

Sierra Scientific Services

**The Geology and Groundwater Hydrology
of the Buena Vista Water Storage District, Buttonwillow, Ca,
including Descriptions of Relevant Facilities and Operations.**

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prepared for:

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Table of Contents

INTRODUCTION..	1
DISCUSSION..	1
1. Description of the Buena Vista Water Storage District..	1
Regional Setting.....	1
Local Setting.....	2
History.....	3
District operations.....	4
District water balance.....	5
2. Description of the District Conveyance Facilities.....	7
Regional conveyance facilities- California Aqueduct.....	7
Regional conveyance facilities- Friant- Kern Canal.....	8
Regional conveyance facilities- Cross Valley Canal.....	8
Regional conveyance facilities- Kern River Channel.....	9
In- district conveyance facilities.....	10
Maples Service Area conveyance system.....	11
Buttonwillow Service Area conveyance system.....	11
3. Description of the District Water Supply.....	12
Kern County Water Supply.....	12
Buena Vista Water Storage District Water Supply.....	14
Surface water chemistry.....	15
4. Geology of the Buena Vista Water Storage District.....	16
California's Great Valley and San Joaquin Valley.....	16
Geologic history of the San Joaquin Valley.....	16
Geology of the Southern San Joaquin Valley (SSJV) Groundwater Basin.....	16
Corcoran Clay.....	18
Geology of the Maples Service Area.....	20
Geology of the Buttonwillow Service Area.....	21
5. Groundwater Hydrology of the Buena Vista Water Storage District.....	22
Hydrology of the overall basin.....	22
Hydrology of the Maples Service Area.....	24
Hydrology of the Buttonwillow Service Area.....	25
Lateral flow across the west BSA boundary.....	26
Lateral flow across the eastern BSA boundary, north of 7th Standard Rd.....	27
Lateral flow across the eastern BSA boundary, south of 7th Standard Rd.....	28
Aquifer properties.....	30
Deep aquifer data.....	30
Shallow aquifer data.....	31
Groundwater chemistry.....	32
Saline groundwater intrusion in the BSA.....	33
REFERENCES.....	37

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INTRODUCTION.

The behaviors of the groundwater aquifers underlying the Buena Vista Water Storage District are dominated by three sets of factors, i.e., 1. the geology and physical properties of the subsurface, 2. the interactions between the groundwater hydrology and the surface hydrology associated with district farming and district water- conveyance operations, and 3. the interactions and responses to conditions along the district boundaries. We will discuss these factors in order to present a complete picture of the properties and behavior of the groundwater basin according to the currently available knowledge of the basin.

The information in this report was excerpted from other documents which have been prepared or are currently in preparation for the Buena Vista Water Storage District by Dr. Robert A. Crewdson, of Sierra Scientific Services, Bakersfield, Ca. This report presents descriptions of 1. the district, 2. conveyance facilities, 3. water supplies, 4. geology, 5 groundwater hydrology, and 6. selected references.

DISCUSSION.

1. Description of the Buena Vista Water Storage District.

Regional Setting.

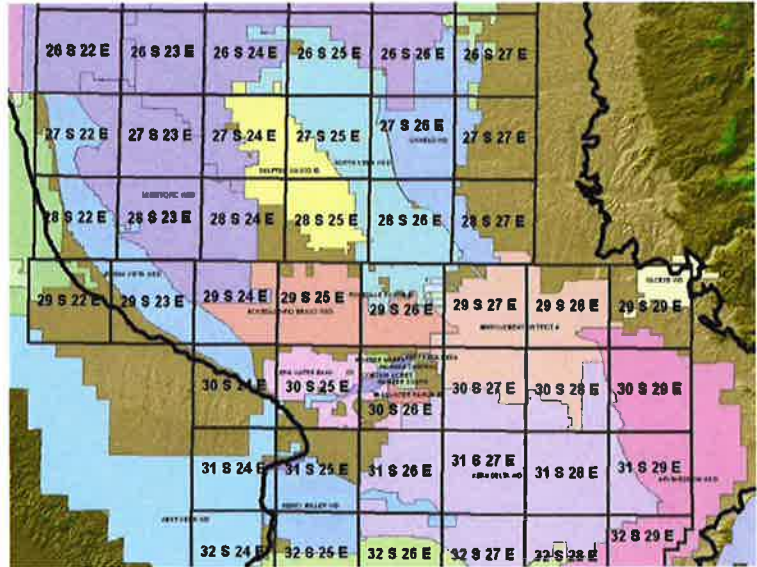
The lands of the Buena Vista Water Storage District (BVWSD or District) lie within the Southern San Joaquin Valley (SSJV) groundwater basin which lies entirely within the geographic boundaries of Kern County, CA. The SSJV groundwater basin covers about 1500 sq.mi. and is bounded on the east, south, and west by the topographic slope break between the flat-lying valley fill and the surrounding dissected foothills on three sides. The basin boundary on the north is the Kern County Line between Kern, Kings, and Tulare Counties, which is a political boundary but not a flow boundary. The longitudinal axis of the valley and groundwater basin is about 80 miles long, trending about N45°W from T10n/R19w-Sec01 SBBM to T25s/R22e-Sec01 MDBM. The transverse width of the valley and groundwater basin, perpendicular to the long axis, is 20 -40 miles depending on where it's measured.

The Buena Vista Water Storage District consists of two service areas, about ten miles apart, referred to as the Buttonwillow Service Area (BSA) and the Maples Service Area (MSA), covering a total of about 76 square miles west of Bakersfield, CA. About 91% of the cropped acreage and crop water consumption are in the Buttonwillow Service Area and the balance of the acreage and water

consumption are in the Maples Service Area. Both service areas overlies a belt of low, very flat, overflow lands and lake bottoms which forms the topographic axis of the valley and separates the alluvial fans of the opposite sides of the valley.

The MSA is about 7 miles long, 1 mile wide, and occupies the overflow lands between the Kern Lake Bed and the Buena Vista Lake bed along the southern toe of the Kern River alluvial fan. The Maples Service Area (MSA) is entirely surrounded by lands of the Kern Delta Water District which overlies the central main groundwater basin south of the Kern River.

The BSA is a 24-mile long, 3- mile wide, thin strip of land along the western basin margin and occupies the overflow lands within the Buttonwillow Syncline, lying between the Elk Hills and Buttonwillow Ridge (Dale, et al, 1966) west of the Kern River alluvial fan. The BSA shares parts of its northern, eastern, and southern boundaries with the Semitropic- and Rosedale -Rio Bravo- Water Storage Districts and the Kern Water Bank. The BSA shares its western boundary with undistricted lands which separate the district from the Belridge Water Storage District and oilfield properties farther to the west.



Local Setting.

The district lands are essentially reclaimed swamp lands located in and along the pre-development course of the lower Kern River which, after exiting the Southern Sierra Nevada mountains near Bakersfield and flowing south and then southwesterly across the southern San Joaquin Valley (SJV), ran down the topographic axis of the valley northwesterly toward its ultimate terminus at a shallow interior drainage basin which was once Tulare Lake. The water conveyance systems in and around the district consist of a network of levees and diversions to control the high flows of the Kern River, as well as an elaborate conveyance system of canals and drains to deliver surface water to- and collect runoff from- the serviceable lands within the District.

The northern half of the Buttonwillow Service Area is different in several respects from the rest of the district. The shallow soils are dense, heavy, and poorly- drained. The soils are underlain by a very shallow, perched water table containing groundwater with a salinity in excess of 2,000 mg/l. These conditions result in poor infiltration, water in the root zone, and shallow salt buildup so that crop selections which are limited to salt- tolerant crops. Crops in this area have lower overall crop yields compared to the same crops in better growing environments in other parts of the district.

The District recognizes from experience that the district water supply, natural drainage system, groundwater aquifer, and soils are all natural resources which must be actively managed in order to preserve a reliable, affordable, and productive agricultural environment. The District is currently in the process of implementing and updating their ground water management plan and other programs to meet this primary objective.

History.

The Buena Vista Water Storage District (referred to herein as District or BVWSD) was formed in 1924 for the purpose of managing the Kern River water rights of the member landowners and to provide for the surface delivery and aquifer recharge of Kern River water and other sources of water on behalf of the landowners and agricultural water users located within the District. The following historical account of the early district history has been excerpted from the 2002 Groundwater Status and Management Plan.

The area which the District now serves was originally developed by two former meat supply merchants from San Francisco, namely Henry Miller and Charles Lux. In the early 1870s, these two men joined forces and set to build a cattle and sheep empire in the San Joaquin Valley. Extensive land holdings were acquired via the "Swamp and Overflow Act", the most productive Kern County portions of which are now within the Buena Vista Water Storage District. Miller and Lux's vast agricultural activities required farm help by way of tenant families many of whom immigrated from Italy. Surface water supplies diverted from the adjoining Kern River and from surface storage within Buena Vista Lake were used to develop lands north of and surrounding the lake, depending on its water levels.

Irrigation activities from the Kern River, in and around the Bakersfield area, were first undertaken in the late 1850s, when small private ditches diverted water for the irrigation of grains. As the upstream diversions increased, controversies over the water arose, which resulted in lengthy litigation between upper and lower river users. Much of today's California appropriative and riparian water rights law resulted from the Supreme Court's decision in the Lux vs. Haggin case. The ruling created what is now known as the "California Doctrine" which recognizes both riparian and appropriative water rights. Despite the court's decision, the dispute continued and was finally settled via the historic Miller-Haggin Agreement of July 28, 1888. This agreement, where both appropriative and riparian rights were recognized, continues to be the basis by which the flow of the Kern River is divided among "First and Second Point" interests. The "Second Point" interests, namely Miller and Lux, received about one-third of the river flows from March through August. A subsequent amendment also apportioned the Second Point some of the high runoff winter flows. The Second Point right equates to an average entitlement of about 158,000 acre-feet per year, delivered by First Point interests to

Second Point of Measurement undiminished by delivery losses.

After the death of Henry Miller in 1916, Miller and Lux Land Company began selling much of their lands to the tenant farmers. Miller and Lux and the new landowners soon realized that a facilitator would be needed to represent the many vested interests of the water right. The Buena Vista Water Storage District was organized in July, 1924 and began operations following its 1927 Project Report. The Buena Vista project provided for the distribution of Second Point water rights that were tied to lands. The project also provided for added facilities to improve the distribution of the surface water supply. With completion of the District's 1927 project, the lands within the district were further developed for intensive agricultural use. Presently [2002], the principal crops being produced are cotton, grain, sugar beets, and alfalfa. Cotton is by far the dominate [sic] crop, making up about 85% of the annual cropping pattern.

Historically, the district has physically stored more water in the groundwater basin than it has removed for irrigation so that the District is said to be in overall positive water balance with respect to the basin, meaning that the cumulative volume of water brought into the district aquifers from historical annual surface water supplies exceeds the cumulative total volume of in-District groundwater extraction. Most of the stored water physically resides in the basin aquifers underlying the district. Some stored water resides in nearby groundwater banking projects and a small amount may temporarily reside in surface reservoirs. The records of the annual operations have been entered into the district's water accounting system as part of its district water balance.

District operations.

The District represents approximately 130 landowners¹ within two separate service areas, referred to as the Buttonwillow Service Area and the Maples Service Area, covering a total of about 78 square miles west of Bakersfield, CA. About 91% of the acreage is in the Buttonwillow Service Area (45,777 ac) and the balance of the total district acreage is in the Maples Service Area (4,350 ac). The total annual volume of applied water is similarly split between the two areas at approximately 135,000 af/y and 13,000 af/y, in the BSA and MSA respectively²

The principal crops grown in the district have changed over time from predominantly cotton and minor other row crops to a more recent preference for less cotton and a switch from row crops to trees. The historical consumptive water use since about 1960 ranged from 90,000 af/yr up to almost 120,000 af/yr and then back down to about 100,000 af/yr. In 2011, the total crop consumptive use in the Buttonwillow Service Area was 106,365 af of water on a total cropped acreage of 40,584 acres, including

¹ There are 130 different entities/landowners. Many of those entities have common owners but are technically different landowners. (Source: BVWSD, 2012).

² Based on district 2011 crop and consumptive use survey.

2,240 acres of wetlands, yielding an average annual consumptive use of 2.62 af/ac.

