01 May 2021

TECHNICAL MEMORANDUM

To: Cosumnes Subbasin SGMA Working Group

From: Anona Dutton, PG, CHg, Environment & Water, Inc. (EKI)
John Fio, EKI
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Subject: Isotopic Recharge Study, Cosumnes Subbasin
(EKI B80081.01, Task 5)

The Cosumnes Subbasin (herein referred to as the "Basin") is a medium priority basin located in Sacramento and Amador Counties and is required to comply with the Sustainable Groundwater Management Act (SGMA). Groundwater meets nearly all the demand for water within the Basin and the long-term sustainability of the resource is critical to the economic vitality and well-being of the beneficial users and uses. As part of Groundwater Sustainability Plan (GSP) development, the Groundwater Sustainability Agencies (GSAs) identified multiple data gaps and/or needs for additional analyses crucial to GSP completion based on stakeholder feedback and recently released guidance. A significant issue for the Basin and the adjacent subbasins is the nature and source of groundwater recharge. This technical memorandum (TM) delineates areas recharged primarily by river depletions versus local precipitation and runoff as it is important for water budget development, and to support effective Basin management (e.g., plans to protect recharge areas). The results of this TM will be incorporated, as applicable, into the Cosumnes Subbasin GSP.

1. INTRODUCTION

The isotopic composition of groundwater, surface water, and precipitation can vary significantly based on environmental conditions such as elevation, temperature, and latitude. Abrupt changes in elevation, as is common in California, can lead to isotopic fractionation as condensation and evaporation occur leading to different compositions of stable isotopes in water sources. For example, precipitation in mountainous regions, such as the Sierra Nevada, have a lower composition of heavier hydrogen and oxygen in comparison to the precipitation in coastal regions (Craig, 1961; Ingram and Taylor, 1986; Williams and Rodoni, 1997).

The measured contrast in isotopic composition of water sources can be employed to elucidate the extent of surface and groundwater interactions and improve the characterization of recharge sources (Craig, 1961; Ingram and Taylor, 1986; Williams and Rodoni, 1997). Accordingly, water samples collected from wells located across the Cosumnes Subbasin (herein referred to as the "Basin") were analyzed for stable isotopes of oxygen and hydrogen to determine their likely sources of recharge. Specifically, this study sought to determine the relative geographic extent of recharge from Cosumnes River leakage and recharge from local precipitation using well water sampling results and relevant results from the following complimentary studies:

- Dunn Environmental Lake Camanche Groundwater Supply Study (2012).

- Sacramento Central Groundwater Authority's (SCGA) Recharge Mapping and Field Study (2015).
- Lawrence Livermore National Laboratory's (LLNL) study of climate effects on California water systems from headwaters to groundwater (2019 and 2020).
- Omochumne-Hartnell Water District's (OHWD) groundwater recharge project and the University of California Groundwater Observatory project (2019).

During July and August of 2020, twenty-five (25) samples were collected from 19 wells (19 samples and 8 duplicate samples for Quality Assurance and Quality Control) within the Basin. The sample locations are shown in **Figure 1**. The samples were delivered to an analytical laboratory (UC Davis Stable Isotope Facility), and the results were compiled and collated with appropriate data from the studies noted above.

2. BACKGROUND

A stable isotope is a form of an element that has the same number of protons, but different number of neutrons, is not radioactive, and can exist in nature while maintaining the same composition over long periods of time (Craig, 1961; Ingram and Taylor, 1986; Williams and Rodoni, 1997). Analysis of stable isotopes can have many applications, though of relevance to this study is the ability to determine a potential source of water based on the composition of the stable isotopes of oxygen (^{18}O) and deuterium (D). The isotopic composition of a water sample is expressed using the delta notation (δ). The delta notation is the ratio between ^{18}O and D relative to the Vienna Standard Mean Ocean Water (VSMOW) with units reported in parts per thousand (‰). A negative δ value indicates the water sample has less ^{18}O and D than VSMOW while a positive δ value indicates a sample with more ^{18}O and D than VSMOW.

The $\delta^{18}O$ composition of precipitation, surface water, and groundwater around and in the Basin, is discussed in the following sections. Lighter, depleted, or more negative compositions describe water that have a smaller ratio of $\delta^{18}O$ while heavier, enriched, or less negative compositions describe water that have a greater ratio of $\delta^{18}O$. These descriptions can be used interchangeably.

2.1. Isotopic composition of precipitation

Previous studies characterized the isotopic composition of local precipitation in or near the Basin. These studies were summarized in detail previously by HydroFocus, Inc. (2015) as described in the Sacramento Central Groundwater Authority's (SCGA) Recharge Mapping and Field Study (2015) noted above.

- Criss , Davisson and Campbell (1993) found of the precipitation collected between 1990-1991, the weighted average value of δ18O was -7.5 ‰. Most sites sampled were located in the City of Davis, which is at an elevation of 60 feet above mean sea level (ft msl) and roughly 35 miles northwest of the Basin.
- A 2008 study of 73 samples from a station in the City of Folsom found the average δ18O of precipitation was -9.00 ‰. The City of Folsom is located at an elevation of 340 ft msl and is roughly 30 miles northeast of the Basin (Bonds, 2015).
- A study in the South American Subbasin utilized a value of -7.5 ‰ to categorize local precipitation (HydroFocus, 2015).
- Visser et al. (2019) characterized local precipitation in the Basin with a δ18O of -7 ‰.

The differences in δ18O values around the Basin are attributed to the influence of elevation on isotopic fractionations (Gat and Gonfiantini 1981). For example, as shown above the lower elevation regions (e.g., Davis) typically have a heavier (more positive) isotopic composition than higher elevation regions (e.g., Folsom) characterized by lighter (more negative) isotopic composition. This study considers δ18O values in the range of -7 ‰ to -7.5 ‰ representative of local precipitation and drainage flows that originate as local runoff.

2.2. Isotopic composition of surface waters

The Cosumnes River forms the northern boundary of the Basin with headwaters located in the western slopes of the Sierra Nevada and elevations greater than 7,000 ft msl. Because river flows originate as precipitation at relatively high elevations, the δ18O value is expected to be more depleted than local precipitation in the Basin. Hence, this study utilized δ18O values of -8 ‰ to -9 ‰ to identify Cosumnes River flows (Visser et. al, 2019; HydroFocus, 2015). The southeasternmost Basin boundary is formed by Camanche Reservoir, which stores Mokelumne River flows. Like the Cosumnes River, the Mokelumne River originates at higher altitudes of greater than 8,000 ft msl in the Sierra Nevada. The isotopic composition of Mokelumne River water is therefore also expected to be more negative (lighter) than local precipitation. Dunn Environmental (2012) identified well water samples influenced by Camanche Reservoir (e.g., Mokelumne River water) as those having δ18O values ranging from -8.3 ‰ to -10.3 ‰.

2.3. Isotopic composition of groundwater

The isotopic composition of groundwater can provide key insights to both the movement and source of recharge. In the Basin, a lighter isotopic composition can be expected for well water samples influenced by source waters derived from cooler, higher elevation regions (e.g., Cosumnes River or Mokelumne River water). In contrast, water samples from wells located further away from the rivers are expected to be minimally influenced by river leakage, and more influenced by local precipitation and leakage from the interior creeks.

