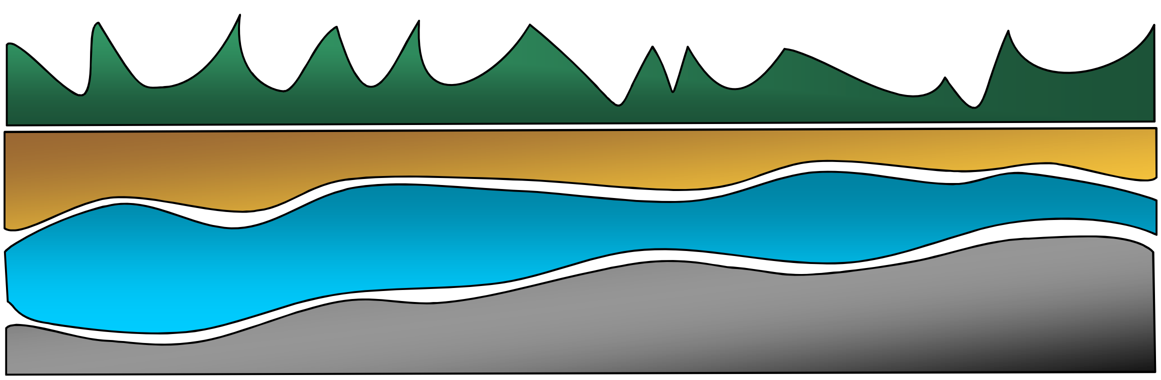
Appendix 4A

KDWCD 2018 Annual Groundwater Report

KAWEAH DELTA
Water Conservation
DISTRICT

2018 Annual Groundwater Report



2018 ANNUAL GROUNDWATER REPORT

This report has been prepared by Kaweah Delta Water Conservation District and presents groundwater measurements that were taken throughout the District. This information is intended to provide the District Board of Directors and participants with groundwater data that will allow for the evaluation of past and current groundwater conditions within the District.

The groundwater measurements were taken in the months of February and October for spring and fall, respectively, at wells located within the Kaweah Delta Water Conservation District boundaries. The data was collected by Kaweah Delta Water Conservation District, Lakeside Irrigation Water District, Kings County Water District and Tulare Irrigation District.

Many groundwater measurements were taken, but only the groundwater depths from well sites in each respective season of 2017 and 2018 were compared within the District. The spring 2018 average comparable depth to groundwater was approximately 133.0 ft., which reflected a groundwater level rise of 7.3 ft. from the prior year. The fall 2018 average comparable depth to groundwater was approximately 142.8 ft., which reflected a groundwater level decline of 7.8 ft. from the prior year.

It should be noted that a majority of the measurements are obtained from active agricultural production wells. Also, there presently is a lack of available well construction data for the wells included in this report. Thereby, the groundwater conditions presented in this report reflect a degree of uncertainty that is commensurate with the complexity of aquifer and measurement conditions.

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KAWEAH DELTA WATER CONSERVATION DISTRICT

WATER YEAR 2017 - 2018
PRELIMINARY REPORT

WATER SUPPLY (AC-FT)

TERMINUS INFLOW	255,023
CREEK FLOW	4,360
CVP	71,775
KINGS RIVER	0
TOTAL	**331,158**

Terminus inflow of 255,023 AF was 60% of the long term average, beginning at the 1904 Water Year.

The April - July flow of 170,237AF was 61% of the long term April - July average, beginning at the 1904 Water Year.

Creek Flow is the water year totals of Dry Creek, Yokohl Creek, and Cottonwood Creek.

KAWEAH DELTA WATER CONSERVATION DISTRICT

AVERAGE GROUND WATER CHANGES (AGENCY)

SPRING 2017 - 2018 COMPARISON

AGENCY CODE	NUMBER OF WELLS MEASURED SPRING 2018	NUMBER OF WELLS COMPARED TO SPRING 2017	AVERAGE CHANGE IN GROUNDWATER DEPTH
5129	18	17	-6.4
5603	96	76	4.5
5604	84	73	19.6
5627	41	36	-5.1
COMBINED	**239**	**202**	**7.3**

FALL 2017 - 2018 COMPARISON

AGENCY CODE	NUMBER OF WELLS MEASURED FALL 2018	NUMBER OF WELLS COMPARED TO FALL 2017	AVERAGE CHANGE IN GROUNDWATER DEPTH
5129	14	14	-2.2
5603	100	85	-10.1
5604	87	68	-4.4
5627	40	39	-10.7
COMBINED	**241**	**206**	**-7.8**

AGENCY CODE	AGENCY DESCRIPTION
5129	Kings County Water District
5603	Kaweah Delta Water Conservation District
5604	Tulare Irrigation District
5627	Lakeside Irrigation Water District

KAWEAH DELTA WATER CONSERVATION DISTRICT

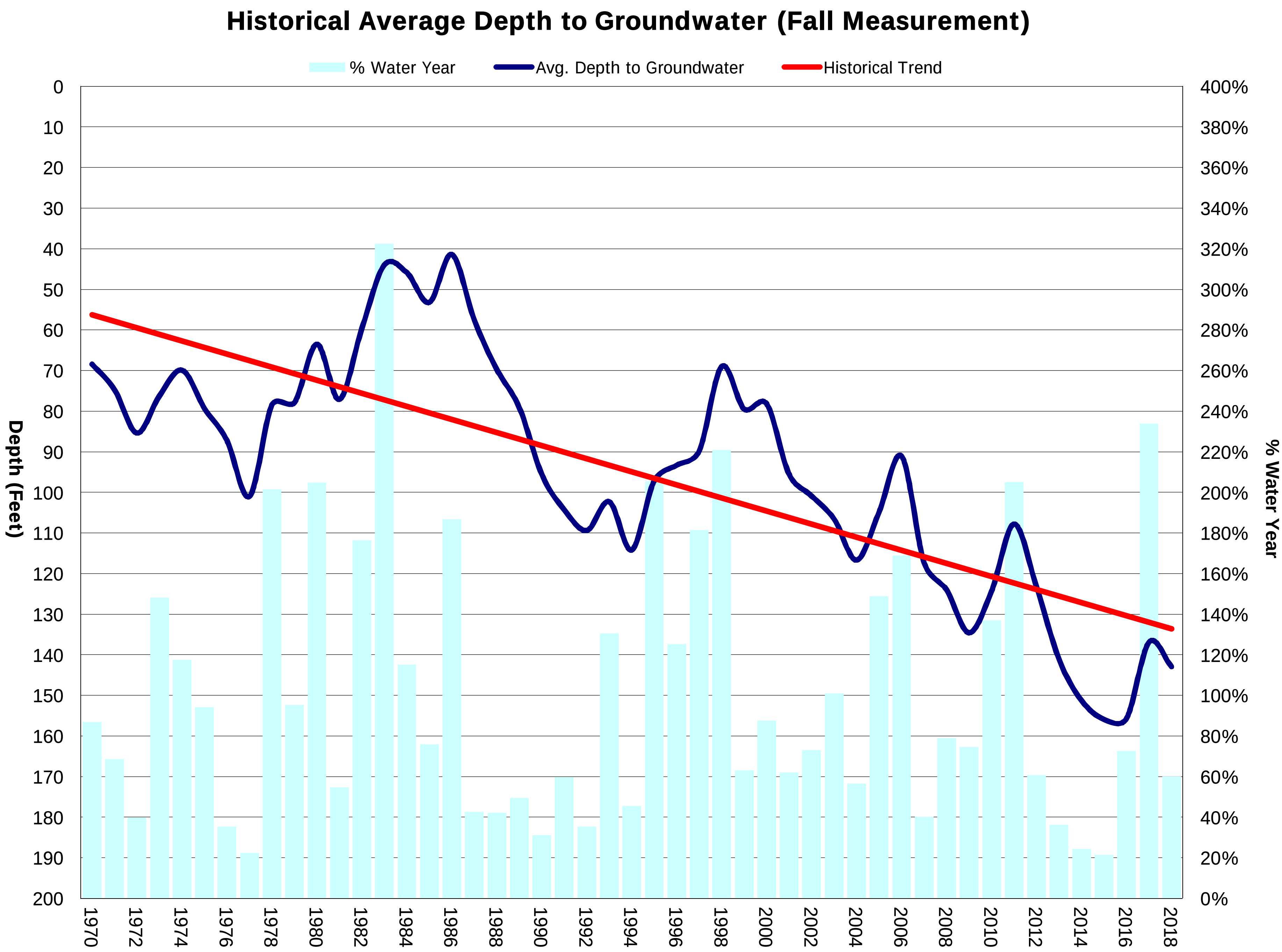
AVERAGE GROUND WATER CHANGES (HYDROLOGIC ZONES)

SPRING 2017 - SPRING 2018

HYDROLOGIC ZONE	NUMBER OF WELLS COMPARED	SPRING 2017 AVERAGE DEPTH TO WATER	SPRING 2018 AVERAGE DEPTH TO WATER	AVERAGE CHANGE IN DEPTH
1	8	27.9	29.7	-1.8
2	14	107.5	103.2	4.3
3	8	136.1	122.2	13.9
4	29	116.9	107.0	9.9
5	71	166.5	148.5	18.0
6	72	143.2	146.7	-3.5
TOTAL	**202**	**140.3**	**133.0**	**7.3**

FALL 2017 - FALL 2018

HYDROLOGIC ZONE	NUMBER OF WELLS COMPARED	FALL 2017 AVERAGE DEPTH TO WATER	FALL 2018 AVERAGE DEPTH TO WATER	AVERAGE CHANGE IN DEPTH
1	8	32.8	33.8	-1.1
2	17	109.0	113.4	-4.5
3	10	113.8	128.4	-14.6
4	31	118.6	128.9	-10.4
5	65	152.9	155.7	-2.9
6	75	145.9	157.5	-11.5
TOTAL	**206**	**135.0**	**142.8**	**-7.8**


Historical Average Depth to Groundwater (Fall Measurement)
% Water Year
Avg. Depth to Groundwater
Historical Trend
Depth (Feet)
% Water Year
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
400%
380%
360%
340%
320%
300%
280%
260%
240%
220%
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
1970
1972
1974
1976
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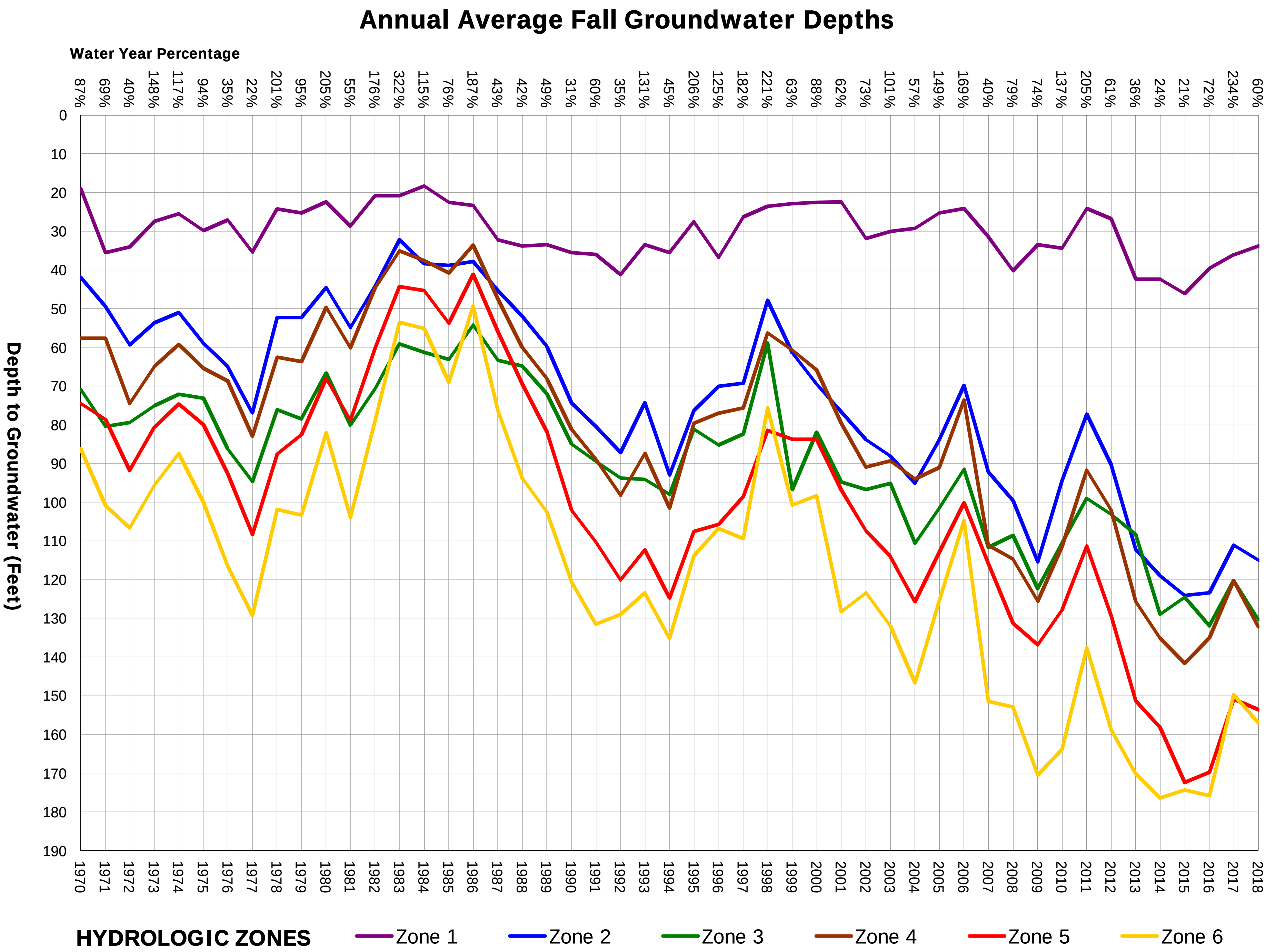
2010
2012
2014
2016
2018



Annual Average Fall Groundwater Depths
Water Year Percentage
87% 69% 40% 148% 117% 94% 35% 22% 201% 95% 205% 55% 176% 322% 115% 76% 187% 43% 42% 49% 31% 60% 35% 131% 45% 206% 125% 182% 221% 63% 88% 62% 73% 101% 57% 149% 169% 40% 79% 74% 137% 205% 61% 36% 24% 21% 72% 234% 60%
Depth to Groundwater (Feet)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
HYDROLOGIC ZONES
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6

KAWEAH DELTA WATER CONSERVATION DISTRICT
AVERAGE DEPTH TO GROUNDWATER (FALL)

(DATA FROM NEW HYDROLOGIC ZONES)

Year	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	District	% WY
1970	19.0	41.9	70.9	57.6	74.5	86.3	68.4	87%
1971	35.6	49.5	80.5	57.7	78.6	100.8	74.7	69%
1972	34.1	59.4	79.4	74.5	91.8	106.7	85.4	40%
1973	27.5	53.7	75.1	65.0	80.7	95.6	76.2	148%
1974	25.5	51.0	72.1	59.3	74.6	87.4	69.9	117%
1975	29.8	59.0	73.1	65.4	80.0	100.0	79.3	94%
1976	27.1	65.0	86.3	68.7	92.6	116.6	87.2	35%
1977	35.4	76.9	94.7	83.0	108.4	129.2	101.0	22%
1978	24.3	52.3	76.1	62.6	87.6	101.9	78.5	201%
1979	25.3	52.3	78.5	63.7	82.6	103.3	77.9	95%
1980	22.4	44.6	66.7	49.7	68.0	82.0	63.5	205%
1981	28.7	54.9	80.1	60.2	78.8	103.9	77.1	55%
1982	20.8	44.1	70.7	44.7	60.2	78.8	59.6	176%
1983	20.8	32.2	59.1	35.1	44.3	53.5	44.0	322%
1984	18.3	38.4	61.3	37.6	45.4	55.1	45.9	115%
1985	22.5	38.9	63.1	40.8	53.8	69.0	53.2	76%
1986	23.4	37.8	54.2	33.6	41.1	49.3	41.4	187%
1987	32.2	45.3	63.3	47.5	55.9	76.4	57.6	43%
1988	33.8	52.0	64.8	60.1	69.4	93.8	69.7	42%
1989	33.5	59.8	72.0	68.1	81.8	102.5	79.1	49%
1990	35.5	74.4	85.0	81.2	102.1	120.6	95.6	31%
1991	36.0	80.5	89.5	89.0	110.3	131.5	104.3	60%
1992	41.3	87.2	93.8	98.2	120.1	129.0	109.4	35%
1993	33.5	74.3	94.1	87.4	112.4	123.4	102.3	131%
1994	35.5	93.0	98.0	101.5	124.8	135.2	114.2	45%
1995	27.6	76.4	81.1	79.7	107.6	113.8	97.2	206%
1996	36.8	70.1	85.2	77.0	105.7	106.8	93.3	125%
1997	26.3	69.3	82.4	75.7	98.6	109.4	89.8	182%
1998	23.6	47.9	58.9	56.3	81.5	75.7	69.0	221%
1999	22.9	61.4	96.7	60.7	83.8	100.7	79.5	63%
2000	22.6	69.5	81.9	65.9	83.7	98.3	78.2	88%
2001	22.4	76.7	94.8	79.7	96.8	128.3	95.6	62%
2002	31.9	83.9	96.7	90.9	107.4	123.4	100.9	73%
2003	30.1	88.1	95.2	89.3	113.9	131.9	106.6	101%
2004	29.3	95.1	110.6	94.0	125.7	146.7	116.7	57%
2005	25.3	84.0	101.5	91.1	112.9	125.5	104.8	149%
2006	24.1	69.8	91.5	73.6	100.2	104.7	91.1	169%
2007	31.4	92.2	111.7	111.2	115.9	151.4	117.3	40%
2008	40.2	99.6	108.6	114.8	131.3	152.9	124.0	79%
2009	33.5	115.4	122.4	125.6	136.8	170.5	134.6	74%
2010	34.4	94.5	110.7	111.5	127.9	163.9	124.3	137%
2011	24.2	77.2	99.0	91.7	111.3	137.7	107.8	205%
2012	26.8	90.2	103.1	102.0	129.2	158.6	123.3	61%
2013	42.4	112.2	108.4	125.7	151.3	170.1	141.1	36%
2014	42.4	119.0	129.0	135.2	158.2	176.4	151.3	24%
2015	46.1	124.1	124.5	141.6	172.4	174.4	155.9	21%
2016	39.6	123.4	132.0	135.0	169.8	175.8	155.7	72%
2017	36.1	111.1	120.2	120.2	150.9	149.7	136.9	234%
2018	33.8	115.0	130.4	132.2	153.6	157.0	142.9	60%

KAWEAH DELTA WATER CONSERVATION DISTRICT

WELLS REMOVED FROM LAST YEAR'S ANNUAL REPORT					
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE
5129	18S23E21J001M	6	5604	19S24E36C001M	5
5603	18S24E06H001M	2	5604	19S24E36R001M	5
5603	18S24E10J001M	2	5603	19S25E10R001M	4
5603	18S24E17L001M	2	5603	19S25E34A002M	4
5603	18S24E31C001M	3	5603	19S26E05N001M	4
5603	18S25E04H001M	2	5603	19S26E33C001M	4
5603	18S25E15A002M	2	5604	20S24E04J002M	5
5603	18S25E19H001M	2	5603	20S24E34C001M	4
5603	18S25E33R001M	3	5603	20S25E21J002M	4
5603	19S22E01N002M	6	5603	20S25E28H002M	4
5603	19S23E07A002M	6	5603	21S23E11D001M	4

WELLS ADDED TO LAST YEAR'S ANNUAL REPORT					
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE
5603	18S23E30D901M	6	5604	20S22E12H001M	6
5603	18S24E15R003M	2	5603	20S22E13E001M	6
5603	19S22E08D902M	6	5604	20S25E04B001M	4
5604	19S22E24A001M	6	5604	20S25E17J001M	4
5604	19S22E36A001M	6	5603	21S22E07J901M	6
5604	19S23E10P001M	3	5604	21S22E24A001M	5
5604	19S25E17H001M	4	5604	21S24E12D001M	4
5604	19S25E28B001M	4	5604	21S24E17D001M	4
5603	20S21E24F901M	6			

KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5603	17S23E27L001M	2	-	-	N/A	-	-	N/A
5603	17S23E34J001M	2	92.4	92.4	0.0	85.3	103.4	-18.1
5603	17S24E26A001M	2	-	105.2	N/A	112.1	107.5	4.6
5603	17S24E27D001M	2	70.2	61.6	8.6	53.8	53.4	0.4
5603	17S24E29F001M	2	96.3	63.0	33.3	65.5	60.7	4.8
5603	17S24E30L001M	2	74.4	-	N/A	92.9	103.3	-10.4
5603	17S24E32F001M	2	105.3	104.3	1.0	-	155.4	N/A
5603	17S24E35H001M	2	112.2	-	N/A	-	-	N/A
5603	17S24E35H002M	2	-	98.2	N/A	90.9	-	N/A
5603	17S24E36H003M	2	114.7	-	N/A	112.5	117.6	-5.1
5603	17S25E29D002M	2	132.1	-	N/A	-	-	N/A
5603	17S25E30H001M	2	-	134.6	N/A	113.0	145.2	-32.2
5603	17S26E36R001M	1	22.4	28.2	-5.8	37.8	-	N/A
5627	18S22E24D001M	6	128.8	143.0	-14.2	134.7	140.0	-5.3
5627	18S22E26F001M	6	-	132.9	N/A	128.4	138.0	-9.6
5603	18S22E32J002M	6	144.9	145.7	-0.8	146.9	-	N/A
5603	18S22E34R001M	6	126.9	96.7	30.2	100.3	105.3	-5.0
5603	18S23E01A001M	2	103.0	107.5	-4.5	156.1	157.1	-1.0
5603	18S23E02Q001M	2	103.4	97.7	5.7	105.2	100.6	4.6
5129	18S23E04Q001M	6	178.9	184.4	-5.5	-	-	N/A
5603	18S23E13H002M	2	145.2	142.9	2.3	180.9	169.3	11.6
5603	18S23E14A002M	2	-	-	N/A	-	-	N/A
5129	18S23E15A001M	6	116.7	131.3	-14.6	127.7	156.7	-29.0
5129	18S23E21J002M	6	135.9	167.2	-31.3	-	-	N/A
5603	18S23E24L001M	2	144.3	-	N/A	167.7	-	N/A
5129	18S23E26L001M	6	154.2	169.6	-15.4	168.7	168.2	0.5
5129	18S23E27P001M	6	139.0	159.0	-20.0	153.0	142.2	10.8
5129	18S23E28B001M	6	116.6	119.4	-2.8	124.0	124.8	-0.8
5129	18S23E28R001M	6	158.7	161.5	-2.8	156.2	151.7	4.5
5129	18S23E29D001M	6	95.7	91.2	4.5	102.2	93.1	9.1
5603	18S23E30D001M	6	-	182.8	N/A	230.9	232.6	-1.7
5603	18S23E30D901M	6	-	64.3	N/A	57.5	61.6	-4.1
5129	18S23E32B001M	6	165.1	236.2	-71.1	-	-	N/A
5129	18S23E33C001M	6	123.2	124.9	-1.7	133.0	131.1	1.9
5603	18S23E33J002M	6	167.7	191.6	-23.9	196.6	194.7	1.9
5603	18S23E35C001M	3	137.7	138.4	-0.7	143.1	142.8	0.3
5603	18S24E02H001M	2	-	-	N/A	-	-	N/A
5603	18S24E03M001M	2	142.8	100.3	42.5	99.0	117.3	-18.3
5603	18S24E07A001M	2	106.5	106.4	0.1	122.9	119.8	3.1

KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5603	18S24E13H002M	2	-	-	N/A	-	-	N/A
5603	18S24E13N001M	2	43.5	109.3	-65.8	103.5	109.2	-5.7
5603	18S24E15R003M	2	-	123.6	N/A	-	-	N/A
5603	18S24E22E001M	2	137.7	137.7	0.0	140.0	146.3	-6.3
5603	18S24E25D001M	3	123.7	124.0	-0.3	124.2	-	N/A
5603	18S24E31M001M	3	126.8	120.0	6.8	125.0	136.9	-11.9
5603	18S24E32H001M	3	-	-	N/A	154.9	-	N/A
5603	18S24E33N001M	3	141.8	-	N/A	-	-	N/A
5603	18S24E35K001M	3	-	-	N/A	-	-	N/A
5603	18S25E05Q001M	2	125.2	116.9	8.3	121.4	124.0	-2.6
5603	18S25E06P001M	2	124.3	105.5	18.8	107.3	112.8	-5.5
5603	18S25E12N001M	2	-	-	N/A	-	-	N/A
5603	18S25E15C001M	2	-	-	N/A	80.8	80.4	0.4
5603	18S25E16B001M	2	-	-	N/A	-	-	N/A
5603	18S25E16F001M	2	109.0	98.8	10.2	-	101.8	N/A
5603	18S25E23H002M	3	-	72.1	N/A	-	68.7	N/A
5603	18S25E25R001M	3	-	-	N/A	-	-	N/A
5603	18S25E25R002M	3	-	64.7	N/A	63.8	68.8	-5.0
5603	18S25E28R001M	3	74.6	-	N/A	79.6	94.3	-14.7
5603	18S25E30Q001M	3	79.2	-	N/A	-	-	N/A
5603	18S25E34A001M	4	-	-	N/A	-	-	N/A
5603	18S25E34A002M	4	94.4	85.0	9.4	87.2	91.2	-4.0
5603	18S26E01Q003M	1	-	-	N/A	-	-	N/A
5603	18S26E02D002M	1	69.0	-	N/A	68.9	69.0	-0.1
5603	18S26E09H001M	1	-	-	N/A	-	-	N/A
5603	18S26E12F001M	1	24.2	21.3	2.9	23.1	20.3	2.8
5603	18S26E14E001M	1	13.5	14.7	-1.2	14.1	12.4	1.7
5603	18S26E16P001M	4	17.1	20.4	-3.3	17.7	21.3	-3.6
5603	18S26E17L001M	1	-	28.3	N/A	26.9	37.8	-10.9
5603	18S26E19B003M	3	-	-	N/A	-	-	N/A
5603	18S26E19P001M	3	50.9	41.6	9.3	39.2	40.9	-1.7
5603	18S26E24J003M	1	58.6	56.2	2.4	66.3	69.0	-2.7
5603	18S26E26E001M	1	61.9	58.5	3.4	61.4	-	N/A
5603	18S26E27B001M	4	24.1	28.2	-4.1	24.7	29.2	-4.5
5603	18S26E29M001M	4	44.6	36.9	7.7	30.7	37.7	-7.0
5603	18S26E32A001M	4	-	-	N/A	-	-	N/A
5603	18S27E05D001M	1	14.3	19.9	-5.6	25.1	21.3	3.8
5603	18S27E05J001M	1	9.7	15.8	-6.1	14.7	17.0	-2.3
5603	18S27E07B001M	1	-	-	N/A	-	-	N/A

KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5603	18S27E18A001M	1	18.6	22.9	-4.3	23.1	23.8	-0.7
5603	19S21E12Q001M	6	-	69.9	N/A	-	74.3	N/A
5627	19S21E13J001M	6	101.3	93.9	7.4	93.9	100.8	-6.9
5627	19S21E24H001M	6	138.8	152.0	-13.2	164.9	167.0	-2.1
5627	19S21E25J001M	6	107.1	102.2	4.9	107.9	100.8	7.1
5627	19S21E26B001M	6	179.2	166.2	13.0	181.5	185.7	-4.2
5603	19S21E27P001M	6	-	-	N/A	-	-	N/A
5603	19S21E34D002M	6	-	-	N/A	-	-	N/A
5129	19S21E35D001M	6	23.5	18.1	5.4	18.9	21.0	-2.1
5627	19S21E36M001M	6	51.7	44.5	7.2	46.0	47.8	-1.8
5627	19S22E01D001M	6	110.3	77.8	32.5	71.8	87.3	-15.5
5603	19S22E02F001M	6	-	-	N/A	-	-	N/A
5627	19S22E03J001M	6	139.7	150.5	-10.8	131.5	146.8	-15.3
5627	19S22E04B001M	6	146.7	-	N/A	146.5	158.3	-11.8
5627	19S22E04J001M	6	148.8	181.7	-32.9	-	189.0	N/A
5129	19S22E04M001M	6	145.5	157.2	-11.7	145.1	143.8	1.3
5627	19S22E06H001M	6	158.0	182.0	-24.0	175.5	-	N/A
5627	19S22E07K001M	6	143.1	162.0	-18.9	160.3	166.1	-5.8
5603	19S22E08D002M	6	181.6	201.7	-20.1	216.5	248.6	-32.1
5603	19S22E08D902M	6	126.7	128.1	-1.4	127.6	128.4	-0.8
5627	19S22E09M001M	6	187.0	252.0	-65.0	227.2	255.7	-28.5
5627	19S22E10C001M	6	141.8	137.4	4.4	126.2	145.1	-18.9
5603	19S22E10R002M	6	134.3	106.2	28.1	98.9	120.3	-21.4
5627	19S22E14M001M	6	151.9	147.3	4.6	153.2	167.2	-14.0
5603	19S22E14N001M	6	136.3	120.4	15.9	125.3	128.5	-3.2
5627	19S22E15M001M	6	149.1	137.2	11.9	137.8	158.1	-20.3
5603	19S22E16A003M	6	-	104.8	N/A	90.8	-	N/A
5627	19S22E17A001M	6	185.0	213.8	-28.8	216.0	238.8	-22.8
5603	19S22E18H001M	6	-	-	N/A	-	-	N/A
5627	19S22E19M001M	6	131.2	134.3	-3.1	135.9	143.1	-7.2
5627	19S22E20A001M	6	161.9	193.3	-31.4	179.9	207.5	-27.6
5603	19S22E21C001M	6	138.2	132.4	5.8	137.2	143.5	-6.3
5627	19S22E21J001M	6	183.3	248.4	-65.1	-	238.7	N/A
5603	19S22E23A001M	6	-	-	N/A	-	-	N/A
5604	19S22E24A001M	6	-	111.0	N/A	-	-	N/A
5603	19S22E24B001M	6	117.3	107.3	10.0	108.7	107.5	1.2
5627	19S22E27A001M	6	196.9	223.0	-26.1	235.7	236.9	-1.2
5627	19S22E28C001M	6	160.8	190.8	-30.0	182.6	132.0	50.6
5603	19S22E28D001M	6	128.4	121.8	6.6	123.7	129.8	-6.1

KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5627	19S22E29D001M	6	168.9	187.2	-18.3	191.4	227.0	-35.6
5603	19S22E30D001M	6	89.1	87.0	2.1	88.6	89.9	-1.3
5603	19S22E31B003M	6	113.8	117.8	-4.0	115.1	135.8	-20.7
5627	19S22E32D001M	6	182.7	-	N/A	211.9	230.8	-18.9
5627	19S22E33B001M	6	134.1	125.8	8.3	130.9	141.3	-10.4
5604	19S22E36A001M	6	-	128.0	N/A	-	121.0	N/A
5129	19S22E36E001M	6	-	123.5	N/A	130.5	134.1	-3.6
5603	19S23E02F001M	3	-	-	N/A	-	-	N/A
5603	19S23E02F002M	3	153.9	187.4	-33.5	188.0	182.0	6.0
5603	19S23E06H001M	6	-	-	N/A	-	-	N/A
5129	19S23E08J001M	6	158.8	115.5	43.3	-	115.8	N/A
5129	19S23E10C001M	6	116.0	98.1	17.9	118.4	103.7	14.7
5129	19S23E10D001M	6	97.4	90.8	6.6	103.8	105.4	-1.6
5604	19S23E10P001M	3	-	157.0	N/A	-	212.0	N/A
5603	19S23E10R001M	3	134.6	126.9	7.7	134.4	130.3	4.1
5129	19S23E11C001M	6	127.2	135.5	-8.3	125.6	126.5	-0.9
5604	19S23E13A003M	5	-	-	N/A	-	-	N/A
5604	19S23E17R001M	5	-	130.0	N/A	130.0	130.0	0.0
5604	19S23E19H001M	5	-	-	N/A	-	-	N/A
5604	19S23E19K001M	5	192.0	180.0	12.0	-	186.0	N/A
5603	19S23E20A001M	5	133.9	-	N/A	124.9	-	N/A
5604	19S23E20C001M	5	-	130.0	N/A	136.0	-	N/A
5604	19S23E21P001M	5	148.0	131.0	17.0	138.0	131.0	7.0
5603	19S23E22H001M	5	-	-	N/A	-	-	N/A
5604	19S23E23D001M	5	153.0	120.0	33.0	122.0	-	N/A
5604	19S23E24L001M	5	152.0	-	N/A	124.0	137.0	-13.0
5604	19S23E25C001M	5	167.0	150.0	17.0	150.0	139.0	11.0
5604	19S23E25L002M	5	168.0	150.0	18.0	159.0	153.0	6.0
5604	19S23E26B001M	5	147.0	-	N/A	-	105.0	N/A
5604	19S23E27A001M	5	152.0	122.0	30.0	-	121.0	N/A
5604	19S23E27L001M	5	159.0	125.0	34.0	141.0	116.0	25.0
5604	19S23E27L003M	5	-	-	N/A	-	-	N/A
5604	19S23E27P001M	5	-	-	N/A	-	-	N/A
5604	19S23E30H002M	5	132.0	122.0	10.0	-	-	N/A
5604	19S23E31R001M	5	158.0	140.0	18.0	-	-	N/A
5604	19S23E32H001M	5	-	-	N/A	-	-	N/A
5604	19S23E33D001M	5	156.0	-	N/A	142.0	143.0	-1.0
5604	19S23E34L001M	5	-	138.0	N/A	123.0	122.0	1.0
5604	19S23E35H001M	5	162.0	141.0	21.0	142.0	159.0	-17.0

KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5604	19S23E36J001M	5	169.0	162.0	7.0	160.0	172.0	-12.0
5603	19S24E02C001M	3	-	146.6	N/A	149.8	153.3	-3.5
5603	19S24E08D002M	3	-	119.0	N/A	-	-	N/A
5604	19S24E10G001M	3	181.0	91.0	90.0	80.0	169.0	-89.0
5604	19S24E13C002M	3	180.0	148.0	32.0	135.0	166.0	-31.0
5604	19S24E14A001M	5	-	-	N/A	-	-	N/A
5603	19S24E15R001M	5	171.0	148.2	22.8	-	168.0	N/A
5604	19S24E16N001M	5	193.0	158.0	35.0	190.0	158.0	32.0
5604	19S24E17A001M	5	-	-	N/A	-	-	N/A
5604	19S24E17B001M	5	176.0	152.0	24.0	-	149.0	N/A
5604	19S24E17L001M	5	190.0	156.0	34.0	175.0	154.0	21.0
5604	19S24E18R001M	5	163.0	153.0	10.0	155.0	155.0	0.0
5604	19S24E19L001M	5	170.0	156.0	14.0	155.0	157.0	-2.0
5604	19S24E20F001M	5	-	-	N/A	135.0	143.0	-8.0
5604	19S24E20J001M	5	178.0	158.0	20.0	171.0	179.0	-8.0
5603	19S24E22C001M	5	-	-	N/A	-	-	N/A
5604	19S24E22C002M	5	-	-	N/A	-	-	N/A
5604	19S24E22E001M	5	178.0	-	N/A	134.0	174.0	-40.0
5604	19S24E22P001M	5	-	-	N/A	-	-	N/A
5604	19S24E23D001M	5	174.0	159.0	15.0	175.0	171.0	4.0
5604	19S24E24A003M	5	185.0	142.0	43.0	148.0	-	N/A
5604	19S24E24R001M	5	181.0	144.0	37.0	153.0	163.0	-10.0
5604	19S24E25C001M	5	175.0	154.0	21.0	-	172.0	N/A
5604	19S24E25D001M	5	-	-	N/A	-	-	N/A
5604	19S24E27C001M	5	180.0	166.0	14.0	180.0	192.0	-12.0
5604	19S24E27H001M	5	-	-	N/A	-	-	N/A
5604	19S24E27Q001M	5	183.0	145.0	38.0	172.0	-	N/A
5604	19S24E28H001M	5	184.0	169.0	15.0	168.0	169.0	-1.0
5604	19S24E29D001M	5	169.0	-	N/A	-	-	N/A
5604	19S24E29R001M	5	185.0	172.0	13.0	185.0	189.0	-4.0
5604	19S24E30J001M	5	174.0	166.0	8.0	180.0	171.0	9.0
5604	19S24E31E001M	5	-	-	N/A	-	-	N/A
5604	19S24E33A002M	5	192.0	173.0	19.0	184.0	193.0	-9.0
5604	19S24E33H001M	5	-	-	N/A	-	-	N/A
5604	19S24E34D001M	5	184.0	-	N/A	184.0	192.0	-8.0
5603	19S25E01E001M	4	99.5	88.3	11.2	94.1	94.9	-0.8
5603	19S25E01P002M	4	102.2	88.2	14.0	88.1	94.3	-6.2
5603	19S25E06A001M	3	-	-	N/A	-	-	N/A
5603	19S25E09H001M	4	122.6	118.0	4.6	115.6	127.3	-11.7

KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5603	19S25E13A002M	4	108.4	93.1	15.3	95.3	99.8	-4.5
5603	19S25E16A002M	4	122.4	112.4	10.0	115.1	122.4	-7.3
5604	19S25E17H001M	4	-	119.0	N/A	-	137.0	N/A
5604	19S25E19B001M	5	162.0	131.0	31.0	135.0	-	N/A
5604	19S25E19H001M	5	155.0	122.0	33.0	125.0	72.0	53.0
5604	19S25E20P001M	5	-	78.0	N/A	43.0	90.0	-47.0
5603	19S25E24M001M	4	120.7	102.3	18.4	99.4	114.4	-15.0
5603	19S25E25H001M	4	-	109.3	N/A	113.3	121.8	-8.5
5603	19S25E27A001M	4	136.8	113.0	23.8	115.6	129.1	-13.5
5604	19S25E28B001M	4	-	-	N/A	-	137.0	N/A
5603	19S25E28H001M	4	139.0	-	N/A	123.5	-	N/A
5604	19S25E29B001M	5	110.0	75.0	35.0	65.0	124.0	-59.0
5604	19S25E29N001M	5	-	-	N/A	144.0	134.0	10.0
5604	19S25E30C001M	5	163.0	-	N/A	152.0	-	N/A
5603	19S25E32J001M	4	-	-	N/A	-	-	N/A
5603	19S25E35B002M	4	-	-	N/A	-	128.0	N/A
5603	19S26E03A001M	4	89.3	89.6	-0.3	-	-	N/A
5603	19S26E05C001M	4	54.8	56.0	-1.2	46.3	56.8	-10.5
5603	19S26E16J002M	4	124.2	123.2	1.0	137.3	139.5	-2.2
5603	19S26E17K001M	4	114.7	107.7	7.0	111.2	117.6	-6.4
5603	19S26E20A001M	4	116.9	-	N/A	113.8	125.3	-11.5
5603	19S26E28E001M	4	123.8	121.9	1.9	120.9	137.6	-16.7
5603	19S26E30D001M	4	-	-	N/A	-	-	N/A
5627	20S21E11D001M	6	242.2	-	N/A	239.6	253.0	-13.4
5627	20S21E11N001M	6	239.7	-	N/A	235.8	256.9	-21.1
5603	20S21E24F001M	6	275.9	314.0	-38.1	280.9	363.0	-82.1
5603	20S21E24F901M	6	9.6	9.9	-0.3	9.8	10.3	-0.5
5603	20S21E36P001M	6	-	-	N/A	-	-	N/A
5604	20S22E01H001M	6	-	131.0	N/A	-	-	N/A
5627	20S22E01Q001M	6	161.9	125.9	36.0	127.0	132.0	-5.0
5627	20S22E02C001M	6	158.5	139.8	18.7	138.5	145.0	-6.5
5627	20S22E03B001M	6	156.8	144.1	12.7	142.9	157.5	-14.6
5603	20S22E03C002M	6	-	-	N/A	-	-	N/A
5627	20S22E03G001M	6	161.5	173.0	-11.5	156.8	164.8	-8.0
5603	20S22E03K001M	6	162.4	157.4	5.0	150.4	169.1	-18.7
5627	20S22E03P001M	6	155.3	128.2	27.1	148.7	131.5	17.2
5627	20S22E04D001M	6	121.1	108.5	12.6	114.0	116.0	-2.0
5627	20S22E05L001M	6	197.7	216.9	-19.2	236.9	251.8	-14.9
5627	20S22E06C001M	6	203.7	183.9	19.8	185.0	182.9	2.1

KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5627	20S22E06H001M	6	175.1	206.9	-31.8	234.9	263.1	-28.2
5603	20S22E06N001M	6	104.4	100.8	3.6	101.9	111.7	-9.8
5627	20S22E07A004M	6	193.9	186.0	7.9	204.0	238.7	-34.7
5603	20S22E08A002M	6	-	-	N/A	-	-	N/A
5627	20S22E08J001M	6	133.7	111.1	22.6	115.9	123.1	-7.2
5627	20S22E09H001M	6	175.0	192.0	-17.0	180.8	194.9	-14.1
5627	20S22E10J001M	6	189.8	-	N/A	162.4	197.7	-35.3
5604	20S22E12H001M	6	-	143.0	N/A	-	153.0	N/A
5603	20S22E13C002M	6	-	-	N/A	-	-	N/A
5603	20S22E13E001M	6	-	177.2	N/A	-	173.0	N/A
5627	20S22E20A002M	6	86.3	61.8	24.5	62.2	68.0	-5.8
5603	20S22E23M001M	6	-	-	N/A	-	-	N/A
5603	20S22E24R001M	6	231.6	277.3	-45.7	225.5	300.9	-75.4
5604	20S22E25R001M	5	-	134.0	N/A	141.0	144.0	-3.0
5603	20S22E27A001M	6	134.9	82.3	52.6	76.0	100.3	-24.3
5603	20S22E33F001M	6	108.3	89.6	18.7	77.4	95.3	-17.9
5603	20S22E35L001M	6	-	-	N/A	-	-	N/A
5603	20S22E36A001M	6	156.5	-	N/A	130.3	-	N/A
5604	20S23E02H001M	5	179.0	155.0	24.0	172.0	-	N/A
5604	20S23E02L001M	5	171.0	153.0	18.0	166.0	172.0	-6.0
5604	20S23E03L001M	5	-	-	N/A	-	-	N/A
5604	20S23E04F001M	5	183.0	165.0	18.0	161.0	159.0	2.0
5604	20S23E04J001M	5	176.0	146.0	30.0	154.0	155.0	-1.0
5129	20S23E05J001M	6	189.9	191.5	-1.6	194.1	229.9	-35.8
5604	20S23E07H003M	5	-	159.0	N/A	152.0	158.0	-6.0
5129	20S23E08G001M	6	179.2	-	N/A	-	-	N/A
5604	20S23E08H001M	5	179.0	164.0	15.0	163.0	159.0	4.0
5604	20S23E09J002M	5	173.0	131.0	42.0	107.0	145.0	-38.0
5604	20S23E11L001M	5	-	158.0	N/A	167.0	-	N/A
5604	20S23E12A001M	5	167.0	161.0	6.0	156.0	169.0	-13.0
5604	20S23E12B003M	5	168.0	161.0	7.0	156.0	169.0	-13.0
5604	20S23E13E002M	5	177.0	153.0	24.0	163.0	-	N/A
5604	20S23E15A001M	5	175.0	150.0	25.0	143.0	-	N/A
5604	20S23E16J001M	5	185.0	160.0	25.0	154.0	175.0	-21.0
5604	20S23E17C001M	5	-	-	N/A	-	-	N/A
5604	20S23E17D001M	5	182.0	170.0	12.0	170.0	171.0	-1.0
5604	20S23E18R001M	5	184.0	169.0	15.0	188.0	175.0	13.0
5604	20S23E19J001M	5	-	-	N/A	-	-	N/A
5604	20S23E21B001M	5	190.0	171.0	19.0	178.0	-	N/A

KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

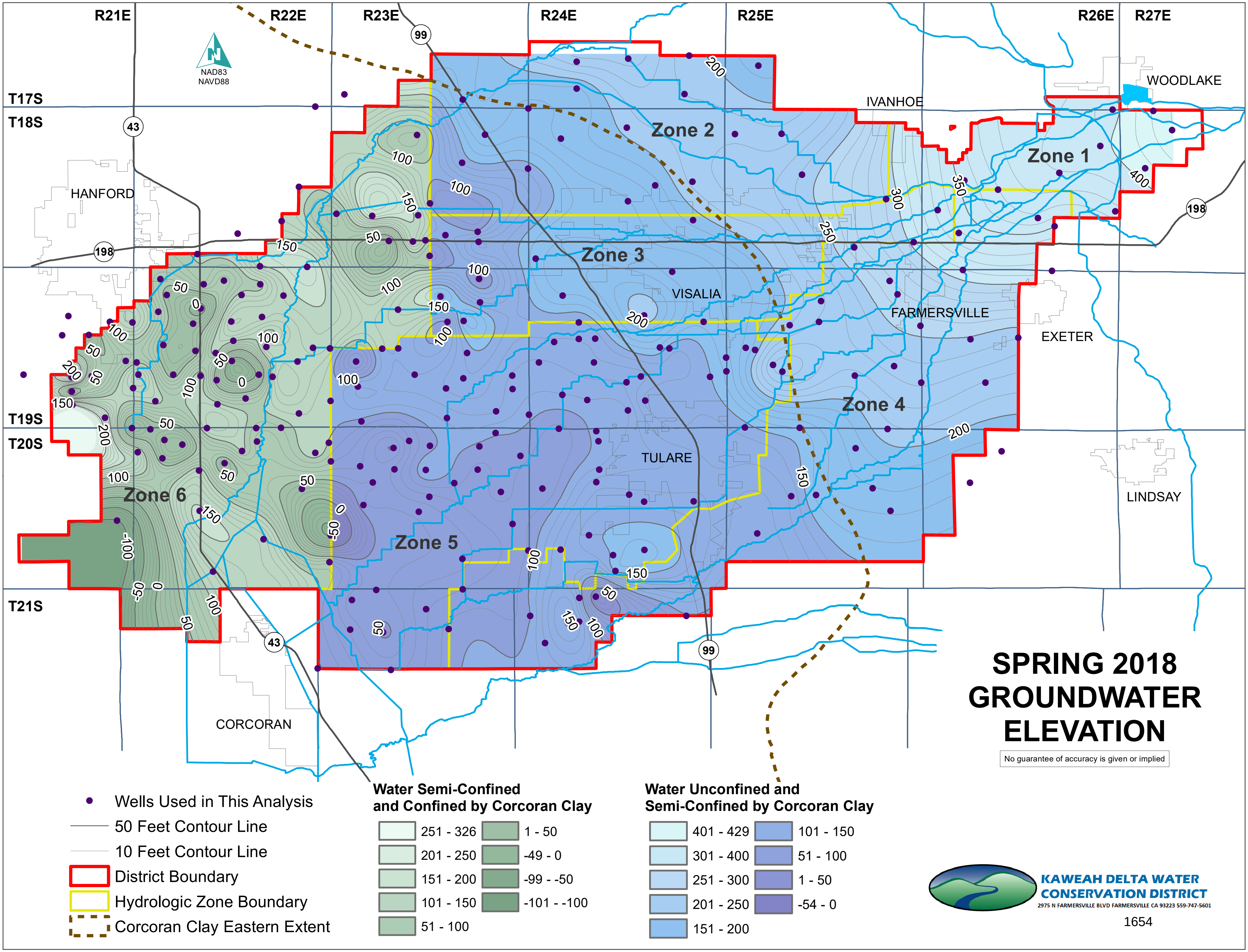
WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5604	20S23E24K001M	5	175.0	157.0	18.0	163.0	171.0	-8.0
5604	20S23E24L001M	5	-	-	N/A	-	-	N/A
5604	20S23E25J002M	4	185.0	150.0	35.0	178.0	168.0	10.0
5604	20S23E26C001M	5	-	-	N/A	-	-	N/A
5604	20S23E26R001M	5	-	-	N/A	-	-	N/A
5604	20S23E27D001M	5	-	-	N/A	-	-	N/A
5604	20S23E27Q001M	5	180.0	165.0	15.0	176.0	-	N/A
5604	20S23E27R001M	5	179.0	164.0	15.0	175.0	169.0	6.0
5604	20S23E29J002M	5	189.0	-	N/A	183.0	192.0	-9.0
5604	20S23E30R001M	5	191.0	-	N/A	183.0	196.0	-13.0
5604	20S24E04D001M	5	179.0	171.0	8.0	185.0	193.0	-8.0
5604	20S24E04E001M	5	-	170.0	N/A	182.0	191.0	-9.0
5604	20S24E06A001M	5	188.0	180.0	8.0	176.0	188.0	-12.0
5604	20S24E07C001M	5	-	-	N/A	152.0	162.0	-10.0
5604	20S24E07F001M	5	-	-	N/A	-	-	N/A
5604	20S24E07G001M	5	-	-	N/A	-	-	N/A
5604	20S24E09C001M	5	157.0	152.0	5.0	148.0	-	N/A
5604	20S24E14R001M	5	150.0	140.0	10.0	137.0	-	N/A
5604	20S24E15P001M	5	130.0	129.0	1.0	122.0	128.0	-6.0
5604	20S24E16H001M	5	148.0	131.0	17.0	136.0	140.0	-4.0
5604	20S24E17A002M	5	-	136.0	N/A	135.0	136.0	-1.0
5604	20S24E17P001M	5	127.0	-	N/A	110.0	-	N/A
5604	20S24E18F001M	5	178.0	172.0	6.0	-	-	N/A
5604	20S24E20M002M	5	-	-	N/A	-	-	N/A
5603	20S24E24H001M	4	-	-	N/A	-	-	N/A
5604	20S24E27L001M	5	104.0	95.0	9.0	94.0	-	N/A
5604	20S24E28L001M	5	99.0	94.0	5.0	90.0	93.0	-3.0
5604	20S24E29B001M	5	109.0	102.0	7.0	105.0	104.0	1.0
5604	20S24E30J002M	4	129.0	116.0	13.0	122.0	123.0	-1.0
5604	20S24E31R001M	5	-	-	N/A	-	-	N/A
5604	20S24E33C001M	5	108.0	95.0	13.0	-	97.0	N/A
5604	20S24E33C002M	5	194.0	182.0	12.0	190.0	-	N/A
5603	20S25E01A002M	4	-	-	N/A	-	-	N/A
5603	20S25E02A001M	4	130.9	110.1	20.8	117.8	128.3	-10.5
5603	20S25E03R001M	4	145.2	122.1	23.1	131.2	140.8	-9.6
5604	20S25E04B001M	4	-	147.0	N/A	-	-	N/A
5604	20S25E06C001M	5	177.0	155.0	22.0	167.0	172.0	-5.0
5603	20S25E06R002M	5	-	-	N/A	-	-	N/A
5603	20S25E12A001M	4	-	-	N/A	-	122.5	N/A

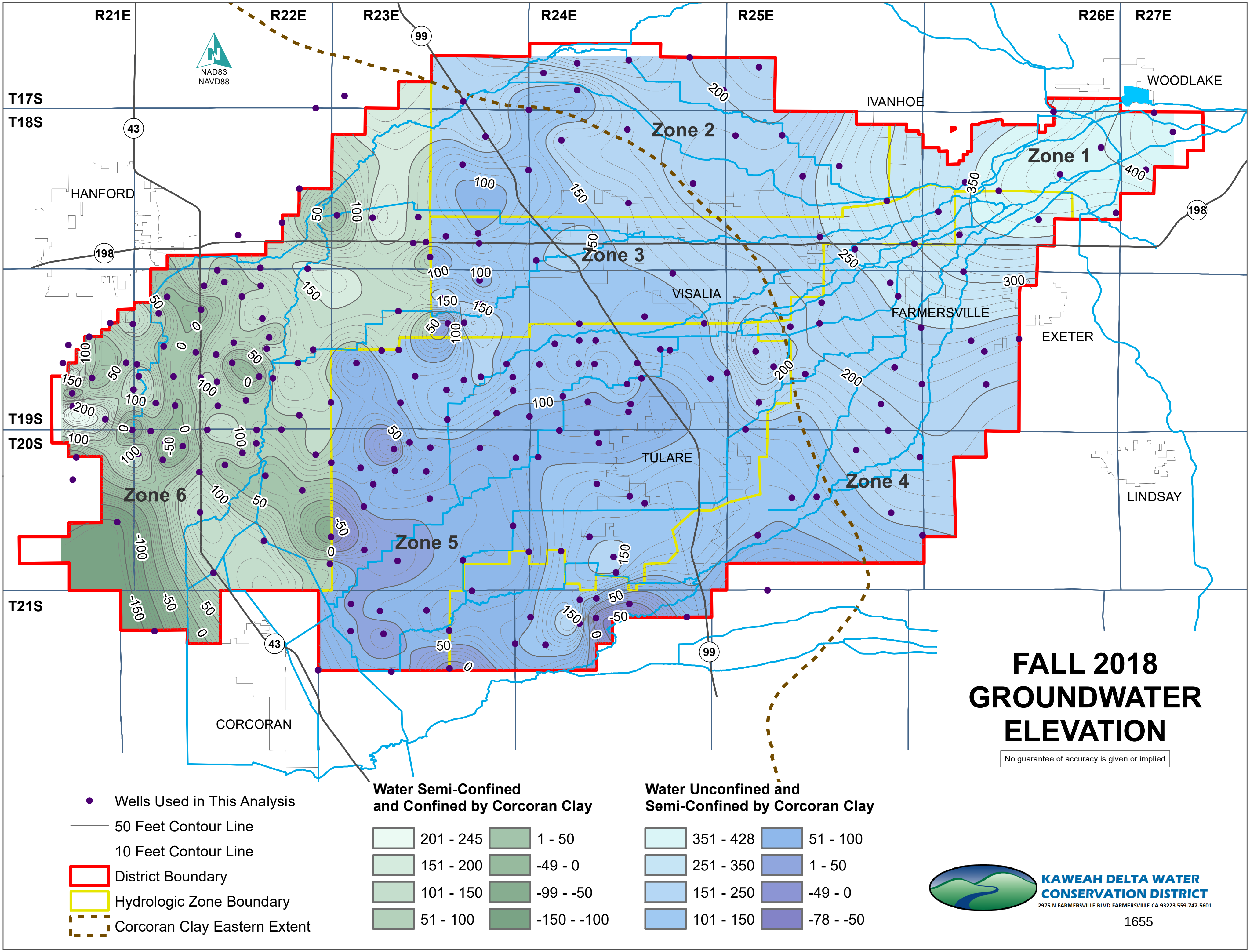
KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

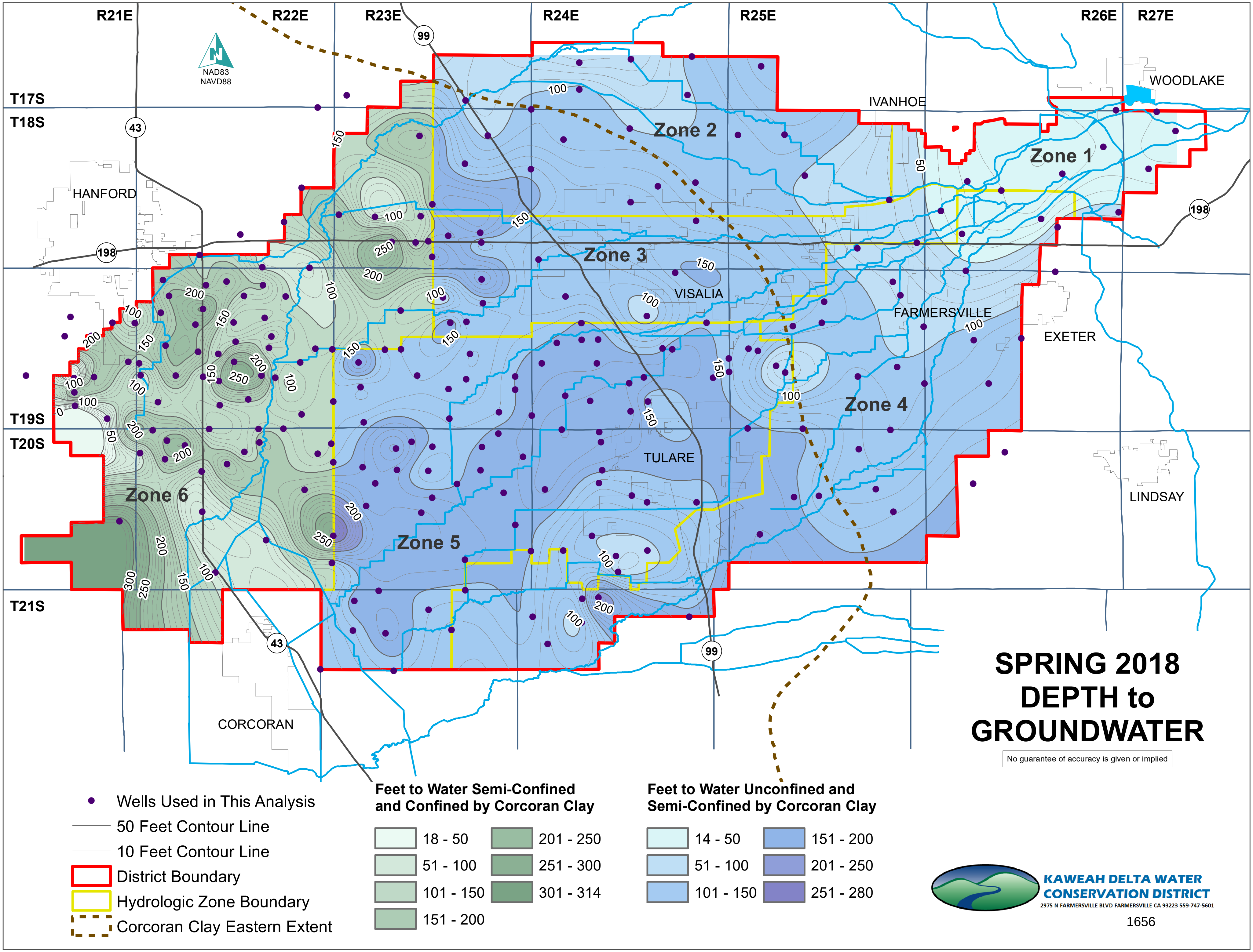
WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5603	20S25E14F004M	4	156.8	124.8	32.0	136.3	-	N/A
5603	20S25E16J002M	4	155.6	135.4	20.2	147.9	174.1	-26.2
5604	20S25E17J001M	4	-	154.0	N/A	-	178.0	N/A
5604	20S25E18M001M	5	-	-	N/A	-	-	N/A
5603	20S25E19R002M	4	164.6	170.5	-5.9	185.3	187.0	-1.7
5603	20S25E24A001M	4	152.5	138.7	13.8	119.2	154.2	-35.0
5603	20S25E24R001M	4	157.2	-	N/A	123.7	171.5	-47.8
5603	20S26E04P001M	4	140.7	147.9	-7.2	160.5	-	N/A
5603	20S26E11D001M	4	154.5	-	N/A	-	-	N/A
5603	20S26E17B001M	4	-	154.6	N/A	171.6	-	N/A
5603	21S22E07J001M	6	282.2	-	N/A	245.8	331.0	-85.2
5603	21S22E07J901M	6	74.3	-	N/A	66.4	70.3	-3.9
5604	21S22E24A001M	5	-	107.0	N/A	-	111.0	N/A
5603	21S23E02A001M	4	164.1	-	N/A	151.1	166.8	-15.7
5604	21S23E02C001M	5	162.0	146.0	16.0	140.0	150.0	-10.0
5604	21S23E03N001M	5	163.0	141.0	22.0	150.0	143.0	7.0
5604	21S23E04A001M	5	-	-	N/A	-	-	N/A
5604	21S23E05A002M	5	174.0	157.0	17.0	166.0	-	N/A
5604	21S23E05E002M	5	-	157.0	N/A	166.0	-	N/A
5604	21S23E05R001M	5	-	-	N/A	-	155.0	N/A
5604	21S23E06J001M	5	172.0	158.0	14.0	166.0	160.0	6.0
5604	21S23E07H001M	5	150.0	139.0	11.0	173.0	152.0	21.0
5603	21S23E07J001M	5	-	-	N/A	132.8	-	N/A
5604	21S23E08F002M	5	-	-	N/A	-	-	N/A
5604	21S23E08R001M	5	178.0	163.0	15.0	152.0	177.0	-25.0
5604	21S23E10J002M	5	-	127.0	N/A	-	133.0	N/A
5603	21S23E13A002M	4	-	-	N/A	-	139.5	N/A
5604	21S23E14C001M	5	-	-	N/A	-	-	N/A
5604	21S23E15R002M	5	195.0	-	N/A	188.0	228.0	-40.0
5603	21S23E18N002M	5	111.8	110.8	1.0	109.4	109.3	0.1
5604	21S23E21C002M	5	155.0	141.0	14.0	150.0	144.0	6.0
5604	21S23E21C003M	5	158.0	141.0	17.0	150.0	144.0	6.0
5603	21S24E01L001M	4	-	-	N/A	-	-	N/A
5603	21S24E03L001M	4	208.4	-	N/A	226.9	266.2	-39.3
5604	21S24E04F001M	5	-	-	N/A	-	-	N/A
5604	21S24E04F002M	5	213.0	209.0	4.0	227.0	148.0	79.0
5603	21S24E05H002M	4	131.2	132.5	-1.3	143.9	134.5	9.4
5603	21S24E07C001M	4	145.8	143.2	2.6	146.7	145.9	0.8
5603	21S24E08A001M	4	108.4	104.4	4.0	122.8	105.8	17.0

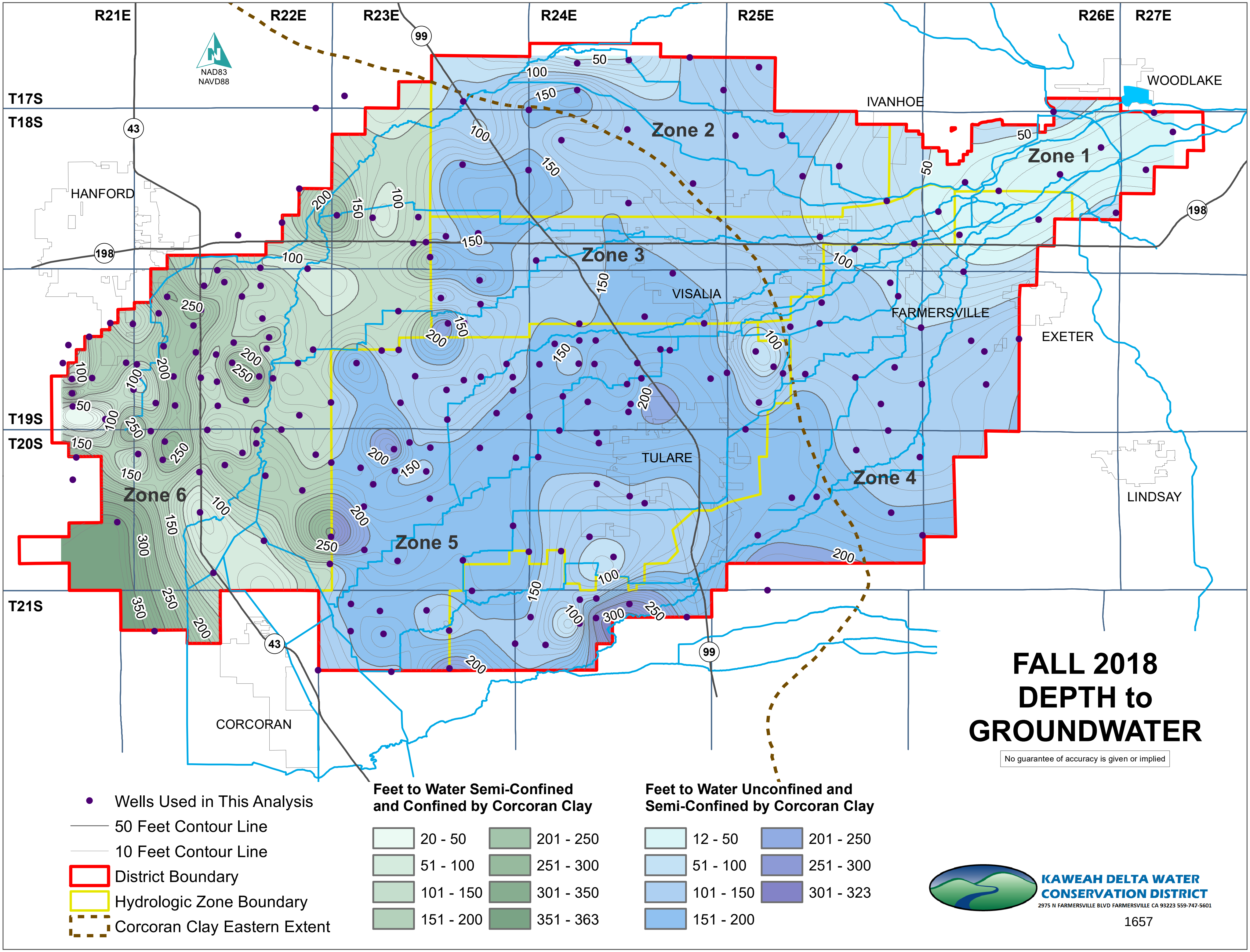
KAWEAH DELTA WATER CONSERVATION DISTRICT
GROUNDWATER DATA

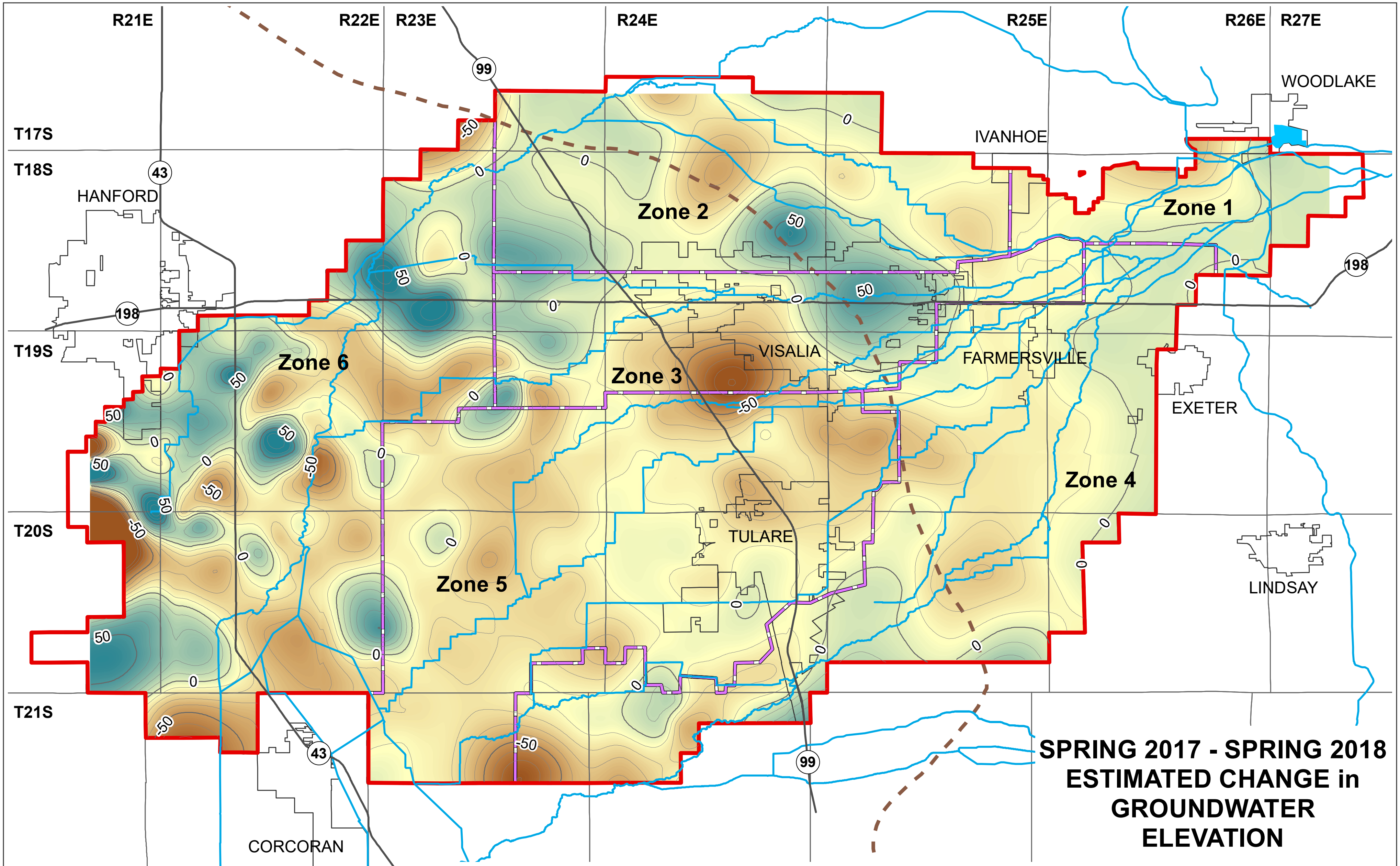
WELL IDENTIFICATION			DEPTH TO WATER (FEET)					
			SPRING			FALL		
AGENCY CODE	WELL NUMBER	HYDROLOGIC ZONE	SPRING 2017	SPRING 2018	SPRING CHANGE	FALL 2017	FALL 2018	FALL CHANGE
5603	21S24E09C002M	4	211.9	-	N/A	232.3	271.0	-38.7
5604	21S24E12D001M	4	-	155.0	N/A	-	187.0	N/A
5604	21S24E17D001M	4	-	222.0	N/A	-	-	N/A
5603	21S24E18A001M	4	144.6	123.0	21.6	-	129.0	N/A


SPRING 2018 GROUNDWATER ELEVATION
No guarantee of accuracy is given or implied
R21E
R22E
R23E
R24E
R25E
R26E
R27E
T17S
T18S
T19S
T20S
T21S
NAD83
NAVD88
HANFORD
CORCORAN
VISALIA
TULARE
IVANHOE
WOODLAKE
FARMERSVILLE
EXETER
LINDSAY
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
99
43
198
Wells Used in This Analysis
50 Feet Contour Line
10 Feet Contour Line
District Boundary
Hydrologic Zone Boundary
Corcoran Clay Eastern Extent
Water Semi-Confined and Confined by Corcoran Clay
251 - 326
201 - 250
151 - 200
101 - 150
51 - 100
1 - 50
-49 - 0
-99 - -50
-101 - -100
Water Unconfined and Semi-Confined by Corcoran Clay
401 - 429
301 - 400
251 - 300
201 - 250
151 - 200
101 - 150
51 - 100
1 - 50
-54 - 0
KAWEAH DELTA WATER CONSERVATION DISTRICT
2975 N FARMERSVILLE BLVD FARMERSVILLE CA 93223 559-747-5601
1654


FALL 2018
GROUNDWATER
ELEVATION
No guarantee of accuracy is given or implied
R21E
R22E
R23E
R24E
R25E
R26E
R27E
T17S
T18S
T19S
T20S
T21S
NAD83
NAVD88
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
WOODLAKE
IVANHOE
HANFORD
VISALIA
FARMERSVILLE
EXETER
TULARE
LINDSAY
CORCORAN
Wells Used in This Analysis
50 Feet Contour Line
10 Feet Contour Line
District Boundary
Hydrologic Zone Boundary
Corcoran Clay Eastern Extent
Water Semi-Confined and Confined by Corcoran Clay
201 - 245
151 - 200
101 - 150
51 - 100
1 - 50
-49 - 0
-99 - -50
-150 - -100
Water Unconfined and Semi-Confined by Corcoran Clay
351 - 428
251 - 350
151 - 250
101 - 150
51 - 100
1 - 50
-49 - 0
-78 - -50
KAWEAH DELTA WATER CONSERVATION DISTRICT
2975 N FARMERSVILLE BLVD FARMERSVILLE CA 93223 559-747-5601
1655


SPRING 2018
DEPTH to
GROUNDWATER
No guarantee of accuracy is given or implied
R21E
R22E
R23E
R24E
R25E
R26E
R27E
T17S
T18S
T19S
T20S
T21S
NAD83
NAVD88
HANFORD
IVANHOE
WOODLAKE
VISALIA
FARMERSVILLE
EXETER
TULARE
LINDSAY
CORCORAN
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
99
43
198
Wells Used in This Analysis
50 Feet Contour Line
10 Feet Contour Line
District Boundary
Hydrologic Zone Boundary
Corcoran Clay Eastern Extent
Feet to Water Semi-Confined and Confined by Corcoran Clay
18 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 314
Feet to Water Unconfined and Semi-Confined by Corcoran Clay
14 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 280
KAWEAH DELTA WATER CONSERVATION DISTRICT
2975 N FARMERSVILLE BLVD FARMERSVILLE CA 93223 559-747-5601
1656


FALL 2018
DEPTH to
GROUNDWATER
No guarantee of accuracy is given or implied
R21E
R22E
R23E
R24E
R25E
R26E
R27E
T17S
T18S
T19S
T20S
T21S
NAD83
NAVD88
WOODLAKE
IVANHOE
HANFORD
VISALIA
FARMERSVILLE
EXETER
TULARE
LINDSAY
CORCORAN
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
Wells Used in This Analysis
50 Feet Contour Line
10 Feet Contour Line
District Boundary
Hydrologic Zone Boundary
Corcoran Clay Eastern Extent
Feet to Water Semi-Confined and Confined by Corcoran Clay
20 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 363
Feet to Water Unconfined and Semi-Confined by Corcoran Clay
12 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 323
KAWEAH DELTA WATER CONSERVATION DISTRICT
2975 N FARMERSVILLE BLVD FARMERSVILLE CA 93223 559-747-5601
1657



SPRING 2017 - SPRING 2018 ESTIMATED CHANGE in GROUNDWATER ELEVATION

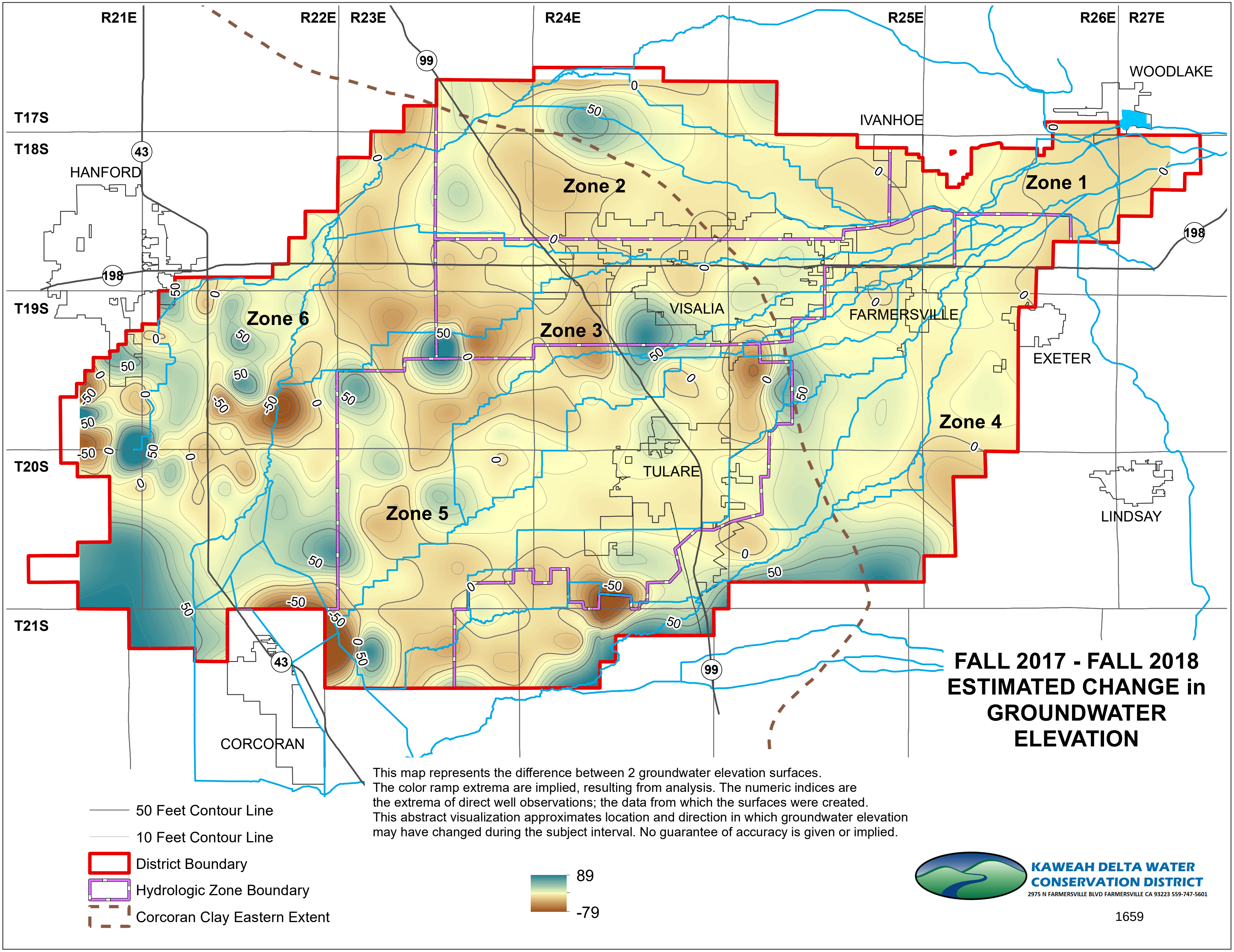
This map represents the difference between 2 groundwater elevation surfaces.
The color ramp extrema are implied, resulting from analysis. The numeric indices are maxima between direct well observations; the data from which the surfaces were created.
This abstract visualization approximates location and direction in which groundwater elevation may have changed during the subject interval. No guarantee of accuracy is given or implied.

