APPENDIX H

HYDROLOGY – WATER QUALITY TECHNICAL STUDY REPORT

amec foster wheeler

HYDROLOGY AND WATER QUALITY IMPACTS ANALYSIS

Pixley Groundwater Banking Project
Tulare County, California

Hydrology and Water Quality

December 21, 2015
Project FR1416066A

This report was prepared by the staff of Amee Foster Wheeler Environment & Infrastructure, Inc., under the supervision of the Hydrogeologist whose seal and signature appear hereon.

The findings, recommendations, specifications, or professional opinions presented inthis report were prepared in accordance with generally accepted professional engineering and/or geologic practice and within the scope of the project. No other warranty, express or implied, is provided.

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David M. Bean, PG, CHg
Principal Hydrogeologist

PROFESSIONAL GEOLOGIST
David M. Bean
No. HG-606
CERTIFIED HYDROGEOLOGIST
STATE OF CALIFORNIA

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Pixley Groundwater Banking Project
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ABBREVIATIONS

(AF)	Acre-Feet
(AF/D)	Acre-Feet per Day
(AF/Y)	Acre-Feet per Year
(BGS)	Below Ground Surface
(CEQA)	California Environmental Quality Act
(CFS)	Cubic Feet per Second
(CVP)	Central Valley Project
(DWR)	California Department of Water Resources
(EPA)	United States Environmental Protection Agency
(FKC)	Friant-Kern Canal
(MNW)	MODFLOW Multi-Node Well Package
(SVWBA)	South Valley Water Banking Authority
(SWPPP)	Stormwater Pollution Prevention Plan
(SWRCB)	State Water Resources Control Board
(TDS)	Total dissolved solids
(USBR)	United States Bureau of Reclamation

1.1 INTRODUCTION AND OBJECTIVES

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler), has prepared this report on behalf of the Project Proponent South Valley Water Banking Authority (SVWBA), to assess the impacts to hydrology and water quality conditions for the proposed Pixley Groundwater Banking Project in southern Tulare County, California (Figure 1).

The SVWBA, as the lead agency at the local level, is preparing a document pursuant to California Environmental Quality Act (CEQA) to examine the environmental impacts of the construction and operation/maintenance of the Pixley Groundwater Banking Project, which would include the following primary structures/features:

1. An approximately 532-acre (surface area) Recharge Basin facility capable of the direct recharge of approximately 45,000 acre-feet per year (af/y). Basin will be excavated approximately 4 to 5 feet below adjacent grade and surrounded by a 1 to 2-foot berm built up from surrounding grade. This will allow the capture of up to 4 to 5 feet of water.

2. A well field of 11 recovery wells located within the Recharge Basins boundary with the capability to recover approximately 25,400 acre-feet of water over an 8-month period;

3. A new 48-inch turnout from the west bank of the Friant-Kern Canal (FKC);

4. A 4.5-mile long, 48-inch diameter, bi-directional, concrete pipeline to convey water via gravity delivery from the new FKC turnout to the in-lieu service area and Recharge Basins. This main pipeline will also support recovery of water from the recovery wells and convey that water back to the FKC.

5. A pumping plant and regulating basin area with associated electrical and control facilities to boost water from the recovery wells east to the FKC to meet scheduled irrigation deliveries of Central Valley Project (CVP) contractors and others within the Deer Creek, White River, Poso Creek, and Kern checks of the FKC.

6. Grower turnouts, related control facilities, connecting pipelines, and up to five groundwater recovery wells within a 3,539 acre in-lieu service area. The in-lieu service area has an effective recharge capacity of up to approximately 6,500 af/y. The five wells would have a potential to recover approximately 8,500 acre-feet of water over an 8-month period to be returned to the FKC.

7. A new 48-inch turnout to be built as an extension of the existing Harris Ditch Turnout on Deer Creek. This new turnout structure from Deer Creek will allow water to be diverted from Deer Creek into the Recharge Basins for direct recharge.

8. The creation of a Monitoring Committee comprised of neighboring landowners and others interested in the Bank's operations as part of this Project. It will monitor the Bank's operations and the changes to groundwater conditions created by the Bank

and will recommend immediate steps that shall be taken should anything regarding Bank operations rise to a level of concern, including but not limited to:

a. Reduce the volume of water being pumped by the Project when the neighbors' wells are running;

b. Rotate which wells in the well field are running to spatially move the cones of depression to avoid pumping close to neighbors' wells that may be running.

c. Move the season of extraction to a time of year when the neighbors' wells are not running.

This environmental compliance document will also examine the environmental effects of approval of a program of groundwater banking and recovery including necessary contracts and supporting actions to provide the ability to place into groundwater storage up to 30,000 af/y of water. Ten percent of the water placed into storage would not be returnable and left to improve groundwater conditions in the area. Up to 90,000 acre-feet of water could be stored at any one time. Up to 30,000 acre-feet of water could be returned to banking partners in any one year.

Potential banking partners include Friant Division CVP contractors, Reclamation, CVP contractors within the Cross Valley, Delta-Mendota, San Luis Unit and Exchange Contractor service areas, the Kern County Water Agency and/or its member units, the Dudley Ridge Water District, the Tulare Lake Basin Water Storage District, and other water agencies, entities or individuals within the Friant Division of the CVP.

Pixley Irrigation District also intends to use the proposed facilities to deliver irrigation water from the FKC or from Deer Creek to the new service area (the in-lieu service area) and to direct recharge via the Recharge Basins at times when the proposed facilities are not obligated for use by banking partners.

2.0 LOCATION AND PHYSIOGRAPHY

The proposed Project is located within the Central Valley physiographic province of California. The Central Valley can be divided into the northern San Joaquin Basin that drains into the Sacramento Delta and the southern Tulare Basin, which is hydrologically closed. The proposed Project is located within Tulare Lake Hydrologic Region, within the Tule Groundwater Sub-Basin number 5-22.13 (Tule Basin) as defined by California Department of Water Resources (DWR) Bulletin 118 (DWR, 2003) (Figure 2). The Tule Basin comprises approximately 467,000 acres and is bordered by Kern County to the south, Tulare Lake to the west, Kaweah River to the north, and the foothills to the east. There are three major surface watersheds located within the boundary of the Tule Groundwater Basin: Tule River, Deer Creek, and White River.

3.0 CLIMATE AND PRECIPITATION

The climate of the proposed Project is semi-arid with mild winters and hot, dry summers and is classified as a Mediterranean steppe climate (Köppen climate classification). The average rainfall received in the proposed Project is approximately 10.4 inches per year (Figure 3) (PRISM, 2014). The eastern edge of the Tule Basin along the foothills experiences higher amounts of rainfall, while the western edge of the Tule Basin is typically more arid and dry. Precipitation primarily occurs from November to March. From May through November, the area generally experiences dry summers where almost no rain occurs. A summary of the 1980-2010, 30-year average monthly temperatures and precipitation in the proposed Project are shown on Figure 3.

4.0 SURFACE WATER HYDROLOGY

There are only two surface waters of significance near the proposed Project: Deer Creek and the CVP FKC (Figure 4). Deer Creek is an intermittent stream extending from the Greenhorn Mountains in the Sierra Nevada and terminating in the Lakeland and Homeland Canals near the Tulare/Kings County border. Prior to diversion for agricultural purposes, Deer Creek ran into the former Tulare Lake bed. The United States Geological Survey operates a gauging station (#11200800) on Deer Creek near Fountain Springs where Deer Creek descends onto the valley floor. A chart of monthly Deer Creek flows from 1968 to present shows that Deer Creek has significant seasonal variability (Figure 5). Peak flows from 40 to 70 cubic feet per second (cfs) typically occur from January through May (Figure 5). The long-term average monthly discharge of Deer Creek is about 30 cfs (60.5 acre-feet per month [af/m]).

The CVP FKC passes within one mile of the eastern edge of the proposed Project (Figure 4). The FKC is operated and maintained by the Friant Water Authority and is used to convey water from the San Joaquin River to Kern County. The canal originates at the Friant Dam, which is operated by the United States Bureau of Reclamation. The FKC flows southeasterly along the western flank of the Sierra Nevada foothills through Fresno, Tulare, and Kern Counties. The FKC has a capacity of approximately 5,300 cfs (10,510 af/d), which decreases to about 2,500 cfs (4,959 af/d) as demand decreases toward its end in the Kern River, near Bakersfield, California.

5.0 SURFACE WATER QUALITY

Surface water quality in the Tulare Lake Basin is generally good, with excellent quality exhibited by most eastside streams (RWQCB, 2004). Common water quality issues are a result of runoff from direct discharge from industrial and commercial activities, resource withdrawal, leaking sewer infrastructure, and illicit dumping during wet weather conditions. Further potential sources of polluted water within the county include past waste disposal practices, agricultural chemicals, and fertilizers applied to landscaping. Characteristic water pollutant contaminants include: sediments, hydrocarbons and metals, pesticides, nutrients, bacteria, and trash.

Irrigated agriculture accounts for most water used in the Tulare Lake Basin. Agricultural drainage, depending on management and location, carries varying amounts of salts, nutrients, pesticides, trace elements, sediments, and other by-products to surface and ground waters (RWQCB, 2004).

The State Water Resources Control Board (SWRCB), in compliance with the Clean Water Act, Section 303(d) (RWQCB, 2011), prepared a list of impaired water bodies in the State of California. The list was approved by the U.S. Environmental Protection Agency (EPA) in 2011. Deer Creek is listed as a Category 5 water body, impaired by an unknown toxicity (303(d) 2011) (RWQCB, 2011). Category 5 criteria indicate a water segment where standards are not met and a Total Maximum Daily Load is required, but not yet completed (RWQCB, 2011).

The water from the San Joaquin River that is delivered via the FKC is considered of excellent quality. The U.S. Bureau of Reclamation (USBR) maintains guidelines for the quality of any water to be introduced into the FKC that doesn't originate from the San Joaquin River (USBR, 2008). These guidelines specify that any water introduced into the FKC must meet Title 22 State drinking water quality standards (the Domestic Water Quality and Monitoring Regulations specified by the State of California, Health and Safety Code (Sections 4010-4037), and Administrative Code (Sections 64401 et seq.), as amended). There is allowance in the guidelines for the introduction of water that may exceed these standards for certain constituents (typically inorganic constituents) but they do not allow any impairment that rises to the level of limiting any beneficial use of the water in the FKC.

6.0 GROUNDWATER HYDROLOGY

The sediments that comprise the Tule Basin's aquifer are continental deposits of Tertiary and Quaternary age (Pliocene to Holocene). These deposits include flood-basin deposits, younger alluvium, older alluvium, the Tulare Formation, and undifferentiated continental deposits.

The flood-basin deposits consist of relatively impermeable silt and clay interbedded with some moderately to poorly permeable sand layers that interfinger with the younger alluvium. These deposits are likely not important as a source of water to wells, but may yield sufficient supplies for domestic and stock use.

The younger alluvium is a complex of interstratified and discontinuous beds of unsorted to fairly well sorted clay, silt, sand, and gravel, comprising the materials beneath the alluvial fans in the valley and stream channels. Where saturated, the younger alluvium is very permeable. However, this unit is largely unsaturated and likely not important as a source of water to wells. The older alluvium consists of poorly sorted deposits of clay, silt, sand, and gravel. This unit is moderately to highly permeable and is a major source of water to wells.