3. WELL SAMPLING

The spatial distribution of recharge sources across the Basin was assessed based on water samples collected from 19 wells and analyzed for 18O and D. The wells were selected based on one or more of the following criteria:

- Spatial distribution that provides a reasonably uniform geographic coverage throughout the Basin, when considered with the previous sampling locations;
- Sites located in proximity to areas of interest (e.g., Cosumnes River);
- Proposed Representative Monitoring Sites for the Cosumnes Subbasin Groundwater Sustainability Plan (GSP);
- Availability of well construction information; and,
- Accessibility at the time of sampling.

The locations of the wells sampled are mapped in **Figure 1**. The water samples were collected by UC Davis Hydrologic Graduate Group staff under the direction of EKI, Inc. personnel between 14 July 2020 and 8 August 2020. Information for the wells sampled, such as geographic coordinates, well construction information, and well-use are summarized below in **Table 1**. A detailed summary of the well sampling protocols is included in **Attachment A**.

Table 1. Construction, Locations, and Uses of Wells Sampled for Stable Isotopes

Map ID	Site Name	Well Depth (ft bgs)	Latitude	Longitude	Well Use
1	Gwerder Domestic	105	38.2402	-121.37	Domestic
2	05N06E30E001M (Gallo)	647	38.2558	-121.3696	Irrigation
3	UCW_MW-5	64	38.3097	-121.376	Monitoring
4	UCW_MW-11	38	38.3049	-121.369	Monitoring
5	06N06E29K001M (Belcher-Onto)	600	38.3421	-121.3399	Irrigation
6	Montrey Bay 20	890	38.2911	-121.2897	Public Supply
7	Industrial Well 22	1,627	38.2734	-121.3135	Public Supply
8	Gateway 14	750	38.2487	-121.286	Public Supply
9	06N06E11J003M (Ernery Domestic)	215	38.3866	-121.2795	Domestic
10	Dillard Elementary	UNK	38.404	-121.2491	Domestic
11	OHWD_TSS_MWC-1D	500	38.4281	-121.2236	Monitoring
12	OHWD_TSS_MWC-1M	325	38.4281	-121.2236	Monitoring
13	OHWD_TSS_MWC-1S	175	38.4281	-121.2236	Monitoring
14	SH_Washburn_Dom	180	38.4448	-121.1873	Domestic
15	07N08E06N001M (Kautz Farms)	135	38.4791	-121.1481	Irrigation
16	Silva_Clay2 (Gary Silva Ag)	UNK	38.3585	-121.1559	Irrigation
17	ACGMA Bamert Rd MW D	163	38.3038	-120.9872	Monitoring
18	ACGMA Bamert Rd MW S	78	38.3038	-120.9872	Monitoring
19	ACGMA Carbondale	215	38.3969	-121.0078	Monitoring

Abbreviations:
ft bgs= feet below ground surface
UNK= unknown

The well-water samples were submitted to the UC Davis Stable Isotope Facility (UCD SIF) and analyzed for their isotopic composition. The UCD SIF utilized a Laser Water Isotope Analyzer V2 to analyze a ratio of ^{18}O and D to VSMOW, the standard measure for isotopic composition as discussed above in Section 2. The results of the isotopic analysis are summarized in **Table 2**.

As described in the draft Cosumnes Subbasin Groundwater Sustainability Plan (GSP), the Basin has two physiographic subareas: the "Basin Plain" subarea and the "Basin Foothills" subarea (See Section 2.1.1 of Technical Memorandum 6 submitted to Working Group 11/2019 [EKI, 2019]). The Basin Plain subarea primarily covers the western and central portions of the Basin, where a majority of the production wells are located (see Figure HCM-7 of Technical Memorandum 6 submitted to Working Group 11/2019 [EKI, 2019]). Additional well samples from wells across the Basin in other isotopic studies were also utilized for this analysis and are shown on **Figure 5**. The data from wells located in the Basin Plain from these studies are reported in **Attachment B** and shown on **Figure 2.**

Table 2. Stable Isotope Sampling Results

Map ID	Lab ID	Well Name	Date	Time	$\delta^{18}O$	δD
1	113294	Gwerder Domestic	7/16/2020	14:10	-7.55	-56.6
2	113289	05N06E30E001M (Gallo)[d]	7/14/2020	8:00	-7.75	-55.3
3	113297	UCW_MW-5[e]	8/31/2020	12:00	-9.99	-69.5
4	113301	UCW_MW-11[d]	8/31/2020	10:30	-5.59	-44.8
5	113290	06N06E29K001M (Belcher-Onto)[e]	7/14/2020	11:25	-8.54	-58.9
6	113291	Monterey Bay 20[d]	7/16/2020	9:04	-7.53	-55.4
7	113292	Industrial Well 22[e]	7/16/2020	10:20	-8.90	-64.4
8	113293	Gateway 14	7/16/2020	11:30	-7.63	-55.4
9	113306	06N06E11J003 (Ernery Domestic)[c]	8/27/2020	12:45	-8.65	-60.3
10	113295	Dillard Elementary	7/21/2020	12:15	-8.34	-60.4
11	113302	OHWD_TSS_MWC-1D[d]	8/25/2020	12:00	-8.45	-60.4
12	113303	OHWD_TSS_MWC-1M[e]	8/25/2020	14:00	-8.41	-58.3
13	113304	OHWD_TSS_MWC-1S	8/25/2020	16:00	-8.17	-56.9
14	113307	SH_Washburn_Dom	8/27/2020	15:00	-7.67	-54.4
15	113296	07N08E06N001M (Kautz Farms)[c]	7/21/2020	13:55	-8.92	-64.1
16	113305	Silva_Clay2 (Gary Silva Ag)[d]	8/27/2020	10:30	-7.04	-51.6
17	113299	ACGMA Bamert Rd MW D	8/13/2020	10:45	-6.91	-52.4
17	113299	ACGMA Bamert Rd MW D	8/13/2020	10:45	-7.01	-52.6
17	11308	ACGMA Bamert Rd MW D[b]	8/13/2020	10:45	-9.00	-65.0
18	113298	ACGMA Bamert Rd MW S[d]	8/13/2020	10:00	-6.90	-50.4
19	113300	ACGMA Carbondale[e]	8/13/2020	13:20	-8.48	-63.5

Abbreviations:
$\delta^{18}O$= Ratio of oxygen-18 to Vienna Standard Mean Ocean Water
δD= Ratio of deuterium to Vienna Standard Mean Ocean Water

Notes:
(a) All values for δD and $\delta^{18}O$ are in units of parts per mil
(b) Questionable field duplicate $\delta^{18}O$ and δD values
(c) Indicates average of field sample and field duplicate reported
(d) Indicates average of field sample and lab replicate reported
(e) Indicates average of field sample, field duplicate, and lab replicate reported

4. RESULTS

Isotope data from wells located in the Basin Plain are shown graphically in **Figure 3** with δ18O plotted on the x (horizontal) axis and δD plotted on the y (vertical) axis. In this graph, the data points for precipitation falling at varying distances from the ocean typically plot on a line near the meteoric water line (MWL). The data points that plot closer to the origin (more negative) represent precipitation that originates farther inland and at higher elevation than the data points that plot farther from the origin (more positive).

