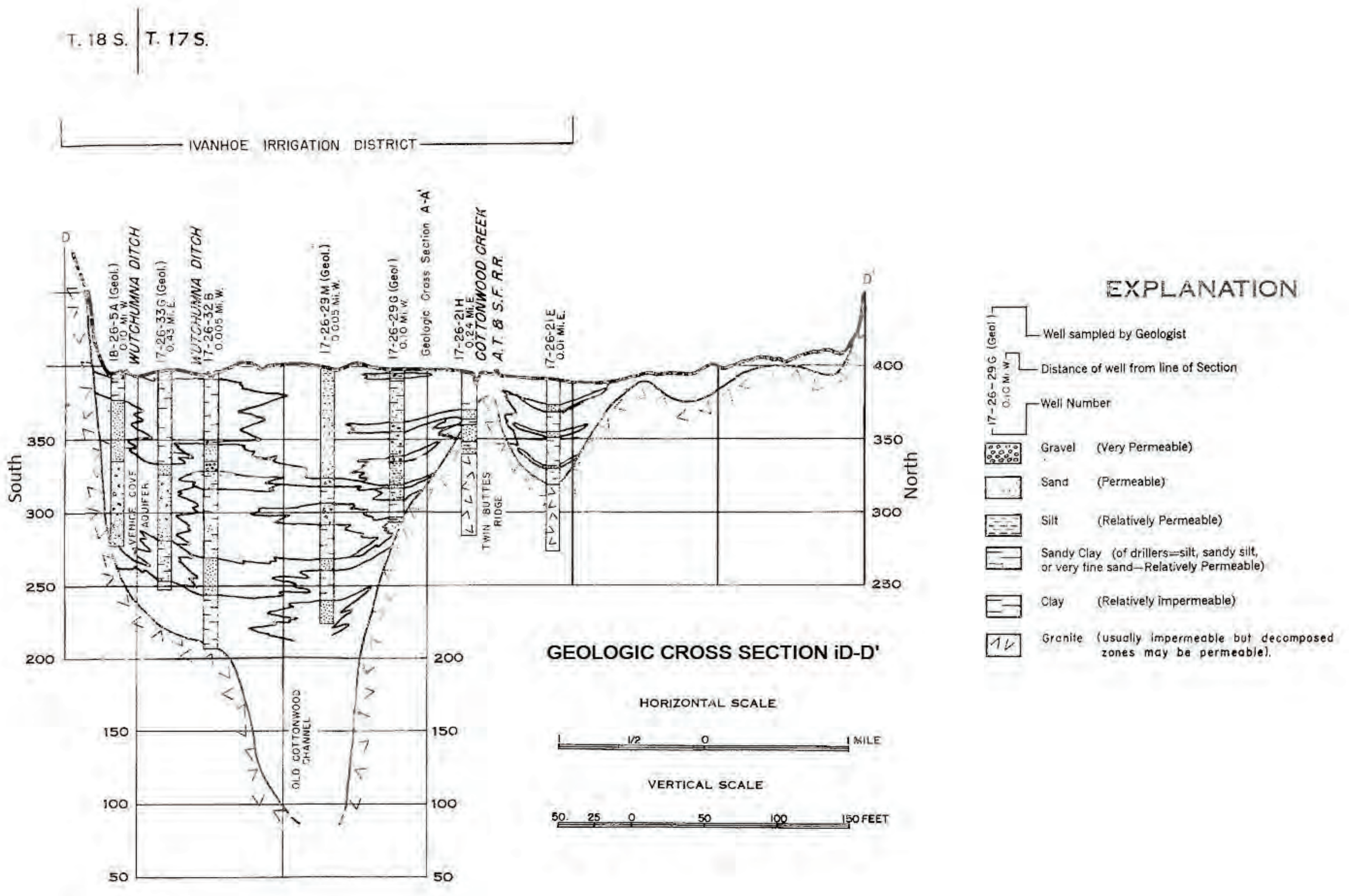


Figure 2-6 Regional Cross-Section iDD', modified from Ivanhoe USBR Technical Report (1949)

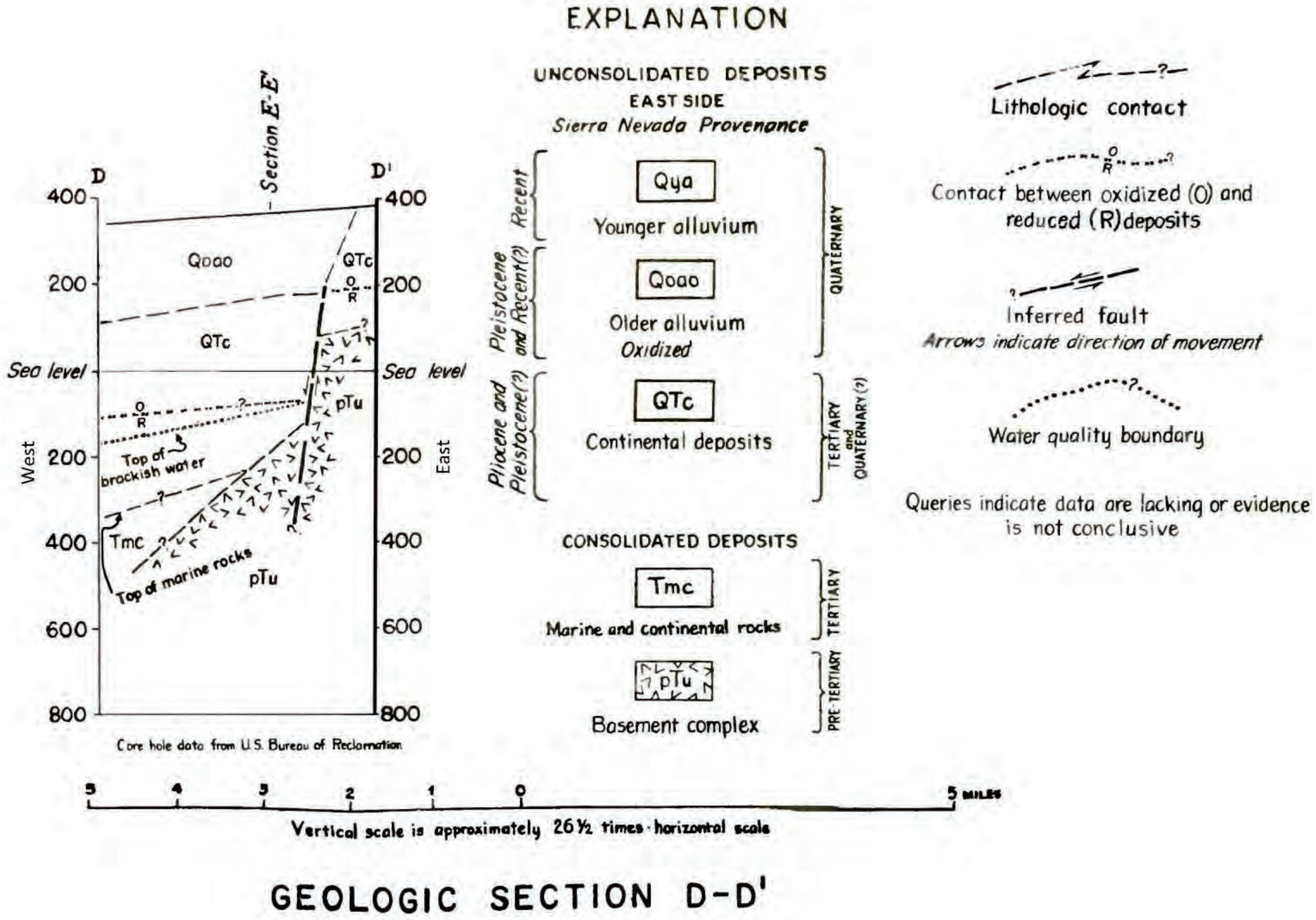


Figure 2-7 Regional Cross-Section DD', modified from Croft & Gordon (1968)

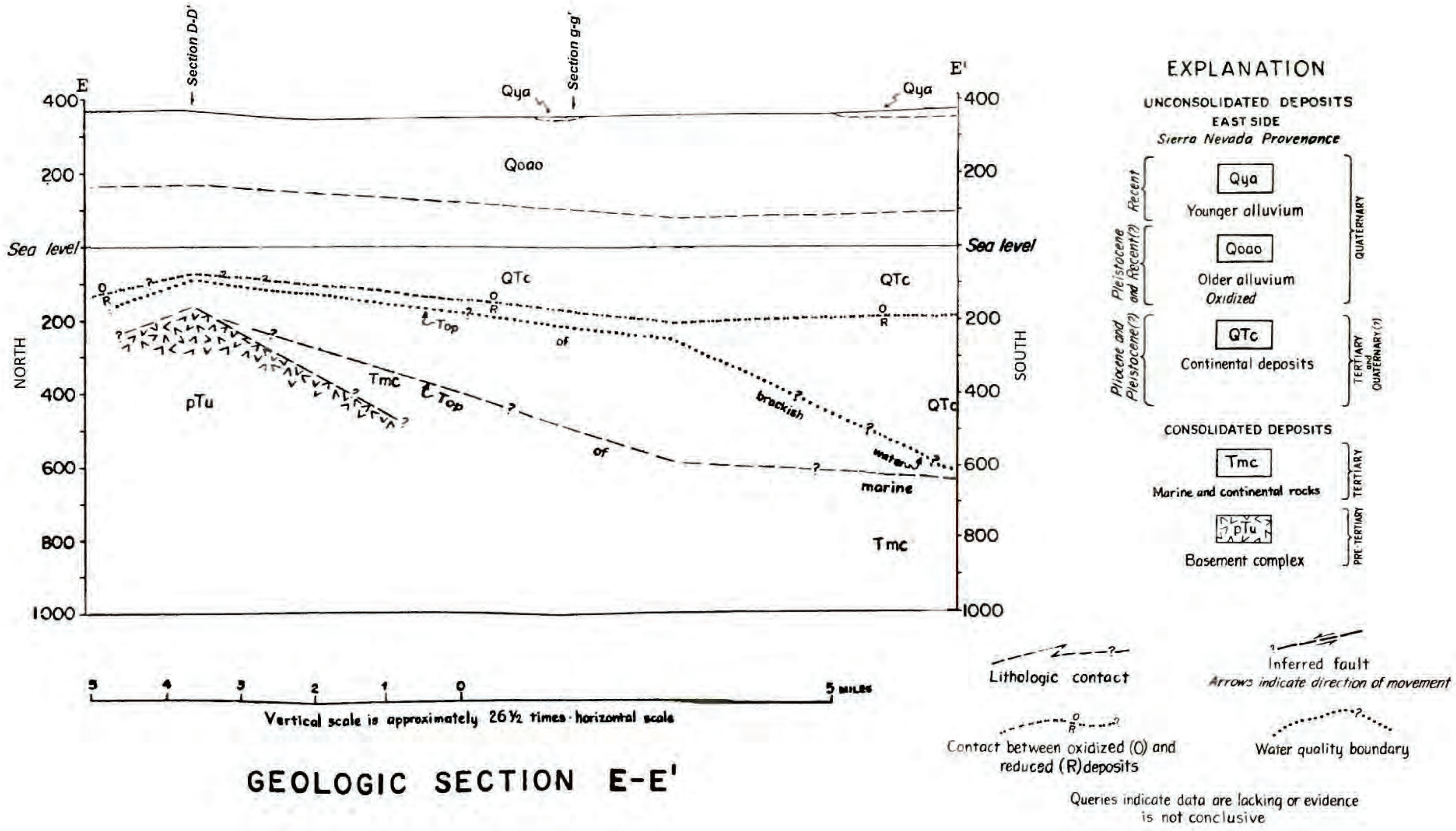


Figure 2-8 Regional Cross-Section EE', modified from Croft & Gordon (1968)

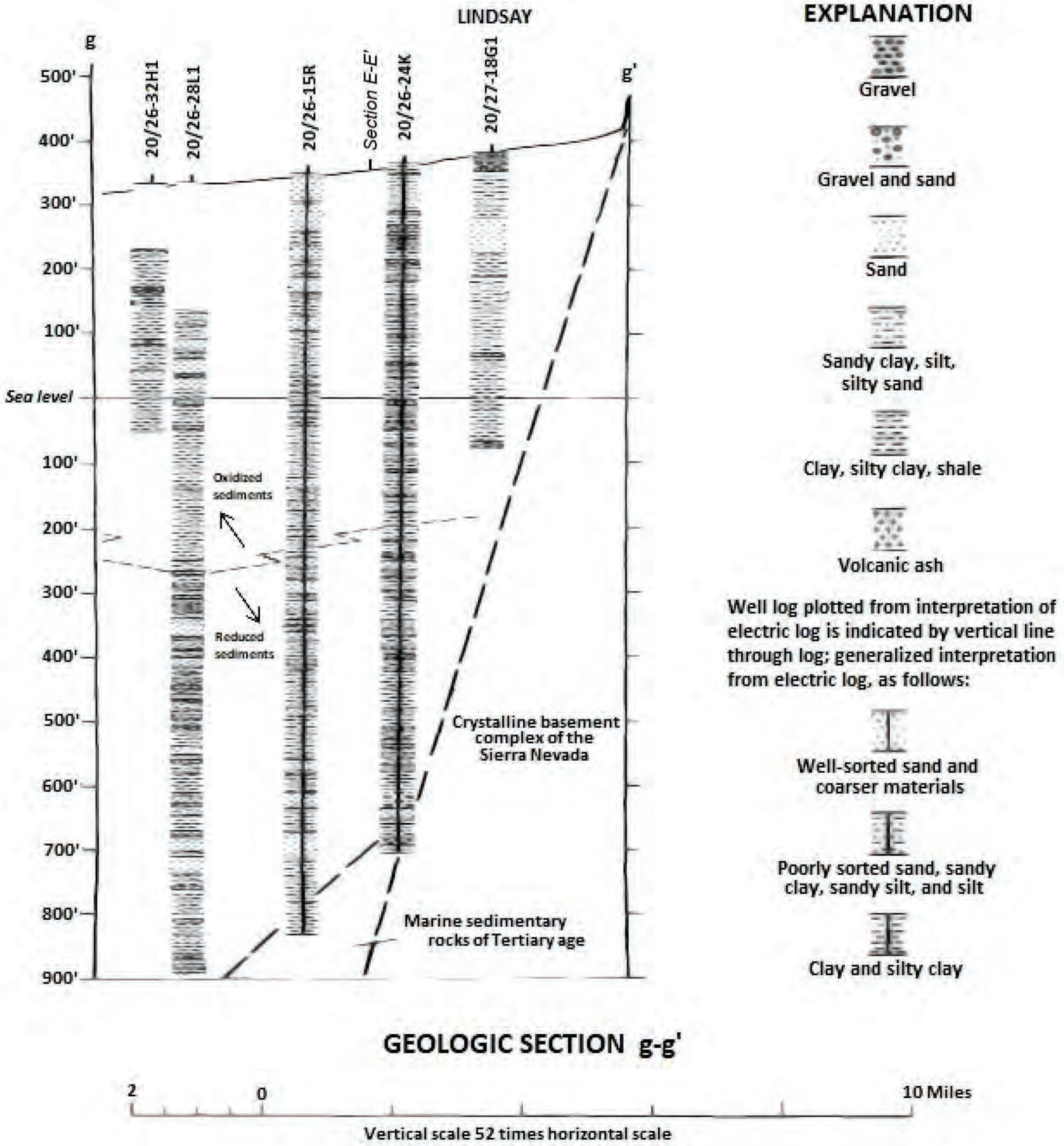


Figure 2-9 Regional Cross-Section gg', modified from Davis et al. (1959)

2.2.3 Lateral Basin Boundaries

Legal Requirements:
§354.14(b)(2) The hydrogeologic conceptual model shall be summarized in a written description that includes lateral basin boundaries, including major geologic features that significantly affect groundwater flow.

The EKGSA is in the eastern part of the Kaweah Subbasin and is bounded to the north by the Kings Subbasin, to the south by the Tule Subbasin, and the GKGSA to the west. To the east the gentle topography of the valley floor rises into the towering Sierra Nevada, where the Kaweah Subbasin's watershed is located.

Figure 2-10 illustrates the Spring 2015 groundwater levels within the EKGSA. This groundwater map was created using data from the Water Data Library and with water level data directly from the irrigation districts. The map illustrates a generally westward flow of groundwater. Water levels appear higher in the vicinity of the Kaweah River, which runs between the two lobes of the EKGSA. The Sierra Nevada mountains significantly influence groundwater flow, acting as an absolute barrier to groundwater and channeling water towards the valley. This map, and water level maps for other years, is discussed in greater detail in **Section 2.4.1.1**.

2.2.4 Bottom of the Subbasin

Legal Requirements:
§354.14(b)(3) The hydrogeologic conceptual model shall be summarized in a written description that includes the definable bottom of the basin.

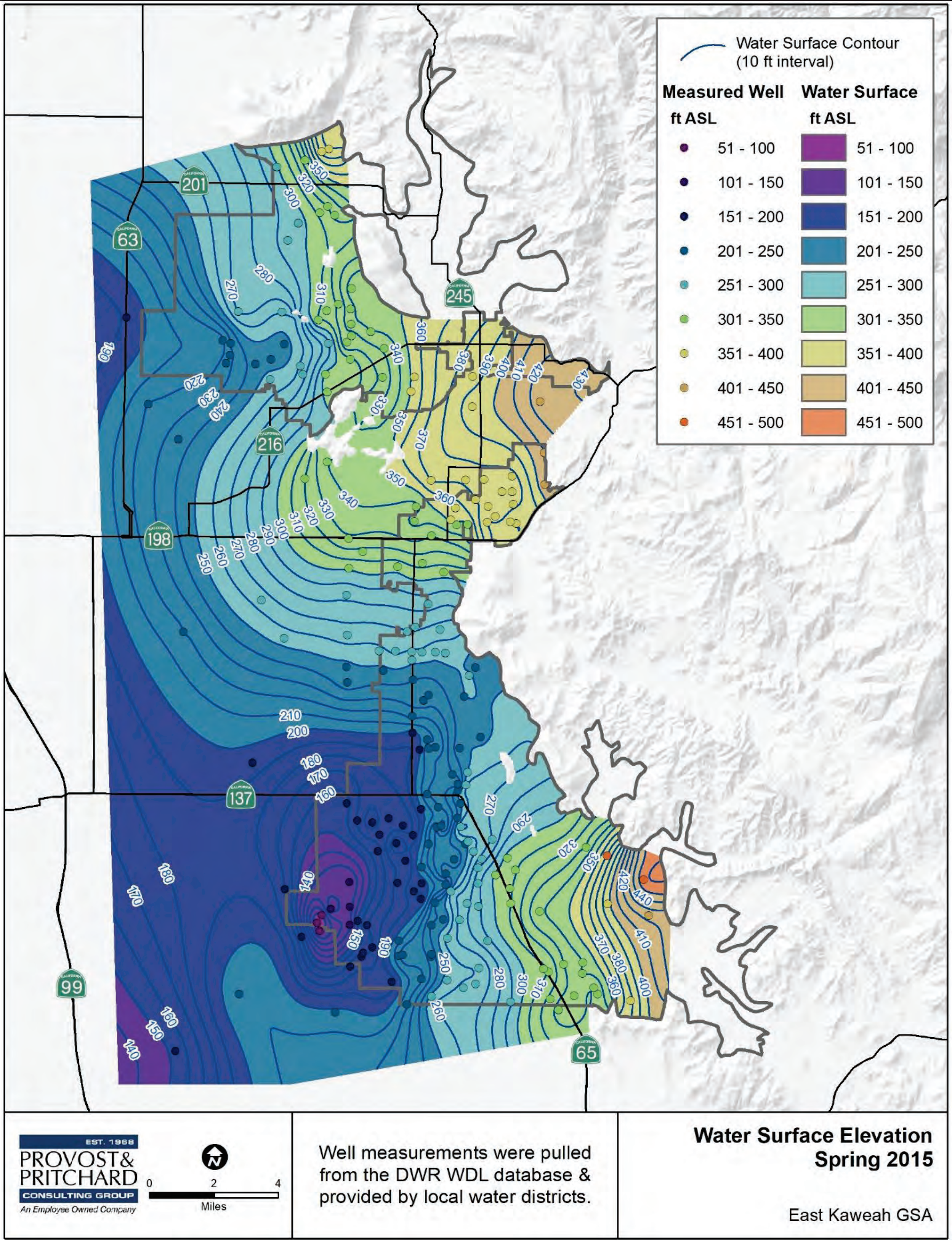
The bottom of the basin is the top of the basement complex where brackish groundwater is not present at depth. Where brackish groundwater is present, the bottom of the basin is the base of the fresh groundwater. The base of freshwater is generally defined as the elevation below which total dissolved solids are greater than 2,000 mg/l (Bertoldi et al, 1991). Where present, the top contact of Tmc marks the effective base of the Kaweah aquifer system due to its low permeability and the brackish quality of its water (B-E, 1972). The base of freshwater is complex and its elevation varies significantly within the unconsolidated deposits, though it generally deepens towards the west.

In the eastern parts of the EKGSA, the sedimentary veneer over the basement is so shallow that the basement complex itself serves as the base of aquifer. East of the Rocky Hill fault the base of the aquifer is as shallow as 50 feet, coinciding with the depth of crystalline bedrock uplifted by the fault. To the west of the Rocky Hill fault the depth of the aquifer increases rapidly. Aquifer thickness is shown in the geologic cross-sections discussed in the previous section and in **Figure 2-11** discussed later in this chapter.

2.2.5 Principal Aquifers and Aquitards of the Subbasin

Legal Requirements:
§354.14(b)(4) The hydrogeologic conceptual model shall be summarized in a written description that includes the principal aquifers and aquitards.

The aquifer system of the EKGSA is currently classified as an unconfined single aquifer system. It is understood that the system consists of alluvial fan materials of both Old and Young Alluvium and are the upper part of a great wedge of continental sediments which thicken westerly toward the trough of the San Joaquin Valley. Each constituent fan of this alluvial plain is elongate and mimics the topography of the surface of the fans. These deposits are lenticular in character. These are interlayered with less permeable sediments which slow the migration of groundwater, but no sediments that would act as absolute groundwater barriers are known to exist within the EKGSA (Exeter & Stone Corral USBR Report, 1949). Groundwater flows southwest toward the Tulare Lakebed, generally following topography (Croft and Gordon, 1968). During GSP Implementation continued data gathering and analyses (i.e. SkyTEM) will be utilized to better understand the aquifer system of the EKGSA and Kaweah Subbasin.



Well measurements were pulled from the DWR WDL database & provided by local water districts.

Water Surface Elevation
Spring 2015

East Kaweah GSA

Figure 2-10 Generalized Groundwater Contour Map, Spring 2015

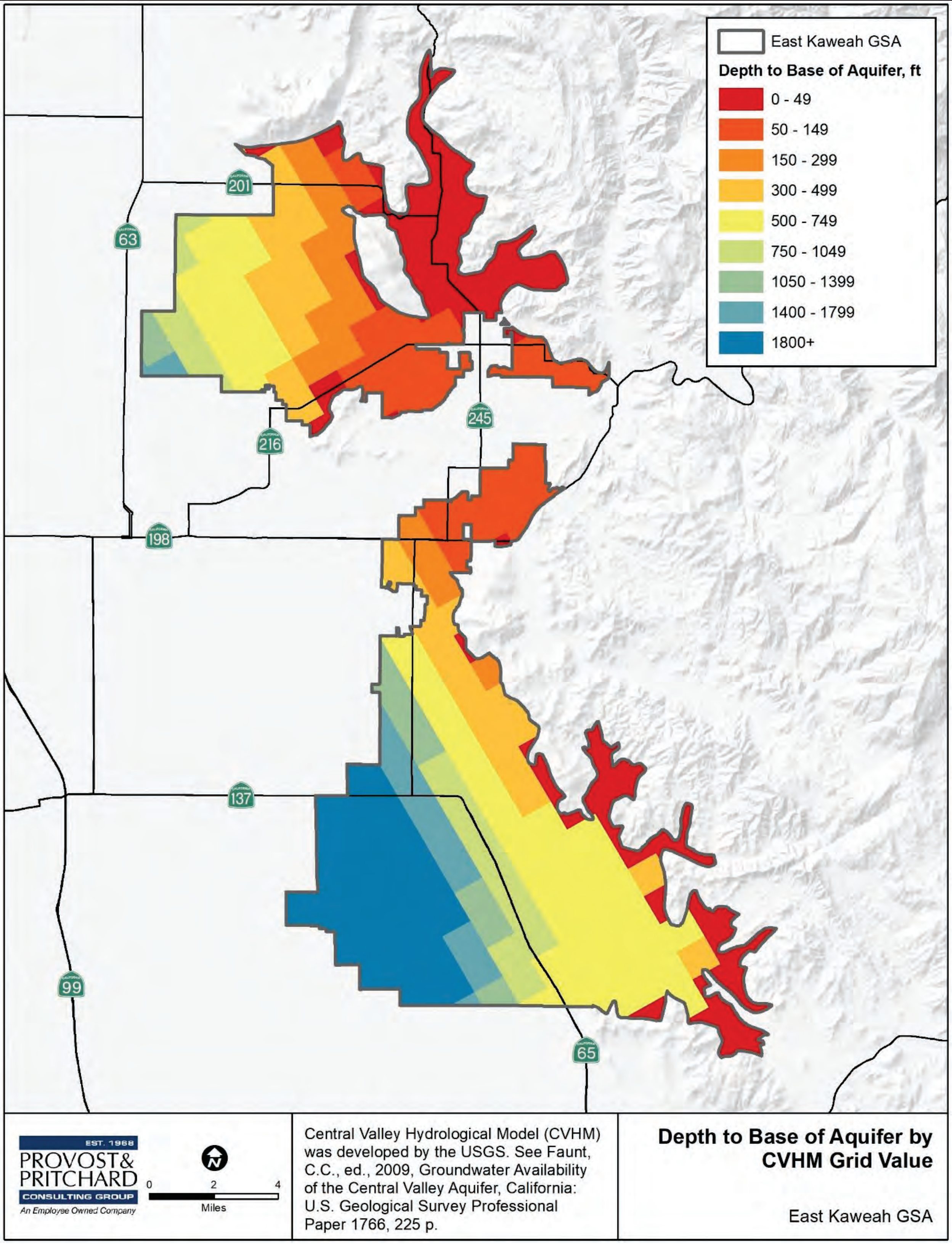


Figure 2-11 Base of Aquifer

2.2.6 Aquifer Characteristics

Legal Requirements:
§354.14(b)(4)(b) Physical properties of aquifers and aquitards, including the vertical and lateral extent, hydraulic conductivity, and storativity, which may be based on existing technical studies or other best available information.

The principle aquifer characteristics of importance to the EKGSA are transmissivity, hydraulic conductivity, and storativity. Hydraulic conductivity is the rate at which water can move through a permeable medium. Transmissivity is the amount of water that can be transmitted horizontally by the fully saturated thickness of the aquifer under a hydraulic gradient of 1. These two properties are related in that transmissivity is the hydraulic conductivity multiplied by saturated aquifer thickness. Storativity is the volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in head, i.e., the amount of space available for groundwater to be stored within the unit (Meinzer, 1932). Storativity is approximately equal to the specific yield in unconfined aquifers. As such, this section discusses specific yield as a close approximation of storativity.

Specific Yield of the Deposits

Specific yield estimates are shown in **Figure 2-12**. They are a composite from Davis et al. (1959) and USGS Professional Paper 1401-D (Williamson et al., 1989). These studies found average specific yields over large areas. Values are mostly from Davis et al. 1959, wherever that data is available. Neither source provided data for the area near the foothills where alluvium interfingers laterally with the Sierra Nevada batholith. **Figure 2-12** shows estimated specific yields across all depth intervals. When change in storage is calculated, it will be calculated using the specific yield of the depth interval in question.

USBR reports developed for Friant Contractors (i.e. Exeter, Ivanhoe, Lindmore, and Stone Corral) provide localized specific yield values. These values are more detailed than those from the USGS reports but cover far less of the area. As a result, the values from these studies were used to check the larger reports and to extend the values found in the larger reports into some data gap areas. The values from the USBR reports are not otherwise represented on the map. **Table 2-2** includes a summary of specific yield values from each report.

Table 2-2 Summary of Specific Yield Estimates

Publication	Estimated Specific Yield Range (%)	Description/Notes
Davis et al. (1959)	6.4 to 11.3	Based on textures in all zones (10 to 50 feet deep, 50 to 100 feet deep, and 100 to 200 feet deep).
Williamson et al. (1989)	6 to 13	Based on textures in all zones.
Exeter & Stone Corral USBR Report (1949)	4 to 14	Based on a zone which approximates the depth of ground water fluctuations between 1921 and 1946 in the Exeter ID.
Ivanhoe USBR Report (1949)	8 to 20	Based on a zone spanning between 45 feet below the ground surface to 4 feet below the surface of the basement complex.
Lindmore USBR Report (1948)	4 to 18	Based on a zone between the fall positions of the water table in 1921 and 1946.
Stone Corral USBR Report (1950)	6 to 14	Based on a zone spanning 20-70 feet below the ground surface, which approximates the depth of ground water fluctuations between 1921 and 1947.

Hydraulic Conductivity and Transmissivity

The hydraulic conductivity of a saturated, porous medium is the volume of water it will transmit in a unit time, through a cross-section of unit area, under a hydraulic gradient of a unit change in head through a unit length of flow (or more simply, it is the ease with which a fluid can move through a medium) (Lohman, 1972). In

USGS Professional Paper 1401-D, Williamson et al. (1989) compiled hydraulic conductivity values estimated from more than 7,400 drillers' logs in the San Joaquin Valley and from power company pump-efficiency tests. Within the aquifer of the EKGSA, estimates of hydraulic conductivity range from a high of 9.8 feet/day (ft/d) in the eastern portion of the Kaweah alluvial fan to a low of 2.9 ft/d in the interfan areas along the eastern side by the foothills.

Transmissivity is the property of an aquifer that is defined as the ability of the aquifer to transmit groundwater flow laterally. It can be calculated by multiplying the thickness of the water producing strata by the hydraulic conductivity of the same strata. Typically, transmissivity values can be determined from the results of aquifer tests. They can also be estimated from the specific capacity values of wells. A conversion between specific capacity and transmissivity was developed by Thomasson et al. (1960), by which an estimate of transmissivity could be calculated by multiplying the specific capacity of a well in an unconfined aquifer by 1,500, or by 2,000 for a well in a confined aquifer.