The Tulare Formation is composed of poorly sorted deposits of clay, silt, sand, and gravel the origin of which is the Coast Ranges (DWR, 2003). The Tulare Formation contains the Corcoran Clay Member, the major confining bed in the Tule Basin. The formation is moderately to highly permeable and yields moderate to large quantities of water to wells (DWR, 2003). Approximately two miles southwest of the proposed Project area the Corcoran Clay occurs between depths of 200 to 300 feet below ground surface (bgs) (Figure 6). The undifferentiated continental deposits contain poorly sorted lenticular deposits of clay, silt, sand, and gravel derived from the Sierra Nevada (DWR, 2003). The unit is moderately to highly permeable and is a major source of ground water in the Tule Basin (DWR, 2003).

7.0 GROUNDWATER OCCURRENCE

The sediments described above comprise the regional aquifer system. Due to the abundance of lenses of fine-grained materials distributed throughout the Tule Basin, two aquifer systems have been developed. In a 1984 report, Poland and Lofgren define the aquifer in the Tule Basin as unconfined or confined based on the absence or presence of the Corcoran Clay (Poland and Lofgren, 1984). In parts of the Tule Basin, the Corcoran Clay separates aquifers with distinctly different water chemistries (USGS, 1959; USGS, 1989). Differences in hydraulic head and water chemistry above and below the Corcoran Clay support the hypothesis that the Corcoran Clay separates the aquifer system into unconfined or semi-confined zones (above the clay) and a confined zone (below the clay). However, in some areas of the Tule Basin, the fine-grained lenses have a combined thickness of several hundred feet. Also, many wells have been perforated above and below the Corcoran Clay, allowing flow through the well casings and gravel packs. In the vicinity of these wells, hydraulic head is equalized. In the eastern areas of the Tule Basin where the Corcoran Clay is absent, head differences between shallow and deeper wells result from restriction of vertical movement by intervening clay layers (USGS, 1989).

The heterogeneous composition of alluvial deposits exhibit classic examples of unconfined and confined aquifers (USGS, 1968). Aquifers in which the heads rises and falls with the water table are defined as unconfined. Aquifers which exhibit a rapid pressure response that do not equilibrate with the water table are defined as confined. Aquifers that respond to changes in pressure over short periods of time, but in which heads adjusts to equilibrium with the water table over long, low stress periods of time, are defined as be semi-confined (USGS, 1968). Beneath most of the proposed Project, the aquifer is unconfined or semi-confined by lenses of fine-grained material. Where the Corcoran Clay is present, the shallow overlying aquifer is unconfined or semi-confined while the aquifer beneath the Corcoran Clay is confined.

8.0 GROUNDWATER LEVELS

Groundwater levels near the proposed Project have been measured on a semi-annual basis by the DWR and cooperating agencies. Long-term hydrographs for wells in the vicinity of the proposed project show that groundwater levels have decreased as much as 100 feet since the 1940s (Figure 7). The regional groundwater decline was somewhat arrested by the availability of CVP water starting in the 1960s; however, CVP water is not available in the immediate vicinity of the proposed project. Groundwater levels continue to decrease in Pixley Irrigation District.

9.0 GROUNDWATER QUALITY

In the northern portion of the Tule Basin the water is characterized as calcium bicarbonate (USGS, 1968), while the southern portion of the Tule Basin is better characterized as sodium bicarbonate (USGS, 1963). Total dissolved solids (TDS) values typically range from 200 to 600 milligrams per liter (mg/L). TDS values of shallow groundwater in drainage problem areas are as high as 30,000 mg/L (USGS, 1995). The Department of Health Services, which monitors Title 22 water quality standards, reports TDS values in 65 wells ranging from 20 to 490 mg/L, with an average value of 256 mg/L.

The groundwater quality characteristics of the Deer Creek/White River Watershed vary from east to west. In general, water quality on the east side of the valley floor of the county in this area is characterized by diminished quality where nitrates, phenols, and salts are present in different concentrations and in different locals. On the westerly side of the Deer Creek/White River Watershed, groundwater quality again declines into unacceptable conditions. Principal among these conditions are elevated levels of arsenic and microsand (very fine sand entrained in the water) conditions (Tulare County, 2012).

10.0 GROUNDWATER IMPAIRMENTS

Over pumping of groundwater beneath the Corcoran Clay has resulted in historical land subsidence of 12 to 16 feet due to deep compaction of fine-grained units beneath portions of the Tule Basin (USGS, 1984). Between 2007 and 2011, continued overdraft pumping in the Tule basin has resulted in an additional 0.5 to 1 foot of subsidence in the Project area (LSCE, 2014).

The eastern side of the Tule Basin, including areas near the proposed Project location, have localized nitrate pollution, likely as a result of agricultural fertilizers.

11.0 WATER BALANCE

An overdraft for the Tulare Lake Basin is projected at 820,000 af/y (Tulare County, 2012). The Tule sub-basin has been identified and defined by Water Code §12924 as a basin in critical condition of overdraft. This designation indicates a basin where a continuation of present water management practices would likely result in significant adverse overdraft-related environmental, social, or economic impacts (DWR, 2003).

The estimated irrigation demand for the Delano-Earlimart Irrigation District is approximately 177,000 af/y. To meet agricultural demand, it is estimated that between 35,000 and 40,000 acre feet is pumped by private landowner wells (P&P, 2008). Pixley Irrigation District has a total irrigated demand of 157,600 af/y, while the District's total water sold to growers averages only 21,600 af/y. The 136,000 af/y deficit is assumed to be pumped from private groundwater wells.

12.0 FLOODING

Portions of the proposed project area are located within the 100-year flood plain of Deer Creek (Figure 8). The 100-year flood is defined as a flood flow that has a 1 percent chance of being equaled or exceeded in any given year (FEMA, 2009). 100-year flood zones are located throughout southern Tulare County from a number of waterways, including the White and Tule Rivers, Deer Creek, and the FKC (FEMA, 2009). A portion of the proposed project area is within the 100-year flood plain of Deer Creek. A turnout will be constructed as part of the Project that will allow water from Deer Creek to be routed into the recharge basins. Although not a Project purpose, some flood water can be diverted into the Recharge Basins providing an increment of additional protection for areas further down-stream from inundation.

13.0 PROPOSED PROJECT IMPACT

a. Would the project violate any water quality standards or waste discharge requirements?

Impact: The proposed Project could result in temporary adverse impacts to groundwater quality. (Less than significant)

Surface water applied to the recharge basins and in-lieu lands would be delivered via Deer Creek and the FKC. The water quality of these deliveries, because of their similar tributary origins, would be comparable to historic water qualities that have naturally recharged the underlying groundwater. Hence no long-term negative impact on groundwater quality would be expected.

However, residual concentrations of nitrates and other agricultural related chemicals (if present) could be mobilized beneath the recharge basins with initial water applications. This would result in short-term impacts to groundwater quality. Assuming a 20 foot thick zone of impacted soils, with soils possessing 15 percent void space, and 30,000 af/y of applied water, the 20 foot zone would be flushed more than 16 times in the first year of recharge, significantly diluting potential impacts to groundwater. Additionally water quality sampling before the Project, and continued sampling during the first year of operation, would quantify the impacts (if any) of any chemical concentrations and the effects of dilution by applied water.

Likewise, care should be taken when recharging the first runoff waters from Deer Creek each season. Allowing the initial flows of Deer Creek to continue past the proposed Project, until the water appears clear, before beginning recharge operations would mitigate the unwanted application of higher chemical concentrations (if present) and the introduction of silts that will likely reduce basin infiltration.

Samples of groundwater taken from existing wells in the area of the proposed Project were obtained and analyzed for quality constituents of concern and compared against Title 22 drinking water quality standards. Twelve wells in total were sampled. The results have been summarized in Table 1. There were two incidents of arsenic and one for lead that exceeded minimum concentration levels allowed by Title 22. All other constituents in all of the balance of the wells did not show any other chemicals exceeding maximum allowed concentration levels. Zone sampling of at least one well or test well should be performed before casing any of the Project wells. This will allow the well designer to blank-off the section of the casing (the groundwater layer) where arsenic is likely to be present (if any) in order to reduce the potential of having any arsenic in the extracted groundwater. Additionally, all of the well water being returned to the FKC will be mixed together before introduction into the FKC further reducing the potential that any water returned to the FKC will be of unacceptable water quality.

Table 1:
Summary of Lab Results –
Key Constituents

				Well Number											
Constituent	Units	Maximum Contaminant Level (MCL)	Secondary Standard	BP No. 2	BP No. 4	BP No. 5	BP No. 6	BP No. 7	BP No. 8	BP No. 11	BP No. 12	BP No. 14	BP No. 16	BP No. 17	BP No. 18
Aluminum	mg/L	1.0	0.20	0.01	ND	ND	0.02	0.01	0.05	0.15	0.02	0.03	0.02	0.02	0.02
Arsenic	ug/L	10	-	3	2	2	2	2	**13**	10	4	ND	5	5	3
Fluoride	mg/L	2.0	-	0	0	0	ND	ND	0.2	0.4	ND	ND	0.1	0.1	ND
Iron	ug/L	-	300	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead	ug/L	15	-	ND	ND	1	1	ND	3	3	ND	**21**	ND	2	ND
Manganese	ug/L	-	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate	mg/L	45	-	18	18	15	12	23	3	1	27	34	12	34	13
Sodium Absorption Ratio	-	-	-	2	1	1	2	1	7	16	3	1	3	2	3
Electrical Conductivity	umhos/cm	-	900 - 1,600	250	269	268	246	332	233	346	390	414	286	426	261
pH	units	-	-	8.2	8.1	8.0	8.2	8.1	9.3	9.2	8.4	8.0	8.9	8.3	8.7
Total Dissolved Solids	mg/L	-	500 - 1,100	150	160	170	140	200	130	200	210	260	170	280	160
DBCP	ug/L	0.20	-	ND	ND	ND	0.05	ND	ND	ND	ND	0.03	0.02	ND	ND
EDB	ug/L	0.05	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3 - Trichloropropane	ug/L		-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Gross Alpha	pCi/L	15	-	0	0	2	0	3	0	2	0	3	1	4	1

Mitigation Measure:

WAT-1: Zone sampling will be performed on test wells or during initial well construction (prior to any water being discharged into/returned to the Friant Kern Canal). The results of the sampling shall be used in well design. Dilution or other industry-accepted remediation methods shall be employed as needed and appropriate to reduce any unacceptable levels of constituents of concern to below Title 22-allowed minimum concentration levels before the Project begins returning water to the FKC. Continued sampling in accordance with the USBR *Policy for Accepting Non-Project Water into the Friant-Kern and Madera Canals, Water Quality Monitoring Requirements, 2008* (or as amended) shall also be performed with necessary remediation of unacceptable constituents of concerns or other mitigation measures employed immediately. These measures will allow adverse impacts to FKC water quality from the Project to be avoided.

This impact would be less than significant with mitigation.

b. Would the Project substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level?

Impact: The proposed Project would have short-term impacts to groundwater levels during recharge and recovery operations. (Less than Significant)

The proposed Project would begin a program of long-term groundwater banking where up to 30,000 af/y of surface water is recharged to groundwater. The Project would provide opportunities for partners to bank water during wet years and recover water in normal and dry years. The proposed Project would operate on a 10 percent “leave behind” fraction, where water recovered would not exceed more than 90 percent of the previously recharged water; thus creating a minimum net benefit of at least 10 percent of the banked groundwater. As a result of the proposed Project the groundwater levels would increase in and around the proposed Project, as compared to conditions remaining unchanged and the Project not existing. Therefore the proposed Project would not substantially deplete groundwater supplies, interfere with groundwater recharge, or result in a net deficit to groundwater levels.