The lightest sample has a δ18O value of -9.99 ‰ (Map ID no. 3 in **Figure 3** and **Figure 4**). This sample is from a shallow well (64 feet deep) and located adjacent to the Cosumnes River channel, where it is likely influenced by Cosumnes River leakage. The samples that plot far to the right of the MWL were influenced by partial evaporation, resulting in a heavier (less negative) isotopic composition. The heaviest sample has a δ18O value of -5.59 ‰ (Map ID no. 4 in **Figure 3** and **Figure 4**). This sample is from a shallow well (38 feet deep) and in an area generally characterized by shallow groundwater conditions. **Figure 4** is modified from Figure GWC-15 of the Draft Cosumnes Subbasin GSP (Technical Memorandum 6 submitted to Working Group 11/2019 [EKI, 2019]) and shows the area of shallowest depth to groundwater within the Basin Plain, which shows δ18O values representing shallow groundwater conditions and Cosumnes River leakage.

The well-water δ18O values from this and other studies across the Basin are posted and contoured in **Figure 5**. In the Basin Foothill Subarea shown in **Figure 5**, δ18O values range from about -10 ‰ to approximately -7 ‰. The isotopic composition of samples influenced by Foothill precipitation have δ18O values from around -7 ‰ to -8 ‰. The lightest samples (most negative) were from wells located near Camanche Reservoir and influenced by Mokelumne River water (Dunn, 2012). In the Basin Plain Subarea, samples from wells located in the central and southern portions of the Basin have δ18O values that range from about -7.0 ‰ to -7.5 ‰, indicating recharge primarily from local precipitation. In contrast, the δ18O values along the northern portion of the Basin are typically more negative (less than -8) where isotopically lighter Cosumnes River water is the primary source of recharge. The river water signature is detected in samples from wells located both north and south of the river, indicating river leakage is a source of recharge to both the South American and Cosumnes subbasins. Visser et. al. (2020) utilized the isotopic data with their age-dating sample results to estimate an annual average Cosumnes River leakage rate of 0.3 to 0.6 acre-feet per year (AFY) per foot of the river, which is generally similar to the leakage rate calculated by the Cosumnes South American North American (CoSANA) numerical model (0.2 AFY per foot of river).

Cross-boundary flow directions inferred from available groundwater elevations support the influence of river leakage on South American and Cosumnes subbasin groundwater (**Figure 6**). The easternmost well pair (1) indicates the horizontal gradient is toward the Cosumnes Subbasin and consistent with the isotopic data which shows river leakage influencing groundwater south of the Cosumnes River. The two intermediate well pairs (2 and 3) have similar water level elevations on either side of the Cosumnes River, and isotopic data show leakage influencing groundwater both north and south of the Cosumnes River. The westernmost well pair (4) indicates flow toward the Basin; however, the isotopic signature of river water is difficult to discern because groundwater has likely been influenced by partial evaporation (see **Figure 4**).

5. SUMMARY

Water samples from wells located in the western portion of the Cosumnes Subbasin (the Basin Plain Subarea) and near the Cosumnes River have a relatively light isotopic composition indicating groundwater is influenced primarily by river leakage. The leakage provides recharge to areas in both the South American and Cosumnes subbasins. Further south of the Cosumnes River, wells located in the central parts of the Basin typically have a relatively heavier isotopic composition that suggest local precipitation is the primary source of recharge. Some of the water samples in the most western portion of the Basin, where groundwater is less than 30 feet below land surface, have been influenced by partial evaporation. In the eastern portion of the Basin, samples from wells located in the Foothill Subarea are influenced by higher altitude precipitation and Mokelumne River water.

6. REFERENCES

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Williams, Alan E. and Rodoni, Daniel P., 1997. Regional Isotope Effects and Application to Hydrologic Investigations in Southwestern California, Water Resources Research, Vol. 33, No. 7, 1721-1729.

TABLES

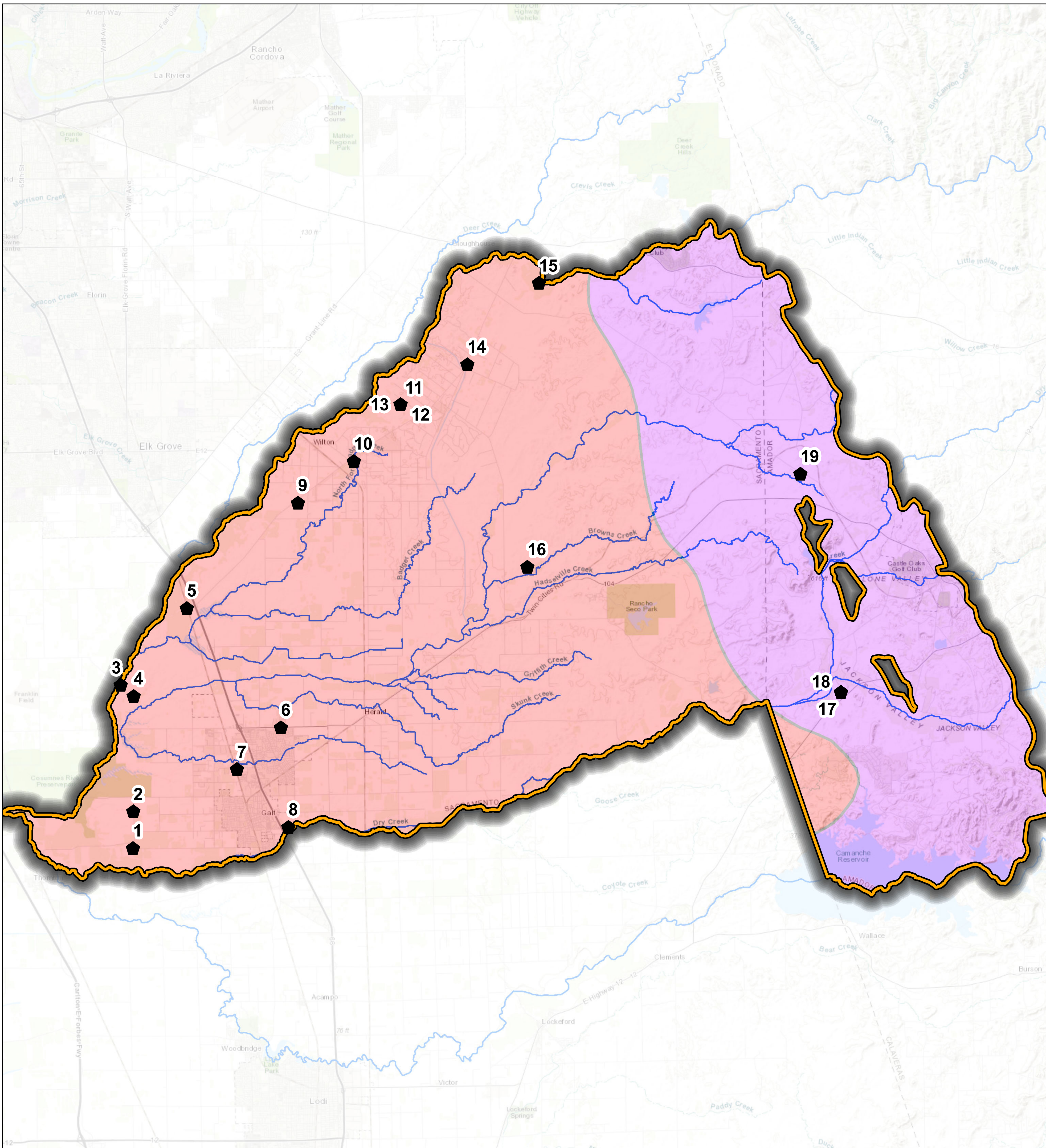
Table 1. Locations, Construction, and Uses of Wells Sampled for Stable Isotopes
Table 2. Isotope Sampling Results