The primary water demand within the District is for agriculture, all of which operates on irrigation. The semi-arid climate provides little precipitation, most of which falls during non-growing periods of the year, and there is no longer any stream or river flow in or near the district because of the upstream diversions of Kern River water created over the previous 130 years. The District owns and administers the water rights and state and federal water contracts, as well as manages the groundwater aquifer on behalf of the landowners. The majority of crop water demand is met by delivery of surface water from seasonally regulated flows of Kern River water, schedulable deliveries of State Water Project (SWP) water through the California Aqueduct, which began operation around 1969, and occasional purchases or exchanges for water from the Federal Central Valley Project, delivered to the Kern River Channel via the Friant- Kern Canal from westward- flowing Sierran drainages north of Kern County.



Irrigation demand that cannot be met by surface water deliveries must be satisfied by groundwater pumping. The BVWSD operates a conjunctive- use program in which surface water is deliberately recharged to and stored in the aquifer in “wet” years of excess surface water supply, for later recovery by pumping for use in “dry” years when the surface water delivery is insufficient to meet the entire crop demand. Over the last thirty years, the district created a net positive water balance relative to the aquifer, i.e., the district recharged an average net 44,000 af/y more surface water into the underlying aquifers than was removed by pumping over that period. A significant volume of that recharged water reaches the underlying aquifer through seepage losses from the district surface- water conveyance system. The average annual seepage losses (from the conveyance system to the groundwater aquifer) in the Buttonwillow- and Maples- Service Areas are 30,300 af/y and 1,100 af/y respectively, for an average total in- district seepage loss of 31,400 acre-feet per year.

District water balance.

A water balance is a written record of the inflows and outflows of water to and from the district, similar to a bank statement which records the credits and debits to someone's savings account. Depending on the purpose, the water balance may show just the physical water which flows in or out of the district's boundaries; alternately, the water balance might show the increases and decreases of

water to or from the district's water account, whether the district has actually taken delivery of such water or not. The written record of all such water transactions is referred to as the district water balance³. The physical flow of surface water through the district starts with new water supply flowing into the district (Inflow) and ends with tailwater flowing out of the district (Outflow). The annual inflow of water constitutes the annual new water supply and is augmented with both district and farm well water to constitute the total annual surface water supply. The flow of surface water enters and traverses the conveyance system and enters the fields to irrigate the crops. Excess surface water runs off the fields and is re-collected into the drain system (tailwater). Most of the tailwater is re-circulated and the remainder is delivered to users outside the district (Outflow). Along each segment of the conveyance channels or drains, water is lost from surface containment in the form of evaporation or percolation (seepage).

The water that leaves the district as annual outflow must be arithmetically equal to the annual Inflow minus the annual in-district consumptive uses and losses. This arithmetic statement is a simplified form of the district water balance. The District measures or estimates the gains, consumptive uses, and losses along every physical pathway in order to define the movement of all water in the district. All of that information is consolidated into a master dataset which can be used to track water usage within a single service area, within a single reach of a canal, or for the overall district. The consolidated data are summarized into an annual water balance which shows the water supplies, consumptive uses, losses, and the change in storage for the year. The water balance for a portion of the Buttonwillow Service Area was recently evaluated by Sierra Scientific Services in order to evaluate the groundwater impacts from canal seepage⁴. The data for that study and for the entire district are based on District records and databases.

For the period 1970 - 2011, the average annual district water supply was +182,574 af/y and the average annual water consumption was -134,911 af/y, including -109,770 af/y crop use and -12,766 af/y outflows. The long term average annual district balance was +46,409 af/y, meaning that the district had received more water supplies than it had consumed over the years. The water district has banked its excess water supply through seepage and deliberate recharge and this water is presently stored in the groundwater basin under the Buttonwillow Service Area and in several of the banking projects along the Kern River channel.

³ BVWSD Water Balance 1970 - 2007, BV Water Management Plan, FEIR, 2009.

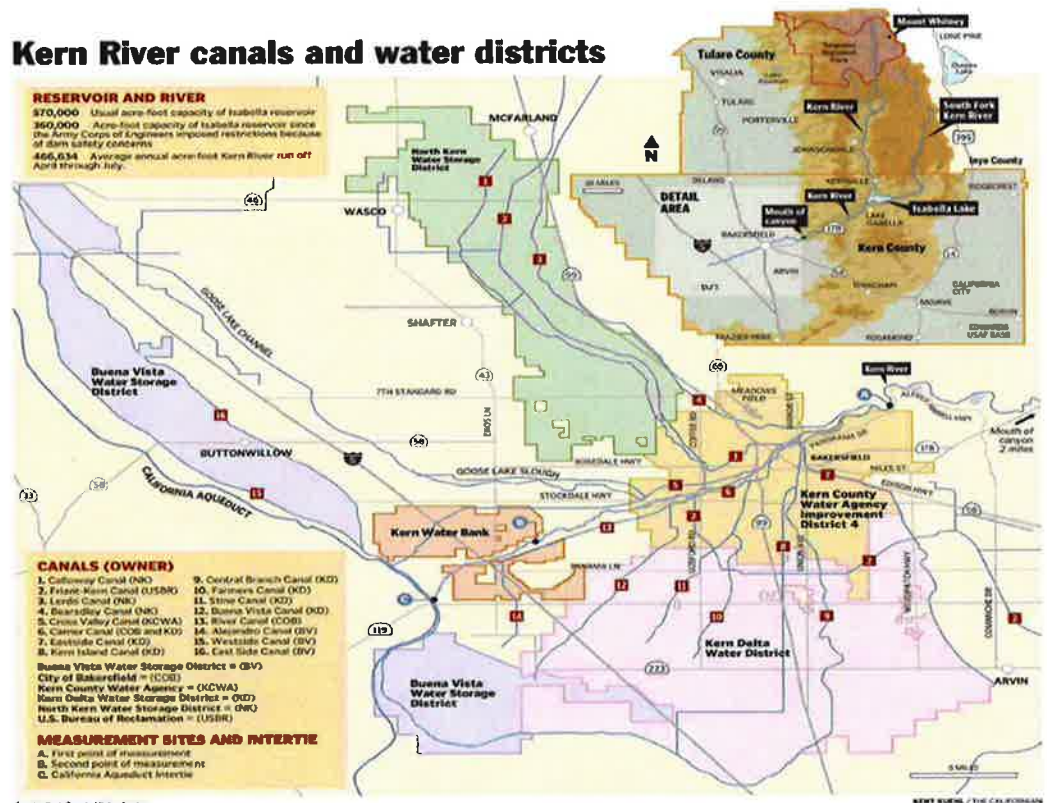
⁴ Crewdson, Robert, A., October, 2012, A Preliminary Groundwater Impact Analysis of a Proposed Change in the Surface Water Conveyance System in the Northern Buttonwillow Service Area of the Buena Vista Water Storage District, Buttonwillow, California, Sierra Scientific Services, Bakersfield, Ca.

2. Description of the District Conveyance Facilities.

The district water conveyance and farming operations create a complex interaction between the surface water hydrology and the groundwater hydrology. To understand the groundwater hydrology, it is essential to also understand the surface water hydrology, i.e., the flow of water through the district's water conveyance facilities.

To better understand the District's facilities, it is useful to first understand the District's relationship to the regional water distribution facilities. More than a dozen major canal systems deliver water to the various

Kern County water districts from three principal water sources inside and outside the county, i.e., the Kern River, the California State Water Project, and the Federal Central Valley Project. The Buena Vista Water Storage District is favorably located to receive waters by gravity flow from all three of these water sources, as described below.



Regional conveyance facilities- California Aqueduct.

In the mid-1960's, the State Water Project (SWP) completed the installation of canals, reservoirs, and pumping plants to re-distribute excess natural runoff in Northern California to urban and agricultural areas in central and southern California. The SWP has a contractual obligation to supply 2.557 million acre-feet per year (Maf/y) of Northern California water to Southern California, including 2.011 Maf/y to the Los Angeles Metropolitan Water District⁵. The SWP currently has a contractual obligation to supply 0.983 Maf/y firm and 94 kaf/y surplus water supply to the Kern County Water Agency and its member units, including the Buena Vista Water Storage District which holds a long-

⁵ Source: California Dept Water Resources Bulletin 132-03, Table 1-6.

term contract for 21,300 af/y firm- and 3,750 af/y surplus water supply⁶. All of this water is conveyed through the California Aqueduct which runs down the west side of the San Joaquin Valley, with a channel capacity of about 5,000 cfs, depending on the reach. The Aqueduct runs down the edge of the topographic slope break along the west side of the San Joaquin Valley, and past the west side of the district for more than 30 miles. The district has four turnouts which provide more than 790 cfs capacity for water delivery from the district's state water supply by gravity flow into the district directly from the Aqueduct.

Regional conveyance facilities- Friant- Kern Canal.

In 1951, the federal Central Valley Project (CVP) completed the construction of the Friant- Kern (FK) canal which connects Sierran water supplies near Fresno to federal- project participants along the eastern side of the San Joaquin Valley through Bakersfield and as far south as the Arvin, Ca area. Depending on the reach, the FK Canal has a channel capacity of 2 ,000 – 4,000 cfs. North of Bakersfield, the FK canal runs parallel to the eastern basin margin near the slope break between the upper alluvial fans and the Sierran foothills on the east side of the SJV at much higher elevations than any of the valley lands to the west. Although the District is not a long- term CVP contractor and has no direct connection with this system, Buena Vista can receive temporary FK water supplies obtained by purchase or exchange through the local Cross Valley Canal, Kern River Channel, and the Kern River Canal, which connect the canal systems on the east side of the southern San Joaquin Valley to those on the west side in the immediate area of the District.

Regional conveyance facilities- Cross Valley Canal.

The Kern County Water Agency was chartered in 1961 by a special act of the California State Legislature and serves as the local contracting entity for obtaining, brokering, and distributing water to thirteen member entities for the State Water Project. The Agency brokers water from the SWP and both receives and delivers SWP waters to all local users. The two main arteries for this delivery system are the California Aqueduct and the 21.5 mile- long Cross Valley Canal (CVC) which was constructed with 900 cfs capacity in 1975 and increased to 1422 cfs capacity in 2012.

The bi- directional- flow CVC connects the conveyance systems of the Bakersfield area on the higher, east side of the San Joaquin Valley to the California aqueduct on the lower west side of the San Joaquin Valley. Westerly flow in the CVC is entirely by gravity, whereas easterly flow from the Aqueduct to Bakersfield is assisted by pumping- lifts on seven successive reaches.

BVWSD is one of the Kern County entities which entered into a long term contract for SWP water in 1967 which currently yields a long term average of approximately 60% of the SWP Table A

⁶ Source: GEI Consultants, 28 November, 2012.

contract amount of 21,300 af/y and access to ‘interruptible’ supplies⁷. Since the District has four of its own turnouts on the Aqueduct, as previously described, the District does not actually need the KCWA to wheel any of the District’s entitlement water through the Agency’s conveyance system. However, when the District purchases FK water, delivers water to banking projects on the Kern River, or fulfills a water transaction with another district, then some or all of these waters may be conveyed in part through the CVC.

Regional conveyance facilities- Kern River Channel.

The Kern River drains a 2,310- square mile (mi²) watershed in the Southern Sierra Nevada Mountain Range, 2,074 mi² of which is above Lake Isabella. The headwaters drain small lakes west of Mt Whitney in the eastern half of Sequoia National Park. The North and South forks of the river pass through Inyo and Sequoia National Forests and the Golden Trout Wilderness before joining at Lake Isabella (created by dam construction in 1954) and then flowing west-southwest through the deeply-incised Kern River Canyon to Bakersfield.

The river meanders about twelve miles from the mouth of the Kern River Canyon (T29s/R30e-06) through the dissected uplands of ancestral alluvial deposits before emerging in the Bakersfield area at the apex of its modern depositional area known as the Kern Fan. The Kern Fan spreads radially outward through a 110° angle from its apex near the Chester Avenue Bridge (T29s/R28e-18). The Kern Fan extends about 19 miles west and 16 miles south from apex to toe with a constant topographic slope of about 7 ft per mile. Over time, the river channel has occupied different locations on the fan and many of the currently- existing irrigation canals that divert water to lands south of the river actually occupy the runs of former river channels. The current river channel runs about 18 miles on a fairly straight course at a bearing of S60W from the fan apex to the California Aqueduct Intertie (T30s/R25e-32) at the west edge of the basin just south of the small town of Tupman. The entire 18-mile length of the river is underlain by a persistent, elongated recharge mound which is the main source- and main location- of basin recharge.

The average annual natural flow of the Kern River is about 742,000 af/y (1894 - 2000). Since the completion of the Lake Isabella Dam in 1954, the United States Army Corps of Engineers (USACE) has controlled the daily flow of the Kern River below the dam for flood control. The USACE also provides releases as determined by the Kern River Watermaster, who represents downstream water rights holders and has the authority to request irrigation releases from the USACE⁸. The lower-river flow

⁷ Source: GEI Consultants, 28 November, 2012.