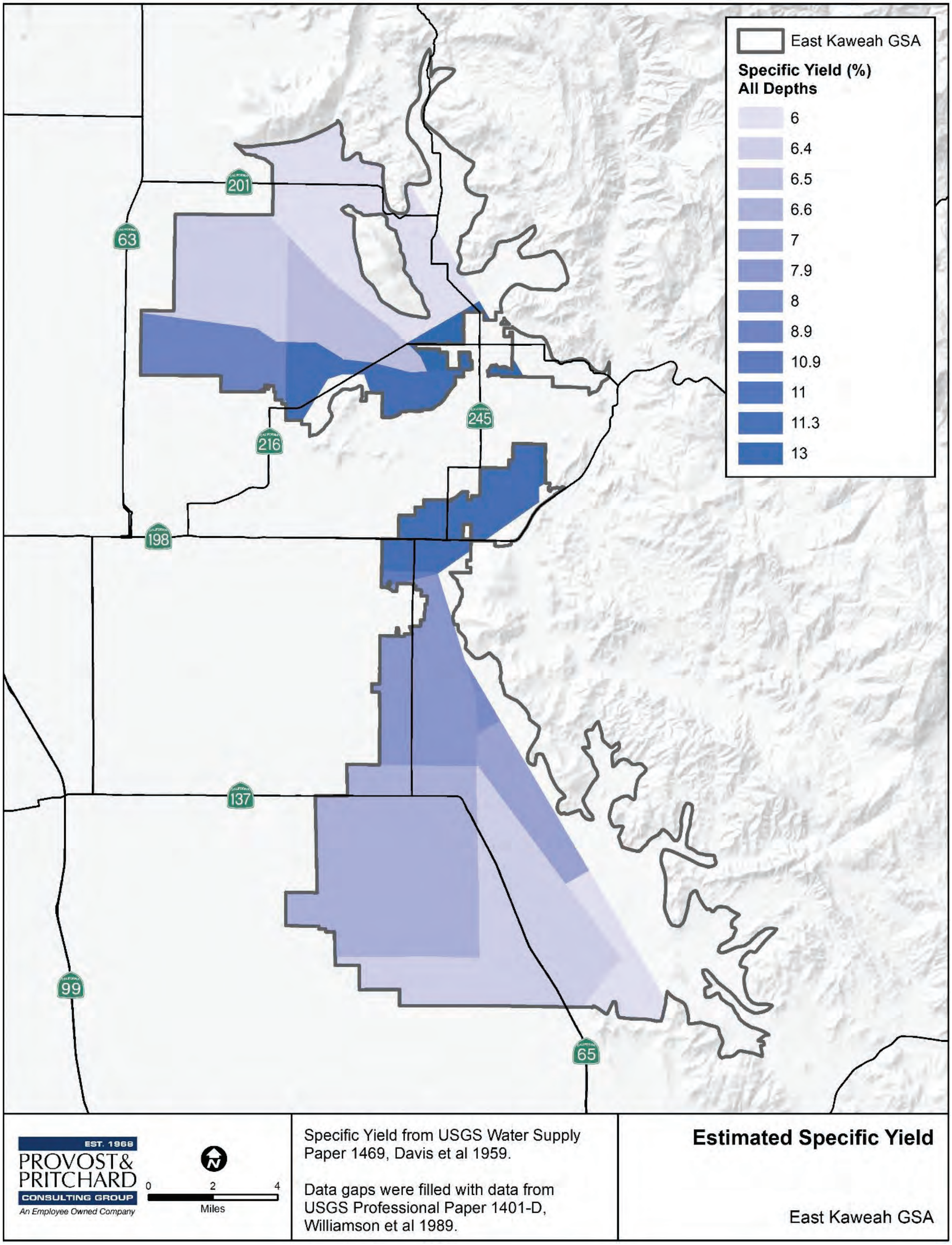
Transmissivity values for the EKGSA can be estimated from specific capacity values by Davis et al. (1964). Estimates of transmissivity in the EKGSA range from a low of 9,000 gallons per day per foot (gpd/ft) to a high of 97,000 gpd/ft. **Table 2-3** includes an estimated transmissivity value summary. **Figure 2-13** depicts these estimates. In general, transmissivity values increase in areas further away from the base of the foothills and decrease in the interfan areas.

Table 2-3 Transmissivity Estimates Summary

Publication	TR	Estimate of Transmissivity (gpd/ft)	Description / Notes
Davis et al. (1964)	16S25E	37,500	Based on specific capacity estimates from Davis et al. (1964) and Thomasson et al. (1960), and the empirical relationship between specific capacity and transmissivity. It should be noted that since these studies wells have been drilled deeper essentially making the aquifer thickness deeper than that studied. Actual transmissivity values may differ than this table summary as a result.
	16S26E	39,000	
	17S25E	45,000	
	17S26E	39,000	
	17S27E	12,000	
	18S25E	97,500	
	18S26E	61,500	
	18S27E	25,500	
	19S26E	49,500	
	19S27E	42,000	
	20S26E	21,000	
	20S27E	9,000	
	21S26E	64,500	
	21S27E	30,000	
	21S28E	66,000	

Vertical Extent

The basement complex is considered to be the base of the aquifer within the EKGSA. **Figure 2-11** shows the depth to the base of the aquifer according to the Central Valley Hydrological Model (CVHM) developed by the USGS (Faunt, 2009). Where the EKGSA abuts the foothills, the proximity of the basement complex to the ground surface prevents the existence of an appreciable aquifer. The calculated depth to the base of the aquifer rapidly increases moving southwest through the EKGSA, extending to depths exceeding 1,800 feet west of California State Highway 65 in the southern lobe of the EKGSA.



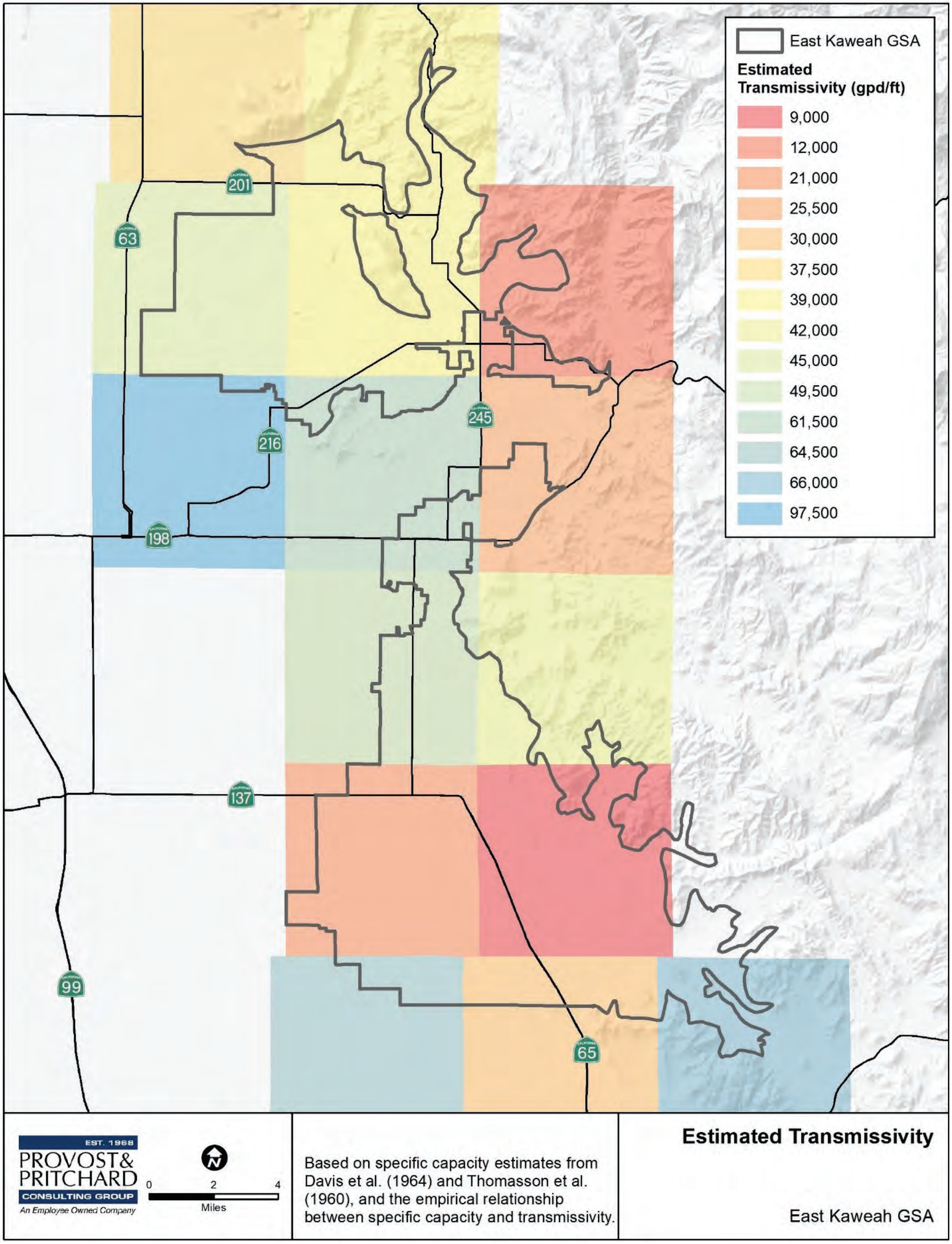
Specific Yield from USGS Water Supply Paper 1469, Davis et al 1959.

Data gaps were filled with data from USGS Professional Paper 1401-D, Williamson et al 1989.

Estimated Specific Yield

East Kaweah GSA

Figure 2-12 Estimated Specific Yields



Based on specific capacity estimates from Davis et al. (1964) and Thomasson et al. (1960), and the empirical relationship between specific capacity and transmissivity.

Figure 2-13 Estimated Transmissivity

2.2.6.1 Structural Properties that Restrict Groundwater Flow

Legal Requirements:
§354.14(b)(4)(c) Structural properties of the basin that restrict groundwater flow within the principal aquifers, including information regarding stratigraphic changes, truncation of units, or other features.

According to DWR's Bulletin 118 (2003), there are no reported groundwater barriers restricting horizontal flow in and out of the Kaweah Subbasin. There is, however, the Rocky Hill fault zone that may affect groundwater flow inside of the Subbasin and potentially cross gradient of flow along the north and south boundaries. Located in the eastern portion of the Subbasin, the Rocky Hill fault disrupts pre-Eocene deposits and may locally penetrate older alluvial deposits. The linearity of ridges in this area defines the fault line (Refer to **Figure 2-4** for the Cross Section Location Map and **Figure 2-7** and **Figure 2-9** for Cross Sections DD' and gg'). The Rocky Hill fault does not offset younger alluvium based on water level data (Croft, 1968); however, lithology data from boreholes suggest that older alluvium may be offset or varied in thickness at the Rocky Hill fault. In addition, Fugro West (2007), suggested that the hydrologic connection of the oxidized alluvial aquifer may be restricted near the Rocky Hill fault; this represents a data gap in groundwater flow across the Rocky Hill fault, and should be evaluated in the future, both within the Subbasin and in association with the northern and southern boundaries of the Subbasin.

The influx of water entering the groundwater from rivers creates a high in the groundwater surface, causing water to flow away from them. Groundwater that would have naturally flowed through the area beneath the river is instead redirected to flow around the river, which amounts to flowing alongside the river instead. The Sierra Nevada mountains are so influential to groundwater flow that all groundwater flows away from them towards the west, and groundwater levels cannot be taken within them as their hydrogeology acts independently from the valley. Outliers of Sierra Nevada basement act as similar (yet less absolute) barriers to groundwater flow, preventing water from flowing through their impermeable roots but allowing water to flow around them with little issue. Colvin mountain (in the north) and the Venice Hills (between Ivanhoe I.D. and the St. Johns River) are prominent examples of these basement outliers.

2.2.6.2 General Water Quality of Principal Aquifers

Legal Requirements
§354.14(b)(4)(d) General water quality of the principal aquifers, which may be based on information derived from existing technical studies or regulatory programs.

The discussion presented below is intended to present a generalized view of groundwater quality in the EKGSA portion of the Kaweah Subbasin. A more detailed discussion on groundwater quality will be included in **Section 2.4** as part of the Groundwater Conditions. According to DWR Bulletin 118 (CDWR, 2003), water in the region is generally safe for most beneficial uses, including agriculture and municipal use.

Groundwater in the oxidized older alluvium and younger alluvium is generally of the calcium bicarbonate type. In the unconsolidated deposits beneath the alluvial fans groundwater is generally low in dissolved constituents. Where recharge is from the major streams, sodium constitutes less than 42% of the cations and TDS ranges from 100 to 270 mg/l. Sodium and bicarbonate are the principal ions in groundwater in the continental deposits and in reduced older alluvial deposits. Sodium accounts for more than 70 percent of the cations in the water from these deposits. TDS ranges from 100 to 500 mg/l. In the interfan areas, where recharge is from intermittent streams, dissolved constituents range from 270 to 650 mg/l and magnesium and chloride are major constituents (Croft & Gordon, 1968).

2.2.6.3 Primary Use of Aquifers

Legal Requirements:
§354.14(b)(4)(e) Identification of the primary use or uses of each aquifer, such as domestic, irrigation, or municipal water supply.

The EKGSA's aquifers are used for agricultural, domestic, industrial, and municipal purposes. There is no formal tabulation of meter records to estimate how much groundwater is pumped in the EKGSA. It is likely that the majority of agricultural wells in the EKGSA do not have totalizing flow meters, although it is recognized that some agricultural pumpers may keep detailed meter records of groundwater use. The amount of water pumped varies based on the crop demand. The estimated amounts of pumping will be described in more detail in **Section 2.5** as part of the Water Budget.

2.2.7 Physical Characteristics

2.2.7.1 Soil Characteristics

Legal Requirements
§354.14(d)(3) Physical characteristics of the basin shall be represented on one or more maps that depict soil characteristics as described by the appropriate Natural Resource Conservation Service soil survey or other applicable studies.

The University of California, Davis, in conjunction with the University of California Division of Agriculture and Natural Resources, developed the Soil Agricultural Groundwater Banking Index (SAGBI). The Index is a composite evaluation of groundwater recharge feasibility on agricultural land (also called Irrigation Field Flooding). The following five parameters are incorporated into the Index:

- Deep percolation is dependent upon the saturated hydraulic conductivity of the limiting layer.
- Root zone residence time estimates drainage within the root zone shortly after water application.
- Topography is scored according to slope classes based on ranges of slope percent.
- Chemical limitations are quantified using the electrical conductivity (EC) of the soil.
- Soil surface condition is identified by the soil erosion factor and the sodium adsorption ratio.

Proximity to a water conveyance system is not a factor considered in the SAGBI composite evaluation. Each factor was scored on a range, rather than discretely, and weighted according to significance. Adjustments were then made to reflect soil modification by deep tillage (i.e., shallow hard pan is assumed to have been removed by historic farming activities) (modified SAGBI). Ultimately, SAGBI seeks to categorize recharge potential according to risk of crop damage at the recharge site. Usefulness of the index is diminished when evaluating locations for dedicated recharge basins. In these cases, a soil profile illustrating deep percolation potential may prove to be more useful. As is the case with any model, the SAGBI is best applied in conjunction with other available data and on-site evaluation.

Figure 2-14 illustrates the modified SAGBI for the EKGSA. The modified Index indicates that a majority of the land within the GSA is favorable for recharge. This model assumes that hardpans have been largely removed by previous farming practices. Hardpans are still extensive within the EKGSA, though, and so this model should be considered in conjunction with the unmodified SAGBI, illustrated in **Figure 2-15**. It is locally well known that surface recharge is ineffective in the area, but water introduced deep enough into the strata infiltrates easily in those areas identified in the modified SAGBI as “good.”

2.2.7.2 Delineation of Recharge Areas, Potential Recharge Areas, and Discharge Areas, Including Springs, Seeps, and Wetlands

Legal Requirements:
§354.14(d)(4) Physical characteristics of the basin shall be represented on one or more maps that depict delineation of existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas, including significant active springs, seeps, and wetlands within or adjacent to the basin.

This section discusses existing and potential groundwater recharge areas, and areas of groundwater discharge. The information is presented on a regional scale and provides a general assessment of the EKGSA’s recharge potential. This information would need to be supplemented with local information for developing site-specific groundwater recharge projects.

Existing Recharge Areas

Recharge in the EKGSA is derived from seepage from the Kaweah and Tule Rivers, Yokohl Creek, Cottonwood Creek, the Wutchumna Ditch, and intermittent stream flows. Seepage of water from rivers, streams, irrigation ditches, and irrigation water applied in excess of plant and soil-moisture requirements constitute the principal sources of water infiltrating to the aquifers. Direct precipitation contributes minor quantities of water to these aquifers (Croft and Gordon, 1968).

Historically groundwater use has been offset though in-lieu recharge, the use of surface water for irrigation instead of groundwater, when supplies are available (Stone Corral ID, Five Year Update Ag Water Management Plan June 2013). In the late 1940s Exeter, Ivanhoe, Lindmore, Lindsay-Strathmore, and Stone Corral Irrigation Districts compiled USBR reports that outlined the need for additional surface water supplies. These reports established allocations through the Central Valley Project (CVP) to correct the levels of groundwater overdraft at the time. CVP water deliveries promptly began in 1951, however, actions such as the San Joaquin River Restoration and issues with Delta diversions, less surface water has been available in recent years which results in more need to pump more groundwater.

Potential Recharge Areas

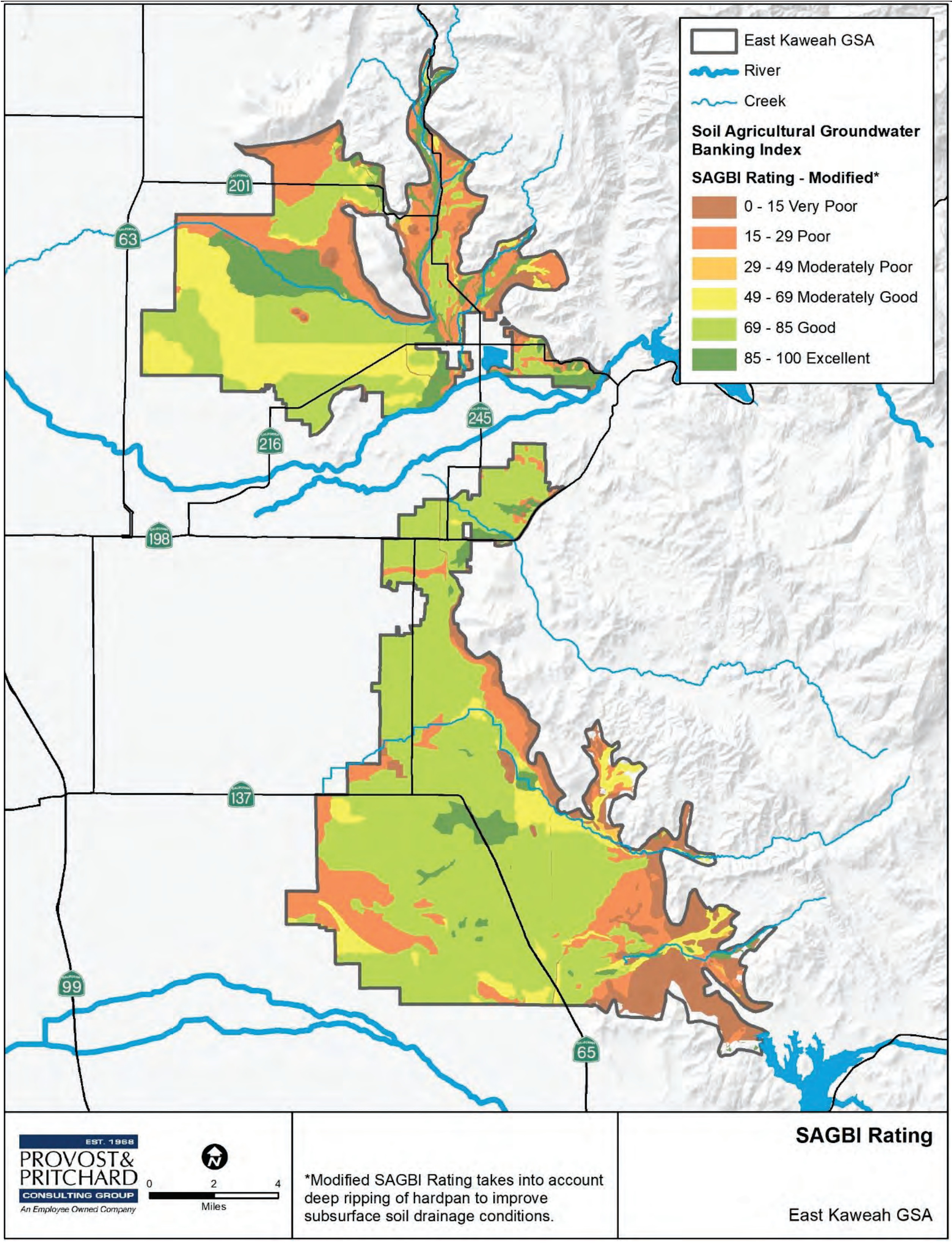
Potential recharge areas can be identified using the soil and geologic maps described in **Figure 2-4**, **Figure 2-14**, and **Figure 2-15**. These maps provide a regional assessment of recharge potential and can be useful for initial screening. It should be recognized that land availability is generally a limiting factor in the selection of recharge areas. Local permeability, geologic structure, and an overall lack of suitable land inhibit the recharge potential of much of the GSA (Geologic Study of the Lindmore ID, 1948). Soil borings of at least 50 ft depth are necessary to determine the suitability of specific potential recharge sites.

Discharge Areas

East of McKays Point the Kaweah River is anecdotally understood to be a gaining stream, meaning that it derives some of its flow from influent groundwater. There are currently no other known groundwater discharges (springs, seeps, etc.) originating in the area. Groundwater level maps will be presented in the Current and Historic Groundwater Conditions chapter of the EKGSA GSP.

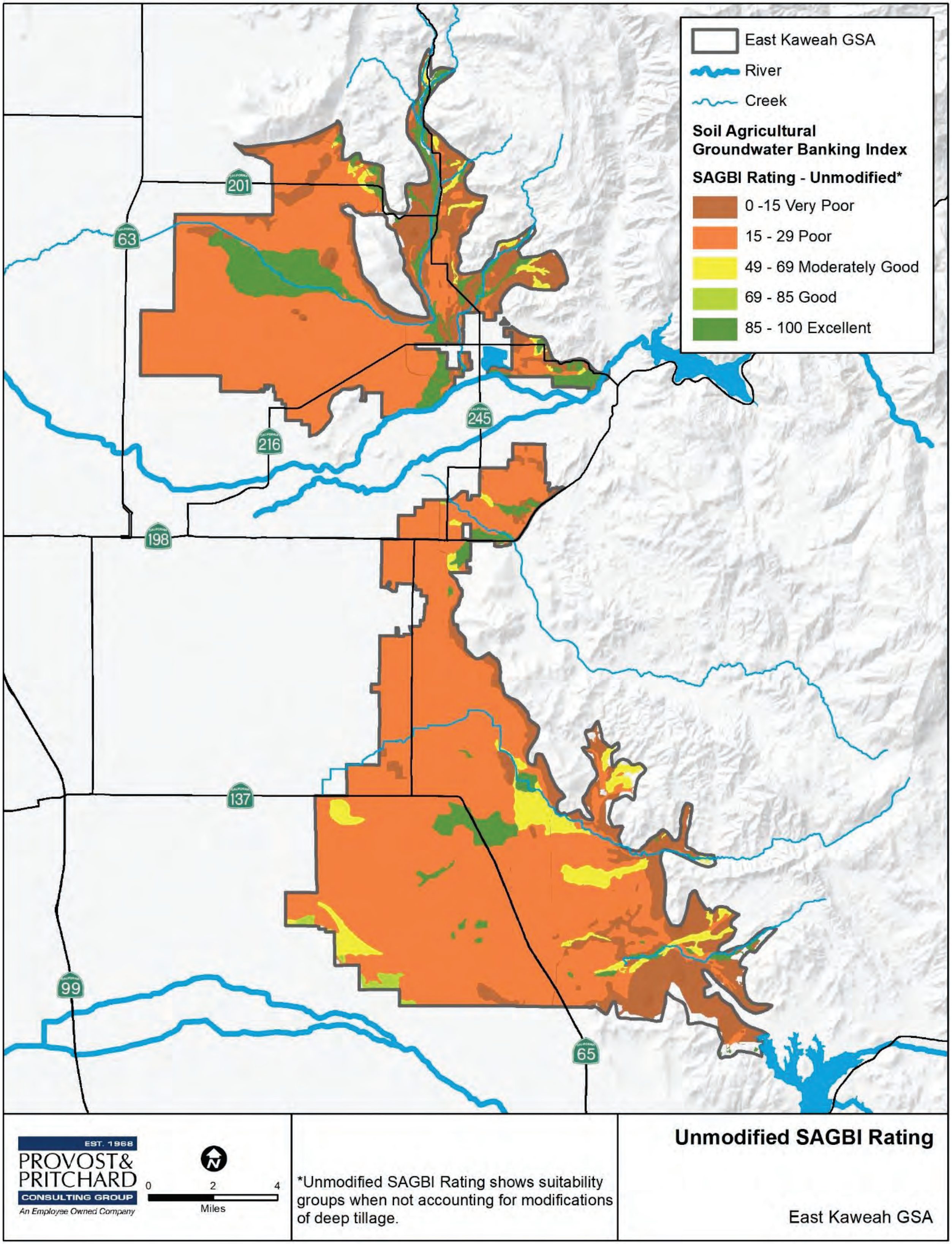
Wetland Areas

Areas indicated as being wetlands in the National Wetland Inventory are illustrated in **Figure 2-16**. Some areas of freshwater emergent wetlands are present in the eastern margins of the EKGSA, where small waterways come down from the foothills. Areas identified as being potential Groundwater Dependent Ecosystems (GDEs) are presented in **Figure 2-17**, and further discussed in **Section 2.4.6**.



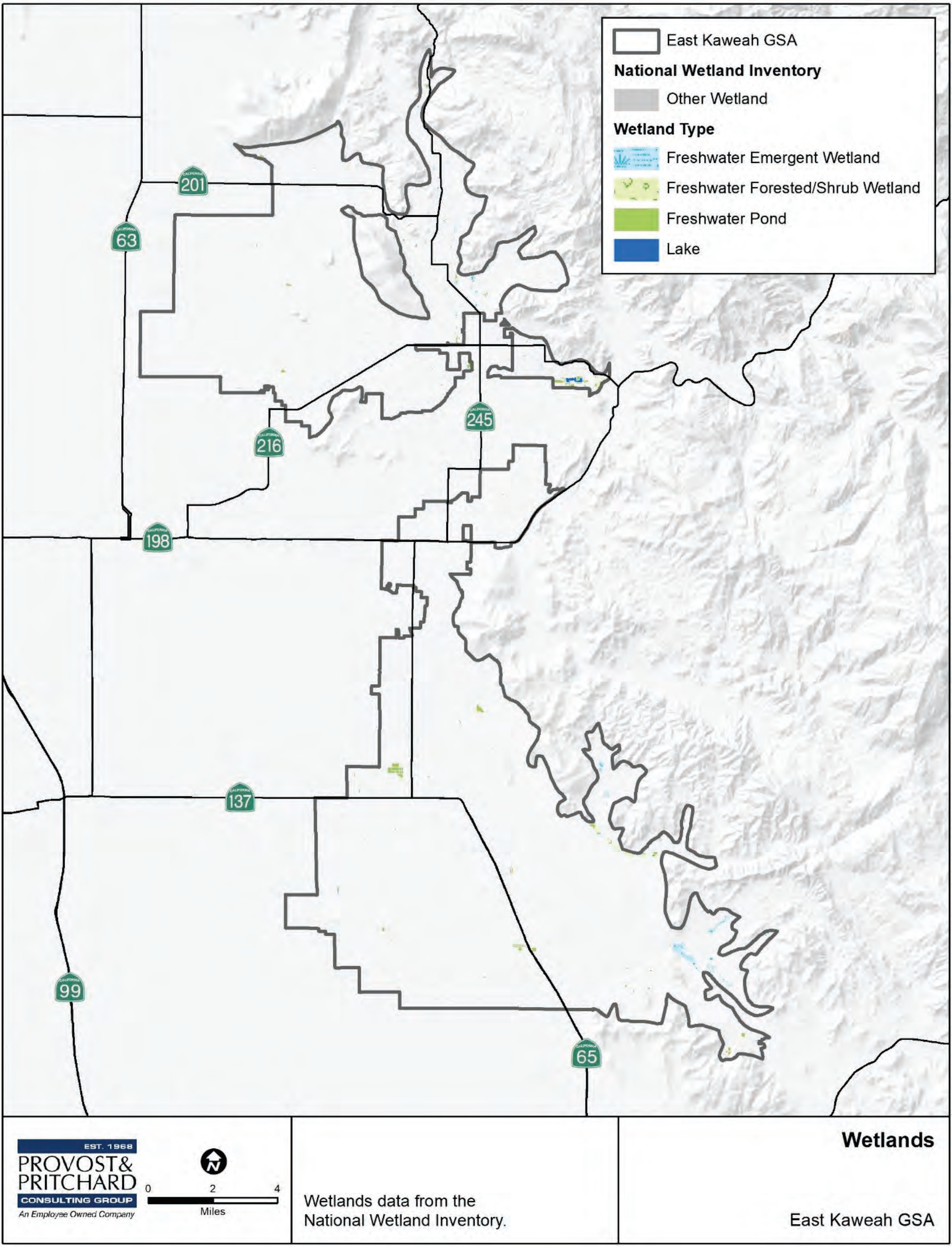
*Modified SAGBI Rating takes into account deep ripping of hardpan to improve subsurface soil drainage conditions.

Figure 2-14 Modified Soil Agricultural Groundwater Banking Index (SAGBI) Rating



*Unmodified SAGBI Rating shows suitability groups when not accounting for modifications of deep tillage.

Figure 2-15 Unmodified Soil Agricultural Groundwater Banking Index (SAGBI) Rating



Wetlands data from the National Wetland Inventory.