A computer model was constructed to simulate baseline conditions without the Project, and showed a probable continual decline in water level elevations under existing conditions (Appendix A). Additionally, a scenario was generated in which the impacts of the proposed water banking Project were simulated. The simulation results indicate that the Project will result in a net benefit (increased aquifer storage and higher groundwater elevations) at the end of the 40 year simulation period compared to the Baseline simulation (Appendix A).

Short-term impacts to groundwater levels and other land-owner well operations are likely to result from the localized draw-down effects of the Project recovery wells operating simultaneously. The modeling evaluated potential impacts of recovery pumping (at maximum rates) when volumes of water stored in the Project were partially depleted, but yet substantial enough to continue to allow water to be withdrawn from the Bank. The proposed Project recovery impacts consist of an additional 30-40 feet of pumping lift to wells on neighboring lands immediately bordering the recovery well field (Appendix A). The modeling also evaluated the potential water level impacts within and immediately surrounding the proposed recovery wells using MODFLOW’s Multi-Node Well Package (MNW). The MNW Package allows for calculations, using the Theim flow equation, of additional head changes due to partial penetration effects, flow into a borehole through a seepage face, changes in well discharge related to changes in lift for a given pump, and intra-borehole flows with a pump intake located at any specified depth within the well (Harbaugh, 2005). The 30-40 feet of pumping lift calculated by MODFLOW represents the average head (or drawdown) within the 40-acre model cell. The head (or drawdown) within each recovery well calculated using the MNW Package indicates as much as 116 feet of drawdown within the recovery well itself due to well inefficiencies. However, the lateral extent of the recovery well drawdown is limited to the area immediately surrounding the well; the cell average head (or drawdown) is more representative of the conditions that neighbors to the project will experience (Appendix A).

The Project also includes the creation of a Monitoring Committee comprised of neighboring landowners and others interested in the Bank's short and long-term operations. The Committee will monitor the Bank's operations and the changes to groundwater conditions created by the Bank and will recommend immediate steps that shall be taken should anything regarding Bank operations-- including depth to groundwater, well interference (if any) and groundwater quality, rise to a level of concern. The Monitoring Committee will notify the SVWBA immediately of any effects taking place that have the potential to or that are adversely affecting any property owner well operations and will recommend immediate steps needed to be taken to minimize these effects to less than significant, including but not necessarily limited to the following:

a. Reduce the volume of water being pumped by the Project when the neighbors' wells are running;

b. Rotate which wells in the well field are running to spatially move the cones of depression to avoid pumping close to neighbors' wells that may be running.

c. Move the season of extraction to a time of year when the neighbors' wells are not running.

Mitigation Measure: No Mitigation is required.

c. Would the Project substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on-or off-site?

Impact: The proposed Project would not significantly alter the existing drainage pattern of the site in a manner which would result in substantial erosion or siltation on or off site. (Less than Significant)

The proposed Project would construct 4 to 5 foot deep recharge basins with 1 to 2 foot tall berms over an approximate 532 acre area. The construction of the basins would alter the existing drainage pattern and could increase the rate of erosion at the site during construction.

Erosion and sediment control measures, if properly prescribed, implemented, and maintained, including a Stormwater Pollution Prevention Plan (SWPPP) in accordance with the Clean Water Act are expected to reduce erosion rates during and after construction to less than significant levels.

Mitigation Measure: No Mitigation is required.

d. Would the Project substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the amount of surface runoff in a manner which would result in flooding on-or off-site?

Impact: Outside of typical groundwater banking operations, the proposed Project would not significantly alter the site's existing drainage pattern in a manner which would result in flooding on or off-site. (Less than Significant with Mitigation)

The proposed Project would construct 4 to 5 foot deep recharge basins with 1 to 2-foot tall berms over an approximate 532 acre area. Unregulated water from Deer Creek, when available and acceptable, will be captured and recharged to basins. The capture of this water will temporally divert water from Deer Creek without permanently altering the course of the creek. The impacts of surface runoff to result in flooding on or off site are less than significant.

Portions of the proposed Project area, including portions of the recharge basins, fall within a 100-year flood zone. The 100-year flood is defined as a flood flow that has a 1 percent chance of being equaled or exceeded in any given year (FEMA, 2009). Special consideration should be taken in the engineering and construction of the berms such that the recharge basins are constructed in a way to capture flows to the extent that the basins are capable, thereby reducing inundation off-site, and in a manner that protect the berms from failure from a 100-year flood.

Mitigation Measure:

WAT-2: Special engineering consideration shall be incorporated in the design of the berms to protect the recharge basins from 100-year flood related failure.

This impact would be less than significant with mitigation.

e. Would the Project create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?

Impact: The Project will not create of contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff. (Less than Significant)

The Project would capture and recharge surface water up to 30,000 af/y. Additionally, rain that falls within the proposed recharge basins will be captured and recharged to groundwater. The capture of unregulated water to Deer Creek, and capture of direct rainfall will produce a net reduction in runoff water as a result of the proposed Project. The basins will be constructed using materials, including existing topsoil, which will not provide substantial additional sources of polluted runoff. Therefore, the impacts of the Project are considered less than significant.

Mitigation Measure: No Mitigation is required.

f. Would the Project Otherwise substantially degrade water quality?

Impact: The proposed Project would not substantially degrade water quality. (Less than significant with Mitigation.)

Surface water applied to the recharge basins and in-lieu lands would be delivered via Deer Creek and the FKC. The water quality of these deliveries, because of their similar tributary origins, would be comparable to historic water qualities that have naturally recharged the underlying groundwater.

Mitigation Measure:

See WAT-1. This impact would be less than significant after mitigation.

Impacts of the Project to substantially degrade water quality are considered less than significant.

Mitigation Measure: No Mitigation is required.

g. Would the Project place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?

Impact: None.

The proposed Project will not place or construct any housing.

Mitigation Measure: No Mitigation is required.

h. Place within a 100-year flood hazard area structures which would impede or redirect flood flows?

Impact: The proposed Project would construct recharge basins within a 100-year flood hazard area which would redirect flood flows. (Less than Significant with Mitigation)

Portions of the proposed Project area, including portions of the recharge basins, fall within a 100-year flood zone. The 100-year flood is defined as a flood flow that has a 1 percent chance of being equaled or exceeded in any given year (FEMA, 2009). Recharge basins, which consist of 3 to 4 foot deep excavations with 1 to 2-foot tall berms, will be constructed. These structures would be constructed for the purpose of capturing surface water deliveries. The redirection of flood flows into the basins would reduce downstream inundation. Special consideration should be taken in the engineering and construction of the berms such that the recharge basins are constructed to capture flows to the extent that the basins are capable, and in a manner that protect the berms from failure from a 100-year flood.

Mitigation Measure:

See WAT-2. This impact would be less than significant after mitigation.

i. Would the Project expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?

Impact: The proposed Project would not expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result or the failure of a levee or dam. (Less than significant)

According to a dam failure inundation map of Tulare County, prepared by the Tulare County Office of Emergency Services, the Project site is not located within an inundation area (Tulare County, 2011). As such the Project would not expose people or structures to a significant risk of loss, injury or death involving flooding. Furthermore, water levels within the excavated recharge ponds will be kept at or below grade, reducing the potential for flooding.

Mitigation Measure: No Mitigation is required.

j) Would the Project expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of involving inundation by seiche, tsunami, or mudflow?

Impact: The proposed Project would not expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result or the failure of inundation by seiche, tsunami, or mudflow. (Less than significant)

The proposed Project area is located on nearly flat topography, with no nearby bodies of water, and is separated from the Pacific Ocean by the Coast Range and approximately 100 miles. Therefore, inundation by seiche, tsunami, or mudflow are not significant hazards to the site.

Mitigation Measure: No Mitigation is required.

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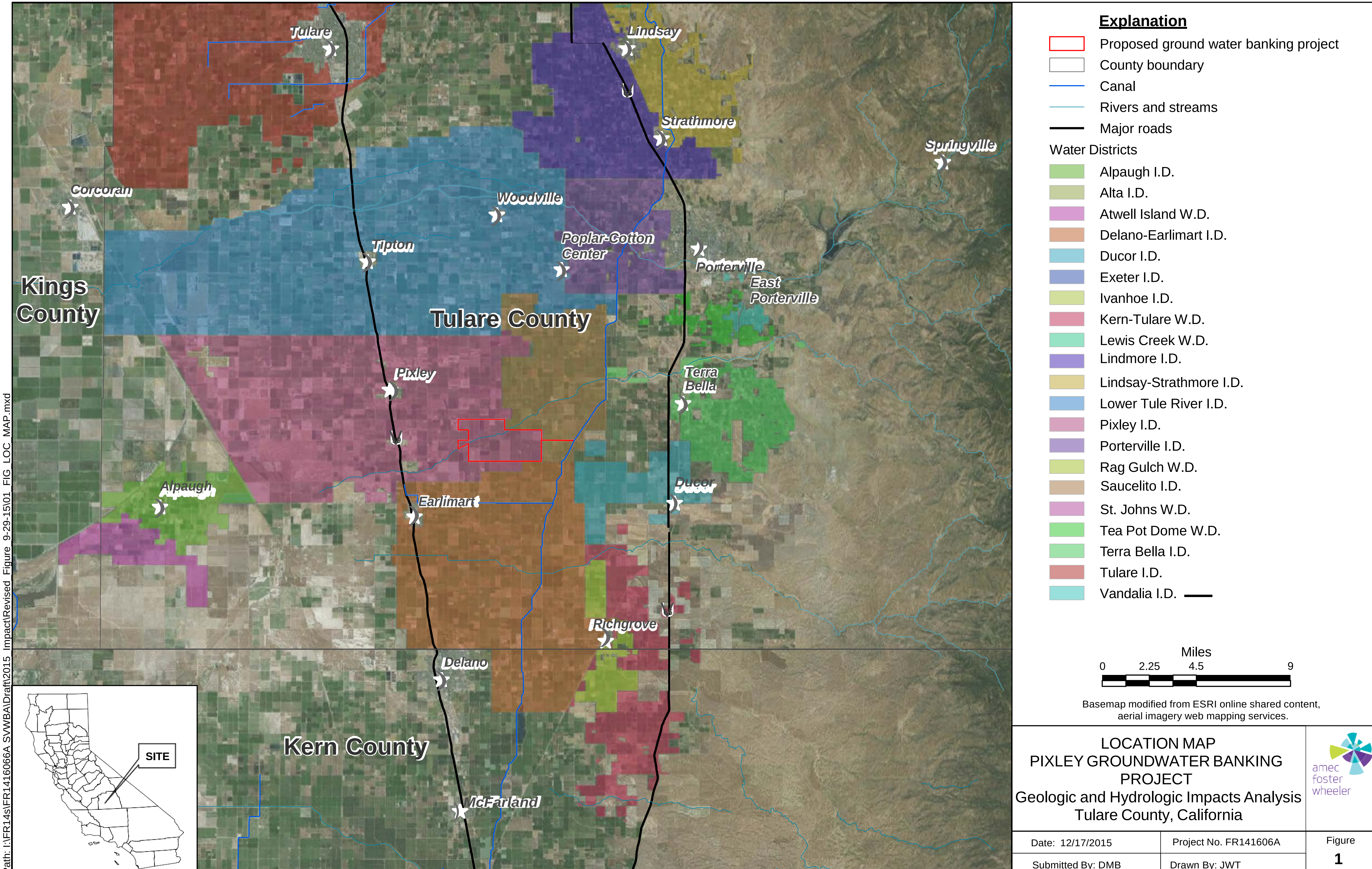
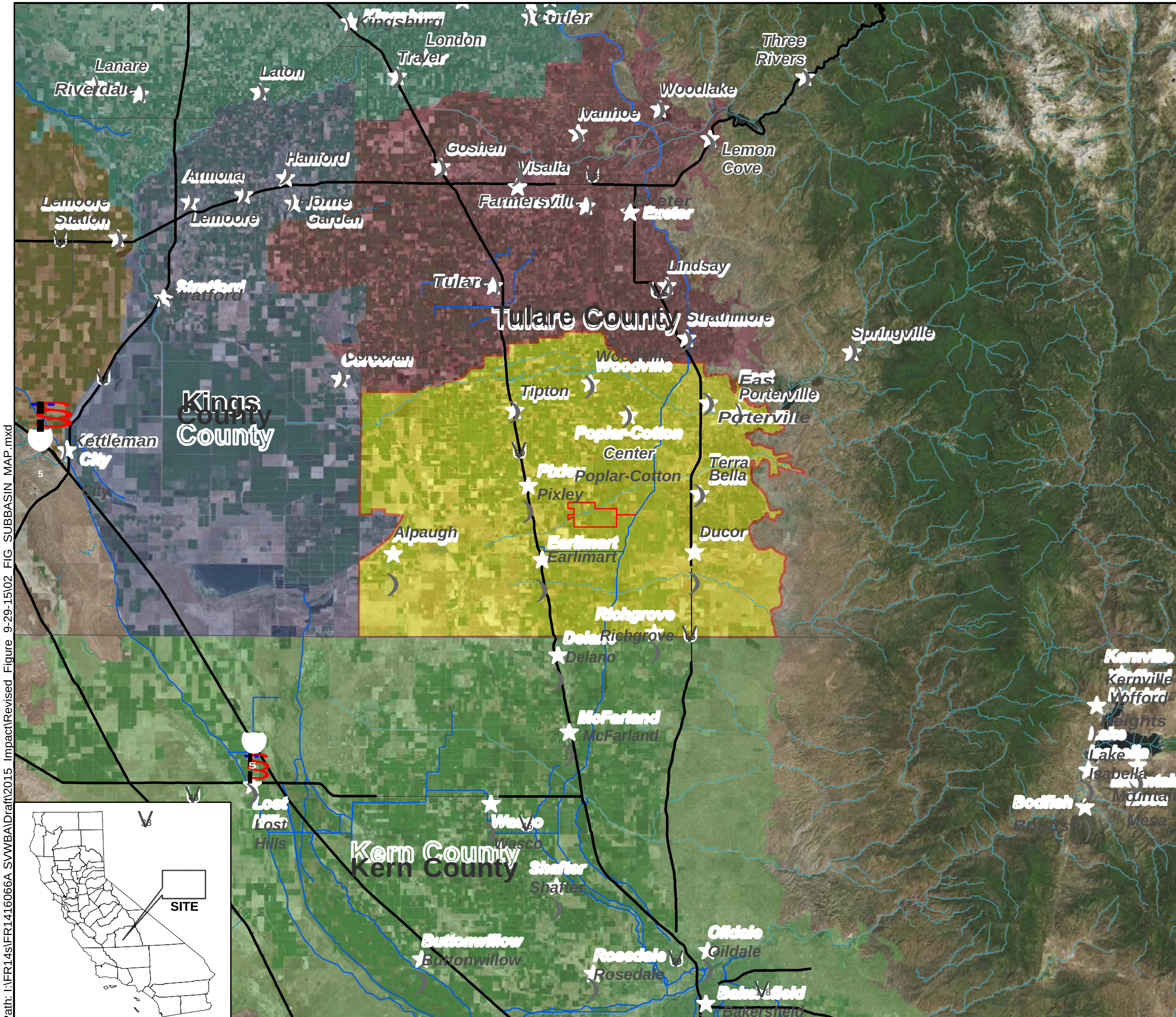


