



TECHNICAL MEMORANDUM

TO: Kevin Kauffman, PE, Acting General Manager
Eastside Water District

DATE: May 11, 2018

CC: Al Rossini, Board Chairman, Eastside Water District
Larry Ernst, PG CHg, Wood Rodgers

PREPARED BY: John M. Lambie, PG, PE

PROJ. NO. 0608-001-07

SUBJECT: Findings for Pilot Study of Groundwater Recharge in Dry Creek, Merced County, CA

This Technical Memorandum (TM) documents the Pilot Study objectives, E-PUR's scope of work, the field data and findings in assessing the fate of waters recharged from Dry Creek in Merced County, California to the groundwater aquifer system beneath the Eastside Water District (EWD).

GROUNDWATER RECHARGE PROJECT BACKGROUND

EWD has the ability to purchase water from Merced Irrigation District (Merced ID) when it is available and have it delivered to EWD through producers within the Merced ID boundary via Dry Creek. There are two or more producers who irrigate land within EWD that have the ability to divert water from Dry Creek. Use of the turnouts within the Merced ID boundary can direct/flow water into Dry Creek and do so by gravity which is very advantageous.

EWD requested a technical analysis by E-PUR of the fate of water diverted from Merced ID's canal water both to groundwater zones adjacent to Dry Creek and also to groundwater zones northwest of Dry Creek beneath land within the EWD boundary. A pilot study (the Study) was planned and designed to assess whether Merced ID water conveyed into Dry Creek would demonstrably recharge groundwater. The Study was also planned to assess whether intentionally recharged groundwater can be projected to benefit EWD's portion of the Turlock Groundwater Subbasin and by how much. The primary objectives established for the Study were:

- to confirm that Merced ID supplied water does recharge groundwater, and
- evaluate the direction of such recharge water in the groundwater system.

Secondary objectives for the Study included:

- assessing the rate of infiltration of surface water from Dry Creek in general, (namely what may be the maximum rate of diversion into Dry Creek before water begins to flow out of the Creek and into the Merced River);
 - assessing whether any of the introduced water will flow toward or back into the Merced River; and,
 - identifying what data gaps exist, or what further data collection and analysis efforts might benefit EWD in intentional recharge project implementation in Dry Creek.
-

Technical Memorandum

Page | 2

PROJECT TECHNICAL BACKGROUND AND APPROACH

E-PUR identified several technical characteristics of both the Sierra Nevada derived water from Merced ID and the response of an aquifer percolating groundwater recharge to use for the Study. Each of these characteristics of the water and the recharge have the potential to enable some determination of the movement of this fresh Sierran water into the groundwater aquifer system beneath Dry Creek and beneath EWD. The technical characteristics that E-PUR selected to assess in the Study were:

1. changes in concentrations of stable isotopes of hydrogen and oxygen in groundwater near Dry Creek;
2. changes in groundwater temperature in wells near Dry Creek;
3. mounding of groundwater in wells near Dry Creek;
4. relative groundwater hydraulic heads in select groundwater wells near to and away from Dry Creek to assess probable groundwater flow directions of recharged water; and,
5. changes in the mineral composition of groundwater near Dry Creek.

Evaporated ocean-water naturally contains stable heavy isotopes of oxygen and hydrogen in known concentrations and ratios. These stable isotopes of oxygen, ^{18}O , and hydrogen, ^2H (deuterium), are heavier than their more abundant counterparts, ^{16}O and ^1H . These heavier isotopes are then preferentially reduced from the atmosphere via condensation and rainfall. They are reduced more and more with distance from the ocean and by the altitude of rainfall, a phenomenon referred to as “rainout”. As a result of rainout, the water supplied by Merced ID from its Sierran source is isotopically much lighter than rainfall within the watershed of Dry Creek. Merced ID water from the Sierras is also isotopically lighter than groundwater beneath EWD where it is predominantly recharged by local rainfall. This large difference in the abundance of heavy isotopes between Merced ID water and local surface water and groundwater provides a strong signal that can be used to confirm the movement of surface water to groundwater in particular areas. Stable isotope analysis has been used to evaluate the origins of groundwater via Sierran river discharges and local rainfall in this region of California.¹ It was used as part of the Study plan.

Another distinguishing characteristic of Merced ID water is its temperature. Its temperature is lower than that of both local rainfall and local groundwater. This provides another signal. The Study design included high frequency electronic data collection of temperature to affirm movement of Merced ID water directly recharging the groundwater aquifer zones that are directly connected to Dry Creek. However, this temperature signal was also anticipated to diminish with time and distance from the recharge source whereas the isotopic signal will persist subject only to local dilution and mixing by heavier isotope water.

Recharging a groundwater aquifer system produces a pressure pulse from the overburden of the weight of water. Measuring groundwater pressure frequently using electronic pressure transducers can detect this pressure wave. It’s not the water molecules moving into the depth interval being monitored but the pressure of the water overlying that is measurable as hydraulic head. This signal however is very often masked or eliminated by nearby groundwater extraction. Use of pressure transducers measuring water levels every 5 minutes was part of the plan design for the Study.

¹ O’Leary, David R., J.A. Izbicki, L. Metzger, 2015, “Sources of high-chloride water and managed aquifer recharge in an alluvial aquifer in California”, Hydrogeology Journal, Springerlink.com, DOI 10.1007/s10040-015-1277-7, Published July 3.

Technical Memorandum

Page | 3

In addition groundwater hydraulic heads, typically expressed as “groundwater elevations” in a well, can describe the direction of groundwater movement in an aquifer system when properly grouped together and mapped. Groundwater elevation data from wells near the Dry Creek combined with contemporaneous groundwater elevation data from areas away from Dry Creek toward and beneath EWD lands can be mapped to assess probable groundwater flow directions. This was part of the plan design for the Study.

Lastly, the mineral composition of groundwater is largely a function of contact time of the water with the aquifer sediments and rock. Younger water generally has a lower concentration of total dissolved solids (TDS), for example dissolved calcium carbonate. The younger Sierran water introduced into Dry Creek has a lower concentration of TDS than local groundwater and local rainfall runoff. This “signal” can be used to evaluate some aspects of groundwater recharge from Dry Creek. Measuring TDS by a surrogate measurement of electrical conductivity (EC) of water in the field was part of the plan design of the Study.

SCOPE OF STUDY AND TECHNICAL SERVICES

E-PUR proposed on September 29, 2017 to collect field data to evaluate and assess changes to these groundwater characteristics. The time period E-PUR chose for the field data collection was approximately four months. The overall time period for the study, four months, was developed to capture anticipated changes to the three different generalized time scales for the characteristics: (1) mounding pulses can be seen in a period of hours; (2) mineral composition shifts take months to emerge; and (3) isotope shifts take 30 to 60 days depending on distance from the creek. The general concept for field data collection was to collect water level measurements and water samples:

- prior to Merced ID recharge water being released,
- approximately 60 days after Merced ID water was released to Dry Creek coincident with a winter rain event in the Dry Creek watershed to sample that water’s isotopic composition, and
- approximately 120 days after Merced ID recharge water release.

The scope of services included near continuous measurement of hydraulic heads using electronic pressure transducers and data recorders placed into three volunteered wells near Dry Creek. In addition groundwater elevations were scoped to be collected manually from these same three wells; this portion of the scope was extended to include manual water level measurements in three additional wells if possible. Manual water level measurements were to be taken before the Merced ID surface-water run, 60-days after, and 120-days after. Electronic pressure transducers in the initial three wells were scoped for two months to try to see the pressure pulse from recharge water, if possible. The scope included field measurement of total dissolved solids, pH, and other general water characteristics using a calibrated field meter to measure both surface water from MID, on-farm canal water, and groundwater from three wells.

E-PUR’s scope included sampling and analysis for stable isotopes. The samples anticipated initially were from Merced ID supplied water (once), Dry Creek watershed water (once), Merced ID water running in Dry Creek (once), along with sampling and analyzing the initial three wells before the surface water run, 60 days after, and 120 days after the surface water run. As the study progressed three (3) additional groundwater sample locations for stable isotopes were evaluated in discussion with Kevin Kauffman to enhance the potential value of the Study assessment and were amended to the scope. These three wells are also being sampled three times each as above for a total of 18 isotope samples of groundwater. In addition E-PUR added two surface water sampling locations for stable isotopes, one for on-farm canal

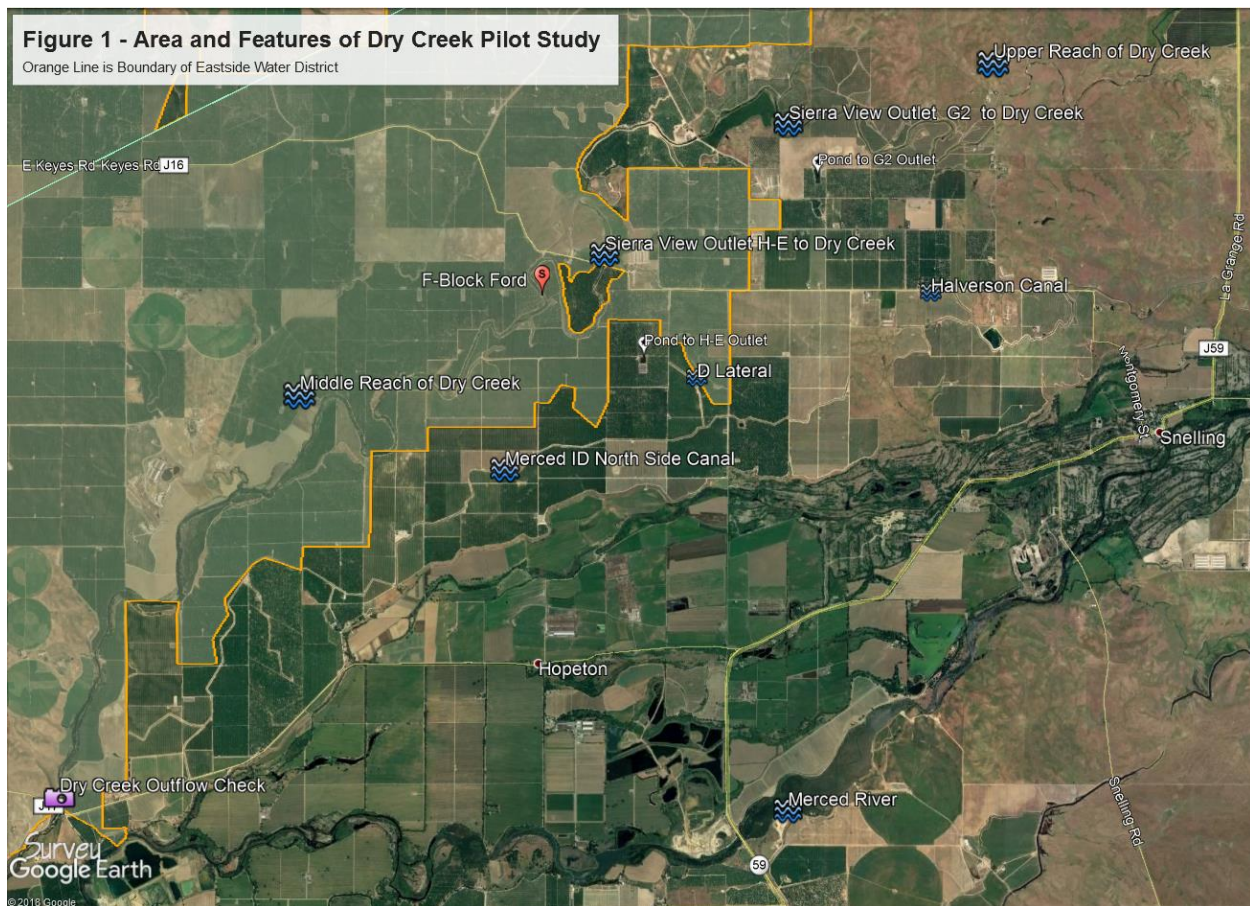
Technical Memorandum

Page | 4

water and one for a lower tributary to Dry Creek at the Vista Livestock Ranch in an effort to better discern the source(s) of water into the area's groundwater and surface water. The scope of isotope analysis now includes a total of 23 samples, 5 surface water and 18 groundwater. Five separate field visits are now scoped to collect the three rounds of data; this is due to both the staggered nature of identifying all of the sample locations and a weeks long delay in field access due to soft ground conditions in the winter (Four site visits have been conducted as of this interim Draft TM, and 17 of 23 isotope samples collected and analyzed).