FIGURES

Figure 1. Wells Sampled for this Study
Figure 2. previous and Current Well Sample Locations in the Basin Plain and North of Cosumens River
Figure 3. Oxygen-18 versus Deuterium
Figure 4. Model-Calculated Depth to Groundwater (Fall 2018), Maximum Extent of Shallow Groundwater (Depth to Water Less than or Equal to 30 Feet Below Land Surface), and Oxygen-18 in Well Water Samples
Figure 5. Distribution of Oxygen-18 in Groundwater
Figure 6. Horizontal Gradients Inferred from Groundwater Elevations

ATTACHMENTS

Attachment A. Isotopic Sampling Protocols
Attachment B. Isotopic Data used from Previous Studies



Legend

Well Sample Locations

EKI, 2020

Cosumnes Subbasin (5-022.16)

Basin Foothills

Basin Plain

Major Streams

Abbreviations

DWR= California Department of Water Resources

EKI= EKI Environment and Water, Inc

Map ID= Map Identification number associated with Table 1 and Table 2.

Notes

1. All locations are approximate.
2. Well Sample Locations labeled with Map ID.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 29 April 2021.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2018.

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Wells Sampled for this Study

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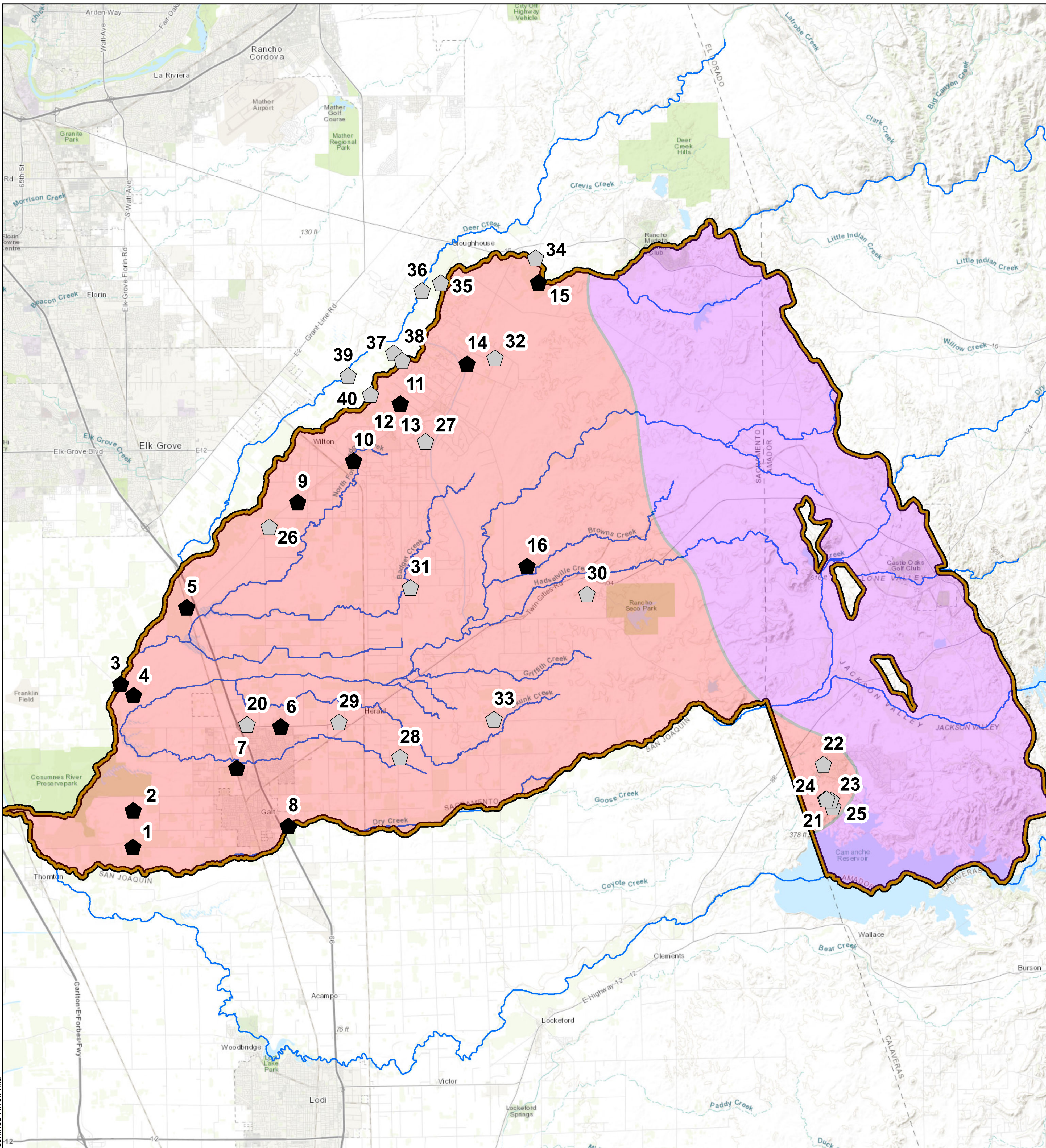
Figure 1

Path: X:\B80081_Cosumnes\Maps\2021\4\Figure 1 Wells Sampled for this Study.mxd



Legend

Well Sample Locations Plotted in Figure 2

- Previous Studies
- EKI, 2020
- Major Streams
- Cosumnes Subbasin (5-022.16)
- Basin Foothills
- Basin Plain

Abbreviations

DWR= California Department of Water Resources
EKI= EKI Environment and Water, Inc
GAMA = Groundwater Ambient Monitoring and Assessment Program
Map ID= Map Identification Number associated with Table 1, Table 2, and Attachment B.
OHWD= Omochumne-Hartnell Water District

Notes

1. All locations are approximate.
2. Well Sample Locations labeled with Map ID.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 29 April 2021.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2018.
3. Previous study sampled wells from the following sources (1) OHWD 2019 sampling (2) Dunn 2011 Sampling and (3) GAMA 2017 sampling.