LOCATION MAP
PIXLEY GROUNDWATER BANKING PROJECT
Geologic and Hydrologic Impacts Analysis
Tulare County, California

amec foster wheeler

Date: 12/17/2015	Project No. FR141606A	Figure
Submitted By: DMB	Drawn By: JWT	1

Path: I:\FR14s\FR1416066A SVWBA\Draft\2015 Impact\Revised Figure 9-29-15\01 FIG LOC MAP.mxd



Explanation

- Proposed ground water banking project
- County boundary
- Major roads
- Canal
- Rivers and streams
- Kaweah 5-22.11
- Kern County 5-22.14
- Kings 5-22.08
- Tulare Lake 5-22.12
- Tule 5-22.13
- Westside 5-22.09

Basemap modified from ESRI online shared content, aerial imagery web mapping services.

SUBBASIN MAP
PIXLEY GROUNDWATER BANKING PROJECT
Geologic and Hydrologic Impacts Analysis
Tulare County, California

amec foster wheeler

Date: 12/17/2015

Project No.

Submitted By: DMB

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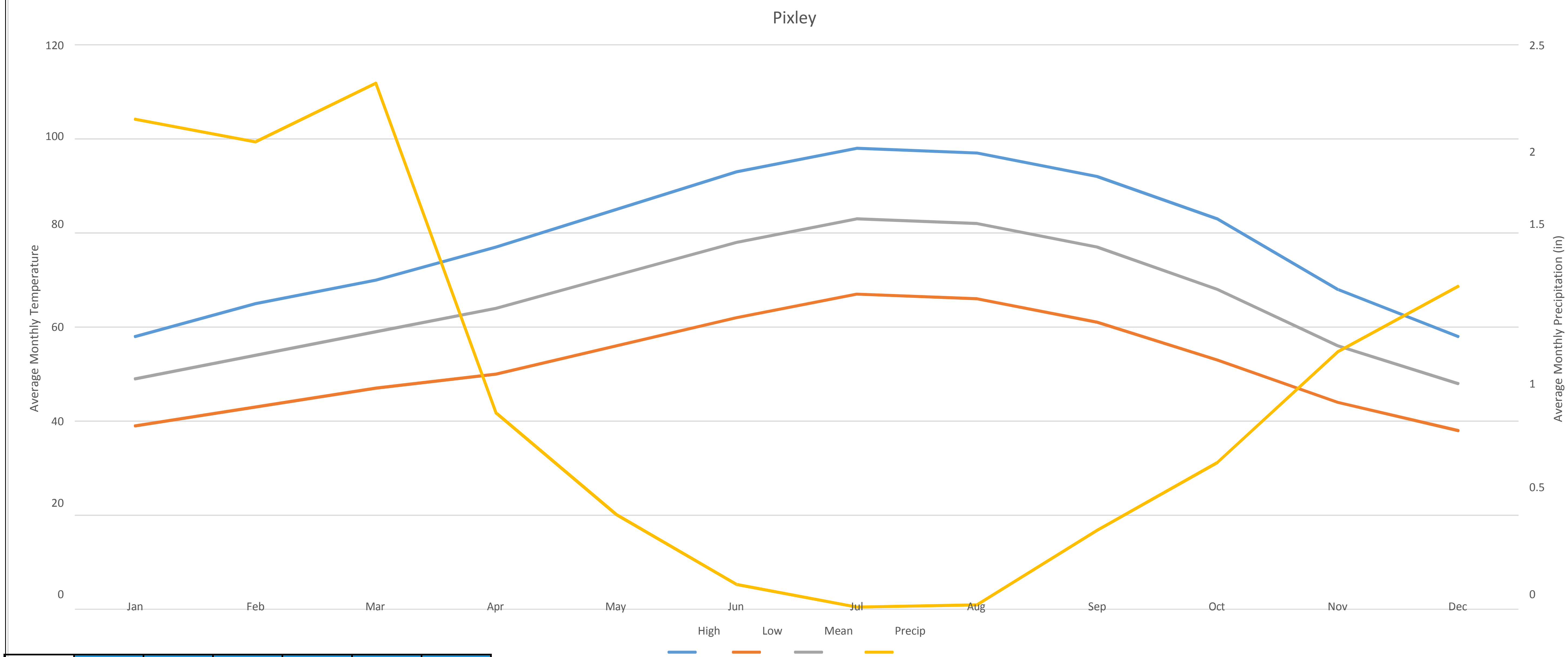
FR141606A Drawn By: JWT

Figure
2



	High	Low	Mean	Precip	Record High	Record Low
Jan	58	39	49	2.17	79 (1986)	19 (1950)
Feb	65	43	54	2.07	85 (1989)	23 (1989)
Mar	70	47	59	2.33	91 (2004)	28 (1971)
Apr	77	50	64	0.87	99 (1981)	29 (1953)
May	85	56	71	0.42	109 (1984)	37 (1975)
Jun	93	62	78	0.11	112 (1976)	30 (1971)
Jul	98	67	83	0.01	113 (1972)	48 (1955)
Aug	97	66	82	0.02	112 (1996)	46 (1968)
Sep	92	61	77	0.35	109 (1950)	37 (1968)
Oct	83	53	68	0.65	103 (1996)	33 (2003)
Nov	68	44	56	1.14	89 (1966)	27 (1993)
Dec	58	38	48	1.43	80 (1981)	16 (1990)
Total				11.57		