Figure 2-16 Wetlands Map

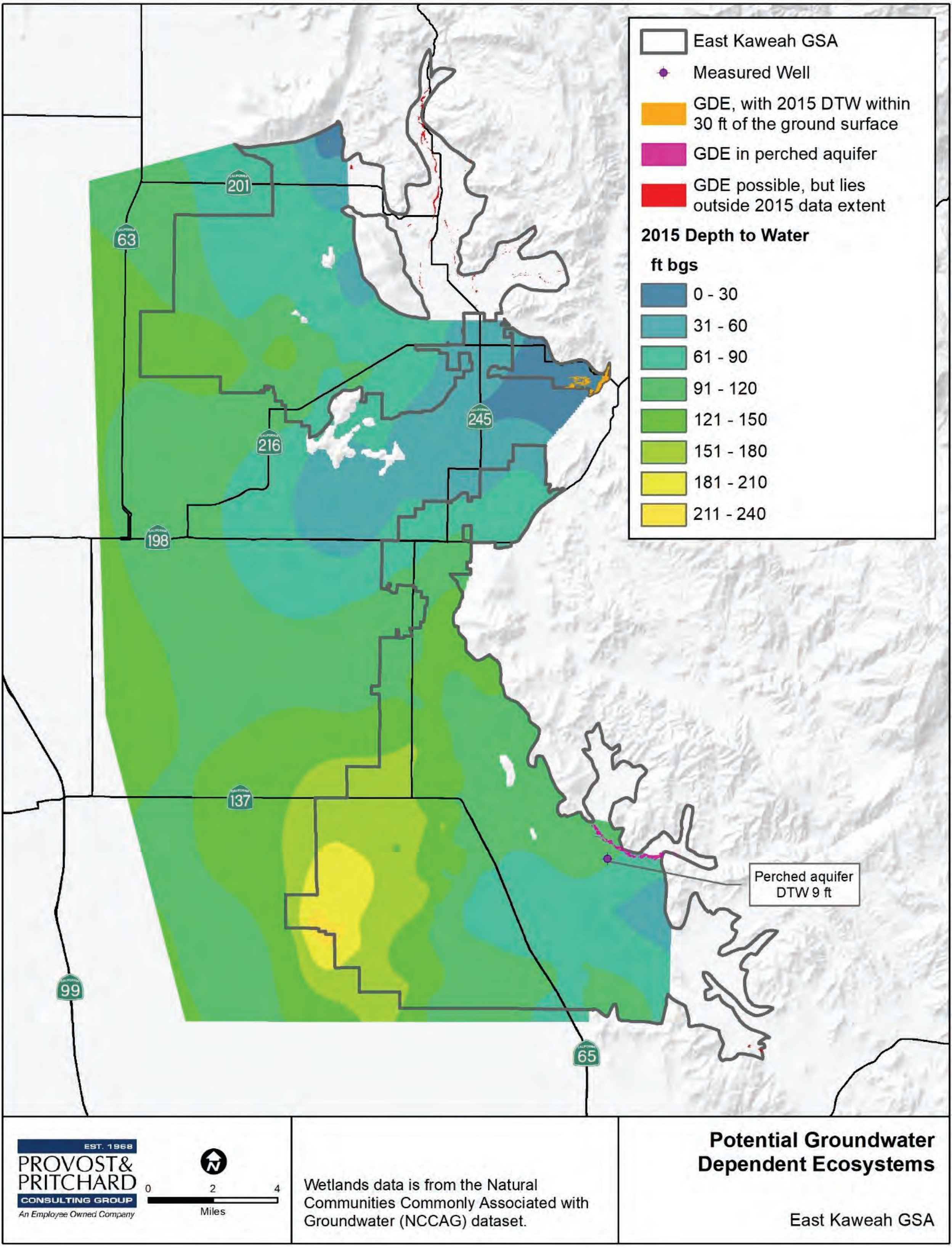


Figure 2-17 Potential Groundwater Dependent Ecosystems

2.2.7.3 Surface Water Bodies

Legal Requirements:
§354.14(d)(5) Physical characteristics of the basin shall be represented on one or more maps that depict surface water bodies that are significant to the management of the basin.

Surface water features important to the management of the EKGSA are shown in **Figure 2-18**.

The Friant-Kern Canal is a primary source of surface water for much of the EKGSA. It runs the length of the EKGSA, usually following the eastern border. East of the City of Lindsay it turns south and runs through the interior of the GSA, skirting Strathmore and continuing to the south. It is managed by Reclamation.

The Kaweah River has its headwaters in the high Sierra Nevada and enters the San Joaquin Valley near the EKGSA. It runs between the two lobes of the EKGSA and is a significant source of recharge to the entire Kaweah Subbasin. The St. Johns River diverges from the Kaweah River at McKays Point, flowing in and out of the northern lobe of the EKGSA. The Wutchumna Ditch is the principal man-made open channel through the northern lobe of the EKGSA. It diverts water from the Kaweah about 1.5 miles above McKays Point and is operated by the Wutchumna Water Company. It flows parallel to and slightly north of the St. Johns River.

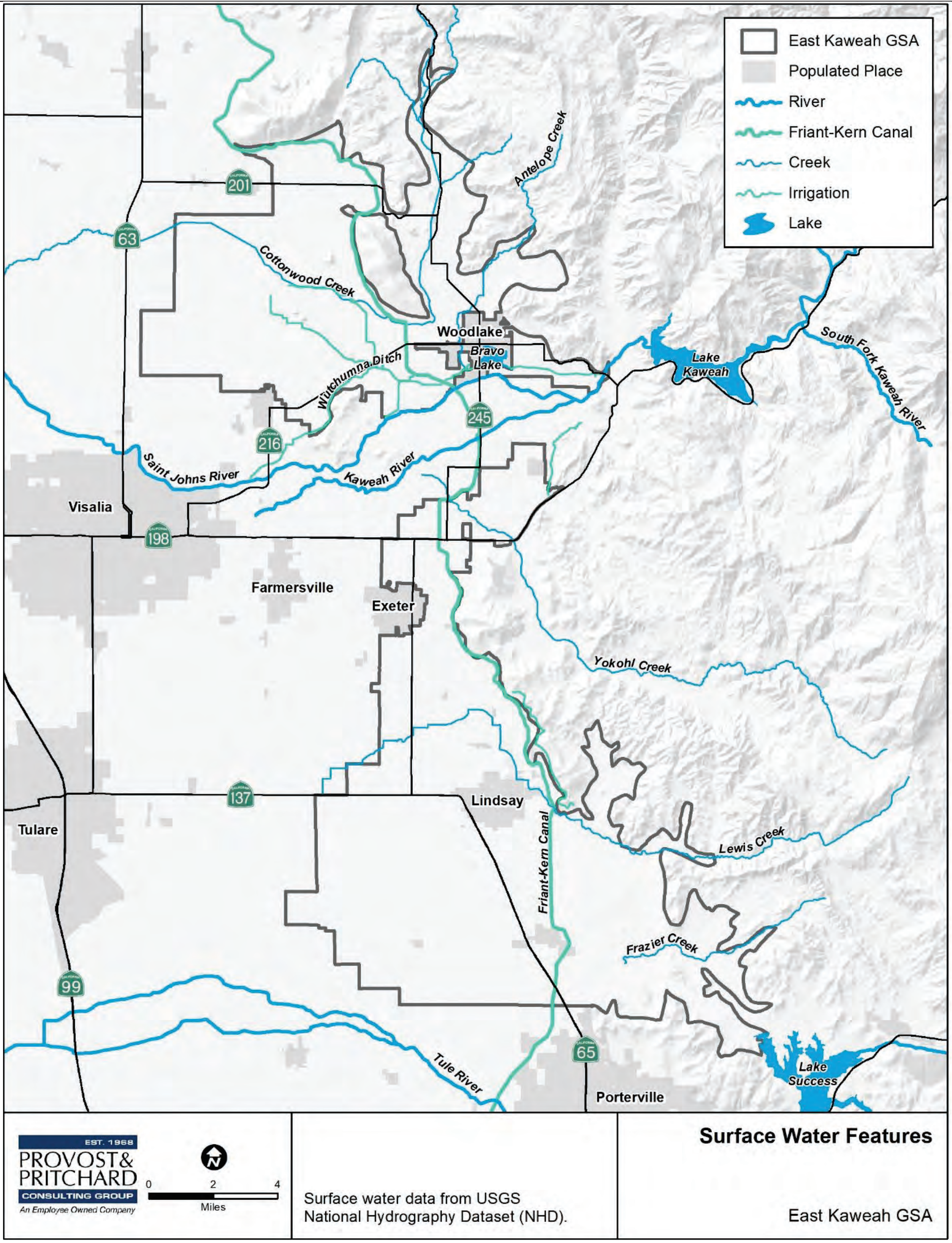
Several intermittent streams have courses that flow into the EKGSA from the Sierra Nevada Mountains. Prominent among these are Cottonwood Creek in the northern lobe of the EKGSA, and Yokohl, Lewis, and Frazier Creeks in the southern lobe.

Lastly, the Tule River flows to the south of the EKGSA. Seepage from the River can contribute to recharge within the EKGSA in wetter periods (Water Supply Study of the Lindmore ID, 1948).

2.2.7.4 Source and Point of Delivery for Imported Water Supplies

Legal Requirements:
§354.14(d)(6) Physical characteristics of the basin shall be represented on one or more maps that depict the source and point of delivery for imported water supplies.

Groundwater use in the EKGSA is directly impacted by the availability and delivery of surface water to lands within the Central Valley Project (CVP) service area. The Friant-Kern Canal (shown in **Figure 2-18**) provides the imported surface-water supplies in the EKGSA (Croft and Gordon, 1968). CVP water is delivered to the Friant CVP contractors within the EKGSA.



Surface water data from USGS National Hydrography Dataset (NHD).

Figure 2-18 Surface Water Features Significant to the Management of the East Kaweah GSA Basin

2.3 Overview of Existing Monitoring Programs

Monitoring is and will be fundamental component of a groundwater management program and is needed to measure progress towards groundwater sustainability. Monitoring programs needed to comply with SGMA will largely relate to the Undesirable Results, such as groundwater level monitoring, land subsidence monitoring, and groundwater quality monitoring. Existing monitoring programs as they relate to SGMA compliance, their history and adequacy for the EKGSA Monitoring Network are described in this section. Additional information is also available in the Kaweah Subbasin Setting document in **Appendix 2-A**. In general, water levels and water quality have been monitored annually, or twice a year where possible, and data reported biennially. Where viable, these existing monitoring networks will be incorporated into the defined monitoring networks for this GSP to be leveraged with monitoring network requirements for SGMA.

2.3.1 Existing Groundwater Level Monitoring Programs

While most member agencies maintain groundwater level records (Friant Contractors per requirements of CVP Contract), there is no comprehensive network throughout the EKGSA area. Many existing local water level monitoring networks were further developed by local water districts in part due to AB-3030 groundwater management planning. The most robust monitoring program is directly west of the EKGSA area, where more than 300 wells are semiannually monitored in the Kaweah Delta Water Conservation District (KDWCD). Many of the redundant and disjointed groundwater level monitoring programs may cease when a SGMA approved groundwater monitoring program is developed and implemented by the GSAs in the Kaweah Subbasin.

2.3.2 Existing Groundwater Quality Monitoring Programs

Legal Requirements:
§354.16(d) 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.

Most of the wells in EKGSA are used for agricultural purposes. These wells have been monitored by the well operators to ensure crop productivity. These monitoring records are typically kept private and are not public information. Water quality monitoring of drinking water sources has been performed by public water systems under the California Safe Drinking Water Act and overseen by the Division of Drinking Water (DDW). Public water systems are defined by California Health & Safety Code § 116275(h) as systems that have either: (1) 15 or more service connections, or (2) serve at least 25 individuals daily at least 60 days out of the year. Private domestic wells that serve one to four connections are not subject to any water quality regulation. Additional testing may be done if a site has specific constituents of concern that need to be monitored. Some limited data is available in smaller communities that include clusters of domestic wells.

Groundwater quality monitoring and reporting is currently conducted through numerous public agencies. The following sections provide a summary of databases, programs and agencies that actively collect groundwater data, provides information on where the data is stored, and how it was used in this Basin Setting. A summary of these programs is provided in **Table 2-4** at the end of this section. The water quality monitoring network needs to be enhanced adding dedicated monitoring wells to track regional trends and to serve as a warning system for changes in water quality.

Irrigated Lands Regulatory Program

The Irrigated Lands Regulatory Program (ILRP) addresses discharge of wastes (e.g., sediments, pesticides, nitrates) from commercial irrigated lands. The goal of the ILRP is to protect surface water and groundwater and reduce impacts of irrigated agricultural discharges to waters of the State. In 1999, the California Legislature passed Senate Bill 390, which eliminated a blanket waiver for agricultural waste discharges. The Bill required the Regional Water Quality Control Board (RWQCB) to develop a program to regulate agricultural lands under the Porter-Cologne Water Quality Control Act. In 2003, the Central Valley Water Board adopted a conditional

Waiver of Waste Discharge Requirements (WDRs) to regulate agricultural discharges to surface waters. In September 2013, the RWQCB adopted the WDR governing the Tulare Lake Region, of which the Kaweah Subbasin is a part, that address discharges to both surface water and groundwater, thus requiring ILRP enrollment for all commercial irrigated agricultural operations.

Irrigated landowners can choose to comply with the WDRs individually or can join a coalition. Coalitions are governing agencies that assist members in complying with ILRP WDRs on a watershed level, thus potentially reducing/eliminating grower interaction with the RWQCB. Coalitions assess fees to cover their costs and RWQCB fees, prepare and implement mandatory regional water quality management and monitoring plans, and report the results of the monitoring efforts and the effectiveness of the plans.

A majority of the Kaweah Subbasin is within the Kaweah Basin Water Quality Association (KBWQA). One of the requirements under WDR was for the KBWQA to prepare a Groundwater Assessment Report (GAR), which is an analysis of the risks to groundwater from nitrates and pesticides as the primary constituents of concern (COCs) that may originate from irrigated agriculture within the coalition area. Both the vadose zone and aquifer have nitrates and pesticide in storage that are the result of past land use practices representing potential impacts that will continue to migrate over time.

Following results from the GAR, the KBWQA developed a Comprehensive Groundwater Quality Monitoring Plan (CGQMP) and Groundwater Trend Monitoring Plan (GTMP). These two works products will be the basis for the KBWQA's groundwater quality monitoring going forward. The KBWQA recently received a conditional approval from the RWQCB for these products, therefore no data is available at this time. In 2018, the first round of groundwater quality trend monitoring occurred. The usefulness of the data collected through the ILRP to the needs of the EKGSA SGMA compliance will be evaluated as data becomes available. The KBWQA will submit their data to the Groundwater Ambient Monitoring & Assessment (GAMA) Geotracker program when available.

Groundwater Ambient Monitoring & Assessment (GAMA) Program

The GAMA Program was created by the State Water Resources Control Board (SWRCB), in 2000. It was later expanded by the Groundwater Quality Monitoring Act of 2001 (AB 599). AB 599 required the SWRCB, to integrate existing monitoring programs and design new program elements as necessary, to monitor and assess groundwater quality. The GAMA Program is based on collaboration among agencies including the SWRCB, RWQCB, DWR, Department of Pesticide Regulations (DPR), USGS and USGS National Water Information System (NWIS), and Lawrence Livermore National Laboratory (LLNL). In addition to these state and federal agencies, local water agencies and well owners also participate in this program. The main goals of GAMA are to 1) improve statewide comprehensive groundwater monitoring, and 2) increase the availability to the general public of groundwater quality and contamination information. Monitoring projects in this program include:

- **Priority Basin Project** which provides a comprehensive groundwater quality assessment to help identify and understand the risks to groundwater. The project started assessing public system wells (deep groundwater resources) in 2002 and shifted focus to shallow aquifer assessments in 2012. The analysis sampled both public and domestic supply wells for deep and shallow aquifer assessments respectively. Since 2002 USGS, the technical lead, has performed baseline and trend assessments and sampled over 2,900 public and domestic water supply wells that represent 95% of the groundwater resources in California.
- **Domestic Well Project** began between 2002 and 2011, the GAMA Program sampled over 1,100 private wells in six California counties (Yuba, El Dorado, Tehama, Tulare, San Diego, and Monterey) for commonly detected chemicals. The voluntary participants received analytical test results and fact sheets, and the water quality data was included in the GAMA GeoTracker online database. This Project is currently on hiatus. Through this project, nitrate data including a stable isotopic analysis for 29 domestic wells within the Kaweah Subbasin were incorporated into the Basin Setting.

- **Technical Hydrogeologic and Data Support** has expanded to include several Divisions and Programs at the SWRCB and RWQCB, other state agencies, and non-governmental organizations. GAMA staff is providing support for a number of activities, including:
    - Hydrogeologic analyses to evaluate drinking water sources
    - Development of geothermal well and water well standards
    - Technical support for state actions involving groundwater
    - Hydrogeologic analysis for desalination projects
    - Technical assistance for developing standard operating procedures for grant projects
    - Source water protection planning
    - Antidegradation in groundwater planning

GeoTracker and EnviroStor Databases

The SWRCB oversees the GeoTracker database. This database systems allows the SWRCB to house data related to sites that impact or have the potential to impact the groundwater. Records available on GeoTracker includes cleanup sites for Leaking Underground Storage Tank (LUST) Sites, Department of Defense Sites, and Cleanup Program Sites. Other records for various unregulated projects and permitted facilities includes Oil and Gas production, operating Permitted Underground Storage Tanks (USTs), and Land Disposal Sites.

GeoTracker is a public portal that can retrieve records and view data sets from multiple SWRCB programs and other agencies through Google maps GIS interface. This database is not only useful for the public, but also to help other agencies, such as the EKGSA, to monitor the progress of cases. It also provides a web application tool for secure reporting of lab data, field measurement data, documents, and reports.

The California Department of Toxic Substances Control (DTSC) oversees the EnviroStor database. This data management system tracks cleanup, permitting, enforcement, and investigation efforts at hazardous waste facilities and sites with known contamination or sites where further investigation is warranted by the DTSC. This database only provides reports, inspection activities and enforcement actions completed on or after 2009. Like the GeoTracker database, this is not only useful for the public, but other agencies may use it to monitor progress of ongoing cases. The primary difference between the two databases is that EnviroStor only houses records for cases that DTSC is the lead regulatory agency, whereas the GeoTracker database houses records to cases from various agencies at the State and local levels. For the Basin Setting, both databases were searched to identify and report on any contamination sites that may have impacts to groundwater water quality.

California State Drinking Water Information System (SDWIS)

All public drinking water systems (a system that has 15 or more service connections or regularly serves 25 individuals daily at least 60 days out of the year) are regulated by the DDW to demonstrate compliance with State and Federal drinking water standards through a rigorous monitoring and reporting program. Required monitoring for each well within each water system is uploaded to the DDW's database and subsequently available for the public through the SDWIS. In addition to providing compliance monitoring data for each regulated water system, other information such as monitoring frequency, basic facility descriptions, lead and copper sampling, violations and enforcement actions, and consumer confidence reports are also available.

All drinking water systems are required to collect samples, known as Title 22 constituents, on a given frequency depending on the constituent and regional groundwater vulnerability. Public water systems provide the most abundant source of data since the testing requirements are fairly frequent intervals. It is important to understand that this characterization is not intended to represent water supplied by purveyors because they may provide wellhead treatment to remove or reduce contamination. The following is a summary of the minimum sampling frequency for a public water supply well:

- General minerals, metals and organics (Synthetic Organic Chemicals and Volatile Organic Compounds) sampling is required every 3 years. If any organics are detected, sampling frequency must be increased to quarterly.
- Nitrate is required annually. If nitrate is ≥5 ppm, then sampling is required quarterly.
- If arsenic is ≥5 ppb, sampling should be increased to quarterly but is not always done.
- Radiologicals (gross alpha and uranium) are sampled one every 3 (when initial monitoring is ≥ ½ the MCL), 6 (when initial monitoring is ≤ ½ the MCL) or 9 (when initial monitoring is non-detect) years depending on historical results.

United States Geological Survey (USGS)

The USGS California Water Science Center (CWSC), provides California water data through data collection, processing, analysis, reporting, and archiving. Data include surface water, groundwater, spring sites, and atmospheric sites, with data often available in real-time via satellite telemetry. The CWSC groundwater database consists of records of wells, springs, test holes, tunnels, drains, and excavations. Available information includes groundwater level data, well depth, aquifer parameters, and more. Studies that were specifically used for the Basin Setting and groundwater characterization are:

- Status and Understanding of Groundwater Quality in the Two Southern San Joaquin Valley Study Units, 2005-2006: California GAMA Priority. Scientific Investigations Report 2011-5218. 2012.
- Environmental Setting of the San Joaquin-Tulare Basins, California. Water Resources Investigations Report 97-4205. 1998
- Groundwater Quality in the Shallow Aquifers of the Tulare, Kaweah, and Tule Groundwater Basins and Adjacent Highlands areas, Southern San Joaquin Valley, CA. USGS and SWRCB. Fact Sheet, 2017.
- Groundwater Quality in the Southeast San Joaquin Valley, California. USGS and SWRCB. June 2012.
- Groundwater Quality Data in the Southeast San Joaquin Valley, 2005-2006: Results from the California GAMA Program. Data Series 351. USGS and SWRCB. 2008.

Department of Pesticide Regulation (DPR)

The DPR Ground Water Protection Program evaluates and samples for pesticides to determine if they may contaminate groundwater, identifies areas sensitive to pesticide contamination and develops mitigation measures to prevent that movement. DPR obtains ground water sampling data from other public agencies, such as SDWIS, USGS and GAMA, and through its own sampling program. Sampling locations and constituents are determined by pesticides used in a region, and from review of pesticide detections reported by other agencies. Because of their sample selection methodology, DPR typically only collects one sample per well, they do not confirm positive detections with repeat sampling. Rather, their focus is on validating contamination through their research and sampling program. These data are reported annually along with the actions taken by DPR and the SWRCB to protect groundwater from contamination by agricultural pesticides. Annual reports are reviewed, and contaminant detections are identified in the groundwater quality characterization. In the Kaweah Subbasin, only legacy pesticides (dibromochloropropane and 1,2,3-trichloropropane) are detected in the public water system wells. No pesticides currently in use were identified.

Central Valley-Salinity Alternatives for Long-term Sustainability (CV-SALTS)

CV-SALTS is a collaborative stakeholder driven and managed program to develop sustainable salinity and nitrate management planning for the Central Valley. The program objective is intended to facilitate the salt and nitrate implementation strategies recommended in the Salt and Nitrate Management Plan (SNMP) developed in 2017. They are designed to address both legacy and ongoing salt and nitrate accumulation issues in surface and groundwater. The overarching management goals and priorities of the control are: 1) ensure safe drinking water supply; 2) achieve balanced salt and nitrate loading; and 3) implement long-term, managed restoration of impaired water bodies. The program is phased with the primary focus of early actions on nitrate impacts to groundwater drinking water supplies and established specific implementation activities. The Kaweah Subbasin is a Priority 1 basin for nitrate management. The nitrate control program schedule is set to begin in 2019, pending State Board adoption of the Salt and Nitrate Control Program basin plan.

CV-SALTS will enact a nitrate control program as part of the SNMP which requires forming a management zone as a regulatory option to comply with the requirements of the nitrate program. The management zones will consist of a defined management area to manage nitrates, ensure safe drinking water, and meet applicable water quality objectives. Local management plans will be created to implement the long-term goals of the nitrate control program. As programs are implemented, there will be versions of management areas to meet the objectives of their individual programs. While ILRP allows for compliance of their regulatory program through coalitions that cover a broad, non-contiguous area based on similar land use, SGMA and CV-SALTS will both require contiguous management areas/zones to be contiguous areas regardless of land use.

Both the ILRP and CV-SALTS programs involve permittees and local stakeholders working towards water management objectives set forth by the State. In this regard, collaborative efforts will likely be made to maximize the resources of each program and provide a more integrated approach to developing local solutions for groundwater management.

Table 2-4 Existing Groundwater Quality Monitoring Programs

Programs or Data Portals	Parameters	Frequency	Objectives	Notes
AB-3030 and SB-1938	Water levels are typically monitored annually An Ag Suitability analysis (limited suite of general minerals) monitoring frequency between annual to once every 3 years.	Semiannual to Annual		Monitoring is recommended as a part of groundwater management planning. Data availability is inconsistent between Districts.
ILRP	Annually: static water level, temperature, pH, electrical conductivity, nitrate as nitrogen, and dissolved oxygen. Once every five years, general minerals will be collected.	Annual Every 5 years	Monitor impacts of agricultural and fertilizer applications on first encountered groundwater	Sampling will begin in Fall 2018 with a limited number of wells sampled. The program will be expanded and may incorporate a shared sampling program with SGMA.
CV-SALTS	Sampling parameters required through WDR's: typically include monthly sodium, chloride, electrical conductivity, nitrogen species (N, NO_2, NO_3, NH_3), pH and other constituents of concern identified in the Report of Waste Discharge. A limited suite of general minerals is required quarterly from the source and annual from the wastewater.	Most constituents sampled monthly, quarterly general minerals from source water and annual general minerals from waste discharge Kaweah is a Priority 1 Basin, meaning that management strategies will be initiated in 2019.	To monitor degradation potential from wastewaters discharged to land application areas.	Water quality monitoring required by CV-SALTS is consistent with the Regional Water Boards existing requirements through their Waste Discharge Requirements process. It is unlikely that additional monitoring will be required. The initial phases of the program are strongly focused on identifying sources of salinity and reducing salinity and nitrogen species in wastewaters discharged to land. By 2030, the program is expected to implement projects to aid with salt and nitrate management in the Central Valley.
SDWIS	Database for all public water system wells and historical sample results. Data	Title 22 General Minerals and Metals every 3 years;	Demonstrate compliance with Drinking Water Standards through	An abundant source of data because of the required testing frequency and list of parameters.

	available includes all Title 22 regulated constituents.	Nitrate as N annually, if ≥ 5 ppm, sampled quarterly; VOCs and SOCs sampled every 3 years; Uranium sampling depends on historical results, varies between 1 sample every 3 (when ≥ 10 pCi/L), 6 (when < 10 pCi/L) or 9 (no historical detection) years.	monitoring and reporting water quality data.	
GAMA. Collaboration with SWQCB, RWQCB, DWR, DPR, NWIS, LLNL	Constituents sampled vary by the Program Objectives. Typically, USGS is the technical lead in conducting the studies and reporting data.	The priority basin project performed baseline and trend assessments sampling over 2,900 public and domestic wells that represent 95% of the groundwater resources in CA. The Domestic Well Project sampled over 180 domestic wells in Tulare County: 29 Wells were within the Kaweah Subbasin.	Improve statewide comprehensive groundwater monitoring. Increase the availability to the general public of groundwater quality and contamination information.	USGS reports prepared for the Priority Basin Project were used to identify constituents of concern in the basin and confirm water quality trends prepared for groundwater characterization.
Geotracker and DTSC Envirostor	Many contaminants of concern, organic and inorganic.	Depends on program. Monthly, Semiannually, Annually, etc.	Records database for cleanup program sites, permitted waste dischargers,	Records available on GeoTracker includes cleanup sites for Leaking Underground Storage Tank (LUST) Sites, Department of Defense Sites, and Cleanup Program Sites. Other records for various unregulated projects and permitted facilities includes Irrigated Lands, Oil and Gas production, operating Permitted Underground Storage

				Tanks (USTs), and Land Disposal Sites.
USGS California Water Science Center	Conducted Multiple Groundwater Quality Studies of the Kaweah Subbasin	Reports and fact sheet publications range from 1998 through 2017.	Special studies related to groundwater quality that provide comprehensive studies to characterize the basin.	Groundwater Quality in the Shallow Aquifer (2017). Status and Understanding (2012). Groundwater Quality in SESJ (2012). Groundwater Quality Data in the SESJ (2008). Environmental Setting (1998).
Department of Pesticide Regulation	Pesticides	Annual	DPR samples ground water to determine (1) whether pesticides with the potential to pollute ground water are present in ground water, (2) the extent and source of pesticide contamination, and (3) the effectiveness of regulatory mitigation measures.	https://www.cdpr.ca.gov/docs/emon/grndwtr/index.htm

2.3.3 Existing Land Subsidence Monitoring

Past, recent and potential future monitoring of land subsidence in the Kaweah Subbasin are summarized in **Table 2-5**. Much of the historical data does not cover the EKGSA area. Newer data sets (2015-2017) provide more coverage. The EKGSA will strive to keep these newer data sets active to avoid data gaps in the future. While land subsidence isn't believed to be a major concern in the EKGSA, it will be monitored to avoid Undesirable Results.

Table 2-5 Summary of Land Subsidence Monitoring in the Kaweah Subbasin

Category	Monitoring Entity(s)	Period of Record
Historic Monitoring	National Geodetic Survey of benchmarks (repeat level survey's)	1926-1970
Recent Monitoring	National Geodetic Survey of benchmarks (repeat level surveys and installation and measurement of extensometers), NASA including both InSAR and UAVSAR programs,	NGS – 1970 to Present, NASA – 2006 to 2017, (excluding 2011-2014)
Future Data Availability	National Geodetic Survey of benchmarks (repeat level surveys and installation and measurement of extensometers), NASA including both InSAR and UAVSAR programs, potentially new extensometers in the Kaweah Subbasin	2018 through 2020

2.3.4 Existing Stream Flow Monitoring

The most useful stream flow gauges monitored within the Subbasin are located outside the EKGSA. The closest water bodies regularly monitored are the Kaweah River, St. Johns River, and Yokohl Creek. The flow gauges are located in the Greater Kaweah GSA. Existing stream flow monitoring represents a data gap for the EKGSA to improve moving forward. Streams of interest for the EKGSA to improve monitoring data are: Cottonwood, Lewis, and Frazier Creeks.

2.4 Groundwater Conditions

Legal Requirements:
§354.16 Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes the following:

This chapter includes a description of the current and historical groundwater conditions within the EKGSA. This chapter includes best available historical and most recently available data to describe the groundwater trends, patterns, and current understanding sustainability indicators in the EKGSA. The sustainability indicators include groundwater levels, groundwater storage, groundwater quality, land subsidence, and interconnections between surface water and groundwater.

2.4.1 Current and Historical Groundwater Level Trends

Legal Requirements:
§354.16(a) Groundwater elevation data demonstrating flow directions, lateral and vertical gradients, and regional pumping patterns, including:
- **(1)** Groundwater elevation contour maps depicting the groundwater table or potentiometric surface associated with the current seasonal high and seasonal low for each principal aquifer within the basin.
- **(2)** Hydrographs depicting long-term groundwater elevations, historical highs and lows, and hydraulic gradients between principal aquifers.

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

The discussion on water level trends must include the context with regard to hydrologic variations in historical wet-dry cycles, referred to “water year type”. Water levels vary in response to the cyclical nature of water supply and deficiency related to precipitation, surface water supplies and deliveries from the Kaweah River system. The Kaweah Subbasin consultant reviewed the record of rainfall recorded in Visalia from water year 1878 through 2017 in the Kaweah Subbasin Basin Setting (**Appendix 2-A**), more detailed discussion can be found in this document. For reference, **Figure 2-19** and **Table 2-6** are pulled into this GSP. The figure shows the departure from mean precipitation, which is the difference between precipitation in a specific year and the mean precipitation for the period. The figure and table emphasize the variable climactic cycles of the southern San Joaquin Valley, which consist of prolonged periods of modest drought punctuated by short wet periods.