50 Feet Contour Line
10 Feet Contour Line
District Boundary
Hydrologic Zone Boundary
Corcoran Clay Eastern Extent

71
-90

KAWEAH DELTA WATER CONSERVATION DISTRICT
2975 N FARMERSVILLE BLVD FARMERSVILLE CA 93223 559-747-5601

1658

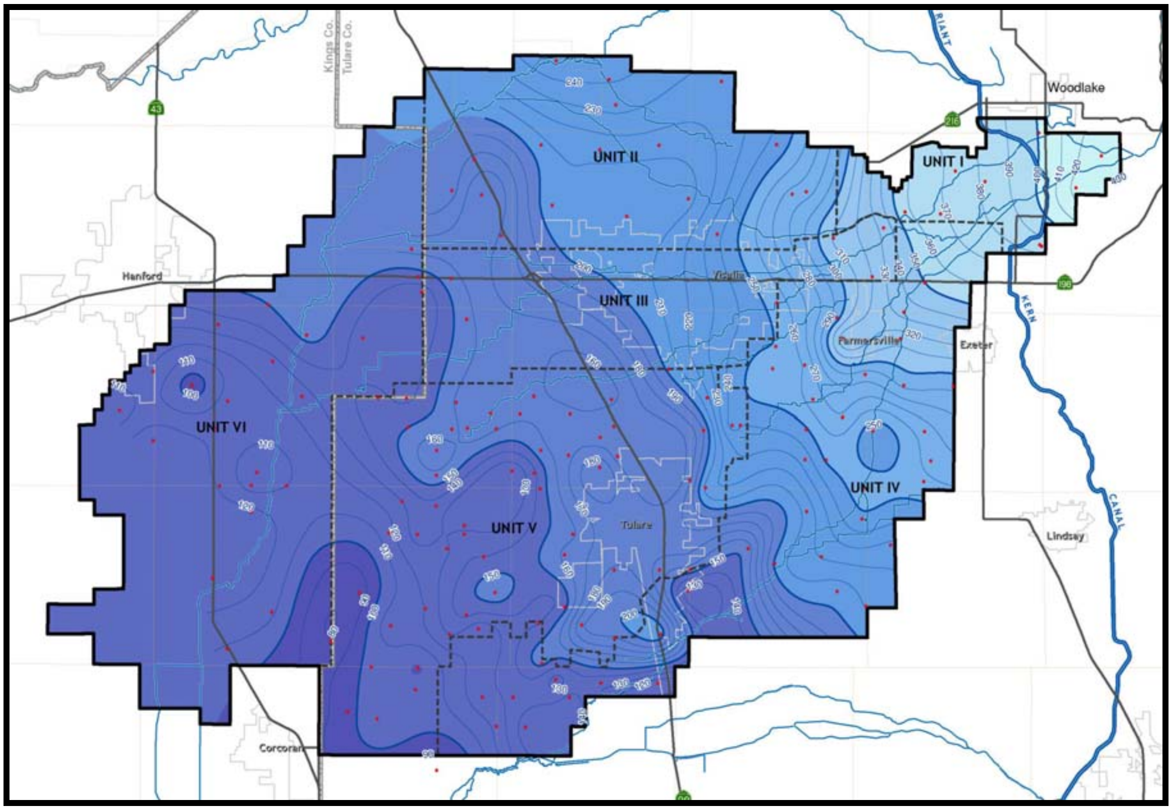


FALL 2017 - FALL 2018
ESTIMATED CHANGE in
GROUNDWATER
ELEVATION
R21E
R22E
R23E
R24E
R25E
R26E
R27E
T17S
T18S
T19S
T20S
T21S
WOODLAKE
IVANHOE
HANFORD
VISALIA
FARMERSVILLE
EXETER
TULARE
LINDSAY
CORCORAN
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
99
43
198
This map represents the difference between 2 groundwater elevation surfaces.
The color ramp extrema are implied, resulting from analysis. The numeric indices are
the extrema of direct well observations; the data from which the surfaces were created.
This abstract visualization approximates location and direction in which groundwater elevation
may have changed during the subject interval. No guarantee of accuracy is given or implied.
50 Feet Contour Line
10 Feet Contour Line
District Boundary
Hydrologic Zone Boundary
Corcoran Clay Eastern Extent
89
-79
KAWEAH DELTA WATER
CONSERVATION DISTRICT
2975 N FARMERSVILLE BLVD FARMERSVILLE CA 93223 559-747-5601
1659

Appendix 4B

KDWCD Groundwater Management Plan

KAWEAH DELTA
Water Conservation
DISTRICT



GROUNDWATER MANAGEMENT PLAN

(Updated: November 7, 2006)
(Amended: July 7, 2015)

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SECTION 1: INTRODUCTION

1.1 Overview

On July 5, 1995, the Kaweah Delta Water Conservation District (District) formally adopted the District's Groundwater Management Plan (Plan). The Plan allows the District to manage groundwater on a local basis in lieu of a mandated plan administered by the State of California Department of Water Resources. The District has long recognized groundwater as an important resource to the area and the Plan gives the District the authority to engage in specific activities, which are beneficial to the groundwater basin within the Plan area.

The Plan was originally prepared and implemented by the District in response to 1992 state legislation AB 3030. Since the establishment of the District's Plan, more recent state legislation SB 1938, current California Water Code interpretation and discussions within the Department of Water Resource's Bulletin 118 led the District to reevaluate the Plan and its components. This document, therefore, is an update of the Kaweah Delta Water Conservation District's 1995 Groundwater Management Plan.

1.2 Plan Authority

The District is an authorized groundwater management agency within the meaning of California Water Code (CWC) § 10753[1](b) and by the establishment of the Plan. The Plan does not conflict with existing groundwater ordinances and groundwater management plans and the District continues to endeavor to coordinate Plan elements with other local agencies that have adopted rules and regulations to implement and enforce their own AB255, or AB 3030 plans as required by CWC § 10753.9(a).

1.3 Background

AB 3030 provided an opportunity for the District to prepare and implement a Groundwater Management Plan. While the legislation allows for separate plans to be developed by each public agency with jurisdiction over water, a well-conceived Plan covering the entire District offers improved management and benefit capabilities for all agencies within the plan area.

The availability of groundwater to serve community and agricultural needs can be impacted by activities that take place a considerable distance beyond local boundaries. There is considerable common use of the

[1] CWC § 10753(b). Any local agency, whose service area includes a groundwater basin, or a portion of a groundwater basin, that is not subject to groundwater management pursuant to other provisions of law or a court order, judgment, or decree, may, by ordinance, or by resolution if the local agency is not authorized to act by ordinance, adopt and implement a groundwater management plan pursuant to this part within all or a portion of its service area.

groundwater resource and this coordinated Plan has been and will continue being a benefit to competing interests using the groundwater resource. This coordination is accomplished through the development of a Memorandum of Understanding (MOU) between the District and other local agencies within the plan area along with a periodic meeting of the MOU participants.

The Plan covers all of the land within the boundary of the District. Any local agency, as that term is defined by Government Code section 10752(g), can exclude the land within its boundary from being covered by the Plan by choosing not to be included in the Plan. Accordingly, the Plan covers all land within the boundary of the District, less that land within the boundaries of local agencies which elect not to participate in the Plan or which may opt out of the Plan (hereinafter the "Plan Area").

1.4 Purpose and Goals

The Plan recognizes that the conjunctive management of water supplies within the Plan Area must be continued. Achieving hydrologic equilibrium requires the management of both surface and groundwater supplies. Maintaining this balance will be the principal benefit to be derived from the Plan. Retaining all existing surface and groundwater supplies within the Plan Area is critical to maintaining this delicate balance.

The Groundwater Management Plan is also a vital element within the District's Integrated Regional Water Management Plan (IRWMP). The Plan provides the organizational foundation for the operation of the IRWMP. Many of the Plan's primary elements are used in carrying out the purpose of the IRWMP. Shared elements between the Plan and IRWMP include;

- ✓ Participation
- ✓ Regional Coverage
- ✓ Regional Objectives
- ✓ Water Management Strategies
- ✓ Integration
- ✓ Project Prioritization

The principal actions called for by the Plan will be gathering and evaluating data concerning the quantity of groundwater. Actions have been and will continue to be developed to enhance the valuable groundwater resource by promoting those measures necessary to reduce the long-term groundwater level decline in the Plan Area. Many of the actions identified are currently being conducted. Other actions will require further study prior to implementation.

Adherence to Plan objectives and procedures will avoid and reduce duplication of activities by local jurisdictions. Additionally, plan elements can be utilized by all the agencies within the Plan Area in long-term planning activities. The Plan is designed to be flexible, allowing updates to be made as needed, based principally on the additional information that is gathered through the monitoring programs.

1.5 Plan Area

The District is located on the alluvial fan of the Kaweah River. This alluvial fan extends approximately 40 miles in a southwesterly direction, commencing in the foothills of the Sierra Nevada range on the east and continuing to near the central axis of the San Joaquin Valley in the vicinity of the east bed edge of Tulare Lake. The north and the northwest boundaries of the District generally abut the service area of the Kings River. The south boundary of the District generally abuts the service area of the Tule River.

The District's Plan includes those areas overlying the groundwater basin or associated groundwater sub-basins within the District. Those areas of the San Joaquin Valley Groundwater Basin resources located within the District include portions of the Kaweah, Kings, Tule and Tulare Lake groundwater sub-basins. These sub-basins are shown on Plate 1.

The District's Plan Area is presented on Plate 2. Areas managed under existing Groundwater Management Plans by local agencies that are excluded by agreement from this Plan include areas within the borders of the Corcoran Irrigation District and specific lands managed under the Tulare Lake Bed Coordinated Groundwater Management Plan (TLBCGMP).

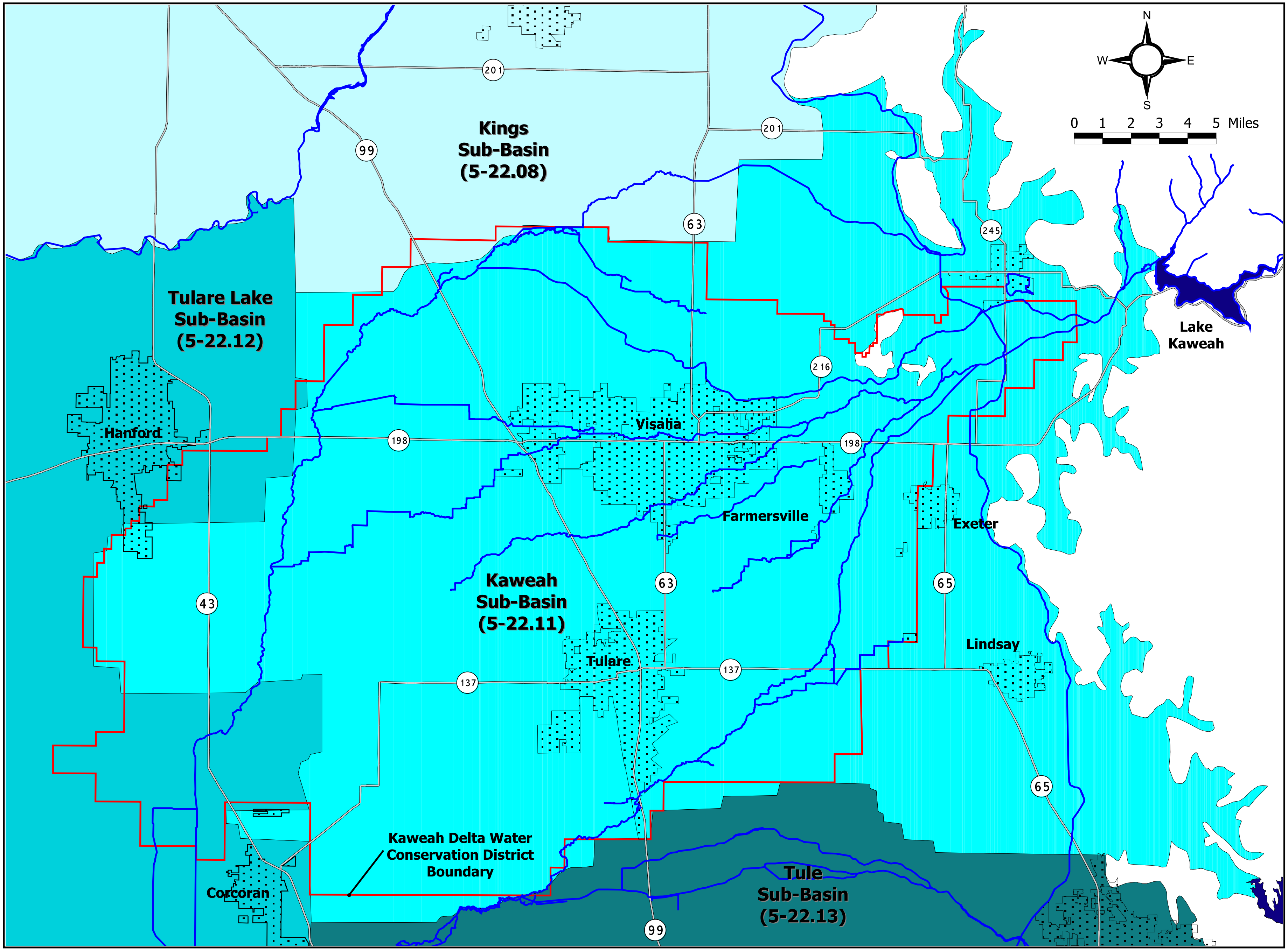


Plate No. 1 : Groundwater Sub-Basins

1668

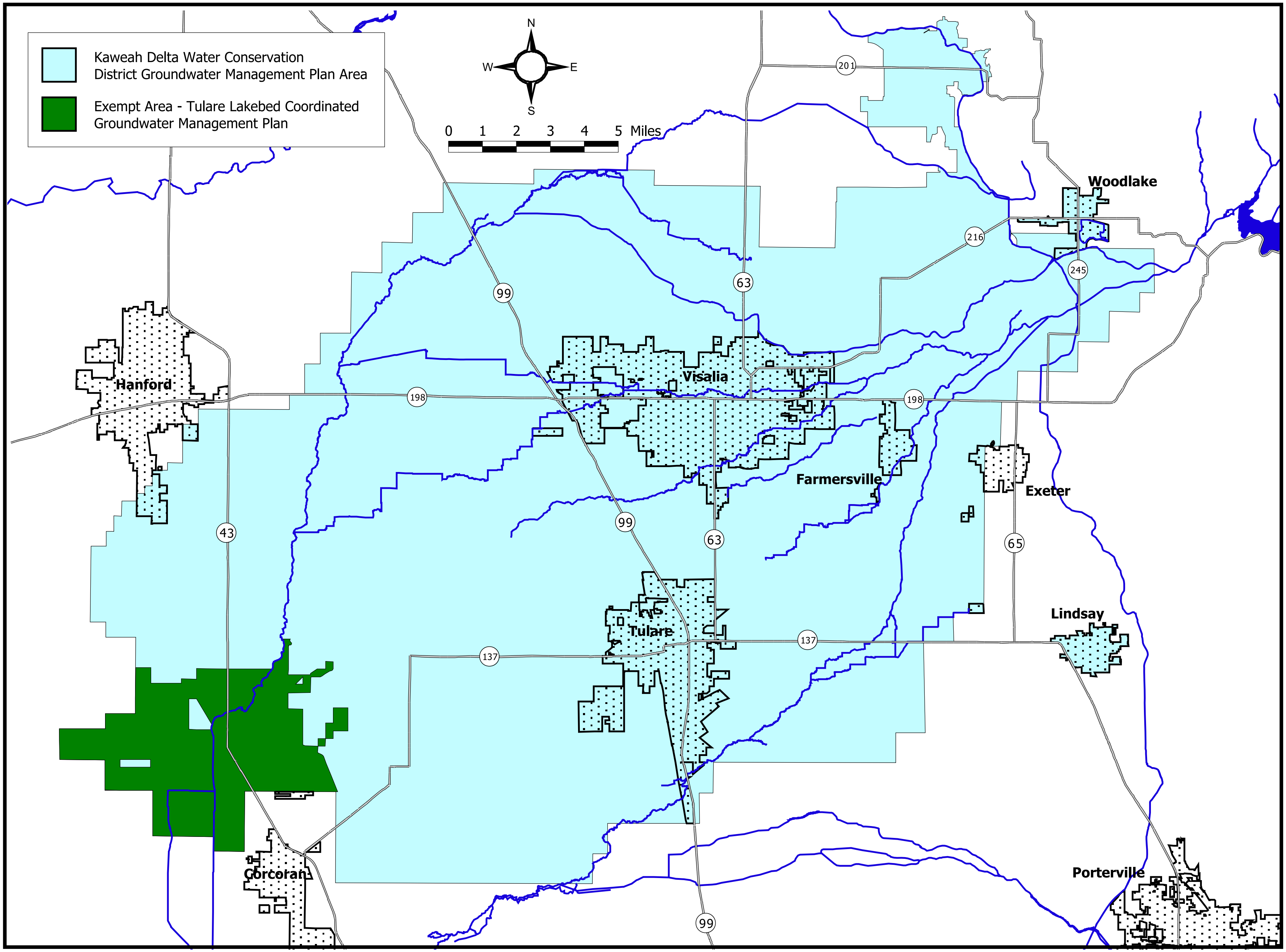


Plate No. 2 : Groundwater Management Plan Area

The District's Plan Area contains multiple local agencies that provide various types of water services. Those local agencies that have been included as stakeholders through the execution of a *Memorandum of Understanding (MOU)* are shown on Plate 3. The list of current stakeholders covered under a MOU is provided below in Table 1.

TABLE 1
PLAN STAKEHOLDERS

California Water Service Company	Kings County Water District (*AB 3030 Plan*)
City of Farmersville	Lakeside Ditch Company
City of Lindsay	Lakeside Irrigation Water District
City of Tulare	St. Johns Water District
City of Visalia	Stone Corral Irrigation District
City of Woodlake	Tulare Irrigation District (*AB 255 Plan*)
Consolidated Peoples Ditch Company	Ivanhoe Irrigation District

1.6 Management Plan Components

The District's Plan includes the following required and recommended components:

- ✓ CWC § 10753.7 (four mandatory components). Recent amendments to the CWC at § 10750 et seq. require a Groundwater Management Plans (GMP) to include several components to be eligible for award of funding administered by the Department of Water Resources (DWR) for the implementation of groundwater related studies, construction of groundwater projects and groundwater quality projects. These amendments to the CWC were included in Senate Bill 1938, effective January 1, 2003.
- ✓ CWC § 10753.8 (12 optional components). CWC § 10753.8 includes 12 specific technical issues that could be addressed in GMPs to manage the basin optimally and protect against adverse conditions.
- ✓ DWR Bulletin 118-2003, Appendix C (six recommended components). The recent 2003 update to the Department of Water Resource's Bulletin 118, *California's Groundwater*, includes discussion of required and recommended components of Local Groundwater Management Plans. Review of the material results in identifying components that are not included in CWC § 10750 et seq.

Table 2 summarizes the required and recommended components of an AB 3030 plan developed pursuant to current State guidance and the appropriate section of the District's Plan where each component is addressed.

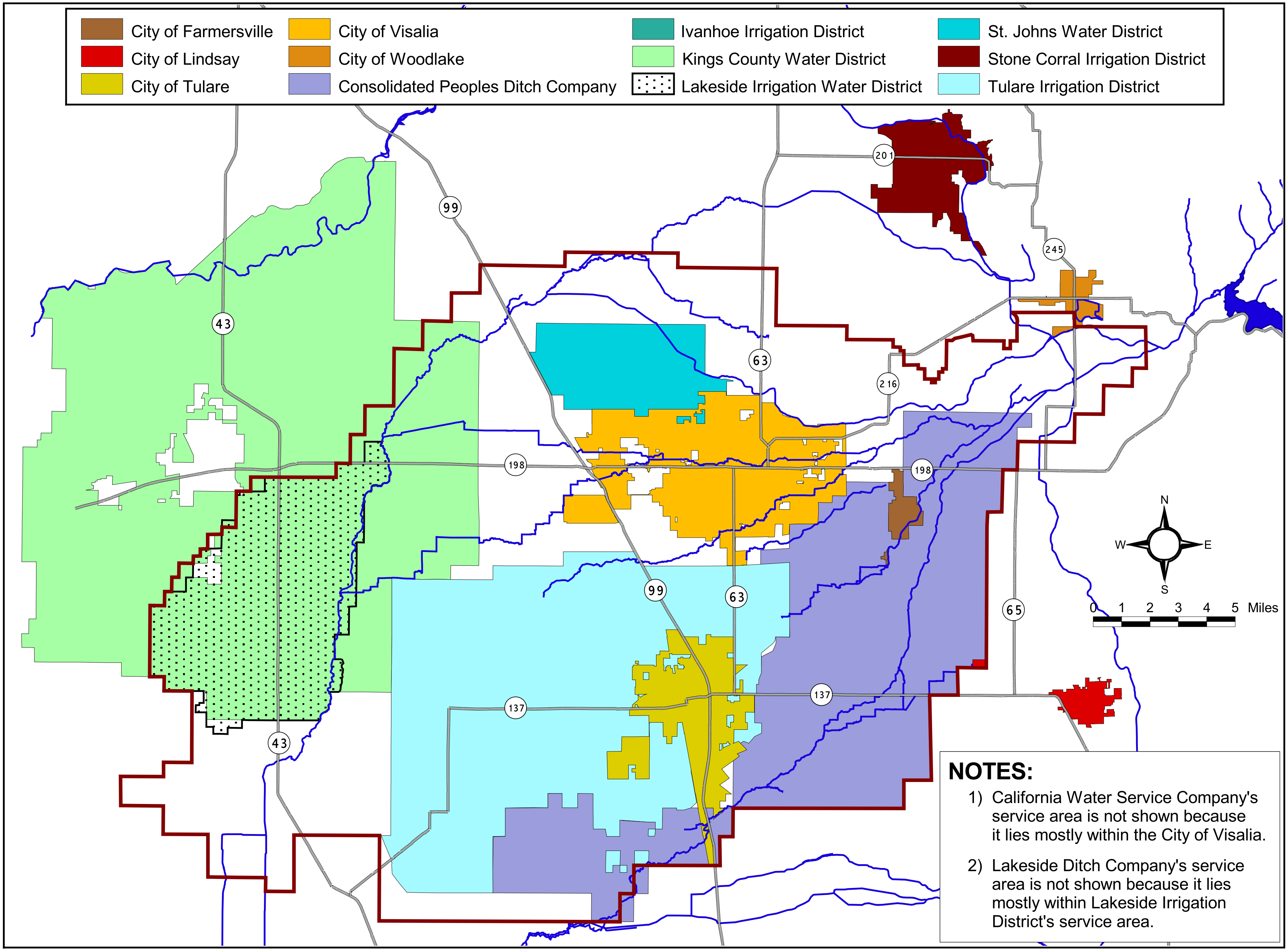


Plate No. 3 : Plan Participants

1671

TABLE 2
GROUNDWATER MANAGEMENT PLAN COMPONENTS

Plan Component Description	District Plan Section
Mandatory Plan Components (CWC § 10753.7(a))	
(1) Basin Management Objectives	3.2
(2) Other Agency Involvement	3.6
(3) Plan Map	1.4
(4) Monitoring Protocols	3.3.5
Optional Plan Components (CWC § 10753.8)	
(a) Saline Water Intrusion	3.4.3
(b) Wellhead Protection	3.4.2
(c) Migration of Contaminated Water	3.4.4
(d) Well Abandonment	3.4.1
(e) Overdraft Mitigation	3.5.2
(f) Groundwater Replenishment	3.5.1
(g) Groundwater Monitoring	3.3.1
(h) Conjunctive Use	3.5.3
(i) Well Construction Policies	3.4.5
(j) Operation of Facilities	3.5.1.4
(k) Relationships with other agencies	3.6.3
(l) Land Use Planning	3.7.1
Recommended Plan Components (BU 118-2003, Appendix C)	
✓ Stakeholder Advisory Committee	3.6.2
✓ Plan Area Description	2.1 – 2.7
✓ Management Objectives Contributions	3.2
✓ Monitoring Program Description	3.3
✓ Periodic Groundwater Reports	3.7.3
✓ Periodic Plan Re-evaluation	3.7.4

SECTION 2: BASIN CONDITIONS

2.1 The District

The District was formed under the provisions of the Water Conservation District Act of 1927 for the purpose of doing those things authorized by the Act. The District, includes lands in both Tulare County and Kings County. The boundary is shown on Plate 4, which also shows hydrologic units established in the District. The total area of the District is about 340,000 acres, with approximately 257,000 acres located in the westerly portion of Tulare County and the balance, or about 83,000 acres, in the northeasterly corner of Kings County.

The lands within the District are used for agricultural purposes, although the cities of Visalia and Tulare constitute significant areas of urbanization. Other communities include Farmersville, Exeter, Goshen, Ivanhoe, Waukena and Guernsey.

2.2 Climate

The area is semi-arid with mild winters and hot, dry summers. The average rainfall, based on District records, is approximately 11 inches per year. Distribution of such rainfall varies from 13 inches on the eastern portions of the District to 7 inches on the western portions. The majority of this rainfall occurs from November through April. With the long, hot summers that normally occur in the valley, there is a potential for about five feet of water that evaporates per year, with the majority of that evaporation occurring during the period from April through October.

Rainfall in the District occurs primarily in the winter months, with virtually no rainfall in the summer months. Annual crop use per acre averages several times the amount of average precipitation. As a result, agricultural crops grown within the District are heavily dependent upon irrigation from surface water deliveries and groundwater pumping, with water needs only partially satisfied by rainfall.

2.3 Land Use

The cropping patterns within the District vary with changes in agricultural economics. In 1981, approximately 77% of the irrigated land was planted in row crops, 20% in permanent plantings and 3% in pasture. In 1999, approximately 71% of the irrigated land was in row crops, 28 % in permanent plantings and 1% in pasture. A tabulation of the land utilization for 1981 and 1999 as compiled in the Final Report (2003) of Water Resources Investigation of the Kaweah Delta Water Conservation District is presented in Table 3.

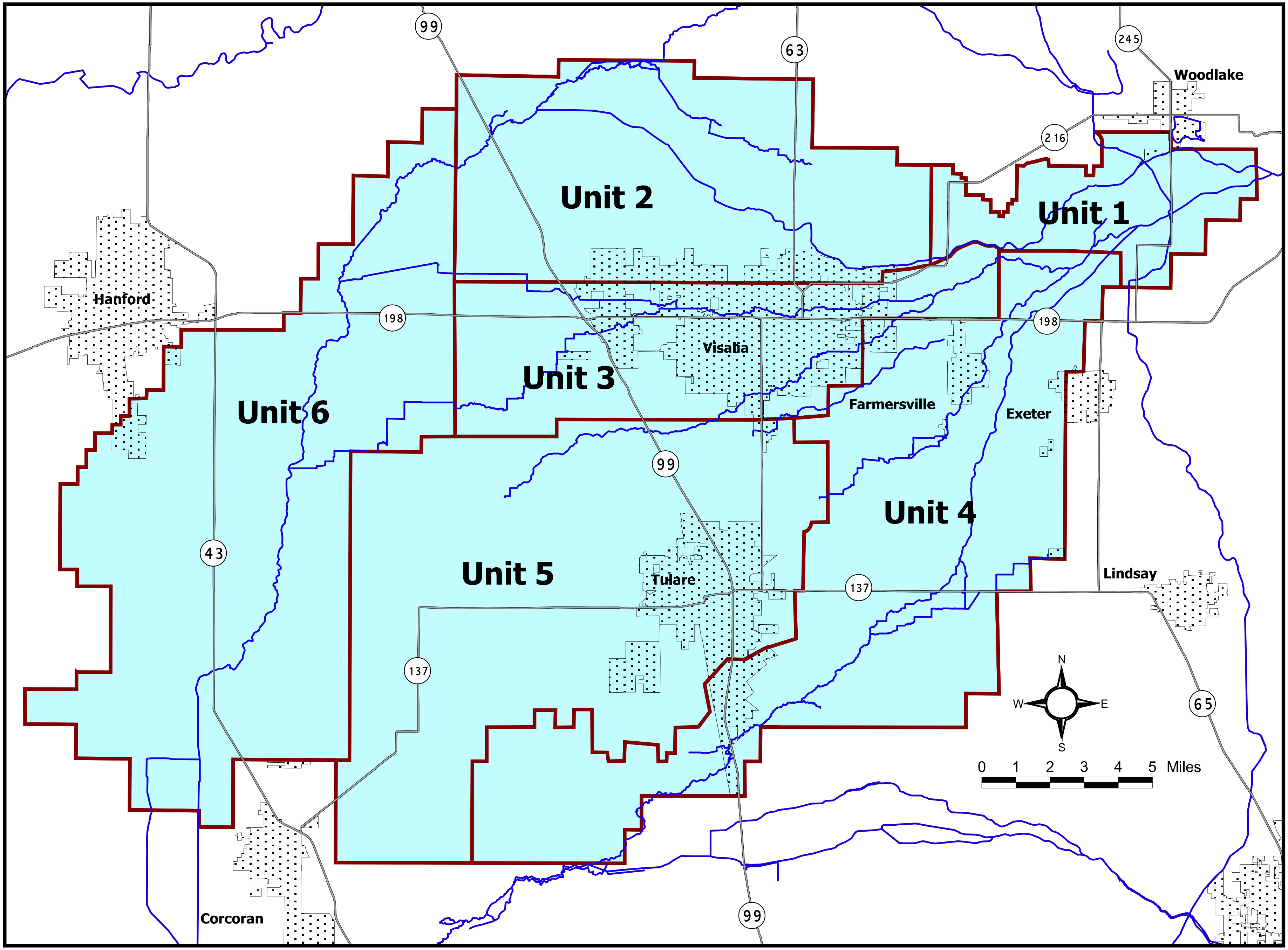


Plate No. 4 : Hydrologic Units

1674

TABLE 3
DISTRICT SUMMARY OF LAND UTILIZATION

(Values in Acres)

Category of Land Use	1981	1990	1999
Irrigated			
Cotton	94,229	93,765	62,295
Alfalfa	33,977	41,257	38,923
Grain	65,062	65,960	87,927
Deciduous and Nuts	36,502	39,262	44,540
Pasture	8,873	4,005	2,954
Miscellaneous Field	2,911	1,053	510
Sugar Beets	1,869	1,100	900
Grapes	9,187	7,492	29,796
Citrus	6,337	6,587	7,184
Rice	313	31	0
Truck	3,995	5,494	10,872
Subtotal, Irrigated	**263,255**	**266,006**	**285,901**
Nonirrigated			
Farmsteads, Dairies, Feed Lots	21,352	29,797	29,508
Urban, Commercial and Industrial	10,397	10,156	13,136
Idle (Fallow)	13,923	7,634	6,958
Roads, Channel and Canals	2,045	3,386	2,433
Undeveloped	28,833	23,047	2,115
Unknown	246	25	0
Sub-total, Nonirrigated	**76,796**	**74,045**	**54,150**
TOTAL	**340,051**	**340,051**	**340,051**

Reference: Water Resources Investigation of the Kaweah Delta Water Conservation District (Final Report 2003)

2.4 Surface Water Hydrology

The majority of the watershed area for the Kaweah River is in the high Sierra Nevada Mountains, which experiences heavy snowfall during most winter months. During the spring and summer months, the snow melts to form tributaries of the Kaweah River. In normal years, the Kaweah River does not reach its highest stage until the middle of May or early June. For the last fifty years, the average annual runoff for the Kaweah River has been 454,295 acre-feet. Average runoff is not the runoff experienced every year. There are great variations in the flows of the Kaweah River, not only from year to year, but also from month to month. Historically, there have been alternating periods of flood and drought in the discharge area of the Kaweah River, which have been greatly curtailed since 1961 with the completion and operation of Terminus Dam.

In addition to the Kaweah River runoff and rainfall, water enters the District by of way canals from the Kings River and smaller tributary streams such as Dry Creek and Yokohl Creek. Water is also often imported into the District from the Central Valley Project.

At McKay Point, a significant geographical feature immediately to the east of the eastern District boundary and about 1½ miles west of the community of Lemon Cove, the Kaweah River divides into the St. Johns River and Lower Kaweah River. Water then enters the District in these two channels. Within the District, these branches continue to divide into both natural and manmade distributaries forming the Kaweah Delta. Included in Section 3.3 of this Plan is Plate No. 16 “Kaweah Watercourses” that displays the extent of the surface water conveyance systems throughout the District.

Numerous public and private entities within the District divert surface water from the Kaweah River and its distributaries. About 250,000 acres within the District have access to surface water supplies from the rivers system. Because of the erratic nature of flows in the Kaweah River, which vary substantially in magnitude from month to month and year to year, nearly all these lands must satisfy supplemental water needs from groundwater. Note that all municipal and industrial uses within the District are supplied exclusively from groundwater.

Terminus Dam and Reservoir, located on the Kaweah River about 3½ miles to the east of the District, was completed in 1962 by the U.S. Army Corps of Engineers. This project was constructed mainly for flood control purposes and to provide storage for irrigation waters. The dam is an earth fill structure with a controlled outlet capacity of up to 8,900 cfs. The reservoir space available for conservation and irrigation re-regulation is about 183,000 acre-feet. The District presently has contracts with the United States for the repayment of operation and maintenance costs allocated to flood control and irrigation re-regulation space purposes. The District is the sole entity that holds the contracts for all the conservation and irrigation storage space in the reservoir.

The Friant-Kern Canal, a feature of the Federal Central Valley Project (hereinafter "CVP"), traverses the easterly portion of the District. San Joaquin River water is delivered to certain lands within the Plan Area via this facility. Both the Tulare Irrigation District and Ivanhoe Irrigation District which lie entirely within the Plan Area, obtain water from the Friant-Kern Canal as they have a long-term contract with the Bureau of Reclamation for CVP water. Although the Tulare Irrigation District and Ivanhoe Irrigation District are the only entities fully within the Plan Area with such a Friant Division contract, the District itself, as well as other entities therein, has historically received substantial quantities of CVP water from time to time through temporary and surplus water service contracts. This water was either percolated or used to offset groundwater extraction. Other special districts located partially within or adjacent to the Plan Area, such as Exeter Irrigation District and Lindmore Irrigation District, also have long-term Friant Division contracts for CVP water.

In common with other areas along the east side of the San Joaquin Valley, the District historically has experienced the anomaly of flood control problems coupled with water deficiency. From time to time, flows in the Kaweah River have reached damaging levels, with substantial volumes of water escaping their channel banks to flood valuable agricultural lands within the District. Even with capture of some of the water associated with these high flood flow events, water supplies are insufficient to meet demands. This is demonstrated in groundwater level declines in all but the eastern portions of the District.

2.5 Hydrogeology

Most of the lands in the District are contained within the Kaweah subbasin of the San Joaquin Valley Groundwater Basin. The San Joaquin Valley Groundwater Basin is surrounded on the west by the Coast Range, on the south by the San Emigdio and Tehachapi Mountains, on the east by the Sierra Nevada and on the north by the Sacramento-San Joaquin Delta and Sacramento Valley. The northern portion of the San Joaquin Valley drains toward the Delta utilizing the San Joaquin River and its tributaries, the Fresno, Merced, Tuolumne and Stanislaus Rivers. The Kings, Kaweah, Tule and Kern Rivers that flow toward the trough of the Tulare drainage basin, which includes the beds of the former Tulare, Buena Vista and Kern Lakes, internally drain the southern portion of the valley.

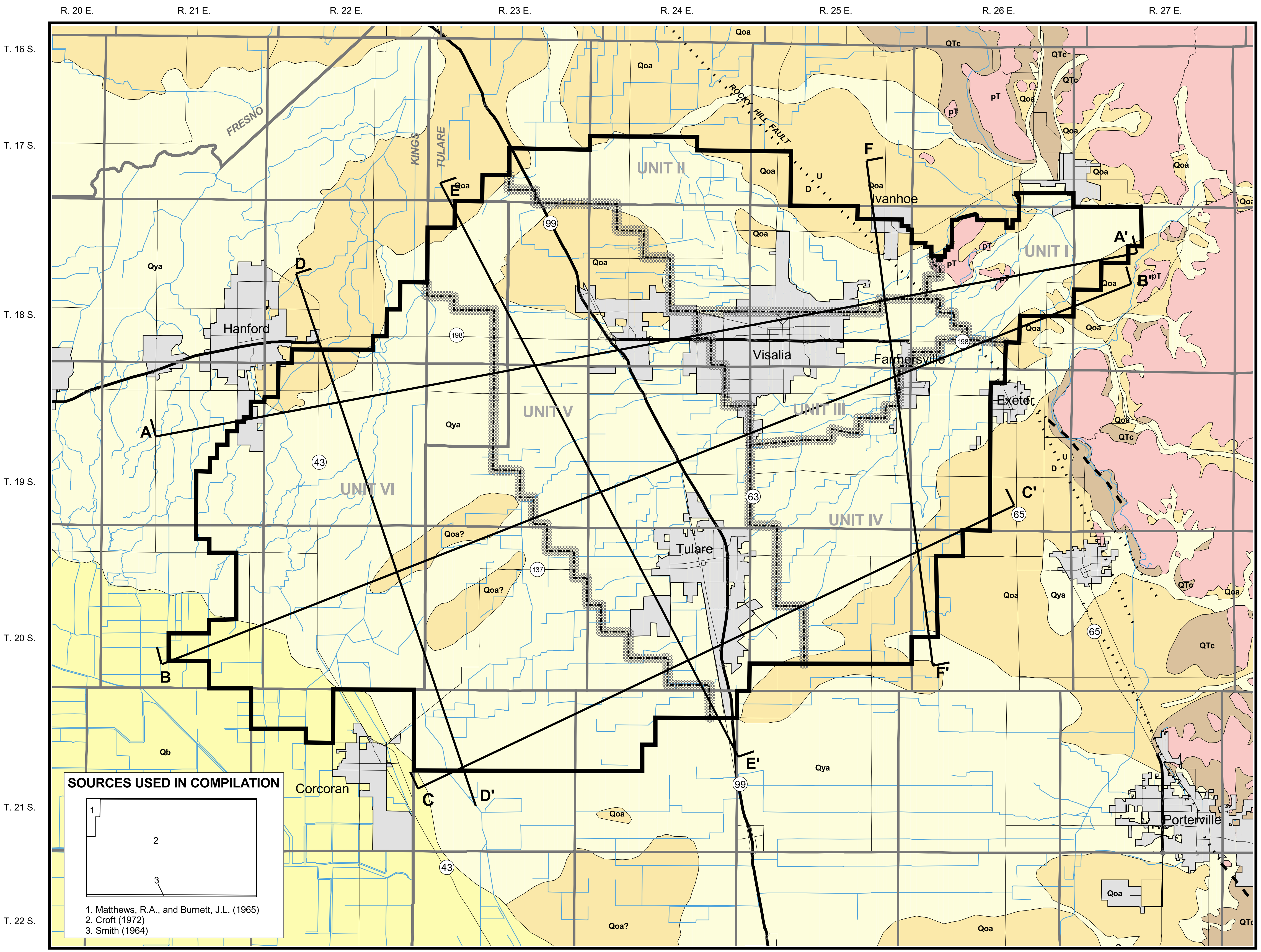
The Kaweah subbasin lies between the Kings Groundwater Subbasin on the north, the Tule Groundwater Subbasin on the south, crystalline bedrock of the Sierra Nevada foothills on the east and the Tulare Lake subbasin on the west. The subbasin is generally comprised of lands in the Kaweah Delta Water Conservation District. Major rivers and streams in the subbasin include the Lower Kaweah and St. Johns Rivers. The Kaweah River is considered a primary surface water source for groundwater recharge to the area.

The sediments that comprise the Kaweah Subbasin aquifers are unconsolidated deposits of Pliocene, Pleistocene and Holocene age. On the east side of the subbasin, these deposits consist of arkosic material derived from the Sierra Nevada and are divided into three stratigraphic units: continental deposits, older alluvium and younger alluvium. In the western portion of the subbasin, near Tulare Lake bed, unconsolidated deposits consisting of flood-subbasin and lacustrine and marsh deposits interfinger with east-side deposits.

The continental deposits of Pliocene and Pleistocene age are divided into oxidized and reduced deposits based on depositional environment. The oxidized deposits, which crop out along the eastern margin of the valley, consist of deeply weathered, poorly permeable, reddish-brown sandy silt and clay with well-developed soil profiles. The reduced deposits are moderately permeable and consist of micaceous sand, silt and clay that extend across the trough in the subsurface to the west side of the valley.

Older alluvium, which overlies the continental deposits, is moderately to highly permeable and is the major aquifer in the subbasin. Younger alluvium consists of arkosic beds, moderately to highly permeable consisting of sand and silty sand. Flood-basin deposits consist of poorly permeable silt, clay and fine sand. Groundwater in the flood-basin deposits is often of poor quality. Lacustrine and marsh deposits consist of blue, green, or gray silty clay and fine sand and underlie the flood-subbasin deposits. Clay beds of the lacustrine and marsh deposits form aquitards that control the vertical and lateral movement of groundwater. The most prominent clay bed is the Corcoran Clay, which underlies the western half of the Kaweah Subbasin at depths ranging from about 200 to 500 feet (DWR 1981). In the eastern portion of the subbasin, groundwater occurs under unconfined and semi-confined conditions. In the western half of the subbasin, where the Corcoran Clay is present, groundwater is primarily confined below the Corcoran Clay.

The geology of the District and surrounding areas is depicted on Plate 5. The associated geologic legend is depicted in Plate 12. Plates 6 through 11 illustrate this geology in cross section.



Legend

- District Boundary
- Hydrologic Unit Boundary
- Cross Section Location
- County Line
- Township and Range Lines
- Streams
- Urban Areas
- Fault--dashed where inferred, dotted where concealed; U, upthrown side; D, downthrown side

Projection: California State Plane, Zone 4, NAD83, Feet

UNCONSOLIDATED DEPOSITS

WEST SIDE (Coast Ranges Provenance)

- QTa — Alluvium, undifferentiated (Pliocene to Holocene)

- Qb — Flood basin deposits (Holocene)
- QTl — Lacustrine and marsh deposits (Pliocene and Pleistocene)

EAST SIDE (Sierra Nevada Provenance)

- Qya — Younger alluvium (Holocene)
- Qoa — Older alluvium (Pleistocene and Holocene (?))
- QTc — Continental deposits (Pliocene and Pleistocene(?))

CONSOLIDATED ROCKS

- pT — Basement complex (gabbro, diorite, granodiorite, and metamorphic rocks) (pre-Tertiary)

N

SCALE = 1:250,000

4 0 4 Miles

Plate No. 5
Regional Geologic Map

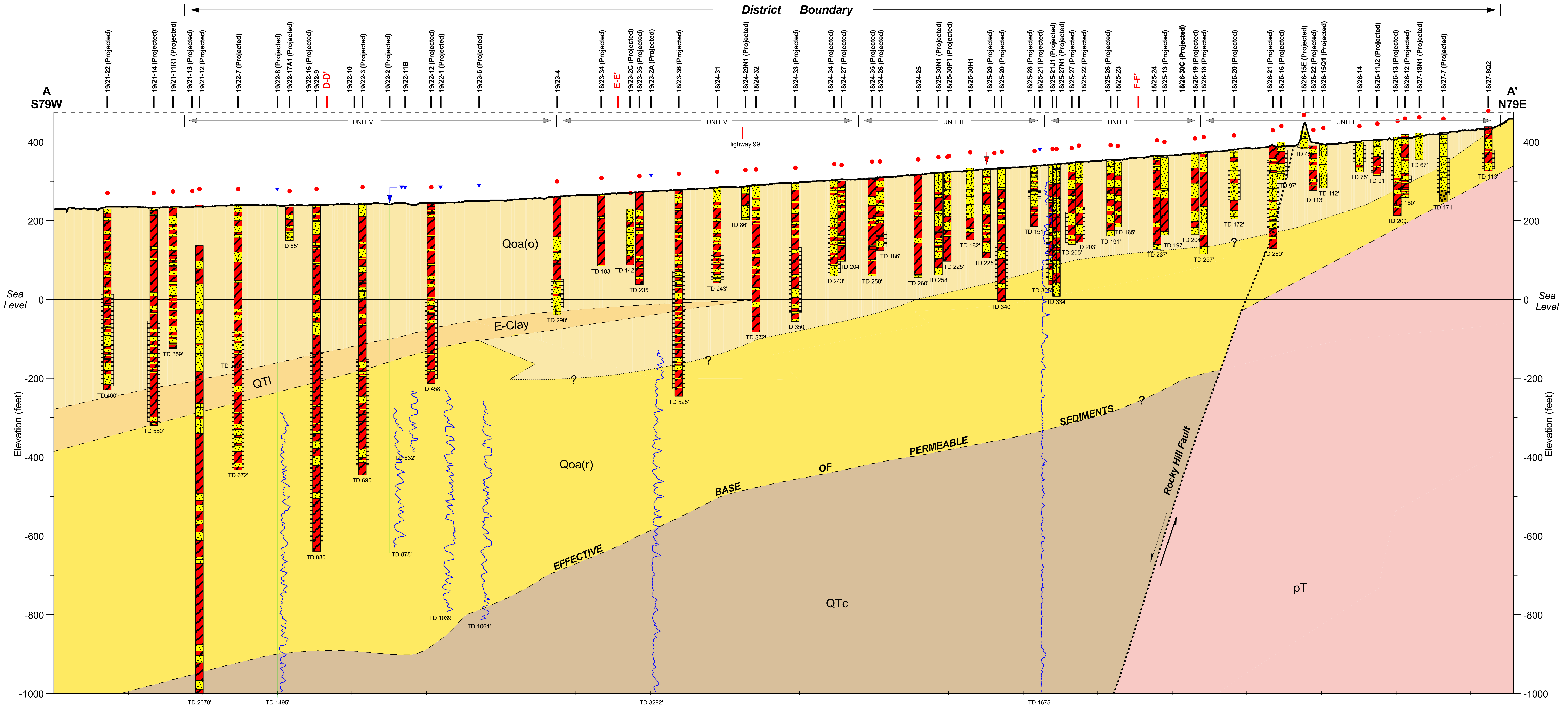


Plate No. 6: Hydrogeologic Section A-A'

Kaweah Delta Water Conservation District Kings and Tulare Counties

1680

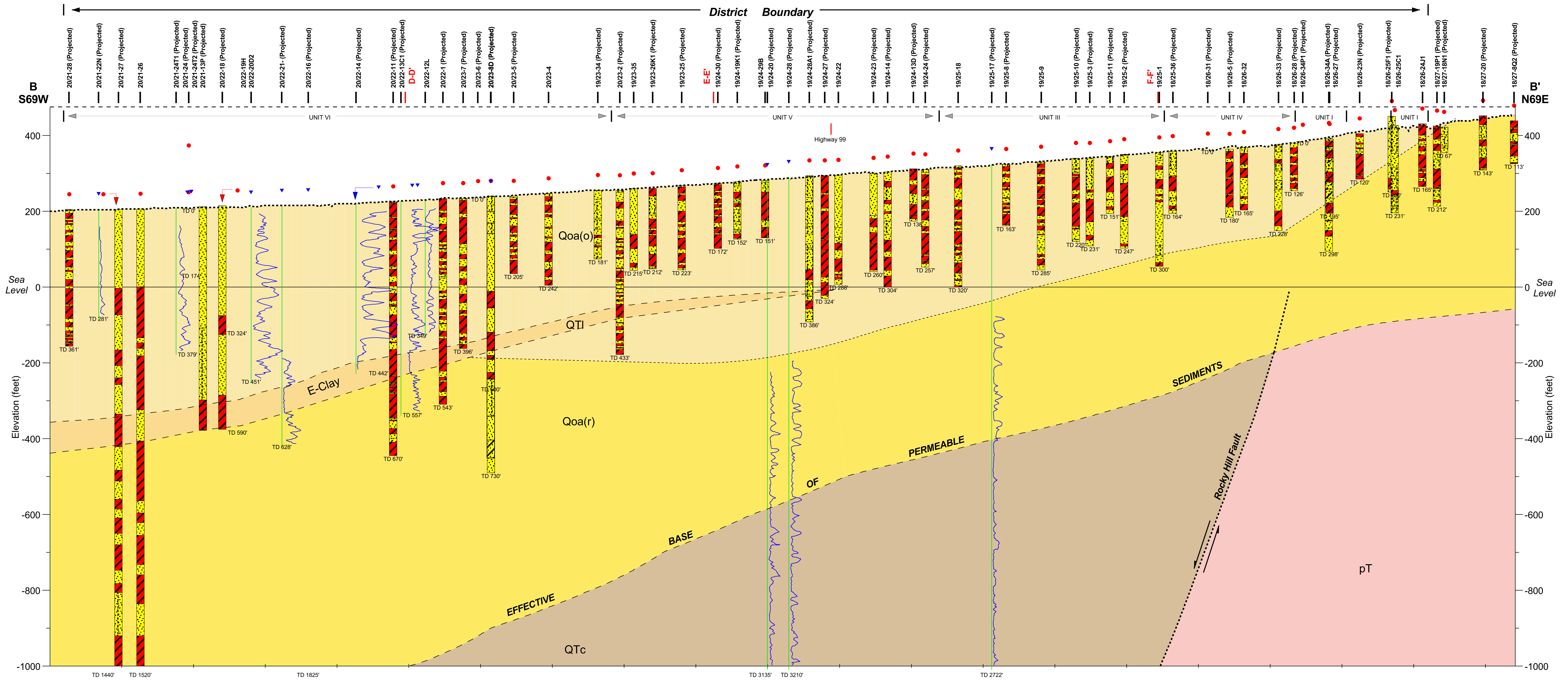


Plate No. 7: Hydrogeologic Section B-B'

Kaweah Delta Water Conservation District

Kings and Tulare Counties

1681

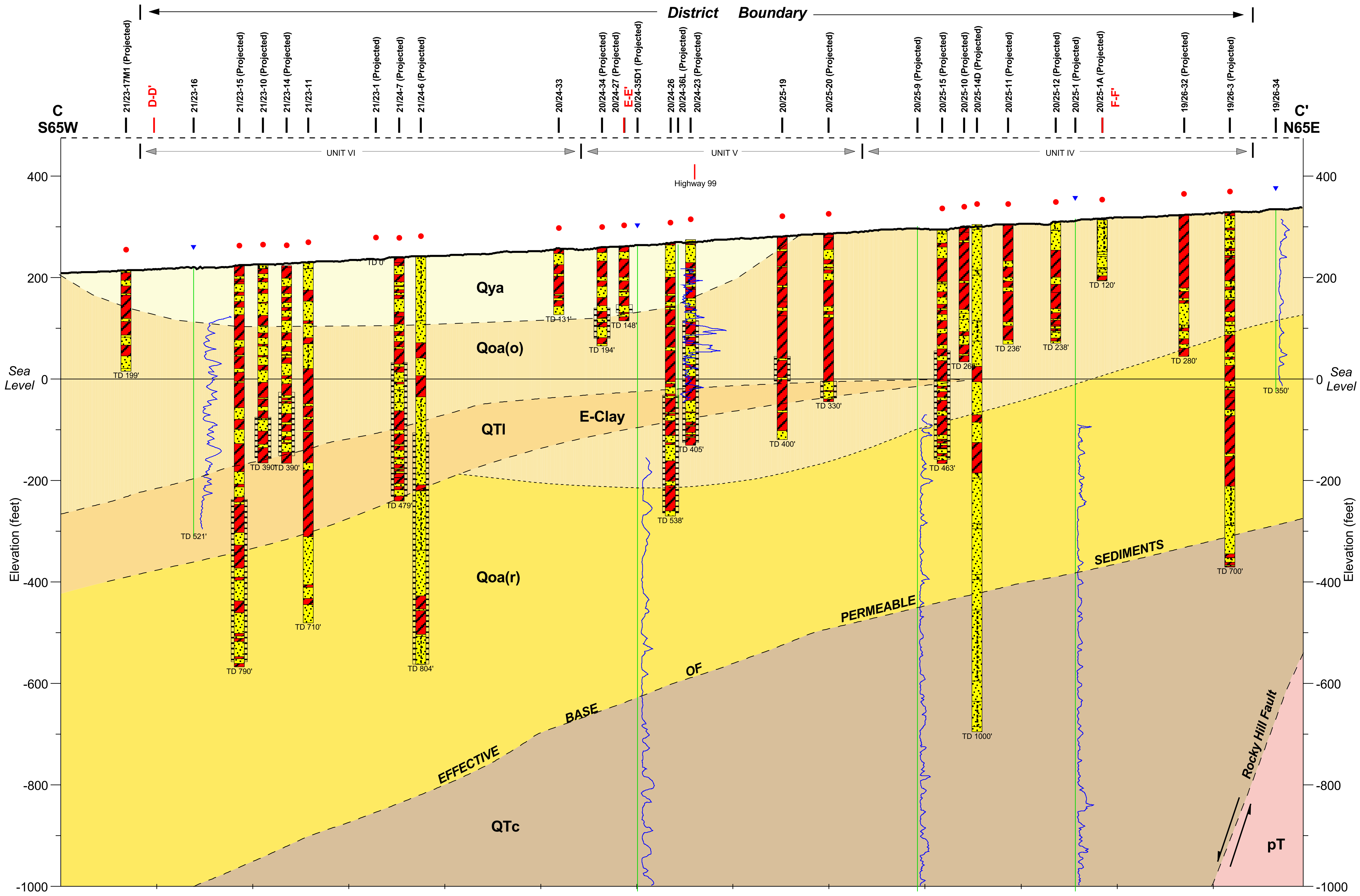


Plate No. 8: Hydrogeologic Section C-C'

Kaweah Delta Water Conservation District

Kings and Tulare Counties

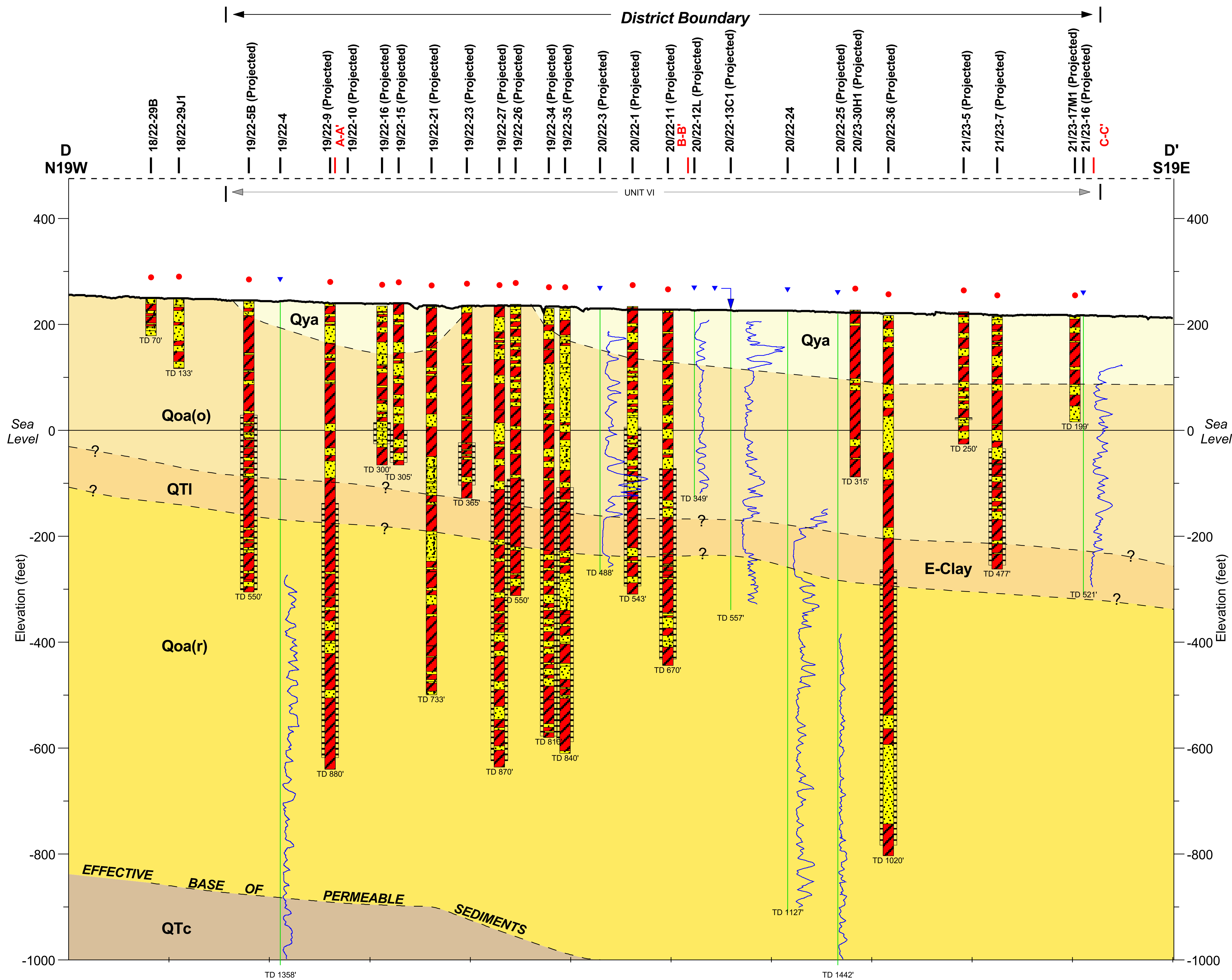


Plate No. 9: Hydrogeologic Section D-D'

Kaweah Delta Water Conservation District

Kings and Tulare Counties

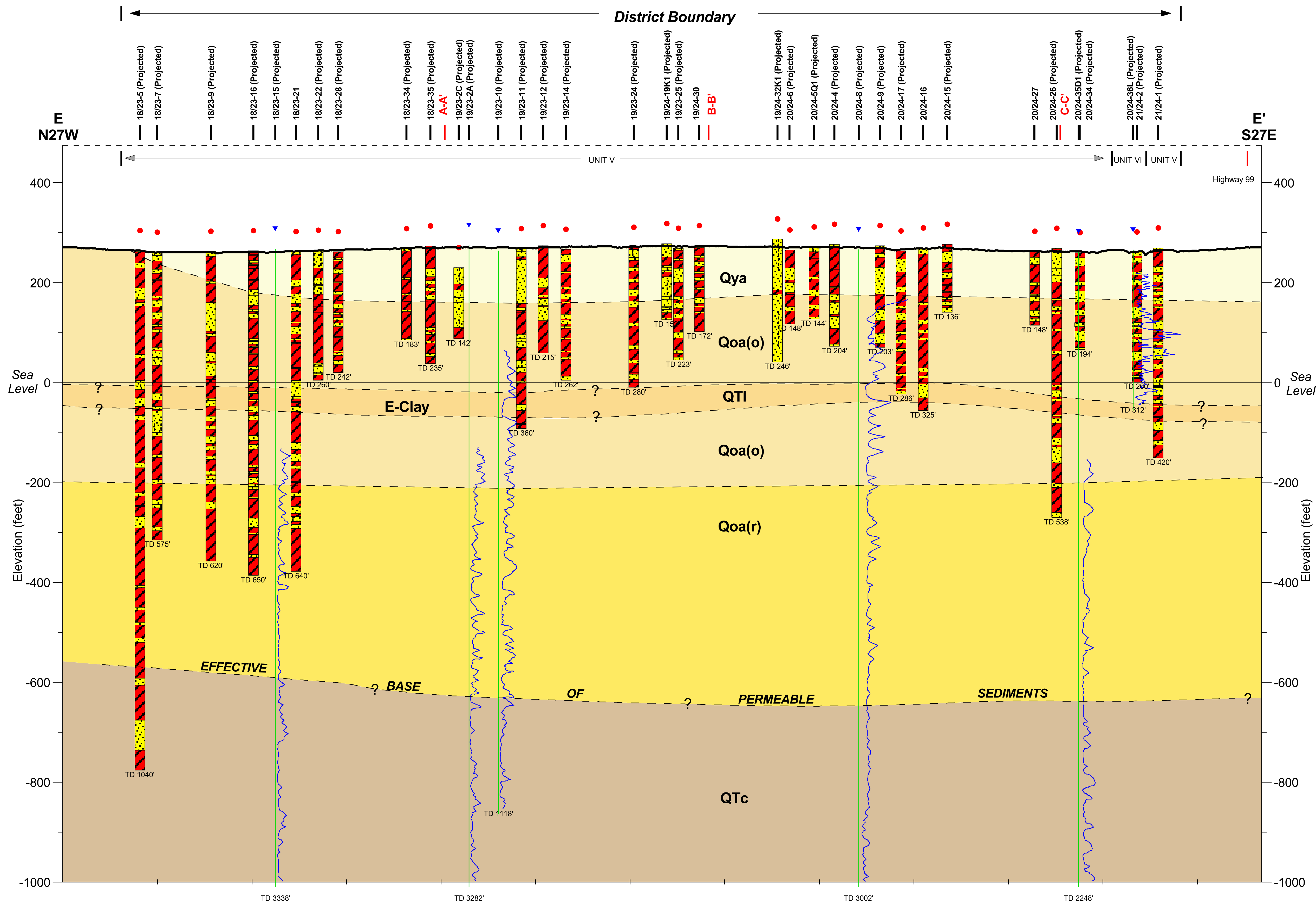


Plate No. 10: Hydrologic Section E-E'

Kaweah Delta Water Conservation District

Kings and Tulare Counties

1684

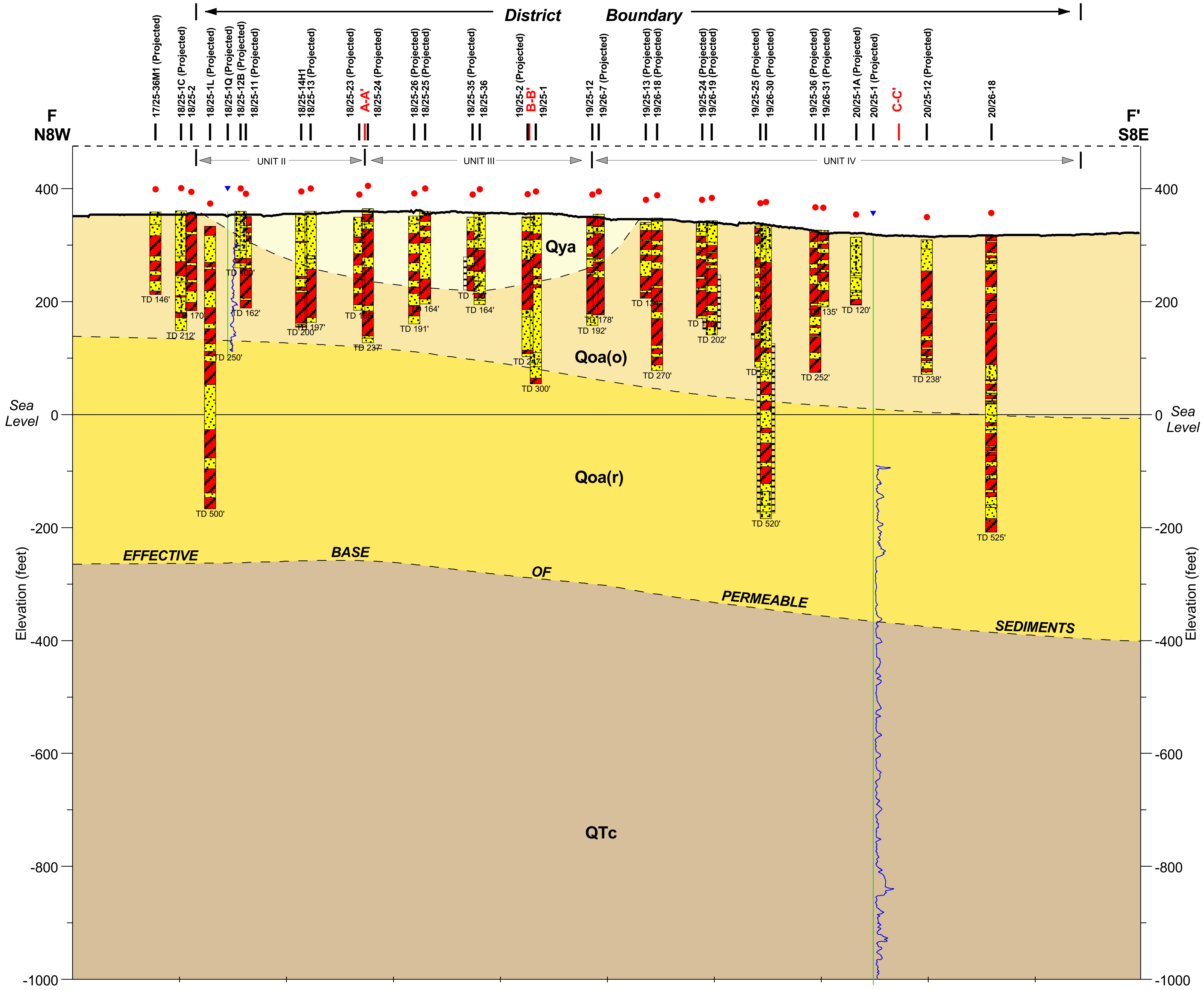
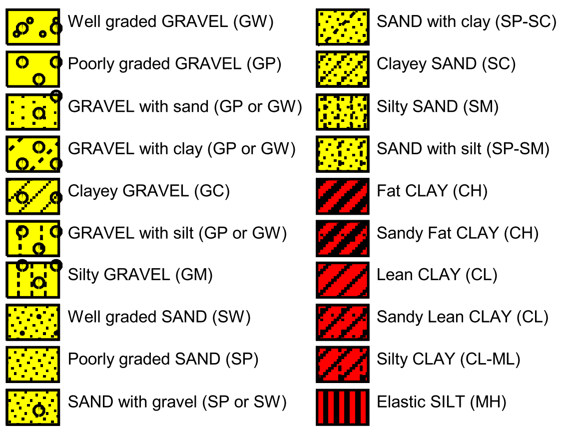
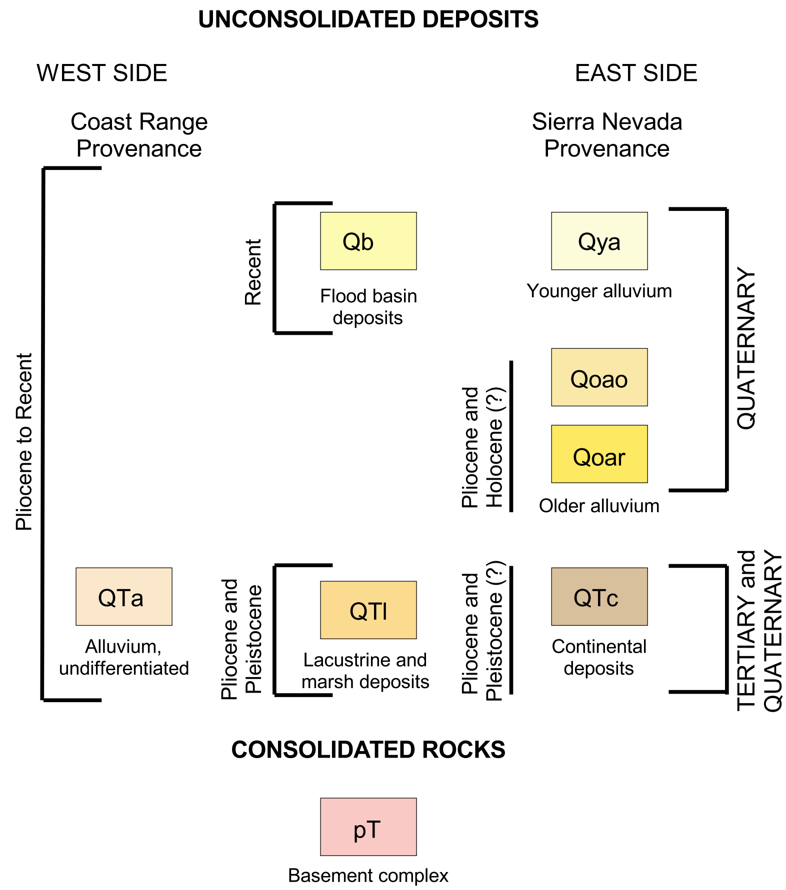
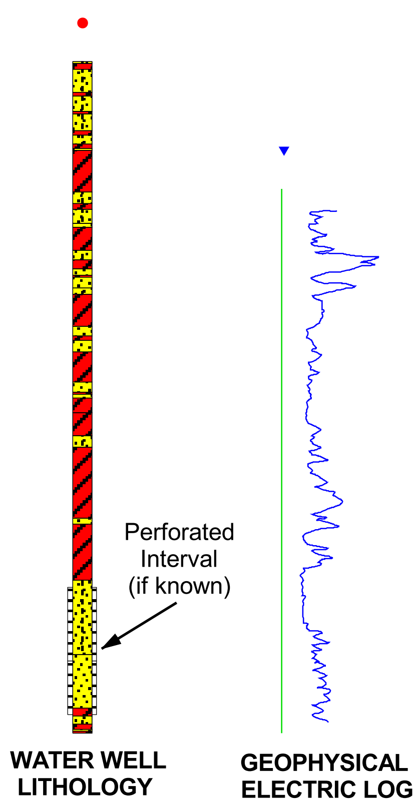


Plate No. 11:
Hydrogeologic Section F-F'
Kaweah Delta Water Conservation District
Kings and Tulare Counties

SOIL TYPES







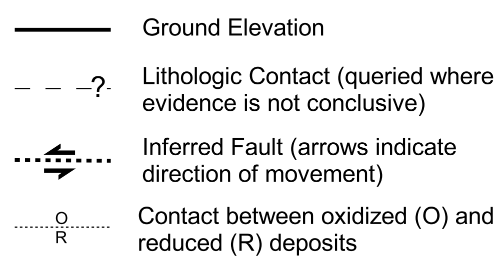


Plate No. 12 : Geologic Legend

1686

2.6 Groundwater

Historically, much of the land within the District had a groundwater table close to the land surface. In the early part of the 20th century, the distance from the ground surface to the groundwater table may have averaged less than fifty feet. Over the last fifty years, each successive drought period has resulted in an increase in groundwater pumping that has caused the water table to drop significantly. It is anticipated that as agricultural land is converted to urban uses and industry grows, the competition for water resources among agricultural, urban, industrial and environmental interests will continue to increase.

Groundwater is the most dependable water supply for the Basin's agricultural, industrial and domestic water users who regularly draw upon this valuable resource from individually owned wells. The continued pumping of groundwater has resulted in an overdraft of the groundwater basin, that is, more water has been pumped from the basin than has been recharged into the basin on a long-term basis. Even though over 3 million acre-feet of surface water has been imported into the District over the past 30 years in an effort to supplement local surface water supply and reduce dependence on groundwater, the average depth to groundwater within the Plan Area has continued to drop.

The District has been monitoring groundwater levels since the 1950’s. This is accomplished through groundwater level measurements taken in the late fall and early spring. Based on the water level readings, there is an overall trend of declining groundwater levels within the Basin. A graphical analysis of historical groundwater levels reveals the areal extent of overdraft throughout the District and is presented on Plate No. 13, “Contours of Equal Difference in Water Levels, 1952 to 1999”. It is important to note that the Basin does have the ability to respond to positive conditions and this is demonstrated during years of above-average precipitation when the decline has been periodically interrupted by short-term groundwater recovery.

The condition of overdraft results in additional pumping costs to accommodate increased lift. As the water table continues to drop, pumping must occur from deeper levels of the aquifer which often have lower porosity and specific yield characteristics than those found in the upper levels of the unconfined aquifer. The long-term impact is a further reduction in the available groundwater supply in storage. Using the collected historical data and the transmissivity factors of the aquifers, a determination can be made of the estimated quantity of inflow and/or outflow of groundwater within the Plan Area. This data allows the District to identify and evaluate areas that could be more severely impacted during periods of sustained drought due to low yield of wells and the limited depths of the aquifers. This important water management tool is useful to the District in developing long-term planning decisions.