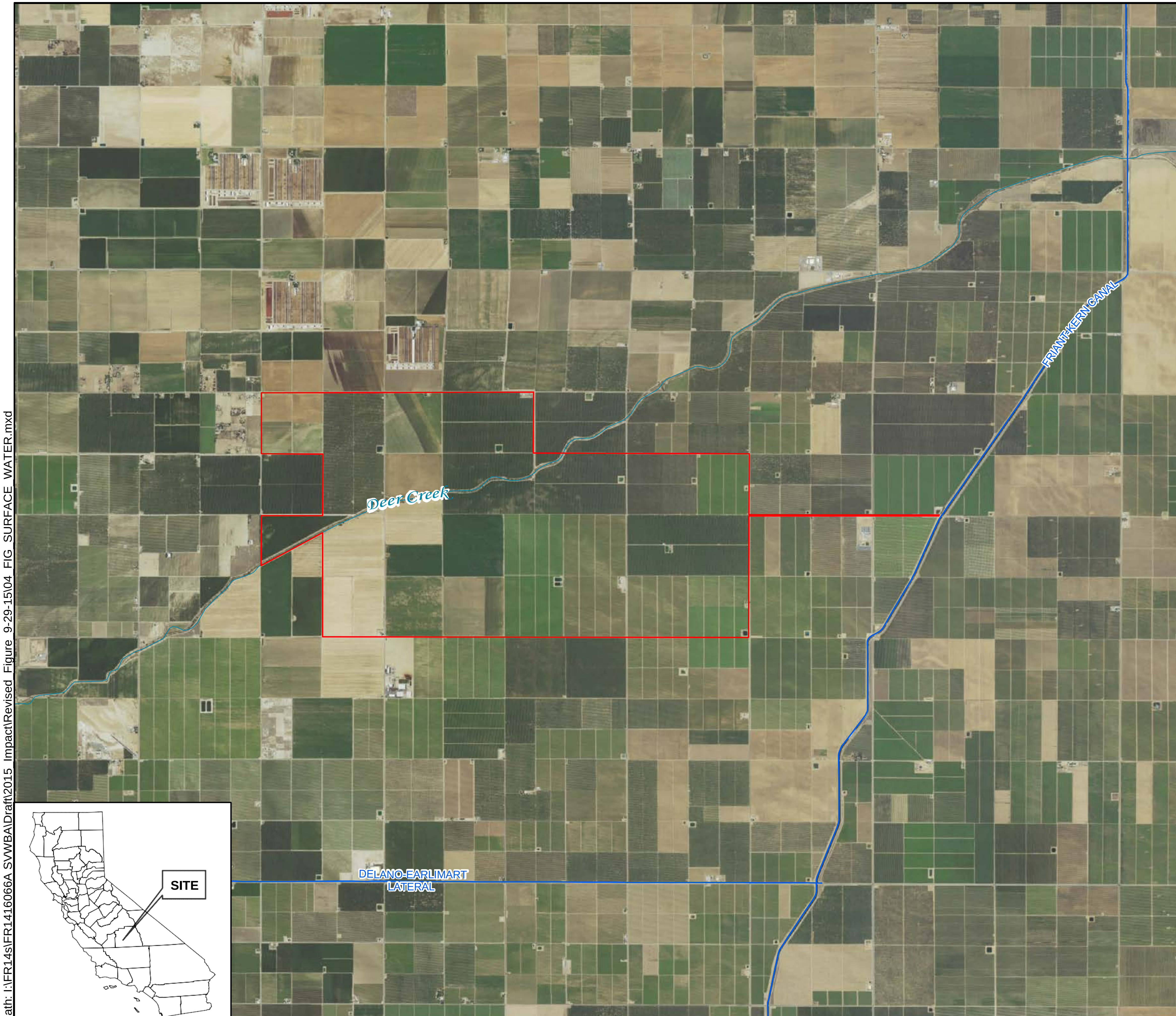
MONTHLY TEMPERATURE AND PRECIPITATION

30 Year Average
Geologic and Hydrologic Impacts Analysis
Tulare County, California

amec foster wheeler

Date: 09/29/2015 | Project No.: FR141606A | Prepared By: JWT

Figure 3



Explanation

Proposed ground water banking project
Canal
Rivers and streams

Miles
0 0.5 1 2

Basemap modified from ESRI online shared content, aerial imagery web mapping services.

SURFACE WATER
PIXLEY GROUNDWATER BANKING PROJECT
Geologic and Hydrologic Impacts Analysis
Tulare County, California

amec foster wheeler

Date: 12/17/2015	Project No. FR141606A	Figure
Submitted By: DMB	Drawn By: JWT	4

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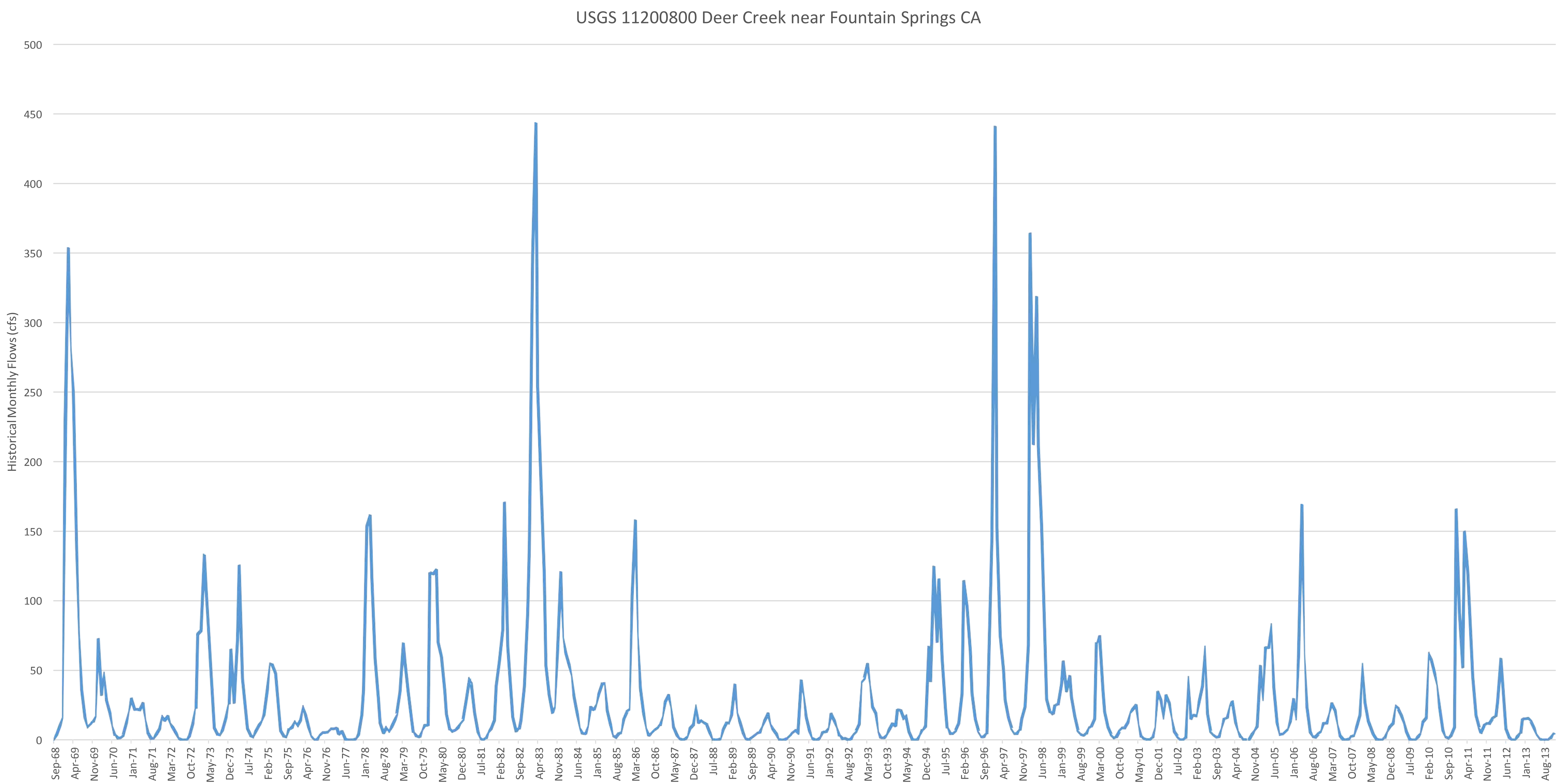
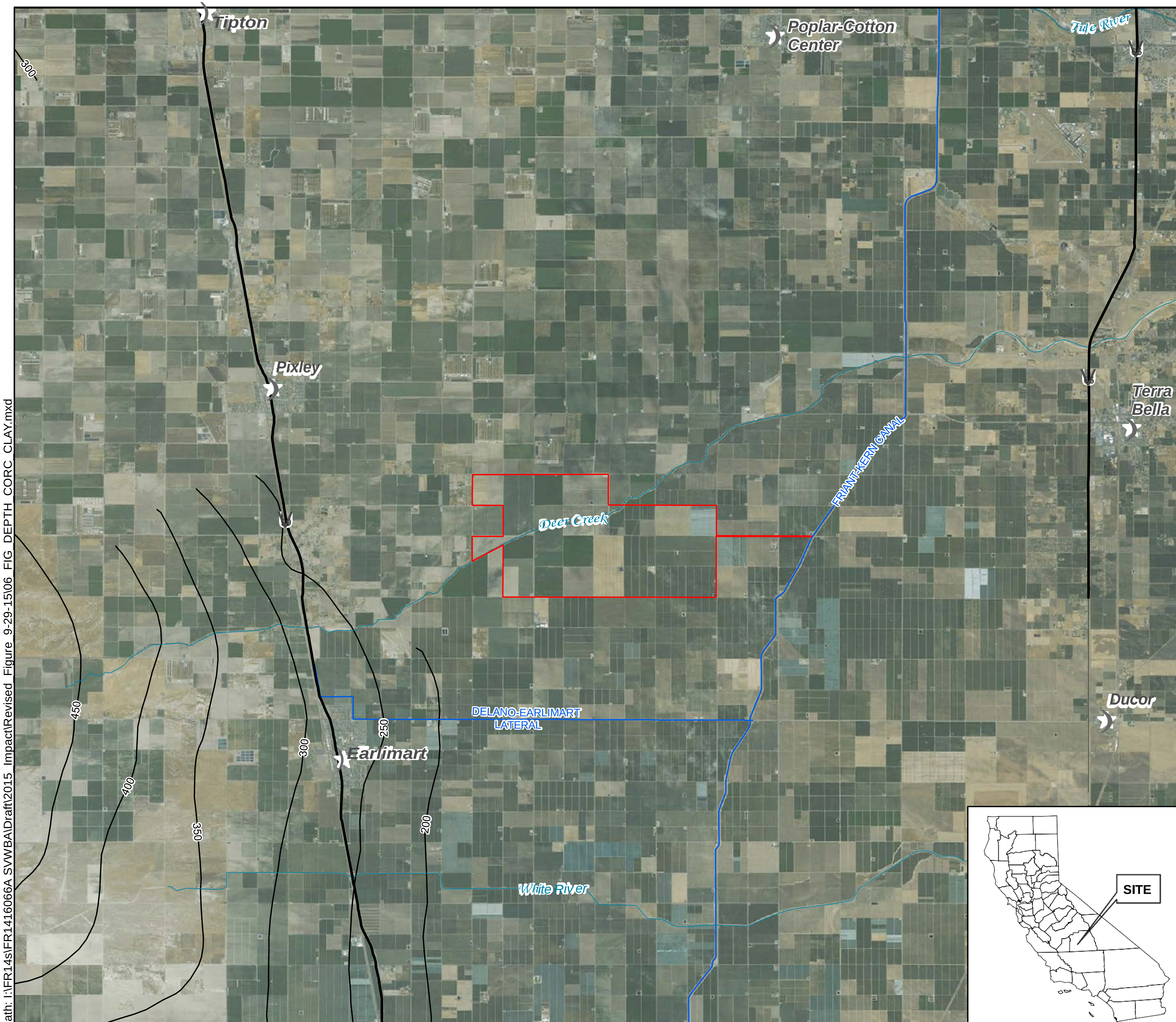


MONTHLY DEER CREEK FLOWS 1968-PRESENT
USGS 11200800

Joint Groundwater Banking Baseline Study
Tulare County, California

Date: 10/02/2015	Project No.: FR141606A	Prepared By: JWT	Figure 5



Explanation

- Proposed ground water banking project
- Major roads
- Canal
- Rivers and streams

Miles
0 1 2 4

Basemap modified from ESRI online shared content, aerial imagery web mapping services.