N

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Previous and Current Well Sample Locations in the Basin Plain and North of Cosumnes River

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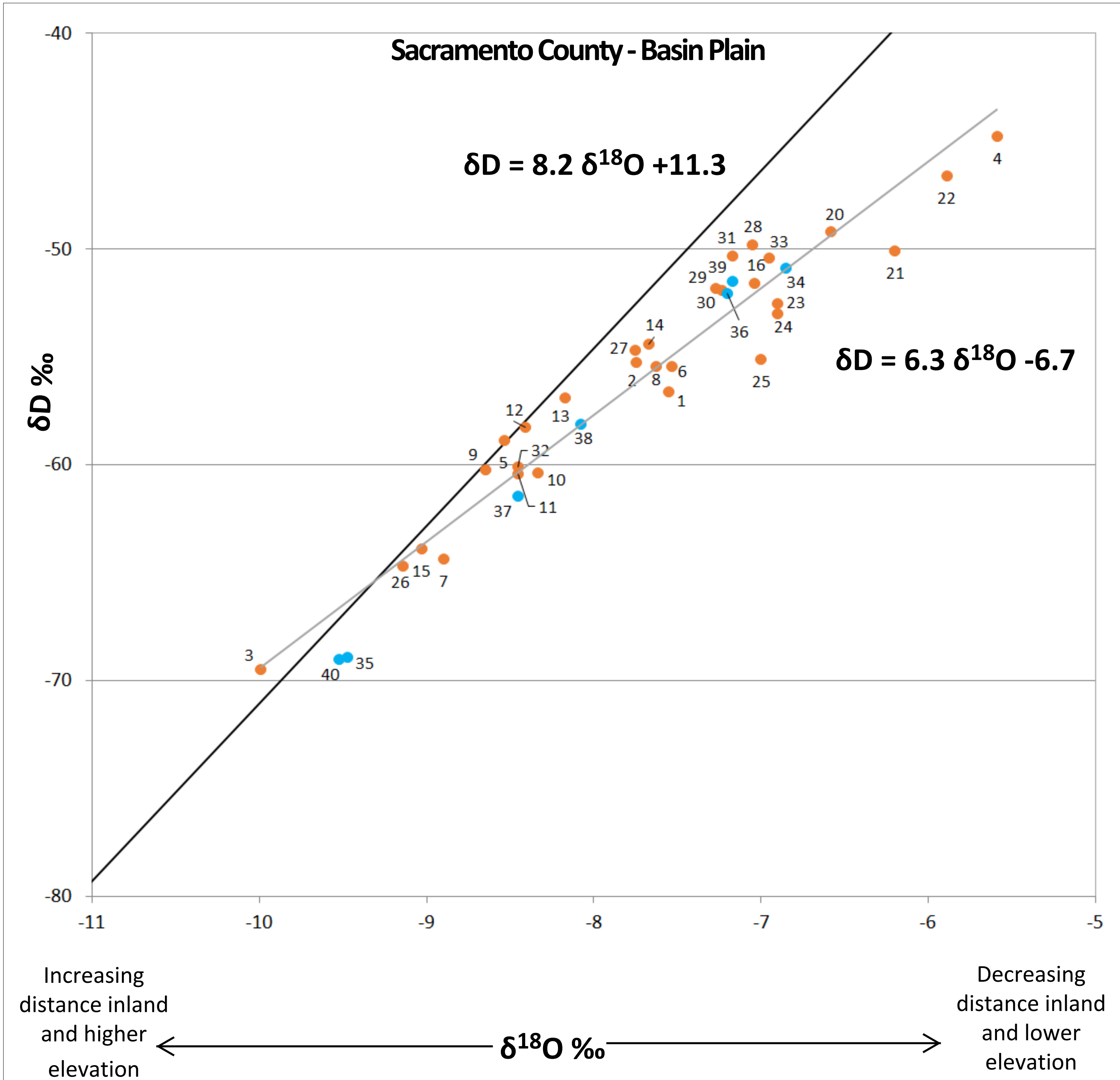
Figure 2

Path: X:\B80081_Cosumnes\Maps\2021\4\Figure 2 Previous and current well sample locations in the Basin Plain and north of Cosumnes River.mxd



= COSb Plain
= SASb Plain
= MWL
= Linear Regression

Abbreviations

$\delta^{18}O$ = Oxygen 18
δ D = Deuterium
‰ = Parts per thousand
COSb = Cosumnes Subbasin
MWL = Meteoric water line for the Central Valley
SASb= South American Subbasin

Notes

1. Source of water from local precipitation and drainage flows that originate as local runoff where where δ18O values are between -7.5 to -7 ‰.
2. Source of water from the Cosumnes River where δ18O values are between -9 to -8 ‰.
3. Source of water from Mokelumne River where δ18O values range from -10.3 to -8.3 ‰.
4. Well numbers correspond to Map ID on Figure 2, Table 2 and Attachment B.

Oxygen-18 versus Deuterium

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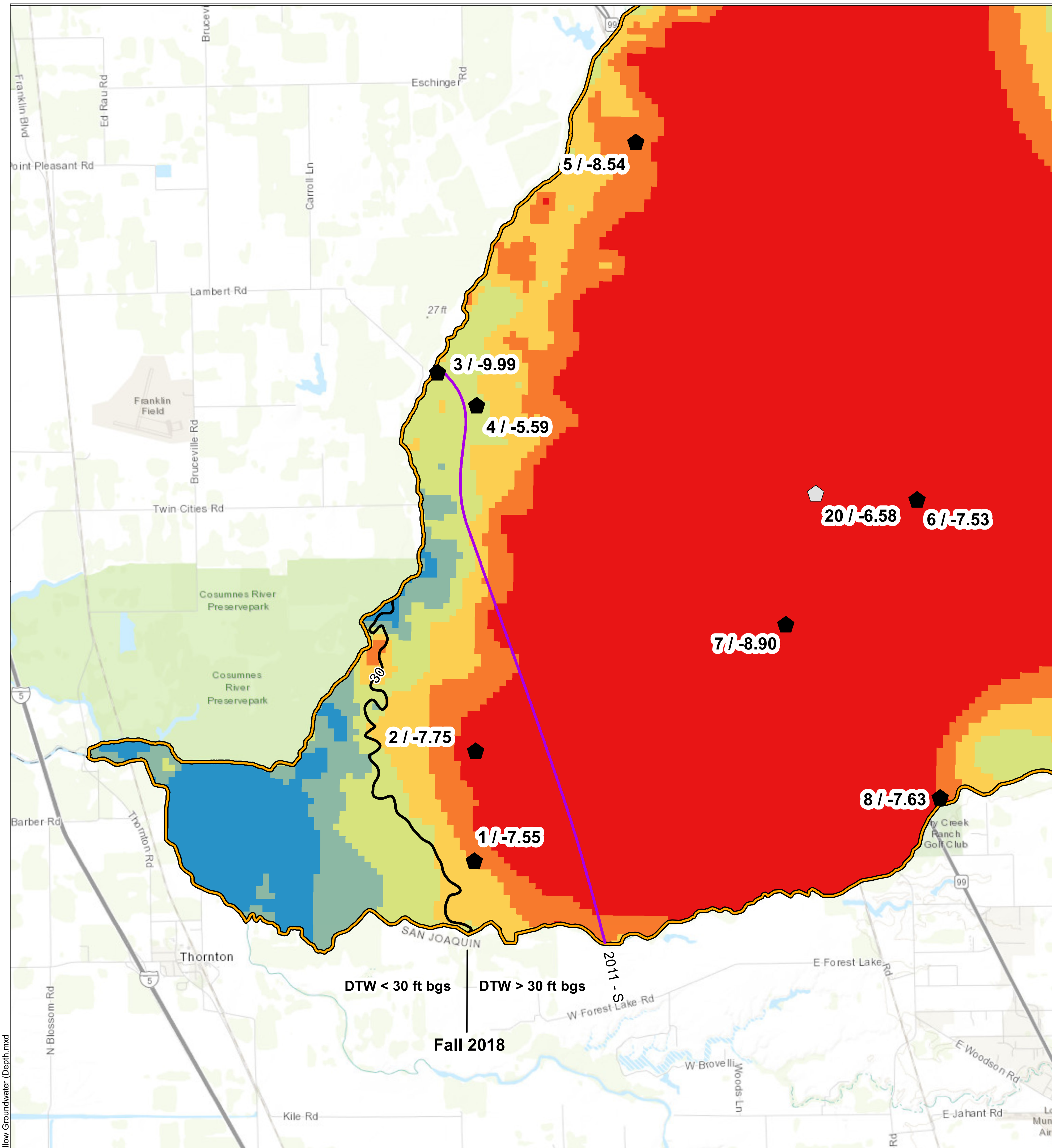
Figure 3