MERCED ID SURFACE WATER RUN DESCRIPTION

Surface water from Merced ID was delivered to their North Side Canal and then turned out to two local supply canals, Halverson Canal and the D Lateral, that supply the portions of Sierra View Ranch inside the Merced ID footprint. Due to the location of the various planting blocks supplied by these two local canals on the southeast side of the Dry Creek watershed, surplus water from Sierra View Ranch drains to Dry Creek. Sierra View Ranch has two outlets for water into Dry Creek that were used in the Pilot Study to enable EWD to purchase water from Merced ID and divert it to Dry Creek via gravity flow. These two outlets to Dry Creek at Sierra View Ranch are depicted on Figure 1 as Outlet G2 and Outlet H-E.



According to reports from the field, Merced ID surface water began to flow into Dry Creek on or after October 17, 2017 via Outlets G2 and H-E. Merced ID reportedly shut down its North Side Canal system run on October 31 or November 1, 2017. Thus water was flowing into Dry Creek for approximately 15-days.

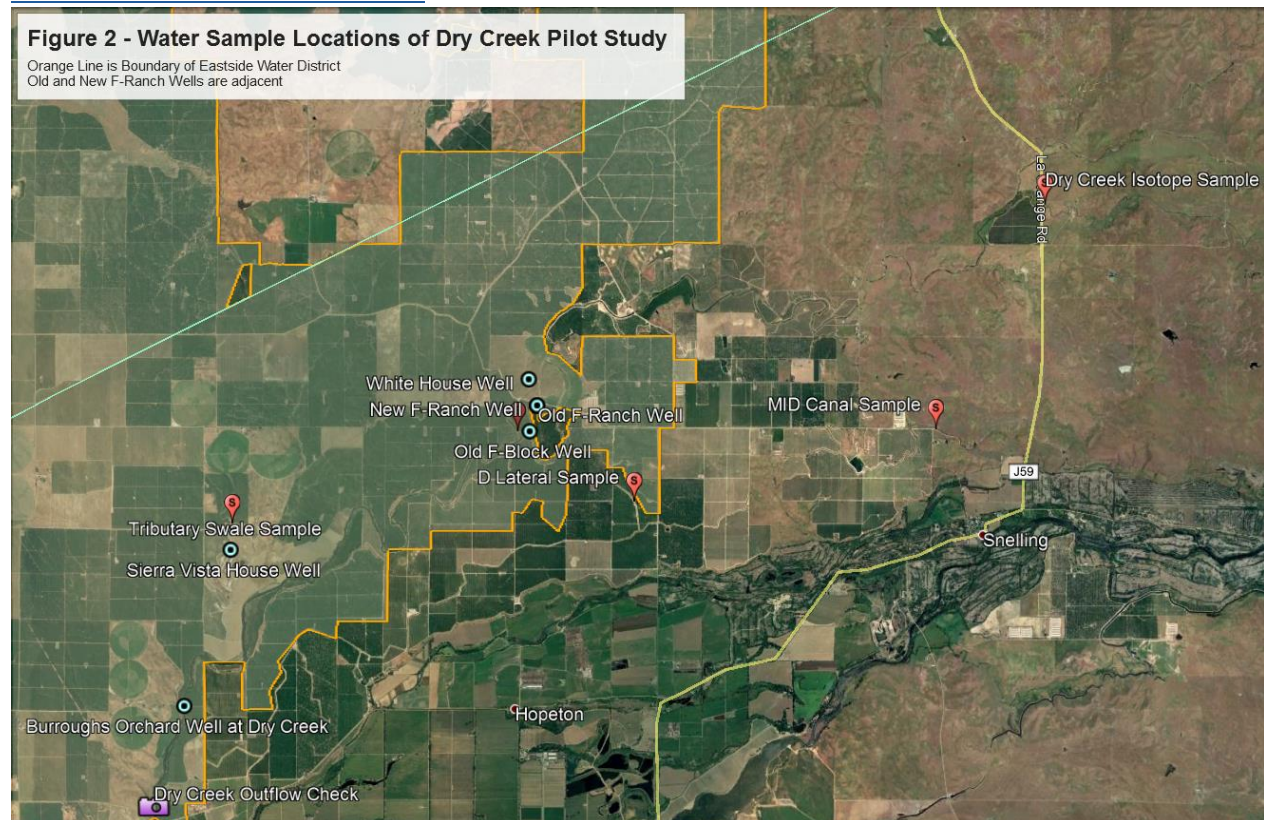
Technical Memorandum

Page | 5

Merced ID billed EWD for 82.311 acre-feet (AF) of water usage. While the surface water run was on-going Mr. Kevin Kauffman visited the area of Dry Creek at the ford on Sierra View Ranch in their F Block on October 26, 2017. He estimated flow in the creek to be on the order of 3 cubic feet per second (cfs) which equates to just under 6 AF per day. At that rate water would have run for approximately 14 days to match the amount billed by Merced ID. At a slightly lower rate of 2.5 cfs water would have run for 16.5 days to match the Merced ID billing. Thus it appears that both the duration and rate of flow estimated for delivered Merced ID water into Dry Creek are in the range of 15 days at 2.5 to 3 cfs; precise flow rates were not obtained as they were not necessary to meet the primary objectives of the Study.

DATA COLLECTION

SURFACE-WATER FLOW OBSERVATIONS



Mr. John Lambie, PE, of E-PUR toured the area on October 5, 2017 with Mr. Kevin Kauffman, PE, to identify features of the area and collect some initial water samples of both surface water and groundwater in advance of Merced ID water delivery.

Three flow observation points were utilized in the Study. Each can be seen on Figure 1. The lower end of the study area was a photo observation point on the bridge of Turlock Road over Dry Creek, “Dry Creek Outflow Check” in Figure 2. The midpoint surface water flow observation location was at the bridge overcrossing at the “Sierra Vista Well at Dry Creek” near their supply well as shown on Figure 2. The upper end surface water flow observation point was the ford of Dry Creek on Sierra View Ranch near the “New F-Ranch Well shown on Figure 2.

Technical Memorandum

Page | 6

No surface water flow was observed exiting the Pilot Study area during the Merced ID run from October 17, 2017 to November 1, 2017 as reported by Mr. Brian Kline of Sierra Vista Ranch and Mr. Kevin Kauffman of EWD. E-PUR made no direct observations during the Merced ID supply period. Based on these observations, all purchased Merced ID water is believed to have infiltrated to groundwater from Dry Creek.

On January 10, 2018 E-PUR personnel visited the Dry Creek catchment after heavy rainfall to gather native surface-water flowing in Dry Creek. On January 10, 2018 surface water flow was observed at La Grange Road and Dry Creek where the native water-sample for isotopic analysis was collected from the south fork of Dry Creek. That same day flow was observed at the Keyes Road bridge over Dry Creek at the edge of Sierra View Ranch's F Block. The flow observed at Keyes Road bridge was not estimated for flow rate. Simultaneously on January 10, 2018, no flow was observed at the ford of Dry Creek within the Sierra View Ranch's F Block. Flow at the F-Block ford appeared to have occurred in the week prior during rain events but flow had ceased by January 10th. Surface ponding was observed that day on the upstream side of the F-Block ford; in contrast there were disconnected shallow surface water pools immediately downstream of the F-Block ford. The F-Block ford appeared to be the end of free flowing surface water in Dry Creek on January 10, 2018.

During groundwater sample collection on March 12, 2018, significant surface water flow was observed at the F-Block ford. A serendipitous streamflow rating was undertaken. Measurements were collected and estimates are made herein of streamflow at the F-Block ford and at the creek culvert on Ward Burroughs property near the "Burroughs Orchard Well at Dry Creek" shown on Figure 2. The area in flow was estimated by pacing stream width over the concrete and gravel roadway and measuring depths at 2 points. Water flow velocity in Dry Creek was estimated at the centerline of the flow using a floating stick and stopwatch, and by measuring the downstream distance travelled by pacing it off. Further flow observations and measurements were not made at the lowermost observation point on March 12 as these readings were not part of the forecast scope of study.

GROUNDWATER DATA COLLECTION

On October 17, 2017 accompanied by Mr. Kevin Kauffman, E-PUR visited the three groundwater well sites initially selected (Burroughs Orchard, Old F-Block, and Old F-Ranch Wells) and added two additional sites (New F-Ranch Well and the White domestic well) to gather groundwater samples for isotope analysis before Merced ID water, the baseline samples. Electronic pressure transducers were deployed in the three groundwater wells initially selected to watch for a pressure pulse. On October 26, 2017 Kevin Kauffman located and sampled an additional well that services both a home and some agricultural water-use at Jimmie Burroughs property at the eastern end of East Avenue (Sierra Vista House Well on Figure 2) bringing the total wells being sampled for changes to stable isotopes, water levels, etc. to six (6). Table B-1 in Attachment B provides a summary of initial field visits to this Study's groundwater wells and the known well characteristics of depth and dates of construction.

On January 10 to 18, 2018 E-PUR visited each of the six wells to gather depth to groundwater data, download pressure transducers, and collect water samples for stable isotope analyses. Sampling these wells on January 10 to 18, approximately 75 days after the Merced ID surface-water run, is thought to represent a sufficient period of time for percolating water from Dry Creek to have migrated to these wells

Technical Memorandum

Page | 7

based upon E-PUR's review of the literature²; again the Merced ID surface-water run ended on or about November 1, 2017. On March 12, 2018 E-PUR again visited each of the six wells used in the study to gather depth to water data and collect water samples for isotopic analysis. These samples were anticipated to show a diminished influence of the Merced ID water percolated out of Dry Creek.

Electronic pressure transducers and data loggers recorded groundwater pressures in three wells, Old F-Ranch, Old F-Block, and the Burroughs Orchard well. The data logging transducers deployed in each well were programmed to record the hydraulic head every 5 minutes or more frequently if hydraulic head in the aquifer zone changed more than a specified amount during any 5-minute interval. Data were successfully downloaded from the Old F-Ranch Well on January 10, 2018 and the transducer retrieved. The Old F-Block well was not accessible on January 10 but was visited on January 18, 2018 once the ground had dried out and firmed up. After examining the transducer data from the Old F-Block well E-PUR made the assessment to continue electronic data collection from this well as it was providing excellent information on both groundwater pressure changes and temperature changes. The Burroughs Orchard well was visited on January 10, 2018 with the new ranch hand, Nick Hibma, and the transducer lead cable was not visible in the wellhead. Mr. Hibma determined that the Burroughs Orchard well has been run in December to abate the unusually dry late fall weather; the transducer had been lost down the well borehole and as a result high-frequency groundwater-level data are not available from the Burroughs Orchard well for this Study.

During our data collection efforts EWD provided the data from its monthly program of data collection from 16 wells within the District to add to the groundwater elevation field data collected in E-PUR's field program. In addition, E-PUR accessed the DWR's Water Data Library to acquire data from four additional locations that are measured semi-annually; data were available from these four wells for October 2017 and data from only two of the four wells were available for March 2018 (one well was inaccessible and one well was discontinued from DWR's program). Table 1 provides a summary of the data collected for groundwater mapping.

SURFACE WATER DATA COLLECTION

Table 2 provides a summary of the five surface water locations selected, sampled, and analyzed for stable isotopes, along with other surface water locations visited and considered for analysis.

On October 5, 2017 surface water isotope samples were collected of Merced ID source water and the canal water within the D Lateral at Sierra View Ranch (anticipated to be a mixture of Sierran and local water for isotopes). Field parameters were measured of surface water at several locations to assess pH, temperature and total dissolved solids. On October 26, 2017 a water sample was collected at the Dry Creek ford at Sierra View Ranch in their F Block as the Merced ID surface-water run was flowing in Dry Creek. A sample of Dry Creek runoff was collected at the La Grange Road overcrossing on January 10, 2018; this is meant to represent native surface water composition for stable isotopes. In addition on January 10, 2018 a similar sample was collected from a local runoff tributary to Dry Creek at the Vista Livestock Ranch near Jimmie Burroughs home to assess the potential difference stable isotopic composition of upper Dry Creek and lower Dry Creek runoff.

² O'Leary, David, J.A. Izbicki, J. Moran, T. Meeth, B. Nakagawa, L. Metzger, C. Bonds, and M.J. Singleton, 2012, "Movement of Water Infiltrated from a Recharge Basin to Wells", NGWA, Groundwater, v. 50(2):242-255.