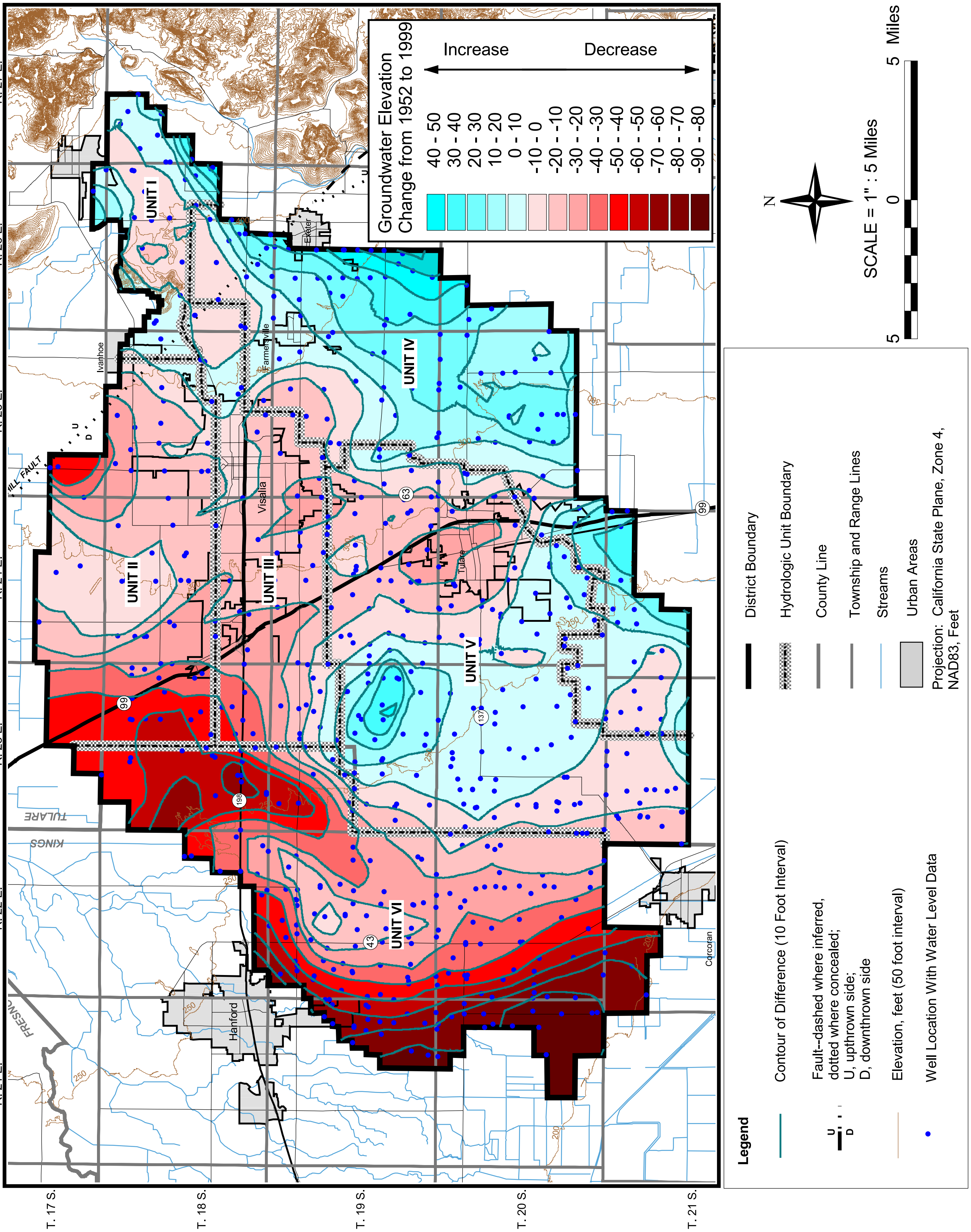


Plate No. 13

Contours of Equal Difference in Water Levels, 1952 to 1999

Kaweah Delta Water Conservation District

1688

2.7 Water Demand and Supply

The dominant use of water within the District occurs from irrigated agricultural. Average annual applied water demand for crops grown in the District is approximately 3.7 acre-feet per acre. The applied water demand ranges from 1.9 acre-feet per acre for truck crops to 6.5 acre-feet per acre for pasture. A summary tabulation of estimated annual water demands for crops grown in the District for the years 1981, 1990 and 1999 is set forth in Table 5 on the following page. Uses outside of irrigated agriculture commonly include municipal, industrial and domestic applications. Table 4 presents a summary of water demands within the District that are not classified as irrigated agricultural.

TABLE 4
ESTIMATED M&I WATER DEMAND IN THE DISTRICT

(Values in Acre-Feet)

Use Classification	1981	1990	1999
Urban Water Demand	24,167	32,947	42,457
Public Water System Demand	5,739	7,222	8,242
Rural Domestic Water Demand	1,876	1,876	1,876
Dairy and Related Water Demand	4,169	10,846	16,255
TOTAL	**35,951**	**52,891**	**68,830**

Reference: Water Resources Investigation of the Kaweah Delta Water Conservation District (Final Report 2003)

The District receives approximately 80% of its average annual surface water supply from the Kaweah River System and approximately 20% of its average surface water supply through imported water. Water demands that are not met from the supply of surface water are pumped from the groundwater basin. Since 1962, records show that over 5 million acre-feet of water has been imported into the District. The annual imported supply is variable and is dependent on available CVP supply. Kings River water is also diverted into the District. The annual imported surface water supply and deliveries (1963 through 2005) are presented in Table 6, Kaweah Delta Water Supply Inventory.

Notable changes that have affected water supplies to the District include the following:

- ✓ Central Valley Project (1950's)
- ✓ Terminus Project (Lake Kaweah: 1962)
- ✓ State Water Project (Tulare Lake Basin Water Storage District: 1968)
- ✓ Terminus Project (Lake Kaweah Enlargement: 2004)

TABLE 5
ESTIMATED APPLICATION OF IRRIGATED WATER TO CROPS IN THE DISTRICT

Category of Land Use	Average Water Demand (Feet)	1981		1990		1999	
		Net Irrigated Area (Acres)	Total Application (Acre-Feet)	Net Irrigated Area (Acres)	Total Application (Acre-Feet)	Net Irrigated Area (Acres)	Total Application (Acre-Feet)
Cotton	3.9	94,229	367,493	93,765	365,684	62,295	242,951
Alfalfa	5.0	33,977	169,885	41,257	206,285	38,923	194,615
Grain	2.8	65,062	182,174	65,960	184,688	87,927	246,196
Deciduous and Nuts	4.0	36,502	146,008	39,262	157,048	44,540	178,160
Pasture	6.5	8,873	57,675	4,005	26,033	2,954	19,201
Miscellaneous Field	3.0	2,911	8,733	1,053	3,159	510	1,530
Sugar Beets	4.0	1,869	7,476	1,100	4,400	900	3,600
Grapes	3.8	9,187	34,911	7,492	28,470	29,796	113,225
Citrus	2.9	6,337	18,377	6,587	19,102	7,184	20,834
Rice	6.0	313	1,878	31	186	0	0
Truck	1.9	3,995	7,591	5,494	10,439	10,872	20,657
	TOTAL	**263,255**	**1,002,200**	**266,006**	**1,005,493**	**285,901**	**1,040,967**

Note: Total annual crop demand obtained from DWR Bulletin 113 or information from California Department of Water Resources for DAU242

TABLE 6
KAWEAH DELTA WATER SUPPLY INVENTORY

(Values in Acre-Feet)

Water Year	SURFACE WATER INFLOW					SURFACE WATER OUTFLOW		
	Terminus Flows	Creek Flows	CVP Imports	Kings River	TOTAL	Spills	Friant-Kern Pumping	TOTAL
1962-63	474,120	10,604	285,741	0	**770,465**	14,027	0	**14,027**
1963-64	228,099	3,703	105,736	0	**337,538**	1,190	0	**1,190**
1964-65	481,989	19,044	276,516	0	**777,548**	5,399	0	**5,399**
1965-66	246,551	1,648	117,175	0	**365,375**	2,900	0	**2,900**
1966-67	1,000,713	79,997	282,316	8,481	**1,371,506**	104,794	0	**104,794**
1967-68	231,545	2,168	134,922	0	**368,635**	3,775	0	**3,775**
1968-69	1,185,412	141,336	186,749	0	**1,513,497**	418,092	0	**418,092**
1969-70	429,185	13,329	113,373	26,468	**582,355**	17,586	0	**17,586**
1970-71	287,302	5,353	113,044	17,294	**422,993**	0	0	**0**
1971-72	163,243	1,835	42,014	0	**207,092**	0	0	**0**
1972-73	609,878	40,565	172,628	28,961	**852,032**	34,229	0	**34,229**
1973-74	485,551	27,093	260,418	19,785	**792,847**	29,566	0	**29,566**
1974-75	376,310	13,916	162,649	20,168	**573,043**	7,589	0	**7,589**
1975-76	135,927	1,505	36,782	1,753	**175,968**	202	0	**202**
1976-77	96,161	196	109	0	**96,467**	0	0	**0**
1977-78	814,317	99,802	122,348	9,037	**1,045,504**	44,863	9,112	**53,975**
1978-79	420,353	19,246	287,179	7,716	**734,494**	13,885	0	**13,885**
1979-80	874,598	62,371	209,303	1,087	**1,147,359**	97,785	5,096	**102,880**
1980-81	246,907	5,697	66,293	11,118	**330,014**	1,956	0	**1,956**
1981-82	742,680	41,983	241,594	3,217	**1,029,474**	58,035	29,532	**87,568**
1982-83	1,398,397	171,130	62,601	0	**1,632,129**	459,619	148,197	**607,816**
1983-84	528,171	37,214	121,468	42,685	**729,538**	79,973	0	**79,973**
1984-85	328,718	6,553	92,348	3,207	**430,827**	367	0	**367**
1985-86	808,032	51,337	163,909	18,068	**1,041,345**	63,660	92,739	**156,399**
1986-87	180,551	3,160	30,671	2,430	**216,812**	0	0	**0**
1987-88	182,282	2,747	99,058	1,995	**286,082**	0	0	**0**
1988-89	207,723	2,269	39,612	1,000	**250,604**	0	0	**0**
1989-90	134,201	859	0	0	**135,060**	0	0	**0**
1990-91	246,485	4,741	7,716	0	**258,942**	0	0	**0**
1991-92	146,744	1,787	17,639	1,226	**167,397**	0	0	**0**
1992-93	545,966	26,420	145,690	7,093	**725,169**	0	0	**0**
1993-94	188,055	2,535	27,777	1,392	**219,760**	0	0	**0**
1994-95	854,667	58,872	125,682	13,383	**1,052,604**	114,966	0	**114,966**
1995-96	518,993	21,753	128,521	33,796	**703,063**	236	0	**236**
1996-97	760,268	68,708	82,930	20,734	**932,641**	170,109	54,780	**224,889**
1997-98	906,426	127,460	79,058	13,918	**1,126,862**	94,306	137,018	**231,324**
1998-99	283,025	25,311	124,909	20,107	**453,352**	7,734	0	**7,734**
1999-00	361,012	35,084	114,236	2,575	**512,907**	21,479	0	**21,479**
2000-01	259,317	5,645	23,296	6,944	**295,203**	8	0	**8**
2001-02	297,368	5,427	41,654	2,095	**346,543**	81	0	**81**
2002-03	426,046	8,704	122,039	11,732	**568,521**	530	0	**2,156**
2003-04	229,667	2,410	34,374	73,973	**340,424**	391	0	**805**
2004-05	614,095	18,274	240,023	80,064	**952,456**	2,372	0	**2,372**
TOTAL	**19,937,050**	**1,279,791**	**5,142,100**	**513,502**	**26,872,447**	**1,871,704**	**476,474**	**2,350,218**
AVERAGE	**463,652**	**29,763**	**119,584**	**11,942**	**624,941**	**43,528**	**11,081**	**54,656**

SECTION 3: MANAGEMENT PROGRAM

3.1 Statutory Authority

The District hereby includes in its groundwater management program the right to engage in all of those activities provided by statutes, which authorize or are related to Plan developments.

California Water Code § 10753.7(a) states that, for the District to have a qualifying plan eligible to receive state funds administered by the Department of Water Resources, that such plan shall include as components all of the following:

(1) Prepare and implement basin management objectives;
(2) Involve other agencies to work cooperatively;
(3) Prepare a Plan Area map detailing the groundwater basin; and
(4) Adopt monitoring protocols designed to detect changes in groundwater conditions.

California Water Code § 10753.8 authorizes the District to include as components in its groundwater management plan the following:

(a) The control of saline water intrusion;
(b) Identification and management of wellhead protection areas and recharge areas;
(c) Regulation of the migration of contaminated groundwater;
(d) The administration of a well abandonment and well destruction program;
(e) Mitigation of conditions of overdraft;
(f) Replenishment of groundwater extracted by water producers;
(g) Monitoring of groundwater levels and storage;
(h) Facilitating conjunctive use operations;
(i) Identification of well construction policies;
(j) The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling and extraction projects;
(k) The development of relationships with state and federal regulatory agencies; and
(l) The review of land use plans and coordination with land use planning agencies to assess activities, which create a reasonable risk of groundwater contamination.

Additionally, the District intends to exercise all of the authority given to a water replenishment district in California Water Code § 60220 through § 60232, together with the authority of a water replenishment district to fix and collect fees and assessments within the Plan Area for groundwater management in accordance with California Water Code § 60300 through § 60352, as may be necessary for the District to accomplish the purposes and goals of the Plan.

Notwithstanding the foregoing, the District reserves the right to decide whether or not it will be involved and to the extent to which it will be involved in each of the activities authorized by the aforementioned statutes. The District assumes no responsibility or liability for any authorized activity in which it is not actually involved. Further, upon thirty (30) days written notice to all other local agencies located within the Plan Area, the District may terminate the Plan, together with any and all activities, which may be a part of its groundwater management program at the time of such termination. The District shall not be required to notify other local agencies, or anyone else, if it merely terminates its involvement in an activity authorized by the aforementioned statutes, without terminating the Plan itself.

3.2 Basin Management Objectives

The goal of the Plan is to offer efficient and effective groundwater management in an effort to provide a sustainable, high quality supply of groundwater for agricultural, environmental and urban use for the future. The groundwater of San Joaquin Valley Groundwater Basin aquifer underlying the Kaweah Delta Water Conservation District is a significant water resource that must be reasonably used and conserved for the benefit of the overlying lands. This can be accomplished by avoiding extractions that exceed safe yield or produce a condition of overdraft within the Plan Area.

To accomplish the Plan's goal, the following management objectives are adopted under the Plan:

- ✓ Stabilize and potentially reverse the long-term decline of groundwater levels
- ✓ Monitor groundwater quality
- ✓ Monitor inelastic land surface subsidence resulting from groundwater pumping
- ✓ Maintain and augment surface water supplies that directly affect groundwater levels
- ✓ Monitor changes to surface water quality that directly affect groundwater quality
- ✓ Evaluate groundwater replenishment projects
- ✓ Evaluate cooperative management projects
- ✓ Provide effective and efficient management of groundwater recharge projects, facilities and programs
- ✓ Coordinate groundwater basin management with local agencies with groundwater authority within the Plan Area

Each of the adopted management objectives is designed toward attaining the Plan's goal. The way in which each objective contributes toward a more reliable supply of groundwater for long-term benefical use is described as follows:

- ✓ Stabilizing or reversing long-term decline of groundwater levels provides a balancing between groundwater demand and supply, ensuring a resource that will be available into the future
- ✓ Monitoring groundwater quality will enable the Plan to assess possible impacts that might diminish the usability of the resource

- ✓ Monitoring inelastic land surface subsidence is valuable in determining available groundwater storage and evaluating groundwater supplies
- ✓ Maintenance and augmentation of surface water supplies will reduce expected impacts of increased demands on groundwater supplies, which is critical in maintaining the ability to stabilize long-term draw down
- ✓ Monitoring surface water quality changes will enable the Plan to assess possible impacts that might diminish the usability of the resource
- ✓ Evaluation of replenishment projects will focus on providing greater recharge productivity, which will make the most efficient and effective use of facilities and resources.
- ✓ Evaluation of cooperative management projects is an effort to provide for greater recharge opportunities, which is important in attaining the stabilization of groundwater levels
- ✓ Providing effective and efficient management of groundwater recharge projects, facilities and programs works toward increasing recharge in the efforts to stabilize groundwater levels
- ✓ Coordinating groundwater basin management will promote a consistency in objectives between local agencies, providing a unified approach to meeting goals.

The interaction between basin management objectives, Plan elements and corresponding activities is fundamental to Plan effectiveness. The Plan will be carried out based upon the specific correlations developed between objectives and activities. The relationships for implementation of the Plan are diagramed in Plate No. 14.

3.3 Monitoring Program

Attaining the Plan's goal requires obtaining a comprehensive understanding of the interactive components that comprise and define the aquifer system. A vital Plan function is the collection of information concerning and related to groundwater conditions. Management objectives have been founded upon the knowledge of past and current conditions ascertained through the District's monitoring efforts. The Plan will continue to progress toward its goal through ongoing monitoring of the following components:

- ✓ Groundwater Supply and Quality
- ✓ Surface Water Supply and Quality
- ✓ Surface Water Management
- ✓ Inelastic Land Surface Subsidence

Consistent and reliable information is critical for any monitoring program. The Plan will be able to achieve this requirement through the implementation of monitoring protocols. Protocols have been and will continue to be developed to track changes in conditions.

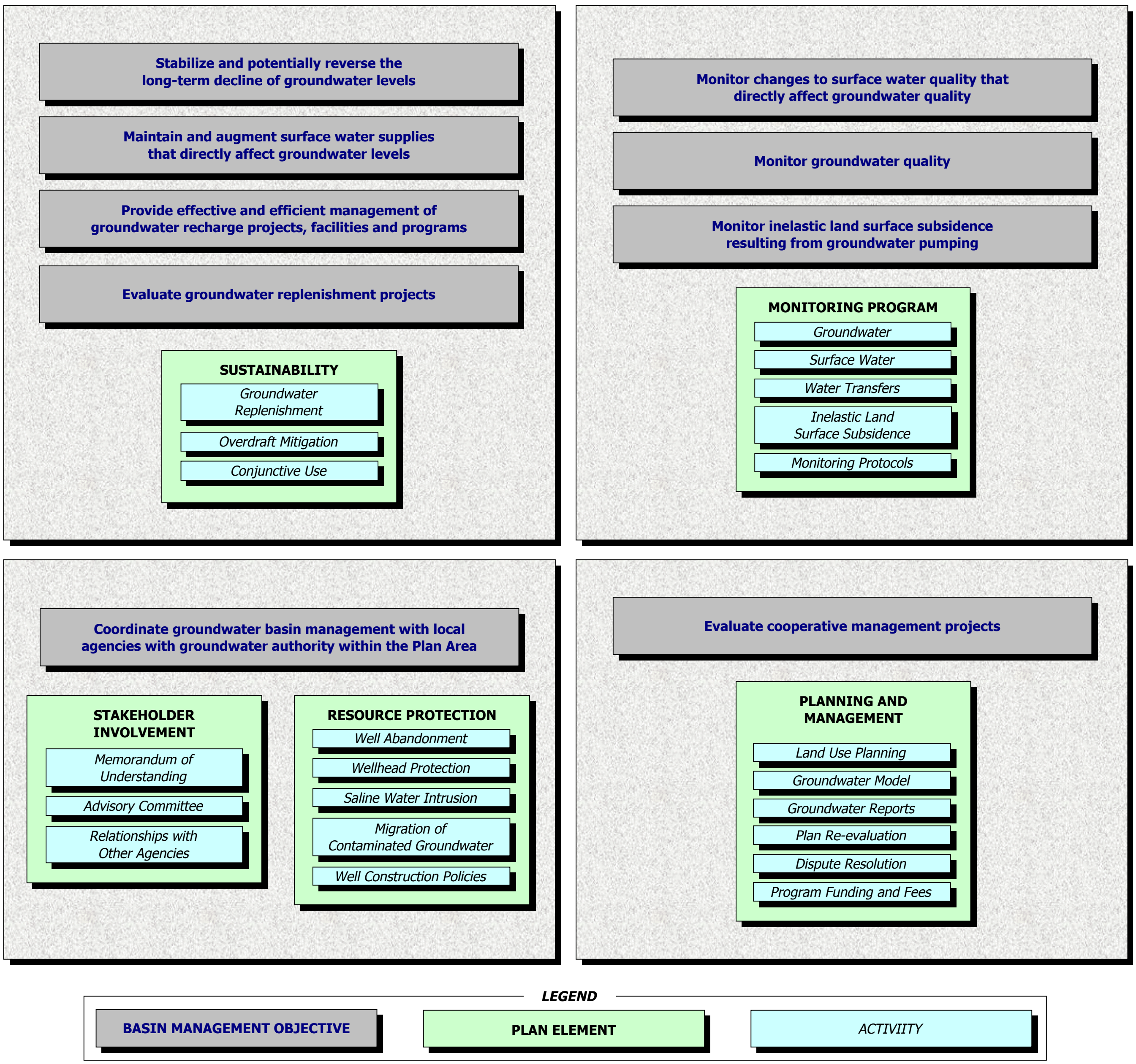


Plate No. 14

Groundwater Management Plan Implementation Diagram

Kaweah Delta Water Conservation District

3.3.1 Groundwater

The District has an extensive monitoring network that was initially established in the 1950's. This network has been maintained and improved in a continuing effort to provide reliable information for annual and long-term assessment of groundwater conditions. Plate 15 identifies the location of monitoring sites where groundwater level measurements are currently collected. Ongoing groundwater monitoring will provide information needed to document current conditions, assess long-term trends and to support development and implementation of objectives associated with:

- ✓ Groundwater levels
- ✓ Groundwater quality
- ✓ Inelastic land surface subsidence

3.3.1.1 Groundwater Levels

Since the establishment of the groundwater monitoring network, the District has performed static groundwater level measurements in the spring and fall periods. Such measuring operations have been performed in coordination with DWR's semiannual requests for groundwater levels. The information is utilized by DWR in mapping groundwater levels for the San Joaquin Valley Groundwater Basin and by the District in annual reporting of groundwater conditions.

The District shall continue to monitor groundwater levels semi-annually. Further, the District will prepare charts depicting the information gathered through the monitoring phase, as well as reports quantifying the water demands, surface water and groundwater supplies. These summaries will assist the District in evaluating the effectiveness of the various elements of its program. The collection of this data will be continued with the conduct of the Plan. The information that has been prepared from this data in the past includes the following:

- ✓ Charts of spring and fall water elevations
- ✓ Charts of spring and fall depths to groundwater
- ✓ Charts showing the changes in groundwater levels

In addition, groundwater reports could include estimates of changes in groundwater storage, water delivered, water use and overdraft. Existing information coupled with possible new data would benefit the evaluation of the effectiveness of management activities.

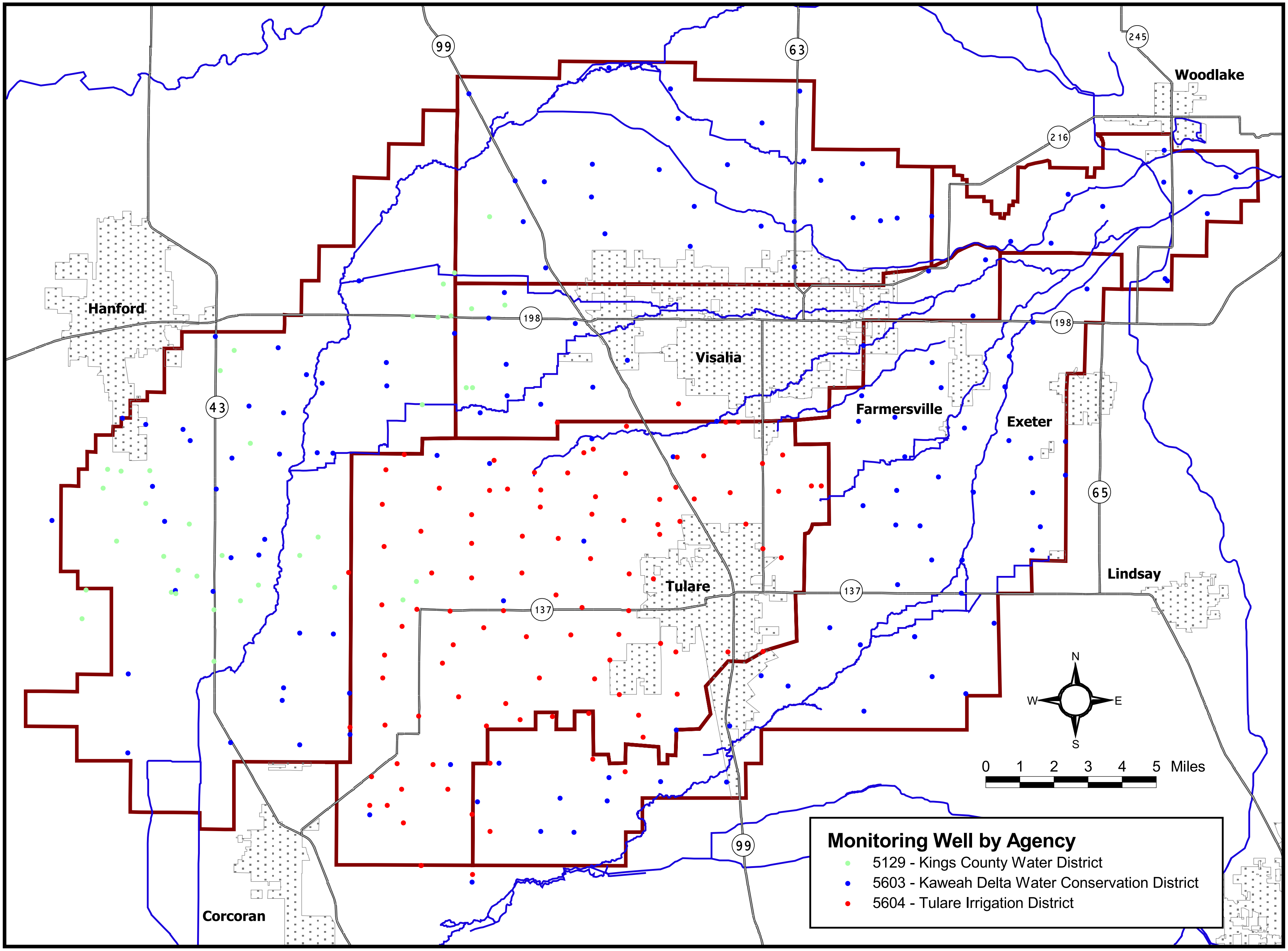


Plate No. 15 : Monitoring Wells (Water Levels)

3.3.1.2 Groundwater Quality

The District will pursue the collection of groundwater quality data from those agencies that have existing programs that record and report on relevant conditions. The effort will be focused toward monitoring key indicators of groundwater quality for the aquifers lying within the District. The indicators that the Plan will concentrate on will consist of the following:

- ✓ Temperature
- ✓ Total Dissolved Solids (TDS)
- ✓ Electrical Conductivity (EC)
- ✓ Acidity (pH)
- ✓ Chloride
- ✓ Sodium
- ✓ Nitrates

The initial effort will be the collection and review of water quality data for adequacy. The Environmental Health Departments of Kings and Tulare Counties will be used as a primary source for acquiring relevant data. Additionally, the Regional Water Quality Control Board can provide information gathered through their regulatory efforts. The District also intends to incorporate findings from the "Ground-Water Ambient Monitoring and Assessment Program" (GAMA) that is currently being performed by the United States Geological Survey and the State Water Resources Control Board. Compiling diverse sources of available information for tracking, trending and reporting within a specified area will be a useful way for the Plan to monitor groundwater quality conditions.

3.3.2 Surface Water

The delivery of surface water throughout the District is known to have a major influence on groundwater conditions. Percolation of surface water delivered through natural and man-made conveyance facilities is a primary source of inflow to the aquifers. Approximately 95 percent of all water usage within the District is for agricultural purposes. The supply for such demands is met with a combination of surface and groundwater. Therefore, the annual quantity and distribution of surface water has a direct correlation to the quantity of groundwater withdrawn from the aquifer. The quality of groundwater can also be affected through its supply source, as well as by changes in aquifer flow conditions that occur from groundwater elevation differences that result from the aquifer's response to water demands.

3.3.2.1 Surface Water Flows

There are two (2) primary surface water supply sources to lands lying within the Plan. The first source is water originating from the Kaweah River Watershed and the second from outside water sources such as the Friant-Kern Canal or Kings River. These available waters are obtained by or entitled to various irrigation companies and districts for delivery for beneficial purposes to lands within their respective service areas. Continual measurement of all such surface flows are made and recorded by these entities for operational and legal purposes. Presently all those entities that have entitlement to Kaweah River water are bound together by the "Kaweah & St. Johns Rivers Association" (Association). The Association functions as Watermaster for delivery of waters to its members by means of the natural watercourses that run throughout the District. In the performance of such duties all surface water deliveries, both Kaweah River and imported sources, are regularly recorded and reported. Plate 16 identifies the watercourses and recording station locations operated or reported by the Association.

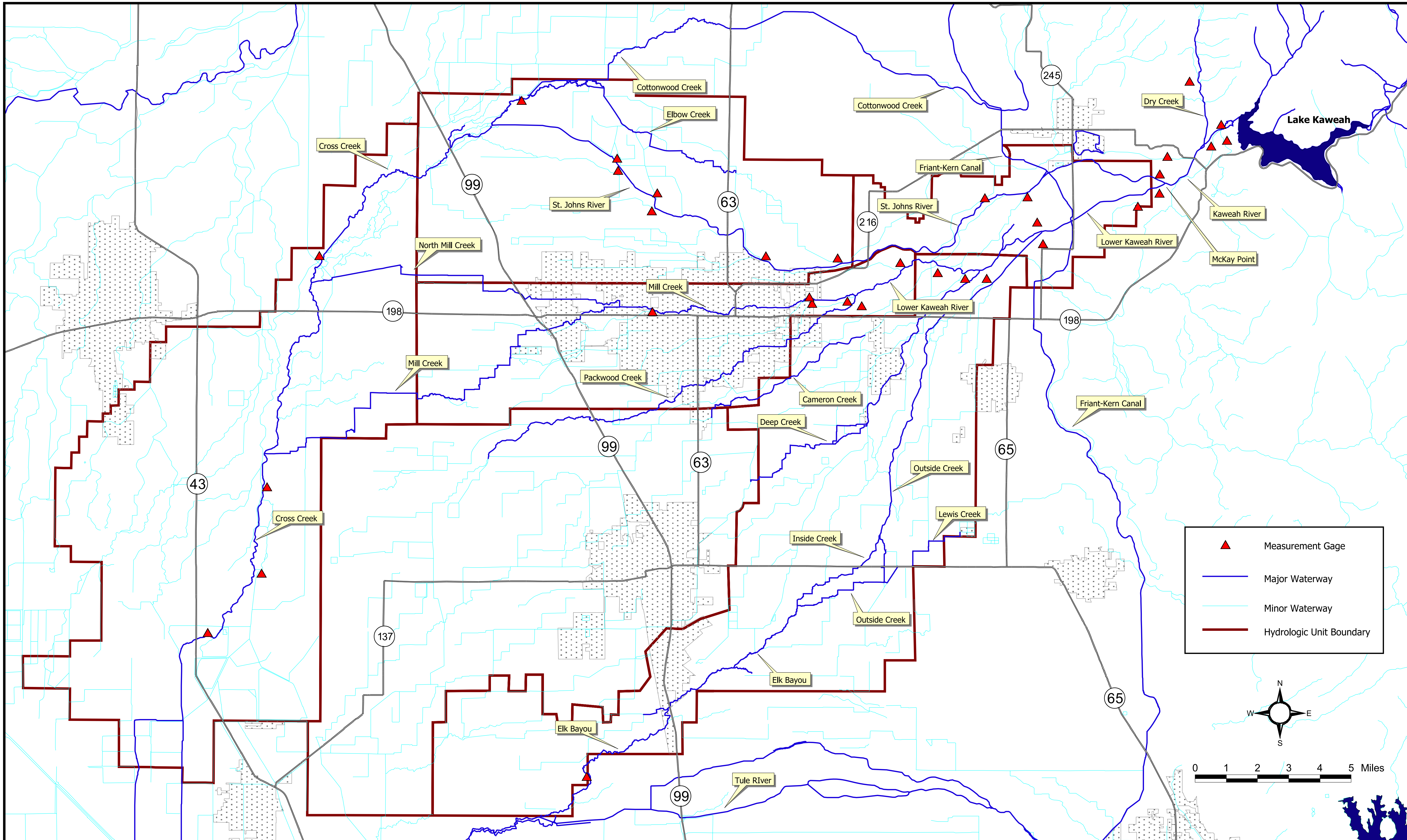
The District is a Kaweah River entitlement holder and member of the Association and as such has access to surface water flow information that will be utilized in exercising the Plan. More importantly, the District is under contract with the Association for performing all management and operational responsibilities. Thereby, the District directly oversees all aspects of measuring and recording surface water flows.

3.3.2.2 Surface Water Quality

The District will pursue the collection of surface water quality data from those agencies or organizations that have existing programs that record and report on relevant conditions. The District may use the surface water quality data it collects to monitor potential contamination of groundwater within the Plan Area. The effort will be focused toward monitoring key indicators of water that is conveyed in the natural systems within the District. Those indicators that the Plan will concentrate will consist of the following:

- ✓ Temperature
- ✓ Total Dissolved Solids (TDS)
- ✓ Electrical Conductivity (EC)
- ✓ Acidity (pH)
- ✓ Chloride
- ✓ Sodium
- ✓ Nitrates

As with groundwater quality monitoring, the Plan's initial effort will be the collection and review for adequacy of surface water quality data. Currently, the Association is engaged in a water quality program in response to the California Regional Water Quality Control Board's "Agricultural Conditional Discharge Waiver." The program involves performing surface water sampling at established locations on a defined cycle. Additionally, the Board also has permits in place for the monitoring and regulation of point source discharges, such as the City of Visalia's treated effluent discharges into Mill Creek. Plate 17 identifies known locations where surface water is sampled and monitored. The Plan will monitor surface water quality based upon available data in an effort to provide a consistent representation of key indicators on an annual and long-term basis.



Kaweah Watercourses

Plate No. 16

1700

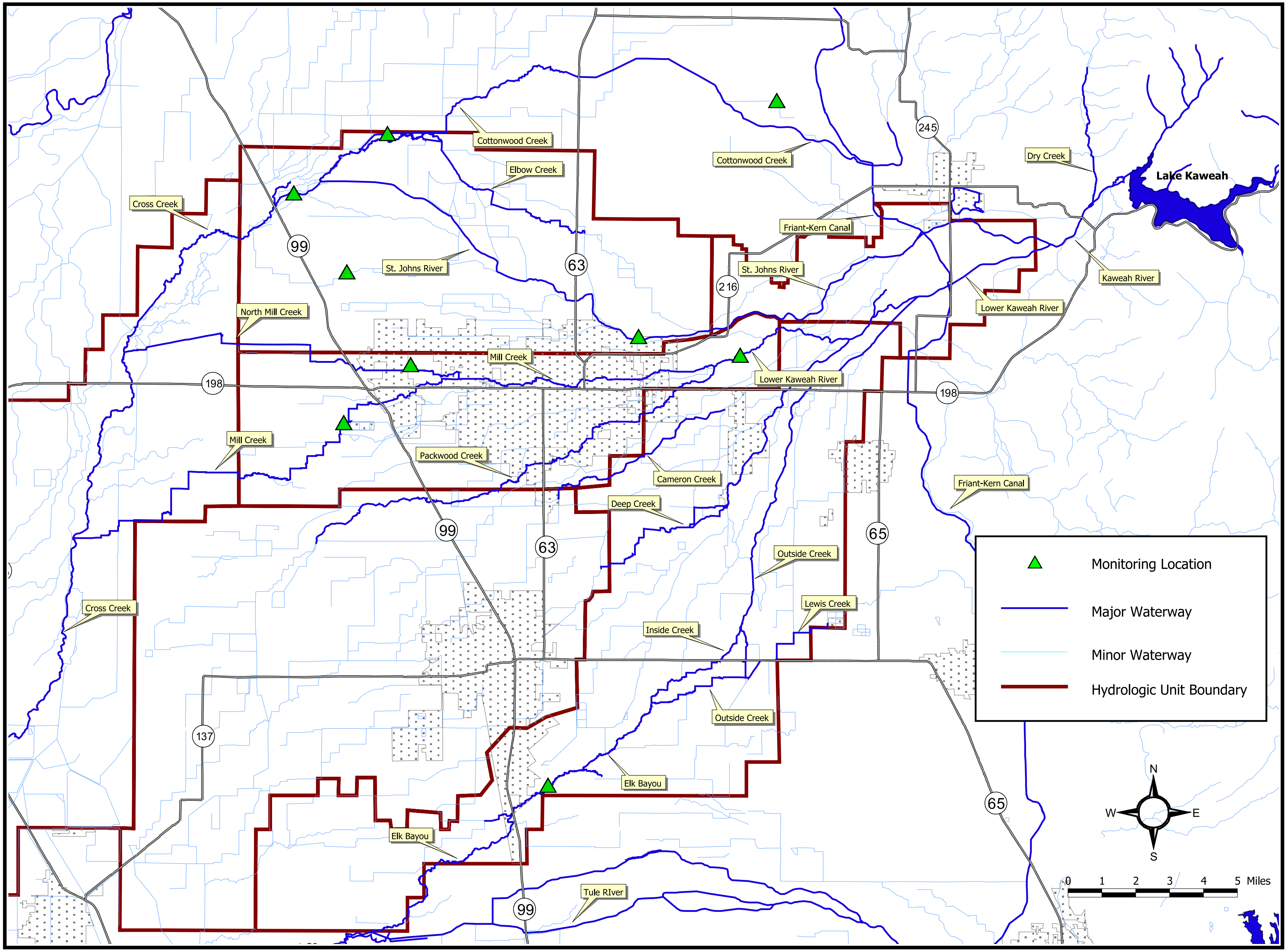


Plate No. 17 : Surface Water Monitoring

1701

3.3.3 Water Transfers

Since the development of water storage facilities, like Lake Kaweah, water users have been able to manage surface water supplies for increased benefit. The ability to store water provides opportunities to acquire additional or release excess supplies through the water transfer process. Water transfers are means for the redistribution of surface waters to meet water demands. Groundwater is influenced by water transfers in such a way that those areas that are able to acquire additional surface supplies will proportionally reduce aquifer withdrawals. The two (2) types of transfers that the Plan is designed to monitor are Intra-District and Inter-District Transfers.

3.3.3.1 Intra-District Transfers

Intra-District surface water transfers are those that occur for the Plan's native water source, the Kaweah River, within the Kaweah River Basin as designated by the Association's "Transfer Policy". A copy of the "Transfer Policy" is included in Appendix "A." Kaweah River entitlement holders that store water within Lake Kaweah have the ability to transfer quantities of water in storage, under defined conditions, between like parties. An entitlement holder's water supply is based upon such factors as mean daily inflows to the lake and an allocation schedule. The most commonly occurring transfer is between users that have supplies in excess of their immediate demand to those users that have insufficient supplies. Frequency and magnitude of transfers are normally a function of the influence of seasonal climatic conditions on run-off from the watershed. Kaweah River water transfers within the Plan Area take place on a routine basis. The Plan has and will continue to monitor these transfers and their influence on groundwater conditions. Water transfers within the Plan Area are permissible and subject to the administration of the Kaweah River Watermaster under the direction of the Association's Board of Directors.

3.3.3.2 Inter-District Transfers

Inter-District surface water transfers are those that transfer Kaweah Water outside the District in exchange for a transfer back into the District from an external water source. The circumstances for these transfers are similar in nature to Intra-District Transfers. Supply and demand is the driving force behind such transactions. The main differences consist of utilizing multi-regional conveyance facilities and prolonged scheduling of deliveries.

Kaweah River water transfers between different water entities have been previously performed and will continue in the future. In the past, the District and Plan participants have completed such transfers on a limited basis. Intra-District transfers are seen as a mechanism that could be used to increase the total water supply within the Plan Area or to augment the water supply in specific areas of the basin during critically dry years. In all cases, transfers shall be such that there is no net loss of water supply to lands within the District. The District shall endeavor to promote advantageous water transfers that increase the water supply available within the Plan Area. The Board of Directors of the District ("District Board of Directors") has the authority to initiate such transfers.

3.3.4 Inelastic Land Surface Subsidence

The San Joaquin Valley has been characterized as the largest human alteration of the earth’s surface. The reason behind this statement comes from inelastic land surface subsidence that has occurred principally from aquifer-system compaction. The lowering of groundwater levels through sustained groundwater overdraft causes this type of subsidence. The impact to groundwater from such subsidence is the reduction in available aquifer storage capacity caused by the compaction of soil void space that retains groundwater. Studies performed by the Department of Water Resources and the United States Geological Survey have identified an area of subsidence in the western portion of the District that correlates with a confining geologic layer known as the Corcoran Clay. The magnitude of subsidence within this portion of the District was in the order of four feet for a study period extending from 1926 to 1970. Plate 18 is a representation of this subsidence in the San Joaquin Valley for this study period as reported in Geological Survey Professional Paper 437-H[2]. Studies performed since these findings have revealed a dramatic decrease in the rate of subsidence. This could be a result of the provision of State Project water to lands that pumped high amounts of groundwater that were in a condition of sustained groundwater overdraft.

The District has adopted a Land Surface Elevation Monitoring Plan for the purpose of evaluating elastic and inelastic land surface movement. The plan consists of the collection and reporting of land surface elevation data within and immediately surrounding the District. Annual reports will be developed and utilized for on-going analysis of the interaction between land surface conditions and aquifer storage changes. The results of the analysis will be presented in annual Plan reports and included in programs that focus on meeting basin management objectives. A copy of the “Land Surface Elevation Monitoring Plan” is included in Appendix “D”.

[2] Figure 5, Page H11 of “Land Subsidence in the San Joaquin Valley, California, As of 1972”, Studies of Land Subsidence, U.S. Geological Survey Professional Paper 437-H, by J.F. Poland, B.E. Lofgren, R.L. Ireland, and R.G. Pugh. Prepared in cooperation with the California Department of Water Resources. (1975)

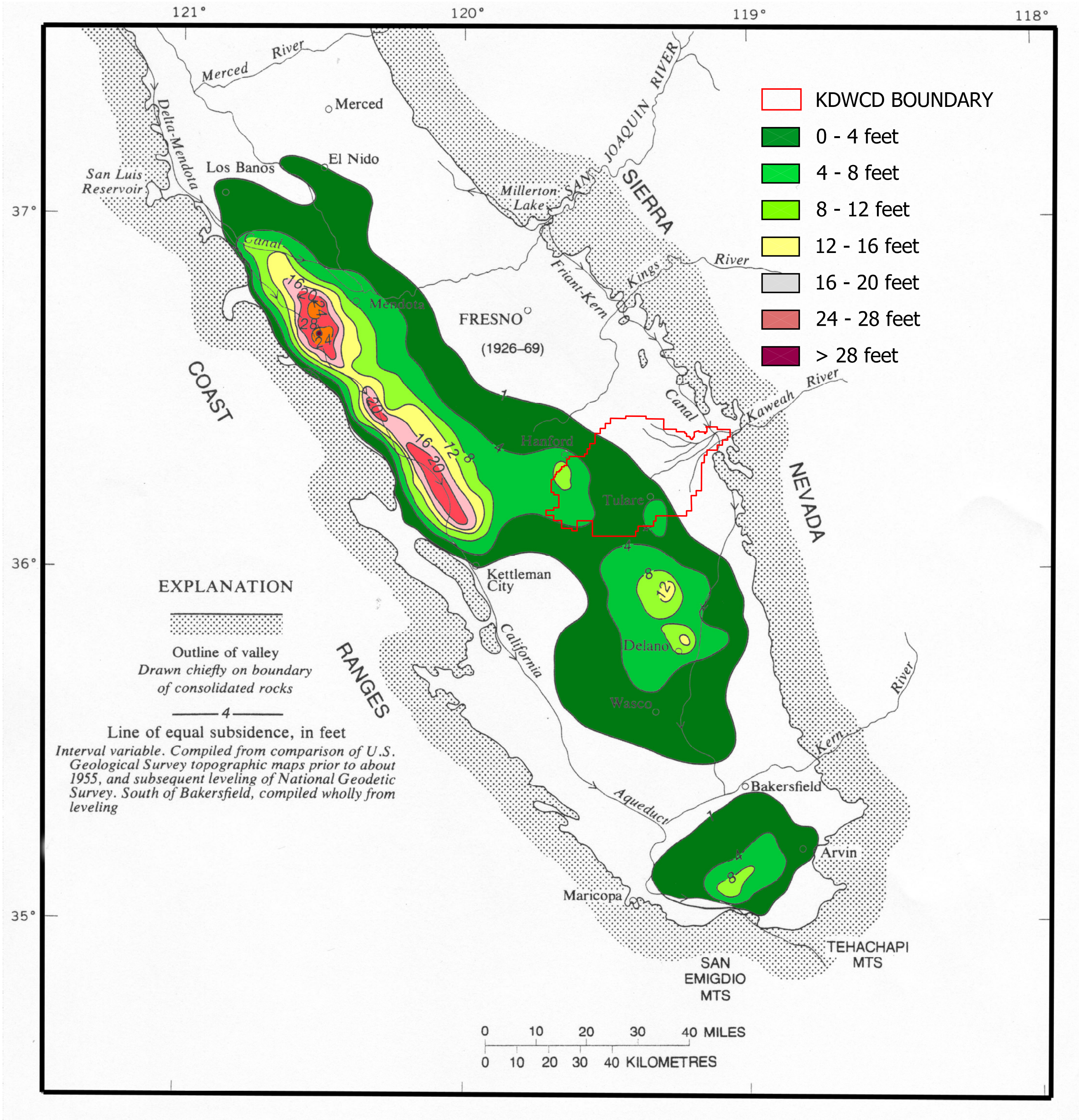


Plate No. 18
Inelastic Land Surface Subsidence
1926 thru 1970

3.3.5 Monitoring Protocols

Adequate assessment of groundwater conditions requires information that is both consistent and reliable. This is necessary in order to properly track and evaluate annual and long-term changes in those conditions that are monitored. The Plan's monitoring program has developed and employs measures to provide dependable and comparable data. The monitoring protocols applied by the Plan are outlined as follows:

<u>Groundwater Levels</u>: Measurements are taken semi-annually by the District and Plan participants in coordination with DWR's Spring and Fall measurement program. All identification, measuring and recording of data is performed in accordance with DWR's standards and procedures. The recorded data is compiled for presentation in the District's annual groundwater report.

<u>Groundwater Quality</u>: The Plan has established seven (7) different groundwater quality indicators that will be monitored. The District will annually compile data for the Plan from agencies that regularly collect groundwater quality data. The information will be organized in a manner for annual presentation and evaluation of the indicators. The effort will be focused on accumulating analogous data for tracking changes or trends in groundwater quality conditions.

<u>Surface Water Flows</u>: The District, in accordance with contracted responsibilities to the Association, regularly acquires surface flow measurements. Most all of the flows are measured on a continuous basis and in accordance with standard accepted practices. All flow information is compiled into annual water year reports. The Plan will draw all necessary surface flow information from this source.

<u>Surface Water Quality</u>: The Plan has established seven (7) different surface water quality indicators that will be monitored. The District will annually compile data for the Plan from agencies that regularly collect surface water quality data. The information will be organized in a manner for annual presentation and evaluation of the indicators. The effort will be focused on accumulating analogous data for tracking changes in surface quality conditions as it relates to groundwater management.

<u>Water Transfers</u>: The District, in accordance with contracted responsibilities to the Association, obtains all water transfer data on an occurrence basis. The collected information is recorded for reporting in the Association's annual water year reports. The Plan will draw all necessary water transfer information from this source. The data will be assembled in such a manner as to report the redistribution of surface water throughout the District and evaluate its influence on groundwater conditions.

Inelastic Land Surface Subsidence: Land surface elevation data will be collected annually by the District. All collected data will be compiled and reported in accordance with adopted Land Surface Elevation Monitoring Plan. The relevant information will be presented for assessing conditions pertaining to inelastic land surface subsidence within the Plan Area.

3.4 Resource Protection

The Plan recognizes the importance of protecting the groundwater aquifer system. This resource is considered a vital component for both the region's economy and public health. California Water Code § 10753.8 authorizes the District to include components in its Plan for the provision of resource protection measures. Notwithstanding the foregoing, the District reserves the right to decide whether or not it will be involved in each of the activities authorized by the aforementioned statute. The Plan provides for resource protection through federal, state and local agency measures currently in place. The Plan will continue to coordinate with agencies that have protection measures in the form of ordinances and programs relevant to the protection of groundwater resources within the Plan Area. The following discussions will focus on those Plan components that address specific resource protection measures.

3.4.1 Well Abandonment

The County of Tulare, Kings County and City of Visalia have adopted Well Ordinances that address well destruction and establish requirements for destroying or abandoning wells within each agencies jurisdiction. All of these ordinances have provisions that stipulate impairment of the quality of water within the well or groundwater encountered by the well is not allowed. Those wells that are identified as defective require correction of the defective conditions or destruction of the well. Both county agencies have promoted programs for the destruction of abandoned wells in an effort to reduce potential sources that could have a negative impact to groundwater. In all cases, the primary responsibility for remedying defective or abandoned wells falls on the landowner and in those cases of non-compliance, the agencies have the authority to take necessary action to abate unsatisfactory conditions.

3.4.2 Wellhead Protection

The federal Wellhead Protection Program was established by Section 1428 of the Safe Drinking Water Act Amendments of 1986. The purpose of the program is to protect groundwater sources of public drinking water supplies from contamination, thereby eliminating the need for costly treatment to meet drinking water standards. A Wellhead Protection Area (WHPA), as defined by the 1986 Amendments, is "the surface and subsurface area surrounding a water well or wellfield supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield." The WHPA may also be the recharge area that provides the water to a well or wellfield. Unlike surface watersheds that can be easily determined from topography, WHPAs can vary in size and shape depending on geology, pumping rates, and well construction.

Wellhead Protection Programs are not regulatory by nature, nor do they address specific sources. They are designed to focus on the management of the resource, rather than control a limited set of activities or contamination sources. Efforts to supply wellhead protection include Kings County's ordinance section for "Special Protection Areas." The ordinance provides for the prevention of mixing water between aquifers where groundwater quality problems are known to exist. Other protection areas within the Plan involve municipal/industrial water systems and small rural domestic water systems that rely on groundwater as a supply source.

3.4.3 Saline Water Intrusion

Saline water can slowly degrade a groundwater basin and ultimately render all or part of a basin unusable. The concentration of minerals in water is also referred to as total dissolved solids (TDS). The dissolved minerals are classified as inorganic salts, thus the term "salinity" is another way to describe mineral concentration. Several sources can contribute to increased salinity in groundwater. In addition to sea water intrusion, saline degradation of groundwater can be caused by use and re-use of the water supply; lateral or upward migration of saline water; downward seepage of sewage and industrial wastes; downward seepage of mineralized surface water from streams, lakes and lagoons; and interzonal or interaquifer migration of saline water.

Salt accumulation in surface water and groundwater in the Central Valley is a natural process inherent to lands with semi-arid to arid climates, enclosed basins, or reduced or impeded drainage. Salt accumulation in surface water and groundwater can impact and eventually eliminate most beneficial uses. Salt accumulation can be exacerbated by a wide variety of human activities including irrigation; importation of surface water; application of fertilizer (including manure and biosolids) and pesticides; land disposal of wastes including those from food processing facilities, wineries and municipal wastewater treatment plants; discharge of urban storm water runoff; and use of recycled wastewater.

Control of saline water intrusion occurs primarily at the state level through the State Water Resources Control Board and the Central Valley Regional Water Quality Control Board.

3.4.4 Migration of Contaminated Groundwater

Groundwater contamination originates from a number of sources or activities such as leaking tanks discharging petroleum products or solvents, or the application of pesticides and fertilizers. Effective control and clean-up of contaminated groundwater requires a coordinated effort between all regulatory agencies involved, source control, understanding of the hydrogeology and delineation of the contamination.

Agencies with a role to play in mitigating groundwater contamination include the Kings and Tulare County Environmental Health Departments, California Regional Water Quality Control Board, California Environmental Protection Agency and the U.S. Environmental Protection Agency. The degree to which each agency participates depends on the nature and magnitude of the problem.

3.4.5 Well Construction Policies

The County of Tulare, Kings County and City of Visalia have adopted Well Ordinances that specify water well construction, deepening and reconstruction standards within each agencies' respective jurisdiction. In all the ordinances, reference is made to State of California, Department of Water Resources Bulletin's 74-81 and 74-90 as that agency's adopted water well standard or supplementary to their established standard. The ordinances have provisions that require permits for well construction, deepening and reconstruction, with oversight provided by the agencies' health or building departments.

3.5 Sustainability

Maintaining the ability to use the underlying aquifer without incurring depletion or permanent damage is one of the Plan's main objectives. The sustainability of the groundwater supply for all beneficial uses is of critical importance to the region's economic, social and environmental well-being. California Water Code § 10753.8 authorizes the District to include components in its Plan to implement measures that progress toward attaining a sustainable groundwater resource. Notwithstanding the foregoing, the District reserves the right to decide whether or not it will be involved in each of the activities authorized by the aforementioned statute. Groundwater replenishment, overdraft mitigation and conjunctive use have been identified by the Plan as fundamental elements in attaining groundwater sustainability.

3.5.1 Groundwater Replenishment

In any conjunctive use area, groundwater recharge is a critical part of the overall Plan. For many years, the District has operated and maintained recharge basins throughout the District. They are generally located in areas of highly permeable soils. One of the District's ongoing objectives is the location and acquisition of additional recharge sites. In addition, effective recharge is also obtained through the natural channels, canals and ditches located within the Plan Area. The reason being that most of the channels are located within soil zones with high permeability. The District has established and will continue to develop programs that promote surface water use that result in additional groundwater recharge and reduction in groundwater pumping.

3.5.1.1 Distribution of District Owned Water

There is a tremendous difference in the aquifer characteristics within the Plan Area. This is evident in both storage capability and yield. The impact of cyclical droughts is revealed by a greater drop in groundwater levels for those areas with limited aquifer thickness in comparison to portions of the Plan Area that are located over a thicker and higher yielding aquifer. The District has surface water sources derived from appropriated Kaweah River entitlement and temporary Central Valley Project Water supply contracts (CVP Section 215 Water). When such waters are utilized, they are distributed in a fashion to maximize the benefits of the resource and effectively recharge groundwater. During critically dry years, District owned surface water, if available, may need to be directed to the most severely impacted areas. The distribution of District owned water is at the discretion of and according to the direction given by the District Board of Directors.

3.5.1.2 Channel Recharge

There are over 200 miles of natural channels and many times that amount of manmade channels located within the Plan Area. One of the primary means of recharging groundwater is accomplished through the seepage that occurs in these channels during the conveyance of water. The transport of surface water throughout the Plan Area generally requires that water be diverted from natural channels into ditch systems. Natural channels are typically located in permeable soils. The effective amounts of channel recharge vary from year to year and are dependent upon water supplies, which are contingent upon annual climatic conditions. Channel recharge can also occur through programs, promulgated by the Plan, that use various sources of surface water to supply either conveyance losses for supplement of irrigation deliveries or that are delivered and retained in the channels solely for recharge.

The Plan participants will continue to use available surface waters to meet demands, which in turn replenish the aquifers by sinking those waters through distribution system seepage. The District will actively seek the cooperation of other government and water entities in the development of programs that promote channel recharge through water conveyance. When feasible, the District will consider delivery of water for channel recharge within the Plan Area. All such deliveries of recharge water shall be at the discretion of the District Board of Directors. The District will endeavor to evaluate and utilize recharge from natural channels, when appropriate. Natural channels with good recharge capabilities will be used as groundwater recharge facilities to receive recharge water.

3.5.1.3 Basin Recharge

Surface water that is conveyed into recharge facilities for the purpose of having such water infiltrate into the aquifer is classified as basin recharge. This type of recharge can be accomplished in a variety of different ways. Basin recharge most commonly occurs during non-irrigation periods when water is released from Terminus Reservoir for flood control purposes. These flows are conveyed throughout the District, distributed in conveyance systems and delivered to recharge basins. The primary purpose of this activity is flood control with a simultaneous benefit of groundwater recharge. Other occurrences of basin recharge consist of programs, promulgated by the Plan, that use various sources of surface water delivered to recharge facilities.

Plan participants will continue to use available surface waters to replenish the aquifers by sinking those waters through recharge basins. The District will actively seek the cooperation of other government and water entities in the development of programs that promote basin recharge through utilization of existing facilities and the creation of new facilities. When feasible, the District will consider delivery of water for basin recharge within the Plan Area. All such deliveries of recharge water shall be at the discretion of the District Board of Directors.

3.5.1.4 In-Lieu Recharge

Another method of recharge occurs when additional surface water supplies are acquired and used to satisfy irrigation demands. These additional supplies proportionately reduce the amount of irrigation demand on groundwater. Thereby, surface water is used in-lieu of groundwater, allowing aquifers the ability to recover through a reduction in demand during irrigation cycles. This type of recharge is considered highly effective because groundwater demand is reduced while at the same time additional recharge is taking place from the delivery channels.

The Plan will continue to promote the acquisition of additional water supplies in order to maximize the amount of surface water available in the promulgation of in-lieu recharge. The District will actively seek the cooperation of other government and water entities in the development of programs that promote in-lieu recharge through the provision of additional water supplies. When feasible, the District will consider delivery of water for in-lieu recharge within the Plan Area. All such deliveries of recharge water shall be at the discretion of the District Board of Directors. The District will endeavor to evaluate and utilize in-lieu recharge, when appropriate.

3.5.1.5 Construction and Operation of Facilities

Presently there are more than forty (40) groundwater recharge basins located within the Plan Area. Most of these basins were constructed and are operated by the District. Additionally, there are Facilities Use Agreements in place between the District and most of the irrigation water entities within the Plan. These agreements grant the District the right to use and operate those companies' facilities for multiple purposes, including the sinking (recharge) of water. The combination of recharge basins and access to conveyance facilities enables the District to capture available water for replenishment to the aquifer throughout the District. The District, in its sole discretion, shall determine which sinking basin(s), natural channel(s), canal(s) or ditch(es) shall be used to sink any water which the District has available for such purpose.

One of the District's objectives, which is integral to the Plan, is the expansion and improvement to the system of facilities that are used in the recharge of groundwater. New developments include cooperative programs that are progressing toward the construction of multi-functional facilities. These programs are expected to result in facilities that will provide composite solutions to such issues as urban storm water runoff, environmental enhancement and groundwater replenishment. The District will actively seek cooperation with other government and water entities in the acquisition and construction of facilities for groundwater replenishment.

3.5.2 Overdraft Mitigation

Since the early 1950's, the District has observed declining groundwater levels and the Kaweah Basin has been identified by the California Department of Water Resources as a basin subject to critical conditions of overdraft.[3] Critical conditions of overdraft are defined as a groundwater basin in which continuation of present practices would probably result in significant adverse overdraft-related environmental, social or economic impacts. Throughout the years the District has accomplished various studies that examined groundwater supplies. The most recent study was completed at the end of 2003. The "*Water Resources Investigation of the Kaweah Delta Water Conservation District*" once again confirmed the Basin was in a state of overdraft. The study was a comprehensive review of all the elements required to determine safe yield for the aquifers within the District. The final conclusion was that annual groundwater supplies were insufficient for water demands not met by surface water in the range of 20,000 to 36,000 acre-feet annually. The Plan will consider certain actions that will help alleviate the ongoing strain on the Basin aquifers. These actions are considered to be of great value in mitigating the existing overdraft of groundwater.

[3] California Department of Water Resources, Bulletin 118-80: *Ground Water Basins in California,* A Report to the Legislature in Response to Water Code Section 12924 (January 1980)

3.5.2.1 Water Conservation

Groundwater overdraft exists mainly because water demands exceed supply, with the difference taken from groundwater. Reducing demands through the most efficient usage of water is considered a viable approach to assist in mitigating overdraft. Water conservation efforts will be encouraged throughout the Plan Area for agricultural, industrial and residential users. Existing and new irrigation methods, reuse of industrial water and domestic water saving devices are and will be encouraged.

District's policies and procedures promote the beneficial use of water. The District will continue to promote policies that enhance water conservation policies. The District Board of Directors has the authority to adopt water conservation and water regulation policies for the District and, pursuant to its Groundwater Management Plan, the Plan Area. If a local public agency adopts and enforces a water conservation plan within its boundaries, such a plan is encouraged to the extent it is not inconsistent with the District's Plan.

3.5.2.2 No Exportation of Groundwater

The Plan recognizes the importance of applying groundwater to lands within the Plan Area. Hydrogeologic conditions are such that equilibrium cannot be achieved or maintained if groundwater supplies are withdrawn and exported from the area. Since the District is located within an overdrafted basin, it is prudent to utilize all groundwater resources within the Plan Area. The District will take all appropriate action to prevent the exportation of water from the Plan Area.

A position has been adopted in the Plan that there shall be no exportation of groundwater that results in any additional net loss to the Plan Area's total available water supplies. The District Board of Directors has the authority to institute any measures proposed to prevent such loss.

3.5.2.3 Reduction in Groundwater Outflow

Groundwater within the Basin is not static, but travels vertically and horizontally due to a range of hydrogeological factors. The direction and quantity of groundwater flow is susceptible to changes that occur to the hydraulic gradient. Groundwater level measurements taken twice a year within the District will be used to identify the direction and quantity of groundwater flow. Typically, this outflow has been to the west and southwest. Groundwater outflow has historically been a naturally occurring condition within the Plan Area. The District will continue its efforts to monitor the amounts of such groundwater outflow annually. Monitoring will be used to assess changes to groundwater outflow resulting from influences outside the Plan Area.

3.5.2.4 Additional Water Supply and Storage

As previously noted, groundwater overdraft is the result of inadequate water supplies. One of the most effective means to overcome this shortfall is acquiring additional supplies of water. These supplies can be obtained from external water sources or be produced as a result of additional storage. Development of additional water supply and storage is a crucial element in the Plan's efforts to mitigate groundwater overdraft.

A supplemental source of surface water necessary to conduct extensive programs is normally available in wet years when floodwaters are available on the Kaweah River or additional water supplies are available from other sources. The District has historically made beneficial use of floodwaters and excess waters for recharging groundwater supplies and will continue to do so in the future. Further, the District will continue to seek opportunities to purchase and import water into the District for groundwater recharge purposes.

Additional water supplies would enhance the local groundwater. Present political and environmental realities discourage developing additional water supplies by building dams and large water storage projects. Yet through the cooperative efforts of Plan participants, the District was able to promote an enlargement project for Lake Kaweah that provides over 42,000 acre-feet of additional storage in Terminus Reservoir. The enlargement project took the United States Army Corps of Engineers over 20 years from the initial study until completion. Water was first stored to the new gross pool elevation in 2005. The District will continue to pursue feasible efforts to secure additional water supply and storage that will be beneficial to the Plan Area.

3.5.2.5 Pumping Restrictions

The progress of those measures taken in mitigating groundwater overdraft will require ongoing evaluation as to their effectiveness. Upon a determination that the measures are not accomplishing desired results, restriction of groundwater pumping could be considered. Pumping restrictions could reduce the amount of groundwater use. Restricting groundwater pumping is highly controversial and would currently be considered as the last alternative to be implemented in mitigating groundwater overdraft.

Implementation of this step could have severe implications to a local economy that relies on unrestricted access to groundwater. Initially, any program requiring pumping restrictions would be voluntary rather than mandatory. From a practical standpoint, when restrictions on urban groundwater water supplies are implemented, mandatory agricultural pumping restrictions would be considered.

Only under special circumstances would pumping restrictions be imposed. The District Board of Directors will not impose such restrictions until consulting with local agencies and holding a mandatory public hearing at least sixty (60) days prior to the effective date of such restrictions. The District Board of Directors could impose such action only by resolution.

3.5.3 Conjunctive Use

Conjunctive use is defined as the coordinated and planned management of both surface and groundwater resources in order to maximize the efficient use of the resource. The District began conjunctive use activities in the 1930's, starting with the construction of groundwater recharge basins for the capture of available Kaweah River water. Facilities Use Agreements accompanied basin development enabling the District to convey and sink water throughout the delta of the Kaweah River. After the completion of Terminus Dam in 1962, conjunctive use was increased as a result of the ability to annually store and regulate river flows.

Conjunctive use within the Plan Area takes place through the distribution of surface water for irrigation and groundwater recharge, with groundwater being used when and where surface waters are unable to fully meet demands, either in time or area. Since the early 1970's, water entities have worked together through a formal association to use available water to its greatest benefit. The Plan will continue to foster and facilitate conjunctive use with an objective toward mitigating groundwater overdraft conditions.

3.6 Stakeholder Involvement

The management of groundwater resources is based upon serving the public interest in a responsible manner. The Plan fulfills this purpose through the involvement of entities with a permanent stake in the availability of the groundwater source. These stakeholder groups consist of various water entities like ditch companies, irrigation districts, water districts and urban water service purveyors. Local government agencies are also included as Plan stakeholders. Interactive participation by stakeholders in the review and planning process is a fundamental element in carrying out the Plan's purpose. The Plan offers a forum for stakeholders through the following elements.

3.6.1 Memorandum of Understanding

The Plan officially recognizes stakeholders through the execution of a Memorandum of Understanding (MOU) between the District and the interested entity. The purpose of the MOU is to document the interests and responsibilities of participants in the adoption and implementation of the Plan. The MOU also promotes the sharing of information, the development of a course of action and the resolving of differences that may arise regarding the Plan. Since the Plan's inception in 1995, the number of stakeholders has regularly grown to the present number of thirteen (13). It is foreseen that stakeholder involvement will increase with time. The District will continue to pursue new stakeholder involvement and shall endeavor to enter into an agreement with other local agencies in the form of a Memorandum of Understanding in compliance with California Water Code § 10750.8. A sample of one form of Memorandum of Understanding is included in Appendix "B".

One of the initial Plan participants was Tulare Irrigation District (TID), who adopted a groundwater management program in accordance with AB 255 in 1992, the first agency in the state to adopt such a program and plan. In 1996, the District and TID executed a MOU obligating both districts to coordinate their respective plan efforts and groundwater management activities within areas of overlap. It is the District's understanding that TID intends to update and amend its plan in accordance with AB 3030 provisions and as may be modified by other state legislation.

3.6.2 Advisory Committee

The Advisory Committee offers one of the primary means that stakeholders are given to participate in the Plan. This committee is open to stakeholders that have been recognized as a Plan participant through a MOU. The Advisory Committee helps guide the development and implementation of the Plan and provides a forum for resolution of controversial issues. Meetings are held annually, at a minimum, for the purpose of review and discussion of past, present and future Plan activities.

3.6.3 Relationships with Other Agencies

The Plan acknowledges that there are interests in the groundwater resource that reach beyond the area covered by the Plan. State and Federal agencies' participation in managing groundwater is an important element to the Plan. The development and enhancement of relationships with other agencies benefits the Plan through the exchange of information and resources that progress toward a better understanding and management of groundwater.

Such agencies not only have regulations that influence the Plan, but extend opportunities by sharing information, providing relevant programs and allocating funds that can be used for programs and projects within the Plan. The Plan has historically tapped into these valuable sources and it is expected to continue to do so in the future. California Water Code § 10753.8 authorizes the District to include components in its groundwater management plan for the development of relationships with state and federal agencies. Notwithstanding the foregoing, the District reserves the right to decide whether or not it will be involved in each of the activities authorized by the aforementioned statute.

3.7 Planning and Management

The establishment of an organized structure is necessary in order for the Plan to fulfill its intended purpose. The Plan is structured to function in such a way that numerous elements relating to or influencing groundwater conditions are brought together and managed for meeting Plan objectives. The planning process also plays an important role in developing such objectives and providing direction in accomplishing goals. Both the process of planning and management combined afford the opportunity to produce the most beneficial use of the groundwater resource.

3.7.1 Land Use Planning

The District has long-standing relationships with both city and county agencies within the Plan Area that oversee land use and zoning activities. The connection between land use and the groundwater resource is reflected in the differing water demands related to land classifications and the need to supply those demands from groundwater. Land use planning coordination enables the Plan to participate in decisions that will affect future groundwater conditions. Coordination also supplies the Plan participants with information pertinent to forming programs that could address forecasted changes to groundwater. Involvement with land use planning essentially affords the Plan the opportunity to be proactive instead of reactive.

California Water Code § 10753.8 authorizes the District to include components in its groundwater management plan for the review of land use plans and coordination with land use planning agencies to assess activities that create a reasonable risk for groundwater contamination. Notwithstanding the foregoing, the District reserves the right to decide whether or not it will be involved in each of the activities authorized by the aforementioned statue.

3.7.2 Groundwater Model

An important planning and management tool that was recently implemented is the District's numerical groundwater flow model. In 2005, utilizing a cooperative grant from the State Department of Water Resources, the District developed a groundwater model to calculate future changes in groundwater conditions that could occur based upon major influences such as changes in population growth, water supply and distribution. The model is able to calculate quantifiable changes to groundwater levels and flow conditions. This analytical tool can be applied to assess how existing and proposed groundwater management actions, changes in cultural practices or changes in hydrologic conditions may influence groundwater sustainability. The knowledge gained from the model will be applied in the development and evaluation of new and existing programs. The expected result will be the progression of programs and policies that will efficiently use available resources to affect the most beneficial influence to groundwater supplies.

3.7.3 Groundwater Reports

Adequate information is a vital element of planning and management of the groundwater resource. The Plan will produce, at a minimum, annual reports summarizing groundwater basin conditions and management activities. These annual reports will include the following presentations as they pertain to the Plan.

- ✓ Summary of monitoring results, including a discussion of historical trends
- ✓ Summary of management actions during the period covered by the report
- ✓ A discussion, supported by monitoring results, of whether management actions are achieving progress in meeting management objectives
- ✓ Summary of proposed management actions for the future
- ✓ Summary of any plan component changes, including addition or modification of management objectives, during the period covered by the report
- ✓ Summary of actions taken to coordinate with other water management and land use agencies, and other government agencies

3.7.4 Plan Re-evaluation

An essential task in determining the value of management activities and goals is a periodic re-evaluation of the entire Plan. The effectiveness of the Plan is a reflection of the success and failure of measures taken in attempts to change or maintain groundwater conditions. Reviews will be focused on identifying potential changes to the Plan that could be beneficial to the groundwater resource. Additionally, assessing changing conditions in the Basin could warrant modifications of management objectives. Periodic Plan re-evaluation will occur at an interval of not more than five years apart. Separate from entire re-evaluations will be adjustments to Plan components on an ongoing basis, if necessary. The re-evaluations will focus on determining if actions under the Plan are meeting management objectives and if the management objectives are achieving the goal of sustaining the resource.

3.7.5 Dispute Resolution

The Plan acknowledges that controversial issues could arise concerning the groundwater resource. Stakeholders are encouraged to work through the Plan in addressing and resolving differences. When this process proves insufficient, the District has an applicable policy in place for dispute resolution. The Plan hereby adopts the District's "Alternative Dispute Resolution Policy", as included in Appendix "C" or the most current version of the policy.

3.7.6 Program Funding and Fees

Plan activities are funded through various sources relevant to the specific program. The District alone regularly performs recharge programs with capital budgeted for that purpose. The District also funds multiple other groundwater programs, such as facility development, operation and maintenance. Respectively, plan participants support their own individual programs from revenue derived from that agency's budget. The Plan additionally fosters and supports multi-agency programs, where participants cooperatively combine funds and resources toward common objectives in a regional approach.

Future activities required to fully implement the Plan may require additional funding sources. Implementing legislation related to AB 3030 allows for the levying of groundwater assessments or fees under certain circumstances and according to specific procedures. Prior to instituting a groundwater assessment or fee structure, the District must hold an election on whether or not to proceed with the enactment of the assessments. A majority of the votes cast at the election is required to implement an additional funding assessment.

The District intends to exercise all of the authority given to a water replenishment district in California Water Code § 60220 through 60232 as may be necessary for the District to accomplish its purposes and goals for the Plan. A water replenishment district has the authority to fix and collect fees and assessments within the Plan Area for groundwater management in accordance with California Water Code § 60300 through 60352. The District reserves the right to decide whether or not it will be involved in this activity authorized by the aforementioned statutes.

SECTION 4: RULES AND REGULATIONS

The below presented items in this section are the Groundwater Management Plan rules and regulations to implement the Groundwater Management Plan of Kaweah Delta Water Conservation District adopted August 1, 1995 and updated on November 7, 2006.

1. <u>Water Monitoring:</u> At least twice per year, the Kaweah Delta Water Conservation District (hereinafter the "District") shall provide staff at its expense to monitor and measure the depth to standing groundwater at well sites within the Plan Area. In its sole discretion, District shall select the number and location of well sites. District shall prepare charts as required by the Plan.

2. <u>Channel Recharge:</u> District shall endeavor to evaluate and utilize recharge from natural channels when appropriate, as determined by District. Natural channels with good recharge capabilities will be evaluated for potential use as groundwater recharge facilities to receive recharge water.

3. <u>Basin Recharge:</u> When feasible, District will consider delivery of water to recharge basins within the Plan Area. All such deliveries of recharge water shall be at the discretion of District Board of Directors ("District Board of Directors").

4. <u>Water Conservation:</u> District's policies and procedures promote the beneficial use of water. The District shall continue to promote policies that enhance water conservation policies. The District Board of Directors has the authority to adopt water conservation and water regulation policies for the District and, pursuant to its groundwater management plan, the Plan Area. If a local public agency adopts and enforces a water conservation plan within its boundaries, such Plan shall be effective to the extent it is not inconsistent with the District's Plan.

5. <u>No Exportation of Groundwater:</u> After the adoption hereof, there shall be no exportation of groundwater that results in any additional net loss to the Plan Area's total available water supplies. The District Board of Directors has the authority to institute any measures proposed to prevent such net loss.

6. <u>Intra-district Water Transfers:</u> Water transfers within the Plan Area are permissible and subject to the administration of the Kaweah River Watermaster under the direction of the Kaweah & St. Johns Rivers Association Board of Directors.

7. <u>Inter-district Water Transfers:</u> District shall endeavor to promote advantageous water transfers (water transfers that increase the water supply available within the Plan Area). The District Board of Directors has the authority to initiate such transfers.

8. <u>Reduction in Groundwater Outflow:</u> The District may monitor the outflow of groundwater from the Plan Area. Before the District takes any steps to prevent such outflow, such steps shall be approved by the District Board of Directors.

9. <u>Pumping Restrictions:</u> Only under special circumstances would pumping restrictions be imposed. The District Board of Directors shall not impose such restrictions until after consulting with local agencies and holding a mandatory public hearing at least sixty (60) days prior to the effective date of such restrictions. The District Board of Directors could impose such action only by resolution.

10. <u>Additional Water Supply and Storage:</u> The District will continue to actively review and evaluate potential new supplies of water and new storage facilities for water which may benefit the Plan Area. To the extent the District Board of Directors determines that it has the capability to do so, the District will fund projects which increase the water supply and water storage which benefit the Plan Area. The District's involvement in any project to increase water supply or water storage shall be approved by the Board of the Directors of the District.