⁸ The Watermaster represents the North Kern Water Storage District, the Buena Vista Water Storage District, the Kern Delta Water District, the Kern County Water Agency, and the City of Bakersfield, California (Kern Water Users), which collectively hold virtually all of the consumptive water rights on the Kern River. The rights are used primarily for irrigation of crops, as well as groundwater recharge benefitting agricultural, municipal and domestic

varies seasonally and daily because of the timing of snowmelt in the watershed and because of the regulated releases from the lake, which are ordered to meet downstream demands and power flow requirements. In most years, essentially all of the water flowing in the Kern River is diverted for irrigation purposes along a 10-mile stretch of the river channel through Bakersfield, from just above the Gordon's Ferry river crossing (T29s/R28e-02) to the Bellevue Weir at River Walk Park (T30s/R26e-01). Downstream from the Bellevue Weir, the Kern River channel is usually dry except in very wet years when the unregulated river flow released by the USACE exceeds the diversion capacity of all of the upstream takeouts. This condition is often referred to as "high- flow" or "flood- flow" by members of the water community.

Because of the riparian use of lower- river water by landowners prior to the formation of the District and because of the terms of an out-of-court settlement of the Lux- Haggin water lawsuits of the 1880s, the Buena Vista Water Storage District now holds a water right to approximately one- third of the 6-month Spring and Summer river flow during the months of March through August less the Kern Island 300 cfs (as measured at the First-point gauging station T28s/R28e-36). The First-point water rights holders must deliver this water undiminished by seepage losses to Buena Vista's point of delivery near the Enos Lane (Hwy 43) crossing of the Kern River channel which is known as "Second-point" (T30s/R25e-24). This water is delivered to Second-point through lined canals including the Carrier Canal and the Kern River Canal owned and operated by the City of Bakersfield. Historically, the District has received an average 158,000 af/y of Kern River water at Second point reduced by the amount of Isabella Reservoir hydrologic losses which average approximately 12,000 af/y.

The BVWSD and North Kern Water Storage District⁹ contracted for 535,000 af of conservation storage space in the Lake Isabella Reservoir from the USACE, which they use to store and regulate their deliveries of river water for irrigation use. The capacity of the reservoir is 568,000 af which has been restricted by the USACE since 2006 to a maximum 360,000 af because of concerns over the physical integrity of the Lake Isabella Dam.

In- district conveyance facilities.

The District lands are contained in two individually- contiguous service areas, referred to as the Buttonwillow Service Area and the Maples Service Area, covering a total of about 76 square miles west of Bakersfield, CA. About 91% of the cropped acreage and crop water consumption are in the Buttonwillow Service Area (about 45,800 ac) and the balance of the acreage and water consumption are in the Maples Service Area (about 4,350 ac).

uses. The Watermaster acts as agent for the Kern Water Users for purposes of controlling the storage and delivery of water to the respective public water users. Source: <http://www.ferc.gov/whats-new/comm-meet/2010/031810/H-2.pdf>

⁹ Source: GEI Consultants, 28 November, 2012, based on BVWSD data.

Maples Service Area conveyance system.

The Maples Service Area (MSA) includes parts of about 12 sections of land in the southern part of township T31s/R26e and the northern part of township T32s/R26e. The MSA receives most of its irrigation water via the fully-lined Alejandro Canal which flows by gravity from a turnout on the Kern River Canal to the Buena Vista Aquatic Lakes, from which the Maples Canal carries water into the MSA. Diversions from the Maples Canal deliver water to the irrigated lands in the MSA. The MSA can also receive SWP deliveries from Aqueduct turnouts that deliver water directly into the western edge of the Buena Vista Aquatic Lakes.

Buttonwillow Service Area conveyance system.

The Buttonwillow Service Area (BSA) includes parts of 73 sections of land in 8 townships from T27s/R22e at the north end to T30s/R24e at the south end. The BSA can receive gravity inflow from turnouts on the California Aqueduct, from Second point via the Main Canal, or from the Buena Vista Aquatic Lakes Recreation Area via the Outlet Canal. The District can also receive high flow Kern River water directly from the lower Kern River channel although this stretch of river is dry most of the time due to prevailing climatic conditions and complete upstream diversion during most years.

The design and operation of the conveyance system within the BSA is controlled by the unique topography of the area. The southern San Joaquin Valley (SJV) is about 20 miles wide, depending on how you define it, in the vicinity of Bakersfield, CA. The BSA occupies a 26-mile long, 3- to 5-mile wide strip of fertile bottom lands along the far-west side of the Valley, where the pre-development course of the lower Kern River ran from the Buena Vista Lake bed northward toward the Tulare Lake bed through the topographic (low) axis of the southern SJV. Because of the great asymmetry of the Valley topography in this area, the axial trough (and therefore the BV District) is much closer to the western geographic edge of the Valley than to the east.

Water is being delivered by gravity flow to essentially all of the farm acreage in the BSA by surface water conveyance systems. Within the long, thin, southeast-northwest trending Buttonwillow Service Area, the topography is slightly lower down the middle than on the east or west sides. This natural feature has been cleverly exploited to develop a very efficient irrigation system in which a system of canals deliver surface water by gravity flow along- and inward from- the long edges of the District. The East Side Canal and West Side Canal run almost the entire length of the District. Water flows by gravity from south to north through the district via the West Side Canal and East Side Canal on opposite sides of the Buttonwillow Service Area. Water from these two peripheral canals is diverted to the interior of the district for irrigation. Water leaves the Side Canals via a distributary system of smaller lateral canals and private ditches which are interconnected by manually-operated weirs and turnouts operated by the District staff which deliver water directly to the fields. Runoff from the fields, sometimes referred to as tailwater, is collected in a tributary system of collection

ditches which flow to a Main Drain running northward down the center of the District at a gradient of about 2 ft per mile. Most of the drain water is reclaimed and re-used by District landowners; the remainder of the drain water is either delivered by natural flow to non-District landowners to the north or pumped to Semitropic lands to the east.

Altogether, there are approximately 125 linear miles of unlined canals and ditches within the two service areas of the District¹⁰. The District operates all of the weirs, turnouts, and control structures and maintains flow records for every stretch of District canal (excluding private ditches). Based on the district records¹¹, the average annual canal seepage loss is about 36,964 af/yr and 1,652 af/y in the BSA and MSA respectively, and is fairly uniformly distributed across the 78 sq.mi. of the District. This represents a district- wide groundwater recharge via infiltration (mostly canal seepage losses) of an average 0.63 ft/yr for every acre of District land, ranging from 0.4 - 1.5 af/ac/yr depending on the location within the District. This large- area seepage represents what is referred to as a “distributed-source” of recharge (rather than a “point- source”) which spreads the recharge impacts over a very large area and creates only small impacts in any small localized areas.

3. Description of the District Water Supply.

The use of groundwater within the district is governed by the year- to- year variations in the district water supply. An overview of the district water supply can benefit from an overview of the water supply for the San Joaquin Valley portion of Kern County.

Kern County Water Supply.

The Buena Vista Water Storage District lies entirely within Kern County, California, which arguably has developed the best inter-connected surface- water conveyance system in the San Joaquin Valley. As a result, several Kern County water districts are strategically located to obtain significant water supplies from three different watersheds, i.e., the Southern Sierra Nevada watershed of the Kern River, the Central Western Sierra Nevada watershed of the federal Central Valley Project supplying the Friant- Kern Canal, and the Northern California watersheds near Mt Shasta and the Modoc Plateau of the California State Water Project.

According to the Kern County Water Agency, the average annual water supply for the San Joaquin Valley portion of Kern County is 2.3 million acre-feet per year, based on a basin-wide water balance for the period 1970 - 1998, as presented in Table 1, below. Besides providing more total water than the local sources alone provide, this mix of local, State, and Federal water sources is actually a

¹⁰ Source: GEI Consultants, 28 November, 2012, based on BVWSD data.

¹¹ BVWSD, December, 2009, Buena Vista Water Storage District Final Environmental Impact Report for the Buena Vista Water Management Program, Appendix A., BVWSD Water Balance for Years 1970-2007.

great benefit because it significantly improves the water supply reliability for the County. Having a distributed water supply makes the County less vulnerable to a drought or a catastrophe on one system than would be the case if the County (or a single district) depended on a single supply¹².

Nevertheless, not all Kern County water districts share in these imported waters, which means that the Kern River is indeed the dominant or entire water supply for some districts. These districts, which are dependent on the Kern River alone for most or all of their water supply, have much lower water supply reliabilities per unit volume than those districts which also share in the imported water resources. The low water supply reliability of the Kern River is due to the extreme natural variability in the river flow, which makes it difficult to predict with sufficient accuracy the expected river flow over periods less than 30 - 40 years.

Table 1. 1970 - 1998 Kern County Water Supply.

(KCWA, August 27, 2001, Initial Water Management Plan, Public Review Draft, p. ES-13.)

<u>Source</u>		<u>Avg flow (af/yr)</u>	<u>Share (%)</u>	
Kern River	(local)	772,800	33.6%	
ep & mls*	(local)	324,000	14.1%	47.7% local
SWP	(imported)	807,500	35.1%	
<u>CVP</u>	(imported)	<u>395,100</u>	<u>17.2%</u>	<u>52.3%</u> imported
Total		2,299,400	100.0%	100.0% total

* = effective precipitation & minor local streams

Due to increases in overall consumptive water use combined with water supply shortages during the seven drought years since 2000, the central San Joaquin Valley portion of Kern County has consumed an estimated 116,000 af/y more water than has been supplied from all sources over the last decade within a 454 sq.mi. central study area for which a water balance is available¹³. The water which has been used to meet the demand in excess of the available water supply, has come from the aquifers of the underlying groundwater basin, evidenced by an average 26.6 ft water level decline throughout the study area. Since the study area receives almost all of the groundwater recharge for the basin but

¹² For a full analysis see: Crewdson, Robert, A., 2004, An Evaluation of Representative Hydrologic Periods for Basin and District Water Balances, Sierra Scientific Services. (prepared for & at the request of the Kern County Water Agency Ad Hoc Groundwater Mediation Technical Committee; authorized and funded by the Buena Vista & Rosedale - Rio Bravo Water Storage Districts.) and Crewdson, Robert, A., 20 November, 2003, An Evaluation of the Long-Term Water Supply of the Rosedale - Rio Bravo Water Storage District, Bakersfield, California, Sierra Scientific Services.)

¹³ Todd Engineers, 18 Sep, 2012, Technical Memorandum No. 1: Site Conceptual Model, "With and Without Banking" Evaluation, Kern Fan Area, prepared for the Kern Fan Monitoring Committee, Kern County, California, p. 34 & Figure 3-32, Todd Engineers, Alameda, Ca.

represents only 30% of the total basin area, the total basin overdraft for the period is extrapolated to be in the range of 380,000 – 700,000 af/y for the last decade. The diversity of County water supplies has not prevented this overdraft water crisis because the total water demand simply exceeds total water supply. Nevertheless, the presence of over one million acre- feet per year of imported water supplies has made the magnitude of basin overdraft significantly less than if the county were dependent on only on its local water supplies.

By one definition¹⁴, the removal of water from the basin in excess of the safe yield results in declining water levels and constitutes overdraft of the basin. If this overdraft were spread uniformly across the groundwater basin, it would have resulted in a basinwide decline in unconfined water levels of -26 to -48 ft. Since the extraction of groundwater has been concentrated in certain areas, groundwater levels have declined in some places by as much as 200 ft¹⁵ and much less than average in others. These water levels will re-equilibrate but the overall basin average water level will not recover unless or until water is put back into the basin to replenish the aquifers.

Groundwater overdraft is also defined¹⁶ as the state of a basin when groundwater extraction exceeds groundwater recharge over a period of years with approximately average conditions. Since the extreme drought conditions of the last decade are not considered to be “approximately normal conditions”, the temporary decline of the basin water levels are expected to be balanced out by future gains in wetter- than- average periods and the basin for the last decade on that basis is not necessarily considered to have been in overdraft.

Buena Vista Water Storage District Water Supply.

Table 2. 1970 - 1998 BVWSD Water Supply. (From BV water balance spreadsheet 62-Date.xlsx)

<u>Source</u>		<u>Avg flow (af/yr)</u>	<u>Share (%)</u>	
Kern River	(local)	129,418	82.0%	
ep & mls*	(local)	00	00.0%	82.0% local
SWP	(imported)	21,416	13.4%	
<u>CVP</u>	(imported)	<u>7,211</u>	<u>4.6%</u>	<u>18.0%</u> imported
Total		157,775	100.0%	100.0% total

¹⁴ GRAC, 2005, California Groundwater Management, 2nd ed, p. 268.