Technical Memorandum

Page | 8

DATA SUMMARIES/RESULTS

HYDRAULIC HEADS

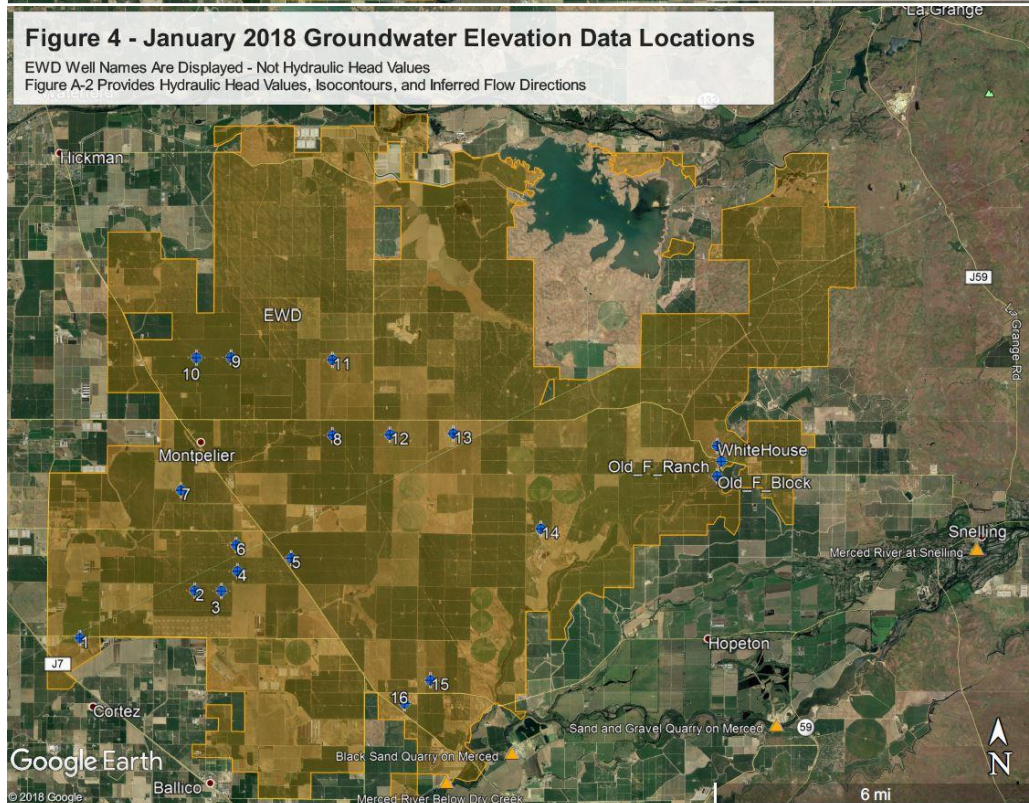
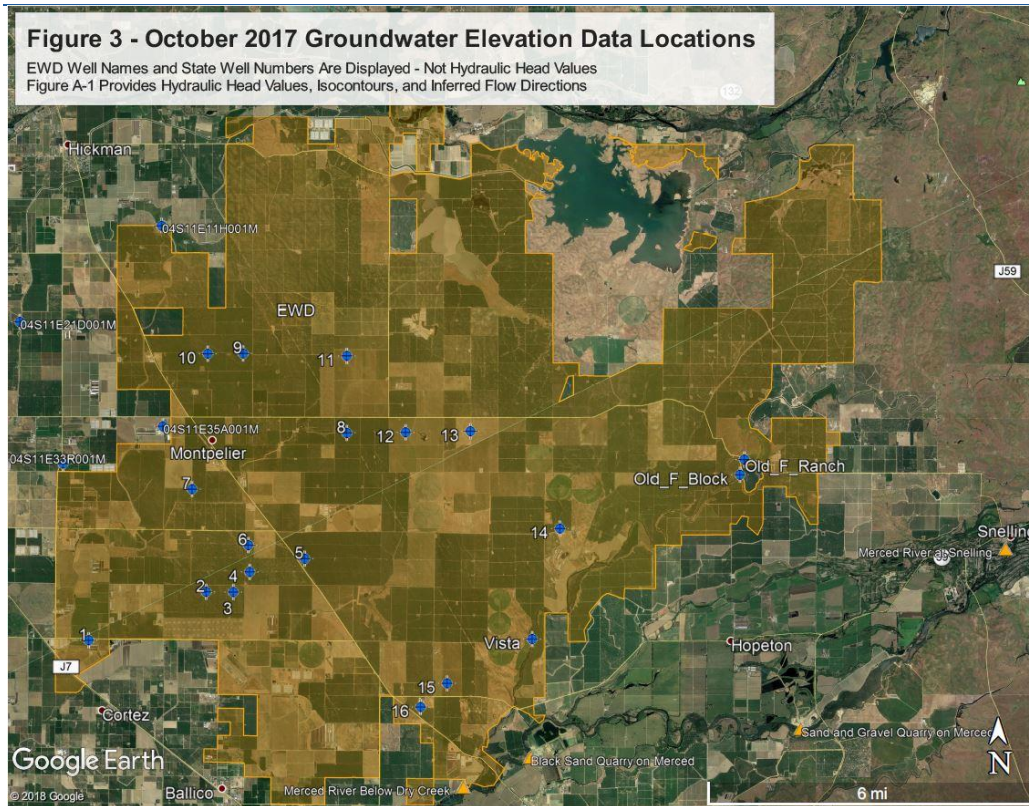
Table 1 on the following page provides a summary of the manual field measurements used in assessing groundwater flow directions. These data were mapped for groundwater hydraulic heads and are presented in Attachment A. Information on the wells visited by E-PUR specifically for the Study are provided in Attachment B in Tables B-1 and B-2.

Technical Memorandum

Table 1 Groundwater Level Data for Mapping

StateWell# or Well Name	Latitude	Longitude	Ref. Point Elevation (ft MSL) See Notes	Dates	Oct-17	Jan-18	Mar-18	Oct-17	Jan-18	Mar-18
					DTW (ft)	DTW (ft)	DTW (ft)	WSE (ft MSL)	WSE (ft MSL)	WSE (ft MSL)
Current F-Ranch Well	37.540028	-120.526712	214.5		136	NM	NM	78	NA	NA
Old F-Ranch Well	37.539951	-120.526763	215.5		134	132	131	82	84	84
Old F-Block Well	37.535921	-120.528217	202		154	143	144	48	59	58
W. Burroughs Orchard Well	37.492226	-120.597610	161		131	NM	238	30	NA	50
J. Burroughs Domestic Well	37.513909	-120.584852	183.0		NM	180	NM	NA	3	NA
Rob White Domestic Well	37.544136	-120.528278	288		250	238	244	38	50	44
05S11E22B001M	37.496700	-120.757800	189 ^a		150	144	142	39	45	47
05S11E13A001M	37.504720	-120.712500	233		222	216	214	11	17	19
05S12E18C001M	37.504720	-120.697800	215		194	197	194	21	18	21
05S12E07Q001M	37.510000	-120.692000	220		207	198	196	13	22	24
05S12E08K001M	37.513610	-120.673890	217		218	210	208	(1)	7	9
05S12E07G001M	37.517200	-120.692780	210		216	204	202	(6)	6	8
05S11E01G001M	37.531940	-120.711670	194		212	177	176	(18)	17	18
04S12E33E001M	37.547500	-120.678000	236		224	217	213	12	19	23
04S12E19N001M	37.568124	-120.694439	256 ^b		245	241	242	11	15	14
04S11E24Q001M	37.568056	-120.706389	235		228	227	222	7	8	13
04S12E21N001M	37.567500	-120.659720	254		253	249	238	1	5	16
04S12E34F001M	37.547200	-120.640000	249		240	235	233	9	14	16
04S12E35C001M	37.547500	-120.618300	264 ^c		248	247	236	16	17	28
05S13E06P001M	37.521670	-120.588300	203		184	177	169	19	26	34
05S12E23M001M	37.480556	-120.626111	232		204	195	195	28	37	37
05S12E27A001M	37.474167	-120.635000	194		205	161	159	(11)	33	35
04S12E27J001M	37.558109	-120.630826	267.4		132	NM		17	NA	
04S11E33R001M	37.538800	-120.755200	149.4		132	NM	145	18	NA	5
04S11E35A001M	37.548746	-120.721495	205 ^d		210	NM	197	(5)	NA	8
04S11E11H001M	37.602097	-120.722116	167.9		136	NM	NM	32	NA	NA
04S11E21D001M	37.576504	-120.769833	151.4		112	NM	NM0	39	NA	NA
Notes:										
EWD Monthly Data Collection Program										
E-PUR Pilot Study Field Data										
DWR Water Data Library Data										
^a Land surface elevation updated to reflect corrected coordinates										
^b Land surface elevation used by DWR is in error by > 40 feet										
^c Land surface elevation updated to reflect corrected coordinates										
^d DWR Land surface elevation is incorrectly stated as 192.36 ft MSL. Reference Point Elevation revised herein ~12 feet to reflect Google Earth estimated LSE at the well coordinates										
NM = Not Measured; NM0=Well Monitoring has been discontinued										
NA = Not Available										

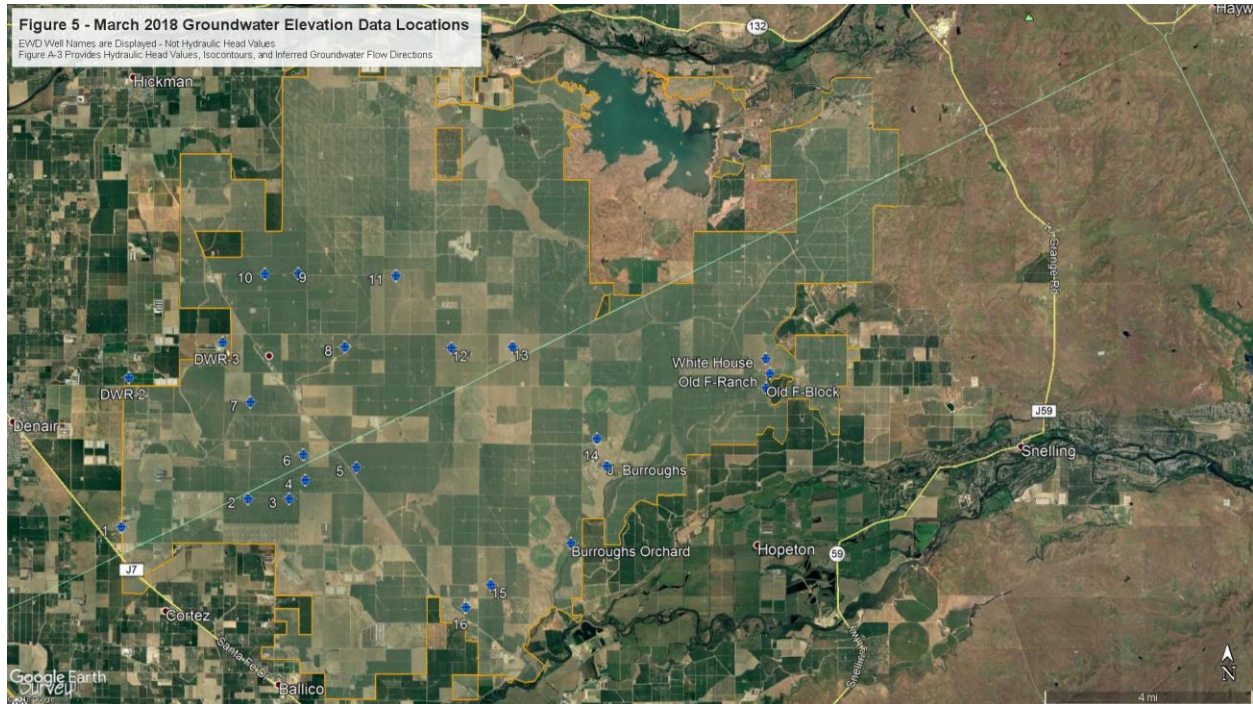
Technical Memorandum



Technical Memorandum

Page | 11

The locations of data collection are shown on Figures 3, 4 and 5 for October 2017, January 2018, and March 2018, respectively.



A summary of the data E-PUR collected for October 2017, January 2018, and March 2018 is given in the figures developed in Attachment A, Figures A-1, A-2 and A-3. Those figures in Attachment A developed with assistance from Wood Rodgers depict hydraulic heads, interpolated contours of the pressure surface and the inferred general groundwater flow direction assuming interconnectivity of subareas and zones.

STABLE ISOTOPE DATA

Table 3 provides a summary of the stable isotopes of hydrogen (deuterium or ^2H) and oxygen (^{18}O) measured in surface water and groundwater samples.