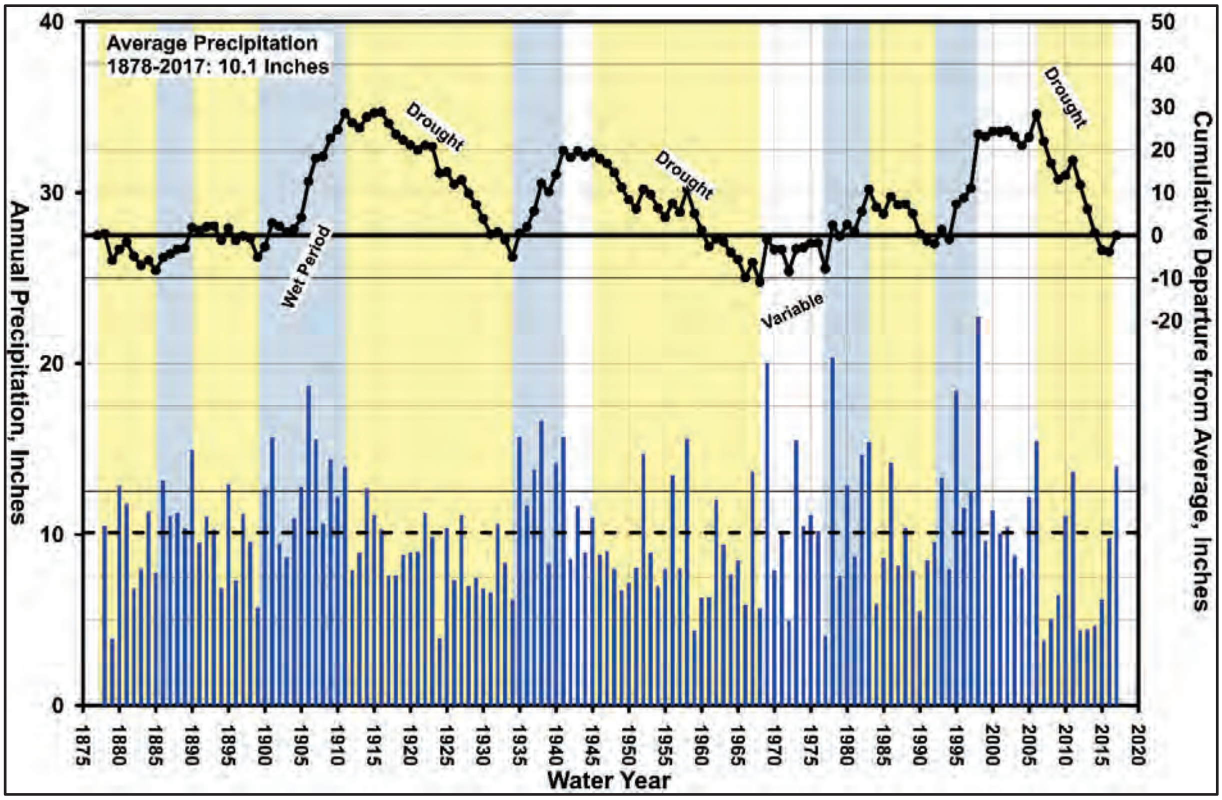


Figure 2-19 Cumulative Departure from Mean Precipitation - Visalia, CA

Table 2-6 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.

The most recent drought (2007 – 2016) was the most extreme in recorded history, in particular the years 2012 through 2015 were exceptionally dry. This led to the unprecedented 0% Class I declarations in 2014 and 2015 for the Friant Division of the Central Valley Project (CVP). The lower precipitation totals and unavailability of CVP water led to water levels throughout the EKGSA to decline to the lowest levels on record since the 1960s. Some areas in the EKGSA experienced water level declines of as much as 100 feet.

It is important to note, that while much of the Subbasin experienced widespread water level declines, there are areas where water levels have experienced only very limited declines. Generally, along the Kaweah River near the foothills in the eastern portion of the Subbasin, some wells have experienced very minimal seasonal fluctuations. These wells are presumed to be both relatively shallow and benefit from almost continual recharge from the flow of the Kaweah and St. Johns Rivers.

2.4.1.1 Elevation and Flow Directions

Historical Conditions (1890 – 1962)

Groundwater elevations naturally experience periods of drawdown and recovery due to seasonal fluctuations, variation in precipitation patterns, and changes in surface water availability. This natural variability is impacted by anthropogenic causes, including groundwater pumping and the diversion of natural surface water features. Impacts of human activity on the groundwater supply of the EKGSA are evident from some of the earliest historical records. In 1890, Lindmore ID reported groundwater levels about 20 feet below the ground surface. By 1917, the beginnings of what would become a serious cone of depression was evident in vicinity of the City of Lindsay (USBR LID Land Class Report). The earliest records in Ivanhoe ID are from 1916, where groundwater levels were between 10 and 15 feet below the ground surface. By 1921 water levels had declined to more than 24 feet below ground surface (USBR IID Factual Report).

Maps of historical groundwater conditions in the EKGSA are presented in **Appendix 2-B**. The earliest map presented is from October of 1925. At that time, groundwater in the northern part of the EKGSA flowed steadily to the west, with water surface elevations (WSE) of at least 405 ft above sea level (ASL) in the east descending to 310-315 ft west of Ivanhoe ID. Groundwater beneath the southern part of the EKGSA flowed toward a depression called the Lindsay Cone, which had a WSE of 255 ft. The region was in the midst of a drought that began in 1912 and would not end for another 9 years.

Water surface elevation contours in 1939 show a pronounced increase in the severity of the Lindsay cone of depression. Its center had been pumped to 170 ft ASL. All groundwater south of CA 198 in the EKGSA flowed towards this depression, and its influence pulled water from beyond the borders of the EKGSA in the south and west. In the northern part of the EKGSA the groundwater levels held steady beneath surface water features (i.e. Cottonwood Creek) but retreated elsewhere, which resulted in a lowering of the WSE by as much as 40 ft across the Ivanhoe and Stone Corral IDs compared to their 1925 levels. The groundwater surface west of Ivanhoe ID had flattened somewhat at about 310 ft ASL.

Groundwater trends in Fall 1945 largely mirrored the Fall 1939 trends. Precipitation in the intervening 6 years had been variable. Groundwater levels in the north remained within about 10 ft of their 1939 levels. The Lindsay cone of depression worsened far beyond what the climate could account for, descending to less than 100 ft ASL at its center.

By 1952 (two figures – Spring and Fall) the Lindsay cone of depression had recovered somewhat from its mid-forties low. Spring 1952 WSE contours show that the center of the depression was at 140 ft ASL and had shifted more than two miles to the south. This rebound can be at least partially attributed to the completion of the FKC in 1951, especially given that the area had been in the midst of a drought since 1946. Fall contours from the same year continue this trend. Groundwater in the north deepened beneath Ivanhoe.

The influx of surface water made a significant difference in the character of the water table in the southern part of the EKGSA by the spring of 1962. A more natural westerly slope replaced the deep pit of the Lindsay Cone despite the continuing drought. Trends in the north continued much as they had before the FKC had been constructed. The overall gradient of the westerly flow steepened somewhat as the groundwater surface to the west of the EKGSA had dropped by about 20 to 30 feet. The mild depression beneath Ivanhoe ID migrated west for 1962. The WSE in the center of this depression dipped below 250 ft ASL.

Current Conditions (1981 – 2017)

Maps for 1981 until the end of the base period in 2017 were constructed using WSE data from the DWR's Water Data Library and from participating EKGSA districts, where applicable. Maps of current groundwater conditions in the EKGSA are presented in **Appendix 2-C**.

Groundwater levels rose across the EKGSA between 1962 and 1981. The groundwater depression beneath western Ivanhoe ID maintained its low at 240 ft ASL, but groundwater levels surrounding it on all sides rose between 20 to 40 feet. The groundwater surface in the south also bottomed out at 240 ft ASL in a mild depression situated between the Lindmore ID and the western border of the EKGSA. This depression does not appear to be related to the historical Lindsay cone – the groundwater surface where the center of the Lindsay Cone existed had risen to 300 ft above sea level, a 200 ft increase from 1945 levels.

Spring 1986 saw similar conditions to 1981. Minimum water surface levels in both the north and south rose on the order of 20 to 30 feet.

Spring of 1991 saw a reversal of the gains seen in the 1980s maps, due at least in part to a drought that began in 1984. WSEs fell by about 10 feet in the east and up to 40 feet in the west. The shape of the water surface retained much of its 1986 character.

Spring of 1996 maintained much of the shape of Spring 1991. Influx from the Tule and Kaweah rivers made their influence more pronounced in this year compared to a slight deepening of the water table in the interfan areas on the order of 10 ft.

A wet period between 1994 and 1998 saw groundwater somewhat replenished by spring of 1999, with groundwater across the EKGSA rising by 10-40 ft. These gains were more pronounced beneath major surface water features. The depression north-west of Ivanhoe ID roughly maintained its lateral extent but rose about 20 ft. Groundwater remained comparatively low beneath the EKGSA west of Lindmore despite rising 10-40ft.

Groundwater levels dropped across the EKGSA by 10 to 30 feet for Spring 2002. The depression north of Ivanhoe had increased in depth by 30 ft, dropping the WSE to 220 feet.

Spring of 2005 saw water levels in further retreat. The depression west of Ivanhoe ID connected to the declining WSE within the GKGSA. Water levels west of Lindmore ID dropped by 40 feet between 2002 and 2005.

The pattern of overall steady decline continued for Spring 2008, despite the lows in the west rebounding by nearly 20 ft. Groundwater in the central and eastern parts of the EKGSA declined on the order of 10 ft.

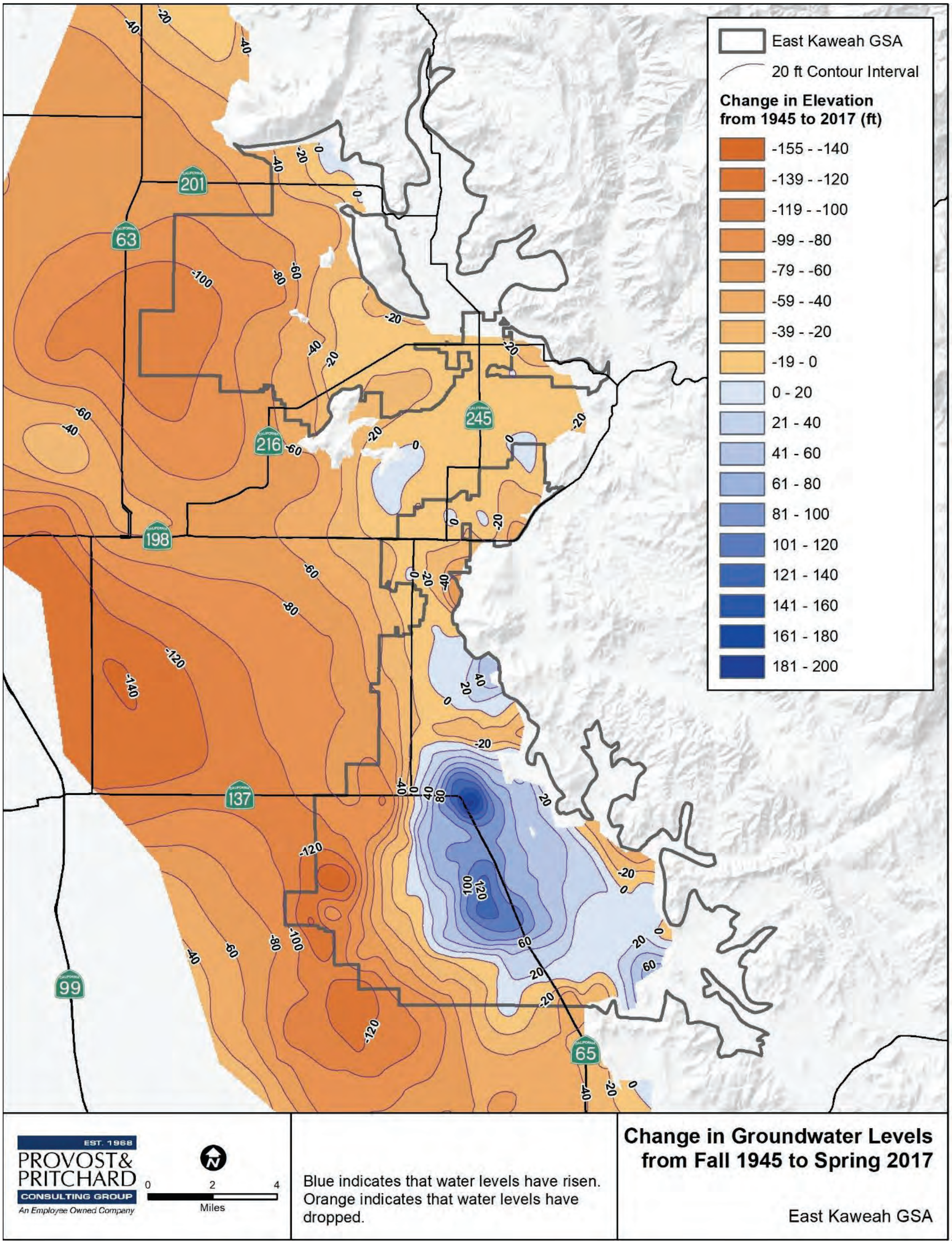
Spring 2011 saw similar water levels to Spring 2008. The impact of inflow beneath the Kaweah and Tule Rivers was more pronounced this year. The depression west of Ivanhoe became more cut off from the lower groundwater surface to the west, reaching a modest low of 230 ft ASL.

The impacts of prolonged drought in the region were making themselves known by Spring 2014. Groundwater across the EKGSA was in decline, on the order of 10 to 40 ft below their 2011 levels. Groundwater near the Kaweah River saw less of this impact, while the depression west of Lindmore declined up to 60 ft from 2011.

Spring 2017 is the last year of the base period. The impacts of the 2007-2016 drought are clearly evident across the EKGSA. While impacts on private domestic groundwater users are currently unquantified within the boundaries of the EKGSA, declines in groundwater levels throughout Tulare County during the drought led to over 1,300 private domestic wells reporting shortages or outages of water (CDWR 2018). West of the Lindmore ID groundwater reached a low of 80 ft ASL. This was a decline of 90 ft in three years. Groundwater levels across the Lindmore and Lindsay-Strathmore IDs fell by nearly 40-50 ft. Impacts in the Exeter ID were more subdued due to the proximity of the Kaweah River, but still saw declines of 20 to 30 ft from 2014. Ivanhoe ID saw declines between 15 to 20 ft. The non-districted area west of Ivanhoe experienced declines of up to 30 ft, forming a cone of depression. Groundwater across the Stone Corral ID declined by about 20 to 30 ft.

Comparing Current and Historical Conditions

When comparing current groundwater conditions with historical conditions, the impact of surface water supplies is very pronounced. In wet periods when surface water is more available, significant increases in the groundwater surface result. This is especially the case pre- and post-implementation of the CVP. **Figure 2-20** depicts the change in groundwater elevation between 1945 (pre-CVP deliveries) and present (2017). Nearly 70 years of CVP deliveries has reversed the Lindsay cone of depression and allowed for minimal groundwater elevation change in other regions of the EKGSA. The figure does also show significant declines in areas since 1945, these areas generally coincide with little to no surface water deliveries.



Blue indicates that water levels have risen. Orange indicates that water levels have dropped.

Change in Groundwater Levels from Fall 1945 to Spring 2017

East Kaweah GSA

Figure 2-20 Groundwater Level Change from 1945 to 2017

2.4.1.2 Well Hydrographs

Hydrographs of individual wells in and around the EKGSA are presented in **Appendix 2-D**. **Figure 2-21** is a map showing locations of these wells. All groundwater well users and communities (such as Lindcove, Tonyville, Tooleville, etc.) in the EKGSA are susceptible to significant changes in groundwater levels, particularly those closer to the foothills on the east side, as the aquifer is shallower to bedrock. These hydrographs depict the span of time between 1981 and 2017. Hydrographs outside the borders of the EKGSA were included to establish boundary conditions. It is difficult to identify wells with records that are complete for the entire base period. The wells depicted often contain data gaps but represent the most complete information available at this time. The dataset used to create these hydrographs associates water levels with a season/year format (e.g. Spr1990) rather than with a specific date. For the purposes of plotting, spring levels were considered to have been taken on March 1, while fall levels were plotted on October 1. Nevertheless, these hydrographs are a useful tool for tracking water level patterns through time across the EKGSA.

Most wells across the area share a consistent pattern. Water levels rose or remained high throughout the early eighties. They declined in the late eighties and early nineties, largely due to drought conditions. Levels slowly rebounded throughout the nineties. Since Fall 2001 water levels have steadily fallen and remained in decline since, slightly rebounding in 2011 before plummeting through 2016 in response to the worst drought on record. The pattern closely mirrors annual hydrologic conditions. Rising groundwater levels coincide with and follow periods of above-average rainfall, while groundwater declines are clearly associated with periods of prolonged drought. There is a slight lag time evident between wet periods and when that water reaches the water table. The most prominent example of this is the water level increase associated with the 2010 water year. Water levels were on the rise by Spring 2011 (immediately following the wet season), but they continued to rise into Fall 2011. They were already on the decline again by Spring 2012, but the increase in the water levels between Spring 2011 and Fall 2011 is indicative of the lag associated with rainwater reaching the aquifer. It should be noted that this lag time is actually quite low compared to many places in the San Joaquin aquifers – the relatively shallow depth to water (DTW) and ready supply of recharge coming from the Sierra Nevada allow for relatively quick replenishment of the aquifer. In time spans where multiple years are consistently either wet or dry, fall levels are expected to be slightly lower than spring levels for the same year. These seasonal norms are evident on many of the hydrographs, independent of hydrologic conditions or location within the EKGSA. The exact magnitude of these seasonal fluctuations, however, varies by location.

Average DTW in the EKGSA was calculated from available hydrographs by year/season. **Figure 2-22** and **Figure 2-23** depicts the average DTW from 1981 through spring 2017 for the northern and southern EKGSA areas, respectively. The pool of hydrographs to pull from diminished in the last decade or so of the period of record. As a result, averages for more recent seasons were created with fewer data points than were used for earlier seasons. It is believed this due in part to some wells going dry and also due to changes in requirements for groundwater level monitoring (i.e. CASGEM). The average depth to water illustrates both seasonal trends and yearly conditions as discussed earlier. Fall levels are predictably lower than their spring counterparts, and averages in times of drought are typically lower than averages in times of plentiful precipitation. When taken by decade, these averages illustrate the deepening of the water table over time. In the eighties average DTW ranged from 27.4 ft to 52.7 ft, with an average depth for the decade of 37.7 ft. The nineties saw seasonal average DTW between 35.8 ft and 68.8 ft, with an average DTW of 52.4 ft. Average DTW for the 2000s was 53.7 ft, with seasonal averages spanning from 36.1 ft to 69.5 ft. The 2010s up to spring 2017 (the end of the study period) experienced average DTW of 79.5 ft. Average DTW in Fall 2015 reached 108.2 ft, the deepest average on record. Throughout the entire base period, the average DTW for the EKGSA was 54.7 ft. DTW for the fall averaged 58 ft, while the average for the spring was at 51.6 ft.

Hydrographs by Geomorphic Region

The following provides discussion on the hydrographs grouped by the geomorphic regions shown in **Figure 2-2**. Grouping in this fashion was done to relate wells with similar region and hydrogeology.

Cottonwood Creek Interfan – Hydrographs in the Stone Corral and Ivanhoe IDs are presented as representing the Cottonwood Creek Interfan Area. The hydrographs of this area are generally similar to one another. Periods of wet verses dry are clearly demarcated, though few wells are shown to have more than 50 feet of change across the nearly 40-year timescale, and even those that exceeded 50 feet only did so during the extended drought of the 2010s. Seasonal fluctuations are clear but rarely pronounced, being usually on the order of several feet and rarely exceeding 10 feet of change between seasons. Overall DTW varies according to proximity to surface water, with wells near Cottonwood Creek and the St. Johns River having consistently lower depth to water (between 15-50 feet, depending on drought conditions) than wells located in the western part of Ivanhoe (between 50-100 feet). Average depth to water during the base period was 54.7 ft.

Kaweah River Alluvial Fan – Hydrographs in Exeter ID north of the City of Exeter and wells located between the two main lobes of the EKGSA are presented representing the Kaweah Alluvial Fan. The temporal behavior of wells in this region vary according to proximity to the Kaweah River and Yokohl Creek. Wells located within about a mile of these waterbodies tend to maintain high groundwater levels regardless of annual hydrologic conditions. Seasonal water level fluctuations are likewise subdued, often on the order of one to three feet. This behavior is expected and demonstrates the gains due to stream seepage from which these wells benefit. Seasonal fluctuations are more obvious in wells further away from the waterbodies. Seasonal differences within a single year can exceed 20 feet, though less dramatic variation is also common, often within the same well. Even during severe drought, historically much of this area maintains DTW within 100 feet of the ground surface. Average DTW during the base period was 49.8 ft.

Lewis Creek Interfan – Hydrographs in Exeter ID wells south of the City of Exeter and wells in or near Lindmore and Lindsay-Strathmore IDs are presented as representing the Lewis Creek Interfan. Much (though not all) of this area receives surface water imports. Deliveries from the FKC have a marked impact on the water levels within the region. Many wells in the Lewis Creek Interfan Area have not experienced groundwater within 50 feet of the surface in the time since 1981. While pumping to the immediate west of the Lindmore ID is a concern, at least some of this DTW is indicative of the natural local low that can be expected of an interfan area between two major rivers. Seasonal fluctuations are usually mild, but consistent shifts of 10 feet are common in areas removed from surface water deliveries. The wells furthest west experienced dramatic seasonal shifts in the second half of the period. The hydrograph for well 20S26E16R001M shows seasonal fluctuations in excess of 70 feet. Wells 20S26E20J001M and 20S26E29N001M nearby show similar fluctuations. Average DTW for the Interfan during the base period was 64.2 ft.

Intermontane Valleys – This classification is included to showcase wells on the eastern border of the EKGSA with significant bedrock outcrop to their west. These wells are located in the small valleys interfingering with the mountain-front and are drilled into shallow alluvium veneering relatively shallow bedrock, with ready access to recharge coming from the mountain-front. They have consistently shallow DTW and low seasonal and hydrological deviation. Typical WSEs within these wells are consistently within 50 ft of the surface. Well 17S26E14L002M is nearly within the Valley proper and likely has deeper alluvium, less-direct recharge, and plentiful irrigation nearby. This well's hydrograph is more akin to wells in the Cottonwood Creek Interfan area as defined above, with greater overall DTW and increased variation between seasons of wet and dry. Average DTW for this grouping of wells was 26.9 ft based on the years with data. There are significant temporal data gaps for this region, during which time none or only one well provided data. Between fall of 2008 and fall of 2012 no data is recorded for any of these wells.

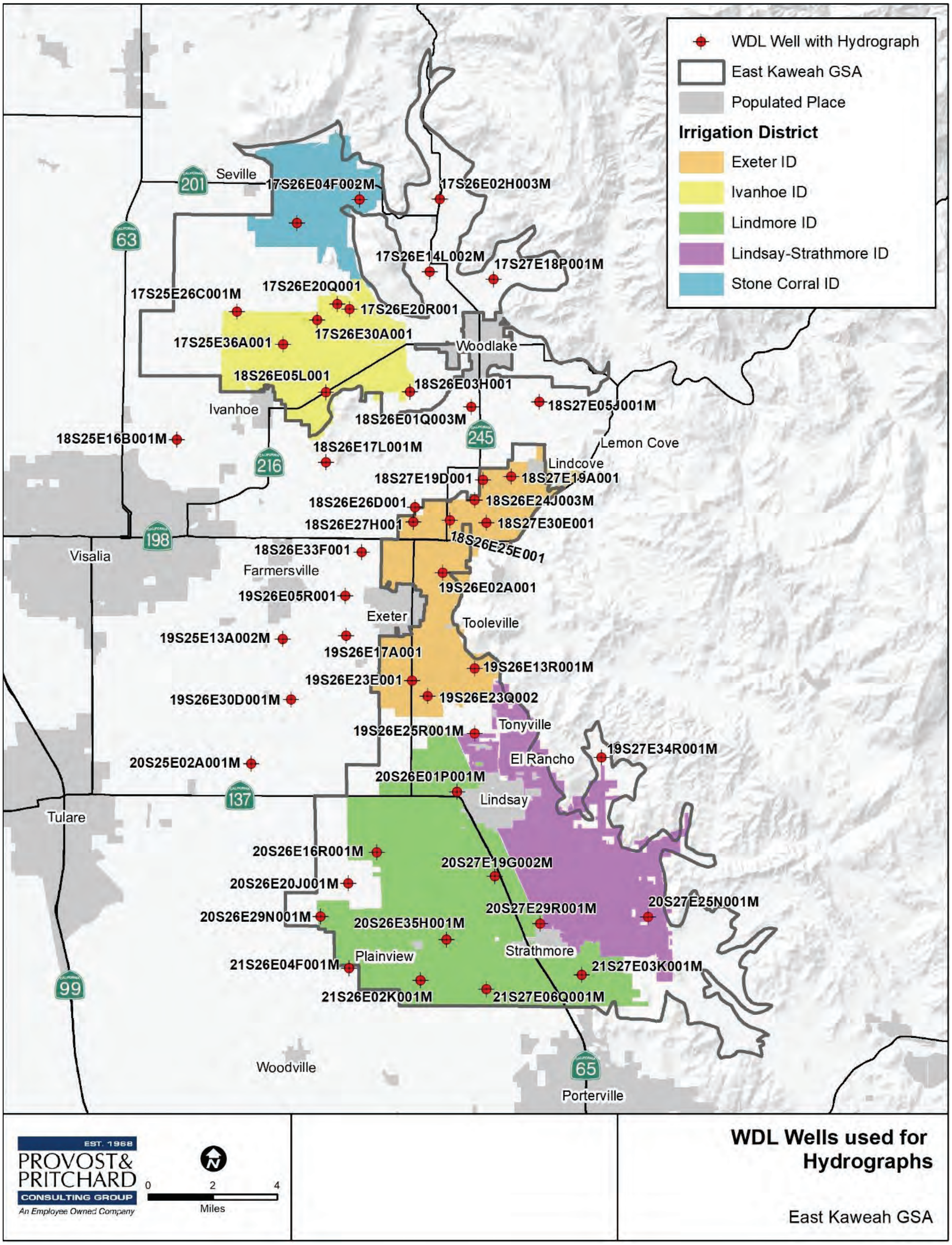


Figure 2-21 Well Hydrographs Location Map

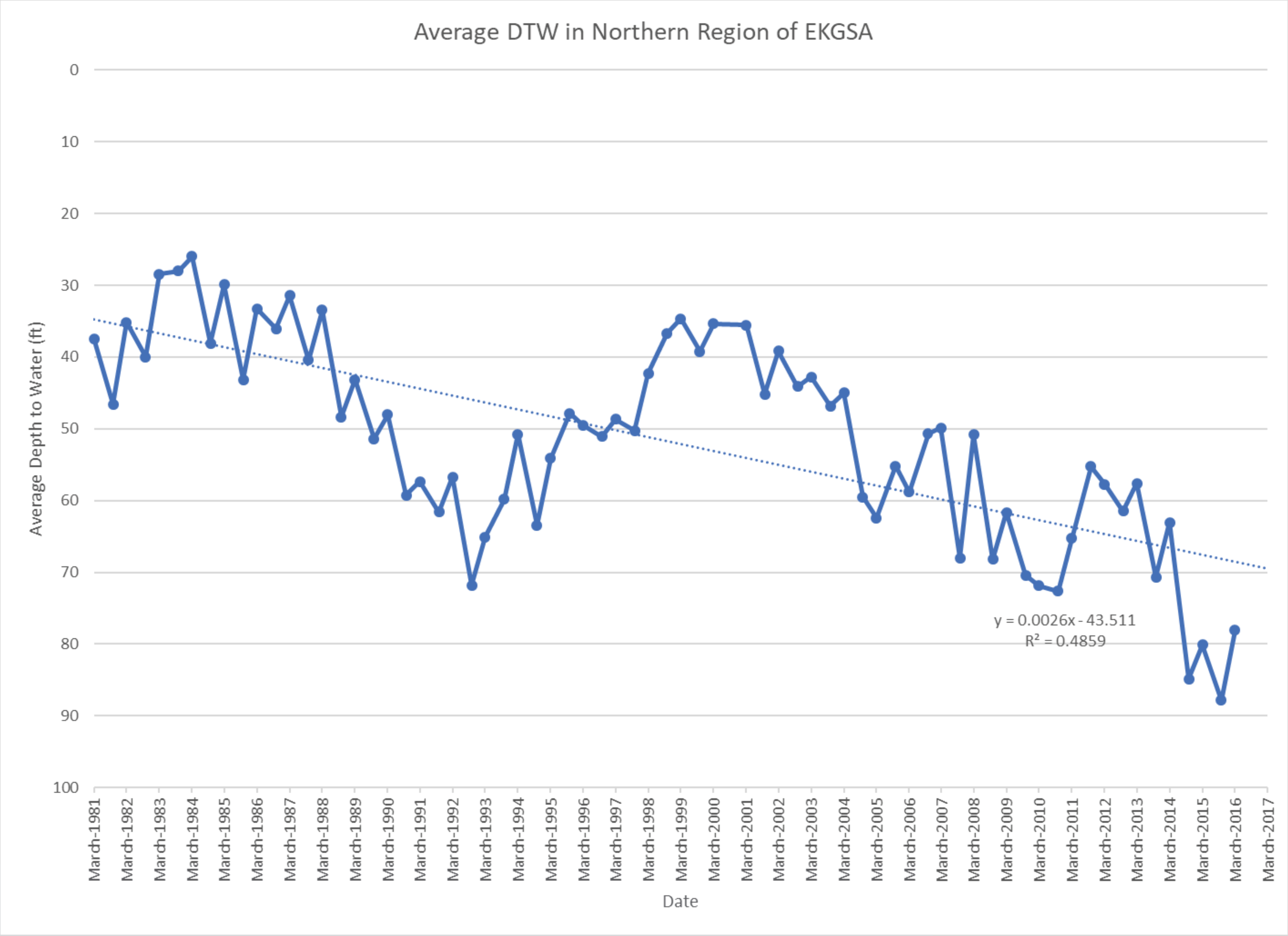


Figure 2-22 EKGSA Average Depth to Groundwater in the Northern Region

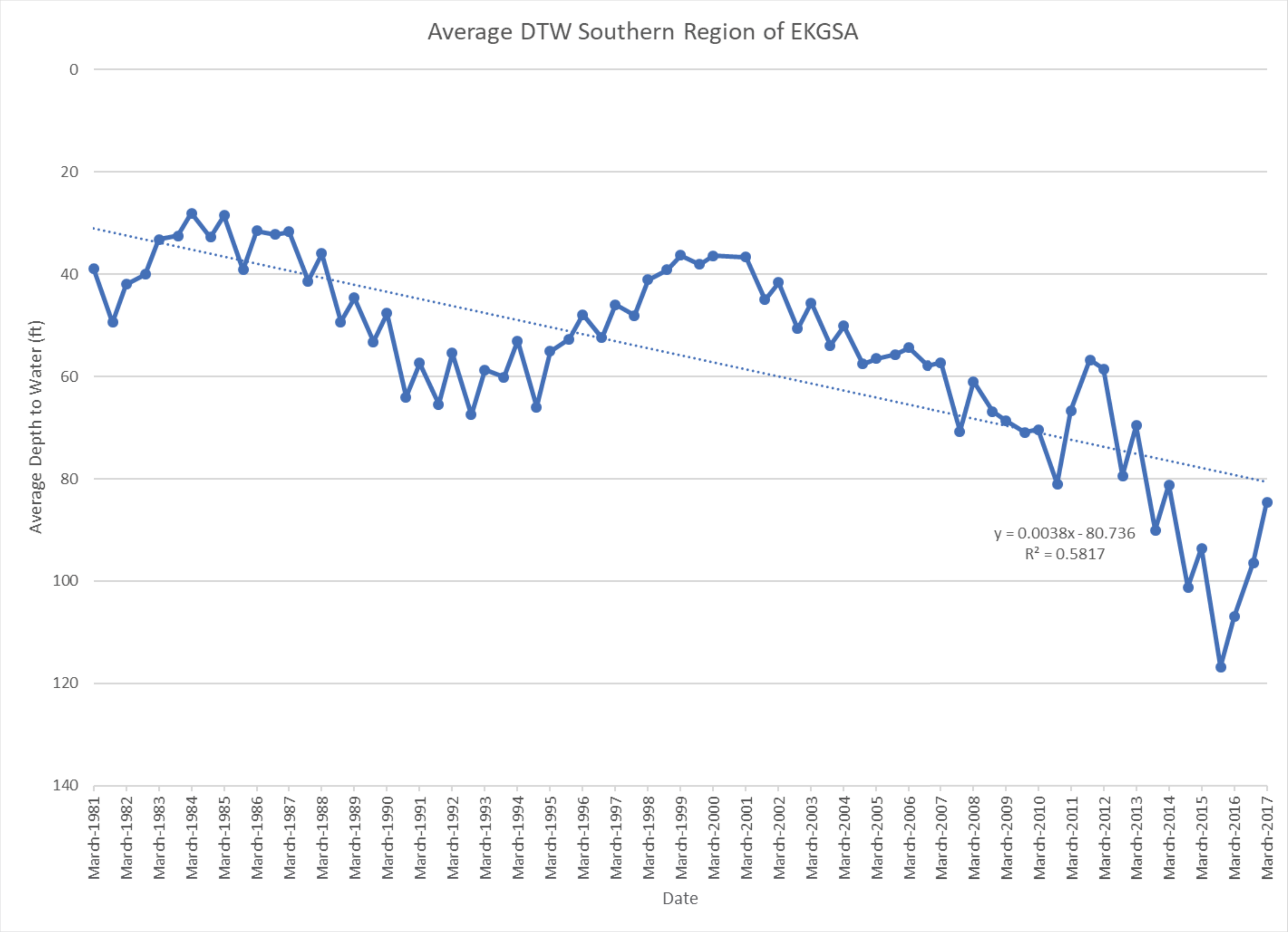


Figure 2-23 EKGSA Average Depth to Groundwater in the Southern Region

Well Depth:

Construction data for wells in the EKGSA was evaluated in a summarized format. Evaluating well logs confidently and accurately to match reports with the actual corresponding well in the field is difficult due to the current nature of the data sets available. This is a data gap that will be filled going forward. **Figure 2-24**, **Figure 2-25**, and **Figure 2-26** display the average completed well depths per section for agricultural, domestic, and public wells respectively. **Appendix 2-E** provides more figures for these three well types, including minimum and maximum completed depths and number of wells per section.