¹⁵ Data from KFMC Change in Potentiometric Surface elevation Maps, middle zone, Spring 07– Spring 08, Spring 08 – Spring 09, Spring 09 – Spring 10; Draft Groundwater Elevation Profiles AA' and BB' of 16 October, 2010; all prepared by Ken Schmidt and Kern County Water Agency.

¹⁶ DWR, 2003, Bulletin 118- update, p.216.

Table 2 shows the district water supply for the same period as the Kern County data presented in Table 1 (1970 - 1998). The average district surface water supply for the period was 157,775 afy, about 10% greater than the district water consumption for the period. The result is that the majority of the 380,000 af of surplus water for the period was stored in the groundwater basin for future use.

In some years, water- delivery scheduling conflicts may prevent the district from meeting its entire water demand with surface- water deliveries, even if the total annual water supply is otherwise sufficient to meet the total annual demand for the year. In this case, groundwater will be pumped from the underlying basin during growing season and surface water will be recharged to the basin at other times and/or at other places. In drought years when the surface water supply needs to be augmented to meet demand, groundwater will be pumped from the underlying basin and this water will be accounted for as district water which has been previously stored in the basin. As long as the district water balance remains positive relative to the basin, then the water levels beneath the district will not decline unless water is lost from the aquifers due to other causes (see also discussion of groundwater hydrology in Section 5).

The way for the district to meet its water demand and avoid overdrafting the underlying basin is to create and sustain a long-term water supply which exceeds the district's long- term water demand by continuing to store water in the underlying aquifers in advance of pumping it out. The way for the district to lessen the amount of groundwater pumping in any given year is to increase its schedulable water supply from non-local sources so as to lessen the impact of the extreme variability of the district's Kern River water supply.

Surface water chemistry.

The district receives their surface water supplies from the Kern River, the State Water Project, and occasionally the federal Central Valley Project. The average reported general mineral chemistry for each of these water sources, based on data from the Kern County Water Agency are as follows: Average SWP surface water TDS = 350 - 450 mg/l; Average Kern River surface water TDS = 90 - 120 mg/l; Average Faint-Kern surface water TDS = 50 mg/l. Based on BVWSD records, the average tailwater TDS = 200 - 400 mg/l.



4. **Geology of the Buena Vista Water Storage District.**

California's Great Valley and San Joaquin Valley.

The continuous, 440-mile long, Great Valley of central California runs from Redding in the north to the townsite of Grapevine 30 miles south of Bakersfield. The west-flowing Sacramento River, which connects the central Sierra Nevada watershed to the Pacific Ocean, splits the Great Valley into two parts and we refer to that portion south of the Sacramento River as the San Joaquin Valley.

Geologic history of the San Joaquin Valley.

The structure and history of the San Joaquin Valley as a northwest-trending structural trough between the Sierra Nevada and the Coast Ranges is described by Bartow, 1991. The division of the San Joaquin Valley into three physiographic regions including the western alluvial fans, the eastern alluvial fans, and the intra- basin deposits, is described by Burow and others, 1998. Within the San Joaquin Valley, the geology of overlapping terrace and alluvial fan systems reported by Marchand and Allwardt, 1981, for study areas outside of- but relevant to- Kern County, indicate that the more recent geologic history of the SJV includes cycles of alluviation, soil formation, and channel incision that were influenced by climatic fluctuations and resultant glacial stages in the Sierra Nevada (Bartow, 1991).

Through the 140+ million years of the Late Jurassic, Cretaceous, and Tertiary Periods of geologic time, the greater San Joaquin Valley was a large marine basin which was being filled with a tremendous volume of marine sediments¹⁷. These sediments have lithified into a sequence of sedimentary rocks, mostly sandstones, siltstones, and shales, which is more than 20,000 ft thick within Kern County. Tertiary crustal pressures during the last ten million years raised the Sierra Nevada, Temblor, and Coast Ranges causing sea level to regress out of the valley to its current position. These crustal deformations created the oil-rich anticlines in the Kern County area and the intervening structural sub-basins. The episodic Pleistocene glaciation and continental erosion on the mountainous margins of the San Joaquin Valley depression was the sediment source for non-marine deposition by alluvial, fluvial, and lacustrine processes in the interior of the Great Valley over the last million years. These more- recent non-marine sediments include the uppermost 700 - 1,000 ft thickness of unconsolidated sediments which comprise the groundwater aquifer and the sediments underlying the present topographic ground surface of the San Joaquin Valley groundwater basin.

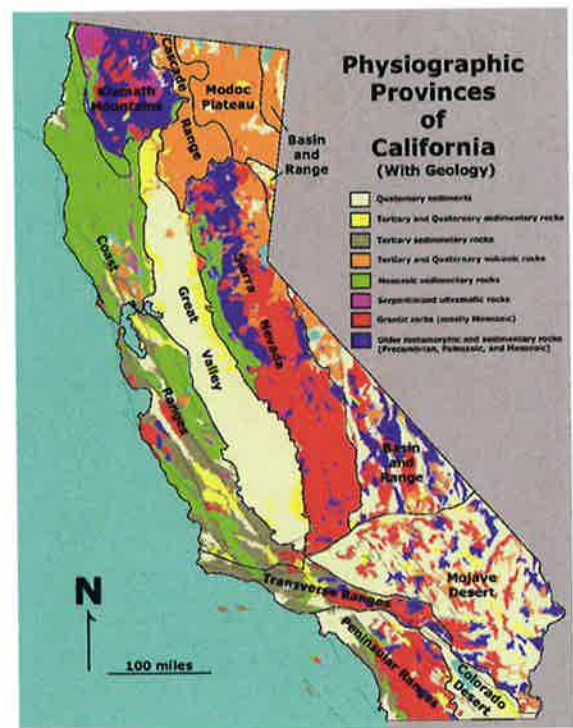
Geology of the Southern San Joaquin Valley (SSJV) Groundwater Basin.

The Kern County portion of the southern San Joaquin Valley is a subbasin of the larger San Joaquin Valley basin and this Kern County subbasin is bounded by both physical and jurisdictional boundaries. The north basin boundary is defined as the vertical plane coinciding with the northern boundary of Kern County. This boundary is a jurisdictional boundary and neither a geological nor a hydrological boundary. The basin perimeter on the east, south, and west sides has been defined by

¹⁷ Bailey, Edgar, H., 1966, Geology of Northern California, CDMG Bulletin 190, see Chapter V. Great Valley Province.

others using the line along the topographic slope break between the flat-lying valley fill and the base of the adjacent dissected foothills or alluvial fans of the surrounding mountains, and also by others as the line of geologic contact between the surficial Holocene- age sediments of the valley fill and the Tertiary and older rocks of the adjacent landforms. It appears that the DWR has used a combination of both of these approaches to define the perimeter of the San Joaquin Valley groundwater basin in the Kern County portion of the Tulare Lake Hydrologic Region¹⁸ (Figure 37, p. 176, DWR Bull. 118-2003). However, geologists are well-aware that the slope break is only rarely the true edge of the basin and that the very youngest quaternary sediments tend to cover up the deeper geological contacts which form the true basin boundary. Furthermore, these bounding sides are rarely vertical at depth and may be as complex as the undulating topography of the adjacent hilly terrain or a mountain flank.

In geological terms, the southern end of the San Joaquin Valley in Kern county is a deep geological trough which is bounded on the east by the Sierra Nevada mountain range, on the south by the Tehachapi Range, and on the west by the Temblor Range. The Sierra Nevada Range comprises primarily pre-Tertiary granitic rocks, and is separated from the Central Valley by a belt of dissected foothills comprised of locally oil-bearing Tertiary marine rocks. The Temblor Range runs along on the western side of the valley and consists of marine and continental sediments of Tertiary to Quaternary age (Gronberg and others, 1998). Prolific oil fields occur along the western basin margin within fold structures which are sub-parallel to the northwest- trending San Andreas Fault, a few miles to the west.

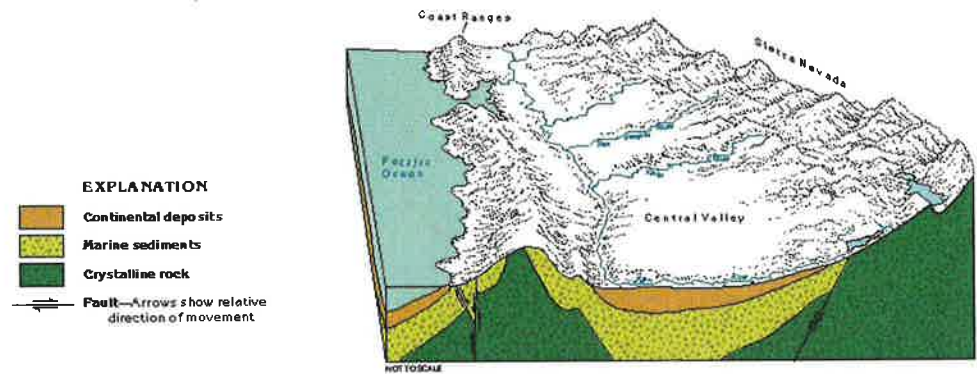


The valley trough has been filled with late Tertiary and Quaternary sediments which are geologically younger than- and derived from- the older rocks of the surrounding ranges. The sediments derived from the granitic terrain to the east consist mostly of unconsolidated, quartzofeldspathic, detrital sands and silts with little clay, which includes the Kern River Formation and younger sediments. The sediments derived from the terrain to the west consist mostly of reworked marine shales and siltstones which yield unconsolidated clays and silts with some sands, which includes the Tulare Formation and younger sediments.

The trough contains a much larger volume of sediments derived from the east than from the west which is interpreted to be caused by a much greater source area to the east than to the west, and a

¹⁸ DWR, 2003, California's Groundwater, Bulletin 118 - 2003, Figure 37, p. 176, Oct. 2003.

much greater orographic precipitation and runoff effect on the east than on the west throughout at least the Late Pliocene - Pleistocene Epochs. The vastly different volumes of sediment derived from opposite sides of the basin have created an asymmetry to the topography and the stratigraphy of the basin. The three large, conical, low-relief, fluvial/alluvial fans created by Poso Creek, the Kern River, and Caliente Creek, which exit the Sierras from north to south along the eastern basin margin,



dominate the eastern boundary and the basin interior from Arvin to Delano. There are no alluvial fans anywhere along the southern and western basin boundaries that compare in size, shape, or importance to these three depo- systems. Rather, the southern and western basin boundaries are flanked by rather uniform, visibly-steeper, broad slopes formed from small, coalescing fans created by intermittent, braided stream or sheet flow deposits from higher elevations. The alluvial fan deposits on both sides of the valley are composed predominantly of coarser-grained sediments near the head of each fan and become finer grained toward the valley trough. The sediments in the eastern alluvial fans are more permeable than sediments in the western alluvial fan region because sediment-source rocks and watershed characteristics are different between the two areas.

The topographic axis of the basin, along which all surface water ultimately drains, is a narrow belt of low elevation separating the toes of the alluvial fans which spread out from opposite sides of the basin. Except for the southernmost part of the basin, the axis lies west of Interstate 5, within 1 - 3 miles of the topographic slope break which defines the western basin boundary, and more than 20 miles west of the eastern basin boundary. Both service areas of the water district straddle the basin axis.

We are interested in the low-salinity, water-bearing strata which fill the shallow, upper portion of the trough. These shallow, mostly Holocene, alluvial and fluvial strata are separated from deeper, high-salinity, Pleistocene, water-bearing strata by impermeable strata. The top of this impermeable boundary is approximately 600 - 3,000 ft deep in the central part of the basin and constitutes the bottom of the groundwater basin for our purposes. The boundary is generally taken to be the contact between the overlying unconsolidated sediments and the underlying sedimentary rocks.