Table 3 Stable Isotope Data in Groundwater and Surface Water			
Location Name	Sampling Date	$\delta^2\text{H H}_2\text{O}$ ‰	$\delta^{18}\text{O H}_2\text{O}$ ‰
Old F Ranch Well 2507 Keyes Road	10/17/2017	-66.2	-8.62
Old F Ranch Well 2507 Keyes Road	1/10/2018	-66.3	-8.74
Old F Ranch Well 2507 Keyes Road	3/12/2018	-66.1	-8.41

Technical Memorandum

Table 3 Stable Isotope Data in Groundwater and Surface Water			
Location Name	Sampling Date	$\delta^2\text{H H}_2\text{O}$ ‰	$\delta^{18}\text{O H}_2\text{O}$ ‰
Current F Ranch Well 2507 Keyes	10/17/2017	-66.5	-8.85
Current F Ranch Well 2507 Keyes	1/10/2018	-66.0	-8.68
Current F Ranch Well 2507 Keyes	3/12/2018	-66.7	-8.86
Old F Block Well	10/17/2017	-63.9	-8.59
Old F Block Well	1/18/2018	-65.2	-8.77
Old F Block Well	3/12/2018	-64.5	-8.63
J. Burroughs Well	10/26/2017	-86.5	-11.69
J. Burroughs Well	1/10/2018	-81.5	-11.14
J. Burroughs Well	3/12/2018	-81.4	-11.10
Vista Livestock Well	10/4/2017	-87.8	-11.91
Vista Livestock Well	1/10/2018	-87.3	-11.91
Vista Livestock Well	3/12/2018	-88.2	-11.99
Rob White Domestic Well	10/17/2017	-63.9	-8.60
Rob White Domestic Well	1/10/2018	-63.6	-8.58
Rob White Domestic Well	3/12/2018	-63.9	-8.52
MID Canal at Keyes Road	10/4/2017	-94.6	-13.11
Ford of Dry Creek at Sierra View F Block	10/26/2017	-88.0	-11.88
Lateral D - AP	10/4/2017	-83.1	-11.25
J. Burroughs Swale	1/10/2018	-79.4	-10.63
Dry Creek	1/10/2018	-72.3	-9.29

Technical Memorandum

Page | 13

DATA ANALYSIS

SURFACE WATER PERCOLATION RATE ANALYSIS

Flow rate estimates herein should be considered rough approximations given the simple and approximating methods of data collection. The data are provided in the table below. Flow at the Dry Creek ford was estimated to be approximately 22 cfs. Similar measurements were made at the concrete culvert for the undercrossing at Sierra Vista Livestock's bridge over Dry Creek; the flow rate was estimated at roughly 10 cfs.

Table 4 – Surface Water Flow Measurements and Rate Estimates								
Location	Latitude	Longitude	Date	Flow Rate (cfs)	Depth (ft)	Width (ft)	Velocity (ft/s)	Comments
Dry Creek at Ford in F-Block	37.535797	-120.5308	3/12/2018	22.0	0.12	50	3.8	Paced off distances. Used floating stick to capture time of travel between fixed points
Dry Creek at Burroughs Orchard Bridge	37.492441	-120.5982	3/12/2018	9.9	0.39	6	4.2	Paced off width. Measured depth(s). Estimated travel distance of stick. Used floating stick to capture time of travel between fixed points of 25 feet in 7.1 seconds. Rechecked three times.

This analysis suggests the percolation rate between the two locations could be 12 cfs or greater. Of note there is a relatively large side tributary of Dry Creek between these two flow-rated locations. This tributary flow would be additive to the upstream 22 cfs making the percolation rate greater than 12 cfs.

As stated in the introductory section the flow rate of introduced water from Merced ID was likely between 2.5 and 3 cfs. All of this flow percolated into the aquifer between these same two observation points. The upper bound of percolation rates with and without spill was beyond the scope of Study. But substantive information has been gathered as to where such estimates would be helpful.

GROUNDWATER ELEVATION DATA ANALYSES

A description and discussion follows of electronic data collected, manual data collected over the Study period, and groundwater elevation mapping from the data accumulated for the Study from three sources.

High Frequency Data

Recharging a groundwater system by percolation of water from above typically produces a relatively small local pressure pulse in the hydraulic heads in nearby wells. This is the result of the overburden weight of the percolated water into the open-air unconfined aquifer zone sitting overtop of the confined zones. This occurs even though no recharge water has directly reached those confined zones. It is a simple pressure response analogous to placing a weight on a scale. The pressure pulse is rapid occurring over a period of

Technical Memorandum

Page | 14

hours to a few days (the time necessary for the percolating water front to travel downward to a continuous saturated interval) , while the area over which this increased pressure is felt is initially very small (i.e. local). The pressure pulse can usually be observed using electronic pressure transducers to record hydraulic heads frequently, for example every 5 to 15 minutes. However, nearby groundwater extraction can obscure the pressure pulse passing thru the nearby observation wells.

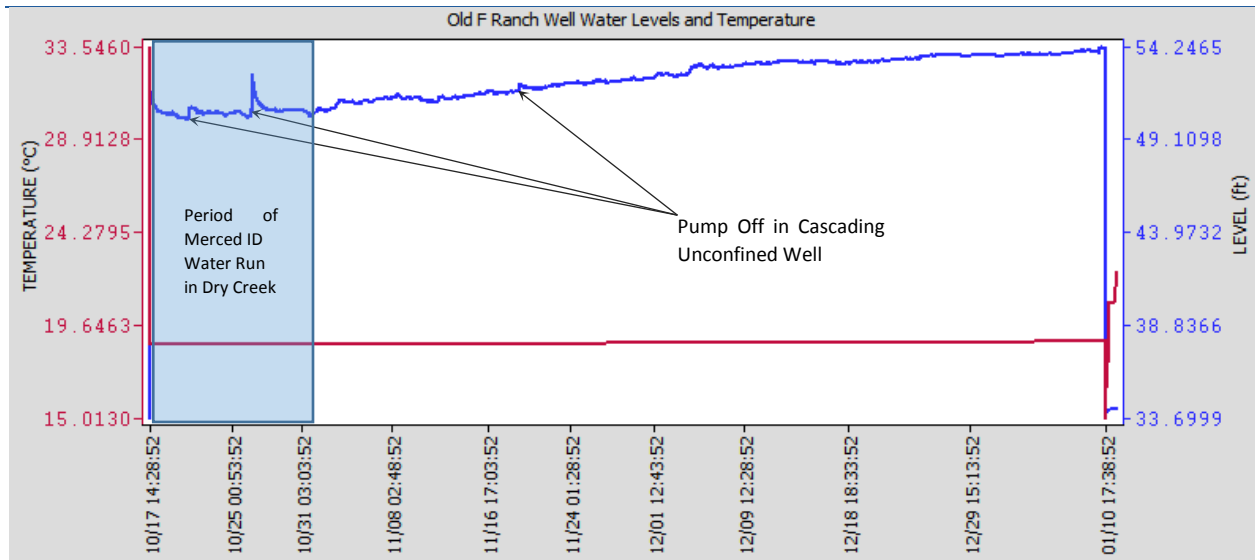
E-PUR collected high-frequency data via electronic pressure transducers and data loggers of hydraulic heads in two wells for the Study, Old F Ranch and Old F Block. These data are depicted graphically on two insets on the following page. Hydraulic heads over time in each of these wells show the effects of both local groundwater extraction and seasonal groundwater recharge by winter rains. The periodic stopping or cessation of groundwater extraction from the new F-Ranch supply well is the apparent source of periodic and sharp increases in hydraulic head in the old F-Ranch supply well nearby. The two F-Ranch wells are relatively shallow. Old F-Ranch Well had a measured depth to water of 133.75 feet and is screened from 125 to 285 feet below ground with apparent deterioration of the well casing beginning at around 65 feet below ground as evidenced by the sound of and detection of cascading water. Thus the hydraulic head in the well is a mix of unconfined and semi-confined hydraulic heads. New F-Ranch Well had a depth to water of roughly 160 feet (it changed rapidly as the supply well cycled on and off repeatedly); this well is effectively screened from 190 to 320 feet below ground indicating the aquifer zones it intercepts are most likely semi-confined. Each of the F-Ranch wells is roughly XXXXXX feet from the center line of Dry Creek situated where the creek snakes north and south. High frequency monitoring of Old F-Ranch Well do not demonstrate clear evidence of short term impacts of Merced ID water. Given the wells unconfined aquifer conditions and the nearby extraction of New F-Ranch well any increases in hydraulic head from percolated water were likely masked by the nearby extraction.

Extraction from the new F Block water supply well stops and starts during the Merced ID surface water run from October 17 to November 1, 2017. The lowering of hydraulic head in the Old F-Block water supply is attributable to these extractions as both wells are known or believed to be screened below a depth of 300 feet (Old F-Block Well log could not definitively be identified but total open well was sounded at 428 feet below top of casing). Each of these wells intercepts confined aquifer zones; these confined aquifer zones rapidly and readily show changes in groundwater pressure due to recharge and extraction.

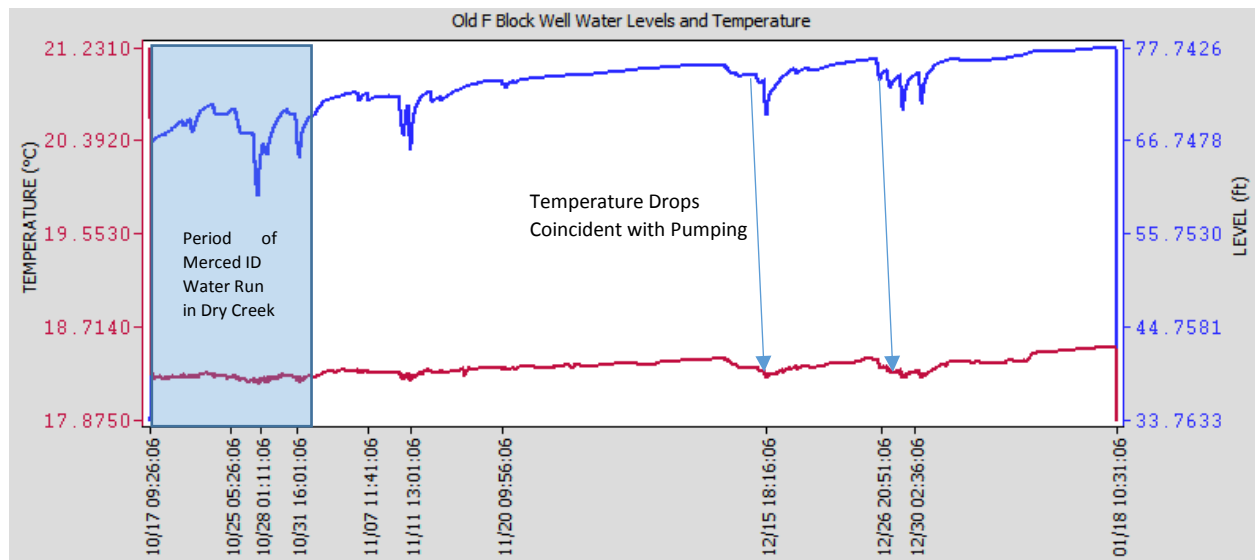
E-PUR high-frequency pressure and temperature data collected from Old F Ranch and Old F Block Wells.

Technical Memorandum

Page | 15



The pressure transducer data primarily show small surges associated with nearby extraction wells turning on and off overprinted on a month's long period of increasing hydraulic heads during the winter. The Pilot Study introduction of water was not a meaningful part of observed head changes. While there is some evidence in the Old F-Block Well from 10/18/2017 to 10/20/2017 of a pressure pulse due to the confined hydraulic head pressure readings from that well, there is nothing observed in the unconfined Old F-Ranch well.