11. <u>Redistribution of Surface Water:</u> The District, in its sole discretion, shall determine which sinking basin(s), natural channel(s), canal(s) or ditch(es) shall be used to sink any water which the District has available for such purpose.

GLOSSARY

A

acre-foot (af) The volume of water necessary to cover one acre to a depth of one foot; equal to 43,560 cubic feet or 325,851 gallons.

alluvial Of or pertaining to or composed of alluvium.

alluvium A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream or other body of running water, as a sorted or semi sorted sediment in the bed of the stream or on it's floodplain or delta, as a cone or fan at the base of a mountain slope**.**

aquitard A confining bed and/or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs, but stores ground water.

aquifer A body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs.

artificial recharge The addition of water to a groundwater reservoir by human activity, such as putting surface water into dug or constructed spreading basins or injecting water through wells.

average annual runoff The average value of total annual runoff volume calculated for a selected period of record, at a specified location, such as a dam or stream gage.

average year water demand Demand for water under average hydrologic conditions for a defined level of development.

B

basin management objectives (BMOs) See management objectives

beneficial use One of many ways that water can be used either directly by people or for their overall benefit. The State Water Resources Control Board recognizes 23 types of beneficial use with water quality criteria for those uses established by the Regional Water Quality Control Boards.

C

confined aquifer An aquifer that is bounded above and below by formations of distinctly lower permeability than that of the aquifer itself. An aquifer containing confined ground water. See artesian aquifer.

conjunctive use The coordinated and planned management of both surface and groundwater resources in order to maximize the efficient use of the resource; that is, the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin during years of above-average surface water supply.

contaminant Any substance or property preventing the use or reducing the usability of the water for ordinary purposes such as drinking, preparing food, bathing washing, recreation, and cooling. Any solute or cause of change in physical properties that renders water unfit for a given use. (Generally considered synonymous with pollutant).

critical conditions of overdraft A groundwater basin in which continuation of present practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts. The definition was created after an extensive public input process during the development of the Bulletin 118-80 report.

D

dairy and related water demand The use of water from those facilities where herds of cows are managed for the production of milk.

deep percolation Percolation of water through the ground and beyond the lower limit of the root zone of plants into groundwater.

drought condition Hydrologic conditions during a defined period when rainfall and runoff are much less than average.

E

electrical conductivity (EC) The measure of the ability of water to conduct an electrical current, the magnitude of which depends on the dissolved mineral content of the water.

environmental water Water serving environmental purposes, including instream fishery flow needs, wild and scenic river flows, water needs of fresh-water wetlands, and Bay-Delta requirements.

evapotranspiration (ET) The quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

G

groundwater basin An alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom.

groundwater budget A numerical accounting, the *groundwater equation*, of the recharge, discharge and changes in storage of an aquifer, part of an aquifer, or a system of aquifers.

groundwater in storage The quantity of water in the zone of saturation.

groundwater management The planned and coordinated management of a groundwater basin or portion of a groundwater basin with a goal of long-term sustainability of the resource.

groundwater management plan A comprehensive written document developed for the purpose of groundwater management and adopted by an agency having appropriate legal or statutory authority.

groundwater monitoring network A series of monitoring wells at appropriate locations and depths to effectively cover the area of interest. Scale and density of monitoring wells is dependent on the size and complexity of the area of interest, and the objective of monitoring.

groundwater overdraft The condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average conditions.

groundwater recharge facility A structure that serves to conduct surface water into the ground for the purpose of replenishing groundwater. The facility may consist of dug or constructed spreading basins, pits, ditches, furrows, streambed modifications, or injection wells.

groundwater recharge The natural or intentional infiltration of surface water into the zone of saturation.

groundwater storage capacity volume of void space that can be occupied by water in a given volume of a formation, aquifer, or groundwater basin.

groundwater subbasin A subdivision of a groundwater basin created by dividing the basin using geologic and hydrologic conditions or institutional boundaries.

groundwater table The upper surface of the zone of saturation in an unconfined aquifer.

groundwater Water that occurs beneath the land surface and fills the pore spaces of the alluvium, soil, or rock formation in which it is situated. It excludes soil moisture, which refers to water held by capillary action in the upper unsaturated zones of soil or rock.

H

hydraulic conductivity A measure of the capacity for a rock or soil to transmit water; generally has the units of feet/day or cm/sec.

hydrograph A graph that shows some property of groundwater or surface water as a function of time.

hydrologic region A study area consisting of multiple planning subareas. California is divided into 10 hydrologic regions.

I

infiltration The flow of water downward from the land surface into and through the upper soil layers.

in-lieu recharge The practice of providing surplus surface water to historic groundwater users, thereby leaving groundwater in storage for later use.

L

land subsidence The lowering of the natural land surface due to groundwater (or oil and gas) extraction.

lithologic log A record of the lithology of the soils, sediments and/or rock encountered in a borehole from the surface to the bottom.

lithology The description of rocks, especially in hand specimen and in outcrop, on the basis of such characteristics as color, mineralogic composition, and grain size.

losing stream A stream or reach of a stream that is losing water by seepage into the ground.

M

management objectives Objectives that set forth the priorities and measurable criteria of local groundwater basin management.

N

natural recharge Natural replenishment of an aquifer generally from snowmelt and runoff; through seepage from the surface.

O

operational yield An optimal amount of groundwater that should be withdrawn from an aquifer system or a groundwater basin each year. It is a dynamic quantity that must be determined from a set of alternative groundwater management decisions subject to goals, objectives, and constraints of the management plan.

ordinance A law set forth by a governmental authority.

P

perched groundwater Groundwater supported by a zone of material of low permeability located above an underlying main body of groundwater.

perennial yield The maximum quantity of water that can be annually withdrawn from a groundwater basin over a long period of time (during which water supply conditions approximate average conditions) without developing an overdraft condition.

perforated interval The depth interval where slotted casing or screen is placed in a well to allow entry of water from the aquifer formation.

permeability The capability of soil or other geologic formations to transmit water. See hydraulic conductivity.

point source A specific site from which wastewater or polluted water is discharged into a water body.

public water system demand The use of water from small, regulated public water systems. Typical facility types included mutual water companies, schools, mobile home parks, golf courses, county facilities, motels, livestock sales yards, and miscellaneous industries such as nurseries, food processing facilities, packing houses, etc.

R

recharge Water added to an aquifer or the process of adding water to an aquifer. Ground water recharge occurs either naturally as the net gain from precipitation, or artificially as the result of human influence. See artificial recharge.

recharge basin A surface facility constructed to infiltrate surface water into a groundwater basin.

runoff The volume of surface flow from an area.

rural domestic water demand The use of water from residences not served by a municipal connection, mutual water company, or other small public water system.

S

safe yield The maximum quantity of water that can be continuously withdrawn from a groundwater basin without adverse effect.

salinity Generally, the concentration of mineral salts dissolved in water. Salinity may be expressed in terms of a concentration or as electrical conductivity. When describing salinity influenced by seawater, salinity often refers to the concentration of chlorides in the water. See also total dissolved solids.

saline intrusion The movement of salt water into a body of fresh water. It can occur in either surface water or groundwater bodies.

seepage The gradual movement of water into, through or from a porous medium. Also the loss of water by infiltration into the soil from a canal, ditches, laterals, watercourse, reservoir, storage facilities, or other body of water, or from a field.

semi-confined aquifer A semi-confined aquifer or leaky confined aquifer is an aquifer that has aquitards either above or below that allow water to leak into or out of the aquifer depending on the direction of the hydraulic gradient.

specific yield the ratio of the volume of water a rock or soil will yield by gravity drainage to the total volume of the rock or soil**.**

stakeholders Any individual or organization that has an interest in water management activities. In the broadest sense, everyone is a stakeholder, because water sustains life. Water resources stakeholders are typically those involved in protecting, supplying, or using water for any purpose, including environmental uses, who have a vested interest in a water-related decision.

surface supply Water supply obtained from streams, lakes, and reservoirs.

sustainability Of, relating to, or being a method of using a resource so that the resource is not depleted or permanently damaged.

T

total dissolved solids (TDS) a quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per liter. See also salinity

transmissivity The product of hydraulic conductivity and aquifer thickness; a measure of a volume of water to move through an aquifer. Transmissivity generally has the units of ft_2/day or gallons per day/foot. Transmissivity is a measure of the subsurface's ability to transmit groundwater horizontally through its entire saturated thickness and affects the potential yield of wells.

U

unconfined aquifer An aquifer which is not bounded on top by an aquitard. The upper surface of an unconfined aquifer is the water table.

unsaturated zone The zone below the land surface in which pore space contains both water and air.

urban water demand The use of water from incorporated cities (Visalia, Tulare, Farmersville, Exeter, Ivanhoe) and in the unincorporated areas served by a municipal water purveyor.

urban water management plan (UWMP) An UWMP is required for all urban water suppliers having more than 3,000 connections or supplying more than 3,000 acre-feet of water. The plans include discussions on water supply, supply reliability, water use, water conservation, and water shortage contingency and serve to assist urban water suppliers with their long-term water resources planning to ensure adequate water supplies for existing and future demands.

usable storage capacity The quantity of groundwater of acceptable quality that can be economically withdrawn from storage.

W

water quality Description of the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose or use.

water year A continuous 12-month period for which hydrologic records are compiled and summarized. Different agencies may use different calendar periods for their water years.

watershed The land area from which water drains into a stream, river, or reservoir.

well completion report A required, confidential report detailing the construction, alteration, abandonment, or destruction of any water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well. The reports were called *Water Well Drillers' Report* prior to 1991 and are often referred to as "driller's logs." The report requirements are described in the California Water Code commencing with Section 13750.

APPENDIX A

KAWEAH & ST. JOHNS RIVERS ASSOCIATION TRANSFER POLICY

KAWEAH & ST. JOHNS RIVERS ASSOCIATION
STATEMENT OF POLICY RE WATER TRANSFERS AND EXCHANGES
(Adopted September 8, 1994)

The purpose of this policy statement is to confirm the intent of the Association to retain waters of the Kaweah River and its tributaries in the Kaweah River hydrologic surface basin ("Basin") for beneficial use therein. The boundaries of the Basin are set forth on Exhibit A, appended hereto and made a part of this statement.

Each of the Member Units shall retain the right and privilege alter, amend, change or modify their respective service areas, without notice to or consent of the Association, provided that the expanded service area of the Member Unit does not extend beyond the boundary of the historical Basin. Should a Member Unit make such an adjustment to its service area, it shall so notify the Watermaster. Documentation shall be provided by the Member Unit, to the Watermaster, adequate to demonstrate that the expanded service area is within the Basin.

Water to which Member Units are entitled shall be utilized only within said Basin boundary except as provided hereinafter for periods of flood release. Transfer(s) of entitlement waters shall be allowed within the Basin upon proper notification to the Watermaster of such impending transfer(s). The Watermaster shall provide notification to the Board of Directors of any such transfer(s). Approval of the Board of Directors shall not be required for any transfer within the Basin. It is acknowledged that under certain flood release conditions, after irrigation and spreading demands have been fully satisfied and the capability of the Basin to retain flood release water has been fulfilled, flood water flows naturally to the historic Tulare Bed which lies within the Basin.

Member Units may enter into water exchange agreements which call for no net loss to the Basin of to any in-Basin water rights holder, subject to administrative rules and regulations adopted by the Board of Directors.

Transfer(s) of riparian waters or waters resulting from settlement of riparian entitlement negotiations shall not be allowed. Transfers of water received under contracts for water made available through the State Water Project, the Federal Central Valley Project or the Cross Valley Canal Exchange Program shall not be subject to these provisions.

This policy shall be implemented by the following additions to the rules and regulations effective upon adoption of the policy by the Board of Directors:

Transfers of water shall be allowed between entities for use within the Basin. Notice of an impending transfer shall be provided to the Watermaster in writing.

Exchanges of water out of the Basin shall be subject to approval of the Board of Directors. Such exchanges shall only be considered when the recipient of the water can demonstrate, to the satisfaction of the Board of Directors, that a hardship situation exists. The required information associated with the documentation of the hardship situation shall be established by the Board of Directors on a case by case basis.

An out-of-Basin water exchange agreement may be entered into by a member unit subject to approval of the Association Board of Directors. Any exchange approved by the Board of Directors shall be conditioned on the full execution of an exchange/return agreement submitted with the petition for approval. Such agreement(s) shall call for no net loss to the Basin or to any in-Basin water rights holder.

To this end, exchanges shall call for channel loss water to be withheld from the total quantity of water available for exchange in the year of the exchange.

The total quantity of water exchanged shall be returned to the Basin for further diversion to a headgate designated by the exchanger subject to coordination with the Watermaster.

To compliment the Terminus and in-Basin storage capabilities available to members of the Association, temporary out-of-Basin storage historically has been permitted on a case-by-case basis and may be permitted in the future. Authority to grant permission to store out-of-Basin shall reside with the Watermaster, subject to appeal to the Board of Directors. Permission shall be predicated on the ability of the requesting entity to demonstrate the eventual delivery within the Basin of waters temporarily stored out-of-Basin. Following removal from storage, documentation shall be provided that the water, less the normal losses, was delivered within the Basin.

APPROVED BY
THE KAWEAH AND ST. JOHNS RIVERS ASSOCIATION BOARD OF DIRECTORS
ON SEPTEMBER 8, 1994.

APPENDIX B

MEMORANDUM OF UNDERSTANDING (SAMPLE)

MEMORANDUM OF UNDERSTANDING BETWEEN KAWEAH DELTA WATER CONSERVATION DISTRICT AND CITY OF TULARE

ARTICLE I - AGREEMENT

The articles and provisions contained herein constitute a bilateral and binding agreement by and between KAWEAH DELTA WATER CONSERVATION DISTRICT (hereinafter the "District") and CITY OF TULARE (hereinafter "Agency").

ARTICLE II - RECOGNITION

The District has developed a Groundwater Management Plan (hereinafter the "Plan") with input from several local agencies located within the District. It is the intent of District to allow and encourage such agencies to coordinate efforts and be a part of the District's Plan by means of a separate Memorandum of Understanding (hereinafter the "MOU") between each agency and District.

ARTICLE III - PURPOSE

It is the purpose of the MOU, entered into willingly, between District and Agency, to document the interests and responsibilities of both parties in the adoption and implementation of the Plan. It is also hoped that such MOU will promote and provide a means to establish an orderly process to share information, develop a course of action and resolve any misunderstandings or differences that may arise regarding the Plan.

ARTICLE IV - COORDINATE

There shall be an annual coordinating meeting (hereinafter the "Meeting") between the District and the Agency. District shall give notice to the Agency thirty (30) days prior to date of the Meeting to discuss the manner in which the Plan is being implemented and other items related to the Plan. If there are concerns or questions regarding the Plan, Agency shall transmit its concerns in writing to District seven (7) days prior to the Meeting.

ARTICLE V - OBLIGATIONS

The Plan shall be binding on the parties hereto unless superseded by the MOU or amendment thereto.

ARTICLE VI - AREA OF PLAN.

The Plan shall be effective in all areas within the Agency boundaries. The Plan shall also be effective in any area annexed to the Agency subsequent to the adoption of the Plan.

ARTICLE VII - TERM

The initial term of the MOU shall commence on the date hereof and continue for five (5) years, and shall continue year to year thereafter, unless terminated by written notice given at least one (1) year prior to such termination.

This Memorandum of Understanding is made and entered into this ___________ day of ____________________, 2004.

KAWEAH DELTA WATER CONSERVATION DISTRICT

By:______________________________

Title:______________________________

By:______________________________

Title:______________________________

CITY OF TULARE

By:______________________________

Title:______________________________

By:______________________________

Title:______________________________

APPENDIX C

KAWEAH DELTA WATER CONSERVATION DISTRICT ALTERNATIVE DISPUTE RESOLUTION POLICY

KAWEAH DELTA WATER CONSERVATION DISTRICT
ALTERNATIVE DISPUTE RESOLUTION POLICY
(Adopted February 3, 2004)

Purpose. The District recognizes that defending or prosecuting lawsuits can be expensive and time-consuming, resulting in a drain on District resources that should be avoided, if reasonably possible. To that end, the District hereby implements this policy to encourage the resolution of disputes, claims and lawsuits through alternative dispute resolution procedures.

Procedures. Whenever the District is named in a lawsuit or receives a written claim or a serious threat of imminent litigation, the District staff shall immediately consult with the District General Counsel regarding the same. Together, the District staff and the District General Counsel shall formulate a recommended response to be considered by the Board of Directors at its next meeting.

Whenever the District becomes aware of any unasserted potential lawsuit, claim or dispute, with a reasonable likelihood of being asserted, against the District, the District staff shall consult with the District's counsel regarding the best method for responding to the same. Possible responses include, but are not limited to, the following:

1. Do nothing.
2. A verbal communication from the District or its general counsel.
3. A written communication from the District or its general counsel.
4. An offer to meet and discuss the matter with District personnel.
5. An offer to mediate the matter before a neutral third-party mediator.
6. An offer to arbitrate the matter before the American Arbitration Association.
7. An offer to arbitrate the matter using the rules of Judicial Arbitration found in California statutes.

District staff shall advise the Board of Directors of any unasserted lawsuit, claim or dispute, with a reasonable likelihood of being asserted, including the District's response to the same. The Board of Directors shall be advised whether or not the matter is resolved. If the potential lawsuit, claim or dispute becomes an actual lawsuit, claim or dispute, the response of the District shall be handled as set forth above in the previous paragraphs.

It shall be the practice of the District to encourage mediation of lawsuits, claims or disputes, whenever reasonably practical, in order to resolve such matters. Mediation shall be by a neutral third-party qualified to mediate such matters.

APPENDIX D

LAND SURFACE ELEVATION MONITORING PLAN

KAWEAH DELTA
Water Conservation
DISTRICT

Land Surface Elevation Monitoring Plan

(Adopted: February 3, 2015)

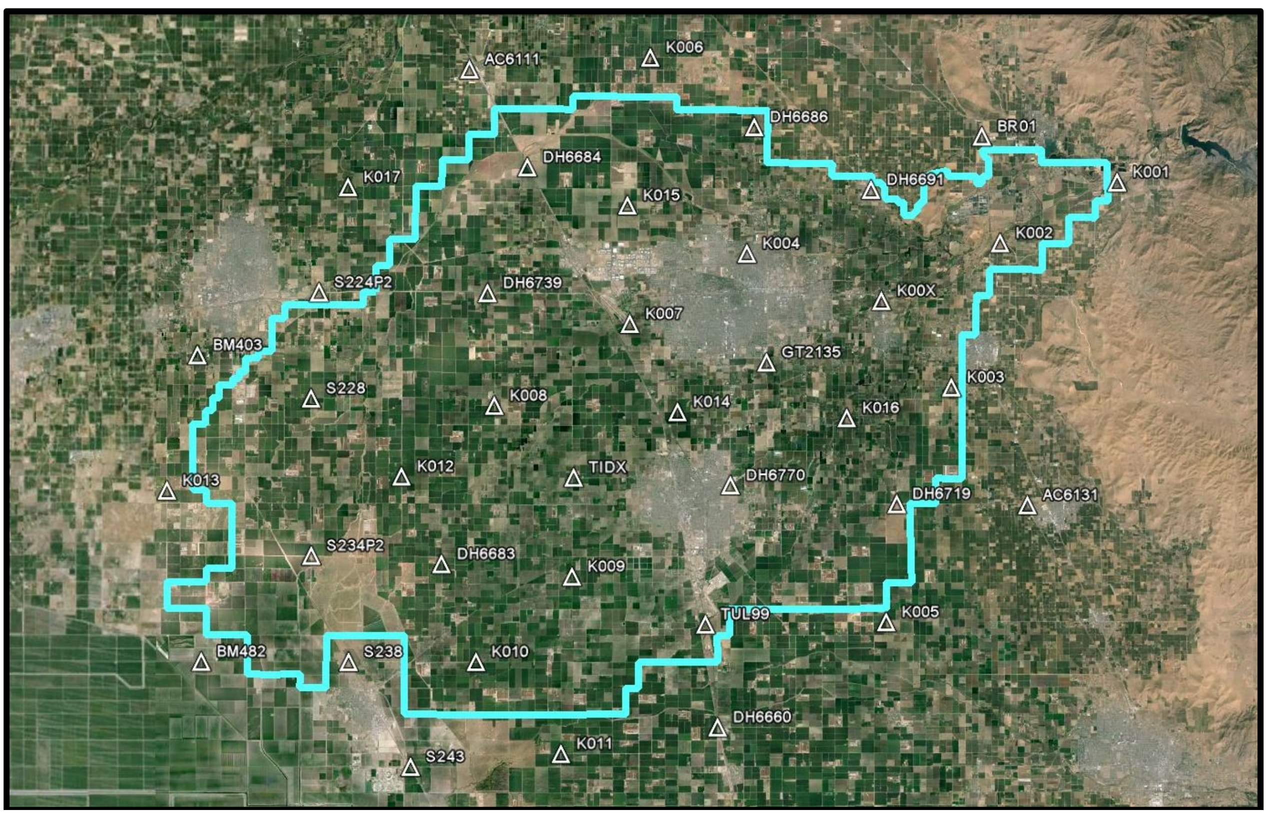


Table of Contents

1. INTRODUCTION

The effective management of surface and groundwater resources requires that Kaweah Delta Water Conservation District ('District') understand the physical properties of the land which determine the location, volume, flow, and environmental interaction of those resources. Knowledge of land surface elevation and change thereof is integral to water conservation management decisions, enabling planners to model and predict how water will most probably behave on and beneath Earth's surface.

This document therefore sets forth the District's Land Surface Elevation Monitoring Program ('Program'). The Program will be based on annual Global Positioning System (GPS) surveys performed by the District and its partner agencies.

The following sections define the scope of the Program; identify its elements and discuss how each contributes to its practicability; and provide guidance to conduct and maintain the Program as a robust, adaptable mechanism with which to study land surface elevation.

2. NETWORK

The District will assemble a network of surveying monuments across its area of interest (AOI) to study land surface elevation. Monuments are interchangeably referred to as stations, points, and marks. Stations will be situated in such a manner geographically and geometrically that measurements of their positions will be the basis for the creation of analytical surfaces which accurately approximate elevation.

2.1. SPATIAL EXTENT

Fundamentally the network must extend beyond the bounds of the District. Geophysical phenomena such as elevation are not discrete; they do not adhere to arbitrary boundaries but vary continuously in magnitude and direction through space. Earth's surface is analog and contains an infinite number of points. Program monuments, limited to an annually manageable number, will be arranged in a network with point distribution and densification sufficient to approximate elevation across the AOI. Observation stations will be located no more than six (6) miles beyond the District boundary. Refer to Figure 1.

2.2. TIME

Except instantaneously, land elevation at any point cannot be precisely delineated. Earth's surface is dynamic; elevation varies with time. Measurements of land are only valid at the moment they are observed. However, because elevation change is typically gradual, occurring over periods substantially longer than an instant, practicality necessitates that we consider elevation values to be useful from one measurement event to the next. In addition to spatial attributes, every point on Earth's surface has a temporal attribute. Elevation is therefore considered spatiotemporally.

2.3. MONUMENTS

Each existing and proposed monument site will first be identified in current remote sensing (RS) imagery and assessed for geographic suitability and geometric fit within the network. Sites which appear acceptable will be physically inspected to determine suitability for occupation. Existing monuments will be evaluated per Section 2.3.1, and installation points per 2.3.2. The network boundary and monument inventory will remain flexible to accommodate a temporally variable topography. Refer to Table 1.

Nature or man may cause stations to be obliterated, rendered unstable, or to suffer degraded or unreliable satellite radio signal reception. Such stations will either be temporarily retired for remediation or permanently abandoned. Monument stability can only be confirmed with long-term, repeated observation. It is necessary to investigate each site's greater area for potential alternate sites, bearing in mind topography and network geometry.

2.3.1. EXTANT MARKS

Where practical, use of existing survey monuments is preferred. Many durable marks exist among the civil infrastructure and are documented online. The Program will only consider monuments placed by public agencies. Selection criteria include location; accessibility; recoverability; stability; designation; pedigree; owning agency; field of view; safety hazards; and proximity to features that obstruct, reflect, or attenuate GPS satellite radio signals.

2.3.2. INSTALLATION OF MARKS

Site selection criteria are more-or-less the same as those for extant marks, except that where it is necessary to construct survey monuments soil properties and ground preparation must also be considered. Monuments will be a modified NGS concrete type illustrated in Figure 2. It is critical that monuments not move independent of the ground, and that they withstand natural and man-made disruptive forces. The basic monument design may be modified as necessary to improve stability and durability. County encroachment permits and utility clearances are required to construct monuments in rights of way (ROW).

If satisfactory civil structures exist at proposed station sites, survey discs will be permanently affixed thereto. Permission from owning agencies is required to attach survey discs.

3. DATA MANAGEMENT

At the core of every study is data. Data is typically only as good as the skill, instruments, and methods with which it is collected. Here management has two parts, collection and processing. Observers will adhere to the conventional practices and collection procedures discussed in Section 3.1. The following Section 3.2 discusses the processing stratagem the District will utilize to meet Program objectives.

3.1. COLLECTION

The first phase in the data life cycle is collection. Because measurements of every station cannot be taken simultaneously, observations will be conducted according to a fixed schedule. The method of data collection too will be narrowly defined.

3.1.1. FREQUENCY

Stations will be measured annually; each within an assigned 15 day period. This constraint reduces year-to-year temporal deviation and exposes observations to similar ionospheric and tropospheric error causative conditions. This practice is relevant to studies of geophysical phenomena such as elevation change and the direction and magnitude of land displacement.

3.1.2. METHODOLOGY

Static occupation strategies may necessarily vary by point but will in every case remain consistent with NGS recommendations. The observer will use a dual-frequency (L1/L2) survey grade GPS receiver to continuously occupy each station for no fewer than 2.0 hours per measurement period. Lower root mean square error (RMSE) correlates directly with longer duration of observation. Commensurately, dilution of precision (DOP) and combined error also tend to be more favorable.

The preferred outcome at each station is to acquire one (1) 4.0+ hour autonomous dataset from one (1) setup. The average of two (2) 2.0+ hour autonomous datasets from two (2) independent setups separated by not more than twenty-four (24) hours is an acceptable alternative. Only occasionally may one (1) 2.0+ hour autonomous dataset may meet the Vertical RMSE (VRMSE) standard.

L-band receivers are 24-hour, all weather capable; however, operations will be limited to daylight hours. Modern receivers are resistant to moisture infiltration but will not be exposed to heavy or sustained precipitation. Fog, haze, overcast, clouds, light rain, and dust should not be problematic. High wind and blowing debris are to be avoided. In cases where environmental elements or man-made conditions threaten observer safety, equipment functionality, or data integrity operations will cease, recommencing only when practicable for at least 2.0 hours.

Prior to initiating collection periods, at 30 minute intervals during the periods, and at times of cessation observers will complete a schedule of system checks in the station field notes. Logging will be enabled during instrument configuration; however, observers shall remain aware and engaged throughout collection periods, ready to take appropriate action.

3.1.3. INTER-AGENCY COOPERATION

Other water agencies also operate within the AOI. The District will collaborate with these agencies to develop joint operational agreements which distribute data acquisition duties and provide access to Program data. Partner agencies will adhere to and document compliance with the data collection procedures and quality standards prescribed herein. Re-occupation of points for which the District determines data suspect or unsatisfactory will be performed by the responsible agency.

3.2. PROCESSING

Data's second phase of life is processing. The processes employed to derive from field observables that which will be reported by the Program will be administered by the District. Partner agencies that wish to supervise their own processing regimes may do so but are still obligated to provide the District with copies of all original datasets.

3.2.1. EXAMINATION AND ADJUSTMENT

All original datasets will be preserved in a permanent stand-alone database. Copies to be post-processed will be examined for coherence and continuity. Errors and deficiencies will be corrected additively or proportionally wherever possible. Unusable datasets will be set aside, and stations of origin re-observed. Further data will not be eliminated unless irreparable defects are revealed by subsequent analysis. Station coordinates will be computed from the quality-checked copies with rigorous relative and absolute adjustment strategies.

Relative coordinate solutions will be computed by the Online Positioning User Service (OPUS), an NGS differential GPS (DGPS) internet application. OPUS solutions are the primary Program deliverables. Primary solutions are given in terms of the computational reference frame on the observation epoch date, and of the standard datum on the current standard epoch date.

Absolute coordinate solutions will be computed by the Automatic Precise Positioning Service (APPS), a National Aeronautics and Space Administration (NASA) - Jet Propulsion Laboratory (JPL) - California Institute of Technology (CIT) precise point positioning (PPP) internet application. APPS solutions are secondary Program deliverables. Secondary solutions are rendered in terms of the computational reference frame on the observation epoch date, and may be transformed to the standard datum adjusted to the current standard epoch date.

Uncertainty is associated with every observation. Every measurement contains error. GPS coordinates are characteristically less accurate in the vertical than in the horizontal. NGS and NASA employ sophisticated strategies to detect and correct systematic error. While many conventions are observed, no single comprehensive adjustment computation protocol exists.

Alternatively corrections can be performed in-office; differentially with local instrument software and continuously operating reference station (CORS) data obtained online from NGS; or absolutely with archived ephemerides and the Global Navigation Satellite System (GNSS)-Inferred Positioning System and Orbital Analysis Simulation Software (GIPSY-OASIS) site package. These options should be considered if OPUS and APPS become problematic.

3.2.2. Online Positioning User Service (OPUS)

OPUS coordinates are averaged from three independent, single-baseline solutions computed with double-differenced, carrier-phase measurements taken from nearby CORS (vertical control stations). Best results are realized when final GPS orbital data with an approximate processing latency of 14 days are referenced. Prior to publication of final orbits the ultra-rapid and rapid OPUS options can be used to preliminarily solve coordinate values and assess data quality. Datasets may include other GNSS observables but only GPS are used.

3.2.3. Automatic Precise Positioning Service (APPS)

APPS uses GIPSY-OASIS software and PPP techniques to compute coordinates for static, dual frequency datasets. APPS solutions are calculated using only GPS satellite navigation data and NASA correction parameters. Highest accuracy is achieved when JPL Final orbit and clock products are used; available after an approximate 10 day processing latency. Prior to publication of final ephemerides JPL Rapid and JPL Real-Time orbits and clocks can be used to preliminarily solve coordinate values and assess data quality.

4. STANDARDS

Program standards are of two types; parametric physical reference frames and statistical indices. Datums, the first type, are scalable geospatial coordinate systems in terms of which the Program will measure and report position. The second type, accuracy standards, are precisely defined limits to which error is compared to objectively estimate the quality of data processing solutions and gauge the efficacy of the Program.

4.1. DATUMS

The following are the Program datums of record. Current epochs are implied. Datums may be updated when newer epochs are introduced or replaced when standards are revised. Program databases will be annotated accordingly.

CCS83 Zone 4 – California Coordinate System of 1983 Zone 4 is part of the nationwide State Plane Coordinate System (SPCS). NAD83 geodetic coordinates (LON, LAT) are transformed into NGS Federal Information Processing Standard (FIPS) 0404 plane coordinates (E, N) by a Lambert Conformal Conic projection based on the GRS80 (Geodetic Reference System of 1980) ellipsoid.

NAD83 – North American Datum of 1983 (the standard datum), the horizontal component of the National Spatial Reference System (NSRS). WGS84 geocentric coordinates (λ, ϕ) are converted to NAD83 geodetic longitude and latitude (LON, LAT).

NAVD88 – North American Vertical Datum of 1988, the vertical component of the NSRS. The geoid height (N) of a given point is applied additively to the NAD83 ellipsoidal height (h) of the point to obtain its NAVD88 orthometric height (H). Several geoids are calculated by various modeling schema. The geoids used to correct for elevation may differ among adjustment strategies. Elevations derived from different geoids are of equal value relative to given datums.

WGS84 – World Geodetic System of 1984, the 3D geocentric ellipsoidal coordinate reference frame in which GPS measurements are captured.

4.2. ACCURACY

The maximum acceptable post-processed VRMSE at any station is 3.048 cm [≅ 0.1 survey foot (SF)]. Consistent with District practice, elevation data will be reported to a precision of 0.1 SF, with an uncertainty of no greater than ± 0.1 SF. Network accuracy will be calculated with traditional statistical methods and classified relative to standard statistical indices.

5. QUALITY

Quality is a real product of every process. While quality can be affected by factors beyond our control, its indices are largely influenced by the extent to which practitioners comply with protocol and the level of attention to detail with which they execute tasks. High quality deliverables typically result from adherence to standard practice and observance of procedures intended to preserve the accuracy, integrity, usability, and durability of data throughout the collection and analyses processes.

5.1. ASSURANCE

The following measures are intended to ensure conformance with best practices; and to reduce systematic errors, prevent blunders, and minimize outliers.

1. Data management procedures will be continually evaluated.
2. Calibration, service and repair, and preventive maintenance will be performed on instruments and collateral equipment as necessary.
3. Computers and software will be maintained.
4. Stations will be inspected prior to occupation.

The Program will be subject to periodic review. Standards will be re-assessed to ensure continued relevance and conformity of data. Responses to advancements in technology, changes of topography, and new operational directives will also be considered.

5.2. ASSESSMENT

Standard measures of quality will indicate which data most probably describe land surface elevation and which should be considered aberrations. As annual data accrue analytics should validate or refute a priori estimates of elevation change. That is to say empirical evidence either will or will not corroborate expectations.

When analysis results comport with observable physical change affirmative statements may be asserted regarding the veracity of data, the efficacy of management practices, and the extent to which actual conditions are accurately described. Predicated on a posteriori knowledge, reasonable predictions regarding the behavior of water relative to a dynamic land surface may then be presented.

6. REPORTING

The typical end products of studies are reports or other such deliverables that adequately communicate results and their relevance to objectives. The Program will publish tabular and graphic representations of final annual findings. Graphical depictions of the land surface across the AOI will approximate annual elevation and periodic spatiotemporal change. Findings not derived from primary solutions will be annotated accordingly.

Additionally, the Program will permanently preserve other relevant data including, but not limited to, the following.

1. Standardized datasheets for all stations.
2. Field notes and digital observation records.
3. Recovery notes for stations maintained in the NGS database will be submitted to NGS to update the online archive. Records for those not yet inventoried by NGS will be submitted after stations are confirmed reliable and their attributes patently determined.

7. GLOSSARY

Absolute measure – measurement of phenomena in terms of or with respect to a well-defined reference frame or scale

Accuracy – the degree to which an observation is correct and free of error

Baseline – a vector defined by coordinates from 2 GNSS receiver stations with simultaneous data

Base station – a fixed GNSS receiver reference station occupying a point with known coordinates

Benchmark – a reference point related to a vertical datum, a vertical control point

Bias – an attribute of a system that produces a predictable outcome, here systematic error

Blunder – an error introduced by an observer mistake

Carrier phase – measurements from the L1 or L2 channel carrier signal consisting of the number of wavelengths plus the fractional part thereof taken since signal lock

Cartesian – a 2D (x,y) biaxial or 3D (x,y,z) triaxial fixed origin coordinate system

Coordinates – here an ordered set of real numbers describing the location of a point on Earth's surface

Cycle slip – a carrier phase ambiguity caused by temporary loss of receiver lock; a discontinuity or corruption of carrier phase measurements

Datum – a reference surface or scale. Here geospatial and temporal reference frames

Deflection of the vertical – the angle between the normals to the ellipsoid and geoid

Differencing – see single-, double-, triple-

Distance – length of a path, defined as *vt*

Double-difference – method of correcting systematic error that eliminates receiver clock bias

Elevation – orthometric height

Ellipsoid – here a 3D model approximating Earth's mean surface as an oblate spheroid, so-called because Earth's major (equatorial) axis is longer than its minor (polar) axis

Ellipsoid height (h) – normal line distance from a point to the ellipsoid, defined as $h = H + N$

Ephemeris – a table of satellite orbital and clock data (plural ephemerides)

Epoch – the Keplerian orbital element that defines an observation in terms of satellite time

Error – the estimated difference between a measured value and a true value, which cannot be incontrovertibly ascertained

Geodesy – a branch of applied mathematics concerned with measuring Earth

Geodetic – of or pertaining to Geodesy

Geodetic coordinates – (λ, ϕ, h), (longitude, latitude, geodetic height), (LON, LAT, h)

Geodetic height – ellipsoid height

Geographic coordinates – (LON, LAT)

Geographic Coordinate System – an ellipsoidal surface used to define points on Earth, comprised of a datum, a prime meridian, and an angular unit of measure

Geoid – a gravimetric equipotential model of Earth's surface to which elevation is referenced. A zero elevation surface locally approximated by MSL

Geoid height (N) – the distance of undulation deviation between the geoid and the ellipsoid along a line normal to the ellipsoid, defined as N = h - H

Horizontal datum – an ellipsoidal approximation of Earth's surface or part thereof, centered either at a point on its surface or at its center

Kinematics – of mechanics, the branch of physics which regards the motion of objects

Latitude – from 0° in the equatorial plane the azimuth of a point on Earth's surface, ranging north to 90° at the north pole and south to -90° at the south pole. The vertex of the angle of latitude is Earth's center

Longitude – here from 0° at the prime meridian the azimuth of a point on Earth's surface, ranging east to 180° and west to -180° at the antimeridian (exactly opposite the prime meridian). The vertex of the angle of longitude is Earth's center

Meridian – on Earth's surface a line of constant longitude (a great circle) running through the Poles. Here the Greenwich Meridian is the Prime Meridian

Navigation Message – data containing satellite broadcast ephemeris, satellite clock (bias), correction parameters, constellation almanac, and satellite health

Normal – perpendicular, orthogonal

Orthometric height (H) – elevation, the plumb line distance from a point to the geoid,

defined as H = h – N

Outlier – a value outside the pattern of a distribution

Perturbation – here an orbital deviation exerted by an external force disturbance

Planimetric – 2D, planar

Point – a unique 0-dimensional location in space represented here by an ordered triplet, e.g. (x, y, z) or (λ, ϕ, h) or (LAT, LON, H) etc.

Position – a point occupied by an object

Precision – here the degree of exactness of a measurement

Projected Coordinate System – a planimetric surface on which length, area, and angle are constant, based on and transformed from a GCS

Random error – cannot be precisely modeled or predicted but may be quantified and propagated through mathematical analysis

Relative measure – measurement of objects or phenomena in terms of or with respect to other objects or phenomena

Rover – a mobile GNSS receiver linked to a base station in RTK operations

Single-difference – method of correcting systematic error that eliminates satellite clock bias and the effects of ionospheric and tropospheric refraction

Spatiotemporal – of space and time

Spheroid – an ellipsoid of constant radius and therefore constant axial length

Static occupation – here a continuous, undisturbed measurement period of no less than 2 hours

Stochastic – probabilistic, determined randomly, may be statistically analyzed but cannot be precisely modeled or predicted

Systematic error – error inherent in a system definable and removable by mathematical models but not detectable through mathematical analysis

Topographic – of or pertaining to land features

Triangulation – determination of position by angles

Trilateration – determination of position by distance. In GPS ranging 3 spheres, each centered on a unique satellite, intersect at 2 points, of which 1 is mathematically eliminated

Triple-difference – method of correcting systematic error that eliminates integer ambiguity, leaving differences in phase-shift and geometric range

Uncertainty – here used more-or-less synonymously with error

Undulation – variation in distance between two surfaces, here at any point the distance of the geoid from the reference ellipsoid, geoid undulation or undulation of the geoid

Vertical datum – a zero elevation, geoidally-adjusted orthometric surface

8. *ACRONYMS*

AOI – area of interest

APPS – Automatic Precise Positioning Service, a NASA-JPL-CIT internet application

C/A-Code – coarse acquisition code, modulated on L1

CIT – California Institute of Technology (CalTech)

CCS83 – California Coordinate System of 1983 (an SPCS)

CHSRA – California High-Speed Rail Authority

CORS – Continuously Operating Reference Station

CSRS – California Spatial Reference System

CT – CalTrans

CVSRN – Central Valley Spatial Reference Network

DD – decimal degrees

DGNSS – Differential Global Navigation Satellite System

DGPS – Differential Global Positioning System

DMS – degrees minutes seconds

DOD – United States Department of Defense

DOP – dilution of precision

ECEF – Earth-Centered, Earth-Fixed

ECI – Earth-Centered Inertial

(E,N) – Easting, Northing

FIPS – Federal Information Processing Standard

GCS – Geographic Coordinate System

GDGPS – Global DGPS

GDOP – geometric dilution of precision

GIPSY-OASIS – GNSS-Inferred Positioning System and Orbital Analysis Simulation Software (NASA-JPL-CIT)

GNSS – Global Navigation Satellite System, comprised of NAVSTAR and other country's satellite constellations

GPS – Global Positioning System (NAVSTAR), an element of GNSS

GRS80 – Geodetic Reference System of 1980, a global geocentric ellipsoid

HARN – High Accuracy Reference Network

HDOP – horizontal dilution of precision

HPGN – High Precision Geodetic Network

HTDP – Horizontal Time-Dependent Positioning

IERS – International Earth Rotation and Reference System Service

IGS – International GNSS Service, and an ECEF coordinate reference frame based on ITRF

ITRF – International Terrestrial Reference Frame, an ECEF coordinate reference frame

JPL – Jet Propulsion Laboratory

KDWCD – Kaweah Delta Water Conservation District

L1 – GPS 1575.42MHz frequency containing C/A-Code, P-Code (or Y-Code), and the Navigation Message

L2 – GPS 1227.60MHz frequency containing P-Code (or Y-Code) and the Navigation Message

LAT – latitude

LON – longitude

MSL – mean sea level

NAD27 – North American Datum of 1927 superseded by NAD83

NAD83 – North American Datum of 1983 (the standard datum), based on and computationally equivalent to GRS80, it is the official US horizontal datum

NANU – Notice Advisory to NAVSTAR Users, a daily USCG Navigation Center publication

NASA – United States National Aeronautics and Space Administration

NAVD88 – North American Vertical Datum of 1988, the official US vertical datum

NAVSTAR – NAVigation Satellite Timing And Ranging, the US (NASA-DOD-USAF) GPS navigational satellite constellation

NGS – National Geodetic Survey

NGSIDB – National Geodetic Survey Integrated Data Base

NGVD29 – National Geodetic Vertical Datum of 1929 superseded by NAVD88

NOAA – United States National Oceanic and Atmospheric Administration

NSDI – National Spatial Data Infrastructure

NSRS – National Spatial Reference System

NSSDA – National Standard for Spatial Data Accuracy

OPUS – Online Positioning User Service

P-Code – precise code, very long sequence binary bi-phase modulation on L1 and L2

PAYGO – process as you go

PCS – Projected Coordinate System

PDOP – positional dilution of precision

PPP – precise point positioning, a highly accurate method of determining absolute measures

PRN – pseudo random noise

RINEX – Receiver INdependent EXchange format contains the three fundamental GPS observables required for post-processing: range, phase, and time.

RMS / RMSE – root-mean-square / root-mean-square error

ROW – right of way

RS – remote sensing

RTK – real-time kinematic

RTN – Real-Time Network

SF – Survey Foot (1 SF is defined as exactly 1200/3937 meters)

SNR – signal-to-noise ratio

SPC – State Plane coordinates, given as (E,N)

SPCS – State Plane Coordinate System, a PCS

SPP – single point positioning, autonomous absolute measures

SVN – Space Vehicle Number (NAVSTAR)

TDOP – time dilution of precision

TID – Tulare Irrigation District

USBR – United States Bureau of Reclamation

USCG – United Sates Coast Guard

USCGS – United States Coast and Geodetic Survey

USGS – United States Geological Survey

VDOP – vertical dilution of precision

VRMS / VRMSE – Vertical RMS / Vertical RMSE

WGS84 – World Geodetic System of 1984, a geocentric equipotential ellipsoid of revolution

Y-Code – DOD encrypted P-Code

2D – two-dimensional

2.5D – a planimetric representation into which vertical attributes are imbedded

3D – three-dimensional

4D – 3D + a discrete or continuous time dimension

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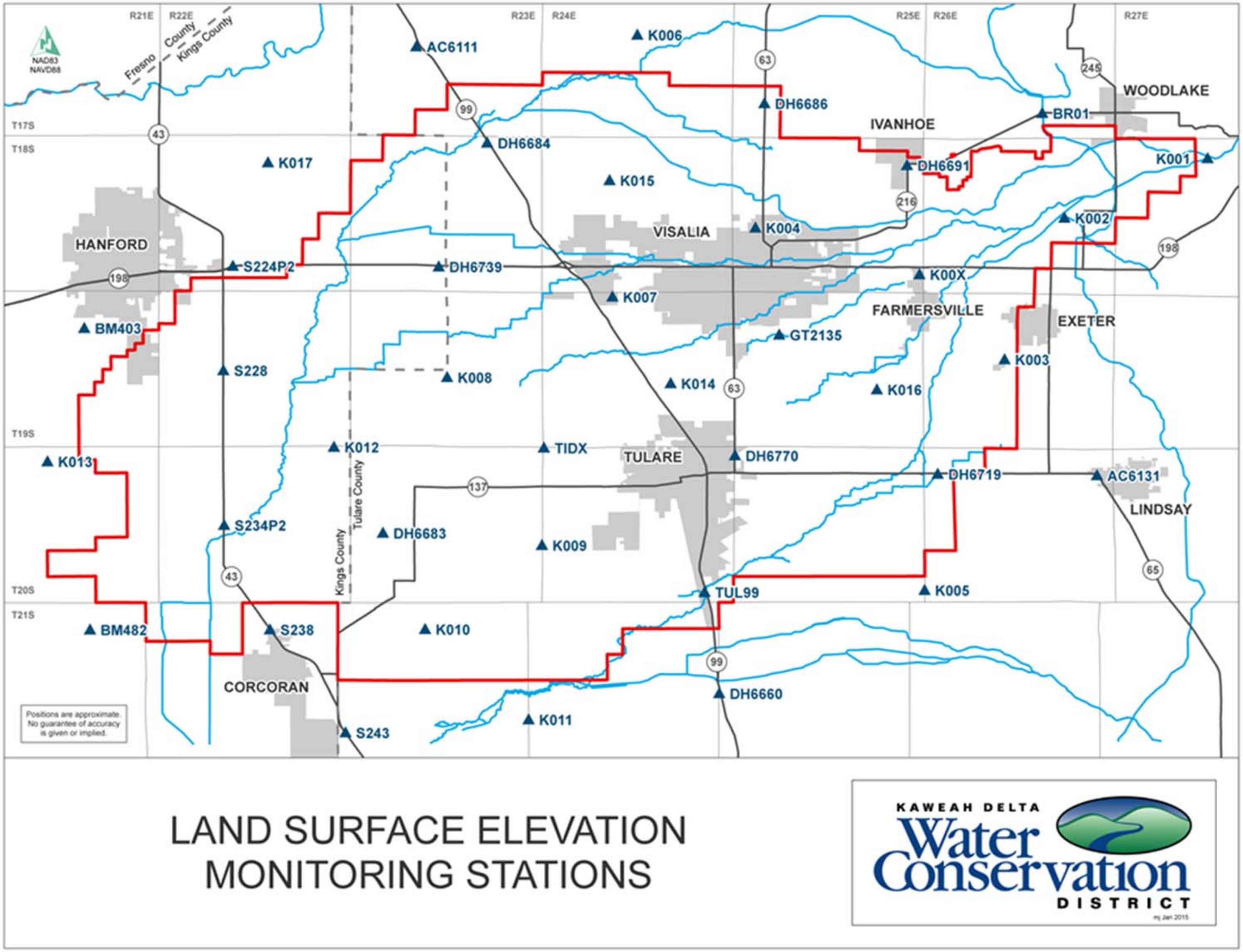
Figure 1 - Map of Initial Station Locations



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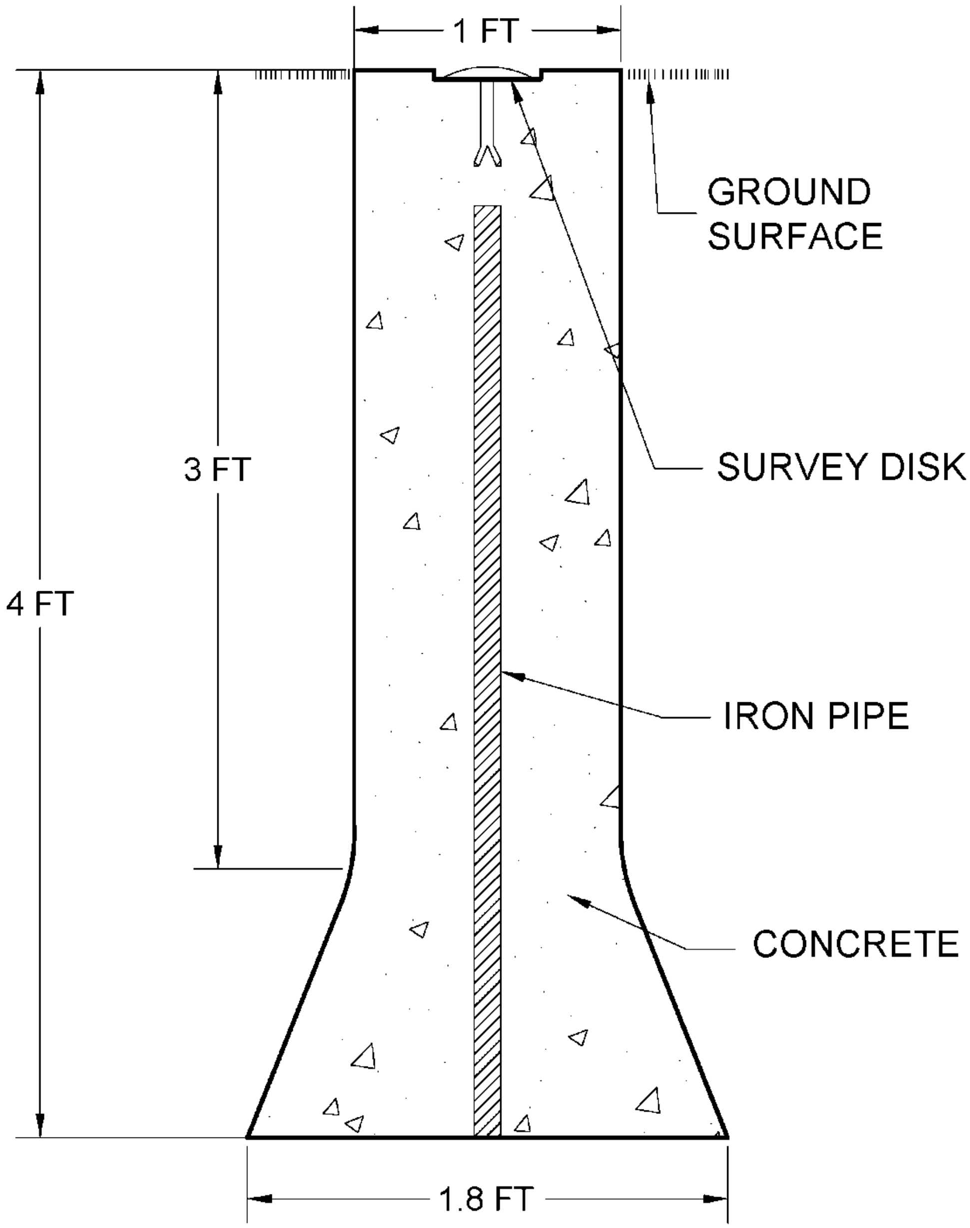


Figure 2 - Modified NGS Concrete Type Survey Monument

MONUMENT INVENTORY

STATION	AGENCY	LONGITUDE	LATITUDE	Z	NOTES
AC6111	CT	-119.492099	36.451508		Wso 99 SEc rd 36/merritt
AC6131	CT	-119.109077	36.210090		NEso 65-137 transition curve
BM403	KCWD	-119.678822	36.293017		0.5 S on ditch Wo 12th/houston
BM482	CID	-119.675621	36.123278		0.25 Eo 12th/newton
BR01	USBR	-119.139876	36.414011		CVP/rd 344/216
DH6660	CT	-119.321618	36.087424		Wso I dr (rt 112) 250' Wo 99
DH6683	CT	-119.510835	36.177688		rd 28 0.25 So av 216
DH6684	CT	-119.452148	36.397310		rd 60 0.9 No av 328 Wso 99
DH6686	CT	-119.296179	36.419509		Wso rd 124 0.6 So av 352
DH6691	CT	-119.215980	36.384697		Wso RR SWc rd 160/av 328
DH6719	CT	-119.198678	36.210893		NEc rd 168/hwy 137
DH6739	CT	-119.479431	36.327625		delta view school 90' So 198
DH6770	CT	-119.312733	36.221302		Eso mooney on TID main
GT2135	CT	-119.287848	36.289276		Wso rd 128 Nso creek Eso RR
K00X	KDWCD	-119.208981	36.323251		KDWCD yard
K001	KDWCD	-119.046842	36.388558		BM2 on LK at mckay point
K002	KDWCD	-119.127391	36.355063		av 312 0.2 Eo peoples on yokhol
K003	KDWCD	-119.161091	36.275361		pond 1 exeter water treatment
K004	KDWCD	-119.301293	36.349501		Nso ferguson 0.25 Wo 63
K005	KDWCD	-119.206070	36.145526		Wso rd 164 0.5 No av 192
K006	KDWCD	-119.367648	36.458118		av 368 1.5 Eo rd 80
K007	KDWCD	-119.381712	36.310634		Wo aviation 250' NEo R-30 CL
K008	KDWCD	-119.474710	36.265362		rd 44 0.25 So av264
K009	KDWCD	-119.421345	36.170818		rd 68 0.25 No av 208
K010	KDWCD	-119.487084	36.123535		Nso av 184 0.75 Eo rd 32
K011	KDWCD	-119.428881	36.072685		0.5 So rd 64/av 160
K012	KDWCD	-119.538340	36.226135		highline canal/kent
K013	KDWCD	-119.699502	36.217968		0.5 No kansas 0.5 Eo 14th av
K014	KDWCD	-119.348958	36.261890		Eso akers 0.5 So av 264
K015	KDWCD	-119.383318	36.376201		basin 0.5 Eo rd 80 0.25 No av 320
K016	KDWCD	-119.232883	36.258457		basin_1
K017	KDWCD	-119.575495	36.386274		100' So elder 0.4 Eo 7th
S224P2	CHSTP	-119.595250	36.327939		Sso lacey 0.3 Eo 43
S228	CHSTP	-119.600561	36.269242		SEc 43/idaho
S234P2	CHSTP	-119.600167	36.182145		Eso 43 0.4 No cross creek
S238	CHSTP	-119.574422	36.123350		Eso 43 1.2 So nevada
S243	CHSTP	-119.531859	36.065348		Eso 43 0.4 So prison turnoff
TIDX	TID	-119.420219	36.225648		TID yard
TUL99	CT	-119.329866	36.144412		250' Wo 99 on elk bayou

Table 1 - Initial Survey Monument Inventory

Appendix 4C

KBWQA Groundwater Trend Monitoring Workplan

KAWEAH BASIN WATER QUALITY ASSOCIATION

Groundwater Trend Monitoring Workplan

Tulare County, California • February 2017



Prepared for:

KAWEAH BASIN
WATER QUALITY ASSOCIATION

Prepared by:

EST. 1968
PROVOST & PRITCHARD
CONSULTING GROUP
An Employee Owned Company

Kaweah Basin Water Quality Association

Groundwater Trend Monitoring Workplan

Tulare County, California
February 3, 2017

Prepared for:

Kaweah Basin Water Quality Association

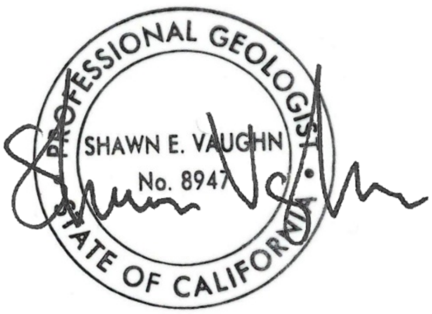
Prepared by:

Provost & Pritchard Consulting Group
EST. 1968
An Employee Owned Company

CERTIFICATIONS

This Groundwater Trend Monitoring Workplan is signed by the following certified professionals:

Provost & Pritchard Consulting Group



PROJECT TEAM

This Groundwater Trend Monitoring Workplan was prepared by the following project team members:

Provost & Pritchard Consulting Group

- Shawn Vaughn, PG
- Linda G. Sloan, PG, CHG
- Sarah Rutherford
- Jason Thomas
- Mallory Serrao

Kaweah Basin Water Quality Association

- Donald Ikemiya, Executive Director

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Abbreviations

AMR........ Annual Monitoring Report
Canal .... Friant-Kern Canal
CASGEM .... California Statewide Groundwater Elevation Monitoring
CGQMP........ Comprehensive Groundwater Quality Management Plan
COC........ constituent of concern
CVHM .... Central Valley Hydrologic Model
CV-SALTS .... Central Valley Salinity Alternatives for Long-Term Sustainability
DAC........ Disadvantaged Community
Dairy GO .... Reissued Waste Discharge Requirements General Order for Existing Milk Cow Dairies
DO .... Dissolved Oxygen
DPR........ California Department of Pesticide Regulation
DWR .... California Department of Water Resources
EC .... electric conductivity
ELAP .... Environmental Laboratory Accreditation Program
GAMA........ Groundwater Ambient Monitoring and Assessment
GAR .... Groundwater Quality Assessment Report
General Order .... Waste Discharge Requirements Order No. R5-2013-0120
GIC........ Groundwater Information Center
GPS .... Global Positioning Systems
GQMP........ Groundwater Quality Management Plan
GSAs .... Groundwater Sustainability Agencies
GTMP........ Groundwater Trend Monitoring Program
GTMW .... Groundwater Trend Monitoring Workplan
HVA .... high vulnerability area
ILRP........ Irrigated Lands Regulatory Program
KBWQA........ Kaweah Basin Water Quality Association
KCWD .... Kings County Water District
KDWCD........ Kaweah Delta Water Conservation District
LVA .... Low Vulnerability Area
MCL .... Maximum Contaminant Level
mg/L .... milligrams per liter

MPEP .... Management Practices Evaluation Program
MRP .... Monitoring and Reporting Program
NMP .... Nutrient Management Plan
NOA .... Notice of Applicability
NRCS .... Natural Resources Conservation Service
NWIS .... National Water Information System
Provost & Pritchard .... Provost & Pritchard Consulting Group
RWQCB .... Central Valley Regional Water Quality Control Board
SCID .... Stone Corral Irrigation District
SGMA .... Sustainable Groundwater Management Act
SSJV .... South San Joaquin Valley
TDS .... total dissolved solids
TID .... Tulare Irrigation District
USEPA .... United States Environmental Protection Agency
USGS .... United States Geological Survey
VK .... vertical conductivity
WDR .... Waste Discharge Requirements

EXECUTIVE SUMMARY

This Groundwater Trend Monitoring Workplan (GTMW) has been prepared for the Kaweah Basin Water Quality Association (KBWQA) to fulfill the requirements of the Central Valley Regional Water Quality Control Board adopted Waste Discharge Requirements of September 19, 2013 for Growers within the Tulare Lake Basin Area that are a member of a Third-Party Group, Order No. R5-2013-0120 (General Order).

The purpose of this GTMW is to establish a Groundwater Trend Monitoring Program (GTMP) as specified in Section IV of the General Order; Monitoring and Reporting Program. The objectives of the GTMP are to determine current groundwater quality conditions relevant to irrigated agriculture and to develop long-term groundwater quality information that can be used to evaluate the regional effects of irrigated agriculture and its practices.

This workplan has been prepared as an initial phase (Phase I) of the GTMW to identify general representative monitoring areas. A second phase (Phase II) of the work plan will be prepared for submittal after approval of the Phase I work plan. Included in the Phase II workplan will be the sampling implementation schedule. This approach allows the KBWQA to implement groundwater quality monitoring in advance of development of other components of the Irrigated Lands Regulatory Program (ILRP), such as a coordinated regional monitoring effort.

Within the KBWQA, there are approximately 356,000 total acres in the Primary Area (San Joaquin Valley floor) and 602,000 total acres in the Supplemental Area (foothill and mountain areas). Of these areas, approximately 160,000 and 3,800 acres, respectively, are enrolled as grower members in compliance with the ILRP as of July 2016.

As discussed in the previously submitted Groundwater Quality Assessment Report (GAR), high vulnerability areas and low vulnerability areas were identified in the GAR based on criteria including groundwater quality exceedances in comparison to maximum contaminant level, up-trending nitrate concentrations in groundwater, and groundwater impacted areas upgradient of Disadvantaged Communities (DAC) or small water systems reliant on groundwater.

Building on the GAR findings, a total of 24 proposed monitoring areas were selected to be included in the groundwater monitoring design. Monitoring areas are not defined by specific acreage or location, but rather by specific criteria. Potential general monitoring areas were initially selected by reviewing crop maps for the largest crop types (by acreage) and selecting areas near each of those crop types that were:

1) located above relatively shallow groundwater;
2) generally upgradient of a DAC or within relatively close proximity of a DAC;
3) located in both low vulnerability areas and high vulnerability areas;
4) in areas with greater potential recharge as documented in the GAR;
5) generally representative of soil textural classes present in the KBWQA area; and
6) not downgradient from an area where other land application practices would potentially lead to water quality issues that could not be differentiated from those resulting from farming practices.

Once the initial crop type monitoring locations were selected, additional proposed monitoring areas were selected to represent deeper groundwater.

Area specific well selections will be conducted in the Phase II GTMW, pending further feedback from the RWQCB and other coalitions. For each of the proposed monitoring areas, one primary and one backup well will be included in the GTMP. Well information from those selections will be included in the Phase II workplan, along with the sampling implementation schedule.

An initial pool of candidate wells will be identified in the Phase II GTMW. Wells in the monitoring areas will be located with the use of aerial photos, member growers' farm evaluation data, Department of Water Resources (DWR) records, other agency sources, and potentially by roadside surveys. Based on the requirement to sample shallow groundwater, it is anticipated that domestic wells will comprise a majority of the monitoring network. As an extra measure of redundancy, backup wells will be selected to ensure continuity of the GTMP. Once candidate wells are identified, available well construction information will be gathered from well owners, DWR records, and other sources in order to assess the wells for minimum criteria for potential inclusion in the GTMP. Criteria to be assessed will include well location and overlying land use, well type, well construction (i.e., depth, perforated intervals, well seal information), and well access and condition. In the event that multiple candidate wells are identified in a monitoring area, a point system will be used to determine the most appropriate wells to be used as monitoring points in the monitoring areas.

As specified in the General Order, the GTMP network wells will be sampled annually at the same of the year. Sampling will begin upon approval of the Phase II work plan. At the time of the initial groundwater monitoring event and every fifth year thereafter, samples from the program wells and backup monitoring wells will be analyzed for electrical conductivity, pH, dissolved oxygen, temperature, nitrate as nitrogen, total dissolved solids, and general minerals. All other years, samples from the program wells will be analyzed for electrical conductivity, pH, dissolved oxygen, temperature, and nitrate as nitrogen.

Annual groundwater sampling will occur approximately June of each year. Sample collection methods will follow industry standard procedures. Collected data from each well will be compiled into an electronic database. The results of trend monitoring are required to be included in the third-party's Annual Monitoring Report and must include a map of the sampled wells, tabulation of the analytical data, and time concentrations charts. The Annual Monitoring Report will include a review of the constituents of concern and will include a discussion of monitoring data relative to applicable water quality objectives and groundwater quality management plans. Once sufficient data is collected, hydrographs and time-series concentration graphs will be included in the annual reports. Additional trend analysis methods such as the Piper and/or Stiff diagrams and statistical analysis will be used. Appropriate statistical methods will be used depending on the presence and number of non-detects, and whether the data is parametric. Potential statistical test methods that may be used include Dixon's Test, Shewhart CUSUM Control Chart, Mann-Kendall, Theil-Sen, and ANOVA.

1 INTRODUCTION

1.1 Kaweah Basin Water Quality Association Organization Background

The Central Valley Regional Water Quality Control Board (**RWQCB**) adopted Waste Discharge Requirements (**WDRs**) for Growers within the Tulare Lake Basin Area that are members of a Third-Party Group, Order No. R5-2013-0120 (**General Order**) on September 19, 2013. The Kaweah Basin Water Quality Association (**KBWQA or Coalition**) (**Figure 1-1**) was authorized by the RWQCB as third-party group to represent growers within its service area by the Notice of Applicability (**NOA**) received from the RWQCB on February 7, 2014.

Within the KBWQA, there are approximately 356,000 total acres in the Primary Area (San Joaquin Valley floor) and 602,000 total acres in the Supplemental Area (foothill and mountain areas). The general boundary and location of the KBWQA is depicted in **Figure 1-2**. Of these areas, approximately 160,000 and 3,800 acres, respectively, are enrolled as grower members in compliance with the Irrigated Lands Regulatory Program (**ILRP**) as of July 2016 (**Figure 1-2**).

1.2 Purpose and Requirements of the Groundwater Trend Monitoring Workplan

As specified in Section IV of Attachment B, Monitoring and Reporting Program, to Order R5-2013-0120 (**MRP**) the purpose of the Groundwater Trend Monitoring Workplan (**GTMW**) is to establish a Groundwater Trend Monitoring Program (**GTMP**). The KBWQA's trend monitoring program and workplan areoutlined below.

1.2.1 Objectives

The General Order describes required objectives of the GTMP. These objectives include:

- Determine current water quality conditions of groundwater relevant to irrigated agriculture; and
- Develop long-term groundwater quality information that can be used to evaluate the regional effects of irrigated agriculture and its practices.

1.2.2 Implementation

- Trend monitoring is to include both high and low vulnerability areas; and
- The trend monitoring well network must consist of shallow wells, although not necessarily wells completed in the uppermost zone of first encountered groundwater. The use of existing monitoring networks, such as those used by AB 3030 and SB 1938 plans, may be considered by the Coalition to be incorportated as part of the GTMP.

1.2.3 Reporting

- Groundwater trend monitoring reports are to include a map of the sampled wells, tabulation of the analytical data, and time concentration charts;
- Groundwater monitoring data is to be submitted electronically to the State Water Board's GeoTracker Database and to the Central Valley Water Board; and
- Once sufficient data has been collected, trend evaluations of the collected groundwater data are to be made.

1.3 Work Plan Phased Approach Summary

This workplan has been prepared as an initial phase (**Phase I**) of the GTMW to identify representative monitoring areas . A second phase (**Phase II**) of the work plan will be prepared for submittal after approval of the Phase I work plan. Included in the Phase II workplan will be the sampling implementation schedule. This approach allows the KBWQA to implement groundwater quality monitoring in advance of development of other components of the ILRP, such as a coordinated regional monitoring effort, described in the following sections.

1.4 Interelated Irrigated Lands Requirements

Fulfillment of requirements outlined in the General Order relies on the implementation of multiple co-dependent elements of the ILRP Program. These elements include the Groundwater Assessment Report (**GAR**), required member reports such as the Farm Evaluation Survey, Nitrogen Management Plan (**NMP**) Summary Reports, the Management Practices Evaluation Program (**MPEP**), and this GTMP. The implementation timelines for these elements vary and resulting data will be incorporated into analysis to be completed by the Coalition as required by the General Order. A cornerstone of the ILRP program is collecting and tracking information provided in Farm Evaluations and Nitrogen Summary Reports. The coalition will track this information over the long term and report annually to the RWQCB. Summary information will also be communicated to individual growers, this feedback enables them to review management practices on an on-farm basis. On the coalition scale these data will be analyzed further with respect to the MPEP and GTMP.

The significance and application of each of these ILRP elements in the ongoing monitoring plan strategy are detailed below.

1.4.1 MPEP

The KBWQA has joined with six other coalitions to form the South San Joaquin Valley **(SSJV)** MPEP Committee, and collaborates actively with a technical team (SSJV MPEP Team) to develop and implement a workplan. As specified in the General Order, the purpose of the MPEP is to determine the effects, if any, of irrigated agricultural practices on first encountered groundwater under varied conditions (e.g. soil type, depth to groundwater, irrigation practice, crop type, nutrient management practices). The SSJV MPEP anticipates using coalition collected data to characterize the extent and locations of implemented practices. On the basis of these and other data characterizing crops, soils, climate, and management systems, performance will be assessed at a field level scale and aggregated at a landscape scale (since this is the scale that influences groundwater quality). This assessment will occur along with MPEP priority investigations to define performance on specific sites. The modeled output will be employed to gauge the performance of implemented practices throughout the region.

The MPEP supports the GTMP by providing calculated constituent fluxes (e.g. volume and mass) through the vadose zone and into groundwater to more accurately determine potential ongoing impacts from agricultural operations, residual impacts, and legacy contamination issues. In turn, the monitoring data generated under the GTMP supports the MPEP by providing feedback in the form of regional groundwater constituent concentrations to assess groundwater quality changes on a regional scale, and their response to changing management practices and other contributing factors.

1.4.2 CGQMP

The KBWQA's Comprehensive Groundwater Quality Management Plan (**CGQMP**) dated September 2016 outlines a strategy to work with growers to implement protective management practices and a monitoring program which will provide feedback on CGQMP progress. Areas to be addressed by the CGQMP include all areas identified in the KBWQA's GAR as high vulnerability areas (**HVAs**). The CGQMP also outlines the limitations of available data and the complex dynamics of decreasing the potential to leach nitrates from irrigated agriculture. The CGQMP relies on data generated by the GTMP to further validate protective practices as well as identify areas of deteriorated water quality.

1.4.3 Grower Information

Farm Evaluation Surveys and NMP Summary Reports are required to be completed by all members in the HVAs as identified by the GAR. Farm Evaluations were required by the General Order to be submitted to the third-party coalition in spring 2016 by large farms (those greater than 60 acres) in HVAs. The Farm Evaluation catalogues field specific crop and irrigation practices, including the implementation of protective practices relevant to irrigation efficiency, nitrogen application efficiency, and sediment and erosion control. The NMP Summary Reports are required to be submitted in spring of 2017 for growers of large farms in HVAs.

Farm Evaluations provide grower information on management practices at a field specific level. This data can be used to track trends in management practices over time including irrigation methods, crop type, and other protective practices. These management practice data can be summarized at a broad scale or reported at more specific locales to potentially analyze correlations in surface management practices and groundwater quality as collected by the GTMP, once sufficient data have been collected.

Nitrogen Summary Reports provide the Coalition with a nitrogen applied over crop yield ratio, from which nitrogen removed values will be calculated by KBWQA and shared back with growers. The KBWQA considers the NMP Summary Report to be a critical component of the ILRP and the information provided will be aggregated and submitted to the RWQCB annually as part of the Groundwater Quality Management Report and Annual Monitoring Report as well as groundwater quality data collected by the GTMP.

1.4.4 GTMP

The water quality data collected by the GTMP is not expected to reflect immediate surface conditions or management practices. As with any groundwater monitoring program the collected data is reflective of prior years percolation. The nitrogen application data may be used to later analyze correlations in surface management practices and groundwater quality as collected by the GTMP.

The coalition will work with growers through the CGQMP and the MPEP to provide outreach and education on management practices (frost protection irrigation, deep ripping, and proper closure of abandoned wells) which are protective of groundwater quality. Currently Tulare County does not maintain well destruction records. Annually, the KBWQA will summarize and evaluate grower information respective of abandoned well procedures to better quantify those areas at highest potential risk.

1.5 Regional Groundwater Trend Monitoring Approach

Groundwater quality monitoring data is currently collected by various entities throughout the state. Programs which require the development, or continuation, of groundwater quality monitoring include government agencies (California Department of Pesticide Regulation [**DPR**], Department of Drinking Water, State Water Resources Control Board and United States Geological Survey [**USGS**]), as well as those created by legislative mandates (SB 1938, AB 3030, and the Sustainable Groundwater Management Act [**SGMA**]). Additionally, dairy industry representatives, Integrated Regional Water Management Groups, municipalities, and water districts, are other stakeholders which may be interested in groundwater quality monitoring data. Despite these many programs and stakeholders, no single integrated and coordinated groundwater monitoring network is currently in place in the Central Valley.

The RWQCB has expressed an interest in the development of a regional groundwater monitoring effort to be coordinated by ILRP coalitions. Other RWQCB programs (dairies, landfills, underground storage tanks, etc.) are designed to monitor targeted contaminants, specific to potential point sources, and do not account for regional trends in groundwater quality. As a nonpoint source program, the ILRP is tasked with monitoring region-wide groundwater quality, intended to document varied groundwater conditions to establish trends over time.

The KBWQA recognizes the importance of coordinating with other ILRP coalitions, as well as other entities, to develop a regional monitoring program. Implementation of groundwater monitoring programs is costly and complex. The development of a coordinated groundwater quality regional monitoring program would be more effective and efficient than multiple programs and agencies working individually.

As described in GTMP plans submitted by other coalitions, coordination, planning, and development of a regional monitoring strategy will require significant effort. Development of a governance structure, monitoring design, and implementation strategy are anticipated to require a minimum of two years, expected to be completed in 2019. As envisioned by other ILRP coalitions, collaboration is expected to include other agencies, groundwater monitoring groups and stakeholders. In particular, Groundwater Sustainability Agencies (**GSAs**) are anticipated to play a key role in development of a regional groundwater monitoring effort. As part of SGMA, GSAs are also required to develop a groundwater monitoring strategy for priority pollutants. However, those monitoring plans are not required to be implemented until 2020, three years after some ILRP coalitions are required to submit their GTMPs. Additionally, General Order requirements for the KBWQA do not coincide with timelines for other ILRP coalitions and groundwater monitoring stakeholders. As described in the General Order, the approval of the GAR determines required submittal deadlines. The KBWQA received conditional approval of the GAR in February 3, 2016 resulting in multiple submittal and monitoring deadlines to be required in advance of other ILRP coalitions.

While continuing to support regional monitoring planning efforts, the KBWQA proposes to monitor groundwater quality areas, as defined in the following sections of this GTMP. The KBWQA monitoring sites could later be incorporated into a regional strategy. As previously noted, development of a regional monitoring strategy is anticipated to be completed in 2019. Groundwater quality data (collected in the interm by the KBWQA) could help inform regional monitoring decisions, as well as provide a baseline for future monitoring. This approach would allow for the collection of groundwater quality data in advance of the development of a coordinated regional monitoring strategy.