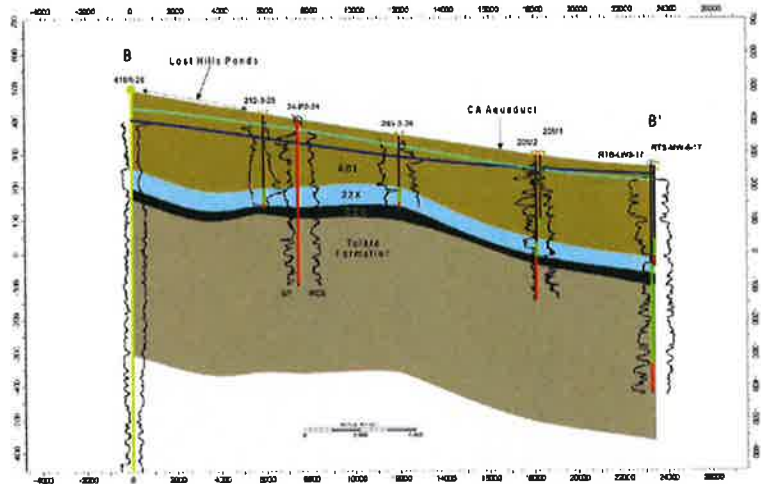
Corcoran Clay

Within the fresh water, upper- portion of the basin, the Corcoran Clay, is a glacial-outwash, lake deposit that is an important subsurface feature in the San Joaquin Valley because it is a laterally extensive confining unit which splits the deeper parts of the SSJV groundwater basin into a

shallow unconfined aquifer and a deeper confined aquifer, as described further below. The Corcoran Clay is a member of the Tulare Formation (Croft, 1972) and has been correlated with the E-clay (Page, 1986), the diatomaceous clay (Davis and others, 1959), and the lacustrine clay within the Turlock Lake Formation to the north of Kern County (Marchand and Allwardt, 1981). Page (1986) used results of previous work and a limited number of well logs and geophysical logs to map the areal extent of this regional confining unit. Burow and others, 2004, have recently used additional lithologic data to modify the mapped extent of this prominent unit in the region.

In the central parts of the main SSJV groundwater basin to the north- northwest and south-southeast of the Kern Fan, the 50-ft thick Corcoran Clay separates an unconfined aquifer shallower than about 300 ft depth from a confined aquifer deeper than about 350 ft. The Corcoran Clay does not exist under the Kern Fan where the shallow unconfined layers are separated from deeper, more confined layers by an intermediate zone of interbedded sands and silts which retard vertical groundwater flow and create an increase in semi- confinement with depth. In the Maples Service Area, the district has three wells which appear to show water level behavior indicative of confined conditions, but we do not have deep- well geophysical logs in the area to confirm whether or not the Corcoran Clay exists under the area.

Based on the work of others, the Corcoran Clay or another, stratigraphically- equivalent clay has been mapped or inferred to exist under the Buttonwillow Service Area. Some of the deeper wells in the southern BSA are completed down to a clay at a depth of about 550 - 600 ft. No wells appear to have been completed deeper because the producing interval above that clay has good water and sufficient productivity to make good irrigation wells.



Based on the work by Aera Energy geologists¹⁹, there is a ± 30 ft thick clay, which they identify as the CCE, or Corcoran Clay Equivalent, which is 220 - 320 ft deep and separates the unsaturated zone and the water- bearing 22K sand, from the underlying Tulare Formation, within the western basin for at least five miles to the west of the BSA, north of 7th Standard Rd.

In 1991, Pacific Geotechnical Associates mapped the "E" Equivalent Clay along the western

¹⁹ RWQCB, 15 November, 2011, Review- Phase II Groundwater Investigation Report, Row4/Lost Hills Wastewater Disposal Facility, South Belridge Oilfield, Kern County, Memorandum to Aera Energy LLC.

basin margin, including the Buttonwillow Syncline, Buttonwillow Anticline, and in parts of the main basin to the east of the water district. PGA reported²⁰ that:

"The "E" Equivalent Clay as identified in well 23s/24e-16B can be mapped as far south as T.30S.-R.24E., MDB&M, within the Buttonwillow trough. The clay can be correlated with confidence from the deepest part of the basin eastward to a line that extends roughly from Delano through McFarland and west of Shafter. The clay reaches depths of -900 feet subsea (1,100± feet subsurface) in T.25S.-R.20E., MDB&M, at the Kern County line."

The PGA report states that the stratigraphic correlations based on E-logs were difficult or impossible where the clay was less than 50 ft thick, and the correlations probably could not have been completed without the extensive amount of proprietary seismic data that were available to them courtesy of ARCO Oil and Gas Co. The structural contour map on the clay which is presented as Plate IX in the PGA Report is currently the definitive map of the Corcoran Clay (aka CCE or E-Clay) in the vicinity of the water district. Because of the double plunge of the syncline, the clay is 450 - 600 ft deep under much of the BSA, rises southward to only about 100 ft deep under the south end of the BSA, and rises northward to about 250 ft deep under the north end of the BSA.

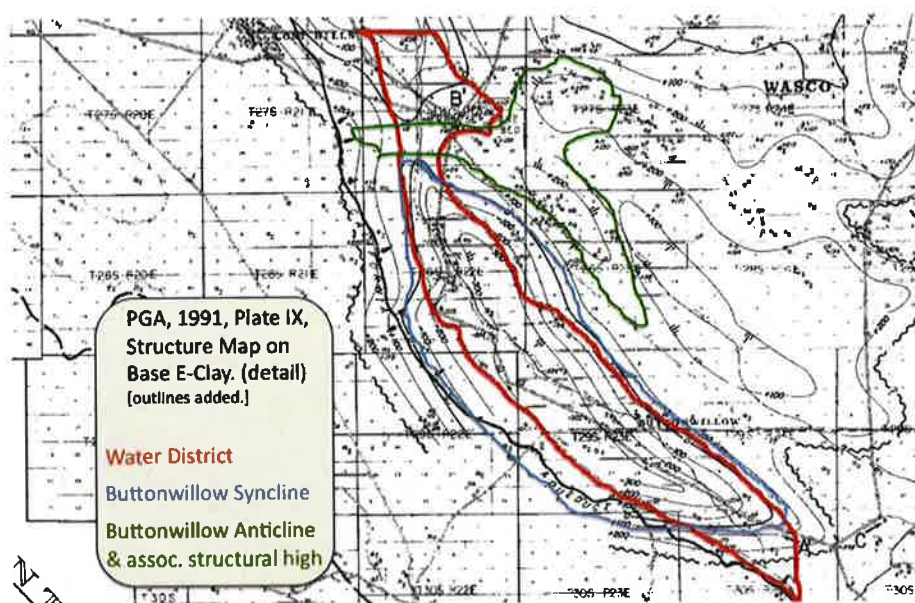
Geology of the Maples Service Area.

The MSA is about 7 miles long, 1 mile wide, and occupies the overflow lands between the Kern Lake Bed and the Buena Vista Lake bed along the southern toe of the Kern River alluvial fan. The MSA overlies the southern flank of the Bakersfield Arch where the basin structure dips steeply southward into the deep part of the southwestern basin. The MSA is underlain by Kern Fan type non-marine sediments, i.e., mostly unconsolidated sands and silts, with the Corcoran Clay equivalent at a depth of about 500ft and the Paloma clay at a depth of about 1,500 ft, according to PGA, 1991.

²⁰ Pacific Geotechnical Associates, 20 September, 1991, Study of the Regional Structure Related to Ground Water Aquifers in the Southern San Joaquin Valley Ground Water Basin, Kern County, California, p. 1.

Geology of the Buttonwillow Service Area.

The BSA is a 24-mile long, 3- mile wide, thin strip of land along the western basin margin and occupies the overflow lands within the Buttonwillow Syncline, lying between Elk Hills and Buttonwillow Ridge (Dale, et al, 1966) west of the Kern River alluvial fan. The BSA overlies a part of the SSJV groundwater basin which is contained within the flanks of the doubly-plunging Buttonwillow Syncline (Figure 8. PGA, 1991, Plate IX detail, Structure Map on Base E-Clay.) and is geologically separated from the main basin to the east by the doubly- plunging Buttonwillow Anticline (PGA, 1991). There is no surface expression to the Buttonwillow Syncline, but the en echelon, axial ridge of the Buttonwillow Anticline forms the Buttonwillow Ridge which is about 30 ft topographically higher than the flat lands overlying the syncline. The Buttonwillow Anticline is approximately three (3) miles wide. Immediately to the east of the Buttonwillow Anticline is the Jerry Slough Syncline which is another en echelon structural trough which is considered to be part of the main basin north of the Kern River channel.



The BSA overlies an area where the underlying Pleistocene sediments (<1 my) are composed of inter-bedded, non-marine sediments which came from separate sediment sources to the east and to the west. These sediments, which inter-finger under the district are the thin, distal terminations of thicker deposits of differing textures and compositions which are characteristic of their separate, respective sources to the east and west. The Pleistocene alluvial, fluvial and lacustrine sediments from the east are part of the Kern River Formation which are characteristic of sediments derived from the igneous granitic bedrock of the Sierra Nevada range. The Pleistocene alluvial sediments from the west are part of the Tulare Formation and are characteristic of reworked marine sediments derived from the ranges to the west. A veneer of Recent alluvium, swamp-, river-, and lake- deposits covers the Pleistocene deposits over most of the southern San Joaquin Valley.

These facies changes under the district lands influence both the complexity of groundwater flow and the mineral chemistry of the waters under the district. The available well data from the

district are sufficient to establish the depositionally complex and laterally- discontinuous style of the local stratigraphy but are not sufficient to actually map the lateral extents of these units in the unmapped areas between wells. Various other workers have observed that some of the Pleistocene and Holocene alluvial sediments are so similar to the underlying Tulare and Kern River sediments that it is virtually impossible to differentiate them in the field.

The groundwater aquifer under the BSA consists of a sequence of interbedded, laterally- discontinuous, Quaternary sandy and silty sediments of non- marine origin. Down to a depth of about 200 ft, silty sediments tend to predominate, but from 200 - 600 ft sandy and silty sediments occur in approximately equal proportion. The sandy strata in this depth interval constitute the groundwater aquifer which is currently being exploited in the area. In the Buttonwillow Service Area, the majority of irrigation wells are completed in the depth interval from 200 - 500 ft deep mainly for reasons of better water quality and better sand productivity at depth. The local irrigation wells have 200 - 300 ft long completion intervals within this depth range and are capable of delivering 3.9 - 5.3 cfs sustained flow at discharge/drawdown ratios in the range of 0.04 - 0.09 cfs/ft.

In the northern half of the Buttonwillow Service Area, the near- surface sediments have significant clay content and create a separate, shallow perched water table only 2 - 12 ft deep, above the underlying aquifer. Other petrophysical data, including geological classification, sieve analyses, consolidation tests, grain and bulk densities, and moisture contents from a hollow stem auger sampling program which will be completed in 2013, will be reported and made available by the District after the project completion.

5. Groundwater Hydrology of the Buena Vista Water Storage District.

The Maples and Buttonwillow Service areas are about ten miles apart and overlie different parts of the basin, with different groundwater hydrologies and water chemistries. This discussion includes an introduction to the overall basin hydrology and summaries of the hydrologies of both service areas, with an emphasis on the Buttonwillow Service Area since it comprises the great majority of the district lands.

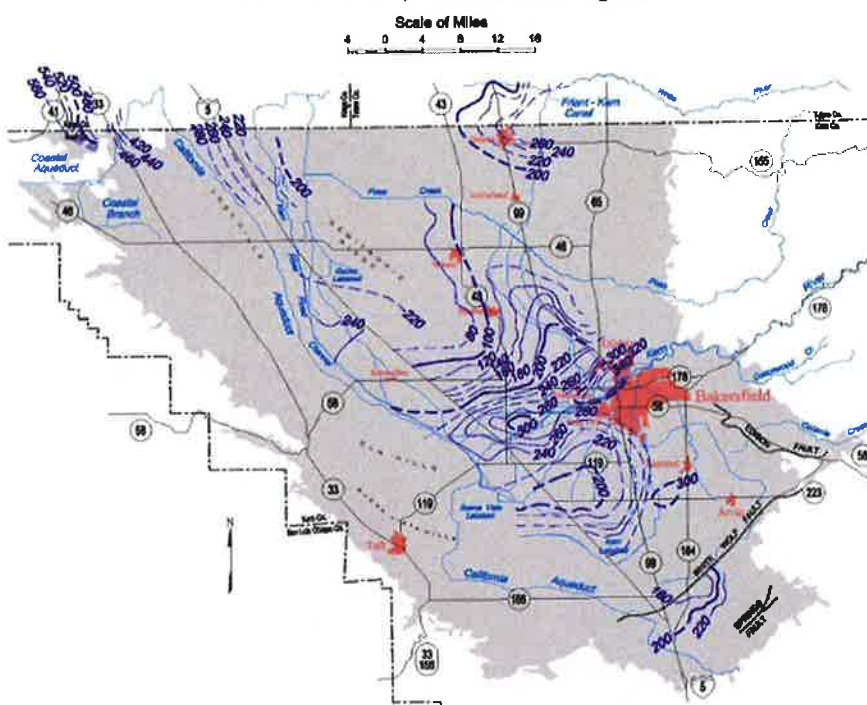
Hydrology of the overall basin.