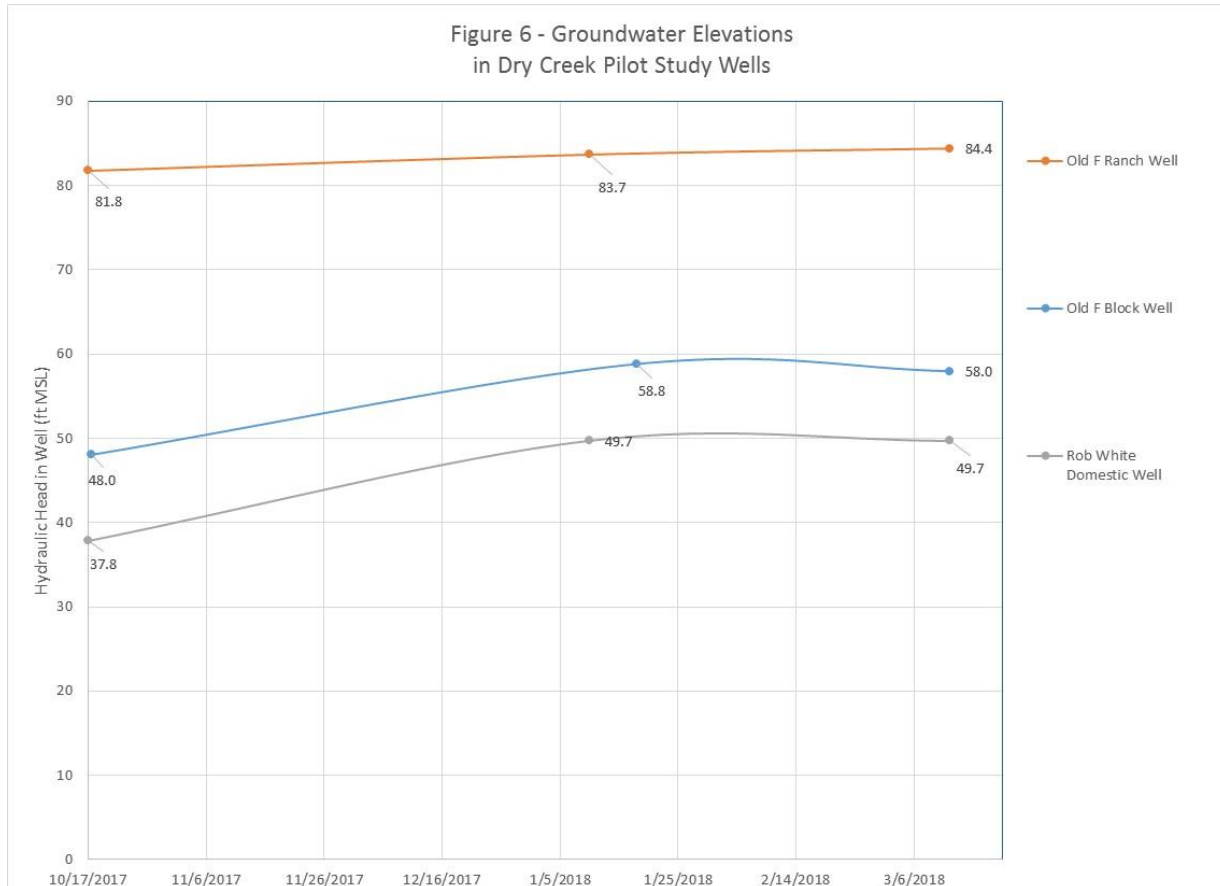
The evidence of the impact of the recharging Merced ID water can clearly be seen in the temperature signal for the Old F Block Well. When the nearby New F Block Well (and others) switch on and off, the hydraulic head changes quickly along with the temperature in the Old F Block Well (an inactive irrigation well). The Merced ID water is/was much colder than ambient groundwater in the region and this represents one clear line of evidence that the Old F Block Well was feeling the impact of the recharged water. Notably the temperature of shallow groundwater in Old F Ranch Well is higher at ~18.7°C than the deeper groundwater in the Old F Block Well at ~18.3°C. While the temperature of deeper groundwater is

Technical Memorandum

Page | 16

rising over the 2 month period to ~18.5°C, the temperature curve shows these clear downward surges lagging extraction by a matter of hours.

Manual Measurements of Hydraulic-Head Data



The winter period of recovery can be seen in the wells with more than one hand measurement of depth to water. These were taken using an electrical sounding tape. This data-trend analysis is supplementary to a secondary objective of the study, identifying data gaps and methods of data collection that may aid EWD in conducting a programmatic recharge project in Dry Creek. The groundwater wells utilized for the Study do not provide a sufficient dataset to evaluate seasonal groundwater storage changes in the unconfined zone near Dry Creek. Such shallow or unconfined aquifer zones wells likely do not exist as they are not useful for water production; however, such wells might be built and utilized as part of a larger intentional recharge program in Dry Creek. Note that in Figure 6 the recharge seen in the Old F Ranch Well is occurring in an unconfined zone.³ While the hydraulic-head change over two months in Old F Ranch is 2.6 feet as compared to the approximately 10 feet of head change in Old F Block Well, the smaller magnitude of change in head at Old F Ranch represents a **much** larger quantity of water than do the

³ Water can be heard cascading within the Old F Ranch Well from its upper screened interval at a depth of ~115 feet below top of casing to the semi-confined to confined intervals at depths of 188 to 315 feet. The nearby new F Ranch Well is extracting from these semi-confined to confined intervals from 190 to 320 feet creating a local difference between shallow and deeper hydraulic-heads which is partially relieved by the Old F Ranch Well.

Technical Memorandum

Page | 17

changes in the confined zone pressure in Old F Block. Confined well hydraulic heads generally depict a local pressure change and unconfined well hydraulic heads represent a material volume change in water stored in the aquifer. This distinction is very important for understanding how much water is in storage in the aquifer.

Groundwater Flow Directions during the Study

To address the objective of evaluating whether percolating water out of Dry Creek will recharge groundwater beneath EWD, E-PUR made hydraulic head maps of monthly data from October 2017, January 2018 and March 2018. Regional groundwater hydraulic heads can describe the direction of groundwater movement in an aquifer system when properly grouped together and mapped.

The contemporaneous groundwater elevation data from Table 1 were mapped using geospatial statistical software to interpolate between data locations based on the assumption that they are within an interconnected aquifer. Figures A-1, A-2, and A-3 in Attachment A depict scaled lines of interpreted equal hydraulic heads.⁴

Also shown on Figures A-1, A-2, and A-3 are the inferred directions of groundwater flow. The direction of groundwater flow is consistently from the south to the north away from the Merced River and Dry Creek northward into the District boundary. Contours of hydraulic head in October indicate patterns of radial flow generally inward toward a hydraulic low centered near the intersection of East Monte Vista Avenue and North Montpelier Road; there are other smaller scale highs and lows in hydraulic head in the interior of EWD's boundary. The predominant pattern is away from the Merced River. As a point of reference the approximate surface water elevation of the Merced River at four locations were placed onto Figures A-1 to A-3. The Merced River is generally believed to be a discharging river thru these upper reaches⁵ and thus flow would generally be away from the Merced River and toward EWD. There is one area of the Study at EWD Well #16 (State Well Number 05S12E27A001M) where a small data gap exists for describing groundwater hydraulic head relative to Dry Creek and EWD.

In January 2018 groundwater elevations have risen an average of 13 feet from October 2017. However, the inferred groundwater flow patterns are similar but without control points in the north supplied by DWR's data collection program. Flow is northerly from Dry Creek into the District. The J. Burroughs domestic well, the New F Ranch Well and the Rob White domestic well were each running intermittently in January 2018 while the large agricultural supply wells were not. Without the control points provided by DWR's data collection program Figure A-2 provides a less accurate representation of regional hydraulic heads and the larger scale regional flow than can be seen in October.

In March 2018 groundwater elevations remain at a seasonal high and groundwater flow has produced local recovery in excess of nearby wells. Figure A-3 continues to demonstrate radial flow inward toward the center-west of EWD but with a few of these notable high spots for groundwater hydraulic head. No production wells in the data collection program were running in March 2018. If this were true for many of the other production wells in the EWD then these data begin to describe an irregular pattern of rebound

⁴ The zones intercepted by the various wells may not be hydraulically well-connected; some may represent confined zones and others unconfined zones but the overall pattern of lateral groundwater movement should be consistent.

⁵ Page 60 of Phillips, S.P., Rewis, D.L., and Traum, J.A., 2015, Hydrologic model of the Modesto Region, California, 1960–2004: U.S. Geological Survey Scientific Investigations Report, 2015–5045, 69 p

Technical Memorandum

Page | 18

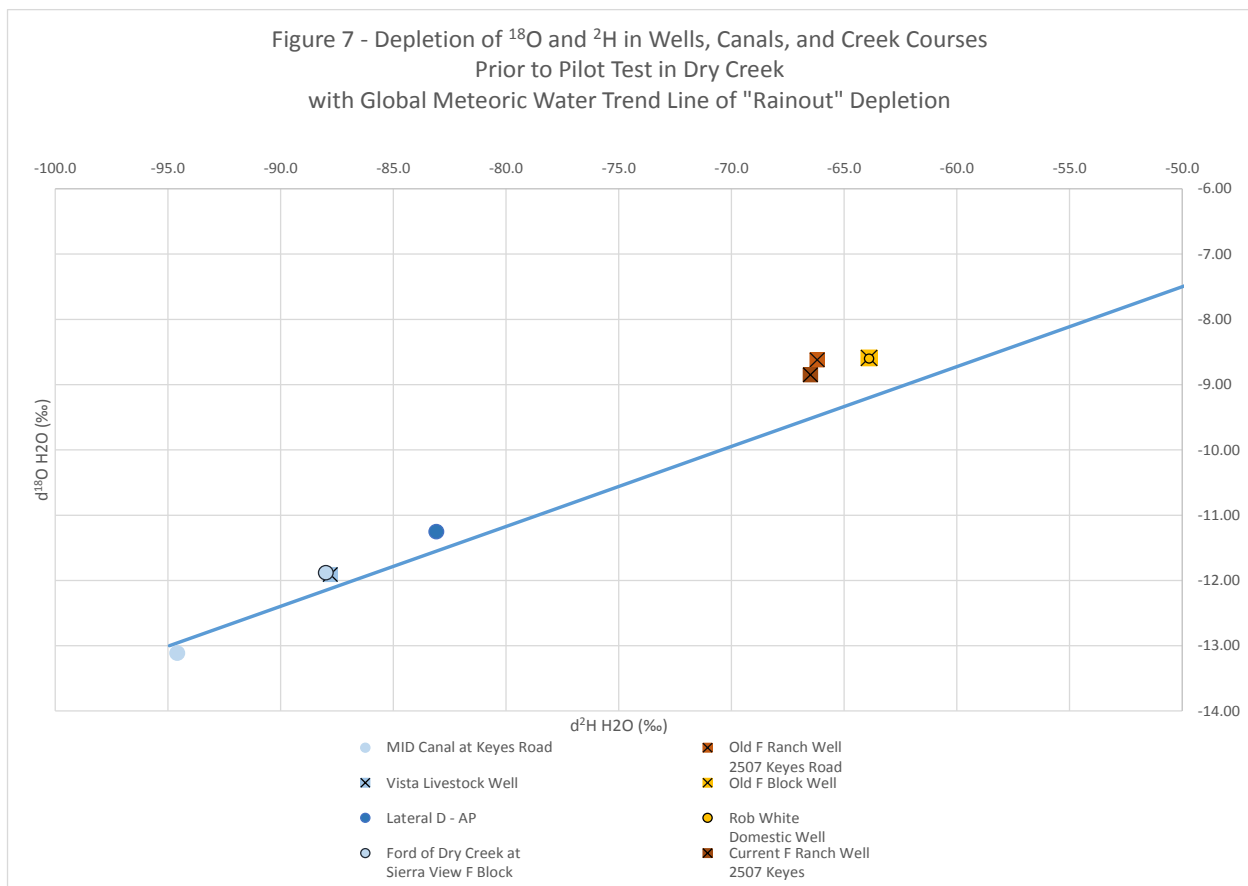
of hydraulic heads. An irregular pattern of hydraulic response is what is anticipated in a structured aquifer. Patterns of preferential recharge from boundary sources of water like Dry Creek and the Merced River may be traceable by both groundwater level rebound and stable isotopes. Temperature may also be a tracer.

STABLE ISOTOPE DATA ANALYSES

Stable isotope data collected for the Study provide a tremendous amount of information and insight into the mechanisms of groundwater recharge from intentional recharge and from natural recharge. The key takeaway points are:

- groundwater in the middle reach of Dry Creek at Sierra View Ranch demonstrates a stable isotope signature of local rainfall,
- groundwater in the lower reach of Dry Creek at Sierra Vista Ranch demonstrate a stable isotope signature of higher elevation rainfall (meaning Merced River recharge), and
- groundwater in the middle reach demonstrated direct recharge of the Merced ID surface water run to the confined zone of the Old F Block Well.⁶

Figure 7 depicts the initial groundwater and surface water sample values for relative depletion of heavy oxygen and deuterium from ocean evaporated water. The data break into two or three groups: (1) heavier