DEPTH TO CORCORAN CLAY
PIXLEY GROUNDWATER BANKING PROJECT
Geologic and Hydrologic Impacts Analysis
Tulare County, California

amec foster wheeler

Date: 12/17/2015	Project No. FR141606A	Figure 6
Submitted By: DMB	Drawn By: JWT	

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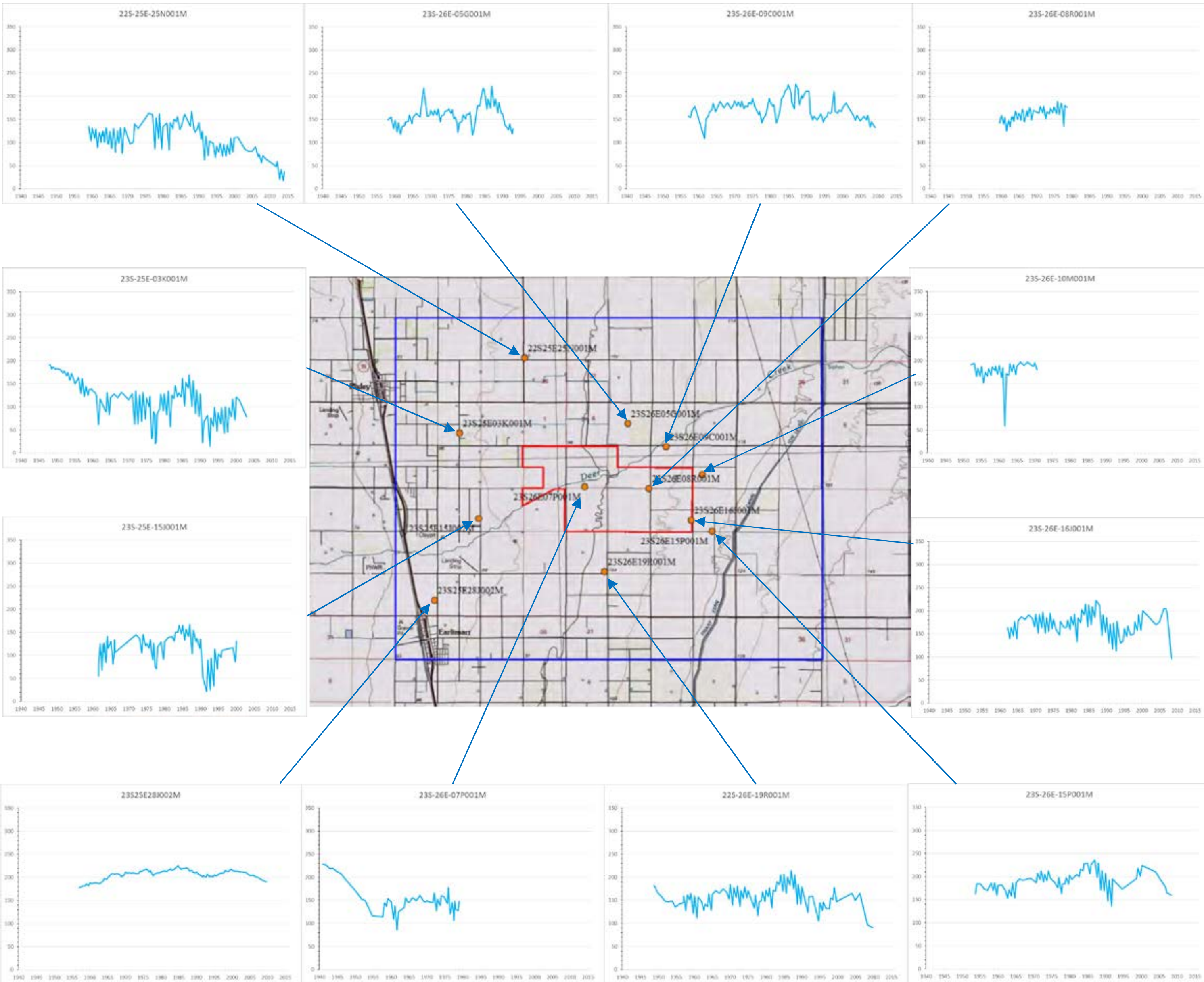


Explanation

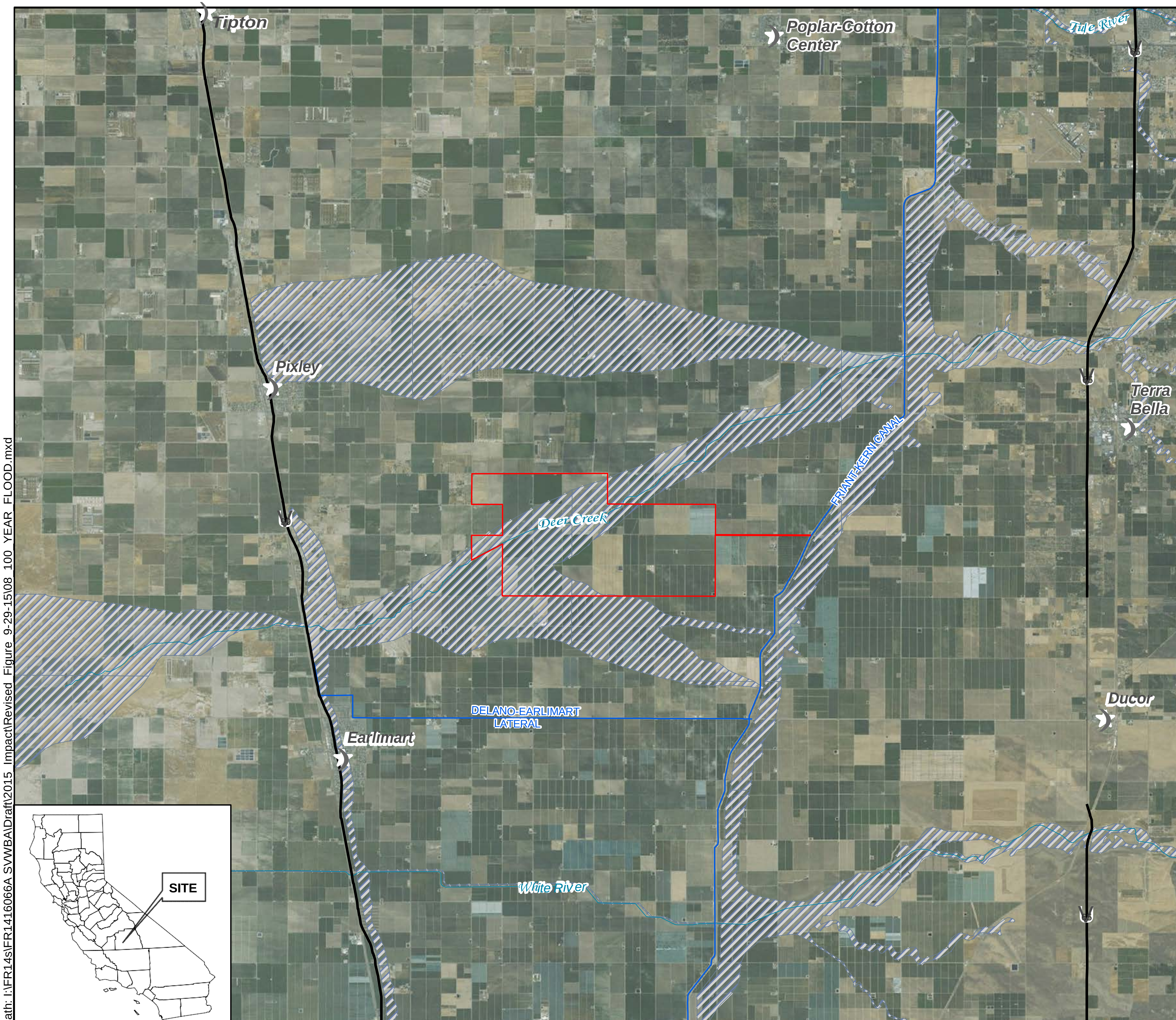
- Proposed project area
- Area of Interest
- Well location

LONG TERM HYDROGRAPHS

Geologic and Hydrologic
Impacts Analysis
Tulare County, California

Figure
7

By:JWT	Date: 09/29/2015	Project No. FR141606A



Explanation

- Proposed ground water banking project
- 100-year flood
- Major roads
- Canal
- Rivers and streams

Miles
0 1 2 4

Basemap modified from ESRI online shared content, aerial imagery web mapping services.

100 YEAR FLOOD ZONES
PIXLEY GROUNDWATER BANKING PROJECT
Geologic and Hydrologic Impacts Analysis
Tulare County, California

amec foster wheeler

Date: 12/17/2015	Project No. FR141606A	Figure 8
Submitted By: DMB	Drawn By: JWT	

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GROUNDWATER MODEL APPROACH AND METHODOLOGY
Pixley Groundwater Banking Project
Tulare County, California

ABBREVIATIONS

(AF)	Acre-Feet
(AF/Y)	Acre-Feet per Year
(AF/Y/A)	Acre-Feet per Year per Acre
(CVHM)	Central Valley Hydrologic Model
(CVP)	Central Valley Project
(DEID)	Delano-Earlimart Irrigation District
(GHBs)	General Head Boundaries
(GUI)	Graphic User Interface
(GWV)	GWVistas
(K_h)	Horizontal Hydraulic Conductivity
(MNW)	MODFLOW Multi-Node Well Package
(PID)	Pixley Irrigation District
(RCH)	MODFLOW Recharge Package
(S_s)	Specific Storage
(S_y)	Specific Yield
(USGS)	United States Geological Survey

1.1 HYDROLGEOLOGIC MODEL BACKGROUND AND PREVIOUS MODELING EFFORTS

The proposed Project area is located in southern Tulare County in the southeasterly portion of the San Joaquin Valley (Figure 1). The Project will be constructed and operated within the Pixley Irrigation District (PID). The PID covers 69,550 acres and borders the Delano-Earlimart Irrigation District (DEID) which lies to the south. The DEID covers 54,418 acres and spans the Tulare/Kern County line between Highway 43 on the west and Road 184 on the east. The PID is a cross-valley canal contractor and a non-long-term contractor of the Friant Division Central Valley Project (CVP). The PID purchases and delivers as much Class 2 water as possible. DEID has a Friant Division CVP contract for 108,000 acre-feet (af) of Class 1 water and 74,500 af of Class 2 water. However, the actual amount of water supplied to DEID in recent years has been significantly less due to recent hydrology and the implementation of the San Joaquin River Restoration Project.

The long-term average rainfall in the area of the proposed Project area is about 10.3 inches per year and occurs largely during winter and spring months (Figure 2). Therefore, agriculture is almost entirely dependent on irrigation.

The previous modeling effort for the proposed water-banking Project included a conceptual groundwater model prepared, but not completed, by Provost & Pritchard Consulting Group in 2009. The conceptual model quantified inflow and outflows, considered seepage, precipitation, available surface water supplies, and groundwater pumping.

1.2 CURRENT MODELING OBJECTIVES

The objectives of the current modeling effort are to:

- evaluate the potential for excessive mounding in groundwater elevations beneath the proposed Project area and potential resulting impacts,
- evaluate the potential for excessive declines in groundwater elevations beneath the study area during periods of recovery and potential resulting impacts, and
- evaluate potential impacts from permanent changes in groundwater storage beneath the study area.

2.1 HYDROGEOLOGIC CONCEPTUAL MODEL

A hydrogeologic conceptual model is a simplified representation of the groundwater flow system, frequently in the form of a block diagram or cross section (Anderson & Woessner, 1992). The nature of the conceptual model determines the dimensions of the numerical model and the design of the grid. The purpose of the conceptual hydrogeologic model is to establish an initial understanding of the groundwater system and organize the associated field data so that the system can be analyzed more effectively. Four steps were completed in developing the conceptual hydrogeologic model for the proposed Project area:

1. Description of the model domain and physiographic features.
2. Delineation of the hydrostratigraphic units.
3. Estimation of the water budget.
4. Approximation of the flow system.

2.2 MODEL DOMAIN AND PHYSIOGRAPHIC FEATURES

The northwestern corner of the proposed Project area is located approximately 3 miles southeast of the unincorporated community of Pixley, while the southwestern corner of the proposed Project area is located approximately 4 miles northeast of the unincorporated community of Earlimart (Figure 1). The model domain, which comprises an area of approximately 400 square miles, extends 7 miles to the east and south, and 10 miles to the north and west from the edge of the proposed Project (Figure 3). Physiographic features of significance include Deer Creek.

Deer Creek is a natural drainage channel that has the potential to produce water for the PID. Deer Creek flows from east to west through southern PID and through the center of the proposed Project area. Historic records indicate that the PID diverted an average annual amount of 10,300 af from Deer Creek from 1994 to 2006. However, 4 of those 13 years provided no diverted water from Deer Creek (Provost & Pritchard, 2008).