Legend

Well Sample Locations

- Previous Studies
- EKI, 2020

Map ID / Oxygen-18 (‰)
10 / -7.55

- Fall 2018 Depth to Water Contour (ft bgs)
- Maximum Extent of 30 ft DTW, 2011 Spring

HCBL Fall 2018 DTW (ft bgs)

- <= 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- >50

Abbreviations

DWR = California Department of Water Resources
DTW = depth to water
ft bgs = feet below ground surface
HCBL = Historical Condition Baseline
Map ID = Map Identification number associated with Table 1, Table 2 and Attachment B.

Notes

1. All locations are approximate.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 29 April 2021.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2018.
3. Previous study sampled wells from the following sources (1) OHWD 2019 sampling (2) Dunn 2011 Sampling and (3) GAMA 2017 sampling.

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(Scale in Miles)

Model-Calculated Depth to Groundwater (Fall 2018), Maximum Extent of Shallow Groundwater (Depth to Water Less Than or Equal to 30 Feet Below Land Surface), and Oxygen-18 in Well Water Samples

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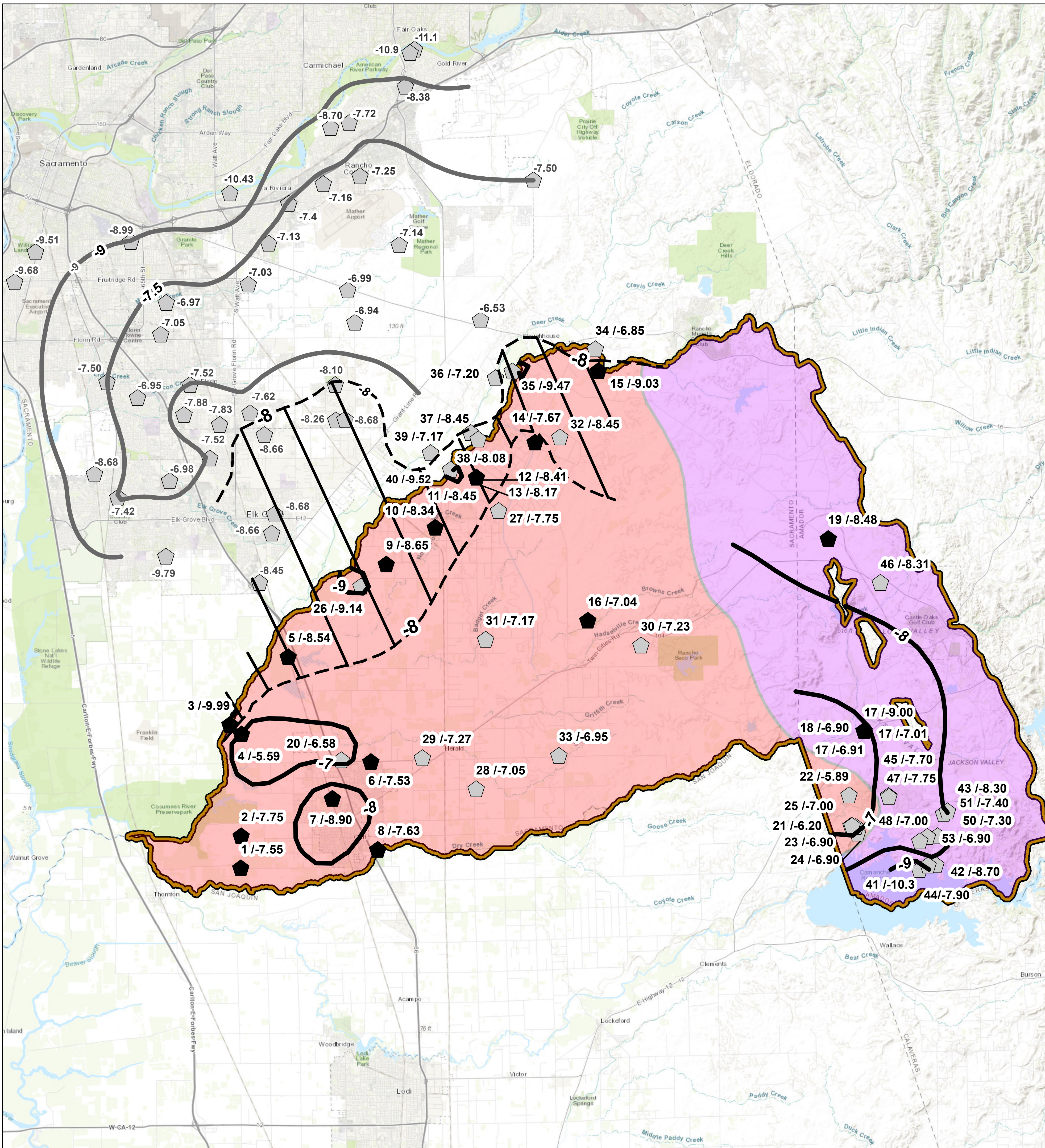
Figure 4

Path: X:\B80081_Cosumnes\Maps\2021\4\Figure 4 Model-Calculated Depth to Groundwater (Fall 2018), Maximum Extent of Shallow Groundwater (Depth.mxd



Legend

Well Sample Locations

- Previous Studies
- EKI, 2020

Map ID / Oxygen-18 (‰)
10 / -7.55

- Oxygen-18 in groundwater (HydroFocus, 2015)
- Oxygen-18 in groundwater (EKI, 2020)
- Inferred Extent of Cosumnes River Recharge

Groundwater Subbasin

- Cosumnes Subbasin (5-022.16)
- Basin Foothills
- Basin Plain

Abbreviations

DWR= California Department of Water Resources
EKI= EKI Environment and Water, Inc.
GAMA = Groundwater Ambient Monitoring and Assessment Program
Map ID= Map Identification number associated with Table 1, Table 2, and Attachment B.
OHWD= Omochumne-Hartnell Water District

Notes

1. All locations are approximate.
2. Oxygen-18 contours and well locations north of the Cosumnes River from 2015 Recharge Mapping and Field Study Report.