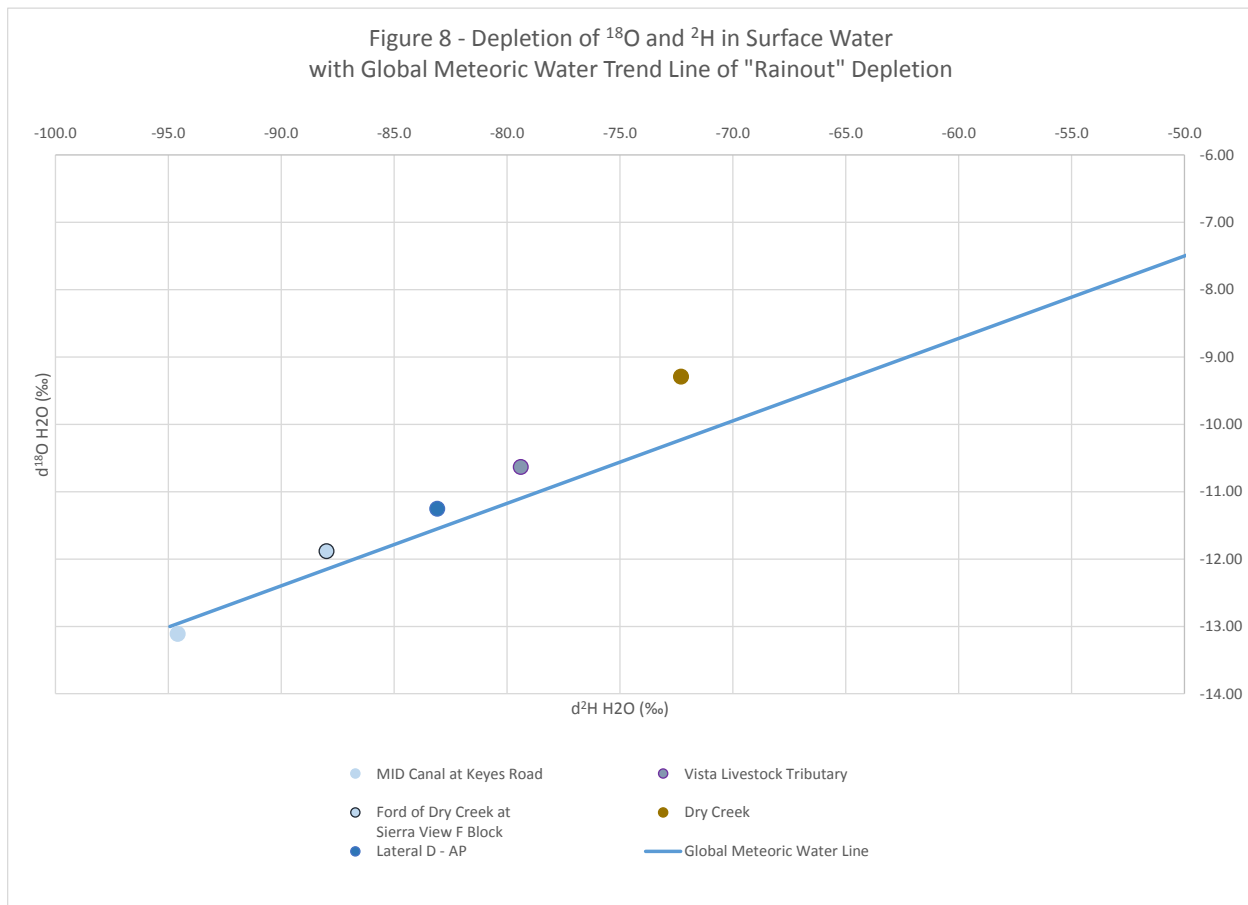
⁶ This directly corroborates the cold temperature pulses seen at Old F Block Well.

Technical Memorandum

Page | 19

water from the local source as seen in the upper right, (2) the light water of the Merced ID source and at Vista Livestock, and (3) a mixture of light and local water at Lateral D. The data show a very big difference between the Merced ID water and the groundwater at Sierra View Ranch. This provided a strong isotope “signal” for this Study (and is available for future studies or assessments of recharged water movement). The pattern in this graphic of both surface water and groundwater proportions of ^{18}O and ^2H fit the worldwide pattern of relative ^{18}O and ^2H depletion, “the Global Meteoric Water Line”. The fit of the data validates the isotope data and enables analysis using either or both stable isotopes to describe their source since they fit the worldwide model of relative depletions of stable heavy oxygen and stable heavy hydrogen.

Figure 8 depicts surface water stable isotope data. It depicts the Merced ID source water in their North Side Canal, the Merced ID surface water run (the Dry Creek ford at Sierra View), the admixture of source and tail water in Lateral D, and local rainfall samples collected from the upper reaches of Dry Creek and from a small local tributary to Dry Creek located on the Sierra Vista Livestock Ranch property.



The data show local rainfall in the upper Dry Creek watershed is relatively heavier water than water from Merced ID. This fits to the rainout model of the Global Meteoric Water Line both for the Dry Creek Watershed’s lower elevation and its smaller distance from the Pacific Coast compared to the high Sierras. Of note, the stable isotope data in native Dry Creek runoff are similar to the groundwater isotope data

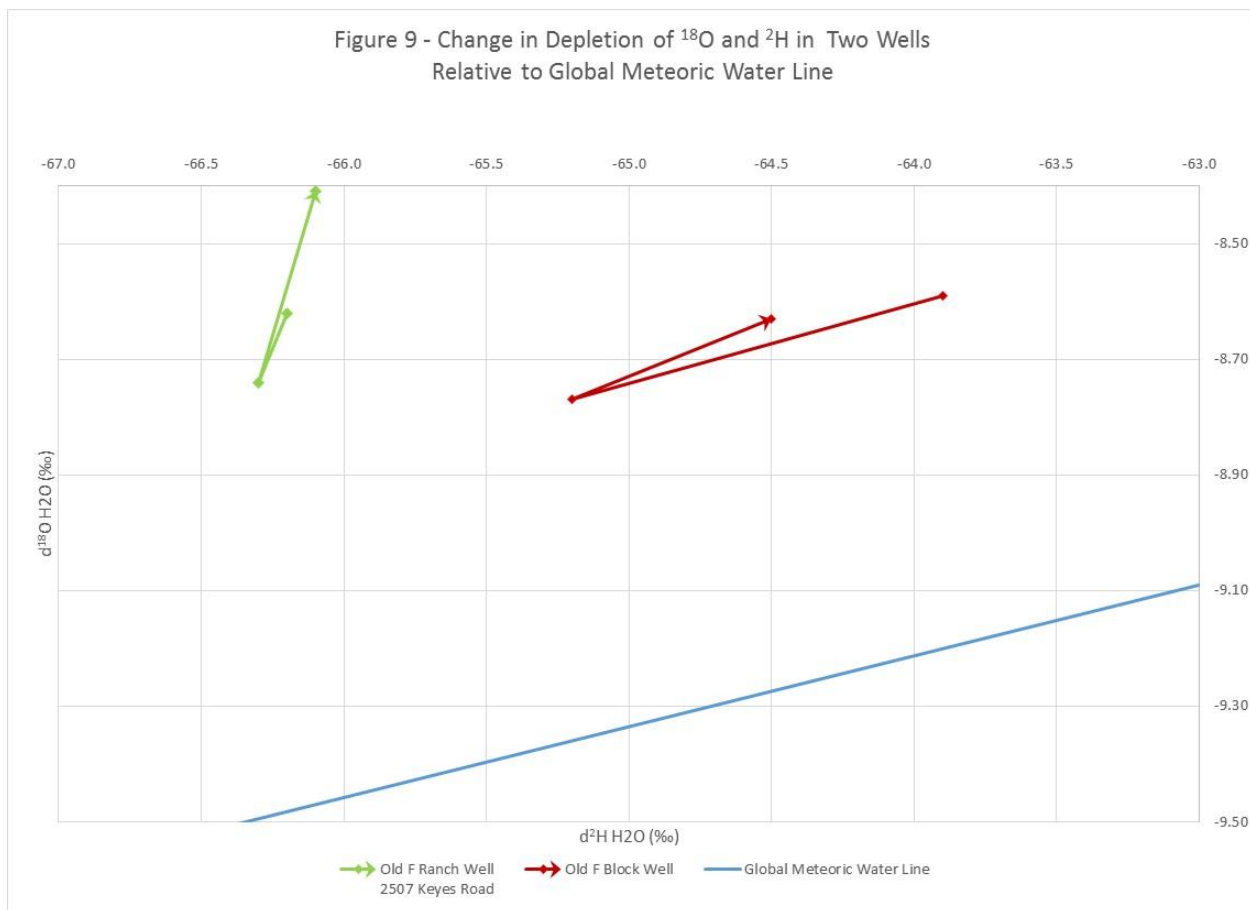
Technical Memorandum

Page | 20

from shallow and deep wells at Rob White's Sierra View Ranch; this signifies that those groundwater zones are recharged from local rainfall and not Merced River leakage.

Conversely, as shown in Figure 7, the stable isotope concentrations and ratio at the Vista Livestock well are similar to those of the Merced ID surface-water run in Dry Creek, prior to the run. This signifies that groundwater at the Vista Livestock well is recharged strongly from the Merced River. This similarity in stable isotope composition between Vista Livestock Well and the Merced water means there is no "signal strength" that can be observed nor was observed in this Study.

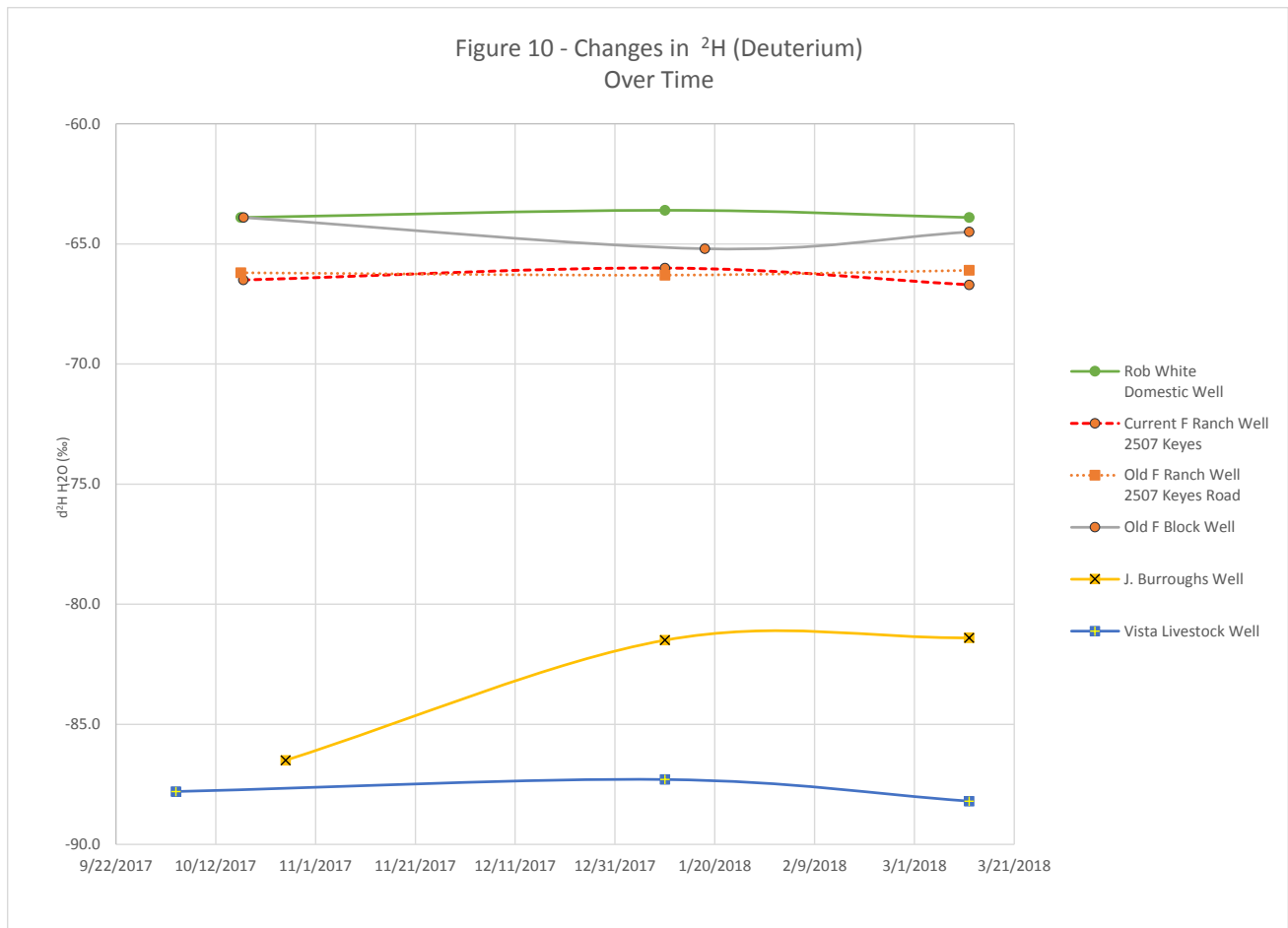
Figure 9 is a zoom in on changes to the concentrations of stable isotopes in two wells at Sierra View Ranch, Old F Ranch and Old F Block wells. They demonstrate a shift toward lighter water 75 days after the Merced ID surface-water run. Old F Blocks trend line parallels the Global Meteoric Water Line indicating this is a singular direct sourcing to a confined hydrogeologic zone that has a surface outcrop in the Dry Creek bed upstream. Old F Ranch follows a trend that indicates the water is becoming isotopically lighter but it suggests this is occurring via mixing of two distinct water sources, one source that has an evaporative enrichment and one (the Merced water) that does not.