The topography of southern Tulare County rises moderately from about 200 feet above mean sea level west of the proposed Project area at the western edge of the county (approximately 17 miles to the west) to approximately 650-feet above mean sea level at the toe of the Sierra Nevada foothills approximately 11 miles to the east. Ground surface elevations within the model domain range from about 215 to 615 feet above mean sea level.

2.3 HYDROSTRATIGRAPHY

The proposed Project area is located within the Great Valley geomorphic province, which is a large, elongate, northwest-trending trough extending more than 430 miles. Sedimentation within the valley consists of several thousand feet of marine and non-marine sedimentary rock derived from Mesozoic through recent age erosion of the Coast Ranges and the Sierra Nevada Mountains (Tulare County, 2012). The proposed Project area is underlain by part of the Great Valley Sequence, primarily younger unconsolidated Quaternary age alluvial fan deposits.

The sediments beneath the proposed Project area and vicinity consist of a sequence of Quaternary age alluvium. Along the eastern margins of the model domain, the sediments consist primarily of Plio-Pleistocene sediments. These sediments are highly heterogeneous and consist of interbedded fine to coarse sand, gravel, silt, and clay deposited as fan deposits from the adjacent Sierra Nevada foothills and channel deposits and overbank deposits from streams draining the foothills. The sediments beneath the proposed Project area are generally Kern River formation grading into Tulare formation in the western part of the district. These sediments consist of interbedded fine grained sand, silt, and clay (including the Corcoran Clay west of the proposed Project area).

2.4 WATER BUDGET

The water budget describes the inflow and outflow to and from the hydrogeologic system. Inflow and outflow can occur from the natural hydraulic boundaries of the system such as precipitation, streams, and lakes or from physical boundaries, such as bedrock, faults or man-made sources like canals, spreading works, water supply wells, and applied water for irrigation. Water balances provide monthly summaries of deliveries, pumping, and recharge water within the proposed Project area. These flows were allocated to model specific boundaries, sources, and sinks as described in the following subsections.

2.3.1 Physical and Hydraulic Boundaries

As shown on the Alquist-Priolo Earthquake Fault Zone map, there are no known earthquake faults within the proposed project area that could act as physical boundary. Additionally, the continental sediments that form the aquifer system at the proposed Project area are between 3,000 and 4,000 feet thick (Williamson et al., 1989).

Aquitard – Sedimentary layers with permeability's so low that they cannot transfer useful amounts of water act as physical boundaries. The Corcoran Clay, which acts as an aquitard over large areas of the Central Valley, has been identified at a depth of 200 feet approximately 2 miles southwest of the proposed Project. Model layers and parameters reflect the presence of the Corcoran Clay outside the Project area.

Bedrock – Compared to the alluvial fans in the valley, the bedrock Sierra Nevada foothills yield little groundwater and essentially form a no-flow boundary. The model domain does not contain any areas where bedrock is at or near the ground surface.

Faults – No known active faults are found within the proposed Project area or within the model domain.

Regional Aquifer System – The regional aquifer system of the proposed Project location is the most significant hydraulic boundary within the model domain. Groundwater pumping and recharge activities outside of the proposed Project area have a direct influence on groundwater levels beneath the proposed Project area.

2.3.2 Sources and Sinks

Several groundwater sources (additions to) and sinks (losses from) influence groundwater levels beneath the proposed Project area. These are described in the following paragraphs.

Sources

Aerial Recharge: Direct aerial recharge from precipitation is a minor source of groundwater recharge within the model domain (DWR, 2012). Rainfall occurs seasonally, primarily during the winter months between November and March. Annual rainfall ranges between 3.71 to 21.32 inches per year and averages 10.3 inches per year (Figure 2).

Streams and Rivers: Recharge from streams and rivers is not a major source of groundwater recharge within the model domain. Historic records indicate that Deer Creek can be a source of recharge within the model domain. However, due to the highly transient nature of flows through the creek, groundwater recharge from Deer Creek was not incorporated into the model.

Water Conveyance: Canals and pipeline distribution systems are not a major source of groundwater recharge within the model domain. Although about 17 miles of the Friant-Kern Canal lies within the model domain, groundwater recharge from the canal is assumed to be minimal since it is concrete lined in this part of its alignment.

Recharge Basins: Recharge basins are a major source of groundwater recharge within the model domain. The model included 800 acres of direct recharge. The Project proposes 576 acres of recharge basins. The 800 acres of recharge basins within the model area are a result of the inability of the model grid, which is a series of squares, to conform identically to the proposed Project, which is an irregular polygon. However, percolation rates were adjusted to account for the larger recharge basin sizes so that simulation results would reflect the proposed 576 acres Project dimension. The proposed Project provides for an annual "put" amount of up to 30,000 af. The hydrology used to determine how often banking partners would be "putting" water into the bank was based upon the hydrology of DEID's surface water availability under their CVP Friant Division contract that was surplus to their in-District water demands.

Applied Water: Applied water recharge rates are highly variable, depending on the crop type and availability of surface water. Deep percolation from application of irrigation water is a major source of groundwater recharge within the model domain. The overall irrigation efficiency, or amount of applied water that reaches the root zone of the plant, for DEID and PID was estimated to range between 75 and 80 percent based on estimated acreage of flood irrigated row crop and drip irrigation permanent crops (CSUF, 1988, P&P, 2008). The remaining 20 to 25 percent of applied water was assumed to be return flow that percolates into the groundwater aquifer.

Sinks

Evapotranspiration: Evaporation and/or evapotranspiration of groundwater that are applied for irrigation purposes, are a minor source of groundwater discharge within the model domain. Evaporation from bare soil can be a significant sink in areas where the water table is near the ground surface (less than 5 feet below ground surface). However, groundwater is first encountered at significant depth (greater than 100 feet) beneath most of the model domain, resulting in little or no direct evaporation of groundwater. Evapotranspiration by agricultural crops of applied water (accounted for externally) can be significant throughout the model domain. However, direct evapotranspiration of groundwater is not a significant sink.

Water Supply Wells: Groundwater pumping by water supply wells is a major source of groundwater discharge within the model domain. It was assumed that most of the groundwater pumping within the Districts and surrounding area is utilized for agricultural purposes. It was further assumed that groundwater would be pumped to supplement surface water supplies when surface deliveries were less than the crop consumptive demand. The resulting product was then simulated utilizing hypothetical, analytical wells centered in one square mile blocks proximal to sections (Figure 4).

2.4 FLOW SYSTEM

The hydrogeologic and water budget information described previously have been used to conceptualize the movement of groundwater through the model domain. The conceptual groundwater flow system is summarized as follows.

The available data indicate groundwater flow is generally from southeast to northwest. Groundwater recharge is seasonal, primarily from the streams draining the foothills and entering the basin (Provost and Pritchard, 2008). Agricultural return flow from applied water, while not significant beneath any one parcel, is a significant source of groundwater recharge across the model domain. Groundwater pumping to supplement surface water deliveries (or where surface water is unavailable) is the primary sink within the model domain.

3.1 MODEL SELECTION

In order to meet the model objectives discussed in Section 1.1, the groundwater flow model code must meet the following criteria:

- be able to simulate three-dimensional groundwater flow within the model domain,
- be well documented and verified against analytical solutions for specific flow scenarios,
- be accepted by regulatory agencies,
- be readily understandable and usable by others for simulation of future groundwater conditions, and
- have a readily available technical support structure.

The model code MODFLOW2005 (Harbaugh, 2005) meets these criteria and was used to develop the site model.

MODFLOW2005 is a modular, finite-difference computer code developed by the United States Geological Survey (USGS) to simulate three-dimensional groundwater flow. The use of MODFLOW2005 is well documented in technical literature and is the de facto standard for groundwater flow modeling worldwide. MODFLOW2005 solves the partial-differential equations that describe three-dimensional groundwater flow by approximating the solution through the finite-difference method, wherein the continuous groundwater flow system is replaced by a finite set of discrete points in time and space. This process leads to a system of linear algebraic equations, which are solved by the computer program to yield values of potentiometric head and groundwater flow velocity at specific locations and at specific points in time (Harbaugh, 2005).

3.2 CODE ASSUMPTIONS AND LIMITATIONS

There are certain model code assumptions and limitations that constrain the accuracy of the model simulations. The assumptions and limitations that may affect the site models are briefly discussed below, including comments relative to the respective characteristics' presence in, or relevance to, the Project study area, if known.

- **Unsaturated flow:** Unsaturated flow is not simulated. MODFLOW2005 simulates flow in the saturated portion of porous media only. The flow of water through the approximate 200 to 300 foot thick vadose beneath the recharge basins will be primarily in the vertical direction, with some lateral spreading in fine grained materials within the vadose zone. However, no laterally extensive fine grained units have been identified in the vadose zone beneath the proposed basins.

- **Rewetting:** Rewetting of dry model cells is assumed to be from the bottom and side of adjacent cells. While rewetting from the bottom only maybe more computationally efficient, it can lead to simulation error in areas of steep groundwater gradients.

- **Recharge Simulation:** Recharge was assumed to occur at the water table of the upper-most active model layer and not at the ground surface. While this is physically unrealistic, it is a necessary assumption given that MODFLOW2005 does not simulate unsaturated flow.

3.3 GRAPHIC PRE/POST-PROCESSOR

To facilitate the preparation and evaluation of each model simulation, Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) utilized the graphics pre/post-processor GWVistas™ Version 6.78. (GWV) by Environmental Simulations, Inc. (ESI, 2012). GWV is a Windows® program that utilizes a graphic user interface (GUI) to build and modify a database of model parameters. The model grid, hydraulic properties, and boundary conditions are input using the GUI and then GWV creates the necessary MODFLOW data input files. The input files generated by GWV are generic (standard) MODFLOW files compatible with USGS MODFLOW-88/96, MODFLOW2000 and/or MODFLOW2005. Amec Foster Wheeler also utilized some in-house utilities and Microsoft EXCEL spreadsheets to generate standard MODFLOW data input files for selected simulations and for post-processing simulation results.

GWV comes supplied with MF2005Win32, a Windows® based version of MODFLOW2005 compiled by Environmental Solutions, Inc. MF2005Win32 is a standard version of MODFLOW2005 optimized to run under the Windows® environment. This version of MODFLOW2005 was utilized for the modeling effort.

GWV was also utilized to post-process the model simulations. GWV can display the simulated head results as plan views and cross sections. In plan view, the contour intervals and labels specified by the user and dry cells are denoted by a different color. In cross-section view, the water table surface is also plotted. Most outputs to the screen can be saved in a number of formats (DXF, WMF, PCX, SURFER, etc.) for utilization in other graphics programs.

4.1 MODEL DESIGN

A simplified numerical groundwater model was prepared for the proposed Project area and vicinity to do a comparative evaluation of potential impacts from the water banking storage and recovery operations. The following sections describe the numerical groundwater flow model for the proposed Project area.

4.2 MODEL DOMAIN/GRID

The model domain is centered on the proposed water banking site and simulates groundwater flow upgradient and downgradient of the Project location so that the model boundaries do not unduly affect the simulation results beneath the Project (Figure 3). The model domain, which comprises an approximate 400 square mile area (256,000 acres), extends approximately 2.5 miles north of the unincorporated community of Tipton at the north to 3.3 miles north of the City of Delano on the south. The eastern model boundary extends 0.25 miles east of the unincorporated community of Terra Bella, and the western model boundary extends 6.5 miles west of the unincorporated community of Pixley.