Wells in the vicinity of rivers and other natural conveyances tend to be completed at shallower depths than wells drilled elsewhere. Wells along the eastern side of the valley are commonly drilled to shallower depths than wells in the western reaches of the EKGSA. Deeper wells in the eastern parts of the EKGSA tap fractured-rock aquifers within the bedrock rather than the aquifers of the valley floor.

The minimum well depth for a well in the EKGSA is a 25 ft. agricultural well. This well is located in T20SR27E23. It is unknown if this well is still in place, however it is likely dry unless it is within a perched aquifer known to exist in the area.

The deepest completed alluvial well on the valley floor within the EKGSA is located in T21SR27E06. It is an agricultural well completed to a depth of 846 ft.

In order to find the average well depth in the EKGSA, a weighted average was taken of the average completed depth field for all sections within the EKGSA. This provided an average well depth of 239.7 ft. This analysis does not consider well type, activity status of the well, or what type of aquifer the well was drilled into (i.e. if the well captures water from a fracture-rock aquifer or an alluvial aquifer).

2.4.1.3 Lateral and Vertical Gradients

Lateral Gradients

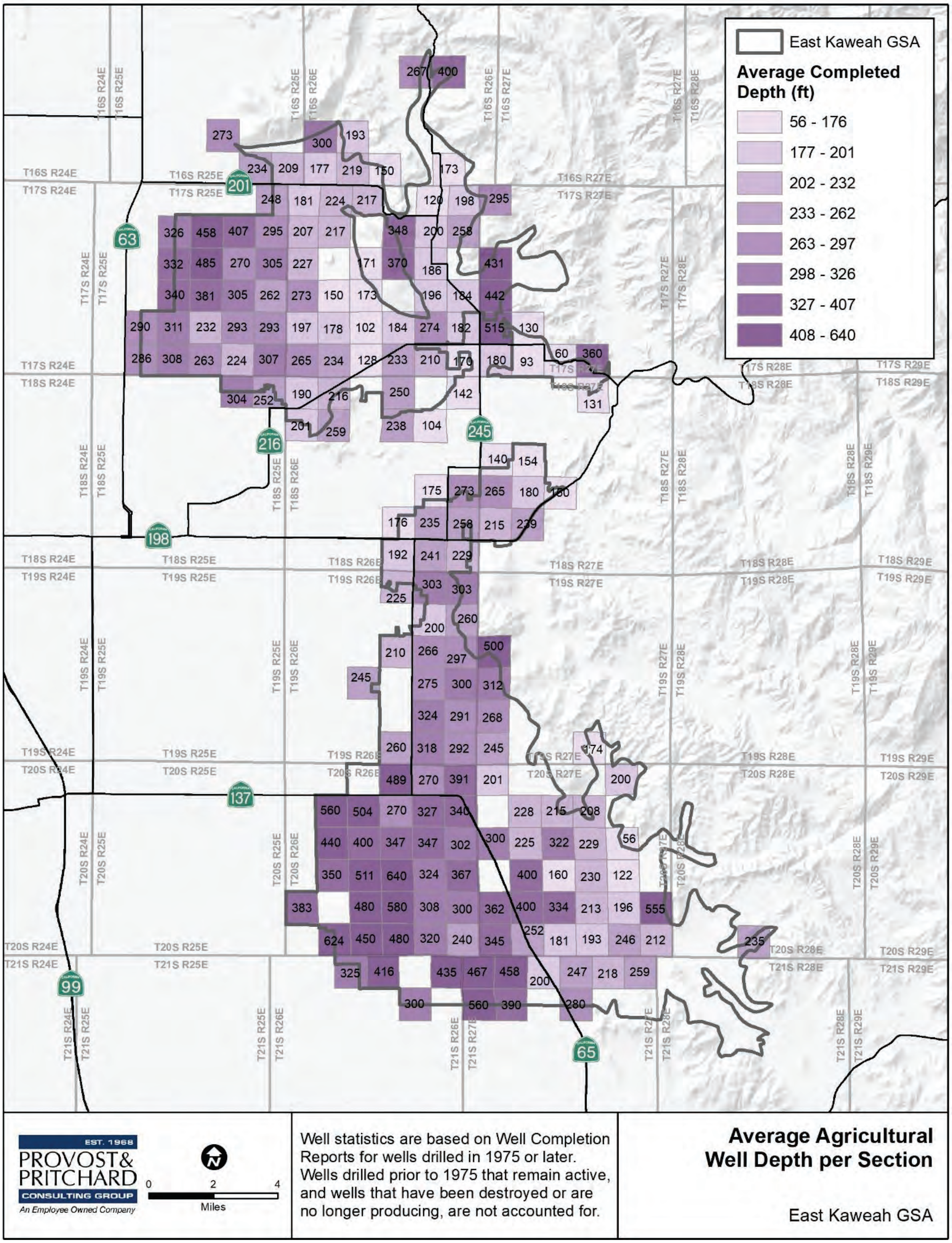
Aquifers in the EKGSA are unconfined. Unconfined groundwater flow rates move in response to the slope of its surface and the permeability of the water-bearing materials. Flow rates are on the order of a several feet per day in higher permeable materials to only a few feet per year in low permeable materials. The gradients of the groundwater in the EKGSA are in the range between 6 and 40 vertical feet per mile, typically averaging around 20 feet per mile (0.003 feet per foot).

Vertical Gradients

Water levels in an unconfined aquifer system coincide with the top of the zone of saturation, where hydrostatic pressure is equal to atmospheric pressure. Seasonal water level variations in such systems are typically subdued. Groundwater conditions at specific locations vary from regional patterns due to localized hydrogeologic conditions and groundwater pumping.

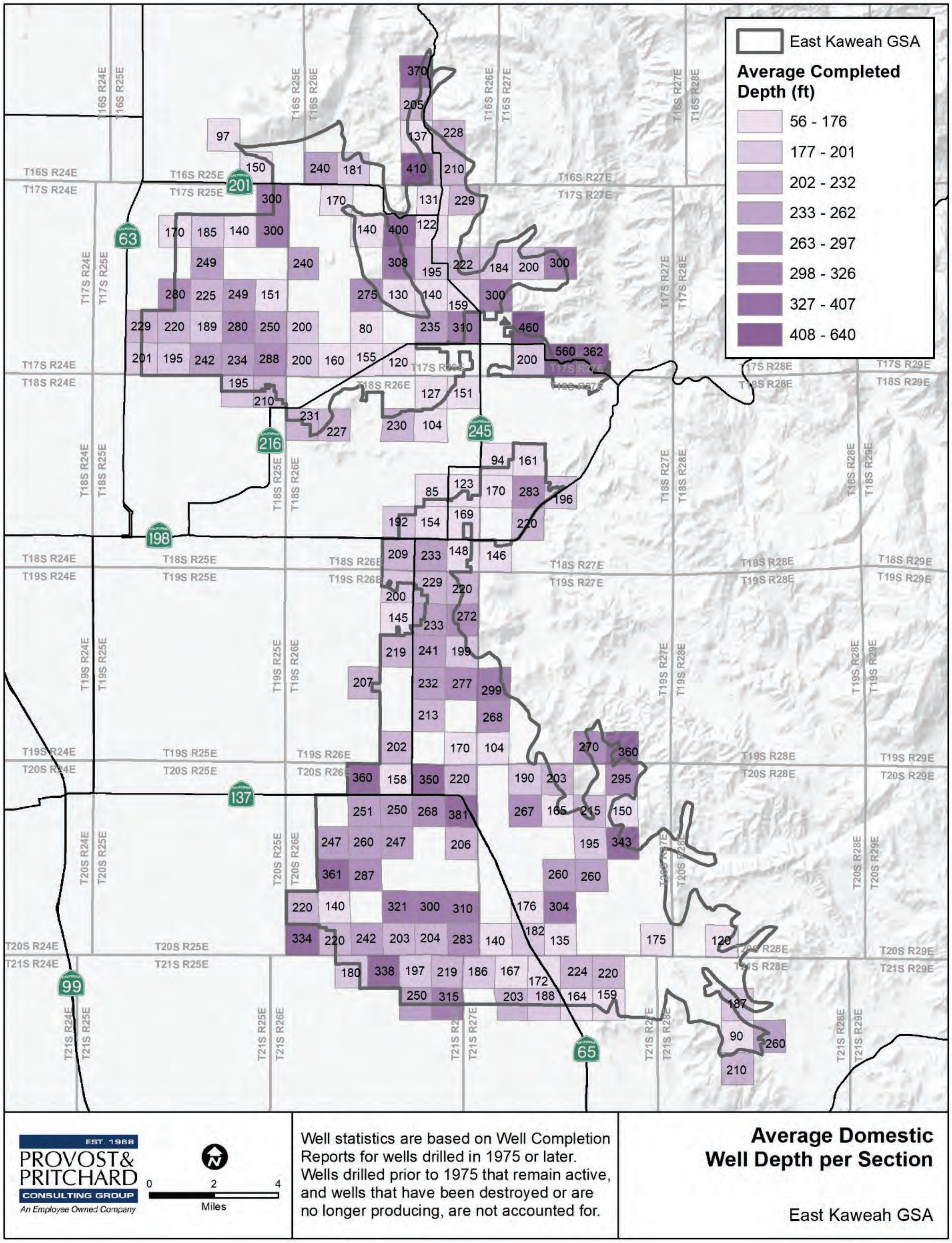
2.4.1.4 Regional Patterns

The groundwater elevation contour maps provided for the current conditions range from Spring 1981 to Spring 2017 (see **Appendix 2-C**). Review of the contour maps indicate that the principal direction of groundwater flow is to the southwest in the unconfined aquifer within the Kaweah River alluvial fan and continental deposits. Subsurface inflow occurs from the Sierra Nevada Mountains to the east, Kings River system to the north, and the Tule River system to the south.



Well statistics are based on Well Completion Reports for wells drilled in 1975 or later. Wells drilled prior to 1975 that remain active, and wells that have been destroyed or are no longer producing, are not accounted for.

Figure 2-24 Average Agricultural Well Depth

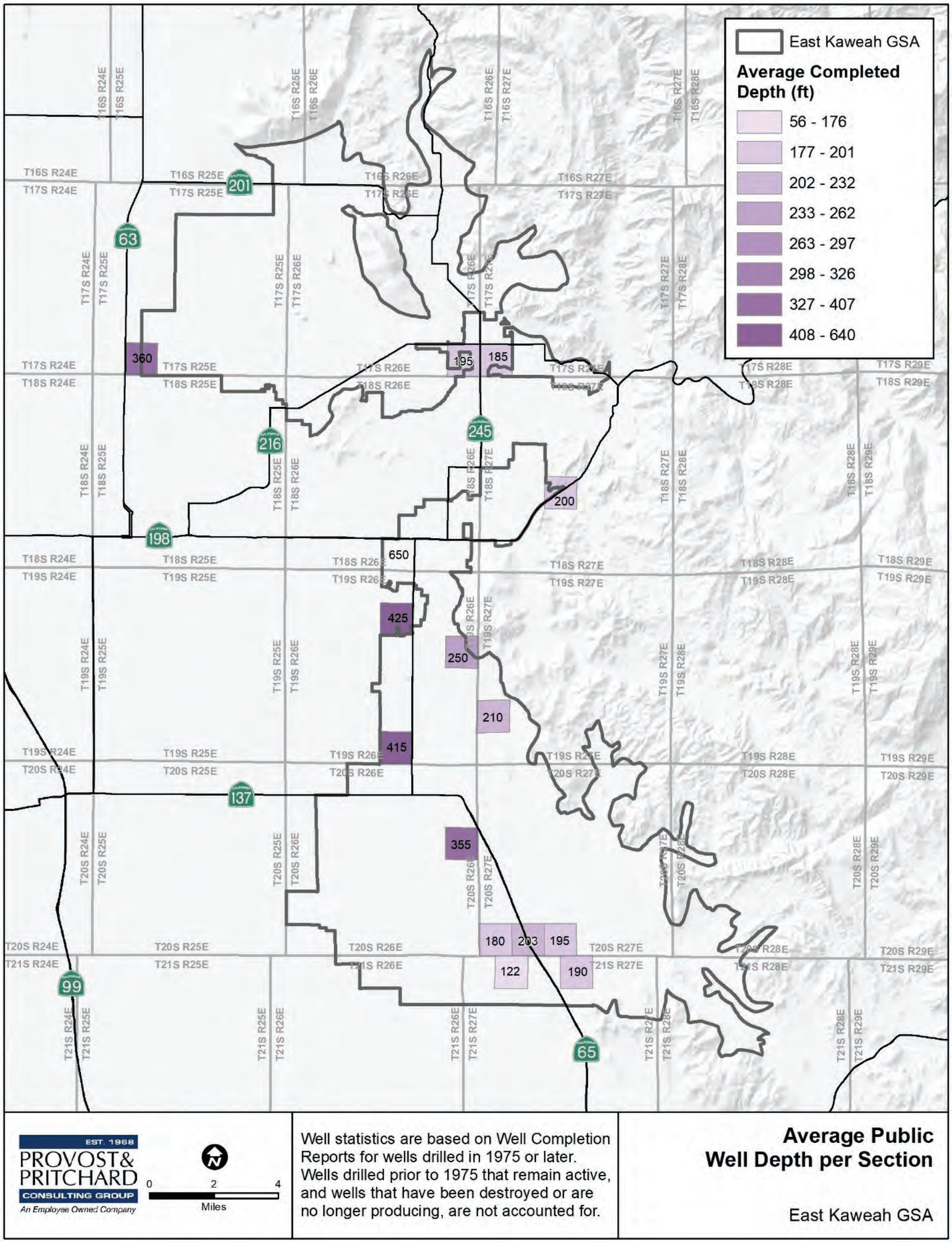


Well statistics are based on Well Completion Reports for wells drilled in 1975 or later. Wells drilled prior to 1975 that remain active, and wells that have been destroyed or are no longer producing, are not accounted for.

Average Domestic Well Depth per Section

East Kaweah GSA

Figure 2-25 Average Domestic Well Depth



Well statistics are based on Well Completion Reports for wells drilled in 1975 or later. Wells drilled prior to 1975 that remain active, and wells that have been destroyed or are no longer producing, are not accounted for.

Average Public Well Depth per Section

East Kaweah GSA

Figure 2-26 Average Public Well Depth

2.4.2 Seawater Intrusion

Legal Requirements:
§354.16(c) Seawater intrusion conditions in the basin, including maps and cross-sections of the seawater intrusion front for each principal aquifer.

Seawater intrusion is not an issue in the EKGSA, or the Kaweah Subbasin as a whole, because there is no 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.

2.4.3 Groundwater Quality

Legal Requirements:
§354.16(d) 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.

The Kaweah Subbasin Basin Setting document in **Appendix 2-A** discusses in more detail the groundwater quality for the Kaweah Subbasin. Groundwater quality discussion specific to the EKGSA has been pulled into this GSP. 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 and Geotracker.

2.4.3.1 Bulletin 118 Overview

Groundwater in the oxidized older alluvium and younger alluvium is generally of the calcium bicarbonate type. In the unconsolidated deposits beneath the alluvial fans, groundwater is generally low in dissolved constituents. Where recharge is from the major streams, sodium constitutes less than 42% of the cations and TDS ranges from 100 to 270 mg/l. Sodium and bicarbonate are the principal ions in groundwater in the continental deposits and in reduced older alluvial deposits. Sodium accounts for more than 70 percent of the cations in the water from these deposits. TDS ranges from 100 to 500 mg/l. In the interfan areas, where recharge is from intermittent streams, dissolved constituents range from 270 to 650 mg/l and magnesium and chloride are major constituents (Croft & Gordon, 1968).

2.4.3.2 Data Sources and Zonal Delineation

For the purpose of establishing minimum thresholds and measurable objectives, hydrogeologic zones of similar characteristics are being delineated at the Subbasin level. The boundaries of these zones will likely be updated and modified regularly. These are presented in the Kaweah Subbasin Basin Setting document. The EKGSA is primarily located within Zones 7, 8, 9, and 10. A portion of the southern lobe extends into Zone 6.

There is a total of 47 public water systems in the Subbasin with data available in SDWIS. These systems are generally representative of the Subbasin as they're located throughout the area. Between all 47 active public water systems, 174 wells were evaluated. In addition to SDWIS, GeoTracker GAMA was searched to identify contaminant plumes, and the SWRCB's Human Right to Water Portal was searched to identify contaminants the are commonly violating drinking water standards. A limited amount of data was available for private domestic wells within the Subbasin. For now, the Subbasin is referring to the SWRCB's GAMA Domestic Well Project.

2.4.3.3 Overview of Groundwater Quality Conditions

While all regulated drinking water constituents were considered, findings from this evaluation show that the most common water quality issues within the EKGSA are: nitrate, arsenic, perchlorate, hexavalent chromium (Chromium VI), 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 (if applicable), potential impacts to beneficial uses in the different regions of the Subbasin, and existing regulatory and monitoring programs dedicated to that constituent.

2.4.3.3.1 Arsenic

Chemical Properties

The following chemical properties are summarized from the SWRCB GAMA Program Groundwater Information sheet for arsenic. Naturally occurring in the environment, arsenic is a semi-metal element. The primary natural source of arsenic found in groundwater is from the weathering of arsenic-containing rocks. The solubility, mobility, and toxicity of arsenic are dependent upon its oxidation state and increase with increasing alkalinity and salinity. Arsenic mobility in groundwater is dependent on adsorption/desorption reactions and precipitation/dissolution reactions. During adsorption reactions, dissolved arsenic adheres to the surface of solid aquifer materials (i.e. clay layers). Desorption removes the arsenic from aquifer materials and releases it in the surround aquifer. Low-oxygen conditions, compression of clay layers, and/or an increase in pH about 8.5 can also displace arsenic from mineral surfaces into its aqueous form (Fendorf et al. 2018).

Arsenic is a known human carcinogen. Specifically, ingestion of arsenic in sufficient quantities can increase the risk of liver, bladder, kidney, lung, and skin cancer. When groundwater is the exposure medium, arsenic is quickly absorbed after ingestion, while dermal (skin) exposure results in a much smaller amount of arsenic entering the body. Ingestion of moderate to elevated arsenic levels (greater than 300 ug/L) may cause stomach and intestine irritation, nausea, vomiting, and diarrhea, abnormal heart rhythm, blood-vessel damage, and impaired nerve functioning. Consumption of large oral doses above 60,000 ug/L is fatal.

Sources and Spatial Distribution in the EKGSA

Based review of the DPR studies and the hydrogeology of the Kaweah Subbasin, the major source of arsenic in the groundwater appears to be naturally occurring from erosion of natural deposits. Data from public water systems shows that arsenic detections around 5-10 ppb are more prevalent in the western portion of the Subbasin, generally where the Corcoran clay is present. The Corcoran clay generally follows the boundary of hydrogeologic zone 4 and extends to the westerns portion of the Kaweah Subbasin. Based upon recorded in Geotracker data, **Appendix 2-F** further depict the spatial distribution of arsenic concentrations throughout the EKGSA throughout the base period (1997-2017).

Existing Regulatory Programs and Monitoring Efforts

Arsenic is a regulated chemical for drinking water sources with monitoring and compliance requirements designated by Title 22, §64431 overseen by the SWRCB Division of Drinking Water. Arsenic has a primary drinking water Maximum Contaminant Level (MCL) of 10 parts per billion (ppb) and an Agricultural Water Quality Goal of 100 ppb. In November 2008, the California MCL for arsenic was reduced to from 50 ppb to 10 pbb. At a minimum, public water systems are required by Title 22 §64432 to monitor for arsenic annually. More frequent monitoring is required if arsenic has been historically detected. Monitoring data from the public water systems is available via DDW's SDWIS database (Section 2.3.2). In addition to DDW regulation, monitoring, and oversight, data on arsenic concentrations is available via the GAMA Priority Basin Project on Geotracker. Arsenic will be monitored as a constituent of concern within the Kaweah Subbasin.

2.4.3.3.2 Dibromochloropropane (DBCP)

Chemical Properties

The following chemical properties are summarized from the GAMA Program Groundwater Information sheet for dibromochloropropane (DBCP). DBCP is a colorless organochlorine compound that was used as a soil fumigant to control nematodes in over 40 different crops. The chemical is highly persistent in the soil and can be easily mobilized and move into groundwater. Denser than water, once in an aquifer, free phase DBCP may sink to the bottom of the aquifer and persist for long periods of time.

In humans, DBCP ingestion can cause gastrointestinal distress and pulmonary edema. Even low exposures via contaminated groundwater consumption may cause sterility in men and other male reproductive effects, such as decreased sperm counts. There is also evidence that DBCP may have the potential to cause cancer with lifetime exposure at levels above the MCL.

Sources and Spatial Distribution in the EKGSA

DBCP is a manufactured chemical that does not occur naturally in the environment. Prior to 1979, DBCP was used extensively on grapes, tomatoes, cotton, and fruit trees throughout Fresno, San Bernardino, Stanislaus, and Tulare counties. Agricultural application of DBCP was banned in California in 1977.

Concentrations of DBCP above the MCL of 0.2 ppb have been detected in the EKGSA a total of seven times from 1997 to 2017 outside of the cities of Exeter, Lindsay, and Plainview. Given the diffuse use of DBCP on agricultural lands throughout Tulare County, DBCP MCL exceedances appear to be wide-spread and scattered throughout the EKGSA without a predictable contaminant plume pattern. 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 has been evaluated for this Subbasin since the levels are generally decreasing. **Appendix 2-F** further depict the spatial distribution of DBCP concentrations throughout the EKGSA throughout the base period (1997-2017).

Existing Regulatory Programs and Monitoring

DBCP is a synthetic organic contaminant with a drinking water MCL of 0.2 ppb. There is no Agricultural Water Quality Goal. The drinking water MCL was set in 1989 and CCR Title 22 requires quarterly monitoring, compliance determinations, and treatment. All public water system monitoring data is available via the SDWIS database.

The SWRCB monitored for DBCP via their GAMA Priority Basin Project and Domestic Well Project. Both of these projects were one-time, assessment studies and not considered continuous monitoring programs. The Priority Basin Project examined the quality of groundwater resources primarily used for domestic drinking-water supplies. Samples taken from monitoring wells between 150 and 500 feet in depth were used in the study to represent the quality of the shallow aquifer. The Tulare Shallow Aquifer Study via the Priority Basin Project sampled 96 wells from November 2014 to April 2015. DBCP was present at concentrations above the MCL in about 1% of groundwater resources used for domestic drinking water (SWRCB 2017). The Tulare County Domestic Well Project was a voluntary monitoring program that tested volunteered domestic wells throughout the county in 2006. DBCP was detected in 27 wells within Tulare County with concentrations ranging from 0.01 to 1.63 ug/L. Eight wells had DBCP concentrations above the MCL of 0.2 ug/L. All monitoring data collected for both the Priority Basin and Domestic Well Project is publicly available via the GAMA Geotracker database.

The discovery of DBCP and other pesticide contamination in groundwater in the early 1980's lead to the passage of the Pesticide Contamination Prevention Act (PCPA) of 1985. The PCPA requires that the Department of Pesticide Regulation (DPR) obtain, report, and analyze the pesticide results for well sampling conducted by public agencies as well as create their own monitoring program to sample wells for the presence of agricultural pesticides (including DBCP). DBCP concentrations data can be accessed via GAMA Geotracker or by filing a public records request with DPR.

2.4.3.3.3 Hexavalent Chromium

Chemical Properties

The following chemical properties are summarized from the GAMA Program Groundwater Information sheet for hexavalent chromium. Hexavalent chromium (Chromium VI) is a metallic element found in natural deposits of ores containing other elements, mostly as chrome-iron ore. Under most conditions, natural chromium in the environment occurs as Chromium III. Under oxidizing conditions, alkaline pH range, and the presence of manganese dioxide, natural chromium may partially dissolve in groundwater as chromium IV.

Chromium VI is known to cause cancer in humans when ingested and can damage the lining of the throat. When consumed, Chromium VI can upset the gastrointestinal tract and damage the liver and kidneys.

Sources and Spatial Distribution in the EKGSA

Recent analyses have indicated that the Chromium VI in California groundwater occurs naturally in most locations throughout the state. Naturally occurring Chromium VI might be associated with serpentinite-containing rock and chromium containing geologic formations. In industrial areas, it can be introduced to the environment via the discharges of dye and paint pigments, wood preservatives, chrome-plating liquid wastes, and leaching from hazardous waste sites.

Chromium VI is not commonly found in concentrations greater than 10 ppb in the Kaweah Subbasin. During evaluation of historical chromium VI results, only one well exceeded 10 ppb. This well is located outside of the EKGSA and there does not appear to be a threat that Chromium VI contamination will be a large-scale issue in the EKGSA. However, due to its potential human health impacts, Chromium VI will still be monitored within the EKGSA. **Appendix 2-F** further depicts the spatial distribution of Chromium VI concentrations throughout the EKGSA throughout the base period (1997-2017).

Existing Regulatory Programs and Monitoring

There is no federal MCL for Chromium VI. In July 2014, California adopted a primary MCL of 10 ppb. However, as of September 2017, the MCL was withdrawn by the SWRCB based on a Superior Court of Sacramento County ruling. While DDW repeats the regulatory process for adopting the new MCL, the federal MCL of 50 ppb for total chromium applies as the drinking water standard. There is no Agricultural Water Quality Goal for Chromium VI.

In 2001, the California Department of Public Heath adopted a regulation that added Chromium VI to the list of unregulated chemicals for which monitoring is required (UCMR). The detection limit for the purposes of reporting (DLR) and the former California state notification level (NL) is 1 ug/L. Between 2001 and 2012, over 12,000 public drinking water systems reported hexavalent chromium concentrations. This data is available via the SDWIS database and public water systems' annual Consumer Confidence Reports.

2.4.3.3.4 Nitrate

Chemical Properties

The following chemical properties are summarized from the GAMA Program Groundwater Information sheet for nitrate. Nitrate (NO3), is produced in the atmosphere from nitrogen and occurs naturally in groundwater at concentrations typically below 2 mg/L (as N). Nitrate is naturally produced from nitrogen gas through biologic fixation and from organic nitrogen through mineralization. High concentrations of nitrate in groundwater are often associated with the use of fertilizers or animal/human waste. Nitrate is highly mobile in groundwater and once dissolved is difficult to remove.

High levels of nitrate in drinking water is considered a human health risk. Infants under six months of age have a greater risk of nitrate poisoning called methemoglobinemia ("blue baby" syndrome). Toxic effects occur when bacteria in the infant's stomach convert nitrate to the more toxic nitrite. Nitrite enters the bloodstream and it interferes with the body's ability to carry oxygen to body tissues. Pregnant women are also susceptible to methemoglobinemia. Further long-term exposure studies are required to determine a direct relationship between nitrate levels and cancer.