Sources

1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 29 April 2021.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2018.
3. Hydrofocus and RMC Water and Environment (2015) Recharge Mapping and Field Study for the Sacramento Central Groundwater Authority
3. Other sampled wells from previous studies include the following sources (1) OHWD 2019 sampling (2) Dunn 2011 Sampling and (3) GAMA 2017 sampling.

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(Scale in Miles)

Path: X:\B80081_Cosumnes\Maps\2021\4\Figure 5 Distribution of Oxygen-18 in Groundwater.mxd

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Distribution of Oxygen-18 in Groundwater

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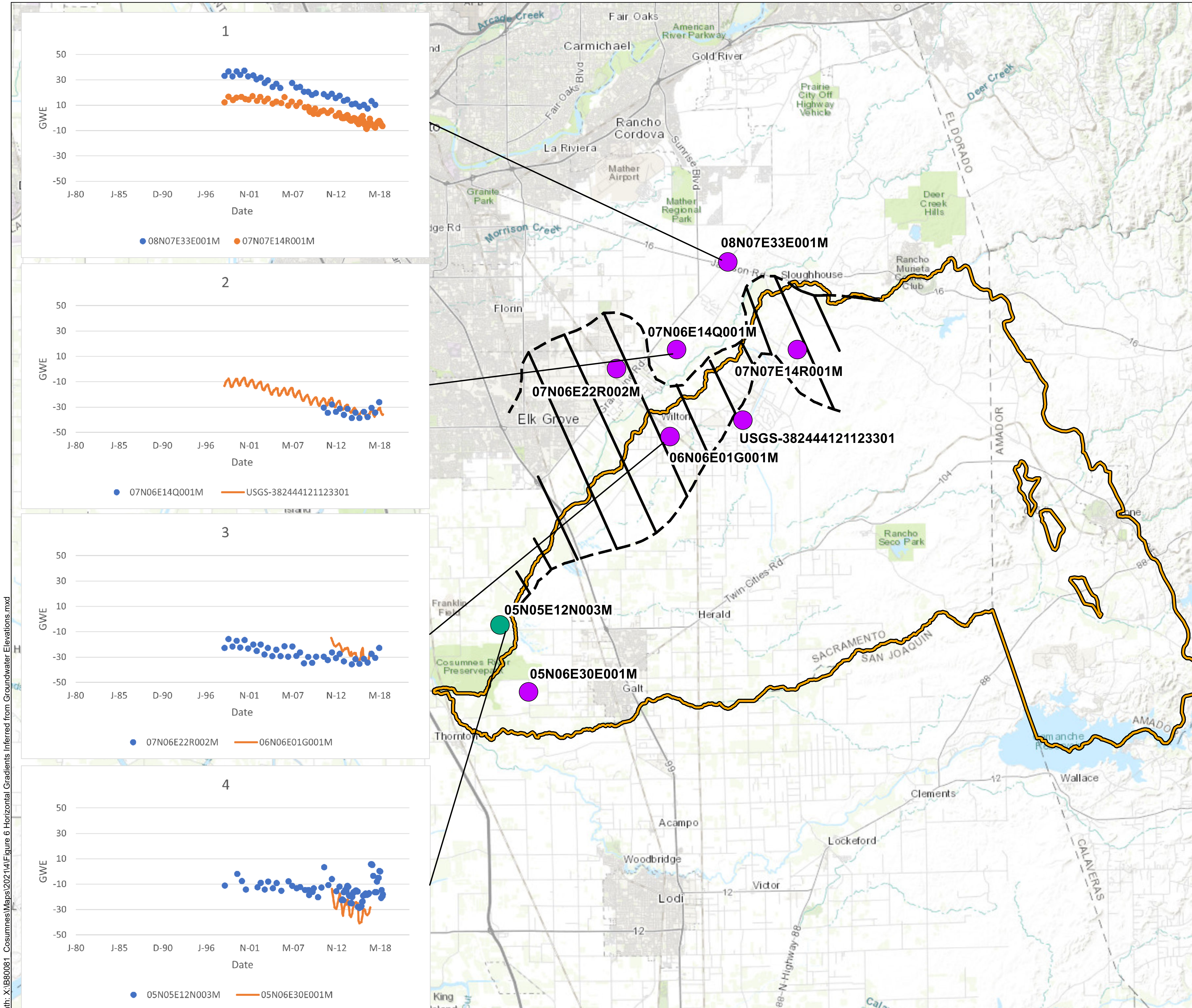
Figure 5



Legend

Well Pairs for Cross-Boundary Flow Analysis

Well Depth

- 101 - 400 ft bgs
- 401 - 700 ft bgs
- Inferred Extent of Cosumnes River Recharge
- Cosumnes Subbasin (5-022.16)

Abbreviations

DWR= California Department of Water Resources
ft bgs = feet below ground surface
GWE= groundwater elevation

Notes

1. All locations are approximate.

Sources

1. 1. Basemap is ESRI's ArcGIS Online world topographic map, obtained 29 April 2021.
2. DWR groundwater basins are based on the boundaries defined in California's Groundwater, Bulletin 118 - 2018.

N

0 3 6
(Scale in Miles)

DRAFT

Horizontal Gradients Inferred from Groundwater Elevations

Cosumnes Working Group
Cosumnes Subbasin
April 2021
B80081.01

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Figure 6

Path: X:\B80081_Cosumnes\Maps\2021\4\Figure 6 Horizontal Gradients Inferred from Groundwater Elevations.mxd

ATTACHMENT A

Isotopic Samping Protocol

Water samples from 19 wells were collected and analyzed for ^{18}O and D. The water samples were collected by trained staff from the UC Davis Hydrologic Graduate Group under direction of EKI, Inc. personnel between 14 July 2020 and 8 August 2020.

The samplers recorded GPS coordinates for the well locations and measured static depth to water; however, static depth to water could not be measured at some sites as the wells were already operating or had recently been operated. Monitoring wells without a permanent pump installed were purged and sampled using a submersible pump. Submersible pump, tubing, and sampling equipment was cleaned and decontaminated between sample sites. A minimum of three casing volumes were purged from the well prior to sampling. For larger wells or wells with permanent pump installations, purging of three casing volumes was not always necessary, or practical, depending on the well's operational history and operational constraints.

Production wells were sampled while the well pump was running, with well-water collected from a spigot nearest the wellhead. The well water travelled through the chamber and into a measuring bucket to determine flow. Samples were never collected from storage tanks, at a long distance from the wellhead, or after any water treatment. Sample ports and sampling equipment were cleaned prior to sample collection.

Field parameters (e.g., pH, specific conductance, temperature, and dissolved oxygen (DO)) were monitored using a YSI multi-meter and flow cell during purging. Field parameters were allowed to stabilize during purging so that variation of each parameter was within appropriate pre-defined limits for three casing volumes. In cases where purging of three casing volumes was not practical, field parameters had to be stable for three successive measurements collected at least three minutes apart. Samples were considered stable when pH was within ± 0.1 , conductivity was within ± 3 %, ORP was within ± 10 mV, and DO was within ± 10 %. Field parameter results are presented in **Table 1**. All field instruments were calibrated and evaluated for drift throughout the day and recalibrated as needed.