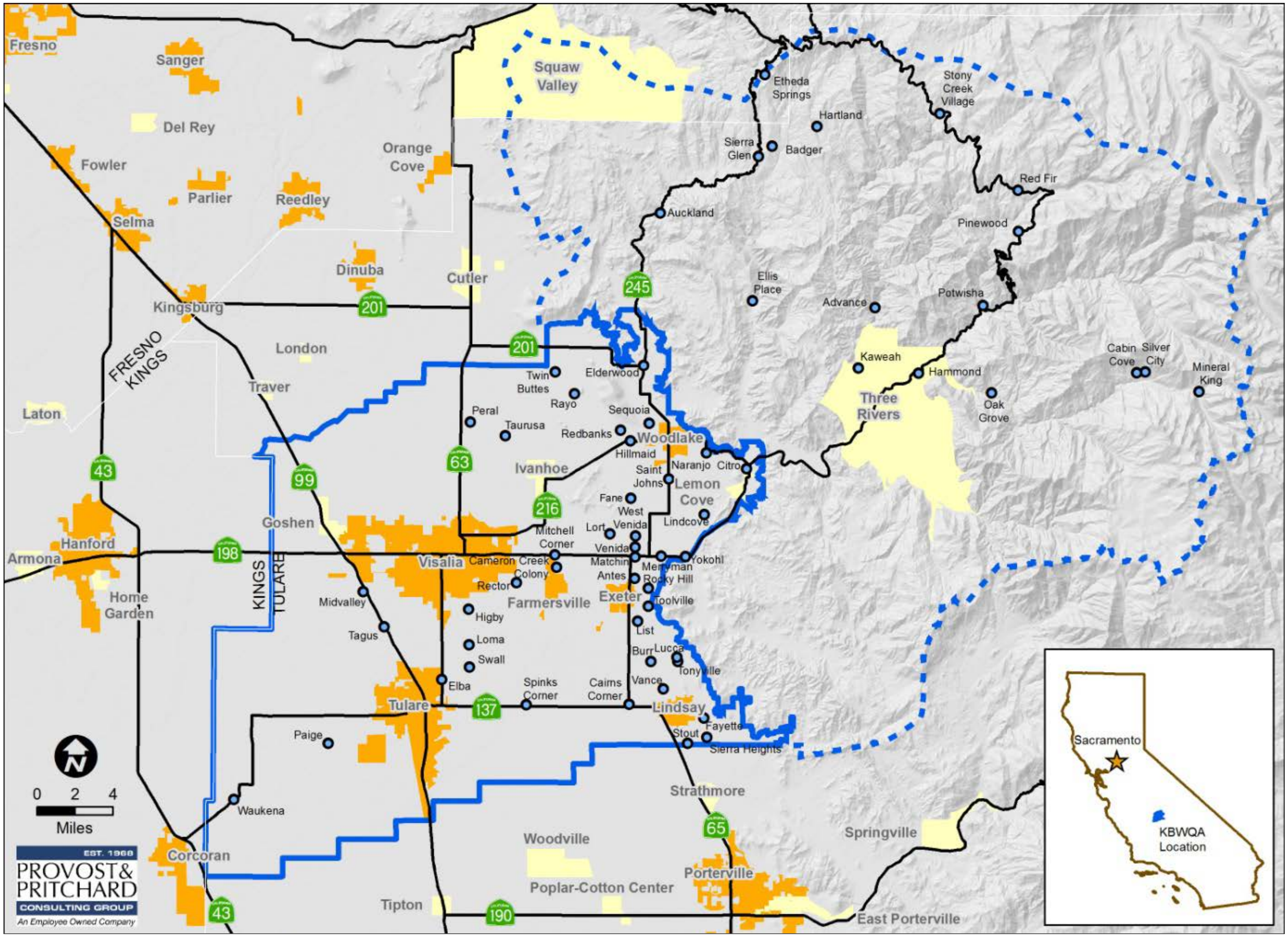


Figure 1-1. Vicinity and Boundary Map

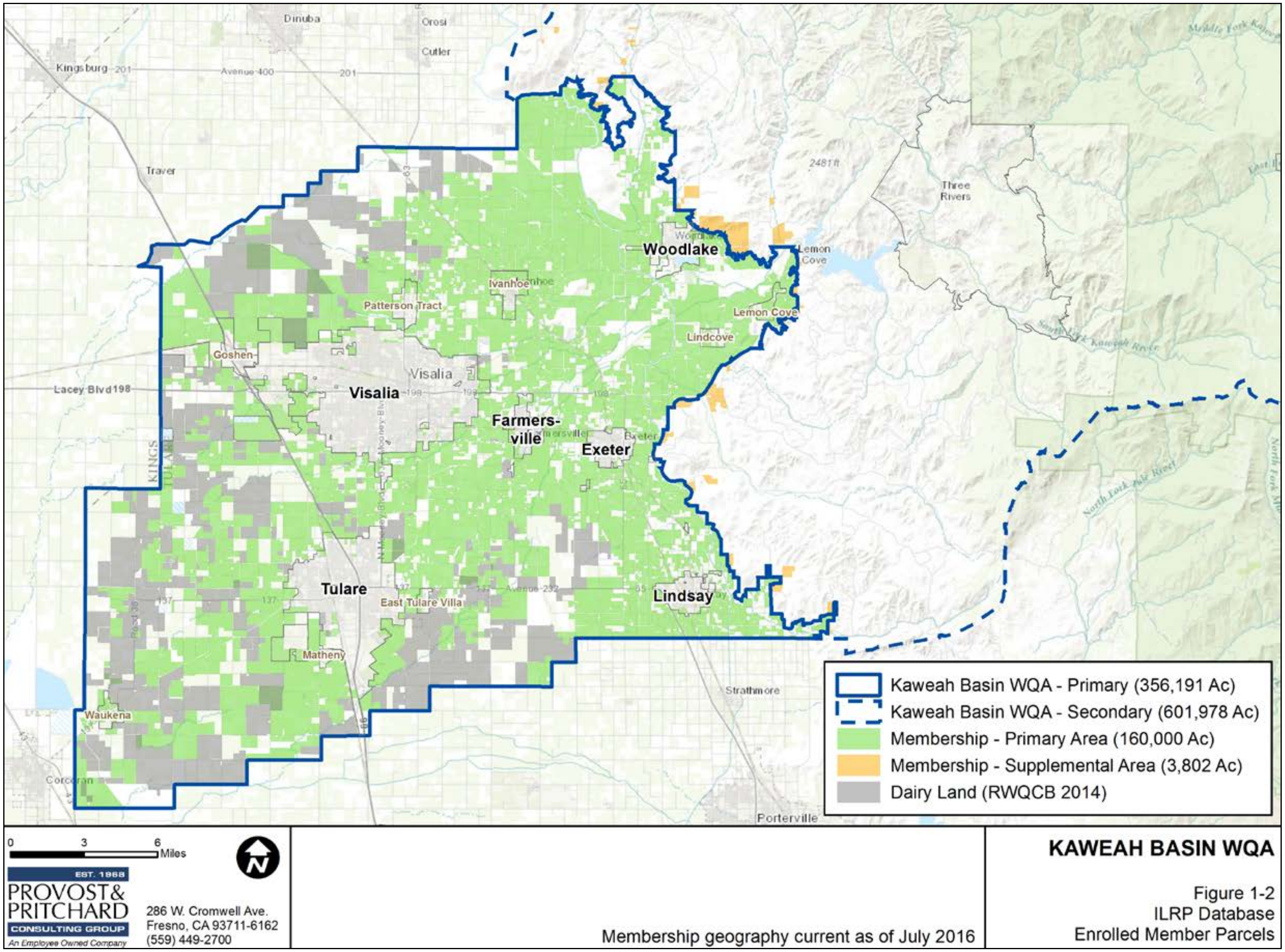


Figure 1-2. KBWQA Enrolled Member Parcels and Dairy Map

2 Regional Setting

2.1 General Characteristics

The KBWQA is primarily located in Tulare County. The eastern edge is bounded by the Sierra Nevada Mountains that contains the watershed of the Kaweah River. The northern boundary roughly follows the Kaweah Delta Water Conservation District (**KDWCD**) northern border, but has been extended further north to include Stone Corral Irrigation District (**SCID**) and portions of Cottonwood Creek. The western boundary generally follows the Kings County Water District (**KCWD**) and Tulare Irrigation District (**TID**) borders. The southern boundary generally follows the KDWCD southern border, but approximately follows the Avenue 212 alignment as it heads towards the foothills.

The boundary area is divided into Primary and Supplemental Areas. The Primary Area, which contains almost all of the irrigated agriculture of the KBWQA, is approximately 356,000 acres (approximately 160,000 irrigated acres). The Supplemental Area, which contains the mountainous regions and little to no irrigated agriculture, is 602,000 acres (approximately 3,802 irrigated acres). The total boundary covers approximately 958,000 acres, making the KBWQA one of the smaller coalition areas within the Southern San Joaquin Valley. The Kaweah River provides the majority of the surface water supply to the area. The KBWQA area is comprised of the Kaweah River, the St. Johns River, the Kaweah River watershed above the Valley floor, and several minor foothill watersheds. Major rivers and streams in the sub-basin are illustrated in **Figure 2-1**.

The Kaweah sub-basin is located on the east side of the south-central portion of the San Joaquin Valley within the Tulare Lake Basin (**Figure 2-2**). The San Joaquin Valley, which is the southerly part of the great Central Valley of California, extends about 250 miles from the Sacramento-San Joaquin Delta area at the north end to the Tehachapi Mountains at the south end. The Kaweah sub-basin lies between the Kings Groundwater sub-basin on the north and west, the Tule Groundwater sub-basin on the south, and crystalline bedrock of the Sierra Nevada foothills on the east. The sub-basin generally comprises lands in the KDWCD and is the approximate extent of the Primary KBWQA area. The sub-basin's watershed is to the east and is the approximate extent of the Supplemental KBWQA area.

The Tulare Lake Basin is defined by the General Order as bounded by the crest of the Sierra Nevada Mountain Range to the east, the San Joaquin River to the north, the Westlands Water Quality Coalition and the crest of the Southern Coast Ranges to the west, and the crest of the San Emigdio and Tehachapi Mountains to the south. Tributary streams drain to depressions, the largest of which is the Tulare Lake bed located to the west of the KBWQA boundary. The Kings, Kaweah, and Tule Rivers and, on occasion, the Kern River, discharge into the Tulare drainage basin including the beds of the former Tulare, Buena Vista, and Kern Lakes at times when flows exceed the capacity of foothill reservoirs and of the irrigation diversion systems. The Tulare Lake Basin is generally considered a "closed basin" as most surface waters are contained within the Basin boundaries and only in years of exceptionally high precipitation do surface waters flow into the San Joaquin River Delta system.

2.2 Climate

The climate in the Primary KBWQA area can be defined as semi-arid desert. The average rainfall in the KBWQA is 10.94 inches, based on historical statistics for the City of Visalia. Nearly 80 percent of the rainfall occurs between November and March, when most crops are not irrigated. Rainfall in summer months, when irrigation is at its highest, is typically negligible. A summary of the monthly averages of temperature and precipitation from the time period of 1981 to 2010 for the Primary Area is provided in **Table 2-1**. On the Valley floor, average monthly rainfall during the wettest month of the year is only approximately 2 inches, while the total annual rainfall averages just under 11 inches.

The climate in the Supplemental Area can be divided into the foothill and mountain areas. Foothill temperatures near Three Rivers tend to be somewhat cooler than the valley floor with a yearly average precipitation of approximately 25 inches. The higher elevation mountain areas near Lodgepole in the Sequoia National Forest are typically the coolest in the region with normal winter lows down to 16°F and summer highs up to 73°F. The mountain area yearly precipitation averages 44.53 inches with the highest average precipitation occurring in January. Much of the winter precipitation occurs in the form of snow, melting in spring and early summer, increasing flows in rivers and streams in the Supplemental Area. A summary of the temperature and precipitation for the Supplemental Area is provided in **Table 2-2**.

2.3 Agriculture

Irrigated agriculture and dairies are the predominant land use within the KBWQA Primary Area. Citrus crops are the dominate land use in the eastern portion. The center of the Primary Area has deciduous fruit and nut crops as the primary crops with urban areas also located in the vicinity. In the western half of the study area, dairy land dominates the land use with forage crops dominating the types of crops grown.

Citrus, walnuts and pecans, pistachios, corn, almonds, small grains, alfalfa, grapes, olives, cotton, and stone fruit make up 95 percent of the crops grown within the KBWQA Primary Area. Citrus is the primary crop grown within the Supplemental Area. Most crops in the Supplemental Area are located adjacent to the border between the two areas. **Table 2-3** summarizes crops by acreage and percentage for the KBWQA area based on the most current grower member farm evaluations. Crop locations are illustrated in **Figure 2-3**.

2.4 Geology and Soils

Information obtained from reports prepared for irrigation and water districts in the area, Central Valley Hydrologic Model (**CVHM**) well log texture data, and Natural Resources Conservation Service (**NRCS**) soils reports were summarized for the preparation of the GAR.

The KDWCD covers approximately 71 percent of the Primary KBWQA area. A report prepared by Fugro West, Inc. indicates that most of the fresh groundwater pumped within the KDWCD is from unconsolidated deposits of Pliocene, Pleistocene, and Recent Age. Consolidated marine rocks of Pliocene age and older which contain brackish or salty water constitute the effective base of fresh water (or permeable sediments).

Geologic units that affect the occurrence and movement of groundwater in the KDWCD are generally classified and described as follows:

a. Basement Rocks of pre-Tertiary age consisting of non-water-bearing granitic and metamorphic rocks. In the subsurface, they slope steeply westward from the Sierra Nevada beneath the deposits of Cretaceous age and younger rocks that compose the valley fill.

b. Marine Rock of Tertiary age consisting of non-water-bearing marine sediments including the San Joaquin Formation which overlap the basement complex and underlie the unconsolidated deposits.

c. Unconsolidated Deposits of older and younger alluvium consisting of non-marine, water-bearing material comprised of the Tulare Formation and equivalent units which thicken from zero along the western front of the Sierra Nevada to a maximum of about 10,000 feet at the west boundary of the KDWCD.

d. Alluvial Deposits consisting of coarse-grained, water-bearing alluvial fan and stream deposits including older oxidized and reduced units, and younger alluvium which underlie the older alluvium. The 200 to 500 feet thick oxidized deposits are red, yellow, and brown, consist of gravel, sand, silt and clay, and generally have well-developed soil profiles. Reduced deposits which extend to about 3,000 feet below land surface are blue, green, or gray, calcareous, are generally finer grained than oxidized deposits, and commonly have a higher organic content than the oxidized deposits.

e. Lacustrine and Marsh Deposits consisting of fine-grained sediments representing a lake and marsh phase of equivalent continental and alluvial fan deposition. Only the E-Clay (or Corcoran Clay member) of the Tulare Formation, one of the laterally continuous clay zones in the southern San Joaquin Valley, is found within the KDWCD, extending from the Tulare Lake Bed to U.S. Highway 99 with vertical bifurcation near Goshen. It is about 140 feet thick near Corcoran and the average thickness is about 75 feet.

Soils developed on younger alluvium show little or no profile development and are generally free of underlying clay subsoil or hardpan. Very coarse soils can be found beneath the channels of the Kaweah, Tule and Kings Rivers, with fine-grained deposits occurring in the channel of Cross Creek.

In the eastern portion of the KDWCD, the Rocky Hill fault disrupts pre-Eocene deposits and may locally penetrate older alluvial deposits, potentially restricting the hydrologic connection of aquifers.

A thickening section of unconsolidated deposits is indicated moving west across the KDWCD with modest warping of the Tulare Formation's surface, suggesting regional folding during and after deposition, but having little effect on the patterns of groundwater flow within or at the KDWCD perimeter boundaries.

Other local irrigation districts include Alta, Stone Corral, Ivanhoe, Exeter and Lindmore. These districts surround the KDWCD along the north and east borders. Most of the districts are sloped ranging from 1 to 30 percent and have some form of shallow hardpan. Adobe clay is commonly found on the smooth valley plain near the foothills with coarser materials along current or old streambeds.

2.4.1 CVHM Well Log Texture

Maps prepared from the available extent of the CVHM percent coarse material data based on the upper 200 feet of well logs in the Primary KBWQA area were reviewed. The maps were based on 50-foot increments and are included in as **Figure 2-4**, **Figure 2-5**, **Figure 2-6**, and **Figure 2-7**. For location references, see **Figure 1-1**.

Coarse grain materials are indicated at the 0 to 50 foot interval at the mouth of the Kaweah River outlet and at a couple of other points along the current St. Johns and Kaweah River footprints; development with increasing depth of a coarse material paleo-channel near the mouth of the current Yokohl Creek; and general coarsening with depth towards the west.

Fine grain materials are indicated at all intervals at the Twin Buttes area to the northeast and the Exeter, Cairns Corner, Tulare, and Lindsay areas to the south and southeast.

The interval with the overall coarsest material is the 50 to 100 foot depth. The finest material in the western area occurs in the shallowest 0 to 50 foot interval with the eastern areas generally consistently of fine materials at all depths unless located at the Kaweah River or Yokohl Creek mouths.

2.4.2 Supplemental Area Regional Geologic Setting

The Sierra Nevada Mountain range, partially located within the KBWQA Supplemental Area, is the result of initial and continued uplifting of the Pacific and North American tectonic plates. As illustrated in **Figure 2-8**, the area is predominately plutonic rocks of the Mesozoic era, interspersed with outcrops of mixed rocks of pre-Cambrian to Mesozoic era. Portions of the Sequoia and Kings Canyon National Parks are located in the uppermost elevations of the area.

Lake Kaweah is centrally located near the western border. Small areas of Quaternary alluvium are located up- and down-stream of the lake, with larger areas along the foothill borders.

2.4.3 Soil and Soil Surface Characterization

Due to the differences in their formation and topography, the soils in the Primary and Supplemental Areas display different characteristics. Soils in the Primary Area are generally finer while the Supplemental Area soils are sandier with sporadic rock outcroppings as illustrated in **Figure 2-9**. These textures can be further defined by soil type as detailed in **Figure 2-10**.

The predominant soil texture in the Primary KBWQA Area is loam at approximately 52 percent. Fine sandy loam (22 percent) and sandy loam (13 percent) located near streams and channels make up another 35 percent. The remaining 13 percent includes more course grained soils, and finer grained materials located along the eastern, north central, and south central boundaries. In general, the areas to the east are more subject to hardpan with coarser soils along the riverbeds atop the alluvial fan and clay deposits off to either side of the fan.

The portion of the Supplemental Area with soil information available is mostly comprised of sandy loam (40 percent), coarse sandy loam (23 percent), loam (13 percent), and rock outcrop (8 percent). Soils that are more coarse are found along the primary river and stream pathways. The number of rock outcroppings increases to the east of the area with information available.

Areas of higher permeability are located within the study area near ancient and modern stream channels, consistent with the CVHM well log texture analysis. Areas of higher runoff potential are located predominantly in the northeastern area and along the eastern border (**Figure 2-11**).

The steepest portion of the KBWQA is in the Supplemental Area, with slopes as high as 20 to 50 percent. The land surface becomes more level as the foothills transition to the valley floor with the Primary Area having little slope and topography.

2.5 Hydrogeology

2.5.1 Groundwater Levels

Recent depth to groundwater was determined based on the Department of Water Resources (**DWR**) Groundwater Information Center (**GIC**) data for Spring 2015 (**Figure 2-12**) and Spring 2016 (**Figure 2-13**). In general, the depth-to-water is shallowest in the northeast and southeast with an overwhelmingly southwest regional direction of flow (**Figure 2-14** and **Figure 2-15**). A groundwater ridge occurs along the Kaweah River footprint with troughs on either side. The deepest groundwater is found in the western area at or near the Tulare County border. The affects of pumping are apparent in groundwater contours. The Supplemental Area has limited data available, but it can be assumed that, other than within fractured bedrock, groundwater will generally follow the topography.

The Terminus Dam was constructed in 1962, which coincides with a regional drop in groundwater levels of 40 feet or more. Recent high water years can be noted in the mid- to late-1980s with water levels generally not reaching those elevations in the years following. The State of California is currently in a drought state of emergency and the Central Valley, in particular, is in a severe overdraft condition, as is apparent in hydrographs for valley floor wells. Groundwater levels have generally been in decline since 1999 with a recent decline of up to 100 feet in some wells since approximately 2008.

Recently, greater than normal rains fell in the Central Valley in 2016 due to El Niño and La Niña weather conditions; however in general, the amount of rain was not sufficient to significantly reduce the amount of groundwater pumping or to alleviate overdraft conditions.

2.5.2 Water Bearing Zones

As discussed in the GAR and further detailed in the referenced *Geology, Hydrology, and Quality of Water in the Hanford-Visalia Area* by M. G. Croft and G. V. Gordon, 1968, the formations underlying the Kaweah primary area can be described by geologic unit as follows in increasing depth order:

- Flood basin deposits from near surface to approximately 50 feet thick with unconfined groundwater of poor quality. Generally perched groundwater.
- Younger alluvium approximately 50 feet thick which is generally unsaturated except in the eastern-most portions.
- Oxidized older alluvium approximately 600 feet thick with unconfined and semi-confined groundwater of calcium or magnesium carbonate type. Considered to be a portion of the major producing aquifer for the Kaweah primary area.
- Reduced older alluvium approximately 1,000 feet thick with semi-confined and confined groundwater of sodium bicarbonate type. Considered to be a portion of the major producing aquifer for the Kaweah primary area.
- Lacustricne and marsh deposits up to 3,000 feet thick with confined groundwater occurring of poor water quality.

Based on information presented in the *California Groundwater Bulletin 118 for the Kaweah Subbasin*, total depths of municipal/irrigation wells in the Kaweah Subbasin range from 100 to 500 feet; however, the data was last updated in 2004. Similarly, information provided in the *Groundwater Ambient Monitoring and Assessment (**GAMA**), Domestic Well Project, Groundwater Quality Data Report, Tulare County Focus Area* (California State Water Resources Control Board, 2013) indicate that domestic wells in the Kaweah Subbasin tend to be completed to total depths of 100 to 300 feet, although some wells are completed to depths as great as 450 feet. Both of these general depth ranges are reasonably corroborated with the Fugro Report's cross sections included in the CGQMP as Appendix B: Fugro Cross Sections. In general, deeper wells are to the west and shallower wells are to the east.

Based on the Fugro Report's cross sections, most wells completed shallower than approximately 400 feet are completed within the oxidized older alluvium (Qooo) and are unconfined. Towards the foothills, the Qooo decreases in thickness and eventually pinches out however most wells are completed correspondingly shallower. Some wells to the west are landed in the E-Clay (QTl – lacustrine or marsh deposits, while some deeper wells throughout and most easterly wells are partially or completely screened in the older reduced alluvium (Qoar). While well identifications are clear in the Fugro Report's cross sections, the well types are not specified. According to the GAMA and Bulletin 118 information, most wells are likely completed within the Qooo formation (Fugro West, Inc., 2007).

Wells either without or with damaged or improperly constructed surface seals may provide vertical preferential pathways for vertical migration between aquifers through the materials filling the annular space between the well casing and the formation walls. Additionally, wells with perforated intervals emplaced across, or both above and below, semi- or confining layers may also provide a vertical preferential pathway. When aquifers of differing water qualities are connected in this manner, water quality may be affected in both aquifers.

2.5.3 Recharge

Recharge areas within the Primary valley floor area were identified and mapped using a combination of publicly available resources. To assess relative recharge rates, identified recharge areas were layered over CVHM vertical conductivity (**VK**) layers of varying thicknesses (**Figure 2-16**). The fastest VK values are included in the areas near the mouths of the Kaweah River and the current Yokohl Creek and extending northwestward. The slowest VK values include the areas to the north and south of the two alluvial fans (Kaweah and Yokohl creek locations) and the better part of the south-central and southeast areas.

The most significant recharge area is at and near the mouth of the Kaweah River due to the shallowest groundwater at less than 50 feet and the upgradient position to the majority of the KBWQA area. The second most significant recharge area is the northwest-southeast trending belt of relatively high VK values and multiple surface waterways and impoundments. Depth-to-water in this area ranges from 50 to 150 feet and less of the KBWQA area is downgradient.

2.6 Hydrology

As described in the following sections, the hydrology of the KBWQA area is chiefly comprised of the Kaweah River and its tributaries. A schematic of the natural and constructed distributary system within the KBWQA is illustrated in **Figure 2-17** which identifies surface water inputs to agricultural conveyance system including multiple turnouts from the Friant-Kern Canal (Kaweah Delta Conservation District, 2010).

2.6.1 Kaweah River

The Kaweah River originates in the Sierra Nevada Mountains at an elevation of more than 12,000 feet and drains a watershed area of about 630 square miles above the foothill line. Terminus Reservoir, located about 20 miles east of Visalia, has a tributary drainage area of about 560 square miles and produces about 95 percent of the total runoff of the watershed. Dry (Limekiln) Creek and Yokohl Creek are tributaries entering the Kaweah River below Terminus Reservoir. Dry Creek has a sufficient amount of runoff generated to add to the flow of the Kaweah River, at least in the spring months, in all years. Yokohl Creek often does not flow year round and only has sufficient volume to reach the Kaweah system in years of above-normal precipitation.

Water in the Kaweah River is largely retained within the KDWCD and only in infrequent years of exceptionally large runoff are there any flows to the Tulare Lakebed. Since completion of Terminus Dam and Reservoir in 1962, seasonal storage of Kaweah River flows has been provided, which assists in regulation of runoff for irrigation demand schedules. Other than maintenance of a minimum pool for recreation, no carryover storage is provided in the reservoir.

At McKays Point, the Kaweah River divides into the St. Johns River and Lower Kaweah River branches. Water is diverted from the St. Johns and Lower Kaweah Rivers and distributed through a complex system of natural channels and canals owned or operated by numerous agencies and entitlement holders within the Kaweah River Basin, all of which have established rights to the use of water from the Kaweah River.

Flows in the Kaweah River have been continuously measured since 1903 at gauging stations near Three Rivers, located about 7 miles upstream from Terminus Reservoir. Completion of Terminus Dam and Reservoir in 1962 required the relocation of an existing gauging station and the establishment of two new upstream stations: 1) Kaweah River at Three Rivers, and 2) South Fork of Kaweah River near Three Rivers. The annual totals of measured flows at these two sites after 1962 continue the long-term record of Kaweah River near Three Rivers. During the period of record from 1903-04 through 1999-2000, the average annual flow was 432,928 AF, ranging from a minimum of 93,400 AF in 1976-77 to a maximum of 1,402,000 AF in 1982-83.

2.6.2 Creeks and Streams

Along with Dry and Yokohl Creeks, there are additional foothill watersheds (Sand Creek, Stokes Mountain, Cottonwood Creek and Lewis Creek) that have the potential to generate runoff which reaches the valley floor. These runoff conditions only exist during years of above normal precipitation conditions and/or during times of foothill-related flood conditions.

Flows from Sand Creek and Cottonwood Creek, if they exist in sufficient volume, intercept the Kaweah River system in the reach of Cross Creek just east of Highway 99. Flows from these watersheds are only sufficient in volume to reach Cross Creek on an approximate once-in-ten year basis. Flows from Stokes Mountain impact only the local valley floor below the watershed. The principal impact is on the Friant-Kern Canal and the Redbanks area, located northeast of Ivanhoe.

The last foothill-level watershed with any potential impact on the valley floor is that of Lewis Creek. Lewis Creek enters the valley floor in the Lindsay area and courses to the northwest before eventually turning west- and southwesterly. The natural channel on the valley floor has been eliminated and replaced with a man-made channel that is directed principally along property lines, eventually entering into the distribution system of the Farmers Ditch Company in the area of the Herbert Preserve, located southeasterly of Spinks Corner. Actions on the lands of the Herbert Preserve by the Sequoia Riverlands Trust are designed to allow Lewis Creek water to spread across the Trust property for beneficial use purposes and to mitigate downstream damage.

2.6.3 Friant-Kern Canal

The Friant-Kern Canal (**Canal**) flows from north to south near the eastern edge of the valley floor, providing irrigation water for several federal water contractors in Tulare and Kings County. Surrounding lands slope gently from east to west. The KBWQA exercises no authority over the Canal water districts, and customers that receive water from the Canal within the KBWQA primarily have either earthen channel or piped distribution systems. At the southernmost point on the Canal, it interties with the Kern River. During high flow events, excess Friant-Kern water is diverted into the Kern River channel in Bakersfield. The water is used for groundwater recharge in the Kern River channel or re-diverted downstream into large groundwater recharge facilities on the Kern River Fan (e.g., Kern Water Bank, Pioneer Banking Project, City of Bakersfield's 2800 Acres).

Table 2-1. Primary Area Temperature and Precipitation Summary

Primary Area Temperature and Precipitation Summary			
Based on Average Weather for Visalia, California 1981 to 2010 http://www.usclimatedata.com/climate/visalia/california/united-states/usca1204			
Month	**Average High Temperature in °F**	**Average Low Temperature in °F**	**Average Precipitation (in)**
January	55	39	1.93
February	61	42	1.85
March	67	46	2.01
April	73	49	0.94
May	82	56	0.35
June	89	62	0.16
July	94	67	0
August	93	65	0
September	88	60	0.16
October	78	53	0.59
November	64	44	1.22
December	55	38	1.73
Annual Average/Total:	**74.9**	**51.8**	**10.94**

Table 2-2. Supplemental Area Temperature and Precipitation Summary

Supplemental Area Temperature and Precipitation Summary			
Based on Average Weather for Three Rivers, California 1981 to 2010 http://www.usclimatedata.com/climate/three-rivers/california/united-states/usca1555			
Month	**Average High Temperature in °F**	**Average Low Temperature in °F**	**Average Precipitation (in)**
January	57	36	4.69
February	61	38	4.49
March	66	41	4.21
April	72	44	2.24
May	82	51	0.91
June	90	58	0.31
July	97	64	0.08
August	96	63	0.04
September	90	58	0.47
October	78	49	1.26
November	64	40	2.68
December	56	35	3.70
Annual Average/Total:	**75.8**	**48.1**	**25.08**

Table 2-3. Crops by Acreage

2015 Crops by Acreage		
Crop	KBWQA Area	
	Acres	Percent of Cropped Area
Citrus	48,354	35.8%
Walnuts & Pecans	26,520	19.6%
Pistachios	10,311	7.6%
Almonds	9,809	7.3%
Alfalfa	6,399	4.7%
Grapes	5,931	4.4%
Corn	5,570	4.1%
Cotton	4,995	3.7%
Olives	4,002	3.0%
Stone Fruit	3,976	2.9%
Grains (Small)	3,788	2.8%

Note: Information based on Kaweah ILRP database compiled from information in 2015 farm evaluation document.