The model grid is oriented approximately 0.75 degrees east of north to align the model grid with the Township/Range/Section grid system, thereby creating 16 cells per section, using the State Plane Coordinate System, California Zone 4, North American Datum 1983. The model grid consists of 50,464 cells with a uniform cell size of approximately 1,320 feet by 1,320 feet (1/4 mile square). The complete model grid consists of 76 rows, 83 columns, and 8 layers.

4.2 MODEL LAYERS

The purpose of model layers is to represent the hydraulic influence of stratigraphy at a scale appropriate to the model objectives. It is understood that stratigraphic variations occur at scales that are both smaller and larger than that characterized for this model. The conceptual and numerical models of the proposed Project area and vicinity were developed based on consideration of several types of hydrostratigraphic information, including existing literature, lithologic and geophysical logs, cross sections, and monitoring well perforation intervals in sub-areas of the proposed Project area. In addition, the model layering scheme in the USGS Central Valley Hydrologic Model (CVHM) was adopted for layers below the Corcoran Clay (Faunt, 2009). The layers are summarized in the table below.

TABLE 1:

Model Layers

Layer	Top Elevation (MSL Feet)	Bottom Elevation (MSL Feet)	Thickness (Feet)	Kh Layer Range (feet/day)	Kz Layer Range (feet/day)
Layer 1	340	60	280	1.4000 – 141.3	0.7411 – 0.9984
Layer 2	60	-220	280	4.0000 – 99.92	0.7380 – 0.8998
Layer 3	-220	-295	75	0.1155 – 59.52	0.1440 – 0.7610
Layer 4	-295	-370	75	0.1155 – 59.52	0.1440 – 0.7610
Layer 5	-370	-570	200	0.1155 – 59.52	0.3413 – 0.7610
Layer 6	-570	-770	200	0.7960 – 63.55	0.1000 – 0.7763
Layer 7	-770	-970	200	0.7960 – 63.36	0.1000 – 0.7760
Layer 8	-970	-1170	200	0.7960 – 65.21	0.1000 – 0.7796
Total			**1510**		

Notes:
1. MSL: Mean Sea Level

4.3 HYDRAULIC PARAMETERS

The hydrostratigraphic heterogeneity of the aquifer system has been simulated in the numerical model at a scale appropriate for the modeling objectives. Given the lack of specific hydrogeologic data for the model domain, the hydraulic properties assigned to model layers were extracted from the CVHM and modified with site specific data for the Project area. As such, the model contains no more complexity than is justified by the available data, the model objectives, and the model results to date.

Hydraulic conductivity ranged from 0.1155 to 141.3 feet per day (ft/d) with approximately 50 percent of the values falling between 5 and 20 ft/d. Vertical hydraulic conductivity ranged from 0.1000 to 0.9984 ft/d with approximately 50 percent of the values falling between 0.04 and 0.09 ft/d. Specific storage ranged between 1.7E-05 and 2.5E-02 with 89 percent of the values falling between 1.7E-05 and 6.7E-03. Specific yield and porosity values were fixed at 0.105 and 0.15, respectively.

4.3.1 Hydraulic Conductivity

The horizontal hydraulic conductivity (K_h) for the model were extracted from the CVHM and modified with site specific data including the results of aquifer pumping tests and lithologic boring descriptions within the Project area. A total of 2,327 hydraulic conductivity values were utilized in the model.

4.3.2 Storage

The specific storage (S_s) values for the model were extracted from the CVHM and modified with site specific data including the results of aquifer pumping tests. The layers above the Corcoran Clay have heterogeneous S_s parameters while the layers below the Corcoran Clay have uniform S_s parameters. A total of 421 S_s parameters were utilized in the model.

4.3.3 Specific Yield

A specific yield (S_y) value of 0.105 was assigned uniformly to all zones. This value is within the published range of values for the clayey to sandy sediment types beneath the proposed Project area and vicinity (Spitz and Moreno, 1996).

4.3.4 Porosity

The porosity value was assumed to be 0.15 for all zones. These values are within the published range of values for the sediment types beneath the proposed Project area (Spitz and Moreno, 1996).

4.4 BOUNDARY CONDITIONS

There are no significant hydraulic boundaries within the model domain.

4.4.1 General Head Boundaries

General head boundaries (GHBs) were assigned to all model layers at the northern and southern edges of the model domain to represent the regional aquifer system beyond the model domain. GHBs were not assigned to the east and west edges of the model as groundwater flow is generally perpendicular to these edges. Specified heads for the GHBs were interpolated from a Spring 2007 potentiometric surface map, which shows a southeast to northwest flow, and long-term hydrographs that exhibit a regional decline between 1.5 and 4.5 feet per year.

4.5 SOURCES AND SINKS

As described in Section 2.3.2, there are a number of groundwater sources and sinks within the model domain. Most of the source and sinks are variable over time during the simulation period.

4.5.1 Net Recharge

The Recharge (RCH) Package of MODFLOW2005 allows for the specification of temporally and spatially variable data arrays. Multiple data arrays are permitted but require extensive re-writing of the master control files. To accommodate simulation of multiple source terms within the proposed Project area model, GWV was used to prepare separate data arrays for recharge basins and applied water. Although these data arrays could be combined within a MODFLOW2005 simulation, it was determined that the separate arrays could be input into a spreadsheet and combined into a single Net-RCH array. Combining the recharge data arrays using a spreadsheet allowed for the rapid re-generation of the Net-RCH input file and simplified generation of the MODFLOW2005 data sets.

4.5.2 Agricultural Pumping

The primary sink in the model is agricultural pumping to meet crop consumptive demand. Annual crop consumptive demand in the area has been estimated to be approximately 2.541 acre feet per year per acre (af/y/a) (P&P, 2008). Assuming an irrigation efficiency of 75%, the total crop demand is approximately 3.4 af/y/a. Actual historical pumping records for most wells within the study area are not available. Therefore, it was assumed that groundwater would be pumped to supplement surface water supplies when deliveries were less than the total crop consumptive demand or where/when surface water deliveries were not available.

A spreadsheet that included surface water deliveries was prepared to estimate agricultural pumping demand in each section. Monthly agricultural pumping was then estimated for hypothetical agricultural wells centered in one square mile blocks (proximal to sections). The difference between agricultural demand and available surface water supply was assumed to be provided by pumping wells. The spreadsheet was used to prepare a file of monthly demand by well for import into GWV. Combining the various data arrays using a spreadsheet allowed for the rapid re-generation of the well input file and simplified generation of the MODFLOW2005 data sets.

MODFLOW computes the head at each grid cell based on the fluid mass balance for fluxes into and out of the cell of interest, including flow in or out of a well located within the cell. However, because of differences between the volume of a cell and the volume of a wellbore, as well as differences between the average hydraulic properties of a cell and those immediately adjacent to a well, it is not expected that the computed head for the model cell will accurately reproduce or predict the actual head or water level in a well at that location. The Multi-Node Well (MNW) Package of MODFLOW can correct for this effect using the Thiem flow equation (Harbaugh, 2005). The MNW Package also allows for calculations of additional head changes due to partial penetration effects, flow into a borehole through a seepage face, changes in well discharge related to changes in lift for a given pump, and intra-borehole flows with a pump intake located at any specified depth within the well. All wells in the model were simulated with the MNW Package.

5.1 PREDICTIVE SIMULATIONS

A 40-year predictive model was prepared (using 240 bi-monthly [~60 day] stress periods) to evaluate potential impacts of the proposed water banking facility on groundwater conditions beneath and in the vicinity of the proposed Project area. A Base Case scenario representative of a No Project Alternative was prepared assuming that agricultural demand, and surface water deliveries for Pixley and Delano-Earlimart Irrigation Districts, would remain consistent with historic records. Also, a potential water banking scenario was prepared using historic hydrology, to simulate periods of recharge and recovery during the 40 year predictive model.

5.2 THE BASE CASE SCENARIO

The Base Case scenario groundwater flow model simulates a future 40-year period during which current conditions of agricultural land use continues, and in which the proposed water bank does not exist. The Base Case scenario assumes that the DEID will continue to receive surface water supplies (supplemented as needed with pumping), while the PID continues to rely on groundwater pumping alone. Surface water supplies and agricultural pumping are simulated on a seasonal basis. The GHBs were set to continue the observed 1.5 to 4.5 feet per year regional decline in the water (see Section 4.4.1). The forecast simulation results were evaluated using three hypothetical observation wells arrayed in a general southeast to northwest direction aligned with groundwater flow (Figure 4). Observation Well 1 is located approximately 3 miles north of the proposed Project area within PID boundary. Observation Well 2 is located at the proposed Project area. Observation Well 3 is located approximately 3 miles south of the proposed Project area within the DEID boundary.

5.2.1 The Base Case Scenario Results

As noted above, the Base Case scenario simulation results were evaluated using three hypothetical observation wells (Figure 4). In the northern third of the model domain, Observation Well 1 had an 87.3 foot decrease in head over the 40 year period (Figure 5). At the site of the proposed Project area, Observation Well 2 had a 71.6 foot decrease in head over the 40 year period (Figure 6). In the southern third of the model domain, Observation Well 3 had a 40.4 foot decrease in head over the 40 year period (Figure 7). The Base Case scenario reasonably simulates the expected change in groundwater levels from continued agricultural practices in the area, including the limitation of surface water delivers to PID and the continued application of DEID’s surface water allotment.

5.3 GROUNDWATER BANKING OPERATIONAL SCENARIO

The Base Scenario was modified to simulate a potential water banking operational scenario. The potential water banking scenario uses the same model grid, boundary conditions, and hydraulic parameters as the Base Case scenario. Agricultural water demand is assumed to also remain the same for the water banking scenario. The proposed Project would operate on the operational rule that recharge to the basins would occur before any recovery, and that there would be a 10 percent “leave behind” of all water contributed to the proposed water bank. As such, a cap of 90 percent was placed on the amount of water that could be recovered following recharge periods.

The water banking scenario was compared with the Base Case scenario using hydrographs and potentiometric surface maps. Simulated hydrographs (Figures 5 through 10) compare the simulated heads of the Base Case to both water banking operational scenario at each of the three hypothetical monitoring wells for model layers 1 and 5. To more easily quantify the net effects of the water banking scenarios on groundwater levels beneath the proposed Project area, the difference between the two sets of simulated potentiometric surface maps were calculated for the stress period where the greatest differences in heads were observed (Figures 11 through 15). These figures show the net change in groundwater levels in 10-foot intervals. The results of the predictive water banking operational scenario is described below.

5.3.1 90K Limit Scenario Results

The proposed water banking scenario represents the proposed Project using historical hydrology and a 90,000 af limitation on the amount of water that can be stored at the Project. There are several cycles of recharge and recovery during the 40-year simulation. The largest recharge mound (over 60 feet at its peak) occurs in July 2050. This groundwater mound extends nearly 2 miles to the north and west of the proposed Project (Figures 11 and 12). The largest recovery related drawdown (cone of depression) is about 30 feet in June 2030. This recovery depression extends beyond the proposed Project over a mile to the north and less than a mile to the west (Figure 13 and 14). As indicated in Section 4.5.2, the head (or drawdown) calculated by MODFLOW represents the average head (or drawdown) within the 40-acre model cell. The head (or drawdown) within each recovery well was calculated using the MNW Package. This indicates as much 116 feet of drawdown within the recovery well itself (Figure 15). However, the lateral extent of the recovery well drawdown is limited to the area immediately surrounding the well; the cell average head (or drawdown) is more representative of the conditions that neighbors to the project will experience.

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