The field duplicate value collected from the well site ACGMA Bamert Rd MW D is considerably more depleted (-9.00) than the field sample (-6.91) and lab replicate (-7.01). Furthermore, this duplicate value indicates a possible sampling or lab error. The sample was not included in the analysis.

Table 1. Field Parameter Results

Map ID	Site	Date	Time	Purge time	Pump rate (gpm)	Sample Port	DTW (ft bgs)	Temp (°C)	Conductivity (µmhos/cm)	pH	DO (mg/L)
1	Gwerder Domestic	7/16/2020	14:10	10	50-100 ?	removed pressure gauge	35.1	--	--	--	--
2	05N06E30E001M (Gallo)	7/14/2020	8:00	35	Sample 2 /Well 500-1000	PVC outside of casing	65.4	18.3	575	7.41	1.37
3	UCW_MW-5	8/31/2020	12:00	30	~1	submersible pump	31	17.7	107	7.71	6.16
4	UCW_MW-11	8/31/2020	10:30	30	~1	submersible pump	26.6	18.3	619	7.15	8.14
5	06N06E29K001M (Belcher-Onto)	7/14/2020	11:25	4	900	Hole inside pump frame	48	16.3	533	7.06	6.96
6	Montrey Bay 20	7/16/2020	9:04	10	1500	Tee w/ nozzle	144	22.7	198	7.91	0.04
7	Industrial Well 22	7/16/2020	10:20	11	Sample 1 / Well 2000	tee port valve	128	28.5	224	8.45	0.03
8	Gateway 14	7/16/2020	11:30	12	500-1000	--	--	20.6	235	7.83	0.03
9	06N06E11J003M (Ernery Domestic)	8/27/2020	12:45	25	30	Valve on domestic well	101	21	209	7.7	5.74
10	Dillard Elementary	7/21/2020	12:15	15	180	copper tube	126	20.8	252	7.52	4.37
11	OHWD_TSS_MWC-1D	8/25/2020	12:00	50	>1	Grundfos pump	113	23	389	8.31	4.2
12	OHWD_TSS_MWC-1M	8/25/2020	14:00	30	>1	Grundfos pump	113	21.9	286	7.84	4.02

Map ID	Site	Date	Time	Purge time	Pump rate (gpm)	Sample Port	DTW (ft bgs)	Temp (°C)	Conductivity (µmhos/cm)	pH	DO (mg/L)
13	OHWD_TSS_MWC-1S	8/25/2020	16:00	20	>1	Grundfos pump	112	23.1	511	8.01	3.52
14	SH_Washburn_Dom	8/27/2020	15:00	25	~10	Top of domestic well	--	20.4	211	7.45	7.63
15	07N08E06N001M (Kautz Farms	7/21/2020	13:55	30	1000	outlet after pressure pump	--	17.3	227	7.23	7.67
16	Silva_Clay2 (Gary Silva Ag)	8/27/2020	10:30	15	~200-500	outlet off main pipe	184	21.3	206	7.43	3.74
17	ACGMA Bamert Rd MW D	8/13/2020	10:45	40	>1	--	13.1	22.3	480	10.3	0.07
18	ACGMA Bamert Rd MW S	8/13/2020	10:00	17	>1	--	13.2	21.9	289	7.17	0.18
19	ACGMA Carbondale	8/13/2020	13:20	34	>1	--	24.1	24	2640	7.82	0.06

Abbreviations:
°C = Degrees Celsius
ft bgs= feet below ground surface
gpm = gallons per minute
mg/L = milligrams per liter
µmhos/cm = micromhos per centimeter

ATTACHMENT B

Isotopic Data used from Previous Studies

Map ID	Well Name	Date	$\delta^{18}O$	δD	Source
20	S7-SAC-C02	8/7/2017	-6.58	-49.2	GAMA
21	LC-036	6/23/2011	-6.2	-50.1	Dunn
22	S7-SAC-C10	8/21/2017	-5.89	-46.6	GAMA
23	LC-006	6/16/2011	-6.90	-52.5	Dunn
24	LC-005	6/15/2011	-6.90	-53	Dunn
25	LC-035	6/22/2011	-7.00	-55.1	Dunn
26	S7-SAC-C01	8/7/2017	-9.14	-64.7	GAMA
27	S7-SAC-C03	8/8/2017	-7.75	-54.7	GAMA
28	S7-SAC-C04	8/8/2017	-7.05	-49.8	GAMA
29	S7-SAC-C05	8/9/2017	-7.27	-51.8	GAMA
30	S7-SAC-C06	8/9/2017	-7.23	-51.9	GAMA
31	S7-SAC-C07	8/10/2017	-7.17	-50.3	GAMA
32	S7-SAC-C08	8/10/2017	-8.45	-60.1	GAMA
33	S7-SAC-C09	8/21/2017	-6.95	-50.4	GAMA
34	S7-SAC-SA01	8/22/2017	-6.85	-50.9	GAMA
35	OHWD_Rooney IW	4/19/2019	-9.47	-68.92	OHWD
36	OHWD_MWR-2	5/15/2019	-7.20	-52.05	OHWD
37	OHWD_Tygert IW1	4/19/2019	-8.45	-61.43	OHWD
38	OHWD_Tygert IW2	4/19/2019	-8.08	-58.13	OHWD
39	OHWD_MWT-2	5/15/2019	-7.17	-51.51	OHWD
40	OHWD_MWT-1	5/15/2019	-9.52	-69	OHWD
41	LC-030	6/26/2011	-10.3	-77	Dunn
42	LC-011	6/25/2011	-8.70	-66.3	Dunn
43	LC-009	6/19/2011	-8.30	-64.3	Dunn
44	LC-029	6/27/2011	-7.90	-60.5	Dunn
45	LC-016	6/21/2011	-7.70	-60	Dunn
46	S7-SAC-C12	11/14/2017	-8.31	-59.8	GAMA
47	S7-SAC-C11	11/14/2017	-7.75	-58.4	GAMA
48	LC-037 (MW-2S)	6/24/2011	-7.00	-56.2	Dunn
49	LC-035	6/22/2011	-7.00	-55.1	Dunn
50	LC-012	6/20/2011	-7.30	-55	Dunn
51	LC-008	6/18/2011	-7.40	-53.8	Dunn
52	LC-005	6/15/2011	-6.90	-53	Dunn
53	LC-007	6/17/2011	-6.90	-52.6	Dunn

54	LC-006	6/16/2011	-6.90	-52.5	Dunn
55	LC-036	6/23/2011	-6.20	-50.1	Dunn
56	S7-SAC-C10	8/21/2017	-5.89	-46.6	GAMA

Abbreviations

GAMA = State Water Resources Control Board Division of Water Quality Groundwater Ambient Monitoring & Assessment Program

OHWD = Omochumne-Hartnell Water District

Sources:

1. Dunn 2011
2. GAMA 2017
3. Visser et al 2019