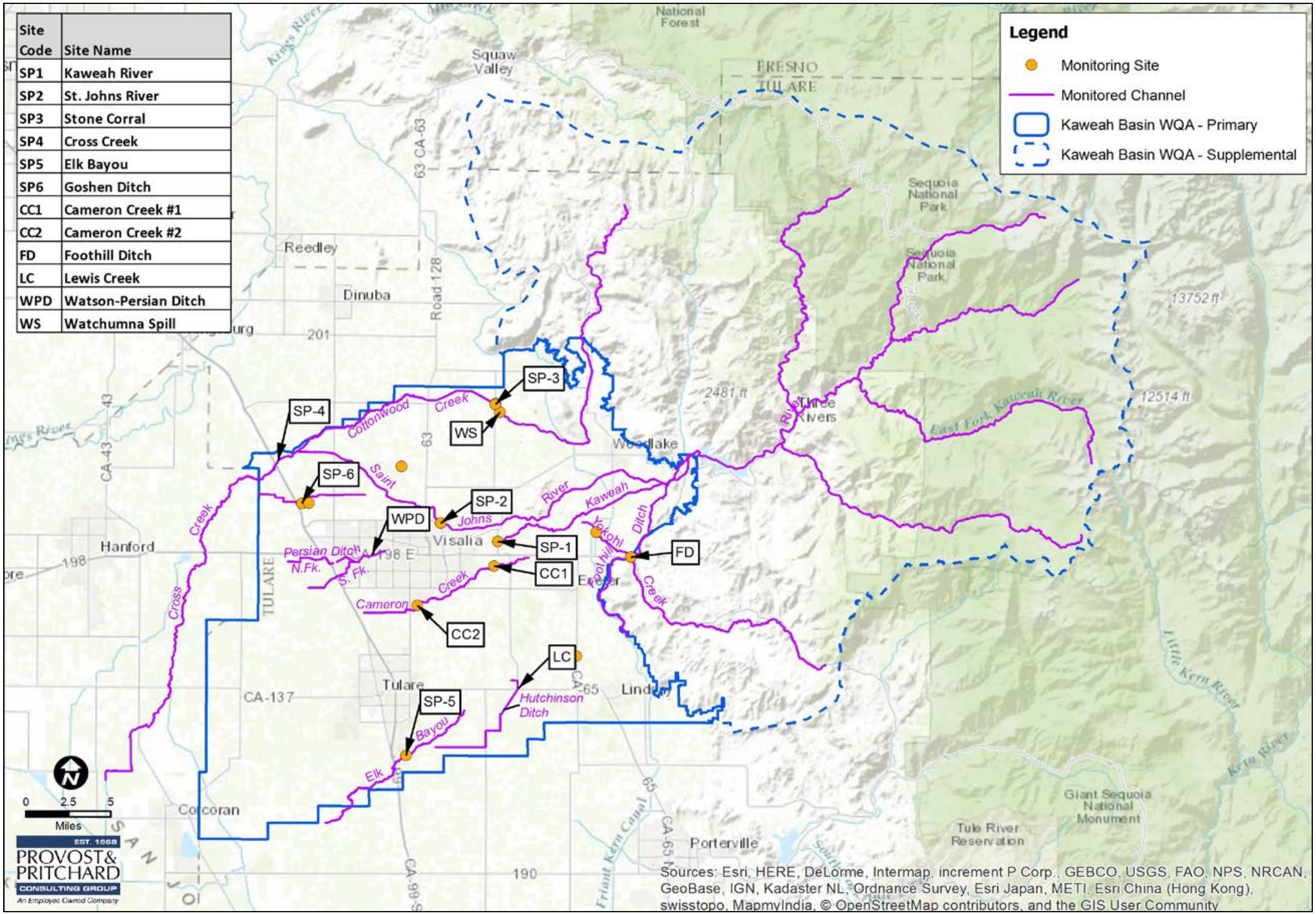


Figure 2-1. Major Hydrology

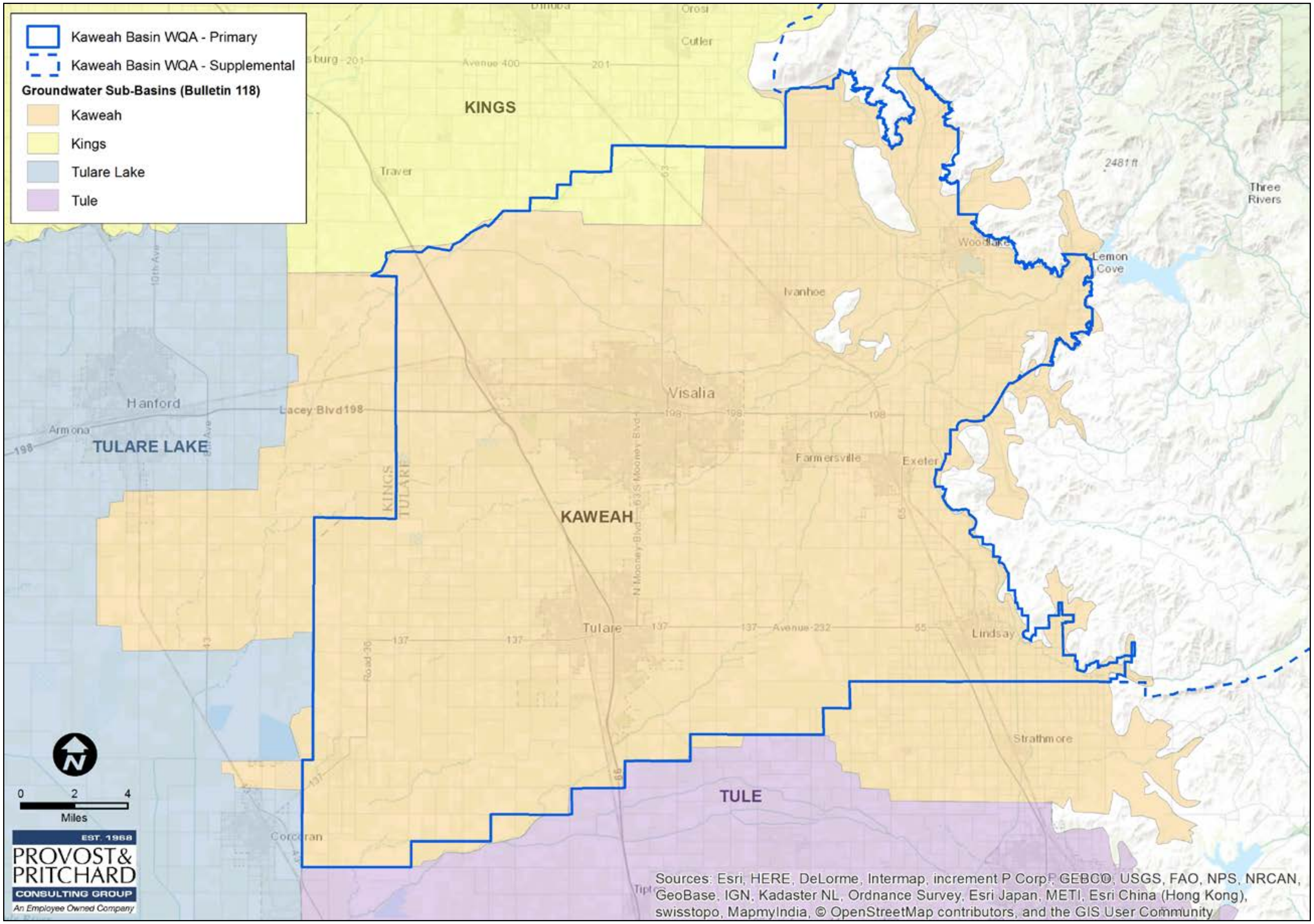


Figure 2-2. Groundwater Basins

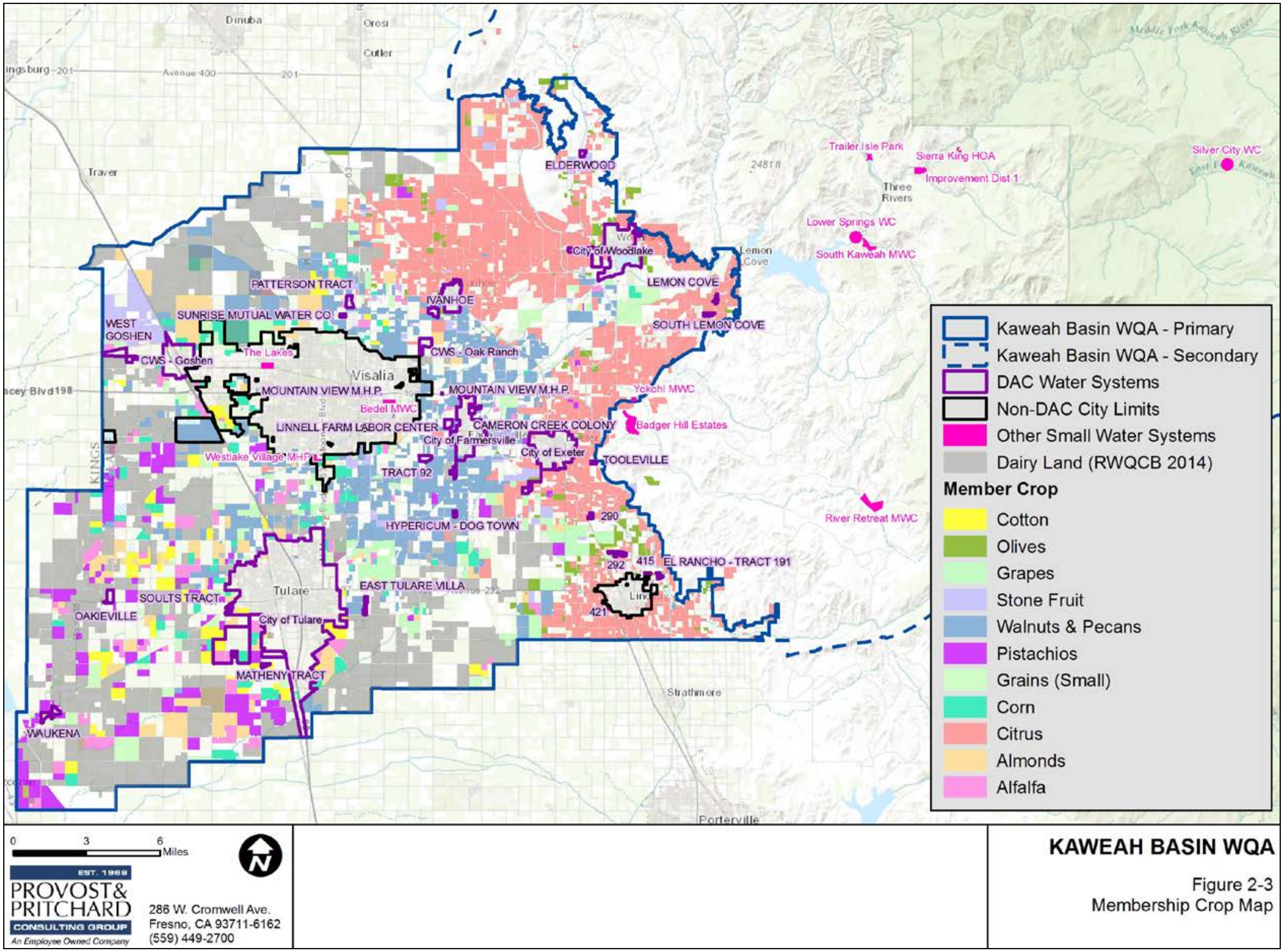


Figure 2-3. Crop Map

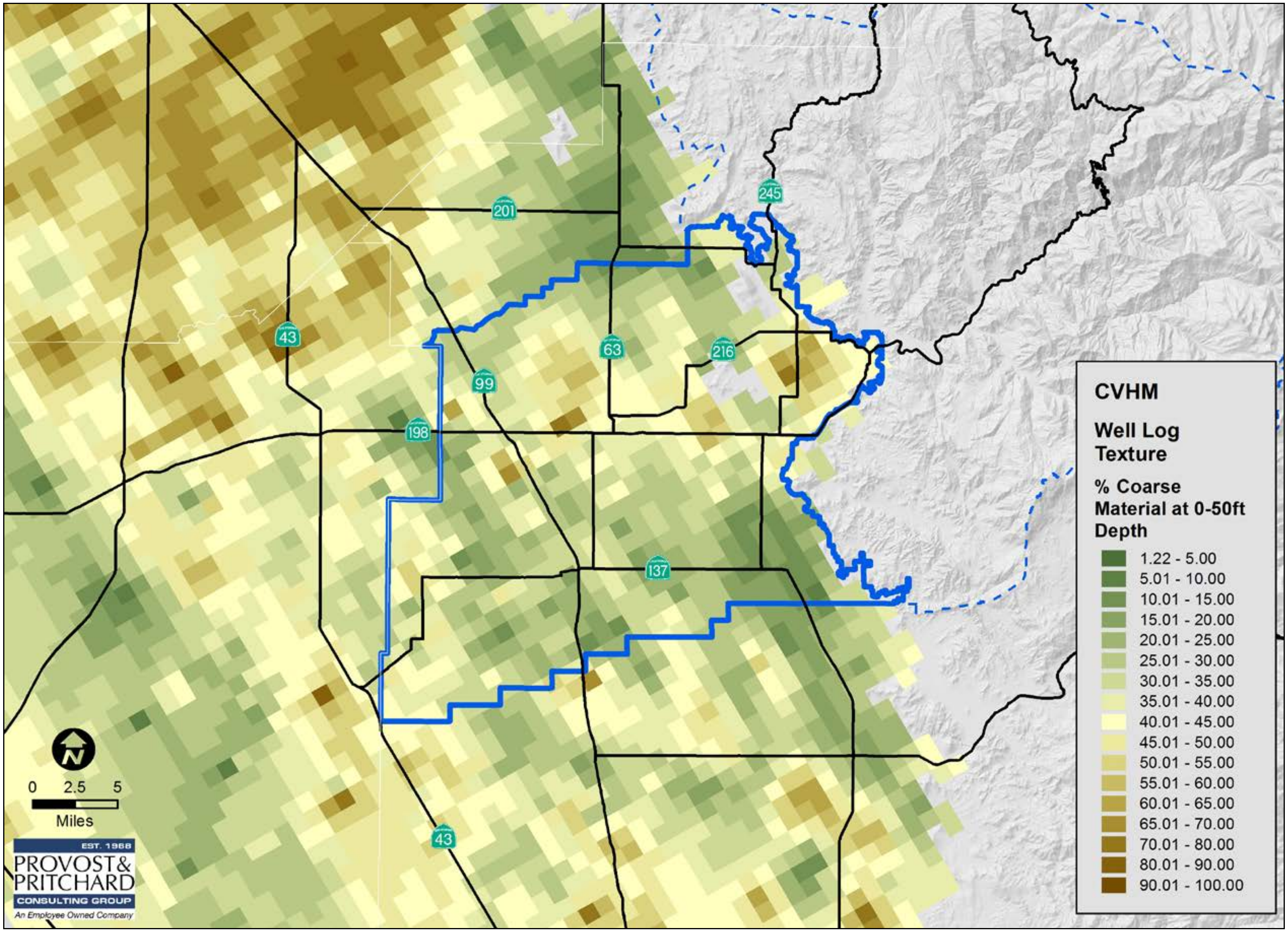


Figure 2-4. CVHM Well Log Texture at Depth 0-50 feet

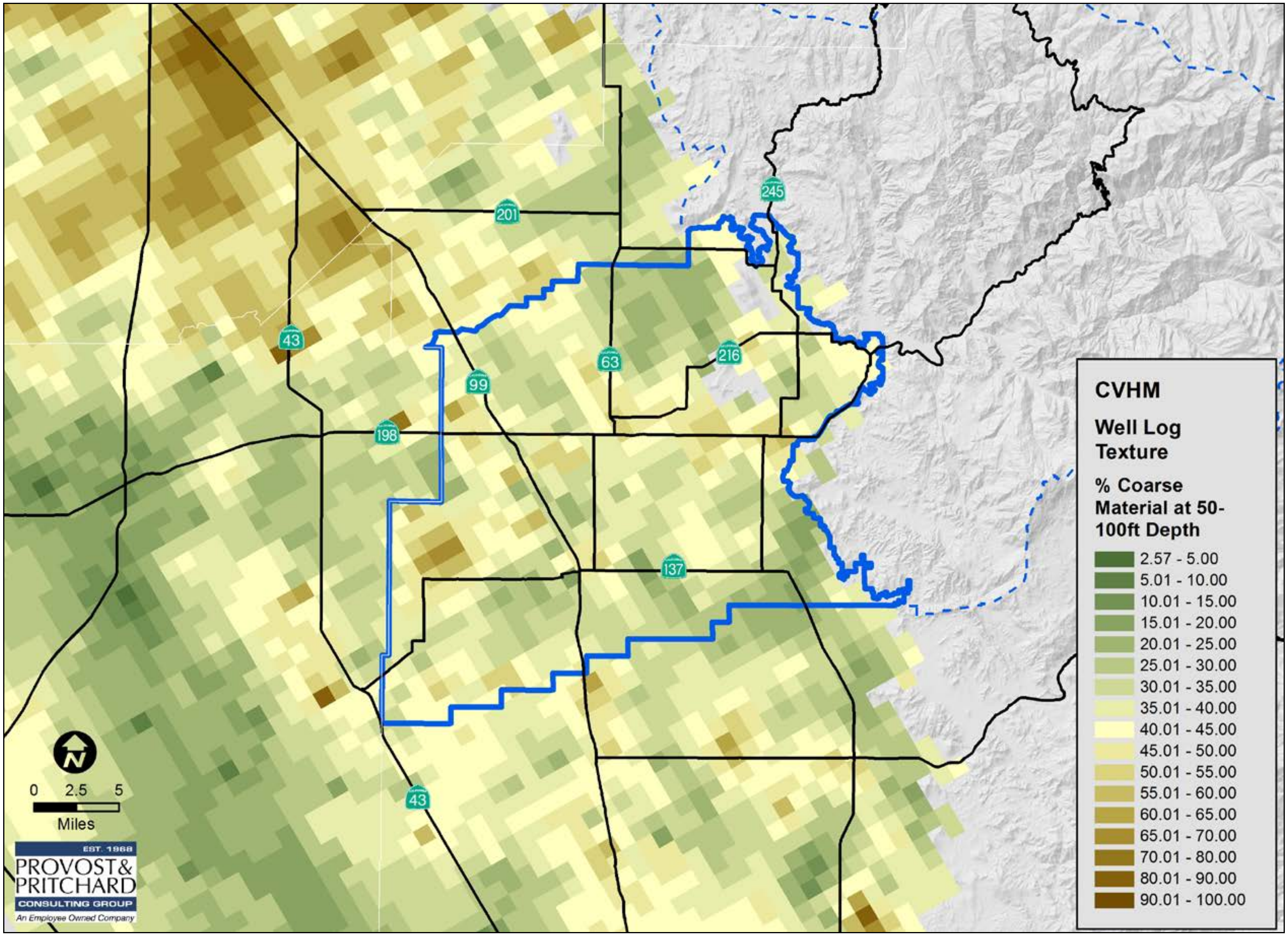


Figure 2-5. CVHM Well Log Texture at Depth 50-100 feet

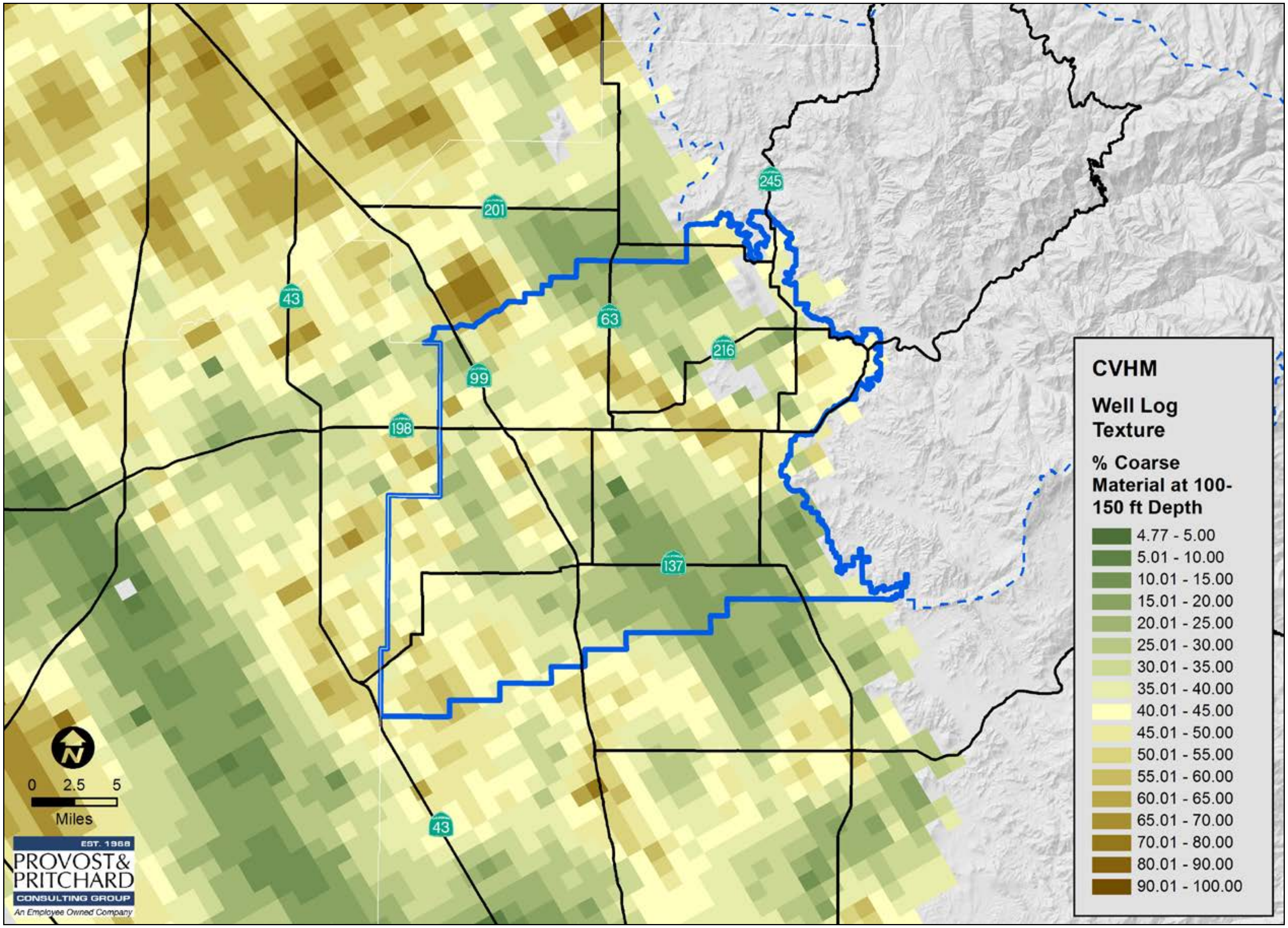


Figure 2-6. CVHM Well Log Texture at Depth 100-150 feet

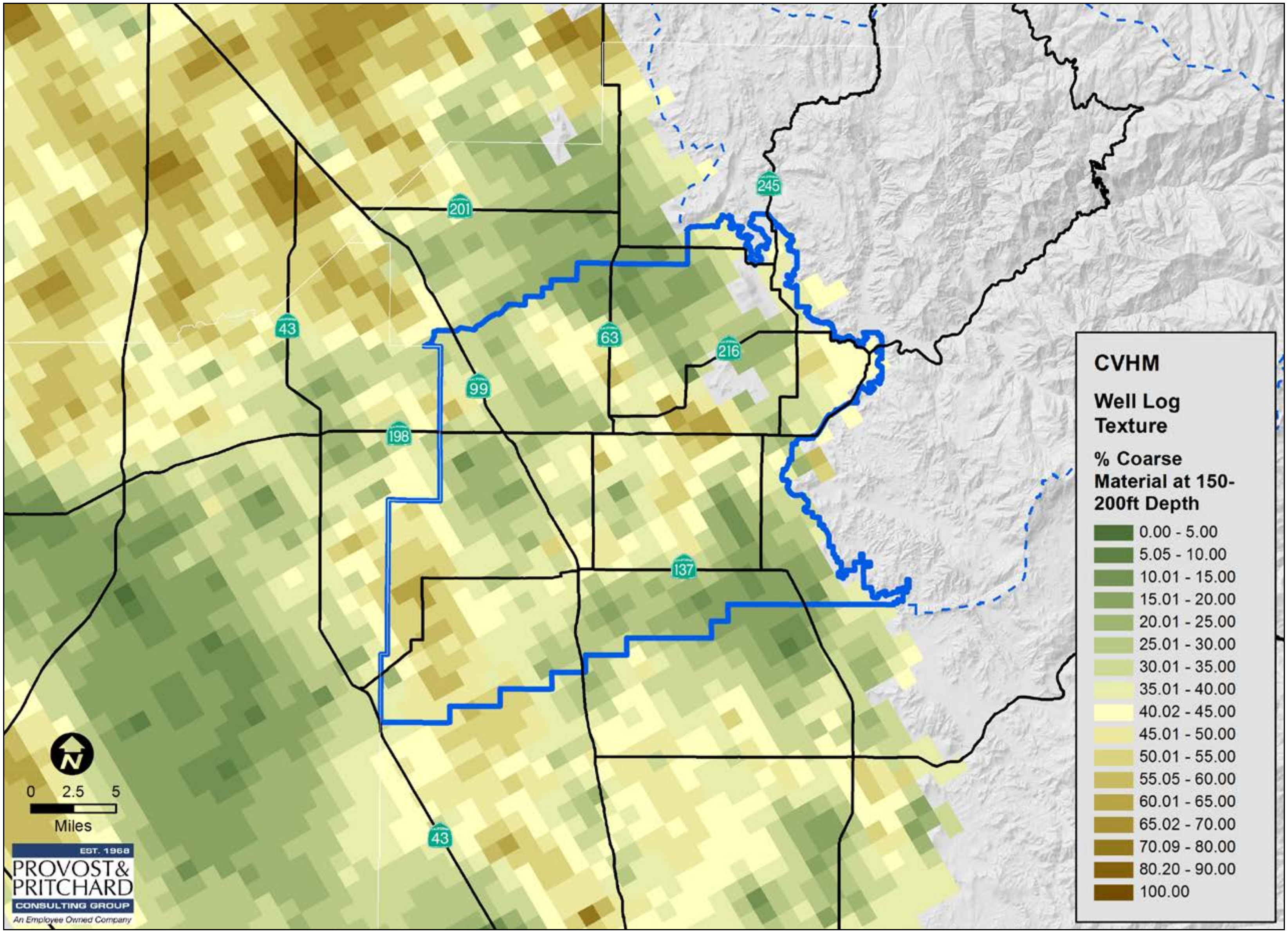


Figure 2-7. CVHM Well Log Texture at Depth 150-200 feet

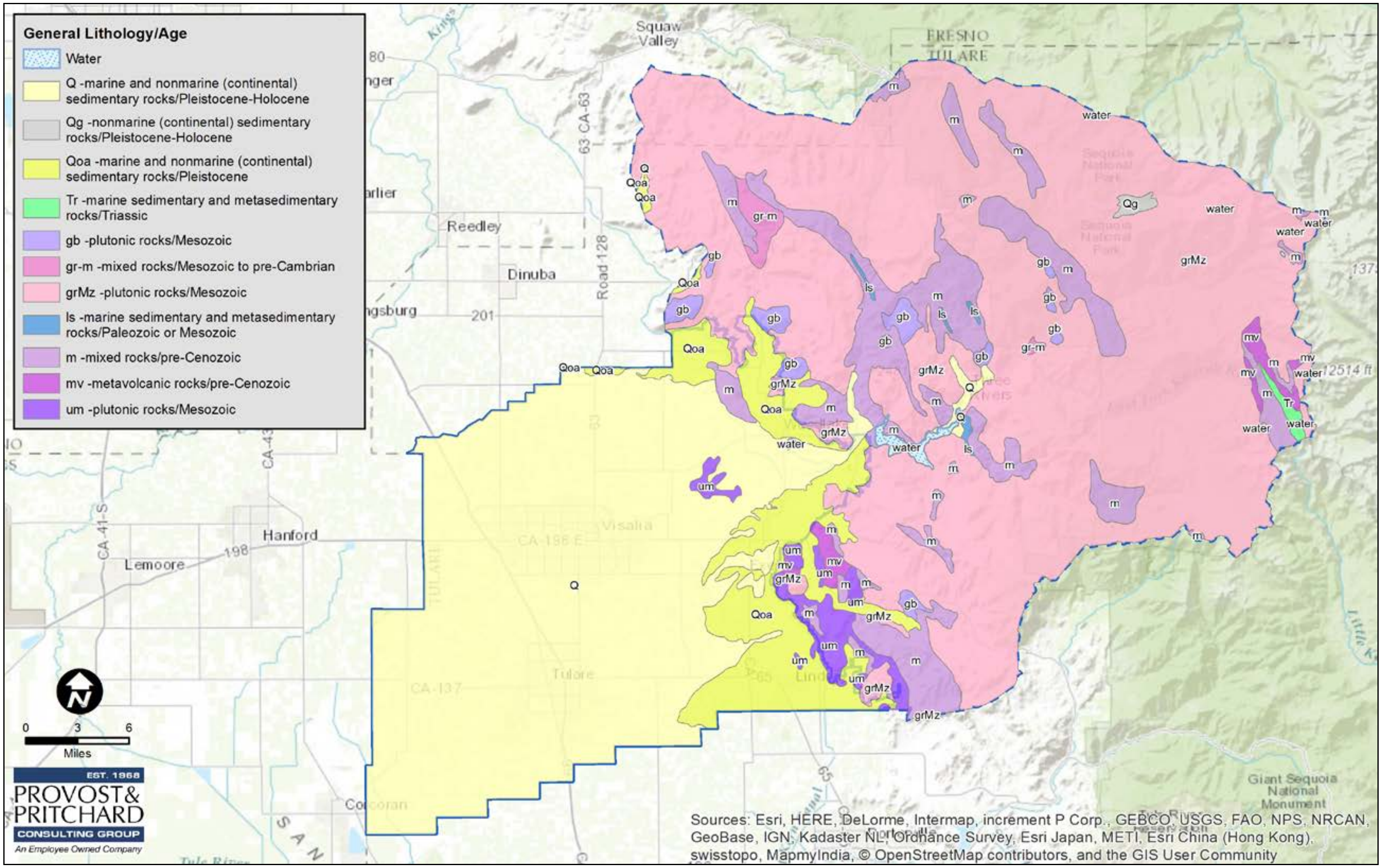


Figure 2-8. Geology Map

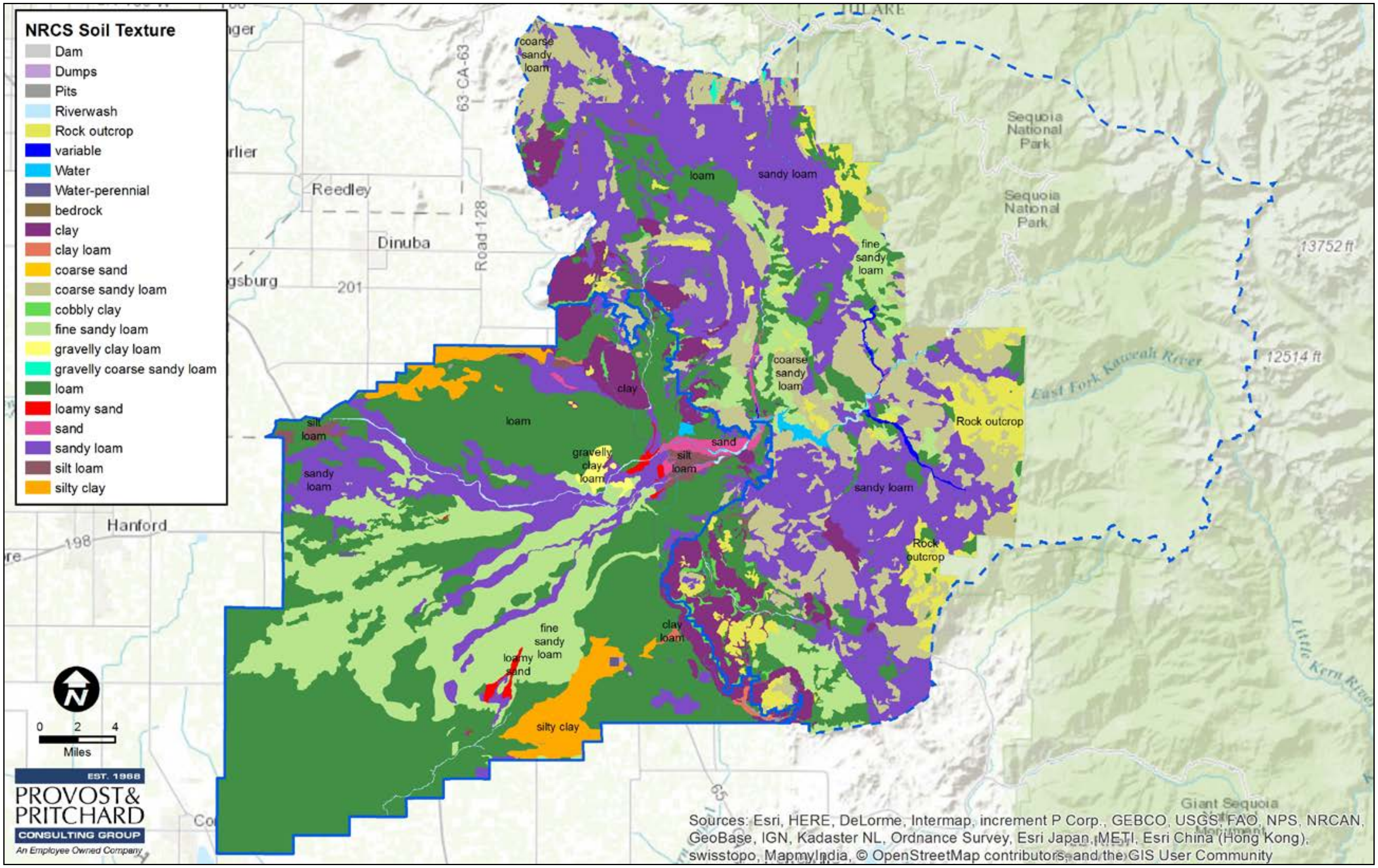


Figure 2-9. Soil Texture

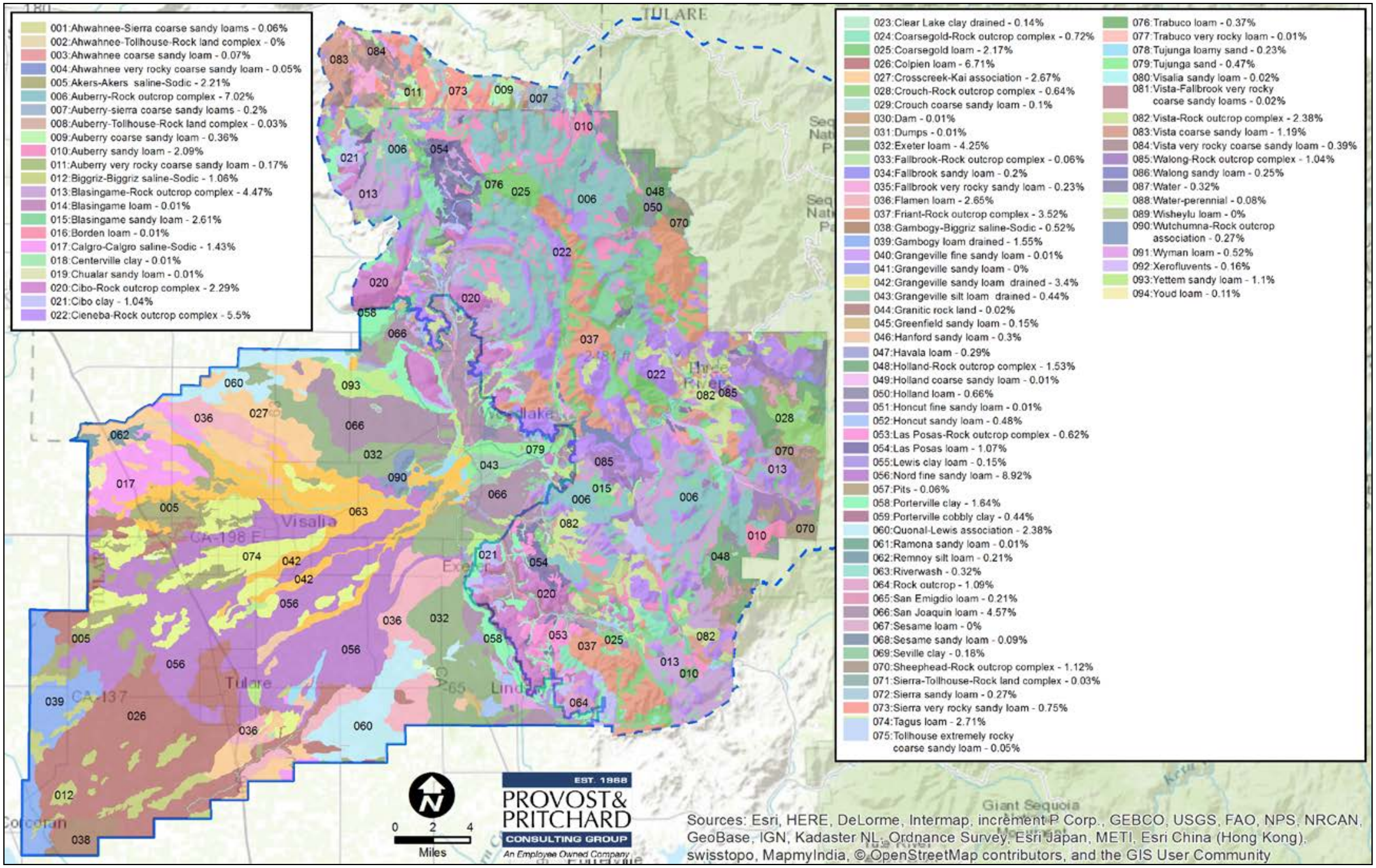


Figure 2-10. Soil Type

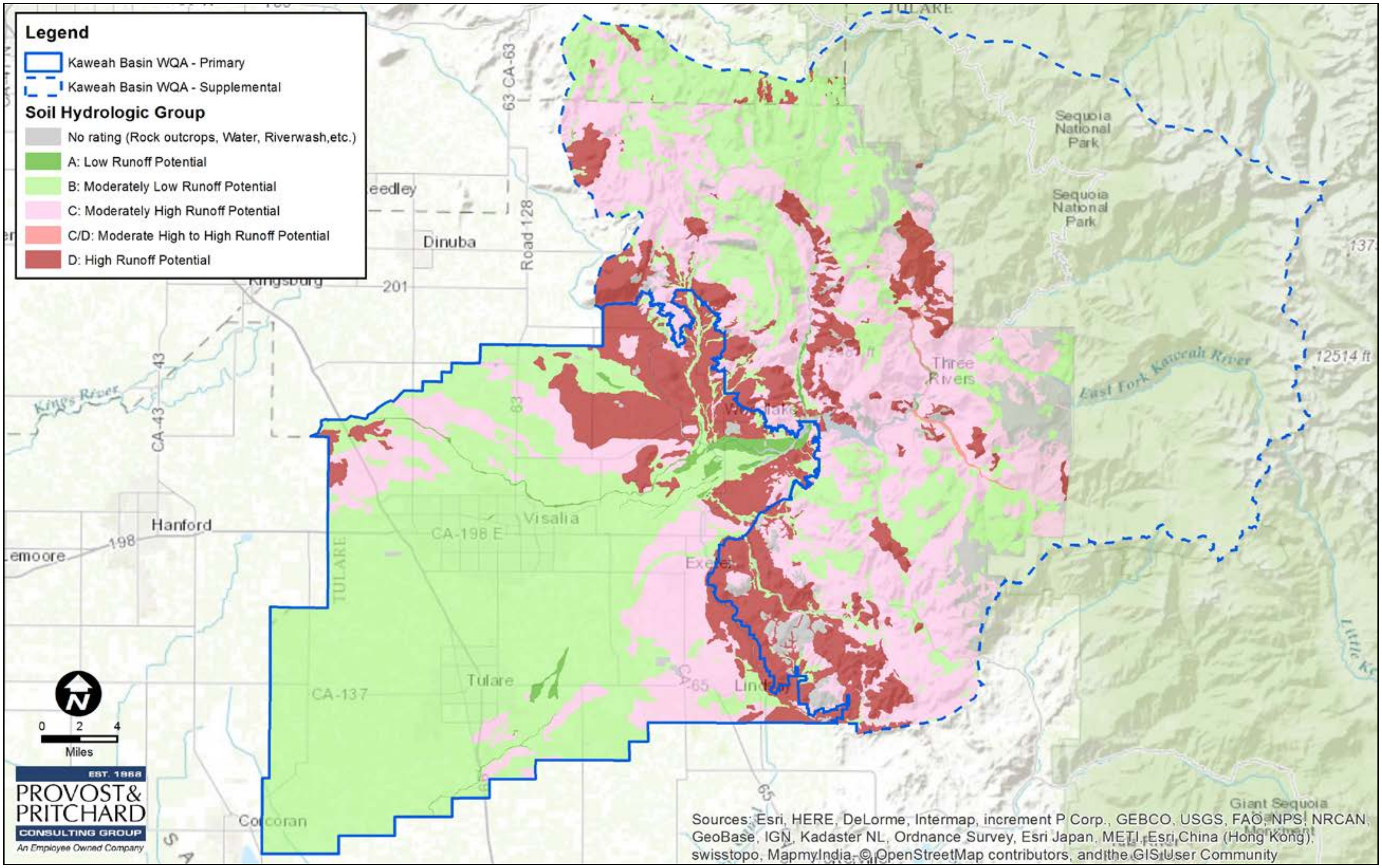


Figure 2-11. Runoff Potential

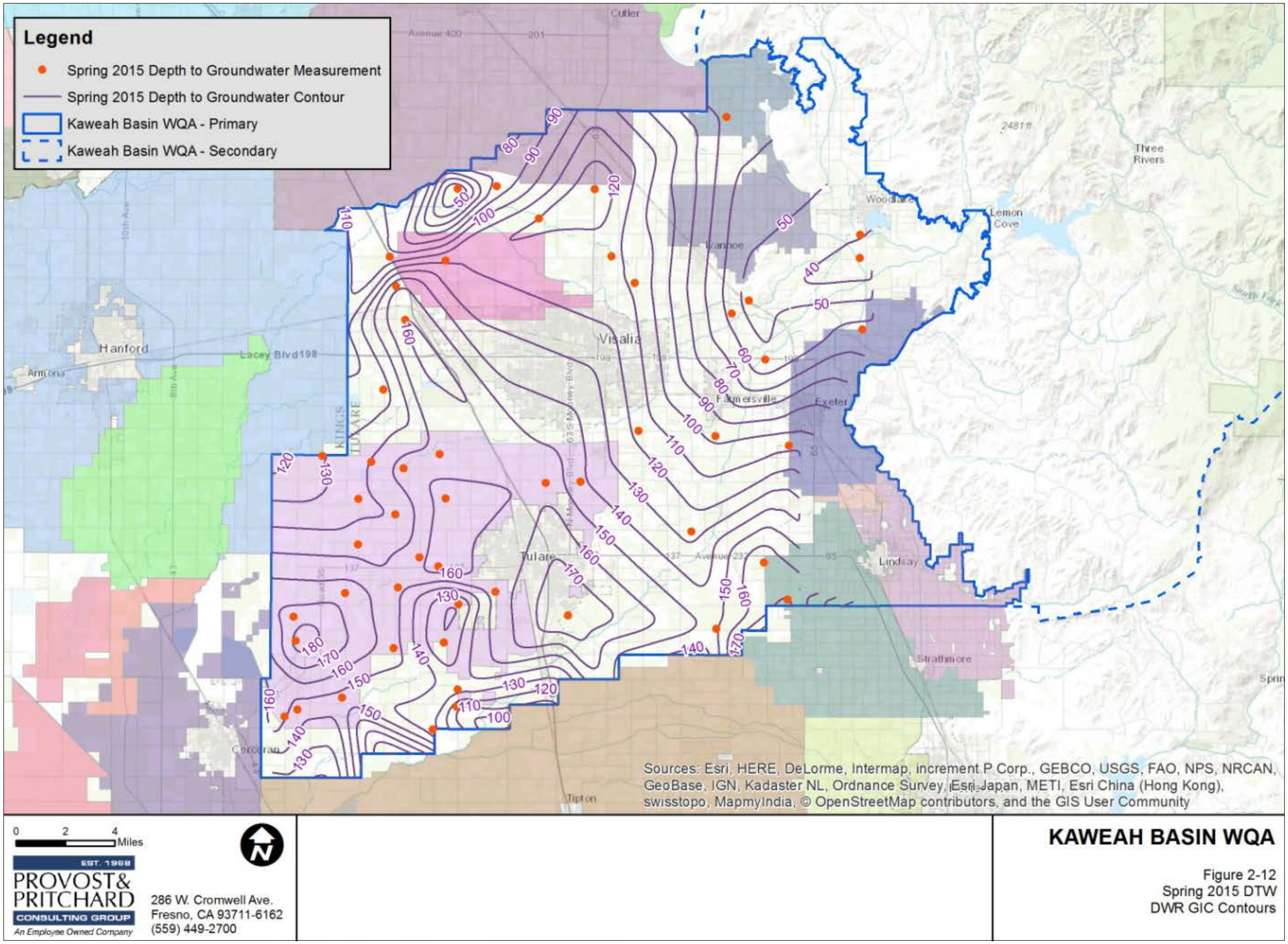


Figure 2-12. Spring 2015 Depth to Groundwater

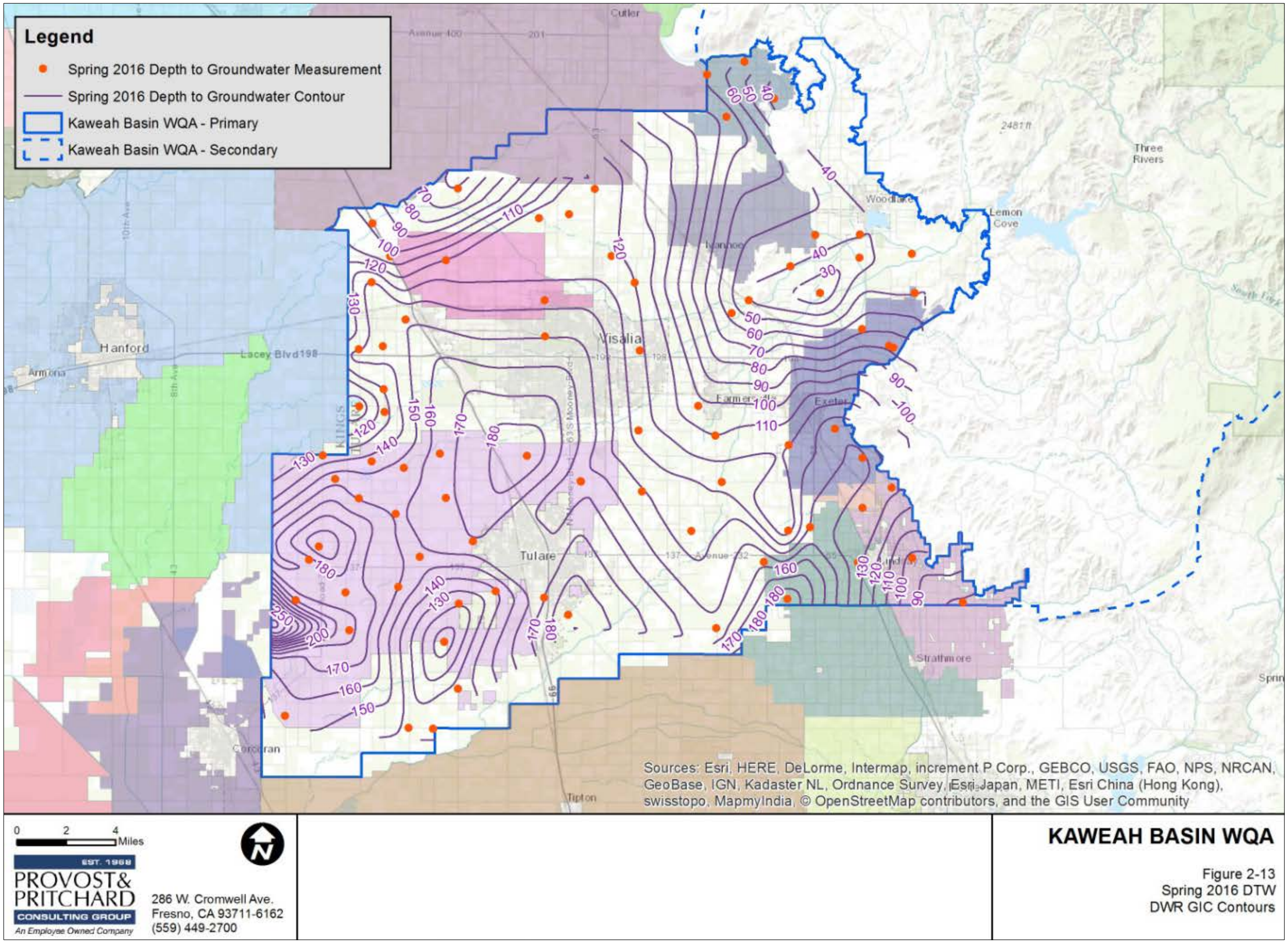


Figure 2-13. Spring 2016 Depth to Groundwater

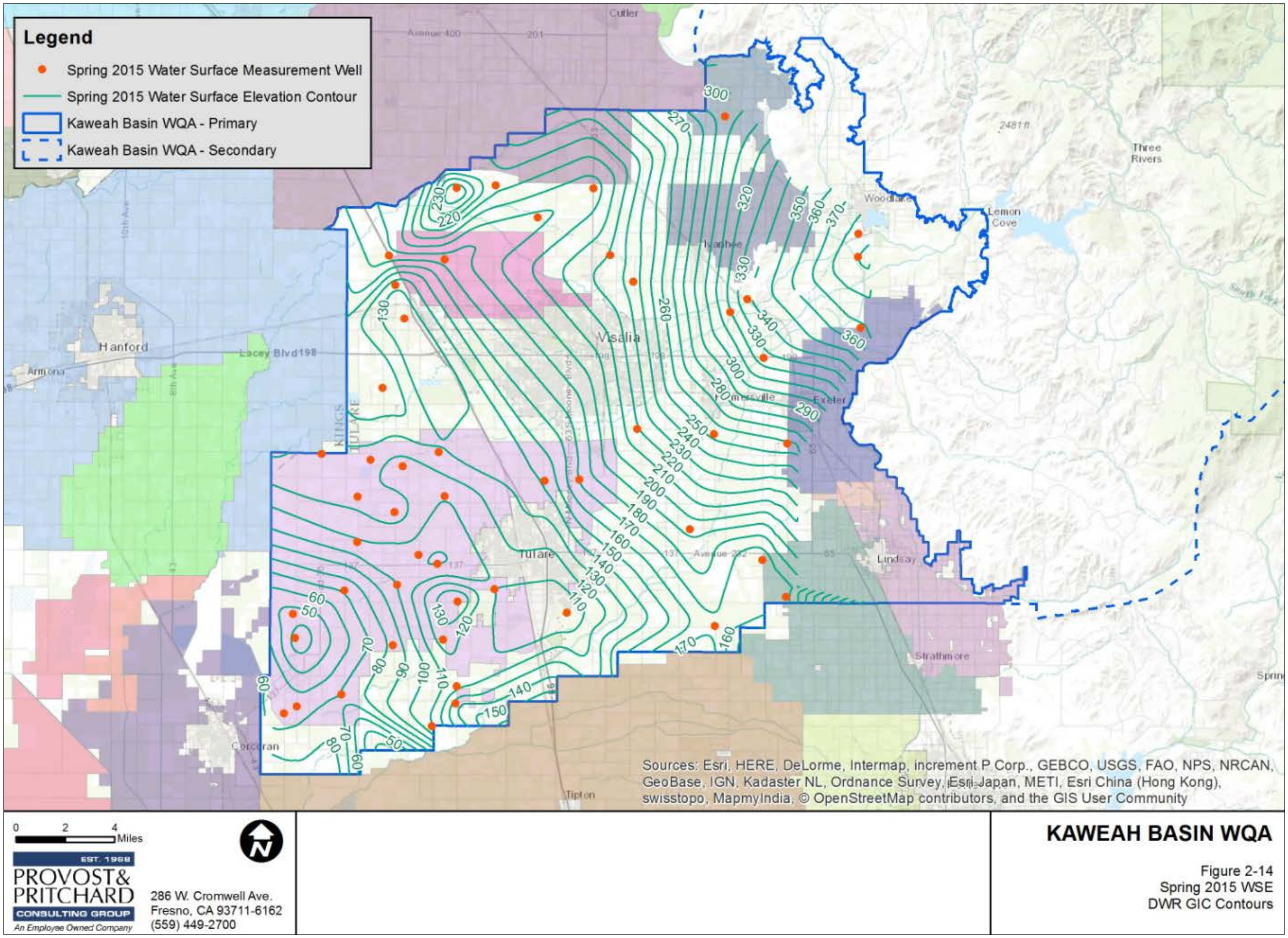


Figure 2-14. Spring 2015 Groundwater Surface Elevation

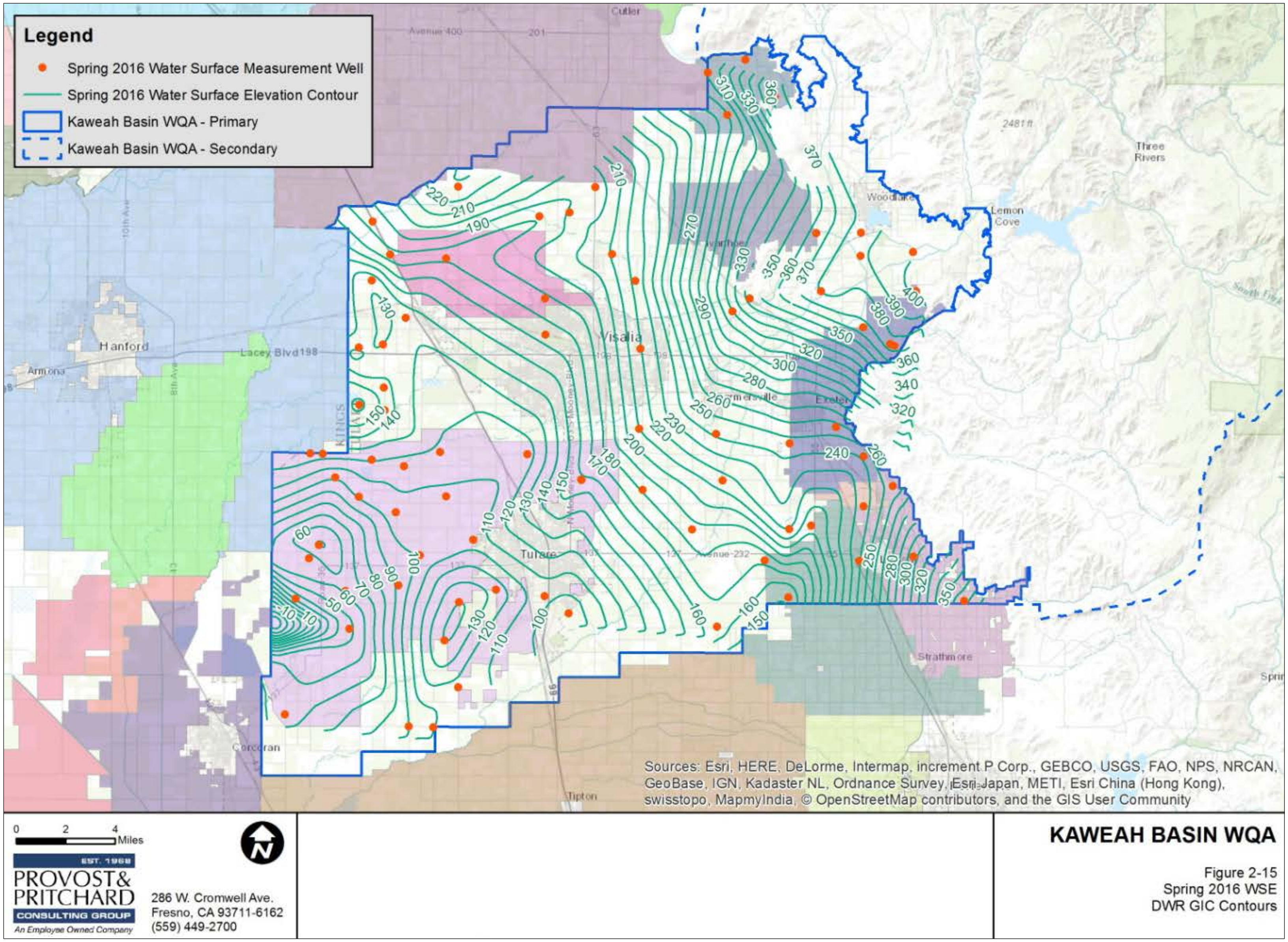


Figure 2-15. Spring 2016 Groundwater Surface Elevation

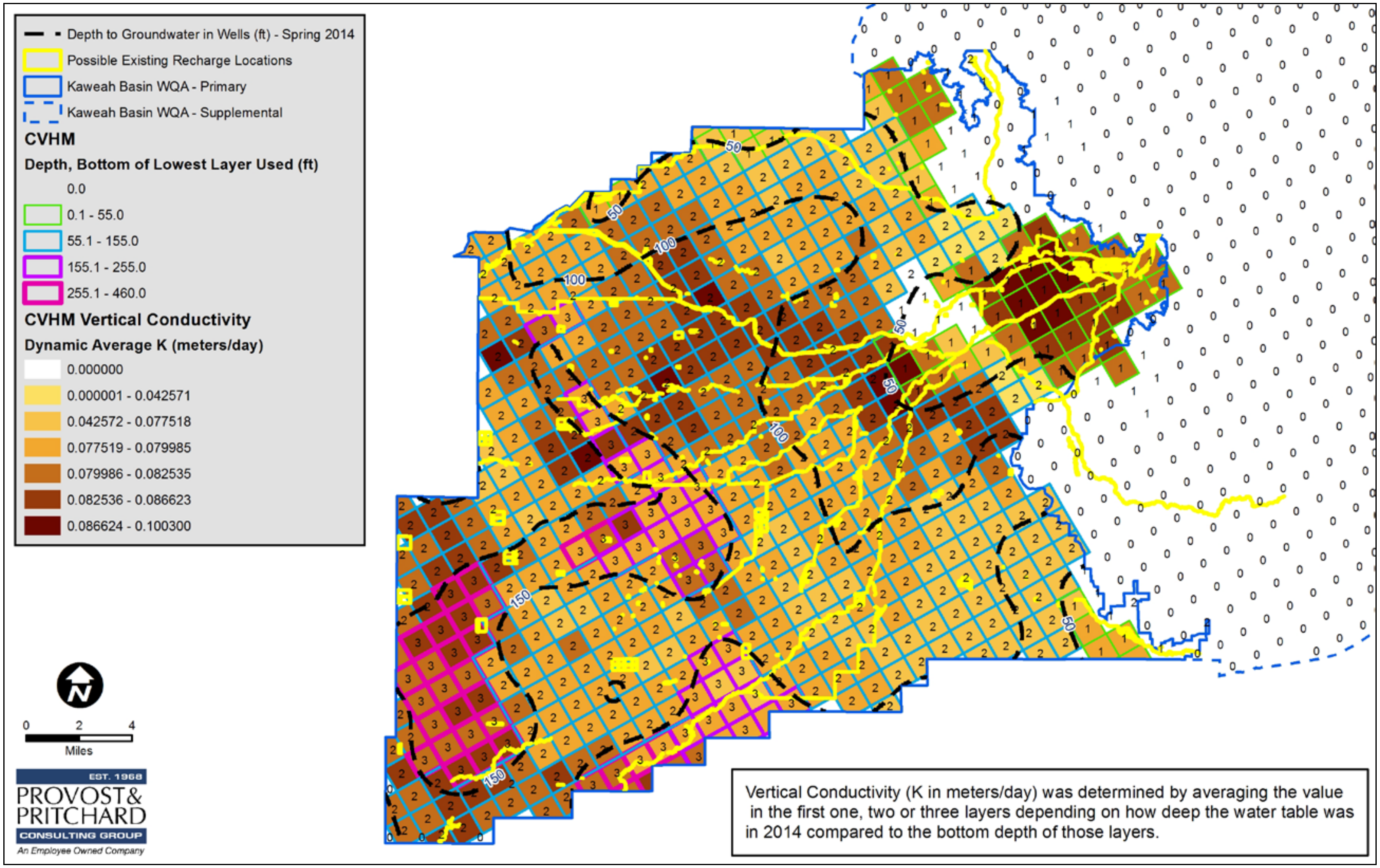
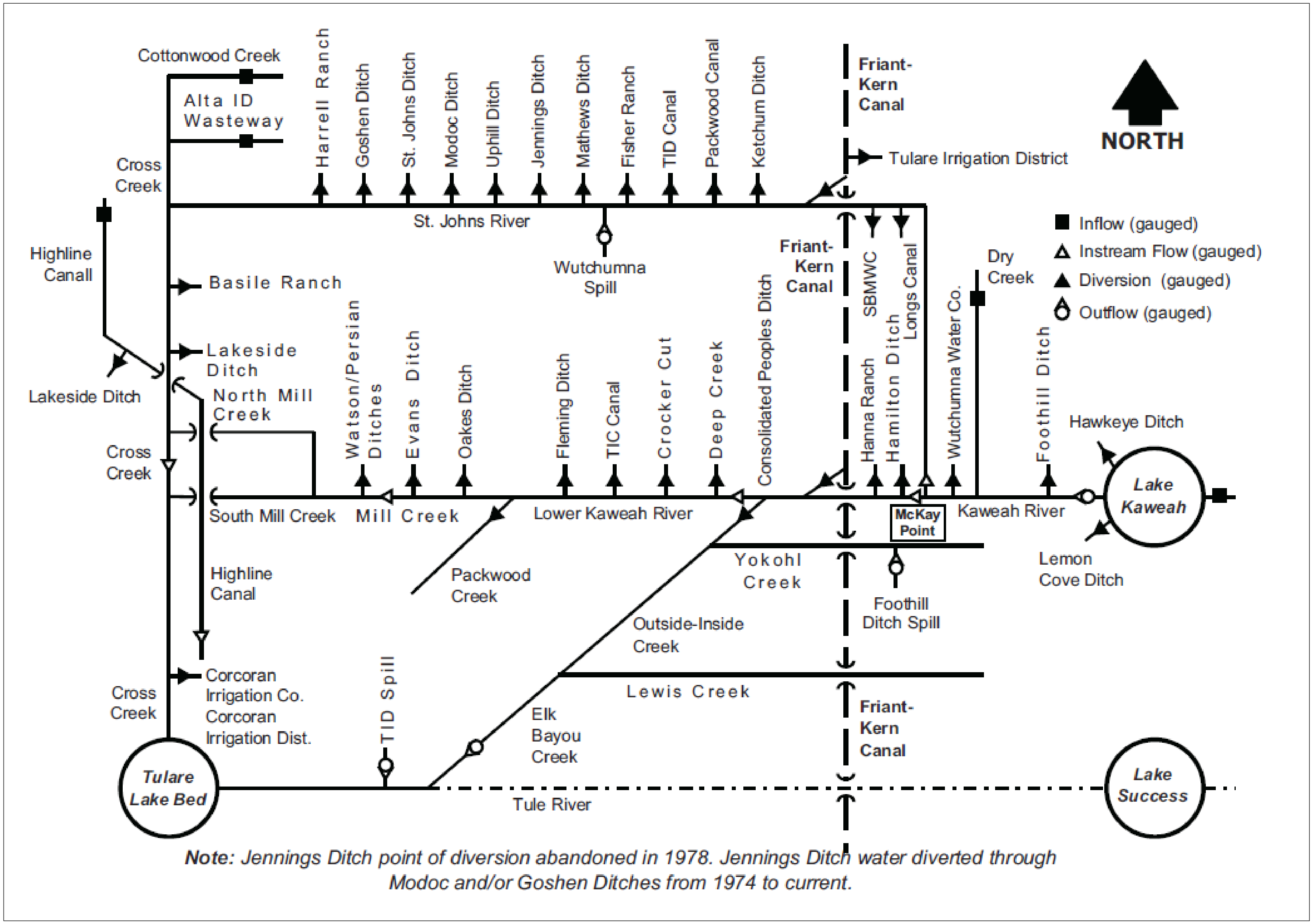


Figure 2-16. Vertical Conductivity and Potential Recharge Areas



Source: Kaweah Delta Water Conservation District, November 2010

Figure 2-17. Kaweah River System Schematic

3 GAR Findings

In part, the purpose of the GAR was to provide the technical basis informing the scope and level of effort for implementation of the General Order's groundwater monitoring and implementation provisions. The KBWQA's GAR findings are summarized below. Figures for this section are as published in the GAR.

3.1 Vulnerability Assessment

As defined in the General Order, a groundwater high vulnerability area is:

1. Where known groundwater quality impacts exist or where conditions make groundwater more vulnerable to impacts from irrigated agricultural activities; or
2. Areas that meet any of the following, which require the preparation of a Groundwater Quality Management Plan:
    a. There is a confirmed exceedance (considering applicable averaging periods) of a water quality objective or applicable water quality trigger limit in a groundwater well and irrigated agriculture may cause or contribute to the exceedance;
    b. The Basin Plan requires development of a groundwater quality management plan for a constituent or constituents discharged by irrigated agriculture; or
    c. The Executive Officer determines that irrigated agriculture may be causing or contributing to a trend of degradation of groundwater that may threaten applicable Basin Plan beneficial uses.

3.1.1 High Vulnerability Designation

HVAs were identified using the following criteria:

- Recent detections within the last 10 years of groundwater quality indicating a condition of pollution defined as maximum contaminant level (**MCL**) exceedances in nitrates or pesticides;
- Longer-term detections of groundwater quality indicating a condition of active degradation defined as statistically significant up-trending nitrate detections; and
- Groundwater impacted areas upgradient of a Disadvantaged Community (**DAC**) or small water system that is reliant on groundwater.

Cropped or potentially cropped areas were classified as located within an HVA if at least 50 percent of a parcel is within a designated CVHM grid cell identified as containing adverse water quality conditions. Groundwater quality attributes of each well are assigned to the entire individual 1-mile CVHM grid cell. Additionally, areas within identified groundwater impact cells that are located directly upgradient of a DAC or small water system that is reliant on groundwater are specifically included in the HVA designation.

Spatial gaps were then assessed for exclusion from the HVAs based on the following criteria:

- Groundwater quality testing over the most recent 10 year time frame indicating a lack of groundwater impacts from nitrate or pesticides;
- Endangered species critical habitat;

- Residential or industrial; and
- Other incompatible land use areas such as gravel mining, landfills, wetlands, and water storage or waterways.

If not excluded from the HVA due to the above criteria, the remaining cropped or potentially cropped areas in both the Primary and Supplemental Areas were assessed for inclusion in or exclusion from the HVAs. Ground-truthing was performed in the Primary Area by a professional geologist and an agricultural specialist in instances where data was insufficient to make a determination.

Water quality data used for the analysis in the GAR did not include information regarding depth to groundwater or the monitored water bearing zone of the collected samples. At the time of GAR completion this associated information was not publicly available. Wells with known depth were used where available in the database. Well logs available in the Fugro report do not have associated groundwater quality data. The KBWQA understands that legislation has since been enacted which allows public access to well logs upon request to the DWR. This information will help in determining areas where first encountered groundwater quality is potentially impacted by irrigated agriculture. Applicable well logs and associated groundwater quality data may be included in future updates to the CGQMP and GAR.

To determine the appropriate data for assessment of HVA designation, the KBWQA prioritized data which would have a comparable timeframe with other relevant data sets such as crop type, irrigation methods, farming practices, land management practices, and water quality. Sufficient water quality data appropriate for analysis was available by using data publicly available from 2003 through the time of GAR development. The KBWQA worked to reduce the effect of additive margins of error in cross comparison of data sets, as well as data used for prioritization of HVAs by selecting data that was no more than 10 years old at the time of GAR development. The resultant data set is considered to be the baseline water quality of the KBWQA. It is anticipated that as new data becomes publicly available, it will be evaluated and incorporated every five years in revisions to the GAR, as required by the General Order. Over time this data will continue to be cross referenced with other data sets (pesticide use records, irrigation methods, crop type, etc.), creating a matrix of water quality data and associated land use and management practices to increase accuracy of areas defined as high vulnerability. This combined data set will be critical in future submittals to further identify areas where water quality may have been impacted by irrigated agriculture, aiding in the development of work plans and management plans. This combined data set will also aide the KBWQA in properly identifying growers in the greatest need of improved management practices in order to most effectively execute management plans.

DACS and other small water systems reliant on groundwater were automatically included as HVAs so recharge potential up-gradient of these areas is inconsequential. For prioritization, DACS and other small water systems reliant on groundwater were afforded the most heavily weighted designation of ‘critical parameter’, ensuring these areas would be included in the first tier to require regulatory activity.

Recharge was not a consideration for the HVA designation process but was part of a weighted set of factors to delineate prioritization. As discussed in Chapter 4 of the GAR, the most important groundwater vulnerability parameters regarding recharge were listed in the prioritization matrix (GAR Table 7-1) as NRCS hydraulic conductivity by soil type, CVHM VK, and farm location upgradient of a designated recharge area.

Although natural channels were selected for inclusion as a designated recharge area, the horizontal and vertical conductivity provided two-thirds of the weighting regarding recharge so would have been the primary weighting factors regarding recharge for the prioritization process.

The assessment criteria results, after resolving the data gaps, are illustrated in **Figure 3-1**. DACs and small water systems that are reliant on groundwater are illustrated as black-hashed polygons with cropped or potentially cropped areas underlain as dark gray. Identified CVHM grids cells having nitrate or pesticide water quality exceedances are illustrated as pink areas, uptrending nitrate cells are identified as yellow-hashed, and non-impacted areas identified as green. These were overlain by the groundwater elevation contour lines from spring 2014 (which are reasonably consistent with historical groundwater contour maps). Cropped or potentially cropped areas with nitrate or pesticide groundwater quality impacts (both exceedances and uptrending), that are located within 0.75 miles upgradient of a DAC or small water system that is reliant on groundwater, are included as HVA properties. To augment this designation, these particular HVA properties were additionally designated as the highest priority. The final Designated High Vulnerability Areas encompassing all the cropped or potentially cropped Primary and Supplemental Areas are illustrated in **Figure 3-2**.

Salinity in groundwater can originate from natural sources, sewage, runoff and deep percolation from urban and agricultural areas, industrial wastewater, and oilfield produced water. Complex hydrogeologic processes often dissolve, transport, dilute, concentrate, and/or precipitate salts. Variations in surface water availability affect recharge with higher quality surface water and subsequent dilution of salts. The sources of applied irrigation water, and the leaching fraction applied, determine the steady-state salinity of percolating water.

The application of water to support agriculture leads to an increase in concentration of solutes in excess water of the rootzone. Generally, improper drainage can result in elevated levels of salts leaching into groundwater. Localized areas of elevated salinity can occur upgradient where inadequate leaching, flushing, and outflow occur due to local drainage impairments such as poorly drained soil or limited surface drainage toward the historic Tulare Lake. The Kaweah River is the primary source of recharge to the area, allowing for some dilution of concentrated salts in groundwater.

Many permanent crops have converted to drip or micro-irrigation systems and application rates are being more closely matched to a crop’s water usage, reducing the amount of water that can potentially be lost to runoff or below the root zone as deep percolation.

Pesticides, and elevated nitrates and salinity have been identified as constituents which do not currently meet applicable groundwater quality objectives defined for basins underlying the KBWQA. As described in the CGQMP, all areas identified in the GAR as HVAs are to be incorporated in the management plan. The CGQMP also outlines the limitations of available data, the physical barriers to representative groundwater monitoring, and the complex dynamics of decreasing the potential to leach nitrate from irrigated agriculture.

Additionally the Central Valley Salinity Alternatives for Long-Term Sustainability (**CV-SALTS**) is an initiative to identify salinity management strategies that will achieve a salt balance and keep agriculture economically viable. CV-SALTShas been a stakeholder driven process, in coordination with the RWQCB. The KBWQA is a contributor to the Central Valley Salinity Coalition and the CV-SALTS process and will remain actively involved in this important stakeholder process.

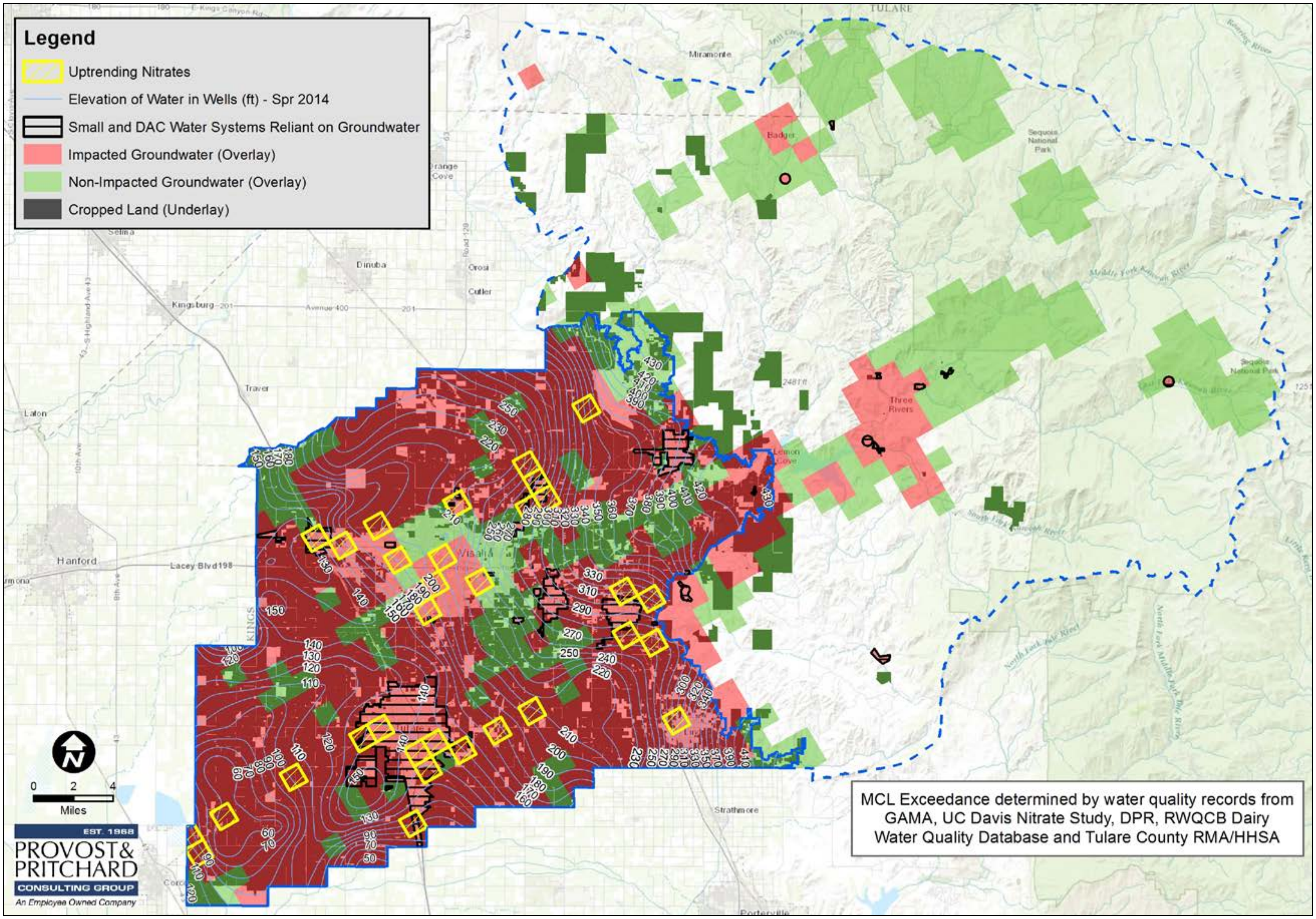


Figure 3-1. Impacted Groundwater

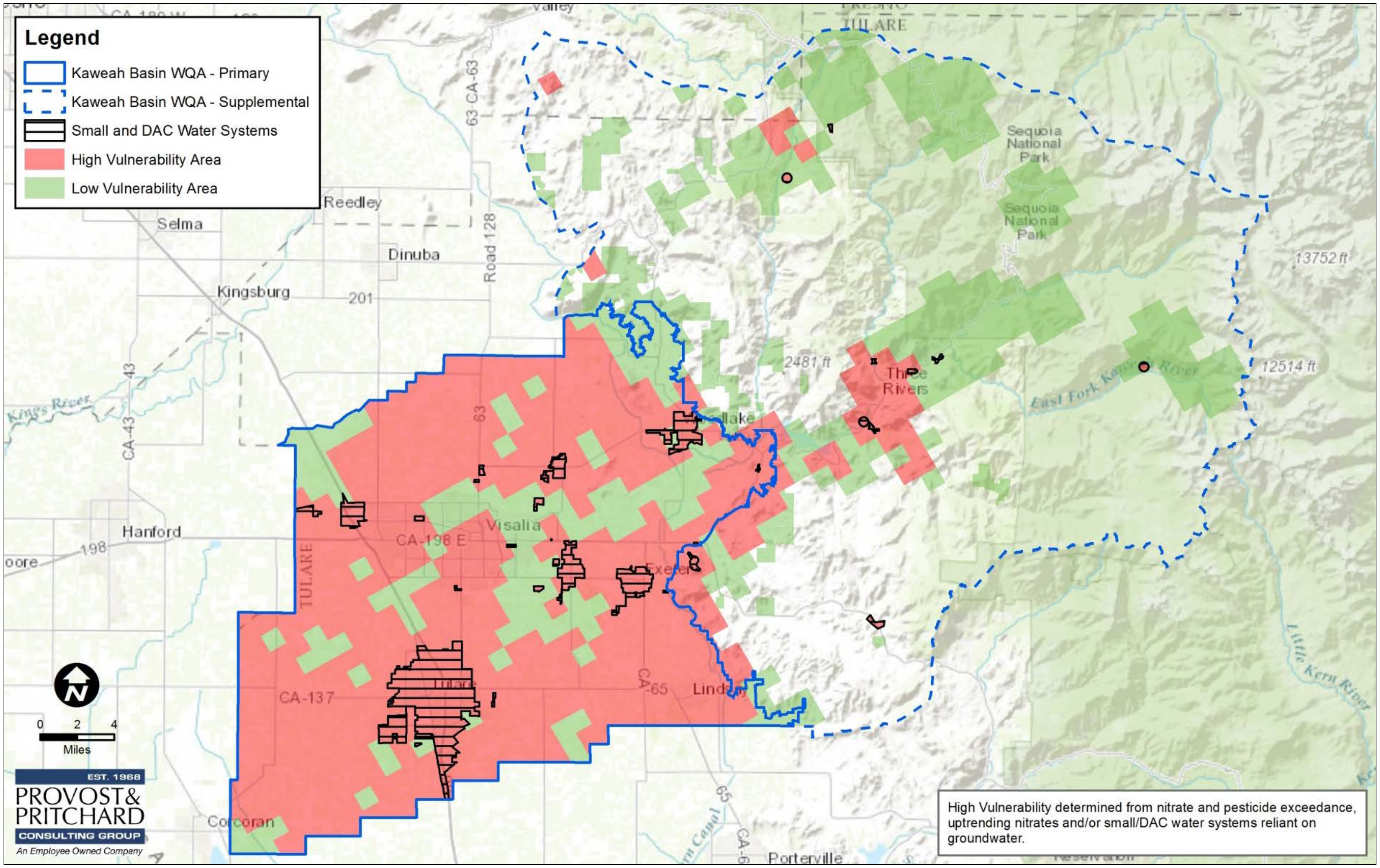


Figure 3-2. Designated High Vulnerability Areas

4 Trend Monitoring Network Design

4.1 Purpose

The primary purpose of groundwater trend monitoring in the KBWQA area is to monitor long-term regional groundwater quality trends as they relate to potential influences from irrigated agriculture and regional changes to agricultural practices.

Design of the GTMP takes into account multiple considerations including:

- The types of agricultural crops grown within the KBWQA area, particularly those with the most irrigated agricultural acreage; and
- Hydrogeologic conditions, such as relative groundwater depths, groundwater flow direction in relation to DACs, dairy land, and significant recharge areas as determined in the GAR.

A significant time-lag between the actions on the land surface and the resulting change in the underlying aquifer likely exists. In general, greater depths to groundwater correlate with longer lag times in transport time from surface to groundwater. Additionally, correlating changes in irrigated agricultural practices to changes in groundwater quality is further complicated by legacy nitrate residing in the unsaturated zone (from historic agricultural practices) acting as an ongoing source to groundwater.

4.2 Approach

Monitoring areas are not defined by specific acreage or location, but rather by specific criteria, Potential general monitoring areas were initially selected by reviewing crop maps for the largest crop types (by acreage) and selecting areas near each of the crop types that were:

1) Located above relatively shallow groundwater;
2) Generally upgradient of a DAC or within relatively close proximity of a DAC;
3) Located in both low vulnerability areas (**LVAs**) and HVAs;
4) In areas with greater potential recharge as documented in the GAR;
5) Generally representative of NRCS soil textural classes present in the KBWQA area; and
6) Not downgradient from an area where other land application practices would potentially lead to water quality issues that could not be differentiated from those resulting from farming practices.

Once the initial crop type monitoring locations were selected, additional monitoring areas were selected so that areas with deeper groundwater were represented. Each of these factors is described in greater detail in the following subsections.

4.2.1 Major Crops by Acreage

As summarized in **Table 2-3**, 11 crop types comprise approximately 95% of cropped acreage in the KBWQA area. In selecting proposed monitoring areas, efforts were made to ensure that each of the 11 most prominent crop types were represented in the trend monitoring network design. Crop types with the largest acreage were considered more strongly than areas with minor crop types with respect to monitoring network coverage. As a result, more proposed monitoring areas were selected from crops with the largest acreage (i.e. citrus, and walnuts and pecans). A crop map with overlayed proposed monitoring areas is presented as **Figure 4-1**.

4.2.2 Hydrogeologic Conditions

As shown on **Figure 2-13**, groundwater depths in the primary KBWQA area ranged from approximately 30 feet in the northeast to 250 feet in the southwest during the Spring of 2016. As shown on **Figure 2-14** (Spring 2015) and **Figure 2-15** (Spring 2016), groundwater flows to the southwest regionally across the KBWQA Primary Area. In an effort to mitigate uncertainties related to the temporal disconnects of changes in agricultural practices, versus changes in groundwater quality, areas with relatively shallow groundwater were considered more strongly over areas with deeper groundwater. As a result there are a larger number of proposed monitoring locations in areas with shallower groundwater depths (i.e. eastern portion of the KBWQA Primary area).

In order to balance out the distribution of monitoring areas in the KBWQA Primary Area, several additional proposed monitoring locations were selected in the central portions where groundwater depths are greater. In selecting these added proposed monitoring areas, consideration was made to ensure that they were upgradient of the extensive dairy lands that are present in the western half of the Primary Area. This will lessen the possibility that groundwater quality data being collected in the proposed monitoring areas is influenced by other regulated dischargers. Additional information regarding dairy lands and their potential effects on the proposed trend monitoring network design is included in the following section.

Proposed monitoring areas overlaid on a Spring 2016 depth to groundwater map is included as **Figure 4-2**. Proposed monitoring areas overlaid on a Spring 2016 groundwater surface elevation map is included as **Figure 4-3**. **Table 4-1** is a tabulated summary of the factors reviewed to select proposed monitoring areas.

4.2.3 Disadvantaged Communities

In selecting the proposed monitoring areas, consideration was given to find areas that were representative of conditions both upgradient and downgradient of DACs or small water systems that are relient on groundwater. A map depicting DACs and proposed monitoring areas is presented as **Figure 4-1.** A tabulated summary of the monitoring area selection factors, including proposed monitoring area hydrologic relationships to DACs is provided in **Table 4-1**.

4.2.4 High Vulnerability Areas and Low Vulnerability Areas

In the GAR, designations of HVAs were made based on a combination of parameters, described in Section 3 of this GTMP. In vetting the proposed monitoring areas, consideration was made to include HVAs and LVAs, as determined in the GAR, in order to ensure that the trend monitoring network design was as representative as possible. A map depicting the proposed monitoring areas overlayed on the HVAs and LVAs, as defined in the GAR, is presented as **Figure 4-6.** A tabulated summary of the monitoring area selection factors is provided in **Table 4-1**.

4.2.5 Areas of Potential Recharge

Analysis completed as part of the GAR evaluated areas of most significant recharge. These areas were defined as; the Kaweah River and the northwest-southeast trending belt of relatively high vertical conductivity in the region of the cities of Exeter, Farmersville, Visalia, and multiple DACs and small water systems reliant on groundwater. In vetting the proposed monitoring areas, consideration was given to include areas that are representative of locations estimated to be the most significant areas of recharge but also included areas with less significant recharge.

A map depicting the proposed monitoring areas overlayed on the vertical conductivity and potential recharge areas map from the GAR is presented as **Figure 4-4.** A tabulated summary of the monitoring area selection factors is provided in **Table 4-1**.

4.2.6 Natural Resources Conservation Services (NRCS) Soil Textures

Surface soil textures can have a significant bearing on the rate of surface water percolation to groundwater, particularly in areas with coarse soils and relatively shallow groundwater. In vetting the proposed monitoring areas, consideration was given to ensure areas were included that were representative of the various surface soil textures present in the KBWQA Primary area. A map depicting NRCS soil textures and proposed monitoring areas is presented as **Figure 4-5.** A tabulated summary of the monitoring area selection factors is included as **Table 4-1**.

4.2.7 Irrigation Methods

Irrigation methods were evaluated and found to have significant correlation with the predominant crop types in the Kaweah primarty area. For example, as shown on **Figure 4-7**, areas with drip or micro irrigation methods correspond to areas of citrus crops (**Figure 4-1**) and likewise surface irrigation corresponds with the walnut and pecan production areas in the central Kaweah Primary area. Additionally, as shown in **Figure 4-7** sprinkler irrigation is sparsely used within the KBWQA. In general, irrigation methods were a secondary concern in vetting the proposed monitoring areas as the type of irrigation method used appears to be heavily influenced by crop type, which was already one of the major factors in selecting monitoring areas.

4.2.8 Dairy Lands

According to RWQCB data, as of 2014 there were approximately 63,712 acres of dairy associated land (dairy facility and manure land application areas) located within the Primary KBWQA area. Dairies are regulated under the RWQCB Order R5-2013-0122 Reissued Waste Discharge Requirements General Order for Existing Milk Cow Dairies (**Dairy GO**) and are not required to enroll as members of a third-party coalition.

As shown in **Figure 4-1**, dairy land is prevalent throughout the western and southern portions of the KBWQA Primary Area. In selecting potential monitoring areas, dairy lands were generally avoided as groundwater quality data attributable to irrigated agricultural farming practices would be difficult to differentiate from that of dairy lands. Due to the high density of dairy land in the west and south (as well as the greater groundwater depths), proposed monitoring areas are located more northerly and easterly.

4.3 Proposed Monitoring Areas

Proposed monitoring areas determined utilizing the general screening method described above are illustrated on **Figure 4-1.** As shown in this figure, monitoring locations have a higher density near the central eastern portion of the Primary Area, with a lower density of locations in the central portions and no monitoring areas proposed west of Highway 99. The proposed monitoring area distribution was highly influenced by several factors including:

- The special distribution of major crop belts such as citrus, and walnuts and pecans;
- The large swaths of dairy land located in the northwest, southwest, and western portions of the Primary Area that were generally avoided as groundwater quality data attributable to general farming practices would be difficult to discern from that of dairy lands;
- The significantly deeper groundwater depths in the western half of the Primary Area that would result in more significant time-lags between the actions on the land surface and the potential resulting changes in groundwater quality; and
- The areas of higher potential recharge, as determined in the GAR, are generally located in the central eastern portion of the Primary Area.

Significant portions of the KBWQA are permanent crops, therefore proposed monitoring areas were defined by predominant crop type. These areas are discussed below.

4.3.1 Citrus

Several monitoring areas are proposed in and around citrus crop zones. As shown on **Figure 4-1**, Monitoring Areas 1, 3, 5, 6, 12, and 21 are proposed to represent citrus crop zones and associated factors influcing groundwater quality. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of the hydrogeologic conditions in the Primary KBWQA area, such as relative groundwater depths (i.e., both shallow and deep), inside and outside of areas of high possible recharge, and in areas of differing surface soil textures. Additionally, they are representative of other selection factors such as locations in LVAs and HVAs, relatively close proximity to DACs, and locations both upgradient and downgradient of DACs.

4.3.2 Walnuts and Pecans

As shown on **Figure 4-1**, Monitoring Areas 10, 18, and 22 are proposed as representative of walnut and pecan crop zones. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of hydrogeologic conditions in the Primary KBWQA area, such as relative groundwater depths (i.e., both shallow and deep) and in areas with differing soil textures. Additionally, they are representative of other selection factors such as locations in LVAs and HVAs, representing multiple types of irrigation, relatively close proximity to DACs, and locations both upgradient and downgradient of DACs.

4.3.3 Pistachios

As shown on **Figure 4-1**, Monitoring Areas 7 and 8 are proposed representative areas for pistachio crop zones. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of the hydrogeologic conditions in the Primary KBWQA area, such as relative groundwater depths (i.e., both shallow and deep), inside and outside of areas of high possible recharge, and in areas of differing surface soil textures. Additionally, they are representative of other selection factors such as locations in LVAs and HVAs, and locations both upgradient and downgradient of DACs.

4.3.4 Corn

As shown on **Figure 4-1**, Monitoring Areas 2, 17, 23 and 24 are proposed representative areas for corn crop zones. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of the hydrogeologic conditions in the Primary KBWQA area, such as relative groundwater depths (i.e., both shallow and deep), inside and outside of areas of high possible recharge, and in areas of differing surface soil textures. Additionally, they are representative of other selection factors such as locations in LVAs and HVAs, representing multiple types of irrigation, relatively close proximity to DACs, and locations both upgradient and downgradient of DACs.

4.3.5 Almonds

As shown on **Figure 4-1**, Monitoring Areas 11 and 24 are proposed representative areas for almond crop zones. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of the hydrogeologic conditions in the Primary KBWQA area, such as relative groundwater depths (i.e., both shallow and deep) and in areas of differing surface soil textures. Additionally, they are representative of other selection factors such as locations in LVAs and HVAs, representing multiple types of irrigation, relatively close proximity to DACs, and locations both upgradient and downgradient of DACs.

4.3.6 Small Grains

As shown on **Figure 4-1**, Monitoring Areas 2, 5, 19, and 24 are proposed representative areas for small grains crop zones. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of the hydrogeologic conditions in the Primary KBWQA area, such as relative groundwater depths (i.e., both shallow and deep). Additionally, they are representative of other selection factors such as locations in LVAs and HVAs, relatively close proximity to DACs, and locations both upgradient and downgradient of DACs.

4.3.7 Alfalfa

As shown on **Figure 4-1**, Monitoring Areas 14 and 20 are proposed representative areas for alfalfa crop zones. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of the hydrogeologic conditions in the Primary KBWQA area, such as inside and outside of areas of high possible recharge, and in areas of differing surface soil textures. Additionally, they are representative of other selection factors such as relatively close proximity to DACs, and locations both upgradient and downgradient of DACs.

4.3.8 Grapes

As shown on **Figure 4-1**, Monitoring Areas 4 and 13 are proposed representative areas for grape crop zones. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of the hydrogeologic conditions in the Primary KBWQA area, such as relative groundwater depths (i.e., both shallow and deep) and in areas of differing surface soil textures. Additionally, they are representative of other selection factors such as locations in LVAs and HVAs, and representing multiple types of irrigation.

4.3.9 Olives

As shown on **Figure 4-1**, Monitoring Areas 1 and 9 are proposed representative areas for olive crop zones. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of the hydrogeologic conditions in the Primary KBWQA area, such as being in areas of differing surface soil textures. Additionally, they are representative of other selection factors such as locations in LVAs and HVAs.

4.3.10 Cotton

As shown on **Figure 4-1**, Monitoring Areas 16 and 17 are proposed representative areas for cotton crop zones. As shown in **Table 4-1**, these proposed Monitoring Areas are representative of the hydrogeologic conditions in the Primary KBWQA area, such as being in areas of differing surface soil textures. Additionally they are representative of other selection factors such as locations in LVAs and HVAs, representing multiple types of irrigation, and relatively close proximitmity to DACs.

4.3.11 Stone Fruit

As shown on **Figure 4-1**, Monitoring Area 15 is the proposed representative area for stone fruit crop zone. As shown on **Table 4-1**, this proposed Monitoring Area is representative of relatively shallow groundwater and is both upgradient and within close proximity to DACs. Additionally, the proposed Monitoring Area is representative of surface irrigation, medium to moderately coarse grained soil texture and is in an area of possible high recharge.

Table 4-1. Monitoring Area Selection Factor Summary

Monitoring Area	Crop Type	DTW				Upgradient of DAC		Proximity to DAC			Vulnerability Class		Possible Area of High Recharge*		NRCS Soil Textural Class				Irrigation Type		
		<40	40-80	80-120	>120	Yes	No	0-1 Miles	1-2 Miles	2-5 Miles	LVA	HVA	Yes	No	Coarse	Mod. Coarse	Medium	Mod. Fine	Drip/Micro	Sprinkler	Surface
1	Olives & Citrus	X				X		X			X	X		X			X		X		
2	Corn & Small Grains	X					X	X			X		X		X		X				X
3	Citrus		X				X		X		X		X		X		X		X		
4	Grapes	X					X		X		X	X	X		X	X			X	X	X
5	Small Grains & Citrus	X					X	X				X	X				X		X		X
6	Citrus			X		X			X			X		X		X	X		X		
7	Pistachios			X		X			X			X	X				X		X		
8	Pistachios		X				X			X		X		X		X	X		X		
9	Olives		X				X			X	X	X		X		X	X		X		
10	Walnuts/Pecans	X					X			X	X		X			X		X	X		X
11	Almonds		X			X			X		X	X		X		X	X	X	X		
12	Citrus		X			X			X		X	X		X			X		X	X	
13	Grapes			X			X			X		X		X	X	X	X		X		X
14	Alfalfa			X		X			X			X		X			X		X		X
15	Stone Fruit		X			X		X			X	X	X			X	X				X
16	Cotton				X		X		X		X		X			X					X
17	Corn & Cotton				X	X		X			X	X	X			X	X		X		X
18	Walnuts/Pecans		X			X		X			X		X			X					X
19	Small Grains		X			X			X			X	X			X					X
20	Alfalfa			X		X			X			X	X			X	X				X
21	Citrus				X	X		X				X		X			X		X		
22	Walnuts/Pecans				X	X			X		X	X	X			X			X		X
23	Corn				X		X		X			X	X			X	X				X
24	Corn/Almonds/Small Grains				X	X		X				X		X		X			X		X

Notes: * = Based on GAR findings of Possible Existing Recharge Locations and areas with highest Vertical Conductivity

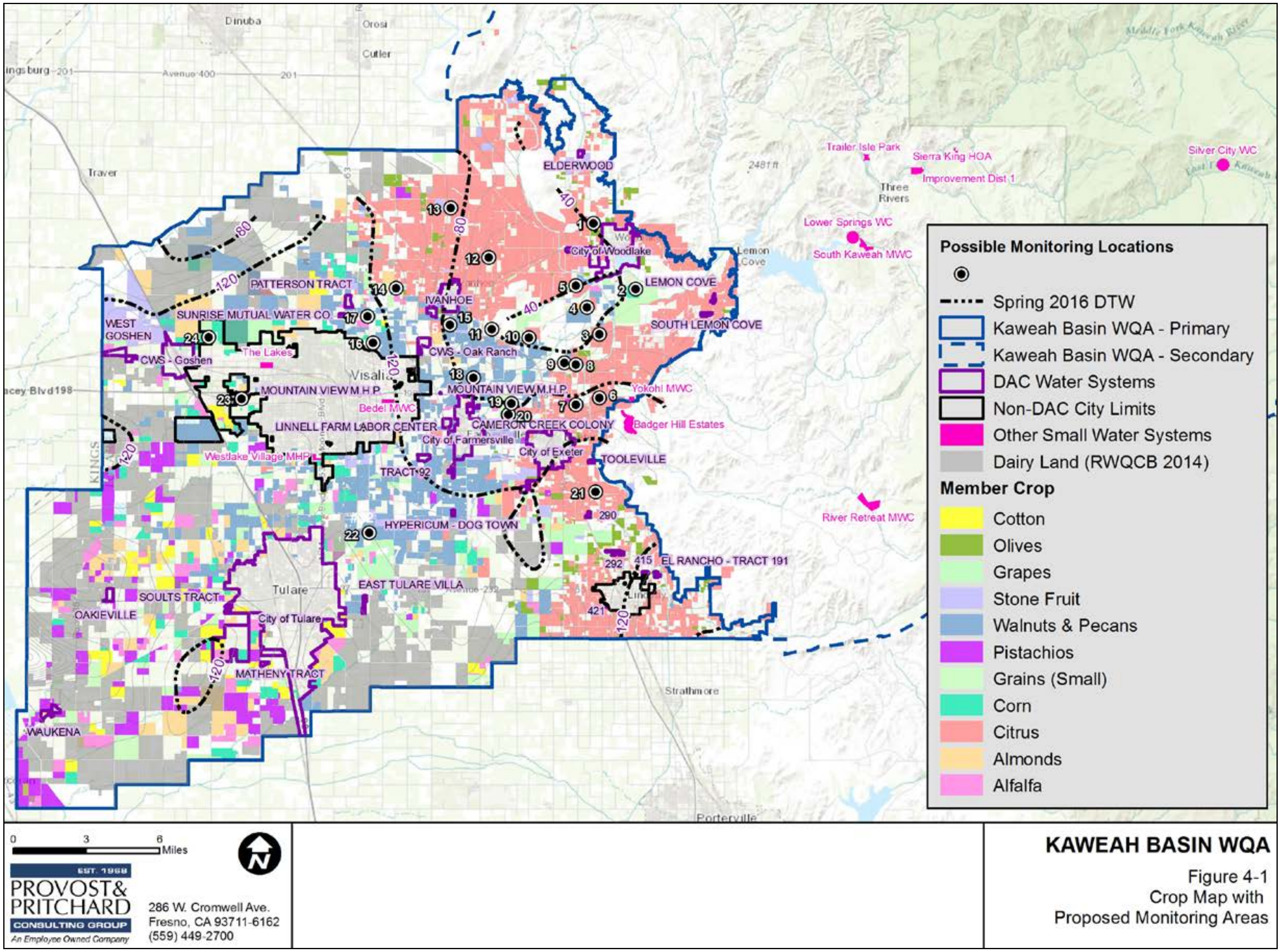


Figure 4-1. Crop Map with Proposed Monitoring Areas

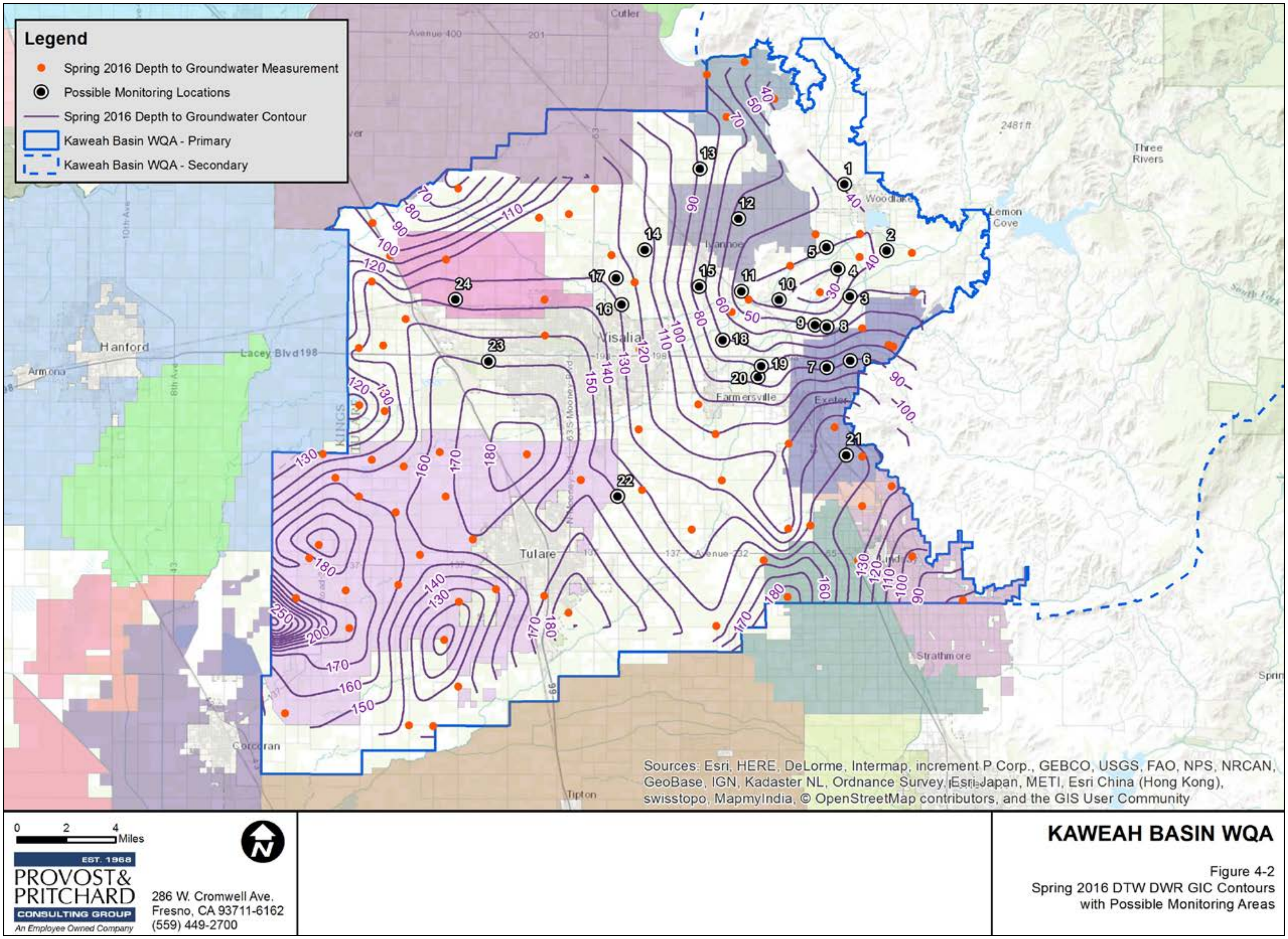


Figure 4-2. Spring 2016 Depth to Water with Possible Monitoring Areas

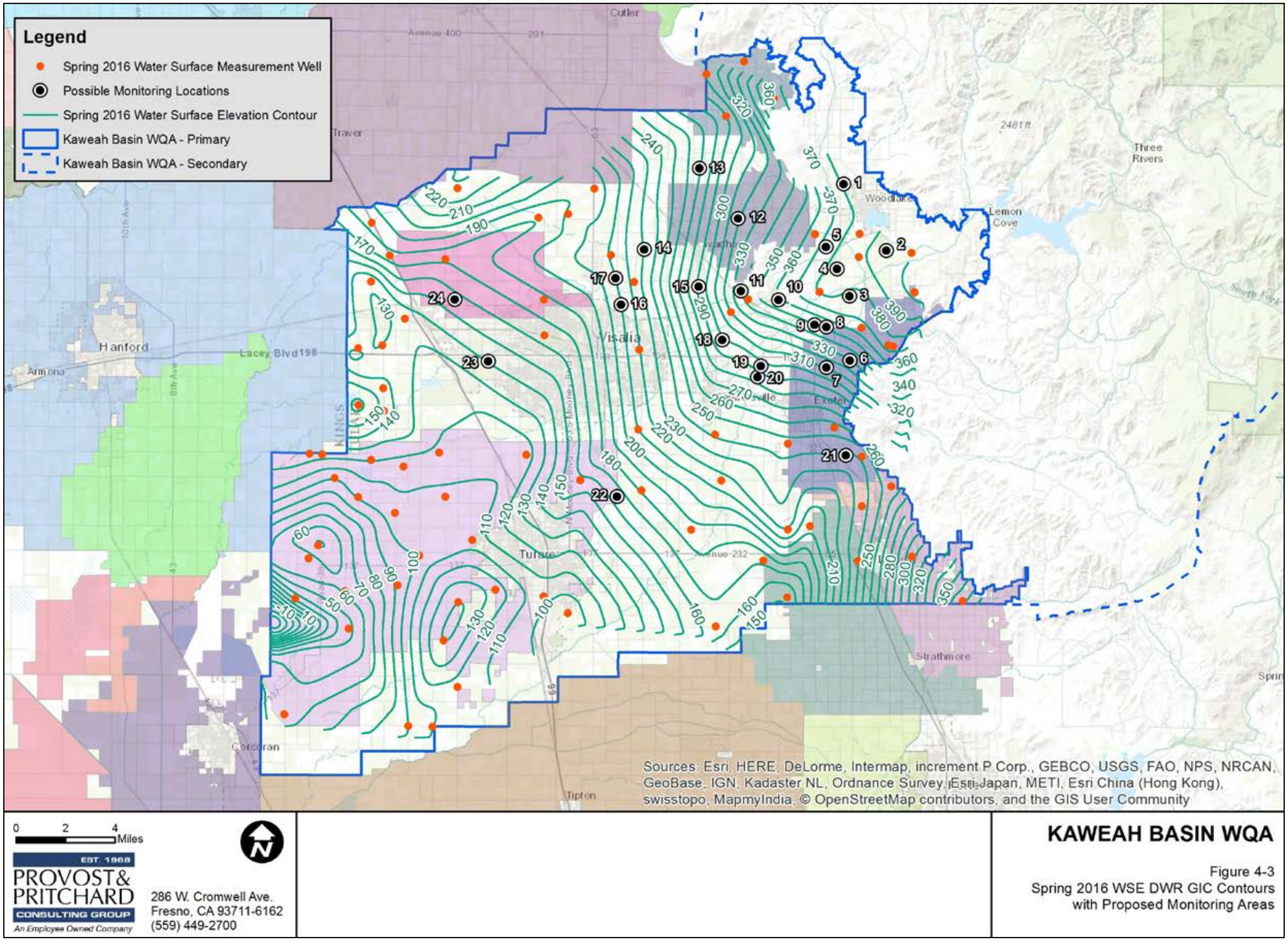


Figure 4-3. Spring 2016 Groundwater Surface Elevation with Possible Monitoring Areas

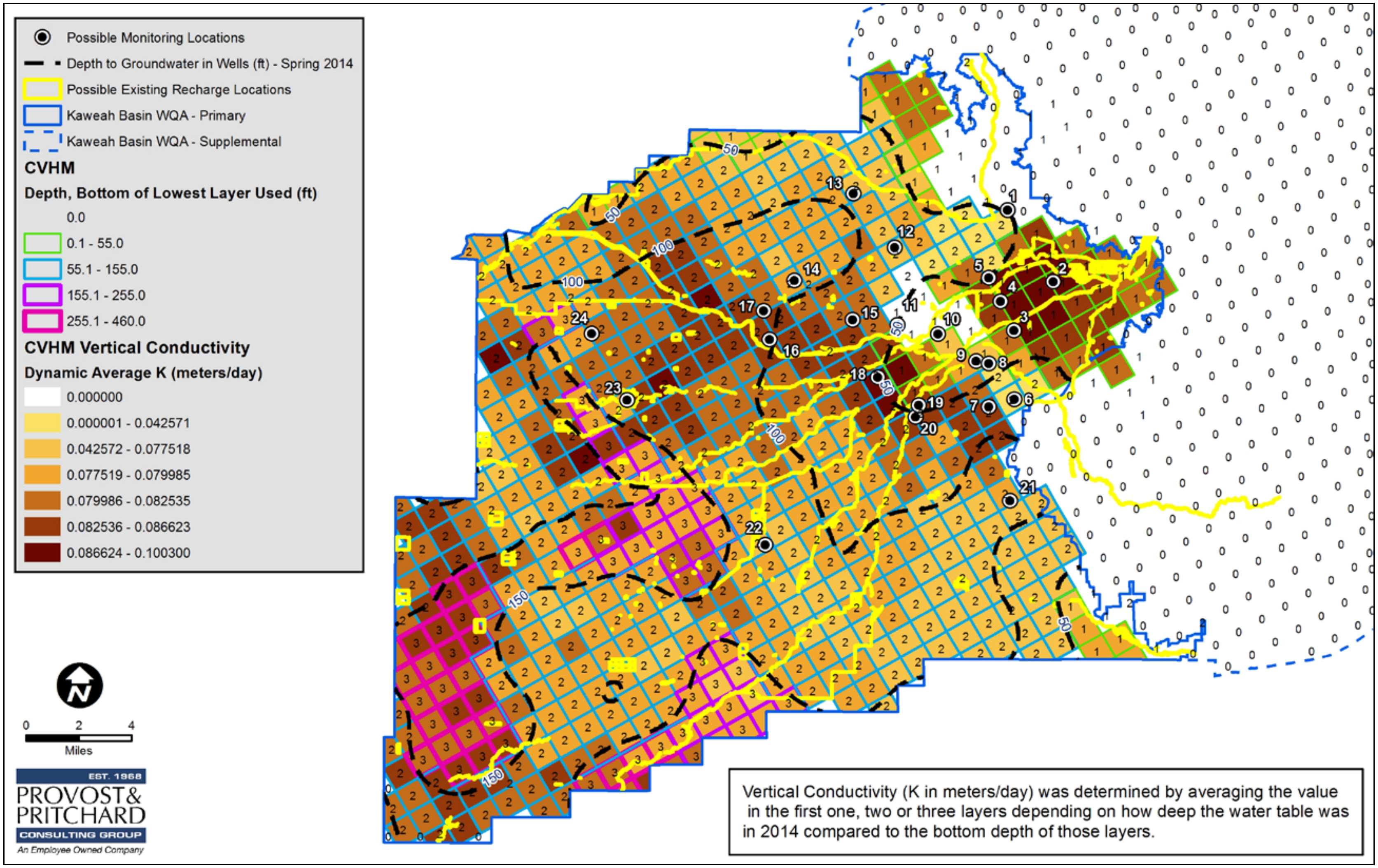


Figure 4-4. Vertical Conductivity and Possible Monitoring Locations

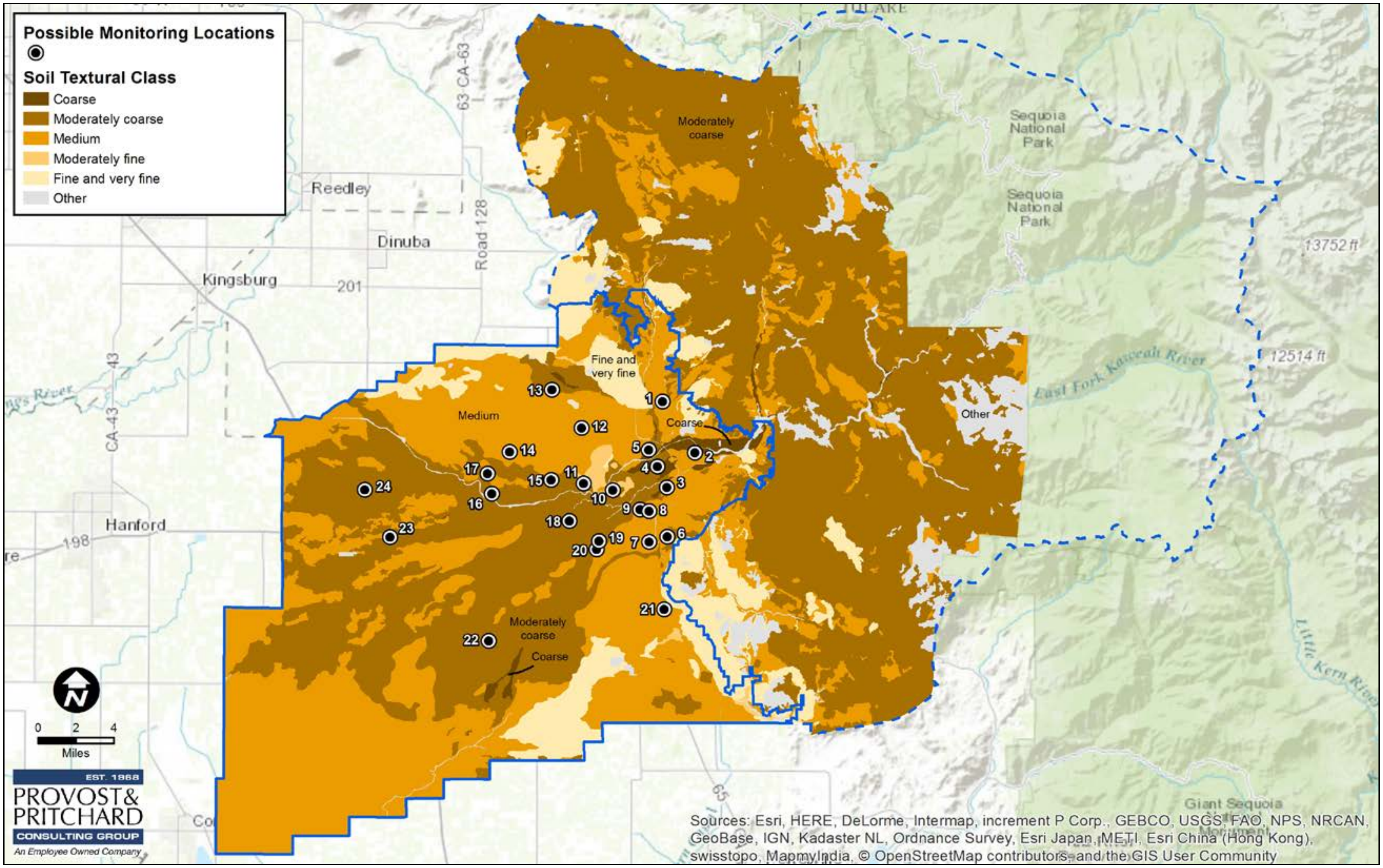


Figure 4-5. Soil Textural Classes and Possible Monitoring Locations

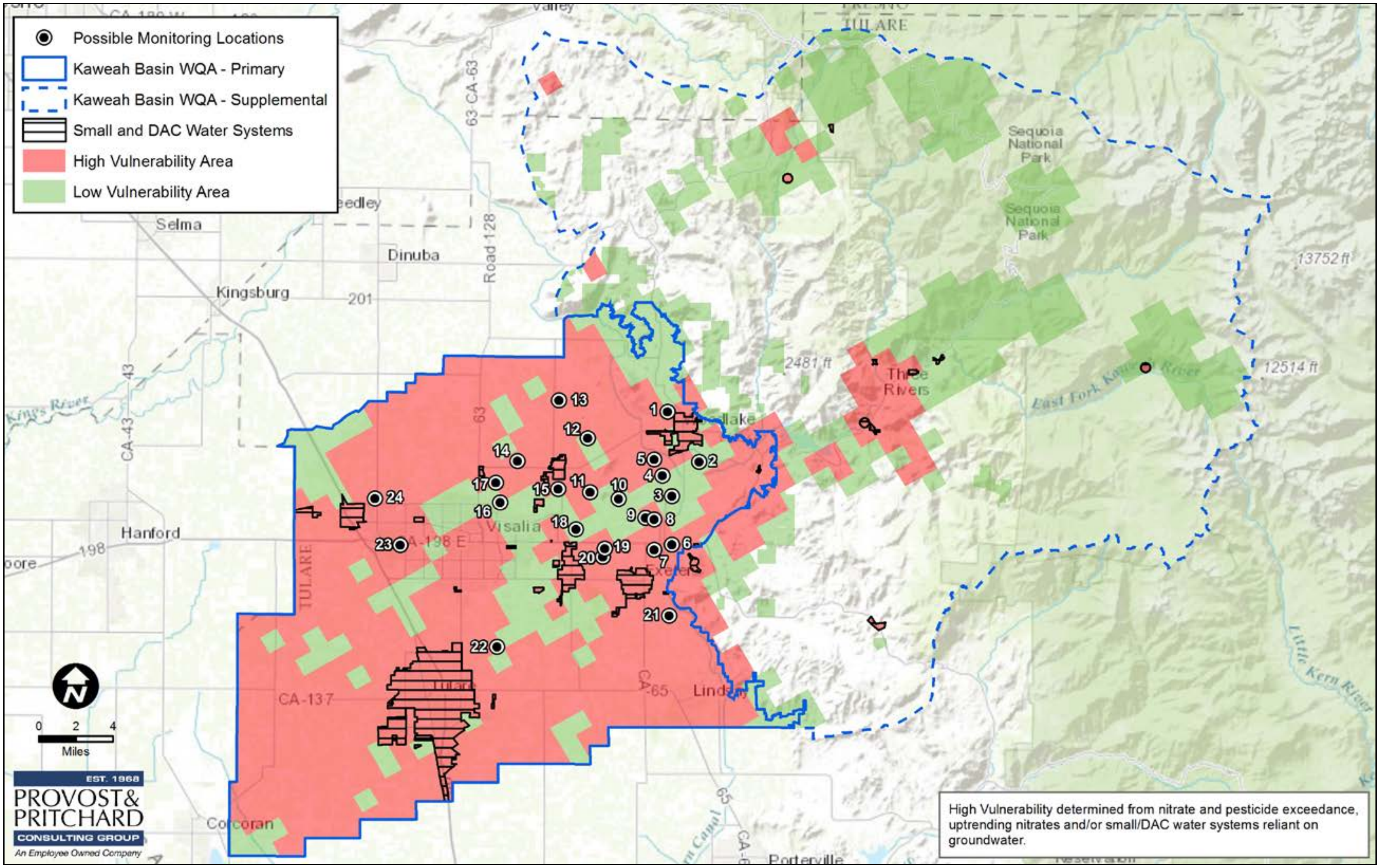


Figure 4-6. High Vulnerability Areas and Possible Monitoring Locations

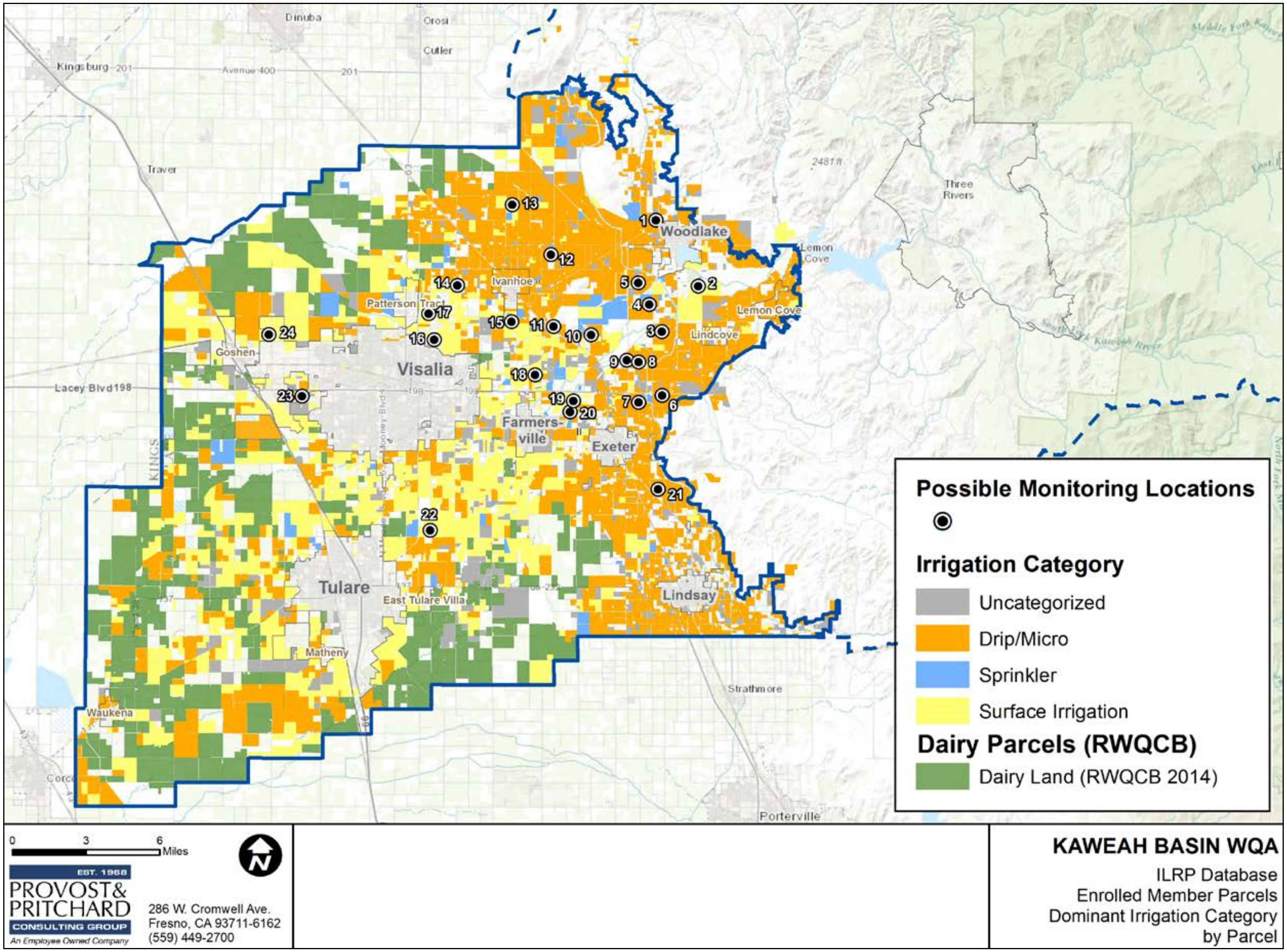


Figure 4-7. Dominant Irrigation Category and Possible Monitoring Locations

5 WELL SELECTION PROCESS AND DATA ACQUISITION

The KBWQA has outlined below the process for Monitoring Area well selections. One primary and one backup well within each of the proposed Monitorning Areas will be included in the GTMP. Area specific well selections will be conducted in the second phase of this GTMW, pending further feedback from the RWQCB and other coalitions. Well information from those selections will be included in the Phase II workplan, along with the sampling implementation schedule.