Sources and Spatial Distribution in the EKGSA

Known sources of nitrate include runoff and leaching from fertilizer use from commercial irrigated agriculture, animal waste from dairy operations, leaching from septic systems and sewage, and very 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 prevalent throughout the Subbasin. According to Burton, Shelton, & Belitz (2012), most nitrate concentrations greater than 5 ppm were detected in the eastern part of the study units. In Hydrogeologic Zones 8, 9, 10 and portions of zone 7, nitrate tend to be higher than 5 ppm with increasing trends. As described in **Section 2.3.2**, the Kaweah Basin Water Quality Association (KBWQA) conducted a Groundwater Analysis Report (GAR) as part of the requirements of the Irrigated Lands Regulatory Program (ILRP). KBWQA findings report that nitrates appear to be the primary groundwater quality issue within the KBWQA boundary area (which covers a majority of the Kaweah Subbasin). High nitrate levels, many of which are already above the MCL, are located throughout the Kaweah Subbasin. Main locations with lower nitrate levels include near the footprint of the Kaweah River, southeast of the city of Visalia, and the foothill to mountain areas. **Appendix 2-F** further depicts the spatial distribution of nitrate concentrations throughout the EKGSA during the base period (1997-2017).

The historical and current predominate land use in the EKGSA is for commercial irrigated agriculture with some interspersed dairy farms. While Burton et. Al (2012) reports nitrate contaminations correlates to areas of agriculture classified as orchard and vineyard land uses, USGS finds that these regions also have medium to high density septic systems. Greater than 50 percent of the land use in hydrogeologic zones 7, 8 and 9 are orchards or vineyards. Septic-system density greater than the Subbasin median value of 5 septic systems in a 500-meter radius around each selected GAMA well occurred hydrogeologic zones 4-9, with very high density of 11.8 septic systems within 500 meters of the selected wells in zones 7, and 11.0 septic systems in zone 9. 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. While the existence of septic systems does not necessarily mean that they are a contributing source of nitrate contamination within the aquifer. However, leaky, poorly maintained septic systems can be a serious source of localized nitrate contamination. It is currently unknown the amount of contamination associated with poorly maintained septic systems. This represents a data gap that the EKGSA and Subbasin will need to evaluate going forward. Data gathered by USGS (Report 2011-5218) 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. 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 is trying to identify septic system density and condition in the Tulare-Kern Funding Area.

Existing Regulatory Programs and Monitoring

Nitrate as Nitrogen (N) has an acute drinking water MCL of 10 parts per million (ppm). There is no Agricultural Water Quality Goal for nitrate. Title 22 §64432.1 requires public water systems to test for nitrate annually. For public systems that use groundwater as a source must sample quarterly for at least one year following any one sample in which the concentration is greater than or equal to 50 percent of the MCL. All results must be reported to DDW, communicated to water users via annual consumer confidence reports, and be publicly available via DDW's SDWIS database.

Discharges of nitrate into groundwater is regulated and monitored by the SWRCB and Regional Boards via the Irrigated Lands Regulatory Program, individually issued Waste Discharge Requirements (WDRs), and the Dairy Order. Food processing related wastewater and industrial wastewater are generally managed by individual facility waste discharge requirements. Within these permits, the Regional Board sets agronomic limits for land application of nitrate contaminated wastewater and mandates quarterly water quality reports.

The Waste Discharge Requirements for Growers within the Tulare Lake Basin that are Members of a Third-Party Group Order R5-2013-0120-07 (ILRP General Order) requires that growers submit annual nitrogen management summary reports that record the amount of nitrogen applied to their irrigated acreage and the amount of nitrogen removed by their commercial crop harvests. In addition, growers must submit farm evaluations detailing the protective practices they utilize on-farm to reduce nitrate percolation into the aquifer. The KBWQA also monitors for nitrate concentrations annually via the groundwater trend monitoring program mandated by the ILRP General Order. All data from the ILRP groundwater trend monitoring program is publicly available via Geotracker. The groundwater trend monitoring program is a more recent ILRP requirement and at this time only one year of data has been collected. In addition, the KBWQA is collaboratively working with other agricultural coalitions to develop mass-loading groundwater protection targets for nitrate.

The Reissued Waste Discharge Requirements General Order for Existing Milk Cow Dairies R5-2013-0122 (Dairy General Order) requires a variety of nitrate mitigation practices to minimize the amount of nitrate traveling into the groundwater aquifer. Requirements of the Dairy General Order include visual inspections, nutrient monitoring, monitoring of surface runoff, and groundwater monitoring. Dairy dischargers must also provide a waste management plan and nutrient management plan to the Regional Board. Similar to the ILRP, dairies must submit data annually on the ratio of total nitrogen applied to land application areas versus uptake by crop harvest and the estimated amount of total manure and process water generated by the facility.

2.4.3.3.5 Perchlorate

Chemical Properties

The following chemical properties are summarized from the GAMA Program Groundwater Information sheet for perchlorate (ClO4 -). Perchlorate is a naturally occurring and man-made anion that consists of one chlorine atom bonded to four oxygen atoms. Perchlorate is highly soluble and mobile in groundwater and resistant to degradation in the environment. Due to its low vapor pressure, perchlorate does not volatize from water or soil surfaces to the air and when released directly to the atmosphere it settles readily though wet or dry deposition.

In the body, perchlorate interferes with the uptake of iodine by the thyroid grants, causing disruption of thyroid hormone production. Inhibited thyroid function can results in hypothyroidism and cause thyroid tumors in rare cases. Pregnant women and their developing fetuses are the most sensitive to perchlorate contamination in drinking water. During the first and second trimesters of pregnancy, the fetal thyroid is not yet fully functional, so the mother's thyroid must be able to produce enough extra hormones to enable her baby's brain to develop properly. Women with critically low levels of iodine can miscarry, or their developing fetuses can suffer congenital hypothyroidism, which may stunt the fetus's physical growth and impede proper development of its central nervous system.

Sources and Spatial Distribution in the EKGSA

Perchlorate may occur naturally, particularly in arid regions such as the southwestern United States. In addition, perchlorate is reported to be present in some caliche formations in Chile that are used to produce nitrate fertilizers. Perchlorate originates as a contaminant in the environment from the release of solid salts of ammonium, potassium, or sodium perchlorate. The majority of perchlorate detections in groundwater (~90%) are associated with the manufacturing or testing of solid rockets fuels for the Department of Defense (DOD) or National Aeronautics and Space Administration (NASA). In addition to rocket fuels, perchlorate salts are also used in the manufacture of fireworks, matches, automotive air bag inflators, leather, rubber, and paint production.

From 1997 to 2017, 13 exceedances of the perchlorate MCL were recorded in the southern portion of the EKGSA around the cities of Lindsay and Strathmore. Current data is not indicative of a specific point source of the perchlorate pollution. **Appendix 2-F** further depict the spatial distribution of perchlorate concentrations throughout the EKGSA throughout the base period (1997-2017).

Existing Regulatory Programs and Monitoring

In January 2001, the Department of Health Services (now managed under the Division of Drinking Water), identified perchlorate as an unregulated chemical requiring monitoring under Title 22. At this time, public water systems began testing for perchlorate in their drinking water supplies. In 2004, the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA) adopted a public health goal (PHG) for perchlorate at 0.006 mg/L (6 ppb). Following statutory mandates, the perchlorate MCL was established at 6 ppb in October of 2007. In 2015, the OEHHA lowered the PHG from 6 ppb to 1 ppb, prompting review of the perchlorate MCL. Pending further review by the State Board, the MCL remains at 0.006 mg/L (ppb). Similar to previously discussed constituents, public water systems are required to test for and report data on perchlorate results. Title 22, Chapter 15, §64432.3, requires that all community and nontransient-noncommunity water systems collect two samples at each source in a year (at least five to seven months apart). For systems that have perchlorate detections, sampling must continue to occur on a quarterly basis. All sampling results are publicly available via the SDWIS database.

Perchlorate is also monitored for within the National Pollutant Discharge Elimination Systems (NPDES) with oversight managed by the State and Regional Boards. Any business that discharges waste into the waters of the state, must apply for an individual waste discharge permit (WDR) or be covered under a General Order. Currently, there are no registered point-source dischargers of perchlorate in the EKGSA.

2.4.3.3.6 1,2,3-Trichloropropane (TCP) Occurrence

Chemical Properties

The following chemical properties are summarized from the GAMA Program Groundwater Information sheet for 1,2,3-trichloropropane (TCP). TCP is a man-made chlorinated hydrocarbon. While only slightly soluble in water, TCP has a low soil sorption coefficient, resulting in easy migration from the soil into groundwater supplies. TCP is generally resistant to biodegradation, hydrolysis, oxidations, and reduction under naturally occurring conditions, making it highly persistent and mobile within the environment.

TCP has acute, chronic, and carcinogenic effects on human health. Acute contact with TCP can irritate and burn the skin, nose, throat, and lungs. It can impact concentration, memory, and muscle coordination. Long-term chronic exposure to TCP can cause liver and kidney damage, reduced body weight, and increased tumor risk. TCP causes cancer in animals and is recognized by the State of California as a human carcinogen.

Sources and Spatial Distribution in the EKGSA

Typically found at industrial or hazardous waste sites, TCP was introduced to California's groundwater as an impurity within DBCP fumigants manufactured by Shell Chemical Company and Dow Chemical Company. As discussed in **Section 2.4.3.3.2**, DBCP contaminated with TCP was extensively used throughout Tulare County as a nematicide. TCP has also been used in solvents in the past. There are no known point sources of TCP from industrial or hazardous waste sites in the EKGSA.

Three wells in the southern half of the EKGSA tested higher than the MCL between 2001-2018 with maximum recorded concentration 0.8 ug/L. Contamination within the EKGSA appears to be diffuse with no specific TCP contamination plume appearing. **Appendix 2-F** further depict the spatial distribution of TCP concentrations throughout the EKGSA throughout the base period (1997-2017).

Existing Regulatory Programs and Monitoring

TCP has a primary drinking water MCL of 5 parts per trillion (ppt). There is no Agricultural Water Quality Goal for TCP. As discussed in **Section 2.4.3.3.2** (DBCP), TCP is no longer permitted for agricultural use. Today, TCP is currently used as a chemical intermediate in the production of other chemicals, such as polysulfone liquid polymers and dichloropropene. Any TCP discharges from a point source is managed through the State's NPDES permit system. There are no permitted facilities discharging TCP in the EKGSA.

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 (UCMR). From this data, DDW determined that the most impacted counties are Kern, Fresno, Tulare, Merced and Los Angeles. Based on detections of TCP in groundwater, EOHHA established a 0.0007 ug/L PHG in 2009. In July 2017, the SWRCB DDW adopted the current MCL for TCP at 0.005 ug/L. All water systems are required to test their wells quarterly beginning in January 2018. Only a few of the 47-public water system had data available in SDWIS at this time, the majority of detections were located in the central portion of the Subbasin. The data quantity available for TCP concentrations will continue to increase over time as given that monitoring regulations went into effect in 2018.

2.4.3.3.7 Tetrachloroethylene (PCE) / Contamination Plume Occurrence

Chemical Properties

The following chemical properties are summarized from the GAMA Program Groundwater Information sheet for tetrachloroethylene (PCE). PCE is a colorless, volatile, and nonflammable hydrocarbon. PCE forms a dense non-aqueous phase liquid (DNAPL) that is insoluble in water. In groundwater aquifers, the half-life degradation rate is estimated to be between 1-2 years but may be considerably longer under certain conditions.

PCE exposure has acute, chronic, and carcinogenic health impacts. Typically, acute exposure levels are experienced via exposure to PCE in the air at concentrations between 100-200 mg/L. Chronic exposure via drinking water over the MCL can cause adverse effects to the liver, kidneys, and central nervous system. Prolonged skin contact can cause irritation, dryness, and dermatitis. Scientific evidences show that PCE may cause cancer from prolonged exposure, even at levels below the MCL. The US EPA classifies PCE as a probable human carcinogen.

Sources and Spatial Distribution in the EKGSA

PCE is a manufactured chemical and does not have any known natural sources. Mainly used as a cleaning solvent in dry cleaning and textile processing. Sources of PCE in the EKGSA 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 DTSC – EnviroStor databases. There is a total of 21 sites identified within the Kaweah Subbasin, none of which are in the EKGSA. Fortunately, per the available reports, none of the sites listed have been determined to have an impact on the aquifer.

Contamination sites will continue to be monitored in the Subbasin to determine the extent of impact to the groundwater. In some instances, sites with shallow monitoring wells went dry due to the water table levels dropping and deeper monitoring wells had to be drilled to continue the investigations. At this time, there is not enough information to determine if the contaminants are sinking with the groundwater levels.

Existing Regulatory Programs and Monitoring

PCE is a volatile organic compound with a primary drinking water MCL of 5 ppb. There is no Agricultural Water Quality Goal for PCE. Public water systems utilizing groundwater sources must initially monitor for PCE during four consecutive quarterly sampling events. If PCE is detected in the groundwater, PCE testing must continue for each compliance period. All data collected by public water systems on PCE concentrations is available via the SDWIS database. California's Site Cleanup Program (SCP) regulates and oversees the investigation and cleanup of "non-federally owned" sites where recent or historical unauthorized releases of pollutants to the environment have occurred. The State and Regional Boards oversee the dischargers clean-up activities to ensure that dischargers provide adequate clean-up and abatement of the contamination. Within the EKGSA, there are no registered SCP sites for PCE. Any potential data for cleanup sites overseen by cities, counties, and health agencies is available via Geotracker. For sites under the jurisdiction of the California Department of Toxic Substances Control (DTSC), the DTSC database, Envirostor, provides data on water quality at cleanup sites.

2.4.3.3.8 Sodium and Chloride Occurrence

Chemical Properties

Sodium is the sixth most abundant element on Earth and is widely distributed in soils, plants, water, and foods. Most of the world has significant deposits of sodium-containing materials, most notably sodium chloride.

Sources and Spatial Distribution in the EKGSA

There are four salinity sources: agriculture, municipal, industrial, and natural. By agriculture, evaporation of irrigation water will remove water and leave 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 is through the use of detergents, water softeners, and industrial processes. Wastewater discharged from Publicly Owned Treatment Works (POTWs) and septic systems can increase salinity levels. An industrial source is through 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.

There are not too many wells within the Kaweah Subbasin that have increasing or elevated sodium and chloride levels. However, there are areas of the EKGSA that have increasing or elevated sodium and chloride levels. Sodium and chloride levels are increasing and, in some cases, already over the Agricultural Water Quality Goal.

Existing Regulatory Programs and Monitoring

Based on drinking water standards, the recommended secondary maximum contaminant level (SMCL) for chloride is 250 ug/L (ppm) with an upper limit of 500 ug/L (ppm). There is no drinking water standard for sodium, however the Agricultural Water Quality Goal (AWQG) for sodium and chloride are 69 ppm and 106 ppm, respectively. The criteria identified are protective of various agricultural uses of water, including irrigation for various types of crops and stock watering. Due to the AWQG being more stringent than sodium and chloride's drinking water SMCL and the importance of irrigated lands within the EKGSA, the Agricultural Water Quality Goals for sodium and chloride will be used when evaluating water quality from agricultural wells.

2.4.4 Land Subsidence

Legal Requirements:
§354.16(e) The extent, cumulative total, and annual rate of land subsidence, including maps depicting total subsidence, utilizing data available from the Department, as specified in Section 353.2, or best available information.

Inelastic (irrecoverable) land subsidence (subsidence) is a concern in some areas of active groundwater extraction as it may lead to increased flood risk in low lying areas; damage or collapse to well casings, canals and infrastructure; and permanent reduction in the storage capacity of the aquifer. Subsidence due to groundwater pumping in the Central Valley has been a burgeoning issue for decades (NASA Report). Subsidence is not a large concern within the EKGSA, since the 1950s there has not been significant subsidence in the area. However, the EKGSA has nearby neighbors that are experiencing impacts due to subsidence, such as areas near Corcoran (to the west) and the Tule Subbasin (to the south). InSAR data obtained from a NASA

UAVSR airborne platform indicates levels of subsidence in the Subbasin have increased since summer of 2014, which coincides with a significant drought period and the first of two years of unprecedented 0% CVP delivery.

2.4.4.1 Cause of Land Subsidence

There are several known processes that may contribute to land subsidence, such as the following: aquifer compaction from overdraft; hydro-compaction (shallow or near-surface subsidence) of moisture deficient deposits above the water table that are wetted for the first time since deposition; petroleum reservoir compaction due to oil and gas withdrawal; and subsidence caused by tectonic forces (Ireland et al., 1984).

Subsidence 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 through groundwater pumping. Clay particles are supported by water when they are deposited but long-term pumping depressurizes the clay. This depressurization allows for the permanent collapse and rearrangement of the structure, or matrix, of particles in fine-grained layers. Groundwater generally cannot re-enter the clay structure after it has 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 surface land subsidence and the thickness of the clay layers are reduced, 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). Nonetheless, 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 is produced from it (Faunt, 2009), likely because it is thick and has low permeability (DWR, 2017).

2.4.4.2 Past Land Subsidence

Historical documentation of subsidence within the Central Valley relies 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 data sets. Within the Subbasin, the National Geodetic Survey has documented subsidence up to 8 feet during the period from 1926 to 1970, generally on the western and southwestern ends of the Subbasin (Ireland et al., 1984). Groundwater overdraft is the primary driver for historical land subsidence in the Central Valley (Faunt et. al., 2009). USGS estimates about seventy five percent of historic land subsidence in the Central Valley occurred in the 1950s and 1960s during a period of extensive groundwater development (Galloway, et al., 1999). Greater rates of compaction are generally correlated with below normal water year indices, (critical, dry, or below normal) while subsidence rates were lower during high water year indices (wet, above normal).

2.4.4.3 Recent Land Subsidence

Recent subsidence studies of the Central Valley have utilized satellite-based, remote sensing data from the Interferometric Synthetic Aperture Radar (InSAR) and aircraft-based L-band SAR or Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) programs, led by NASA and Jet Propulsion Laboratory (JPL), as well as other international researchers. These datasets provide a continuous estimate of subsidence over a large portion of the Subbasin. Additionally, subsidence in the Subbasin and in the Tule Subbasin (to the south) can also be observed at point locations through continuous GPS (CGPS) stations and other land surface monitoring stations. Most of these are not located within the EKGA, representing a data gap. 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). Annual averages of CGPS or future extensometer data may permit a more meaningful comparison and/or calibration with InSAR data in the future.

Recent and historical subsidence data is summarized in **Table 2-7**. The data presented includes a summary of InSAR data published in a subsidence study commissioned by the California Water Foundation (LSCE, 2014) and by JPL (Farr et al., 2015 and 2016). The InSAR data was collected from a group of satellites (Japanese

PALSAR, Canadian Radarsat-2, and European Space Agency's (ESA) satellite-borne Sentinel-1A and -1B), from 2006 to 2017, however there is a data gap for the EKGSA prior to 2015 due to the limit of study and absence of satellite data collection data prior to the ESA Sentinel satellites in 2014 (Farr et. al., 2016).

According to the California Water Foundation study (LSCE, 2014), subsidence is an on-going problem that is leading to significant impairment of water deliveries from the FKC south of the Kaweah Subbasin. According to DWR (2014), the Kaweah Subbasin is at a high risk for future subsidence due to 1) a significant number of wells with water levels at or below historic lows; 2) a documented pattern of historical subsidence; and 3) current reports of subsidence. Moreover, the largest amount of subsidence is exhibited to the west, southwest, and south of Kaweah in adjacent Subbasins. The extent of future subsidence will be determined by the further decline in groundwater elevations and the length of time water levels remain at historic lows. Stable groundwater elevations may help limit the risk of future subsidence that occurs as a result of groundwater pumping.

2.4.4.4 Future Data Availability

According to USGS, the ESA's Sentinel satellites collect InSAR data at approximately weekly intervals and the data is made available for download and personal use. Likewise, post-processed CGPS data is continuously available for personal use. Although no extensometers are currently within the Kaweah Subbasin and there are a limited number of extensometers in adjacent basins. The EKGSA will try to rely on InSAR data going forward as it provides coverage for the EKGSA area.

2.4.4.5 Map of Subsidence Locations

Historical rates of subsidence across the Subbasin are presented in the Kaweah Subbasin Basin Setting Document in **Appendix 2-A**. This document also includes hydrographs for selected wells (generally western portion of the Subbasin) plotted against subsidence data for the purpose of comparison. Although reported levels of subsidence are strongly related to declines in groundwater elevations and the potentiometric surfaces in deeper aquifers, other major contributing factors are the presence of regional fine-grained stratigraphic units, such as the Corcoran Clay, and localized areas with thick, fine-grained layers. Due to the Kaweah Subbasin's disposition to the effects of subsidence, the locations of vital infrastructure shall be considered in the assessment of areas sensitive to the effects of land subsidence. For the EKGSA, the FKC is the vital structure.

Cumulative rates of recent subsidence (Spring 2015 through 2017) are presented in **Figure 2-27**. This time period covers a significant drought, and there appears to be some correlation between land subsidence in recent years in response to an increased groundwater demand to offset the limited surface water supplies due to drought. This trend is magnified in areas outside the EKGSA and reasonably corresponds with other regional data sets[2]. It should be noted the 2015 through 2018 cumulative shows significant portions of the EKGSA as static to slight uplift indicating there is some elasticity in the area.

2.4.4.6 Measured Subsidence

The following tabulated data includes cumulative inches of subsidence within and/or near the EKGSA, and approximate annual rates for various data collection periods. Although the highest rates of subsidence occur outside of the EKGSA, particularly to the west and south; data shows there has been some subsidence within the area. It appears there is correlation with subsidence and both a decline in water levels and pumping from deeper levels. Annual subsidence rates vary spatially but have increased in magnitude during the recent drought conditions as a higher demand has been placed on groundwater to meet demands.

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[2] The higher rate of "subsidence" in the Frazier Valley area in the southeastern portion of the EKGSA is associated with land development during the referenced period.

Table 2-7 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.
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
Kaweah Subbasin *(Highest values near Corcoran)*	2015 - 2017	0 – 26.7	0 – 13.4	InSAR. Downloaded from DWR SGMA Viewer.
Mile Post 88. 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	

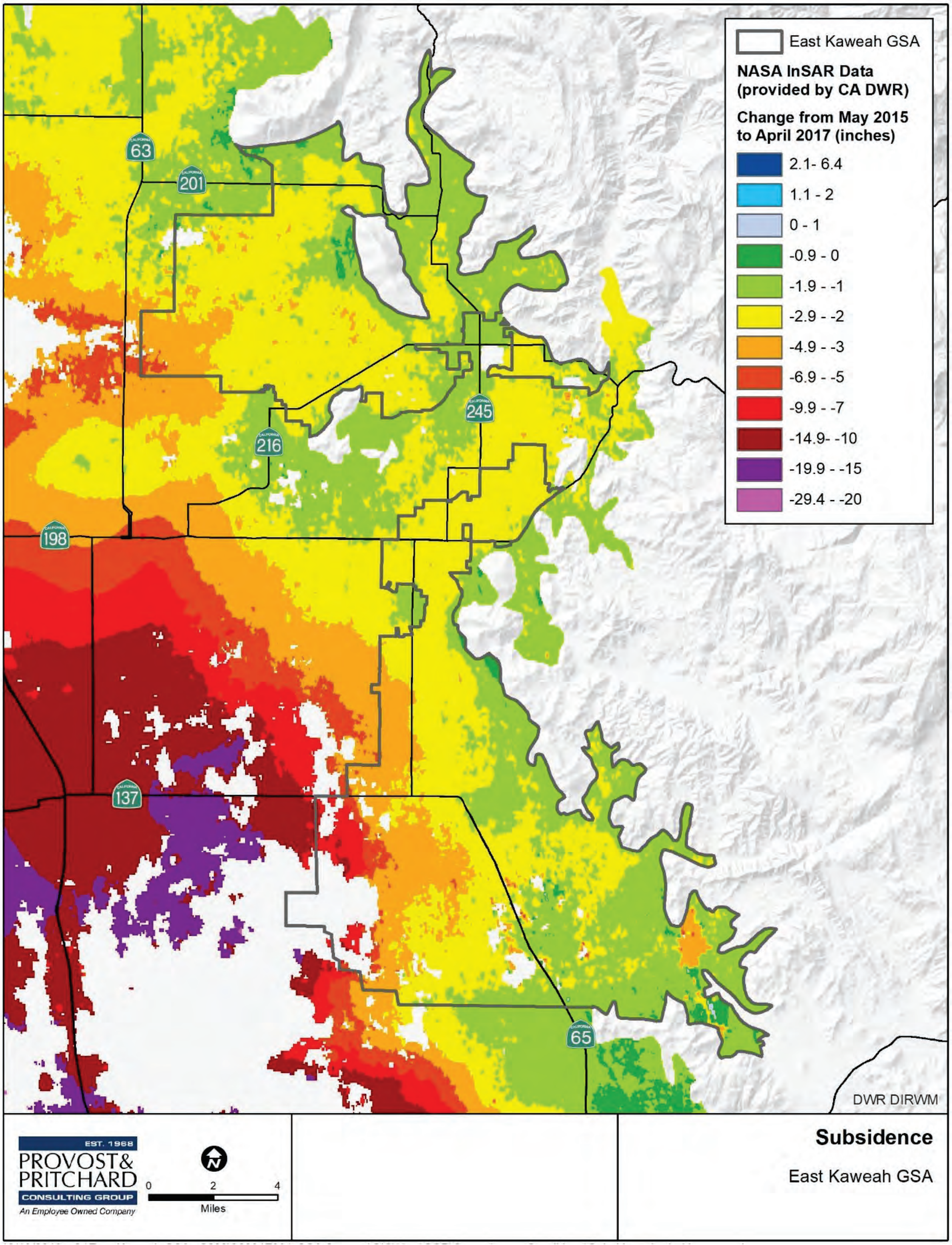


Figure 2-27 InSAR Subsidence Data for the EKGSA

2.4.5 Interconnected Surface Water Systems

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

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 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.

An analysis of baseline conditions has been performed, which considered both local knowledge of natural streamflow within the Kaweah Subbasin 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 planning base period.

Generally, the only available streamflow data is outside the EKGSA. Cottonwood, Lewis, and Frazier Creeks do not have gauges. However, monthly to semiannual groundwater-level measurements collected within the EKGSA support the understanding of the variability of the proximity and 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 throughout the EKGSA are considered losing channels throughout the year with no connectedness between the surface water and groundwater system. However, some upper reaches of the creeks near the foothills and the Kaweah River upstream of McKays Point are more likely to be relatively neutral to gaining stream reaches during times of year. Locations where interconnectivity was possible during the Spring of 2015 are shown in **Figure 2-28.**

2.4.6 Groundwater Dependent Ecosystems

Legal Requirements:
§354.16(g) Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or best available information.

Where groundwater and surface water are separated by significant distances, as is the case with the majority of the EKGSA, the groundwater does not interact with the natural streams or manmade ditches, and therefore, no possibility exists for the presence of Groundwater Dependent Ecosystems (GDE). However, there are locations near the foothills of the Sierra Nevada where groundwater levels are closer to the surface.

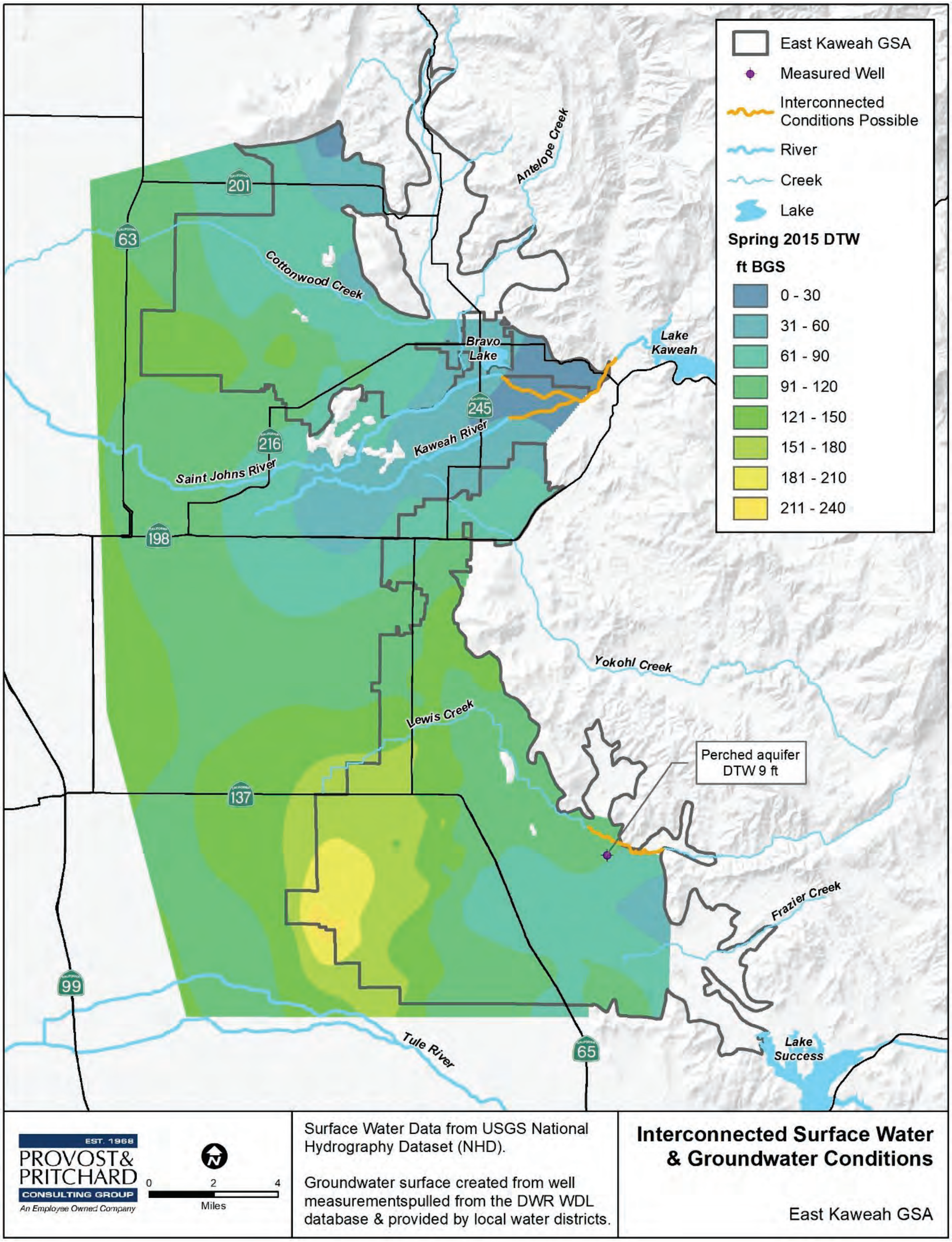
Areas where groundwater is within 30 feet of the ground surface are primarily located along the Kaweah River (primarily in GKGSA), the Stone Corral ID area, and near Lewis Creek in the Lindsay-Strathmore ID area. **Figure 2-28** represents areas where groundwater elevations as of the Spring of 2015 were within 30 feet of the ground surface. **Figure 2-29** depicts a map of the EKGSA with 30-foot DTW contours for various water year types through the Base Period (1997-2017). This highlights potential areas that may be considered interconnected surface waters and/or GDE with further evaluation. Wetlands within these areas may be considered GDE, however additional study, data, and field verification are necessary. This data gap will be addressed as part of further study going forward.