The SSJV groundwater basin is often considered to be a single, large bathtub- like basin but, in detail, there are several small subbasins caused by local geological complexities along the east, south, and west basin boundaries. Each of these small subbasins has some degree of isolation from the main basin as manifested by some form of isolated water level behavior, distinct water chemistry, and delayed and/or attenuated pressure response to main- basin events, or vice versa.

A large and persistent groundwater recharge mound exists under the present Kern River channel traversing the Kern Fan which has separated the SSJV groundwater basin into two isolated flow regimes, one subbasin to the northwest and one subbasin to the southeast. These two subbasins²¹ remain fully hydrologically connected and, together with the Kern Fan area, are considered to constitute the main basin. Historically, the average water levels in the southeast subbasin have been about 100 ft higher than the average water levels in the northwest subbasin, and the difference has been maintained by the intervening recharge mound. Hypothetically, if some or all of the Kern River recharge mound ceased to exist, then groundwater would flow from the southeast basin into the northwest basin driven by the existing head difference.

Kern Groundwater Basin

Spring 2000, Lines of Equal Elevation of Water in Wells, Unconfined Aquifer



Contours are dashed where inferred. Contour interval is 20 feet.

The overall SSJV groundwater basin boundaries on the west, south, and east sides are considered to be no-flow boundaries so that the basin neither gains nor loses groundwater by lateral groundwater flow on these three sides. The basin boundary on the north is the Kern County Line which is a jurisdictional boundary but not a hydrological boundary and merely separates the Kern County portion of the basin from its physical continuation to the north/northwest. Hydrologically speaking, the groundwater basin inside Kern County is connected to- and mirrored by- its continuation in Kings and Tulare counties to the north. Groundwater is completely free to flow north out of Kern County or to flow south into Kern County depending on the prevailing hydrological gradient across the boundary at any time. Based on a review of water level maps over the last 80 years, the basin dynamics on opposite sides of the county line have mirrored each other, resulting in no persistent groundwater gradients and, therefore, no significant groundwater flow across the boundary either into or out of the basin. Virtually all of the gains and losses of groundwater from the basin occur across the

²¹ Subbasins, as defined by the isolation of their respective flow regimes.

ground surface. The basin gains essentially all of its groundwater by either natural or manmade percolation of surface water. The basin loses groundwater by water wells for domestic and municipal water supplies or agricultural irrigation. These gains and losses are reflected in the rise and fall of the unconfined water table and by the rise and fall of pressure in the confined aquifer.

The base of the groundwater basin is sometimes defined as the boundary between fresh groundwater and underlying saline groundwater, which reportedly varies in the depth range from 700 to 2,000 ft. The separation of the two regimes based on chemistry is often taken to be a basal no-flow boundary underlying much of the main basin. The majority of deep irrigation wells are completed no deeper than 600 - 700 ft deep and have encountered no reported saltwater invasion from greater depth, so this shallower zone is the interval for which the most information is available, and has traditionally been the portion of the basin which is accessible to- and used by- the overlying farm and urban groundwater users. According to the Kern County Water Agency²²:

The main groundwater basin in the San Joaquin Valley portion of Kern County covers about 963,000 acres. The estimated storage capacity of the top 600 ft is about 50 million acre-feet. Total groundwater in storage [as of 2001] is estimated at 40 million acre-feet, with 10 million acre-feet of dewatered storage capacity.

Hydrology of the Maples Service Area. The groundwater hydrology under the MSA (mostly in the southern sections of T31s/R26e) is characteristic of the hydrology of the interior portion of the main basin which is south of the Kern River. The aquifers under the MSA are fully interconnected to the aquifers under the adjacent lands. From 1929 to the early- 1960s, groundwater flowed under the MSA from the northeast. The groundwater gradient under the MSA was consistently about -10 ft/mi, more or less, as groundwater flowed toward the southwest away from the Kern River recharge mound. During that 30-year period, the average groundwater elevation declined from about 280 ft to 260 ft.

Starting in the mid- 1960s, the groundwater gradients reversed, causing groundwater to flow under the MSA from the southwest, at gradients of -4 to -15 ft/mi, under the influence of a growing pumping depression to the northeast centered in the west half of township T31s/R27e. From the 1960s to the mid- 1980s, the average groundwater elevation remained at about 260 ft.

Basin water levels began to decline in 1988 and by the Spring, 1989, average water levels in the MSA had dropped from 260 ft to about 200 ft elevation, and the deep portion of the pumping depression had spread to include the Maples Service Area, so that the MSA received inward flow from all directions. As the drought continued into 1995, the Kern River recharge mound declined and the

²² KCWA, 2001, Initial Water Management Plan, Public Review Draft, 27 August, 2001, p. ES-10.

southwest end of the mound receded upriver until, for the first time, groundwater began to flow out of the southeast basin, under the MSA, under the southwestern-most stretch of the Kern River, and into the northwest basin. Water levels declined in the MSA and fluctuated between 180 - 200 ft elevation for the period.

During the wet period from 1995 to 1998, recharge along the Kern River reformed the groundwater mound which re-isolated the two main subbasins and raised the overall water levels. The MSA was still underlain by the pumping depression and water flowed into the MSA generally from the south. Water levels remained steady at about 200 ft elevation for the period.

The wet period was followed by another multi- year drought from 1999 into 2005, in which the recharge mound again declined almost to the point of re-opening a flowpath between the two subbasins. Water levels under the MSA declined from about 200 ft to 160 - 180 ft elevation and flow into the area was from the south. After the two wet years of 2006 - 2007, in which the water levels in the MSA recovered somewhat, water levels declined to new historic lows of 150 and 120 ft elevation in 2009 and 2010 as the MSA began to be drained by two pumping depressions, one to the northeast and one to the southwest.

Hydrology of the Buttonwillow Service Area. The Buttonwillow Service Area of the Buena Vista Water Storage District occupies a partially- isolated subbasin on the western basin margin northwest of the Kern River. For purposes of description, we divide the BSA into two parts, the northern and southern BSA based on the presence of a perched aquifer in the northern area, and somewhat different hydrology along the district margins of the two areas. Based on district groundwater elevation contour maps, the divide²³ between the northern and southern half of the BSA is located approximately at 7th Standard Rd. The water table under the northern half of the BSA is shallow, 2 - 12 ft deep, flat, featureless, and largely unchanged from year to year. The volume of canal seepage losses during the seasonal surface water irrigation run (average 111-days long from May - Aug) exerts a significant influence on both the depth and the salinity of the shallow groundwater. The water table under the southern half of the BSA is 200 - 250 ft deep and exhibits some water table fluctuations which mimic the hydrology of the climatic wet/dry cycle similar to that seen in the main basin to the east and southeast.

The vertical relationship between the perched aquifer and underlying aquifer is not clear based on available data except that the perching layers appear to terminate to the south near 7th Standard Road (near the boundary between townships T28s & T29s). To the north of this boundary, perched water exists and to the south of this boundary, the shallow section remains unsaturated down to the deeper aquifer water table. There is southward flow of perched water across this boundary which

²³ The location of the dividing line between the northern and southern BSA, as described, runs from the West Side Canal to the East Side Canal through the intersection of Imperial St and Main Drain Rd on a bearing of N45°E.

serves to percolate and recharge the aquifer to the south via a sloping water table.

According to district water level data, the groundwater gradients across the district boundaries north of 7th standard Rd have been essentially zero over time, so that very little groundwater has flowed laterally into or out of the northern BSA across the west, north, or east district boundaries. Heading to the southeast from the north-south divide, the groundwater elevation deepens at a rate of 5 - 6 ft per mile for 10 - 12 miles, i.e., almost all the way to the southeast end of the district. The volumetric flow rate out of the perched zone, and the corresponding impacts on the salinity and chemistry of the deeper zone, have not been determined to date.

In the Buttonwillow Service Area, the majority of irrigation wells are completed in the depth interval from 200 - 500 ft deep mainly for reasons of better water quality and better sand productivity at depth. The local irrigation wells have 200 - 300 ft long completion intervals within this depth range and are capable of delivering 3.9 - 5.3 cfs sustained flow at discharge/drawdown ratios in the range of 0.04 - 0.09 cfs/ft.

Lateral flow across the west BSA boundary.

The main basin boundary is located several miles to the west of the California Aqueduct, which is approximately 1.5 – 2.5 miles west of- and parallel to- the west-side District boundary, north of State Highway 58. Based on data from Aera Energy, the stratigraphy under the Belridge Water Storage District, west of the aqueduct and north of State Highway 58 is similar to that in the BSA, except that the Corcoran Clay equivalent is much shallower than under the BSA. The RWQCB reports that:

“Aera’s groundwater investigation identified three aquifer zones. discontinuous water- bearing sand layers, separated by clay layers within the Holocene alluvium are designated as the unconfined Aquifer I (AQI). Underlying the AQI is a discontinuous clay aquitard which is underlain by the 22K Sand. Where water-bearing, the 22K Sand is designated as the semi-confined 22K Aquifer (22K). Underlying the 22K is a regionally continuous aquiclude, the Corcoran Clay Equivalent (CCE). The CCE correlates with the Corcoran Clay six miles to the east. Below the CCE is the Pleistocene Upper Tulare Formation, a thick sequence of relatively continuous, permeable, water-bearing sands and alternating clay layers, designated as the confined Aquifer II (AQII).”

A few miles to the west-northwest of the water district, all three zones contain natural groundwaters with elevated TDS, and the top two aquifers have been locally impacted by oilfield wastewater brine plumes. The groundwater gradient in this area is northeasterly, i.e., with a component of easterly groundwater flow toward the BSA from the west. To date, however, the district has not observed the encroachment of the wastewater plume into the groundwater under the district.

The groundwater gradient data from the few available wells on the west BSA boundary suggest

that there is very little or no groundwater gradient at all across the district boundary. This fact alone would seem to argue that the BSA cannot receive a significant amount of lateral inflow recharge from the west, and this basin boundary must therefore essentially be a no-flow boundary. On the contrary, there are water chemistry anomalies along the western edge of the groundwater basin within BVWSD and elsewhere that argue for the presence of inflow from the west. BVWSD is currently undertaking studies, including discussions with oilfield operators to the west who have detailed geological information, to try to improve the understanding of the basin boundary, but that study is in its early stages as of Spring, 2013.

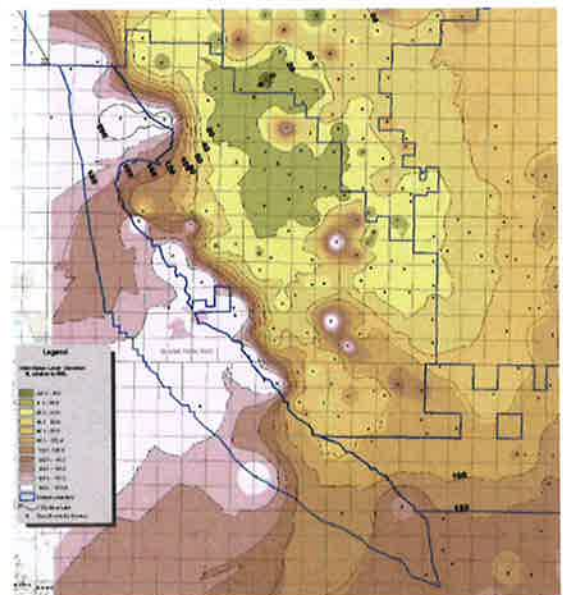
Detailed shallow groundwater maps, along the western district boundary north of Seventh Standard Rd and south of State Highway 46, reveal that groundwater pumping by a line of irrigation wells located outside the district along the west side of the West Side Canal creates a linear pumping depression which appears to cause groundwater to flow westerly from the district interior toward the wells where the groundwater is, at least seasonally, 6 - 10 ft deeper than in the district interior. Because of the placement of these wells, this represents a true flux of shallow groundwater which leaves the district. However, this clearly cannot represent the natural groundwater flow and whether or not this should be included in a groundwater balance or groundwater analysis would depend on exactly what the boundary flow, however small, was intended to represent.

Lateral flow across the eastern BSA boundary, north of 7th Standard Rd.

The water level elevations (200+ ft msl) within the northern portion of the BSA are significantly shallower than the water level elevations (± 0 ft msl) in the large pumping depression a few miles to the east- northeast, centered in township T27s/R23e. The -200 ft step- like drop in groundwater elevation occurs across a 2 - 3 mile- wide zone which parallels the eastern district boundary.