The proposed well selection process is detailed below with a flowchart presented as **Figure 5-1**.

5.1 Identification of Candidate Wells in Proposed Monitoring Areas

An initial pool of candidate wells will be identified in Phase II of the GTMW. Wells in the Proposed Monitoring Areas will be located with the use of aerial photos, member growers farm evaluation data, DWR records, National Water Information Sytem (**NWIS**) data, other agency data sources, and potentially by roadside surveys.

Based on the requirement to sample shallow groundwater, it is anticipated that domestic wells will comprise a majority of the monitoring network. Irrigation and other production wells would likely pull water from too deep in the aquifer and are not appropriate for this program. Similarly, several potential issues exist with the use of monitoring wells associated with other regulatory programs, where water quality issues from point-sources are likely to exist (e.g. dairies, food processors, etc.) including the difficulty in discerning which water quality issues are potentially attributable to farm practices and not to the intended monitoring location.

Temporal continuity is better assured with domestic well sampling as, in the event the well becomes unusable, there is a high likelihood that a replacement well in the same approximate location would be installed, thus future trend monitoring in that area could continue relatively undisturbed. With other types of wells (e.g. irrigation or monitoring wells for release sites) there is less likelihood that a damaged or dry well would be replaced with a similar well in the same area, which would be a disruption to continued trend monitoring.

As an extra measure of redundancy, backup wells will be selected to ensure continuity of the trend monitoring program.

5.1.1 Evaluation of Existing Monitoring Networks

It is unlikely that existing monitoring wells for other regulatory programs will be selected for inclusion in the trend monitoring network. It is possible that existing water supply wells from larger monitoring networks may be utilized. In the event that acceptable domestic wells cannot be identified in the proposed monitoring areas, existing monitored wells may be evaluated for inclusion as candidate wells.

- Dairy Representative Monitoring Program
- Individual Dairy Monitoring Wells
- Food Processors
- Solid Waste and Wastewater Treatment Facilities
- CASGEM – California Statewide Groundwater Elevation Monitoring
- KDWCD and/or other water/irrigation districts

5.2 Candidate Well Vetting and Selection

Once wells are identified, available well construction information will be gathered from well owners, DWR records, and other sources in order to assess the wells for minimum criteria for potential inclusion in the GTMP. These minimum criteria are discussed below.

5.2.1 Well Location and Land Use

The locations of wells relative to the Proposed Monitoring Areas is considered to be one of the most important factors in determining well suitability for inclusion in the GTMP. Wells within the Proposed Monitoring Areas or within close proximity will be preferred to wells located outside the monitoring areas or at greater distances, allowing the KBWQA to appropriately interpret monitoring results.

The well's location relative to overlying land use is also an important factor in determining well suitability for inclusion in the GTMP.

5.2.2 Well Type

Domestic style groundwater wells will be considered more favorably in the well selection process based on the requirement to sample shallow groundwater. While other style wells may be considered, depending on other factors, domestic style wells will be preferentially selected over deeper irrigation/production wells or monitoring wells installed for other regulatory programs where water quality issues from point-sources are likely to exist.

5.2.3 Well Construction

Characteristics related to the well construction are a critical consideration in identification of wells suitable for use as part of the trend monitoring network. Important information relating to well construction include well depth, perforated intervals (depths to the top and bottom of perforations), and seal presence, depth, and material. Some of these well details are available in public well databases, however, well details should be confirmed by DWR Well Completion Reports with matching well log and construction details, whenever possible, or through other reliable means, as appropriate. Well construction details and other well information that must be available in order for a well to be included in the pool of candidate wells are listed below.

- Total well depth
- Perforated intervals
- Well seal information (presence, type of material, length of seal)

5.2.4 Historic Groundwater Quality Records

The existence and duration of historic groundwater quality data is another factor in considering candidate trend monitoring wells, as such data provide a foundation with which to evaluate long-term trends in concentrations especially as they relate to legacy conditions and changing trends and concentrations resulting from agricultural practices. Primary considerations relating to the historic water quality results will be given during the well selection process. For the purposes of identifying potential candidate monitoring wells, the availability of historic nitrate and total dissolved solids (**TDS**) concentration data will be considered as these parameters are useful indicators of influences from irrigated agriculture and because they are more widely available than many other water quality parameters.

5.2.5 Well Owner Access Agreement

Wells meeting the minimum criteria as described above will be assessed for well owner agreement to include the wells in the GTMP. If agreement cannot be reached initially, discussions will continue with the well owner. Additionally, other suitable well owners within the same area will be contacted. Discussions with all well owners will continue until an appropriate well is selected and owner agreement is reached.

5.2.6 Field Assessment of Well

Candidate wells with access agreements will be visited by a qualified technician to conduct a field assessment of the well. Observations as to the accessibility of the well for sampling; general well surface condition; and proximity of the well to various influences such as animal enclosures, septic systems, or surface water features will be made. Additionally, the wells will be assessed for water treatment systems, and sampling and access ports.

Wells that are found to be unacceptable during the field assessment will be removed from future consideration for inclusion in the GTMP.

5.3 Candidate Well Ranking System

In the event that multiple candidate wells are identified in a monitoring area, a point system will be established once field assessment criteria have been reviewed. Candidate wells will be ranked on the point system to determine the most appropriate wells to be used as monitoring points in the defined subareas. Point values will be assigned to the wells based on well type, screen interval with respect to groundwater depth, and historic sampling data. Wells and backup wells for each subarea with the highest total point value will then be selected for inclusion in the GTMP.

A summary discussion of the wells selected for inclusion in the GTMP will be included in the second phase of the GTMW. Pertinent well information will be included in the second phase workplan, including:

- Total well depth
- Screen intervals (top and bottom perforation depths)
- Well seal information (presence, type of material, length of seal)
- GPS coordinates
- Physical address of the property on which the well is situated, if available
- California State well number (if known)
- Depth of standing water (static water level), if available

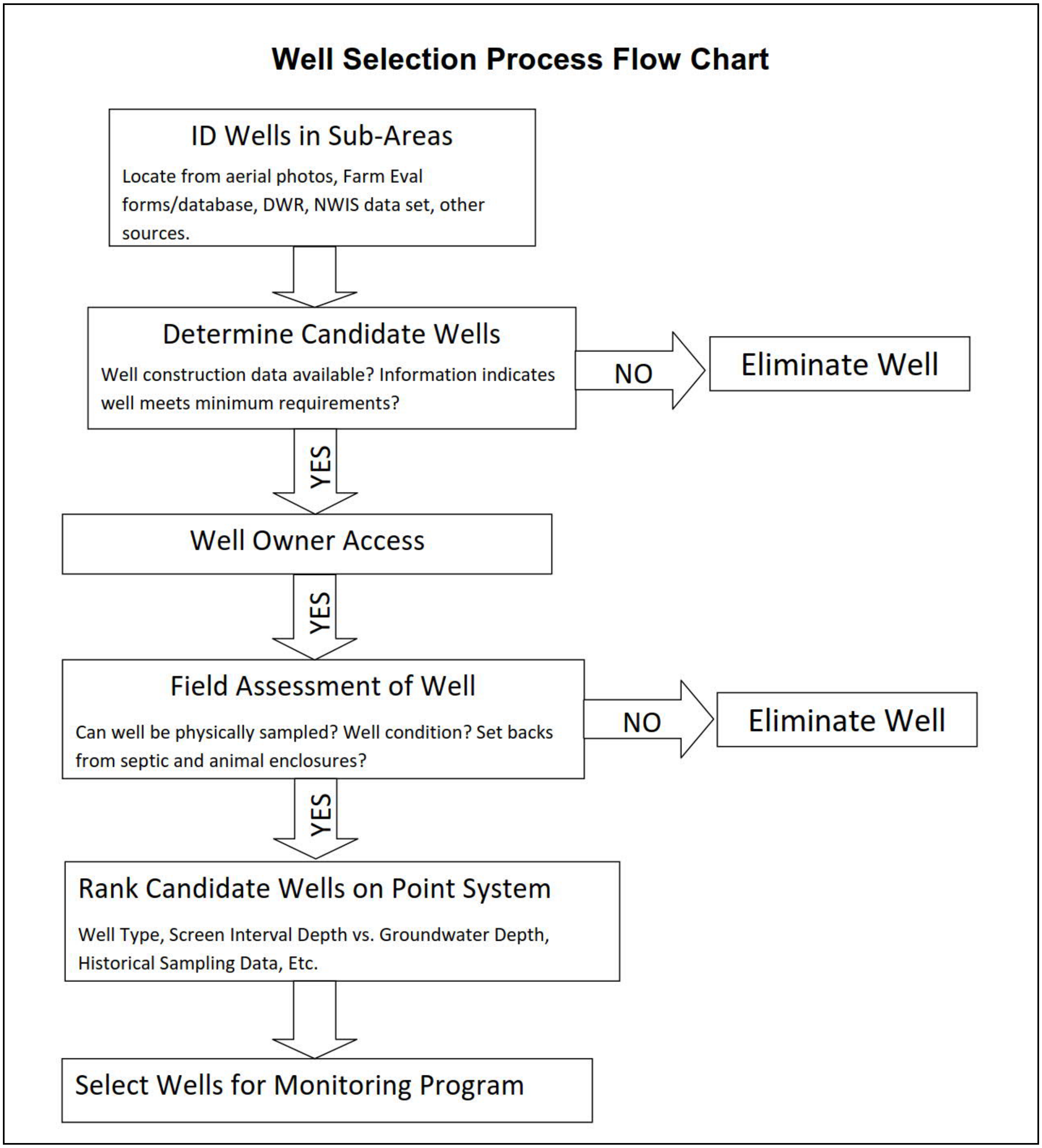


Figure 5-1. Well Selection Process Flow Chart

6 Proposed Implementation

6.1 Groundwater Monitoring Schedule

As specified in the General Order, the GTMP network wells will be sampled annually at the same time of the year in approximately June. Sampling will begin upon approval of the Phase II workplan. The analytical constituents for groundwater sampling are presented in the following subsections.

6.1.1 Initial Groundwater Sampling and Survey

As specified in the General Order, GTMP wells and back up monitoring points will initially be sampled for the constituents listed in **Table 6-1** below.

Table 6-1. Initial Groundwater Sampling Analyses

Initial Groundwater Sampling Analyses				
Indicator Parameter	**Reporting Units**	**Field Measurement**	**Laboratory Analysis**	**Analysis Method**
Electrical Conductivity (**EC**)	µmhos/cm	✓		Field Instrument
pH	pH units	✓		Field Instrument
Dissolved Oxygen (**DO**)	mg/L	✓		Field Instrument
Temperature	°C	✓		Field Instrument
Nitrate as Nitrogen	mg/L		✓	Method 300.0
Total Dissolved Solids (TDS)	mg/L		✓	Method 2540C
General Minerals Anions (carbonate, bicarbonate, chloride, sulfate)	mg/L		✓	Method 2320B
General Minerals Cations (boron, calcium, sodium, magnesium, potassium)	mg/L		✓	Method 200.7

Concurrent with the initial monitoring event, a wellhead survey will be performed by a Provost & Pritchard Consulting Group (**Provost & Pritchard**) licensed land surveyor registered in the State of California. A combination of Global Positioning System (**GPS**) and ground survey methods will be used based on the following datums:

- Horizontal – North American Datum of 1983 (NAD83), California Coordinate System of 1983 (CCS83) state plane coordinates.
- Vertical – North American Vertical Datum of 1988 (NAVD88)

Survey measurements will be reported to +/- 0.01 feet. The survey information will be tabulated and used for hydrograph preparation.

6.1.2 Annual Groundwater Sampling

Following the initial groundwater sampling event, the GTMP wells will be sampled annually for the constituents listed in **Table 6-2** below. After the initial sampling event, backup monitoring points will not be sampled every five years.

Table 6-2. Annual Groundwater Sampling Analyses

Annual Groundwater Sampling Analyses				
Indicator Parameter	**Reporting Units**	**Field Measurement**	**Laboratory Analysis**	**Analysis Method**
Electrical Conductivity	µmhos/cm	✓		Field Instrument
pH	pH units	✓		Field Instrument
Dissolved Oxygen	mg/L	✓		Field Instrument
Temperature	°C	✓		Field Instrument
Nitrate as Nitrogen	mg/L		✓	Method 300.0

6.1.3 Five-Year Groundwater Sampling

Every fifth year, the GTMP wells and backup monitoring points will be sampled for the constituents listed in Table 6-3 below.

Table 6-3. Five-Year Groundwater Sampling Analyses

Five-Year Groundwater Sampling Analyses				
Indicator Parameter	**Reporting Units**	**Field Measurement**	**Laboratory Analysis**	**Analysis Method**
Electrical Conductivity	µmhos/cm	✓		Field Instrument
pH	pH units	✓		Field Instrument
Dissolved Oxygen	mg/L	✓		Field Instrument
Temperature	°C	✓		Field Instrument
Nitrate as Nitrogen	mg/L		✓	Method 300.0
Total Dissolved Solids	mg/L		✓	Method 2540C
General Minerals Anions (carbonate, bicarbonate, chloride, sulfate)	mg/L		✓	Method 2320B
General Minerals Cations (boron, calcium, sodium, magnesium, potassium)	mg/L		✓	Method 200.7

6.2 Groundwater Reporting

Annual sampling will occur approximately June of each year. Collected data from each monitoring point will be compiled, which may include pertinent historical groundwater data. The results of trend monitoring are required to be included in the third-party's Annual Monitoring Report (**AMR**) and must include a map of the sampled wells, tabulation of the analytical data, and time concentration charts. Groundwater monitoring data are to be submitted electronically to the State Water Resources Control Board's GeoTracker Database and to the RWQCB. Data validity is discussed in the following Section 7 Groundwater Monitoring Procedures. Data sufficiency is addressed in this chapter.

As part of fulfillment of General Order requirements, AMRs will include tabulated water level and water quality data (in Excel) and select trend analyses based on the suitability of the accumulated data set. These analyses may include the following:

- Maps - monitoring point locations, iso-concentration
- Graphs – groundwater elevation, time-series concentration
- Diagrams – Piper, Stiff
- Statistics
- Other analyses as appropriate - to be determined based on findings of the above

Constituents of concern (**COCs**) may include nitrate, total dissolved solids and select general minerals. Collected data will be reviewed annually and the AMR will include a discussion of monitoring data realative to applicable water quality objectives and groundwater quality management plans.

6.3 Data Sufficiency

Once each annual data set is tabulated, it will be assessed for data sufficiency. Some trend analysis methods require an accumulation of data over time, and others require minimum analytical suites. The sufficiency needs for each analytical tool that is anticipated to be included in the AMRs are detailed below.

6.3.1 Maps

An initial monitoring point location map will be prepared once the GTMP network wells are established. The map will be updated if any of the selected wells are removed from the GTMP.

Iso-concentration maps will be prepared annually for appropriate COCs. A catalogue of maps will develop over time and help to evaluate minimum and maximum concentration areas, as well as changes in those areas over time. The sparse well spatial distribution will likely cause data gaps in these maps however, it is anticipated that the usefulness of the maps will improve over time.

6.3.2 Graphs

Groundwater elevation graphs (hydrographs) will be prepared from the initial monitoring event and updated annually. To be meaningful, these graphs rely on the change in elevation over time. It is anticipated that a minimum of five to ten years of data will be needed to begin to provide a representation of the changes in groundwater levels. It is anticipated that the usefulness of the hydrographs will improve over time.

Time-series concentration graphs will be prepared from the initial sampling results and updated annually. As with the hydrographs, these graphs rely on the change in constituent concentrations over time. A minimum of five to ten years of data will be needed to begin assessing the concentration changes. The usefulness of the time-series graphs will improve over time.

6.3.3 Diagrams

Both Piper and Stiff diagrams require general mineral analyses as will be utilized for the initial monitoring event and every five years thereafter. Prior to diagram preparation, the monitoring data will be reviewed for internal consistency by comparing ionic balances of cations and anions using the commonly accepted standard of $\pm$5%. The initial set of diagrams will be useful for determining water type spatial distribution in the region. Subsequent diagram sets will be compared each five years to assess changes over time. As with the other trend analyses, the accuracy and precision of interpretations will improve with longer data sets.

6.3.4 Statistics

Statistical analysis methods will be used to assess the existence of groundwater quality trends. These analyses are compromised by poor ionic balances, limiting the ability to draw hard and fast conclusions.

To minimize use of invalid datasets in statistical tests, each complete general mineral analytical suite result will be reviewed for internal consistency by comparing ionic balances of cations and anions using the commonly accepted standard of ±5%.

Statistical tests also require certain minimum datasets and most lose power with smaller datasets. Listed are potential statistical analyses that may be performed and the sufficiency needs for each. Interpretation abilities will increase as the well datasets are collected in subsequent years. Initial statistical analysis will be limited and will likely include interwell analysis. Appropriate statistical methods will be used depending on the presence and number of non-detects, and whether the data is parametric.

Table 6-4. Potential Statistical Tests

Potential Statistical Tests		
Test	**Purpose**	**Requirements**
Dixon's Test	Assess outliers	Only recommended on sample sizes up to 25, small datasets may mask outliers
Shewhart CUSUM Control Chart	Detection of changes in the dataset	Minimum 2 sets
Mann-Kendall	Trend	Minimum 4 sets
Theil-Sen	Trend slope calculations	Minimum 8 sets
ANOVA	Interwell analysis for spatial variabiity	Minimum 4 sets

6.3.5 Other Analyses

Box and whisker plots may be used to help identify outliers on a constituent by constituent basis. A minimum of 4 sets would be needed.

Parametric and non-parametric analyses can be used depending on the dataset.

7 Groundwater Monitoring Procedures

7.1 Well Owner Notification and Coordination

Prior to sampling events, coordination with well owners and tenants will be conducted as necessary in order to provide notification of upcoming monitoring and to provide necessary instructions.

7.2 Water Level Measurement

Prior to each sampling event for a pumping well, the static depth to water will be measured to calculate the elevation of the water surface. Generally, a weighted water level meter will be used to measure the depth to groundwater. All measurements will be recorded to the nearest 0.01 foot from a fixed and identifiable reference point at the top of the well.

7.3 Purging Wells

In order to obtain a representative sample of the groundwater contained within the saturated zone, stagnant water within the well casing and filter material must be removed, and fresh formation water allowed to replace it. Removal of the stagnant water is accomplished by pumping or bailing the water contained within the well. Purged water will be dispersed on site.

Field parameters (pH, temperature, EC, and DO) will be monitored and recorded during the purge operations. Stabilization of pH, temperature, and EC parameters will be indicated by values within 10% of one another for a minimum of three consecutive readings. Field parameters will be measured using a pH meter calibrated to standard buffers, and an EC meter equipped with a thermometer. Field equipment will be standardized at the beginning of each use, according to the manufacturers' specifications and consistent with the Environmental Protection Agency Test Methods SW-846 Manual.

The methodology and procedures used to collect groundwater samples from groundwater wells included in the GTMP may vary depending on the type of each well. Industry standard protocols typically differ for groundwater monitoring wells (i.e., wells installed for the sole purpose of monitoring groundwater), agricultural production wells, and domestic wells. It is anticipated that the wells that will make up the trend monitoring network will be comprised chiefly of domestic wells.

7.3.1 Domestic Wells

Prior to purging and sampling, the condition of the well casing and water supply line(s) will be observed and documented. Collecting samples from a domestic well requires minimal equipment as the groundwater supply system typically includes a pump and pressure tank that can provide a reliable sample stream.

Water bibs closest to the wells and prior to any water treatment units will be used for purging and sampling in order to minimize the amount of piping the water will travel through, reduce purge times, and collect representative samples. As conditions allow, the same sample location at each well will be utilized during each sampling event. Prior to sampling, the wells will be purged by running the nearest available water bib or tap for up to 20 minutes or until a volume of water equal to the volume of the pressure tank has been removed. A hose may be used during purging activities to direct purge water away from the sampling point but will be removed prior to collecting samples from the water bib. Groundwater samples will then be collected immediately after purging.

7.3.2 Groundwater Monitoring Wells

Prior to each sampling event for a monitoring well, the static depth to water and depth to the bottom of the well will be measured in each monitoring point well. These data will be used to calculate the elevation of the water surface and the required purge volume. Generally, a weighted water level meter will be used to measure the depth to groundwater and bottom-of-well measurements. All measurements will be recorded to the nearest 0.01 foot from a fixed and identifiable reference point at the top of the well.

If groundwater monitoring wells without dedicated purging and sampling devices are used, the monitoring wells will be purged with one or more of the following temporary devices. The purging and sampling devices will be placed near the top of the screened interval to ensure that shallow groundwater is sampled.

- Positive gas-displacement, Teflon™ and/or stainless steel-housed Teflon™ bladder pump;
- Teflon™ or stainless steel bailer with bottom discharge unit;
- Stainless steel submersible pump with galvanized piping;
- Peristaltic pump;
- Centrifugal pump;
- Two-stage air-lift pump (Teflon™ or stainless steel); or
- Disposable polyethylene bailers with polypropylene check ball.

When purging a low-yield well (one that yields less than three casing volumes prior to being purged to dryness), the well will be purged to dryness twice. When the well recovers the third time, and when it contains a sufficient volume of water for the required analyses, samples will be collected. At no time will a well be purged to dryness if the rate of recharge is such that formation water will cascade down the sides of the casing, or if a purge rate of greater than one-quarter gallon per minute can be maintained.

Groundwater samples will be removed from a monitoring well of moderate- to high-yield only after a minimum of three casing volumes have been purged from the well casing, and purging has been of sufficient duration to result in stabilization of pH, temperature, and EC measurements.

7.3.3 Agricultural Production Wells

If agricultural production wells are used, groundwater samples will be collected from the nearest available water supply valve or discharge opening prior to water treatment systems. Prior to sampling, the pump will be run for a minimum of 30 minutes or until at least three well volumes have been purged from the well.

7.4 Sample Collection

Samples of fresh formation water will be collected only after the appropriate volume of water has been purged from the casing, and field parameters have stabilized. To increase the likelihood that groundwater samples are representative of the groundwater contained within the formation, it is important to minimize physical or chemical alteration of the sample during the collection process.

Samples will be collected in such a manner as to minimize the volatilization of a sample due to agitation and/or transference from pump or bailer to sample container. The sampling flow rates will not exceed the purging process flow rate and will generally be much less. When a bailer is used to retrieve a sample, a bottom discharge unit will be used to minimize volatilization during transference between bailer and sample container.

7.5 Equipment Cleaning

When dedicated purging and sampling equipment is not used, equipment that may come in contact with the sample will be thoroughly cleaned prior to arrival to the project site. Non-disposable bailers and positive gas-displacement bladder pumps will be disassembled, steam-cleaned, rinsed with (steam-distilled) water, and then reassembled. Wires, hoses and connectors will be cleaned in a similar manner.

7.6 Equipment List

Depending on the type of well to be sampled, equipment from the below lists may be used during purging and sampling operations.

7.6.1 Decontamination Equipment

- 2 – 5-gallon buckets
- Simple Green or other non-phosphate detergent
- Small head long handled scrub brush
- 1 ½” or 2” bottle brush

7.6.2 Purging Equipment

- Waterra Powerlift II actuator, Grundfos pump, or disposable bailers
- Horiba multimeter, or similar, with calibration solutions
- Solinst water level indicator or similar
- DO meter or other as needed
- extra Waterra tubing, footer valves, and surge block if using the Waterra system
- 2 – 5-gallon buckets
- Generator with gas
- Extension cord

- Tie-down strap or bungie
- Tool bucket (wrenches, pliers, all thread, zip ties)
- Latex gloves

7.6.3 Sampling Equipment

- Sample bottles
- Gallon self-sealing plastic bags
- Ice chest with ice
- Eye and ear protection
- Field camera
- Clipboard or forms box with the following:
- Client contact information
- Site map with well locations
- Field purge records
- Daily field records
- Waterproof fine point marker and ball point pens
- Sample labels
- Chain-of-custody forms

7.7 Field Sampling Log

A field sampling log will be maintained for each sampling event and will include the following:

- Sampler's identification;
- Well identification;
- Climatic conditions;
- Depth to water prior to purging;
- Type of purging and sampling device;
- Purging rate and volume;
- Relative well yield volume;
- Field parameter measurements (pH, temperature, EC, DO);
- Type and number of samples collected; and
- Date and time collected.

7.8 Sample Packaging and Transport

7.8.1 Sample Labeling

Sample containers will be labeled in the field. Labels will contain the following information:

- Consultant's identification;
- Project number or identification;
- Sampler's identification;
- Date and time of collection; and
- Sample identification.

7.8.2 Sample Transport

All samples will be delivered to the laboratory within a time frame to allow for analyses within the appropriate holding times. Sealed sample containers will not be opened by other than the laboratory personnel who will perform the requested analyses.

7.8.2.1 Custody Seal

If it is necessary for samples or sample chests to leave the field technician's control prior to delivery to the laboratory, such as for shipment by a common carrier, a custody seal will be placed on each sample container and/or sample chest to discourage tampering during transportation. The custody seal will contain the sampler's signature, and the date and time the seal was emplaced.

7.8.2.2 Chain of Custody

In order to document and trace sample possession, a positive signature chain-of-custody record will accompany the sample through the laboratory analyses. The completed chain-of-custody record will be included in the laboratory's final report.

7.8.2.3 Sample Analyses

Groundwater samples will be analyzed by a California Certified Environmental Laboratory Accreditation Program (**ELAP**) laboratory.

Requests for sample analyses will be made in writing and will be included as part of the chain-of-custody record.

7.9 Quality Assurance and Quality Control

7.9.1 Field Quality Assurance/Quality Control

Travel and equipment blanks will be collected as appropriate and handled and transported in the same manner as the groundwater samples. Travel blanks prepared by the laboratory will be utilized at a rate of one per ice chest. Equipment blanks will be collected from non-dedicated sampling equipment will be collected at a rate of one per sampling episode by circulating steam-distilled water through cleaned sampling equipment during the final rinse stage.

7.9.2 Laboratory Quality Assurance/Quality Control

Duplicate samples may be collected at a total duplicate rate of 20 percent for the project. Blind duplicate samples will be delivered to the primary laboratory to verify the reliability of the laboratory's analyses.

Split samples may be collected at the discretion of the project manager. The split sample will be handled the same as the primary sample, but will be delivered to a second laboratory. A comparison of the split sample results will be made to further evaluate the primary laboratory's performance.

Duplicate and/or split samples collected from a single well will be collected from a single casing volume when possible. When a single casing volume is insufficient, samples will be collected in as rapid a succession as possible.

Quality assurance/quality control sample analytical data will be used to monitor the laboratory performance, sampling technique, and as indicators of potential sample analyses or sample collection anomalies.

For general minerals analysis, a cation/anion balance will be calculated by the laboratory as an error check using the commonly accepted standard of ±5%.

8 LIMITATIONS

The evaluations of groundwater conditions and water supply submitted in this workplan are based upon the data obtained from a review of generally available geologic literature for the subject areas. The validity of the opinions, findings, and recommendations presented in this workplan are based on the assumptions that the data reviewed and referenced are valid, accurate, and correct.

As conditions change due to natural processes, climatic conditions or human intervention on or adjacent to the properties within the region, or changes occur in the nature or design of the subject areas, or if substantial time lapse between the date of this workplan and the start of work in the subject area, the findings and opinions contained in our workplan will not be considered valid unless the changes are reviewed by Provost & Pritchard and the findings and opinions contained in the workplan are modified or verified in writing.

Judgments leading to our opinions, conclusions, and recommendations are made without a complete knowledge of the subsurface conditions. No assessment can eliminate uncertainty or all risk regarding site conditions.

The workplan has been prepared in a manner consistent with the standards of care and skill ordinarily exercised by members of the profession practicing under similar conditions in the geographic vicinity (Tulare County) and at the time the services will be performed. Regulations and professional standards applicable to Provost & Pritchard's services are continually evolving. Techniques are, by necessity, often new and relatively untried. Different professionals may reasonably adopt different approaches to similar problems. Therefore, no warranty or guarantee, expressed or implied, is included in Provost & Pritchard's scope of service.

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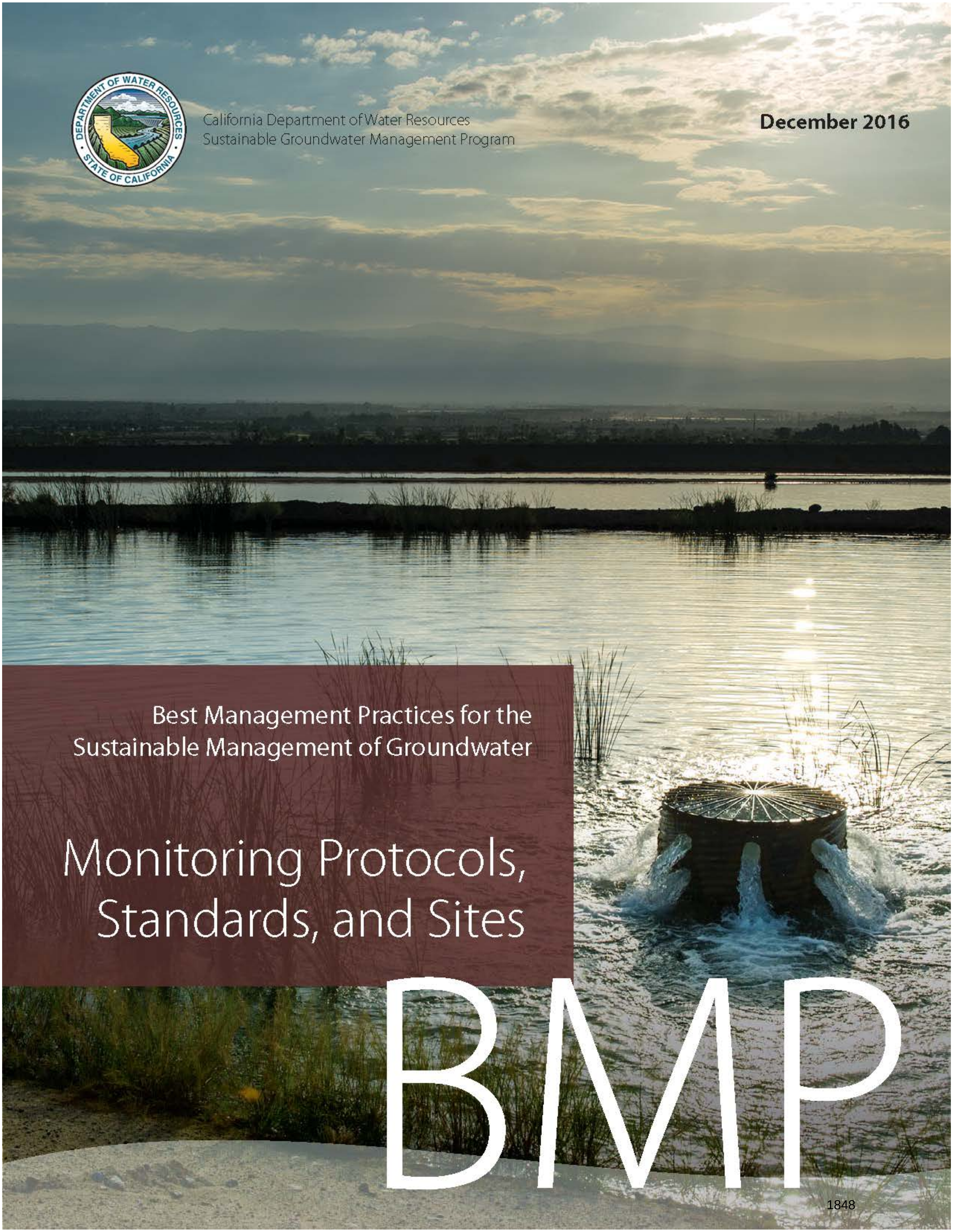
Kaweah Basin
Water Quality Association

www.kaweahbasin.org

Appendix 4D

DWR Monitoring Protocols, Standards, and Sites BMP



California Department of Water Resources
Sustainable Groundwater Management Program

December 2016

Best Management Practices for the
Sustainable Management of Groundwater

Monitoring Protocols, Standards, and Sites

BMP

State of California
Edmund G. Brown Jr., Governor

California Natural Resources Agency
John Laird, Secretary for Natural Resources

Department of Water Resources
Mark W. Cowin, Director

Carl A. Torgersen, Chief Deputy Director

Office of the Chief Counsel
Spencer Kenner

Public Affairs Office
Ed Wilson

Government and Community Liaison
Anecita S. Agustinez

Office of Workforce Equality
Stephanie Varrelman

Policy Advisor
Waiman Yip

Legislative Affairs Office
Kasey Schimke, Ass't Dir.

Deputy Directors

Gary Bardini	**Integrated Water Management**
William Croyle	**Statewide Emergency Preparedness and Security**
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John Pacheco (Acting)	**California Energy Resources Scheduling**
Kathie Kishaba	**Business Operations**
Taryn Ravazzini	**Special Initiatives**

Division of Integrated Regional Water Management

Arthur Hinojosa Jr., Chief

Prepared under the direction of:

David Gutierrez, Sustainable Groundwater Management Program Manager
Rich Juricich, Sustainable Groundwater Management Branch

Prepared by:

Trevor Joseph, BMP Project Manager

Timothy Godwin
Dan McManus
Mark Nordberg
Heather Shannon
Steven Springhorn

With assistance from:

DWR Region Office Staff

Groundwater Monitoring Protocols, Standards, and Sites Best Management Practice

1. Objective

The objective of this *Best Management Practice* (BMP) is to assist in the development of Monitoring Protocols. The California Department of Water Resources (the Department or DWR) has developed this document as part of the obligation in the Technical Assistance chapter (Chapter 7) of the Sustainable Groundwater Management Act (SGMA) to support the long-term sustainability of California's groundwater *basins*. Information provided in this BMP provides technical assistance to Groundwater Sustainability Agencies (GSAs) and other stakeholders to aid in the establishment of consistent data collection processes and procedures. In addition, this BMP can be used by GSAs to adopt a set of sampling and measuring procedures that will yield similar data regardless of the monitoring personnel. Finally, this BMP identifies available resources to support the development of monitoring protocols.

This BMP includes the following sections:

1. Objective. A brief description of how and where monitoring protocols are required under SGMA and the overall objective of this BMP.
2. Use and Limitations. A brief description of the use and limitations of this BMP.
3. Monitoring Protocol Fundamentals. A description of the general approach and background of groundwater monitoring protocols.
4. Relationship of Monitoring Protocols to other BMPs. A description of how this BMP is connected with other BMPS.
5. Technical Assistance. Technical content providing guidance for regulatory sections.
6. Key Definitions. Descriptions of definitions identified in the GSP Regulations or SGMA.
7. Related Materials. References and other materials that provide supporting information related to the development of Groundwater Monitoring Protocols.

2. USE AND LIMITATIONS

BMPs developed by the Department provide technical guidance to GSAs and other stakeholders. Practices described in these BMPs do not replace the GSP Regulations, nor do they create new requirements or obligations for GSAs or other stakeholders. In addition, using this BMP to develop a GSP does not equate to an approval determination by the Department. All references to GSP Regulations relate to Title 23 of the California Code of Regulations (CCR), Division 2, Chapter 1.5, and Subchapter 2. All references to SGMA relate to California Water Code sections in Division 6, Part 2.74.

3. MONITORING PROTOCOL FUNDAMENTALS

Establishing data collection protocols that are based on best available scientific methods is essential. Protocols that can be applied consistently across all basins will likely yield comparable data. Consistency of data collection methods reduces uncertainty in the comparison of data and facilitates more accurate communication within basins as well as between basins.

Basic minimum technical standards of accuracy lead to quality data that will better support implementation of GSPs.

4. RELATIONSHIP OF MONITORING PROTOCOL TO OTHER BMPS

Groundwater monitoring is a fundamental component of SGMA, as each GSP must include a sufficient network of data that demonstrates measured progress toward the achievement of the sustainability goal for each basin. For this reason, a standard set of protocols need to be developed and utilized.

It is important that data is developed in a manner consistent with the basin setting, planning, and projects/management actions steps identified on **Figure 1** and the GSP Regulations. The inclusion of monitoring protocols in the GSP Regulations also emphasizes the importance of quality empirical data to support GSPs and provide comparable information from basin to basin.

Figure 1 provides a logical progression for the development of a GSP and illustrates how monitoring protocols are linked to other related BMPs. This figure also shows the context of the BMPs as they relate to various steps to sustainability as outlined in the GSP Regulations. The monitoring protocol BMP is part of the Monitoring step identified in **Figure 1**.

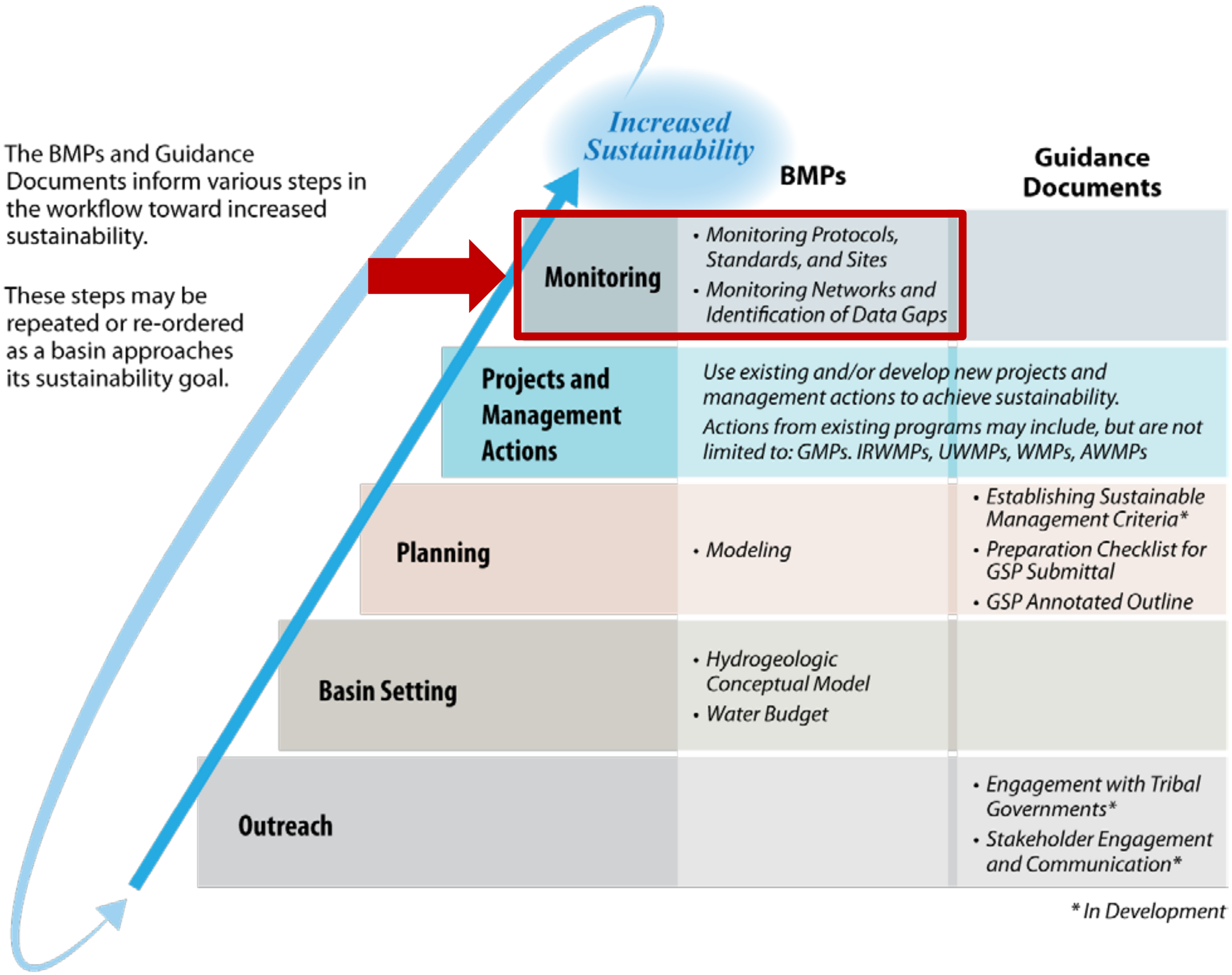

Figure 1 – Logical Progression of Basin Activities Needed to Increase Basin Sustainability

5. TECHNICAL ASSISTANCE

23 CCR §352.2. Monitoring Protocols. Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:
(a) Monitoring protocols shall be developed according to best management practices.
(b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.
(c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary.

The GSP Regulations specifically call out the need to utilize protocols identified in this BMP, or develop similar protocols. The following technical protocols provide guidance based upon existing professional standards and are commonly adopted in various groundwater-related programs. They provide clear techniques that yield quality data for use in the various components of the GSP. They can be further elaborated on by individual GSAs in the form of standard operating procedures which reflect specific local requirements and conditions. While many methodologies are suggested in this BMP, it should be understood that qualified professional judgment should be used to meet the specific monitoring needs.

The following BMPs may be incorporated into a GSP's monitoring protocols section for collecting groundwater elevation data. A GSP that adopts protocols that deviate from these BMPs must demonstrate that they will yield comparable data.

PROTOCOLS FOR ESTABLISHING A MONITORING PROGRAM

The protocol for establishment of a monitoring program should be evaluated in conjunction with the *Monitoring Network and Identification of Data Gaps* BMP and other BMPs. Monitoring protocols must take into consideration the *Hydrogeologic Conceptual Model, Water Budget, and Modeling* BMPs when considering the data needs to meet GSP objectives and the sustainability goal.

It is suggested that each GSP incorporate the Data Quality Objective (DQO) process following the U.S. EPA *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA, 2006). Although strict adherence to this method is not required, it does provide a robust approach to consider and assures that data is collected with a specific purpose in mind, and efforts for monitoring are as efficient as possible to achieve the objectives of the GSP and compliance with the GSP Regulations.

The DQO process presents a method that can be applied directly to the sustainability criteria quantitative requirements through the following steps.

1. State the problem – Define sustainability indicators and planning considerations of the GSP and sustainability goal.
2. Identify the goal – Describe the quantitative measurable objectives and minimum thresholds for each of the sustainability indicators.
3. Identify the inputs – Describe the data necessary to evaluate the sustainability indicators and other GSP requirements (i.e. water budget).
4. Define the boundaries of the study – This is commonly the extent of the Bulletin 118 groundwater basin or subbasin, unless multiple GSPs are prepared for a given basin. In that case, evaluation of the coordination plan and specifically how the monitoring will be comparable and meet the sustainability goals for the entire basin.
5. Develop an analytical approach – Determine how the quantitative sustainability indicators will be evaluated (i.e. are special analytical methods required that have specific data needs).
6. Specify performance or acceptance criteria – Determine what quality the data must have to achieve the objective and provide some assurance that the analysis is accurate and reliable.
7. Develop a plan for obtaining data – Once the objectives are known determine how these data should be collected. Existing data sources should be used to the greatest extent possible.

These steps of the DQO process should be used to guide GSAs to develop the most efficient monitoring process to meet the measurable objectives of the GSP and the sustainability goal. The DQO process is an iterative process and should be evaluated regularly to improve monitoring efficiencies and meet changing planning and project needs. Following the DQO process, GSAs should also include a data quality control and quality assurance plan to guide the collection of data.

Many monitoring programs already exist as part of ongoing groundwater management or other programs. To the extent possible, the use of existing monitoring data and programs should be utilized to meet the needs for characterization, historical record documentation, and continued monitoring for the SGMA program. However, an evaluation of the existing monitoring data should be performed to assure the data being collected meets the DQOs, regulatory requirements, and data collection protocol described in this BMP. While this BMP provides guidance for collection of various regulatory based requirements, there is flexibility among the various methodologies available to meet the DQOs based upon professional judgment (local conditions or project needs).

At a minimum, for each monitoring site, the following information or procedure should be collected and documented:

- Long-term access agreements. Access agreements should include year-round site access to allow for increased monitoring frequency.
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact (if necessary), type of information to be collected, latitude, longitude, and elevation. Each monitoring location should also track all modifications to the site in a modification log.

PROTOCOLS FOR MEASURING GROUNDWATER LEVELS

This section presents considerations for the methodology of collection of groundwater level data such that it meets the requirements of the GSP Regulations and the DQOs of the specific GSP. Groundwater levels are a fundamental measure of the status of groundwater conditions within a basin. In many cases, relationships of the sustainability indicators may be able to be correlated with groundwater levels. The quality of this data must consider the specific aquifer being monitored and the methodology for collecting these levels.

The following considerations for groundwater level measuring protocols should ensure the following:

- Groundwater level data are taken from the correct location, well ID, and screen interval depth
- Groundwater level data are accurate and reproducible
- Groundwater level data represent conditions that inform appropriate basin management DQOs
- All salient information is recorded to correct, if necessary, and compare data
- Data are handled in a way that ensures data integrity

General Well Monitoring Information

The following presents considerations for collection of water level data that include regulatory required components as well as those which are recommended.

- Groundwater elevation data will form the basis of basin-wide water-table and piezometric maps, and should approximate conditions at a discrete period in time. Therefore, all groundwater levels in a basin should be collected within as short a time as possible, preferably within a 1 to 2 week period.
- Depth to groundwater must be measured relative to an established Reference Point (RP) on the well casing. The RP is usually identified with a permanent marker, paint spot, or a notch in the lip of the well casing. By convention in open casing monitoring wells, the RP reference point is located on the north side of the well casing. If no mark is apparent, the person performing the measurement should measure the depth to groundwater from the north side of the top of the well casing.
- The elevation of the RP of each well must be surveyed to the North American Vertical Datum of 1988 (NAVD88), or a local datum that can be converted to NAVD88. The elevation of the RP must be accurate to within 0.5 foot. It is preferable for the RP elevation to be accurate to 0.1 foot or less. Survey grade global navigation satellite system (GNSS) global positioning system (GPS) equipment can achieve similar vertical accuracy when corrected. Guidance for use of GPS can be found at USGS http://water.usgs.gov/osw/gps/. Hand-held GPS units likely will not produce reliable vertical elevation measurement accurate enough for the casing elevation consistent with the DQOs and regulatory requirements.
- The sampler should remove the appropriate cap, lid, or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement should follow a period of time to allow the water level to equilibrate.
- Depth to groundwater must be measured to an accuracy of 0.1 foot below the RP. It is preferable to measure depth to groundwater to an accuracy of 0.01 foot. Air lines and acoustic sounders may not provide the required accuracy of 0.1 foot.
- The water level meter should be decontaminated after measuring each well.

Where existing wells do not meet the base standard as described in the GSP Regulations or the considerations provided above, new monitoring wells may need to be constructed to meet the DQOs of the GSP. The design, installation, and documentation of new monitoring wells must consider the following:

- Construction consistent with California Well Standards as described in Bulletins 74-81 and 74-90, and local permitting agency standards of practice.
- Logging of borehole cuttings under the supervision of a California Professional Geologist and described consistent with the Unified Soil Classification System methods according to ASTM standard D2487-11.
- Written criteria for logging of borehole cuttings for comparison to known geologic formations, principal aquifers and aquitards/aquicludes, or specific marker beds to aid in consistent stratigraphic correlation within and across basins.
- Geophysical surveys of boreholes to aid in consistency of logging practices. Methodologies should include resistivity, spontaneous potential, spectral gamma, or other methods as appropriate for the conditions. Selection of geophysical methods should be based upon the opinion of a professional geologist or professional engineer, and address the DQOs for the specific borehole and characterization needs.
- Prepare and submit State well completion reports according to the requirements of §13752. Well completion report documentation should include geophysical logs, detailed geologic log, and formation identification as attachments. An example well completion as-built log is illustrated in **Figure 2.** DWR well completion reports can be filed directly at the Online System for Well Completion Reports (OSWCR) http://water.ca.gov/oswcr/index.cfm.

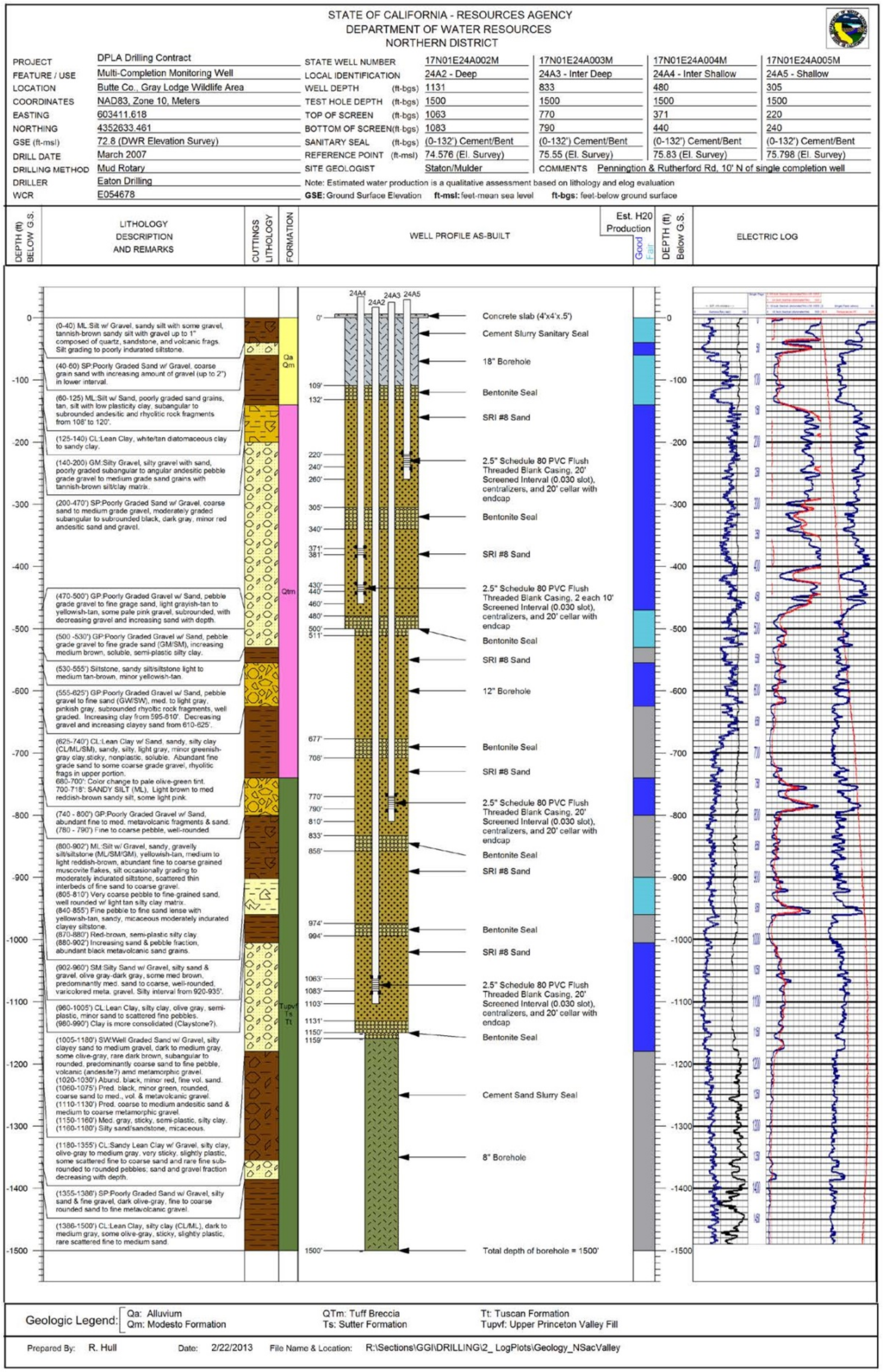

Figure 2 – Example As-Built Multi-Completion Monitoring Well Log

<u>Measuring Groundwater Levels</u>

Well construction, anticipated groundwater level, groundwater level measuring equipment, field conditions, and well operations should be considered prior collection of the groundwater level measurement. The USGS *Groundwater Technical Procedures* (Cunningham and Schalk, 2011) provide a thorough set of procedures which can be used to establish specific Standard Operating Procedures (SOPs) for a local agency. **Figure 3** illustrates a typical groundwater level measuring event and simultaneous pressure transducer download.

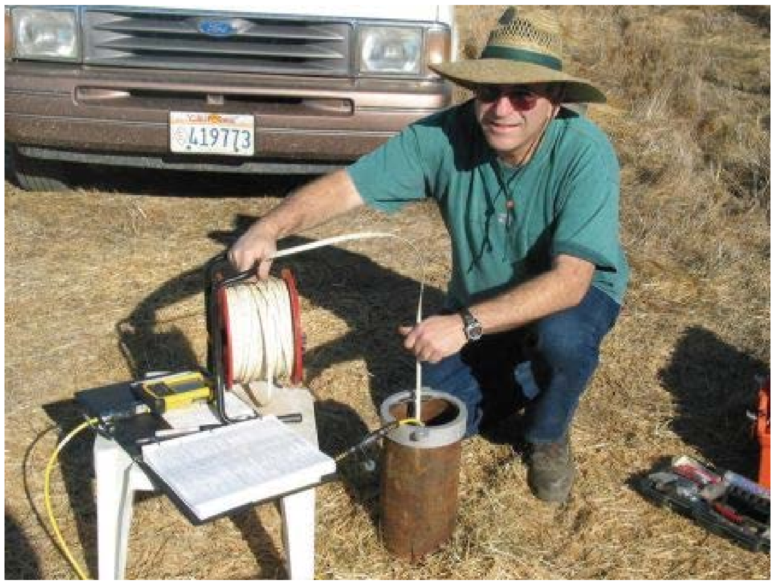

Figure 3 – Collection of Water Level Measurement and Pressure Transducer Download

The following points provide a general approach for collecting groundwater level measurements:

- Measure depth to water in the well using procedures appropriate for the measuring device. Equipment must be operated and maintained in accordance with manufacturer's instructions. Groundwater levels should be measured to the nearest 0.01 foot relative to the RP.
- For measuring wells that are under pressure, allow a period of time for the groundwater levels to stabilize. In these cases, multiple measurements should be collected to ensure the well has reached equilibrium such that no significant changes in water level are observed. Every effort should be made to ensure that a representative stable depth to groundwater is recorded. If a well does not stabilize, the quality of the value should be appropriately qualified as a

questionable measurement. In the event that a well is artesian, site specific procedures should be developed to collect accurate information and be protective of safety conditions associated with a pressurized well. In many cases, an extension pipe may be adequate to stabilize head in the well. Record the dimension of the extension and document measurements and configuration.

- The sampler should calculate the groundwater elevation as:

$$GWE = RPE - DTW$$

Where:

GWE = Groundwater Elevation
RPE = Reference Point Elevation
DTW = Depth to Water

The sampler must ensure that all measurements are in consistent units of feet, tenths of feet, and hundredths of feet. Measurements and RPEs should not be recorded in feet and inches.

<u>Recording Groundwater Levels</u>

- The sampler should record the well identifier, date, time (24-hour format), RPE, height of RP above or below ground surface, DTW, GWE, and comments regarding any factors that may influence the depth to water readings such as weather, nearby irrigation, flooding, potential for tidal influence, or well condition. If there is a questionable measurement or the measurement cannot be obtained, it should be noted. An example of a field sheet with the required information is shown in **Figure 4**. It includes questionable measurement and no measurement codes that should be noted. This field sheet is provided as an example. Standardized field forms should be used for all data collection. The aforementioned USGS *Groundwater Technical Procedures* offers a number of example forms.
- The sampler should replace any well caps or plugs, and lock any well buildings or covers.
- All data should be entered into the GSA data management system (DMS) as soon as possible. Care should be taken to avoid data entry mistakes and the entries should be checked by a second person for compliance with the DQOs.

STATE OF CALIFORNA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WELL DATA

STATE WELL NUMBER	COUNTY	REFERENCE POINT ELEV.	MEASURING AGENCY
			DWR

NO MEASUREMENT	QUESTIONABLE MEASUREMENT
0. Measurement discontinued	0. Caved or deepened
1. Pumping	1. Pumping
2. Pump house locked	2. Nearby pump operating
3. Tape hung up	3. Casing leaky or wet
4. Can't get tape in casing	4. Pumped recently
5. Unable to locate well	5. Air or pressure gauge measurement
6. Well has been destroyed	6. Other
7. Special	7. Recharge operation at or nearby well
8. Casing leaky or wet	8. Oil in casing
9. Temporarily inaccessible	

DATE	N M	Q M	TAPE AT RP	TAPE AT WS	RP to WS	OBSR VR	COMMENTS

DWR 1213

Figure 4 – Example of Water Level Well Data Field Collection Form

Pressure Transducers

Groundwater levels and/or calculated groundwater elevations may be recorded using pressure transducers equipped with data loggers installed in monitoring wells. When installing pressure transducers, care must be exercised to ensure that the data recorded by the transducers is confirmed with hand measurements.

The following general protocols must be followed when installing a pressure transducer in a monitoring well:

- The sampler must use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation. It is recommended that transducers record measured groundwater level to conserve data capacity; groundwater elevations can be calculated at a later time after downloading.
- The sampler must note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.
- Transducers must be able to record groundwater levels with an accuracy of at least 0.1 foot. Professional judgment should be exercised to ensure that the data being collected is meeting the DQO and that the instrument is capable. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers should be included in the evaluation.
- The sampler must note whether the pressure transducer uses a vented or non-vented cable for barometric compensation. Vented cables are preferred, but non-vented units provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.
- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that DQOs are being met for the GSP.
- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.
- The transducer data should periodically be checked against hand measured groundwater levels to monitor electronic drift or cable movement. This should happen during routine site visits, at least annually or as necessary to maintain data integrity.

- The data should be downloaded as necessary to ensure no data is lost and entered into the basin's DMS following the QA/QC program established for the GSP. Data collected with non-vented data logger cables should be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data should be deleted from the data logger to ensure that adequate data logger memory remains.

PROTOCOLS FOR SAMPLING GROUNDWATER QUALITY

The following protocols can be incorporated into a GSP's monitoring protocols for collecting groundwater quality data. More detailed sampling procedures and protocols are included in the standards and guidance documents listed at the end of this BMP. A GSP that adopts protocols that deviate from these BMPs must demonstrate that the adopted protocols will yield comparable data.

In general, the use of existing water quality data within the basin should be done to the greatest extent possible if it achieves the DQOs for the GSP. In some cases it may be necessary to collect additional water quality data to support monitoring programs or evaluate specific projects. The USGS *National Field Manual for the Collection of Water Quality Data* (Wilde, 2005) should be used to guide the collection of reliable data. **Figure 5** illustrates a typical groundwater quality sampling setup.

Figure 5 – Typical Groundwater Quality Sampling Event

All analyses should be performed by a laboratory certified under the State Environmental Laboratory Accreditation Program. The specific analytical methods are beyond the scope of this BMP, but should be commiserate with other programs evaluating water quality within the basin for comparative purposes.

Groundwater quality sampling protocols should ensure that:

- Groundwater quality data are taken from the correct location
- Groundwater quality data are accurate and reproducible
- Groundwater quality data represent conditions that inform appropriate basin management and are consistent with the DQOs
- All salient information is recorded to normalize, if necessary, and compare data
- Data are handled in a way that ensures data integrity

The following points are general guidance in addition to the techniques presented in the previously mentioned USGS *National Field Manual for the Collection of Water Quality Data.*

Standardized protocols include the following:

- Prior to sampling, the sampler must contact the laboratory to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.
- Each well used for groundwater quality monitoring must have a unique identifier. This identifier must appear on the well housing or the well casing to avoid confusion.
- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead. Samples should not be collected from storage tanks, at the end of long pipe runs, or after any water treatment.
- The sampler should clean the sampling port and/or sampling equipment and the sampling port and/or sampling equipment must be free of any contaminants. The sampler must decontaminate sampling equipment between sampling locations or wells to avoid cross-contamination between samples.
- The groundwater elevation in the well should be measured following appropriate protocols described above in the groundwater level measuring protocols.
- For any well not equipped with low-flow or passive sampling equipment, an adequate volume of water should be purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. Purging three well casing volumes is generally

considered adequate. Professional judgment should be used to determine the proper configuration of the sampling equipment with respect to well construction such that a representative ambient groundwater sample is collected. If pumping causes a well to be evacuated (go dry), document the condition and allow well to recover to within 90% of original level prior to sampling. Professional judgment should be exercised as to whether the sample will meet the DQOs and adjusted as necessary.

- Field parameters of pH, electrical conductivity, and temperature should be collected for each sample. Field parameters should be evaluated during the purging of the well and should stabilize prior to sampling. Measurements of pH should only be measured in the field, lab pH analysis are typically unachievable due to short hold times. Other parameters, such as oxidation-reduction potential (ORP), dissolved oxygen (DO) (in situ measurements preferable), or turbidity, may also be useful for meeting DQOs of GSP and assessing purge conditions. All field instruments should be calibrated daily and evaluated for drift throughout the day.
- Sample containers should be labeled prior to sample collection. The sample label must include: sample ID (often well ID), sample date and time, sample personnel, sample location, preservative used, and analytes and analytical method.
- Samples should be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection.
- Samples should be collected according to appropriate standards such as those listed in the *Standard Methods for the Examination of Water and Wastewater*, USGS *National Field Manual for the Collection of Water Quality Data,* or other appropriate guidance. The specific sample collection procedure should reflect the type of analysis to be performed and DQOs.
- All samples requiring preservation must be preserved as soon as practically possible, ideally at the time of sample collection. Ensure that samples are appropriately filtered as recommended for the specific analyte. Entrained solids can be dissolved by preservative leading to inconsistent results of dissolve analytes. Specifically, samples to be analyzed for metals should be field-filtered prior to preservation; do not collect an unfiltered sample in a preserved container.
- Samples should be chilled and maintained at 4 °C to prevent degradation of the sample. The laboratory's Quality Assurance Management Plan should detail appropriate chilling and shipping requirements.

- Samples must be shipped under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.
- Instruct the laboratory to use reporting limits that are equal to or less than the applicable DQOs or regional water quality objectives/screening levels.

Special protocols for low-flow sampling equipment

In addition to the protocols listed above, sampling using low-flow sample equipment should adopt the following protocols derived from EPA's *Low-flow (minimal drawdown) ground-water sampling procedures* (Puls and Barcelona, 1996). These protocols apply to low-flow sampling equipment that generally pumps between 0.1 and 0.5 liters per minute. These protocols are not intended for bailers.

Special protocols for passive sampling equipment

In addition to the protocols listed above, passive diffusion samplers should follow protocols set forth in USGS Fact Sheet 088-00.

PROTOCOLS FOR MONITORING SEAWATER INTRUSION

Monitoring seawater intrusion requires analysis of the chloride concentrations within groundwater of each principal aquifer subject to seawater intrusion. While no significant standardized approach exists, the methodologies described above for degraded water quality can be applied for the collection of groundwater samples. In addition to the protocol described above, the following protocols should be followed:

- Water quality samples should be collected and analyzed at least semi-annually. Samples will be analyzed for dissolved chloride at a minimum. It may be beneficial to include analyses of iodide and bromide to aid in determination of salinity source. More frequent sampling may be necessary to meet DQOs of GSP. The development of surrogate measures of chloride concentration may facilitate cost-effective means to monitor more frequently to observe the range of conditions and variability of the flow dynamics controlling seawater intrusion.
- Groundwater levels will be collected at a frequency adequate to characterize changes in head in the vicinity of the leading edge of degraded water quality in each principal aquifer. Frequency may need to be increased in areas of known preferential pathways, groundwater pumping, or efficacy evaluation of mitigation projects.
- The use of geophysical surveys, electrical resistivity, or other methods may provide for identification of preferential pathways and optimize monitoring well placement and evaluation of the seawater intrusion front. Professional judgment

should be exercised to determine the appropriate methodology and whether the DQOs for the GSP would be met.

PROTOCOLS FOR MEASURING STREAMFLOW

Monitoring of streamflow is necessary for incorporation into water budget analysis and for use in evaluation of stream depletions associated with groundwater extractions. The use of existing monitoring locations should be incorporated to the greatest extent possible. Many of these streamflow monitoring locations currently follow the protocol described below.

Establishment of new streamflow discharge sites should consider the existing network and the objectives of the new location. Professional judgment should be used to determine the appropriate permitting that may be necessary for the installation of any monitoring locations along surface water bodies. Regular frequent access will be necessary to these sites for the development of ratings curves and maintenance of equipment.

To establish a new streamflow monitoring station special consideration must be made in the field to select an appropriate location for measuring discharge. Once a site is selected, development of a relationship of stream stage to discharge will be necessary to provide continuous estimates of streamflow. Several measurements of discharge at a variety of stream stages will be necessary to develop the ratings curve correlating stage to discharge. The use of Acoustic Doppler Current Profilers (ADCPs) can provide accurate estimates of discharge in the correct settings. Professional judgment must be exercised to determine the appropriate methodology. Following development of the ratings curve a simple stilling well and pressure transducer with data logger can be used to evaluate stage on a frequent basis. A simple stilling well and staff gage is illustrated in **Figure 6**.

Streamflow measurements should be collected, analyzed, and reported in accordance with the procedures outlined in USGS Water Supply Paper 2175, *Volume 1. – Measurement of Stage Discharge* and *Volume 2. – Computation of Discharge.* This methodology is currently being used by both the USGS and DWR for existing streamflow monitoring throughout the State.

Figure 6 – Simple Stilling Well and Staff Gage Setup

PROTOCOLS FOR MEASURING SUBSIDENCE

Evaluating and monitoring inelastic land subsidence can utilize multiple data sources to evaluate the specific conditions and associated causes. To the extent possible, the use of existing data should be utilized. Subsidence can be estimated from numerous techniques, they include: level surveying tied to known stable benchmarks or benchmarks located outside the area being studied for possible subsidence; installing and tracking changes in borehole extensometers; obtaining data from continuous GPS (CGPS) locations, static GPS surveys or Real-Time-Kinematic (RTK) surveys; or analyzing Interferometric Synthetic Aperture Radar (InSAR) data. No standard procedures exist for collecting data from the potential subsidence monitoring approaches. However, an approach may include:

- Identification of land subsidence conditions.
    - Evaluate existing regional long-term leveling surveys of regional infrastructure, i.e. roadways, railroads, canals, and levees.
    - Inspect existing county and State well records where collapse has been noted for well repairs or replacement.
    - Determine if significant fine-grained layers are present such that the potential for collapse of the units could occur should there be significant depressurization of the aquifer system.

  - Inspect geologic logs and the hydrogeologic conceptual model to aid in identification of specific units of concern.
  - Collect regional remote-sensing information such as InSAR, commonly provided by USGS and NASA. Data availability is currently limited, but future resources are being developed.
- Monitor regions of suspected subsidence where potential exists.
  - Establish CGPS network to evaluate changes in land surface elevation.
  - Establish leveling surveys transects to observe changes in land surface elevation.
  - Establish extensometer network to observe land subsidence. An example of a typical extensometer design is illustrated in **Figure 7**. There are a variety of extensometer designs and they should be selected based on the specific DQOs.

Various standards and guidance documents for collecting data include:

- Leveling surveys must follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- GPS surveys must follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- USGS has been performing subsidence surveys within several areas of California. These studies are sound examples for appropriate methods and should be utilized to the extent possible and where available:
  - http://ca.water.usgs.gov/land_subsidence/california-subsidence-measuring.html
- Instruments installed in borehole extensometers must follow the manufacturer's instructions for installation, care, and calibration.
- Availability of InSAR data is improving and will increase as programs are developed. This method requires expertise in analysis of the raw data and will likely be made available as an interpretative report for specific regions.

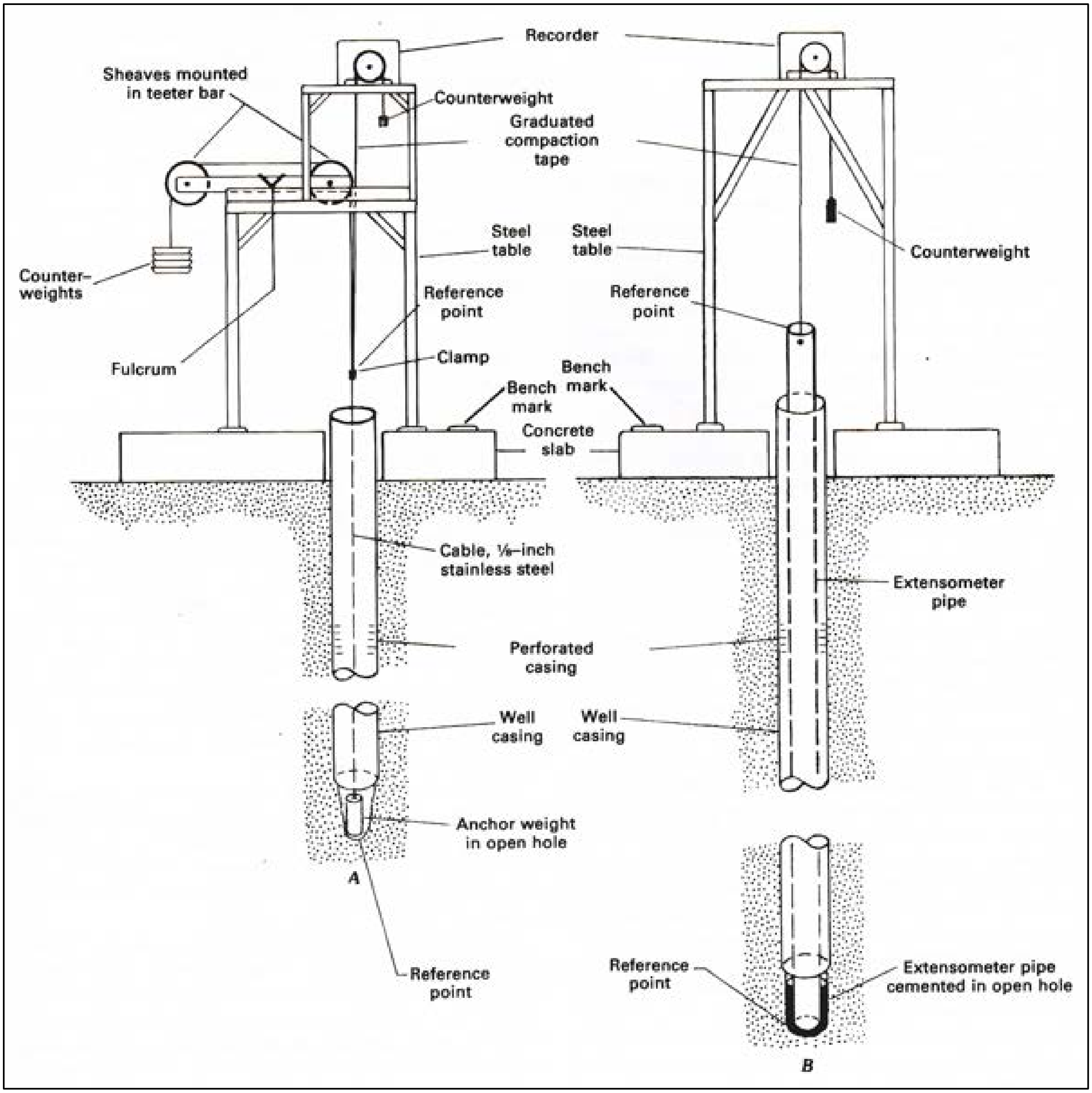

Figure 7 – Simplified Extensometer Diagram

6. KEY DEFINITIONS

The key definitions and sections related to Groundwater Monitoring Protocols, Standards, and Sites outlined in applicable SGMA code and regulations are provided below for reference.

Groundwater Sustainability Plan Regulations (California Code of Regulations §351)

- §351(h) "Best available science" refers to the use of sufficient and credible information and data, specific to the decision being made and the time frame available for making that decision, that is consistent with scientific and engineering professional standards of practice.
- §351(i) "Best management practice" refers to a practice, or combination of practices, that are designed to achieve sustainable groundwater management and have been determined to be technologically and economically effective, practicable, and based on best available science.

Monitoring Protocols Reference

§352.2. Monitoring Protocols

Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:

(a) Monitoring protocols shall be developed according to best management practices.

(b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.

(c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary.

SGMA Reference

§10727.2. Required Plan Elements

(f) Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin. The monitoring protocols shall be designed to generate information that promotes efficient and effective groundwater management.