Technical Memorandum

Page | 21

Figure 10 depicts changes over time of just one of the stable isotopes, deuterium, to provide a view of the pattern of changes in wells in the lower reach of Dry Creek represented at Sierra Vista Livestock Ranch and the mid reach of Dry Creek represented at Sierra View Ranch. The trend at the top of the chart of water becoming lighter in Old F Block Well soon after the Merced ID water run is distinct and signifies the percolation of water into interconnected material that connects to the aquifer zone that is 300 feet or deeper at the Old F Block Well. Evaluation of the geologic structure of the region and a preliminary hydrogeologic conceptual model of these zones following the regional orientation of Mehrten Formation beds suggests that permeable zones of the Mehrten Formation “daylight” or outcrop in the streambed of Dry Creek just downstream of the Sierra View Ranch’s G2 Outlet. The Old F Ranch Well, the Current F Ranch Well and the Rob White Domestic Well each show no real decrease or increase in deuterium. Each of these wells is screened in a shallow portion of the aquifer and may not be connected significantly to the nearby reaches of Dry Creek. In the case of the Old F-Ranch Well the contribution of very shallow unconfined zone water that would have received some recharge of Merced ID water directly may explain the small but notable dip in heavy hydrogen in January 2018.



The increase in deuterium in groundwater from the J. Burroughs domestic and agricultural supply well at the bottom of the graph suggest that this well receives some larger fraction of local water recharge in the winter but a much larger fraction of Merced River water recharge during the summer, explaining its overall

Technical Memorandum

Page | 22

lighter water characteristics but its heavier water uptick in the winter. The data from the J. Burroughs well do not affirm recharge of groundwater from the Merced ID surface water run. At the same time the data are not definitive that recharge did not occur in this region or reach; the isotopic signal is too small to detect that effect from Merced ID water but in this area the influence of more local recharge water can be seen from the winter rains in the Dry Creek watershed.

SUMMARY FINDINGS AND RECOMMENDATIONS

The Pilot Study demonstrated that Merced ID supplied water run in Dry Creek does recharge groundwater beneath the creek and EWD. The Study provided strong indication of where and how this recharge occurs in the middle reaches of Dry Creek; however the scope of this Study was not sufficient to assess whether and where recharge may occur in the lower reach of Dry Creek. Nor was the scope sufficient to quantify the upper bound of percolation from the middle to lower reaches of Dry Creek just based upon successive flow rate gaging.

The Study found that the probable flow of recharged water in the groundwater system will be toward EWD. The Study found that it is highly unlikely that the effects of any intentionally recharged water will generate flow toward or back into the Merced River. However, **E-PUR recommends further evaluation of the hydraulics of surface water percolated in the mid reaches of Dry Creek and the groundwater capture by nearby wells to improve the net benefit of intentional recharge.** For instance, if intentional recharge of Merced ID purchased water in the mid reaches of Dry Creek acts to disrupt the current groundwater-recharge that is induced from the Merced River then the purchased water will produce less benefit than if the timing and location of this intentional recharge does less to replace this on-going induced recharge of Merced River water that can be seen in the Vista Livestock well.

The Study found that the available rate of infiltration of surface water out of Dry Creek before water begins to “spill” out of the Creek and into the Merced River is greater than 2.5 to 3 cfs. The data collected after a winter rain event suggests the percolation rate in the mid reaches of Dry Creek exceeds 12 cfs but it is unknown if that rate comes with a high spill rate of outflow from the lowermost reaches of Dry Creek back to the Merced River. Further study is warranted of flow rates and percolation rates within different segmented reaches of Dry Creek. **One recommendation is that successive purchases of surface water be made to run at sequentially higher rates until “spill” is observed** at the lowermost observation point. In the ideal no surface water would “spill” at the maximum diversion available (100% effectiveness or efficiency). However, given the likelihood that at some rate of introduced flow in Dry Creek water will flow out, **we recommend a structured approach to finding that threshold and then subsequently collecting stream bed data to again optimize toward a desirable efficiency**, in order to maximize the quantity of water that can be introduced to the EWD and the East Turlock Basin GSA boundary when water is available. For instance a 75% efficiency on 20 cfs purchased for a net recharge rate of 15 cfs may be cost-effective when compared to 100% efficiency on 6 cfs if in the end that added 9 cfs provides a higher quantity of available water at a reasonable cost. **We recommend further studies to develop these concepts of optimized recharge as to timing, rate, and location.** With that we recommend installation of one or more stream gages along Dry Creek.

The Study identified a few data gaps for a program of intentional recharge. **We recommend development and implementation of a groundwater elevation monitoring program** capable of identifying and testing a hydrogeologic conceptual model of movement of surface water out of Dry Creek. **We recommend**

Technical Memorandum

Page | 23

identifying an existing well in the southernmost portion of the EWD suitable for groundwater elevation monitoring and adding it to the East Turlock GSA monitoring program; this well(s) would better constrain groundwater flow directions throughout the southeastern portion of the East Turlock GSA. **We also recommend adding additional shallow wells in the unconfined zone near Dry Creek and to the north to the East Turlock GSA monitoring program;** these unconfined zones would provide high value data for both intentional recharge in Dry Creek as well as for monitoring basin water storage changes within the East Turlock Basin GSA boundary. It is anticipated that those shallow unconfined zone wells do not exist and would need to be constructed as part of Subbasin or GSA area monitoring program. Any such well installation should be done with an eye toward Groundwater Sustainability Plan (GSP) development and with an eye toward potential funding sources for their design, construction, and monitoring.

ACKNOWLEDGEMENTS

This Study was made possible by the access to property and generous time made available by Mr. Rob White of Sierra View Ranch and by the access provided by Sierra Vista Livestock Ranch and the assistance of Brian Kline, Jimmie Burroughs, Ward Burroughs, Bruce Burroughs, and Nick Hibma.

E-PUR is pleased to have had the opportunity to conduct this Study for EWD and wishes to acknowledge the assistance of Mr. Kevin Kauffman in coordinating the wide range of access and activities, and for making himself and his “Buffs” tape available in the field.

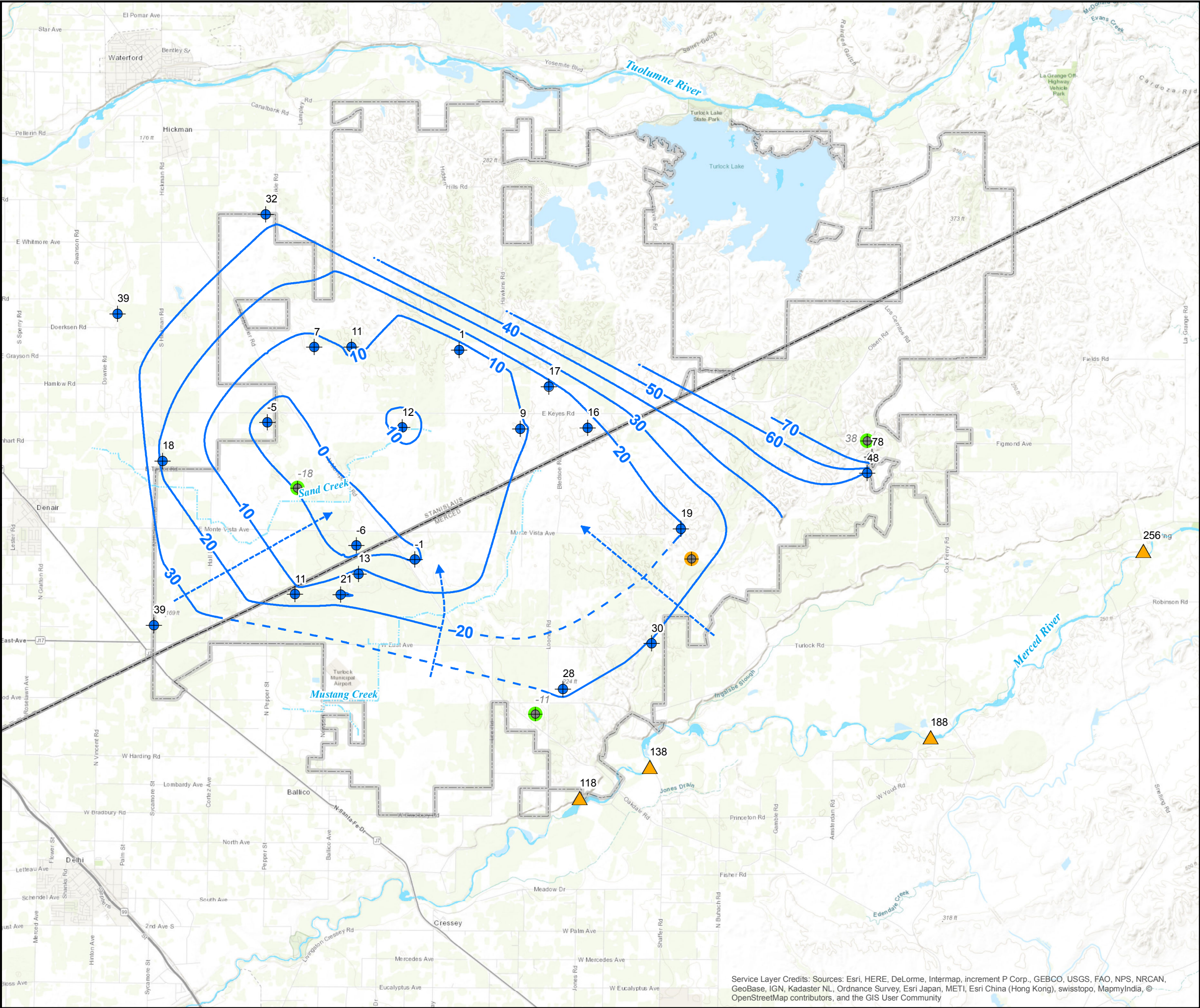


ATTACHMENTS:

Attachment A: Groundwater Elevation Contour Maps with Inferred Flow Directions and Data

Attachment B: Groundwater Well Construction and E-PUR Field Data Tables

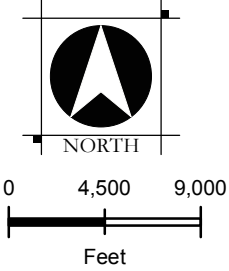
Attachment A – Groundwater Elevation Contour Maps
with Inferred Flow Directions and Data Displayed



GROUNDWATER ELEVATION CONTOUR MAP

OCTOBER 2017

EASTSIDE WATER DISTRICT - DRY CREEK
STANISLAUS AND MERCED COUNTIES, CA
APRIL, 2018



October 2017 Water Surface Elevation (ft, msl)

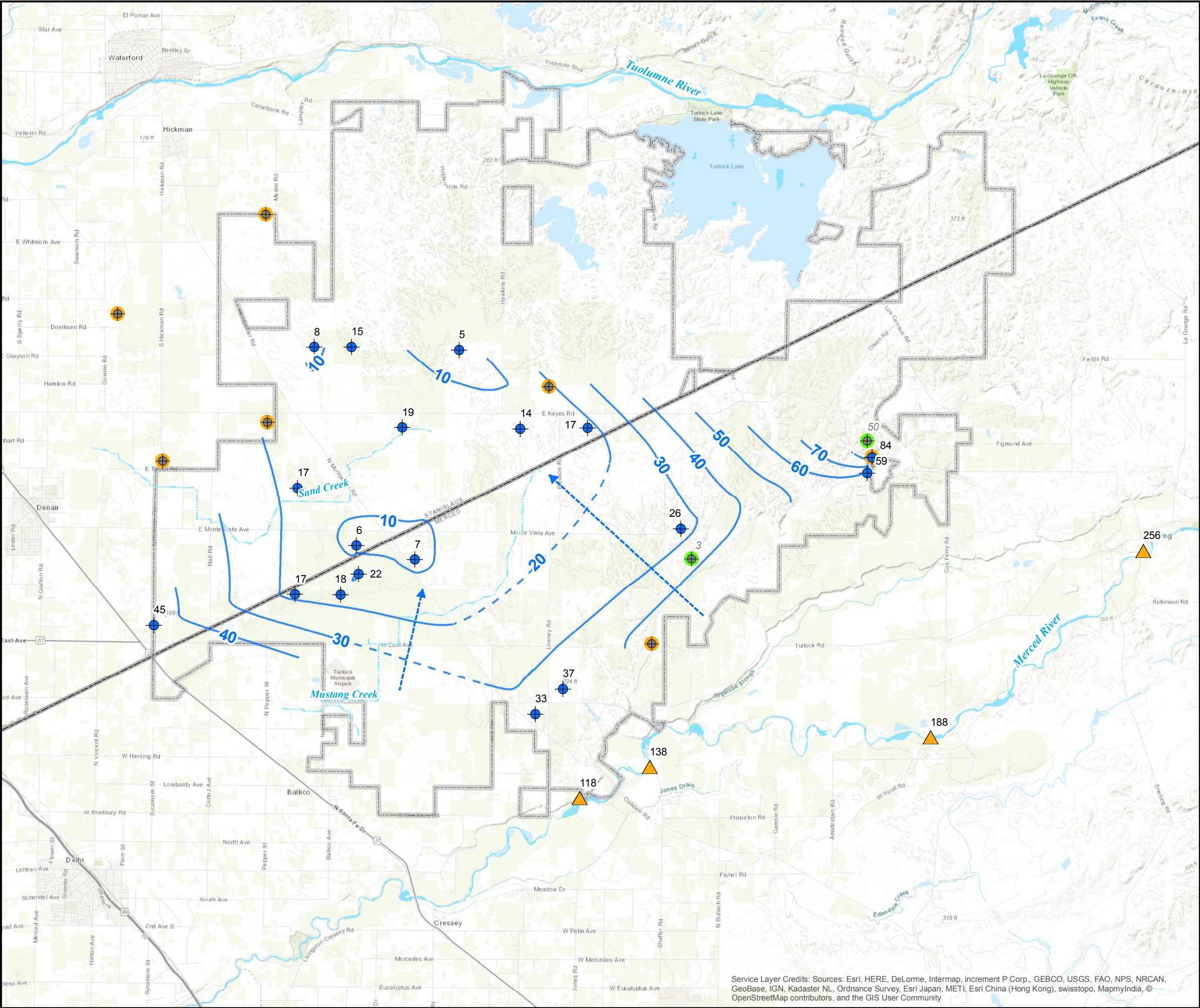
- Groundwater Data Point
- Well was Pumping (Not used for Contouring)
- Data Not Available for Well
- Surface Water Data Point (Not used for Contouring)
- Groundwater Elevation Contour (10-ft Interval)
- Groundwater Elevation Contour - Inferred
- Direction of Groundwater Flow (Approximate)
- Eastside Water District
- County Boundary

NOTES:
1. Contour lines were generated using October 2017 groundwater elevation data only, and applying the Natural Neighbor interpolation method.
2. Three wells were pumping in October 2017; therefore, these data were not used to generate groundwater elevation contours. The pumping water elevations are shown in gray italics.
3. Measurement dates for the surface water data points were not available.