Regional ground- water elevation maps clearly show that the water level contours which define the T27s/R23e pumping depression are asymmetric in the E-W direction with an inward gradient on the east of -10 ft/mi and an inward gradient on the west of -70 to -80 ft/mi. The pumping depression is east of this steep, step-like groundwater gradient while the BSA is west of the gradient.

Within the local water community, this narrow zone of steep gradients between BVWSD and the pumping depression has been interpreted to be a no-flow boundary caused by geologic structures running close to- and parallel



to- Interstate 5. The 1991 "Clay Study"²⁴ by Pacific Geotechnical Associates indicates that the geological axis of the Buttonwillow Anticline runs along this area, and is clearly visible in the local topography as an elongated hill. The district does not have well data which can be used to confirm whether or not the anticline or related geologic structures have affected the hydrology of the top 600 ft of strata in that area. But if this zone is a no-flow boundary, then the groundwater lateral flow across this zone would be zero.

The narrow zone of steep groundwater gradient might also be interpreted to be the result of substantial thinning of the aquifer due to geologic structures in the area between the BSA and the pumping depression to the east. A thinner aquifer would have a significantly reduced transmissivity (T), with or without an associated change in hydraulic conductivity, resulting in the groundwater elevations to the west remaining high, while a relatively small flux of water "spills" eastward through the linear zone of reduced transmissivity. The gradient across the area would be similar to that which is actually observed, given the limits of the existing data, and the groundwater flux across the zone would depend on the value of T, i.e., the thickness-conductivity product of the permeable strata within this zone. There may be other geological structures or conceptual models which might explain the presence of the zone of steep gradients, but we currently have no data from which can select a preferred model or estimate the lateral flow of groundwater through this zone.

The groundwater gradients across the actual eastern district boundary which lies 1 - 2 miles west of this linear feature are approximately zero at least along the eastern boundary of the northern half of the BSA. As was the case for the western boundary, the component of the groundwater gradient which crosses the east district boundary is so close to zero at almost every point that the aggregate inflows and outflows, if any, must be nearly zero, or too small to estimate given the uncertainties in the data at this time.

The tentative conclusion, given the amount of available data as of Spring, 2013, is that the lateral groundwater flow across the western, northern, and eastern district boundaries in the northern BSA must be very small, at least within the unconfined aquifer, since the groundwater gradients across both lateral boundaries are very small. The persistence of a very shallow water table over time appears to be consistent with a lack of significant lateral outflow of groundwater from under the district.

Lateral flow across the eastern BSA boundary, south of 7th Standard Rd.

Based on the groundwater elevation maps, a portion of the eastern boundary south of 7th Standard Rd is hydrologically interconnected with the main basin to the east. There is a four-mile stretch of district boundary from a point in T29s//R23e-11P to a point in T29s/R24e-28Q that exhibits an

²⁴ Pacific Geotechnical Associates, September 20, 1991, Study of the Regional Geologic Structure Related to Ground Water Aquifers in the Southern San Joaquin Valley Ground Water Basin, Kern County, California.

average outward directed groundwater gradient of about 35 ft/mile. If we assume a basic water balance on the district, we can estimate the flow parameters along this portion of the eastern BSA boundary.

The water balance representing the change in the volume of groundwater in aquifer storage over a specified time period for the Buttonwillow Service Area can be represented mathematically as follows: *Change in groundwater storage = Water in - Water out.* A positive water balance means that the groundwater aquifer under the BSA physically gained water while a negative balance means that the groundwater aquifer under the BSA physically lost water for the period. If we can quantify two of these terms, we can calculate the third.

The change in groundwater storage under the BSA over time has been determined by the California Energy Commission. In January, 2013, the California Energy Commission released a report²⁵ in which they evaluated the long term change in water levels under the BSA. Based on 19 water level hydrographs spread throughout BSA, the CEC concluded that the BSA- wide average water level rose +6.8 ft/decade since 1974. Using an estimated specific yield of 0.15, the CEC concluded that this represented a long- term average rate of increase in groundwater storage under the BSA of +4,600 af/y. This number represents the (annualized) average increase in groundwater storage.

The long term volume of water placed into groundwater storage has been determined by the water district staff. Based on the 1970 - 2007 district water balance, the district consumed less water than its water supply provided, and placed a net average annual +36,964 af/y into groundwater storage under the BSA. Since there is no significant inflow across the service area boundaries, the percolation of surplus district water supply constitutes the entire inflow to the basin. This number represents the (annualized) volume of water which flowed into basin storage. According to these two numbers, the basin water level is rising far less than it should be for the long term average volume of water that the water district is putting into the basin each year.

Therefore, we calculate using the water balance formula that the net average annual outflow of groundwater from the BSA is -32,364 af/y. This number represents the annual amount of groundwater that must flow out of the basin in order to reconcile the volume of inflow with the smaller observed increase in the volume of water in storage. This rate of outflow, equal to only 89 af/d, is equivalent to 9 water wells, each pumping all year at a constant rate of 5 cfs. This annual outflow volume is also equivalent to the total groundwater extraction of about 18 irrigation wells, each pumping at a constant rate of 5 cfs for about half a year, which is a reasonable scenario for the subbasin areas outside the BSA for which no surface water delivery system exists. In other words, it is possible that ±32,000 af/y of

²⁵ Conway, Mike, Fio, John, and Deverel, Steve, January, 2013, Preliminary Water Supply Analysis, California Energy, Commission.

BV's surplus water is being extracted by non- district water wells which are located outside the district boundary but inside the Buttonwillow subbasin. The district currently has not determined to what extent this may be true. This annual outflow may also be due to natural outflows.

The loss of $\pm 32,000$ af/y from the basin may also be due to natural groundwater lateral outflow from the southern BSA along a 4-mile stretch of the eastern district boundary from about T29s/R23e-11P to T29s/R24e-28Q. An outward flux of 89 af/d, across a 4-mile stretch of district boundary, through a net 400 ft of aquifer thickness, under a gradient of 35 ft/mi, and a hydraulic conductivity of 70 ft/d will completely explain the loss of $\pm 32,000$ af/y from storage under the BSA. The water district currently has insufficient data to determine whether the parameters or the existence of such lateral flow are correct, but all of the combined physical properties which are required to account for such an outflow are consistent with the expected groundwater flow behaviors in the area. The actual outflow of groundwater from under the BSA is probably a combination of natural outflow and groundwater extraction by non- district water wells.

Aquifer properties.

The aquifer materials under the district are all unconsolidated sediments which are classified by grain size as sands, silts, or clays. The physical properties of interest include the in situ porosity, permeability, density, compressibility, moisture content, and grain size distribution. These properties help us to quantify the flow and storage properties of the aquifer strata. The district has recently begun to acquire aquifer data through core sampling and well testing. Based on the results of a Phase- 1 aquifer study which was performed by URS in 2009 - 2010, we have numerical values for the deep-aquifer storage and transport properties in the area near Seventh Standard Rd and Main Drain Rd. Based on the preliminary results of a Phase-2 aquifer study of which is currently being analyzed by Sierra Scientific Services²⁶, we have some numerical values for the perched- aquifer storage and transport properties in the area where Seventh Standard Rd intersects the East Side- and West Side- Canals. The district has not yet obtained aquifer property data for the rest of the district.

Deep aquifer data.

In late 2009 - early 2010 URS conducted aquifer tests in seven farm irrigation wells located in the central Buttonwillow Service Area of the Buena Vista Water Storage District, Kern County, California. All seven locations are within about 1.2- mile of the intersection of Seventh Standard Rd and Main Drain Rd (T29s/R23e- 04). At the District's request, URS selected these wells- of- opportunity

²⁶Sierra Scientific Services has completed eight of ten proposed hollow-stem auger boreholes located throughout the district for the purpose of collecting sediment core samples to depths of 100 ft. The samples from all eight holes have been analyzed for physical properties by a Soils Engineering, Inc., of Bakersfield, Ca. See SEI Report of 02 Sep, 2011. The remaining two borings are scheduled for completion in Summer, 2013, after which, Sierra Scientific Services will present a final report of findings and interpretations. The protracted program duration is due to scheduling decisions associated with one of the district's projects.

for testing because of their appropriate spacing and proximity to the proposed BVWSD Brackish Groundwater Remediation Project well field. URS designed the well- testing program to obtain T & S values in order to validate the assumptions of their 2009 computer model of the potential drawdown impacts of the proposed well field. URS also designed the program to obtain water chemistry data on the distribution of higher- and lower- TDS waters known to exist within the aquifer.

URS presented their findings in a March, 2010 report titled: *Hydrogeologic Data Acquisition Report, Groundwater Monitoring and Process- Water Well- Field Development Project; prepared by URS for Hydrogen Energy California, Kern County, California, March, 2010*. Sierra Scientific Services provided a critical review of the report and an independent analysis of the test data and presented their findings in a June, 2010 report titled: *A Review of the Draft Report: Hydrogeologic Data Acquisition Report, Groundwater Monitoring and Process- Water Well- Field Development Project; prepared by URS for Hydrogen Energy California, Kern County, California, March, 2010; including an independent interpretation of the URS 2009 Well Test Data and an editorial review of the URS draft Report, 17 June, 2010, Sierra Scientific Services, Bakersfield, Ca.*

To summarize the URS findings, the deep aquifer is defined as extending from 200 - 600 ft depth below ground surface. The local irrigation wells have 100 - 300 ft long completion intervals within this depth range and are capable of delivering up to 3.9 - 5.3 cfs sustained flow at discharge/drawdown ratios in the range of 0.04 - 0.09 cfs/ft (equivalent to: 25853 - 58169 gpd/ft or 0.08 - 0.18 af/d/ft). On the basis of these tests, the aquifer transmissivity ranges from 15,000 - 25,000 ft²/d, and the average transmissivity in the central BSA is 18,200 ± 4400 ft²/d. Using the aquifer net sand thickness from E-logs of the tested wells, the analysis of the BSA well test data gives hydraulic conductivities in the range of 30 - 80 ft/d, with an average K-value of 77±± 31 ft/day. The groundwater TDS is variable, depending on the depth zone, but ranges from 1,000 - 2,700 mg/l in the area of the well tests.

Shallow aquifer data.

In April - May, 2011 SSS conducted down- borehole petrophysical sampling and analyses as part of the Phase-2 study for the proposed BVWSD Brackish Groundwater Remediation Project well field. Soils Engineering, Inc. performed the requested lab analyses and presented the results in a data report of 02 September, 2011.

The preliminary results indicate that the hydraulic conductivities of the sands in the top 100 ft depth are 3 - 20 ft/d, quite permeable but much lower than the conductivities in the deep zone. However, the macro vertical permeability is quite low because of the presence of interbedded silt and clay layers. The TDS of the shallow, perched zone ranges from 850 - 5,500 mg/l based on district data from shallow piezometers. Other petrophysical data, including geological classification, sieve analyses, consolidation tests, grain and bulk densities, and moisture contents will be reported in SSSs final report after the completion of the analyses of the samples from the final two auger borings which are

scheduled for Summer, 2013.

Groundwater chemistry.

Most of the groundwater in the SSJV groundwater basin is one of three types: high- very high TDS, Na-Cl water, moderate- high TDS, Na/Ca-SO₄ water, or low- moderate TDS, Ca-HCO₃ water. The areas and zones where these distinct types of groundwater come into contact with each other are characterized by waters of intermediate TDS and mixed chemistry.

The chemistry of the low TDS, Ca-HCO₃ type groundwater is similar to the chemistry of Kern River water, which is the main source of recharge for most of the basin. This type of water is referred to as east-side water because it is characteristic of the surface waters which drain from the granitic Sierra Nevada Range to the east of the basin. This type of water recharges the basin along the Kern River recharge mound and along Poso Creek and is widespread across the interior of main basin down to about 600 - 700 ft depth.

The chemistry of the moderate- high TDS, Na/Ca-SO₄ type groundwater is similar to the chemistry of surface water runoff that drains from outcrops of Miocene- Pliocene marine sediments, and is primarily found in a strip along the west basin margin for more than 60 miles. This type of water is referred to as west-side water because it is characteristic of the surface waters which drain from the hills of the Temblor Range to the west side of the basin. There is far less runoff from the west side than from the east side, so there is far less SO₄ groundwater than HCO₃ groundwater in the basin.

The high-TDS, Na-Cl type groundwater is generally found in the deeper parts of the basin, regardless of what type of groundwater it underlies. No unique geological association has been established for this water type.

In the Maples Service Area, water wells have encountered east- side- type Na- HCO₃ groundwater which dominates the basin to the north and east of the MSA, as well as mixed HCO₃/SO₄ groundwater which dominates the areas of the Buena Vista Lake Bed and basin margin to the west and south, respectively. The east- side HCO₃ groundwater has a TDS in the range of 200 - 500 mg/l, while the mixed- chemistry groundwater has a TDS in the range of 800 - 1,600 mg/l.