2.4.7 Conditions – January 1, 2015

Groundwater levels measured in the spring and fall of each year by the member agencies provide the data required to document groundwater conditions January 1, 2015. To document the groundwater conditions as of

January 1, 2015, data from the first round of groundwater level measurements that occurred after that date, which is generally Spring (March), are being utilized and are presented in **Figure 2-28**.

Review of groundwater level monitoring data indicate that water levels were at or near the lowest levels on record since the 1960s in the EKGSA. In 2015 the State was experiencing a severe drought, which led to high groundwater pumping. Additionally, the drought led to 0% Friant CVP allocations. Approximately 70% of the EKGSA area is receives surface water from the Friant CVP. Lack of delivery of this imported supply significantly impacted the EKGSA in 2015.



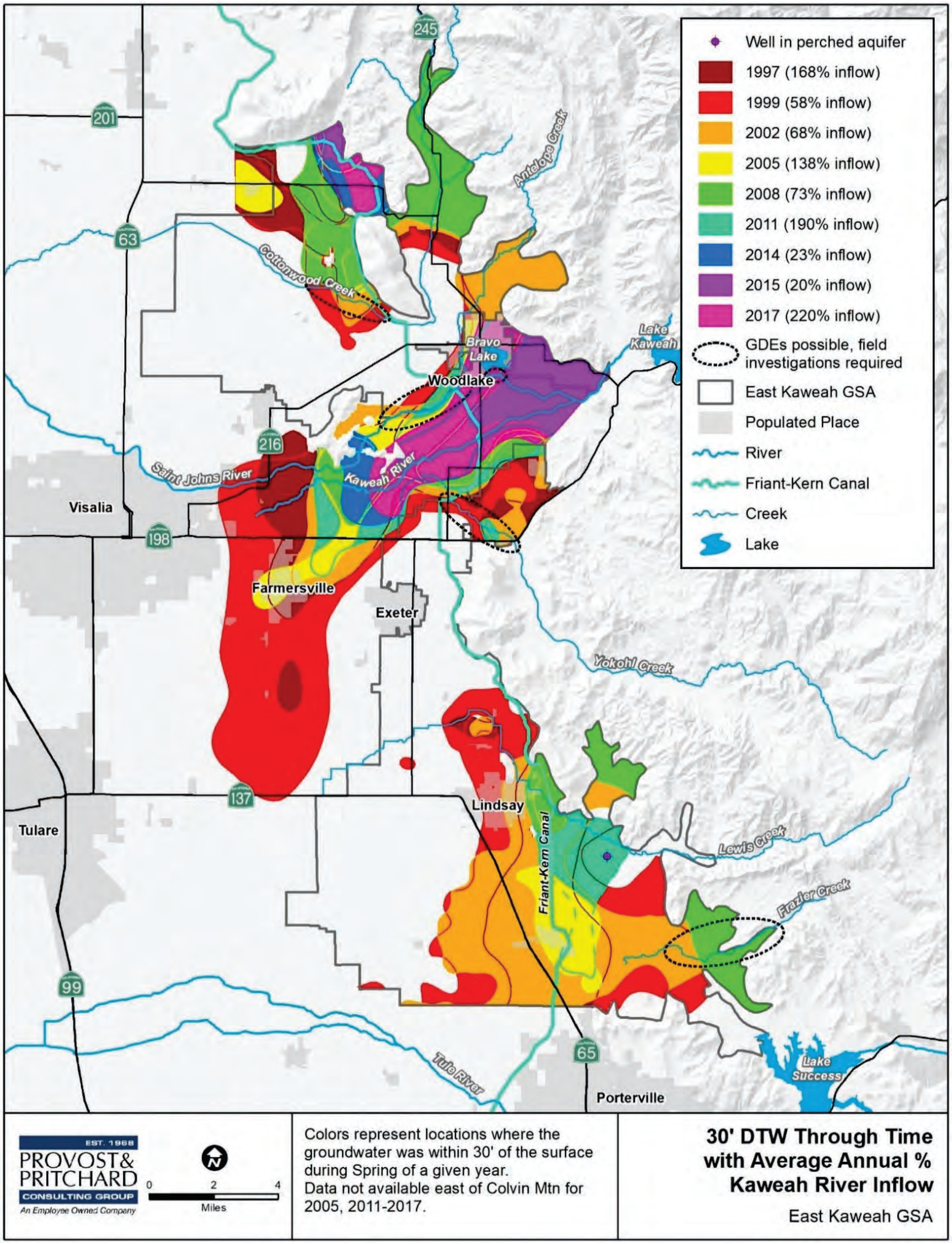
Surface Water Data from USGS National Hydrography Dataset (NHD).

Groundwater surface created from well measurementspulled from the DWR WDL database & provided by local water districts.

Interconnected Surface Water & Groundwater Conditions

East Kaweah GSA

Figure 2-28 Potential Groundwater Dependent Ecosystems



Colors represent locations where the groundwater was within 30' of the surface during Spring of a given year.
Data not available east of Colvin Mtn for 2005, 2011-2017.

30' DTW Through Time with Average Annual % Kaweah River Inflow

East Kaweah GSA

Figure 2-29 Potential GDE Analysis Areas through Select Base Period Groundwater Levels

2.5 Water Budget §354.18

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

The Kaweah Subbasin water budget was developed for the entire Subbasin using data between water years 1981 and 2017. A "water year" refers to the inclusive period from October 1 through the following September 30. The date of the water year is, by convention, named as the ending year, such that "water year 1981" begins on October 1, 1980 and ends on September 30, 1981. Components contributing to the inflow and outflow of surface and groundwater within the GSA were used to calculate the historical water balance. The Subbasin-wide water budget estimates uses "the best available information" to the quantity the surface and groundwater flow during each year in this 37-year period. The results are presented in the Kaweah Subbasin Basin Setting Document in **Appendix 2-A**.

This Water Budget Section for the EKGSA will focus on the Subbasin's approved planning period, using data between water years 1997 and 2017. This 21-year planning period includes a more robust data set for groundwater inflows and outflows, includes more current land uses and on-farm practices, and is more representative of surface water use in the Subbasin. This section of the GSP summarizes the available data from the period of record and the general methodology used for quantification of each of the water budget components into and out of the groundwater system. From the available data, the accumulated overdraft in the planning period is quantified and presented. The water budget components are summarized into water year totals, from which the annual change in groundwater storage is calculated. Finally, an estimate of the sustainable yield for the EKGSA's share of Subbasin is presented.

The water budget is simply a statement of the balance of total water gains and losses in groundwater. In very simple terms, the water budget is summarized by the following equation:

$$\text{Inflow} = \text{Outflow} (\pm) \text{Change in Storage}$$

The water budget components in the EKGSA were calculated from a variety of compiled sources from Reclamation, DWR, USGS, and district-reported water use data. The water budget components used in the calculations for the EKGSA, and Subbasin as a whole, include the following:

Table 2-8. Water Budget Components

Inflow Components	Outflow Components
Subsurface inflow	Subsurface outflow
Percolation of Precipitation	Agricultural water demand and consumptive use
Streambed percolation and delivered water conveyance losses	Municipal and Industrial Pumping
Artificial recharge	Agricultural Pumping
Percolation of irrigation return water	Consumptive use by phreatophytes
Percolation of wastewater	Evaporative losses
	Exported water

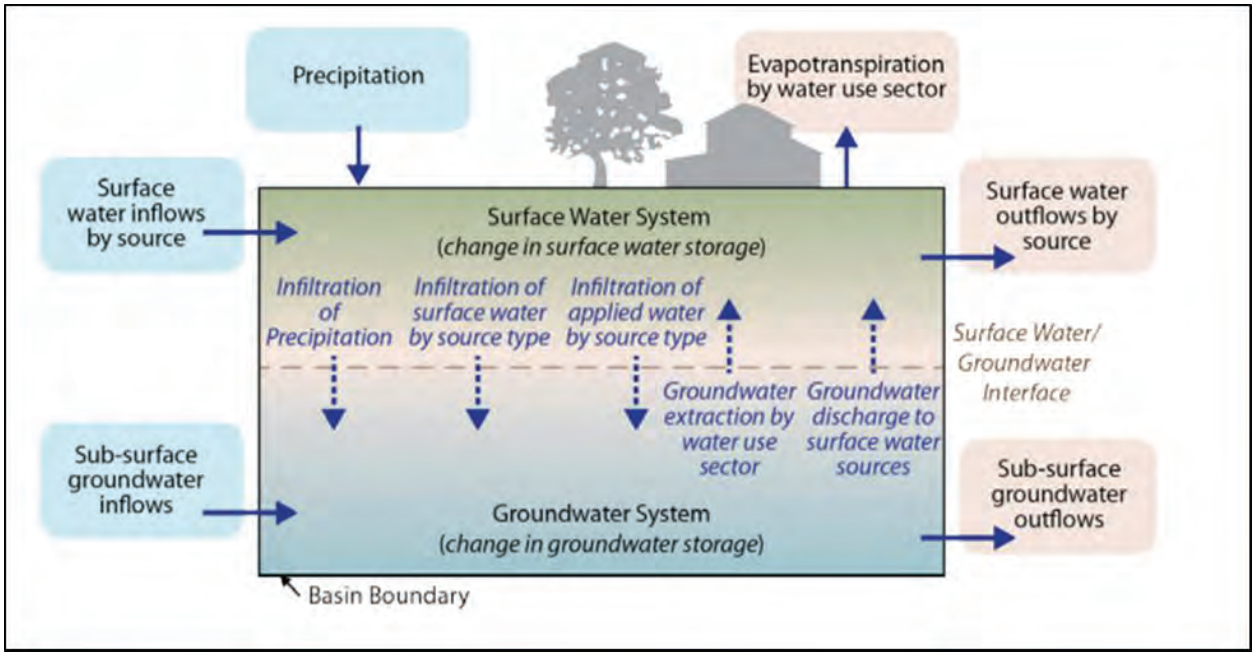


Figure 2-30 Water Budget Components

2.5.1 Numerical Model

Legal Requirements
§354.18 **(e)** Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, climate change, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow. If a numerical groundwater and surface water model is not used to quantify and evaluate the projected water budget conditions and the potential impacts to beneficial uses and users of groundwater, the Plan shall identify and describe an equally effective method, tool, or analytical model to evaluate projected water budget conditions. **(f)** The Department shall provide the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) and the Integrated Water Flow Model (IWFM) for use by Agencies in developing the water budget. Each Agency may choose to use a different groundwater and surface water model, pursuant to Section 352.4.

A numerical groundwater model using MODFLOW was developed to support implementation of GSPs for all three GSAs in the Kaweah Subbasin. The model, known as the Kaweah Subbasin Hydrologic Model (KSHM), represents a new SGMA tool that includes complex hydrologic analyses in addition to groundwater flow.

The KSHM is based on an existing groundwater model developed by Fugro in 2005 that covers the KDWCD portion of the Kaweah Subbasin, which is approximately equal to 75 percent of the Subbasin area. This original numerical model was revised, expanded and updated to support the objectives of the GSPs in the Subbasin. The KSHM will be used to predict future groundwater conditions with and without proposed management actions in the GSAs and cumulatively for the entire Subbasin. Additional discussion on the model specifics, its principal elements, relationship to the historical and current water budgets, and the results of its use to develop the projected water budgets is provided in **Appendix 2-G**.

2.5.2 Current and Historical Water Budget

Legal Requirements:
§354.18

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

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

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

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

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

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

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

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

The current and historical water budget was created to quantify the inflow and outflow through the EKGSA, and Subbasin, based on records of historical hydrology, water supply availability, water demand, and land use. The data was collected for the 37-year beginning in water year 1981 and extends through water year 2017. This 37-year base period includes two wet-dry hydrologic cycles, variations in available surface water supply and changes to water demand patterns due to new cropping patterns and land uses. Since water supply and land use during this period has a great deal of climatic and hydrological variability the effects on the aquifer are believed to be representatively evaluated and quantified. The historical water budget was compiled for the three GSAs within the Subbasin to evaluate the historical availability and reliability of past surface water supply deliveries to gauge the aquifer response to water supply and demand trends by water year type. The data was collected, and water budget compiled in accordance with a coordination agreement between the three GSAs "to ensure that the three GSPs are developed and implemented utilizing the same data and methodologies, and that the elements of the GSPs necessary to achieve the sustainability goal for the basin are based upon consistent interpretations of the basin setting."

2.5.2.1 Base Period Selection

Water years for 1997 to 2017 have been selected for the water budget planning period since the range satisfies both the historical and current water budget requirements. This period covers the 10-year minimum and is sufficient to calibrate the tools and methods used in estimates and future water budget and aquifer response projections. The period for the water budget also includes "the most recently available information." Since the base period ends in 2017 it incorporates recent cultural conditions, including an unprecedented lack of imported surface water availability between 2012 and 2015. This four-year period set a new record for the driest four-year period of statewide precipitation. In 2013 many communities reported the lowest levels of rainfall on record and 2015 included the driest January on record statewide (2016 Drought Contingency Plan). Although the period between 2012 and 2015 included extreme dry-weather events the precipitation patterns for the years leading into the beginning of the base period have many similarities.

This period was selected by comparing the average Kaweah River runoff and precipitation for the period compared to the long-term averages for the period of record. The relation between runoff and precipitation during this period was also compared and displays a relatively robust correlation. The period of record for Kaweah River runoff dates back to 1904, and the period of record for precipitation dates back to 1876.

Records from the Visalia precipitation station were used for the analysis of the Kaweah Subbasin since this station has a long period of data, is centrally located within the Subbasin, and it gives the best estimate of the average rainfall across the Subbasin. Average rainfall at this station is 10.1 inches per year. The average annual precipitation for the 1997 to 2017 period is approximately 9.7 inches, or 96% of the long-term average, for a variance of approximately four percent for the 141-year historical record.

During the period of record between water years 1904 and 2017, the average annual runoff within the Kaweah River at Three Rivers was 426,569 acre-feet (AF), with a range from 90,114 AF (2015) to 1,360,000 AF (1983). The average annual runoff for the 1997 to 2017 period is approximately 431,900 AF, or 101% of the long-term average, for a variance of approximately one percent from 113-year historical record. Kaweah River runoff variations shown in **Figure 2-31**, 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. An analysis of the statistical relationship between the composite precipitation and river flow data sets is presented as **Figure 2-32**. The average composite precipitation and Kaweah River runoff during the reference period allows for the approximation of the long-term average (within several percent).

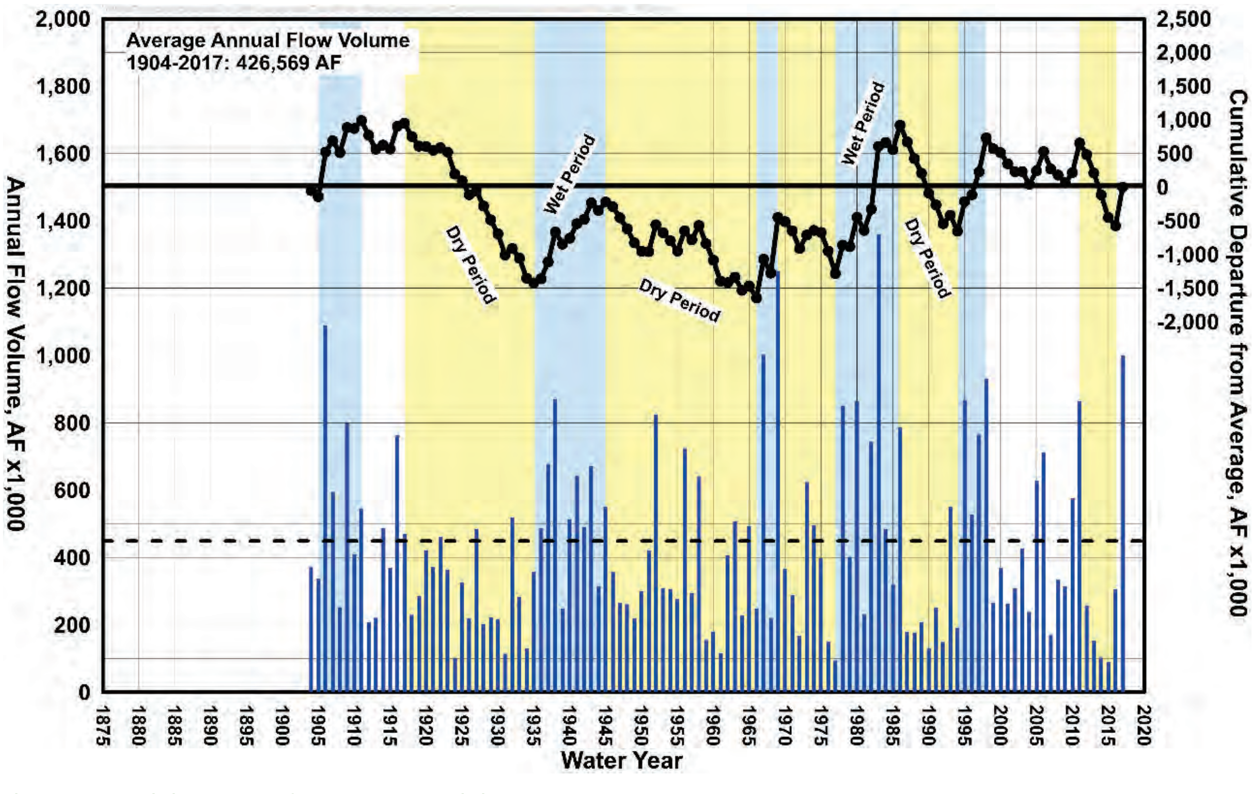


Figure 2-31 Cumulative Departure from Average Annual Flow

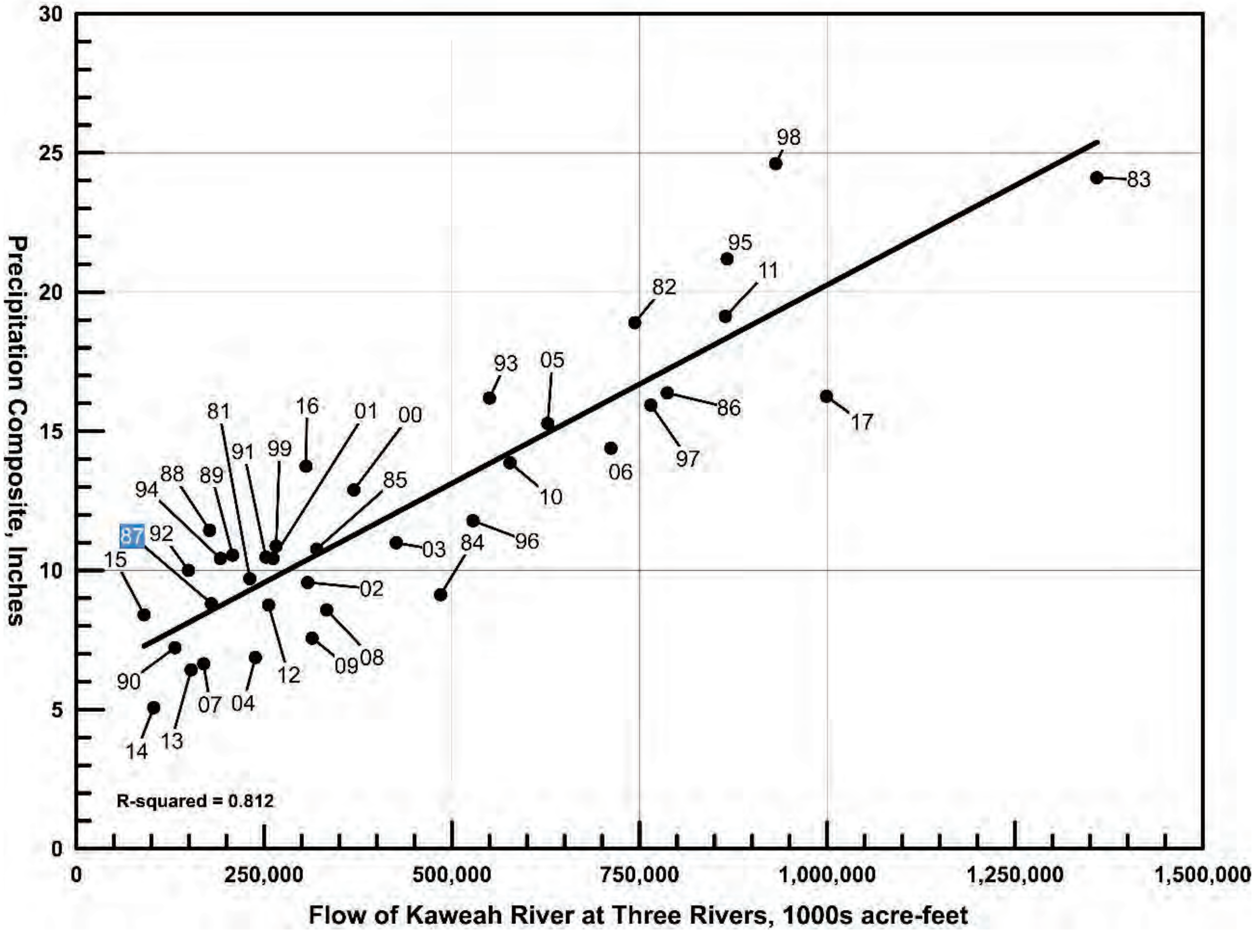


Figure 2-32 Kaweah River Runoff Versus Mean Precipitation

2.5.3 Quantification of Water Budget Components

Legal Requirements:

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

(1) Total surface water entering and leaving a basin by water source type.

(2) Inflow to the groundwater system by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.

(3) Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow.

2.5.3.1 Surface Water

The two sources of surface water to the EKGSA are Kaweah River water and Friant Division CVP supplies. The Kaweah River is the primary source of local surface water throughout the Subbasin. However, the Wutchumna Water Company (WWC) is the primary entity in the EKGSA to take surface water from the Kaweah River. On average, the WWC diverts just over 67,000 AF per year (AFY) of Kaweah River water. Approximately one-third (23,300 AFY) of this total is delivered to WWC shareholders within the EKGSA boundary.

The Subbasin, and the EKGSA in particular, has been using supplemental surface water supplies for decades. In the early 1950s additional surface water supplies were made available to the region through contracts with Reclamation. These supplies have been brought into the region through the CVP's Friant-Kern Canal (FKC).

The EKGSA has eight long-term contractors for CVP supplies. On average, these contractors diverted approximately 84,500 AFY from the FKC for agricultural and municipal uses.

Deliveries of supplemental surface water supplies are necessary for agricultural water users to mitigate the undesirable results from overdraft. Historically, the region would receive surface water supplies at the contracted amount with Reclamation and there was enough water to prevent a decline in groundwater levels. For example, during the 1987 to 1992 drought, imported water was available without significant contract limitations, therefore, no significant water level declines were noted. However, beginning in the 2010s, long-term surface water allocations were reduced to comply with the terms of a settlement on the San Joaquin River Restoration Program. In the recent 2012 to 2015 drought, CVP contract deliveries were severely limited, such that in 2012 only 57% Class 1 water was delivered; in 2013 only 62% and in both 2014 and 2015, no contracted water was delivered. Corresponding to this unprecedented lack of surface water, groundwater levels declined to new record low levels.

On average, during the 1997 – 2017 period, a total of approximately 101,240 AFY of imported CVP and Kaweah River was diverted for use within the EKGSA. 98% of this total was delivered for agricultural irrigation. Gross irrigation demand is supplied by both surface and groundwater. There are several small creeks and with tributary waters that contribute to the EKGSA, however, these waterways lack gauges so their contribution to overall water use is not easily accounted for. The minor creeks and streams that flow into the EKGSA include: Cottonwood Creek, Lewis Creek, and Frazier Creek. Since it is difficult to estimate these seasonal flows in the absence of flow meters, the contributions of these waterways are captured in the estimations for Mountain Front recharge.

Surface Water Crop Delivery

Surface water is primarily applied to irrigated crops since agriculture uses a majority of the water resources in the EKGSA. The calculation for the volume of surface water delivered to fields for agricultural crop demands is described with the following equation adapted from previous methods (Fugro, 2007; 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 the following sections with an emphasis placed on the relationship between surface water “loss” and aquifer inflow. The activities contributing to water system losses include riparian diversions, recycled water use, ditch system percolation, recharge basin diversions, and spills. Each of these factors as they relate to the EKGSA will be presented and discussed in the following paragraphs. Based on the calculation above, the total average volume of surface water delivered to crops in the EKGSA is just over 99,000 AFY. Total agricultural crop demand for the EKGSA is currently estimated at approximately 250,000 AFY. The surface water deliveries are used to offset groundwater pumping to meet the irrigated agriculture demand.

Headgate Diversions (HG_{DIV})

Headgate diversions refer to water diverted through headgates from a conveyance facility (i.e. FKC or Kaweah River). These diversions are the gross water diverted before accounting for losses and spills. From 1997-2017, the EKGSA diverted approximately 109,550 AFY of surface water through headgates.

Riparian Diversions *(R_{DIV})*

Riparian users are property owners with water rights adjacent to rivers, creeks and streams. All riparian diversions are all located within GKGSA; therefore, no riparian water is included in the EKGSA Water Budget.

Recycled Water (RW)

In the EKGSA, the City of Lindsay operates a wastewater treatment plant (WWTP) that treats City effluent and citrus processing wastewater. The City has been percolating recycled citrus processing wastewater from two nearby plants since 1985. The Regional Water Quality Control Board limits the quantity of applied effluent to 0.45 million gallons per day and the flow the land application site averaged 40 to 70 million gallons from 2009-2011 (RWQCB Waste Discharge Requirements Order R5-2012-0122). Effluent is mixed with irrigation water at a ratio of one-part wastewater to four parts well water then it is applied to the fields via flood irrigation. Crops grown with this treated effluent include alfalfa, wheat and corn. The overall quantity of recycled water used in the EKGSA per year is very small at approximately 170 AF/year.

Total Ditch System Percolation ($TotDS_P$)

The volume of the total ditch system percolation is the portion of water that percolates into the groundwater table through unlined ditches and canals before it is delivered on-farm for agricultural irrigation. There is only one such facility in the EKGSA, the Wutchumna Ditch operated by the WWC. From 1997 - 2017, the annual volume of surface water that percolates through this ditch is 8,835 AFY.

Recharge Basin Diversions (RB_{DIV})

Recharge basin diversions represent the quantity of delivered water that migrates to the water table from recharge basin percolation. While there are some tailwater basins located in some irrigation districts in the EKGSA, no recharge basin diversions are quantified at this time. Going forward this data will be more accurately quantified in EKGSA.

Spills (S)

In wet years when there is an abundance of surface water that exceeds crop demands, recharge basin capacities and conveyance system capacities. During these years surface water leaves the Subbasin in the form of surface water “spills.” Spill points are typically located on the low spots of conveyance structures and generally occur on the west side of the Subbasin and not within the EKGSA. Within the EKGSA surface water can leave the boundary through the Wutchumna Ditch delivery to the Tulare ID Main Intake Canal and Frazier Creek into the Lower Tule River ID. Deliveries to Tulare ID are accounted for in the Mid-Kaweah GSA water budget. Due to lack of data and infrequency of occurrence, no spill is accounted for Frazier Creek spill to Lower Tule River ID.

Surface Water Delivered to Crops

Per the calculations for surface water deliveries, the average annual amount of surface water delivered to meet crop demand within the EKGSA is about 99,100 AFY over the 1997-2017 period. Documented deliveries varied over this base period and ranged from about 40,000 AFY (2015) to 148,000 AFY (1998). Approximately 98% of the total water diverted in the EKGSA is ultimately delivered for irrigation.

2.5.3.2 Inflows to the Groundwater System

This section quantifies the components of inflow to the groundwater system. The components include the following:

- Subsurface inflow
- Percolation of precipitation
- Streambed percolation in natural and man-made channels
- Artificial recharge

- Percolation of irrigation water
- Percolation of wastewater

Subsurface Inflow

Subsurface inflow is defined as the natural flow of water beneath the surface of the earth as part of the water cycle. Annual estimates were prepared to determine the subsurface flow for flow within the Subbasin between the three GSAs and the flow into and out of the Subbasin as a whole. These calculations were performed using the Darcy flow equation, that uses the input values of groundwater gradient and hydraulic conductivity to estimate the natural diffusion of groundwater over a period of time. The gradient was calculated for every year of the base period using the groundwater contour maps prepared for the Subbasin. 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 earlier in the Basin Setting. Hydraulic gradient data derived from annual water level contour maps developed for this GSP were analyzed on an annual basis over the base period. The cross-sectional areas of the aquifer thickness were estimated using GIS analysis along various lines, known as flux lines, throughout the Subbasin. A total of 23 groundwater flux lines were used to analyze subsurface flow into and out of different areas of the Subbasin. From these, annual magnitudes of subsurface flow were tallied. A map of these flux lines in available in the Kaweah Subbasin Basin Setting document in **Appendix 2-A**.

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. Based on several sources, mountain-front recharge is estimated to contribute an average of 52,000 AFY to the Kaweah Subbasin. A summary of the total annual subsurface inflow and outflow estimated for the EKGSA is presented in **Table 2-10**.

Percolation of Precipitation

The amount of rainfall that migrates through the subsurface geology and enters the water table depends on several factors, some of which include soil type and structure; density of vegetation; intensity, duration and quantity of precipitation; vertical soil permeability; and local topography. Rainfall will not deeply percolate until the initial soil moisture deficiency is exceeded. Typically, rainfall will not penetrate beyond the root zone of native vegetation since the quantity and duration of rainfall is insufficient to sustain deep percolation. In contrast, reported percolation of precipitation over irrigated lands is higher since the artificial application of water increases the seasonal soil moisture content and less annual rainfall is required to exceed the soil moisture deficiency. Once a storm fills the moisture deficiency within the root zone excess precipitation will travel downward and contribute to the groundwater reservoir.

Estimates for deep percolation of precipitation through the older data period from water years 1981 to 1999 were obtained using a method that relates the distribution of known crop types, rainfall patterns, reference evapotranspiration (ETo) rates from the California Irrigation Management Information System (CIMIS) and soil data. This data was paired with a monthly moisture model that contains data for immediate evaporation, effective rainfall, percolation of infiltrated rainfall, and percolation of runoff from rainfall. The model for the percolation of precipitation was developed from the relationship between land use parameters and precipitation records (Fugro West, 2007). For the period between 2000 and 2017, estimates of the percolation of precipitation were conducted by a more accurate alternate method that relies on a daily root zone water balance model and crop evapotranspiration (ET) obtained from a combination of remote sensing (satellite) images and computer simulations. The method utilizes Davids Engineering's "Normalized Difference Vegetation Index" (NDVI) analysis methods, which were applied to the entire Subbasin (Davids, 2018). More detail of the methodology is provided in the Kaweah Subbasin Basin Setting document in **Appendix 2-A**.