WOOD RODGERS

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



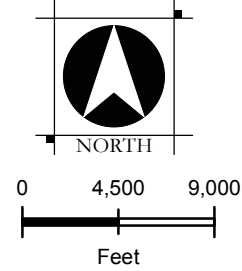
GROUNDWATER ELEVATION CONTOUR MAP

JANUARY 2018

EASTSIDE WATER DISTRICT - DRY CREEK

STANISLAUS AND MERCED COUNTIES, CA

APRIL, 2018



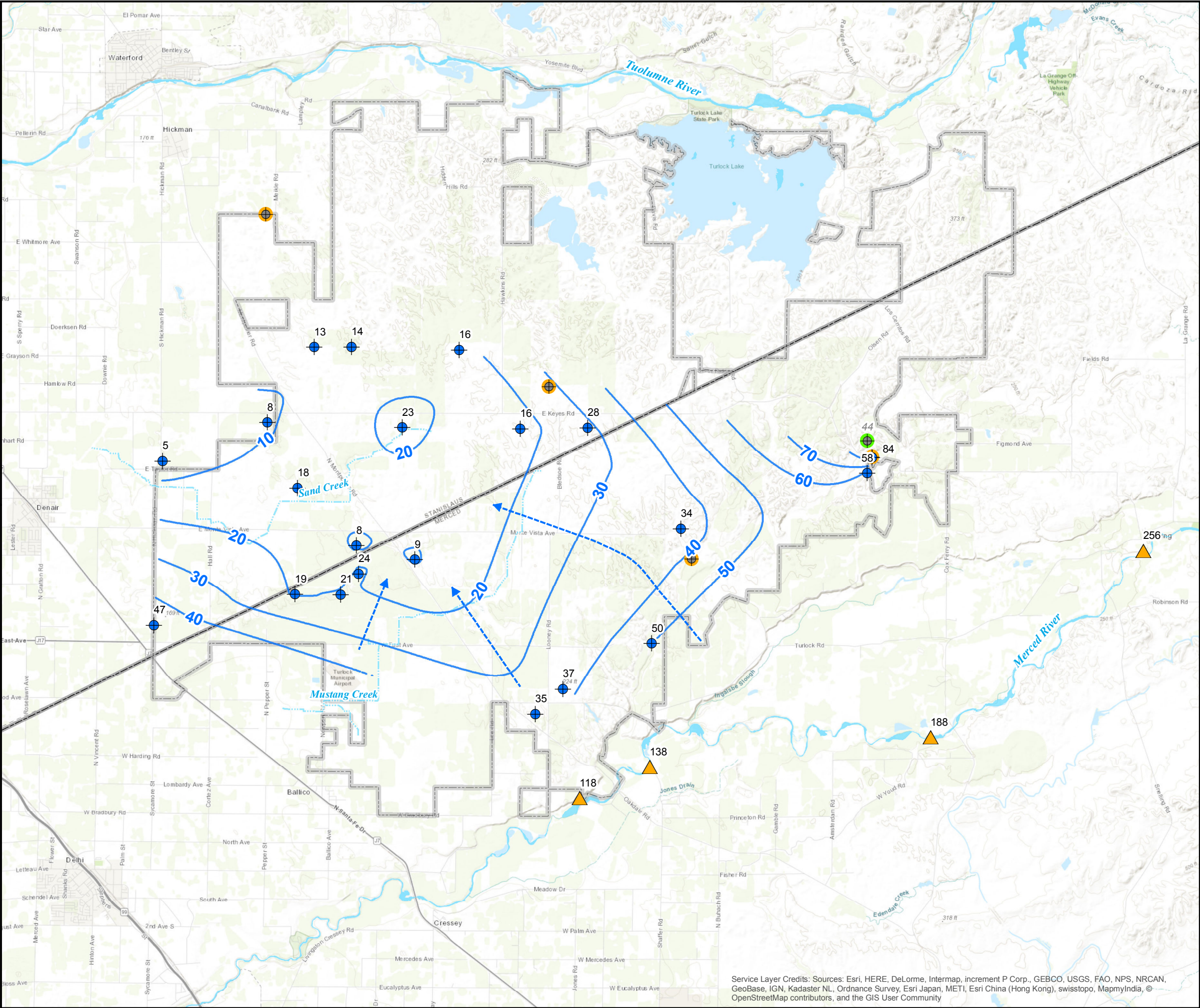
January 2018 Water Surface Elevation (ft, msl)

- Groundwater Data Point
- Well was Pumping (Not used for Contouring)
- Data Not Available for Well
- Surface Water Data Point (Not used for Contouring)
- Groundwater Elevation Contour (10-ft Interval)
- Groundwater Elevation Contour - Inferred
- Direction of Groundwater Flow (Approximate)
- Eastside Water District
- County Boundary

NOTES:
1. Contour lines were generated using January 2018 groundwater elevation data only, and applying the Natural Neighbor interpolation method.
2. Two wells were pumping in January 2018; therefore, these data were not used to generate groundwater elevation contours. The pumping water elevations are shown in gray italics.
3. Measurement dates for the surface water data points were not available.



Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



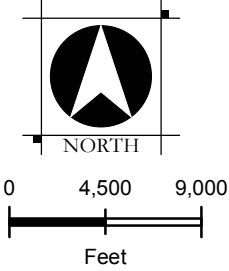
GROUNDWATER ELEVATION CONTOUR MAP

MARCH 2018

EASTSIDE WATER DISTRICT - DRY CREEK

STANISLAUS AND MERCED COUNTIES, CA

APRIL, 2018



March 2018 Water Surface Elevation (ft, msl)

- Groundwater Data Point
- Well was Pumping (Not used for Contouring)
- Data Not Available for Well
- Surface Water Data Point (Not used for Contouring)
- Groundwater Elevation Contour (10-ft Interval)
- Direction of Groundwater Flow (Approximate)
- Eastside Water District
- County Boundary

NOTES:
1. Contour lines were generated using March 2018 groundwater elevation data only, and applying the Natural Neighbor interpolation method.
2. One well was pumping in March 2018; therefore, the data point was not used to generate groundwater elevation contours. The pumping water elevation is shown in gray italics.
3. Measurement dates for the surface water data points were not available.



Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

FIGURE A-3

Attachment B – Well Construction and E-PUR Field Data Tables

Table B-1 - Pilot Study Assessment Well Information																		
Study Well Names	StateWellName	Latitude	Longitude	Initial Static Depth to Water (feet)	Date Installed	Land Surface Elevation (ft MSL)*	Estimated TOC Elevation	Well Depth (ft)	Diameter of Well (in)	Diameter of Borehole (in)	Depth Top of Screen (feet)	Depth Top of Gravel Pack (feet)	Depth Bottom of Screen (feet)	Depth Bottom of Gravel Pack (feet)	Date Visited	Depth to Water	Isotope Analysis	Comments
Old F-Ranch Well 2507 Keyes	04S13E34Q001M	37.539951	-120.526763	168.4	8/12/1961	214	215.5	250	12	16	125	NA	285	NA	10/17/2017	133.75	Yes	Transducer Deployed ~150' Below TOC. 5 minute sample interval
Current F-Ranch Well 2507 Keyes	04S13E34Q002M	37.540028	-120.526712	122	11/7/2011	214	214.5	320	6	11	220	190	320	320	10/17/2017	161.03	Yes	Sampled from truck water supply area hose
Old F-Block Well	05S13E03B001M	37.535921	-120.528217	?	1961?	202	202	421.4	14	20	250	225	428	430	10/17/2017	153.96	Yes	Transducer Deployed at ~180' from top of well cap. Sampled by bailer from within screened interval
White House Domestic Well	04S13E34F001M	37.544136	-120.528278	?	?	287	288.0	300.1	5	10	364	350	384	400	10/17/2017	250.18	Yes	Sampled from spigot on wellhead
Jimmie Burroughs Domestic and Ag. Well	05S13E07C001M	37.513909	-120.584852	86	7/12/1979	181	183.0	329.7	10	16	252	NA	336	open hole	10/26/2017	NM	Yes	Sampled at valve on piping to supply tank
Ward Burroughs Orchard Well	05S13E07F001M	37.492226	-120.59761	64	4/8/1982	160	161.0	414.25	16	22	232	NA	336	NA	10/4/2017	130.53	Yes	Transducer Deployed to ~ 200' below well pipe. Sampled from fill pipe to storage tank

* Land Surface Elevations estimated from Google Earth

Table B-2 - Groundwater Level Data from Isotope Monitored Wells in Pilot Study

Well Names	Date	Top of Casing Elevation (ft MSL)*	Depth to Water (ft)	Groundwater Level (ft MSL)	Comments
Current F Ranch Well 2507 Keyes	11/7/2011	214.5	122	92.5	Measurements at time of Well Construction
Current F Ranch Well 2507 Keyes	10/17/2017	214.5	136.3	78.2	Pump off
Current F Ranch Well 2507 Keyes	1/10/2018	214.5	NM	NM	Pump on
Current F Ranch Well 2507 Keyes	3/12/2018	214.5	NM	NM	Pump on
Old F Ranch Well 2507 Keyes	8/12/1961	215.5	28	187.5	Measurements at time of Well Construction
Old F Ranch Well 2507 Keyes	10/17/2017	215.5	133.8	81.8	Transducer Deployed
Old F Ranch Well 2507 Keyes	1/10/2018	215.5	131.8	83.7	Transducer Retrieved
Old F Ranch Well 2507 Keyes	3/12/2018	215.5	131.1	84.4	Current F Ranch Pump Buzzing starts 5 minutes later. Pump believed to be off. Audible sound of water cascading in well
Old F Block Well	10/17/2017	202.0	154.0	48.0	Transducer Deployed
Old F Block Well	1/18/2018	202.0	143.2	58.8	Transducer Re-Deployed
Old F Block Well	3/12/2018	202.0	144.0	58.0	Transducer Retrieved
Rob White Domestic Well	10/17/2017	288.0	250.18	37.82	Well Running
Rob White Domestic Well	1/10/2018	288.0	238.28	49.72	Pump Status Unknown
Rob White Domestic Well	3/12/2018	288.0	238.3	49.7	Pump on and off
Jimmie Burroughs Domestic and Ag. Well	7/12/1979	182.0	86	96.0	Measurements at time of Well Construction
Jimmie Burroughs Domestic and Ag. Well	10/26/2017	183.0	NM	NM	Wellhead not accessible due to sealed surface packer
Jimmie Burroughs Domestic and Ag. Well	1/10/2018	183.0	180	3	Pump On Measurement Quality Poor - Tape Tangle on Packer
Jimmie Burroughs Domestic and Ag. Well	3/12/2018	183.0	NM	NM	Pump On
Ward Burroughs Orchard Well	4/8/1982	160.0	64	96.0	Measurements at time of Well Construction
Ward Burroughs Orchard Well	10/4/2017	161.0	130.53	30.47	Pump Off
Ward Burroughs Orchard Well	1/10/2018	161.0	NM	NM	Loss of Transducer
Ward Burroughs Orchard Well	3/12/2018	161.0	117.2	43.8	Loss of Transducer

* Elevation Approximated from Google Earth LSE plus Measured Height Above Grade