7. Related Materials

CASE STUDIES

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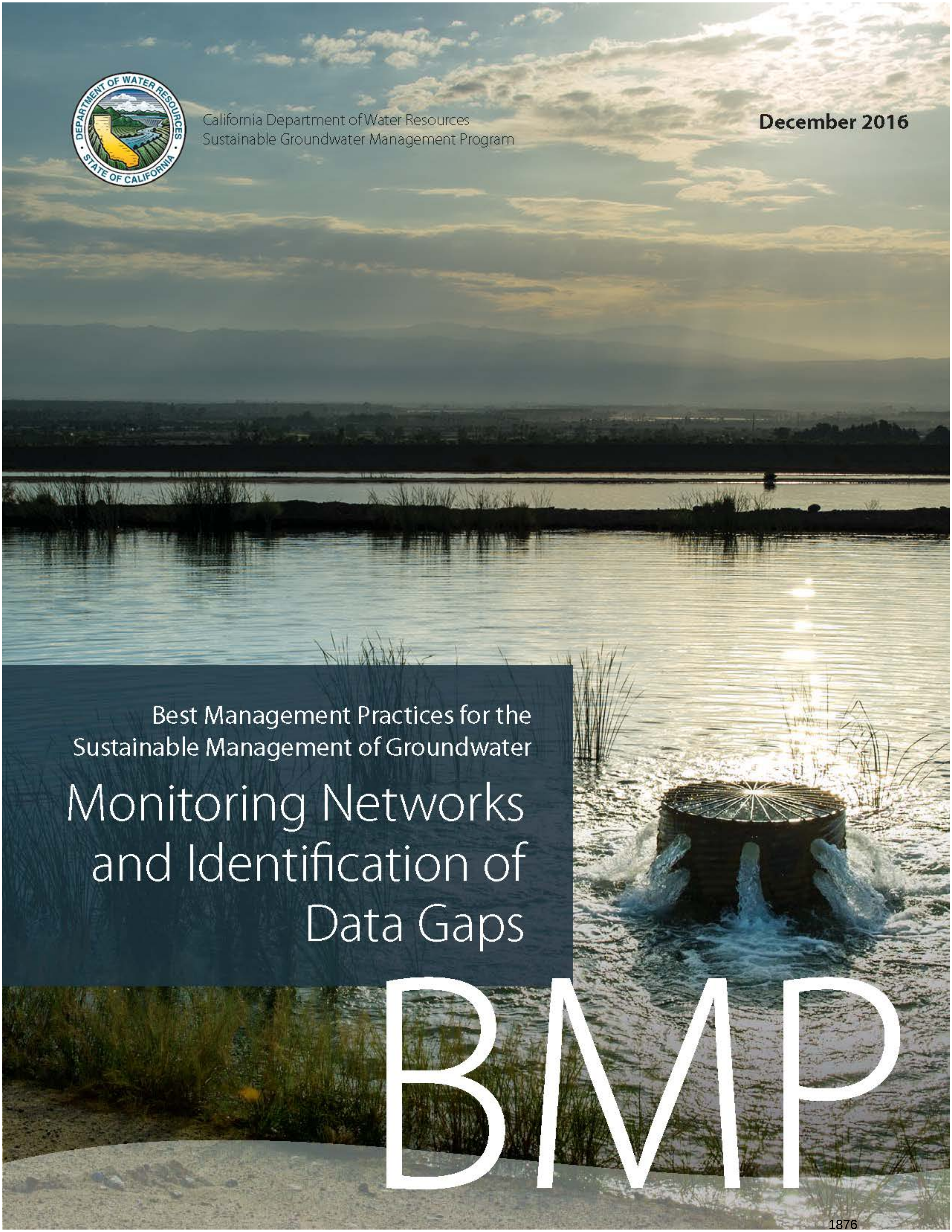
Appendix 4E

DWR Monitoring Networks and Identification of Data Gaps BMP



California Department of Water Resources
Sustainable Groundwater Management Program

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Best Management Practices for the Sustainable Management of Groundwater

Monitoring Networks and Identification of Data Gaps

BMP

State of California
Edmund G. Brown Jr., Governor

California Natural Resources Agency
John Laird, Secretary for Natural Resources

Department of Water Resources
Mark W. Cowin, Director

Carl A. Torgersen, Chief Deputy Director

Office of the Chief Counsel
Spencer Kenner

Public Affairs Office
Ed Wilson

Government and Community Liaison
Anecita S. Agustinez

Office of Workforce Equality
Stephanie Varrelman

Policy Advisor
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Taryn Ravazzini	**Special Initiatives**

Division of Integrated Regional Water Management

Arthur Hinojosa Jr., Chief

Prepared under the direction of:

David Gutierrez, Sustainable Groundwater Management Program Manager
Rich Juricich, Sustainable Groundwater Management Branch

Prepared by:

Trevor Joseph, BMP Project Manager

Timothy Godwin
Dan McManus
Mark Nordberg
Heather Shannon
Steven Springhorn

With assistance from:

DWR Region Office Staff

Monitoring Networks and Identification of Data Gaps Best Management Practice

1. Objective

The objective of this Best Management Practice (BMP) is to assist in the development of Monitoring Networks and Identification of Data Gaps. The California Department of Water Resources (the Department or DWR) has developed this document as part of the obligation in the Technical Assistance chapter (Chapter 7) of the Sustainable Groundwater Management Act (SGMA) to support the long-term sustainability of California's groundwater *basins*. Information provided in this BMP provides technical assistance to Groundwater Sustainability Agencies (GSAs) and other stakeholders to aid in the development of a monitoring network that is capable of providing sustainability indicator data of sufficient accuracy and quantity to demonstrate that the basin is being sustainably managed. In addition, this BMP is intended to provide information on how to identify and plan to resolve data gaps to reduce uncertainty that may be necessary to improve the ability of the GSP to achieve the sustainability goal for the basin.

This BMP includes the following sections:

1. Objective. A brief description of how and where monitoring networks are required under Sustainable Groundwater Management Act (SGMA) and the overall objective of this BMP.
2. Use and Limitations. A brief description of the use and limitations of this BMP.
3. Monitoring Network Fundamentals. A description of the general approach and background of groundwater monitoring networks.
4. Relationship of Monitoring Network to other BMPs. A description of how this BMP is connected with other BMPs.
5. Technical Assistance. Technical content of BMP providing guidance for regulatory sections.
6. Key Definitions. Descriptions of those definitions identified in the GSP Regulations, SGMA, or Basin Boundary Regulations.
7. Related Materials. References and other materials that provide supporting information related to the development of Groundwater Monitoring Networks.

2. USE AND LIMITATIONS

BMPs developed by the Department provide technical guidance to GSAs and other stakeholders. Practices described in these BMPs do not replace the GSP Regulations, nor do they create new requirements or obligations for GSAs or other stakeholders. In addition, using this BMP to develop a GSP does not equate to an approval determination by the Department. All references to GSP Regulations relate to Title 23 of the California Code of Regulations (CCR), Division 2, Chapter 1.5, and Subchapter 2. All references to SGMA relate to California Water Code sections in Division 6, Part 2.74.

3. MONITORING NETWORK FUNDAMENTALS

Monitoring is a fundamental component necessary to measure progress toward the achievement of any management goal. A monitoring network must have adequate spatial and temporal collection of multiple datasets, including groundwater levels, water quality information, land surface elevation, and surface water discharge conditions to demonstrate compliance with the GSP Regulations.

SGMA requires GSAs to establish and track locally defined significant and unreasonable conditions for each of the sustainability indicators. In addition, the collection of data from a robust network is required to ensure that uncertainty is appropriately reduced during the analysis of these datasets. Data collected in an organized and consistent manner will aid in ensuring that the interpretations of the data are as accurate as possible. Also, the consistency of the types, methods, and timing of data collection facilitate the sharing of data across basin boundaries or within basins.

Analyzing data from an adequate monitoring network within a basin can lead to refinement of the understanding of the dynamic flow conditions; this leads to the optimization of sustainable groundwater management.

4. RELATIONSHIP OF MONITORING NETWORKS TO OTHER BMPS

Groundwater monitoring is a fundamental component of SGMA as each GSP must include a sufficient network that provides data that demonstrate measured progress toward achievement of the sustainability goal for each basin. For this reason, a sufficient network will need to be developed and utilized to accomplish this component of SGMA.

It is important that data are developed in a manner consistent with the basin setting, planning, and projects/management actions steps identified on **Figure 1** and the GSP

Regulations. The inclusion of monitoring protocols in the GSP Regulations also emphasizes the importance of quality empirical data to support GSPs and provide comparable information from basin to basin.

Figure 1 provides a logical progression for the development of a GSP and illustrates how monitoring networks are linked to other related BMPs. This figure also shows the context of the BMPs as they relate to various steps to sustainability as outlined in the GSP Regulations. The monitoring protocol BMP is part of the Monitoring step identified in the logical progression illustration in **Figure 1**.

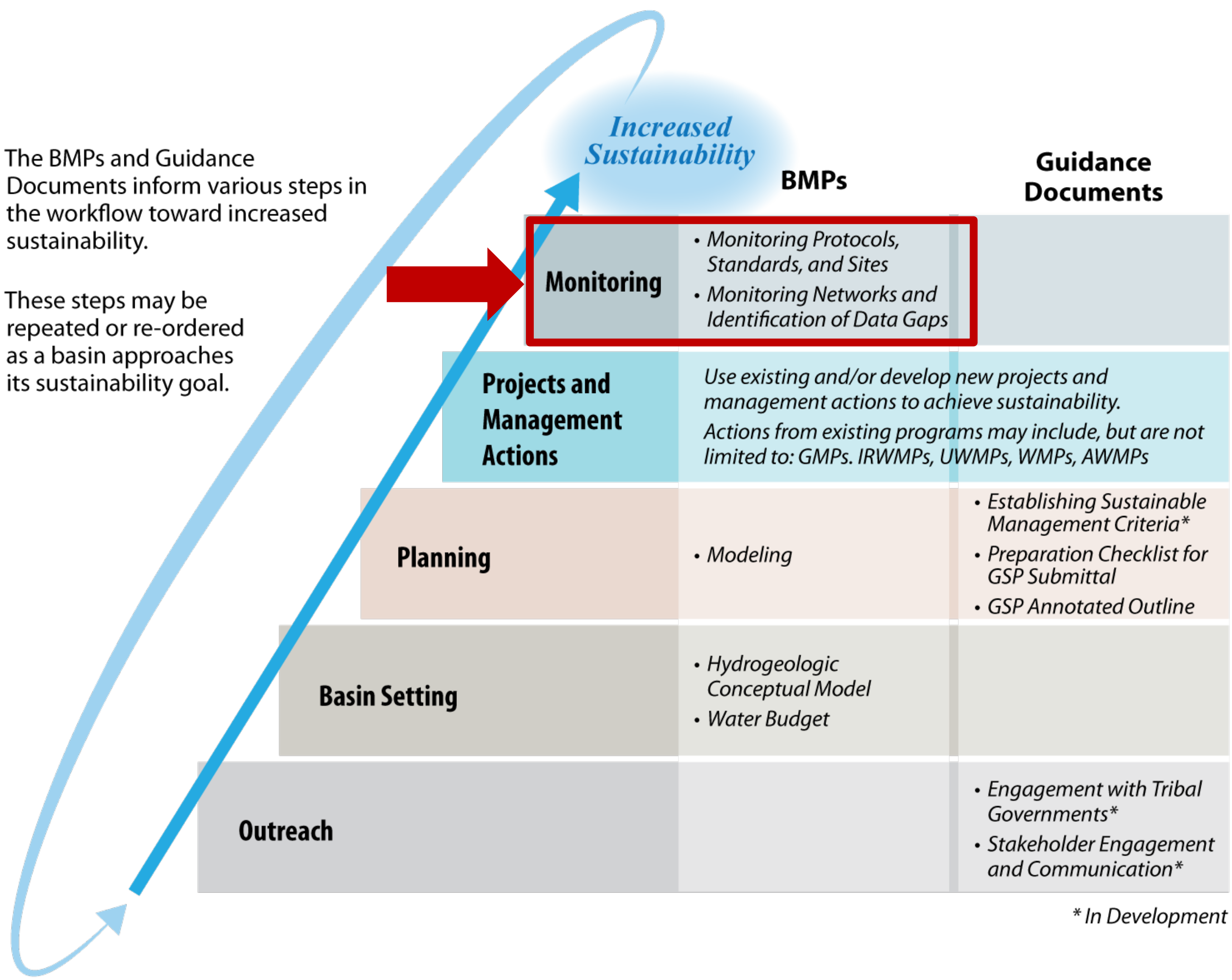

Figure 1 – Logical Progression of Basin Activities Needed to Increase Basin Sustainability

5. TECHNICAL ASSISTANCE

This section provides technical assistance to support the development monitoring networks and identification of data gaps.

GENERAL MONITORING NETWORKS

23 CCR §354.32 Introduction to Monitoring Networks* and *§354.34 (a) and (b) Monitoring Network

> ***23 CCR §354.32. Introduction to Monitoring Networks***
> *This Subarticle describes the monitoring network that shall be developed for each basin, including monitoring objectives, monitoring protocols, and data reporting requirements. The monitoring network shall promote the collection of data of sufficient quality, frequency, and distribution to characterize groundwater and related surface water conditions in the basin and evaluate changing conditions that occur through implementation of the Plan.*
>
> ***23 CCR §354.34. Monitoring Network***
> *(a) Each Agency shall develop a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation. (b) Each Plan shall include a description of the monitoring network objectives for the basin, including an explanation of how the network will be developed and implemented to monitor groundwater and related surface conditions, and the interconnection of surface water and groundwater, with sufficient temporal frequency and spatial distribution to evaluate the affects and effectiveness of Plan implementation. The monitoring network objectives shall be implemented to accomplish the following:*
> *(1) Demonstrate progress toward achieving measurable objectives described in the Plan.*
> *(2) Monitor impacts to the beneficial uses or users of groundwater.*
> *(3) Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds.*
> *(4) Quantify annual changes in water budget components.*

The GSP Regulations require GSAs to develop a monitoring network. The monitoring network must be capable of capturing data on a sufficient temporal frequency and spatial distribution to demonstrate short-term, seasonal, and long-term trends in basin conditions for each of the sustainability indicators, and provide enough information to evaluate GSP implementation. A monitoring network should be developed in such a way that it demonstrates progress toward achieving measureable objectives.

As described in the Monitoring Protocols, Standards, and Sites BMP, it is suggested that each GSP incorporate the Data Quality Objective (DQO) process following the US EPA *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA, 2006). Although strict adherence to this method is not required, it does provide a robust approach to ensuring data is collected with a specific purpose in mind, and efforts for monitoring are as efficient as possible to achieve the objectives of the GSP and compliance with the GSP Regulations.

The DQO process presents a method that can be applied directly to the sustainability criteria quantitative requirements through the following steps:

1. State the problem – define sustainability indicators and planning considerations of the GSP and sustainability goal
2. Identify the goal – describe the quantitative measurable objectives and minimum thresholds for each of the sustainability indicators
3. Identify the inputs – describe the data necessary to evaluate the sustainability indicators and other GSP requirements (i.e., water budget)
4. Define the boundaries of the study – This is commonly the extent of the Bulletin 118 groundwater basin or subbasin, unless multiple GSPs are prepared for a given basin. In that case, evaluation of the coordination plan and specifically how the monitoring will be comparable and meet the sustainability goals for the entire basin should be described
5. Develop an analytical approach – Determine how the quantitative sustainability indicators will be evaluated (i.e., are special analytical methods required that have specific data needs)
6. Specify performance or acceptance criteria – Determine what quality the data must have to achieve the objective and provide some assurance that the analysis is accurate and reliable
7. Develop a plan for obtaining data – Once the objectives are known determine how these data should be collected. Existing data sources should be used to the greatest extent possible

These steps of the DQO process should be used to guide GSAs to development of the most efficient monitoring process to meet the measurable objectives of the GSP and the sustainability goal. The DQO process is an iterative process and should be evaluated regularly to improve monitoring efficiencies and meet changing planning and project needs. Following the DQO process GSAs should also include a data quality control and quality assurance plan to guide the collection of data.

GSAs should first evaluate their existing monitoring network and existing datasets when developing the monitoring network for their GSP, such as the California Statewide Groundwater Elevation Monitoring (CASGEM) program. The *Assessment and Improvement of Monitoring Network* Section of the Regulations describes a process by which GSAs can identify and fill in gaps in their monitoring network. The existing monitoring networks may require evaluation to ensure they meet the DQOs necessary for the GSP. Other considerations for developing a monitoring network include:

- Degree of monitoring. The degree of monitoring should be consistent with the level of groundwater use and need for various levels of monitoring density and frequency. Areas that are subject to greater groundwater pumping, greater fluctuations in conditions, significant recharge areas, or specific projects may require more monitoring (temporal and/or spatial) than areas that experience less activity or are more static.
- Access Issues. GSAs may have to deal with access issues such as unwilling landowners, access agreements, destroyed wells, or other safety concerns with accessing a monitoring site.
- Adjacent Basins. Understanding conditions at or across basin boundaries is important. GSAs should coordinate with adjacent basins on monitoring efforts to be consistent both temporally and spatially. Coordinated efforts and shared data will help GSAs understand their basins' conditions better and potentially better understand groundwater flow conditions across boundaries.
- Consider all sustainability indicators. GSAs should look for ways to efficiently use monitoring sites to collect data for more than one or all of the sustainability indicators. Similarly, when installing a new monitoring site, GSAs should take that opportunity to gather as much information about the subsurface conditions as possible.

There are many other considerations that GSAs must understand when developing monitoring networks that are specific to the various sustainability indicators: chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, land subsidence, or depletions of interconnected surface waters. In addition, establishment of a monitoring network should be evaluated in conjunction with the Monitoring Protocols, Standards, and Sites; Hydrogeologic Conceptual Model (HCM); Water Budget; and Modeling BMPs when considering the data needs to meet GSP measurable objectives and the sustainability goal.

SPECIFIC MONITORING NETWORKS

23 CCR §354.34(d)-(j):

(d) The monitoring network shall be designed to ensure adequate coverage of sustainability indicators. If management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the basin setting and sustainable management criteria specific to that area.

(e) A Plan may utilize site information and monitoring data from existing sources as part of the monitoring network.

(f) The Agency shall determine the density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends based upon the following factors:

(1) Amount of current and projected groundwater use.

(2) Aquifer characteristics, including confined or unconfined aquifer conditions, or other physical characteristics that affect groundwater flow.

(3) Impacts to beneficial uses and users of groundwater and land uses and property interests affected by groundwater production, and adjacent basins that could affect the ability of that basin to meet the sustainability goal.

(4) Whether the Agency has adequate long-term existing monitoring results or other technical information to demonstrate an understanding of aquifer response.

(g) Each Plan shall describe the following information about the monitoring network:

(1) Scientific rationale for the monitoring site selection process.

(2) Consistency with data and reporting standards described in Section 352.4. If a site is not consistent with those standards, the Plan shall explain the necessity of the site to the monitoring network, and how any variation from the standards will not affect the usefulness of the results obtained.

(3) For each sustainability indicator, the quantitative values for the minimum threshold, measurable objective, and interim milestones that will be measured at each monitoring site or representative monitoring sites established pursuant to Section 354.36.

(h) The location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used.

(i) The monitoring protocols developed by each Agency shall include a description of technical standards, data collection methods, and other procedures or protocols pursuant to Water Code Section 10727.2(f) for monitoring sites or other data collection facilities to ensure that the monitoring network utilizes comparable data and methodologies.

(j) An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish a monitoring network related to those sustainability indicators.

Monitoring data provide the basis for demonstrating that undesirable results are avoided and are necessary for adequately managing the basin. The undesirable result associated with each sustainability indicator is based on a unique set of representative monitoring points. Therefore, a single monitoring network may not be appropriate to address all sustainability indicators. The monitoring network will consist of an adequate magnitude of monitoring locations that will characterize the groundwater flow regime such that a GSA will have the ability to predict sustainability indicator responses to management actions and document those results. The data collected from these networks will be the foundation for communication to other connected basins as one may affect another. The transparent availability of data is intended to alleviate conflict by demonstrating conditions in a consistent manner such that assessment of the sustainability indicators is relatively consistent from basin to basin.

The use of existing monitoring networks established during implementation of CASGEM, Irrigated Lands Reporting Program (IRLP), Groundwater Ambient Monitoring and Assessment Program (GAMA), National Groundwater Monitoring Network, Existing Groundwater Management Planning, and other local programs could be used for a base monitoring network from which to build. These networks should be evaluated for compliance with GSP Regulations and DQOs.

This section addresses the design and installation of monitoring networks and sites. Agencies must address a number of issues prior to designing the monitoring site, including, but not limited to, establishing the reason for installing the monitoring site, obtaining access agreements, assessing how the monitoring site may improve the basin conceptual model, assessing how the monitoring site may reduce uncertainty, etc. Where management areas are established, each area must be considered when developing the monitoring network for each sustainability indicator.

Professional judgement will be essential to determining the degree of monitoring that will be necessary to meet the needs for the GSP. This BMP provides guidance, but should be coupled with site-specific monitoring needs to address the complexities of the groundwater basin and DQOs.

The following sections are organized by each of the sustainability indicators. These considerations should be applied to the network as a whole to ensure the quality of the data is consistent and reliable, and so that sound representative monitoring locations can be established, as described in the Representative Monitoring Points (RMP) section of this BMP.

A. Chronic Lowering of Groundwater Levels

> ***§354.34(c):*** *Each monitoring network shall be designed to accomplish the following for each sustainability indicator:*
> *(1) Chronic Lowering of Groundwater Levels. Demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features by the following methods:*
> *(A) A sufficient density of monitoring wells to collect representative measurements through depth-discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer.*
> *(B) Static groundwater elevation measurements shall be collected at least two times per year, to represent seasonal low and seasonal high groundwater conditions.*

The observation and collection of groundwater level data is the cornerstone of data collected for SGMA compliance. Design of the groundwater level data monitoring network will be dependent upon the initial hydrogeologic conceptual model and will likely undergo refinement both temporally and spatially as management in the basin progresses. This isn't to say that the monitoring network will continually expand, but rather, through increased understanding, be more refined to gather the necessary information in the most efficient way possible to demonstrate sustainability, and exercise the basin to maintain conditions consistent with the sustainability goal and sustainable yield of the basin. The use of groundwater levels as a surrogate for other sustainability indicators will require reliable, consistent, high-quality, defendable data to demonstrate the relationship prior to use as a surrogate for other sustainability indicators.

Wells that are part of the monitoring program should be dedicated groundwater monitoring wells with known construction information. The selection of wells should be aquifer-specific and wells that are screened across more than one aquifer should be avoided where possible. If existing wells are used, the perforated intervals should be known to be able to utilize water level or other data collected from that well. Development of the monitoring well network must evaluate and consider both unconfined and confined aquifers, and assess where pumping wells are screened that affect monitoring at these locations. Agricultural or municipal wells can be used temporarily until either dedicated monitoring wells can be installed or an existing well can be identified that meets the above criteria. If agricultural or municipal wells are used for monitoring, the wells must be screened across a single water-bearing unit, and care must be taken to ensure that pumping drawdown has sufficiently recovered before collecting data from a well.

Each well selected for inclusion in the monitoring network should be evaluated to ensure that water level data obtained meet the DQOs for that well. For example, some wells may be directly influenced by nearby pumping, or injection and observation of the aquifer response may be the purpose of the well. Otherwise, the network should contain an adequate number of wells to observe the overall static conditions and the specific project effects. Well construction details and pumping information for active and inactive wells located in the area of the selected monitoring well location should be reviewed to determine whether construction details or pumping activity at those wells could affect water level or water quality data for the selected monitoring site.

There is no definitive rule for the density of groundwater monitoring points needed in a basin. **Table 1** was adopted from the *CASGEM Groundwater Elevation Monitoring Guidelines* (DWR, 2010). This table summarizes existing references to quantify the density of monitoring wells per hundred square miles. While these estimates may provide guidance, the necessary monitoring point density for GSP depends on local geology, extent of groundwater use, and how the GSPs define undesirable results. The use of Hopkins (1984) analysis incorporates a relative well density based on the degree of groundwater use within a given area. Professional judgement will be essential to determining an adequate level of monitoring, frequency, and density based on the DQOs and the need to observe aquifer response to high pumping areas, cones of depression, significant recharge areas, and specific projects.

Table 1. Monitoring Well Density Considerations

Reference	Monitoring Well Density (wells per 100 miles^2)
Heath (1976)	0.2 - 10
Sophocleous (1983)	6.3
Hopkins (1984) Basins pumping more than 10,000 acre-feet/year per 100 miles^2	4.0
Basins pumping between 1,000 and 10,000 acre-feet/year per 100 miles^2	2.0
Basins pumping between 250 and 1,000 acre-feet/year per 100 miles^2	1.0
Basins pumping between 100 and 250 acre-feet/year per 100 miles^2	0.7

In addition to monitoring well network density, the frequency of monitoring to characterize the groundwater dynamics within a basin or area is important. The discussion presented in the *National Framework for Ground-water Monitoring in the United States* (ACWI, 2013) utilizes a degree of groundwater use and aquifer characteristics to aid in determining an appropriate frequency. **Figure 2** (ACWI, 2013) and **Table 2** (ACWI, 2013) describe these considerations and provide recommended frequency of long-term monitoring. It should be noted that the initial characterization is not included; the initial characterization of a monitoring location will require more frequent monitoring to establish the dynamic range and identification of external stresses affecting the groundwater level. An understanding of the full range of monitoring well conditions should be reached prior to establishing a long-term monitoring frequency. The considerations presented in **Figure 2** and **Table 2** should be evaluated to determine if the guidance meets the DQOs to support the GSP. Professional judgment should be used to refine the monitoring frequency and density.

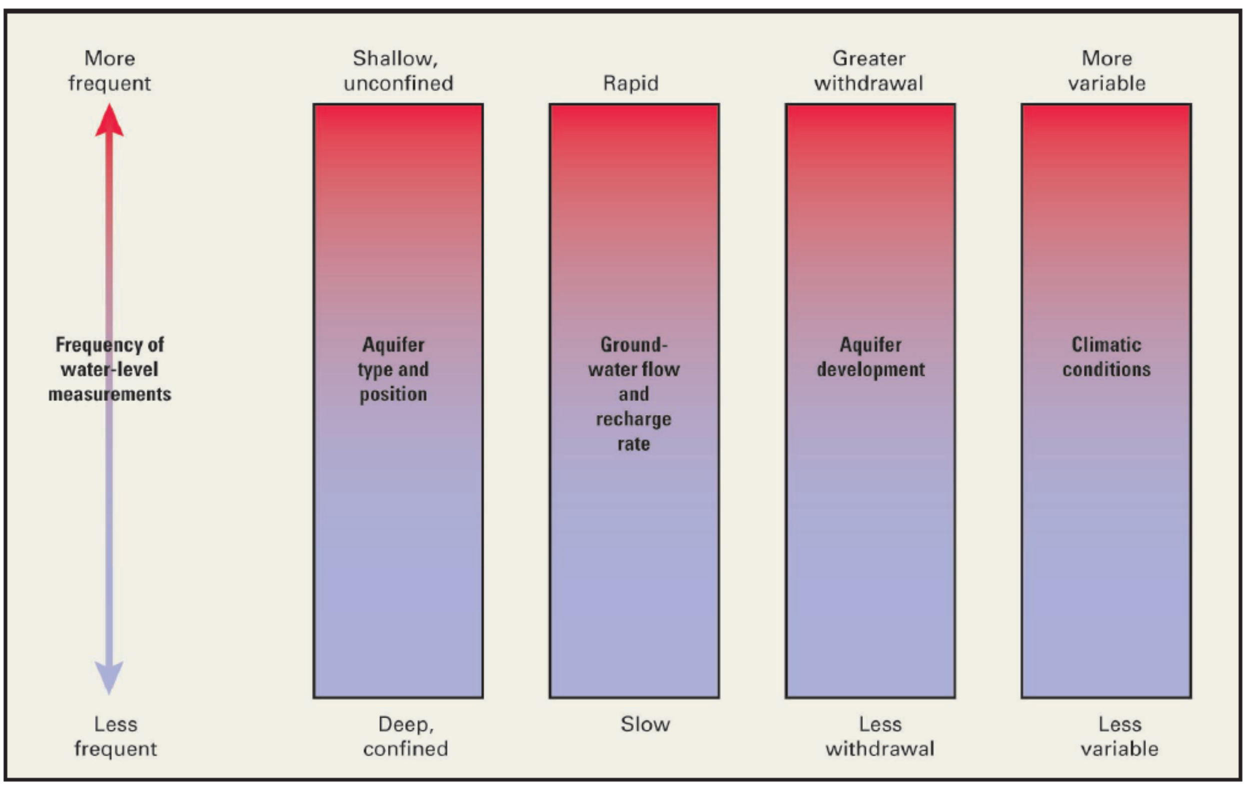

Figure 2. Factors Determining Frequency of Monitoring Groundwater Levels (Taylor and Alley, 2001, adapted from ACWI, 2013)

Table 2. Monitoring Frequency Based on Aquifer Properties and Degree of Use (adapted from ACWI, 2013)

Aquifer Type	Nearby Long-Term Aquifer Withdrawals		
	Small Withdrawals	Moderate Withdrawals	Large Withdrawals
Unconfined			
"low" recharge (<5 in/yr)	Once per quarter	Once per quarter	Once per month
"high" recharge (>5 in/yr)	Once per quarter	Once per month	Once per day
Confined			
"low" hydraulic conductivity (<200 ft/d)	Once per quarter	Once per quarter	Once per month
"high" hydraulic conductivity (>200 ft/d)	Once per quarter	Once per month	Once per day

The discussion below provides specific management practices for implementation of the GSP, where the general approaches for considering monitoring network density and frequency described above provide some guidance for the expectations for network design.

- New wells must meet applicable well installation standards set in California DWR Bulletin 74-81 and 74-90, or as updated.
- Groundwater level data will be collected from each principal aquifer in the basin.
- Groundwater level data must be sufficient to produce seasonal maps of potentiometric surfaces or water table surfaces throughout the basin that clearly identify changes in groundwater flow direction and gradient.
- Groundwater levels will be collected during the middle of October and March for comparative reporting purposes.
    - While semi-annual monitoring is required, more frequent, quarterly, monthly, or daily monitoring may be necessary to provide a more robust understanding of groundwater dynamics within the system.
    - Agencies will need to adjust the monitoring frequency to address uncertainty, such as in specific places where sustainability indicators are of concern, or to track specific management actions and projects as they are implemented.
    - Select wells should be monitored frequently enough to characterize the season high and low within the basin.

- Data must be sufficient for mapping groundwater depressions, recharge areas, and along margins of basins where groundwater flow is known to enter or leave a basin.
- Well density must be adequate to determine changes in storage.
- Data must be able to demonstrate the interconnectivity between shallow groundwater and surface water bodies, where appropriate.
- Data must be able to map the effects of management actions, i.e., managed aquifer recharge or hydraulic seawater intrusion barriers.
- Data must be able to demonstrate conditions at basin boundaries.
    - Agencies may consider coordinating monitoring efforts with adjacent basins to provide consistent data across basin boundaries.
    - Agencies may consider characterization and continued impacts of internal hydraulic boundary conditions, such as faults, disconformities, or other internal boundary types.
- Data must be able to characterize conditions and monitor adverse impacts as they may affect the beneficial uses and users identified within the basin.

Additional Information:

Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data
http://pubs.usgs.gov/circ/circ1217/pdf/circ1217_final.pdf

A National Framework for Ground-Water Monitoring in the United States
Fact Sheet: http://acwi.gov/sogw/NGWMN_InfoSheet_final.pdf
Full Report: http://acwi.gov/sogw/ngwmn_framework_report_july2013.pdf

Statistical Design of Water-Level Monitoring Networks
http://pubs.usgs.gov/circ/circ1217/pdf/pt4.pdf

Design of Ground-Water Level Observation-Well Programs
http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.1976.tb03635.x/epdf

B. Reduction of Groundwater Storage

> ***23 CCR §354.34(c)(2):*** *Reduction of Groundwater Storage. Provide an estimate of the change in annual groundwater in storage.*

While reduction in groundwater storage is not a directly measureable condition, it does rely heavily on the collection of accurate groundwater levels, as described in the preceding section, and a robust understanding of the HCM and textural observations from boreholes. The identification in the HCM of discrete aquifer units and surrounding aquitards will be essential in assessing changes in groundwater storage. The changes in groundwater levels reflect changes in storage and can thus be estimated with assumptions of thickness of units, porosity, and connectivity. These observations will be essential for use in calculating the water budget; see the Water Budget BMP for more detail.

Estimates of changes in storage are available from remote sensing-based investigations, but should be used cautiously as they tend to be regional in nature and may not provide the level of accuracy necessary to fully determine the conditions within the basin. The National Aeronautics and Space Administration (NASA) mission, Gravity Recovery and Climate Experiment (GRACE) satellites provide analysis results of differential gravity response associated with changes in groundwater occurrence and terrestrial water storage, http://www.nasa.gov/mission_pages/Grace/#.WATU_fkrKUk .

C. Seawater Intrusion

> ***23 CCR §354.34(c)(3):*** *Seawater Intrusion. Monitor seawater intrusion using chloride concentrations, or other measurements convertible to chloride concentrations, so that the current and projected rate and extent of seawater intrusion for each applicable principal aquifer may be calculated.*

The monitoring network for seawater intrusion must capture changes in water quality conditions associated with the dynamic seawater-freshwater interface along coastal aquifers. This system is largely controlled by differences in water density and hydraulic head to maintain the advancement of the seawater front. A robust understanding is necessary to identify the preferential flow pathways where seawater can intrude inland and associate with freshwater groundwater extractions or declines in head. The following practices should be considered, at a minimum, to provide data supporting the assessment of seawater intrusion:

- Monitoring groundwater elevation in all seawater intrusion-specific monitoring locations should be consistent with the water level monitoring network and protocols described in this and the Monitoring Protocol, Standards, and Sites BMP.
- Monitor groundwater quality data from each principal aquifer in the basin that is currently, or may be in the future, impacted by seawater intrusion.
    - The spatial density must be adequate to map an isocontour of chloride advancement front as a representation of seawater. It may be useful to include other ions such as bromide and iodide for evaluation of source of high salinity water.
    - Monitoring should occur at least quarterly and correspond with seasonal highs and lows, or more frequently as appropriate. Professional judgment should be used to evaluate the necessary frequency and density of monitoring to meet the DQOs.
    - The above points do not include initial characterization, where more frequent monitoring may be necessary to evaluate the full dynamic range of aquifer response and associated seawater intrusion.
- Collect groundwater quality data from each principal aquifer in the basin that is currently, or may be in the future, impacted by degraded water quality.
    - Agencies should use, to the greatest degree possible, existing water quality monitoring data. For example, these could include ILRP, GAMA, existing Regional Water Quality Control Board (RWQCB) monitoring and remediation programs, and drinking water source assessment programs.
    - Collection of water quality samples are required to be analyzed for chloride concentration.
        - Additional analytes may be desirable for characterization and planning of mitigation measures.
        - The use of a surrogate must be demonstrated through correlative analysis and should be periodically quantitatively assessed following implementation of use.
- Define the three-dimensional extent of any existing seawater intrusion, or degraded water quality.
- Samples should be sufficient for mapping movement of seawater or degraded water quality.

- Samples should be sufficient to assess groundwater quality impacts on beneficial uses and users.

Spatial distribution of monitoring locations may be optimized by including geophysical techniques to identify the preferential pathways controlling seawater intrusion, and target critical connections to existing water supply wells and mitigation efforts.

D. Degraded Water Quality

> ***23 CCR §354.34(c)(4)***: *Degraded Water Quality. Collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues.*

Groundwater quality monitoring networks should be designed to demonstrate that the degraded water quality sustainability indicator is being observed for the purpose of meeting the sustainability goal. The monitoring network should consist largely as supplemental monitoring locations where known groundwater contamination plumes under existing regulatory management and monitoring exist, and additional safeguards for plume migration are necessary. In addition, some monitoring may be necessary to address other degraded water quality issues in which migration could impact beneficial uses of water, including, but not limited to, unregulated contaminant plumes and naturally occurring water quality impacts. Seawater intrusion and degraded water quality are naturally related, as many practices are interchangeable. The following represent specific practices to be employed in the execution of the GSP:

- Monitor groundwater quality data from each principal aquifer in the basin that is currently, or may be in the future, impacted by degraded water quality.
  - The spatial distribution must be adequate to map or supplement mapping of known contaminants.
  - Monitoring should occur based upon professional opinion, but generally correlate to the seasonal high and low, or more frequent as appropriate.
    - Where regulated plumes exist, monitoring should coincide with regulatory monitoring for plume migration comparison purposes.
    - Where unregulated degraded water quality occurs, monitoring should be consistent with the degree of groundwater use in the regions of the known impacts.
- Collect groundwater quality data from each principal aquifer in the basin that is currently, or may be in the future, impacted by degraded water quality.

  - Agencies should use existing water quality monitoring data to the greatest degree possible. For example, these could include ILRP, GAMA, existing RWQCB monitoring and remediation programs, and drinking water source assessment programs.
- Define the three-dimensional extent of any existing degraded water quality impact.
- Data should be sufficient for mapping movement of degraded water quality.
- Data should be sufficient to assess groundwater quality impacts to beneficial uses and users.
- Data should be adequate to evaluate whether management activities are contributing to water quality degradation.

Additional References:

Framework for a ground-water quality monitoring and assessment program for California (GAMA)
http://pubs.usgs.gov/wri/wri034166/

Estimation of aquifer scale proportion using equal area grids: Assessment of regional scale groundwater quality
http://ca.water.usgs.gov/projects/gama/pdfs/Belitz_etal_2010_wrcr12701.pdf

E. Land Subsidence

23 CCR §354.34(c)(5): *Land Subsidence. Identify the rate and extent of land subsidence, which may be measured by extensometers, surveying, remote sensing technology, or other appropriate method.*

Inelastic land subsidence has been recognized in California for many decades. Observation of land subsidence sustainability indicators can utilize numerous techniques, including levelling surveying tied to known benchmarks, installing and tracking changes in borehole extensometers, monitoring continuous global position system (CGPS) locations, or analyzing interferometric synthetic aperture radar (InSAR) data. As with most sustainability indicators, conditions of subsidence, or lack thereof, can be correlated to groundwater levels as a surrogate. Each of these approaches uses different measuring points and techniques, and is tailored for specific data needs and geologic conditions.

Existing data should be used to the greatest extent. The USGS has conducted numerous studies and much of the data can be located through their webpage and reports: http://ca.water.usgs.gov/land_subsidence/index.html . In addition, DWR has developed supporting studies and data available in the Groundwater Information Center interactive maps and reports: http://www.water.ca.gov/groundwater/gwinfo/index.cfm. The use of existing regular surveys of state infrastructure may also present a record of historical changes in elevation along roadways and canals. Prior to development of a specific subsidence monitoring network a screening level analysis should be conducted. The screening of subsidence occurrence should include:

- Review of the HCM and understanding of grain-size distributions and potential for subsidence to occur.
- Review of any known regional or correlative geologic conditions where subsidence has been observed.
- Review of historic range of groundwater levels in the principal aquifers of the basin.
- Review of historic records of infrastructure impacts, including, but not limited to, damage to pipelines, canals, roadways, or bridges, or well collapse potentially associated with land surface elevation changes.
- Review of remote sensing results such as InSAR or other land surface monitoring data.
- Review of existing CGPS surveys.

In general, the network should be designed to provide consistent, accurate, and reproducible results. Where subsidence conditions are occurring or believed to occur, a specific monitoring network should be established to observe the sustainability indicator such that the sustainability goal can be met. The following approaches can be used independently or in coordination with multiple methods and should be evaluated with the specific conditions and objectives in mind. Various standards and guidance documents that must be adhered to when developing a monitoring network include:

- Levelling surveys must follow surveying standards set out in the California Department of Transportation's *Caltrans Surveys Manual*. Specific websites where additional information can be found include:
    - http://www.dot.ca.gov/hq/row/landsurveys/
    - http://www.ngs.noaa.gov/datasheets/
    - https://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-geodetic-control-networks.htm#3.5

- CGPS surveys must follow surveying standards set out in the California Department of Transportation's *Caltrans Surveys Manual*. Specific websites where additional data can be found include:
    - http://www.dot.ca.gov/hq/row/landsurveys/
    - http://www.ngs.noaa.gov/CORS/
    - http://www.unavco.org/instrumentation/networks/status/pbo
    - http://www.dot.ca.gov/dist6/surveys/CVSRN/sitemap.htm
    - http://sopac.ucsd.edu/map.shtml

- The construction and use of borehole extensometers can yield information about total and unit-specific subsidence rates depending upon construction and purpose. Specific sites where additional data can be found include:
    - Extensometer methods commonly used by the USGS http://hydrologie.org/redbooks/a151/iahs_151_0169.pdf
    - Extensometry principles (p. 20-29) http://wwwrcamnl.wr.usgs.gov/rgws/Unesco/
    - Examples of extensometer construction, instrumentation, and data interpretation
        - Single-stage pipe extensometer (Edwards Air Force Base, CA; 1990), p. 20-23: http://pubs.usgs.gov/wri/2000/wri004015/
        - Dual-stage pipe extensometer (Lancaster, CA; 1995), p. 8-12: http://pubs.usgs.gov/of/2001/ofr01414/
        - Dual-stage pipe extensometer (San Lorenzo, CA; 2008), p. 12-13: https://pubs.er.usgs.gov/publication/ds890

- The use of InSAR data can be useful for screening and regular monitoring, especially as the technology becomes more widely available and usable. Specific sites where additional data can be found are listed below.
    - Interferometric Synthetic Aperture Radar (InSAR) techniques are an effective way to measure changes in land-surface altitude over large areas. Some basic information about InSAR can be found here:
        - https://pubs.usgs.gov/fs/fs-051-00/pdf/fs-051-00.pdf
        - http://pubs.usgs.gov/fs/fs06903/pdf/fs06903.pdf
    - Raw data (not processed into interferograms) are available from a variety of foreign space agencies or their distributors at variable costs (including free):
        - European Space Agency http://www.esa.int/ESA
        - Japanese Space Exploration Agency http://global.jaxa.jp/
        - Italian Space Agency http://www.asi.it/en

    - Canadian Space Agency http://www.asc-csa.gc.ca/eng/
    - German Aerospace Center http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10002/
- Data Processing: Processing raw data to high-quality InSAR data is not a trivial task.
    - Open source/research-grade software packages and commercially available software packages. A list of available software can be found here: http://www.unavco.org/software/data-processing/sar-software/sar-software.html
    - There are commercial companies that process InSAR data.
    - Processing raw data to quality-controlled InSAR data is an essential part of InSAR processing because of the numerous common sources of error. Discussions of these error sources are found here:
        - http://pubs.usgs.gov/sir/2014/5075/
        - https://pubs.er.usgs.gov/publication/sir20135142

F. Depletion of Interconnected Surface Water

23 CCR §354.34(c))(6): *Depletions of Interconnected Surface Water. Monitor surface water and groundwater, where interconnected surface water conditions exist, to characterize the spatial and temporal exchanges between surface water and groundwater, and to calibrate and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. The monitoring network shall be able to characterize the following:*
(A) Flow conditions including surface water discharge, surface water head, and baseflow contribution.
(B) Identifying the approximate date and location where ephemeral or intermittent flowing streams and rivers cease to flow, if applicable.
(C) Temporal change in conditions due to variations in stream discharge and regional groundwater extraction.
(D) Other factors that may be necessary to identify adverse impacts on beneficial uses of the surface water.

Monitoring of the interconnected surface water depletions requires the use of tools, commonly modeling approaches, to estimate the depletions associated with groundwater extraction. Models require assumptions be made to constrain the numerical model solutions. These assumptions should be based on empirical observations determining the extent of the connection of surface water and groundwater systems, the timing of those connections, the flow dynamics of both the surface water and groundwater systems, and hydrogeologic properties of the geologic framework connecting these systems.

The following components should be included in the establishment of a monitoring network:

- Use existing stream gaging and groundwater level monitoring networks to the extent possible.

- Establish stream gaging along sections of known surface water groundwater connection.
    - All streamflow measurements should be collected, analyzed, and reported in accordance with the procedures outlined in USGS Water Supply Paper 2175, *Volume 1. - Measurement of Stage Discharge* and *Volume 2. - Computation of Discharge.*
        - https://pubs.er.usgs.gov/publication/wsp2175_vol1
        - https://pubs.er.usgs.gov/publication/wsp2175
    - Specific websites where additional information can be found include:
        - General source: http://water.usgs.gov/nsip/
        - Standards for the Analysis and Processing of Surface-Water Data and Information Using Electronic Methods https://pubs.er.usgs.gov/publication/wri20014044
        - USGS Streamflow Information
            - Real-time Streamflow Data for the Nation
            - Historical Streamflow Data for the Nation
            - WaterWatch
            - StreamStats
    - Location selection must account for surface water diversions and return flows; or select gaging locations and reaches over which no diversions or return flows exist.

- Establish a shallow groundwater monitoring well network to characterize groundwater levels adjacent to connected streams and hydrogeologic properties.
    - Network should extend perpendicular and parallel to stream flow to provide adequate characterization to constrain model development.
    - Monitor to capture seasonal pumping conditions in vicinity-connected surface water bodies.

- Identify and quantify both timing and volume of groundwater pumping within approximately 3 miles of the stream or as appropriate for the flow regime.

- Establish qualitative monitoring by use of GPS survey of the timing and position along stream where ephemeral or intermittent streams cease to flow. Should be conducted annually or as appropriate to capture stream flow change.

It may be beneficial to conduct other initial characterization surveys to establish an appropriate monitoring method to develop assumptions for a model or other technique to estimate depletion of surface water. These may include:

- Stream bed conductance surveys
- Aquifer testing for hydrogeologic properties
- Isotopic studies to determine source areas
- Geochemical studies to determine source areas
- Geophysical techniques to determine connectivity to stream channels and preferential flow pathways.

REPRESENTATIVE MONITORING POINTS

The use of RMPs, which are a subset of a basin's complete monitoring network as demonstrated in **Figure 3,** can be used to consolidate reporting of quantitative observations of the sustainability indicators.

23 CCR §354.36. Representative Monitoring (a)-(c): *Each Agency may designate a subset of monitoring sites as representative of conditions in the basin or an area of the basin, as follows:*
(a) Representative monitoring sites may be designated by the Agency as the point at which sustainability indicators are monitored, and for which quantitative values for minimum thresholds, measurable objectives, and interim milestones are defined.
(b) Groundwater elevations may be used as a proxy for monitoring other sustainability indicators if the Agency demonstrates the following:
(1) Significant correlation exists between groundwater elevations and the sustainability indicators for which groundwater elevation measurements serve as a proxy.
(2) Measurable objectives established for groundwater elevation shall include a reasonable margin of operational flexibility taking into consideration the basin setting to avoid undesirable results for the sustainability indicators for which groundwater elevation measurements serve as a proxy.
(c) The designation of a representative monitoring site shall be supported by adequate evidence demonstrating that the site reflects general conditions in the area.

In this figure, the complete monitoring network is represented by black dots. The RMPs for each sustainability indicator are represented by various colored bull's-eyes. In this example, the network of RMPs is unique for each sustainability indicator. Agencies can adopt a single network of RMPs or have a unique set of RMPs for each sustainability indicator.

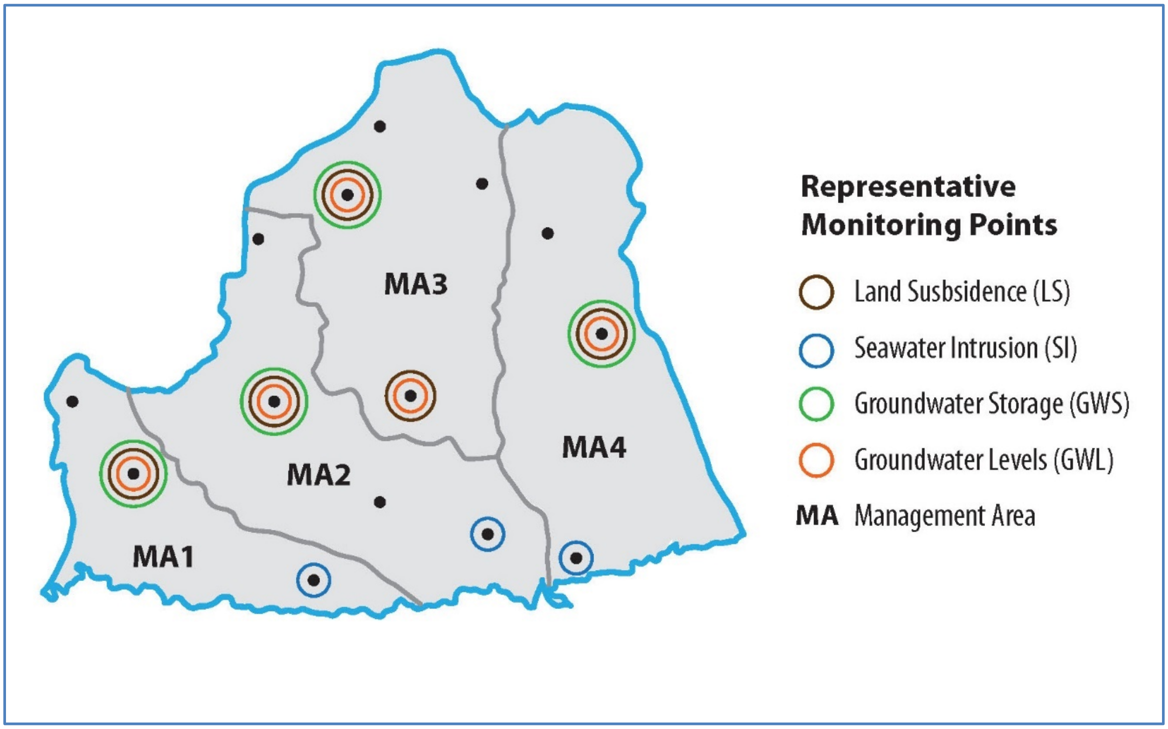

Figure 3: Representative Monitoring Points

If RMPs are used to represent groundwater elevations from a number of surrounding monitoring wells, the GSP should demonstrate that each RMP's historical measured groundwater elevations, groundwater elevation trends, and seasonal fluctuations are similar to the historical measurements in the surrounding monitoring wells. If RMPs are used to represent groundwater quality from a number of surrounding monitoring wells, the GSP should demonstrate that each RMP's historical measured groundwater quality and groundwater quality trends are similar to historical measurements in the surrounding monitoring wells.

The use of groundwater levels as a proxy may be utilized where clear correlation can be made for each sustainability indicator. The use of the proxy can facilitate the illustration of where minimum thresholds and measureable objectives occur. A series of RMPs or a single RMP may be adequate to characterize a management area or basin. Use of the RMP should include identification and description of possible interference with the monitoring objective.

NETWORK ASSESSMENT AND IMPROVEMENTS

23 CCR §354.38. Assessment and Improvement of Monitoring Network (a)-(e)

(a) Each Agency shall review the monitoring network and include an evaluation in the Plan and each five-year assessment, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin.

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

(c) If the monitoring network contains data gaps, the Plan shall include a description of the following:

(1) The location and reason for data gaps in the monitoring network.

(2) Local issues and circumstances that limit or prevent monitoring.

(d) Each Agency shall describe steps that will be taken to fill data gaps before the next five-year assessment, including the location and purpose of newly added or installed monitoring sites.

(e) Each Agency shall adjust the monitoring frequency and distribution of monitoring sites to provide an adequate level of detail about site-specific surface water and groundwater conditions and to assess the effectiveness of management actions under circumstances that include the following:

(1) Minimum threshold exceedances.

(2) Highly variable spatial or temporal conditions.

(3) Adverse impacts to beneficial uses and users of groundwater.

(4) The potential to adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of sustainability goals in an adjacent basin.

Network assessment and improvements are commonly identified as 'data gaps' in the monitoring network and refer to "a lack of information that significantly affects the understanding of basin setting or evaluation of the efficacy of the Plan implementation, and could limit the ability to assess whether a basin is being sustainably managed." The monitoring network is a key component in the development of GSPs and will influence the development and understanding of the basin setting, including the hydrogeologic conceptual model, groundwater conditions, and water budget; and proposed minimum thresholds and measurable objectives. GSAs should consider previous analyses of data gaps of their monitoring network through existing programs, such as CASGEM monitoring plans. **Figure 4** shows a flowchart that demonstrates a process that GSAs should use to identify and address data gaps.

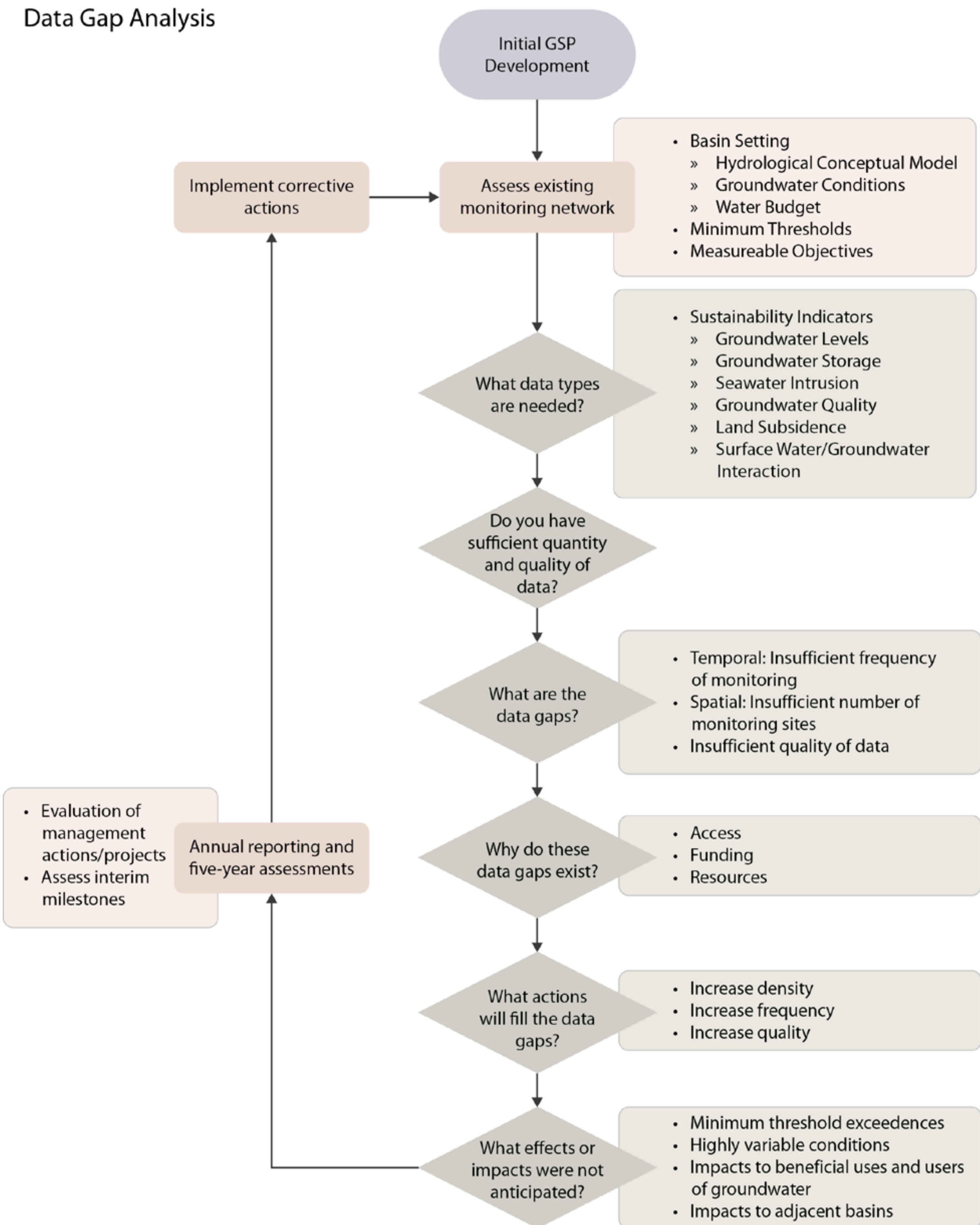

Figure 4. Data Gap Analysis Flow Chart

Professional judgment will be needed from GSAs to identify possible data gaps in their monitoring network of the sustainability indicators. Data gaps can result from monitoring information that is not of sufficient quantity or quality. Data of insufficient quantity typically result from missing or incomplete information, either temporally or spatially. Examples of temporal data gaps include a hydrograph with data that is too infrequent, has inconsistent intervals, or has a short historical record, as shown in **Figure 5**. Spatial data gaps may occur from a monitoring network with low or uneven density in three dimensions, as shown in **Figure 6**.

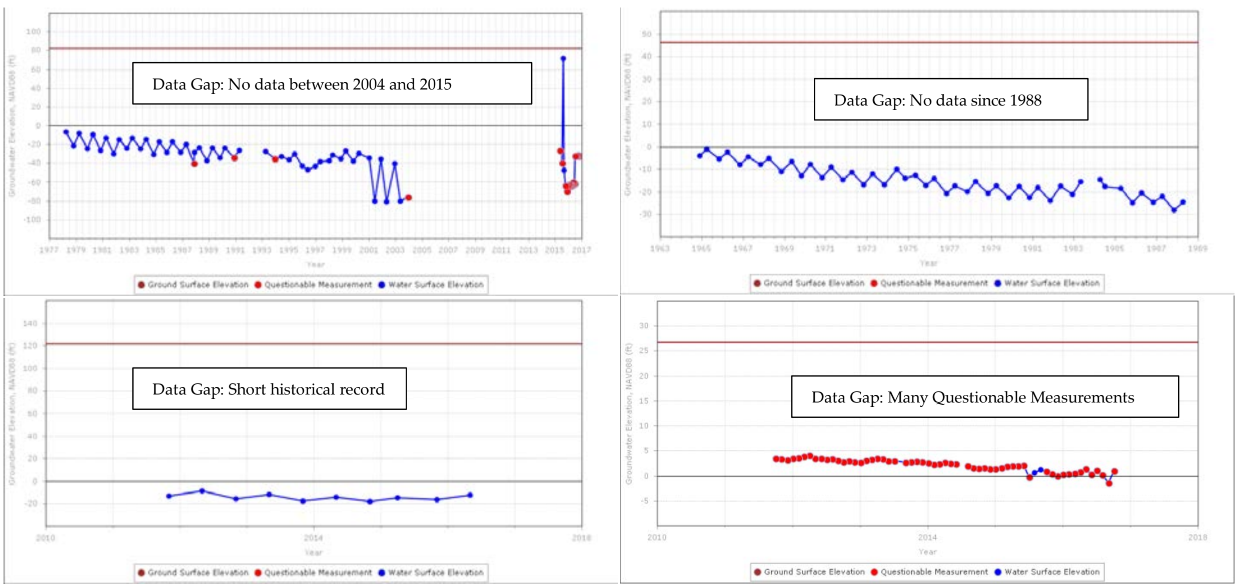

Figure 5. Examples of Hydrographs with Temporal Data Gaps

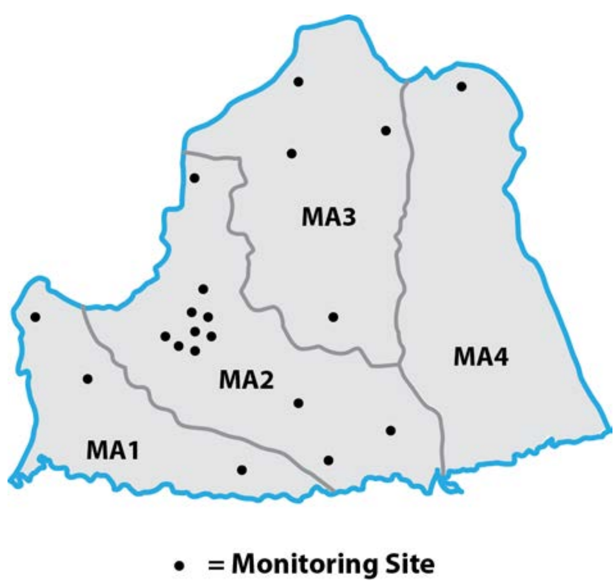

Figure 6. Example Monitoring Network with Spatial Data Gaps

Poor quality data may also be the cause of data gaps. Data must be of sufficient quality to enable scientifically defensible decisions. Poor quality data may at times be worse than no data because it could lead to incorrect assumptions or biases. Some things to consider when questioning the quality of data include: collection conditions and methods, sampling quality assurance/quality control, and proper calibration of meters/equipment. As part of the CASGEM program, DWR reports groundwater elevation data from local agencies, which include the option for "Questionable Measurement Codes." These codes are one way of identifying poor quality data.

There may be various reasons for data gaps, including site access, funding, and lack of staffing resources. By identifying and correcting the reasons behind data gaps, GSAs may be able to avoid further data gaps.

Direct actions GSAs could take to fill data gaps include:

- Increasing the frequency of monitoring. For instance, some groundwater elevation measurements are taken twice a year in the spring and fall, but perhaps those measurements need to be increased to quarterly, monthly, or more frequently, if needed.
- Increasing the spatial distribution and density of the monitoring network.
- Increasing the quality of data through improved collection methods and data management methods.

As GSPs are implemented, GSAs may identify other data gaps, especially if there are minimum threshold exceedances, highly variable spatial or temporal conditions, adverse impacts to beneficial uses and users of groundwater, and impacts to adjacent basins' ability to achieve sustainability. Any or all of these conditions may indicate a need to refine the monitoring network.

Agencies are required to assess their monitoring networks every five years. During those assessments, data gaps may also be identified as agencies monitor the progress of their management actions/projects and the status of their interim milestones. These regular assessments will allow the GSAs to adaptively manage, focus, and prioritize future monitoring.

DATA REPORTING

> ***23 CCR §352.6. Data Management System***
> *Each Agency shall develop and maintain a data management system that is capable of storing and reporting information relevant to the development or implementation of the Plan and monitoring of the basin.*

The use of a Data Management System (DMS) is required for all GSPs. The DMS should include clear identification of all monitoring sites and a description of the quality assurance and quality control checks performed on the data being entered. Uploading of the collected data should occur immediately following collection to address any quality concerns in a timely manner and prevent the potential for development of data gaps. Coordination of data structures between adjacent basins will facilitate data sharing and increase data transparency.

DWR will be providing an update to this BMP as the suggested data structure is developed, as necessary.

6. KEY DEFINITIONS

SGMA DEFINITIONS (CALIFORNIA WATER CODE §10721)

(r) "Planning and implementation horizon" means a 50-year time period over which a groundwater sustainability agency determines that plans and measures will be implemented in a basin to ensure that the basin is operated within its sustainable yield.

(u) "Sustainability goal" means the existence and implementation of one or more groundwater sustainability plans that achieve sustainable groundwater management by identifying and causing the implementation of measures targeted to ensure that the applicable basin is operated within its sustainable yield.

(v) "Sustainable groundwater management" means the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.

(w) "Sustainable yield" means the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result.

(x) "Undesirable result" means one or more of the following effects caused by groundwater conditions occurring throughout the basin:

(1) Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.

(2) Significant and unreasonable reduction of groundwater storage.

(3) Significant and unreasonable seawater intrusion.

(4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.

(5) Significant and unreasonable land subsidence that substantially interferes with surface land uses.

(6) Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

GSP REGULATIONS DEFINITIONS (CALIFORNIA CODE OF REGULATIONS §351)

(l) "Data gap" refers to a lack of information that significantly affects the understanding of the basin setting or evaluation of the efficacy of Plan implementation, and could limit the ability to assess whether a basin is being sustainably managed.

(o) "Interconnected surface water" refers to surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted.

(q) "Interim milestone" refers to a target value representing measurable groundwater conditions, in increments of five years, set by an Agency as part of a Plan.

(s) "Measurable objectives" refer to specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin.

(t) "Minimum threshold" refers to a numeric value for each sustainability indicator used to define undesirable results.

(u) "NAD83" refers to the North American Datum of 1983 computed by the National Geodetic Survey, or as modified.

(v) "NAVD88" refers to the North American Vertical Datum of 1988 computed by the National Geodetic Survey, or as modified.

(y) "Plan implementation" refers to an Agency's exercise of the powers and authorities described in the Act, which commences after an Agency adopts and submits a Plan or Alternative to the Department and begins exercising such powers and authorities.

(aa) "Principal aquifers" refer to aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems.

(ab) "Reference point" refers to a permanent, stationary and readily identifiable mark or point on a well, such as the top of casing, from which groundwater level measurements are taken, or other monitoring site.

(ac) "Representative monitoring" refers to a monitoring site within a broader network of sites that typifies one or more conditions within the basin or an area of the basin.

(ad) "Seasonal high" refers to the highest annual static groundwater elevation that is typically measured in the Spring and associated with stable aquifer conditions following a period of lowest annual groundwater demand.

(ae) "Seasonal low" refers to the lowest annual static groundwater elevation that is typically measured in the Summer or Fall, and associated with a period of stable aquifer conditions following a period of highest annual groundwater demand.

(ag) "Statutory deadline" refers to the date by which an Agency must be managing a basin pursuant to an adopted Plan, as described in Water Code Sections 10720.7 or 10722.4.

(ah) "Sustainability indicator" refers to any of the effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, cause undesirable results, as described in Water Code Section 10721(x).

(ai) "Uncertainty" refers to a lack of understanding of the basin setting that significantly affects an Agency's ability to develop sustainable management criteria and appropriate projects and management actions in a Plan, or to evaluate the efficacy of Plan implementation, and therefore may limit the ability to assess whether a basin is being sustainably managed.

7. Related Materials

NETWORK DESIGN

- Design of a Real-Time Ground-Water Level Monitoring Network and Portrayal of Hydrologic Data in Southern Florida
    - http://fl.water.usgs.gov/PDF_files/wri01_4275_prinos.pdf

- Optimization of Water-Level Monitoring Networks in the Eastern Snake River Plain Aquifer Using a Kriging-Based Genetic Algorithm Method
    - http://pubs.usgs.gov/sir/2013/5120/pdf/sir20135120.pdf

GUIDANCE

California Department of Water Resources, 2010. *California statewide groundwater elevation monitoring (CASGEM) groundwater elevation monitoring guidelines*, December, 36 p. http://www.water.ca.gov/groundwater/casgem/documents.cfm

Heath, R. C., 1976. *Design of ground-water level observation-well programs*: Ground Water, V. 14, no. 2, p. 71-77.

Hopkins, J., 1994. *Explanation of the Texas Water Development Board groundwater level monitoring program and water-level measuring manual*: UM-52, 53 p. http://www.twdb.texas.gov/groundwater/docs/UMs/UM-52.pdf

Sophocleous, M., 1983. *Groundwater observation network design for the Kansas groundwater management districts, USA*: Journal of Hydrology, vol.61, pp 371-389.

Subcommittee on ground water of the advisory committee on water information, 2013. A National Framework for Ground-Water Monitoring in the United States, 168 p. http://acwi.gov/sogw/ngwmn_framework_report_july2013.pdf

Appendix 5A

Appendix 6 of the Kaweah Subbasin Coordination Agreement

SUSTAINABILITY GOAL AND UNDESIRABLE RESULTS

Appendix 6 to Kaweah Subbasin Coordination Agreement

Table of Contents

Appendix

Appendix 6-1: Technical Approach for Developing Chronic Lowering of Groundwater Level SMC for the Kaweah Subbasin
Appendix 6-2: Potential Well Impact Analysis
Appendix 6-3: Mitigation Program Framework

6. Sustainability Goal and Undesirable Results

6.1 Introduction

This Appendix provides location-specific significant and unreasonable conditions as well as undesirable results for five of the six sustainability indicators to guide and support the Kaweah Subbasin Groundwater Sustainability Agencies (GSAs) in developing sustainable management criteria (SMC) in their individual groundwater sustainability plans (GSP). This Appendix includes the Subbasin-scale SMC guidance as required by 23 Cal. Code Regs. §§354.22-.26, i.e., the sustainability goal and a complete listing of undesirable results, including their causes, criteria and effects on beneficial uses and users. Pursuant to 23 Cal. Code Regs §354.26(d) no sustainable management criteria need to be set at this time for the undesirable results of Seawater Intrusion. Thus, pursuant to 23 Cal. Code Regs §354.26(e)[1], undesirable results associated with Seawater Intrusion will not be discussed herein.

6.2 General Approach

As described later in this Appendix, the Subbasin identified minimum thresholds, based on declining groundwater levels (hereinafter "water level" or "level") that result in significant and unreasonable results to the beneficial uses and users of groundwater within the Kaweah Subbasin. Measurable objectives are similarly based on using a trend line approach to afford the ability to provide a buffer for drought years prior to encountering minimum thresholds. The relationship of these measurable objectives and the long-term success in achieving the objectives is discussed in the context of neighboring GSAs in the Subbasin and their respective actions undertaken during GSP implementation.

The Kaweah Subbasin GSAs developed SMC within a framework of data, which currently has gaps. Every effort was made to coordinate SMC between the three GSAs. If SMCs (such as minimum thresholds and measurable objectives) vary substantially between adjacent GSAs, then the GSAs will endeavor to adjust the particular SMC as additional data becomes available so that the GSAs eliminate any substantial variance which could inhibit a GSA from implementing its GSP and achieving sustainability within its jurisdictional area.

The metrics and approaches to be employed by the Subbasin for the six sustainability indicators are shown in **Table 6-1**.

[1] 23 Cal. Code Regs §354.26(e) provides "An Agency that has demonstrated that undesirable results related to one or more sustainability indicators are not present and are not likely to occur in a basin, as described in Section 354.26, shall not be required to establish minimum thresholds related to those sustainability indicators.

6.3 Sustainability Goal

> 23 Cal. Code Regs. § 354.24. *Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline. The Plan shall include a description of the sustainability goal, including information from the basin setting used to establish and sustainability goal, a discussion of the measures that will be implemented to ensure that the basin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved within 20 years of Plan implementation and is likely to be maintained through the planning and implementation horizon.*

Table 6-1: Sustainable Management Criteria by Sustainability Indicator

SMC Summary for Kaweah Subbasin		
Sustainability Indicators	**Basis for Minimum Threshold**	**Basis for Measurable Objective**
Chronic Lowering of Groundwater Levels	Protection of greater than the 90th percentile of all beneficial uses and users without allowing a greater rate of historical level decline[1]	Flexibility for at least 5 years of drought storage
Reduction in Storage	Calculated based on groundwater levels[2]	Calculated based on groundwater levels[2]
Land Surface Subsidence	Total subsidence of no more than 9 feet, and a subsidence rate of no more than 0.67 feet/year	Zero Subsidence
Water Quality	Reference to other regulators [3]	Reference to other regulators [3]
Seawater Intrusion	Not Applicable	Not Applicable
Interconnected Surface Waters	50% of channel losses in selected waterways[4]	30% of channel losses in selected waterways[4]

[1] Determined by representative monitoring sites in Analysis Zones
[2] Storage volume changes and associated SMC determined as function of water level changes
[3] e.g. SWRCB Division of Drinking Water requirements for public supply wells, RWQCB Irrigated Lands Regulatory Program
[4] This indicator applies to the East Kaweah and Greater Kaweah GSAs. The two GSAs will be implementing a Work Plan to fill data gaps and better refine understanding of location and impacts caused by groundwater pumping

The broadly stated sustainability goal for the Kaweah Subbasin is for each GSA to manage groundwater resources to preserve the viability of existing agricultural enterprises of the region, domestic wells, and the smaller communities that provide much of their job base in the Sub-basin, including the school districts serving these communities. The goal will also strive to fulfill the water needs of existing and amended county and city general plans that commit to continued economic and population growth within Tulare County and portions of Kings County.

This goal statement complies with §354.24 of the Regulations. This Goal will be achieved by:

- The implementation of the EKGSA, GKGSA and MKGSA GSPs, each designed to identify phased implementation of measures (projects and management actions) targeted to ensure that the Kaweah Subbasin is managed to avoid undesirable results and achieve measurable objectives by 2040 or as may be otherwise extended by DWR.

- Collaboration with other agencies and entities to arrest chronic groundwater-level and groundwater storage declines, reduce or minimize land subsidence where significant and unreasonable, decelerate ongoing water quality degradation where feasible, and protect the local beneficial uses and users.
- Assessments at each interim milestone of implemented projects and management actions and their achievements towards avoiding undesirable results as defined herein.
- Continuance of projects and management actions implementation by the three GSAs, as appropriate, through the planning and implementation horizon to maintain this sustainability goal.

6.4 Groundwater Levels

23 Cal. Code Regs § 354.26*(a). Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.*

The terms "significant and unreasonable" are not defined by SGMA, and are left to GSAs to define within their GSPs. The process to define "significant and unreasonable" began with stakeholder and landowner discussions. In the view of the Kaweah Subbasin GSAs and its stakeholders, the following impacts from lowering groundwater levels are viewed as "significant and unreasonable" as they would directly impact the long-term viability of beneficial uses/users (domestic, agricultural, municipal, etc.) to meet their reasonable water demands through groundwater:

- Inability of the groundwater aquifer to recover in periods of average/above average precipitation following multi-year drought periods
- Dewatering of a subset of existing wells below the bottom of the well
- Substantial increase in costs for pumping groundwater, well development, well construction, etc. that impact the economic viability of the area
- Adverse effects on health and safety
- Interfere with other sustainability indicators

6.4.1 Causes leading to Undesirable Results

23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (1) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.*

The primary cause of groundwater conditions that would lead to chronic lowering of groundwater levels is groundwater pumping in excess of natural and artificial recharge over a multi-year period that includes both wetter than average and drier than average conditions. A transition to permanent crops and development of large dairies have both hardened water demand in all years. In addition to natural drought-cycles, the increase in groundwater pumping may also be the result of restricted access to imported supplies due to a variety of factors, including but not limited to, increased restrictions in the Delta, which may increase the likelihood imported supplies from Millerton Lake will be delivered outside the Kaweah Subbasin. The restriction of imported supplies may return the Kaweah Subbasin to a state it existed in prior to the development of the Friant Division of the Central Valley Project. Climate change may also affect the availability and rate upon which natural and artificial recharge is available.

6.4.2 Criteria to Define Undesirable results

23 Cal. Code Regs § 354.26 *(b). The description of undesirable results shall include the following: (2) The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.*

The GSAs within the Kaweah Subbasin have determined that undesirable results for groundwater levels may be significant and unreasonable when a subset of existing and active wells is dewatered. This is being described this way because the Subbasin has a significant data gap related to where all active wells are, how the active wells are constructed and how much the active wells are pumping. The Subbasin GSAs have plans to obtain this information from local landowners in the future. As this data gap is addressed, the description of an Undesirable Result for the Kaweah Subbasin will be further refined based on the more complete and accurate information.

Groundwater elevations shall serve as the sustainability indicator and metric for chronic lowering of groundwater levels and, by proxy, for groundwater storage. An Undesirable Result occurs when one-third of the monitoring sites exceed the respective minimum threshold groundwater elevation.

It is the preliminary determination, after consideration of all users and uses, that the values identified herein represent a sufficient number of monitoring sites in the Subbasin such that their exceedance would represent an undesirable result for water-level declines and reduction in groundwater storage. Total completion depth data for all beneficial users (agricultural, municipal, and domestic wells), as identified in the technical Appendix 6-1 and 6-2 attached to this Appendix, has been evaluated and undesirable results are defined by the quantity of wells completely dewatered by 2040 if Minimum Thresholds are met or exceeded. However, the Kaweah Subbasin GSAs are committing to implementing a Mitigation Program to mitigate certain impacts to active wells as groundwater levels transition to a more sustainable long-term condition (see Appendix 6-3). Based on future observed groundwater levels and not less frequently than at each five-year assessment, the GSAs will evaluate whether these values need to be changed.