Percolation of precipitation on non-irrigated lands was estimated using published methods based on the distribution of annual precipitation with comparable parcel areas provided by Davids Engineering (Williamson et.al., 1989) Based on this method, approximately 8% of annual precipitation percolates into the groundwater each year. Estimates for the percolation of precipitation are presented in **Table 2-10**. These results show the average annual percolation of precipitation adds 23,200 AFY to the groundwater in the EKGSA.

Natural Channels

The EKGSA lacks reliable, long-standing stream gauges on the four major tributaries that flow into the area from the Sierra Nevada foothills. There is a single stream flow gauge on Yokohl Creek, while the other water bodies Cottonwood, Lewis, and Frazier Creeks do not have permanent gauges. In the absence of data, streambed percolation for the EKGSA was determined by an alternate method. The percolation from these creeks was assumed to be included in the mountain-front recharge accounted for in the Subsurface Flow. This is a data gap that will be further evaluated going forward. In addition to these creeks, a portion of the St. Johns River runs along the boundary between the EKGSA and GKGSA. It is assumed percolation over this stretch enters both the EKGSA and GKGSA. Per these estimates, the average annual natural percolation into the EKGSA is 2,000 AFY as shown in **Table 2-10**.

Ditches

The Wutchumna Ditch is the only open channel ditch within the EKGSA that delivers surface water. Estimates for the percolation of water from this ditch into the EKGSA are based on WWC data. The annual volume of surface water that percolates through this ditch is estimated at 8,835 AFY when accounting for losses associated with evaporation at Bravo Lake. The resulting value is a conservative estimate that will likely be further examined during implementation period.

Artificial Recharge

Artificial recharge basins are constructed in regions with permeable soils to capture surface water for percolation into the groundwater table. Recharge basin diversions represent the quantity of delivered water that migrates to the water table from recharge basin percolation. While there are some tailwater basins located in some irrigation districts in the EKGSA, no recharge basin diversions are quantified at this time. Going forward this data will be more appropriately quantified in EKGSA.

Percolation of Irrigation Return Water

Estimates for percolation of irrigation return water were developed using a database model as described by Davids Engineering (2013 and 2018) and are described in detail in the Kaweah Subbasin Basin Setting document in **Appendix 2-A**. This form of groundwater recharge is substantial, as the average percolation of irrigation return water is estimated at 42,700 AFY for the EKGSA.

Percolation of Wastewater

The City of Lindsay also owns and operates a wastewater treatment facility and has been diverting a portion of treated effluent for use in groundwater recharge since 1985. At this facility, wastewater is discharged to holding ponds for percolation, evaporation, or agricultural reuse. The annual sum of wastewater that percolates to groundwater within EKGSA are approximately 1,500 AFY.

2.5.3.3 Outflows from the Groundwater System

This section quantifies the components of outflow to the groundwater system. The components include the following:

- Subsurface outflow
- Agricultural groundwater pumping
- Municipal & Industrial (M&I) groundwater pumping

- Phreatophyte extraction
- Evaporation

Subsurface Outflow

Subsurface outflow is the flow of groundwater at depth that exceeds the downgradient boundary of a groundwater basin. In the case of the EKGSA, generally most subsurface outflow stays within the Kaweah Subbasin as the outflow moves into the GKGSA to the west. Other potential outflows can be to the northwest into the Kings Subbasin or to the south into the Tule Subbasin. Outflows into these other basins is largely dependent on water year type. During the planning period, an average of 13,000 AFY flowed out of the EKGSA each year. Subsurface outflow calculations were performed using the Darcy equation method described in the Subsurface Inflow section for every year of the base period.

Agricultural Water Demand and Consumptive Use

Irrigated agricultural lands are the principal component of water use within the EKGSA and Kaweah Subbasin as a whole. Similar to the analysis for percolation of precipitation and percolation of irrigation water, the calculations for the agricultural water demand were conducted using two different methods based on available information for the Subbasin during the data period. In the earlier portion of the data period (1981 to 1999), the agricultural water demand is principally based on periodic land surveys with some frequencies that are separated by as many as 10 years (Fugro West, 2007). These methods were updated with remote sensing methods that incorporate data from a total of 154 raw satellite images during the period from September 1998 through the end of water year 2017.

For the period between 2000 and 2017 clipped GIS files of 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 all irrigated acres. Due to the significance of this water budget component a considerable amount of database model error checking was performed. The Davids Engineering database model also accounts for the agricultural land that has been converted to urban land use over time to yield more a more accurate estimate. The results of the gross applied irrigation water analyses for the EKGSA indicate approximately 250,000 AFY, from a combination of surface and groundwater sources, were delivered to the agricultural lands during the planning period between 1997 and 2017. Due to the reliance on land use surveys, estimated soil characteristics, estimated irrigation practices and efficiencies, remote sensing technologies, and necessary calibration checks, this water budget item will continue to be evaluated and updated through the implementation of the GSP.

Agricultural Pumping

Groundwater is primarily extracted for application to irrigated agriculture within the EKGSA, which accounts for approximately 98% of the total groundwater pumping.

The distribution of groundwater pumping was determined based on the spatial distribution of crops, water demand and annual surface water deliveries to individual appropriator/district service areas. Crop water demand was calculated using two different methods for the 37-year data period. The analysis for water years 1981 through 1999 used estimated crop water use from DWR land use surveys and irrigation efficiency factors (Fugro West, 2007). The analysis for water years 1999 through 2017 was based on Davids Engineering's method (2018) of using satellite data to calculate the normalized difference vegetation index (NDVI). A detailed spatial distribution of crop water demand is available from the NDVI analysis method.

The surface water supply in the EKGSA is from a combination of local Kaweah River and imported CVP supplies. Since 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 agriculture and distribution pattern among surface water appropriators was well established in the Kaweah Subbasin prior to the start of the 37-year Subbasin study period (Bookman-

Edmonston, 1972 and Fugro West, 2007) so the appropriator service areas have remained virtually unchanged. Minor changes have occurred in the form of disjointed conversions of agricultural lands to urban developments (Davids Engineering, 2018) and land use changes in some service areas. These minor changes to the appropriator service areas are considered in the surface water delivery analysis.

To determine the distribution of groundwater pumping 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, according to the following equation:

$$AP = CD - SWc$$

where:

AP = Agricultural Pumping
CD = Agricultural Crop Demand
SWc = Surface Water Crop Delivery

The results of this calculation show, on average, a total of 151,000 AFY was pumped from the ground each year. These values range from a low of 84,000 AF in 1998, to a high of over 234,000 AF in 2014 during the recent drought and associated lack of imported surface water.

This analysis was performed for all years in the base period that are included in the water budget. 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 followed extended periods of drought, such as during the 2012 to 2015 period when imported water supplies were limited or non-existent.

Municipal and Industrial Pumping

A variety of methods were used to estimate municipal and industrial (M&I) pumping in the EKGSA and the Subbasin. The categories of water users included in this summarized component include:

- Urban
- Small public water system
- Rural domestic
- Golf course
- Dairy

The total estimate for M&I groundwater pumping within the EKGSA is the sum of the individual estimates for groundwater demand as presented in the following sections. Data and methodologies from the WRI reports (Fugro West, 2007; Fugro Consultants, 2016) and additional information compiled for the purpose of this study were used to estimate the M&I demand summary. Data was derived from 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.

Urban Demand

Urban demand in the EKGSA is the demand on groundwater that occurs in the larger communities of Lindsay and Strathmore, whom partially rely on groundwater to meet their demands. In most years, Strathmore utilizes its CVP supplies to meet demand. The City of Lindsay meets approximately 60% of their demand with surface water through the CVP. The remaining 40% is supplied by pumped groundwater. Through the 1997-2017 period urban demand (40% of the City of Lindsay demand) in the EKGSA averaged about 1,100 AFY.

Small Water Systems Pumping

Calculations for the annual water demand in small, regulated public water systems in the EKGSA were based on methodologies within the WRI 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. Water system listings provided the following information: facility identification/name, general location within respective counties, codes related to the approximate number of service connections for the facility, and a contact name and phone number for each facility. Examples of typical facility types are 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 rural settings. Per previous studies, about 70% of this pumped groundwater is believed to return to the water table through septic system percolation (Dziegielewski and Kiefer, 2010). The overall use by small water systems is 485 AFY which is minimal in the context of the overall water use. However, the groundwater demand for small water systems increased each year, which is attributed to population changes within Tulare County.

Rural Domestic Pumping

Rural domestic water demand 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 population of three per dwelling unit. Total water demand for such dwelling units is on the order of 2 acre-feet per year.

Unlike the small, public water system demand estimates that were indexed for population changes in Tulare County, the density of rural domestic dwellings has not changed significantly since 1981, other than a small portion of properties replaced by urban expansion. Similar to the rural small water system analysis above, 70% of the pumped rural domestic water is assumed to return to groundwater via septic system percolation and irrigation return flows (Dziegielewski and Kiefer, 2010). Aerial analysis of the EKGSA resulted in there being approximately 18.6 dwelling units per square mile in the areas outside urban and small water system centers. These areas cover roughly half of the EKGSA (90 square miles). This resulted in approximately 1,700 units whose total pumping is estimated at 3,400 AFY, of which 70% is returned to groundwater leaving a net average of 1,000 AF consumed by rural consumers each year.

Golf Course Pumping

There are no golf courses within the EKGSA boundary. Therefore, this pumping component is not included in the EKGSA water budget.

Dairy Pumping

Dairies and associated processing and distribution facilities utilize a significant amount of water. Estimates of net water consumed by dairy operations (farms) were based on cow census records kept by Tulare County and a per-cow based water use factor. Conversations with County personnel indicate the gross daily water use per cow is in the order of 125 gallons per day (gpd). Net water use (considering the recycled water used to irrigate adjacent agricultural lands) is approximately 75 gpd (Fugro West, 2007). This equates to approximately 0.084 AFY per cow. Current estimates of dairy cow population suggest there are approximately 4,400 cows within the EKGSA. The analysis results in a net average of 370 AFY of water is consumed and must be pumped to meet dairy demand in the EKGSA.

Total M&I Groundwater Pumping

The total M&I groundwater pumping estimate is the sum of the individual components described in the preceding paragraphs. For several of the M&I components, such as small water systems and rural domestic users, a portion of the pumped groundwater deep percolates and returns to the groundwater reservoir so adjustments are incorporated. Factoring in the percolation returns a remaining volume of 3,000 AFY of pumped groundwater was removed from the groundwater reservoir yearly during the 1997 – 2017 period.

Phreatophyte Extractions

Phreatophyte extractions are groundwater losses due to consumption by plants with deep root systems. Within the EKGA phreatophyte extractions were calculated using GIS clip analysis similar to the method used in the WRI analysis (Fugro West, 2007). The results of phreatophyte extraction analysis indicate this component constitutes a minor extraction from the groundwater reservoir of about 100 AFY.

2.5.3.4 Change in Groundwater Storage

Annual variations in the volumes of groundwater storage were calculated for each year of the base period. The changes in storage for the planning period from water year 1997 to 2017 were used to evaluate conditions of water supply surplus and deficiency, and in recognizing conditions of overdraft. **Table 2-10** presents the annual amounts of each water budget component for inflow and outflow within the EKGSA as computed by the use of the equation of hydrologic equilibrium (the "inventory method"). The results of the water budget show that the Kaweah Subbasin is in overdraft. The magnitude of the overdraft for the Kaweah Subbasin during the planning period averaged 77,600 AFY. As indicated in **Table 2-10**, the EKGSA accounted for an accumulated 590,000 AF of the water supply deficiency of over the 21-year period, or an average deficit of 28,000 AFY.

2.5.3.5 Safe Yield

The safe or perennial yield of a groundwater basin is typically defined as the volume of groundwater that can be pumped on a long-term average basis without producing undesirable results. Long-term withdrawals in excess of the safe yield is considered overdraft. While the definition of "undesirable results" mentioned in the definition have changed in recent years and are now 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 pumping, which in any given year, often exceed the safe yield of the Subbasin. The Subbasin, however, has a very large amount of groundwater storage that can be used as carryover storage during years when there is little natural recharge, and replaced in other years when pumping is reduced (when surface water is available or from various types of projects, including, artificial recharge).

There are several available methods to estimate the safe yield under the conditions of water supply and use that prevailed during the 37-year data 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. One of the methods assumes that the safe yield is equal to the long-term recharge. Although there are considerable assumptions used to estimate each component of inflow in the hydrologic equation, the data suggests the safe yield of the Subbasin is in the range of 720,000AFY.

The Kaweah Subbasin GSAs split this water in three types of water (Native, Foreign, and Salvaged) through an agreed-to methodology, known as the Water Accounting Framework (WAF), that assigns groundwater inflow components to each GSA. **Table 2-9** shows the components of groundwater inflow in the three types of water coordinated amongst the Kaweah Subbasin GSAs. This is the beginning of a potential groundwater allocation, but presently provides each GSA a groundwater supply for their region. Through this accounting, the EKGSA is allotted approximately 124,600 AFY, with the largest portion being the Native supply at nearly 97,000 AFY. This coordinated WAF is in the Coordination Agreement and also included in **Appendix 2-H**. Through this WAF accounting the sustainable Native yield for the Subbasin is approximately 364,000 AFY. Not included in this number is subsurface inflow from the surrounding subbasins which totals approximately 60,000 AFY.

During GSP Implementation the Kaweah Subbasin intends to coordinate on this groundwater component with the neighboring subbasins.

It is the intent of the Kaweah Subbasin GSAs to continue to discuss water balances and groundwater conditions during the GSP implementation. The groundwater net inflow balances and hydrogeologic water budgets of each GSA region will be given due consideration in these future discussions. The current Subbasin WAF is a preliminary starting point from which to establish a future framework to assess GSA responsibilities in achieving the Subbasin Sustainability Goal and eliminating Undesirable Results by 2040. As additional data becomes available and water budget component are refined, the Subbasin and individual GSA water budgets will be periodically reevaluated, no less frequent than the five-year GSP assessments as submitted to DWR. Furthermore, in time the safe yield estimate will likely be superseded by forthcoming sustainable yield values for the basins, which will avoid undesirable results and achieve measurable objectives.

Table 2-9 WAF Components of Groundwater Inflow

Native:	**Inflows which all well owners have access to on a pro-rata basis**
•	Percolation from rainfall
•	Streambed percolation (natural channels) from the Kaweah River watershed sources
•	Agricultural land irrigation returns from pumped groundwater
•	Mountain-front recharge
Foreign:	**All imported water entering the Subbasin from non-local sources under contract by local agencies or by purchase/exchange agreements**
•	Streambed percolation from imported sources
•	Basin recharge from imported sources
•	Ditch percolation from imported sources
•	Agricultural land irrigation from imported sources
Salvaged:	**All local surface and groundwater supplies that are stored, treated, and otherwise managed by an appropriator/owner of the supply and associated water infrastructure systems**
•	Ditch percolation from previously appropriated Kaweah River sources
•	Additional ditch/field recharge from over-irrigation
•	Captured storm water returns
•	Wastewater treatment plant returns
•	Basin percolation from previously appropriated Kaweah River sources
•	Agricultural land irrigation returns from Kaweah River watershed sources

Table 2-10 EKGSA Water Budget Summary

Estimated Deep Percolation, Extractions and Change in Storage - East Kaweah GSA

Values in 1,000s af

Water Year	Rainfall		Components of Inflow						Components of Outflow								*Total Inflow*	*Total Outflow*	Change in Storage	Cumulative Change in Storage
									Groundwater Pumpage											
	Inches	% of Average	Subsurface Inflow	Wastewater Inflow	Steambed Percolation and Conveyance Losses	Percolation of Recharge Basins	Percolation of Irrigation Water	Percolation of Precipitation on Crop Land	M & I	Gross Applied Irrigation Water (Crop Water Demand)	Delivered Surface Water	*GW Pumping for Irrigated Agriculture*	*Total Net Extraction*	Extraction by Phreatophytes	Evaporative Losses	Subsurface Outflow			*Inventory Method*	*Inventory Method*
1997	12.5	124%	112.5	1.2	13.2	0.0	43.3	28.0	2.7	243.7	147.9	*95.8*	*98.5*	0.1	1.8	17.3	*198.2*	*117.7*	*80.5*	*80.5*
1998	22.8	226%	110.2	1.3	14.0	0.0	46.4	53.3	2.5	210.2	126.7	*83.5*	*86.1*	0.2	1.8	23.7	*225.2*	*111.8*	*113.4*	*193.9*
1999	9.6	95%	55.9	1.3	4.8	0.2	45.8	21.1	3.3	226.5	116.0	*110.8*	*114.1*	0.1	0.6	27.0	*129.1*	*141.7*	*-12.6*	*181.3*
2000	11.4	113%	62.7	1.3	9.9	0.3	48.3	26.3	3.0	252.4	117.6	*135.1*	*138.2*	0.1	1.4	29.9	*148.8*	*169.6*	*-20.8*	*160.5*
2001	10.1	100%	66.0	1.3	9.7	0.0	41.0	16.0	2.4	257.7	98.9	*158.8*	*161.2*	0.1	1.3	24.6	*133.9*	*187.3*	*-53.4*	*107.1*
2002	10.4	104%	48.4	1.4	9.5	0.4	43.2	17.7	3.5	265.4	107.7	*158.1*	*161.6*	0.1	1.3	25.7	*120.5*	*188.7*	*-68.2*	*39.0*
2003	8.7	87%	45.4	1.4	11.0	0.0	41.8	18.0	3.1	253.7	112.5	*141.2*	*144.3*	0.1	1.5	18.9	*117.6*	*164.8*	*-47.2*	*-8.3*
2004	8.0	79%	14.0	1.4	6.7	0.0	39.4	13.1	3.6	262.6	104.8	*157.8*	*161.4*	0.1	0.9	11.8	*74.6*	*174.2*	*-99.6*	*-107.9*
2005	12.2	121%	70.1	1.4	11.7	0.3	38.1	25.5	2.9	221.7	110.4	*111.6*	*114.5*	0.1	1.6	5.6	*147.1*	*121.9*	*25.2*	*-82.6*
2006	15.4	153%	87.5	1.5	21.5	0.0	43.6	34.2	3.1	236.1	112.8	*123.2*	*126.3*	0.1	3.3	11.1	*188.2*	*140.8*	*47.4*	*-35.2*
2007	3.8	38%	44.6	1.5	6.9	0.0	41.7	9.9	3.1	265.6	80.2	*185.5*	*188.6*	0.0	1.0	17.9	*104.5*	*207.6*	*-103.0*	*-138.2*
2008	5.0	50%	43.9	1.5	9.6	0.5	42.0	17.0	3.1	261.6	98.6	*163.5*	*166.7*	0.0	1.5	8.1	*114.5*	*176.3*	*-61.8*	*-200.0*
2009	6.4	64%	27.9	1.5	9.7	0.4	38.5	10.5	3.1	274.7	90.3	*184.8*	*187.9*	0.1	1.5	**-0.6**	*88.5*	*188.9*	*-100.3*	*-300.3*
2010	11.1	110%	74.0	1.6	16.8	0.1	42.9	23.4	3.4	245.3	110.7	*134.7*	*138.0*	0.1	2.5	10.0	*158.7*	*150.7*	*8.1*	*-292.3*
2011	13.7	135%	145.6	1.6	16.4	0.9	46.9	53.6	3.8	240.2	116.4	*125.4*	*129.2*	0.1	2.3	11.5	*265.1*	*143.2*	*121.9*	*-170.4*
2012	4.4	44%	43.8	1.6	10.1	0.0	42.7	15.6	2.8	262.6	79.8	*182.8*	*185.5*	0.0	1.4	12.4	*113.8*	*199.4*	*-85.5*	*-255.9*
2013	4.4	44%	41.0	1.6	5.4	0.0	41.2	9.0	2.7	274.9	82.1	*192.8*	*195.5*	0.0	0.7	9.4	*98.2*	*205.6*	*-107.4*	*-363.2*
2014	4.7	46%	1.9	1.6	10.1	0.0	43.2	7.0	2.5	282.7	48.4	*234.3*	*236.8*	0.0	1.7	5.9	*63.7*	*244.4*	*-180.7*	*-543.9*
2015	6.2	61%	25.4	1.6	4.2	0.0	39.6	13.3	2.4	256.5	40.2	*216.3*	*218.8*	0.1	0.6	0.5	*84.2*	*219.9*	*-135.7*	*-679.7*
2016	9.8	97%	53.8	1.6	9.2	0.2	39.5	30.5	2.6	226.1	76.9	*149.4*	*152.0*	0.1	1.3	**-3.1**	*134.7*	*150.4*	*-15.6*	*-695.3*
2017	14.0	139%	138.3	1.6	18.2	0.7	48.6	43.8	2.7	227.0	103.5	*124.1*	*126.8*	0.1	2.5	4.3	*251.3*	*133.8*	*117.5*	*-577.8*
Maximum	22.8	226%	145.6	1.6	21.5	0.9	48.6	53.6	3.8	282.7	147.9	234.3	236.8	0.2	3.3	29.9	265.1	244.4	121.9	
Minimum	3.8	38%	1.9	1.2	4.2	0.0	38.1	7.0	2.4	210.2	40.2	83.5	86.1	0.0	0.6	-3.1	63.7	111.8	-180.7	
Average	**9.7**	**97%**	**62.5**	**1.5**	**10.9**	**0.2**	**42.7**	**23.2**	**3.0**	**249.9**	**99.2**	**150.9**	**153.9**	**0.1**	**1.6**	**12.9**	**141.0**	**168.5**	**-27.5**	
% of Total			44%	1%	8%	0%	30%	16%	2%			90%		0.06%	0.93%	8%				
			100%						100%											

Italic = Calculation
🟦 = Component of Inflow
🟧 = Component of Outflow

2.5.4 Projected Water Budget

Legal Requirements:
§354.18

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

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

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

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

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

The projected water budget in the Kaweah Subbasin will be estimated by applying the numerical groundwater model to past and present trends. Alternative future water supply and demand scenarios will be developed in coordination with the three GSAs and input to the numerical groundwater model. This section describes the estimated impact of climate change on groundwater supply, surface water availability and projected water demands, and is based from the Kaweah Subbasin Basin Setting document in **Appendix 2-A**.

2.5.4.1 Climate Change Analysis and Results

SGMA requires local agencies developing and implementing GSPs to include water budgets that assess the current, historical, and projected water budgets for the basin, including the effects of climate change. Additional clarification is found in DWR's Water Budget and Modeling BMPs that describe the use of climate change data to compute projected water budgets and simulate related actions in groundwater/surface water models. DWR also provides SGMA Climate Change Data and published a guide for Climate Change Data Use During Groundwater Sustainability Plan Development (Guidance Document) as the primary source of technical guidance (DWR, 2018). The DWR-provided climate change data is based on the California Water Commission's Water Storage Investment Program (WSIP) climate change analysis results that use 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 future conditions between 2030 and 2070. 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. Change projections for upstream inflow into Kaweah Lake and imported water from the FKC, are computed using a baseline period of 1981 to 2003. Representative periods were chosen from the baseline analysis period for the Basin Settings report, available concurrent climate projections, (calendar years 1915 to 2011) and derived hydrologic simulations (water years 1922 to 2011) from the SGMA Data Viewer.

2.5.4.1.1 Data Processing

The 2030 and 2070 precipitation and evapotranspiration (ET) data is 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 FKC 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.

2.5.4.1.2 Projected Changes in Evapotranspiration

Crops require more water to sustain growth in warmer climates, 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 water requirement increases of 3.2% from the baseline period. In 2030 the largest monthly changes will occur in winter and early summer and projected increases of 4.3% to 4.8% will occur in January and 3.8% to 4% will occur in June. Under 2070 conditions, annual evapotranspiration is projected to increase by 8.2% from the baseline period in all three GSA areas. Predictions for 2070 show the largest monthly changes will occur in December with projected increases of between 12.8% to 13.5%. Summer increases peak approximately 8% in May and June.

2.5.4.1.3 Projected Changes in Precipitation

The seasonal distribution of precipitation in the Kaweah Subbasin is projected to change. Decreases in precipitation are anticipated in early fall and late spring while an increase in rainfall is projected in winter and summer. Under 2030 conditions, the largest monthly changes will occur in May where there is a projected decrease of 14% while March and August will receive increases of approximately 9% and 10%, respectively. Under 2070 conditions, rainfall will decrease by up to 31% in May and the largest increases will occur in September (25%) and January (17%). Although the precipitation pattern is anticipated to change, all three GSA areas will experience minimal changes in total annual precipitation. Increases in annual precipitation for the EKGSA is projected at 0.4% from the baseline period in 2030. By 2070, small decreases in annual precipitation are projected with a change of 0.6% projected for the EKGSA.

2.5.4.1.4 Projected Changes in Full Natural Flow

The quantity of surface water that flows into Kaweah Lake, the main local water source, is projected to decrease. Under current climactic conditions Kaweah Lake receives 465 thousand acre-feet (TAF) in 2030; in 2070 this quantity is expected to decrease to 442 TAF. Similarly, peak flows are 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. Additionally, significant changes in the seasonal timing of flows are expected. In 2030, the monthly inflows into the reservoir are projected to peak in May. By 2070, inflows are projected to occur earlier in the water year, with peak monthly inflows occurring in March.

2.5.4.1.5 Projected Changes in Imported Flow Diversions

Climate change can also impact the quantity and timing of imported water delivered to the Kaweah Subbasin from the CVP. The Friant Water Authority developed a technical memorandum that shows the impacts climate change and the San Joaquin River Restoration Program (SJRRP) have on water deliveries through the FKC. The analysis evaluated five different scenarios incorporating climate change and SJRRP implementation. The results indicate that relative to baseline conditions, the central tendency of water deliveries from the Friant 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 Subbasin needs to prepare for decreasing water deliveries from Friant in the 'Near-Future' and most scenarios in the 'Far-Future.'

2.5.4.2 Impacts of Climate Change Projections on Water Balance

Overall, total surface water supply in Kaweah Subbasin is projected to decrease from 672 TAF during baseline conditions to 625 TAF in 2030 and 603 TAF by 2070. Conversely, total water demand is projected to increase from 1,073 TAF under baseline conditions to 1,105 TAF in 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 401 TAF under baseline conditions to 480 TAF in 2030 conditions and 552 TAF by 2070 unless measures are implemented to increase supply and/or reduce demand.

2.5.4.3 Future Demand Estimates

Using 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 predict total demand for this period, two components of demand were considered: extractions from the groundwater reservoir and agricultural and M&I pumping.

2.5.4.3.1 Future Agricultural Demand

In the base period, irrigated agriculture water demand averaged 1,055,700 AFY and was provided through a combination of surface water and groundwater for a wide variety of crops including almonds, alfalfa, citrus, cotton, grapes, olives, truck crops, walnuts, wheat and several others (Davids Engineering, 2018). Crop evapotranspiration (ET) was derived for each of these crops for each year during the recent period of 1999 to 2017, using trends in water use for each crop. During the period, total water demand related to almond farming increased by 14%, while total water demand to satisfy miscellaneous field crops has declined by 18%. Considering the trends for a total of 16 crop categories on a net basis, the average change in crop water ET demand has remained relatively unchanged after a modest increase each year from 1999 and 2017.

Crop water demand was 1,046,900 acre-feet in 2017 for the Subbasin. Future projection of crop demand to 2030 and 2070 indicates that agricultural demand will increase to 1,138,200 acre-feet in 2030 and 1,239,500 acre-feet in 2070, including projected climate change affects.

2.5.4.3.2 Future M&I and Other Demands

To estimate future M&I demands, which includes dairies, small water systems, rural domestic systems, golf courses, and nursery farms in addition to the main urban centers, 2015 Urban Water Management Plans for the Cities of Visalia (Cal Water, 2016) and the Tulare (City of Tulare, 2015) and California Department of Finance population projections (California Department of Finance, 2017) were utilized.

M&I and other demands in the Kaweah Subbasin were 76,400 acre-feet per year in 2015, which was primarily supplied through groundwater pumping. M&I and other demand is projected to increase to 126,421 AFY by 2030 and 186,455 AFY in 2070.

During the projected future period, water supply availability is projected to decrease approximately 10% in response to climate change and SJRRP implementation. During this same period demand for agricultural, M&I, and other demands is anticipated to increase approximately 26%. This gap will be filled through sustainable groundwater use. This sustainable yield will be established based on a set of measurable objectives evaluating the five present sustainability indicators throughout the Subbasin. Groundwater modeling will be used to estimate the sustainable yield through the use of initial thresholds and objectives.

2.6 Identification of Data Gaps

Legal Requirements:
§354.38(b) Each Agency shall identify data gaps wherever the basin does not contain a sufficient number of monitoring sites, does not monitor sites at a sufficient frequency, or utilizes monitoring sites that are unreliable, including those that do not satisfy minimum standards of the monitoring network adopted by the Agency.

Identification of data gaps will continue to be a work in progress. The principal data gaps are listed below, which are subject to revision during the course of completion of this GSP. The EKGSA is intending to fill these gaps during the next five years.

- Geological/hydrogeological information for all areas of the EKGSA.
    - The SkyTEM effort should assist in filling this data gap
    - New and/or better well logging for monitoring and production wells can also be informative in locations with little or no data
- Well construction information such as: depth of well, perforation intervals, casing diameter, and use
    - Strongly encourage the Kaweah Subbasin GSAs and Tulare County initiate a well canvas of the area to develop a better data set
    - Potential Drinking Well Observation Plan can assist with gathering well data for specific drinking water wells in the region
- Spatial extent and density of monitoring network
    - Improve water level monitoring in gap areas by construction of new wells
    - Improve water quality monitoring through increased monitoring
- Stream flow monitoring on Cottonwood, Yokohl, Lewis, and Frazier Creeks
    - Gauges are proposed to be constructed, especially for the creeks potentially to be used for recharge activities
    - Specific watershed studies for these creek watersheds can be performed to better inform the estimations of creek flows and seepage
- Consistent subsidence monitoring
    - Likely remedied with more consistent InSAR data
    - Specific infrastructure to be surveyed for subsidence impacts
- Presence of Interconnected Surface Water/GDE
    - Likely linked with the added stream flow monitoring
    - More consistent groundwater level monitoring in the intermontane valleys
    - Likely to perform more studies and field verification by qualified professionals
- Water Budget Components
    - Further development of subsurface inflows and outflows from the mountain front and neighboring subbasins
    - Improved understanding of surface water deliveries within district boundaries
    - Retention/Recharge basin data collection and tracking as more recharge is developed
    - Improved understanding of irrigation demand and method for crop and soil types within the Subbasin and EKGSA
    - Improved tracking of M&I demands