In the Buttonwillow Service Area, water wells have encountered groundwater of all three of the main water types plus mixed waters with associated TDS values which range from 500 to 5,000 mg/l. Dale, et al, 1966, (p. 66) reports:

"Ground water found in the axial trough²⁷ is a mixture of east-side and west-side ground water as well as

²⁷ The axial trough refers to the subbasin which underlies the Buttonwillow Service Area.

surface water which finds its way to the trough area before percolating downward to the ground-water body. The water is of the sodium type, but has many different sources. It varies widely both in concentration and chemical character of the anions. Generally, axial water nearer to west-side ground water exhibits more erratic quality change than does the axial water nearer to east-side ground water.

The contact between the east-side and axial ground water was placed at 1 equivalent per million (epm) of either sulfate or chloride. The fresh water east of the boundary, with the exception of the two saline areas, contains less than 1 epm, and the water west of the line contains more than 1 epm of sulfate or chloride."

Saline groundwater intrusion in the BSA.

The theory that the Miocene and younger marine sediments of the Coast Ranges are the source of saline groundwaters which are observed along the western margin of the southern SJV groundwater basin appears to have been originally proposed in the early 1960s by workers from the U.S. Geological Survey, although Dale, et al, 1996, report that Mendenhall (1916) attributed the high mineral content of certain waters to the Miocene - Pliocene marine sediments with which they were associated. Of the five related papers listed below, the paper by Dale, et al, 1966 covers the two service areas of the Buena Vista Water Storage District, but especially the BSA.

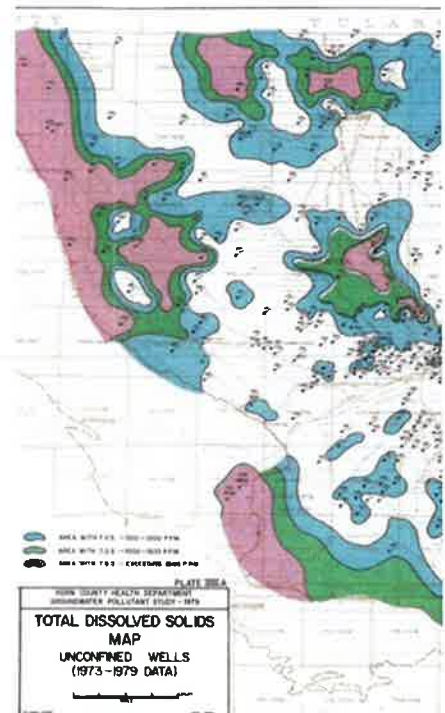
Croft, M.G., 1972. Subsurface geology of the Late Tertiary and Quaternary water-bearing deposits of the southern part of the San Joaquin Valley, California, U.S. Geol. Surv. Water-Supply Paper 1999H, 29 p.

Dale R.H., J.J. French, G.V. Gordon, 1966, Ground-water geology and hydrology of the Kern River alluvial fan area, California, U.S. Geol. Surv. Water Res. Div. Open-File Report.

Page, R.W., 1986. Geology of the fresh ground-water basin of the central valley, California, with texture maps and sections, U.S. Geol. Surv. Prof. Paper 1401C, 54 p.

Wood, P.R., and Dale, R.H., 1964, Geology and Ground-Water Features of the Edison- Maricopa Area Kern County, California, USGS WSP 1656.

Wood, P.R., and Davis, G. H., 1959, Ground-Water Conditions in the Avenal-McKittrick Area, Kings and Kern Counties, California, USGA WSP 1457.



In the early 1980s, a coalition of Kern County workers and consultants prepared a water quality study of the Kern County portion of the southern SJV groundwater basin in cooperation with the RWQCB and with Federal funding under the provisions of Section 208 Groundwater Pollutant Study (GPS) of Public Law 95-500. Two reports resulted from this effort, as listed below.

Kern Co. Health Dept, DEH, March, 1980, Groundwater Pollutant Study, San Joaquin Valley, Kern County, California.

Kern Co. Health Dept, DEH, and Kern County Water Agency, March, 1982, Groundwater quality Report, San Joaquin Valley, Kern County, California.

The same set of constituent concentration maps was provided with both reports, and the distributions of TDS in the unconfined and confined aquifers are displayed on maps VIII-A and VIII-B, respectively in the 1982 GPS Report (a copy of Maps VIII- A&B are included in the data package). As displayed on the maps, (Figure 2. 1982 GPS Map VIII-A, Unconfined Aquifer TDS Map.) the band of highest TDS concentrations is along the western basin margin, and concentrations decrease toward the basin interior.

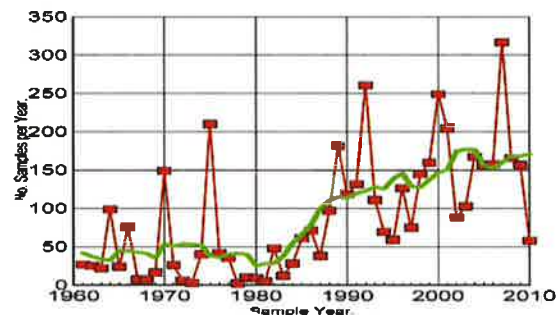
The distribution of TDS concentrations is consistent with the theory that the saline waters are derived from sources to the west and get progressively diluted and ion- exchanged as they progressively mix with Sierra- Nevada derived waters in the basin interior to the east. This band of high- salinity and its associated basinward decrease in salinity can be followed for more than 60 miles along the western basin margin and is significantly more widespread than just the western edge of the water district.

The water district staff accepts the USGS theory that the naturally- occurring saline groundwater flows into the district from sources to the west, as does the DWR as reported in Bulletin 118-03, page 178. The district also accepts the findings of the referenced 1980 & 1982 Groundwater Pollutant Study Reports that there is an easterly gradient of decreasing groundwater TDS content under the general area of Buttonwillow Service Area. The district is not trying to advocate or to prove the theory, but the district groundwater chemistry data support both sets of findings.

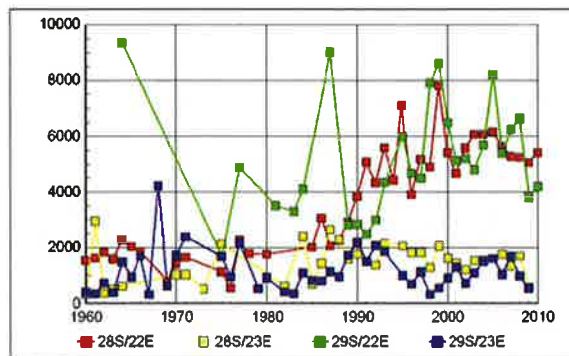
The water quality (EC) data from the BVWSD database are consistent with both the USGS theory of origin and the TDS constituent distributions mapped in the 1980s reports. Water chemistry data from water wells in the BSA corroborates the water quality trends which had previously been described by other workers. We analyzed water quality data from a four- township area centered on the BSA straddling 7th Standard Rd. (28s/22-23e, 29s/22-23e). The dataset includes 4,476 records, including 4,119 records of EC-only, 342 records of both EC and TDS, and 15 records of TDS- only, from 1,296 wells within the 144 sq.mi. area. Prior to the late- 1980s, there are insufficient data to illustrate the

temporal groundwater trends in individual wells. So we have calculated the average annual EC value for each year from 1960 to 2010 for a four township area, i.e., T28s/R22e, T28s/R23e, T29s/R22e, and T29s/R23e (Figure 3. EC in 4 Project- Area Townships, 1960 - 2010).

The 4- township dataset contains a total of about 40 EC records per year for the period from 1960 - 1980. The number of EC measurements per year increased throughout the 1980s and for the period from 1990 to 2010 the dataset contains an average of almost 150 EC measurements per year (Figure 1).

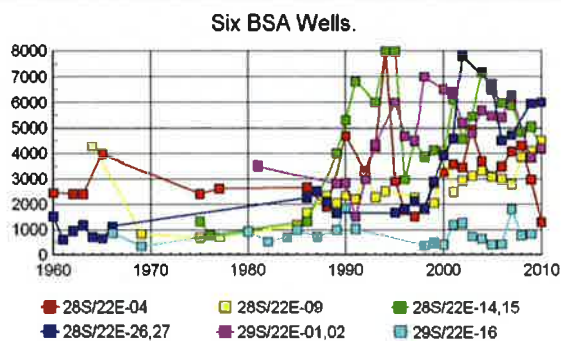


The average groundwater ECs in the two easterly townships (T28s/R23e and T29s/R23e) are approximately constant for the 50-year period from 1960 to 2010 at 1,450 uS/cm and 1,170 uS/cm, respectively, equivalent to an average TDS of 928 mg/l and 748 mg/l, respectively.



The average groundwater ECs in the two westerly townships (T28s/R22e and T29s/R22e) are significantly higher and show increases in EC over time. In township T28s/R22e, the average EC from 1960 to 1989 is 1,820 uS/cm (1,164 mg/l TDS) and the average EC from 1990 to 2010 is an average 5,373 uS/cm (3,439 mg/l TDS). In this township, most of the increase in EC occurs during the last half of the 1980s. In township T29s/R22e, the average EC from 1960 to 1989 is 4,829 uS/cm (3,091 mg/l TDS) and the average EC from 1990 to 2010 is 5,308 uS/cm (3,397 mg/l TDS). In this township, most of the increase in EC appears to occur from the early 1980s to the early 1990s. Based on these data, we conclude that the EC and TDS data demonstrate that the area between the West Side Canal and the Main Drain Canal near- and to the north of- the latitude of 7th Standard Rd is underlain by saline groundwater which interfaces with fresher groundwater to the east. Based on the existing data, the groundwater salinity between the canals is estimated to be in the range of 2,560 to 6,400 mg/l TDS content

The composite, average groundwater EC in both westerly townships exhibits considerable fluctuation over time. For the 30-year period from 1960 to 1989, the two westerly townships (T28s/R22e and T29s/R22e) had no recorded EC analyses anywhere in each township in 10 and 22 different years, respectively. The temporal sparseness makes it difficult to determine the significance or presence of trends in the data (Figure 4. EC v. Time Plots for 6 Wells, 1960 - 2010.)



The low spatial data density makes it difficult to map the lateral boundary (i.e., the interface) between the fresh and brackish waters under the district. Regardless of whether we define the boundary between fresh and brackish water as 1,000 or 1,500 mg/l, we have insufficient data to identify the exact location of the interface between the fresh and brackish waters under the district more precisely than somewhat east of the main drain. The groundwater chemistry data are insufficient to determine whether or not the interface is migrating over time.

The available water quality data are also insufficient at this time to prove that saline groundwater is flowing into the district from sources to the west. However, historical trends in irrigation practices suggest that the water quality west of the main drain has, in fact, degraded over time. It is reported that:

The local pumpers have documented, by progressive replacement of their wells from west to the east, the degradation [sic] water quality over time on the west side of the BSA.²⁸

To the farmers in the water district, the abandonment and replacement of water wells due to the degradation of water quality over time is an expensive hardship which lessens the value of their land, increases their cost of water, and may require fallowing the land. Twenty years ago, more or less, when this was happening, no one in the water district felt that it was necessary to document, by way of water sampling, what was happening in the groundwater that was causing the farmers to relocate or abandon their irrigation wells, and/or fallowing their ground. Therefore, what the water district claims is not that we have the data which proves what was going on in the aquifer, but that whatever it was, the quality of the groundwater degraded to the point that the farmers in the western part of the district no longer used their wells and/or fallowed their ground. Today, one of the primary reasons that the water district has so little groundwater data along the west side of the district north of 7th Standard Rd is that so few wells exist in the area.

The theory that the saline groundwater under the BSA flows in from the west appears to contradict the observation that there is no observable groundwater gradient across the western BSA boundary. Both can't be true but the district does not currently have enough data to test the theories or resolve the issues, because the limited amount of available data just do not cover the entire boundary or all aquifer depths. The lack of observable saline groundwater migration within the district suggests that inflow may not occur continuously but only in short, infrequent, inflows, and perhaps only during the very wettest episodes of the climatic wet/dry cycle. During the rest of the time, the observable groundwater gradient may, in fact, be essentially zero. The district recognizes the source of saline water and the nature of the boundary flow on the west side as issues, among several others, for further study.

²⁸ Quote from Dan Bartel (GEI) Memorandum to Maurice Etchechury (BVWSD), dated 15 March, 2013.

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